

DRAFT FINAL RESEARCH PAPER

SPATIAL AUTOCORRELATION PATTERN ANALYSES:

Willamette Valley Ecoregion Recovery

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Geospatial Characterization and Analyses of Environmental Recovery Actions  
in the Willamette Valley Ecoregion, Oregon

*Abstract: Geographers have come to recognize the need to characterize and analyze the state of conservation recovery actions to better understand contemporary ecosystem sustainability. Over twenty mitigation banks and thousands of Federal and State recovery grant projects are now established and ongoing in the Willamette Valley Ecoregion. Both regulatory and nonregulatory recovery programs embrace the notion that solutions should contain elements that support resilience and functionally sustainable systems. The theory supporting the ranking system used to characterize Willamette Valley ecoregion recovery actions assumes recovery actions are intrinsically important, but more important if they enhance existing natural resources and that their importance is proportional to their size and proximity to one another. A Geographic Information System was selected as a logical technology to create the necessary characterization model and framework for conducting the analyses. Two pattern recognition tools are used to identify statistically significant ecoregion recovery hot spots, cold spots, and spatial outliers. A cursory review and characterization of five hot spot areas identified by the pattern analyses tools was done to help verify whether the model is making appropriate Willamette Valley ecoregion recovery hot spot selections. The model appears to be correctly identifying suitable Willamette Valley ecoregion recovery actions for larger proximate first order hot spots. There is more analysis review work needed to discern the model's sensitivity for identifying smaller and more isolated areas of significant recovery activity.*

## 1. Introduction

Both applied and research geographers have come to recognize the need to characterize and analyze the state of conservation recovery actions to better understand contemporary ecosystem sustainability. For complete results, these efforts require the examination of both regulatory recovery solutions, like mitigation and conservation banking, and nonregulatory strategies, such as grant funded restoration actions on private and public lands. Spatial and temporal scales crossing multiple human systems and knowledge domains are germane to this research (Reid 2006). The notion that solutions should embrace factors that support resilience and functionally sustainable systems is relatively recent in the mainstream thinking that faces increasingly complex world problems (Walker and Salt 2012). As modern and revolutionary as these concepts may seem, one could argue they are the logical result of a long history of cartographic representation by applied geographers (Slocum, McMaster, and Howard 2009).

For the past 15 to 20-years, a mitigation and conservation banking program (ORS 196.668 – 196.622) in concert with public and private lands ecological recovery efforts have been steadily growing around the state of Oregon. Over 20 mitigation banks and thousands of

Federal and State recovery grant projects are now established and ongoing in the Willamette Valley Ecoregion (Table 1). Both regulatory and nonregulatory recovery programs embrace the notion that solutions should contain elements that support resilience and functionally sustainable systems. Many of these efforts are targeting the recovery of historically diminished native wet prairie and impaired salmonids and other anadromous fish as part of their overarching management and long-term protection strategy. Recovery of historically diminished and present day rare resources are supported and encouraged by the State of Oregon's Conservation Strategy (ODFW 2006).

Table 1. Descriptive Statistics for Overarching Willamette Valley Ecoregion Recovery.

<b>Willamette Ecoregion Recovery Activities (Acres)</b>	
<b>Count</b>	<b>5368</b>
<b>Minimum</b>	<b>&lt; 1</b>
<b>Maximum</b>	<b>36,475</b>
<b>Sum</b>	<b>397,630</b>
<b>Mean</b>	<b>57</b>
<b>Median</b>	<b>3</b>
<b>Standard Deviation</b>	<b>728</b>
<b>Classification Method</b>	<b>Natural Breaks</b>
<b>Source</b>	RIBITs and USFWS geodatabase/ ORBIC Stewardship Geodatabase. December 2013. Modified from: US Geological Survey, Gap Analysis Program (GAP). November 2012. Protected Areas Database of the United States (PADUS), version 1.4./ Oregon Watershed Enhancement Board, OWRI Database

## 2. Definitions

**Mitigation Bank** – lands managed for the preservation, enhancement, restoration or creation of a wetland, stream, or habitat conservation area and which offsets, or compensates for expected adverse impacts to similar nearby ecosystems.

**Conservation Bank** – lands that are conserved, permanently protected, and managed for species that are endangered, threatened, candidates for listing as endangered or threatened, or are otherwise species-at-risk, to offset adverse impacts to these species elsewhere.

**Compensatory Mitigation** –the restoration (re-establishment or rehabilitation), creation, enhancement, and/or in certain circumstances preservation of wetlands, streams and other aquatic resources for the purposes of offsetting unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization has been achieved.

Wetland – Land where an excess of water is the dominant factor determining the nature of soil development and the types of animals and plant communities living at the soil surface. It spans a continuum of environments where terrestrial and aquatic systems intergrade.

Wet Prairie - Seasonally flooded wetland, dominated by herbaceous plants (predominantly a combination of native forbs and graminoids) occurring in poorly drained and relatively flat terrain, typically from November through April or May.

Imperiled Species – Species listed as threatened or endangered under the U.S. Endangered Species Act or the state's endangered species act, or species or ecological communities classified by NatureServe as GH (possibly extinct), G1 (critically imperiled), or G2 (imperiled).

Imperiled Habitat – Habitat essential to the continued survival and / or recovery of imperiled species.

Perpetuity Protection – Legally required and financially allocated protection and management of land for an indefinite future, dedicated to preservation and conservation of natural systems and habitat, and frequently banned from being subjected to a host of alternative uses that might otherwise impair its natural resource management goals and objectives.

### 3. Problem Statement

Close to 99% of the pre-European occupation wet prairie, generally classified as Palustrine Emergent Wetland (Cowardin 1979), in the Willamette Valley has been converted to pasture and other agricultural uses or urban development (Habeck 1961, Johannessen et al 1971, Christy and Alverson 2004). Additionally, displacement of aboriginal peoples and their cultural practices of prairie burning (Bosse 2008, Pendergrass 1995, Alverson 2006, Alverson 2004) to drive game for hunting and maintaining native prairie food plants, such as Camas, has led to an accelerated colonization by woody species and nonnative invasive weeds (largely transported and introduced by European settlers and their descendants) on the remaining 1 or 2% of the original prairie. These weedy species are overtaking and severely degrading the remaining prairie condition (Pendergrass 1995, Norman 2008, Pfeifer-Meister 2008), thereby limiting its capability to support already imperiled plant and wildlife species (Titus et al 1996).

Declines of Pacific salmon population segments followed post European settlement of the Pacific Northwest in the 19th century. Loss and degradation of habitat continue to be significant factors in their declines. Exploitive land uses on both public and private lands in the region altered river and stream related salmonid habitats that will require considerable time for recovery. Complete return to historical conditions will never occur over most of the landscape. Forestry, agricultural, and urban development of floodplain habitats has been one of the most pervasive under-regulated forms of habitat loss and degradation. (Gregory and Bisson 1997).

Relatively recent analyses of the status and trends of wetlands nationwide indicate there has been no net loss of freshwater wetlands overall from 2004 to 2009, albeit some variation of loss vs gain as applied to a breakdown of freshwater wetland types (Dahl 2011):

- *Freshwater Ponds:* 3.2% +
- *Freshwater Vegetated:* 0.2% -
- *Freshwater Emergent:* 1.0% +
- *Freshwater Shrub:* 1.0% +
- *Freshwater Forested:* 1.2% -

The apparent marked decreased rates of wetland area decline and net gain of some wetland types are attributed to wetland reestablishment and creation on agricultural lands and other land use types due to various conservation programs (Dahl 2011). In the interest of future protection and management of regulated resources in the Willamette Valley Ecoregion, there is a need for a quantitative assessment of the combined contributions of mitigation and conservation banking and nonregulatory related recovery actions. Overarching metrics of interest are: what are the benchmarks for states of successful recovery? How can we discern where we are on the trajectory toward ecological recovery in the Willamette Valley? How much progress have we made? How far do we have to go? How is this progress distributed spatially and what are the options for offsetting further losses of Willamette Valley imperiled natural resources?

#### 4. Objectives:

- Determine the range, mean, median, minimum, maximum, and total acreages for recovery actions in the Willamette Valley ecoregion.
- Develop a model that identifies statistically significant recovery action areas in the Willamette Valley ecoregion.

#### 5. Methodology and Problems Encountered

A Geographic Information System (GIS) was selected as a logical technology to create the necessary characterization model and conduct the analyses. The first step toward building the GIS was to inventory and acquire the GIS data required. Six GIS data layers are identified for acquisition and use (Table 2). Some of the original datasets were standalone downloads while others required various data editing and data preparation procedures before they could be used in this project. Once data preparation procedures were completed, the datasets were each imported into an appropriately themed file geodatabase feature dataset set. This served to convert the different existing data projections to a common NAD 1983 UTM Zone 10 projection. The geodatabase was added to a series of ArcMap projects in ArcGIS 10.4 desktop software for the data preparation and spatial pattern analyses operations. SQL queries, geo-processing tools, and various scripts were run on the data to help complete the objectives of this research effort.

The preliminary review of the data acquired for this project and attempts to organize it into logical themes for query began to reveal a growing number of inconsistencies, duplicate data, and missing data. All efforts to get clarification and updates on these issues from the respective data stewards were either not responded to at all, met with extensive paperwork and formal fee requirements, or relegated to an indefinite hold. Also, this public domain data,

accessible by the internet, were stored in several different databases managed by separate data stewards, each using a different schema. It soon became apparent that there were considerable tasks related to data cleaning, organization, and preparation required before the intended analyses could be started. Due to the time constraints on completing this class project, a decision was made to coarsely aggregate the nonregulatory and regulatory data into a common category called ‘Recovery Data’ and to redefine the analyses accordingly.

Table 2. Project Data.

Map Data Themes	Data Type	Source	ComProjStatic
Ecoregion Boundary	Polygon	Institute for Natural Resources	NAD_1983_UTM_Zone_10N
Willamette Valley Mitigation and Conservation Banks	Polygon	US Army Corps of Engineers (RIBITS)	NAD_1983_UTM_Zone_10N
Protected Areas Database	Polygon	US Geological Survey, Gap Analysis Program (GAP). Protected Areas Database of the United States (PADUS), version 1.4.	NAD_1983_UTM_Zone_10N
Oregon Watershed Restoration Inventory (OWRI)	Polygon Line Point	Oregon Watershed Enhancement Board (OWEB)	NAD_1983_UTM_Zone_10N
NWI Wetlands	Polygon	US Fish and Wildlife Service	NAD_1983_UTM_Zone_10N
Rivers and Streams	Line	US Geological Survey – National Hydrography Database	NAD_1983_UTM_Zone_10N

In other words, there was no attempt to differentiate the regulatory from the nonregulatory contributions to ecological recovery, nor was there any attempt to differentiate recovery by resource type (e.g., wet-grass prairie wetland; salmonid spawning, rearing, and migration; forested wetland; imperiled plant species, etc.). There was no attempt to differentiate which actions were permanently protected by fee ownership or a permanent endowment funded long-term management plan and conservation easement by a qualified land steward like The Nature Conservancy or the US Fish and Wildlife Service or which actions were only temporarily protected, such as a 15-year Natural Resource Conservation Service Wetland Reserve Program easement held by a local government, such as Lane County. A break down of the costs of the different restoration actions on specific land parcels by the respective agencies and / or nonagency landowners involved was not possible. Finally, there was no attempt to track the geographic locations, magnitudes, or types of development debits accrued as mitigation and conservation bank credits were sold to off-set the impacts by developers. Instead, the overarching goal of the research effort was modified to focus on coarsely examining the spatial pattern of the aggregate ‘recovery’ actions in the Willamette Valley Ecoregion and then, if clustered patterns could be detected, mapping the major concentrations of the high value restoration.

Two pattern recognition tools in ArcToolbox (Local Moran’s I and Getis-Ord G\*) were used. The Getis-Ord G\* hot spot analysis identifies statistically significant hot spots and cold spots

using the Getis-Ord  $G_i^*$  statistic. It indicates where high and low vector values cluster by *comparing the value of each feature with its neighboring features* inside a user defined distance threshold. The z-scores and p-values measures a statistical significance and indicates whether or not to reject the null hypothesis by determining if an observed spatial pattern of high or low values is clustered more than one would expect in a random distribution of those values. The Anselin Local Moran's I tool identifies statistically significant hot spots, cold spots, and spatial outliers using the Local Moran's I statistic. It identifies concentrations of high values, concentrations of low values, and spatial outliers. Local Moran's I z-scores and p-values are measures of statistical significance which is used to determine if it is quantitatively acceptable to reject the null hypothesis. Basically, they indicate whether the apparent similarity (or dissimilarity) in values *for a given feature's neighbors* is greater than one would expect in a random distribution.

The primary difference is Local Moran's I *analyzes and reports only on the 'neighbors'* while Getis-Ord  $G_i^*$  *analyzes and reports on all the relevant features*. Depending on the size of the distance bands selected, it is possible a high value feature would show up as a hot spot in Getis-Ord  $G_i^*$  even though it is surrounded by low value features while in a Local Moran's I run, it would show up as a high value feature associated with low value features

To augment the two analyses sensitivity to relevant and easily retrievable database information, a weighted recovery focal type classification was developed. It is based on a subjective estimates of recovery focal type importance (recovery actions, NWI wetlands, and stream corridors) weighted by their respective areal coverages. The basic structure of this data ranking system is as follows:

Recovery Focal Types  
and their Ranks:

Recovery Actions (3);  
NWI Wetlands (3); and  
2000-ft wide river and stream corridors (2).

Rank:

1 – Relatively Low Importance;  
2 – Relatively Moderate Importance;  
3 – Relatively High Importance;

Weighted Rank  
(WtRank):

Rank x Acres or Areal Extent

Adjusted Weighted  
Rank (AdjWtRank):

1 – 7, Natural Breaks Classification of WtRank

The principle, albeit simplistic, theory supporting this ranking system is that recovery actions are intrinsically important but they are more important if they enhance existing natural resources. Also, recovery actions that affect larger areas and that augment resources that cover larger areas have a proportionally greater positive effect on overall ecological connectivity and recovery. It is interesting to note that this ranking system, as applied to 2000-foot wide Willamette Valley stream and river corridors, appears to also serve as a plausible proxy for a ranking by stream

order. It should be noted that the ranking system has an inherent bias toward aquatic resources, a factor that may warrant tweaking in future applications. Also, subjective ranks can theoretically be used as flexible variables in future applications of the model. For example, they could conceivably be tailored to be more sensitive to existing site conditions by being informed by results from some future comprehensive analysis and spatially explicit identification of those conditions.

Using a combination of merge, add fields, classifications, and field calculator operations, three new output polygons are created with a calculated and populated AdjWtField (1 – 7) using the ranking system above (Figure 1). These three polygons are each converted to a raster with a value field that holds the 1 – 7 value formerly in the AdjWtField. A weighted overlay sum tool is used to add the respective georeferenced pixel scores of the three Recovery Focal Type rasters to generate a final total sum by pixel output raster (Figure 2). This raster, after being converted from a continuous surface into an integer data type, is then converted to a polygon (Figure 3) that can be used to run the spatial pattern recognition tools described above (Figures 4 and 5).

## 6. GIS Workflow

- Step 1. Merge Regulatory and Non-regulatory polygons to single 'Recovery' polygon:  
  
Merge WV\_PADUS4Easements TO WV\_PADUS4Fee TO WV\_OWRI TO WV\_MitigationBanks
- Step 2. Add Field short int 'Rank' and use field calculator to: [Rank] = 3.
- Step 3. Add Field double 'WtRank' and use field calculator to: [Acres] \* [Rank] = [WtRank].
- Step 4. Add Field short int 'AdjWtRank' and classify on WtRank field to 7 class ranges.
- Step 5a. Select by Attribute: WtRank >= 0 AND WtRank <= 322.59
- Step 5b. Use field calculator to: [AdjWtRank] = 1.
- Step 5c. Select by Attribute: WtRank >= 322.60 AND WtRank <= 1446.11
- Step 5d. Use field calculator to: [AdjWtRank] = 2.
- Step 5e. Select by Attribute: WtRank >= 1446.12 AND WtRank <= 4094.35
- Step 5f. Use field calculator to: [AdjWtRank] = 3.
- Step 5g. Select by Attribute: WtRank >= 4094.36 AND WtRank <= 9824.17
- Step 5h. Use field calculator to: [AdjWtRank] = 4.
- Step 5i. Select by Attribute: WtRank >= 9824.18 AND WtRank <= 19341.53
- Step 5j. Use field calculator to: [AdjWtRank] = 5.
- Step 5k. Select by Attribute: WtRank >= 19341.54 AND WtRank <= 40895.66
- Step 5l. Use field calculator to: [AdjWtRank] = 6.
- Step 5m. Select by Attribute: WtRank >= 40895.67 AND WtRank <= 109423.50
- Step 5n. Use field calculator to: [AdjWtRank] = 7.



- Step 6a. Merge Recovery\_Actions with WV\_Ecoregion and output to RecoveryBaseline.
- Step 6b. Edit RecoveryBaseline use field calculator to [Rank], [WtRank], and [AdjWtRank] = 0.
- Step 7. Convert RecoveryBaseline Polygon to Raster RecoveryBaseline\_PolygonToRa1
- Step 8. Apply Buffer tool to WV\_Rivers and create 1000-foot buffers and 2000-foot waterway corridors named WV\_Rivers\_Corrid\_1000ft
- Step 9. Add Field short int 'Rank' and use field calculator to: [Rank] = 2.
- Step 10. Add Field double 'WtRank' and use field calculator to: [Shape\_Area] \* [Rank] = [WtRank].
- Step 11. Add Field short int 'AdjWtRank' and classify on WtRank field to 7 class ranges.

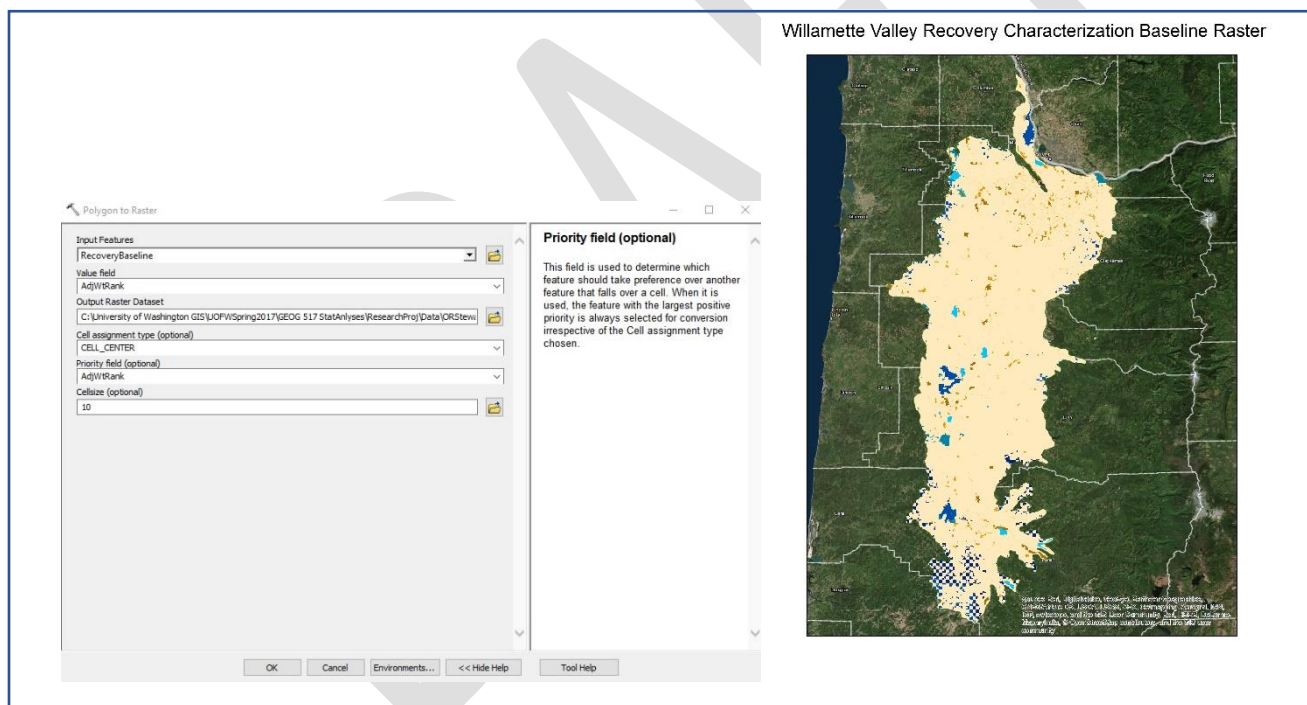


Figure 1. Conversion of recovery baseline polygon to raster (10-meter pixels).

- Step 12a. Select by Attribute: WtRank >= 587361.93 AND WtRank <= 5290655.83
- Step 12b. Use field calculator to: [AdjWtRank] = 1.
- Step 12c. Select by Attribute: WtRank >= 5290655.84 AND WtRank <= 10667713.75
- Step 12d. Use field calculator to: [AdjWtRank] = 2.
- Step 12e. Select by Attribute: WtRank >= 10667713.76 AND WtRank <= 20375255.15
- Step 12f. Use field calculator to: [AdjWtRank] = 3.
- Step 12g. Select by Attribute: WtRank >= 20375255.16 AND WtRank <= 36964707.53

- Step 12h. Use field calculator to: [AdjWtRank] = 4.
- Step 12i. Select by Attribute: WtRank >= 36964707.54 AND WtRank <= 70140969.49
- Step 12j. Use field calculator to: [AdjWtRank] = 5.
- Step 12k. Select by Attribute: WtRank >= 70140969.50 AND WtRank <= 128272696.62
- Step 12l. Use field calculator to: [AdjWtRank] = 6.
- Step 12m. Select by Attribute: WtRank >= 128272696.63 AND WtRank <= 365052486.62
- Step 12n. Use field calculator to: [AdjWtRank] = 7.
- Step 13a. Merge WV\_Rivers\_Corrid\_1000ft with WV\_Ecoregion and output to WV\_Rivers\_Corrid\_1000ft\_Merg
- Step 13b. Edit RecoveryBaseline use field calculator to [Rank], [WtRank], and [AdjWtRank] = 0.
- Step 14. Convert WV\_Rivers\_Corrid\_1000ft Polygon to Raster RiverCorridBaseline\_PolygonToRa2
- Step 15. Clip Oregon NWI wetlands to WV\_Ecoregion to create WV\_Wetlands.
- Step 16. Add fields double 'Acres', integer 'Rank', double 'WtRank', and integer 'AdjWtRank.'
- Step 17. Use Calculate Geometry function to calculate each wetland record acreage.
- Step 18. Use field calculator to: [Rank] = 3.
- Step 19. Use field calculator to: [Shape\_Area] \* [Rank] = [WtRank].
- Step 20. Add Field short int 'AdjWtRank' and classify on WtRank field to 7 class ranges.
- Step 21a. Select by Attribute: WtRank >= 0.007219 AND WtRank <= 24.462791
- Step 22b. Use field calculator to: [AdjWtRank] = 1.
- Step 23c. Select by Attribute: WtRank >= 24.462792 AND WtRank <= 101.807457
- Step 24d. Use field calculator to: [AdjWtRank] = 2.
- Step 25e. Select by Attribute: WtRank >= 101.807458 AND WtRank <= 286.408706
- Step 26f. Use field calculator to: [AdjWtRank] = 3.
- Step 27g. Select by Attribute: WtRank >= 286.408707 AND WtRank <= 677.024747
- Step 28h. Use field calculator to: [AdjWtRank] = 4.
- Step 29i. Select by Attribute: WtRank >= 677.024748 AND WtRank <= 1346.354080
- Step 30j. Use field calculator to: [AdjWtRank] = 5.
- Step 31k. Select by Attribute: WtRank >= 1346.354081 AND WtRank <= 8025.845538
- Step 32l. Use field calculator to: [AdjWtRank] = 6.
- Step 33m. Select by Attribute: WtRank >= 8025.845539 AND WtRank <= 14045.028344
- Step 34n. Use field calculator to: [AdjWtRank] = 7.
- Step 35a. Merge WV\_Wetlands with WV\_Ecoregion and output to WV\_RecoveryWetlands





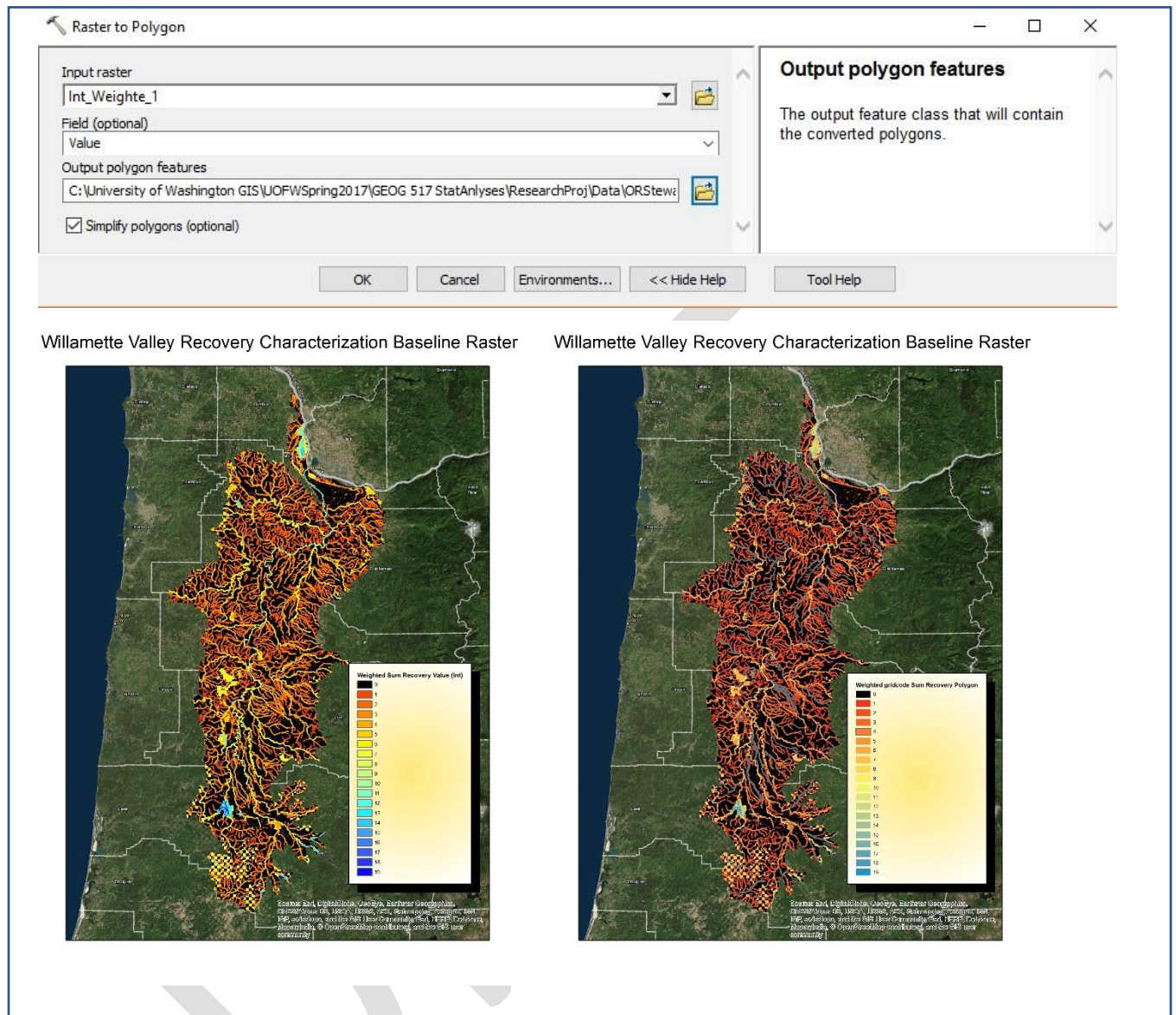


Figure 3. Conversion of integer (derived from continuous surface weighted-sum output raster) output raster to polygon.

- Step 36b. Edit WV\_RecoveryWetlands use field calculator to [Rank], [WtRank], and [AdjWtRank] = 0.
- Step 37. Convert WV\_RecoveryWetlands Polygon to Raster WV\_RecoveryWetlands Baseline\_PolygonToRa2.
- Step 38. Use Int (Spatial Analyst Tool) to convert each pixel in the weighted sum raster to an integer by truncation.

- Step 39. Use Raster to Polygon Tool to convert raster to a polygon that can be used in pattern analyses.
- Step 40. Run Local Moran's I on output polygon converted from weighted sum overlay raster (Figure 4).

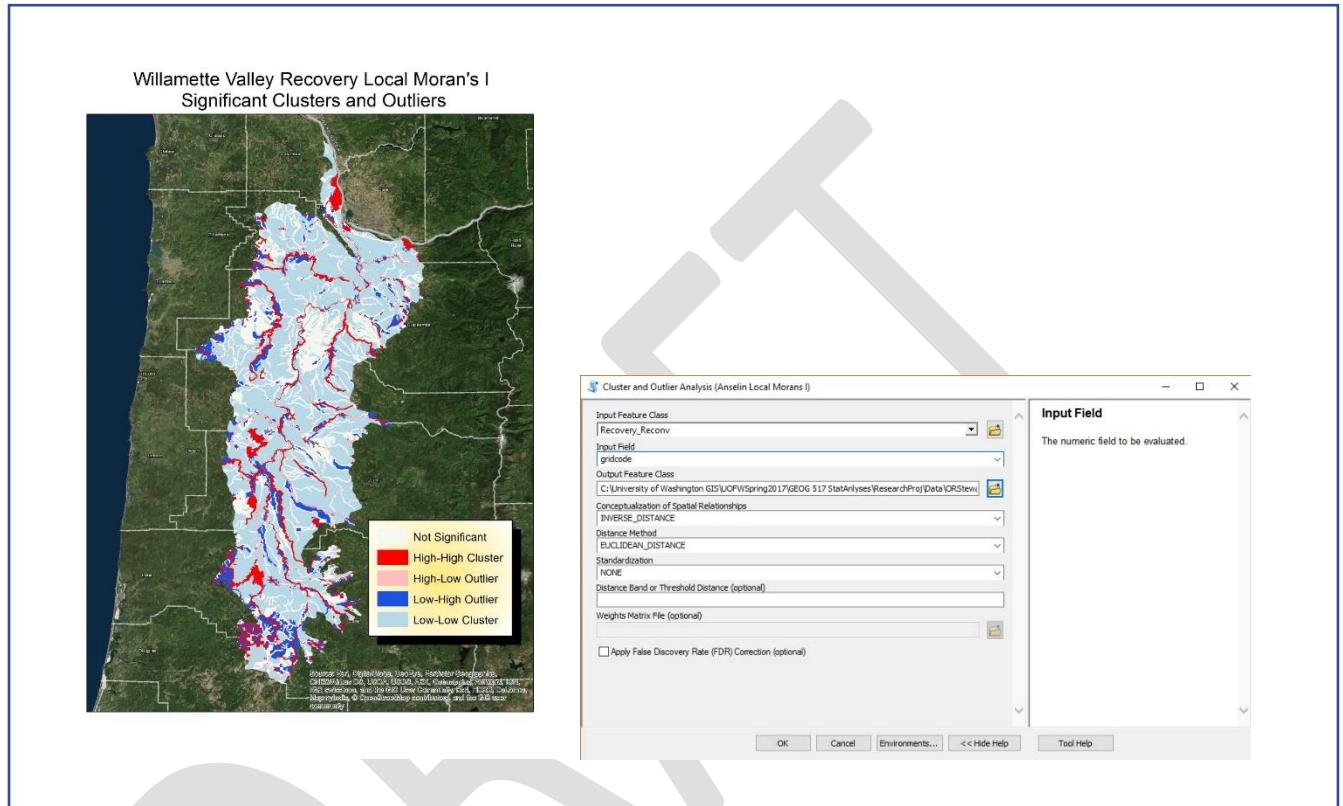


Figure 4. Local Moran's I output polygon.

A positive value for  $I$  (Zhang et al 2008) indicates that a feature has neighboring features with similarly high or low attribute values (e.g., High-High: Red or Low-Low: Light Blue) and that this feature is part of a cluster. A negative value for  $I$  indicates a feature has neighboring features of dissimilar values (e.g., High-Low: Rose or Low-High: Blue) and that the feature is an outlier. In either case the  $p$ -value must be statistically significant ( $\leq 0.05$ ). Generally, in the application displayed in Figure 4, the High-High clusters and the Low-High outliers appear to be aligning relatively consistently with major tributaries to the Willamette River and stretches of the main-stem Willamette River. The High-Low outlier and the Low-Low clusters form a patchwork matrix in the associated watersheds of the main tributaries to the Willamette River and the main-stem Willamette River. With respect to natural resource associations, the former pattern is likely heavily influenced by the stream corridor parameter used in the model

while the latter is probably more influenced by the wetlands parameter. Both patterns are of course also influenced by the geographic distribution of ecoregion recovery actions.

Step 41. Run Getis-Ord  $G^*$  on output polygon converted from raster converted from weighted sum overlay raster (Figure 5).

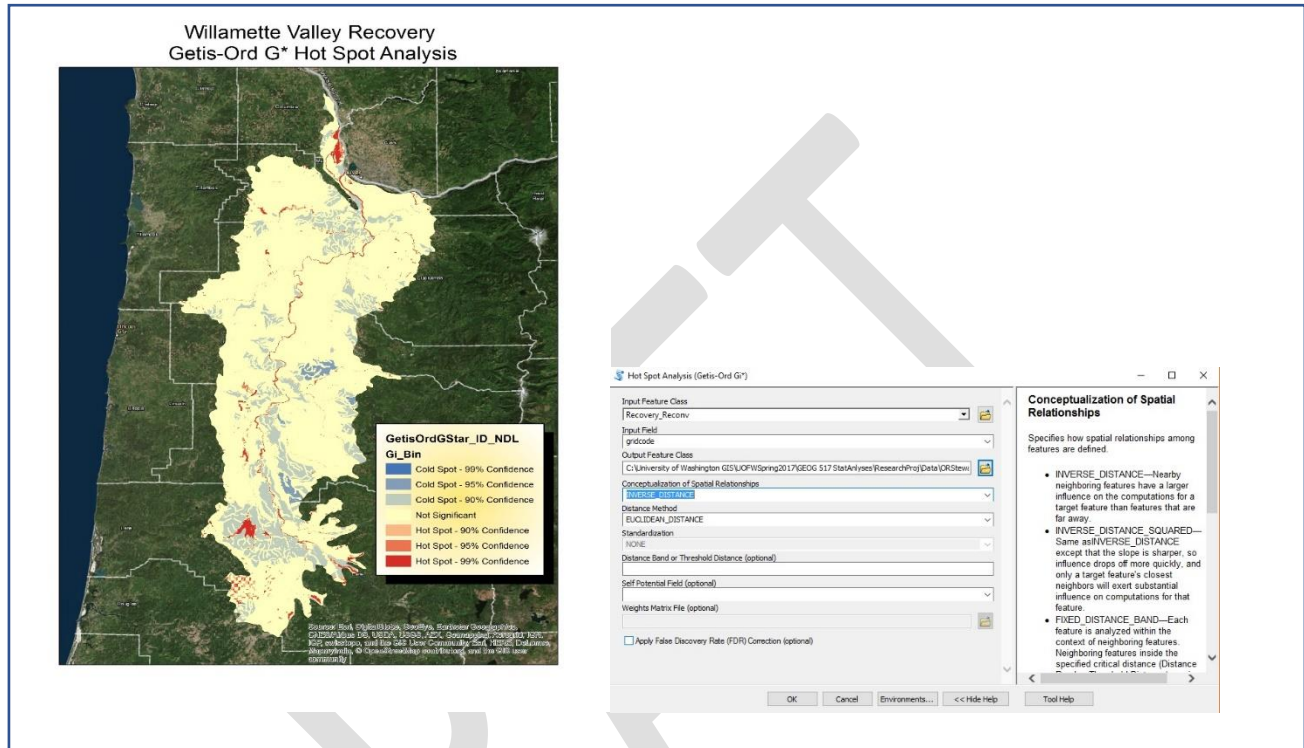


Figure 5. Getis-Ord  $G^*$  output polygon.

The Getis-Ord  $G^*$  statistic (Harris et al 2016) identifies those cluster patterns with higher (hot spot) and lower values (cold spot) than would be statistically expected in a random distribution. The hot spots are differentiated by their statistical significance ( $\leq 0.01$ : Red and  $\leq 0.05$ : Rose). Cold spots are also differentiated by their statistical significance ( $\leq 0.01$ : Blue and  $\leq 0.05$ : Light Blue). Generally, in the application displayed in Figure 5 the aggregate larger hot spots are restricted two areas at the northern and southern ends of the Willamette Valley with a few spotted or intermittent linear patterns largely associated with the main-stem Willamette River and some of the larger tributaries to the Willamette River. Cold spots also appear to have a north end / south end affinity, albeit with broader connector bands between. But much of the Willamette Valley registers as statistically insignificant for recovery actions in this model. Overall, the Getis-Ord  $G^*$  application is much less inclusive of recovery activities as compared to the Local Moran's  $I$  application. Hot spots identified in Moran's  $I$  are also picked up in Getis-Ord  $G^*$ , but with the possible exceptions of Sauvie Island and Fern Hill Wildlife Area, the latter appears to be far more conservative in hot spot assignment coverage.



## 7. Hot Spot Areas Identified in Each Pattern Analysis

A very cursory review and characterization of five hot spot areas identified by the pattern analyses was done to help verify whether the model was making appropriate Willamette Valley ecoregion recovery hot spot selections. High value clusters at the 99% confidence level and covering relatively larger areal cover were chosen for this review. A determination of “suitable hot spot” determination was based on: 1) a review of the value and sensitivity of the area’s associated natural resources, 2) evidence of significant ecosystem level recovery actions, and 3) evidence of a long-term management and protection in perpetuity strategy.

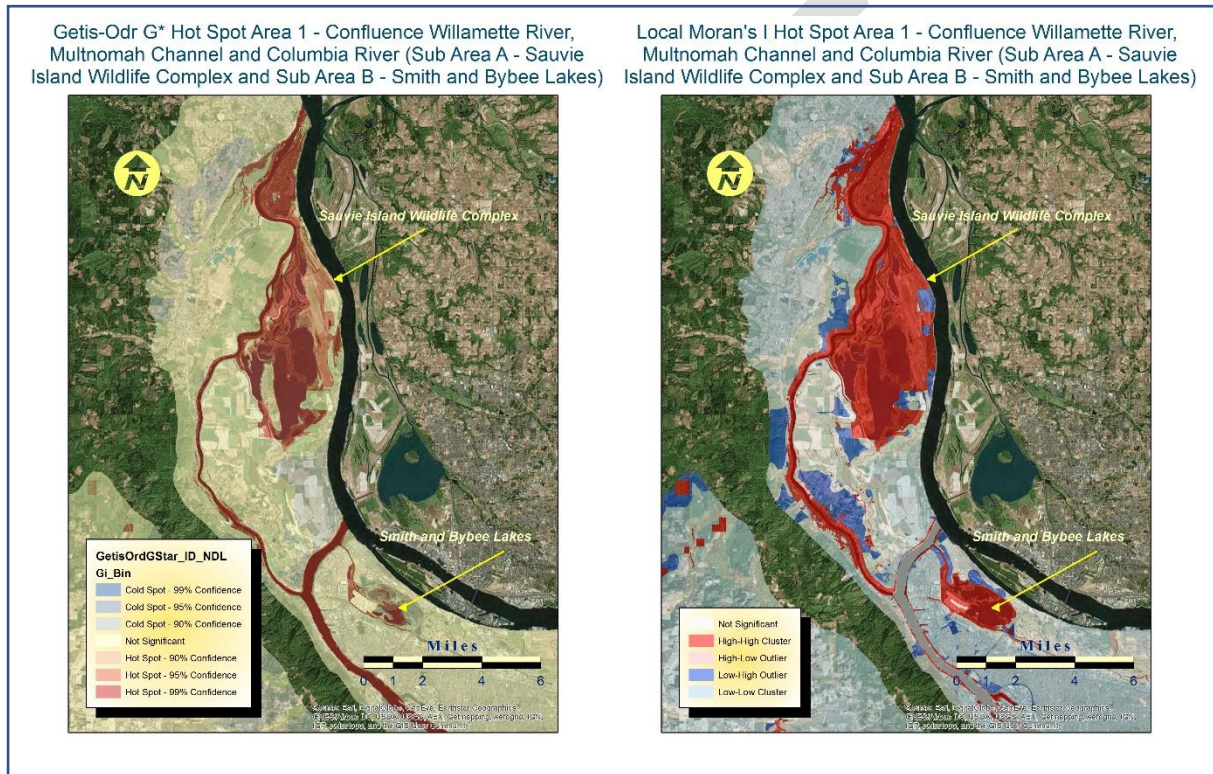


Figure 6. Hot Spot Area 1 (Confluence Willamette River, Multnomah Channel, and Columbia River).

**The Sauvie Island Wildlife Area** (Figure 6) consists of over 11,500 acres of state-owned habitat for over 275 species of birds, 37 species of mammals, 12 species of reptiles and amphibians, and numerous species of fish and plants. Thirteen listed salmonid runs or Evolutionary Significant Units (ESUs) are known to or may possibly occur on the wildlife area including chum, coho, Chinook (federally threatened), sockeye, and steelhead (federally threatened). White sturgeon and Pacific lamprey (federal species of concern) also use Sauvie Island aquatic habitats. Salmon, steelhead, and trout occur in waters outside the levees on the wildlife area (ODFW 2012).

Wetlands and other bodies of water, including 21 lakes as well as a complex network of sloughs, connecting channels, and streams. Over-wintering waterfowl can number over 200,000 ducks, geese, and swans. Fall brings migrating Sandhill cranes, Snow geese, Tundra swans, Cackling and Canada geese. Great Blue Heron and Osprey nest on the island, and Bald eagles both breed and congregate in winter along with wintering Red-tailed Hawks, Northern Harriers, Peregrine Falcons, and the less common Rough-legged Hawks and Merlin. Shorebird numbers have reached over 30,000. Three species of birds once common and now rare or unusual on Sauvie Island include the Lewis Woodpecker, Western Meadowlark, and (Streaked) Horned Lark (federally listed as threatened).

Determination: **Suitable Hot Spot.**

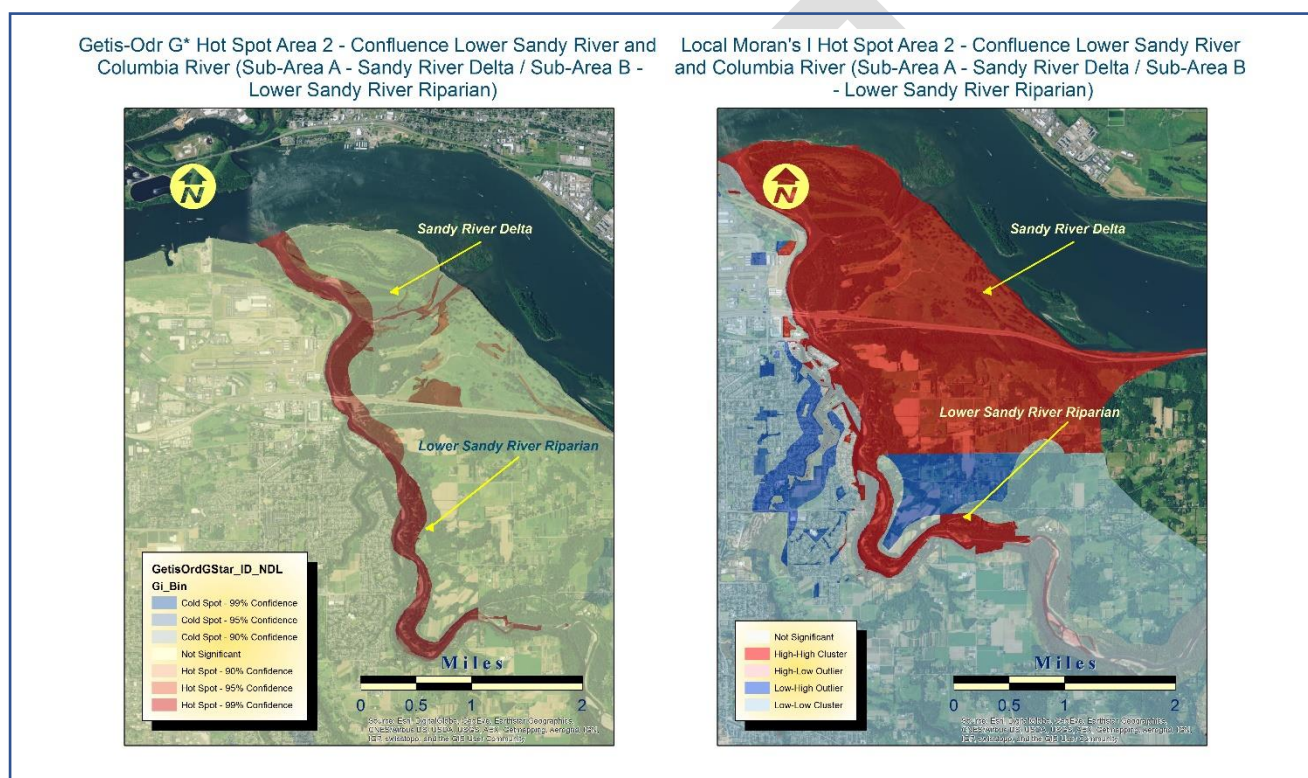


Figure 7. Hot Spot Area 2 (Sandy River Delta).

**The Sandy River Delta** (Figure 7) was historically a wooded, riparian wetland with components of ponds, sloughs, bottomland woodland, oak woodland, prairie, and low and high elevation floodplain. It has been greatly altered by past agricultural practices and the Columbia River hydropower system. It became heavily infested with weedy species such as reed canary grass, blackberries and thistles; some portions were drained and planted to pasture grasses. The main channel of the Sandy River was blocked in the 1930's, and diverted into the "Little Sandy River". The original Sandy River channel filled in and largely became a slough. The Sandy River Delta restoration project has focused on riparian forest and wetland expansion and enhancement. Also, The US Forest Service proposes to remove the 1930's dam across the Sandy River to help restore the historic hydrologic pattern and improve estuarine habitat (tidal



freshwater) for anadromous fish. Restoration of open upland (meadow/prairie) is also occurring (USFS 2010).

Restoration actions include: 1) wetlands restoration and monitoring of restoration success, 2) controlling invasive species (e.g., reed canary grass) and replacing native plant communities, 3) expanding seasonal open water areas, 4) creating palustrine emergent wetlands, and 6) restoring bottomland riparian forest (black cottonwood, willow, and ash). Benefits will accrue to neo-tropical migrant birds, sensitive red-legged frogs and Western pond turtles, great blue herons, raptors, and anadromous fish (USFS 2010).

Determination: **Suitable Hot Spot.**

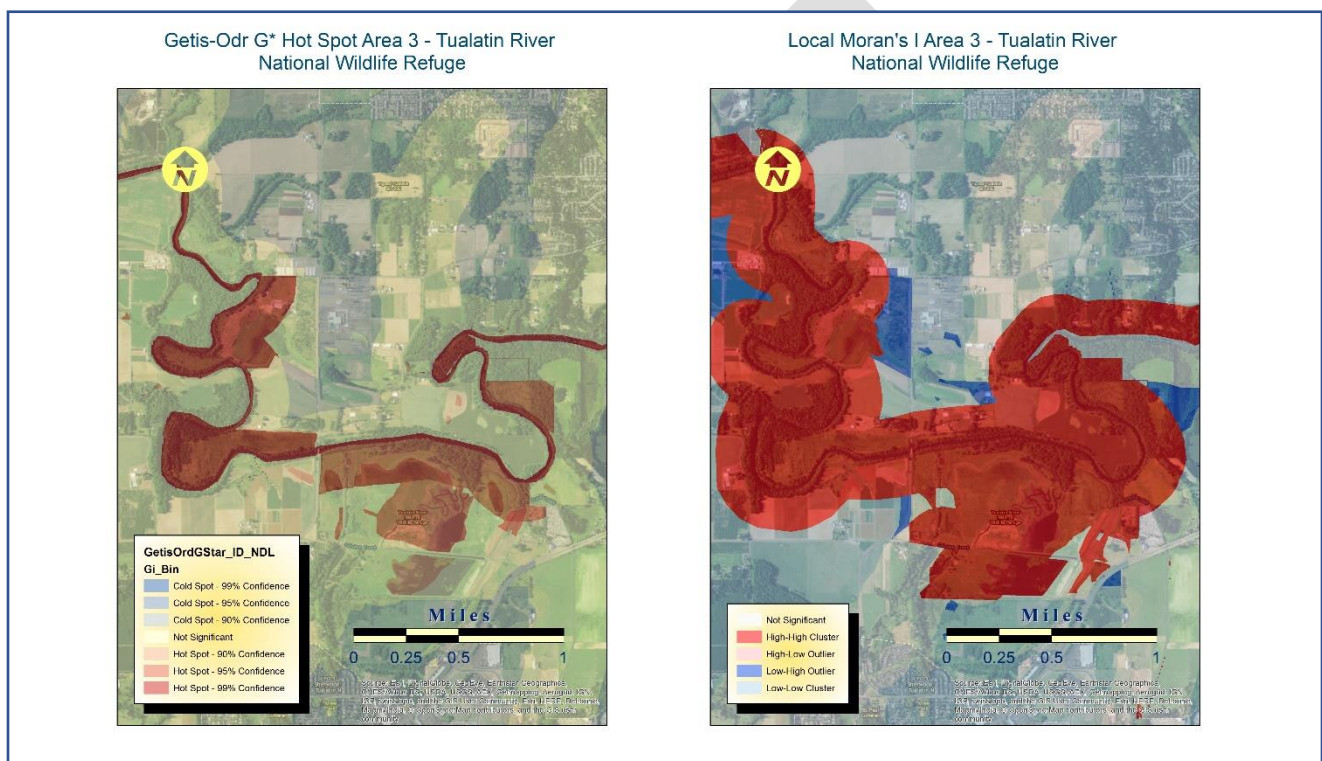


Figure 8. Hot Spot Area 3 (Tualatin River National Wildlife Refuge - TRNWR).

**The Tualatin River National Wildlife Refuge** (Figure 8) was historically a mosaic of peat wetland and floodplain riparian habitat until post European settlement converted it to agricultural and industrial uses, with hog and dairy farms, crops such as corn and onions, and old abandoned chromium leaching tannery sites.

Today, the TRNWR spreads out over ten miles along the Tualatin River, Rock Creek, and Chicken Creek. Birds at the refuge include Canada Geese, Wood Ducks, swans, Northern Pintails, Green Herons, Belted Kingfishers, Great Blue Herons, Sandhill Cranes, Pacific-slope Flycatchers, Red-tailed Hawks, Peregrine Falcons, Yellow Warblers, Western Flycatchers, Killdeer, Northern Harriers, Ospreys, egrets, owls, and Black-headed Grosbeaks.

This refuge was established to protect and restore native habitats and associated fish and wildlife species. Special focus is on protecting neotropical songbirds, wading birds and shorebirds, and wintering waterfowl. The habitat focus for these species includes protecting and restoring Tualatin River floodplains and riparian areas. This also benefits water quality, flood storage, and water recharge. Management strategies support the recovery of federally listed threatened and endangered species as well as preventing candidate species and species of concern from reaching a state of further degradation (USFWS 2016).

Determination: **Suitable Hot Spot.**

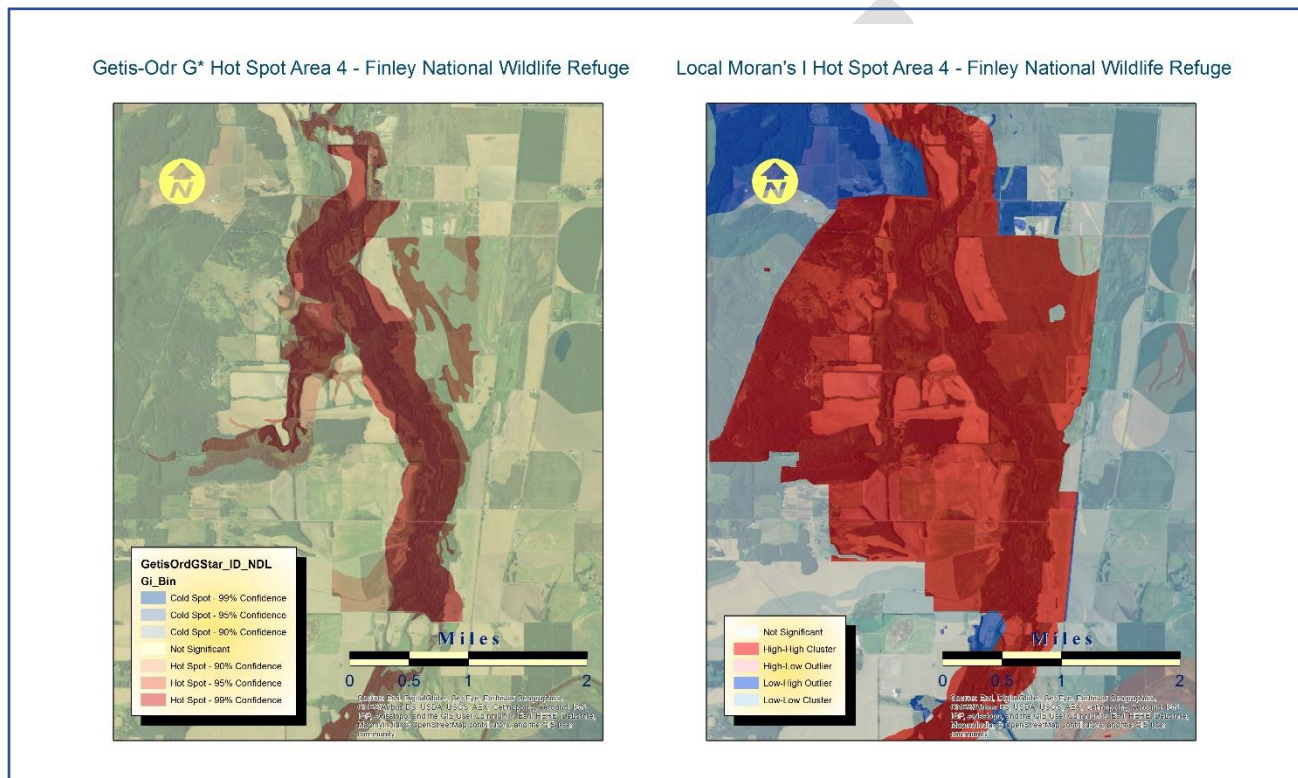


Figure 9. Hot Spot Area 4 (William Finley National Wildlife Refuge).

**The William Finley National Wildlife Refuge** (Figure 9) was established in 1964 to provide winter habitat for Dusky Canada Geese, a subspecies that winters primarily in the Willamette Valley. Four other Canada Geese subspecies also regularly winter here. Grass fields provide forage for wintering goose flocks, and restored wetlands provide roosting habitat for geese, as well as habitat for other waterfowl. A riparian ash forest, oak-conifer woodland, oak savanna, wet prairie, and upland prairie provide habitat for other wildlife and rare native plants.

The riparian habitat on the refuge supports Partners in Flight focal species Yellow Warbler and Swainson's Thrush. Oak woodlands support Partners in Flight focal species Bushtit, Bewick's Wren, and Western Wood-Pewee. The refuge contains several rare natural communities, including three Research Natural Areas. The Willamette Floodplain RNA contains 475-acres of undisturbed wet prairie. Approximately 1,000 acres of Oregon white oak woodland and savanna are found on the refuge, including 70-acres of oak woodland in the Pigeon Butte RNA. Maple



Knoll RNA consists of 100-acres of old-growth bigleaf maple. The refuge also contains 12-acres of upland prairie and 500-acres of Oregon ash riparian forest. The refuge supports large numbers of waterfowl during the winter. The 2001 mid-winter waterfowl count totaled 55,950 ducks and geese on the refuge on one day.

The wetland prairie in Finley NWR is the largest contiguous tract of historic (remnant) wetland prairie habitat remaining within the Willamette Valley. It contains a high diversity of native species, unaltered hydrology, and topography with mounds, hummocks, and vernal pools. It was established as a Research Natural Area (RNA) in 1966, at which time prescribed burning was used to maintain the prairie habitat structure. Fire was used only sparingly until 1990, when a fire plan was implemented and burning increased. Selective mowing and brush cutting with chain saws have also been utilized as methods for controlling woody vegetation. All mechanical work, including mowing and removal of felled trees/shrubs, is done using a low ground pressure skid-steer tractor. The preferred fire interval on the wetland prairie management units is 2-4 years. Active wetland prairie restoration was begun in 1999 on approximately 130 acres of retired agricultural fields within the NWR. Typical restoration in these areas has involved herbicide treatments for two successive growing seasons, often with prescribed fire in one or both seasons depending on herbaceous cover, and no-till drilling of native wet prairie grasses and forbs in the second fall. The first-year follow-up treatment may involve late spring mowing to reduce seed

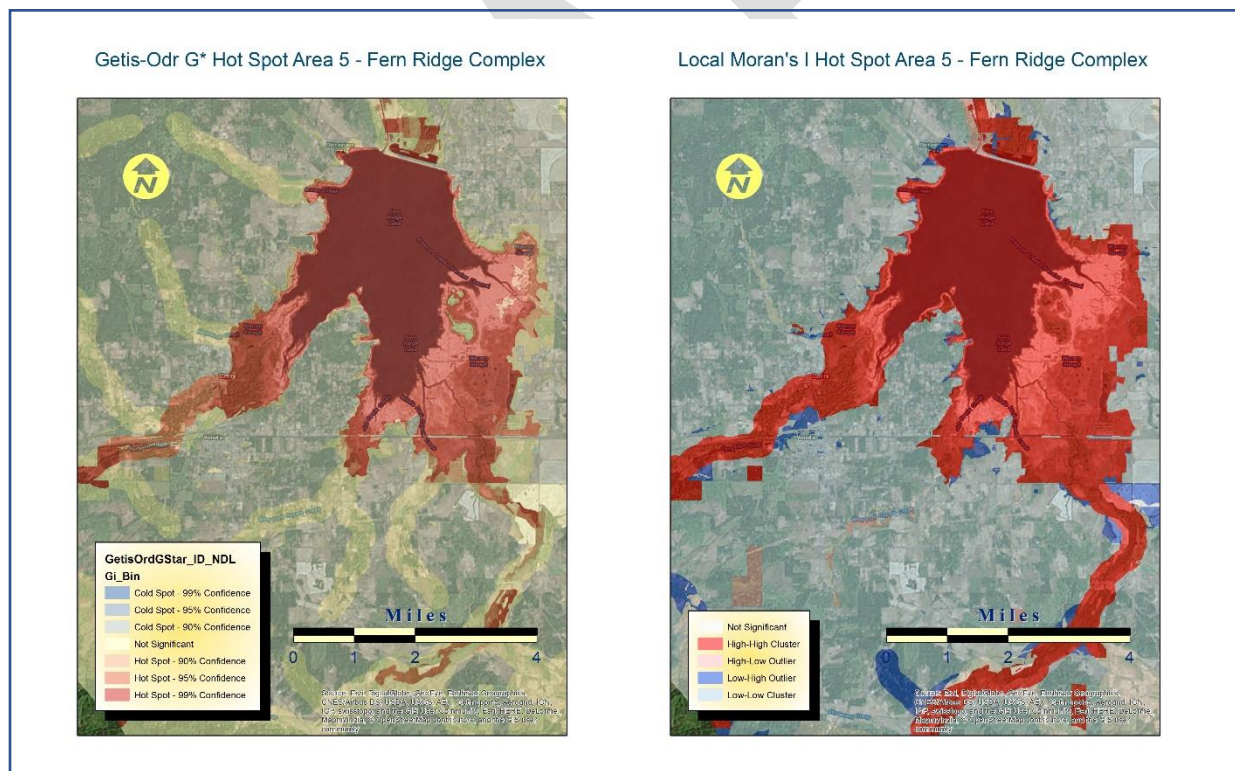


Figure10. Hot Spot Area 5. (Fern-Ridge Wildlife Area)

set of non-native annuals, spot herbicide treatment of invasive plants that may impact native establishment, and supplemental seeding to increase species diversity (USFWS 2011).

Determination: **Suitable Hot Spot.**

**The Fern Ridge Wildlife Area** (Figure 10) was created in 1957 under a license agreement between the Corps of Engineers (USACE) and Oregon Game Commission (now Oregon Department of Fish and Wildlife - ODFW). The agreement provides authority for the state to "develop, conserve, and manage all wildlife resources on a 5,010-acre portion of the 12,716 acres owned by the USACE around the Fern Ridge Reservoir.

Management emphasis on the wildlife area centers primarily around waterfowl and wetlands habitat management to provide food, water, and sanctuary for wintering waterfowl, shorebirds, and other wildlife. The expansive marsh / Pacific Flyway proximity in the southern Willamette Valley ideally supports use by many wetland bird species. Active management techniques are combined with protective measures to provide a habitat base that supports wildlife diversity. Over 250 species of birds utilize the area at some point in their life cycle, either as resident and nesting birds or as seasonal migrants.

Four Primary goals guide management programs and project developments on the Fern Ridge Wildlife Area. These goals are integrated with resource management strategies identified by the Wildlife Management Districts encompassing the Willamette Valley, Pacific Flyway Plans, and ODFW Statewide Waterfowl and Wildlife Diversity Plans. By integrating management goals for Fern Ridge with plans addressing a broader geographic area, the Fern Ridge Wildlife Area becomes part of a connective landscape network for wildlife and wildlife habitat management within the Willamette Valley ecosystem. These goals are: 1) attract and support waterfowl in the Southern Willamette Valley, 2) manage for wildlife oriented recreation that is compatible with conservation of wildlife resources, 3) manage habitats for wildlife species diversity, and 4) provide for wildlife and habitat orientated education (ODFW 2009).

Determination: **Suitable Hot Spot.**

## **Conclusion**

The model appears to be correctly identifying suitable Willamette Valley ecoregion recovery action hot spots. The initial post pattern analyses review revealed an identification of five very high profile centers of ecological recovery activity in areas with existing and /or potentially imperiled natural resources. They were all also uniquely managed and protected for their ecological values. The fact that the model has found these important natural resource areas is encouraging but not surprising. In fact, if it had missed any one of these areas, there would be a significant cause for concern for the model's design.

But what about smaller and more isolated recovery action hot spots? There is more analysis review work needed to discern the model's sensitivity for identifying these areas. The Local Moran's I appears to be doing a somewhat better job than the Getis-Ord G\* at capturing the mitigation and conservation bank operations, which do tend to be much smaller in size and more geographically isolated from other hot spot areas. The question becomes, which pattern recognition application is making the appropriate hot spot omissions and inclusions? Perhaps

the mitigation banks should be captured but rank lower in a hierarchy of recovery action hot spots. Or maybe the model's spatial relationship setting should be changed to help assure a more inclusive hot spot clustering operation. Other adjustments may be needed as well. Alterations to resource scores, weighting methods, spatial relationship settings, and / or distance band thresholds are all recommended for future iterative trials of the model. At this point, new variables are not proposed, but that may be another avenue of iterative approaches that could help achieve the best possible results.

It should be noted that the largest land area (35,475-acres) record in the Recovery Area Database was designated for multiple use land management including extractive uses such as timber harvest and mining (Figure 11). It is at least partially containing Oregon and California

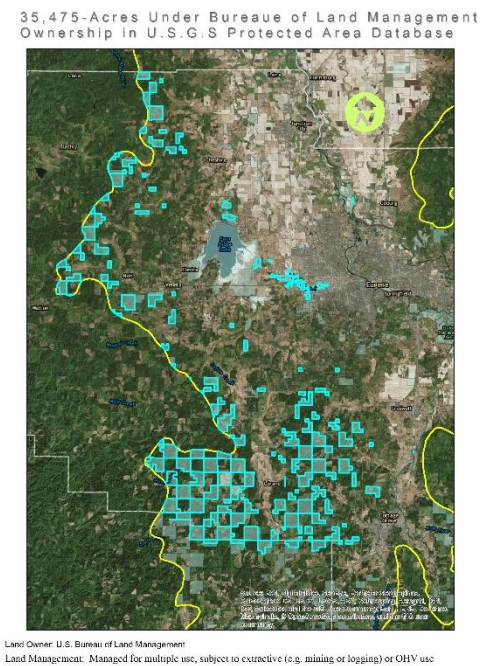


Figure 11. BLM Multiple Use Lands Ownerships in Southern Willamette Valley Ecoregion.

Railroad (O&C) holdings where there is an ongoing debate over whether management priorities are dictated by the O&C Act of 1937 (43 U.S.C. 1181a et seq.) or the 1994 Northwest Forest Plan, a controversy that is even further complicated by Federal Agency responsibilities under the Federal Endangered Species Act (16 U.S.C. 1531 - 1544). Because ecological recovery and protection were not unilateral goals on these parcels, they were excluded from being considered as viable candidate Willamette Valley ecoregion recovery hot spots. However, further investigation into individual parcels is likely warranted and recommended.

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## WEB LINKS

### Sauvie Island:

[http://www.dfw.state.or.us/resources/visitors/sauvie\\_island/](http://www.dfw.state.or.us/resources/visitors/sauvie_island/)  
<http://audubonportland.org/local-birding/iba/iba-map/sauvie>  
<https://www.fws.gov/oregonfwo/articles.cfm?id=149489450>  
[http://www.dfw.state.or.us/wildlife/management\\_plans/wildlife\\_areas/docs/SIWA%20Management%20Plan%20April%202012.pdf](http://www.dfw.state.or.us/wildlife/management_plans/wildlife_areas/docs/SIWA%20Management%20Plan%20April%202012.pdf)  
[http://www.dfw.state.or.us/fish/CRP/docs/lower\\_columbia\\_sturgeon/LCR white sturgeon conservation plan.pdf](http://www.dfw.state.or.us/fish/CRP/docs/lower_columbia_sturgeon/LCR_white_sturgeon_conservation_plan.pdf)

### Sandy River Delta:

[http://www.conservationregistry.org/assets/0000/2703/Sany River Delta Habitat Restoration Annual Progress Report 2010 .pdf](http://www.conservationregistry.org/assets/0000/2703/Sany_River_Delta_Habitat_Restoration_Annual_Progress_Report_2010_.pdf)

### Tualatin River National Wildlife Refuge:

[file:///C:/Users/jlmar/Downloads/TRNWR\\_IMP\\_FINAL\\_04262016.pdf](file:///C:/Users/jlmar/Downloads/TRNWR_IMP_FINAL_04262016.pdf)

### Finley National Wildlife Refuge:

<http://netapp.audubon.org/IBA/Reports/2582>  
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<https://www.fws.gov/willamettevalley/finley/wildlife.html>  
<https://www.fws.gov/pacific/planning/main/docs/OR/Willamette%20Valley/WillValleyFinalCCPforWeb.pdf>  
<https://www.fws.gov/pacific/planning/main/docs/OR/docswillamettevalley.htm>

### Fern Ridge Wildlife Area

[http://www.dfw.state.or.us/resources/visitors/fern\\_ridge\\_wildlife\\_area/management.asp](http://www.dfw.state.or.us/resources/visitors/fern_ridge_wildlife_area/management.asp)  
[http://www.dfw.state.or.us/wildlife/management\\_plans/wildlife\\_areas/docs/FRWA%20Management%20Plan%20June%202009.pdf](http://www.dfw.state.or.us/wildlife/management_plans/wildlife_areas/docs/FRWA%20Management%20Plan%20June%202009.pdf)  
[http://www.dfw.state.or.us/resources/visitors/fern\\_ridge\\_wildlife\\_area/index.asp](http://www.dfw.state.or.us/resources/visitors/fern_ridge_wildlife_area/index.asp)

### Regulatory In-lieu Fee and Bank Information Tracking System (RIBITS):

[https://ribits.usace.army.mil/ribits\\_apex/f?p=107:2](https://ribits.usace.army.mil/ribits_apex/f?p=107:2)

### Oregon Watershed Restoration Inventory

<http://oregonexplorer.info/content/enhancing-watersheds-oregon?topic=56&ptopic=38#TheOWRIDatabaseandGISdata>

## WEB LINKS (Continued)

U.S. Geological Survey New Protected Area Database (PAD-US)

<https://gapanalysis.usgs.gov/padus/data/download/>

<https://www.usgs.gov/news/new-protected-area-database-pad-us-released>

<https://www.usgs.gov/products/maps/gis-data>

<https://maps.usgs.gov/padus/>

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