Herrera Environmental Consultants, Inc.

Final Memorandum

To	Kimberly Swan, Clackamas River Water Providers
From	Jennifer Schmidt, Herrera Environmental Consultants
Date	May 31, 2012
Subject	GIS Forestry Activities Risk Analysis Results

Introduction

The Clackamas River is a source of drinking water for more than 300,000 people in Clackamas County and is an important resource for helping to meet future water demand in the region. The Clackamas River Water Providers (CRWP) represents five municipal surface water intakes on the Clackamas River: City of Estacada, Clackamas River Water, North Clackamas County Water Commission, South Fork Water Board, and City of Lake Oswego. In 2010, the CRWP developed a Drinking Water Protection Plan that outlined a series of strategies and programs to address potential threats to source water quality in the Clackamas River watershed. Herrera Environmental Consultants (Herrera) was hired to complete a series of geographic information system (GIS) analyses in order to help identify potential pathways for pollutant export from the Clackamas River Watershed. The following major high-risk activity categories were identified in the Drinking Water Protection Plan (Clackamas River Water Providers 2010):

- Septic Systems
- Agricultural Activities
- Forestry Activities
- Vulnerable Soils
- Urban Development
- Point-Source Pollutants

The goal of these GIS analyses was to map risk factors known to have a strong negative correlation with drinking water quality in the Clackamas River watershed. Mapped risk "hot spots" for each category will provide a spatial context for both the geography and intensity of risk by activity that can be used by the CRWP help prioritize mitigation efforts. This memorandum focuses specifically on the methods and results of the GIS Forestry Activities Risk Assessment portion of the Drinking Water Protection Plan.

Potential Threats from Forestry Activities

The Clackamas River Water Providers (CRWP) have identified stormwater runoff from forestry activities as being one of the most significant sources of risk to drinking water quality in the

Clackamas River watershed. The primary threats to source water from forestry activities include (U.S. EPA 1993):

1. Non-point source pollution from sediments, nutrients, forest chemicals, organic debris (residual logs, slash, litter) and oxygen-depleting organic soil matter from timber harvesting, mechanical equipment operation, prescribed burning, regeneration methods, and road construction and use.

2. Increased stream and waterbody temperature as a result of vegetation removal through timber harvesting or herbicide use in riparian areas.

3. Increased streamflow as a result of vegetation removal, resulting in channel scour, eroding streambanks, increased sedimentation, and increased peak flows. The amount of streamflow increase "is related to total area harvested, topography, soil type, and harvesting practices" (Likens et al., 1970; Eschner and Larmoyeux, 1963; Blackburn et al., 1982).

Approximately 90% of the Clackamas River watershed is comprised of forest and shrubland (WPN 2005). The majority of this area (roughly 70%) is in the upper watershed within the Mt. Hood National Forest and is managed by the U.S. Forest Service (USFS); the area in between the national forest and the lower watershed also includes parcels of land owned by private timber companies and the Bureau of Land Management (BLM) (Clackamas River Water Providers 2010). Forested watersheds, like the Clackamas, produce better water quality than any other surface water source; however, forestry activities that are not properly managed can have significant adverse impacts on downstream water quality (Morgenstern 2006).

GIS Forestry Activities Risk Analysis

Herrera performed a GIS analysis mapping the extent and intensity of forestry activities in the Clackamas River watershed to help predict the potential risk of stormwater runoff from these activities to source water quality. This methodology involved gathering, ranking, and overlaying the following datasets in GIS:

- Forestry activities on federal, state and private forest land over a several year time period, including 1) fertilizer and herbicide use; 2) clearcutting; 3) pre-commercial and commercial thinning; 3) burning; 4) road construction; 5) site preparation; and 6) other harvest activities

- Proximity of forestry activities to riparian stream buffers and surface water

- Soils that are highly sensitive to erosion and landslide areas

The following sections provide more detailed information on this risk analysis, including analysis objectives, methods for how each of the risk datasets were generated, and data sources used and limitations.

Analysis Objectives

The primary objectives of the GIS forestry activities risk analysis were to:

1. Identify and characterize forest land in the Clackamas River watershed.

2. Use information from the Forest Activity Computerized Tracking System (FACTS) maintained by USFS and the Oregon Department of Forestry (ODF) to map the distribution of forest practice activities related to growing and harvesting timber in the watershed.

3. Identify and map vulnerable soils, floodplains, and landslide areas that could contribute to water quality impacts from forestry activities.

4. Rank, weight, and overlay each dataset and risk factor to produce a map of potential risk to source water quality for each major category of forestry activities in the Clackamas River watershed.

Data Sources and Limitations

The primary GIS datasets required to assess the risk to source water quality from forestry activities in the Clackamas River watershed are the extent and intensity of forest practices extracted from the Forest Service Activity Tracking System (FACTS) and vulnerable soils and landslide areas. The following sections describe these datasets in more detail, including any major data limitations that are important to keep in mind when interpreting the GIS forestry activities risk analysis results. Documentation on all datasets used in the analyses can be found in Table 1. Herrera converted all GIS datasets used in the forestry activities risk analysis to the Oregon State Plane North HARN 83 map projection, with both the vertical and horizontal datum measured in feet.

Forestry Service Activity Tracking System (FACTS) Database

FACTS is a database used by all levels of the Forest Service to track information about forest practice activities occuring on forest land related to growing and harvesting timber. Herrera obtained FACTS activity data from two sources for the Clackamas River watershed: 1) Mt. Hood National Forest from USFS; and 2) private and state forest land from the Oregon Department of Forestry (ODF).

Mt. Hood National Forest FACTS Database

Herrera obtained data extracted from the USFS FACTS database in GIS format from USFS GIS staff at Mt. Hood National Forest GIS representing nearly 3,000 forestry activities in the national forest portion of the watershed for more than 50 categories with planned fiscal years from 1979 to 2020. Information provided for each forestry activity area included the number of affected acres, planned and accomplished activity dates, site slope and elevation, and equipment used. This dataset is summary in nature only and does not provide detailed activity information for sites, such as pounds of fertilizer applied.

Private and State Forest Land

Oregon State law OAR 629-605-0140 requires a written notice be sumitted to the State Forester a minimum of 15 days before any of the following operations take place on forest land: 1) harvesting of forest trees; 2) application of chemicals; 3) pre-commercial thinning; 4) clearing of forestland to non-forest used; 5) construction, reconstruction, and improvement of roads; and 6) site preparation for reforestation involving clearing or use of heavy machinery. The ODF FACTS database contains summary information on all notifications of operations for private forest land in the Clackamas River watershed, including names and addresses of the listed operator, landowner, and timber owner; declared size of each operation unit and types of activities; legal description for the location of each unit; and special conditions that may exist (http://www.oregon.gov/ODF/privateforests/fpaFACTS.shtml).

Herrera downloaded FACTS databases for state and private forest land for 2007 to 2009 from the ODF website and mapped the information by activity type in GIS based on provided legal descriptions. This dataset included the locations of approximately 230 forestry activities in 12 categories on state and private forest land in the Clackamas River watershed. There are two important limitations to keep in mind when interpreting risk analysis results based on data extracted from the ODF FACTS databases. First, the legal descriptions provided for activity areas are based on township-section-range data and are referenced to the quarter-quarter quad level. This means that the mapped locations are approximate as compared to the information obtained from USFS. In some cases, township-section-range data in the Clackamas River watershed is irregularly shaped; for these areas, it was not possible to refine the activity area to beyond the entire township-section-range. Second, the information in the ODF FACTS databases is summary in nature only and does not contain all data available on the paper notification of operation forms regarding activity information such as chemical application rates. However, each activity polygon does contain a notification form identifier; this will allow the CRWP to easily request these forms for forestry activity "hot spots" in the future.

Vulnerable Soils and Floodplains

Higher sediment loads from soil erosion due to log removal, site preparation, and other forestry activities can have a major impact on water quality downstream of forested areas (McNulty et. al. 1995). Soil erosion resulting from road construction and road use in particular is the primary source of non-point source pollution from forested land, "contributing up to 90% of the total sediment from forestry operations" (EPA 2012). In addition, soils that have experienced past erosion are more likely to erode again in the future (Wall et. al. 2003).

Herrera obtained a GIS dataset of soils with high soil erosion potential for use in the forestry activities risk analysis from the Oregon Department of Environmental Quality (DEQ). This

Table 1. GIS datasets used to help assess the risk from forestry activities to source water quality in the Clackamas River watershed.

Dataset Description	Source	Date	Online Metadata (if available)
Aerial photography	United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP)	2009	http://libweb.uoregon.edu/map/orephoto/imagery.html
Clackamas River watershed boundary	Oregon Metro Regional Land Information System (RLIS)	November 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Forest Service Activity Tracking System (FACTS) notifications	U.S. Forest Service (USFS) and Oregon Department of Forestry (ODF)	1992 – 2012 (National); 2007 - 2009 (Private)	Private forests program: http://www.oregon.gov/ODF/privateforests/fpaFACTS.shtml
High soil erosion potential areas	Oregon Department of Environmental Quality (DEQ)	August 2007	None
Landslides	Oregon Department of Geology and Mineral Industries (DOGAMI)	March 2011	http://www.oregongeology.org/sub/slido/
National Land Cover Dataset (NLCD)	United States Geological Survey (USGS) Multi-Resolution Land Characteristics Consortium (MRLC)	June 2005	http://www.mrlc.gov/nlcd2006.php
Potential Contaminant Source (PCS) points	Oregon DEQ	June 2005	http://www.deq.state.or.us/wq/dwp/invresults.htm
Proclaimed National Forest boundary	USFS	1988	http://www.fs.fed.us/r6/data-library/gis/mthood/metadata/proclaimed_metadata.htm
Public land boundaries	U.S. Bureau of Land Management (BLM)	June 2011	http://www.blm.gov/or/gis/data.php
Northwest Forest Plan Riparian Reserve Areas	USFS	1994	http://www.fs.fed.us/r6/data-library/gis/mthood/metadata/nwfp_ripres_metadata.htm
Streams and waterbodies	Oregon Metro RLIS	November 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite
Taxlot boundaries	Oregon Metro RLIS	November 2011	http://rlismetadata.oregonmetro.gov/index.cfm?startpage=main.cfm?db_type=rlislite

dataset is based on analysis of slope, erodibility K-Factor, and sediment yield potential from multiple sources of GIS soils data in the Clackamas River watershed.

Landslide Areas

Landslides are a dominant erosion process on steep, forested slopes in western Oregon (OBF 2001). Landslides generate large quantities of sediment, posing a significant risk to water quality as the sediment moves downhill and into rivers and streams. Herrera mapped landslide areas in the Clackamas River watershed using the Statewide Landslide Information Database for Oregon (SLIDO-2) from the Oregon Department of Geology and Mineral Industries (DOGAMI), which is a database of landslides and landslide related features compiled from more than 300 published and unpublished geologic hazard studies. Approximately 1,250 landslide deposits and landslide-related features and 605 historic landslide point locations were mapped by DOGAMI in the Clackamas River watershed.

Methodology

This section describes the GIS methods used by Herrera to identify and characterize forest land in the Clackamas River watershed; map the locations of forestry activities in Mt. Hood National Forest and state and private forest land; identify and map vulnerable soils and landslides; and rank, weight, and overlay the datasets based on their impact to source water quality.

Identifying and Characterizing Forest Land

The first step in assessing potential risk to source water quality from forestry activities in the Clackamas River watershed was to identify and characterize all public and private forest land (GeoSyntec 2011), including: 1) Mt. Hood National Forest; 2) forest land owned by the Bureau of Land Management (BLM); and 3) private forest land. To accomplish this, Herrera first obtained GIS data showing the extent of the Mt. Hood National Forest and areas owned by BLM and overlaid this data with the Clackamas River watershed boundary. Next, Herrera used tax parcel data and aerial photography to identify forest parcel owned by private timber companies. Finally, 2006 NLCD land cover data was used to characterize other areas of forested land in the watershed.

A summary of acreages of forest land by type is provided in Table 2; it is important to keep in mind that due to the methods and data sources used for estimating land owned by private timber companies and other forested areas in the watershed, acreages in these categories are approximate. The spatial distribution of forest land in the watershed is shown in Figure 1.

Mapping Forestry Activities

After Herrera identified and characterized forest land in the Clackamas River watershed, the next step was to use data extracted from the USFS and ODF FACTS databases to map areas of forestry management activities in the watershed over time. FACTS data obtained from the USFS was provided in a GIS compatible format and was overlaid with the watershed boundary; Table 3 provides a summary of the number of activities mapped for each general activity category for all years within the Mt. Hood National Forest. The FACTS data obtained for ODF was not provided in a GIS compatible format; Herrera digitized these locations in GIS based on township-section-

range data at the quarter-quarter section level provided in the database for each activity. This information is summarized in Table 4. General activity categories provided in Tables 3 and 4 were assigned by Herrera to help narrow the list of activities down to a manageable size for further analysis.

Table 2. Categories of forest land in the Clackamas River watershed.

NPDES Permit Category	Land Owner or Manager	Area (acres)	Percent of Total Watershed
Mt. Hood National Forest	U.S. Forest Service	419,367	69.5%
Other Public Forest Areas	Oregon Bureau of Land Management	13,350	2.2%
Privately-Owned Forest	Various timber companies	29,032	4.8%
Other Forest Areas	Various owners	41,253	6.8%

After mapping the extent of forestry activities based on both the USFS and ODF FACTS databases, Herrera determined that based on differences in activity classifications, activity polygon resolution, and years of data analyzed, it was most appropriate to analyze enough risk categories from each FACTS dataset seperately rather than for the watershed as a whole. This process is described in more detail in the next section.

Table 3. Forestry activities performed or planned in the Mt. Hood National Forest from 1979 to 2020 based on information extracted from the USFS FACTS database.

Activity Category	Activity Description	Number of Recorded Activities
Burning	Broadcast Burning - Covers a majority of the unit	10
	Burning of Piled Material	127
Clearcutting	Clearcutting	171
	Stand Clearcut	1
Fertilization	Area Fertilizing	120
	Fertilization	13
	TSI Certification - Fertilization	65
	TSI Need Created- Fertilization	132
Other Harvest Activities	Group Selection Cut (UA/RH/FH)	14
	Overstory Removal Cut (from advanced regeneration)	6
	Partial Removal	12
	Salvage Cut (intermediate treatment, not regeneration)	250
	Sanitation Cut	29
	Seed-tree Seed Cut (with and without leave trees)	42
	Selection Cut	3
	Shelterwood Establishment Cut (with or without leave trees)	168
	Shelterwood Removal Cut	1
	Special Cut	1
Site Preparation	Certification of Natural Regeneration with Site Prep	1
	Site preparation for planting	58
	Site Preparation for Planting - Other	91
Thinning	Commercial Thin	370
	Precommercial Thin	71
	TSI Certification - Thinning	4
	TSI Need Created- Precommercial Thin	56

Table 3. (continued) Forestry activities performed or planned in the Mt. Hood National Forest from 1979 to 2020 based on information extracted from the USFS FACTS database.

Activity Category	Activity Description	Number of Recorded Activities
Other Activities	Animal Damage Control for Reforestation	7
	Certification of Natural Regeneration without Site Prep	40
	Certification-Planted	231
	Chipping of Fuels	8
	Fill-in or Replant Trees	8
	Fill-in planting concurrent with site prep	4
	Fire Protection Inventory	12
	Fuel Inventory	104
	Full planting concurrent with site prep	185
	Piling of Fuels, Hand or Machine	13
	Plant Trees	77
	Plantation Survival Survey	34
	Post Treatment Exam Fuels Mgt	13
	Post Treatment Timber Stand Improvement Evaluation	2
	Pretreatment Exam for Reforestation	1
	Pretreatment Exam for Release or Precommercial Thinning	1
	Rearrangement of Fuels	4
	Reforestation Need Change due to Other (windthrow, etc)	20
	Reforestation Need Change due to Stocking Changes	14
	Reforestation Need Created by Fire	1
	Reforestation Need Created by Harvest	240
	Reforestation Need created by Insect or Disease Agents	1
	Silvicultural Stand Examination	1
	Special Products Removal	13
	Stocking Survey	84
	TSI Need (fertilization) Eliminated	2
	TSI Need Created- Pruning	23
	Watershed Resource Road Obliteration - Area	4
	Wildlife Habitat Chemical treatment	6
	Wildlife Habitat Grasses and forbs	7
	Wildlife habitat inventory	16

Table 4. Forestry activities performed or planned on state or private forest land from 2007 to 2009 based on information extracted from the ODF FACTS database.

Activity Category	Activity Description	Number of Recorded Activities
Clearcutting	Clear Cut	30
	Clearing for Land Use	4
Herbicide Use	Herbicide Application	17
Other Harvest Activities	Partial Cut	63
	Other Harvest	21
Road Construction	Road Construction	15
	Road Reconstruction	28
Site Preparation	Site Preparation	16
Thinning	Pre-Commercial Thinning	5
Other Activities	Felling and Bucking	2
	Treatment of Slashing	18
	Other Activities	9

Calculating Aggregate Forestry Activities Risk in Mt. Hood National Forest

After Herrera mapped the extent of forestry activities based on data extracted from the USFS FACTS database for Mt. Hood National Forest, the next step completed was to calculate potential aggregate risk from each category of forestry activities to downstream water quality. Potential aggregate risk for each activity polygon category was based on: 1) highly erodible soils; 2) landslide presence; 3) ratio of the effected activity area to the total watershed area; and 4) proximity to the Mt. Hood National Forest riparian management area. This analysis was completed using the following methodology.

First, each category of forestry activites was extracted seperately from the USFS FACTS database. Then each risk variable was analyzed by forestry activity polygon: soil erosion and landslide data were intersected with each polygon to calculate total coverage; the area of each forestry activity polygon was divided by the total watershed to calculate the ratio of affected polygon area; and proximity to forest riparian stream buffers was calculated.

Next, the attributes for each individual resulting dataset were assigned a ranking scheme on a scale of 1 to 5, with a value of 1 indicating a low risk to source water quality from a category of forestry activities and a value of 5 indicating a high risk. The ranking scheme for each dataset was determined using two primary methods. The first method ranked each dataset based on presence or absence. For example, highly erodible soils that overlap with mapped forestry activity areas were assigned a value of 5; areas that did not overlap were assigned a value of 0. The second method involved assigning scientifically meaningful rankings to dataset attributes on a literature review of best available science. For example, riparian stream buffers obtained from

Mt. Hood National Forest provide established stream setback widths that should not be encroached on by forestry activities based on regulation guidelines (http://www.fs.fed.us/r6/data-library/gis/mthood/metadata/nwfp_ripres_metadata.htm); forestry activity polygons mapped within this area given a high-risk ranking of 5. Table 5 shows the detailed ranking scheme applied to each dataset in the risk analyses; the same ranking scheme was applied to all seven forestry activity risk analyses completed within Mt. Hood National Forest. No weighting was applied to the datasets used in this risk analysis.

Table 5. Ranking, ranking criteria, and weighting factors applied to each GIS dataset to determine the risk from each category of forestry activities to source water quality in the Clackamas River watershed.

Dataset	Ranking Factor	Ranking Criteria
Landslide presence	Yes	5
High soil erosion potential	Yes	5
Proximity to riparian stream buffer boundaries	Within the boundary	5
	< 150 feet	4
Ratio of affected activity area to total watershed size	< 0.00005	1
	--	--
	0.0005 to 0.0002	3
	--	--
	> 0.0002	5

After the ranking factors were applied, the final step was to convert each dataset to a raster grid with 10-meter pixels and overlay the grids together to calculate acumulative risk value for each pixel. These results were then mapped into low, moderate, and high risk categories. The results of the analyses showing aggregate risk from each category of forestry activities in the Mt. Hood National Forest to source water quality in the Clackamas River watershed are shown in Figures 2A through 2G. A brief discussion on interpreting the risk trends shown in theses figures is included in the Results and Recommendations section.

Calculating Aggregate Forestry Activities Risk from State and Private Forest Land

Next Herrera repeated the analysis described above to calculate potential aggregate risk from each category of forestry activities in other forest areas (public BLM land and private forest) to downstream source water quality in the Clackamas River watershed based on data extracted from the ODF FACTS database. The methodology used for this set of analyses was nearly identical to the methodolgy used for the Mt. Hood National Forest analyses; the primary difference was in calculating the proximity to surface water variable. Because the riparian stream buffer areas used in the first set of analyses are specific to Mt. Hood National Forest only; Herrera had to use a different method for calculating stream proximity for activities on state and private forest land in the rest of the watershed. To accomplish this, Herrera calculated proximity from the stream channel centerline in increasing distances with progressively lower risk scores. Table 6 shows the detailed ranking scheme applied to each dataset in these risk analyses; the same ranking

scheme was applied to all seven forestry activity risk analyses completed for state and private land in the Clackamas River watershed. No weighting was used in this risk analysis.

Table 6. Ranking, ranking criteria, and weighting factors applied to each GIS dataset to determine the risk from each category of forestry activities to source water quality in the Clackamas River watershed.

Dataset	Ranking Factor	Ranking Criteria
Landslide presence	Yes	5
High soil erosion potential	Yes	5
Ratio of affected activity area to total watershed size	< 0.00005	1
	--	--
	0.0005 to 0.0002	3
	--	--
	> 0.0002	5
Proximity to surface water	< 150 feet	5
	150 to 300 feet	4
	300 to 500 feet	3
	500 to 1,000 feet	2
	> 1,000 feet	1

The results of the analyses showing aggregate risk from each category of forestry activities in state and private forest land to source water quality in the Clackamas River watershed are shown in Figures 3A through 3G. A brief discussion on interpreting the risk trends shown in theses figures is included in the Results and Recommendations section

Results and Recommendations

Herrera mapped the locations of more than 2,000 forestry activities in Mt. Hood National Forest, and approximately 230 forestry activities in public and private forest land in the Clackamas River watershed in 9 general categories: 1) thinning; 2) clear-cutting; 3) herbicideuse; 4) site preparation; 5) fertilization; 6) other harvest activities; 7) road construction; 8) fertilizer use; and 9) burning activities. Herbicide application and road construction activities were specific to state and private forest land; fertilizer use and burning activities were specific to Mt. Hood National Forest. As shown in Table 3, the most prevalent forestry activities in the Mt. Hood National Forest based on number of records listed in the USFS FACTS database are: 1) commercial thinning (Thinning risk analysis category); 2) salvage cuts (Other Harvest category); and Reforestation Needs and Certification (Other Activities category). The most prevalent forestry activities for other forest areas in the Clackamas River watershed are 1) partial cutting (Other Harvest risk analysis category); 2) clear cutting; and 3) road reconstruction. It is important to keep in mind that this is based on prevalence of activities, and not total acres of affected area.

As shown in Figures 2 and 3, the overall risk analysis categories that appear to have the most significant numbers of "hot spots" in the Mt. Hood National Forest are thinning activities, fertilizer applications, and burning activities; for state and private forest land, they are road construction activities and clear-cutting. However, the risk analysis results for each forestry activity category are intended to assess geographic risk by category and are not intended to compare risk between groups of activities. This is due to the fact that the water quality impacts between activity categorie may not be directly comparable. For example, the water quality impacts from fertilizer application are primarily from nitrogen and phosphorous runoff, while the primary impact from road construction is sedimentation. For this reason, Herrera did not produce maps of cumulative risk for all forestry activities in the Clackamas River watershed. Results of the risk analyses by activity category within Mt. Hood National Forest are shown in Figures 2A through 2G, and are shown in Figures 3A through 3G for state and private forest land activities. The most appropriate method for interpreting these results is to look at overall geographic trends rather than activity-level results due to the potential for data anomalies.

This analysis effort was primarily intended to provide a baseline overview of forestry activities in the Clackamas River watershed on public and private forest land, and therefore mapped a very large number of forestry activities in several broad categories. Herrera recommends that this analysis be repeated in three to five years after the CRWP has completed pollutant load modeling or further water quality monitoring work, and that the GIS analysis focus on the subset of forestry activities and geographic "hot spots" that indicated as having the most significant impacts on source water quality. For example, rather than analyzing all forestry activities, the forestry activities non-point source risk analysis completed for the McKenzie River watershed by EWEB focused specifcally on the impact from forest chemical application rates to source water quality on private commercial timber land (Morgenstern 2006) .

The following adjustments could also be made to a future GIS analysis effort to help refine the results:

1) ODF provides a subscription service on a daily, weekly, or monthly basis of all notications of operation submitted to the State Forester either for specific township-section-range areas or by county. Herrera recommends that the CRWP subscribe to this service for areas indicated as high risk based on the results of the analysis to help track activities in these areas over time.

2) Linear distance of stream affected is a better metric of water quality impact than proximity to surface water, but is difficult to measure at the watershed scale. The CRWP could use aerial photography to analyze a high-risk subset of the watershed to assess average linear length of stream affected by forestry activities. For example, riparian vegetation loss is evident in aerial photography.

3) A longer time-frame of ODF notice of operations should be obtained and digitized for high-risk activities or watershed areas.

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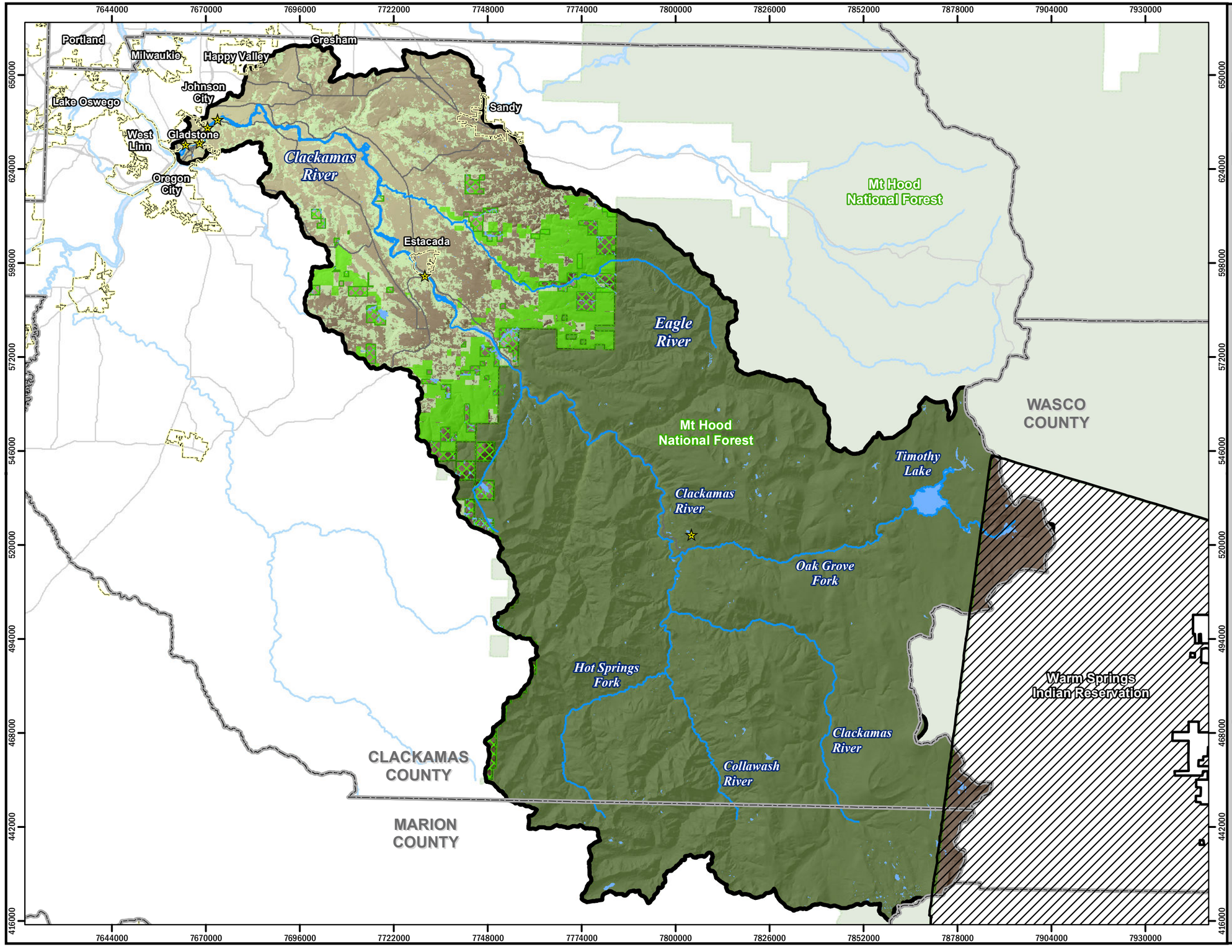
FIGURES

Figure 1.
National Forest, BLM, and private timber land and other forested areas in the Clackamas River watershed.



Legend

- National Forest boundary
- BLM land
- Private timber land
- Other forested areas
- Surface water intake
- County boundary
- City limits
- Clackamas River Watershed boundary
- Warm Springs Indian Reservation

N

0 13,000 26,000 52,000

feet

Clackamas River Water Providers
Working together to protect and conserve our drinking water.

HERRERA

Coordinates: Oregon State Plane North
HARN NAD83 (feet)

Produced By: GIS (JAS)
Project:
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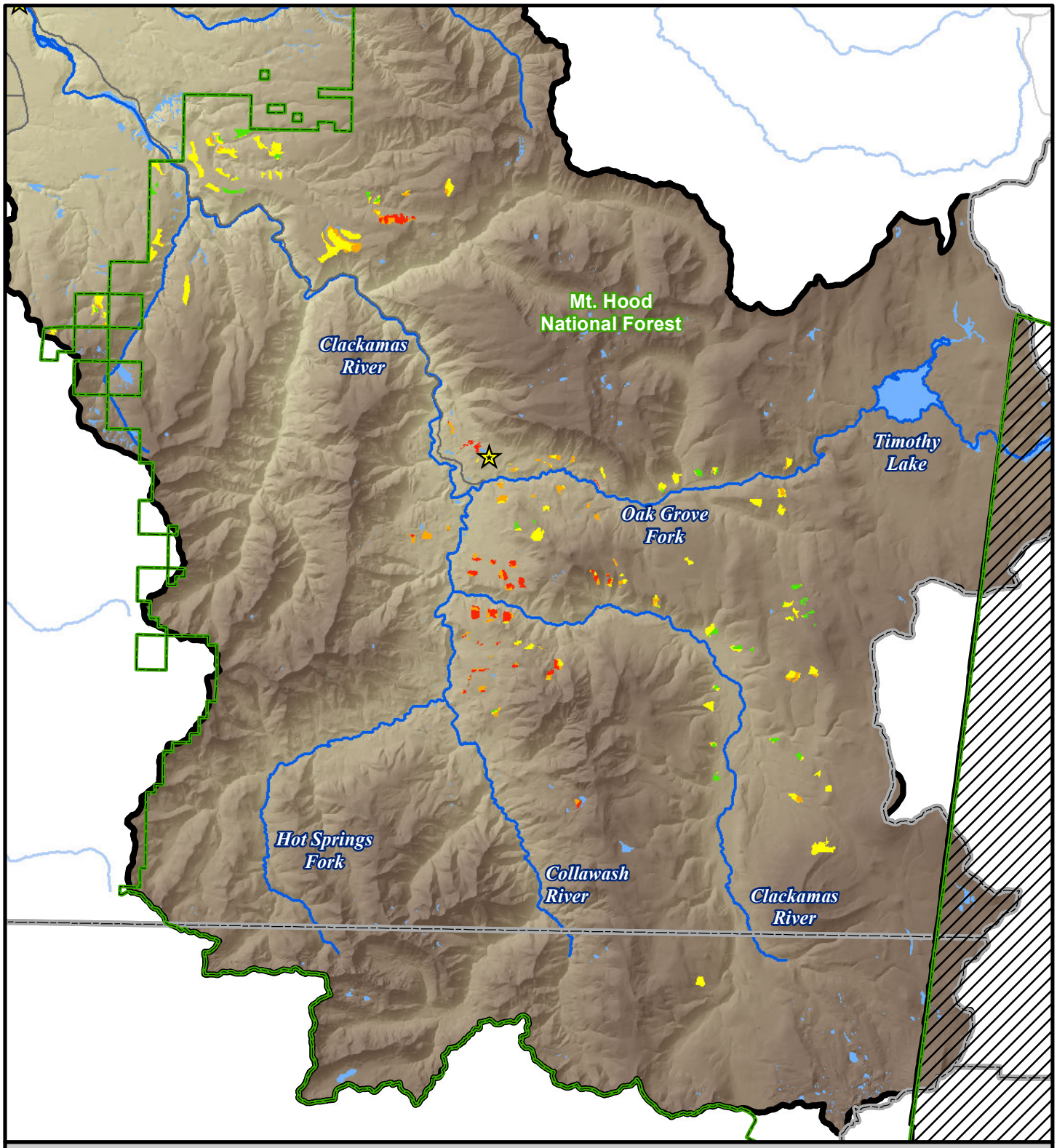


Legend

Potential risk

- Low
- Moderate
- High
- Very high
- Surface water intake
- National Forest boundary
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2A. Potential risk from fertilizer activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

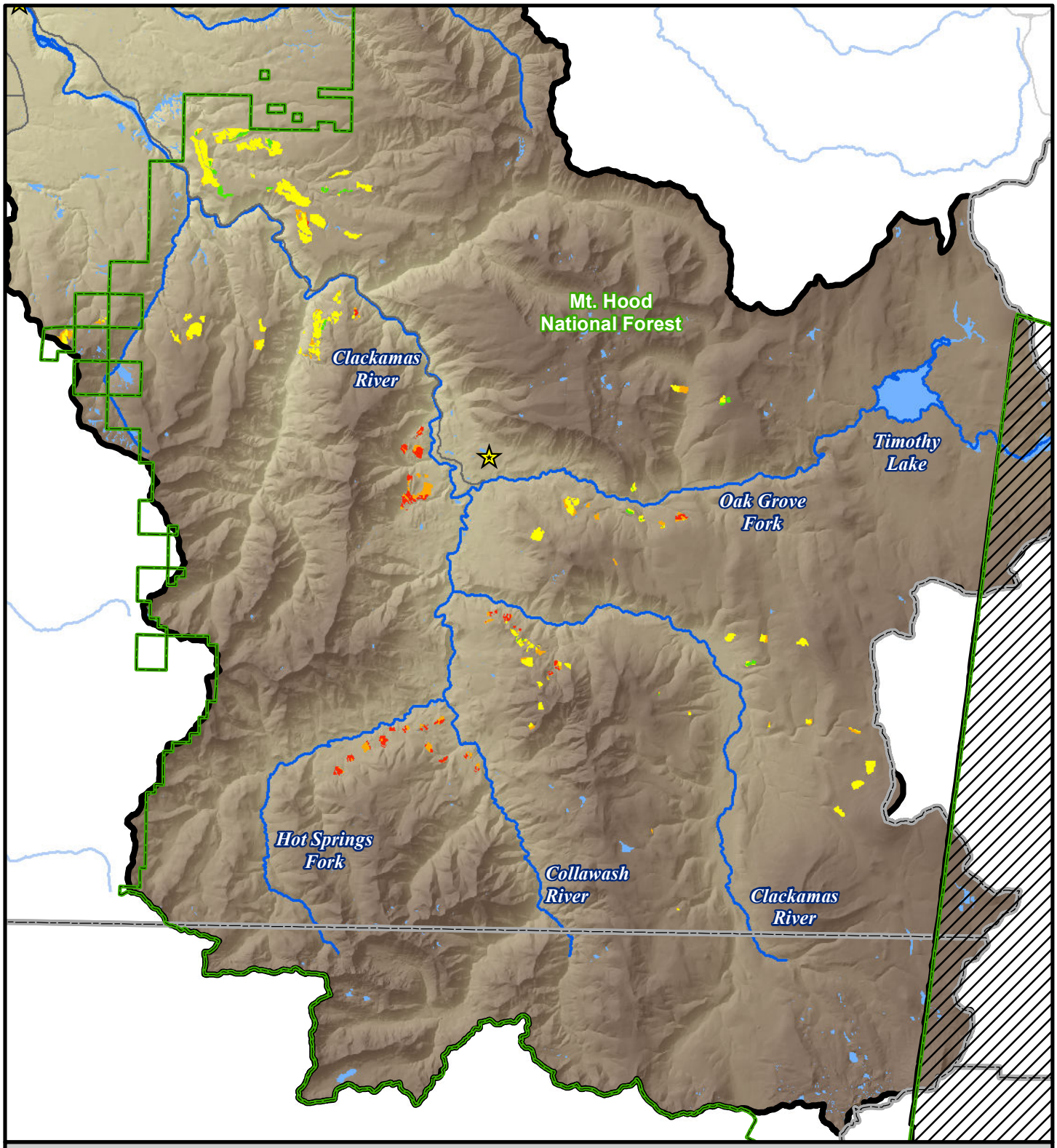
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high
- Surface water intake
- National Forest boundary
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2B. Potential risk from burning activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

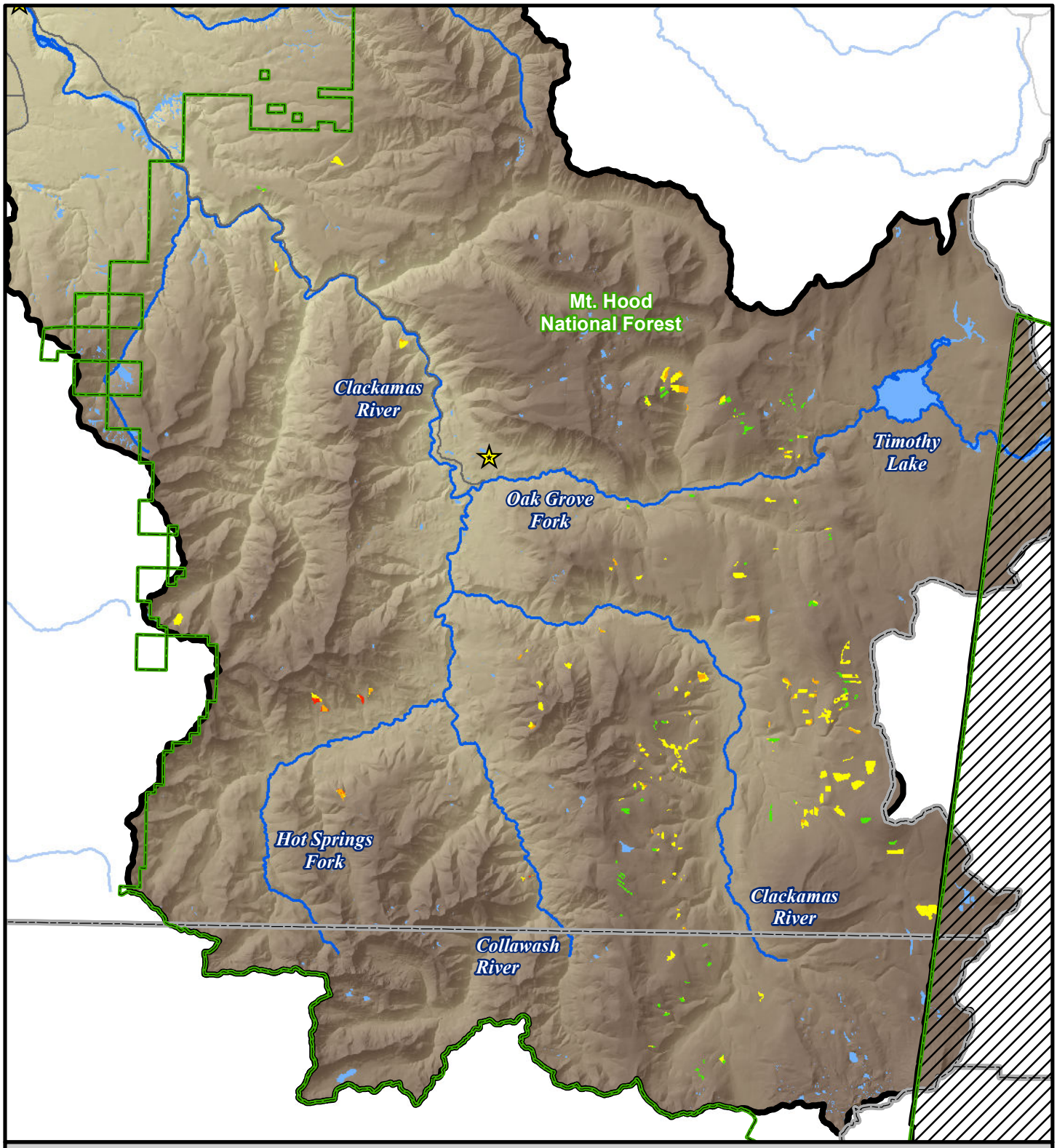
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high
- Surface water intake
- National Forest boundary
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2C. Potential risk from site preparation activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

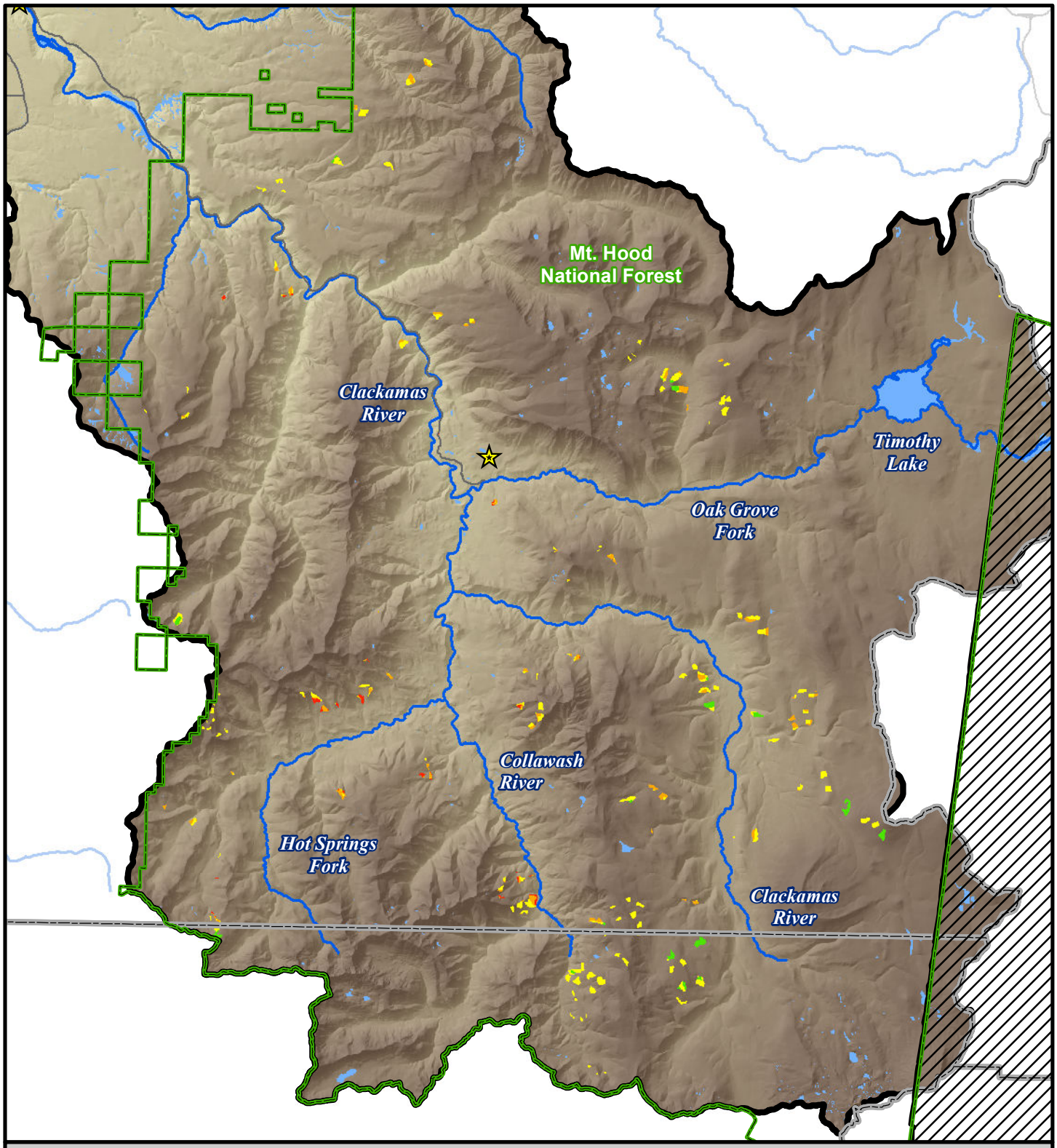
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high
- Surface water intake
- National Forest boundary
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 2D. Potential risk from clear cutting activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

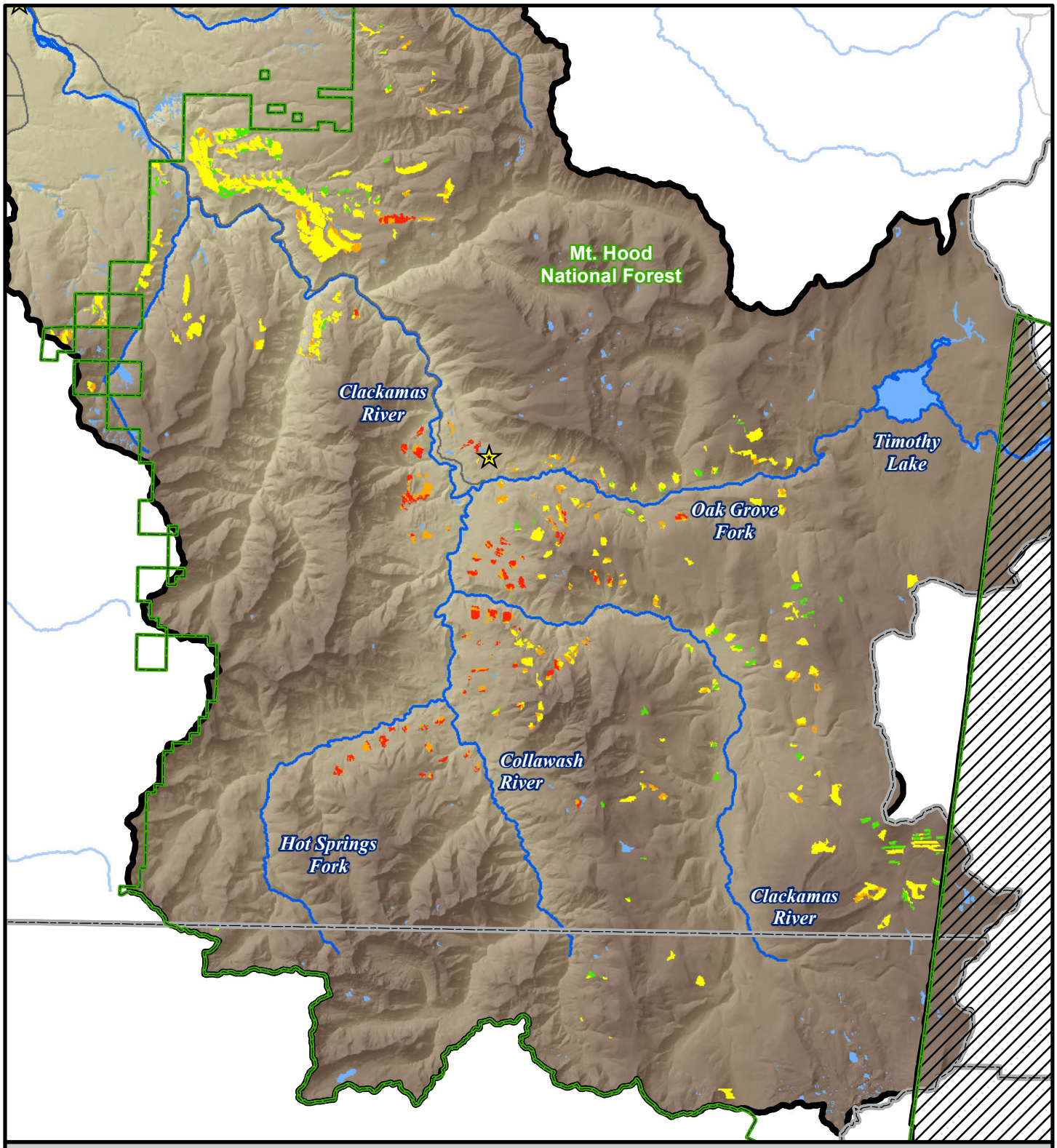
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high

- National Forest boundary
- Warm Springs Indian Reservation
- Surface water intake
- County boundary
- Clackamas River Watershed boundary

Figure 2E. Potential risk from thinning activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

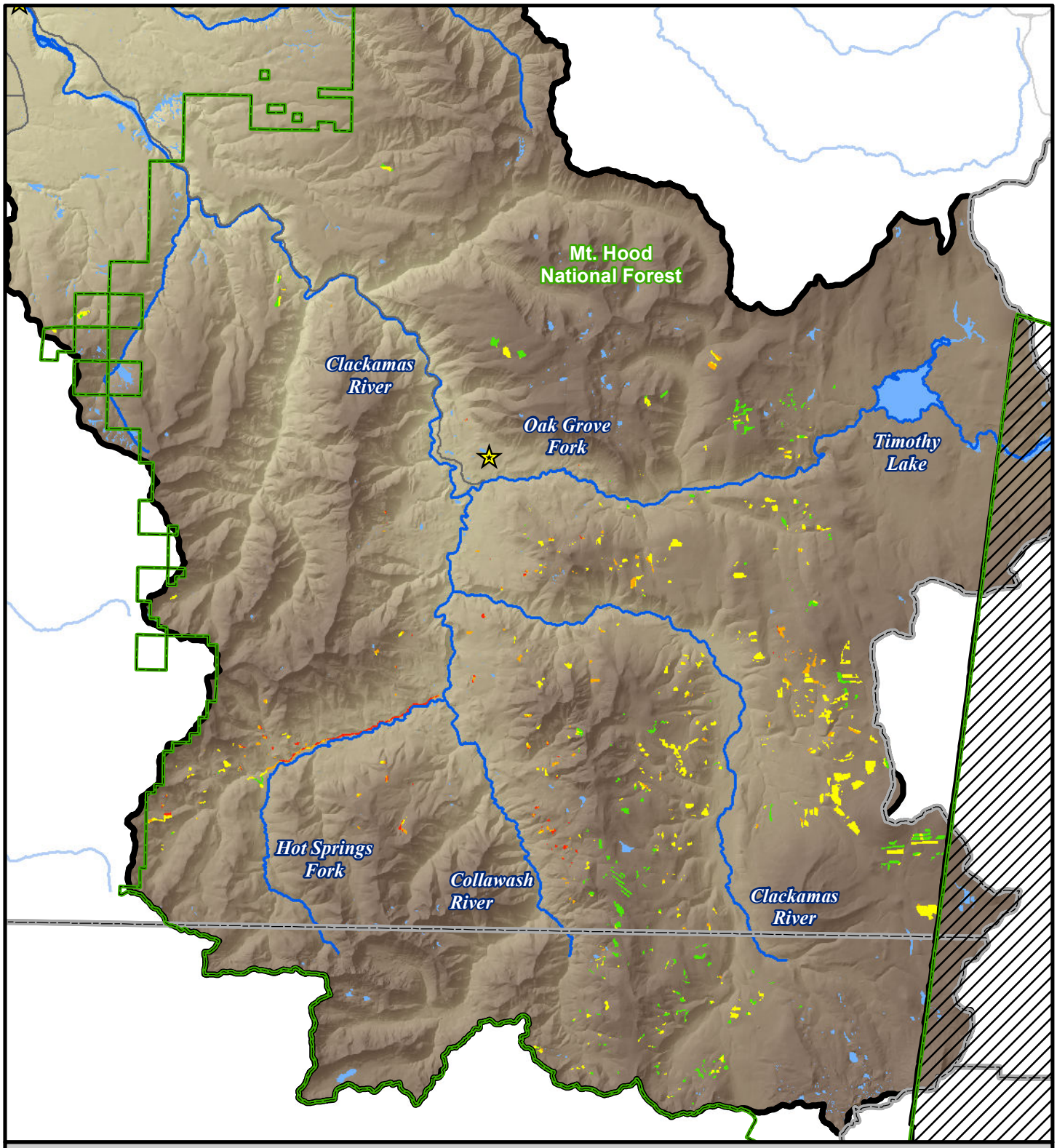
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high

- National Forest boundary
- Warm Springs Indian Reservation
- Surface water intake
- County boundary
- Clackamas River Watershed boundary

Figure 2F. Potential risk from other harvest activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

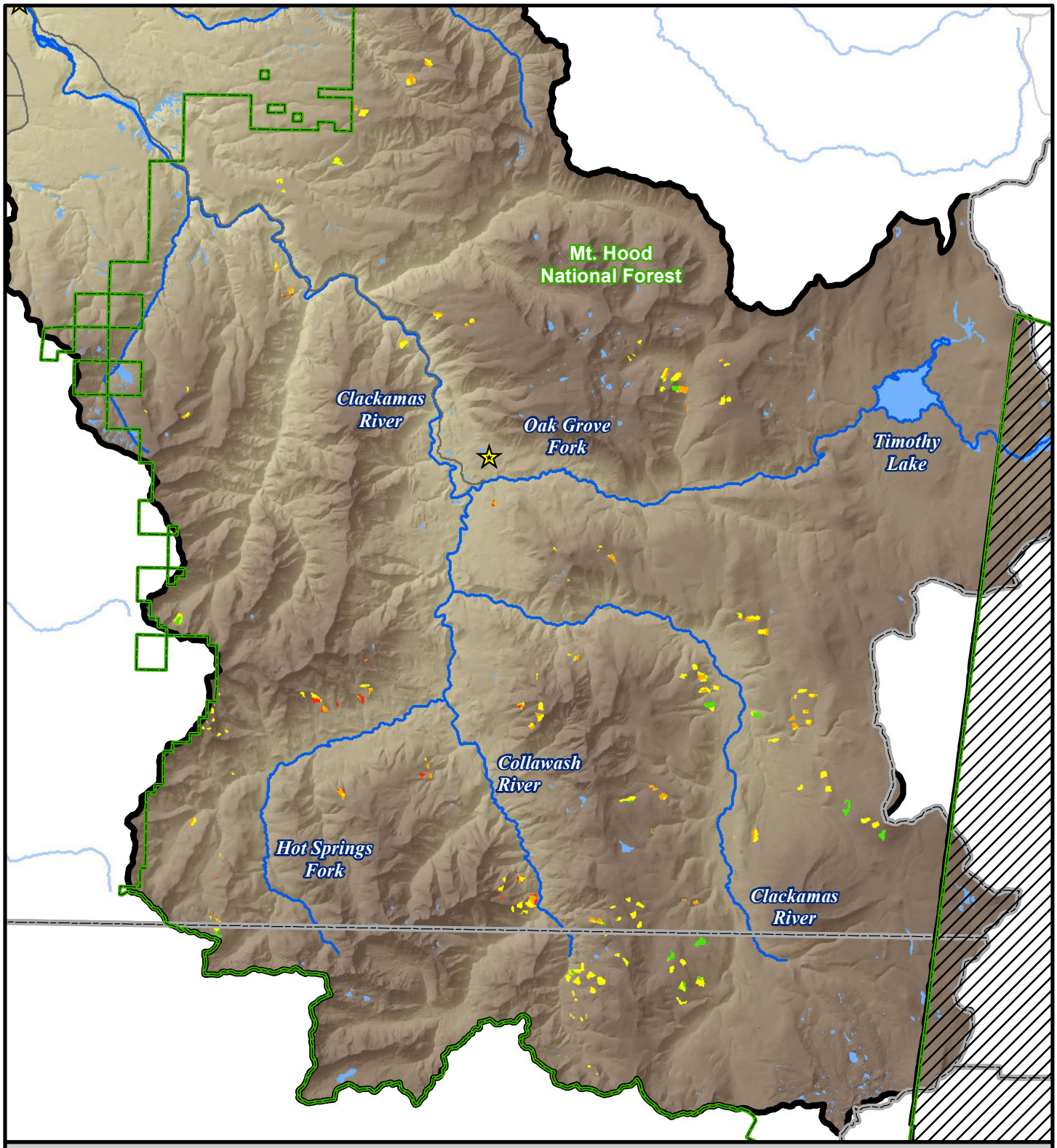
N

0 11,000 22,000 44,000

Feet

HERRERA

K:\Projects\10-04900-001\Project\Result_Maps\Forestry_Activities_Results_MtHood_Extent.mxd (6/12/2012)



Legend

Potential risk

- Low
- Moderate
- High
- Very high

- National Forest boundary
- Warm Springs Indian Reservation
- Surface water intake
- County boundary
- Clackamas River Watershed boundary

Figure 2G. Potential risk from other activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

0 11,000 22,000 44,000

Feet

HERRERA

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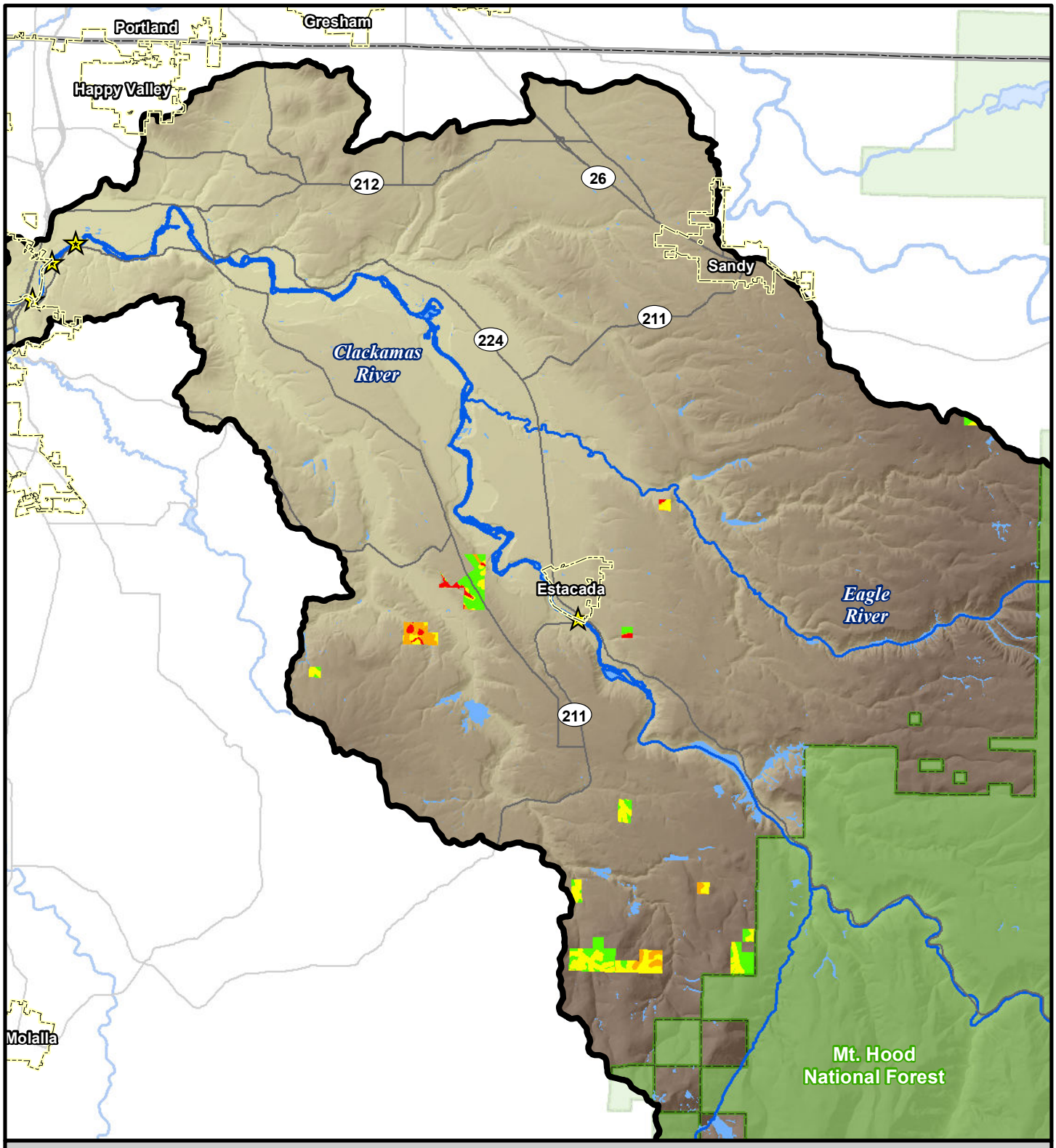

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3A. Potential risk from herbicde use to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

0 8,000 16,000 32,000

Feet

HERRERA

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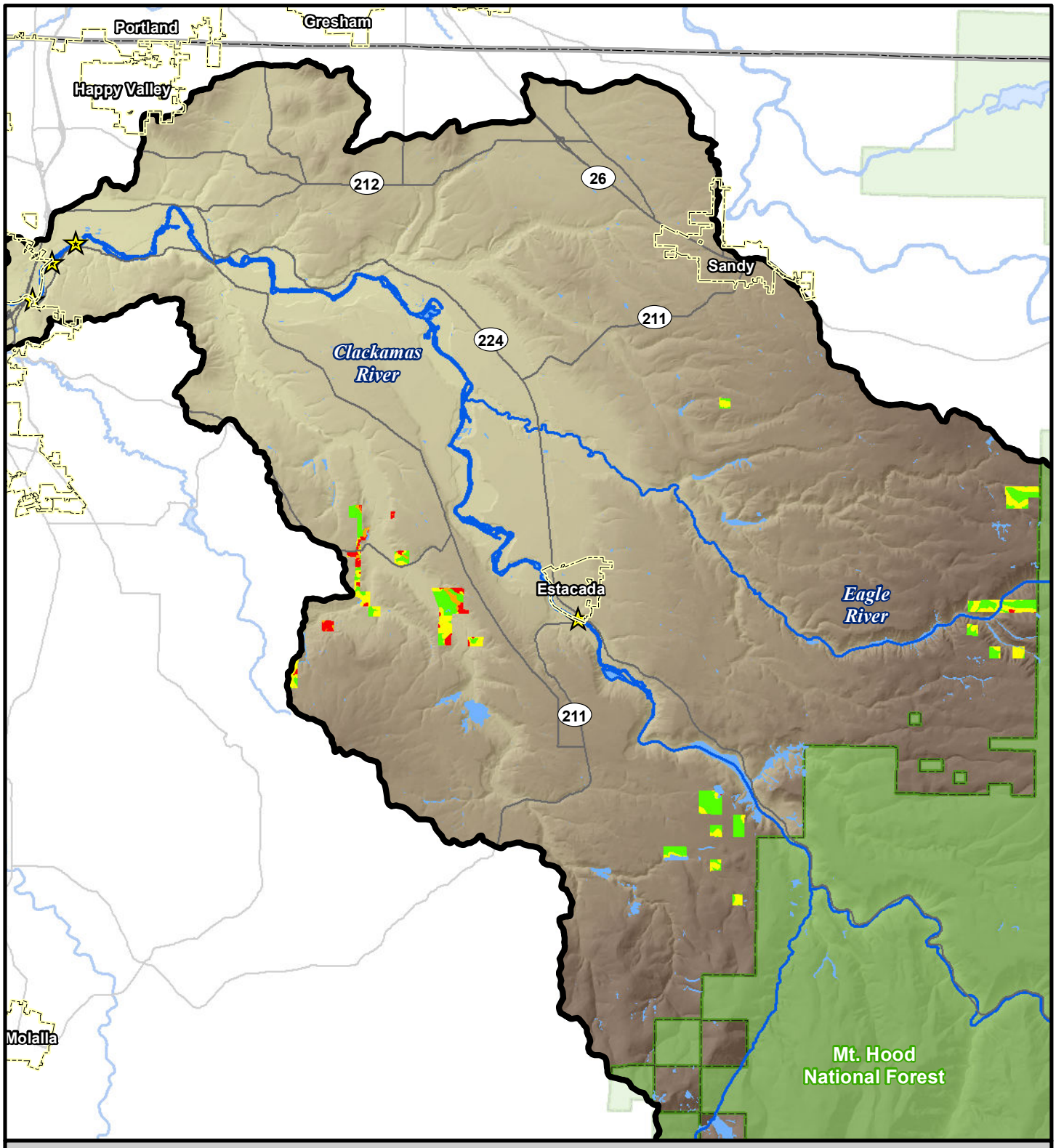

Legend

Potential risk
- Low
- Moderate
- High
- Very High
- Surface water intake

- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3B. Potential risk from road construction to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

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Feet

HERRERA

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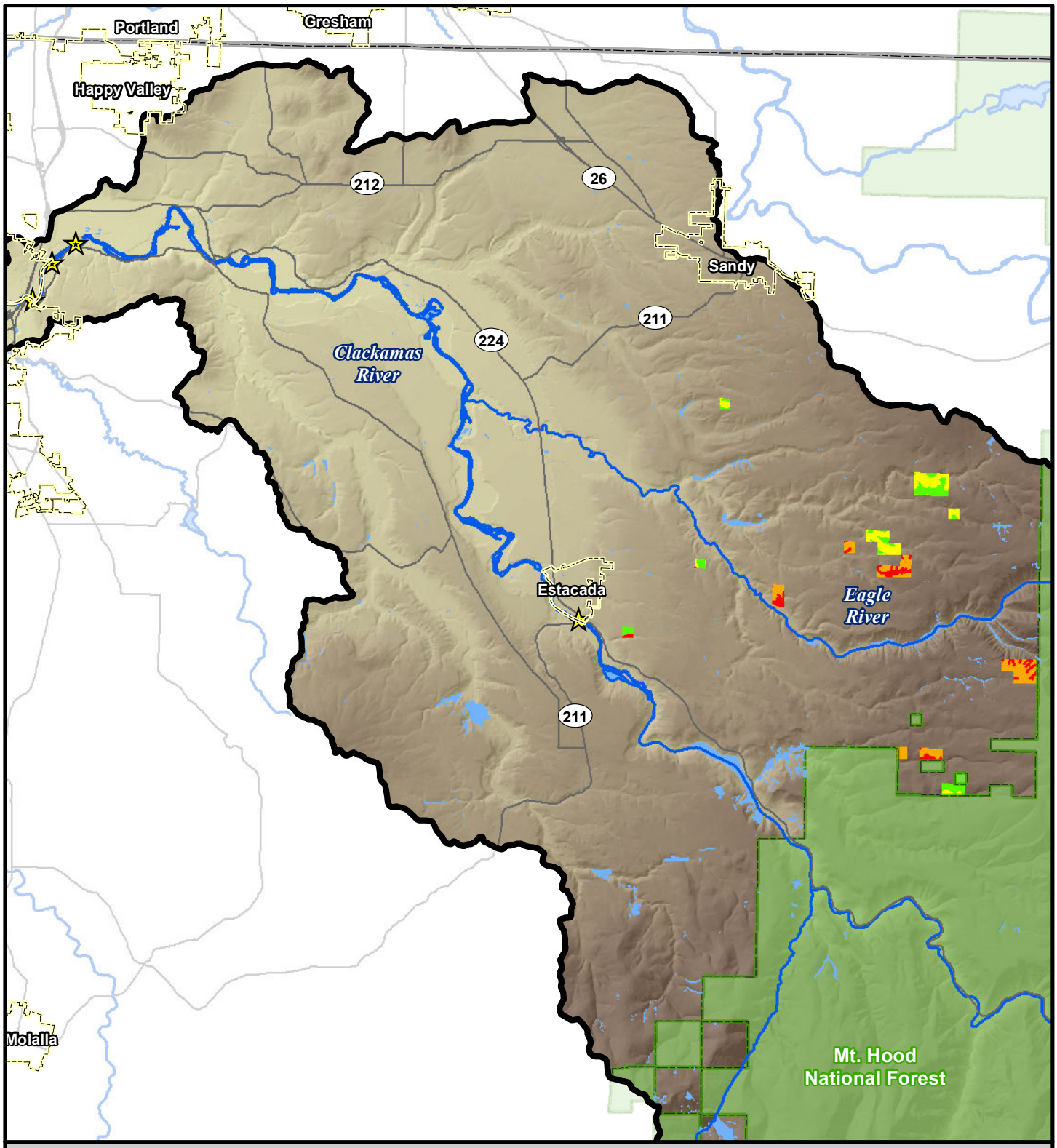

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3C. Potential risk from site preparation activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

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Feet

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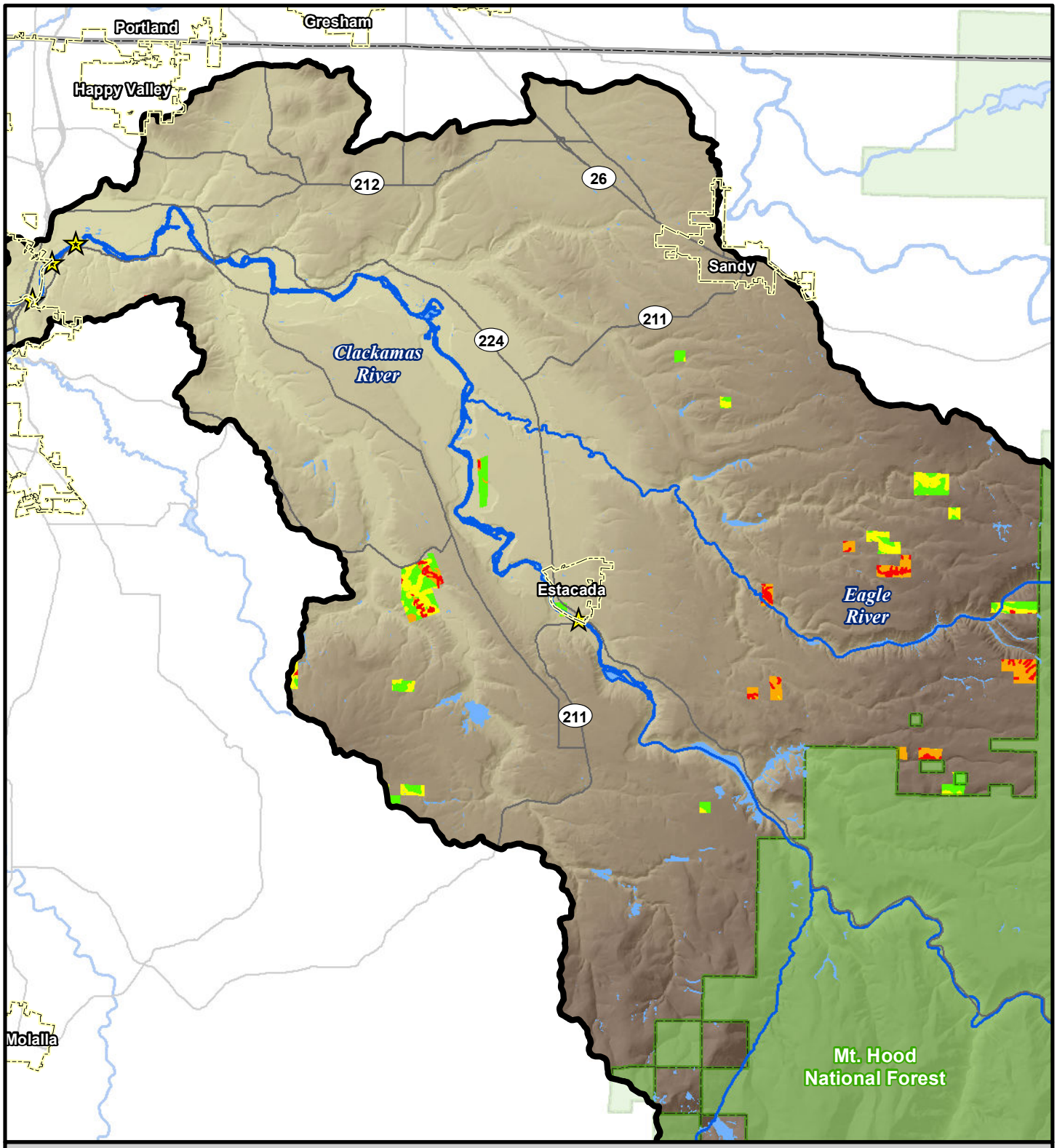

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3D. Potential risk from clear cutting activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

0 8,000 16,000 32,000

Feet

HERRERA

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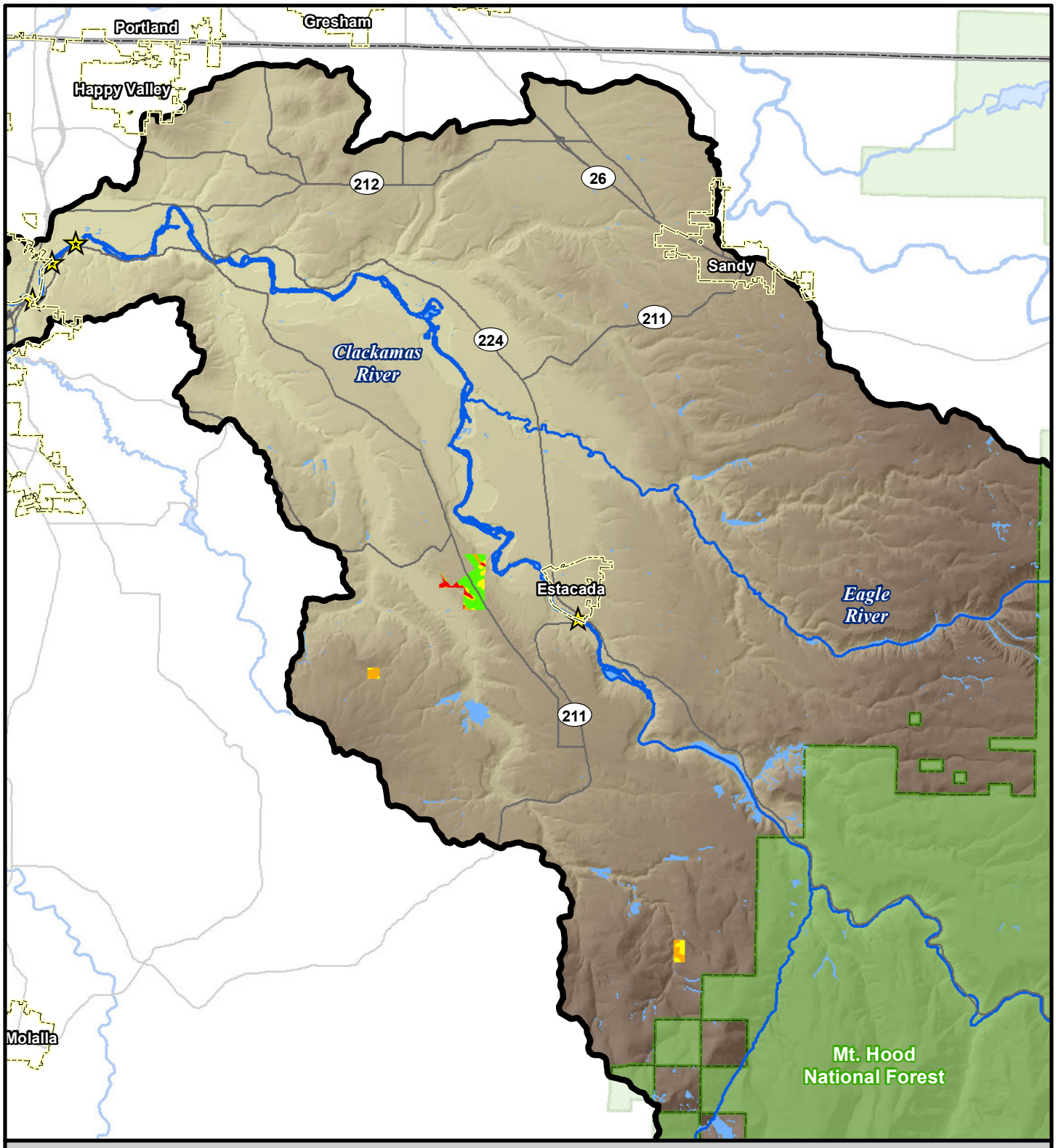

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3E. Potential risk from thinning activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

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Feet

HERRERA

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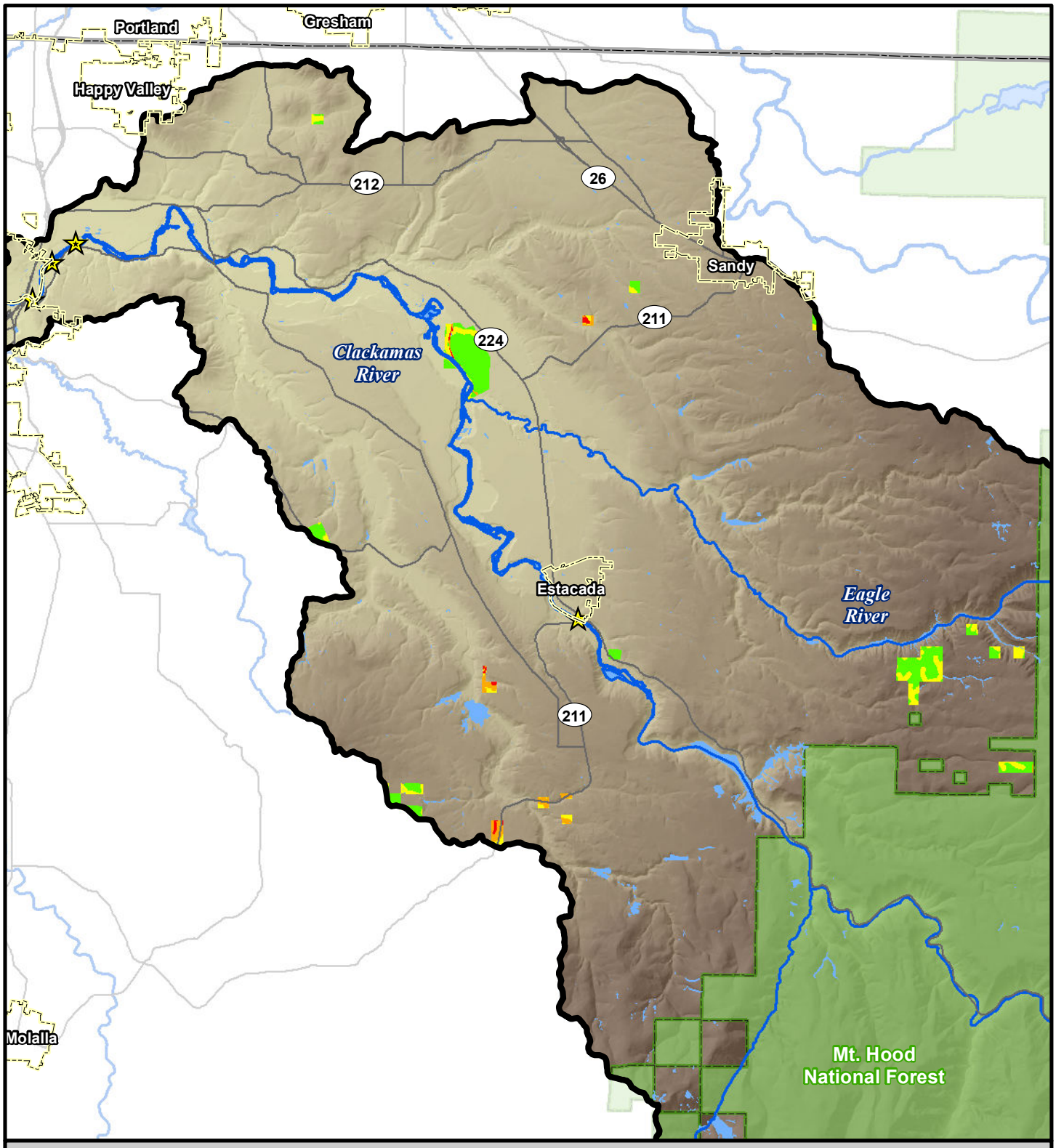

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3F. Potential risk from other harvest activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

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Feet

HERRERA

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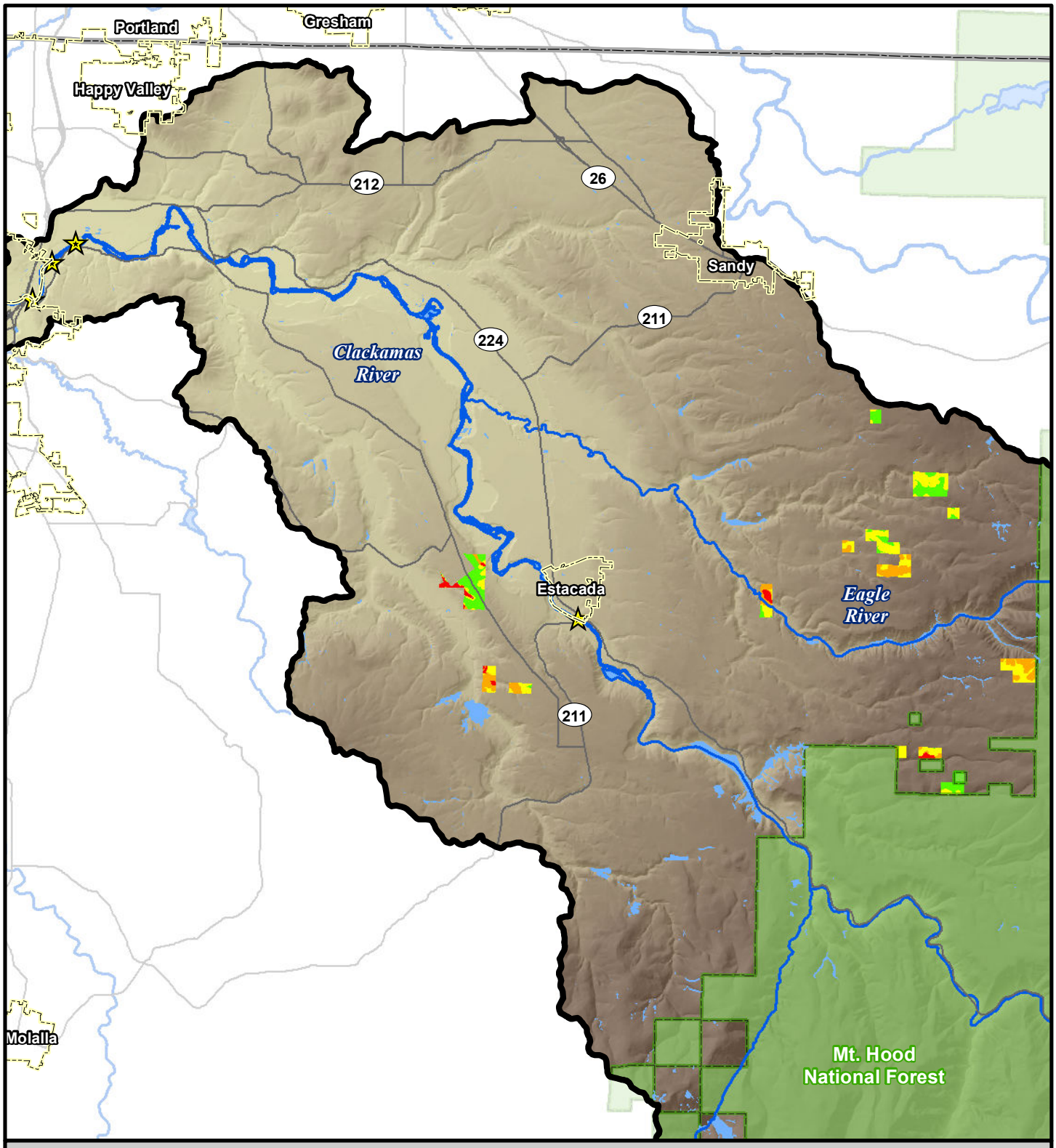

Legend

Potential risk

- Low
- Moderate
- High
- Very High
- Surface water intake
- National Forest boundary
- City limits
- Warm Springs Indian Reservation
- County boundary
- Clackamas River Watershed boundary

Figure 3G. Potential risk from other forestry activities to source water quality in the Clackamas River watershed based on GIS predictive modeling.

N

0 8,000 16,000 32,000

Feet

HERRERA

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