



## Technical Memorandum 1

**To:** Members of the Joint Water Commission's (JWC) Source Water Protection Technical Advisory Committee (TAC)

**From:** GSI Water Solutions, Inc.

**Date:** October 17, 2013

**Re:** **Source Water Assessment Geodatabase Development and Explanation of Geospatial Analysis Methodology and Results**

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### 1.0 Introduction

This technical memorandum discusses the development of the Joint Water Commission's (JWC) source water assessment geodatabase, the data sources used, how to update and maintain the geodatabase, the geospatial analysis performed, and the results of the geospatial analysis (i.e., the watershed risk, sensitivity, and susceptibility analysis results).

### 2.0 Purpose and Scope of Work

Over the past year, the Joint Water Commission (JWC) began developing tools to assist in the drafting of the JWC's first comprehensive source water protection plan. These tools include a Microsoft Access-based water quality database and a source water assessment-specific ArcGIS geodatabase. Both tools have been designed to work in conjunction with one another to aid in the identification of areas that pose risk to the JWC's drinking water source area (i.e., the watershed or the study area). Once potential risks and impact areas are identified, the JWC can develop specific source water protection programs to help minimize risk and/or sensitivity posed by each potential impact area. This technical memorandum presents a discussion of the ArcGIS geodatabase tool. A separate memorandum (Tech Memo #2) describes the water quality database.

### 3.0 Geodatabase Development Methodology

#### 3.1 Approach and Geodatabase Data Structure

GSI and the JWC project team researched and selected specific GIS data to include in the source water assessment geodatabase based on review of other similar agencies' source water protection plans, review of the 2010 Trust for Public Lands' Demonstration Project, DEQ's 2003 Source Water Assessment Report, and local knowledge of the study area. Various potential

GIS data sources were discussed with the JWC project team and the JWC made the final decision on what GIS data would be included in the source water geodatabase.

GSI performed a number of necessary geoprocessing tasks (querying, clipping, selecting, reprojecting, etc.) to each GIS data layer and then imported each layer into the geodatabase as a feature class (point, line, or polygon) or raster dataset. Feature classes are almost exactly the same as shapefiles (representing vector data), that are developed and stored within a geodatabase. Raster datasets are numeric pixel representations of GIS data. Each raster consists of a grid of pixels whose pixel values correspond to the numeric attribute of the GIS layer that is being modeled (i.e., elevation, slope, risk rankings, etc.). For the purposes of this technical memorandum both the feature classes and raster datasets in the geodatabase are described as “layers”.

Each feature class in the geodatabase resides within a feature dataset. Feature datasets act as folders within the geodatabase that help to organize layers that are related to each other. For example, each feature class related to soils resides in the “Soils” feature dataset. Feature classes used for the watershed risk and sensitivity analysis reside in the “Risk\_Analysis” and “Sensitivity\_Analysis” feature datasets. Currently, ArcGIS geodatabases do not allow raster datasets to reside within feature datasets.

For file organizational purposes, GSI named each layer in the geodatabase with the first word in each raster datasets’ name representing the name of the original data source or the name of the category of the geospatial analysis (risk, sensitivity, or susceptibility) for which it was created. For example, the raster dataset “USGS\_10m\_DEM” represents a 10 meter resolution digital elevation model (DEM) from the USGS. The raster dataset “Risk\_Ag” represents the agricultural chemical applications category of the watershed risk evaluation.

## 3.2 Data Sources

Simple metadata was also created for each layer in the geodatabase. The metadata describes the original data source, any pertinent contact information, when the data was acquired and/or modified, and any important geoprocessing steps that were used to create the layer.

The 13 main data sources that were used for the development of the source water assessment geodatabase are listed below. Appendix C, Table 1 describes each data sources’ data type and contact information in more detail.

- The Oregon Department of Agriculture (ODA)
- The Oregon Department of Environmental Quality (DEQ)
- The Oregon Department of Forestry (ODF)
- The Oregon Department of Geology and Mineral Industries (DOGAMI)
- The Oregon Department of Transportation (ODOT)
- The Regional Government for the Portland Metropolitan Area (METRO)
- The Yamhill County GIS Department (Yamhill Co)
- The US Department of Agriculture (USDA)
- The USDA Natural Resources Conservation Service (NRCS)
- The US Geological Survey (USGS)
- The Nature Conservancy (TNC)
- The Wetlands Conservancy (TWC)
- The Federal Emergency Management Agency (FEMA)

Procedures for updating the geodatabase are presented in Appendix C.

## 4.0 Approach to Defining Risk Rankings and Weighting Factors

GSI and the JWC project team decided that the most effective use of the GIS layers developed for the JWC's source water protection efforts was to quantify risk associated with various potential sources of contamination and to quantify the sensitivity of lands within the study area. Once risk and sensitivity are quantified, the results can be combined to quantify susceptibility of lands within the study area to contamination.

GSI collaborated with the JWC team to determine what layers needed to be included in the geospatial analysis. Once this was done, GSI gathered and/or updated those layers and created an analysis matrix for both the risk and sensitivity portions of the geospatial analysis. Appendix A illustrates the overall process and layers included in the geospatial analysis and how the risk/sensitivity rankings and weighting factors were applied to characterize potential contaminant risk and sensitivity of different portions of the study area to contamination.

Once the analysis matrixes for both the risk and sensitivity portions of the geospatial analysis were developed, GSI generated draft risk rankings and weighting factors for each layer involved in the risk and sensitivity analysis and presented them to the JWC Technical Advisory Committee (TAC) for review in a memorandum dated February 21, 2013. The JWC TAC provided input on the draft risk and sensitivity evaluation process, specifically on criteria risk rankings and weighting factors. Based on that input, GSI revised the risk rankings and weighting factors for each layer involved in the risk and sensitivity analysis. The JWC TAC's input was integral in developing the geospatial analysis to understand the potential risks to JWC's source water quality. Risk rankings and weighting factors were determined based on professional judgment, familiarity of activities occurring within the study area, known contaminant sources in the study area, and knowledge of various aspects of the study area's natural features.

GSI's approach to the geospatial analysis involved using a GIS analysis technique known as "weighted overlay". Weighted overlay is a common analysis method for projects that involve numerous criteria, all of which have a direct influence on the output of the analysis. The weighted overlay process combines numerous layers by: 1) assigning rankings from a common measurement scale to the features within each layer, 2) weighting each layer according to its importance to the overall analysis, and 3) performing a weighted sum of the layers. This method creates an integrated, comprehensive view of what is being modeled. A big advantage of weighted overlay analysis is that it is flexible as criteria can be easily modified, added, or removed to refine the analysis results or eliminate data errors.

One of the main goals of the JWC's source water protection plan is to reduce risk of contamination of the JWC's water supply. GSI collaborated with the JWC to identify the different layers that best represented items that pose risk to the JWC's water supply. These layers included contaminants of concern, septic tank locations, areas where chemicals are being applied, etc. While it is useful to look at each of these layers individually, it is not easy to understand how they relate to each other without overlaying or combining them in some fashion. Therefore, a weighted overlay analysis was completed. By assigning risk or sensitivity rankings within each layer in a common measurement scale (i.e., 1 to 10, with 10 being the highest), the layers can then be combined using weights that indicate the importance of each layer to the overall analysis. Weights were expressed as a percentage, with the combined total for all data layers equaling 100%. This methodology and analysis provided outputs that quantified risk to the JWC's water supply and sensitivity of lands to contamination at any location within the study area, based on multiple layers of input. Ranking and weighting factors were selected by

comparing and prioritizing the potential risks of the included activities and watershed characteristics. The selected values represent the potential risk of the activities relative to one another. For comparison purposes, a parallel equal-weighted analysis was run in which the weighting factors for each layer were the same.

The geospatial analysis phase of this project analyzed risk and sensitivity of the lands within the study area. The risk analysis incorporated layers for

- chemical applications (both from agricultural and forestry activities),
- potential contaminant sources,
- septic tank locations,
- areas of urban development, and
- proximity to public roads and railroads.

The sensitivity analysis incorporated layers associated with watershed features including

- flood zones,
- forestry activities,
- surface water time of travel zones,
- unstable and/or vulnerable soils,
- wetlands, and
- proximity to surface water.

Once the risk and sensitivity analyses were finalized, an additional watershed susceptibility analysis was performed that multiplies the output of the risk and sensitivity analysis. The results of these three different analyses will be vital to the overall development of the JWC's source water protection plan.

Appendix A presents each data category used in the risk and sensitivity evaluations and includes a brief explanation of the geoprocessing used to create each category, the risk or sensitivity rankings applied to each layer, and the weighting factors that were used for each category of the analysis. More specific information about each data layer can be found in their respective metadata.

## 5.0 Watershed Risk Analysis

The risk analysis consisted of six categories comprised of either an individual layer or groups of layers. When an individual layer was used, risk rankings were applied to each feature in the layer based on the specific attributes of that feature. For example, the potential contaminant sources layer contains numerous locations (features), each posing a distinct risk. After reviewing the information about each location, different risk rankings were applied based on the activity that was occurring. When groups of layers were used to represent a risk analysis category, GSI applied the risk rankings (see Appendix A) to each layer and combined them. When the different layers overlapped spatially and did not change from year to year, the higher risk rankings truncated the lower rankings. When yearly datasets were combined, the risk values from the separate years were averaged into one risk value.

## 5.1 Risk Analysis Input - Agricultural Chemical Applications

The first category examined in the risk analysis was Agricultural Chemical Applications. The analysis for this category began with a combination of three individual layers that identified growing crop types using satellite imagery:

- USDA\_Cropland\_2009
- USDA\_Cropland\_2010
- USDA\_Cropland\_2011

The types of agricultural crops grown and their total land area within the JWC's watershed are listed in Appendix B, Table 1 for the period 2009-2011. Three separate years of crop data were used to account for crop rotation in the study area. Of the 199,996 acres within the study area, an average of 46,000 acres (23%) was in agricultural production over the three year time period. There was little variation in crop type between the three years. Of the agricultural lands, 17-32% was in grassland production, 20-31% in hay pasture, 7-13% in sod/seed grass, 7% in winter and spring wheat, and 3-11% in other hay/non-alfalfa. Other crops that occur in smaller percentages are clover/wildflowers, tree crops, Christmas trees, corn and oats. One to 14% of the land was either barren or fallow/idle crop land.

Since agriculture can present potential contamination risks from both pesticide and fertilizer use a risk ranking was developed for both pesticide and fertilizer use, then combined to understand how different crop types present different levels of risk. Then the overall risk values for each year were averaged to form one risk layer. The pesticide and fertilizer ranking process is explained in detail below.

### 5.1.1 Relative Risk of Pesticides, Herbicides, Insecticides, and Fungicides

It is estimated that over 100 different pesticides (herbicides, insecticides, and fungicides) are utilized within the watershed in Washington County (OSU Extension Service, 1989). The 117 pesticides most likely applied to specific crops in the study area from 2009 to 2011 are listed in Appendix B, Table 2. These pesticide data were primarily derived from an Oregon State University Extension Service publication (Special Report 843) listing the pesticide use estimates in 1987, which was the last compilation of pesticide use as a function of crop type in Oregon. In 1999, the Oregon Legislature established the requirement (OAR 603-057-0405) that each pesticide user must report pesticide use to the Oregon Department of Agriculture. This data was reported to the public annually, beginning in 2006, through the Pesticide Use Reporting System (for example, see <http://www.oregon.gov/ODA/PEST/docs/pdf/pursreport08web.pdf> for the 2008 data). This reporting system was discontinued subsequent to 2008 as a result of state budget limitations. The more recent pesticide reporting data described above is not crop specific, but rather lists the top 5 pesticides typically used on a general category of crops. As an example, agriculture, which accounts for more than 75% of pesticide use in Oregon (Oregon Department of Agriculture, 2008), is described using terms such as field crops, vegetables, fruit/nuts, etc. Therefore we chose to use the 1987 data that identifies crop specific pesticides for alfalfa, corn, winter wheat, etc., for the purposes of this risk assessment. Data from the 2008 Pesticide Use data was reviewed to ensure that the 1987 data was still relevant.

GSI devised a relative ranking system that prioritizes the potential risks from pesticides, herbicides, insecticides, and fungicides that are used in the watershed. Critical to this risk ranking system was choosing parameters representing risk that are readily available and represent the same environment for each chemical. Because there are no set standards for

selecting these parameters and these chemicals represent risk to both humans and biota, GSI chose to use the parameters of toxicity and persistence for this evaluation, i.e., what is the risk to human health and how long does the chemical persist in the environment?

Data regarding the toxicity of chemicals to human health is generally not available as a result of the general lack of willing test subjects and the necessity of long-term studies. In contrast, the toxicity of given chemicals to laboratory animals is readily available. For the purpose of relative risk ranking, GSI chose to evaluate the toxicity of a given chemical using data from tests performed on rats as a surrogate for assessing toxicity to humans. Specifically, we have chosen to use the oral LD50 for the chemical of concern. The oral LD50 is the chemical concentration (in mg/Kg body weight) that, when ingested by a specific rat population results in a 50% mortality for that population. The ready availability of the LD50 data for rats provides a consistent method for evaluating relative risk to health posed by different chemicals and it is a commonly applied approach in human health risk assessment. Using the range of LD50 values for each chemical and the natural numerical distribution of these values, a relative risk factor ( $RR_T$  Factor) ranging from 0 to 4 (lower to higher risk) was set as shown in Table 1 below. As shown in the table, the lower the chemical concentration necessary to cause 50% mortality in rats, the higher the risk factor.

**Table 1:** Relative risk ( $RR_T$ ) factors to human health based on the oral LD50 for rats (mg/Kg body weight)

<b>LD 50</b>	<5.1	5.1 - 50	51 - 300	301 – 2000	2001 -5000	>5000
<b><math>RR_T</math> Factor</b>	4	3	2	1	0.5	0.25

The persistence of a chemical, generally described in terms of its half-life ( $T_{1/2}$ ), refers to the length of time that the chemical continues to exist in the soil environment. The longer the chemical persists, the greater is the risk that the chemical may cause harm to drinking water. Chemicals with a longer  $T_{1/2}$  pose a greater risk than those that breakdown quickly. Typically, the  $T_{1/2}$  is reported in several different environments, e.g., surface water, the soil zone, and groundwater. For consistency, GSI chose to use the value reported for the soil environment for each chemical. Using the range of chemical half-life for each chemical and the natural numerical distribution of these values, a relative risk of a chemical as it relates to persistence ranging from 0 to 4 (lower to higher risk) was assigned according to Table 2 below.

**Table 2:** Relative risk ( $RR_P$ ) factors to human health based on the persistence of the chemical as expressed as its half-life ( $T_{1/2}$ ) in days.

<b><math>T_{1/2}</math> (days)</b>	>365	181 – 365	31 – 180	7 – 30	<7
<b><math>RR_P</math> Factor</b>	4	3	2	1	0.25

After the relative risk rankings for toxicity ( $RR_T$ ) and persistence ( $RR_P$ ) were determined, the final combined relative risk ( $RR_C$ ) was determined for a scale of 0 to 10 (lower to higher) using the formula:

$$RR_C = ((RR_T + RR_P)/8)*10$$

Using this equation, relative risk factors for the pesticides, herbicides, insecticides, and fungicides, identified as being potentially used in association with agriculture and forestry activities in the JWC watershed were determined. The number of total pesticides used per crop type, and the number of higher risk pesticides for that crop are given in Appendix B, Table 3. The number of high risk pesticides for each crop type varies from 1 to 7. Pesticide information was not reviewed for the 15 crop types that covered less than 1% of the study area.



### 5.1.2 Relative Risk of Fertilizers

Two primary components of fertilizer are nitrogen and phosphorous. These constituents enhance crop growth as well as plant and algal growth in surface water, a concern for JWC source water quality. Since actual fertilizer application data on crops within the watershed does not exist, an alternate evaluation method had to be found. A compilation completed by Herrera Environmental Consultants, Inc. (Schmidt 2012) averaged the minimum and maximum recommended application rates reported in agricultural guides. These application rates were utilized to set potential risk rankings for each crop.

The Schmidt (2012) data are presented as application rates in pounds/acre of nitrogen and phosphorous. Because of the relative importance of phosphorous in organic matter production in surface water, the application rate for phosphorous was weighted at a higher level than that of nitrogen. Specifically, the expression below was used:

$$\text{Crop Fertilizer Application Risk} = \text{Nitrogen (lbs/acre)} + 4 \times \text{Phosphorous (lbs/acre)}$$

To assign a relative risk factor based on each crops' fertilizer application total, the statistical distribution of all the Fertilizer Application Total values was examined for crops grown in the watershed. From this distribution, a range of relative risk factors from 1 to 7 was applied for a given crop as shown in Table 3 below.

**Table 3:** Relative risk ( $RR_F$ ) factors to environmental health based on the individual application rates (lbs/acre) of nitrogen and phosphorous (see text for weighting factors)

App (lbs/acre)	>800	601 – 800	401 – 600	201 - 400	<201
$RR_F$ Factor	7	5	3	2	1

The maximum value was chosen to be 7, equal to the maximum number of high risk pesticides for any one crop.

### 5.1.3 Relative Risk of Crop Types

To find the overall potential contamination risk presented by different crop types the pesticide and fertilizer risks were combined, giving more emphasis on fertilizers. The overall risk ranking for each crop type was calculated as follows:

- Multiply the total number of high risk pesticides for each crop type by 2 but do not allow resulting number to exceed 10. The end result represents the pesticide risk ranking.
- Combine the pesticide risk ranking with the fertilizer risk ranking using the following weighted equation: (pesticide \* 40%) + (fertilizer \* 60%)
- Resulting values represent the overall risk ranking for each crop type.
- The 15 crop types that covered less than 1% of the study area were given a risk ranking of 1.

A list of crops grown, pesticide application ranks, fertilizer application ranks and total risk value for each crop is shown in Appendix B, Table 4.

Once the risk rankings for each crop type were calculated they were applied to pixels in each year's raster dataset. The three years' raster datasets were then combined by averaging the risk values to create the raster dataset named "Risk\_Ag" that represented the Agricultural

Chemical Applications category of the risk analysis. Figure 1 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk rankings from 4 to 6.19) makes up 2% (4,000 acres) of the study area.
- Medium risk (risk rankings from 2 to 4) makes up 7% (14,000 acres) of the study area.
- Low risk (risk rankings from 0 to 2) makes up 91% (181,996 acres) of the study area.
- Areas of high risk are mostly concentrated within the 1 mile corridor along Gales Creek between the JWC Intake and the intersection of Highways 8 and 6 and within the 1 mile corridor along the Tualatin River between the JWC Intake and 4 miles west of Gaston.
- Areas of high and medium risk are prevalent near the JWC intake and in the lowland areas 3 to 4 miles northeast and southeast of Gaston.
- This analysis does not utilize actual pesticide or fertilizer application data so the results should only be used to focus efforts for additional data collection and program development.

## 5.2 Risk Analysis Input - Forestry Chemical Applications

The second category examined for the risk analysis was Forestry Chemical Applications. This category was a combination of three separate years (September 2009 through 2010, 2011, and 2012) of forestry notifications that contained pesticide or herbicide chemical applications. GSI mapped the forestry notifications per  $\frac{1}{4}$   $\frac{1}{4}$  section (40 acres) based on information derived from the Oregon Department of Forestry's Forestry Activity Computerized Tracking System (FACTS) database. The resulting layer is named "ODF\_FACTS\_Sept2009toSept2012".

To generate risk rankings for each chemical listed in the ODF FACTS database, GSI employed the same methodology as the Agricultural Risk Analysis (described in section 5.1.1). This methodology focused on toxicity (oral LD50 in rats) and persistence (length of time that the chemical continues to exist in the soil environment) of each identified chemical. Using this methodology, GSI developed risk rankings for chemicals listed in the ODF FACTS database (see Appendix B, Table 3). Since it would be very time intensive to assign each  $\frac{1}{4}$   $\frac{1}{4}$  section a different risk ranking based on the number of high risk pesticides actually used, it was reasonable to view forestry activities together as a whole and give all parcels with forestry activity the same pesticide risk ranking. This also makes the agricultural and forestry pesticide risk analysis more comparable. Overall the forestry database included 4 high risk pesticides, so all  $\frac{1}{4}$   $\frac{1}{4}$  sections that included forestry pesticide use was given a risk ranking of 4.

Once the risk rankings were assigned to each year's forestry chemical data they were assigned to the pixels in each year's raster dataset. The three raster datasets were then combined using a weighted formula with equal weights to create the raster dataset named "Risk\_Forestry" that represented the Forestry Chemical Applications category of the risk analysis. Figure 2 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk rankings from 3 to 4) makes up 5% (10,000 acres) of the study area.
- Medium risk (risk rankings from 2 to 3) makes up 9% (18,000 acres) of the study area.
- Low risk (risk rankings from 0 to 2) makes up 86% (171,996 acres) of the study area.



- Risk is predominantly in the center of the study area in rural and forested areas that are in close proximity to minor/intermittent streams.
- The overall quality of the ODF FACTS data greatly limits better characterization of the risk posed by forestry chemical applications. The data resolution is only to the nearest ¼ section; thus, the analysis results should only be used to focus efforts for additional data collection and program development.

### 5.3 Risk Analysis Input - Potential Contaminant Sources

The third category examined for the risk analysis was Potential Contaminant Sources. This category represents the locations that contamination may occur through a point source discharge. The “All\_Potential\_Contaminant\_Sources” layer is a combination of eleven individual layers:

- DEQ\_Dry\_Cleaner\_Sites
- DEQ\_ECSI\_Site\_Permits (permit locations from the Environmental Cleanup Site Information database)
- DEQ\_State\_Fire\_Marshall\_HSIS\_Facilities (hazardous material storage locations from the Hazardous Substance Information Survey database)
- DEQ\_Leaking\_USTs (known leaking underground storage tanks)
- DEQ\_USTs (underground storage tank locations)
- DEQ\_UICs (underground injection control system locations)
- DEQ\_NPDES\_and\_WPCF\_Site\_Permits (National Pollutant Discharge Elimination System and Water Pollution Control Facility permit locations)
- DEQ\_WQ\_Outfalls (other water quality outfall locations)
- DEQ\_PCSs (a variety of potential contamination sources identified in DEQ’s 2003 source water assessment for the JWC)
- DEQ\_Solid\_Waste\_Site\_Permits
- ODA\_CAFOs (confined animal feedlot operations)

GSI and the JWC reviewed the 11 layers for duplicate occurrences and removed them from the data set. Then a list of the specific activities/potential contaminant sources was created to assign a relative risk score of “High” or “Low/Medium” to each location. This method is the same that was used in DEQ’s 2003 Source Water Assessment. Potential contaminant source locations with a relative risk score of “High” were assigned a numeric risk ranking of 7 and those with a relative risk score of “Low/Medium” were assigned a numeric risk ranking of 3.

Specific activities/contaminant sources that were given a relative risk score of “High” included:

- Automobile Machine Shops
- Boarding Stables
- Confined Animal Feeding Operations
- Current and Historic Gas Stations
- Grazing Animals
- Hazardous Materials Storage
- Historic Drug Labs
- Irrigated Crops
- Junk/Salvage Yards
- Known Contaminant Site/Plume/Spill Locations
- Land Application Sites
- Metal Plating/Finishing/Fabrication

- Permitted Stormwater Discharge Site or Outfall
- Railroad Yards
- Rock Quarries
- Utility Stations and/or Powerplants
- Waste Landfills or Transfer/Recycling Stations
- Wastewater/Stormwater Lagoon or Disposal Sites
- Wastewater Treatment Plants
- Wood Processing Sites

Specific activities/contaminant sources that were given a relative risk score of “Low/Medium” included:

- Above Ground Storage Tank Locations
- Airport Maintenance and/or Fueling Areas
- Automobile Body Shops
- Automobile Repair Shops
- Automobile/Machinery Repair and/or Maintenance for Farms or Rural Homesteads
- Campground/Park Locations
- Cemeteries
- Dry Cleaners
- Fire Stations
- Fire Training Facilities
- Fish Hatcheries
- Food Processing Locations
- Certain Hazardous Materials Storage (*specifically for Schools, Fire Departments, Food Processing Sites, Aquatic Centers, and Drinking Water Treatment Plants*)
- Lawn Care – Highly Maintained Areas
- Leaking Underground Storage Tank Locations
- RV and/or Mini Storage Locations
- Motor Pools/Fleet Terminals/Parking Lots
- Reservoir or Dam Locations
- School Locations
- Underground Storage Tank Locations
- Drinking Water Treatment Plants

Once the final list of potential contaminant source locations and their associated risk rankings were determined, each location was buffered by 1,000 feet to represent the single points as areas and the appropriate risk ranking was assigned to each resulting polygon. Using a buffer distance of 1,000 feet was determined to be the best option to adequately show the potential contaminant sources without over-emphasizing their influence in the overall risk analysis.

In the initial phase of the risk analysis, an area representation of each potential contaminant source location was generated by using its associated tax lot as a boundary. This was deemed inadequate because of numerous locational errors in most all of the potential contaminant source locations placing them +/- 500 feet away from the correct tax lot boundary. Also using tax lot boundaries significantly exaggerated the spatial extent of many of the potential contaminant sources. For example, Gales Creek Campground and Overlook has restrooms,

maintenance shops/equipment storage, campgrounds, and RV parks that cover less than 5 acres of land. However, the two tax lots that represent these locations total an area of 7,056 acres. If represented by their respective tax lots the areas completely unrelated to the potential contaminant sources would also be identified as high-risk areas. This would greatly skew the impact of the potential contaminant sources in the overall risk analysis and considerably misrepresent the actual spatial extent of each potential contaminant source.

Once the 1,000 foot buffer polygons for the potential contaminant source locations were generated and the numeric risk rankings were assigned, cluster analysis was performed to determine which potential contaminant sources were in close proximity to each other. A cluster was defined as three or more polygons intersecting at least one other polygon in the group or were located in close proximity to a group of intersecting polygons. Any polygon that was identified as part of a cluster had its risk ranking increased by 3.

Once the risk rankings for each individual polygon were finalized, a “dissolve” was performed in GIS using the risk rankings as the “dissolve field”. The output is four multi-part polygons, each a combination of the individual polygons with the same risk ranking determined in the previous steps. Once the “dissolve” was complete for each risk ranking, the “clip” option in ArcMap’s editing toolbar was used to essentially delete the combined polygon of lower risk rankings where they overlap with the combined polygon of higher risk rankings. Performing these multiple clips ensured that the final boundaries of the combined polygons never overlapped. Once the clips were completed, the resulting 1,000 foot potential contaminant source buffer layer was converted to a raster dataset where the pixel values represented the risk rankings. The result was the raster dataset named “Risk\_PCS” that represents the Potential Contaminant Sources category of the risk analysis. Figure 3 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk rankings from 7 to 10) makes up 6% (12,000 acres) of the study area.
- Medium risk (risk ranking of 6) makes up 1% (2,000 acres) of the study area.
- Low risk (risk rankings from 0 to 3) makes up 93% (185,996 acres) of the study area.
- Areas of high risk are mostly concentrated within the 1 mile corridor along the Gales Creek between the JWC Intake and just past the intersection of Highways 8 and 6, within the 2 mile corridor of Hwy 47 between the JWC Intake and Gaston, within the 1 mile corridor along the Scoggins Creek and Highway 47 between Hagg Lake and Forest Grove, and the area south of Gaston along Hwy 47 to the study area’s eastern border.
- Areas of high and medium risk are prevalent within the city limits of Forest Grove and Gaston, near the JWC intake, and in the lowland areas 3 to 4 miles northeast and southeast of Gaston.
- It must be noted that this analysis includes very little actual contaminant release information, only potential for a release based on the type of activity. Consequently, the results should only be used to focus efforts for additional data collection and program development.

## 5.4 Risk Analysis Input - Septic Tanks

The fourth category examined for the risk analysis was Septic Tanks. Since no GIS data exists for septic tank locations in the study area, GSI used tax lot data to determine where septic tanks may exist. Three layers were combined to produce the overall tax lot layer (“Taxlots\_all”) that was used to identify potential septic tank locations:

- Taxlots\_METRO\_WashCo
- Taxlots\_YamhillCo
- METRO\_Sewer\_Districts

The methodology used for determining if a tax lot likely has a septic tank is as follows: the tax lot had to exist outside of a known sewer district and the tax lot had to have information that indicated a building was present (specific indicators included a site address, building square footage, and a year built). Once the tax lots with septic tanks were identified, a risk ranking of 7 was assigned to each tax lot.

Since septic system locations were represented as tax lots, refinements were done to limit the influence of large tax lots. Tax lots that were less than or equal to two acres in size were selected and cluster analysis was performed on only those. A cluster was defined as any group of tax lots where three or more intersected or were located in close proximity to a group of intersecting tax lots. Any tax lot that was identified as part of a cluster had its risk ranking increase by 3. Once the risk rankings for each polygon were finalized, the resulting “Tax\_Lots\_with\_Septic\_Tanks” layer was converted to a raster dataset where the pixel values represent the risk rankings. The result was the raster dataset named “Risk\_Septic” that represents the Septic Tanks category of the risk analysis. Figure 4 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk ranking of 10) makes up 0.2% (400 acres) of the study area.
- Medium risk (risk ranking of 7) makes up 25.8% (51,599 acres) of the study area.
- Low risk (risk ranking of 0) makes up 74% (147,997 acres) of the study area.
- Of the 10,870 tax lots that exist within the study area 3,362 have been identified as likely having a septic tank and were categorized as medium risk.
- Of the 3,362 tax lots that were identified as likely having a septic tank, 604 were identified as being part of a cluster and categorized as high risk.
- Areas where septic tanks are potentially located (and have a medium risk ranking of 7) are generally found throughout the eastern half of the study area in the lowland areas, except within the city limits of Forest Grove and Gaston. Specifically the areas adjacent to Gales Creek and to the study area’s eastern border, and from the Hagg Lake/Cherry Grove area to the study area’s southern and eastern borders.
- Clusters of septic tanks on tax lots smaller than 2 acres classified as high risk are scattered throughout the area where septic tanks are potentially located.
- This analysis did not confirm the actual location of septic systems; it made the best possible estimation with the resources available. Also, this analysis does not consider the age, maintenance, or performance level of the septic systems. Additional evaluation, including inspection of County septic tank records, could be done to further assess the actual number of septic tanks, the number and size of clusters, and the distance that the clusters are from the nearest stream. We recommend focusing on the clusters that are located closest to streams.

## 5.5 Risk Analysis Input - Urban Development

The fifth category examined for the risk analysis was Urban Development. This category was made up of five individual layers:

- METRO\_City\_Limits (city limit boundaries)
- METRO\_UGBs (urban growth boundaries)
- METRO\_Urban\_Reserve\_Boundaries (urban reserve boundaries)
- Zoning\_METRO\_WashCo
- Zoning\_YamhillCo

The first step to represent the Urban Development category of the risk analysis was to create three distinct areas and assign a different risk ranking to each. Those areas were:

- Areas within city limit boundaries
- Areas between city limit boundaries and urban growth boundaries (UGBs)
- Areas between UGBs and urban reserve boundaries

Where any of those three areas intersected commercial, industrial, or manufacturing zoning designations, the risk rankings were increased by 2. Once the risk rankings were finalized, the areas were combined into a single layer named “Urban\_Development” and converted to a raster dataset where the pixel values represented the risk rankings. The result was the raster dataset named “Risk\_Urban” that represents the Urban Development category of the risk analysis. Figure 5 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk rankings of 8 and 10) makes up 2% (3,100 acres) of the study area.
- Medium risk (risk ranking of 4 and 6) makes up <1% (676 acres) of the study area.
- Low risk (risk rankings of 0) makes up 98% (196,220 acres) of the study area.
- Areas of high risk only appear within the city limits of Forest Grove and Gaston.
- Areas of low and medium risk only exist in the sections adjacent to the northwest and southeast edge of the city limits of Forest Grove.

## 5.6 Risk Analysis Input - Transportation Setbacks

The sixth and final category examined for the risk analysis was Transportation Setbacks. The analysis included public roads in all areas of the including highways, arterial roads, streets, and forestry roads, all paved and unpaved. Privately owned roads were removed from analysis. 200 foot buffers were assigned to either side of the centerline for the following layers:

- METRO\_Public\_Roads (all of the road centerlines from the “METRO\_Roads” layer except those with a “TYPE” value of 1700, 1740, 1750, 1760, 1800, and 1850)
- ODOT\_Railroads (railroad centerlines)

Once the buffered areas were created for both layers, a risk ranking of 8 was assigned to the resulting polygons. Different types of roads were not given different risk rankings. Heavier used roads (Highways 47, 6 and 8) and the railroad present a risk due to higher traffic levels and higher risk of accidents and spills. Gravel forestry roads present risks of turbidity, failures from culvert maintenance needs landslides and nearly sole use by heavy trucks. The buffered areas were then combined into the layer named “Transportation\_Setbacks”.

“Transportation\_Setbacks” was then converted to a raster dataset where the pixel values represent the risk rankings. The result was the raster dataset named “Risk\_Trans” that represents the Transportation Setbacks category of the risk analysis. Figure 6 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High risk (risk ranking of 8) makes up 14% (28,800 acres) of the study area.
- Low risk (risk ranking of 0) makes up 86% (171,196 acres) of the study area.
- Areas of high risk only appear within the 200 foot corridor along all public roads within the study area.

## 5.7 Overall Risk Analysis Results

To model potential contaminant risk within the study area, the resulting rasters from the six risk analysis categories were combined using the weighted overlay GIS analysis technique. The following weights were applied to each raster dataset:

- 20% Agriculture Chemical Use
- 20% Forestry Chemical Use
- 20% Potential Contaminant Sources
- 10% Septic Systems
- 15% Urban Development
- 15% Transportation

The resulting risk values ranged between 0 and 5.88 and were statistically classified into four categories using the “natural breaks” method. This method allows classification of the activities as no risk (0), low risk (1), medium risk (2), and high risk (3). Figure 7 illustrates the risk analysis results. Observations and interpretations of the resulting raster dataset from the initial weighted overlay risk analysis include:

- High Risk areas make up 5% (9,884 acres) of the study area.
- Medium Risk areas make up 12% (24,585 acres) of the study area.
- Low Risk areas make up 35% (70,452 acres) of the study area.
- No Risk areas make up 48% (95,075 acres) of the study area.
- Risks posed by agricultural chemical applications, forestry chemical applications, and septic tanks are a smaller relative risk than posed by potential contaminant sources, urban development, and transportation setbacks.
- Areas of high and medium risk appear where potential contaminant sources overlap the other categories used in the risk analysis.
- Areas of high risk are prevalent within the city limits of Forest Grove, within the city limits of Gaston, and where potential contaminant sources overlap the other categories used in the risk analysis.

In order to see how the selected weighting scheme impacted the analysis results, another analysis was performed with each risk category being equally weighted. The following weights were used in the equal weighted analysis:

- 16.67% Agriculture



- 16.67% Forestry
- 16.67% Potential Contaminant Sources
- 16.66% Septic
- 16.67% Urban
- 16.66% Transportation

Figure 8 illustrates the results of the equal weighted risk analysis. The resulting raster dataset contains risk values between 0 and 6.40. Again, the risk values were statistically classified into four categories using the “natural breaks” method giving classifications of no risk (0), low risk (1), medium risk (2), and high risk (3). Observations and interpretations of the resulting raster dataset from the equal weighted risk analysis include:

- High risk areas make up 7% (14,149 acres) of the study area.
- Medium risk areas make up 16% (32,671 acres) of the study area.
- Low risk areas make up 31% (61,842 acres) of the study area.
- No risk areas make up 46% (91,334 acres) of the study area.
- Using the equal weighting in the overlay decreases the influence of forestry activities, mostly to the low risk category.
- Areas of high and medium risk in the agricultural and potential contaminant sources risk analyses are still prevalent. These areas include the city limits of Forest Grove and Gaston, within the 1 mile corridor along the Gales Creek between the JWC Intake and the intersection of Highways 8 and 6, within the 2 mile corridor of along Hwy 47 between the JWC Intake and to Cherry Grove, the lowland areas 3 to 4 miles northeast and southeast of Gaston, near the JWC intake, and within the 1 mile corridor along the Scoggins Creek.
- When the transportation network intersects high risk agricultural and forestry zones it becomes an overall High risk area.
- The equal weighted risk analysis approach does not differentiate one risk analysis category over the others making it more difficult to prioritize particular programs that target particular risks.

## 5.8 Conclusions on Watershed Risk Analysis

The results of any weighted overlay calculations give a wide range of values that can be classified many different ways. In this instance it is preferred to statistically classify the results of the risk analysis using the natural breaks method. This method was specifically created for mapping and visualization purposes. It classifies the data in groups by calculating the maximum similarity within each group and the maximum difference between each group.

The results of the initial weighted and equally weighted overlay provides insight into how the six risk categories and their risk rankings relate to each other. Each analysis results amplify and/or downplay the risk posed by each of the risk analysis categories differently. While arguments could be made in support of either analysis result, GSI favors the initial weighted overlay risk analysis. This analysis amplifies the risk posed by the risk categories that are more prevalent than in the equal weighted overlay risk analysis results. While the equal weighted risk analysis results are useful, they do not allow the user to easily differentiate between the different risk categories making it difficult to assess the results in any meaningful way.

## 6.0 Watershed Sensitivity Analysis

A separate geospatial analysis was performed to assess the sensitivity of the watershed to a number of physical characteristics (e.g. vulnerable soils). The sensitivity analysis consisted of six categories, with each category being comprised of individual layers or groups of layers. The sensitivity analysis incorporated layers associated with watershed features including

- flood zones,
- forestry activities,
- surface water time of travel zones,
- unstable and/or vulnerable soils,
- wetlands, and
- proximity to surface water.

Similar to the risk analysis method, where an individual layer was used, sensitivity rankings were applied to each feature in the layer based on specific attributes of that feature. Also, when groups of layers were used to represent a sensitivity analysis category, GSI applied the sensitivity rankings in Appendix A to each layer and combined them such that where the different layers overlapped the higher sensitivity rankings truncated the lower rankings.

### 6.1 Sensitivity Analysis Input - Flood Zones

The first category examined for the sensitivity analysis was Flood Zones. This category used FEMA's 100 year and 500 year flood zone (also referred to as floodplain) boundaries from the layer named "FEMA\_Q3\_Floodplains". 100 year flood zone boundaries were assigned a sensitivity ranking of 6. The 500 year flood zone boundaries outside of the 100 year floodplain boundaries were assigned a sensitivity ranking of 3. Once the sensitivity rankings were finalized, the flood zone areas were combined into a single layer named "Flood\_Zones" and converted to a raster dataset where the pixel values represent the sensitivity rankings. The result was the raster dataset named "Sensitivity\_Flood" that represents the Flood Zones category of the sensitivity analysis. Figure 9 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity ranking of 6) makes up 5.5% (11,005 acres) of the study area.
- Medium sensitivity (sensitivity ranking of 3) makes up 0.2% (323 acres) of the study area.
- Low sensitivity (sensitivity ranking of 0) makes up 94.3% (188,668 acres) of the study area.
- Areas of high sensitivity are widespread within the 1 mile river and stream corridors in the east half of the study area, near Haag Lake and Barney Reservoir, near the JWC intake (specifically in the sections immediately northeast, northwest, and southwest of the intake), and in the lowland areas 3 to 4 miles northeast and southeast of Gaston.

### 6.2 Sensitivity Analysis Input - Forestry Activities

The second category examined for the sensitivity analysis was Forestry Activities. This category included three separate years (September 2009 through 2010, 2011, and 2012) of forestry notifications that contained non-chemical application related activities. These activities

included thinning, clear cutting, road construction, harvesting, and other forestry activities. GSI mapped the forestry notifications per ¼ ¼ section based on information derived from the Oregon Department of Forestry's FACTS database. The resulting layer is named "ODF\_FACTS\_Sept2009toSept2012". Unfortunately, a majority of the non-chemical forestry activities (thinning, clear cutting, road widening, etc.) in the original FACTS database were not imported into the GIS layer because at the time the custom programming and querying were setup, the only objective was to extract chemical applications from the FACTS database.

Sensitivity rankings for each forestry activity type were assigned to each ¼ ¼ section that contained non-chemical application forestry activity notifications. Once the sensitivity rankings were finalized, the forestry activity ¼ ¼ sections were converted to a raster dataset where the pixel values represent the sensitivity rankings. The result was the raster dataset named "Sensitivity\_Forestry" that represents the Forestry Activities category of the sensitivity analysis. Figure 10 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity rankings of 7 and 10) makes up <1% (1,344 acres) of the study area.
- Medium sensitivity (sensitivity ranking of 2 and 5) makes up <1% (597 acres) of the study area.
- Low sensitivity (sensitivity rankings of 0) makes up 99% (198,055 acres) of the study area.
- Sensitivity posed by forestry activities is scattered throughout the study area in no significant pattern that would allow for any meaningful interpretation of the data, due to the poor quality of the ODF FACTS data and its low resolution (¼ ¼ section).
- The overall quality of the ODF FACTS data greatly limits our ability to better characterize the sensitivity posed by forestry activities. Unless this database is improved in the future, we do not recommend relying on it. Instead, the JWC should work with land owners and managers to characterize and manage risks posed by higher risk activities including chemical application near streams, clear cuts, and road building.

### 6.3 Sensitivity Analysis Input - Surface Water Time of Travel

The third category examined for the sensitivity analysis was Surface Water Time of Travel. The basis for this layer was "USGS\_NHD\_Watercourses". Prior travel time estimates made in DEQ's 2003 Source Water Assessment determined that the 8 hour time of travel zone to the JWC intake was 7.6 river miles upstream. This time of travel was used because it represents a time period in which it would be difficult to contain an accidental spill. Since no layer existed for the 8 hour time of travel zone, the layer was created from scratch. The first task was to identify all of the polylines in "USGS\_NHD\_Watercourses" that exist 7.6 river miles upstream from the JWC intake. The layer named "SW\_8hour\_TOT\_Zone\_Watercourses" contains the main surface water bodies that were within the 8 hour time of travel zone. GSI buffered this layer by 200 feet and assigned sensitivity rankings of 8 to all of the polygons in the resulting buffered layer named "SW\_8hour\_TOT\_Zone". Once the sensitivity rankings were finalized, "SW\_8hour\_TOT\_Zone" was converted to a raster dataset where the pixel values represent the sensitivity rankings. The result was a raster dataset named "Sensitivity\_SWTOT" that represents the Surface Water Time of Travel category of the sensitivity analysis. Figure 11 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity ranking of 8) makes up 0.8% (1,697 acres) of the study area.
- Low sensitivity (sensitivity ranking of 0) makes up 99.2% (198,299 acres) of the study area.
- Areas of high sensitivity only appear within the 200 foot corridor along all waterways that make up the 8 hour time of travel zone to the JWC intake.

## 6.4 Sensitivity Analysis Input – Unstable/Vulnerable Soils

The fourth category examined for the sensitivity analysis was Unstable/Vulnerable Soils. This category was a combination of seven individual layers:

- DEQ\_NRCS\_Highly\_Erodible\_Lands (soil units considered as highly erodible lands)
- DEQ\_NRCS\_High\_Permeability\_Soils (soil units with high permeability)
- DEQ\_NRCS\_High\_Runoff\_Potential\_Soils (soil units with high runoff potential)
- DOGAMI\_Landslide\_Deposits (landslide deposit areas)
- Slope\_15to33percent (areas where the land surface slope ranged from 15% to 33%)
- Slope\_greaterthan33percent (areas where the land surface slope was greater than 33%)
- Transient\_Snow\_Zones (areas where land surface elevation was 1500 feet or above mean sea level)

Each layer was assigned a different sensitivity ranking (see Appendix A, Table 2). Then they were combined so that where they overlapped, the higher sensitivity ranking truncated any of the lower rankings. The combined single layer is named “Unstable\_Vulnerable\_Soils”. Then it was converted to a raster dataset where the pixel values represent the sensitivity rankings and named “Sensitivity\_UVSoils”. Figure 12 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity rankings of 7 and 10) makes up 12% (24,000 acres) of the study area.
- Medium sensitivity (sensitivity rankings of 4 and 5) makes up 51% (101,998 acres) of the study area.
- Low sensitivity (sensitivity rankings of 0 and 3) makes up 37% (73,998 acres) of the study area.
- Areas of high sensitivity are prevalent in areas where the land surface slope is >33% and where high runoff potential soils exist.
- Areas of medium sensitivity are widespread in areas where the land surface slope ranges between 15% and 33% and areas where transient snow zones exist.

## 6.5 Sensitivity Analysis Input - Wetlands

The fifth category examined for the sensitivity analysis was Wetlands. In order to create this category, GSI extracted non-linear (along rivers or creeks) palustrine wetland polygons from the layer named “TWC\_Wetlands” and created a layer named “TWC\_Wetlands\_NonLinear\_Palustrine”. A sensitivity ranking of 8 was assigned to each wetland polygon and “TWC\_Wetlands\_NonLinear\_Palustrine” and converted to a raster dataset where the pixel values represent the sensitivity rankings. The result was the raster dataset

named “Sensitivity\_Wetlands” that represents the Wetlands category of the sensitivity analysis. Figure 13 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity ranking of 8) makes up 0.01% (1,700 acres) of the study area.
- Low sensitivity (sensitivity ranking of 0) makes up 99.99% (198,296 acres) of the study area.
- Areas of high sensitivity only appear where the palustrine wetlands exist.

## 6.6 Sensitivity Analysis Input - Water Setbacks

The sixth and final category examined for the sensitivity analysis was Water Setbacks. This category was made up of 200 foot buffers of all of the surface water features that were in the “USGS\_NHD\_Waterbodies” and “USGS\_NHD\_Watercourses” layers. Once the buffered areas for each layer were created, a risk ranking of 8 was assigned to the resulting polygons. The buffered areas were then combined into the layer named “Water\_Setbacks”. “Water\_Setbacks” was then converted to a raster dataset where the pixel values represent the sensitivity rankings. The result was the raster dataset named “Sensitivity\_Water” that represents the Water Setbacks category of the sensitivity analysis. Figure 14 illustrates the resulting raster dataset.

Observations and interpretations of the resulting raster dataset include:

- High sensitivity (sensitivity ranking of 8) makes up 30% (60,176 acres) of the study area.
- Low sensitivity (sensitivity ranking of 0) makes up 70% (139,820 acres) of the study area.
- Areas of high sensitivity only appear within the 200 foot corridors along all waterbodies and watercourses throughout the study area. However, it should be noted that most of the watercourses in this category are intermittent watercourses and do not exist year-round.

## 6.7 Sensitivity Analysis Results

The six categories of the watershed sensitivity analysis were geoprocessed and converted from polygon-based layers to raster datasets whose pixel values represent the rankings. To model sensitivity of lands within the study area to contamination, the raster datasets were combined using the weighted overlay GIS analysis technique. The following weights were applied to each layer:

- 20% Flood
- 10% Forestry
- 25% Time of Travel
- 20% Unstable and Vulnerable Soils
- 5% Wetlands
- 20% Water Setbacks

The resulting sensitivity values ranged between 0 and 6.60 and were statistically classified using the natural breaks method. The results can be visualized as no sensitivity (0), low sensitivity (1), medium sensitivity (2), and high sensitivity (3). Figure 15 illustrates the sensitivity

analysis results. Observations and interpretations of the resulting raster dataset from the sensitivity weighted overlay analysis include:

- High Sensitivity areas make up 1% (1,300 acres) of the study area.
- Medium Sensitivity areas make up 3% (6,535 acres) of the study area.
- Low Sensitivity areas make up 31% (61,599 acres) of the study area.
- No Sensitivity areas make up 65% (130,562 acres) of the study area.
- Areas of high sensitivity are predominant within the 200 foot corridor along all waterways that make up the 8 hour time of travel zone to the JWC intake.
- Areas of medium sensitivity are prevalent within the 200 foot corridors along all waterbodies and watercourses throughout the study area.
- The highest concentration of sensitivity (all sensitivity rankings) appears where high runoff potential soils exist, especially where it overlaps with flood zones.
- Areas within the 200 foot corridors along all waterbodies and watercourses throughout the study area are considered low sensitivity.

In order to see how the selected weighting scheme impacted the analysis results, another analysis was performed with each risk category being equally weighted. The following weights were used in the equal weighted analysis:

- 16.67% Flood
- 16.66% Forestry
- 16.67% Time of Travel
- 16.67% Unstable and Vulnerable Soil
- 16.66% Wetlands
- 16.67% Water Setbacks

Figure 16 illustrates the results of the equal weighted sensitivity analysis. The resulting overall sensitivity values range between 0 and 6.17 and were statistically classified using the natural breaks method. Observations and interpretations of the resulting raster dataset from the equal weighted sensitivity analysis include:

- High sensitivity areas make up 1% (1,555 acres) of the study area.
- Medium sensitivity areas make up 5% (10,845 acres) of the study area.
- Low sensitivity areas make up 32% (64,435 acres) of the study area.
- No sensitivity areas make up 62% (123,161 acres) of the study area.
- The highest sensitivity areas are similar to the areas in the initial weighted overlay. They appear in the waterways of the 8 hour time of travel.
- Medium sensitivity areas are predominately the waterways within the flood zone.
- The influence of high sensitivity areas in the Unstable/Vulnerable soils has more influence in the equal weighted analysis, as seen in the lower watershed, south of Gaston.
- Since the categories that had the greatest increase in weight between the initial and equal overlay analysis also cover the least area, Wetlands and Forestry, they have little influence on the results.



## 6.8 Conclusions on Watershed Sensitivity Analysis

The results of the initial weighted overlay and the equal weighted sensitivity analyses provide insight into how the six sensitivity analysis categories relate to each other. Each of the analysis results amplify and/or downplay the sensitivity posed by each of the sensitivity analysis categories differently than the other analysis results. While arguments could be made in support of each analysis result, GSI favors the initial weighted overlay sensitivity analysis. The initial weighted overlay sensitivity analysis highlights the impact of the sensitivity posed by the sensitivity categories that are prevalent throughout the study area (unstable/vulnerable soils and water setbacks). GSI feels that this is a better representation of the actual sensitivity of lands within the study area.

## 7.0 Watershed Susceptibility Analysis

Once the study area's risks and sensitive areas were identified and classified, they were combined to identify the areas most susceptible to potential contamination risks. First the results from the initially weighted overlays of the risk and sensitivity analysis were combined by multiplying them together using the raster calculator.

The susceptibility results ranging from 0 to 33 were classified into no, low, medium, and high susceptibility using the "natural breaks" statistical method. The reclassified values were saved into a new raster dataset named "Susceptibility\_Analysis\_Result\_v2". Figure 17 illustrates the reclassified susceptibility analysis results. Observations and interpretations of the resulting combined raster dataset from the initial susceptibility analysis include:

- High susceptibility areas (>8.41 to 33.00) make up 1% (2,627 acres) of the study area.
- Medium susceptibility areas (>3.49 to 8.41) make up 7% (13,040 acres) of the study area.
- Low susceptibility areas (>1.04 to 3.49) make up 22% (45,026 acres) of the study area.
- No susceptibility areas (0 to 1.04) make up 70% (139,303 acres) of the study area.
- Areas of high and medium susceptibility correlate well with areas of high risk/sensitivity from the initial individual weighted overlay analysis results. These areas include the 1 mile corridor along the Gales Creek between the JWC Intake and the intersection of Highways 8 and 6, the 2 mile corridor of along the Tualatin River between the JWC Intake and 5 miles west of Gaston, the lowland areas 3 to 4 miles northeast and southeast of Gaston, the areas near the JWC intake, and the areas within the 1 mile corridor along the Scoggins Creek and Highway 47 between the Haag Lake and Forest Grove.
- The areas within the city limits of Forest Grove and Gaston have low susceptibility rankings, especially compared to high risk rankings the area received. This is because these areas were not identified as highly sensitive.
- Overall, the areas within the 1,000 foot buffers of the potential contaminant sources throughout the study area are ranked much lower for susceptibility than their risk ranking indicated because they are not all located within sensitive areas.

In order to better understand how weighting affects the susceptibility analysis, the equal weighted contaminant risk and watershed sensitivity analysis results were multiplied together to get an equal weighted view of susceptibility. The results were then classified using the natural

breaks method. Figure 18 illustrates equal weighted version of susceptibility ("Susceptibility\_Analysis\_Result\_v4"). Observations and interpretations of the resulting raster dataset from the equal weighted susceptibility analysis include:

- High susceptibility areas make up 2% (3,006 acres) of the study area.
- Medium susceptibility areas make up 7% (13,625 acres) of the study area.
- Low susceptibility areas make up 21% (41,354 acres) of the study area.
- No susceptibility areas make up 71% (142,011 acres) of the study area.
- Areas of high and medium susceptibility correlate well with areas of high risk/sensitivity from the initial weighted overlay analysis results except within the city limits of Forest Grove and Gaston.
- Susceptibility is amplified for certain risk and sensitivity analysis categories (potential contaminant sources, transportation setbacks, surface water time of travel, and water setbacks) but not enough to justify using this equal weighting analysis method over the initial susceptibility analysis method.
- Since septic tanks have a higher percentage of weight in the equal weighting analysis, the susceptibility results are more contiguous because septic tanks are represented by tax lots.
- Where the road and stream networks cross or are parallel to each other appear more clearly in the susceptibility analysis and have greater influence than they do alone in the risk or sensitivity analysis. These areas have a higher susceptibility rank in the equal weighting method because their rank is relatively higher than in the initial weighting method.
- The equal weighted susceptibility analysis results do not allow differentiation of one susceptibility analysis category over others, due to the equal weighting scheme. This makes it difficult to evaluate the results and is going to be more difficult to prioritize particular programs that target particularly susceptible areas.

## 7.1 Conclusions on Watershed Susceptibility Analysis

Comparing the results of the initial and equal weighted susceptibility analysis provide insight into how the twelve risk and sensitivity analysis categories relate to and interact with each other. The results of the susceptibility analyses are similar and highlight the same areas of high susceptibility. While arguments could be made in support of either susceptibility analysis result, GSI favors the initial susceptibility analysis. While the equal weighted susceptibility analysis results are useful, they do not allow the user to easily differentiate between the different risk/sensitivity analysis categories and therefore make it difficult to assess the results in any meaningful way.

## 8.0 Recommendations

While the results of the risk, sensitivity, and susceptibility analysis are valid based on the input data layers, GSI recommends that the JWC use the analysis methodology and GIS layers as a starting point to a more refined analysis. During the course of this phase of the project, GSI found significant limitations in some of the available datasets. These data limitations were especially profound in the layers used for agricultural crop types, forestry activities, forestry chemical applications, potential contaminant sources, septic tank locations, and surface water

time of travel. These layers were compiled from various data sources, each with its own unique problems that reduced the accuracy of the resulting layers that were used in the analysis. In order to better pinpoint areas in need of source water protection efforts, we recommend that the JWC invest its resources in obtaining more comprehensive and higher resolution data for the following analysis categories:

- 1) Agricultural Chemical Applications. As a result of the 2008 Farm Bill, the USDA cannot provide information on landowners' crop types and chemical usage without the individual landowner's consent. It is unlikely that this consent will be granted and so we recommend working with entities that already have connections with farmers and have programs focused on reducing chemical use and preventing chemicals from entering waterways.
- 2) Forestry Chemical Applications and Activities. The FACTS database provided by the Oregon Department of Forestry was never intended for use in a GIS platform. Due to that, a significant amount of out-of-scope custom programming and querying had to be performed to get a table built that could be used to create a GIS layer for forestry activity notifications. Unfortunately, at the time the custom programming and querying were setup, the only objective was to extract chemical applications from the FACTS database. Due to this, the majority of the non-chemical forestry activities (thinning, clear cutting, road widening, etc.) in the original FACTS database were not imported into the resulting GIS layer.

ODF has indicated that a GIS-version of FACTS is in the works and has a tentative release date of mid-2014. GSI recommends that the JWC stay in regular contact with ODF on the status of the GIS database release. If ODF indicates that the GIS database will not be comprehensive or the release will be significantly delayed, GSI recommends that the JWC revises the custom programming and querying in the "GSI\_FACTS.mdb" database to ensure that the non-chemical forestry activities are included in the output GIS layer.

Another issue with the FACTS database is that it only included forestry notifications from September 2009 to the present. Numerous historical forestry activities relevant to the analysis performed as part of this phase of the project are not in the FACTS database. In order to get a better view of forestry activities in the study area, the JWC could contact ODF and try to obtain copies of the original paper forms that were submitted to ODF prior to 2009. This could help build a much clearer picture of forestry activities that have happened in the study area in the last few decades. An alternative the JWC could consider is using high resolution multi-spectral satellite imagery to identify areas where clear cuts and road building has occurred in recent years.

Additionally, GSI could not locate toxicity (oral LD50 in rats) and persistence (length of time that the chemical continues to exist in the soil environment) data for each chemical in the ODF FACTS database. Due to this, GSI was unable to assign chemical-specific risk rankings to every chemical in the FACTS database. This limited the impact and influence of the forestry data in the overall risk analysis. GSI recommends that if ODF produced a useable FACTS database, the JWC should research toxicity and persistence data for every chemical in the ODF FACTS database so that the forestry data can be better represented in the overall risk analysis.

In addition, the JWC should work with larger forest land owners and managers to characterize and manage risks posed by higher risk activities including clear cuts, road building, and chemical application near streams.

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- 3) Potential Contaminant Sources. The data used for the analysis performed in this phase of the project comes from the Oregon Department of Environmental Quality and was developed in 2003. No updates have been made to the data since then and there are no updates scheduled in the near future. GSI found that many of the potential contaminant sources were not locationally accurate and did not appear in the property boundaries for the business to which they were related.

However, Environmental Data Resources (<http://www.edrnet.com/>) provides radius map reports that have current and high resolution locations for various potential contaminant sources. There is a fee for their services but their data is much more accurate and comprehensive than what the DEQ provided for this project.

- 4) Septic Tanks. Neither Washington County nor Yamhill County provides a GIS layer for actual septic tank locations. However, both counties have septic tank permits on file at their respective offices. If the JWC could obtain copies of these permits, they could better map locations and age of septic tanks in the study area and get a better idea where clusters of older septic tanks are located. This information could also be used to get a better understanding of the age and structural integrity of the septic tanks within the identified clusters. This work should particularly focus on septic tank clusters located close to waterways.
- 5) Surface Water Time of Travel. The layer developed to represent an 8 hour time of travel zone to JWC's intake was estimated using observations on how long it takes water released from Scoggins Dam to reach the JWC intake. However, Geosyntec Consultants will be refining the current estimates of the JWC intake's 8 hour time of travel zone. Upon completion of their analysis, they will provide the JWC with GIS layers (based on USGS National Hydrography Dataset data) that represent the revised 8 hour time of travel zone. Once the JWC has the revised GIS layers, they can revise the susceptibility analysis results.

## 9.0 References Cited

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Schmidt, J., Herrera Environmental Consultants, "GIS Agricultural Activities Risk Analysis Results", Final Memorandum to Clackamas River Water Providers, May 31, 2012

## 10.0 Figures

Figures 1-18      Maps of analysis for individual Risk and Sensitivity categories weighted and equal-weighted analysis for Risk, Sensitivity and Susceptibility

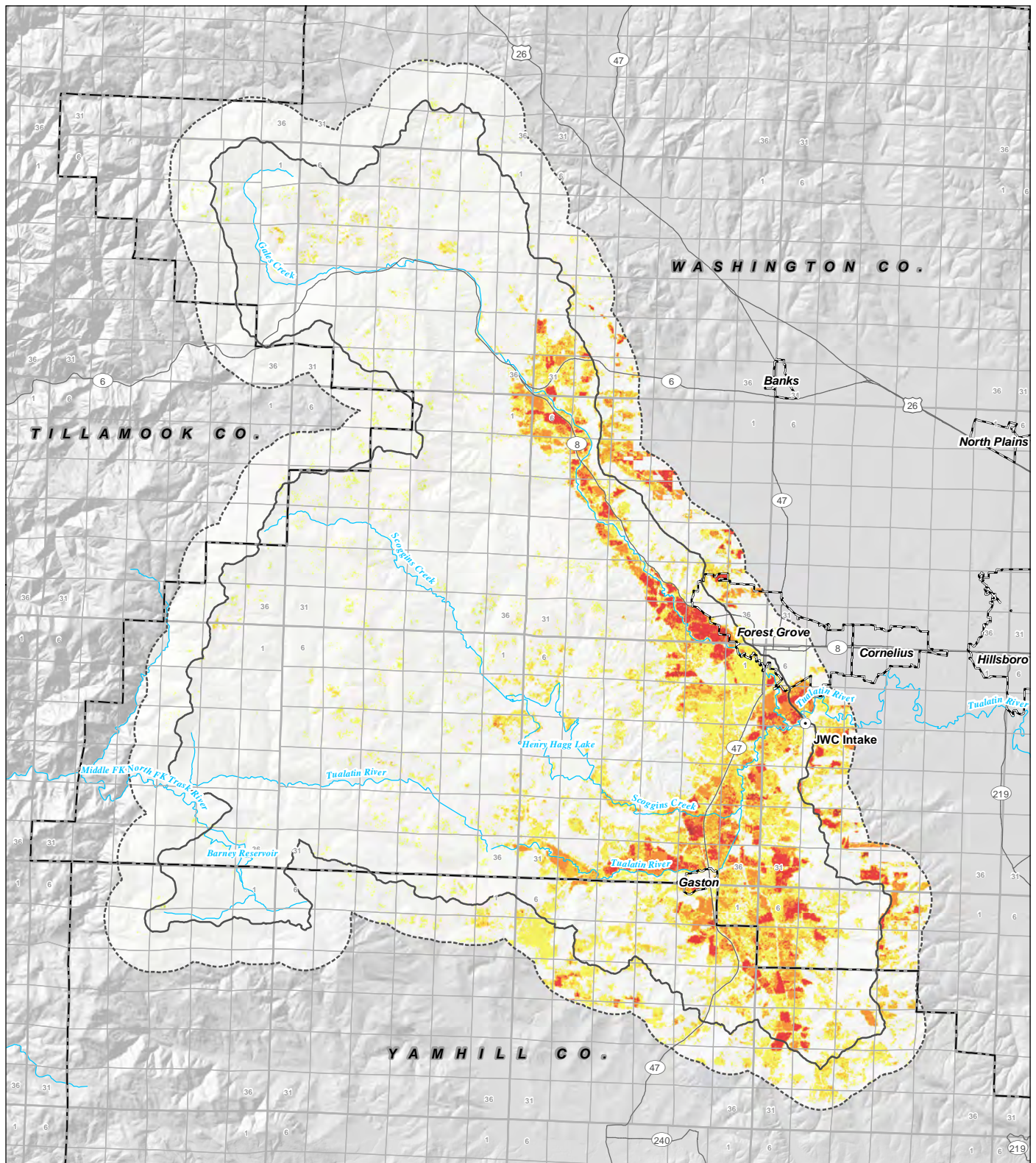
## 11.0 Appendixes

- A) Risk and sensitivity analysis methodology including evaluation flowcharts and details on geoprocessing, ranking and weighted overlay.
- B) Supporting information to calculate risk for agricultural and forestry chemical applications.
- C) Methodology for updating the geodatabase.
- D) DVD containing the final source water assessment geodatabase titled "JWC\_Source\_Water.gdb" and a working map titled "JWC\_SW\_Working\_Map.mxd".
- E) DVD containing the raster datasets that represent the analysis results for watershed risk, sensitivity, and susceptibility.
- F) DVD that contains "GSI\_FACTS.mdb" database and original FACTS data received from the Oregon Department of Forestry.

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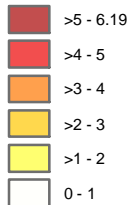
## Figures



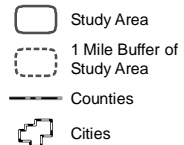


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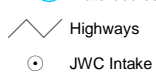
## Risk Rankings



## All Other Features



## Waterbodies

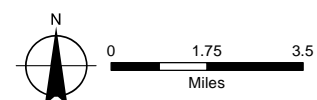


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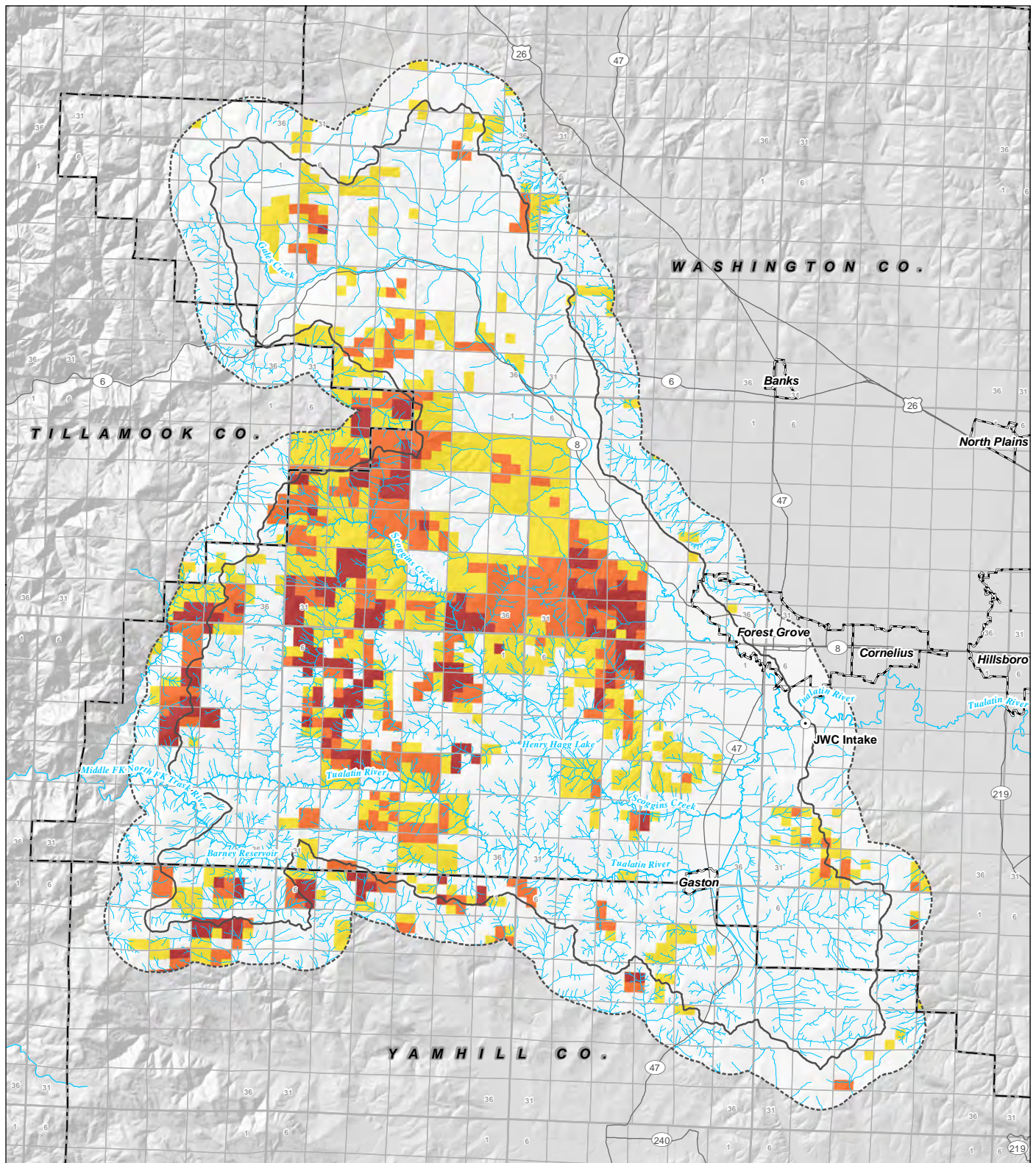
Date: August 8, 2013  
Data Sources: USDA, City of Hillsboro, OR DEQ, USGS, ESRI

## FIGURE 1

Risk Analysis  
Agricultural Chemical Applications  
JWC Source Water Assessment





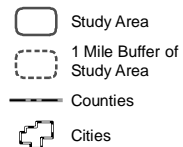


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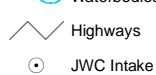
### Risk Rankings



### All Other Features



### Waterbodies

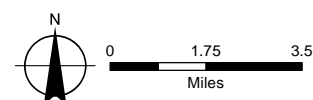


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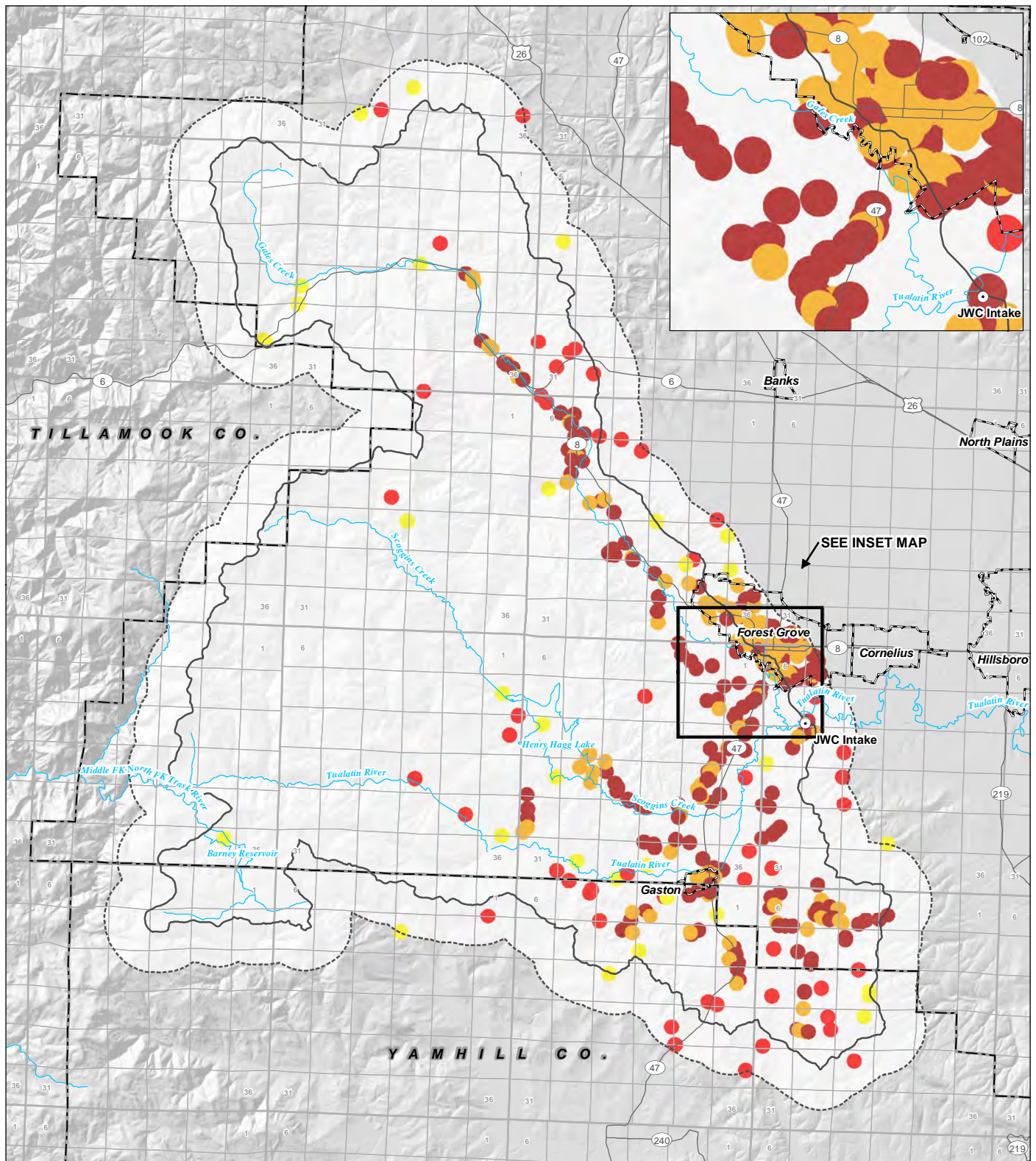
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Data Sources: ODF FACTS, City of Hillsboro, OR DEQ, USGS, ESRI

## FIGURE 2

Risk Analysis  
Forestry Chemical Applications  
JWC Source Water Assessment





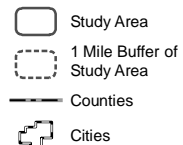


# LEGEND

## Risk Rankings



## All Other Features



## Waterbodies

Waterbodies

Highways

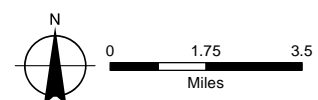
JWC Intake

## MAP NOTES:

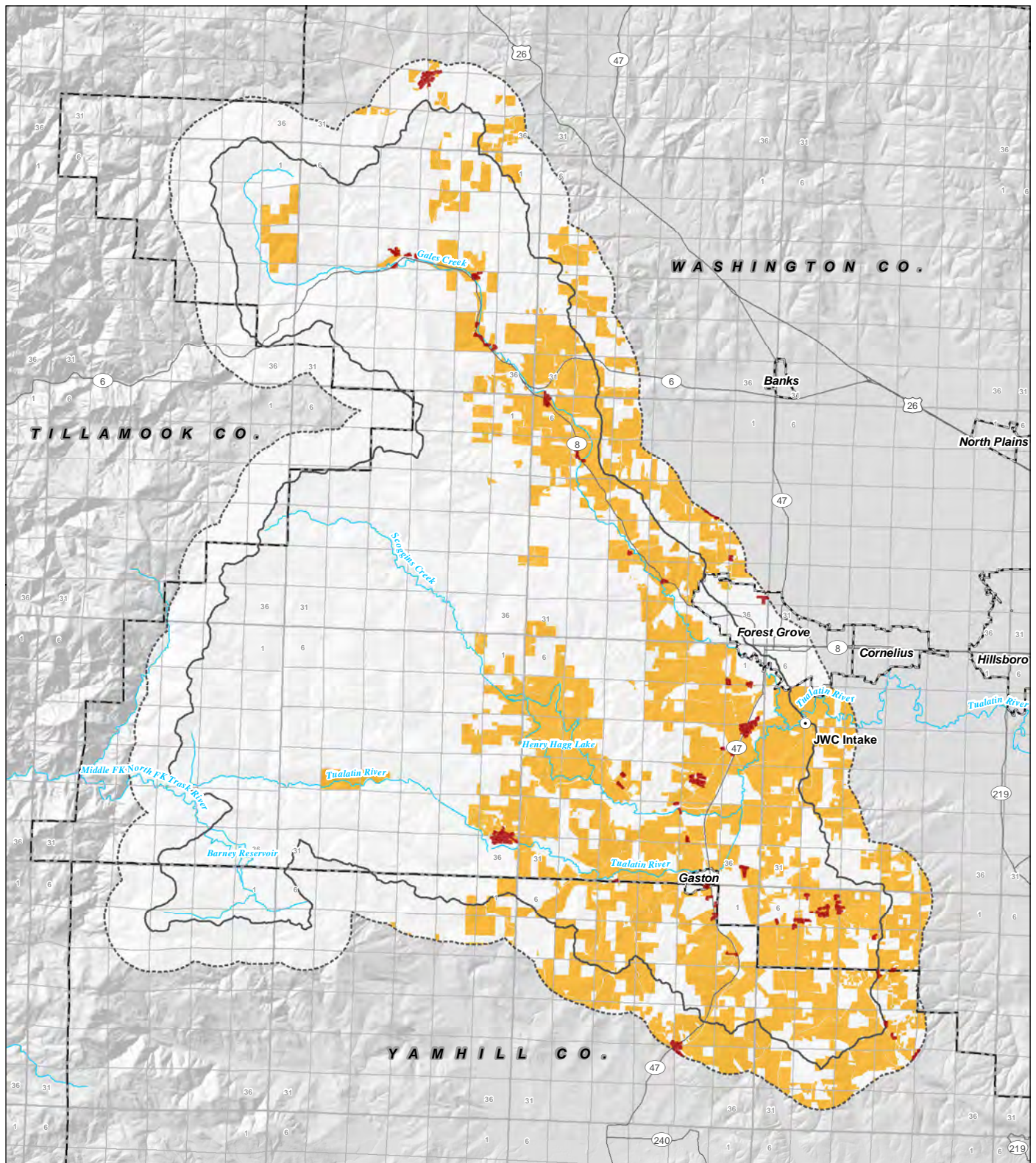
Date: August 8, 2013  
Data Sources: METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, USGS, ESRI

## FIGURE 3

Risk Analysis  
Potential Contaminant Sources  
JWC Source Water Assessment

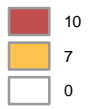




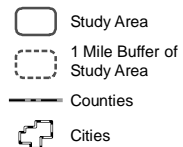


# LEGEND

## Risk Rankings



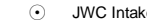
## All Other Features



## Waterbodies



## Highways



## JWC Intake



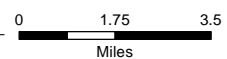
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Data Sources: METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, USGS, ESRI

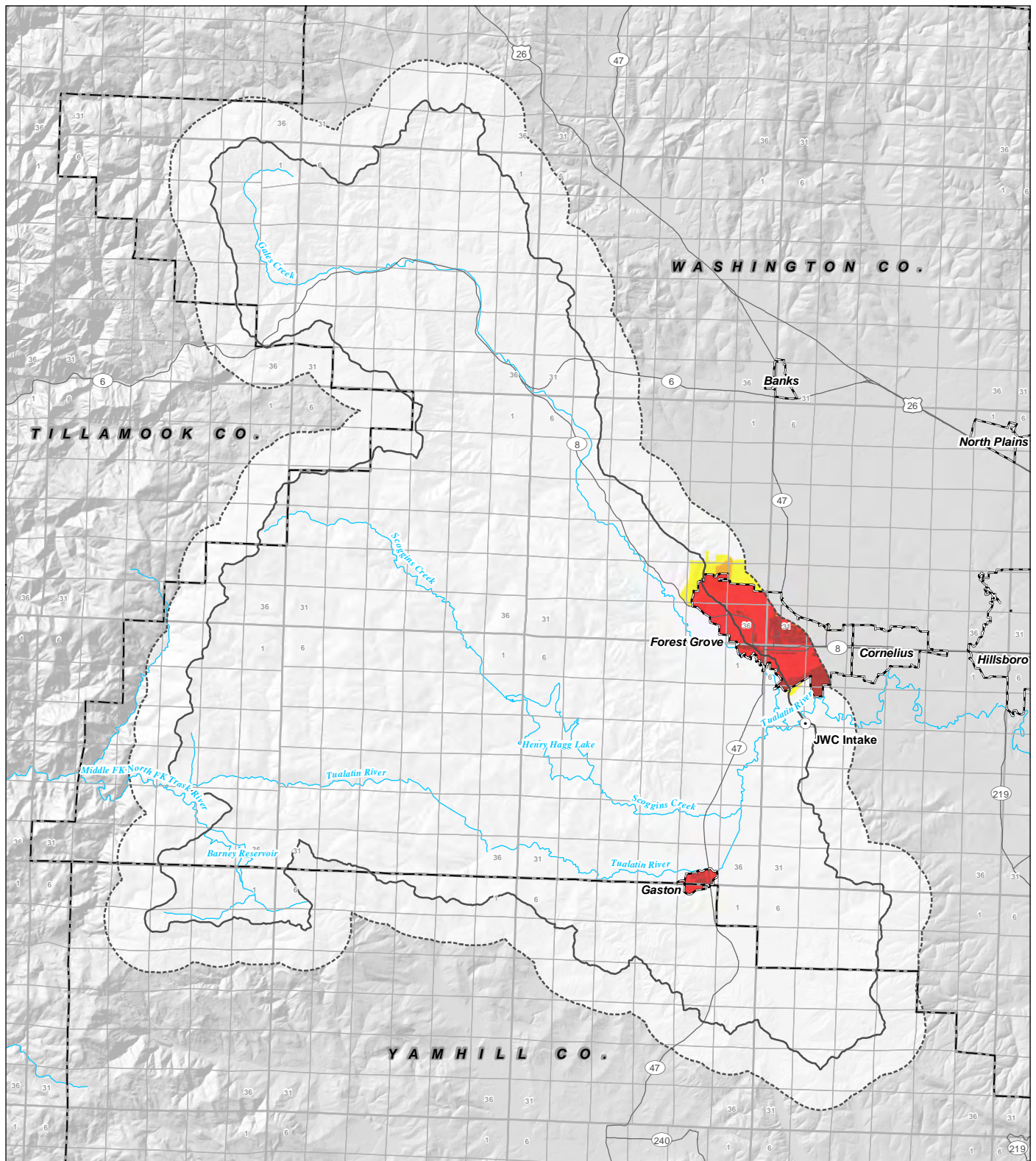
# FIGURE 4

## Risk Analysis Septic Tanks

## JWC Source Water Assessment





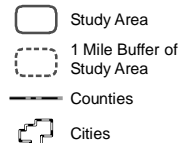


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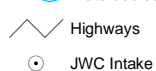
## Risk Rankings



## All Other Features



## Waterbodies



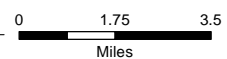
JWC Intake

## MAP NOTES:

Date: August 8, 2013  
Data Sources: METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, USGS, ESRI

## FIGURE 5

Risk Analysis  
Urban Development  
JWC Source Water Assessment





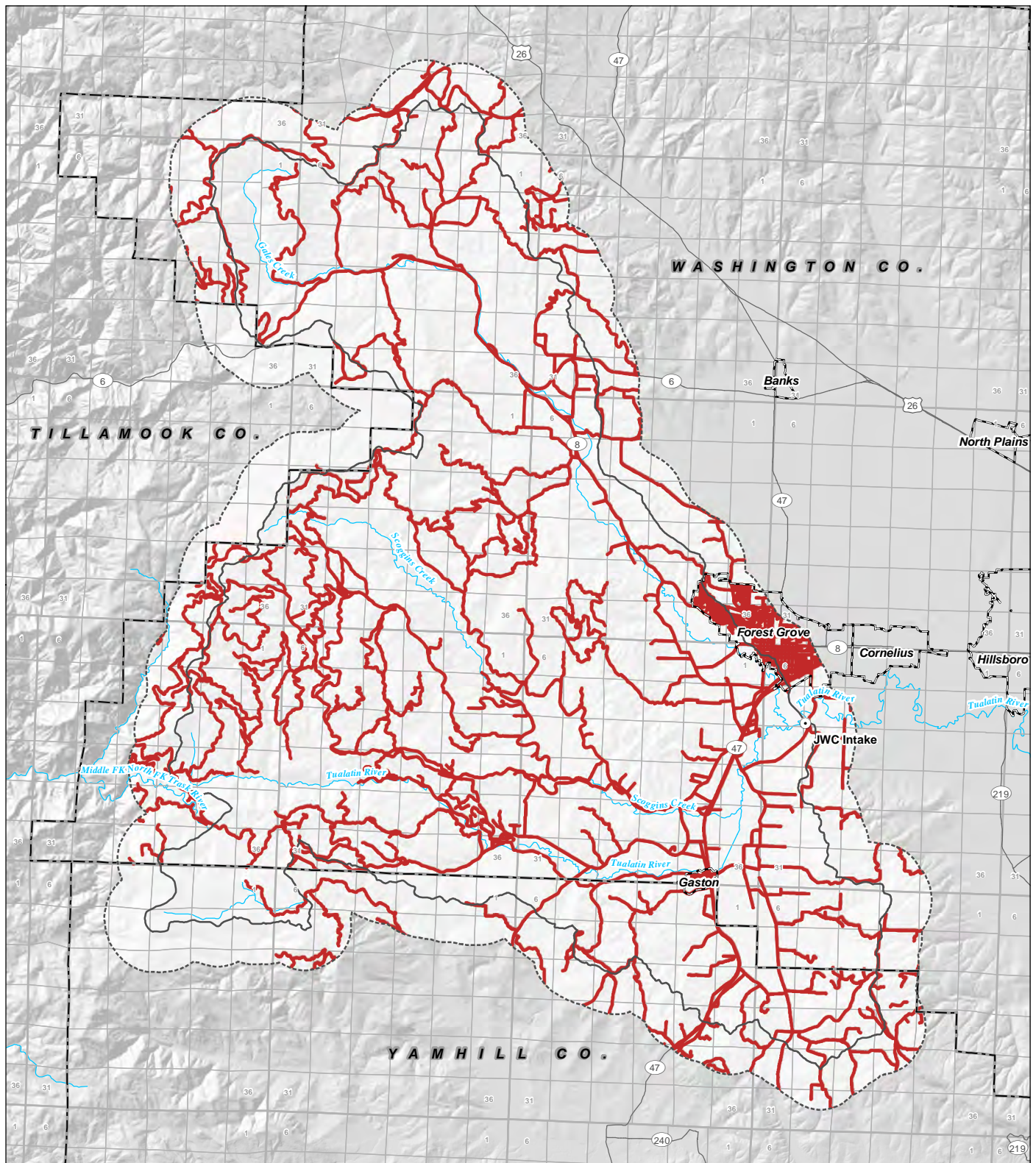


FIGURE 6

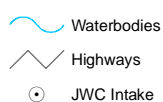
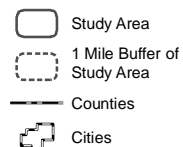
Risk Analysis  
Transportation Setbacks  
JWC Source Water Assessment

**LEGEND**

**Risk Rankings**

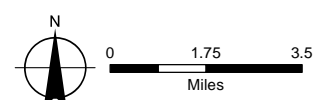


**All Other Features**

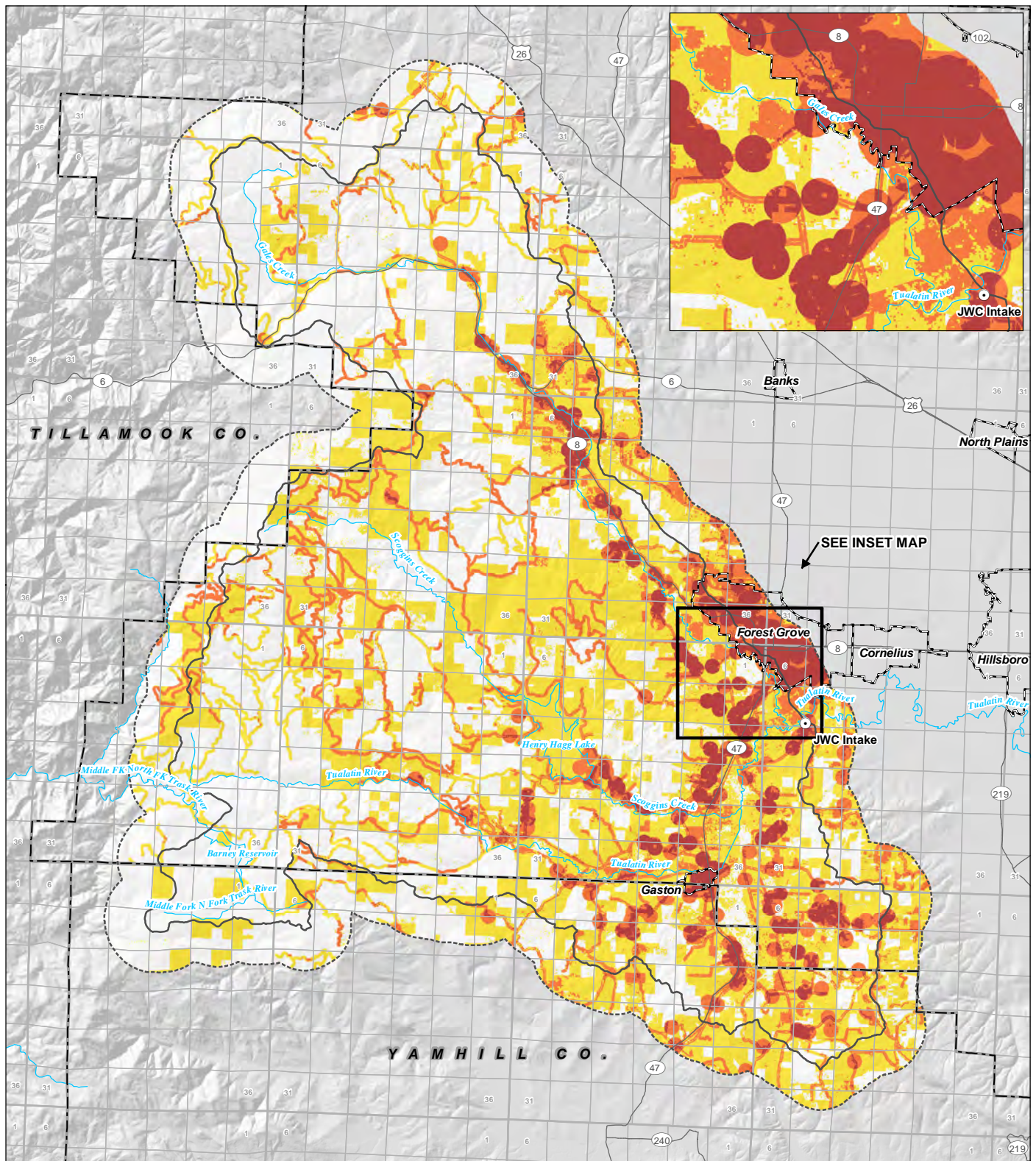


**MAP NOTES:**

Date: August 8, 2013  
Data Sources: METRO RLIS, ODOT, City of Hillsboro, OR DEQ, USGS, ESRI







# LEGEND

## Risk Rankings

- 3 - High
- 2 - Med
- 1 - Low
- 0 - None

## All Other Features

- Study Area
- 1 Mile Buffer of Study Area
- Counties
- Cities

## Waterbodies

- Highways
- JWC Intake

## MAP NOTES:

Date: August 8, 2013  
Data Sources: USDA, ODF FACTS, METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, ODOT, USGS, ESRI

File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure10\_Risk\_Results\_v2.mxd

# FIGURE 7

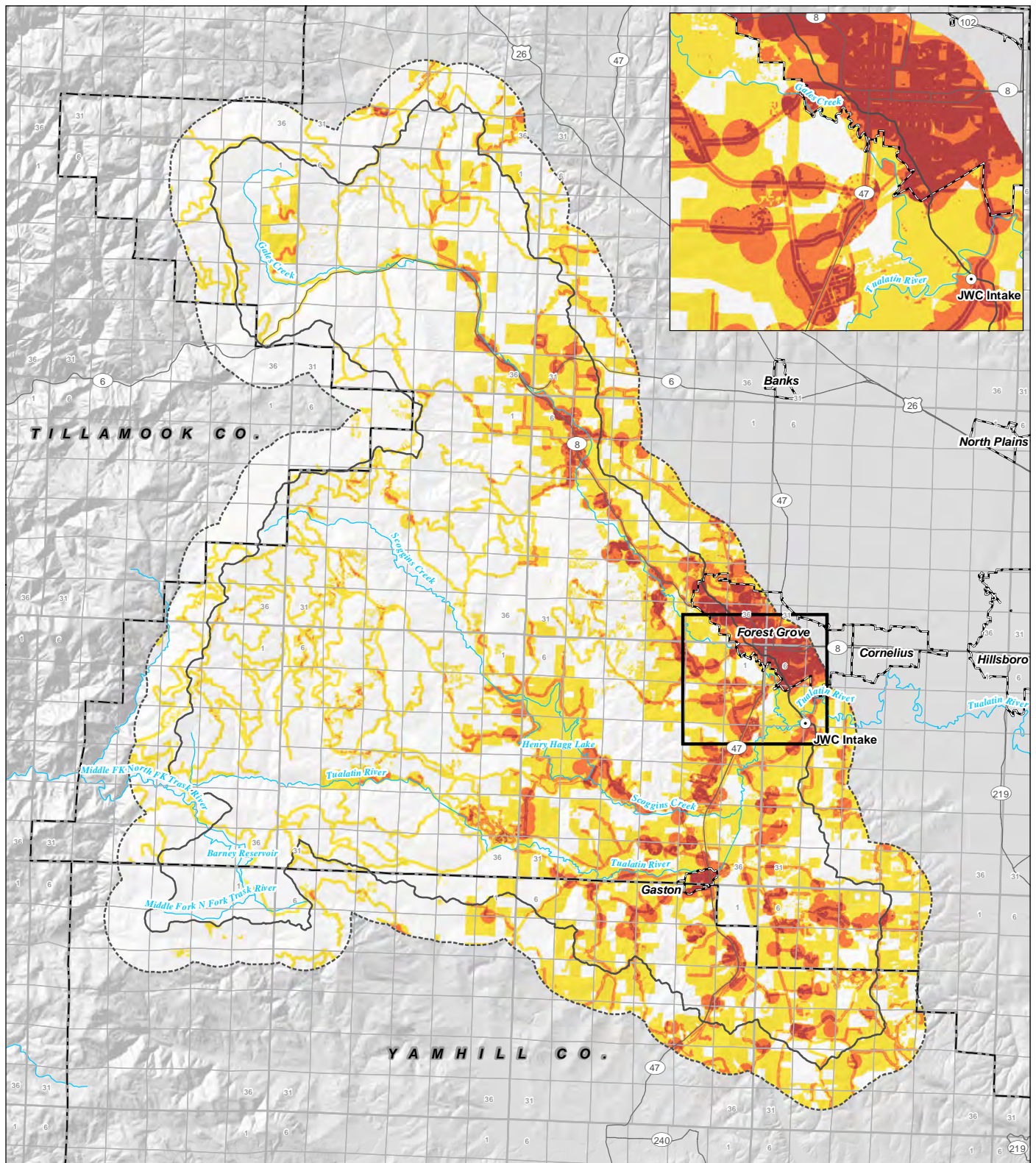
## Risk Analysis

Weighted Overlay Analysis Results  
Classified by Natural Breaks (Jenks)

JWC Source Water Assessment







# LEGEND

## Risk Rankings

- 3 - High
- 2 - Med
- 1 - Low
- 0 - None

## All Other Features

- Study Area
- 1 Mile Buffer of Study Area
- Counties
- Cities
- Waterbodies
- Highways
- JWC Intake

## MAP NOTES:

Date: August 8, 2013  
Data Sources: USDA, ODF FACTS, METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, ODOT, USGS, ESRI

File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure10\_Risk\_Results\_v2.mxd

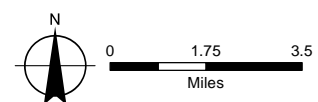
## FIGURE 8

### Risk Analysis

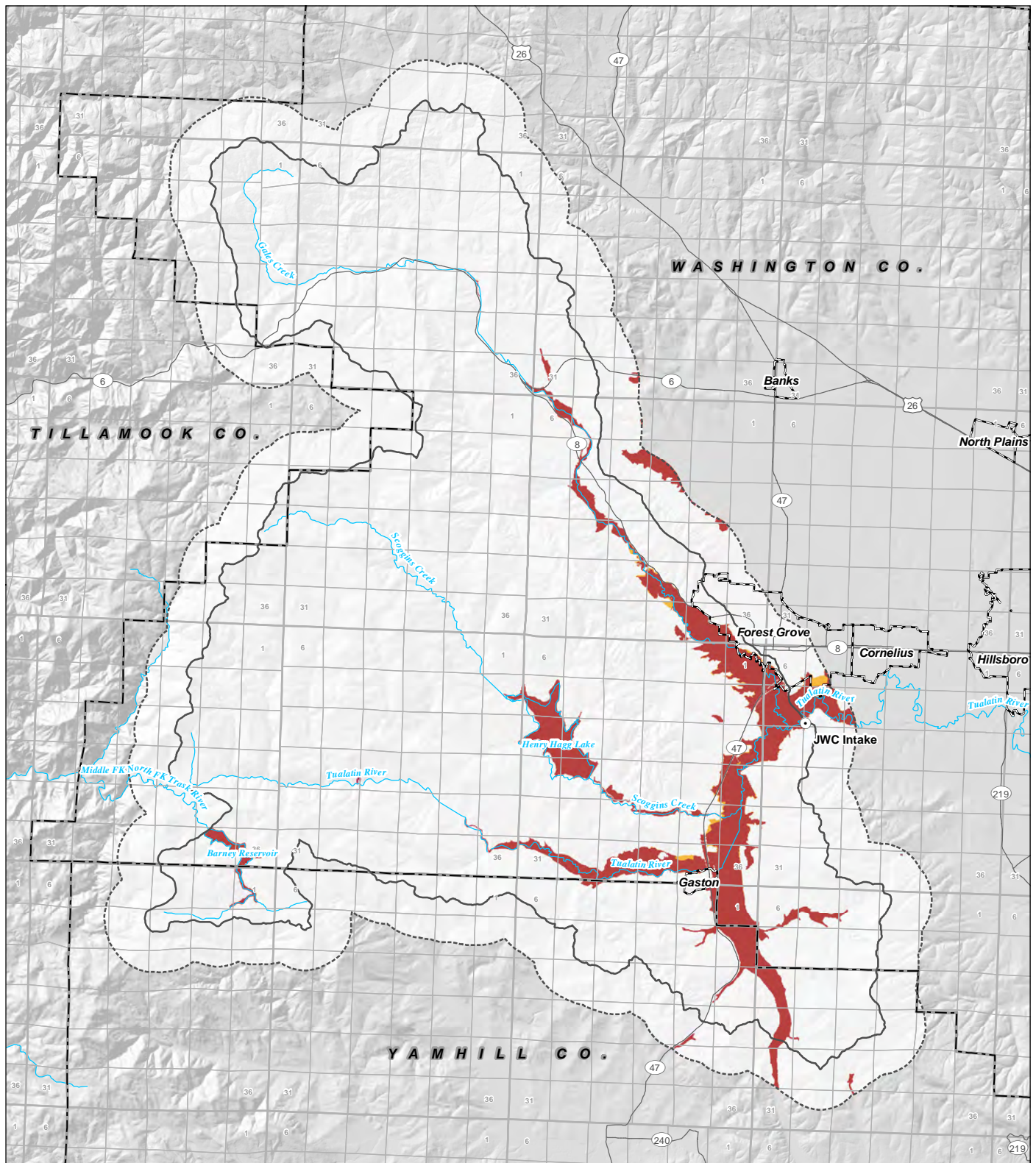
### Equal Weighted Overlay Analysis Results

### Classified by Natural Breaks (Jenks)

### JWC Source Water Assessment





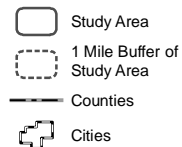


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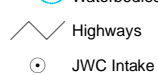
### Sensitivity Rankings



### All Other Features



### Waterbodies



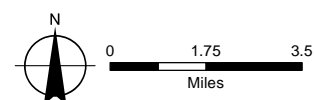
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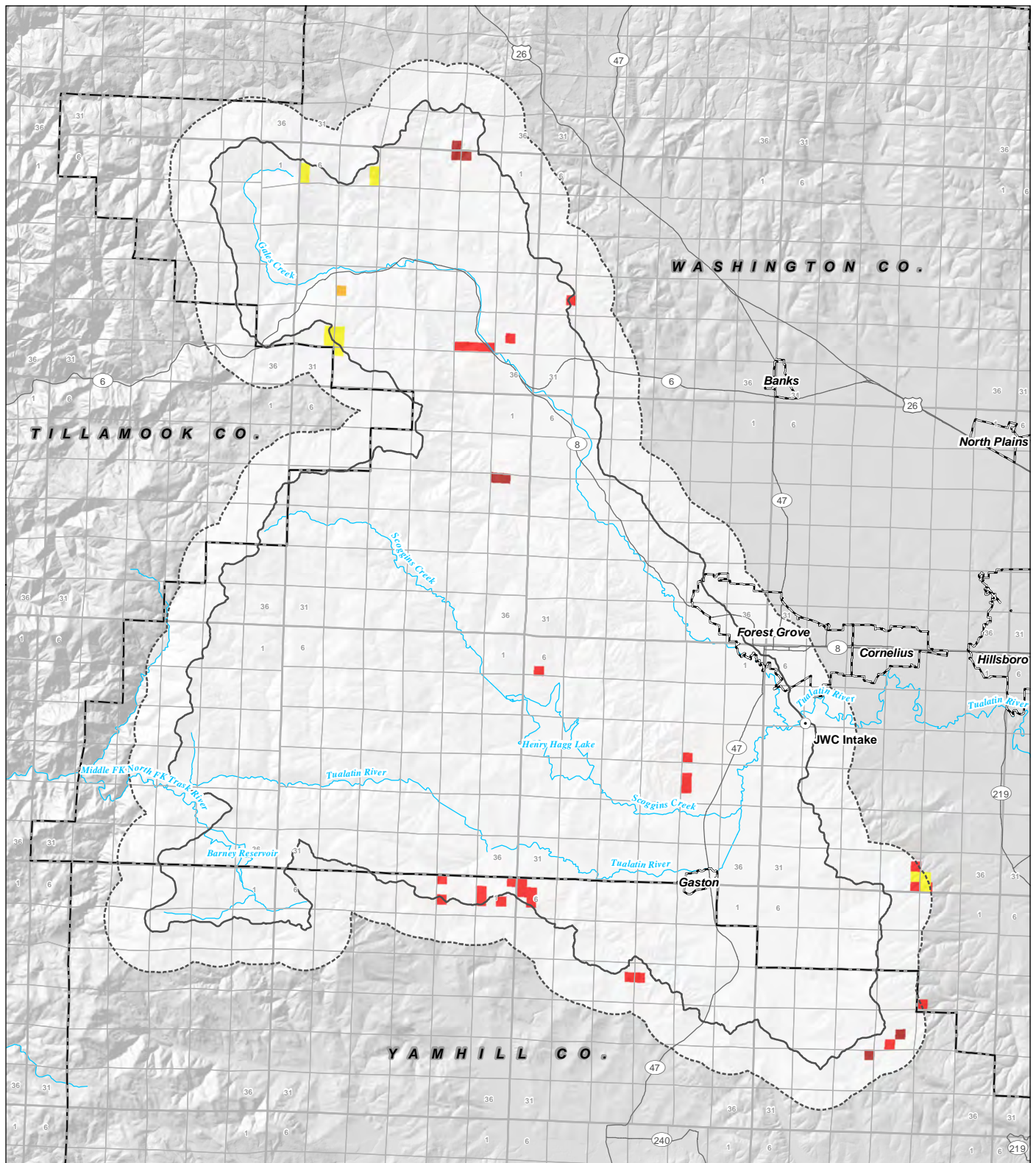
Date: August 8, 2013  
Data Sources: FEMA, City of Hillsboro, OR DEQ, USGS, ESRI

## FIGURE 9

### Sensitivity Analysis Flood Zones

### JWC Source Water Assessment



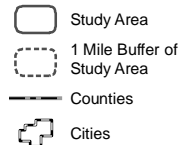


# LEGEND

## Sensitivity Rankings



## All Other Features



## Waterbodies

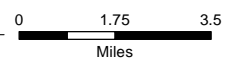


# FIGURE 10

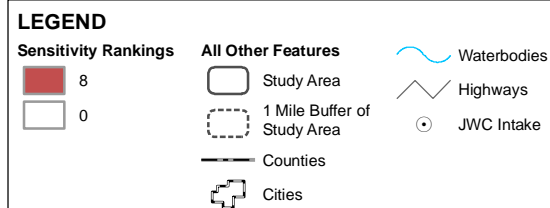
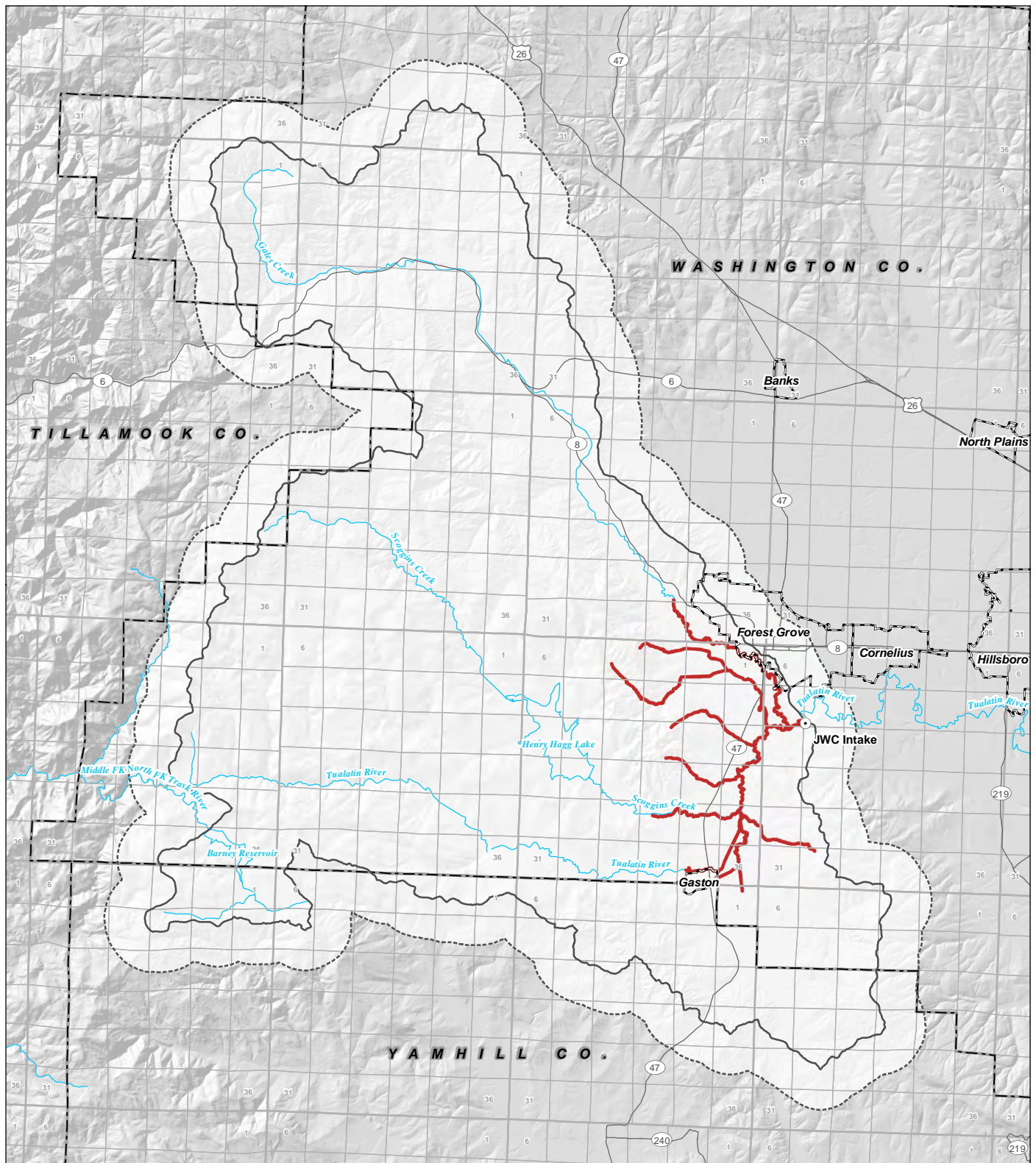
Sensitivity Analysis  
Forestry Activities  
JWC Source Water Assessment

## MAP NOTES:

Date: August 8, 2013  
Data Sources: ODF FACTS, City of Hillsboro, OR DEQ, USGS, ESRI







**MAP NOTES:**  
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 Data Sources: City of Hillsboro, OR DEQ, USGS, ESRI

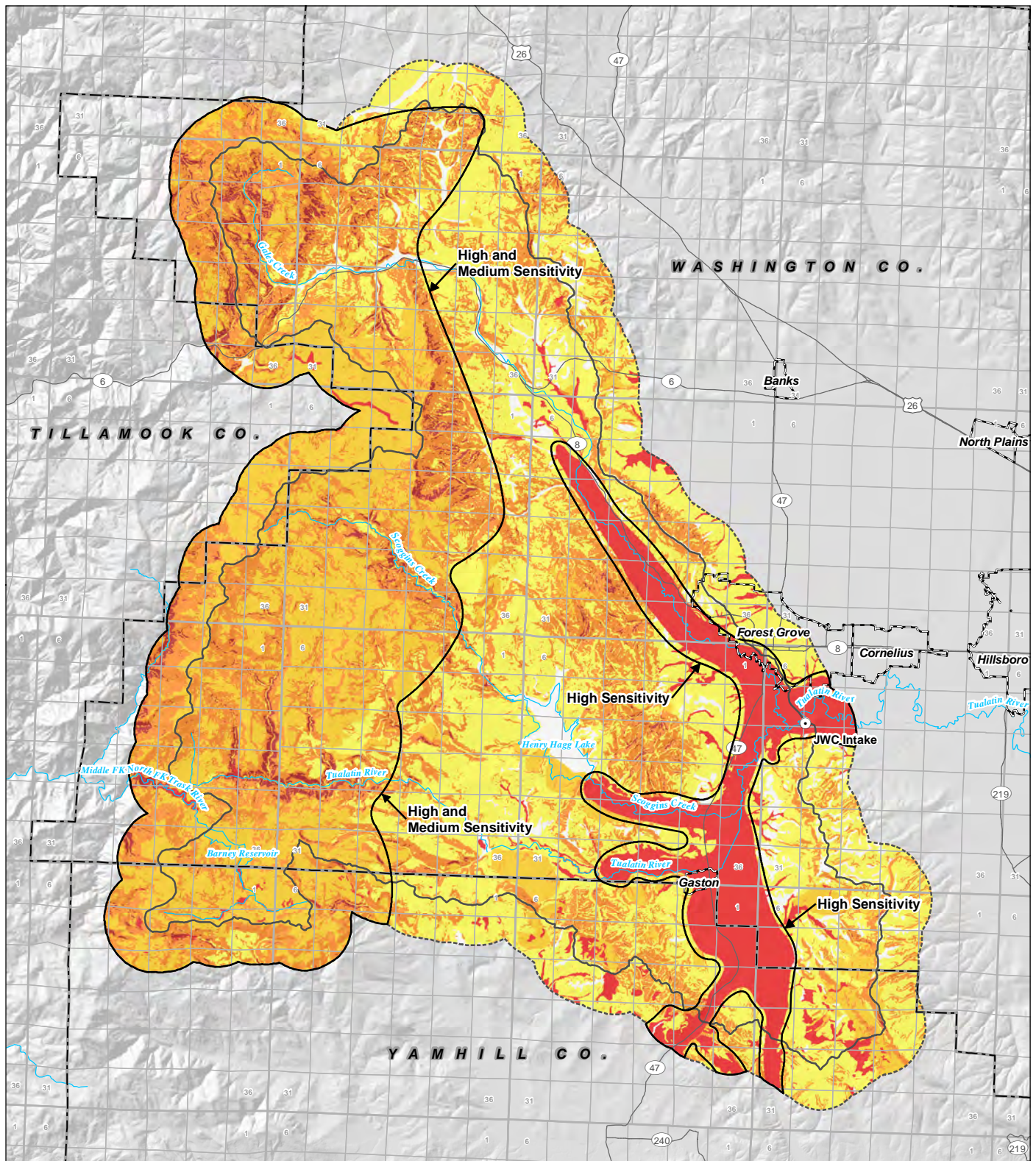
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**FIGURE 11**

Sensitivity Analysis  
 Surface Water Time of Travel  
 JWC Source Water Assessment



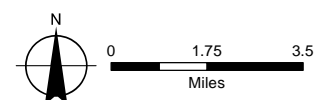




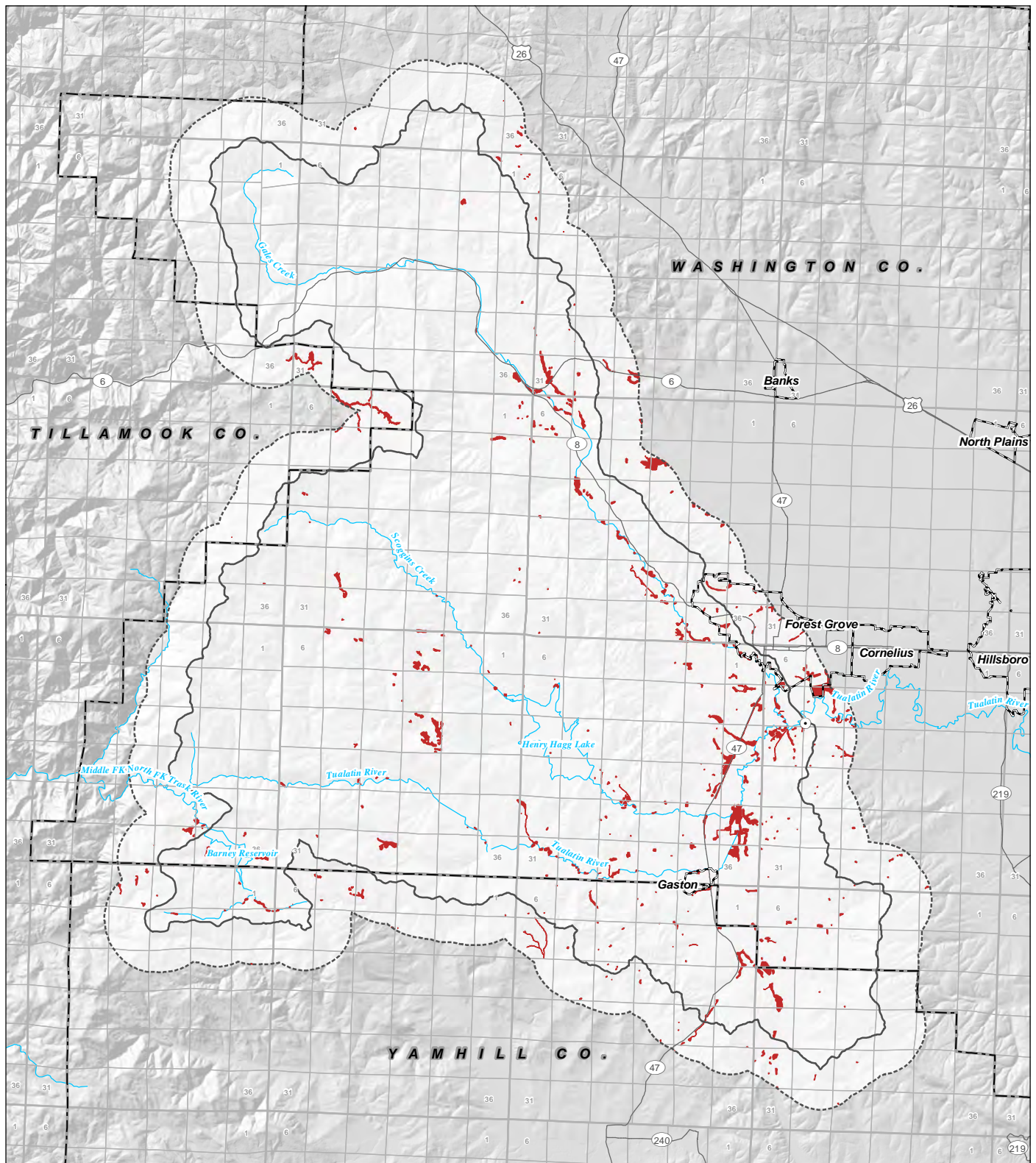
**MAP NOTES:**  
 Date: August 8, 2013  
 Data Sources: USDA NRCS, DOGAMI, City of Hillsboro, OR DEQ, USGS, ESRI

File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure15\_Sens\_UVSoils.mxd

**FIGURE 12**  
 Sensitivity Analysis  
 Unstable/Vulnerable Soils  
 JWC Source Water Assessment





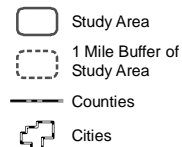


## LEGEND

### Sensitivity Rankings



### All Other Features



### Waterbodies

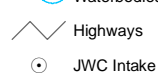


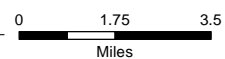
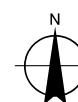
FIGURE 13

Sensitivity Analysis  
Wetlands

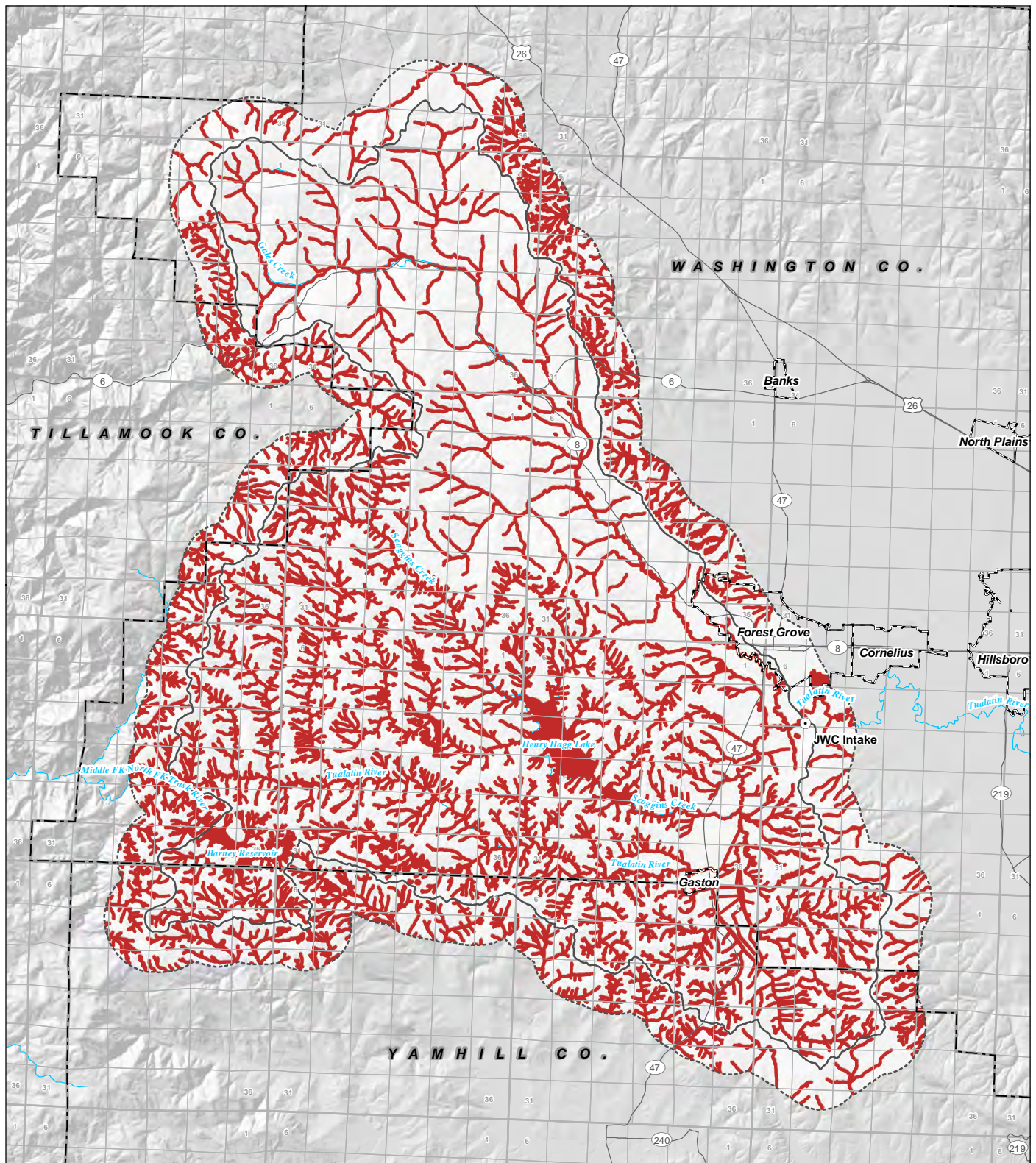
JWC Source Water Assessment

### MAP NOTES:

Date: August 8, 2013  
Data Sources: The Wetlands Conservancy, City of Hillsboro, OR DEQ, USGS, ESRI





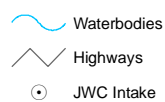
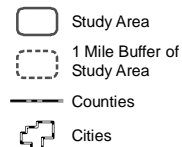


# LEGEND

## Sensitivity Rankings



## All Other Features

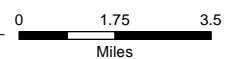
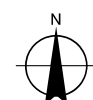


## FIGURE 14

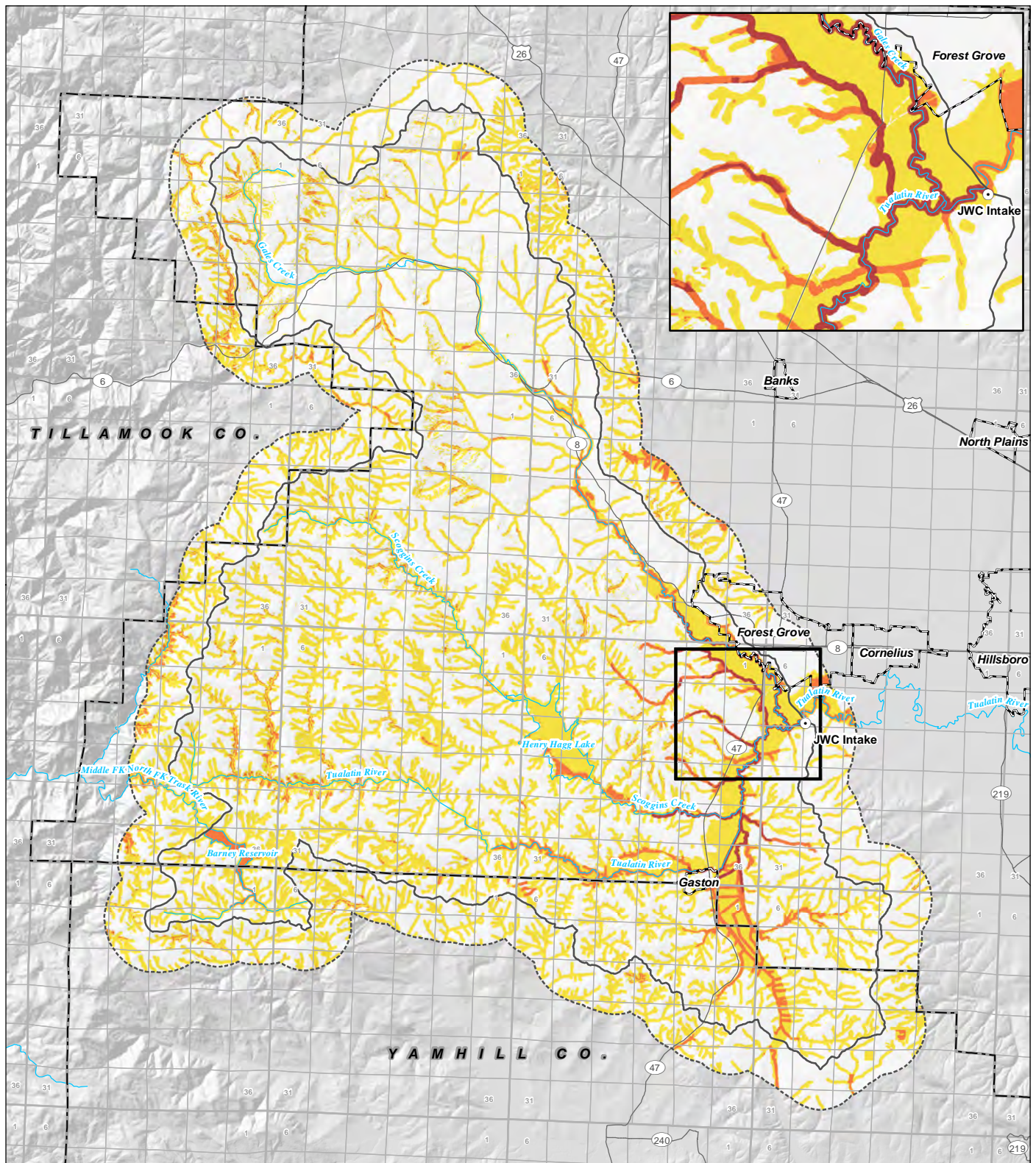
Sensitivity Analysis  
Water Setbacks  
JWC Source Water Assessment

## MAP NOTES:

Date: August 8, 2013  
Data Sources: City of Hillsboro, OR DEQ, USGS, ESRI







# LEGEND

## Sensitivity Rankings

- 3 - High
- 2 - Med
- 1 - Low
- 0 - None

## All Other Features

- Study Area
- 1 Mile Buffer of Study Area
- Counties
- Cities

## Waterbodies

- Highways
- JWC Intake

FIGURE 15

Sensitivity Analysis  
Weighted Overlay Analysis Results  
Classified by Natural Breaks (Jenks)  
JWC Source Water Assessment

## MAP NOTES:

Date: August 8, 2013  
Data Sources: FEMA, ODF FACTS, USDA NRCS, DOGAMI, The Wetlands Conservancy, City of Hillsboro, OR DEQ, USGS, ESRI

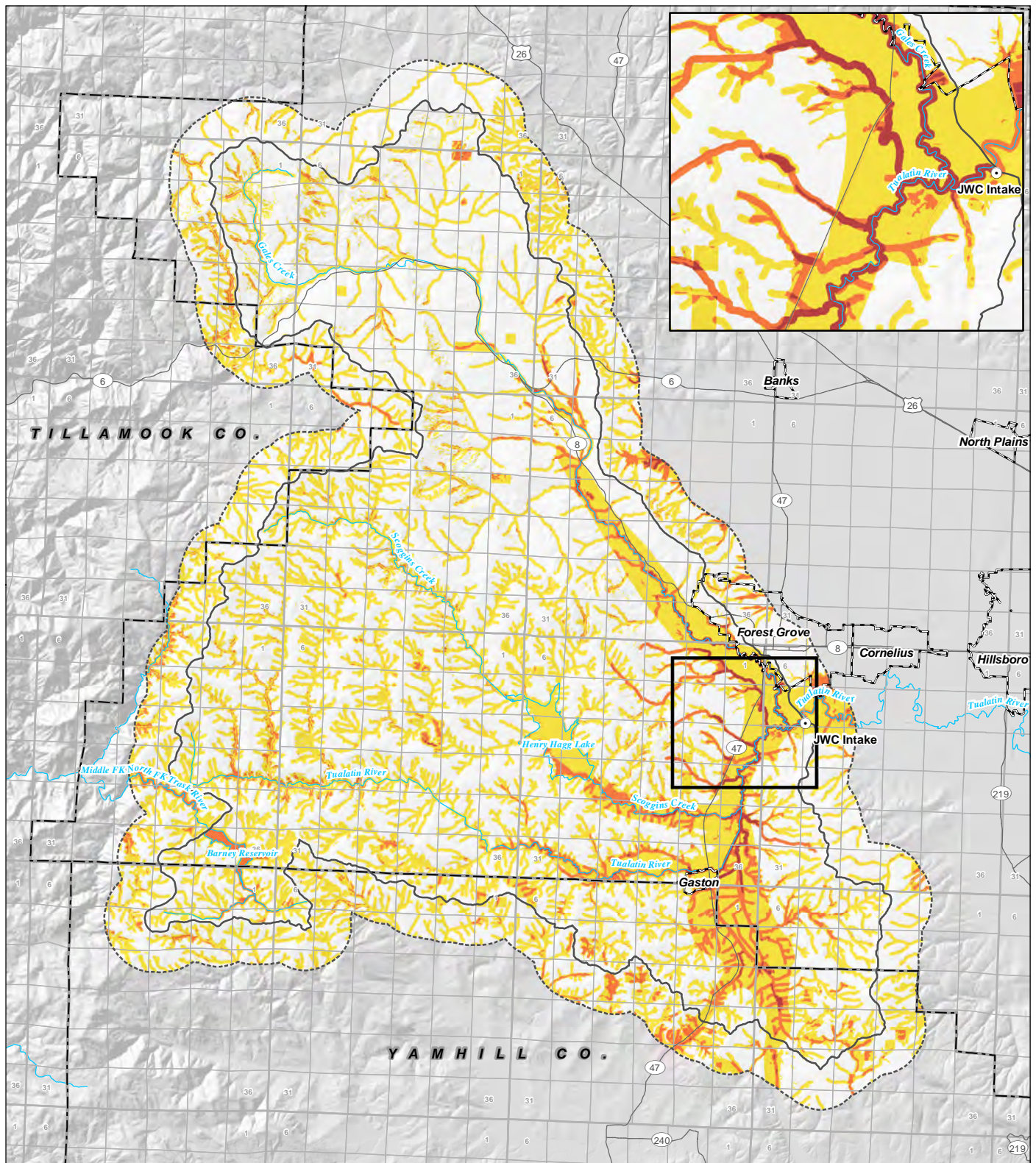
File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure19\_Sens\_Results\_v2.mxd



0 1.75 3.5  
Miles







# LEGEND

## Sensitivity Rankings

- 3 - High
- 2 - Med
- 1 - Low
- 0 - None

## All Other Features

- Study Area
- 1 Mile Buffer of Study Area
- Counties
- Cities

## Waterbodies

- Highways
- JWC Intake

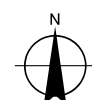
FIGURE 16

Sensitivity Analysis  
Equal Weighted Overlay Analysis Results  
Classified by Natural Breaks (Jenks)  
JWC Source Water Assessment

## MAP NOTES:

Date: August 8, 2013  
Data Sources: FEMA, ODF FACTS, USDA NRCS, DOGAMI, The Wetlands Conservancy, City of Hillsboro, OR DEQ, USGS, ESRI

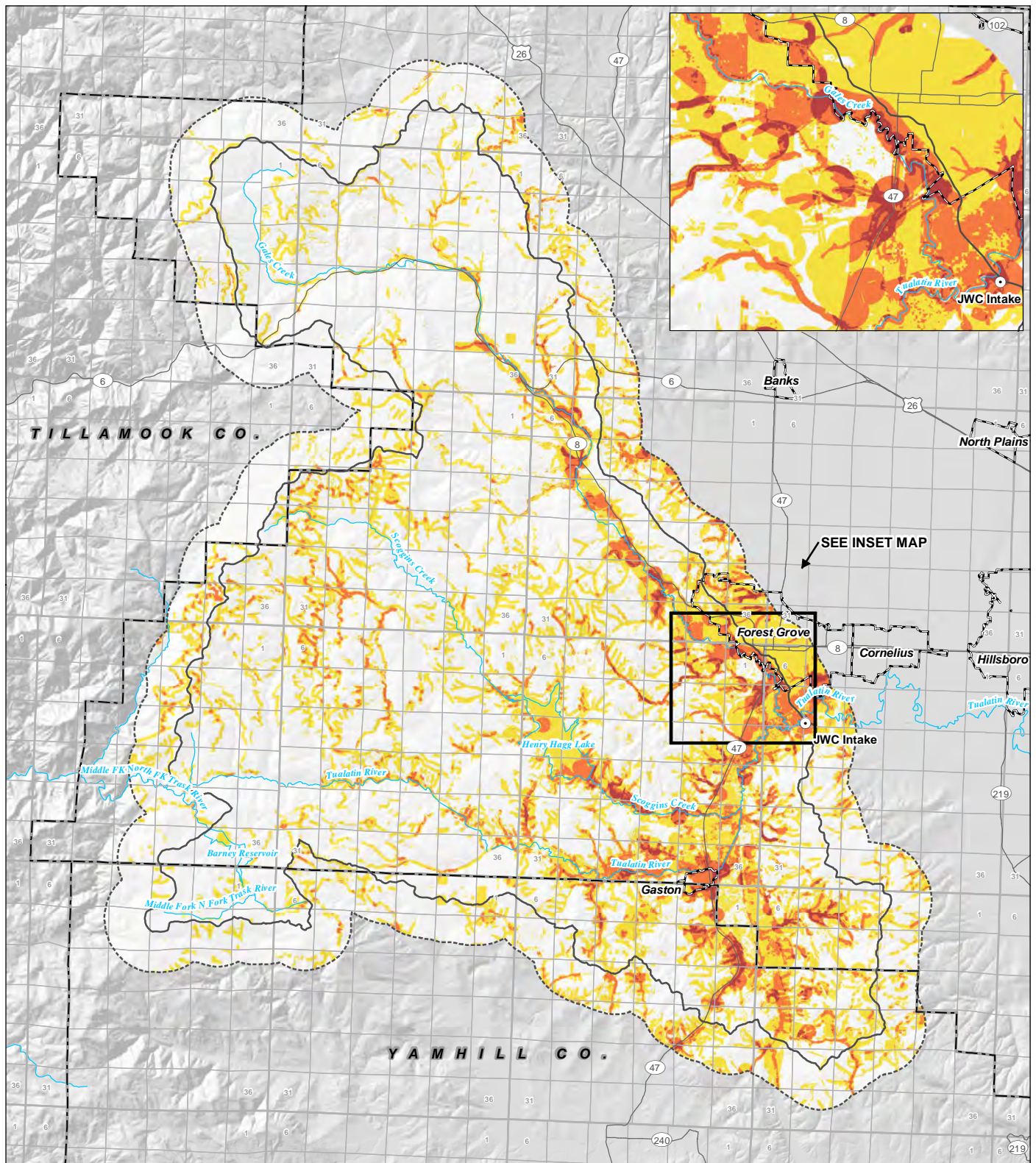
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0 1.75 3.5  
Miles





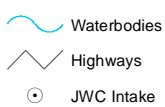
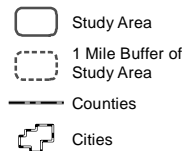


## LEGEND

### Susceptibility Rankings



### All Other Features



JWC Intake

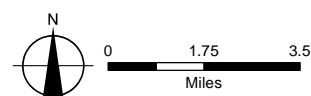
## FIGURE 17

Susceptibility Analysis  
Weighted Overlay Analysis Results  
Classified by Natural Breaks (Jenks)  
JWC Source Water Assessment

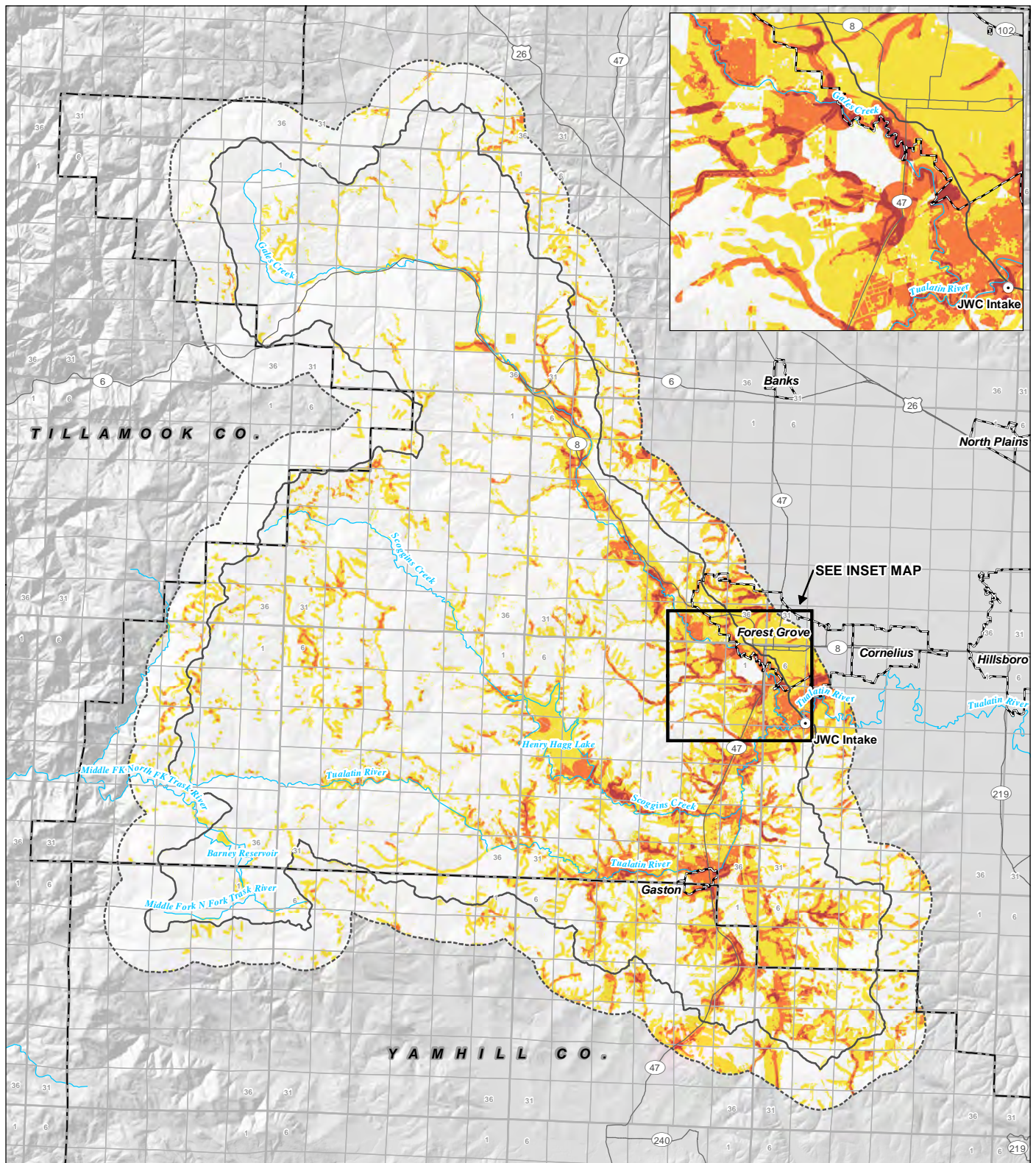
### MAP NOTES:

Date: August 8, 2013  
Data Sources: FEMA, ODF FACTS, USDA, USDA NRCS, DOGAMI, The Wetlands Conservancy, METRO RLIS, Yamhill Co, City of Hillsboro, OR DEQ, ODOT, USGS, ESRI

File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure22\_Suscep\_Results\_v2.mxd







## LEGEND

### Susceptibility Rankings



### All Other Features

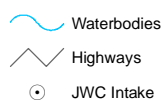
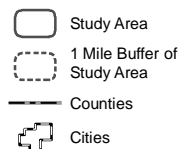


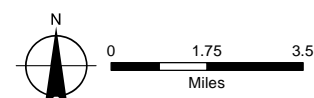
FIGURE 18

Susceptibility Analysis  
Equal Weighted Overlay Analysis Results  
Classified by Natural Breaks (Jenks)  
JWC Source Water Assessment

### MAP NOTES:

Date: August 8, 2013  
Data Sources: FEMA, ODF FACTS, USDA, USDA NRCS, DOGAMI, The Wetlands Conservancy, METRO RLIS, Yamhill Co., City of Hillsboro, OR DEQ, ODOT, USGS, ESRI

File Path: P:\Portland\254 - Joint Water Commission\010-Source Water Assessment\Project\_GIS\Project\_mxd\TM1\Final\Figure22\_Suscep\_Results\_v2.mxd

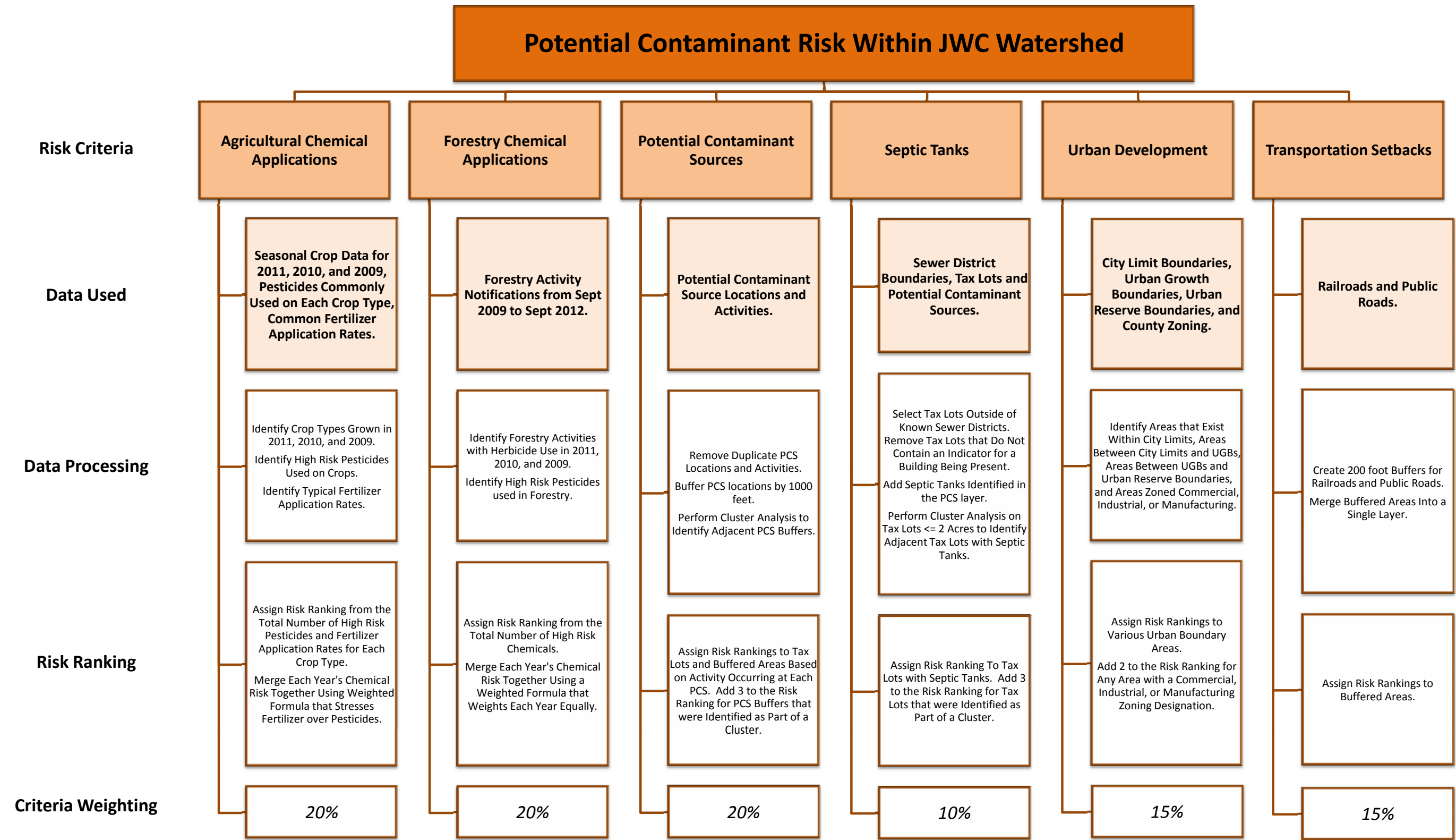




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**Appendix A**  
**Risk and Sensitivity Analysis Methodology:**  
**Evaluation flowcharts and details on geoprocessing, ranking**  
**and weighted overlay**

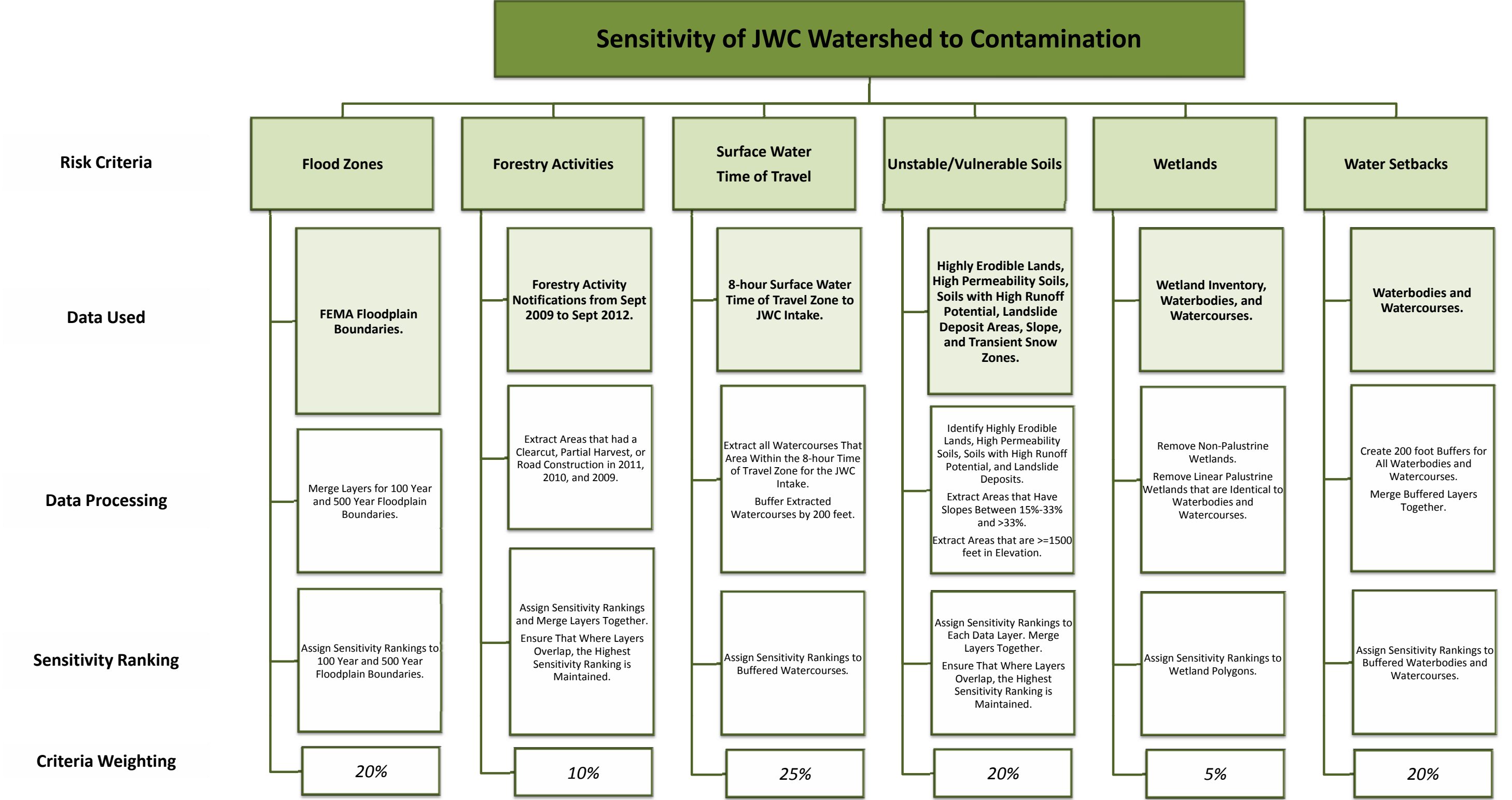
**Appendix A. Figure 1:** Overview of methodology to quantify the risk of potential contamination sources in the study area.



**Appendix A, Table 1:** Details on methodology to perform risk ranking for each risk category.

RISK CATEGORY	RISK RANKING (1 to 10 with 10 representing the highest risk)	METHODOLOGY	AVAILABLE GIS DATA LAYERS
Agricultural Chemical Applications	<p>Rankings for pesticides will be determined by the total number of high risk pesticide chemicals that are typically used on each crop type.</p> <p>Rankings for fertilizers will be determined by the application rates (lbs/acre) per crop type.</p> <p>Overall risk ranking for each year's crop data will be a combination of the pesticide and fertilizer risk rankings.</p>	<p>Identify individual crop types grown in the study area for 2009, 2010, and 2011. Identify the number of high risk pesticides used on each crop type. Multiply the total number of high risk pesticides for each crop by 2 (but do not allow result to exceed 10) to get an overall pesticide risk ranking for each crop type. Identify the typical fertilizer types and application rates for each crop type. Assign fertilizer risk ranking to each crop type based on application rate (lbs/acre) or nitrogen and phosphorous. Use the following weighted equation to combine the pesticide risk rankings with the fertilizer risk raster rankings to get an overall risk ranking for each crop type: (pesticides * 40%) + (fertilizer * 60%)</p> <p>Convert each year's crop data into a raster-based dataset where the pixel values would be the overall risk rankings.</p>	<p>USDA_Cropland_2009 USDA_Cropland_2010 USDA_Cropland_2011</p>
Forestry Chemical Applications	<p>Forestry activity notifications with pesticide or herbicide use = 4</p>	<p>Identify forestry activity notifications that contain pesticide or herbicide use from 2010, 2011, and 2012. Assign a risk ranking to any polygon that contains a pesticide/herbicide use notification. Convert each year's forestry activity notifications into a raster-based dataset where pixel values would be the risk rankings. Use a weighted equation to combine each year's forestry activity notifications. Suggested weighted equation: (2009 * 33.33%) + (2010 * 33.33%) + (2011 * 33.34%)</p>	<p>ODF_FACTS_Sept2009toSept2012</p>
Potential Contaminant Sources	<p>Rankings will depend on activity occurring at each PCS location.</p> <p>PCS buffers that are part of an identified cluster will have their risk ranking increased by 3 (but not allowed to exceed 10).</p>	<p>Remove septic tanks from PCS layer. Remove any duplicate PCS locations and/or activities. Assign risk rankings to each PCS location based on activity associated with each PCS. Use GIS to buffer each PCS location by 1000 feet. Use GIS to perform cluster analysis to identify clusters of PCSs. For PCSs that exist within an identified cluster, increase their risk rankings by 3. If resulting polygon representation of PCS locations contains overlapping polygons, assign highest risk ranking to overlapping area from polygons that make up the overlapping area. Convert output into a raster-based dataset where pixel values would be the risk rankings.</p>	<p>All_Potential_Contaminant_Sources</p>
Septic Tanks	<p>Tax lots with septic tanks = 7</p> <p>Tax lots with septic tanks that are part of an identified cluster will have their risk ranking increased by 3.</p>	<p>Use GIS to select tax lots that exist outside of known sewer districts. Remove any tax lots from the selection that do not have a designation for a building being present. Resulting selection will be considered as tax lots with septic tanks. QC results with septic tank locations from the PCS layer and ensure that all septic tank locations from PCS layer are included in tax lots with septic tanks layer. Assign risk rankings to resulting layer. Use GIS to perform cluster analysis on tax lots &lt;=2 acres to identify adjacent tax lots with septic tanks. Clustered tax lots with septic tanks will have 3 added to their previously assigned risk ranking. Convert output into a raster-based dataset where pixel values would be the risk rankings.</p>	<p>METRO_Sewer_Districts Taxlots_METRO_WashCo Taxlots_YamhillCo</p>
Urban Development	<p>Areas within City Limit boundaries = 8</p> <p>Areas between City Limits and UGBs = 6</p> <p>Areas between UGBs and Urban Reserve Boundaries = 4</p> <p>Areas identified above that exist within commercial, industrial, or manufacturing zones will have their risk ranking increased by 2.</p>	<p>Use GIS to create areas that exist within City Limits, areas between City Limits and UGBs, and areas between UGBs and Urban Reserve Boundaries. Since the Forest Grove City Limits has holes within it (excluded areas), we will fill those holes in and consider them as being within the City Limits. Assign risk rankings to each data layer. Combine data layers so that where layers overlap, the highest risk ranking from the overlapping layers will be maintained in the output. Add 2 to the risk ranking of the output in areas where the output exists within commercial, industrial, or manufacturing zoning designations. Convert output into a raster-based dataset where pixel values would be the risk rankings.</p>	<p>METRO_City_Limits METRO_UGBs METRO_Urban_Reserve_Boundaries Zoning_METRO_WashCo Zoning_YamhillCo</p>
Transportation Setbacks	<p>Public road setbacks = 8</p> <p>Railroad setbacks = 8</p>	<p>Buffer all features in public roads and railroad data layers by 200 feet, merge resulting polygons into a single layer, and assign risk rankings to layer. Convert output into a raster based dataset where pixel values would be the risk rankings.</p>	<p>METRO_Public_Roads ODOT_Railroads</p>

Appendix A, Figure 2: Overview of methodology to quantify the sensitivity of the study area.





**Appendix A, Table 2:** Details on methodology to perform sensitivity ranking for each sensitivity category.

SENSITIVITY CATEGORY	SENSITIVITY RANKING (1 to 10 with 10 representing the highest risk)	METHODOLOGY	AVAILABLE GIS DATA LAYERS
Flood Zones	100-year Flood Zones = 6 500-year Flood Zones = 3	Assign sensitivity rankings to flood zones in the floodplains data layer. Convert data layer into a raster-based dataset where pixel values would be the sensitivity rankings.	FEMA_Q3_Floodplains
Forestry Activities	Thinning activities = 7 Clear cutting activities = 10 Road construction activities = 7 Other harvesting activities = 5 All other activities = 2	Identify forestry activity notifications from 2010, 2011, and 2012 that contain non-chemical application activities. Assign sensitivity rankings based on activity type occurring in each forestry activity notification. Convert identified forestry activity notifications into a raster-based dataset where pixel values would be the sensitivity rankings. Ensure that conversion to raster maintains the highest sensitivity ranking in areas of overlap between forestry activity notifications.	ODF_FACTS_Sept2009toSept2012
Surface Water Time of Travel	Surface water 8-hour Time of Travel Zones = 8	Use GIS to create JWC's 8-hour surface water time of travel zone ( <i>NOTE - prior estimates are 8-hour time of travel is 7.6 river miles upstream of JWC Intake</i> ). Extract all watercourses that are within 7.6 river miles of the JWC intake. Buffer extracted watercourses by 200 feet and assign sensitivity ranking to buffered polygons. Convert data layer into a raster-based dataset where pixel values would be the sensitivity rankings.	JWC_SW_8hr_TOT_Zone
Unstable/Vulnerable Soils	Highly erodible lands = 3 High permeability soils = 6 High runoff potential soils = 8 Landslide deposit areas = 3 Slopes 15% to 33% (medium landslide potential) = 5 Slopes >33% (high landslide potential) = 10 Transient snow zones = 4	Use GIS to extract slope % categories that identify areas with low, medium, or high potential for landslides and assign sensitivity rankings to each category. Use GIS to select areas with elevations of 1500 feet above sea level or higher, resulting selection will be considered as transient snow zones. Assign sensitivity rankings to all other layers. Combine data layers so that where layers overlap, the highest sensitivity ranking from the overlapping layers will be maintained in the output. Convert output into a raster-based dataset where pixel values would be the sensitivity rankings.	DEQ_NRCS_Highly_Erodible_Lands DEQ_NRCS_High_Runoff_Potential_Soils DOGAMI_High_Permeability_Soils DOGAMI_Landslide_Deposits Transient_Snow_Zones USGS_10m_DEM_Slope
Wetlands	Wetlands = 8	Use GIS to extract non-linear Palustrine wetlands from wetland layer and assign sensitivity rankings to resulting data layer. Convert output into a raster-based dataset where pixel values would be the sensitivity rankings.	TWC_Wetlands
Water Setbacks	Water setbacks = 8	Buffer all features in data layers for waterbodies and watercourses by 200 feet, merge resulting polygons into a single layer, and assign sensitivity rankings to layer. Convert output into a raster-based dataset where pixel values would be the sensitivity rankings.	USGS_NHD_Waterbodies USGS_NHD_Watercourses

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**Appendix B**  
**Supporting Information to Calculate Risk for Agricultural and  
Forestry Chemical Applications**

**Appendix B, Table 1:** Crop types grown and the total acres according to USDA satellite imagery. Agricultural lands comprise approximately 23% of the 199,996 acre study area.

<b>CROP TYPE</b>	<b>2009</b>	<b>%</b>	<b>2010</b>	<b>%</b>	<b>2011</b>	<b>%</b>
Alfalfa	40	0%	62	0%	29	0%
Apples	-	0%	1	0%	3	0%
Barley	5	0%	0	0%	9	0%
Barren/Fallow/ Idle	4,271	10%	6,472	15%	695	1%
Blueberries	54	0%	43	0%	66	0%
Broccoli	6	0%	5	0%	0	0%
Cabbage	-	0%	1	0%	0	0%
Camelina	-	0%	11	0%	-	0%
Canola	-	0%	3	0%	0	0%
Cauliflower	9	0%	2	0%	2	0%
Cherries	222	0%	134	0%	367	1%
Christmas Trees	1,171	3%	786	2%	533	1%
Clover/Wildflowers	1,803	4%	2,113	5%	2,281	5%
Corn/Sweet Corn	1,582	4%	867	2%	1,194	3%
Cranberries	116	0%	31	0%	36	0%
Dry Beans	39	0%	69	0%	73	0%
Garlic	1	0%	1	0%	3	0%
Grapes	202	0%	122	0%	489	1%
Grassland Herbaceous	8,491	19%	7,526	17%	14,945	32%
Greens	5	0%	-	0%	0	0%
Herbs	12	0%	6	0%	7	0%
Hops	122	0%	9	0%	22	0%
Mint	18	0%	127	0%	9	0%
Misc Veggies & Fruits	9	0%	0	0%	0	0%
Mustard	1	0%	-	0%	-	0%
Oats	421	1%	1,000	2%	939	2%
Onions/Green Onions	12	0%	-	0%	5	0%
Other Crops	1,647	4%	1,786	4%	1,179	3%
Other Hay/Non Alfalfa	4,837	11%	1,258	3%	2,644	6%
Other Tree Crops	1,732	4%	1,220	3%	2,411	5%
Pasture/Hay	9,118	20%	13,736	31%	12,067	26%
Peas	10	0%	155	0%	10	0%
Peppers	2	0%	-	0%	-	0%
Plums	-	0%	10	0%	1	0%
Potatoes	10	0%	14	0%	8	0%
Prunes	8	0%	12	0%	37	0%
Radishes	2	0%	1	0%	59	0%
Sod/Grass Seed	5,760	13%	3,185	7%	3,325	7%
Sorghum	1	0%	-	0%	53	0%
Soybeans	-	0%	0	0%	3	0%
Squash	12	0%	8	0%	2	0%
Strawberries	5	0%	2	0%	2	0%
Sugar Beets	19	0%	3	0%	4	0%
Sunflower	-	0%	-	0%	2	0%
Triticale	1	0%	167	0%	1	0%
Turnips	1	0%	3	0%	2	0%
Vetch	27	0%	41	0%	115	0%
Walnuts	100	0%	50	0%	191	0%
Wheat/Winter & Spring	2,978	7%	3,265	7%	3,292	7%
<b>TOTAL</b>	<b>44,882</b>	<b>100%</b>	<b>44,311</b>	<b>100%</b>	<b>47,116</b>	<b>100%</b>

**Appendix B, Table 2:** List of 117 pesticides potentially used on agricultural and forested lands within the study area.

2,4,5-T	Difenzoquat	Metsulfuron Methyl
2,4-D	Dimethoate	Mevinphos
2,4-DB	Dinoseb	Naled
Acephate	Diphenamid	Napropamide
Alachlor	Diquat	Norflurazon
Aldicarb	Disulfoton	Oryzalin
Aminopyralid TIPA	Diuron	Oxamyl
Atrazine	EDTA	Oxydemeton Methyl
Azinphos Methyl	Endosulfan	Oxyfluorfen
Benefin	Endothall	Paraquat
Benomyl	EPTC	Parathion
Bensulide	Ethion	PCNB
Bentazon	Ethofumesate	Pendimethalin
Bifenox	Fensulfothion	Permethrin
Bromoxynil	Fenvalerate	Phenmedipham
Butylate	Fluazifop	Phorate
Captan	Fonofos	Phosalone
Carbaryl	Glyphosate	Phosmet
Carbofuran	Hexazinone	Picloram
Carboxin	Imadacloprid	Pronamide
Chloramben	Imadazole	Propachlor
Chlorothalonil	Imazapyr	Propargite
Chloroxuron	Iprodione	Simazine
Chlorpyrifos	Lecithin	Sulfometuron Methyl
Chorothalonil	Lindane	Terbacil
Clopyralid	Malathion	Terbufos
Cyanazine	Mancozeb	Thiabendazole
Cycloate	Maneb	Thiophanate
Cyhexatin	MCPA	Thiram
DCNA	Metadehyde	Triadimefon
DCPA	Metalaxyl	Triclopyr
Demeton	Metaldehyde	Triclopyr BEE
Desmedipham	Methamidophos	Triethylamine
Diazinon	Methidathion	Trifluralin
Dicamba	Methiocarb	Triforine
Dichlobenil	Methomyl	Vernolate
Dichlone	Methoxychlor	Vinclozolin
Diclofop	Metolachlor	Zineb
Dicofol	Metribuzin	Ziram



Appendix B, Table 3: Pesticide risk ranking for crop types that comprise greater than 1% of the agricultural lands and forested lands. Each of the common pesticides used on each crop is ranked according to toxicity and environmental persistence (see Table 1 and Table 2).

Risk Ranking	High RR ≥4.9	Medium RR = 3.0 -4.9	Low RR < 3.0	PESTICIDES ASSOCIATED WITH CROP TYPE AND THE RELATIVE RISK RANKING BASED ON TOXICITY AND PERSISTENCE																		No. of Pesticides	No. of High Risk Pesticides
CROP TYPE																							
Alfalfa	2,4-DB	Benefin	Carbaryl	Carbofuran	Chlorpyrifos	Diazinon	Dimethoate	Diuron	EPTC	Glyphosate	Hexazinone	Malathion	Metribuzin	Mevinphos	Paraquat	Parathion	Phosmet	Pronamide	Simazine		19	5	
	3.8	2.5	3.8	7.5	5.0	3.8	3.8	4.4	3.8	2.5	3.8	2.5	3.8	5.3	7.5	6.3	3.8	2.5	3.1				
Apples	2,4-D	Azinphos Methyl	Carbaryl	Chlorpyrifos	Cyhexatin	Diazinon	Dichlobenil	Diuron	Endosulfan	Glyphosate	Methidathion	Napropamide	Oryzalin	Paraquat	Simazine	Ziram					16	5	
	1.6	6.3	3.8	5.0	ND	3.8	4.4	4.4	5.0	2.5	5.0	3.1	1.9	7.5	3.1	2.5							
Barley	2,4-D	Bromoxynil	Carboxin	Dicamba	Diclofop	Difenzoquat	Dimethoate	Disulfoton	Diuron	Glyphosate	Lindane	Malathion	MCPA	Metribuzin	Parathion	PCNB	Thiabendazole	Thiram	Triadimefon		19	5	
	1.6	2.5	1.6	2.5	3.8	5.0	3.8	6.3	4.4	2.5	7.5	2.5	3.8	3.8	6.3	ND	5.6	2.5	3.8				
Blueberries	Azinphos Methyl	Benomyl	Captan	Carbaryl	Carbofuran	Diazinon	Dichlobenil	Diuron	Glyphosate	Malathion	Methiocarb	Methomyl	Napropamide	Paraquat	Pronamide	Simazine	Terbacil	Triforine	Vinclozolin		19	5	
	6.3	4.4	1.9	3.8	7.5	3.8	4.4	4.4	2.5	2.5	6.3	5	3.1	7.5	2.5	3.1	3.1	1.3	1.3				
Broccoli	Bensulide	Carbaryl	Chlorothalonil	DCPA	Disulfoton	Endosulfan	Fonofos	Glyphosate	Metalaxyl	Methamidophos	Methomyl	Methoxychlor	Mevinphos	Napropamide	Oxydemeton Methyl	Trifluralin					16	7	
	2.5	3.8	2.5	ND	6.3	5	7.5	2.5	3.8	5	5	3.1	5.3	3.1	5	2.5							
Cabbage	Azinphos Methyl	Benomyl	Chlorothalonil	Endosulfan	Fonofos	Glyphosate	Metalaxyl	Methomyl	Oxydemeton Methyl	Paraquat	PCNB	Trifluralin									12	6	
	6.3	4.4	2.5	5	7.5	2.5	3.8	5	5	7.5	ND	2.5											
Cauliflower	Carbaryl	Chlorpyrifos	Chlorothalonil	Fonofos	Glyphosate	Maneb	Metalaxyl	Metalddehyde	Mevinphos	Oxydemeton Methyl	Paraquat	PCNB	Trifluralin								13	6	
	3.8	5	2.5	7.5	2.5	3.1	3.8	5	5.3	5	7.5	ND	2.5										
Cherries	2,4-D	Captan	Carbaryl	Chlorothalonil	Diazinon	Dichlobenil	Dimethoate	Endosulfan	Malathion	Methidathion	Methiocarb	Napropamide	Oryzalin	Paraquat	Parathion	Simazine					16	5	
	1.6	1.9	3.8	2.5	3.8	4.4	3.8	5	2.5	5	6.3	3.1	1.9	7.5	6.3	3.1							
Christmas Trees	2,4-D	Acephate	Atrazine	Carbaryl	Chlorothalonil	Dicofol	Endosulfan	Glyphosate	Hexazinone	Malathion	Oxydemeton Methyl	Pronamide	Propargite	Propargite	Simazine						16	2	
	1.6	1.6	4.4	3.8	2.5	3.8	5	2.5	3.8	2.5	5	2.5	3.1	3.1	3.1								
Clover/ Wildflowers	2,4-DB	Benefin	Chlorpyrifos	Demeton	Diquat	Diuron	EPTC	Malathion	MCPA	Metadehyde	Methoxychlor	Oxydemeton methyl	Pronamide	Trifluralin							14	5	
	3.8	2.5	5	5	5	4.4	3.8	2.5	3.8	5	3.1	5	2.5	2.5									
Corn/ Sweet Corn	2,4-D	Alachlor	Atrazine	Butylate	Captan	Chlorpyrifos	Cyanazine	EPTC	Fonofos	Glyphosate	Metolachlor	Parathion	Permethrin	Phorate	Vernolate						15	4	
	1.6	2.5	4.4	2.5	1.9	5	3.8	3.8	7.5	2.5	4.4	6.3	3.8	7.5	3.8								
Cranberries	2,4-D	Chlorothalonil	Dichlobenil	Glyphosate	Malathion	Maneb	Napropamide	Parathion	Simazine												9	1	
	1.6	2.5	4.4	2.5	2.5	3.1	3.1	6.3	3.1														
Dry Beans	Bentazon	Dimethoate	EPTC	Oryzalin	Pendimethalin	Trifluralin															6	0	
	2.5	3.8	3.8	1.9	3.8	2.5																	
Garlic	Bromoxynil	Chlorothalonil	DCNA	Fluazifop	Iprodione	Paraquat	Pronamide														7	1	
	2.5	2.5	ND	0.9	3.1	7.5	2.5																
Grapes	Benomyl	Captan	Diazinon	Dicofol	Diuron	Glyphosate		Oryzalin	Oxyfluorfen	Simazine	Triadimefon										11	1	
	4.4	1.9	3.8	3.8	4.4	2.5	3.1	1.9	3.1	3.1	5												
Grassland Herbaceous	2,4-D	Bromoxynil	Carbaryl	Chlorothalonil	Chlorpyrifos	Diazinon	Dicamba	Dimethoate	Diuron	Ethofumesate	Fonofos	Glyphosate	Maneb	MCPA	Simazine						15	2	
	1.6	2.5	3.8	2.5	5	3.8	2.5	3.8	4.4	2.5	7.5	2.5	3.1	3.8	3.1								
Hops	Metalaxyl	Norflurazon	Paraquat	Zineb																	4	2	
	3.8	5	7.5	3.1																			

Appendix B, Table 3: Pesticide risk ranking for crop types that comprise greater than 1% of the agricultural lands and forested lands. Each of the common pesticides used on each crop is ranked according to toxicity and environmental persistence (see Table 1 and Table 2).

Risk Ranking	High RR >4.9	Medium RR = 3.0 -4.9	Low RR < 3.0	PESTICIDES ASSOCIATED WITH CROP TYPE AND THE RELATIVE RISK RANKING BASED ON TOXICITY AND PERSISTENCE																		No. of Pesticides	No. of High Risk Pesticides
CROP TYPE																							
Mint	Acephate	Bentazon	Chlorothalonil	Chlorpyrifos	Diuron	Fonofos	Methomyl	Napropamide	Oxamyl	Oxyfluorfen	Paraquat	Propargite	Terbacil										
	2.5	2.5	2.5	5	4.4	7.5	5	3.1	5	3.1	7.5	3.1	3.1									13	5
Oats	2,4-D	Bromoxynil	Carboxin	Dicamba	Disulfoton	Diuron	Malathion	MCPA	Thiophanate	Thiram													
	1.6	2.5	1.6	2.5	6.3	4.4	2.5	3.8	3.1	2.5												10	1
Onion/ Green Onions	Chlorothalonil	Chlorpyrifos	Diazinon	Ethion	Maneb	Oxyfluorfen	Paraquat	Zineb															
	2.5	5	3.8	5	3.1	3.1	7.5	3.1														8	3
Other Hay/ Non Alfalfa	2,4,5-T	2,4-D	Atrazine	Benomyl	Captan	Carbaryl	Diazinon	Dicamba	Dichlone	Dicofol	Glyphosate	Malathion	MCPA	Picloram	Triclopyr								
	3.8	1.6	4.4	4.4	1.9	3.8	3.8	2.5	3.8	3.8	2.5	2.5	3.8	4.4	3.8							15	0
Other Tree Crops	Acephate	Benomyl	Bifenox	Captan	Carbaryl	Chlorothalonil	Chlorpyrifos	Diazinon	Dichlobenil	Diphenamid	Diuron	Glyphosate	Malathion	Maneb	Metalaxyl	Metaldehyde	Napropamide						
	1.6	4.4	2.5	1.9	3.8	2.5	5	3.8	4.4	NA	4.4	2.5	2.5	3.1	3.8	5	3.1					17	2
Pasture/Hay	2,4,5-T	2,4-D	Atrazine	Benomyl	Captan	Carbaryl	Diazinon	Dicamba	Dichlone	Dicofol	Glyphosate	Malathion	MCPA	Picloram	Triclopyr								
	3.8	1.6	4.4	4.4	1.9	3.8	3.8	2.5	3.8	3.8	2.5	2.5	3.8	4.4	3.8							15	0
Potatoes	Aldicarb	Captan	Carbofuran	Chlorothalonil	DCNA	Dinoseb	Disulfoton	EPTC	Fensulfothion	Fonofos	Mancozeb	Maneb	Metolachlor	Metribuzin	Pendimethalin	Permethrin	Thiophanate	Trifluralin	Zineb				
	7.5	1.9	7.5	2.5	ND	6.3	6.3	3.8	3.8	7.5	0.9	3.1	4.4	3.8	3.8	3.8	3.1	2.5	3.1			19	5
Prunes	2,4-D	Azinphos Methyl	Benomyl	Captan	Chlorothalonil	Chlorpyrifos	Diazinon	Dichlobenil	Endosulfan	Iprodione	Napropamide	Oryzalin	Parathion	Simazine									
	1.6	6.3	4.4	1.9	2.5	5	3.8	4.4	6.3	3.1	3.1	1.9	6.3	3.1								14	4
Radishes	Captan	Chlorpyrifos	Diazinon	Fonofos	Zineb																		
	1.9	5	3.8	7.5	3.1																	5	2
Sod/ Grass Seed	2,4-D	Bromoxynil	Carbaryl	Chlorothalonil	Chlorpyrifos	Diazinon	Diclofop	Dimethoate	Diuron	Ethofumesate	Fonofos	Glyphosate	Maneb	MCPA	Simazine	Triadimefon							
	1.6	2.5	3.8	2.5	5	3.8	3.8	3.8	4.4	2.5	7.5	2.5	3.1	3.8	3.1	5						16	3
Squash	Carbaryl	Chloramben	Diazinon	Dinoseb	Endosulfan	Naled	Napropamide	Propachlor	Zineb														
	2.7	3.1	3.8	6.3	5	2.8	3.1	ND	3.1													9	2
Strawberries	2,4-D	Benomyl	Captan	Carbaryl	Carbofuran	Chloroxuron	Cyhexatin	Diphenamid	Endosulfan	Napropamide	Oxydemeton Methyl	Simazine	Vinclozolin										
	1.6	4.4	1.9	2.7	7.5	ND	ND	ND	6.3	3.1	5	3.1	1.4									13	3
Sugar Beets	Cycloate	Desmedipham	Endothall	Ethofumesate	Fonofos	Phenmedipham	Phorate	Terbufos	Triadimefon	Trifluralin													
	ND	ND	3.8	ND	3.8	ND	7.5	6.3	3.8	2.5												10	2
Vetch	2,4-DB	Benefin	Chlorpyrifos	Demeton	Diquat	Diuron	EPTC	Malathion	MCPA	Metadehyde	Methoxychlor	Oxydemeton Methyl	Pronamide	Trifluralin									
	3.8	2.5	5	5	5	4.4	3.8	2.5	3.8	5	3.1	5	2.5	2.5								14	5
Walnuts	Diazinon	Fenvalerate	Glyphosate	Malathion	Napropamide	Paraquat	Phosalone	Simazine															
	3.8	3.8	2.5	2.5	3.1	7.5	5	3.1														8	2
Wheat/Winter or Spring	2,4-D	Benomyl	Bromoxynil	Carboxin	Clopyralid	Dicamba	Diclofop	Dimethoate	Disulfoton	Diuron	Glyphosate	Lindane	Malathion	Mancozeb	Maneb	Metadehyde	Metribuzin	Thiabendazole	Thiophanate	Thiram			
	1.6	4.4	2.5	1.6	3.1	2.5	3.8	3.8	6.3	4.4	2.5	7.5	2.5	0.9	3.1	5	3.8	5.6	3.1	2.5		20	4
Forestry	2,4-D	Aminopyralid TIPA	Atrazine	Clopyralid	Diquat	EDTA	Glyphosate	Hexazinone	Imadacloprid	Imadazole	Imazapyr	Iprodione	Lecithin	Metsulfuron Methyl	Picloram	Sulfometuron Methyl	Triclopyr	Triclopyr BEE	Triethylamine				
	1.6	3.1	4.4	3.1	7.5	3.8	2.5	3.8	5	6.3	1.9	3.1	3.1	3.1	3.1	1.9	3.8	7.5	3.8			19	

**Appendix B, Table 4:** Risk ranking for each crop type. Pesticide and fertilizer applications were ranked separately and then combined into one Agricultural Chemical risk ranking.  
Pesticide and fertilizers application information was not reviewed for crop types covering <1% of the study area and were assigned an overall risk ranking of 1.

<b>Crop/Activity</b>	<b>Pesticide Application Ranking (range 0-10)</b>	<b>Fertilizer Application Ranking (range 1-7)</b>	<b>Overall Risk Ranking (range 1-8.2)</b>
Alfalfa	10	2	5.2
Apples	10	7	8.2
Barley	10	2	5.2
Blueberries	10	1	4.6
Broccoli	10	5	7.0
Cabbage	10	5	7.0
Camelina	na	na	1.0
Canola	na	na	1.0
Cauliflower	10	5	7.0
Cherries	10	1	4.6
Christmas Trees	4	5	4.6
Clover/Wildflowers	10	1	4.6
Corn/Sweet Corn	8	2	4.4
Cranberries	2	1	1.4
Dry Beans	0	3	1.8
Garlic	2	5	3.8
Grapes	2	1	1.4
Grassland Herbaceous	4	2	2.8
Greens	na	na	1.0
Herbs	na	na	1.0
Hops	4	2	2.8
Mint	10	2	5.2
Misc Veggies & Fruits	na	na	1.0
Mustard	na	na	1.0
Oats	2	2	2.0
Onions/Green Onion	6	7	6.6
Other Crops	na	na	1.0
Other Hay/Non Alfalfa	0	2	1.2
Other Tree Crops	6	1	3.0
Pasture/Hay	0	2	1.2
Peas	na	na	1.0
Peppers	na	na	1.0
Plums	na	na	1.0
Potatoes	10	5	7.0
Prunes	8	7	7.4
Radishes	4	5	4.6
Sod/Seed Grass	6	2	3.6
Sorghum	na	na	1.0
Soybeans	na	na	1.0
Squash	4	3	3.4
Strawberries	6	2	3.6
Sugar Beets	4	3	3.4
Sunflower	na	na	1.0
Triticale	na	na	1.0
Turnips	na	na	1.0
Vetch	10	1	4.6
Walnuts	4	7	5.8
Wheat/Winter or Spring	8	2	4.4



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## **Appendix C**

### **Methodology for Updating the Geodatabase**

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## Updating Procedures and Methodology

Since a majority of the owners of data sources used for this project update their data on a regular basis GSI recommends the JWC update the layers either annually or biannually. The updating process is relatively simple. It is recommended that a copy of the geodatabase be made prior to beginning the updating process. Then contact the original owners of the data (see Appendix C, Table 1 or each data layer's metadata for the data source's contact information) to obtain the updated version of layer(s) they maintain. New data layers gathered from the original owners should be saved outside of the geodatabase.

The next step is to perform any necessary geoprocessing tasks in order to ensure that the layer's spatial extent does not go beyond the boundary of the "Study\_Area\_1milebuffer" layer. For feature classes, this requires that the GIS user perform a "select" or "clip" on the new data layers using the "Study\_Area\_1milebuffer" layer as the input "select" or "clip" layer. For raster datasets, this requires that the GIS user perform an "extract by mask" (NOTE: this geoprocessing tool requires that the GIS user has the "Spatial Analyst" license installed) using the "Study\_Area\_1milebuffer" layer as the "mask" layer. Once the "select", "clip", or "extract by mask" has been performed, export the results to a temporary folder as a new shapefile/raster dataset.

The final step is to import the geo-processed layers into the geodatabase. GSI highly recommends that the old layers being updated not be deleted before the new layers are imported. Each of the old layers has metadata that can be directly copied to the new layers and the old layers can be used for quality control to ensure that the new layers are configured correctly. To accomplish this, simply import the new layers with the same name as the old layers with the import date added to the end of the new layers' names. Then import the old layer's metadata into the new layer using ArcCatalog. Once the importation is complete, simply view both the old and the new layers in ArcMap to ensure that the extent of the new layers is correct and that the attributes and metadata of the new layer are structured and populated similarly to the old layers. Once the user has verified that the new imported layers are setup correctly, delete the old layers and remove the import date from the end of the file names of the new layers. By performing the steps outlined in this paragraph, the JWC will maintain consistency of the file structure within the geodatabase and premade maps/figures will be updated as soon as they are reopened in ArcMap.

Two layers in the geodatabase require more work to update correctly. The first is the layer named "ODF\_FACTS\_Sept2009toSept2012". This layer was derived from the Oregon Department of Forestry's Forestry Activity Computerized Tracking System (FACTS) database. Unfortunately, FACTS was not setup to be used in a GIS environment. The original FACTS data comes in the arrangement of seven individual .csv files and an empty template Microsoft Access database. The template database allows the user to easily import the .csv files into various tables within the database. Once the .csv file importation is complete, the user can query and report FACTS data for specific areas and/or forestry activities. This structure works well in the Microsoft Access environment but does not translate well to the GIS environment. In order to get FACTS into a usable GIS format, the user must create a table within Microsoft Access that contains the FACTS data of interest. Each row of this table must include a notification number and the ¼ ¼ section the notification occurs within to be able to link to and function within GIS.

Since the original FACTS database is not setup in the needed format, GSI created specific queries that extract and format the FACTS data for importation into GIS. A digital copy of that database, named "GSI\_FACTS.mdb", is included in the appendices of this technical memorandum and can be used to update the FACTS table that is formatted for GIS. Also

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included in the appendixes of this technical memorandum are digital copies of the original ODF FACTS data tables that GSI received from ODF in October of 2012. However, it should be noted that after the geospatial analysis was performed as part of this project, the JWC discovered that many of the non-chemical FACTS notifications (thinning, clear cutting, road widening, etc.) were not included as part of the end result FACTS table that was formatted for GIS. Additional work needs to be performed on the queries in GSI's version of the FACTS database to ensure that all of the non-chemical FACTS notifications are included in the output table that can be used in GIS.

Once a GIS-friendly table of the FACTS data has been created, the user can perform an attribute table join between the FACTS table and the "ODF\_FACTS\_PLS\_QQ\_Sections\_XY" layer in the geodatabase. By performing the table join, the resulting FACTS data table will now contain XY coordinates for each FACTS notification, per  $\frac{1}{4}$   $\frac{1}{4}$  section of the notification. This will allow the user to create a point-based layer for the FACTS data based on the XY coordinates. The user can then perform a "one-to-many" spatial join between the point-based FACTS layer and the "PLS\_QQ\_Sections" layer in the geodatabase. This will give a  $\frac{1}{4}$   $\frac{1}{4}$  section representation of each FACTS notification in the study area.

The other layer that will require additional work to update correctly is the layer named "All\_Potential\_Contaminant\_Sources". This layer contains all of the point-based features representing the locations of potential contaminant sources in the study area. This includes the locations of dry cleaners, sites of storage and known or potential contamination of hazardous material, underground injection control systems (UICs), leaking and non-leaking underground storage tanks, water quality permit discharge locations, and confined animal feedlots. The individual layers that were incorporated into one the "All\_Potential\_Contaminant\_Sources" layer and their data sources are outlined in Section 5.3.

In order to successfully update the "All\_Potential\_Contaminant\_Sources" layer, the user must follow these steps:

- 1) Request updated versions of the individual layers listed in section 5.3 from each layer's data source.
- 2) Perform the initial geoprocessing steps described in paragraphs 2 and 3 of this section to effectively update each layer in the geodatabase.
- 3) Add four attribute fields to the attribute table of each of the individual layers being updated. Those fields are "PCS\_NAME" (name of the business, site, or general activity of what is occurring at each PCS location), "ACTIVITY" (overall description of the general activity or contaminant source at each location), "DETAILS" (a more specific description about the activity or contaminant source that is occurring at each location), and "DATA\_SRC" (name of the source layer so it can later be referenced back to the original data source).
- 4) Perform a "merge" in GIS to combine all of the layers into an all-encompassing and updated version of the "All\_Potential\_Contaminant\_Sources" layer.
- 5) Import the updated version of the "All\_Potential\_Contaminant\_Sources" layer into the geodatabase.
- 6) Review the data for duplicates and eliminate any duplicate locations.

After all the individual data layers have been updated and imported into the geodatabase, all polygons must be converted into rasters. Then the risk, sensitivity and susceptibility analysis must be performed using the raster calculator.



**Appendix C Table 1.** Data sources and contact information for updating data.

DATA SOURCE	TYPES OF DATA	WEBSITE	CONTACT NAME	CONTACT EMAIL
The Oregon Department of Agriculture (ODA)	Locations of confined animal feeding operations (CAFOs)	<a href="http://www.oregon.gov/ODA/NRD/Pages/cafo_front.aspx">http://www.oregon.gov/ODA/NRD/Pages/cafo_front.aspx</a>	Diana Walker	<a href="mailto:dlwalker@oda.state.or.us">dlwalker@oda.state.or.us</a>
The Oregon Department of Environmental Quality (DEQ)	Potential contaminant source types and locations, study area boundary	<a href="http://www.deq.state.or.us/news/databases.htm">http://www.deq.state.or.us/news/databases.htm</a>	Steve Aalbers	<a href="mailto:AALBERS.Steven@deq.state.or.us">AALBERS.Steven@deq.state.or.us</a>
The Oregon Department of Forestry (ODF)	Forestry activity computerized tracking system (FACTS) database	<a href="http://www.oregon.gov/ODF/privateforests/pages/fpafacts.aspx">http://www.oregon.gov/ODF/privateforests/pages/fpafacts.aspx</a>	Susan Brandt	<a href="mailto:susan.brandt@state.or.us">susan.brandt@state.or.us</a>
The Oregon Department of Geology and Mineral Industries (DOGAMI)	Landslide deposit areas, high permeability soils	<a href="http://www.oregongeology.org/sub/default.htm">http://www.oregongeology.org/sub/default.htm</a>	See website	See website
The Oregon Department of Transportation (ODOT)	Highways, mileposts, railroads	<a href="http://www.oregon.gov/ODOT/tdtdata/Pages/gis/odotgis.aspx">http://www.oregon.gov/ODOT/tdtdata/Pages/gis/odotgis.aspx</a>	See website	See website
The Regional Government for the Portland Metropolitan Area (METRO)	City limits, roads, sewer districts, urban growth boundaries, urban reserve boundaries, Washington County tax lots, Washington County zoning	<a href="http://www.oregonmetro.gov/index.cfm/go/by.web/id=593">http://www.oregonmetro.gov/index.cfm/go/by.web/id=593</a>	See website	Consult Hillsboro GIS or See website
The Yamhill County GIS Department (Yamhill Co)	Tax lots and zoning for Yamhill County	<a href="http://www.co.yamhill.or.us/GIS/GIS.asp">http://www.co.yamhill.or.us/GIS/GIS.asp</a>	See website	Consult Hillsboro GIS or See website
The US Department of Agriculture (USDA)	Crop types and locations	<a href="http://www.nass.usda.gov/research/Cropland/SARS1a.htm">http://www.nass.usda.gov/research/Cropland/SARS1a.htm</a>	See website	See website
The USDA Natural Resources Conservation Service (NRCS)	Soil types and characteristics	<a href="http://soildatamart.nrcs.usda.gov/">http://soildatamart.nrcs.usda.gov/</a>	See website	See website
The US Geological Survey (USGS)	Ground surface elevation and slope, surface water, percent imperviousness	<a href="http://ned.usgs.gov/">http://ned.usgs.gov/</a> <a href="http://nhd.usgs.gov/">http://nhd.usgs.gov/</a> <a href="http://extract.cr.usgs.gov/distmeta/servlet/gov.usgs.edc.MetaBuilder?TYPE=HTML&amp;DATASET=NLCD06LANC">http://extract.cr.usgs.gov/distmeta/servlet/gov.usgs.edc.MetaBuilder?TYPE=HTML&amp;DATASET=NLCD06LANC</a>	See websites	See websites
The Nature Conservancy (TNC)	Regional vegetation types and land use activities	<a href="http://www.nature.org/">http://www.nature.org/</a>	See website	See website
The Wetlands Conservancy (TWC)	Wetland boundaries	<a href="http://oregonexplorer.info/wetlands/DataCollections/GeospatialData_Wetlands">http://oregonexplorer.info/wetlands/DataCollections/GeospatialData_Wetlands</a>	See website	See website
The Federal Emergency Management Agency (FEMA)	100 year and 500 year floodplain boundaries	<a href="https://msc.fema.gov/webapp/wcs/stores/servlet/CategoryDisplay?catalogId=10001&amp;storeId=10001&amp;categoryId=12003&amp;langId=-1&amp;userType=G&amp;type=2">https://msc.fema.gov/webapp/wcs/stores/servlet/CategoryDisplay?catalogId=10001&amp;storeId=10001&amp;categoryId=12003&amp;langId=-1&amp;userType=G&amp;type=2</a>	See website	See website