SOUTHERN WILLAMETTE VALLEY GROUNDWATER MANAGEMENT AREA

NITROGEN/NITRATE BUDGET REPORT

Prepared by
Lane Council of Governments

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Table of Contents

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Executive Summary

This document details work to link public policy and planning with best available science and associated data. The project identifies potential sources of elevated levels of nitrate in drinking water in the Southern Willamette Valley Groundwater Management Area (GWMA). A better understanding of the quantities of nitrogen applications and potential nitrate contributions, provide a tool to help guide future choices in land use management practices.

The GWMA is an area with historically high monitored levels of groundwater nitrate. The area is home to about 21,000 residents most relying on the shallow groundwater for drinking water. The area is predominantly agricultural (93 percent), with four relatively small cities. About 2,700 rural residents rely on domestic wells for drinking water and septic systems for sewage disposal. The combination of the use of the shallow aquifer for drinking water and a mixture of land uses that contribute to high nitrate levels in an area of complex groundwater movement and geo-chemistry, gives rise to the need to envision changes in landscape management—landscape trajectories. These changes could produce conditions of quality drinking water for the residents of the area, robust and efficient agricultural practices, and sound environmental conditions.

The efforts this project details, occur within the context of a longer relationship with researchers, planners, and the full range of stakeholders of the area in addressing the nitrate problem. Since it's declaration in 2004 the GWMA committee has met on a quarterly basis, developed a voluntary based Action Plan to address nitrate, and now are moving forward with Action Plan implementation. This relatively simple nitrogen budget provides an assessment of the relative contributions of sources and the potential benefit of changes in management practices in the GWMA. Our goals are to:

- Provide a tool for assessing nitrogen/nitrate contributions to groundwater in the GWMA.
- Identify and quantify how much nitrogen/nitrate specific land uses are contributing and how much nitrate reduction can be expected as strategies from the GWMA Action Plan are implemented.
- Facilitate sound decision-making that results in policy adoption and prioritized strategy development and implementation to reduce nitrate contributions.
- Preserve and enhance the health of the aquifer while maintaining traditional and/or locally appropriate land uses. Emphasis is on the development of specific voluntary strategies that avoid leaching nitrate to groundwater.

This project relies on simple methods to estimate, using best available data, the amount of nitrogen contributed to groundwater from four primary identified sources for which data could be collected spatially: agricultural crops, confined animal feeding operations (CAFO's), large on-site sewerage systems, and rural residential septic systems. No effort has been made to specifically model groundwater chemical processes or flows. Spatial correlations between estimated nitrogen contributions from modeled sources to sampled groundwater nitrate levels are made at an aggregate scale on a one square-mile grid.

Not surprisingly, given the land use make up of the GWMA, agricultural land use practices are the largest contributor to groundwater nitrate levels as measured by gross spatial correlation of estimated nitrogen inputs to groundwater and total volume of input for the area. This is not unexpected given the predominance of intensive agricultural land use in the management area. While none of the data produced in this report is statistically significant, stronger correlations are seen to CAFO's and to crops, particularly crops under modeled good and poor utilization which incorporates good and poor management practices. Overall, residential septic systems appear to be a smaller contributor to groundwater contamination on a regional scale, though locally constrained conditions certainly exist, especially in Lane County. Large permitted wastewater treatment facilities contribute the smallest amount although data for these facilities are limited.

Future efforts to reduce contributions to groundwater contamination from nitrate should focus on all land use sectors with priority given to agricultural land uses. The model demonstrates the gains that can be made through good crop utilization which incorporates using best management practices to control nitrate leaching to groundwater. There is an opportunity to reduce nitrogen contributions from a handful of livestock operations. In addition, progress can likely be made with localized reductions in nitrogen contributions from septic systems. For large permitted wastewater treatment facilities further data collection will allow these systems to have a better cross-program, cross environmental media analysis.

Section 1 – Introduction and Background

Introduction

The Oregon Department of Environmental Quality (DEQ) considers the Southern Willamette Valley to be a priority area for groundwater assessment and protection for four primary reasons:

1) severity and extent of documented non-point source groundwater contamination;
2) vulnerability of shallow groundwater to adverse impacts from population growth;
3) reliance on groundwater for drinking water of many residents of the valley; and
4) need for integration of groundwater quality protection strategies with other ongoing water quality improvement efforts, such as the Total Maximum Daily Load (TMDL) allocations for impaired waterways and Oregon Department of Agriculture (ODA) Water Quality Plans (Kalakay, 2004).

Over the last 20 years, many studies and sampling programs have focused on groundwater quality in the Southern Willamette Valley. The results have identified nitrate contamination of shallow groundwater in some parts of the Valley. In May 2004, the DEQ declared a portion of the Southern Willamette Valley a Groundwater Management Area (GWMA) because of elevated groundwater nitrate levels. Although low levels of nitrate are natural, a variety of human activities have caused high nitrate concentrations in the groundwater in the Southern Willamette Valley (Eldridge, 2004). Consequently, the DEQ formed a stakeholder group in the fall of 2004, known as the Groundwater Management Area Committee (GWMA Committee), to develop nitrate reduction strategy recommendations for a region-wide, DEQ-approved Action Plan. Since the formation of the GWMA Committee, a GWMA Action Plan containing strategies and recommendations for nitrate reduction was developed and approved by the DEQ in December of 2006.

In order to better address high nitrate values, a comprehensive picture of nitrate sources and quantities must be drawn. This report describes the development of a nitrogen/nitrate budget for the Southern Willamette Valley GWMA. It provides a view of the region's history, current status, and projected impacts from land uses on groundwater nitrate concentrations. The nitrogen budget is a planning tool that is based on the estimation of gross nitrogen contributions from four land uses throughout the GWMA. After establishing loading values, the application of land use changes to reduce nitrate contamination can be assessed. This budget also examines soil features that influence nitrate contamination risk, such as permeability and denitrification potential. Estimating potential changes of nitrate loading under various land use practices combined with soil features provides a better understanding of where nitrogen reduction efforts will be best focused to lead to lower nitrate levels.

Purpose and Goals

The goals of this budget are to:

- Provide a tool for assessing nitrogen/nitrate contributions in the GWMA.

- Identify and quantify how much nitrogen specific land uses are contributing and an estimation of how much nitrogen reduction can be expected as strategies from the GWMA Action Plan are implemented.

- Facilitate sound decision-making that results in policy adoption and geographically prioritized strategy development and implementation to reduce nitrate contributions.

- Preserve and enhance the health of the aquifer while maintaining traditional and/or locally appropriate land uses. Emphasis is on the development of specific voluntary strategies that avoid leaching nitrate to groundwater.

This report describes the development of a nitrogen/nitrate budget for the purposes of providing decision-makers and the public with a regional planning level impact analysis of potential nitrate contributions in the Southern Willamette GWMA. Though the best effort to provide a useful tool has been made, the quantification of the nitrogen cycle within a given area, such as the GWMA, is an extremely complex task. Several factors that affect nitrogen transport, deposition, and uptake by crops, vegetation, and soil were beyond the scope of this project to specifically quantify. In some cases these factors are nearly impossible to quantify for such a specific area (e.g., atmospheric deposition from out-of-state sources), and are therefore not discussed in this document. It is for this reason that this report should be used as an informational tool rather than a definitive calculator of all nitrogen sources and the fate of nitrogen entering the groundwater within the GWMA.

Report Organization
This report is organized into three sections:

Section One – Introduction and Background includes a regional profile describing the area's characteristics such as land use and local jurisdictions. This Section also provides an overview of the sampling studies conducted in the area, health concerns related to nitrate, and a broad overview of potential nitrate sources in the region.

Section Two – Methodology identifies specific potential nitrate contamination sources within the GWMA and how they relate to land use. This Section also explains the sources and collection of data and how it was used to develop the nitrate budget.

Section Three – Results, Findings, and Recommendations explains and displays the results of the nitrogen/nitrate budget model. This Section also provides suggestions and prioritization of geographic area and strategies to reduce contamination risk.

Regional Profile
The Willamette Valley is one of Oregon's fastest growing regions and depends heavily on groundwater for private wells, public drinking water, irrigation, industrial operations, and other beneficial uses. The GWMA is comprised of approximately 230 square miles of land within the Southern Willamette Valley. The GWMA boundary begins on the northern edge of the Eugene/Springfield metropolitan area, the second largest in the state of Oregon, and extends 50 miles north just beyond the city of Corvallis. The area includes portions of Lane, Linn, and Benton Counties and the cities of Harrisburg, Junction City, Coburg, Monroe, and a small portion of Corvallis (see Map 1).

Residents

There are approximately 21,200 residents in the GWMA, 80 percent of which rely solely on groundwater for their drinking water supply.   Approximately 12,500 residents live in urban areas and get their drinking water from public municipal water systems.   There are also several small public water system wells that serve GWMA residents living outside of municipal areas but the majority of these estimated 8,700 residents use groundwater from household wells. Table 1 shows the breakdown of urban and rural residents within the GWMA by county. The Lane County portion of the GWMA is the most heavily populated with half of all GWMA residents and nearly 60 percent of all rural residents.

Map 1: Regional Context

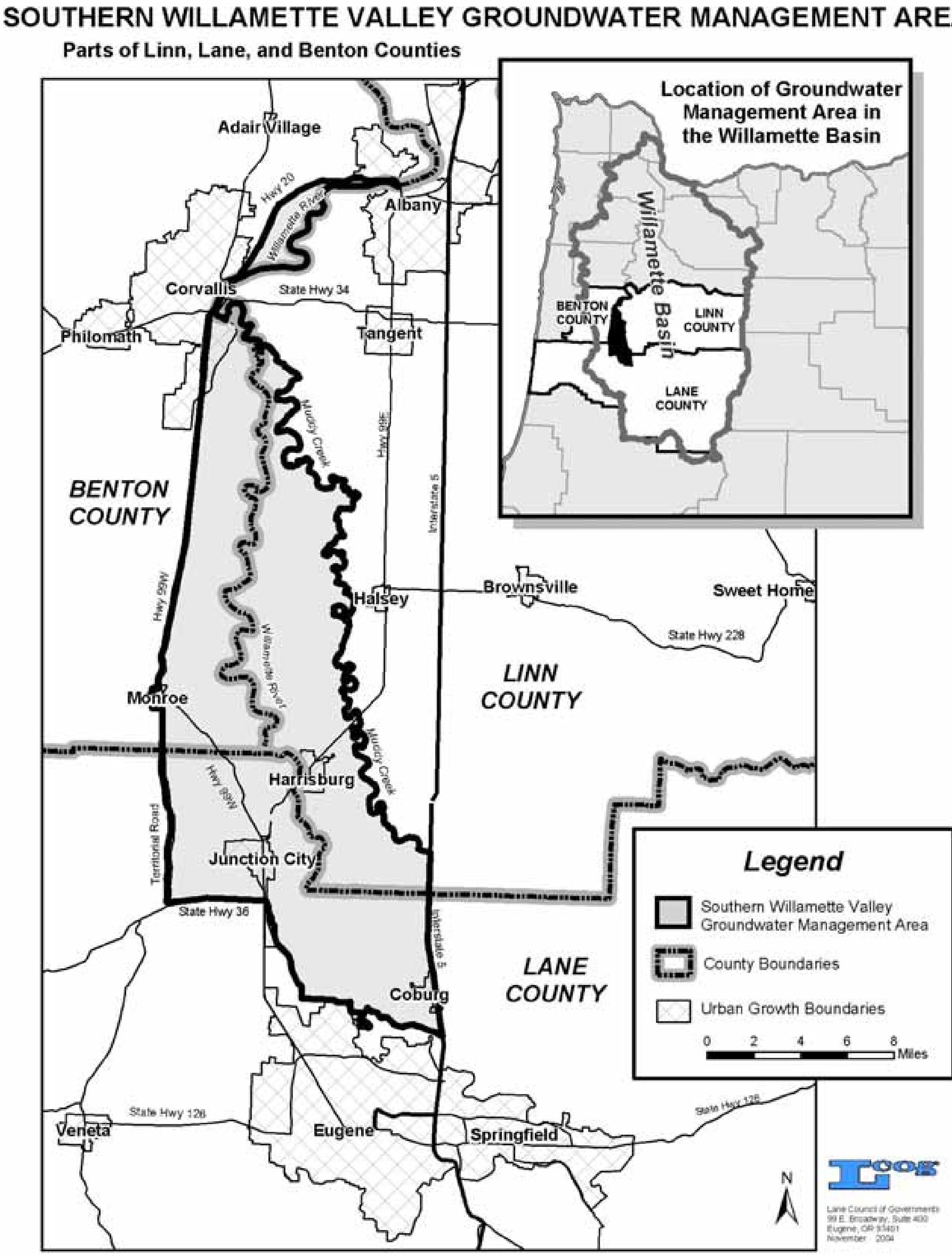


Table 1: Southern Willamette Valley Groundwater Management Area Urban and Rural Population by County

	Lane County	Benton County	Linn County	Total
Rural Population	5,033	2,010	1,640	**8,683**
Population by City				
Coburg	958			
Junction City	4,630			
Corvallis*		3,936		
Monroe		597		
Harrisburg			2,427	
Urban Total	5,588	4,533	2,427	**12,538**
Total Population	10,621	6,533	4,067	**21,221**

Rural population from 2002 Census based on location of block center falling outside of city limits.
Urban population from 2002 Census based on location of block center falling in city limits.
*Corvallis population only includes Census Block whose centers fall within the GWMA Study Area

Surface and Groundwater
The main surface water feature in the GWMA is the Willamette River. Groundwater flow generally follows the contour of the land and slowly moves towards the Willamette River. As groundwater flows closer to a river, it starts to move in the same direction as the river and some groundwater can be incorporated into the river. During the drier months, groundwater will often help sustain river flows. However, under the right conditions, water can flow into the aquifer from the river.

Some 12,000 to 15,000 years ago, massive flooding events distributed large cobbles, gravels, sands, and silts over the valley and created temporary lakes in the area. Finer-grained materials eventually settled out of these lakes, and created the hydrogeologic unit know as the Willamette Silt. Evidence suggests that the Willamette Silt may provide some protection to the aquifer from land activities because the smaller soil particles are less permeable and can act as a barrier to contaminant movement (USGS, 2005). Some studies have even demonstrated that the Willamette Silt may help break down nitrate to inert nitrogen gas, offering even more protection to the groundwater under the silt layers (Haggerty 2004). Since the formation of the Willamette Silt, portions of it have been eroded or washed away by the rivers and creeks within the valley. Perhaps the best example is along the modern floodplain of the Willamette River where, in many places, all that remains at the surface are highly permeable soils resting directly on top of the aquifer.

The majority of the drinking water supply in the region comes from the underlying groundwater resource known as the Willamette Aquifer. According to the US Geologic Survey water supply data (Hinkle, 1997), “more than 80 percent of the groundwater used in the

Willamette Basin is pumped from the alluvial aquifer" (the shallow portion of the aquifer made up of sediments). There are several productive zones within this aquifer including a very productive shallow zone, which is primarily adjacent to, or on the west side of, the river. This productive zone is an *unconfined* aquifer usually less than 40 feet deep, averaging about 20 feet in thickness. Usually, an *unconfined* aquifer is one where there is a direct link between the aquifer and the land surface, meaning there is no relatively impermeable soil or rock barrier to restrict the downward percolation of water and potential contaminants.

The majority of the soil overlying the shallow aquifer is well drained. Consequently, the historically high amount of rainfall makes this shallow groundwater very susceptible to any land use contamination. Due to the geology of the area, this heavily used, uppermost aquifer is the groundwater resource most likely affected by human activities (Eldridge, 2004)

In some areas beneath this upper saturated soil zone, there is a deeper zone which can extend to over 200 feet thick, especially in areas where rivers have merged (such as the McKenzie and the Willamette.) The deeper zone generally starts around 60 feet below the surface and in some areas is confined where it contains localized, relatively impermeable zones of rock or soil. Due to this fact, some areas of the GWMA will have very good connections between the shallow and deeper zones of the aquifer, while other areas contain impediments (confining layers) that may help reduce the risk of contaminated groundwater moving directly into the deeper zones.

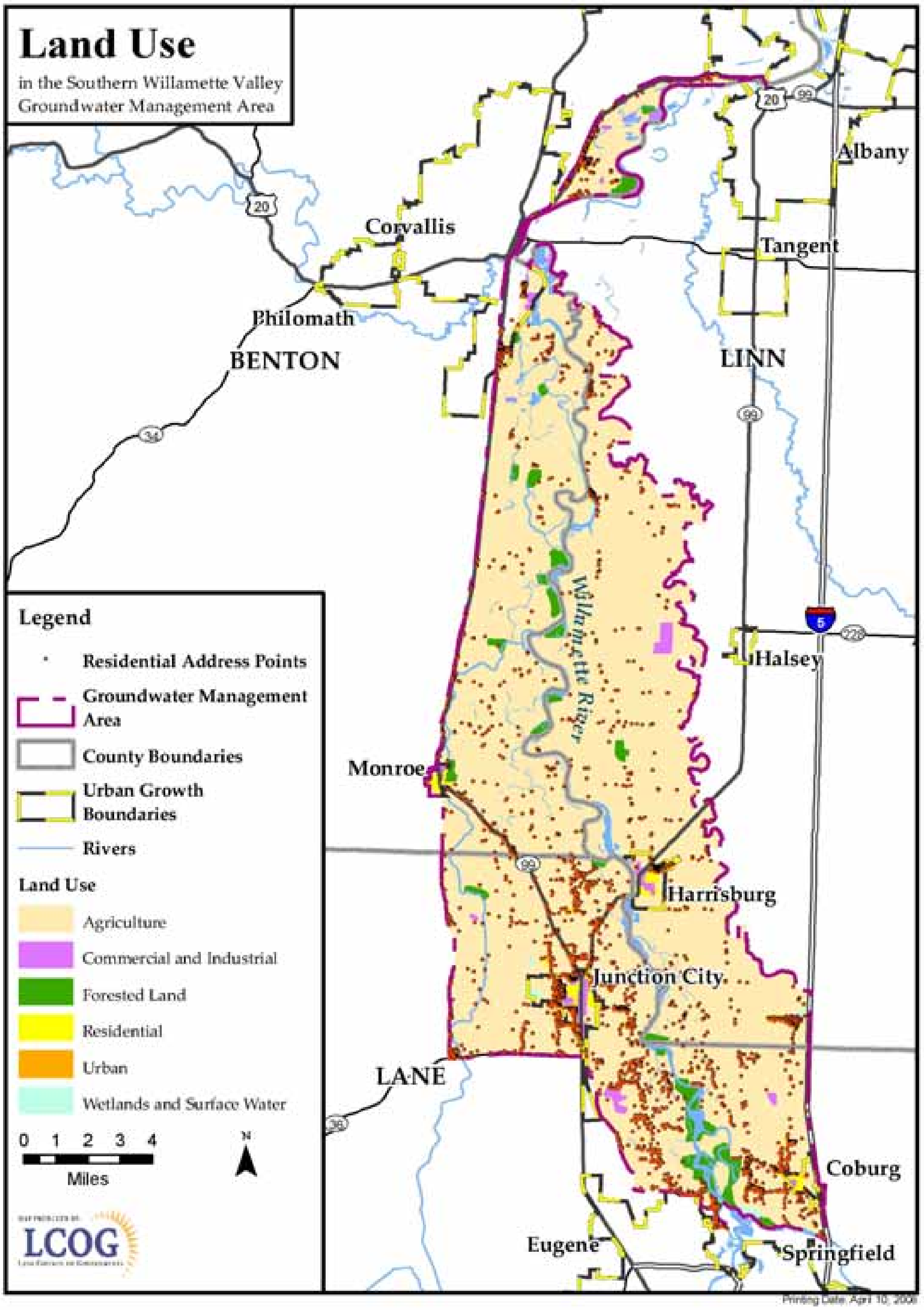
Land Use

Fertile lands of the Willamette Valley are a natural place for people to live and cities to develop. The region is one of the most productive agricultural areas in the world. About 93 percent of the GWMA is in agricultural land use, providing a significant economic base for all three counties in the GWMA. Valley soils and climate are ideal for crop, livestock, and dairy production. A little over six percent of the GWMA is dedicated to urban or rural residential land use. Urban uses include city residential areas, as well as commercial and industrial operations both inside and outside of city boundaries. Businesses in the Southern Willamette Valley range from golf courses to recreational vehicle manufacturers to pulp and paper industries. There are approximately 2,700 rural residential homes in the area. The majority of these homes rely on private wells and septic systems. Many rural residential lots also support small scale livestock production. Map 2 displays types of land use in the GWMA.

Groundwater Nitrate Studies

In the Willamette Valley, numerous studies provide evidence of widespread nitrate contamination in portions of the valley. Sampling in the 1990s by the DEQ, Oregon State University (OSU), OSU Extension Service, and the USGS indicated elevated nitrate in the region (Eldridge, 2004). More recent sampling and analysis by the DEQ Laboratory has confirmed previous nitrate study results. Between 2000 and 2002, the DEQ undertook two additional studies to examine the magnitude and extent of nitrate in shallow groundwater. The 2000-2001 study sampled 476 wells in the study area and over 20 percent (100 wells) had nitrate at or above 7 mg/L. In 2002, DEQ re-sampled the wells that had nitrate values greater than 7mg/L. This re-sampling found nitrate concentrations that were consistent with previous levels. The Department of Human Services (DHS) requires public water systems to monitor for nitrate and 15 systems in the GWMA have tested positive for nitrate levels greater than 7 mg/L in the past five years.

Map 2: Land Use



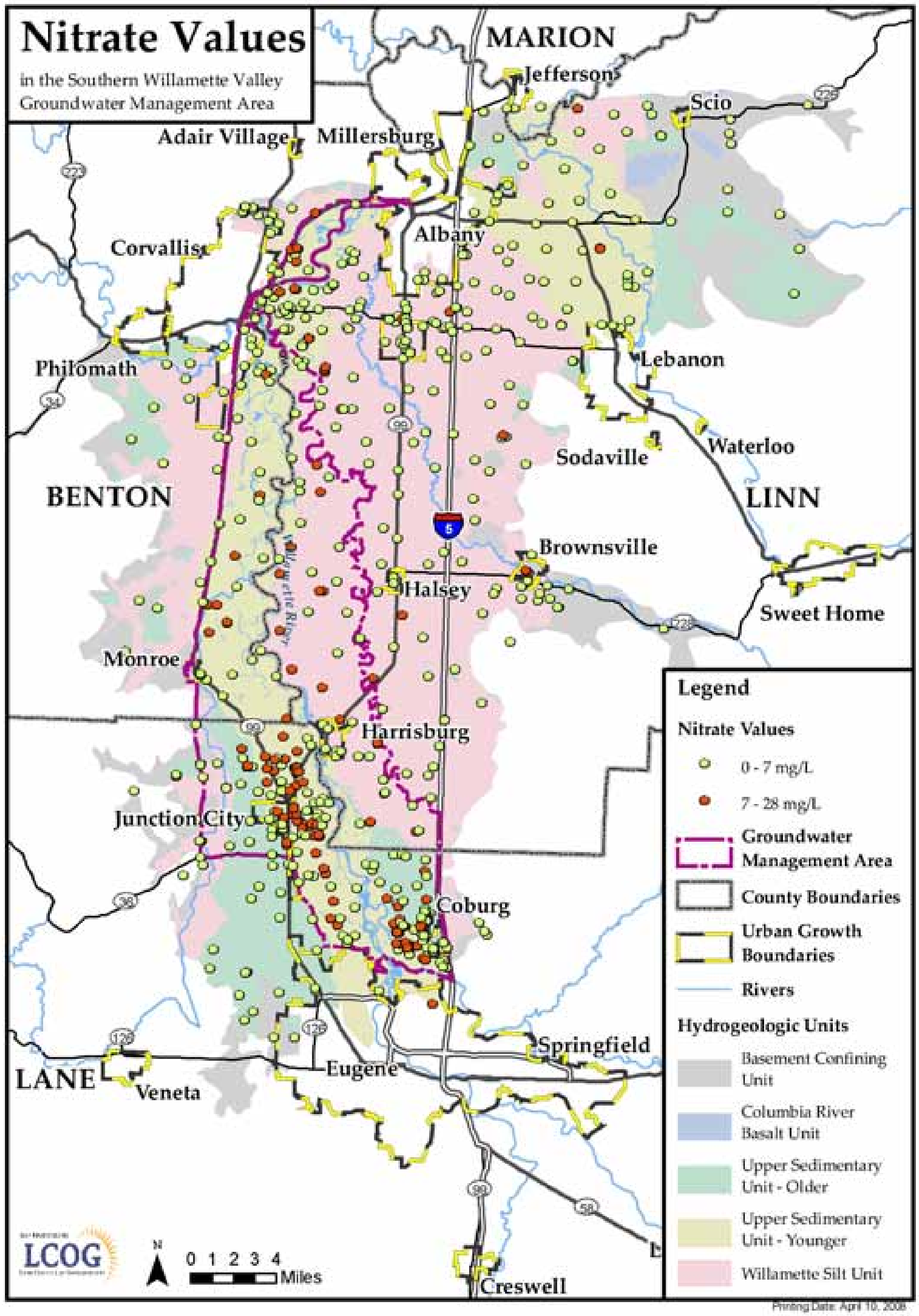
Many of the studies in the Southern Willamette Valley have focused on shallow groundwater as measured by the use of wells that are less than 75 feet below the land surface. The few deeper wells identified and sampled during the 2002 study all had low nitrate concentrations (none with levels greater than 1.3 mg/L), even though a corresponding shallow well in the same area had nitrate values up to 20 mg/L. There is insufficient data to determine if there is an impact to the deeper (greater than 75 feet) groundwater. However, as found in the 2002 investigation, there is a large amount of information connecting high nitrate values with recent alluvium and the younger deposits adjacent to the Willamette River in the 100-year floodplain. These are areas where the Willamette silt has likely been removed by the erosional forces of the Willamette River. Nitrate levels in these areas have been measured up to 27 mg/L (Eldridge, 2004).

Of the 100 wells sampled in 2002, nine wells that had nitrate values greater than 7 mg/L were located in the area mapped as Willamette Silt. These wells are likely drawing from the portion of the aquifer located beneath the silt, as the Willamette Silt unit is not known to be capable of consistently supplying an adequate quantity of water to private wells. Map 3 shows the DEQ study area and the results of the nitrate sampling conducted by the U.S. Geologic Survey, public water systems, and the DEQ 2000-2002 studies. The map also shows the relationship of nitrate values to the hydro-geologic composition of the area. Not surprisingly, there appears to be a relationship between high nitrate and the younger alluvium (the Willamette 100 year floodplain). In general this area is absent of Willamette silt, has highly permeable soils, is heavily populated, and has a predominance of irrigated crops because of the relatively easy access to irrigation water.

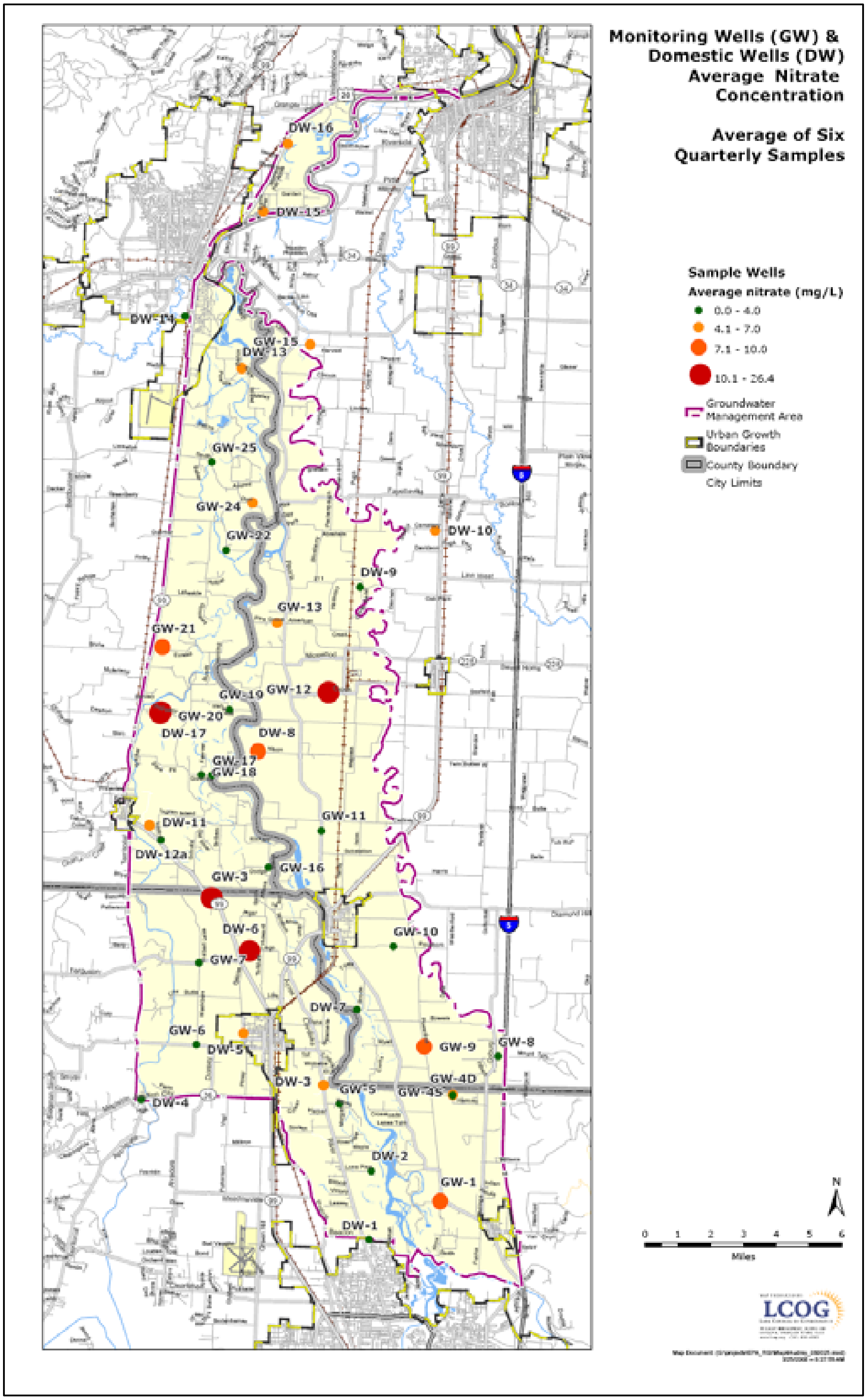
The most recent nitrate sampling conducted in the GWMA comes from the 41 monitoring and domestic wells that make up the baseline and long-term monitoring program. Starting in 2006, the DEQ started monitoring at 41 distinct Southern Willamette Valley locations. Samples from these locations are collected and analyzed quarterly (once every three months). The 41 monitoring points were determined on a quasi-random basis. The monitoring program uses a combination of 24 monitoring wells and 17 domestic wells. At the time of this report, six quarters of data have been collected. Results are shown on Map 4.

Map 3: Nitrate Values in the Southern Willamette Valley Study Area

Department of Environmental Quality 2000-2002 Studies



Map 4: Baseline and Long-term Monitoring Sites and Average of First Six Quarters of Nitrate Values In the Groundwater Management Area



Health Concerns
Public water systems must adhere to specific EPA drinking water standards for nitrate and other contaminants. The EPA drinking water standard for nitrate is 10 mg/L. Public water systems are required to monitor water quality on a regular basis, report their results, and apply treatment when necessary. Owners of individual household wells are not required to monitor regularly or adhere to drinking water standards.

Although methemoglobinemia is very rare, the EPA standard for public drinking water was set at 10 mg/L to protect the susceptible infant population. Until recently it was widely believed that nitrate was only a concern for households with infants. However, in the past ten years, toxicology and public health research has suggested that adults may develop other illnesses as a result of consuming high levels of nitrate.

Scientific studies have found that in addition to methemoglobinemia, nitrate may be associated with diabetes, various forms of cancer, and adverse reproductive outcomes such as miscarriages, congenital defects, and premature birth (Ward, 2005). A limited number of studies have also found links to thyroid dysfunction, impaired immune response, decreased liver function, and respiratory infection. However, at this time, research findings are not consistent and evidence is not conclusive.

Overview of Nitrate Sources
Nitrate is an inorganic compound that is a naturally occurring form of nitrogen and can be found at low levels in soil, air, and water. Low levels of nitrate (0-2 mg/L) are generally considered to be naturally occurring background concentrations (USGS 1996). Many of the public water systems in the GWMA report no nitrate in their routine monitoring, indicating that for at least some portions of the GWMA natural nitrate levels are closer to 0 mg/L (Nelson, 2008). When nitrate levels are measured above 1-2 mg/L it is usually an indication that human activities have contributed more nitrogen than the plants and soils can process. Human activities can increase nitrate levels and cause contamination of water supplies. Nitrate is highly soluble in water and mobile in the soil. This makes it relatively easy for nitrogen from a variety of point and non-point sources to leach through the soil and into the groundwater as nitrate.

The Clean Water Act defines the term 'point source' very broadly. A point source is any discernible, confined, and discrete conveyance of pollution, such as a pipe, ditch, channel, tunnel, or conduit from which pollutants are or may be discharged. Non-point sources of pollution can originate from relatively large areas, can be associated with particular land uses, and may consist of several pollutants. These features make it extremely difficult to trace all individual sources and identify which pollutant came from which specific source. In general, these pollutants can arise from activities that the everyday person has control over.

Potential point and non-point sources of nitrate pollution in the Southern Willamette Valley nitrogen budget study are found across land use sectors in the region and include:

- Fertilizers
- Animal waste
- Septic systems
- Large wastewater facilities

Fertilizers: The three fertilizer manufacturing and sales facilities in the GWMA are potential point sources for fertilizer contamination. A bulk fertilizer facility generally offers commercial quantities of various custom-blended fertilizers, herbicides, and pesticides for the agricultural community and other large fertilizer applications. There are no known recent releases of fertilizers from existing businesses in the GWMA. Previous manufacturing facilities at these same locations, however, may have had periodic releases to the ground that could still have residual contributions.

Non-point sources of nitrate can come from fertilizers used by homeowners, commercial and industrial businesses, farmers, and city and county parks. The actual use of a fertilizer is not necessarily a practice that will contribute nitrate to the groundwater. Rather, it is the amount, timing, frequency and type of fertilizer, as well as the timing of irrigation relative to the application of fertilizers that can cause nitrate to be flushed beyond the root zone. For purposes of this nitrogen/nitrate budget, an analysis of fertilizer use is focused on agricultural uses since 93 percent of the GWMA is in agricultural use.

Fertilizers come in many different forms such as granular, water soluble foliar applied, quick release and slow release. Slow-release fertilizers, as their classification implies, release nutrients at a slower rate throughout the season and are less likely to leach to the groundwater. Although they are initially more expensive, less frequent applications are required.

Regardless of the form of nitrogen applied, it is eventually converted in the soil to nitrate. Nitrate in soil water solution is readily taken up by actively growing plants. However, if plants are not actively growing or are unable to take up all available nitrate, nitrate dissolved in water percolates through the soil below the root zone into groundwater. Over-watering practices combined with over-fertilizing can exacerbate the problem and be a cause for groundwater impacts.

Animal Waste: Animal waste has the potential to contribute nitrate to groundwater if not managed properly. All animal waste contains nitrogen although the amount is largely dependent on animal species and diet. Nitrate contributions from animal waste can come from either point or non-point sources. By law confined animal feeding operations (CAFOs), are considered point sources. These facilities are often permitted and hold relatively large numbers of animals including chickens, swine, and cattle. Small acreage rural residential lots with fewer animals are considered non-point sources and can also contribute to nitrate loading in the groundwater. Even the family dog can contribute a small amount of nitrate. Like fertilizer, animal waste does not have to be a source of nitrate to groundwater. Animal waste on small acreage lots can often be managed by covering manure during the rainy season and then using the waste as compost during the growing season. Larger permitted facilities address nitrate leaching by implementing Animal Waste Management Plans. For purposes of this nitrogen/nitrate budget, data from CAFOs is integrated into the model. The Animal Waste Management Plans provide the data for the animal waste portion of the budget model.

Septic Systems: Septic systems can be a non-point source of nitrate contamination. Standard septic systems used at individual households release water containing nitrate from the drainfield even if they are functioning properly. While values can vary depending on the system and household load, nitrate in effluent percolating through the soil one to three feet below the drainfield trench can be as high as 40 mg/L (Anderson and Gustafson, 2004). A large number of septic systems in close proximity may introduce more nitrate than can be diluted by the underlying groundwater, and thus contribute to increased groundwater nitrate levels. There are alternative treatment technology wastewater systems that can substantially reduce nitrate levels, some of which can nearly eliminate nitrate contributions to the groundwater. While more effective than standard systems in treating nitrate, they are also more expensive.

Wastewater Treatment Facilities: Potential point sources of nitrate include permitted wastewater treatment facilities. With the exception of Coburg, all of the cities within the GWMA have their own permitted wastewater treatment system. In addition, many of the commercial and industrial facilities located within Coburg or outside of the other cities have large permitted wastewater treatment systems. These systems include relatively large onsite treatment that uses a drainfield (similar to an individual septic system only at a larger scale), or treatment lagoons followed by land applications. The water usage in the commercial/industrial facilities is different than a typical household, because water is primarily used for kitchen and restroom purposes and rarely includes shower and laundry facilities. Total nitrogen levels in the effluent are typically higher in these systems than for household septic systems because the waste is more concentrated. Treatment lagoons have the potential for nitrate contributions if the lagoon is not sealed properly. Certain organic waste materials such as processed municipal sewage sludge, reclaimed water, food processing wastes, and other similar materials may be recycled and land applied under DEQ regulations and permit. Some of these wastes may be high in nitrogen.

Section 2
Methodology

Introduction

This section describes the methodology used in the development of the nitrogen/nitrate budget. This includes a description of the data and how it is used to help draw a clearer picture of land use and its relationship to nitrogen/nitrate contributions in the Southern Willamette Valley GWMA. The compilation of scientific natural resource and land use planning information related to sources of high groundwater nitrate concentrations help answer the core project question: "What land uses, behaviors, and soil characteristics are contributing to elevated concentrations of nitrate in the groundwater of the Southern Willamette Valley?" Answering this question allows prioritization of management activities and interventions yielding the highest return on investment in decreasing anthropogenic nitrogen inputs.

Nitrogen/Nitrate Budget Model

Nitrate inputs to groundwater are assessed through a simple input model, whereby estimates are made for the spatially explicit quantity or rate of nitrogen addition to the land surface. The model was developed on the Environmental Systems Research Institute's ArcGIS 9.1 platform using the data inputs described subsequently. Figure 1 provides a conceptual framework for the development of the budget and the processes and relationships between the data inputs. A summary of all data inputs and reference data sets is provided in Table 2.

Figure 1: Nitrogen/Nitrate Budget Model Process Diagram

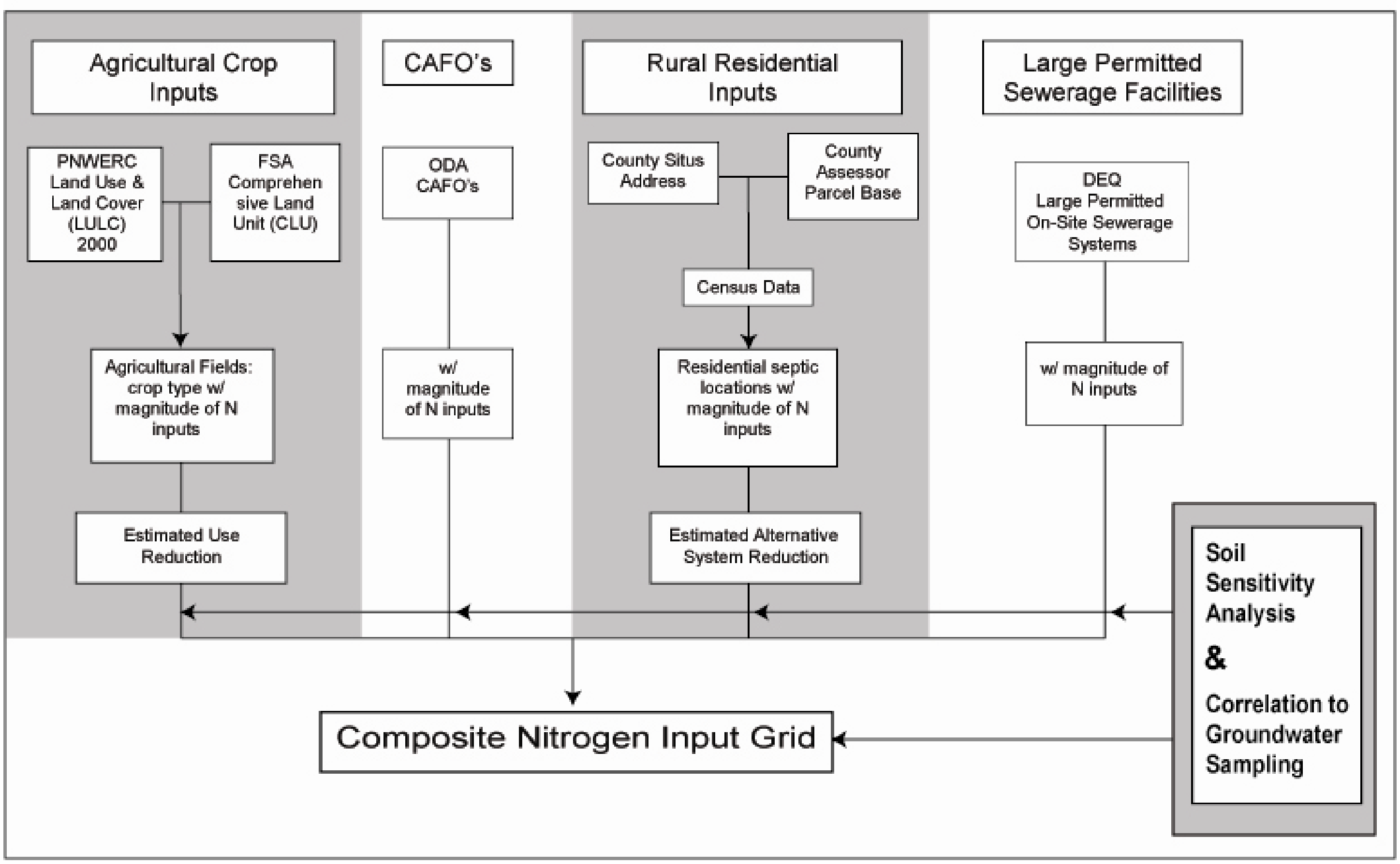


Table 2. Model Input and Reference Datasets

Data Set	Source	Date	Application (use)	Acceptance Criteria
Model Input Data				
Address points, Parcel polygons	Benton County, Lane County, Linn Coutny	July 2006	Location of households with septic systems; magnitude of input.	Accurate location, attributes on human occupancy.
2000 Census Data	US Census	2000	Estimates of dwelling occupancy.	NA
Confined Animal Feeding Operations (CAFO's)	Department of Agriculture	July 2006	Location and relative quantity of large animal waste inputs.	Accurate location, attributes relating magnitude of inputs.
Large Permitted On Site Sewerage Systems	Department of Environmental Quality	2005	Non-municipal and municipal potential sources of nitrogen/nitrate inputs to groundwater.	Accurate location and attribution of magnitude of inputs.
Comprehensive Land Unit (CLU)	Farm Service Agency	2005	Polygonal delineation of agricultural fields; to be used in combination with PNWERC LULC 2000	Accurate agricultural field delineation from recognized source to be compared to aerials and LULC 2000.
Land Use & Land Cover (LULC) 2000	Pacific Northwest Ecosystem Research Consortium (PNWERC-EPA).	2003	Location, extent, and type of commercial/industrial agricultural activities.	Relative location, extent, and type of agricultural activities.
Soils	Natural Resource Conservation Service	2006	Septic performance criteria; soil sensitivity analysis	Recognized national data set with attributes relating to septic performance in relation to soil characteristics.
N03_DEQ	Department of Environmental Quality	2008	6 quarters of sampling of 40 monitoring and domestic wells with water source location and magnitude of nitrate content.	Accurate location and recorded level of nitrate content.
Model Reference Data				
Data Set	**Source**	**Date**	**Application (use)**	**Acceptance Criteria**
Tax Lots	Benton County, Lane County, Linn County	July 2006	Supplemental residential attributes to address points.	Accurate location, attributes on human occupancy.
Hydro-Geologic Units	Department of Environmental Quality	July 2006	Hydro-geologic context	Accurate delineation of areas with differing hydro-geologic characteristics.
N03_DEQ	Department of Environmental Quality	2006	Three sampling events of domestic water source location and magnitude of nitrate content.	Accurate location and recorded level of nitrate content.
NO3 - USGS	US Geological Survey	1993	Monitoring site locations and magnitude of nitrate content.	Accurate location and recorded level of nitrate content.
NO3 – Public Water Systems	Department of Human Services	2006	Public water source location and magnitude of nitrate content	Accurate location and recorded level of nitrate content.
2005 1 meter and 0.5 meter Digital Ortho Quads	Oregon Geospatial Enterprise office (ODEO)/USDA	2005	Visual/spatial reference for other data sets.	Spatially accurate imagery.

Source Water Protection Areas	Department of Human Services (*via* ODEO)	2004-2006	Drinking Water Program Source Water Assessment results for community and non-transient non-community public water systems for public water systems that were active in June 1999 (when Oregon's Source Water Assessment Plan was approved by EPA)..	Accurate delineation of areas as Source Water Protection Areas.
National Land Cover Data Set	USGS	2000	Gross land cover Data used in national nitrate studies	NA
Probability of Nitrate Contamination of Groundwaters in the US	USGS	2002	Estimation of probability of contamination for comparative purposes.	NA

Data Inputs

This project relies on secondary information from local governments (Linn, Benton, and Lane Counties as well as many municipalities), state agencies (DEQ, ODA, DHS, OSU Extension, etc.), and other sources (USGS, NRCS) providing *Best Available Data*. Data quality acceptance criteria for input data vary by input and are related in Table 2. The data are used to locate and quantify sources of nitrogen/nitrate inputs into groundwater and analyze the return on investment of programmatic elements (e.g. best management practices) to reduce inputs from these sources. Data also provides an assessment of geologic and hydrologic context for the areas studied, and points of drinking water withdrawal from the aquifer. As a groundwater flow model is not employed, relative spatial accuracy of data can be relatively coarse, and is generally exceeded by the data sets. Magnitude of nitrogen/nitrate inputs may be contained in the source data or may be estimated through data attributes and ancillary documentation of input magnitude (e.g. relative crop fertilizer applications linked to known crop location and extent). Data inputs to the model are estimations of nitrogen loading to the ground from four main sources: agricultural crops, CAFO's, rural residential septic systems, and large permitted on site sewerage systems. What follows is a discussion of the potential sources of nitrogen/nitrate contribution to the land surface and/or to groundwater and inputs used within the model.

Inputs of Potential Agricultural Sources of Nitrogen/Nitrate

For purposes of the budget model, potential agricultural sources of nitrate in the groundwater include crop fertilization and CAFOs.

Crop Fertilizer

About 91 percent of the GWMA includes agricultural crop lands which are fertilized to varying degrees depending on the crop type and management practices. Many studies show that where intensive agricultural production occurs with high nitrogen inputs and irrigation practices, groundwater nitrate levels can be expected to approach and exceed the 10 mg/L drinking water standard. Studies measuring nitrate loss to groundwater from vegetable fields, mint crops, and even organic growing operations found nitrate levels exceeding 10 mg/L below the root zone (Feaga and Selker, 2004). Both timing and amount of fertilizer are often a factor in nitrogen loss. OSU Extension Service found that applying nitrogen late in the season or applying amounts above 225 lbs/acre (mint crop rate), resulted in excess soil nitrogen remaining after harvest. In one study of grass seed production, Mark Mellbye (2002) found increased residual soil nitrate levels at rates of 180 lbs/acre on annual ryegrass.

It is an art of estimation to ascribe nitrogen application rates to geographic information system (GIS) polygons of crop fields. Several factors contribute to the difficulty of estimating these rates from field to field, including specifics of identifying crop type, rotation practices, crop fertilization practices of individual farm operators, and the variability of crop fertilization practices based on annual variations in weather patterns.

Land use and cover classifications developed by the Pacific Northwest Ecosystem Research Consortium (PNWERC) for the year 2000 provides crop field type identification in the form of an ESRI GRID file. This ESRI GRID file is a data structure representing a grid of 30 meter square pixels (about .22 acres for each pixel). Due to the cellular variability in land cover classification, Farm Service Agency Comprehensive Land Unit (CLU) polygons help define field boundaries. These polygons are populated with the majority cell value found within the field. ODA and DEQ staff reviewed, refined, and updated the data using aerial photography and some field verification. Aerial photo analysis and field verification noted changes in crop distribution and areas where concentrations of crop types changed, but overall very little net change occurred. The PNWERC data describes the landscape in approximately 100 categories, fourteen describing agriculture (Map 5). While some of these descriptions are crop-type specific (sugar beet seed), others are collections of a variety of similar crops (grass seed), and others a crop rotation practice (irrigated annual rotation).

Crop nitrogen fertilizer inputs are generated and analyzed in three different ways:

1. The total amount of fertilizer applied using OSU Extension Service rates
2. An estimate of the amount of nitrogen removed using a “poor utilization” scenario
3. An estimate of the amount of nitrogen removed using a “good utilization” scenario

Crop management guides published by the OSU Extension Service provide nitrogen fertilizer application rates for specific crop types. Some of these application rates have been adjusted based on expert knowledge of ODA personnel regarding the amounts typically being applied by farmers in the area. As the two sets of categories, field crop type and crop nitrogen application rate, do not have a direct relationship, a crosswalk relates the two classifications, as shown in Table 3. Mean annual rates by crop type are averaged across field classifications to describe a range of annual application rates per field, and are shown in Figure 2, showing low, median, and high application rates. The rates are weighted according to the percentages of the crops that comprise each field classification.

Map 5: Land Use and Land Cover

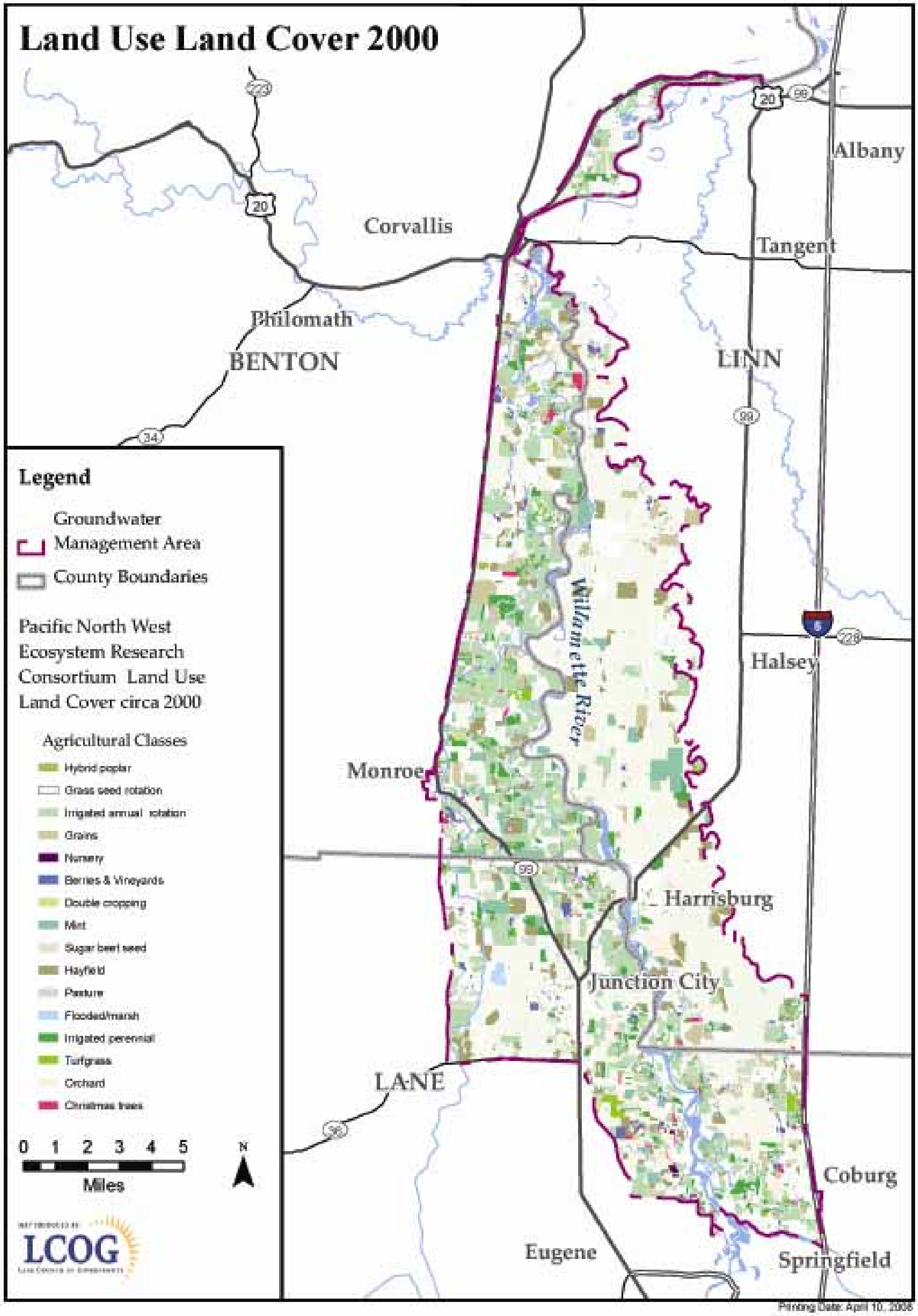
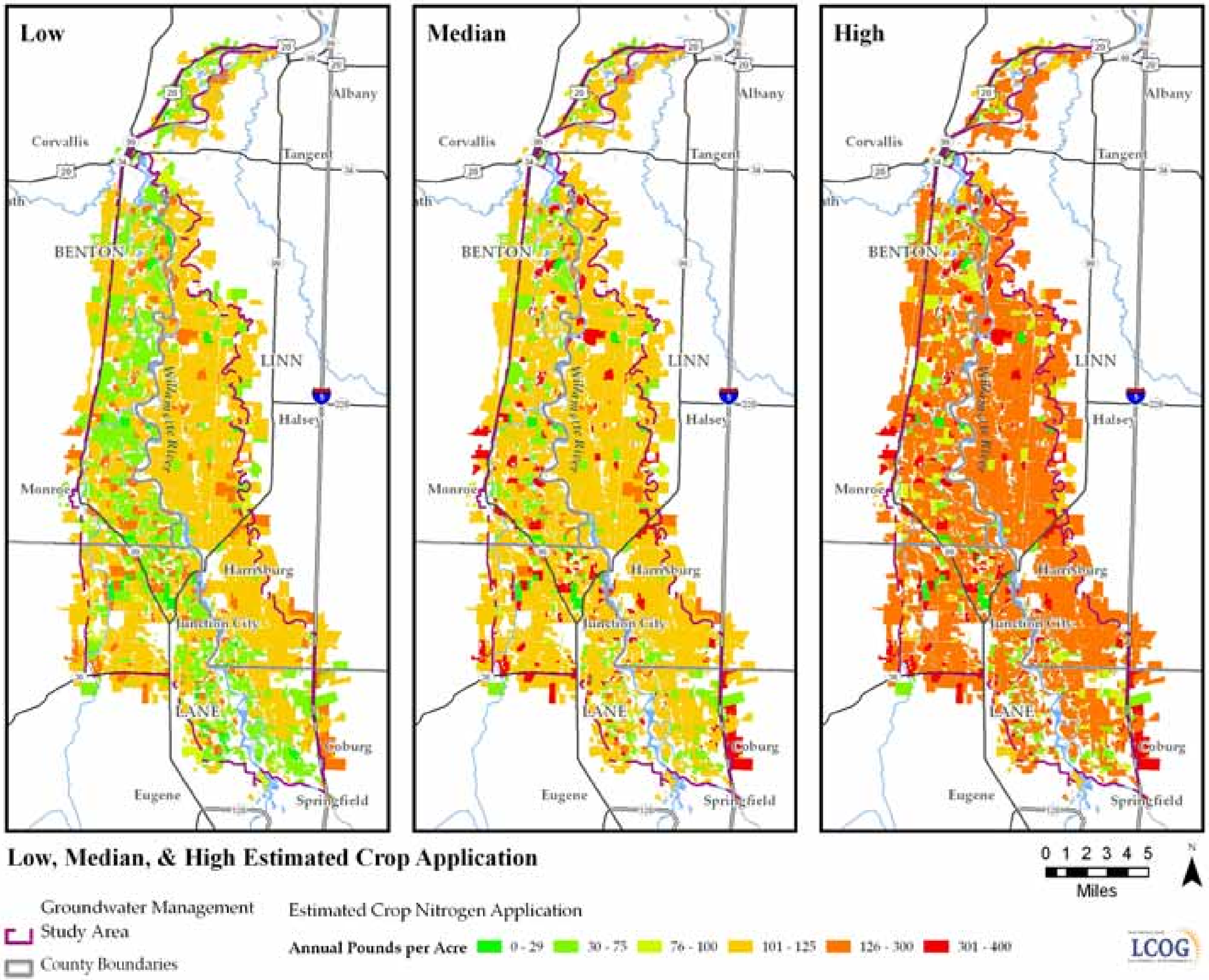


Table 3. Fertilizer Application Crosswalk

Field Classification (crop type)	Low Weighted lbs/acre	Median Weighted lbs/acre	High Weighted lbs/acre
Alfalfa	30	55	80
Beans/Peas	50	70	115
Berries & Vineyards (Caneberries, Hops)	65	92	115
Christmas Trees	75	110	150
Clover (Crimson, Vetch, Field Peas, Spring Clover)	0	0	0
Corn	87	109	131
Double Cropping	50	80	125
Grains (Spring grains, Winter wheat)	33	62	92
Grass Seed Rotation (Annual Ryegrass, bentgrass seed, Fine Fescue seed, Orchardgrass seed, Perennial ryegrass for seed, Tall Fescue for seed)	101	116	131
Hayfield	300	350	400
Irrigated Annual Rotation (vine crops)	60	105	150
Irrigated Perennial (Strawberries)	40	55	70
Mint	200	200	200
Orchard (Apple, Hazelnuts, Pears)	22	29	41
Pasture	90	105	120
Sugar Beet Seed	130	150	170
Turfgrass	45	68	90

Figure 2: Low, Median, and High Crop Fertilizer Application Rates



For the purposes of this report it is assumed that any nitrate left below the root zone after the growing season is available to leach to groundwater. The amount of nitrate that is left below the root zone is dependent on many factors. These factors are defined as the "utilization" of nitrogen from fertilizer applied. This utilization factor includes such things as volatilization of nitrogen to the atmosphere, denitrification by microorganisms in the soil, crop uptake ratios, type of fertilizer applied, timing of application, soil physical and chemical conditions, amount and method of irrigation water applied, and weather at the time of application and immediately following. An analysis of available literature (Brandi-Dohrn, 1997), (Feaga, Dick, Louie, and Selker, 2004), (Feaga and Selker, 2004), (Hermanson, Pan, Perillo, Stevens, and Stockle, 2000), (Sullivan, Hart, and Christensen, 1999) and data from the ODA generate estimates for both poor utilization and good utilization values for nitrogen in applied fertilizer. These utilization values are displayed in Table 4. Poor utilization and good utilization take into account all factors that may influence how nitrogen moves through and is lost from soil to both the atmosphere and the groundwater. A large portion of efficient utilization is dependent on how a particular operation is managing its crops — highlighting the importance of implementing best management practices related to irrigation and fertilization.

Whether or not a particular crop in a particular year has good utilization or poor utilization includes, but is not limited to, the following factors:

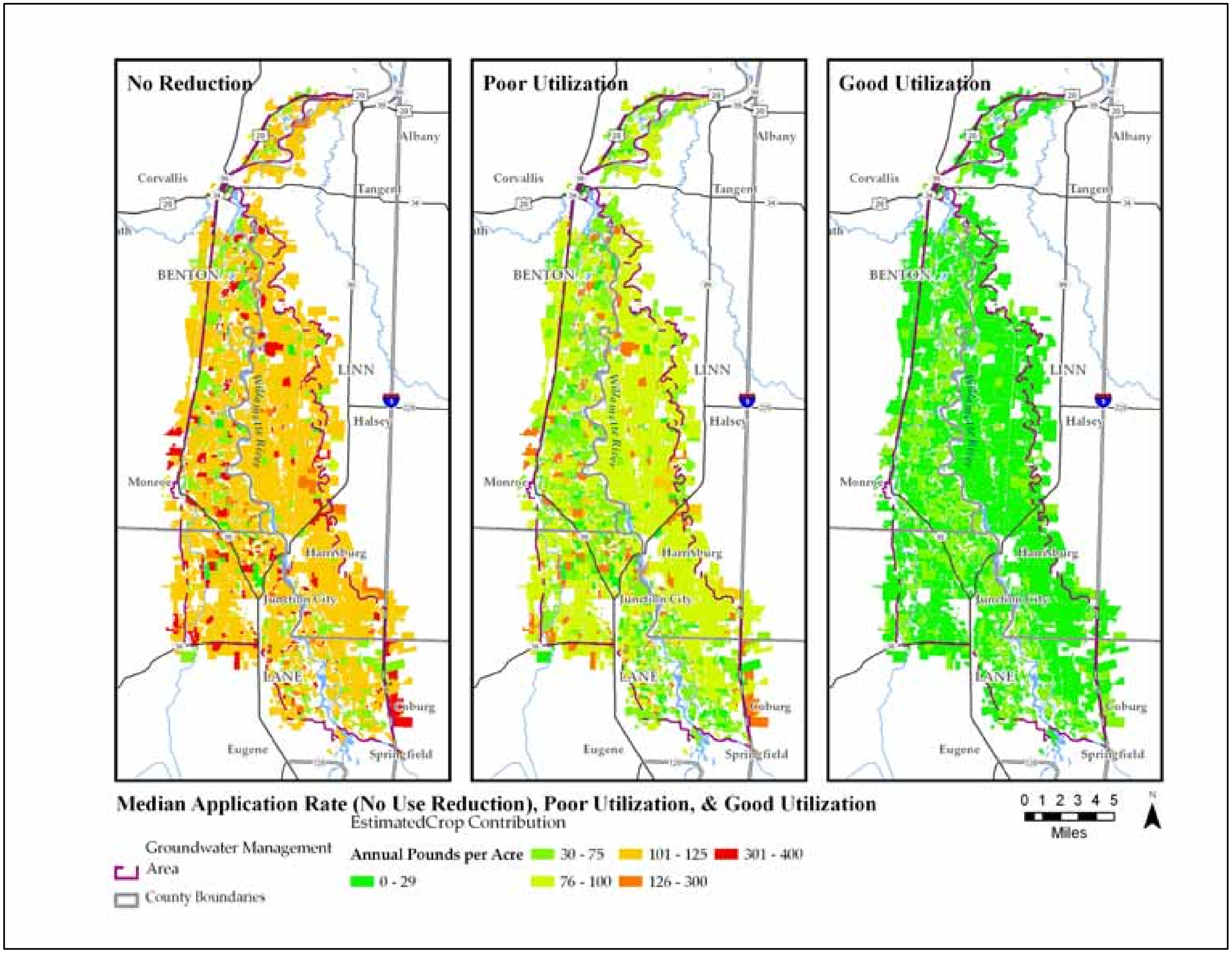
- Application of fertilizer at a time when plants are actively growing or about to enter the active growing season;
- Planning for predicted precipitation;
- In the absence of precipitation, applying the proper amount of irrigation evenly after fertilizer application;
- Taking into consideration specific application rates based on soil type;
- Considering cropping history and amount of nutrients left in the soil from previous practices;
- Accounting for the level of nutrients already in the irrigation water;
- The sensitivity of the soil underlying the crop;
- The permeability and/or denitrification potential of the soil; and
- The depth to the aquifer (or rather - the thickness of the unsaturated zone).

Areas of poor utilization or good utilization are not specifically identified rather scenarios are laid out with those assumptions for the entire GWMA. A contrast of total nitrogen applied, uptake using good utilization, and uptake using poor utilization is displayed in Figure 3. This figure represents three nitrogen contribution scenarios taking into consideration the different crop types (Map 5), soil characteristics (Maps 12, 13, 14), and management practices (described above). The pounds of nitrogen contribution per acre shown in Figure 3 good and bad utilization scenarios represent an estimate of the pounds of nitrogen "lost" - likely contributed to groundwater.

Table 4: Crop Management Practice Reduction Ratios

Field Classification	Percent of Crop Lands	Poor Utilization (low) Uptake Ratio	Good Utilization (high) Uptake Ratio
Alfalfa	.29%	15%	60%
Beans/peas	.19%	10%	60%
Berries & vineyards	1.29%	30%	70%
Christmas trees	.34%	50%	80%
Clover	1.13%	15%	60%
Corn	.13%	30%	65%
Double cropping	.10%	30%	70%
Grains	4.26%	10%	80%
Grass seed rotation	56.60%	40%	85%
Hayfield	6.59%	40%	85%
Irrigated annual rotation	12.55%	50%	50%
Irrigated perennial	3.18%	60%	90%
Mint	2.52%	40%	65%
Orchard	.96%	60%	90%
Pasture	3.93%	40%	85%
Sugar beet seed	.69%	50%	70%
Turfgrass	.90%	40%	85%

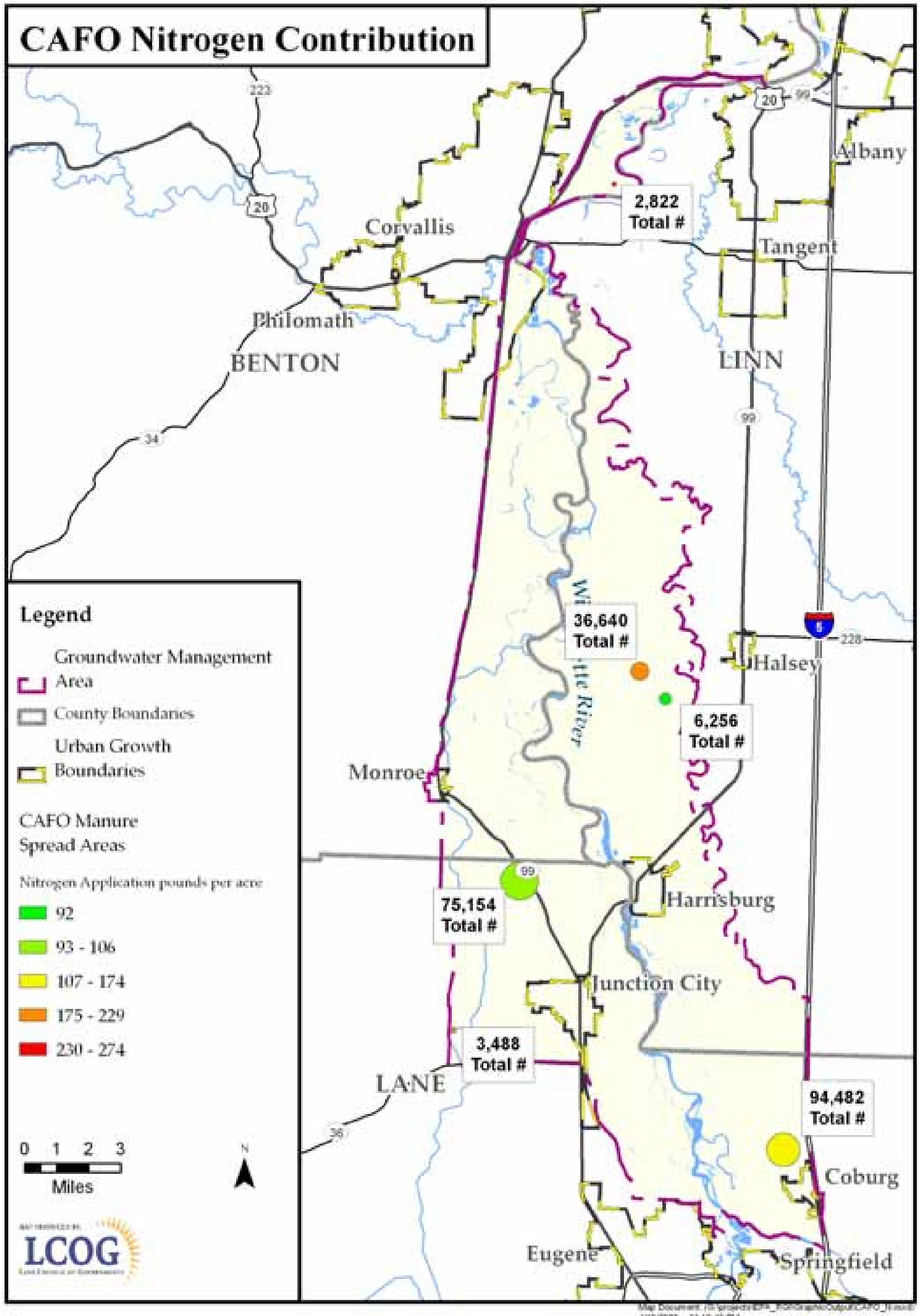
Figure 3. No Reduction, Poor Utilization, and Good Utilization Nitrogen Contributions by Crop Type (Pounds per acre potentially lost to groundwater)



Confined Animal Feeding Operations (CAFOs)
About two percent of the GWMA includes permitted CAFOs. There are currently eight CAFOs in the GWMA permitted by the CAFO Program of the ODA. These include dairy, beef, hog, and chicken facilities. Operations that require a permit are those where the animals are confined for at least 120 days and have a waste treatment works or have the potential to discharge or are discharging wastewater to surface or groundwater. These facilities hold annual operating permits, must meet state requirements, and are inspected once a year to ensure compliance. The potential for nitrate from these facilities is predominantly associated with manure waste leaching into groundwater.

ODA approved Animal Waste Management Plans for six of the CAFOs within the GWMA provide site-specific locations and quantities of nitrogen production and distribution. Locations and attributes as related in the Animal Waste Management Plans compared to aerial photographs, Comprehensive Land Unit polygons, and tax lot records determine the disposition of the waste (i.e. in sewage lagoons, field spread, or exported off site). CAFO locations and magnitude of nitrogen inputs are related in Map 6, Estimated CAFO Nitrogen Contributions. Estimated nitrogen inputs do not include a reduction value depending on the crop type and utilization.

Map 6: Estimated CAFO Nitrogen Contribution



Inputs From Potential Residential Sources of Nitrogen/Nitrate

The principle residential structures that may contribute nitrate to groundwater are septic systems. There are an estimated 2,745 septic systems serving rural residential households in the GWMA.

As was noted in the introductory section, even a properly functioning standard septic system may contribute more than 40 mg/L of nitrate in the effluent leaving the septic tank drainfield trenches. All of the rural residential tax lots with houses as well as a few small commercial facilities within the GWMA, have a septic system for treating wastewater. Currently, the City of Coburg also includes nearly a thousand residents residing on about 410 lots, that all rely on septic systems rather than a public treatment facility. A large number of septic systems in close proximity may introduce more nitrate than can be adequately diluted by the underlying groundwater, and thus contribute to increased groundwater nitrate levels. Some areas of the GWMA have dense clusters of rural homes, especially near the cities of Coburg and Junction City.

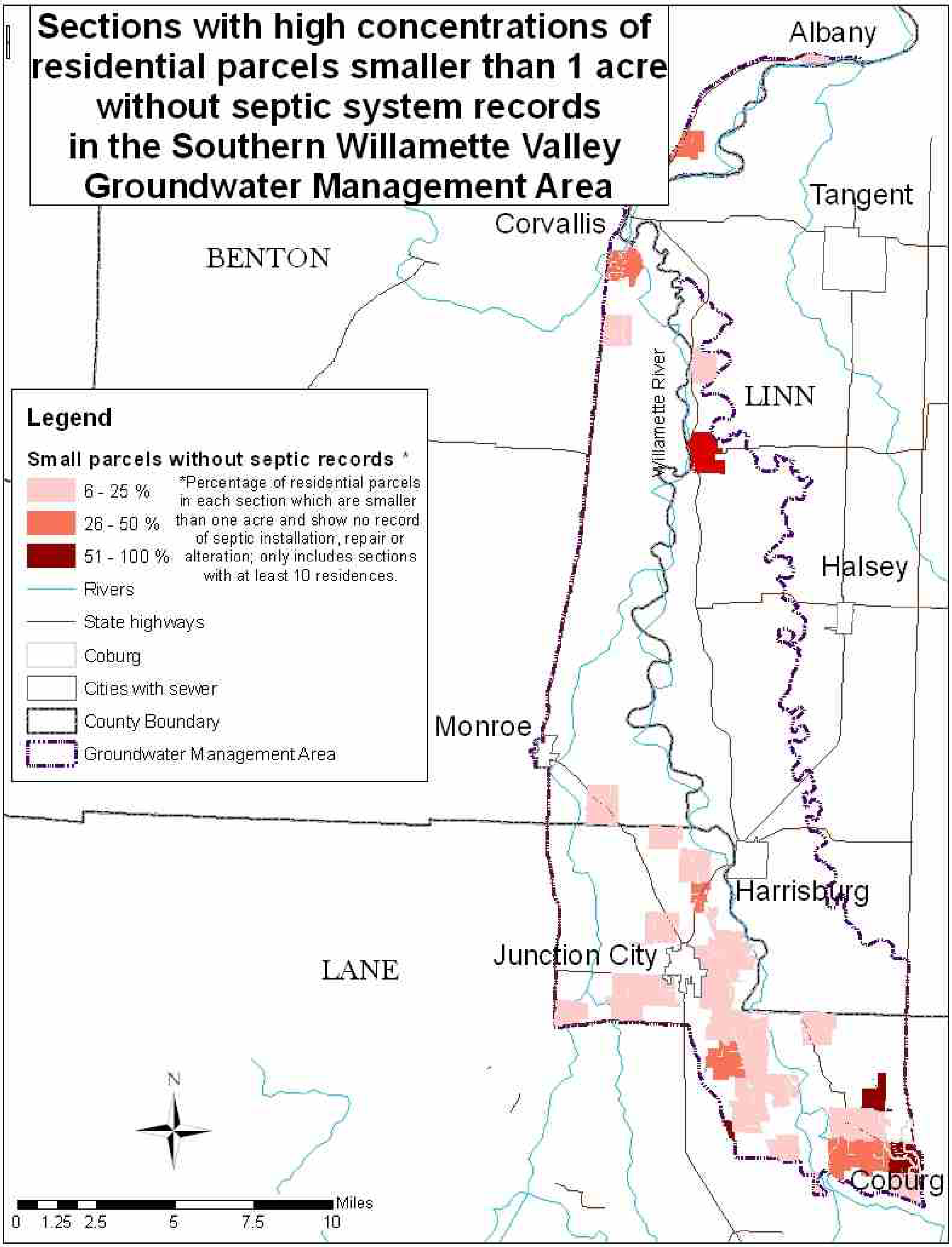
As shown in Table 5, the majority (68 percent) of the estimated residential septic systems in the GWMA do not have a septic system record. Systems without a record have not been installed, repaired, or altered since 1974, when significant changes were made to DEQ's onsite wastewater treatment rules. Older systems may have been installed much closer to wells and, since older wells were often driven or hand-dug, this may create a scenario where nitrate can move directly to the aquifer without being filtered by the soil. The 1974 rules refined and strengthened the standards related to soil requirements for adequate wastewater treatment. Older systems installed in soils without proper drainage may allow sewage to flow overland in the winter and reach the aquifer. Map 7 displays the areas in the GWMA where there are relatively high concentrations of small residential parcels without septic system records.

Table 5: Estimated Septic Systems With and Without a Septic Permit in the GWMA

Septic Record Summary	Lane County	Benton County	Linn County	Total
Residential parcels With dwelling unit with septic system record †	592	128	153	873
Residential parcels with dwelling unit without an identified septic permit	1,112	481	279	1,872
Total Residential Parcels *	1,704	609	432	2,745

Source: Benton, Linn, and Lane County Environmental Health Records
† defined as permits issued since 1974 for new installations, repairs or alterations
***** defined as non-vacant residential lots outside of city limits, as well as lots within Coburg city limits

Map 7: One Acre or Smaller Parcels without Septic Records



Rural residential addresses are identified from combined address point and tax lot data from the three counties intersecting the study area. Selection criteria differed from county to county to accommodate differences in data base construction. City limits are used as the extent of municipal sewerage systems, with the exception of Coburg, which still relies on septic systems, although the city is in the process of developing a municipal wastewater treatment system.

A calculation of nitrogen loading from residential dwellings is based on an estimation of dwelling occupancy (persons per dwelling) and an estimation of human daily nitrogen production. Human daily nitrogen production is estimated at 60 mg/L nitrogen (Sikora et al, 1976). Dwelling occupancy is determined by comparing address data to 2000 census data at the tract level for persons per household and vacancy rates. Nitrogen produced per household per day is calculated at:

280 liters/day/person * 60 mg/L nitrogen * persons per household

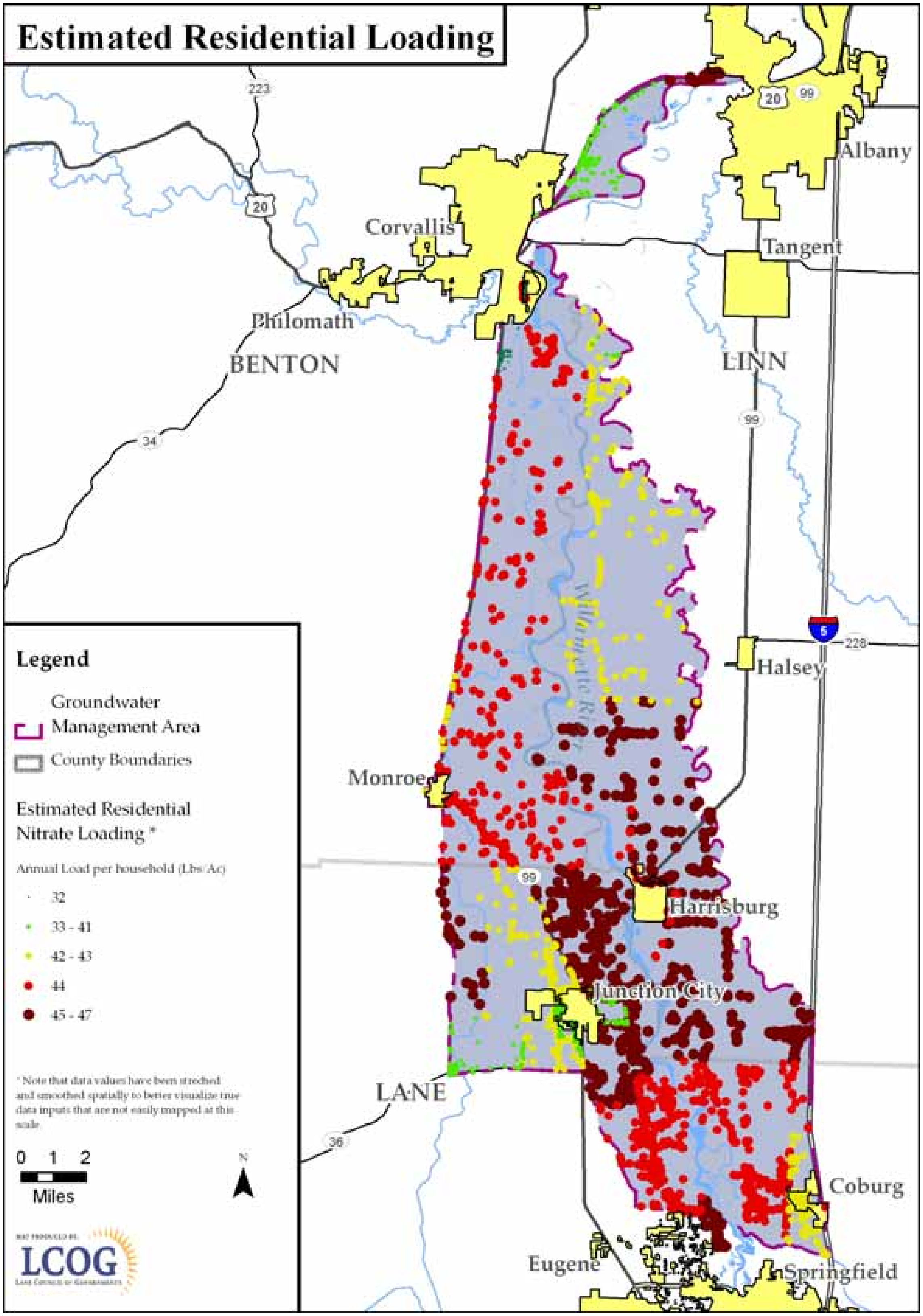
(Sikora et al, 1976).

This data is displayed in Map 8, Estimated Septic System Contributions. As can be seen in Map 8, there are fairly dense clusterings of rural homes near all of the cities and along major roadways.

A change in land use practices could gain reductions in nitrogen/nitrate contributions from septic systems if a portion of those systems were replaced with alternative systems. Two examples are given for comparative purposes:

1. The amount of nitrogen contributions reduced when the City of Coburg builds a centralized wastewater treatment facility and decommissions about 410 septic systems; and
2. The amount of nitrogen contributions reduced if 30 percent of systems are replaced with an alternative system such as Nitrex. For example, the Nitrex system is estimated to reduce nitrate contributions by 97 percent as compared to standard systems.

Map 8: Estimated Septic System Contributions



Inputs From Potential Municipal, Industrial, and Commercial Nitrogen/Nitrate Sources

For purposes of this nitrogen budget, the primary sources of nitrogen/nitrate for municipal, industrial, and commercial facilities relates to wastewater treatment. These include:

- Individual Large On-site Systems/Treatment Facilities
- Public Wastewater Treatment Lagoons
- Land Application of Reclaimed Water, Biosolids and Similar Wastes

Commercial, industrial and municipal treatment facilities within the City of Coburg or outside other urban areas must manage their wastewater on an individual basis. This is usually done through the use of a large-scale onsite wastewater treatment system, wastewater treatment lagoons and/or some sort of land application. All of these facilities hold permits issued through the DEQ. Map 9 shows the locations of the large permitted treatment facilities in the GWMA. The table below displays the type of water quality permits, the total number of permits present in the GWMA, and the number of renewals necessary before December 2007.

Table 6: DEQ Water Quality Permits in the GWMA

Type of Water Quality Permit	Total Number	Renewals before 12/2007
Large Onsite	5	2
Public Wastewater Treatment Lagoons	4	2
Other Permits that allow discharges to groundwater	4	3

(Source: DEQ, 2005)

Large On-site Systems and Wastewater Treatment Facilities

There are at least four large onsite systems in the Coburg area in the southeast corner of the GWMA. There is at least one other DEQ-permitted individual large onsite system in the GWMA. These facilities receive individual permits from the DEQ and wastewater monitored at the edge of the facility must meet the EPA drinking water standard for nitrate (10 mg/L). Unless using advanced technology, these systems are typically contributing a much higher than 10 mg/L level of nitrogen-nitrate to the drainfield, but the mg/L level can be greatly reduced once it is diluted in the groundwater prior to entering the compliance zone.

Wastewater Treatment Lagoons

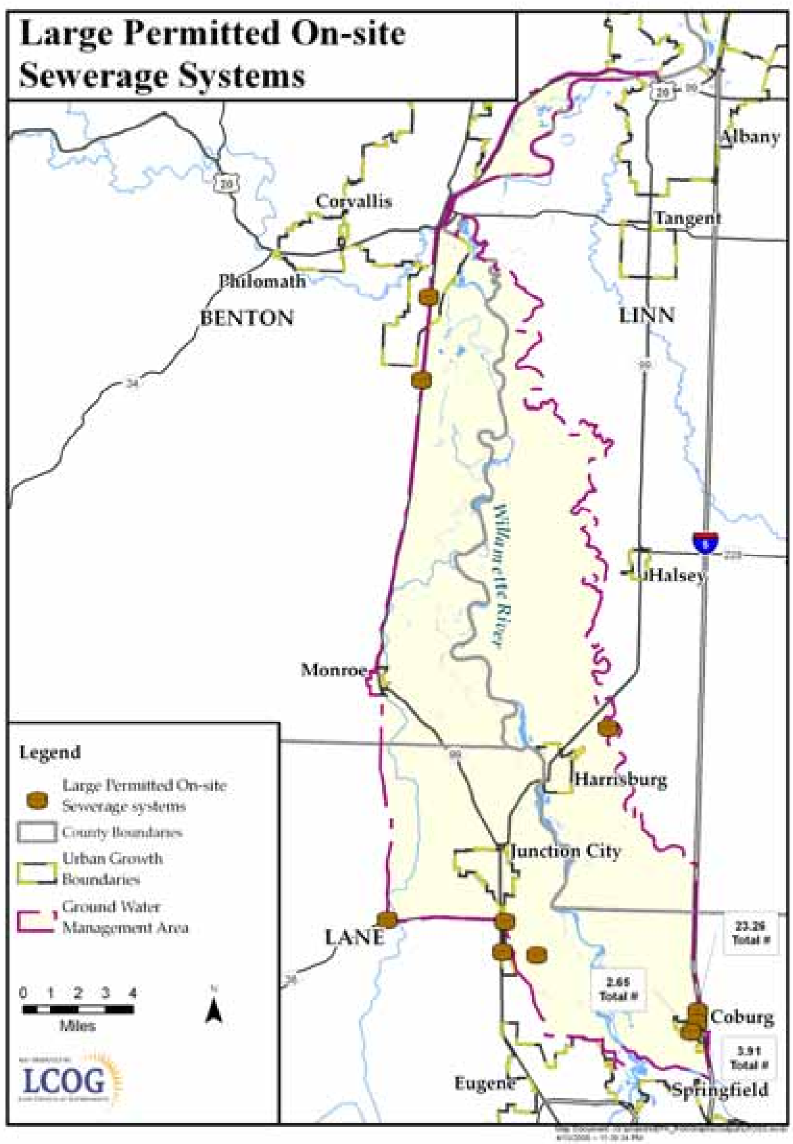
This category includes those wastewater treatment systems that have the potential to impact groundwater from the lagoon portion of their treatment facilities. Public treatment facilities may be located inside or outside of urban areas. These facilities are permitted by the DEQ, but there is still potential for contamination if the lagoon base or liner is not adequately sealed.

There are four public wastewater treatment lagoon systems in the GWMA including facilities for Harrisburg, Junction City, Monroe, and a Springfield public school. There is also one private industrial facility that uses its own wastewater lagoon for employee and kitchen wastes. Although not actually inside the GWMA, the Eugene/Springfield Water Pollution Control Facility and the Eugene/Springfield Regional Biosolids Management Facility are directly adjacent to the southwest border of the GWMA.

Land Application of Reclaimed Water, Biosolids, and Other Materials
Biosolids (processed municipal sewage sludge), reclaimed water (water that has gone through an initial treatment), and other similar materials can be applied to land under DEQ regulations and permit. The waste is usually applied to crops and/or poplar tree farms so that the plants take up the nutrients rather than allowing the nitrogen to leach into the ground. Land application of these wastes can help maintain productive soils and stimulate plant growth while reducing the need to add other fertilizers. The DEQ is currently reviewing the inventory of land application sites in the Southern Willamette Valley.

Available data for these systems are limited. Data includes only three of the systems discharges from January, 2007 discharge monitoring reports as shown in Map 9.

Map 9: Large Permitted On-Site Sewerage Systems



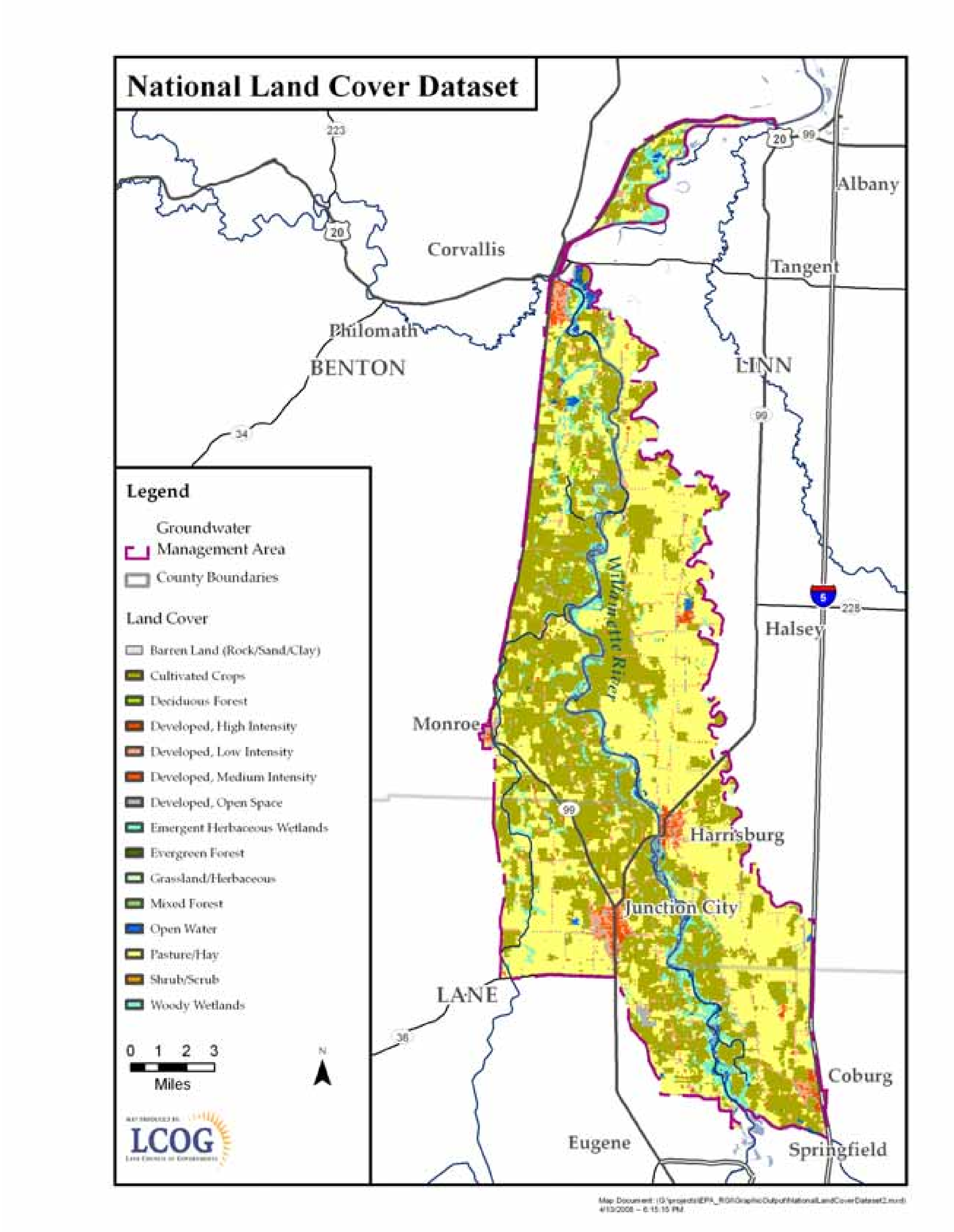
Soil Characteristics
Inputs as have been discussed include the total amount of nitrogen contributed by the four primary land use sectors and factors within those sectors: Agricultural crops, CAFOs, rural residential septic systems, and large permitted wastewater treatment facilities. While the total amount of nitrogen applied provides a sense of where the primary sources of nitrate might be coming from, other factors influence the likelihood of applied nitrogen becoming a problem as nitrate in groundwater. Natural factors influencing risk of nitrate contamination include soil denitrification potential, soil sensitivity to nitrate leaching, and soil permeability. While these natural factors are key pieces of information in identifying priority areas they are difficult if not impossible to quantify in terms of modeling their influence. Following is a discussion of the natural factors that have the ability to influence nitrate contamination.

The USGS National Water Quality Assessment Program monitors water quality in 51 major river basins representing one-half the land area of the continental US. Data developed at this level, while coarse at the regional level, is a useful reference. Data developed by the USGS and other agencies has been used to develop a predictive assessment model on a national scale. The model uses best available nation-wide data sets including estimates of county-level fertilizer applications and the National Land Cover Data Set (see Map 10)(Nolan & Hitt 2001, 2003, 2006, Nolan, Rudy et al 1997). This model uses a limited set of explanatory variables to predict the likelihood or risk of nitrate concentrations in groundwater exceeding 4 mg/L. The results for the GWMA are shown on Map 11. The variables used in determining the probability of nitrate contamination of recently recharged groundwaters in the Conterminous United States include:
Nitrogen Input:
- Nitrogen Fertilizer applications by county
- Percentage of Agricultural land Use
- 1990 Population Density

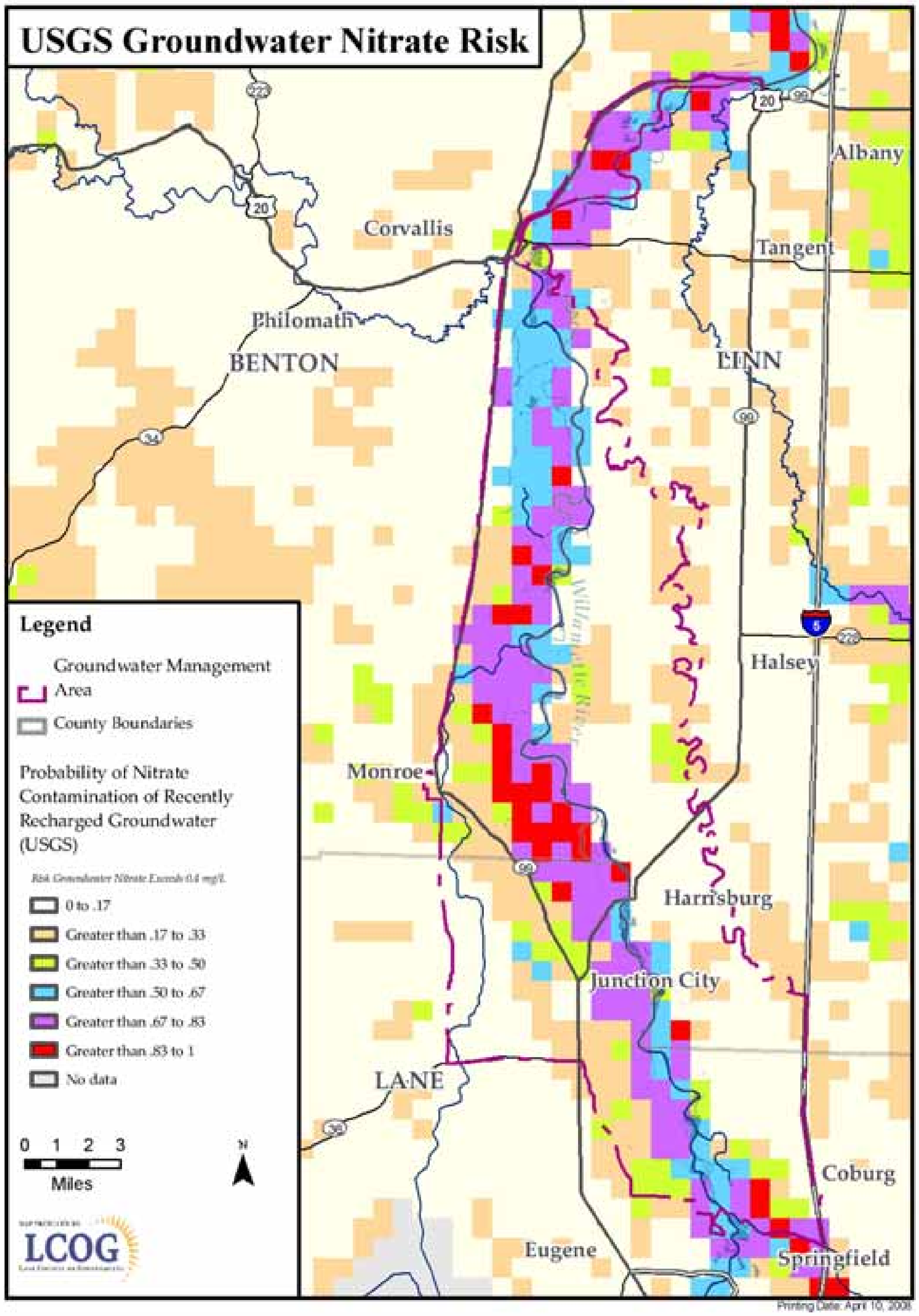
Aquifer susceptibility
- Percentage of well drained soils
- Depth to seasonally high water table
- Presence or absence of sand and gravel aquifers.

Soils data can potentially be used to indicate the influence in nitrate loading on the spatial scale of the GWMA. Correspondence with Steve Campbell of the NRCS, Kerie Hitt and Chris Barnes of the USGS, and Roy Haggerty, John Selker, and Dan Sullivan of OSU and OSU Extension Service demonstrate a range of opinions on the viability of estimating loading reductions based on soil type or other related features of the landscape. Although there are likely factors in the NRCS soils data base that may be useful in modeling the affect of soil denitrification potential (permeability, water column/soil moisture, and temperature), specific loading reductions based on these criteria have not been assigned.

Map 10: National Land Cover



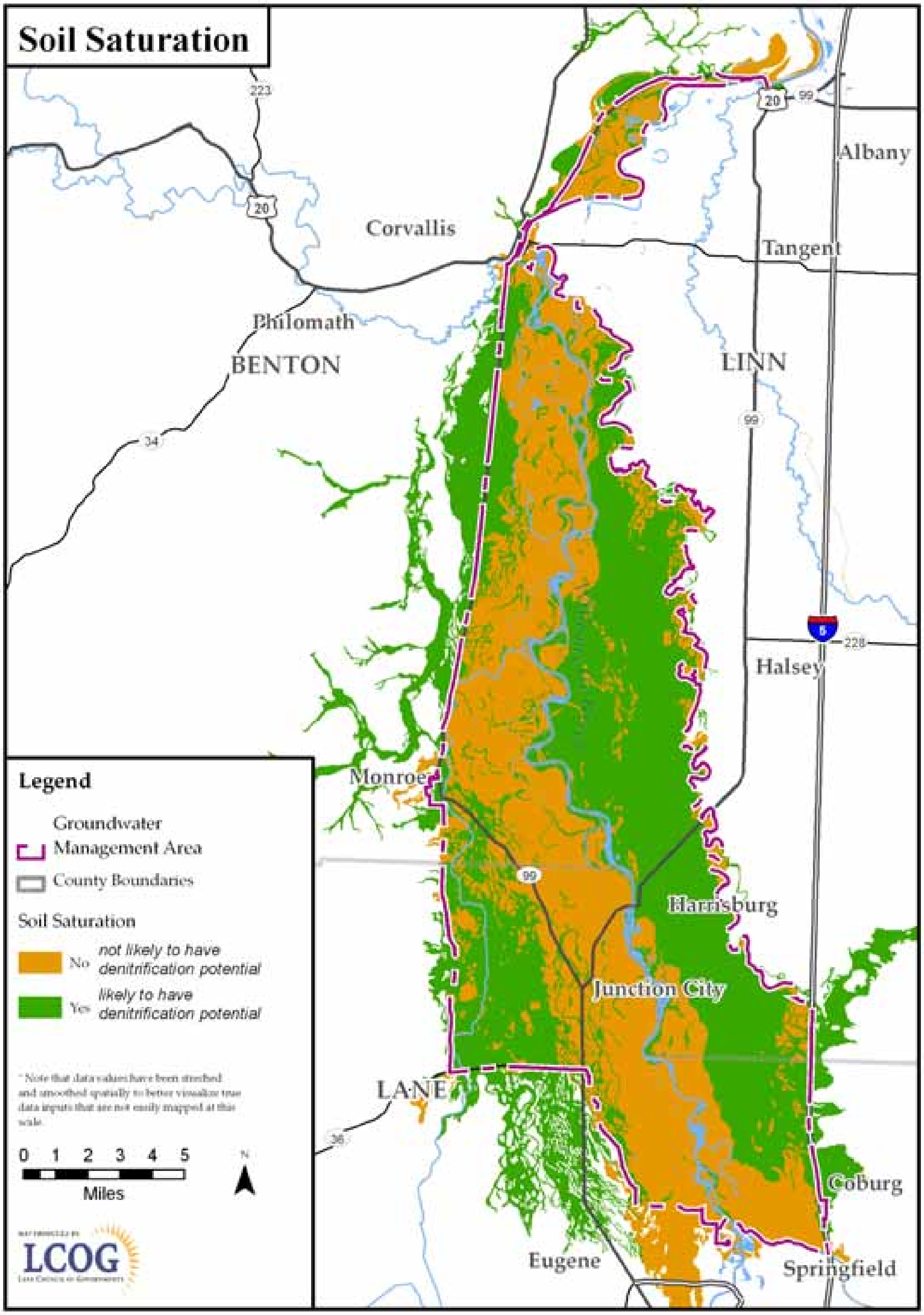
Map 11: Groundwater Contamination Risk in the Groundwater Management Area



There are areas of the GWMA where denitrification is likely occurring during at least portions of the cooler and wetter seasons. However, since denitrification potential varies by area and number of days with the necessary components of soil moisture and temperature there is no way of assigning a denitrification value to those areas.   Perhaps more importantly, there are areas of the GWMA that likely have no denitrification occurring during any part of the year because those areas rarely if ever have saturated conditions. Map 12 shows the areas in the GWMA where denitritication occurs at least during a portion of the year and where denitrication is not likely to occur during any portion of the year.

Soils that are poorly drained have the highest denitrification potential. Soils that are somewhat poorly and moderately well drained have less denitrification potential while those that are excessively drained have the lowest potential. It may be possible to use a combination of drainage class and water table depths to develop classes of denitrification potential (Campbell, 2006).   Map 13 shows soil drainage characteristics for the GWMA. In general, areas with the highest drainage and no denitrification at any time of the year tend to be held within the younger alluvium, 100 year floodplain of the Willamette River.

Map 12: Soil Saturation



Soil sensitivity is a soil's general tendency to allow a chemical to be transported through the soil to groundwater. It is expressed as a rating in one of five classes ranging from Very Low to Very High. Very Low soil sensitivity ratings imply that it is unlikely that a chemical will reach and contaminate groundwater. Very High ratings imply that the soil is unable to act as a buffer to protect groundwater from contaminants. Risk of groundwater contamination also depends on the chemical's properties and the management practices associated with its use.

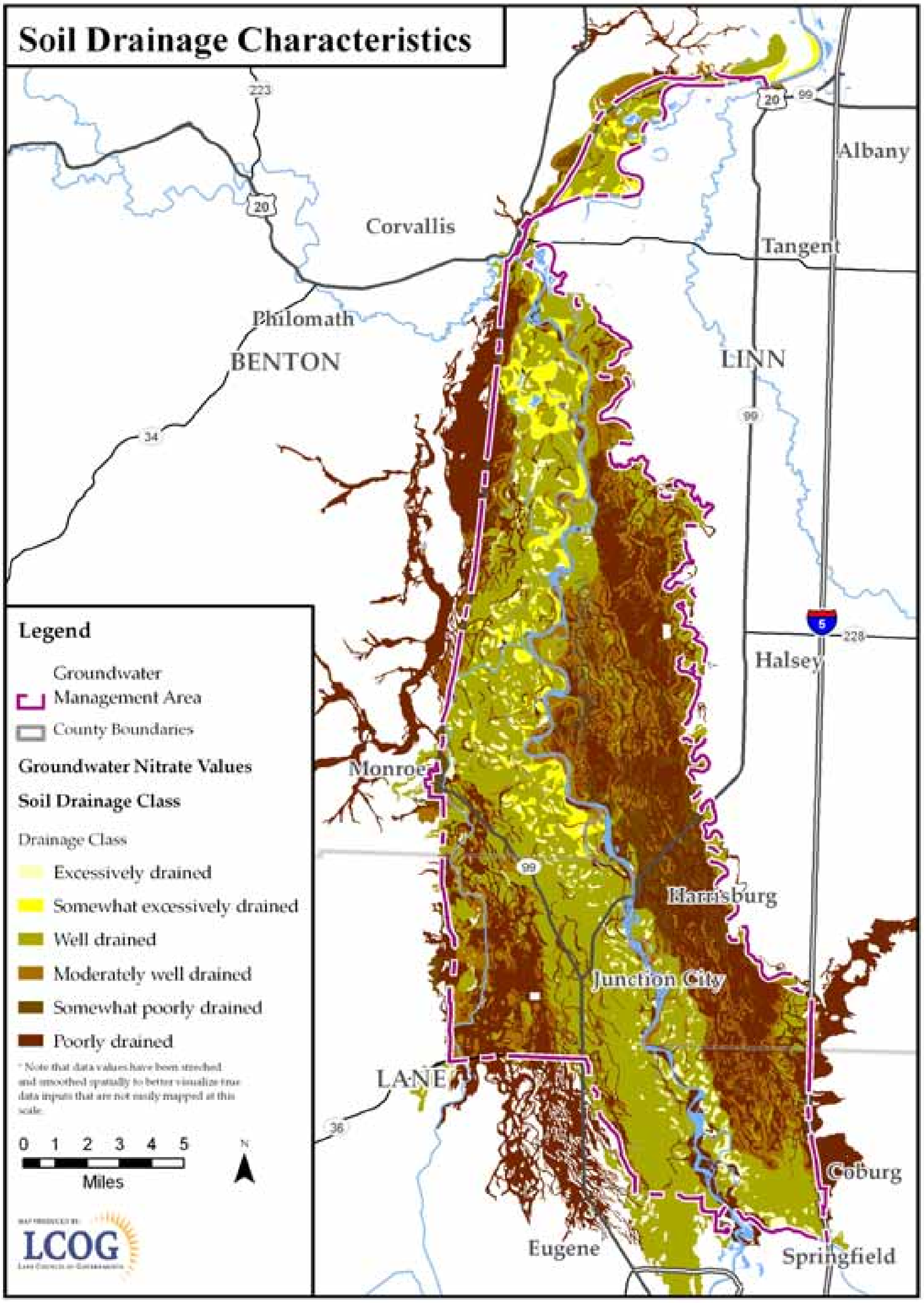
Soil sensitivity depends on two kinds of soil behavior: leaching potential and sorption potential. Leaching potential is a measure of the driving force available to move chemicals down through the soil. It is determined by soil permeability, soil depth, depth to groundwater, and hydraulic loading. Soils with a high leaching potential generally are more sensitive because water tends to move rapidly and completely through the soil to the water table. Sorption potential is the measure of the soils ability to retain chemicals in the soil by reaction with particles of clay and organic matter. Soils with a high sorption potential are not very sensitive because they tend to retain the chemical until it can degrade naturally. In this way, sorption potential can counteract some of the sensitivity due to leaching potential. Soil sensitivity ratings are a function of leaching potential and sorption potential. (Huddleston, 1998)

Map 14 displays the soil sensitivity levels of areas within the GWMA. Similar to the soil permability and denitrification potential maps, soils are generally more sensitive within the younger alluvium hydrogeologic unit on the Benton County side of the Willamette River and along both sides of the Willamette River in Lane County. All of the very high sensitive soils are within Benton County (522 acres) and Benton County has over 50 percent of the combined very high and high sensitive soils within the GWMA. Lane County has about 36 percent of the high sensitive soils with Linn County soils being not as susceptible to contaminants with only about 13 percent of the high sensitive soils. See Table 7.

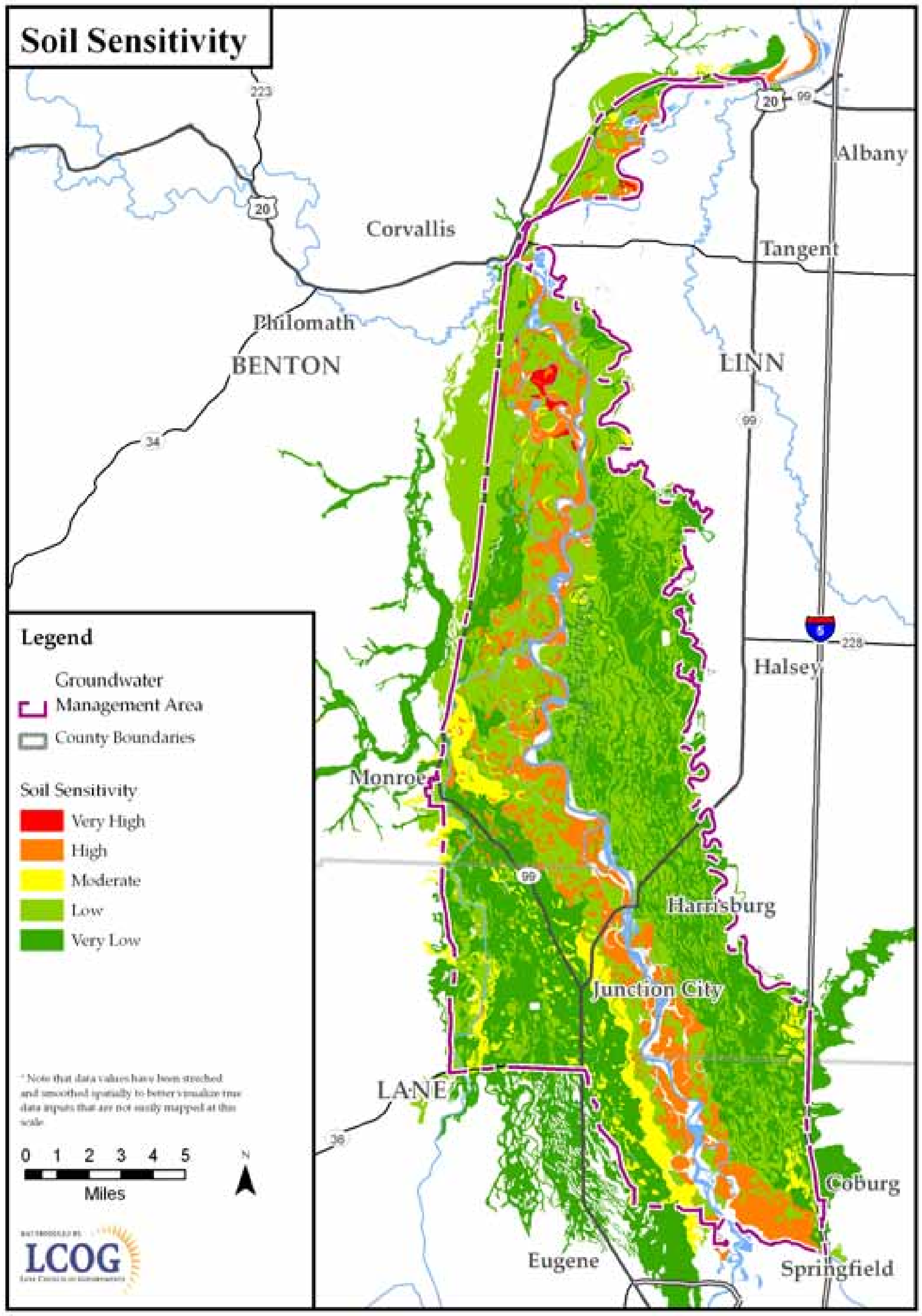
Table 7
High and Very High Soil Sensitivity by County

County	Soil Sensitivity	Acres
Benton	High and Very High	9,382
Lane	High	6,628
Linn	High	2,414

Map 13: Soils Drainage Characteristics



Map 14: Soil Sensitivity



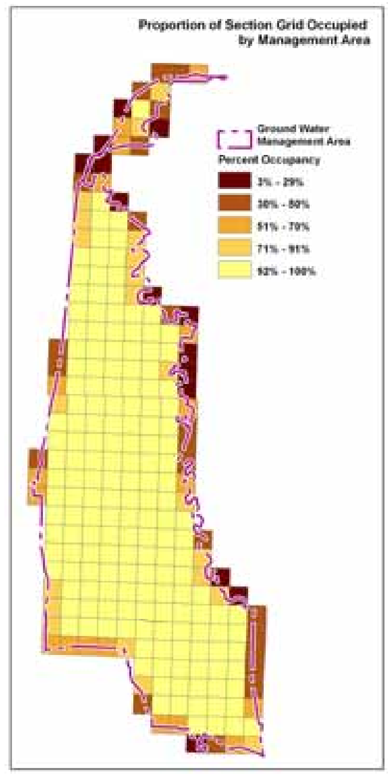
Section 3
Results, Conclusions, Recommendation

Introduction

As has been noted, the purpose of the nitrogen/nitrate budget model is to provide estimations of the relative contributions of nitrogen/nitrate loading to the groundwater of the GWMA by the major land use categories identified. The budget model is not intended to be a predictive model of actual groundwater concentrations of nitrate. It has become widely recognized that groundwater nitrate levels can vary widely in a small area due to relatively small differences in soil drainage and dissolved oxygen (Nolan 2002). Results are presented both as the summary inputs from the described sources and comparison of these inputs to known groundwater nitrate levels.

Presentation of results begins with the composite loading and then follows the major source categories described in previous sections: agriculture—both crop fertilization and CAFO's, residential septic systems, and municipal or large wastewater treatment systems.

Section Grid



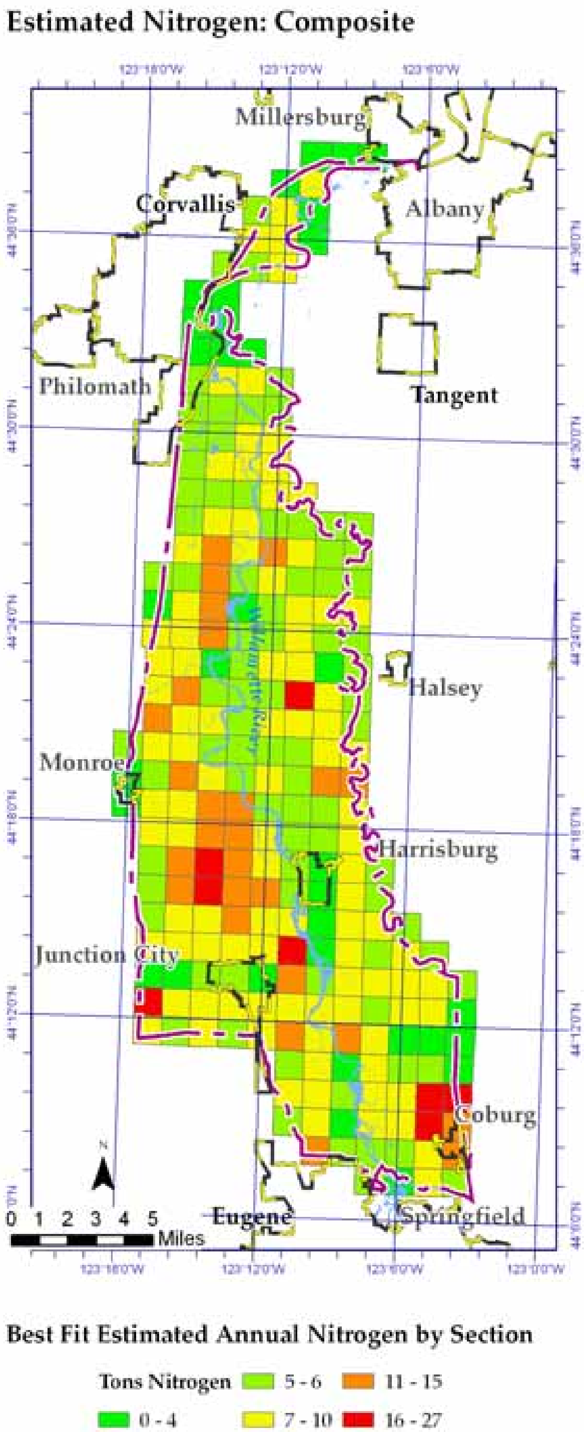
A note about mapped representation of results:

Model processes began with the conversion of the four primary and attributed nitrogen/nitrate loading sources (fertilized crops, CAFOs, septic systems, permitted wastewater facilities) to ESRI GRID format. The sources are then summed spatially on a 30 meter cell-by-cell basis for the study area. The results for the individual nitrogen/nitrate loading sectors and the composite estimate of contributions are presented in summary by a geographic one square mile section grid. Not all sections covering the GWMA area are completely filled or occupied by land use data within the section. Where this occurs, the section's value for loading has been adjusted for the proportion of the section occupied by the study area.

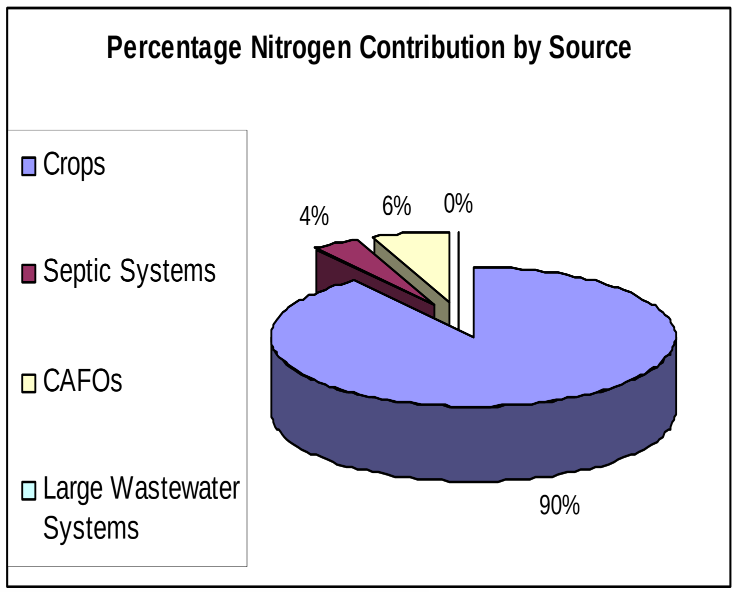
Composite Loading

Map 15 shows the additive values for the four contributing sources considered on a cell-by-cell basis for the GWMA summed to the section grid for comparison between the source values. The composite data shows the majority of the nitrogen/nitrate inputs in the GWMA to be from agricultural crop activities (90 percent) and CAFO's (six percent). Residential contribution comprises four percent and large permitted wastewater treatment facilities make relatively insignificant contributions at less than one percent. The composite data uses the median agricultural crop contribution data assuming good utilization due to soil types and management practices. As can be seen on Map 15, the highest nitrogen contribution areas tend to be in those areas where two or more of the analyzed land uses converge. This is especially true in the areas on the outskirts of Junction City and Coburg where there are rural residential septic systems and nearby CAFOs, in the midst of crop land. Nearly all of the sections with the highest nitrogen contributions have a CAFO associated with them.

Map 15 Composite Total Nitrogen Input
From Crops (median crop application, good utilization)**, CAFOs, Septic Systems, and Large Wastewater Treatment Facilities**



Composite Total Nitrogen Input		
Input	**Annual Tons Nitrogen**	**Percent of Total**
Crops	1,704	90%
CAFOs	109	6%
Septic Systems	74	4%
Large Wastewater Systems	0	0%
Total	**1,887**	**100 %**



Agriculture Results

Crop Fertilization

As has been noted, the agricultural crop land application of nitrogen values generates a low, median, and high contribution applied to the agricultural cropping data. Figure 4, on the next page, shows the relative quantities of nitrogen applied under the differing utilization assumptions. The first map in the figure shows the median nitrogen application based on field management guides and no reduction in nitrogen from natural factors or management practices. As can be seen, nitrogen contributions are relatively high when uptake is not considered. Poor utilization and good utilization values are derived through an estimation of the amount of nitrogen used by and harvested with the crop along with influences of soil factors. Figure 4 visually displays the value in using good management practices to reduce nitrogen/nitrate contributions. The Figure also displays that even under a good utilization scenario, there is still nitrogen that is potentially lost to groundwater.

Totals for all crop application rates for the management area are shown in the graph below. This graph reinforces the positive influences of good management practices. For example the total nitrogen applied is about 8,300 tons (using the median application rate). Once plant uptake, soil conditions, and management practices are taken into consideration, nitrogen contribution drops to about 5,000 tons under a poor utilization scenario and further down to about 1,700 tons in the good utilization scenario. Although significant improvements are made with good utilization assumptions, this 1,700 tons still represents the amount of nitrogen potentially lost to groundwater.

Figure 5:
Low, Median, and High Nitrogen Application Estimates of Tons of Nitrogen Applied to Crops and Poor and Good Reductions (applied to median application rates)

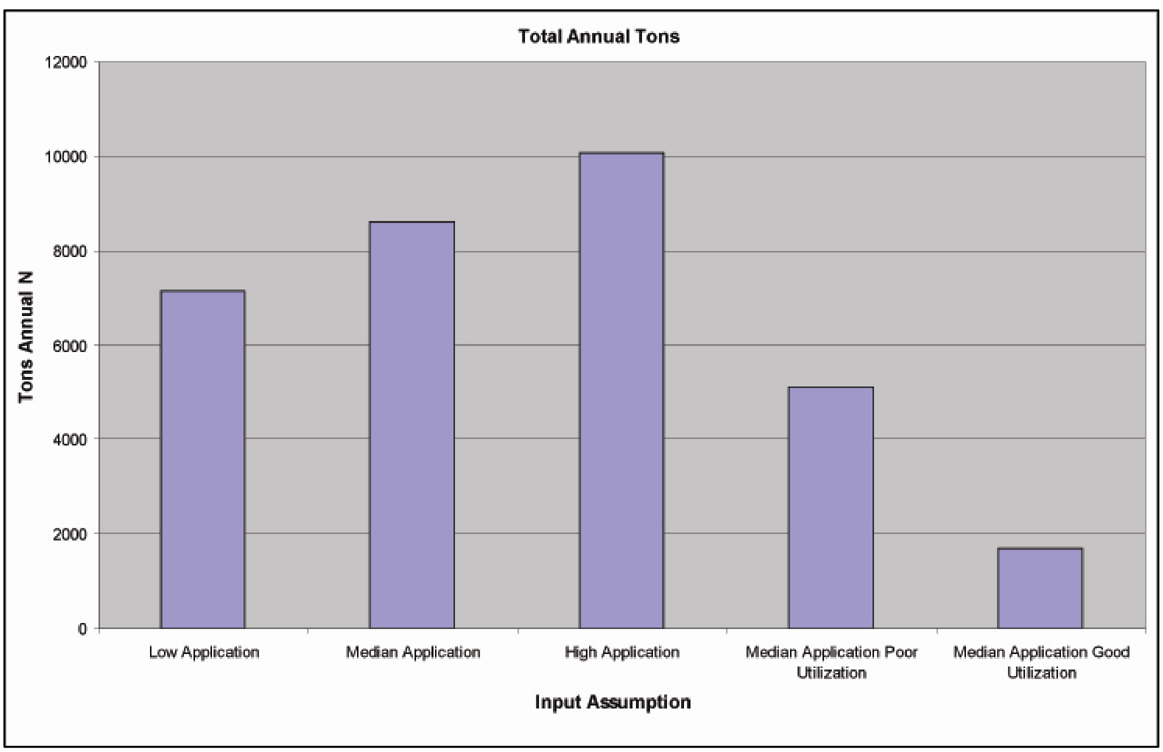


Figure 4: Crop Nitrogen Contributions Median Application Rate: **No Reduction, Poor Utilization, Good Utilization (Pounds nitrogen potentially lost per acre)**

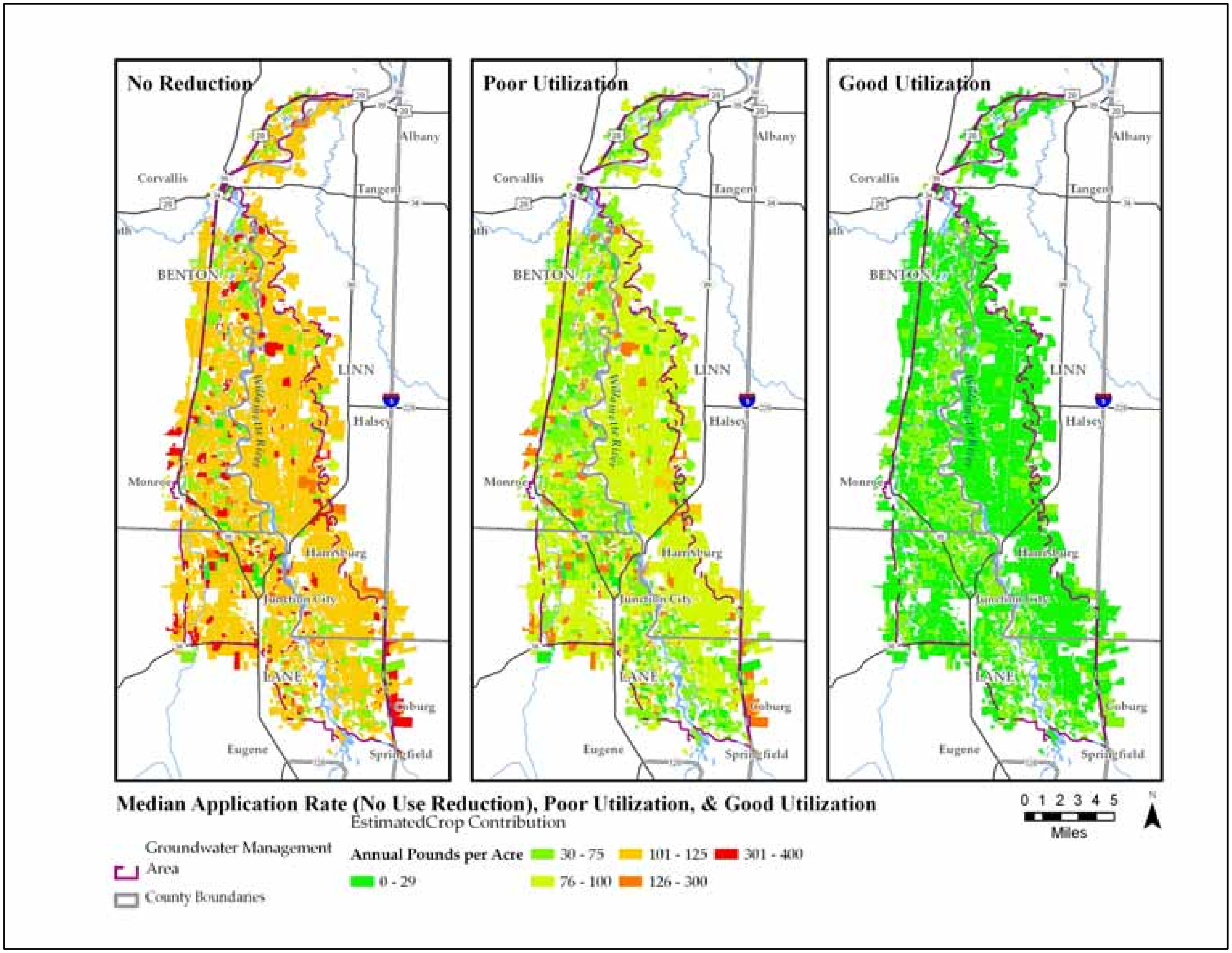
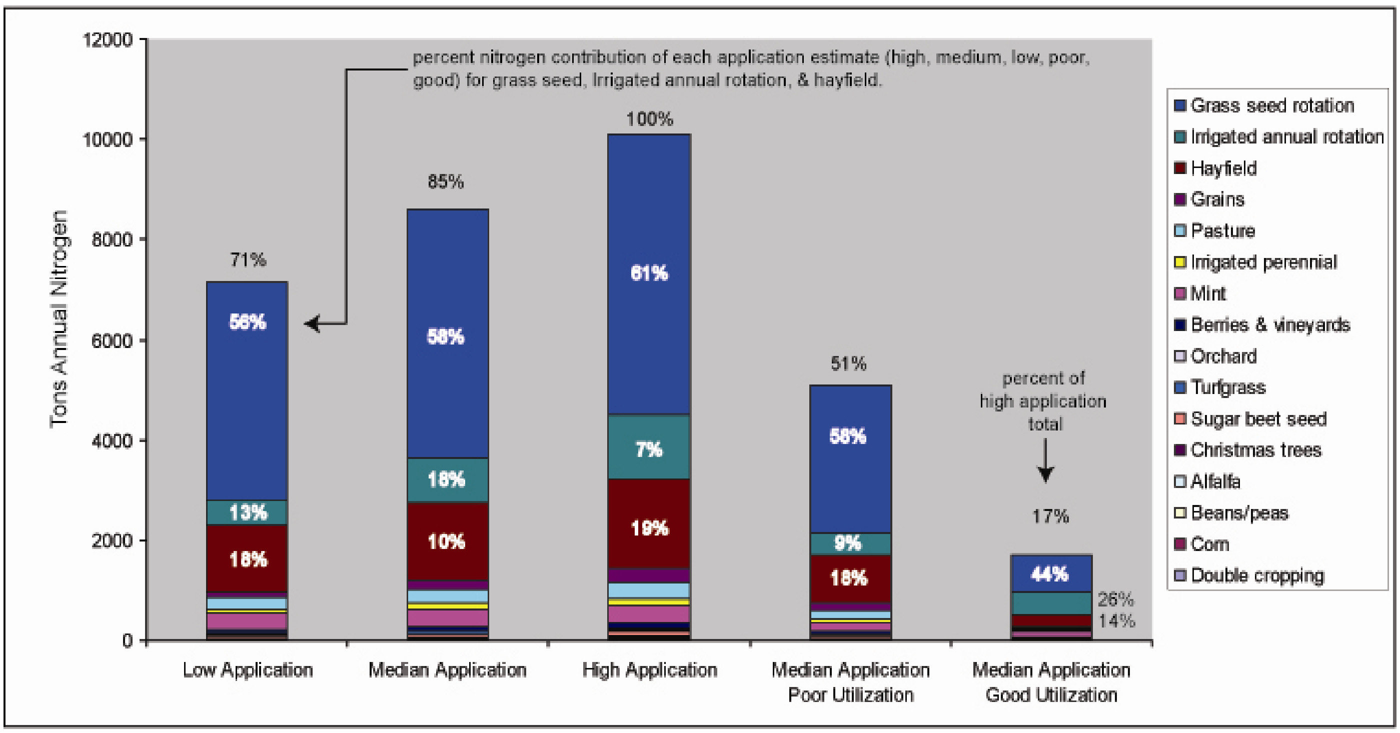
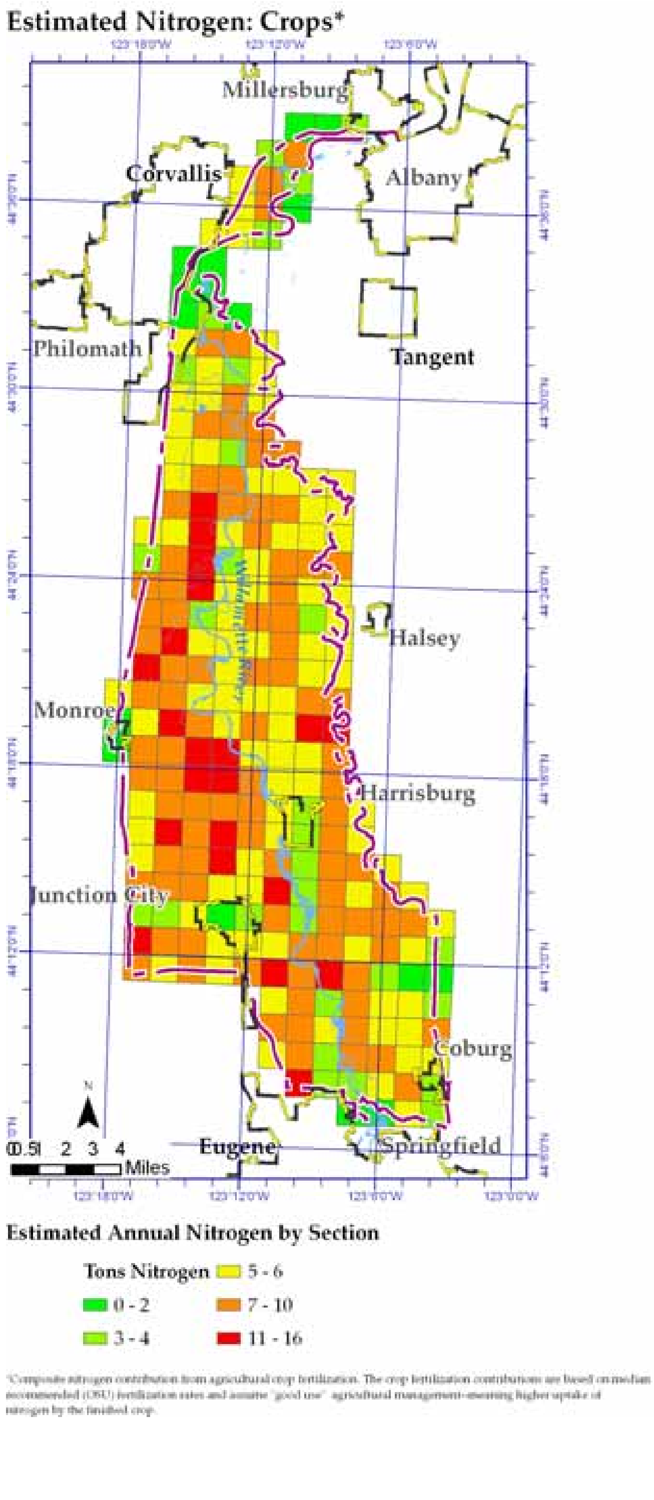


Figure 6 shows the percentage of fertilizer applied by crop type. About 57 percent of the agricultural land in the management area is devoted to grass seed production, and a similar figure is seen for its relative contribution to the agricultural nitrogen contribution to the lands surface under the median application rate. Figure 6 provides an indication of how nitrogen reductions can be accomplished. For example, by using the median application rate rather than the high rate, the total nitrogen applied drops by 15 percent. This Figure also highlights the benefits of some crop types and good management practices. For example, for the median application rate with no reduction, 58 percent of the total tons of nitrogen contributed is from grass seed crops, 16 percent from irrigated annual rotation (vinecrops) and 10 percent from hay crops. Taking the good utilization reduction factor into account, as can be seen on the last bar of the graph, the total nitrogen drops from over 8,000 tons to less than 2,000 tons. Because annual and perennial rye grass are the most common grass seed crops and because these crops have a good uptake ratio if managed well, the percentage contributed from grass seed crops drops to 44 percent.

Figure 6
Percentage of Fertilizer Applied by Crop Type Using Different Scenarios

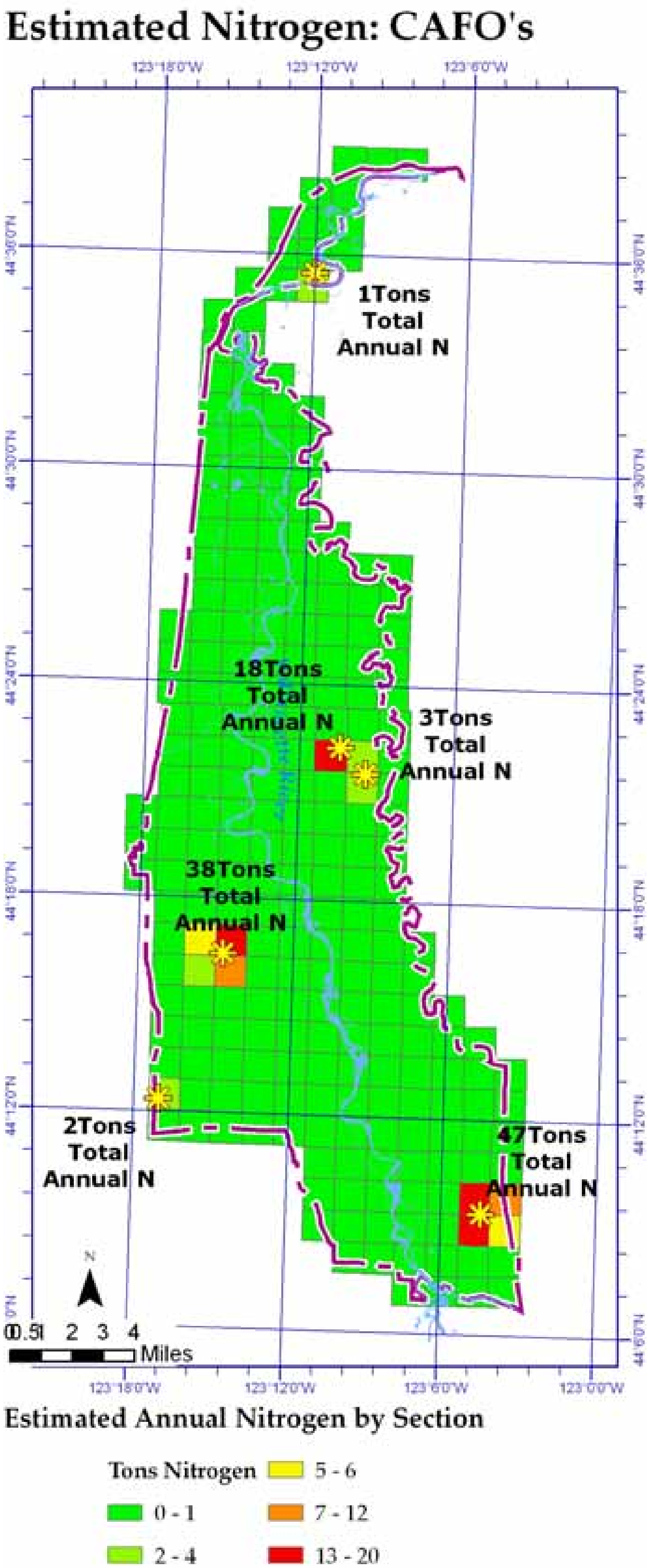


Map 16
Crop Fertilizer Applications With a Good Utilization Scenario



Map 16 displays a square mile section grid that compares crop fertilization values using the median application rate and a good utilization scenario. As can be seen, most of the highest nitrogen contribution values are to the west of the Willamette River. Generally, many of the higher application rates using the good utilization scenario are also within areas of highly permeable soils and where denitrification is likely not occurring.

Map 17



CAFO's

Eight confined animal feeding operations are within the GWMA with six of those having available data. Together these facilities contribute about six percent of the total nitrogen applied to the land within the management area. Three of the six facilities contribute about 94 percent of the total CAFO nitrogen contributions influencing localized impacts. One facility alone produces about 43 percent of the CAFO-derived input.

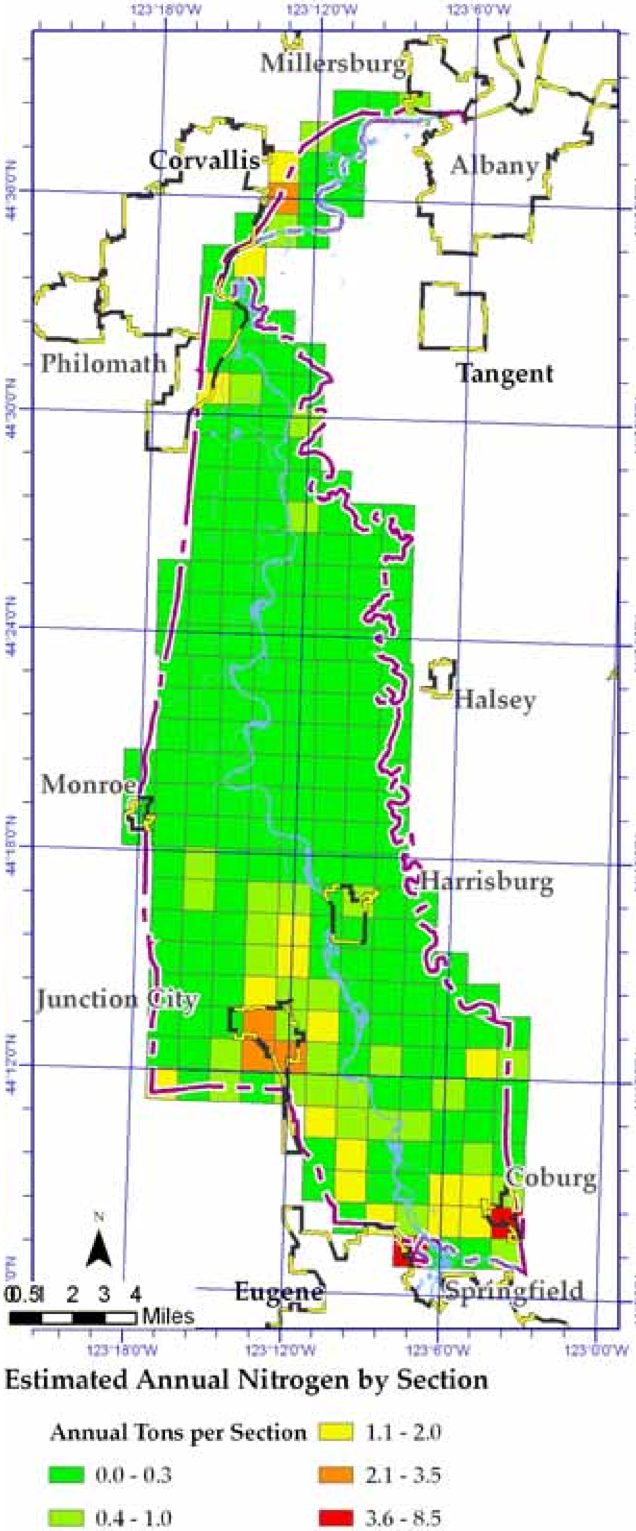
Rural Residential Septic System Results

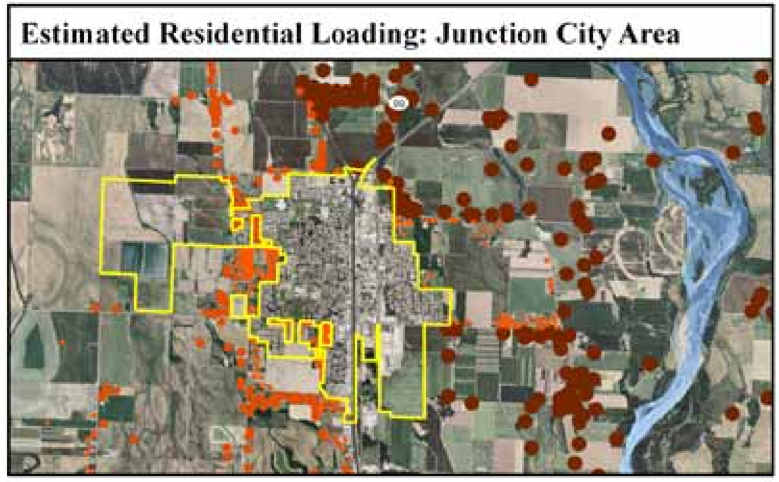
Nitrogen from residential septic system sources is relatively low compared to agricultural inputs, contributing an estimated four percent of the total. Although total contributions are smaller than agricultural inputs, there are localized influences from septic systems that are important. Septic contributions summed to the section grid are shown in Map 18. Areas of greater concentration appear in the vicinity of Coburg, Junction City, Corvallis, and other areas of concentrated rural dwellings as shown on the inset maps. As can be seen in Map 18, the Lane County portion of the GWMA sees higher contributions of nitrogen from rural residential uses which is consistent with Lane County having over half (58 percent) of the rural population in the GWMA.

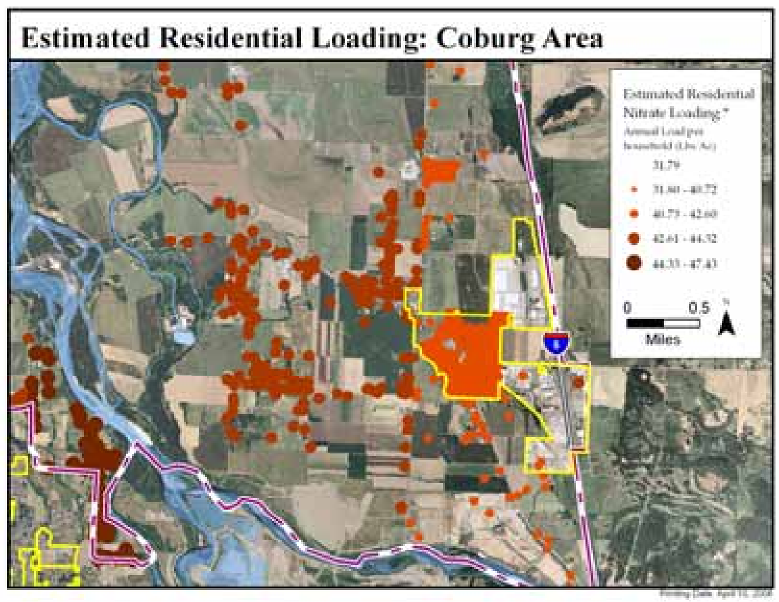
Reductions in residential septic system contributions could be seen with reductions in the use of standard septic systems. For example, if 30 percent of the standard septic systems were replaced with an alternative system or upgraded with a nitrate reducing additive component (such as the Nitrex component) the GWMA could benefit from a reduction of about 24 tons of nitrogen. When the City of Coburg finalizes the construction of a centralized wastewater treatment facility, almost nine tons of nitrogen contributions will be reduced annually.

Map 18

Estimated Nitrogen: Residential Addresses

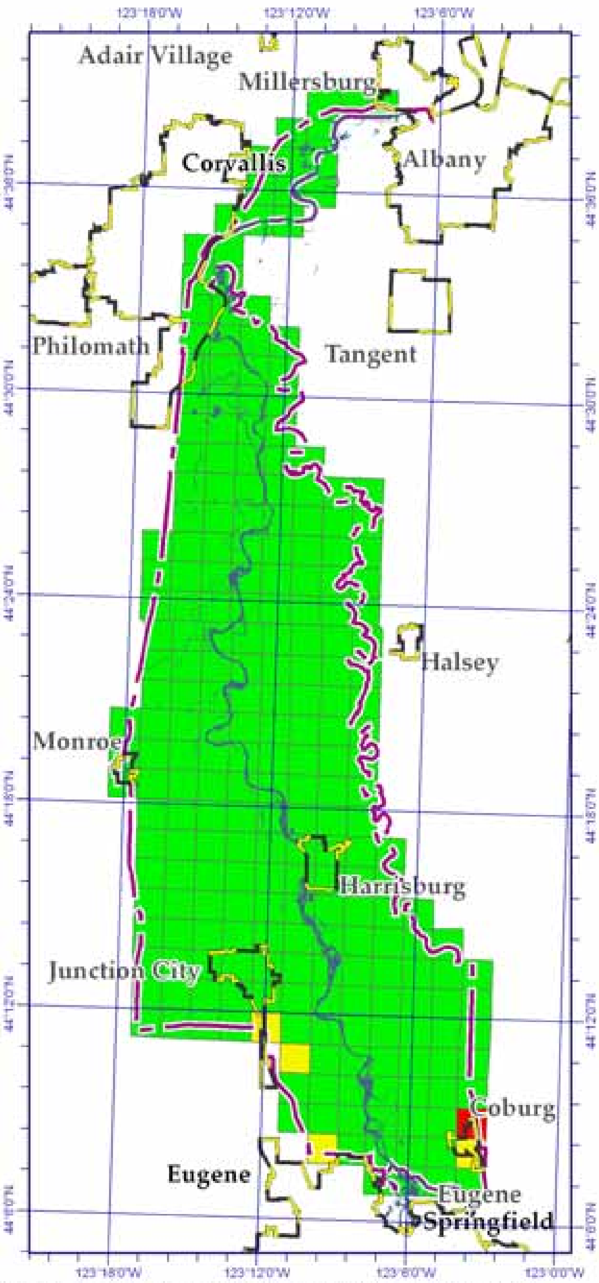






Map 19

Estimated Nitrogen Contribution: Large Permitted Onsite Sewerage Systems



Estimated Annual Nitrogen/Nitrate by Section

Annual lbs per section

- 0.00 - 2.49
- 2.50 - 9.18
- 9.19 - 27.17

Large permitted onsite sewerage systems contribute the least of all estimated sources (using best available data). These systems are estimated to contribute less than one ton of nitrogen applied to the land in the management area. Contributions from permitted systems are shown in Map 19. It is unknown what additional nitrogen contributions would be attributed to large permitted facilities if the bio-solid and/or reclaimed water spread areas were included in the analysis. For example, the aerial photo below displays Junction City's sewage treatment lagoons and nearby spread area. Junction City irrigates the corn fields to the east and two grass fields to the south. The dark green of the spread area that lies to the east of the lagoons (shown below) indicates that nitrogen is applied in these areas but data is not available to identify the quantity of nitrogen application.

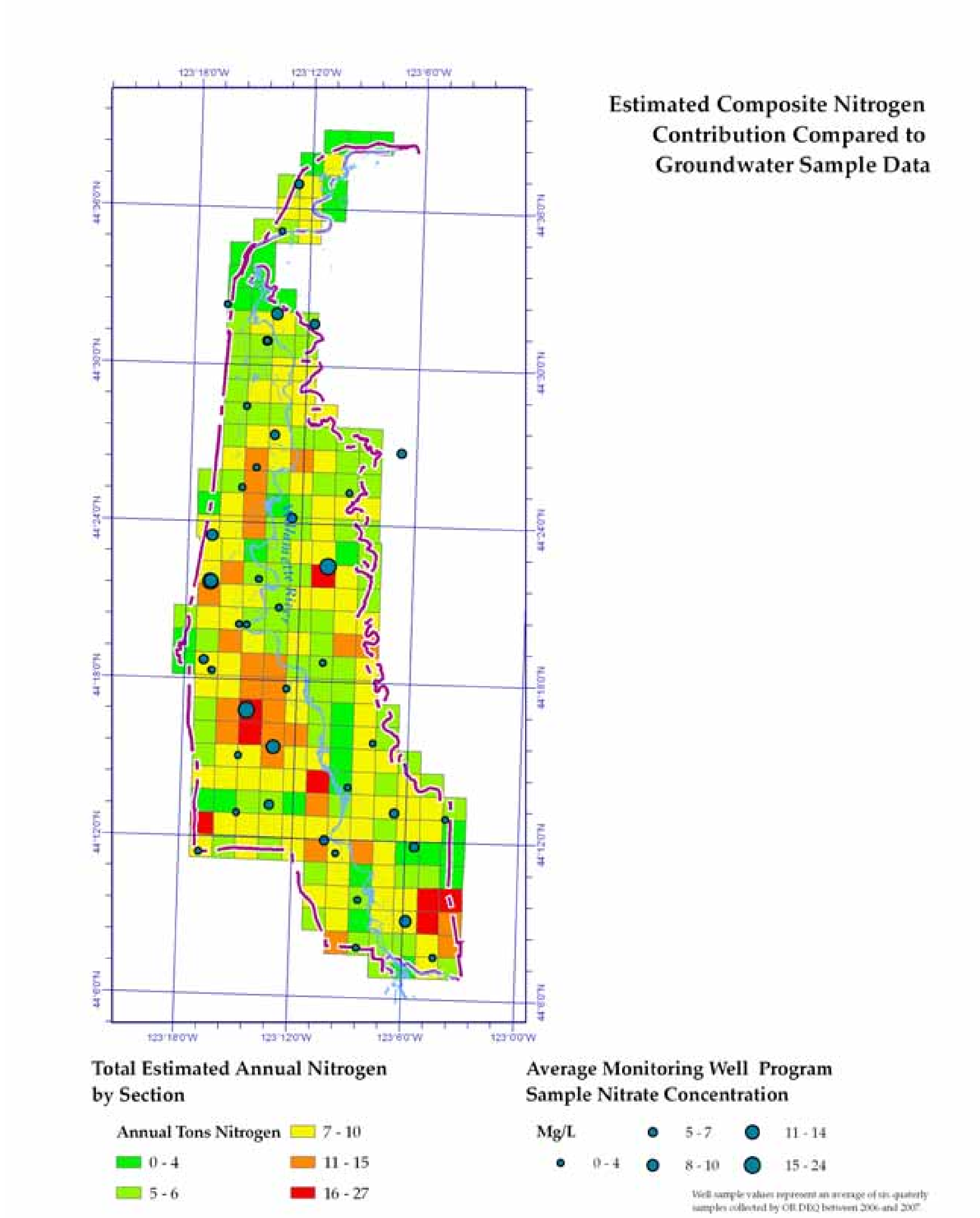
Comparison to Sample Data

This study is intended to provide a best estimate of nitrogen/nitrate contributions within the management area, and is not intended to be a statistically robust study or to have been designed as a long-term modeling and monitoring approach. This being stated, it is still informative to examine the estimated nitrogen contributions in regard to sampling data available. Map 20 shows the composite nitrogen loading (using the median crop fertilizer application rate and the good utilization scenario) in relationship to the 41 monitoring locations and values. Table 8 presents the correlation data by source inputs. The 41 monitoring and domestic wells associated with the long-term monitoring program provide the sampling data for this analysis. The number of sampling points limits the statistical robustness of the analysis, but correlation analysis between input values and groundwater samples show a correlation of 0.71, where 1.0 would be an absolute correlation. Within the inputs, very little significance is seen between the residential septic and the large permitted onsite sewerage inputs, while agricultural inputs show a relatively high correlation between estimated inputs and sampled groundwater.

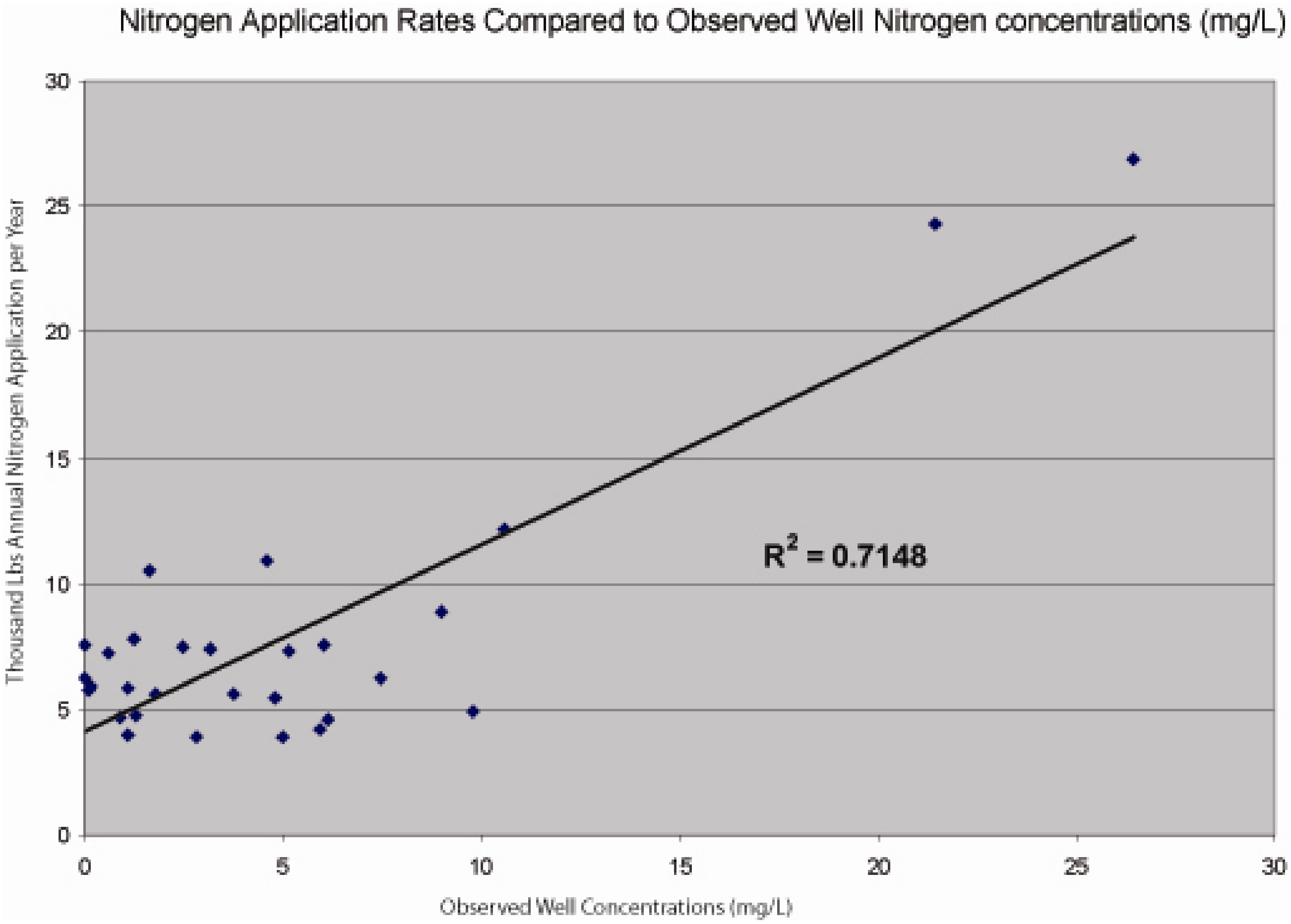
Table 8
Correlation of Source Inputs and Nitrate Concentrations for the Southern Willamette Valley Groundwater Management Area

Estimated Nitrogen Contribution Source	Correlation with Nitrate Concentration
Composite (No crop uptake reduction)	0.530928168
Composite (Poor crop utilization)	0.644490551
Composite (Good crop utilization)	0.84543954
Agriculture crops no crop uptake reduction	0.229231172
Agriculture crops poor utilization	0.214939034
Agriculture crops good utilization	0.317529181
Large permitted onsite sewerage systems	No Data
Confined animal feeding operations	0.862861207
Residential septic systems	0.103424741

Map 20


Estimated Composite Nitrogen Contribution Compared to Groundwater Sample Data
Total Estimated Annual Nitrogen by Section
Annual Tons Nitrogen
0 - 4
5 - 6
7 - 10
11 - 15
16 - 27
Average Monitoring Well Program Sample Nitrate Concentration
Mg/L
0 - 4
5 - 7
8 - 10
11 - 14
15 - 24
Willamette River

Correlation of Nitrogen Application and Nitrate Concentrations
In the Southern Willamette Valley Groundwater Management Area



Conclusions and Recommendations

The results in the modeled contributions of land use activities to groundwater nitrate, support and are similar to, the observed levels of nitrate in groundwater. As stated, no attempt has been made to model geophysical processes of groundwater or its flows. None-the-less results are indicative of the sources plausibly expected from land use distribution and observations of the management area.

Not surprisingly, given the land use make up of the GWMA, agricultural land use practices are the largest contributor to groundwater nitrate levels as measured by gross spatial correlation of estimated nitrogen inputs to groundwater and total volume of input for the area. This is not unexpected given the predominance of intensive agricultural land use in the management area. While none of the data produced in this report is statistically significant, stronger correlations are seen to CAFO's and to crops, particularly crops under modeled good utilization which incorporates good management practices. Overall, residential septic systems appear to be a smaller contributor to groundwater contamination on a regional scale, though locally constrained conditions certainly exist especially in Lane County. Large permitted wastewater treatment facilities contribute the smallest amount although data for these facilities are limited.

The agricultural contribution (CAFOs and crops) are about 96 percent of total contributions according to the sources modeled. However, not all residential sources such as fertilized lawns and small acreage livestock were included in the model since data was not available for these sources. In addition, data was only available for three of the permitted large wastewater treatment facilities and no data was available for the bio-solid or effluent spread areas for the large permitted wastewater treatment facilities. If these additional sources were able to be modeled, the results would not have changed dramatically but it is possible that contributions would even more closely mirror land uses and thus possibly reduce the total agriculture contribution a couple of percentage points.

The fate of nitrogen in the biochemical groundwater transport process is a complex and variable phenomena. Concentrations of nitrate in groundwater can vary sharply over small intervals of space and time. This project examined these phenomena in a simple but realistic fashion, producing results with application to land use practices in the management area. Future efforts to reduce contributions to groundwater contamination from nitrate should focus on all land use sectors with priority given to agricultural land uses. The model demonstrated the gains that can be made through good crop utilization which incorporates using best management practices to control nitrate leaching to groundwater. In addition, gains can likely be made with localized reductions in nitrogen contributions from septic systems. This has been demonstrated in other areas that have switched to alternative systems or centralized community wastewater treatment facilities. For large permitted wastewater treatment facilities further data collection will allow these systems to have a better cross-program, cross-environmental media analysis.

Following is a summary of conclusions and recommendation for each of the four analyzed nitrogen/nitrate contributors. The recommendations are based on the results of the nitrogen/nitrate budget model and are integrated with strategies already identified in the *Southern Willamette Valley Groundwater Management Area Action Plan.*

Fertilized Crops:
Fertilized crops are the largest contributor of nitrogen in the GWMA at an estimated 1,509 tons comprising about 90 percent of total nitrogen contributed (good utilization scenario). Differences in crop fertilization, soil characteristics and management practices can be seen geographically on a county scale. In general, there tend to be higher applications of fertilizer on the Linn County side of the GWMA (under the no reduction scenario). However, crops grown on the Linn County side tend to be those with good utilization values which reduce potential groundwater impacts. Although there are lower applications on the Benton and Lane County portions of the GWMA, these counties have higher percentages of soils that are permeable, are likely to have little or no denitrification occurring, and higher concentrations of areas with sensitive soils. Efforts can be targeted geographically and with focused work with targeted groups. Grass seed production comprises the largest field classification of crop grown in the GWMA (57 percent) presenting an opportunity to narrow assistance to farmers growing the crops that make up this field classification. Recommendations for agricultural crops include:

- There are higher applications of fertilizer (no reduction scenario) on the Linn County side of the GWMA, but the soils are less sensitive and have greater denitrification potential – focus on reducing application rates or finding ways to increase efficiency of nitrogen use.

- Lower applications of fertilizer occur on the Benton and Lane County areas of the GWMA but soils tend to be more sensitive – examine best management practices and evaluate opportunities to tailor fertilizer applications to specific soil and crop properties.

- Generally, prioritize efforts on the west side of the Willamette River in Benton County where there are higher nitrogen levels (under the "good utilization" scenario) and the most sensitive soils.

- In Lane County, generally prioritize efforts in areas on both the east and west sides adjacent to the Willamette River in the younger alluvium where soils tend to be most sensitive.

- Focus outreach and technical assistance efforts with grass seed growers (and Associations) that represent over half (57 percent) of the crops grown.

- Discuss the nitrogen budget at the "GWMA Research Symposium" and determine further research needed to possibly refine budget model and available research that points towards reductions in nitrate loading due to fertilizer applications.

- Work directly with fertilizer sales field representatives to help determine refined fertilizer application techniques in sensitive areas. Current high fertilizer costs provide an opportunity to encourage more precision farming throughout the Southern Willamette Valley.

- Begin discussions with OSU Extension Service to review current available research that consider environmental factors such as nitrogen loading. OSU Extension Service should consider and possibly adjust recommended application rates especially in sensitive areas.

- Inform farmers of areas on their farm that have higher soil sensitivity to contamination. Provide research supported information about potential practice changes such as precision farming techniques, profitable alternative crops, and irrigation applications that could reduce the nitrogen/nitrate loading especially in sensitive areas.

- Integrate nitrogen budget information in with subbasin Water Quality Management Plan strategies.

- Look for funding for new aerial photos of the GWMA, ideally with two flights in one year to better depict current crop types and typical crop rotations during a one year cycle. Repeat the process every 3-5 years to keep abreast of typical crop rotations and/or changes in crop types as a result of a changing marketplace.

CAFOs:
Measured nitrate and CAFOs indicate the highest correlations (.86) of the land uses analyzed and indicate localized impacts of nitrate to groundwater. While CAFOs contribute less nitrogen (109 tons) compared to crops (1,509 tons), there is an opportunity to work with relatively few operators (six to eight) compared to the hundreds of farmers in the region. Gains can be made through review of the CAFO Water Quality Management Plans and increased outreach. Perhaps the biggest gains, both environmentally and economically can be garnered through efforts to make CAFO "waste" a resource instead of something operators are mainly trying to dispose of. Trends in global economies affecting the production of petrochemically based fertilizers and their transport nationally may provide opportunities for locally available sources of nitrogen. Recommendations for CAFOs include the following:

- Review CAFO Water Quality Management Plans to determine if they are adequate for facilities within the GWMA - this would include the assumptions used in the plans – i.e., volatilization, etc.).

- Increase outreach (education and operation site visits) especially to the smaller operations that tend to lack the on-site technical expertise of the larger operations.

- Increase up-gradient and down-gradient monitoring near sites to help ensure that land applications are not resulting in nitrogen loses to groundwater.

- Make animal "waste" a resource, especially with the larger operations, by exploring the following:
    - Tax credits
    - Methane gas production
    - Sales to nearby farmers

Residential Septic Systems:
Although total nitrogen contributions from septic systems is similar to CAFOs (4 percent as compared to 6 percent of total), the nature of the contribution is very different. Whereas the few CAFOs contribute nitrogen in a relatively small area, septic systems are generally much more dispersed. Contributions and potential impacts from septic systems become more considerable

in areas where these systems are relatively close together and where these systems lie within areas of sensitive soils. A significant gain will be made in reducing septic system contributions once the City of Coburg has a wastewater treatment facility. This change will result in a decrease of about 8.7 tons nitrogen annually or about 12 percent of the total nitrogen contribution from residential septic systems. Additional achievements can be made by targeting areas of septic system clustering and in areas where soils are sensitive. Bringing alternative treatment technology into the GWMA should focus on rural Lane County which has the largest rural population (about 5,000). Efforts should also target Benton County which has a smaller rural population (about 2,000) but 50 percent of the total very high and high sensitive soils. Recommendations for residential septic systems include the following:

- In general, target areas where rural residential development is “clustered”, located within sensitive soils, and/or within areas where denitrification does not typically occur.
- Encourage counties to require nitrogen removing alternative treatment systems for new development or replacement of systems in these sensitive areas.
- Explore tax credits and other financial incentives to encourage alternative treatment systems.
- Incorporate into the “Land Use Action Kit” for the counties alternatives and options for addressing nitrogen contributions from septic systems. Share results of the nitrogen budget with County staff and decision makers to target appropriate areas for nitrogen reductions from septic systems.

Large Permitted Wastewater Systems:

As has been noted, data is limited for the large permitted wastewater systems in the GWMA showing less than a ton of nitrogen being contributed for this source. Discharge data was available for only three of the six facilities in the area and no data is readily available for bio-solid or effluent spread areas. Near-term efforts should focus on compiling data and making that data readily available for cross-program analysis and benefit. Additionally, although wastewater treatment facilities contribute the smallest amount of nitrogen of the analyzed sources, these facilities are likely having localized impacts. Those impacts can be reduced with an adherence to a 7 mg/l standard and by exploring treatment alternatives that will lessen nitrogen/nitrate loading. Following are the recommendations for large permitted wastewater treatment systems in the GWMA:

- Complete an inventory of land application treatment facilities within the GWMA.
- Compile and track data such as bio-solid and effluent spread areas related to large permitted systems.
- Inspect lagoon and spread area sites.
- Continue to ensure permit requirements consider the requirement to meet the 7mg/L threshold instead of 10 mg/L.

- Initiate and convene internal DEQ discussions between Onsite, GWMA, and Drinking Water program staff to review permitting and tracking procedures and discuss potential areas of improvement.

- Complete literature review of wastewater treatment technologies that reduce nitrate and share with DEQ internal staff and treatment system operators.

- Work with wastewater treatment system operators to help ensure that bio-solids and effluent are being applied at appropriate rates.

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