EPA Lower Yakima Valley Project
Nitrogen Loading Screening Analysis

June 2012
USEPA Region 10

Report Organization

Section One: Introduction

Purpose

The purpose of this screening analysis was to develop a better understanding of the relative quantities of nitrogen generated in Yakima County from different sources. The results from this screening analysis were used to assist in the study design for an EPA project that evaluated the contribution from various land uses to the high nitrate levels in groundwater and residential water wells in the Lower Yakima Valley.

Scope

This report evaluates the amount of nitrogen generated and potentially applied to the land from various nitrogen sources in Yakima County. While the focus of EPA's activities are in the Lower Yakima Valley, the majority of information available (e.g., crops) is from Yakima County.

The screening analysis combined information on land use with some simple calculations to estimate the amount of potential nitrogen loading from several sources that can be applied to the land. The report does not evaluate the amount of nitrogen in the form of nitrate that is transported in the soil and could eventually impact groundwater and private wells.

It is recognized that a complete nitrogen budget analysis would take into account all nitrogen inputs and outputs, the factors that effect nitrogen transport, deposition, and uptake by crops, vegetation, and soil and the amount entering groundwater. However, evaluating these factors was beyond the scope of this screening analysis. The estimates derived from the screening analysis were used as relative values to compare with other source estimates to assist in the study design for EPA's Lower Yakima Valley project. This is an informative tool and not a definitive nitrogen budget model or calculator.

While there are multiple sources of nitrogen, this report focuses on:

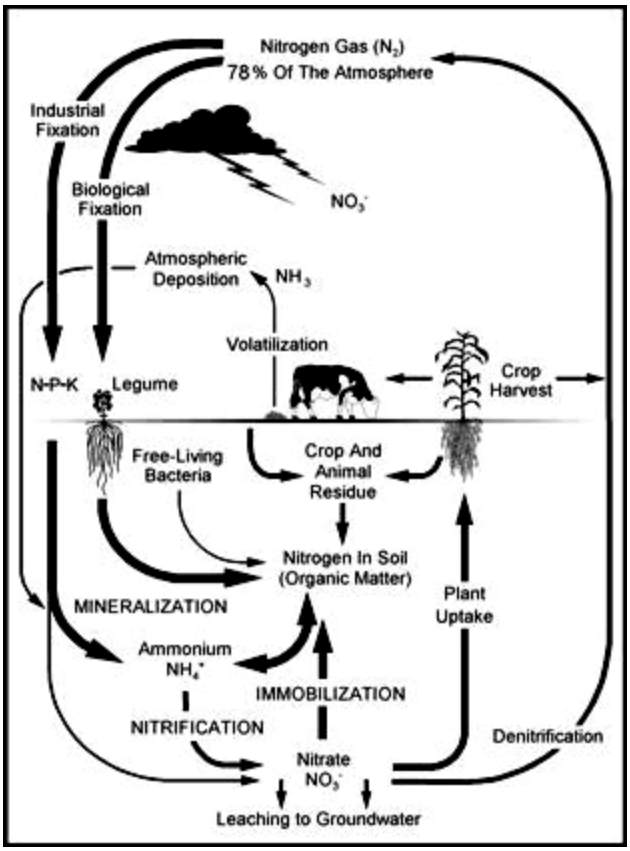
- Irrigated crops (fertilizer)
- AFOs and CAFOs (animal waste)
- Septic systems and biosolids (human waste)
- Nitrogen deposited by precipitation

Some of the additional sources of nitrogen not included in this report include: legume plow-down, urban residential sources such as lawn fertilizers and golf courses, and application of food processing waste. Many of these sources of nitrogen are small or like urban runoff difficult to quantify their contribution. However, none of these sources are expected to contribute more than 2% of the nitrogen inputs in Yakima County based on similar nitrogen loading models for Idaho and Oregon.

Background

Nitrate is an inorganic compound and a naturally occurring form of nitrogen. On a national scale nitrate is typically found in shallow groundwater at concentrations up to 1.1 mg/L.[1] Higher nitrate concentrations than this usually indicates that human activities have contributed additional nitrate to the groundwater. [2] Nitrate is highly soluble in water and mobile in soil, which makes it relatively easy for nitrogen from a variety of point and non-point sources to move through the soil and into the groundwater as nitrate.

Exposure to nitrate in drinking water beyond health based standards (10 mg/L measured as nitrogen) may cause a number of health problems. Excess nitrate exposure can result in methemoglobinemia (blue-baby syndrome) in infants and susceptible individuals which can lead to death in extreme cases.[3] Methemoglibinemia is caused by the reduction of nitrate to nitrite in the body.[4] Nitrite binds to hemoglobin and lowers the body's ability to carry oxygen in the blood.[5] Health effects associated with longer-term exposure have shown a positive association between nitrate levels in drinking water and increased risk of cancer and certain reproductive outcomes while other studies have shown no association or an inverse association.[6] Some researchers found that the consumption of antioxidants such as vitamin C can be a protective factor against the effects of nitrate in the human body.[7]



Numerous water quality investigations over the last 30 years, including the 2002 investigation by the Valley Institute for Research and Education (VIRE), have found nitrate contamination in some wells in the Yakima Valley above the Environmental Protection Agency (EPA) Drinking Water Standard of 10 mg/L measured as nitrogen.[8] Nitrate contamination in groundwater is primarily a risk for rural populations in Yakima Valley that rely on private wells for drinking water. Public water systems are tested regularly for nitrate and the data is reported to the Washington Department of Health. Monitoring public water supplies falls under state drinking water regulations, but private well water is not included in these regulations. The State Department of Ecology and Health recommends testing private well water to rural residents, but there is no regulation in place to require this testing.

Comparative Studies

While this report uses mainly Regional or local sources of information, its scope and methods are patterned after two other high-quality reports:

- *Southern Willamette Valley Groundwater Management Area: Nitrogen/Nitrate Budget Report* prepared by the Lane Council of Government with funding from the Environmental Protection Agency's Regional Geographic Initiatives Grant in June 2008.[9]

- *Lower Boise/Canyon County Ground Water Quality Management Plan* prepared by the Lower Boise/Canyon County Ground Water Quality Management Committee and the Idaho Department of Environmental Quality in November 2005.[10]

While there are differences in these systems from the Yakima Valley (e.g., Willamette Valley has different climate) these reports were selected for comparison because they provide simple methodologies for evaluating nitrogen loadings. Other reports from different locations were researched but not used due to their difference in geographic location and because the methods used were beyond the scope of this project.

Section Two: Irrigated Crops

Yakima Valley is one of the world's most fertile growing regions with more than 240,000 acres of cropland in the county.[11] Agriculture is the primary economic activity in Yakima County, accounting for approximately 70-80% of land use.

Inorganic fertilizers can contain high amounts of nitrogen. Nitrogen application is essential to crop growth and development. Application of nutrients or water at rates greater than plant demand can result in excess nitrogen infiltrating through the soil below the root zone into the groundwater. Also, nitrogen applied at appropriate rates but with high irrigation rates can move rapidly through the vadose zone, prior to full crop uptake. The amount, timing, frequency, and type of fertilizer, as well as the timing and amount of irrigation relative to the application of fertilizer and plant water demand affect the contribution to groundwater from fertilizer. Other factors such as denitrification in the soil by microorganisms, soil type, and volatilization to the atmosphere, also affect the amount of nitrate in groundwater.

Methodology

Both historic and current use of fertilizers in Yakima County has contributed to groundwater nitrate levels. However, it is difficult to establish historic contributions and to accurately gauge on-going activities. In addition, crop management has advanced substantially over the past 20 years with more precise nutrient and water management for crops including hops, grapes, and fruits.

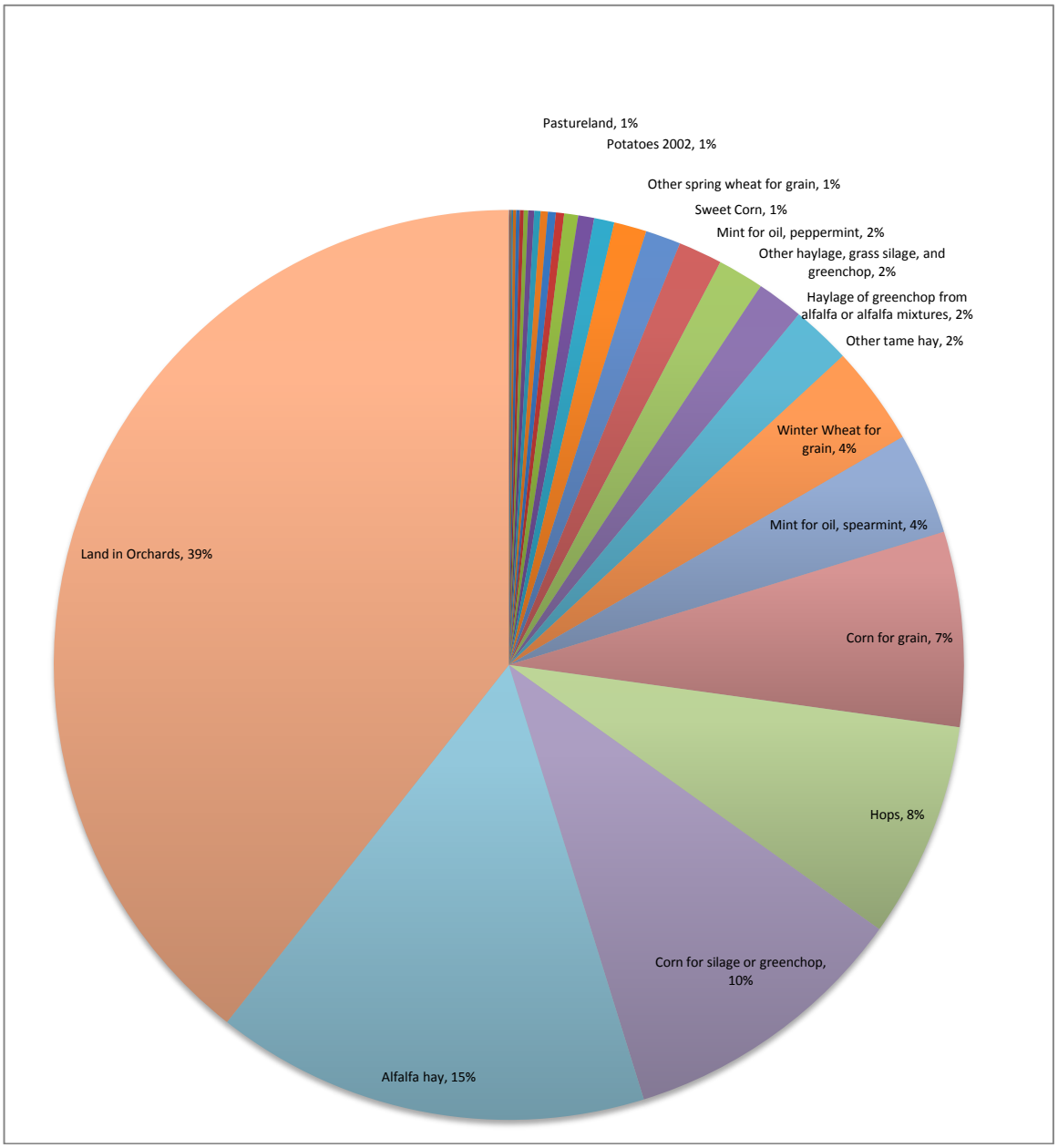
The first step to estimate the amount of current nitrogen that is being added to the land by irrigated crops is to determine the amount of irrigated crop acreage by individual crops. These amounts are included in Table 1. Specific crop data was taken primarily from the 2007 Census of Agriculture.[12] When the 2007 census did not provide adequate information, crop data from the 2002 Census of Agriculture was used.[13] Figure 1 provides a breakout of the percentage of total acres for each agricultural activity.

Each crop requires a different nitrogen fertilizer application rate. Since application rates specific to Yakima Valley could not be found, the recommended average nitrogen application rates for each crop was obtained from the Washington State University fertilizer guidelines.[14] The average of the high and low fertility rates was used to approximate annual nitrogen input by crop. It is recognized that these rates are general rates and the specific application rates by farmers will vary.

The nitrogen fertilizer application rate for orchard land was acquired from the "Southern Willamette Valley Groundwater Management Area Nitrogen/Nitrate Budget Report" since this rate was not available from WSU. It was assumed that the application rate would be the same for all orchard crops. All of the rates are shown in Table 1. The estimated amount of nitrogen applied annually to each crop was calculated by multiplying the Yakima County crop acreage by the average nitrogen application rates. (See Table 1 and Figure 2)

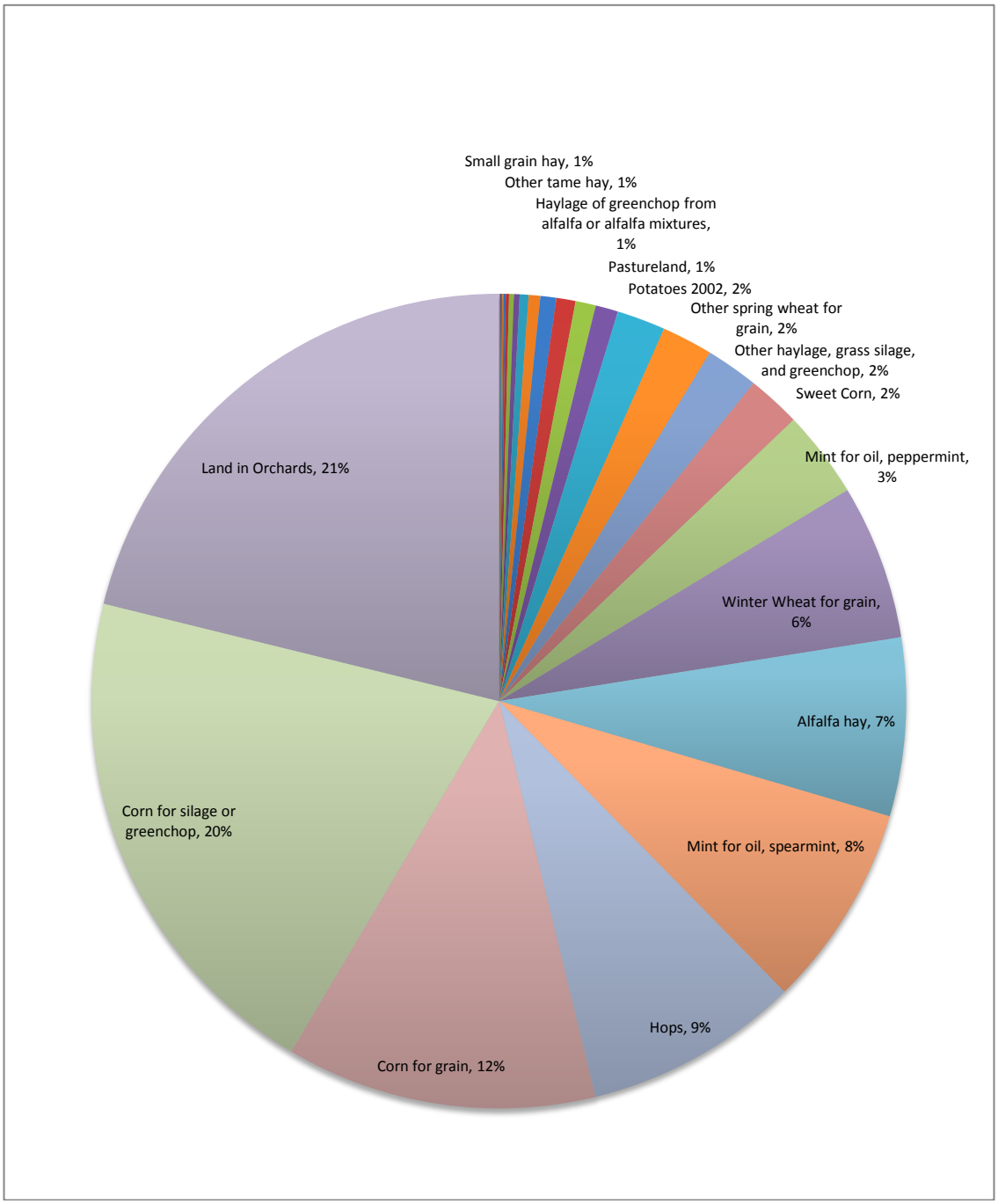
Fertilizer application rates for pumpkins and tomatoes could not be found in the WSU fertilizer application guide so they are not included in the tables for irrigated agriculture. However, the acreage for these two crops is small and the potential impact in the total numbers is small.

Figure 1: Agricultural use by Crop Type (1)



1. 2007 Census of Agriculture unless otherwise noted.

Figure 2: Nitrogen fertilizer applied annually by crop (1)



1. Nitrogen Rates acquired from Washington State University fertilizer guide except for Orchard land.. Orchard land Nitrogen rate acquired from "Southern Willamette Valley Groundwater Management Area Nitrogen/Nitrate Budget Report". Crop acreage acquired from 2007 Census of Agriculture except otherwise noted

Table 1: Crop Acreage, Fertilizer Application Rates and Estimated Nitrogen Loading Totals

Crop (1)	Total Irrigated Acre in Yakima County	WSU Fertilizer Application Guidelines (lbs/acre) (2)	Estimated Total Pounds of Nitrogen Applied Annually per Irrigated Crop
Barley for grain – 2002	69	67	4,623
Corn for grain	16,755	136	2,278,680
Dry edible beans, excluding limas	537	78	41,886
Triticale	622	137	85,214
Winter Wheat for grain	8,547	133	1,136,751
Other spring wheat for grain	2,803	133	372,799
Alfalfa Seed	683	35	23,905
Alfalfa hay	37,363	35	1,307,705
Small grain hay	1,203	97	116,691
Other hay	5,134	97	148,798
Wild hay	79	97	7,663
Haylage of greenchop from alfalfa or alfalfa mixtures	4,017	35	140,595
Other haylage, grass silage, and greenchop	3,983	97	386,351
Corn for silage or greenchop	25,047	150	3,757,050
Hops	18,587	85	1,579,895
Mint for oil, peppermint	3,775	170	641,750
Mint for oil, spearmint	8,786	170	1,493,620
Asparagus	336	104	34,944
Onions, dry 2002	521	125	65,125
Peas, Chinese 2002	40	30	1,200
Peas, green 2002	367	30	11,010
Peppers, bell	320	45	14,400
Peppers other than bell 2002	72	45	3,240
Potatoes 2002	1,737	205	356,085
Pumpkins 2002	99	N/A	N/A
Squash 2002	705	98	6,909
Sweet Corn	3,034	129	391,386
Tomatoes in the open 2002	256	N/A	N/A
Land in Orchards (3)	95,351 Apples (54,676); Grapes (18,871); Cherries (10,838); Pears (8393); Peaches (1024); Nectarines (611); Plums (405)	41	3,909,391
Pastureland	1,377	120	165,240
Totals	242,205		18,482,906

1. All Crop data acquired from the 2007 Census of Agriculture report unless noted otherwise.
2. Recommended fertilizer application rates acquired from the Washington State University fertilizer guide.
3. Orchard land Nitrogen rate acquired from "Southern Willamette Valley Groundwater Management Area Nitrogen/Nitrate Budget Report".

Results

The crops with the potentially highest nitrogen loading from crop fertilizers are:

- Orchard Land – 21%
- Corn for silage or greenchop – 20%
- Corn for grain – 12%
- Hops – 9%
- Mint for oil, both peppermint & spearmint – 8%
- Alfalfa Hay – 7%
- Winter wheat for grain – 6%

These seven crops account for nearly 83% of the total nitrogen loading from crop fertilization in Yakima County. Corn is of particular interest because of its high nitrogen application rate. Orchard land has a relatively low nitrogen application rate but because the total acreage it accounts for the highest nitrogen loading in Yakima County for irrigated crops. However, as stated above, the crop management practices for crops in orchard land are generally very closely monitored because of the need to ensure high quality products.

Section Three: Confined Animal Feeding Operations

In 2008, there were 69 dairies registered with the Washington Department of Agriculture that housed over 130,000 animals in Yakima County.[15] Manure from these dairies has been historically applied back to the land to aid in crop growth. If the manure is applied in too large a quantity, excess nitrogen in the form of nitrate can leach into the groundwater.

In 1998, the Dairy Nutrient Management Act was established to require all dairy farms to develop and implement a nutrient management plan in order to prevent discharge of livestock wastes into state waters. Enforcement of this act is the responsibility of the Washington State Department of Agriculture (WSDA). The WSDA must inspect all dairies in Yakima County at least once every 22 months. Up until 2003, the NPDES permitting process was under the jurisdiction of the Department of Ecology but due to a reduction in state inspection resources, jurisdiction was handed over to the WSDA.

Methodology

The number of dairies and dairy cows in Yakima County was acquired from the WSDA. The WSDA collected the data directly from dairy farmers when they were required to report to the WSDA in order to maintain their permits. Data for other animals, including beef cows was acquired from the 2007 Census of Agriculture for Yakima County.[16] A nitrogen production rate for dairy cattle was taken directly from the WSDA data. The values in this report are for the total annual nitrogen production without calculating in estimated losses from handling, storage, and transportation (35,658,623 lbs/year).

A nitrogen production rate for all other animals including beef cattle was acquired from a 2006 United States Geological Survey report.[17] These rates do not include the nutrient losses due to volatilization during storage, handling, and application of manure. The estimated rates were then multiplied by the number of animals to establish an estimated annual nitrogen production for each animal type.

Results

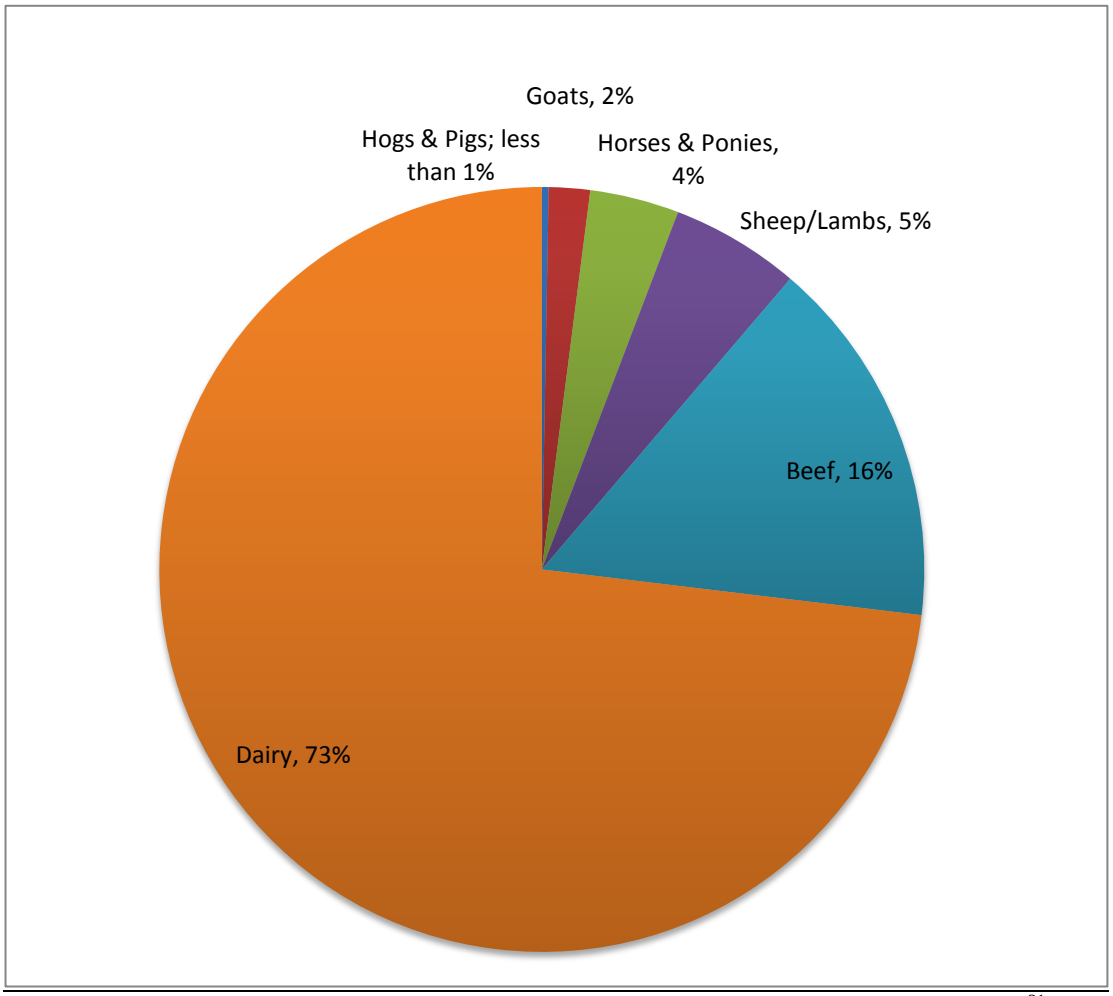
Cattle in general are the larger nitrogen producers of all of the livestock in Yakima County, but dairy cows specifically are the largest contributor of nitrogen in the Yakima Valley. Dairy cows account for 73% of the total livestock in Yakima County (Figure 3), and produce 89% of the total nitrogen contributed to the Yakima County system from livestock (Figure 4 – using the total nitrogen production without calculating in estimated losses). Beef cattle were the next largest nitrogen producer accounting for 16% of the total livestock in Yakima County (Figure 3), and producing 9% of the total nitrogen contributed to the Yakima County system from livestock (Figure 4).

Table 2: Livestock Nitrogen Production in Yakima County

Livestock Type (1)	# of Animals	Estimated Nitrogen (lbs/animal/yr) (2)	Total Nitrogen (lbs/yr) (3)
Dairy	133,541	267.02	35,658,623
Beef	28,594	120.7	3,451,296
Sheep/Lambs	9,971	18.51	184,563
Horses & Ponies	6,893	102.2	704,465
Goats	3,175	23	73,025
Hogs & Pigs	528	21.73	11,473
Total:	182,702		40,083,445

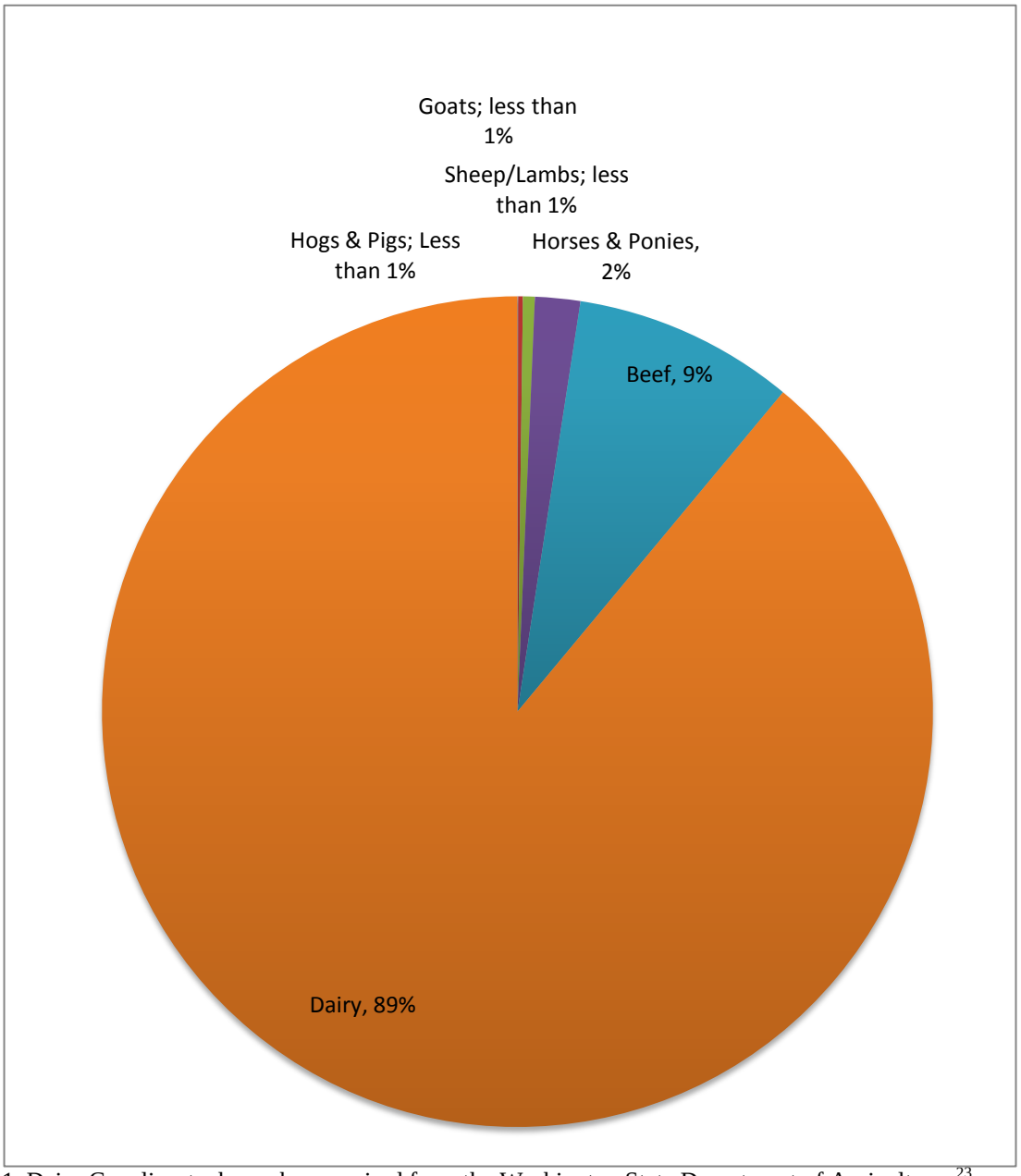
1. Livestock numbers acquired from 2007 Census of Agriculture except Dairy Cow.[18] Dairy Cow number acquired from the Washington State Department of Agriculture.[19]
2. Nitrogen rate for Dairy Cows acquired from the Washington State Department of Agriculture. Nitrogen rates for all other animals acquired from 2006 USGS 2006 report "County-Level Estimates of Nutrient Inputs to the land Surface of the Conterminous United States, 1982-2001".[20]
3. Does not include losses from storage, handling, and transportation

Figure 3: Total Livestock by Percentage in Yakima County, 2007/2009 (1)



1. Dairy Cow livestock number acquired from the Washington State Department of Agriculture.[21]
All other Livestock numbers acquired from 2007 Census of Agriculture[22]

Figure 4: Source of Animal Manure (1)



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Section Four: Septic, Wastewater Systems, and Biosolids

Human waste is managed primarily by city wastewater treatment plants, but in Yakima County, a large percentage of the mostly rural population relies on septic systems as well. As of 2009, there were about 22,000 septic systems registered with the Yakima County. Septic systems are of varying sizes and efficiency. The size of a system can determine the amount of nitrogen input from this system.

Methodology/Results

There are 16 permitted wastewater treatment facilities in Yakima County.[27] Wastewater treatment facilities process and treat wastewater to produce a biosolid. Biosolids are a nutrient-rich organic material produced when treating wastewater solids. After the solids have been processed and treated they are recycled as fertilizer and soil amendment. Once applied to the land, the biosolids release nitrogen, phosphorous, potassium, and zinc.

A few wastewater treatment facilities handle their biosolids themselves, but the majority of biosolids generated in Yakima County are handled by a private company, Natural Selection Farms. The company has a network of local farms that can apply the biosolids to their crops. Natural Selection Farms also accepts biosolids from out-of-county sources to meet their demand.

The Yakima Health District monitors the program in Yakima County. The amount of biosolids applied each year varies depending on the needs of the individual farms involved in the program. Table 3 summarizes information provided by the Yakima County Health Department on the total amount of nitrogen in pounds applied to the land from biosolids in Yakima County from 2005-2009.

The amounts of nitrogen were derived by taking the rate of nitrogen application allowed per field in pounds and multiplying by the number of acres for the field. As the table indicates, the amount of nitrogen, the number of acres and the number of fields where the biosolids are applied vary by year. The Department of Ecology requires soil nitrogen monitoring for biosolids application and does not allow application of biosolids to cropland that has received more nitrogen than permits allow. In addition, Ecology requires these facilities to conduct groundwater monitoring and corrective action if groundwater quality standards are violated. The average amount of nitrogen applied to the land for the five years of reporting is about 186,000 pounds per year.

Table 3: Amount of Biosolids Utilized in Yakima County

	2005	2006	2007	2008	2009
Total Lbs Nitrogen/year applied	58,305	105,669	419,174	175,300	173,667
# acres biosolids applied	346	831	2994	1982	1381
# fields biosolids applied	11	28	63	41	59

In order to determine the potential generation of nitrogen from anthropogenic sources including septic systems, a simple methodology was used. A nitrogen rate of approximately 6 pounds of nitrogen per person per year was adopted from the EPA's Regional Applied Research Effort (RARE) for the Yakima River Basin.[28] According to 2007 United States Census data, the population of Yakima County is 234,564. The nitrogen production rate (6 pounds per year) was multiplied by the 2007 population amount to get the total potential amount of anthropogenic nitrogen contribution per year.

Table 4: Anthropogenic Nitrogen Rates

Total Population (2007) (1)	234,564
Anthropogenic Nitrogen Rate (2)	6 lb/yr/person
Total:	1,407,384 lb/yr

1. Population acquired from 2007 U.S. Census Bureau
2. Nitrogen Rate acquired from RARE report, EPA 2009[29]

The total amount of nitrogen from biosolids and from other anthropogenic sources is 1,593,807 pounds per year.

Section Five: Nitrogen deposited by Precipitation

Precipitation contributes a small amount of nitrate to the Yakima County, but was included in this report to provide prospective to the nitrogen loading model created in this report.

Methodology/Results

In order to calculate total nitrate contribution a formula was created. Yakima County receives an average of 8 inches of precipitation a year.[30] According to the 2002 United States Census, the county covers 4,296.23 square miles. Data for the approximate amount of nitrate in precipitation was acquired from the National Atmospheric Deposition Program's (NADP) Mount Rainier National Park monitoring station and a 0.195 mg/L nitrate concentration was established.[31] The NADP has five monitoring stations in Washington state which sample rainwater weekly for concentration values of various compounds including NO3 (nitrate as nitrogen). The volume of rainfall was calculated for Yakima County using the annual rainfall and county area and then was multiplied by the NADP's nitrate concentration to get a nitrogen loading of 97,202.6 lbs annually. It was assumed that the nitrate was equal to the total nitrogen for this analysis.

Table 5: Precipitation nitrogen contribution calculations

County Area U.S. Census Bureau 2002	Annual Rainfall	Nitrate (NO3-N) Concentration (NADP, 2007)	Total Nitrogen Load (lbs/year)
4,296.23 square miles	8 inches	0.195 mg/L	**972,023**

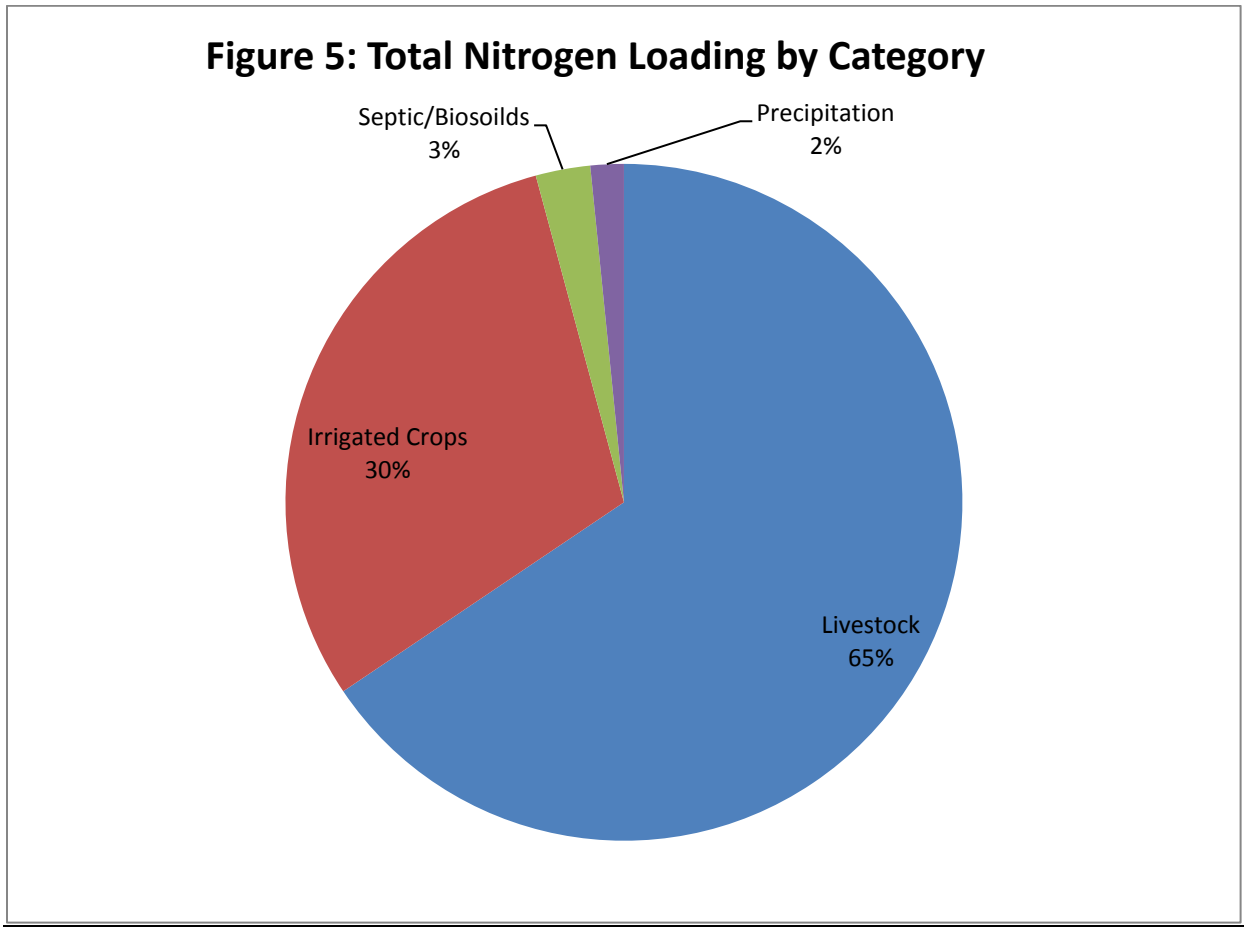
Section Six: Summary

The results from this screening analysis were used by EPA in the study design for the Lower Yakima Valley project. Based on this screening analysis and other information, EPA focused its sampling efforts on three sources: dairies; irrigated cropland, and residential septic systems. EPA is working to further refine these estimates and further evaluate nitrogen fate and transport in a collaborative project between EPA and the USGS.

Based on the estimates from this screening analysis, livestock account for about 65% of the nitrogen generated in Yakima County (Table 6 and Figure 5). The second largest nitrogen contribution comes from irrigated crops, which accounts for about 30% of the total nitrogen loading calculated (Table 6 and Figure 5). The remaining 5% comes from either septic systems and biosolids or precipitation.

Table 6: Total Nitrogen Loading by Category

Source	Nitrogen Loading (lbs/year)	Percentage of Total
Irrigated Crops	18,482,906	30%
Livestock	40,083,445	65%
Septic and Biosolids	1,593,807	3%
Precipitation	972,023	2%
Total:	61,132,181	



More specifically, dairy cows were estimated to contribute about 58 percent of the nitrogen generated in Yakima County (Figure 6). Beef cattle were estimated to contribute about 6% of the total nitrogen load in Yakima County (Figure 6).

The next highest contributor is irrigated cropland, which accounted for nearly 30% (Figure 6) of the total nitrogen loading with the following crops contributing the most.

- Corn – 10%
- Orchards – 6%
- Mint – 3%
- Hops – 2%
- Winter Wheat – 2%
- Alfalfa Hay – 2%

The three other sources looked at during this study, precipitation, septic and biosolids and other livestock types, all contributed a minimal amount of nitrogen to the Yakima County system accounting for about 10% combined (Figure 6).

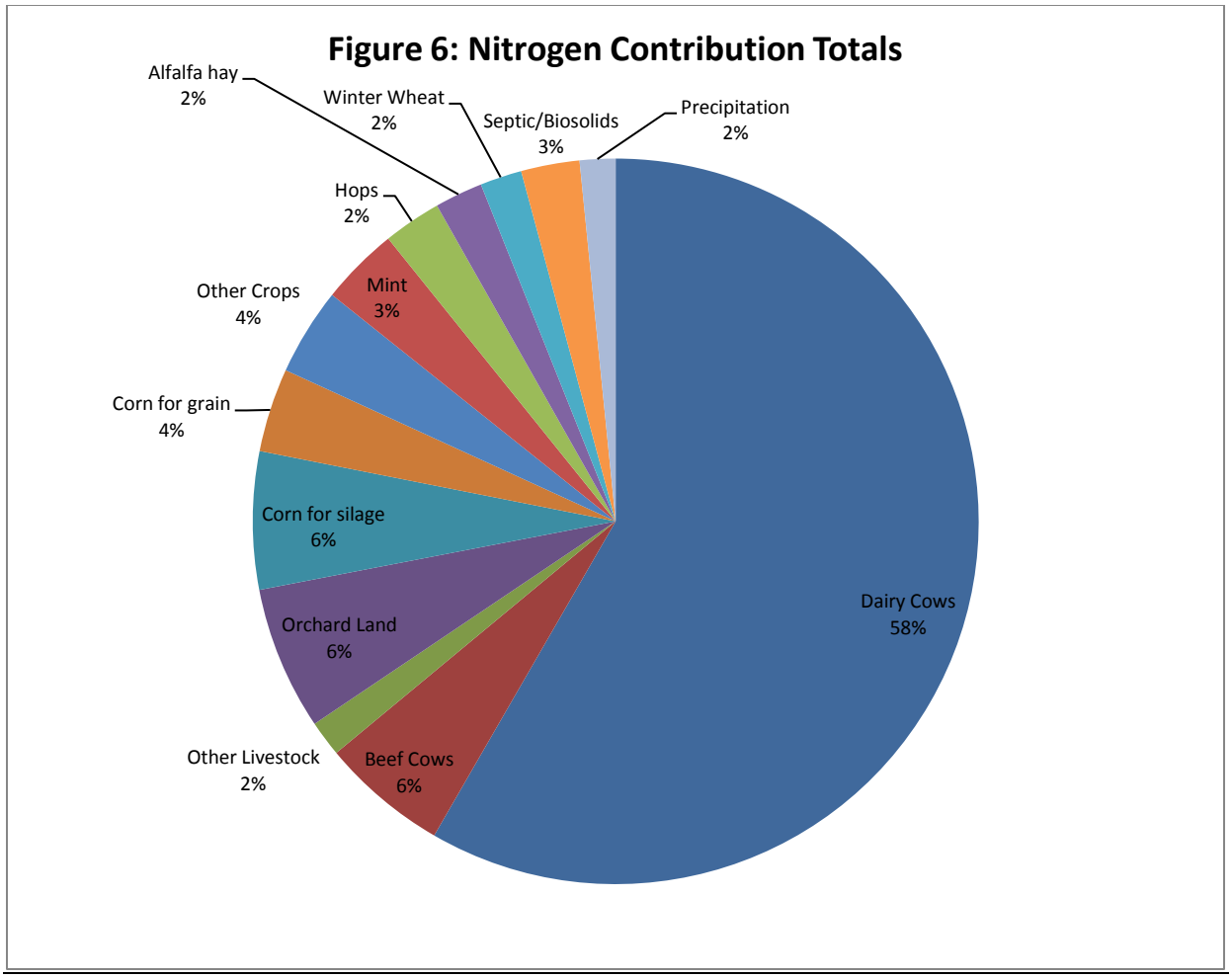


Figure 6: Nitrogen Contribution Totals
Alfalfa hay 2%
Winter Wheat 2%
Septic/Biosolids 3%
Precipitation 2%
Hops 2%
Other Crops 4%
Mint 3%
Corn for grain 4%
Corn for silage 6%
Orchard Land 6%
Other Livestock 2%
Beef Cows 6%
Dairy Cows 58%

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