Chapter 6 Source, Linkage, and Loading Analysis

An analysis of salt and nutrient loading occurring due to land use activities is presented to identify sources of salt and nutrients, the linkages between those sources and the drinking water aquifer, and the mass of salts and nutrients loaded to the drinking water aquifer from those sources.

Salt and nutrient loading from land use activities to the Santa Rosa Plain groundwater basin is due to numerous sources, including:

- Irrigation water (e.g., potable water, groundwater, and recycled water);
- Agricultural inputs (e.g., fertilizer and amendments);
- Human waste (e.g., septic systems);
- Animal waste (e.g., dairy manure spreading); and
- Infrastructure (e.g., infiltration from recycled water storage ponds).

Most of these sources are associated with rural and agricultural areas. Urban area salt and nutrient loads are assumed to be primarily routed to the municipal wastewater system for recycling or discharge rather than to groundwater, except for landscape irrigation. Other sources of salts and nutrients, such as atmospheric loading, are not considered a significant contributing source of salts and nutrients and are not captured in the loading analysis.

This chapter of the Plan describes how the salt and nutrient loads are estimated and how changes to the loading model assumptions impact predicted loading. The salt and nutrient loads developed in this chapter are combined with loading estimates for surface water, loading estimates based on recycled water goals, existing water quality, and water balance information to perform an antidegradation analysis, as described in Chapter 7. As previously stated, benefits of increased storm water recharge are not included in the analysis.

6.1 Methodology

To support this Plan and to better understand the significance of various loading factors, a GIS loading model was developed. The loading model is a simple, spatially-based mass balance tool that represents TDS and nitrogen loading on an annual-average basis. It is not a calibrated model as insufficient data are available to support such an effort, and therefore the model results are more uncertain than results from a fully-calibrated model. Despite the uncalibrated nature of the model, it is considered suitable for this analysis of basin conditions, with the recognition that a more rigorous model, potentially based on the ongoing USGS modeling effort, may be developed in a future update to the Plan.

Primary inputs to the model are land use, irrigation water source, recycled water storage ponds locations, septic system areas, and surface geology characteristics. These datasets are described in the following sections. The general process used to arrive at the salt and nutrient loads is as follows:

- Identify the analysis unit to be used in the model. In the case of the Santa Rosa Plain, parcels from the Sonoma County Assessor's Office are used as the analysis unit.
- Categorize land use categories into discrete groups. These land use groups represent land uses that have similar water demand as well as salt and nutrient loading and uptake characteristics.
- Apply the land use group characteristics to the analysis units.
- Apply the irrigation water source to the analysis units. Each water source is assigned concentrations of TDS and nitrogen.
- Apply the septic system assumption to the analysis units.
- Apply the infrastructure assumption to the analysis units.
- Apply the surface texture characteristics to the analysis units.
- Estimate the water demand for the parcel based on the irrigated area of the parcel and the land use group.

- Estimate the TDS load applied to each parcel based on the land use practices, irrigation water source and quantity, septic load, and infrastructure load. The loading model assumes that no salt is removed from the system once it enters the system. Other transport mechanisms could reduce the total quantity of salt in the basin.
- Estimate the nitrogen load applied to each parcel based on the land use practices, irrigation water source and quantity, septic load, and infrastructure load. The loading model assumes that a portion of the applied nitrogen is used by plants and removed from the system. Additional nitrogen is converted to other species and is lost from the system as well. Hydraulic conductivity is used to reflect the vertical mobility of the nitrogen into the aquifer before being converted or used.

Depending on the analysis being performed, the loading can also be analyzed on a per acre basis so as to be able to compare the relative loading of large and small parcels to one another.

6.2 Data Inputs

6.2.1 Land Use

Land use data are obtained from the 2005 Sonoma County Assessor's Office parcel dataset. This dataset contains several hundred discrete land use categories. These categories are consolidated into the following land use groups:

- **Urban commercial and industrial**
- **Farmsteads**
- **Vines**
- **Urban residential**
- **Pasture**
- **Grassland/ Herbaceous**
- **Dairy production areas**
- **Urban landscape**
- **Water features**
- **Perennial forages**
- **Non-irrigated vines**
- **Shrub/Scrub**
- **Non-irrigated orchard**
- **Barren land**
- **Urban commercial and industrial, low impervious surface**
- **Flowers and nursery**
- **Other confined animal feeding operations**
- **Paved areas**
- **Other row crops**
- **Orchard**
- **Warm season cereals and forages**

Local stakeholders and Plan partners confirmed that the land use is substantially unchanged since that time, within the accuracy requirements of this type of analysis. The spatial distribution of land uses is shown in Figure 7-1. Because there are so many distinct categories, a discrete color for each type could not be assigned. Therefore, land use categories with similar characteristics (i.e. urban, non- irrigated agriculture, irrigated agriculture) are shown as a color category.

Each land use group is assigned characteristics including:

- Applied water;
- Percent irrigated;
- Applied nitrogen;
- Used nitrogen;
- Leachable nitrogen; and
- Applied TDS.

Leachable nitrogen is assumed to be the applied nitrogen less 10 percent of the applied nitrogen for gaseous loss, less the used nitrogen (uptake). Table 7-1 consists of a matrix of loading values for these land use categories and characteristics.

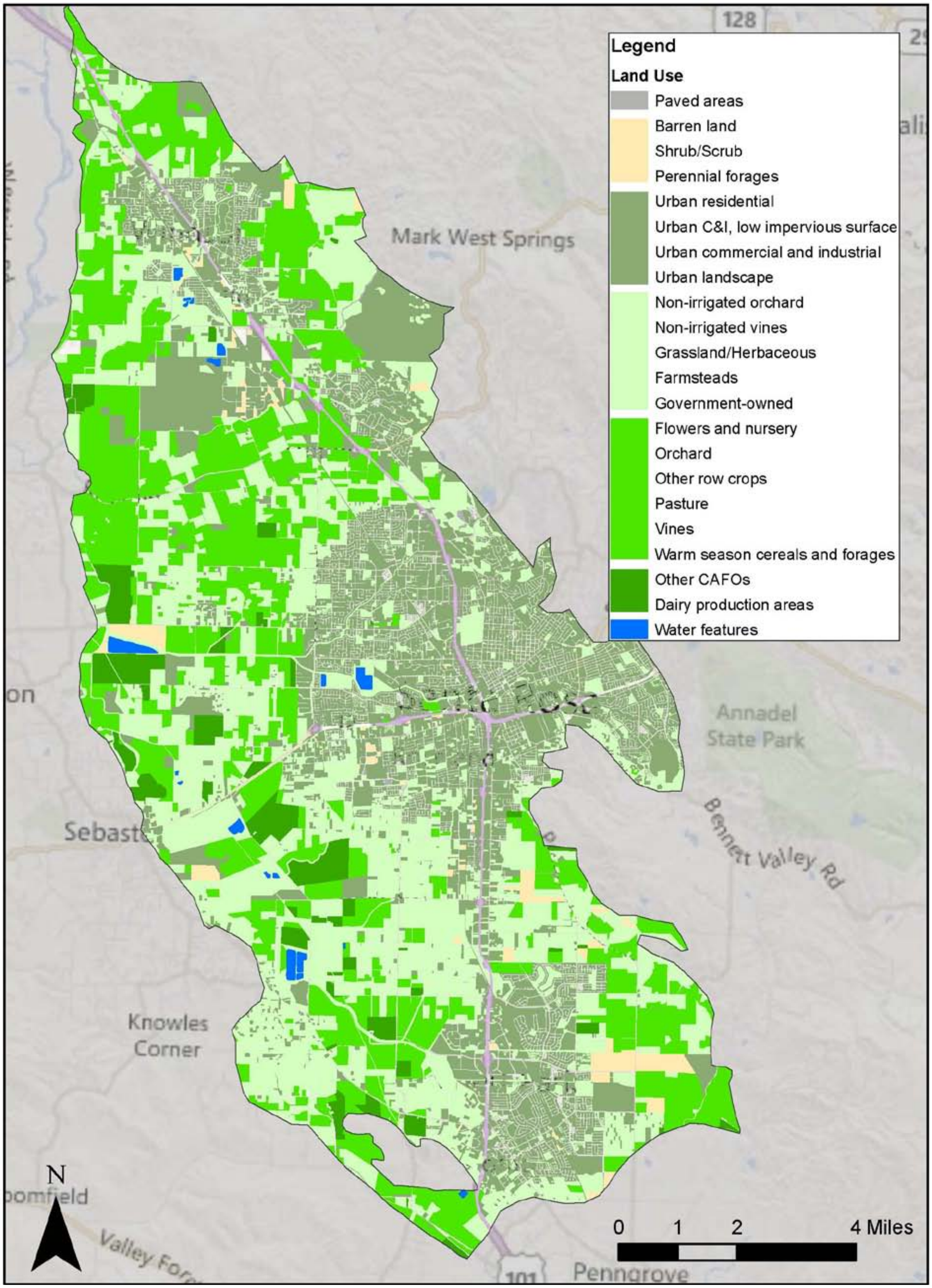

Figure 6-1: Land Use

Table 6-1: Land Use Related Loading Factors

Land Use Group	Applied Water[2] (in/yr)	Percent Irrigated[3]	Applied Nitrogen[4] (lbs/acre-year)	Used Nitrogen[5] (lbs/acre-year)	Leachable Nitrogen[6] (lbs/acre-year)	Applied TDS[7] (lbs/acre-year)
Urban Commercial and Industrial	46.8	5%	91	59	23	717
Farmsteads	46.8	30%	83	54	21	717
Vines	9.4	100%	29	23	3	168
Urban Residential	49.2	25%	91	59	23	478
Pasture	49.2	40%	60	39	15	637
Grasslands/ Herbaceous	0	0%	0	0	0	0
Dairy Production Areas[1]	0	0%	See Table 6-2			
Urban Landscape	46.8	20%	91	59	23	637
Water Features	0	0%	0	0	0	0
Perennial Forages	49.2	0%	21	15	4	398
Non-Irrigated Vines	0	0%	17	16	0	478
Shrub/Scrub	0	0%	0	0	0	0
Non-Irrigated Orchard	0	0%	75	60	7	319
Barren Land	0	0%	0	0	0	0
Urban C&I, Low Impervious Surface	46.8	10%	91	59	23	478
Flowers and Nursery	38	100%	124	81	31	956
Other Concentrated Animal Feeding Operations (CAFOs)	0	10%	83	0	75	797
Paved Areas	0	0%	0	0	0	0
Other Row Crops	20.4	100%	100	65	25	558
Orchard	29.6	100%	133	100	20	1,195
Warm Season Cereals and Forages	23.2	100%	124	87	25	558

Footnotes provided on the following page.

Table 6-1 Footnotes:

1 See discussion on dairy parcels below.

2 Base applied water values and other climatic data are taken from DWR land and water use data (http://www.water.ca.gov/landwateruse/anlwuest.cfm). On this website, four years of data are available. Climatic data averages, based on these four years of data, were compared to the 21-year average of available CIMIS climatic data for the Santa Rosa area. As the two data sets correspond well, the average DWR applied water values were used, with some adjustment using crop coefficients for the Santa Rosa area to fit the study land use classes.

3 Percent of land area assumed to be irrigated within each class is estimated is based review of aerial photography and professional judgment of a reasonable, broad average for each class.

4 Applied nitrogen estimates are based on literature review for individual land cover classes and professional judgment. Applied nitrogen was then calculated for total acreage and checked against fertilizer sales records for Sonoma County (available from the California Department of Food and Agriculture). Application rates were then scaled to match sales records.

5 Uptake of nitrogen was estimated from available literature by multiplying reported yield figures by reported nitrogen concentrations for harvested plant parts. Balances between uptake and application were checked to ensure that nitrogen use efficiencies were in the reported ranges, adjusted for professional knowledge of irrigation and fertilization practice in each land cover class.

6 Maximum nitrogen leaching calculations for each land cover unit were calculated based on the balance between application, gaseous loss (volatilization and denitrification), and uptake. The maximum was then reduced by varying amounts depending on soil conditions mapped for the area.

7 Applied TDS estimates are based on literature review for individual land cover classes and professional judgment. Applied nitrogen was calculated for total acreage and checked against fertilizer and amendment sales records for Sonoma County (available from the California Department of Food and Agriculture). Application rates were then scaled to match sales records. Fertilizer tonnages were calculated from an average of available materials, weighted by their proportion of sales in Sonoma County, and with sufficient nitrogen content to satisfy nitrogen demand from applied nitrogen.

Due to the significance of dairies as a source of salts and nutrients within the Santa Rosa Plain basin boundaries, some additional consideration was applied to dairy parcels. To better reflect land use practices, the applied, used, and leachable nitrogen characteristics and the applied TDS characteristic were further subdivided into production areas, ponds, and land application areas. Leachable nitrogen was calculated the same way as for the other land use groups except that gaseous loss was assumed to be 20 percent as opposed to the 10 percent assumed loss for other land use groups. Table 6-2 summarizes the assumed dairy characteristics, which were developed with review and input from representatives of the Western United Dairymen, to best reflect the typical operations of local organic dairies.

Table 6-2: Assumed Characteristic Dairy Values for the Loading Model

Dairy Subdivision Designation	Percent of Total Parcel Area Used Per Designation	Applied Nitrogen **(lbs/acre-year)**	Used Nitrogen **(lbs/acre-year)**	Leachable Nitrogen **(lbs/acre-year)**	Applied TDS **(lbs/acre-year)**
Production Area	6%	20	0	8	82
Ponds	1%	141	0	113	933
Land Application Area	93%	367	352	30	1,280

6.2.2 Irrigation Water Source

The irrigation water source data input is the result of a compilation of several different data sets. Potable water service areas served as the initial layer. Those areas not served by a potable municipal water source were then assumed to obtain irrigation water from local groundwater wells. Those parcels in a recycled water service area are assumed to use recycled water for outdoor application. The spatial extent of these water sources was determined by city service limits, recycled water studies, local knowledge, and stakeholder input.

For each irrigation water source, TDS and nitrogen concentrations were obtained from annual water quality reports and past and ongoing studies. Table 6-3 summarizes the water quality inputs used for each irrigation water source. The spatial distribution of water source is shown in Figure 6-2.

Table 6-3: Water Quality Parameters for Loading Model Water Sources

Source	TDS (mg/L)	Nitrate (as N) (mg/L)
Russian River	150	0
Russian River / Groundwater Blend	190	2
Groundwater	290 [a]	1.3 [a]
Recycled Water (Airport-Larkfield-Wikiup Sanitation Zone)	442	7.3
Recycled Water (Santa Rosa/Rohnert Park)	428	11.7
Recycled Water (Windsor)	460	6.45

a. Groundwater concentrations listed are the initial conditions for the loading model. This parameter changes in the model as groundwater concentrations change.

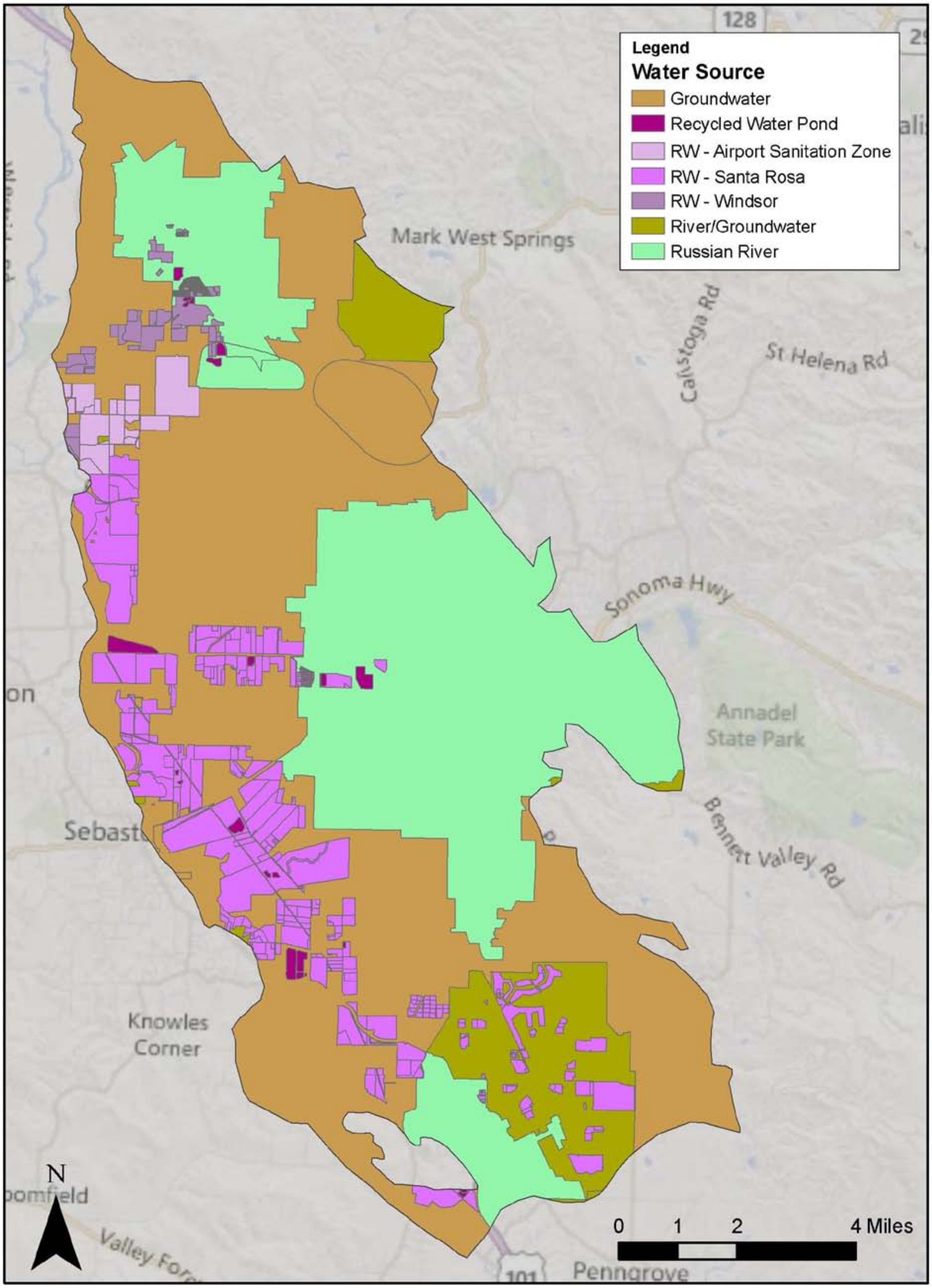

Figure 6-2: Water Source (Current)

6.2.3 Septic System Area

A dataset documenting which parcels have septic systems was not available. Locations of septic inputs were identified by analyzing city limits and the land use dataset. Parcels outside of the city limits were considered candidates for use of a septic system. Of those parcels, septic systems were assumed where a residence was identified in the land use dataset. Each parcel with a septic system was assumed to produce 263 gallons per day (gpd), based on 75 gpd/person with 3.5 people per system. The septic waste was assumed to have TDS concentrations of 450 mg/L and N concentrations of 40 mg/L. TDS concentrations are based on the average concentration of recycled water within the basin. Concentrations of N are based on medium strength untreated domestic wastewater as listed in Metcalf and Eddy (2003). The locations of parcels assumed to have septic systems are shown in Figure 6-3.

6.2.4 Recycled Water Ponds

Recycled water pond locations were identified through prior studies, familiarity with the recycled water systems within the basin boundaries, and stakeholder input. Regardless of the land use designation by the County Assessor's parcel dataset, no loading other than from infiltrating recycled water was assumed at pond locations. Table 6-4 summarizes the infiltration rate and concentrations of the constituents for each recycled water pond type. It should be noted that the infiltration rate of 63.5 in/yr is based on a study at Shone Farm (Brelje & Race, 2010), which likely has coarser soils than much of the Santa Rosa Plain, making this value conservative for the analysis. The location of the recycled water ponds is indicated in Figure 6-2.

Table 6-4: Loading Parameters for Recycled Water Ponds

Recycled Water Source	Infiltration Rate **(in/yr)**	TDS **(mg/L)**	N **(mg/L)**
Santa Rosa	63.5	428	11.7
Windsor	63.5	460	6.45
Other	63.5	442	7.3

6.2.5 Surface Textures

Surface textures (e.g., clay, silt, sand, and gravel) were obtained from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database. Surface textures for the basin are classified into textural classes which are, in turn, assigned a hydraulic conductivity and a permeability class. The permeability classes, defined by the USDA-NRCS, were used to develop an adjustment factor through linearly scaling the estimated permeabilities from 0.1 (lowest permeability) to 1.00 (highest permeability). The adjustment factor is used to represent how likely the nitrogen is to migrate to the aquifer relative to textural classes.

Similar logic was not applied to TDS as salts are assumed to be stable and do not adsorb into the soil. Table 6-5 summarizes the surface textures found within the basin boundaries and how those textures are represented in the loading model. The spatial distribution of surface textures, based on the SSURGO database, is shown in Figure 6-4.

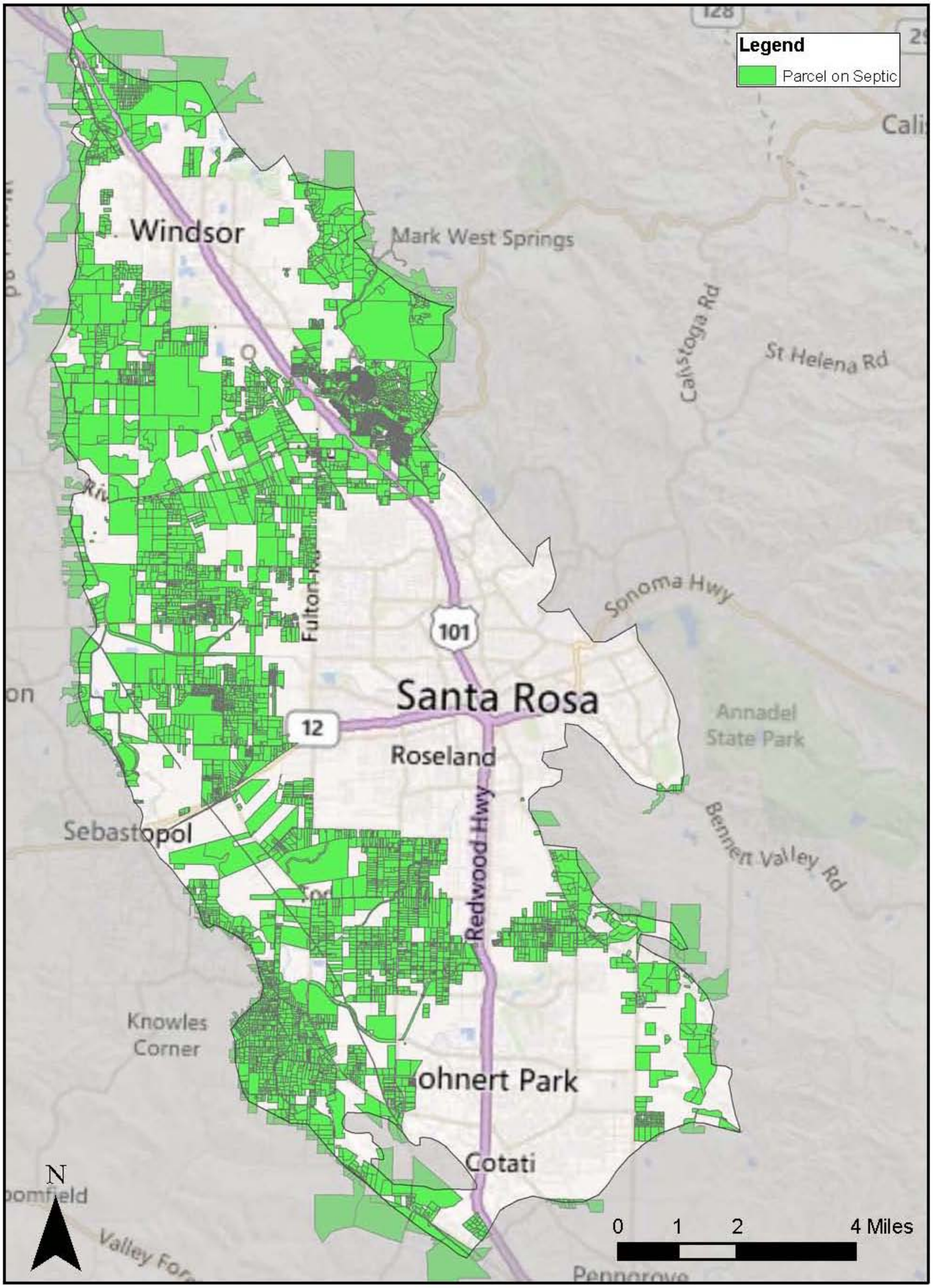

Figure 6-3: Septic Systems

Table 6-5: Loading Parameters for Surface Textures

Surface Texture	Textural Class	Symbol	Saturated Hydraulic Conductivity **(in/hr)**	Adjustment Factor[1]
Clay	Clay	c	0.03	0.10
Clay loam	Clay loam	cl	0.18	0.13
Cobbly clay loam	Clay loam	cl	0.18	0.13
Fine sandy loam	Sandy loam	sl	1.98	0.49
Gravelly clay loam	Clay loam	cl	0.18	0.13
Gravelly loam	Loam	l	0.73	0.24
Gravelly sand	Sand	s	4.49	1.00
Gravelly sandy loam	Sandy loam	sl	1.98	0.49
Gravelly silt loam	Silty loam	sil	0.48	0.19
Loam	Loam	l	0.73	0.24
Sandy loam	Sandy loam	sl	1.98	0.49
Silt loam	Silty loam	sil	0.48	0.19
Silty clay loam	Silty clay loam	sicl	0.23	0.14
Unweathered bedrock	-	-	0.00	0.00
Variable	-	-	0.48	0.19
Very gravelly loam	Loam	l	0.73	0.24
Very gravelly sand	Sand	s	4.49	1.00
Very gravelly sandy loam	Sandy loam	sl	1.98	0.49

a. Adjustment factors are based on permeability classes, defined by the USDA-NRCS. The factor linearly scales estimated permeabilities from 0.1 (lowest permeability) to 1.00 (highest permeability). The adjustment factor is used to represent how likely the nitrogen is to migrate to the aquifer, relative to the other textural classes.

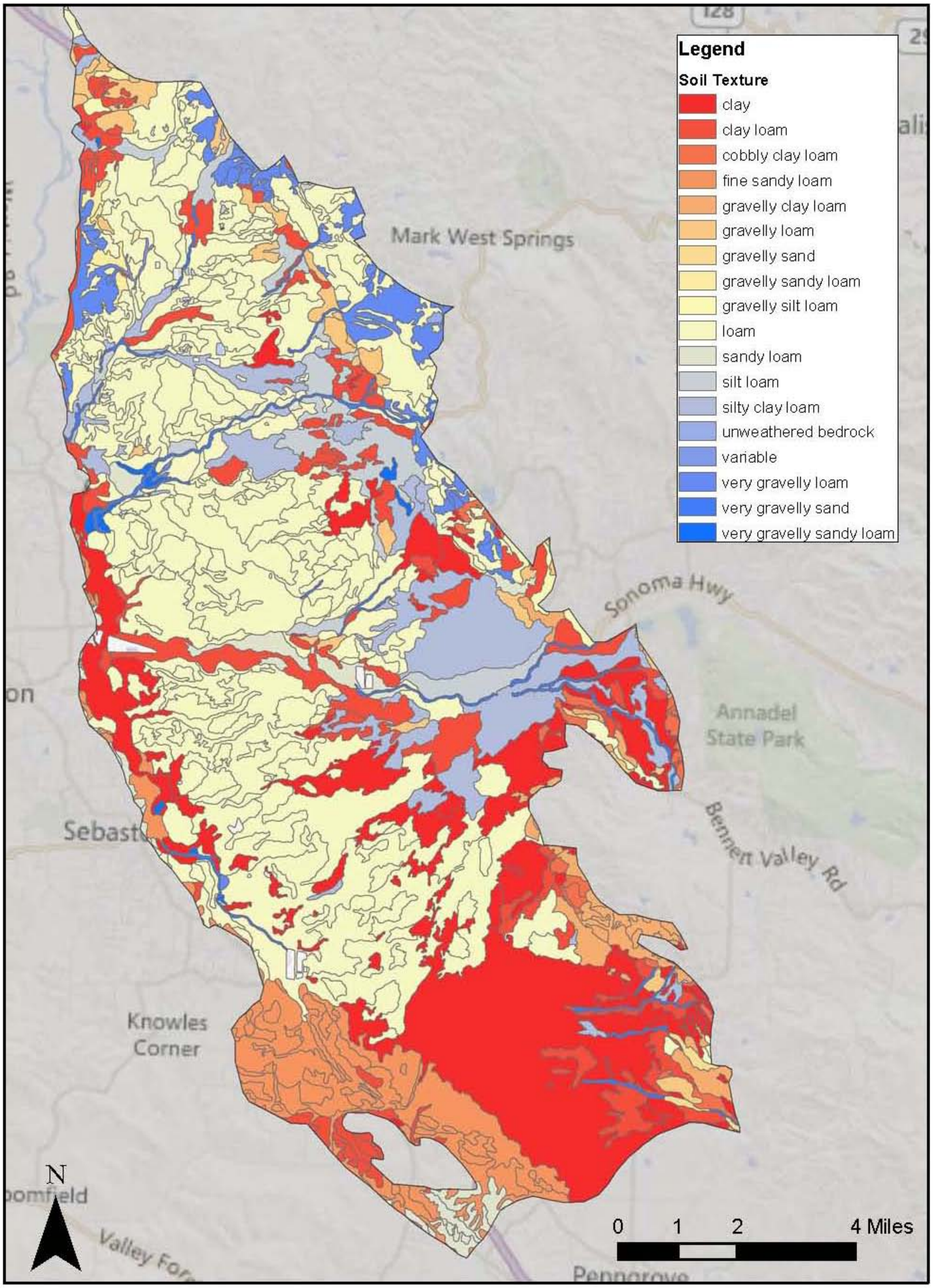

Figure 6-4: Surface Textures

6.3 Results

Based on the loading parameters and methodology described above, the loading model was used to develop TDS and nitrate loading rates across the basin. Table 6-6 summarizes the overall contribution of each land use group to total TDS and nitrate loading. The spatial distribution of TDS and nitrate loadings rates are shown in Figure 6-5 and Figure 6-6, respectively. The loading analysis estimates higher loading of TDS and nitrate in the rural areas of the basin; however, the localized exceedances of TDS and nitrate were found in the urban section. This misalignment could be the result of historical land use practices. Monitoring will help in understanding trends, as more data become available through the monitoring program.

Table 6-6: TDS and Nitrate Loading

Land Use Group	Total Area (acres)	Percent of Total Area	Percentage of Total TDS Loading	Percentage of Total Nitrate Loading
Urban Commercial and Industrial	8,062	11%	3%	3%
Farmsteads[a]	14,285	20%	31%	31%
Vines	10,707	11%	20%	16%
Urban Residential	11,855	17%	15%	14%
Pasture	3,498	5%	14%	17%
Grasslands/ Herbaceous	8,805	13%	1%	3%
Dairy Production Areas[b]	2,644	4%	7%	8%
Urban Landscape	2,623	4%	3%	1%
Water Features	579	1%	4%	3%
Perennial Forages	0	0%	0%	0%
Non-irrigated vines	0	0%	0%	0%
Shrub/Scrub	0	0%	0%	0%
Non-irrigated Orchard	0	0%	0%	0%
Barren Land	9,595	14%	0%	1%
Urban C&I, Low Impervious Surface	134	0%	0%	0%
Flowers and Nursery	185	0%	1%	1%
Other CAFOs	177	0%	0%	0%
Paved Areas	129	0%	0%	0%
Other Row Crops	68	0%	0%	0%
Orchard	61	0%	0%	1%
Warm Season Cereals and Forages	54	0%	0%	0%

a. Assumes farmsteads utilize septic systems.
b. See previous discussion on dairy parcels.

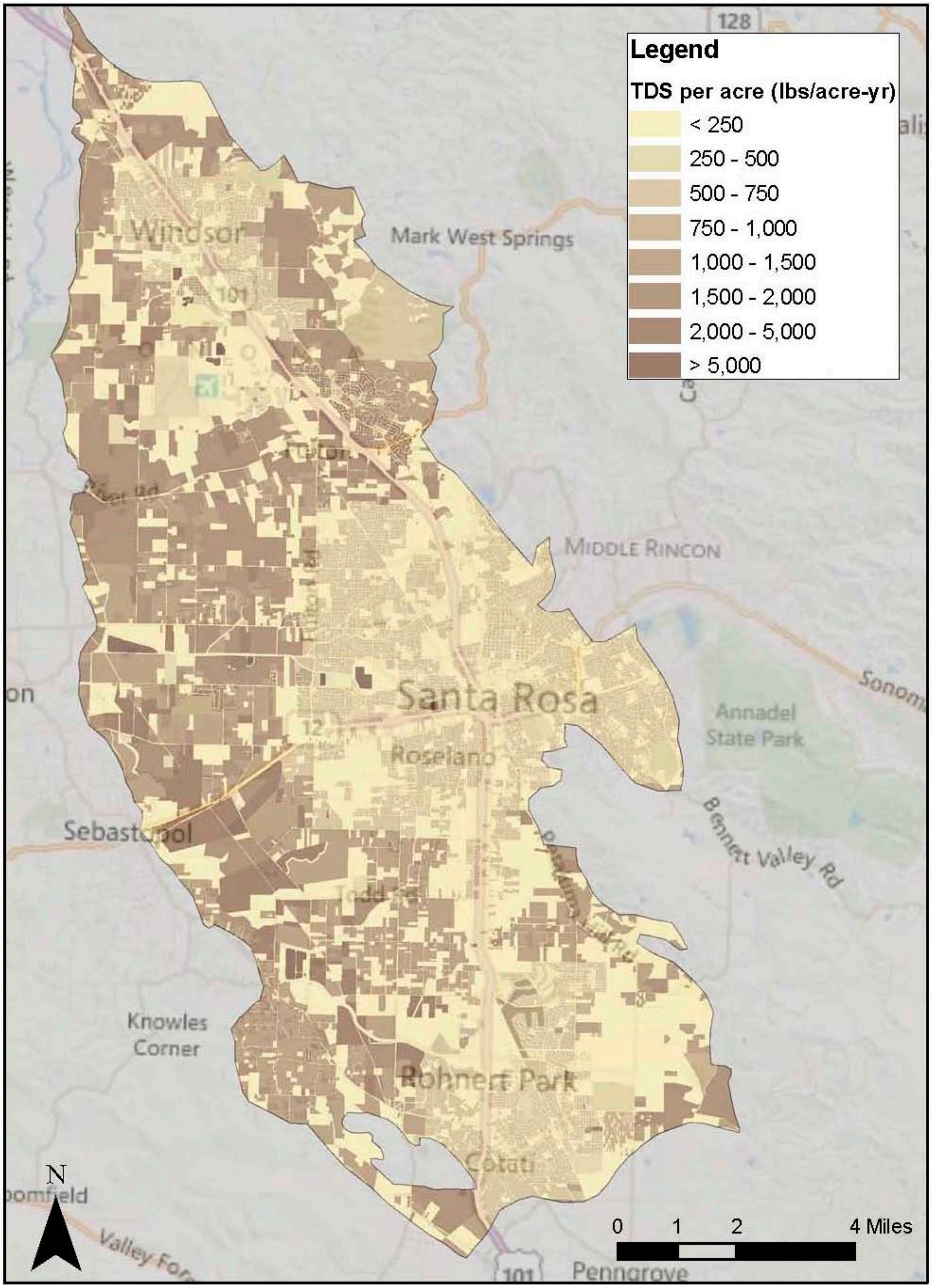

Figure 6-5: Estimated TDS Loading

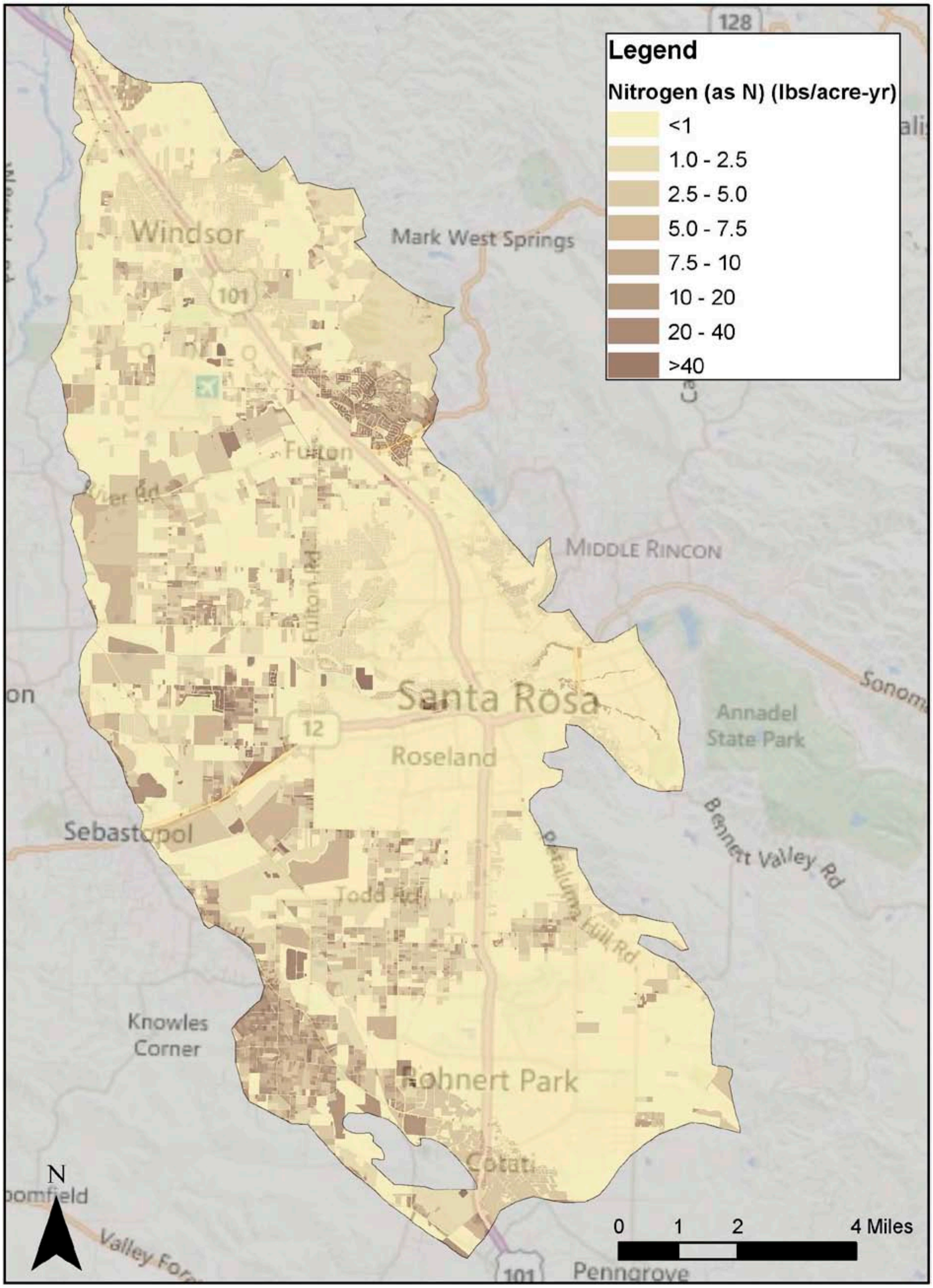

Figure 6-6: Estimated Nitrate Loading