7.0 TAHOE CITY/WEST SHORE NUTRIENT LOADING

7.1 Description of Study Area

The Tahoe City/West Shore area eastern extent begins at Dollar Point and extends west and south to Meeks Bay. For ease of presentation, this area has been split into five subregions (Figure 7-1). The North Tahoe City subregion includes the developed regions of Lake Forest and Tahoe City north of the Truckee River. The Ward Valley subregion includes the developed region south of the Truckee River including Sunnyside. Tahoe Pines and Homewood make up the Homewood subregion. Tahoma and Meeks Bay each make up individual subregions in the southern reach of the area. The major creeks consist of Dollar Creek, Lake Forest Creek, Barton Creek, Burton Creek, Ward Creek, Blackwood Creek, Madden Creek, Homewood Creek, Quail Lake Creek, McKinney Creek, and General Creek.

Human development is limited to a narrow band along the lake shore as the terrain is not conducive to development further west. The land use is primarily made up of single and multi-family residential, commercial and recreational land use types.

7.2 History of Development (Lindstrom et al. 2000)

During the 1850s and 1860s major thoroughfares were built through the Truckee River Canyon and along Tahoe's north shore. This brought the beginning of the resort development in Tahoe City in the 1860s. By the early 1860s the first log cabin was built and hay was being harvested from the meadows surrounding Tahoe City. Tahoe City town site was laid out in 1863 and became an official town site by 1868. Tourism flourished in the 1880s and resorts began to expand. During this time, Tahoe City was also considered a "medium large" logging camp. The early 1900s brought the railroad connecting Truckee and Tahoe City. This brought about another boost for tourism in the area. Beginning in the mid twenties, through the 1950's subdivisions were established in the Tahoe City area.

7.3 Local Geology

The geologic units that dominate the Tahoe City area, north of the Truckee River are Tertiary volcanic and Quaternary Basaltic rocks. Quaternary sedimentary deposits occur only as a narrow bank along the margins of Lake Tahoe, mostly near the outflow of the Truckee River and beneath Tahoe City. The area near Tahoe City does not have exposed granitic or metamorphic rock at the surface. The rocks are covered by younger volcanic rocks and sedimentary deposits (West Yost & Associates 1995).

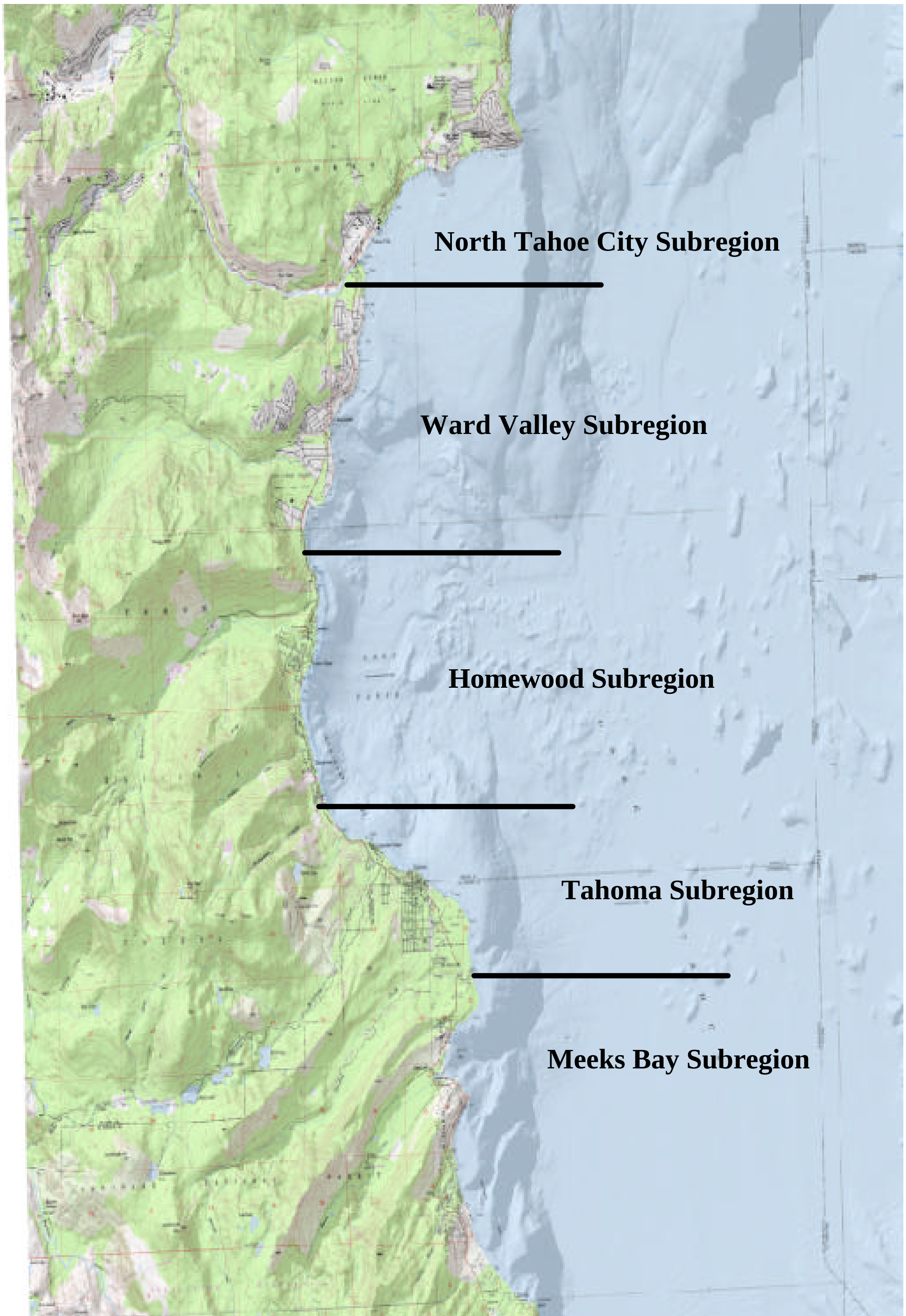
South of the Truckee River, in the Sunnyside area, the surficial geology is dominated by Quaternary glacial and sedimentary deposits. Most of the floor of Ward Creek and north of the creek is covered by extensive glacial till and outwash. Near the shoreline, glacial deposits are mapped near Sunnyside with lower elevation lacustrine deposits bordering the lake (West Yost & Associates 1995). In the McKinney Creek area, surficial geology consists of Quaternary sedimentary deposits of glacial outwash, till and lake beds. Limited subsurface information seems to show glacial outwash exists in the shallow subsurface. The Rubicon area contains precenozoic bedrock of granitic intensive rocks in uplands extending to the lakeshore. (West Yost & Associates 1995)

The basin-fill comprises glacial deposits and lacustrine sediments. This material is composed of rock ranging from fine silt to large boulders that have been sorted and stratified by the action of water flowing from glaciers (Freeze and Cherry 1979). The hydraulic conductivity is estimated to range from 0.3 to 30.5 m/day (1 to 100 ft/day), with the mean at 15 m/day (50 ft/day).

An estimate based on drilling logs from the area, finds the depth of bedrock at the groundwater-lake water interface extends to a maximum depth of 61 meters (200 feet). The basin fill deposits are shallow beginning at Dollar Point, and increase to a depth of 30 meters (98 feet) near Lake Forest. At Tahoe City the depth is approximately 61 meters (200 feet) and remains at this approximate depth through Ward Valley. From Ward Valley south to Rubicon Point the depth to bedrock along the lake shore varies and likely ranges from as thin as 3 meters (10 feet) to as thick as 61 meters (200 feet). From this point south to Emerald Bay, the area is dominated by bedrock and a moraine. Two to three faults have been approximated (Schweickert and others) in the Tahoe City Watershed area. These normal faults roughly parallel the shoreline in a north-south direction. They are thought to be just inland from the shoreline.

The length of the shoreline representing groundwater recharge for the Tahoe City Watershed was measured from the volcanic outcropping, located at Dollar Point to Rubicon Point. The length of shoreline is estimated at 30,000 meters (18.2 miles).

Figure 7-1. Tahoe City/West Shore Subregion Delineation



7.4 Previous Tahoe City/West Shore Investigations

7.4.1 Ward Valley Investigation (Loeb 1979)

Loeb's study was conducted in the Ward Valley watershed. The study estimated the total groundwater flow from the Ward Valley watershed into Lake Tahoe from basic hydraulic principles. A geophysical survey and mapping was done to determine the configuration of the aquifer and the cross sectional area through which flow was to be determined. Loeb sampled six wells for water-table levels to determine the hydraulic gradient across the cross section. Constant pump-rate tests were performed to estimate transmissivity. Chemical analysis was performed for nutrient forms of nitrate and total dissolved phosphorus on all samples, while only some wells were sampled for ammonia.

Loeb determined the aquifer was a single unconfined layer overlying a consolidated formation which acted as an aquiclude. The aquifer thickness was determined to reach a maximum of 60 meters (197 feet) with an average of 34 meters (112 feet). The aquifer length Loeb estimated during the study was 1,900 meters (1.2 miles). Loeb used an average transmissivity value calculated from the constant pump-rates test of 310 square meters/day (3,337 square feet/day). The average hydraulic gradient as determined by measured water levels was 0.019. Using these values, Loeb estimated a groundwater discharge rate into Lake Tahoe of 4.1×10^6 cubic meters/year (3,300 acre-feet/year).

Loeb estimated the average nitrate concentration detected was 0.162 mg/L and the average dissolved phosphorus concentration was 0.073 mg/L. Ammonia in the groundwater was below the detection limit (0.015 mg/L) in all samples. On the basis of the averages, Loeb estimated that the loading of nitrate and dissolved phosphorus from groundwater to Lake Tahoe was 660 kg/year (1,500 lbs/year) and 300 kg/year (660 lbs/year), respectively. The study showed that groundwater discharge from Ward Valley was 10% of the total precipitation in the watershed. The nitrate and dissolved phosphorus loading was 49% and 44% of the loading from the watershed, respectively.

7.4.2 UC Davis Institute of Ecology Study (Loeb 1987)

In the mid 1980s, Loeb revisited the Ward Valley investigation published in 1979. The objectives of Loeb's study were to determine the degree of nutrient contamination of the groundwater, quantify the amount of water and associated nutrients entering Lake Tahoe via groundwater, assess the impact of groundwater inflow on the growth rate of algae in Lake Tahoe and outline mitigation measures to prevent further and potential future degradation of groundwater quality.

Through the results of groundwater sampling, Loeb observed that downgradient nitrate-nitrogen concentrations were higher than upgradient. The upgradient groundwater had an average concentration ranging from 0.051 mg/L while the downgradient average concentration was reported as 0.195 mg/L. The other constituents did not show any major upgradient-downgradient differences. When comparing the data from this study to his previous study (Loeb

1979), a marked change in the overall nitrate and soluble reactive phosphorus distribution was observed. The average nitrate-nitrogen concentrations decreased by about 21% and the average soluble reactive phosphorus decreased by about 38%.

Loeb determined the gradient in Ward Valley was 0.0189 and transmissivity was 314 square meters/day (3,380 square feet/day). Based on this hydraulic data, Ward Valley discharged 3.1×10^6 m^3/year (2,500 acre-feet/year) of water into Lake Tahoe. Using the nutrient values from the groundwater monitoring network, the groundwater loaded 525 kg (1,200 lbs) of nitrate-nitrogen per year into Lake Tahoe, representing 60% of the total dissolved inorganic nitrogen loading of Lake Tahoe from this area. Annual loading of 185 kg (410 lbs) soluble reactive phosphorus was discharged from Ward Valley, representing 45% of the watershed's total loading of soluble reactive phosphorus.

7.4.3 USGS, Tahoe City PUD, Placer County Environmental Management & California DHS Water Quality Monitoring

North Tahoe City Subregion

Twelve wells are located within the North Tahoe City Subregion. Two of the wells are located in the Dollar Point area and have no major monitoring activities associated with them. Of the little nitrogen data associated with these wells, all analysis was non-detect for nitrate and nitrite. The remaining ten wells are located closer to Tahoe City. Three of these wells are part of the Tahoe City golf course monitoring program (176 – 178). The remaining seven wells are either municipal or small provider drinking water wells. Wells 175,174, and 165 have been used by the USGS for monitoring purposes. The Table 7-1 and Figure 7-2 depicts information and locations for the golf course wells and those used by the USGS for monitoring.

Table 7-1. North Tahoe City Well Construction Information

Site No.	Elevation, ft above msl	Depth of well, meters
165	6,245	--
174	6,390	--
175	6,580	116
176, 177, 178	--	--

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, LRWQCB, TCPUD, California DHS, and California DWR.
4. 1 meter = 3.2808 feet.

Nutrient data has been collected for the Tahoe City Golf Course wells since 1989. The USGS only collected sampling data for well 174 in 1991. Wells 165 and 175 have been monitored by the USGS from 1989 and continue to be monitored. The California DHS retains monitoring data for the drinking water wells to monitor compliance with drinking water standards. All analytical results for wells in this region were non-detect for nitrate and nitrite.

Groundwater elevation data is much more sparse for the area, and was only available for well 175. The well was only measured on two occasions, once in 1986 and again in 1999. Table 7-2 depicts the groundwater average, minimum and maximum water levels recorded during these events.

Table 7-2. North Tahoe City Subregion Groundwater Elevation Data, ft above msl

	Well ID	
	175	Lake Elevation
Average Water Level	6,400.25	6,227.04
Minimum	6,397.00	6,226.20
Maximum	6,403.50	6,227.88

Notes:
1. Data provided by USGS.

The gradient as calculated from the information in Table 7-2 is 0.04. This value is likely higher than the actual gradient to the lake, as this site is located a great distance from the lake (approximately 1,200 meters [4,000 feet]), and in an area of steep topography compared to that near the lake. Because of the error associated with this measurement, an average basin wide gradient, as developed by Thodal, 0.02, is used for the area.

Ward Valley Subregion

Five wells from which data was collected are located within the Ward Valley Subregion. One of the wells, 159, has only public drinking water compliance monitoring activities associated with it. The remaining four wells (155, 166, 169 and 170) have been used by the USGS for monitoring purposes. The wells are either municipal, private or small provider drinking water wells. Most of the wells are located near the lake shore, however, one well is located in the mountains (170). The following table depicts information for the wells used by the USGS for monitoring.

Table 7-3. Ward Valley Subregion Well Construction Information

Site No.	Elevation, ft above msl	Depth of well, meters
155	6,260	81
159	--	50
166	6,480	137
169	6,460	--
170	7,300	91

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, Placer County, TCPUD, CA DHS and CA DWR.
4. 1 meter = 3.2808 feet

The USGS collected sampling data for well 170 in 1986. Well 169 monitoring began in 1986 and ceased in 1997. The other two wells have been monitored periodically by the USGS from 1986 and continue to be monitored. Placer County retains monitoring data for the drinking water wells to monitor compliance with drinking water standards. Placer County possessed data associated with well 159.

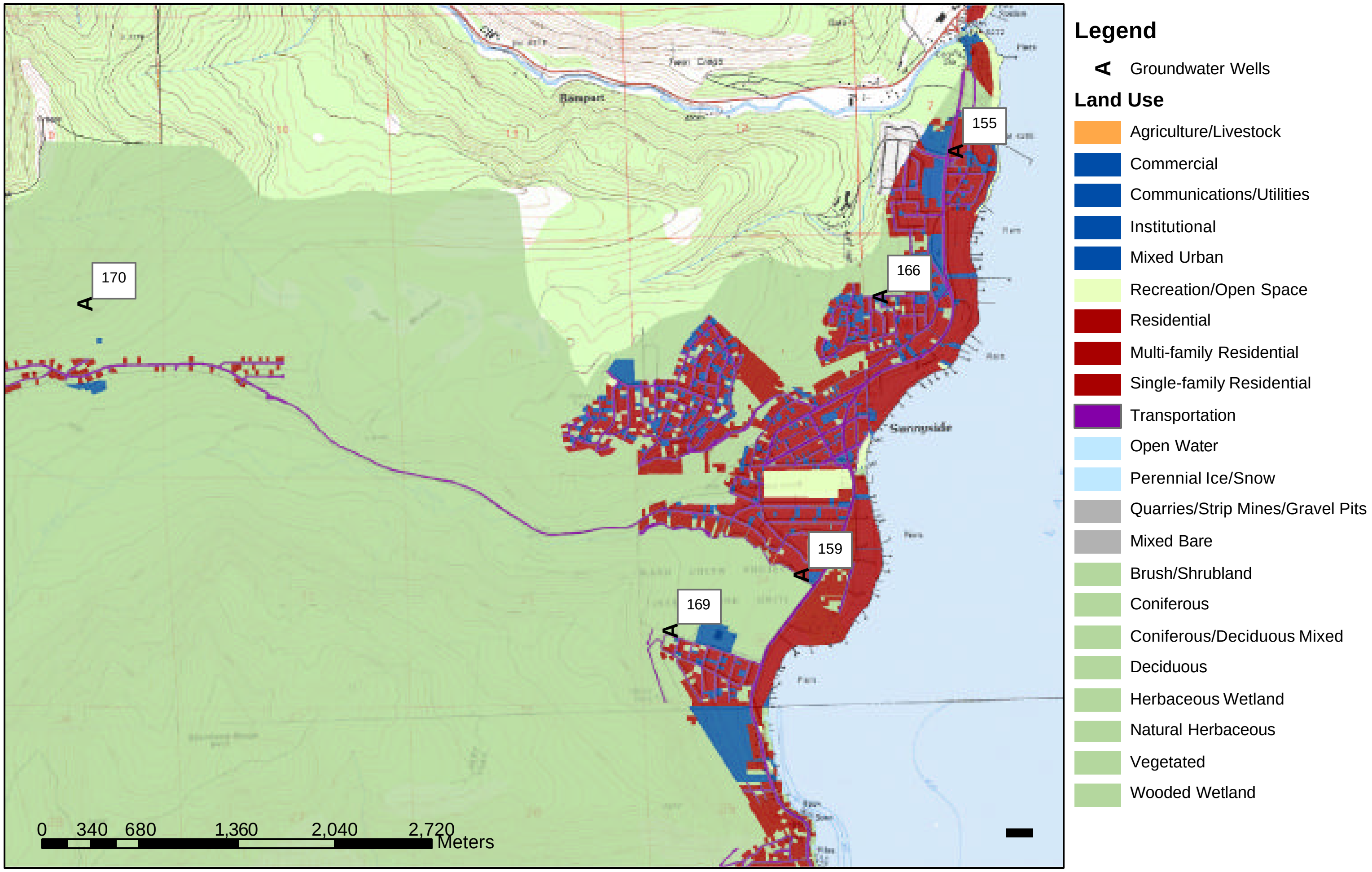
Groundwater elevation data is limited for the area. Groundwater elevation data was available for three of the wells, but only one event each. Well 170 was one of those wells, but considering its placement is not suited for determining hydraulic gradient. The remaining two wells had an average gradient of 0.013. This is similar to Loeb's (1979) hydraulic gradient of 0.019. Table 7-4 depicts the groundwater levels measured during these events.

Table 7-4. Ward Valley Subregion Groundwater Elevation Data, ft above msl

	Well ID			
	166	155	170	Lake Elevation
Average Water Level	6,289.00	6,222.16	7,300.00	6,224.68
Minimum	--	--	--	6,222.39
Maximum	--	--	--	6,227.74

Notes:
1. Data Obtained from USGS
2. Only one elevation was measured for each well.

Figure 7-3. Ward Valley Area Groundwater Wells and Land Use



Notes:
1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

Homewood Subregion

Only two wells are located within the Homewood Subregion. The northern most well is located near Kaspian point and has no major monitoring activities associated with it. The remaining well is used by the USGS for monitoring purposes. The following table depicts information for the two wells.

Table 7-5. Homewood Subregion Well Construction Information

Site No.	Elevation, ft above msl	Depth of well, meters
164	--	20
213	6,270	37

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, Placer County, TCPUD, CA DHS and CA DWR.
4. 1 meter = 3.2808 feet

Nutrient data has been collected for well 213 since 1989 and continues to be monitored. Only one nitrate sample is available for well 164.

Groundwater elevation data is also limited for the area. Groundwater elevation data is available for well 213 only. The well was only measured on one occasion. Table 7-6 depicts the groundwater level measured during this event.

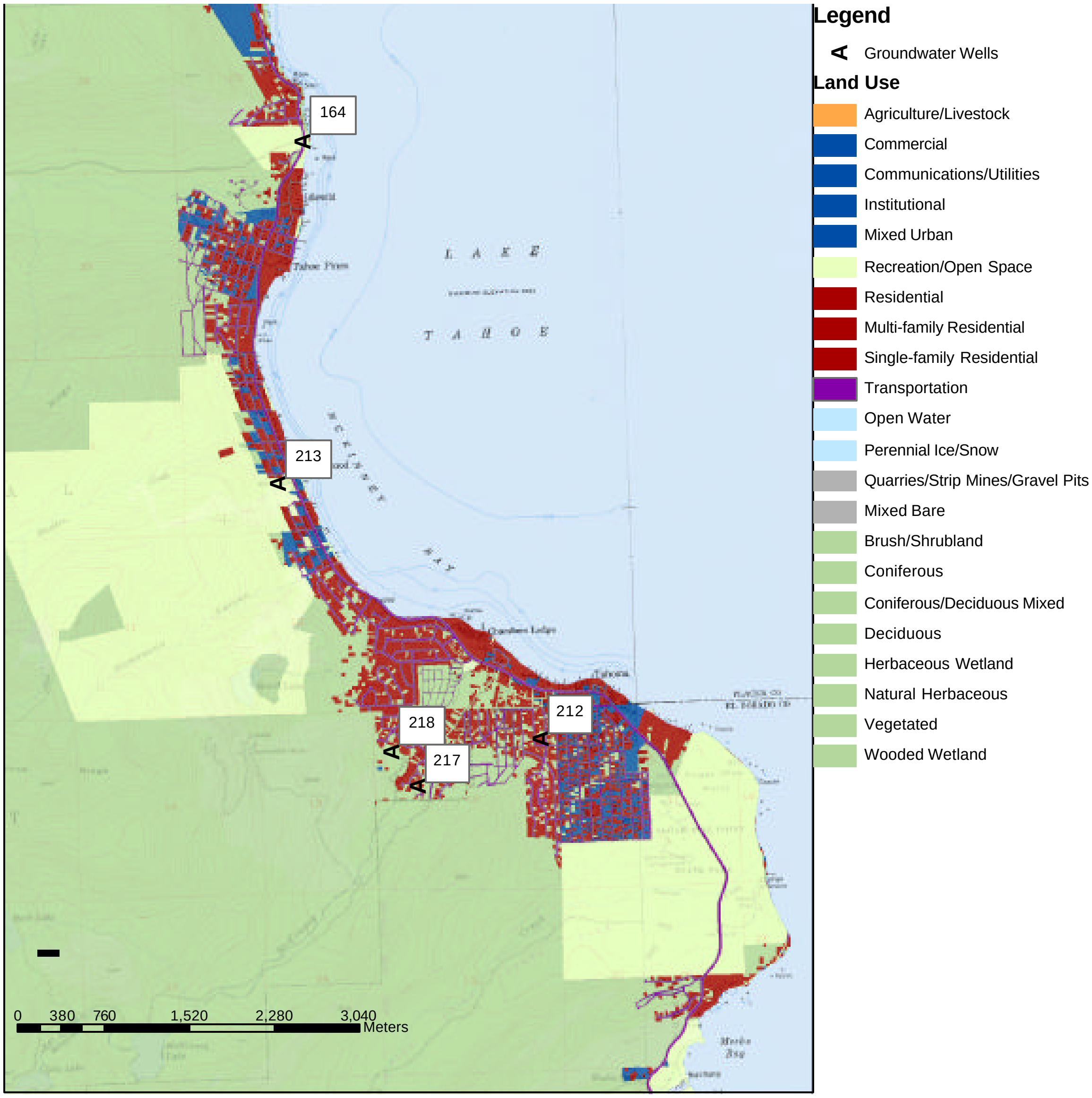
Table 7-6. Homewood Subregion Groundwater Elevation Data, ft above msl

	Well ID	
	213	Lake Elevation
Average	6,233	6,227.13

Notes:
1. Data obtained from USGS.
2. Only one elevation was measured for well 213.

The gradient between the well and the lake as calculated from this above information is 0.008. This value is likely lower than the actual gradient to the lake, as this site is similar to the Ward Valley area which has a steeper gradient (0.013 – 0.019).

Figure 7-4 Homewood/Tahoma Subregions Groundwater Wells and Land Use



Notes:

1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

Tahoma Subregion

Eight wells are located within the Tahoma Subregion. Monitoring data has only been collected from the three wells shown on Figure 7-4. Well 217 only has nitrate sampling, but the other two have been sampled by the USGS for additional constituents. Nutrient data has been collected for these wells since 1989. No groundwater elevation data has been collected for this region. Table 7-7 depicts information for the wells used by the USGS for monitoring.

Table 7-7. Tahoma Subregion Well Construction Information

Site No.	Elevation, ft above msl	Depth of well, meters
212	6,305	--
217	--	128
218	6,380	107

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, Placer County, TCPUD, CA DHS and CA DWR.
4. 1 meter = 3.2808 feet

Meeks Bay Subregion

Data has been collected for five wells within the Meeks Bay Subregion. Three of the wells have been sampled during only one event (210, 211 and 214). Well 216 was monitored by the USGS in 1991 and 1992. The only well that has been consistently monitored is 215. This well has had data collected beginning in 1986, and continuing to the present. The wells are either municipal or small provider drinking water wells. The following table depicts information for the wells.

Table 7-8. Meeks Bay Subregion Well Construction Information

Site No.	Elevation, ft above msl	Depth of well, meters
210	--	--
211	6,240	--
214	6,410	128
215	6,315	98
216	6,240	--

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, Placer County, TCPUD, CA DHS and CA DWR.
4. 1 meter = 3.2808 feet

Again, groundwater elevation data is limited. Groundwater elevation data was available for well 211 only. The well was only measured on one occasion. Table 7-9 depicts the groundwater level measurement during this event.

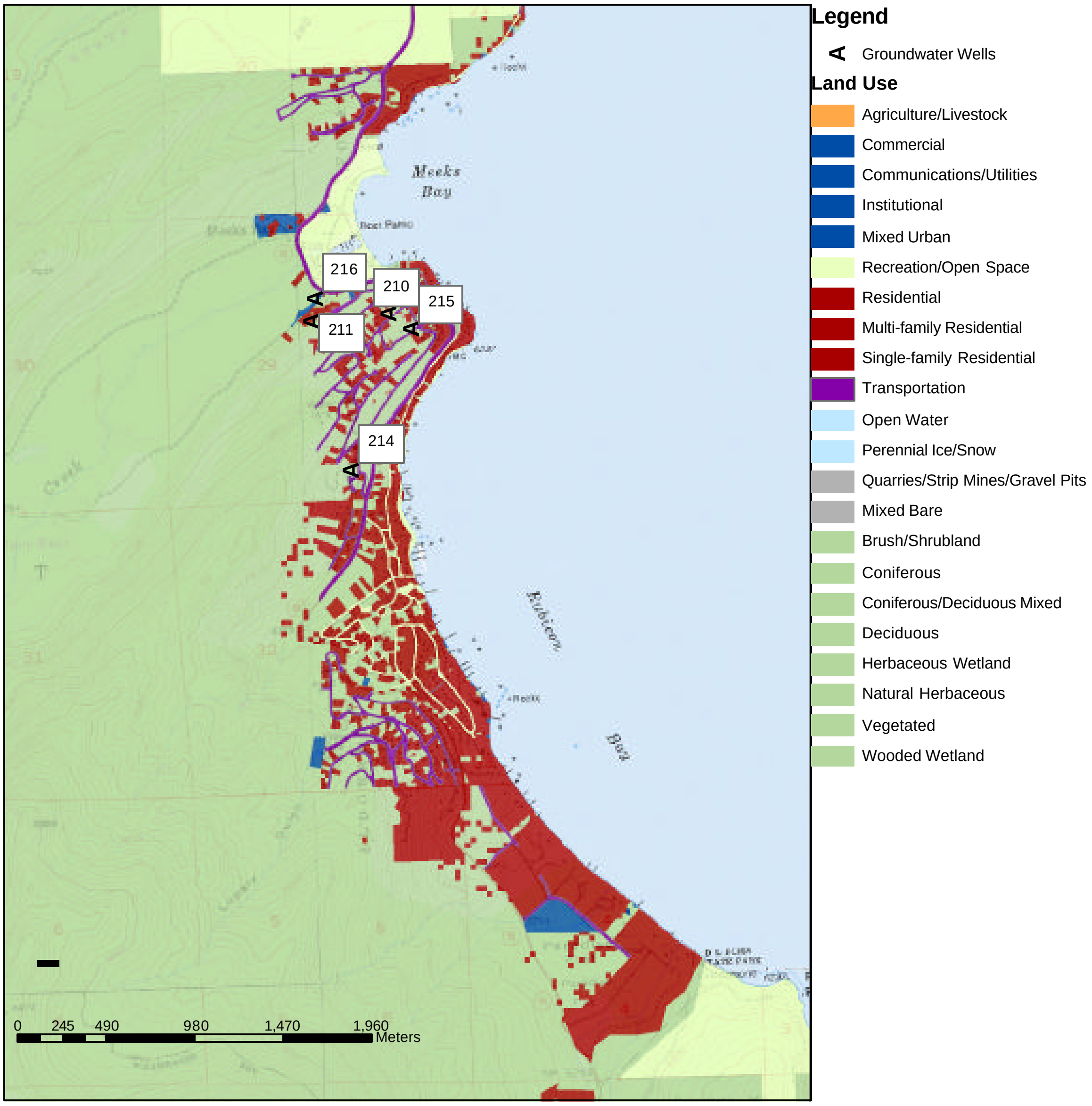
Table 7-9. Meeks Bay Subregion Groundwater Elevation Data, ft above msl

	Well ID	
	211	Lake Elevation
Average	6,234.27	6,227.88
Minimum	--	--
Maximum	--	--

Notes:
1. Data obtained from USGS
2. One one elevation was measured for well 211.

The groundwater flow direction in this area cannot be determined because of lack of data. However, based on the topography, it is likely that groundwater flows from well 211 towards Meeks Creek rather than towards Lake Tahoe. Nevertheless, the gradient between well 211 and Lake Tahoe was calculated from the data presented in Table 7-9. The gradient was 0.0038. This value is likely lower than the actual gradient to the lake. Due to lack of data in this area, the gradient calculated for the Ward Valley area (0.013 to 0.019) is more appropriate to use.

Figure 7-5. Meeks Bay Subregion Groundwater Wells and Land Use



Notes:

1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

7.5 Nutrient Concentrations

The USGS has sampled wells periodically since 1989. These wells are sampled as part of a Tahoe Basin-wide monitoring program. The USGS samples for dissolved ammonia dissolved Kjeldahl nitrogen, dissolved nitrate plus nitrite, dissolved orthophosphorus and total dissolved phosphorus. Wells 174, 170, 214, and 211 have only been sampled once for the same constituents as listed for the other wells.

The California DHS requires sampling for nitrate and nitrite in drinking water wells. The municipal wells are sampled for nitrate annually. Nitrite samples are collected every three years. There is typically only one to three sets of data available in the DHS database for these wells. Many wells only being monitored for public health contain nitrate and nitrite below the levels of detection.

LRWQCB requires Tahoe City golf course to conduct monitoring activities on site. This monitoring is used to evaluate the golf course's effects on groundwater from fertilization activities. The nutrient constituents analyzed are dissolved Kjeldahl nitrogen, dissolved nitrate plus nitrite and dissolved orthophosphorus.

7.5.1 North Tahoe City Subregion

All of the wells located within this area are part of the USGS monitoring network or Tahoe City golf course.

The dissolved ammonia + organic nitrogen concentrations range from 0.001 mg/L to 0.5 mg/L, averaging 0.089 mg/L. The dissolved nitrate concentrations, which include nitrite, range from 0.01 mg/L to 0.35 mg/L with an average of 0.089 mg/L. This results in an average total dissolved nitrogen concentration of 0.16 mg/L.

Orthophosphorus concentrations range from 0.01 mg/L to 1.4 mg/L, averaging 0.12 mg/L. The range of total dissolved phosphorus is 0.031 mg/L to 0.13 mg/L, averaging 0.071 mg/L. No total phosphorus concentrations were measured for the Tahoe City golf course.

The highest total nitrogen concentration is found in the most upgradient and deepest well (175). When evaluating the wells only within the golf course (176 – 178), the downgradient wells show a slight increase in nitrogen concentration through the golf course, but a decrease in orthophosphorus. In addition to the golf course as a source of contamination to the wells, a school is located upgradient of monitoring well 177. Well 165 is located downgradient from a variety of land uses including, residential, commercial, and recreational, Figure 7-2. No land use data is available upgradient of the remaining wells.

Table 7-10. North Tahoe City Subregion Average Nutrient Concentrations (mg/L)

Constituent	Well ID 175	174	165[a]	176	177	178
Land Use			Recreational		Recreational	
Ammonia + Organic	0.086	0.040	0.067	0.089	0.089	0.093
Nitrate	0.190	0.110	0.044	0.080	0.073	0.090
Total Nitrogen	0.280	0.150	0.110	0.150	0.150	0.170
Orthophosphorus	0.050	0.043	0.052	0.190	0.150	0.090
Total Phosphorus	0.067	0.054	0.076	na	na	na
Top of Open Interval (ft bgs)	<380	--	--	Shallow	Shallow	Shallow

Notes:
1. All concentrations reported are dissolved.
2. Data obtained from USGS, CADHS, Placer County
3. Top of Open Interval with a – indicates the open interval is unknown. A < indicates less than the total depth of the well.
4. Nitrate concentrations include nitrite
5. Total Nitrogen concentration is calculated by adding ammonia + organic + nitrate
6. na – not analyzed
7. All wells are used in the development of average nutrient concentrations.
8. [a] – Well used in developing downgradient nutrient concentrations.
9. For each nutrient concentration, averages are based on 1 sample for well 174; 14-15 samples for well 165; 17 samples for well 175; 28 samples for well 176; 28-29 samples for well 178; and 28-30 samples for well 177.
10. Not all wells have an assigned land use because they are outside the watershed boundary.

7.5.2 Ward Valley Subregion

All of the wells located within this area are part of the USGS monitoring network or California DHS.

The dissolved ammonia + organic nitrogen concentrations range from 0.01 mg/L to 1 mg/L, averaging 0.14 mg/L. The dissolved nitrate concentrations, which include nitrite, range from 0.01 mg/L to 1.6 mg/L with an average of 0.12 mg/L. This results in an average total dissolved nitrogen concentration of 0.26 mg/L.

Orthophosphorus concentrations range from 0.02 mg/L to 8.8 mg/L, averaging 0.34 mg/L. The range of total dissolved phosphorus is 0.03 mg/L to 0.37 mg/L, averaging 0.13 mg/L.

An extremely high level of orthophosphorus, 8.7 mg/L, was detected in November of 1999 in well 166. Including this estimate, the average orthophosphorus concentration in well 166 is 0.61 mg/L. This detection is likely due to a specific incident and is not related to the average concentration found in the well. The average concentration presented for well 166 in Table 7-11 was determined using all other sampling events. The average concentration for all wells in the area disregarding the 8.7 mg/L concentration is 0.10 mg/L. All of the wells within this region are deep. This provides no chemistry data for the shallow aquifer which could contain higher concentrations of nutrients. Wells 170 and 169 are located downgradient of and within a vegetated area. These two wells are likely only influenced by natural conditions. Well 155 is located downgradient of a commercial area while well 166 is located on the edge of a residential neighborhood. The placement of the wells does not allow for analysis of the chemical behavior downgradient.

Table 7-11. Ward Valley Subregion Average Nutrient Concentrations (mg/L)

Constituent	Well ID			
	169	166	170	155
Land Use	Vegetated	Commercial	Vegetated	Residential
Ammonia + Organic	0.049	0.073	0.300	0.310
Nitrate	0.048	0.170	0.100	0.130
Total Nitrogen	0.070	0.250	0.400	0.440
Orthophosphorus	0.093	0.063	0.020	0.180
Total Phosphorus	0.110	0.079	0.030	0.210
Top of Open Interval (ft bgs)	--	299	<300	255

Notes:

1. All concentrations reported are dissolved.
2. Data obtained from USGS, CADHS, Placer County.
3. Top of Open Interval with a – indicates the open interval is unknown. A < indicates less than the total depth of the well.
4. Nitrate concentrations include nitrite
5. Total Nitrogen concentration is calculated by adding ammonia + organic + nitrate
6. na – not analyzed
7. All wells are used in the development of average nutrient concentrations.
8. For each nutrient concentration, averages are based on 1 sample for well 170; 9-15 samples for well 169; 10 samples for well 155; and 14-16 samples for well 166.

7.5.3 Homewood, Tahoma and Meeks Bay Subregions

All of the wells located within this area are part of the USGS monitoring network or California DHS.

The dissolved ammonia + organic nitrogen concentrations range from 0.001 mg/L in Homewood to 0.5 mg/L in Tahoma. The dissolved nitrate concentrations, which include nitrite, range from 0.004 mg/L in Meeks Bay to 0.2 mg/L in Tahoma and Meeks Bay. The average total dissolved nitrogen concentrations for Homewood, Tahoma and Meeks Bay are 0.12 mg/L, 0.119 mg/L and 0.17 mg/L, respectively.

Orthophosphorus concentrations range from 0.003 mg/L in Homewood to 0.48 mg/L, in Meeks Bay. The average total dissolved phosphorus for Homewood, Tahoma and Meeks Bay are 0.046 mg/L, 0.048 mg/L and 0.19 mg/L, respectively.

Homewood only has one monitoring point for the area, which is located downgradient of a ski resort. Unfortunately, this well is not representative of the majority of surrounding land uses. The downgradient well in Tahoma shows a slight increase in nitrogen concentration and no change in phosphorus. Tahoma well 218 is located within a vegetated land use with no upgradient source other than natural concentrations. Well 212 is located within a residential neighborhood, but is at the upgradient extent of this area. This well does not represent the entire residential area or how it could cumulatively be affecting the lake. Most land use within the Tahoma area are residential and mixed urban. None of the wells are close to the lake, so the cumulative impacts cannot be determined. Meeks Bay wells 215 and 214 are isolated from other wells in the area therefore no comparisons can be made pertaining to upgradient versus downgradient affects. Meeks Bay wells 211 to 216 show a decrease in nitrogen concentrations downgradient and are stable for phosphorus. All of the wells located in these three regions are deep. This limits the ability to evaluate the effects of local sources as much of the nutrient concentration likely goes undetected in the shallow aquifer.

Table 7-12. Homewood, Tahoma and Meeks Bay Subregions Average Nutrient Concentrations (mg/L)

	Well ID						
	Homewood	Tahoma		Meeks Bay			
Constituent	213	218	212	214	215	211	216
Land Use	Recreational	Vegetated	Residential	Vegetated	Vegetated	Residential	Vegetated
Ammonia + Organic	0.049	0.049	0.064	0.200	0.059	0.200	0.120
Nitrate	0.072	0.035	0.091	0.150	0.096	0.100	0.022
Total Nitrogen	0.120	0.084	0.150	0.350	0.160	0.300	0.140
Orthophosphorus	0.023	0.031	0.031	0.140	0.103	0.060	0.400
Total Phosphorus	0.046	0.048	0.048	0.150	0.120	0.600	0.450
Top of Open Interval (ft bgs)	<120	<350	--	200	190	--	--

Notes:

1. All concentrations reported are dissolved.
2. Data obtained from USGS, CA DHS, Placer County
3. Top of Open Interval with a – indicates the open interval is unknown. A < indicates less than the total depth of the well.
4. Nitrate concentrations include nitrite
5. Total Nitrogen concentration is calculated by adding ammonia + organic + nitrate
6. na – not analyzed
7. All wells are used in the development of average nutrient concentrations.
8. For each nutrient concentration, averages are based on 1 sample for wells 211 and 214; 3 samples for well 216; 13 samples for well 218; 15-16 samples for well 212; 15-17 samples for well 215; and 16 samples for well 213.

7.6 Groundwater Discharge

No seepage meter measurements have been taken in this area. This limits the discharge calculation to the Darcy's Law approach.

7.6.1 Darcy's Law Calculation Using Estimated Hydraulic Conductivity

A simple Darcy's Law calculation can be executed using the average gradient, median hydraulic conductivity and aquifer area. The average hydraulic gradient ranges from (0.013 to 0.02). The median hydraulic conductivity, 12-15 m/day (40 – 50 ft/day) as determined from the boring logs was used. The length of the basin fill aquifer is estimated at 16,000 – 29,000 meters (10 - 18 miles). A depth of 3-30 meters (10 –100 feet) represents the depth of basin fill deposits. An aquifer depth of 15 meters (50 feet) was used to estimate the average aquifer thickness.

The calculation yields an estimated discharge rate of 1.4×10^7 to 4.8×10^7 m^3/year (11,100 to 39,000 acre-ft/year).

The length of the basin fill aquifer is the factor that makes this discharge rate vary the most. The estimations of the length vary widely among sources.

7.6.2 Darcy's Law Calculation Using Estimated Transmissivity

A Darcy's Law calculation can be executed similar to that above, except using transmissivity estimates rather than using the hydraulic conductivity and aquifer area. The same hydraulic gradients were used and the range of aquifer fill length remained the same. The transmissivity estimate that was developed by Loeb, 310 m^2/day (3,337 ft^2/day) was used.

The calculation yields an estimated discharge rate of 2.4×10^7 to 6.6×10^7 m^3/year (19,200 to 53,700 acre-ft/year).

7.7 Nutrient Loading

The potential range of nutrient discharge via groundwater from the Tahoe City/West Shore area to Lake Tahoe was calculated by multiplying the estimates of annual groundwater discharge by concentrations of nutrients found in monitoring wells. The method of using the downgradient wells is not used in this region, as most of the wells are positioned either within or at the upgradient edge of the development. Details of the methodology used are described in Section 3.2.

The nutrient concentrations vary widely along the lake shore. To account for this variation, a weighted average concentration was developed. The weighted average is based on the length of shoreline for each region. Table 7-13 includes the percentage of shoreline in each subregion. The average nutrient concentration is multiplied by the percent of shoreline for the subregion. The sum of the concentrations becomes the weighted average used in the estimation.

Table 7-13. Percent of Shoreline by Subregion in the Tahoe City/West Shore Area

Region	Shoreline Length meters	miles	Percent of Total Shoreline
North Tahoe City	5,020	3.1	17%
Ward Valley	7,100	4.4	25%
Homewood	7,520	4.7	26%
Tahoma	5,530	3.4	19%
Meeks Bay	4,090	2.5	14%
Total	29,000	18	

Notes:
1. 1.2 miles was added to the Homewood shoreline length to account for the area south of Meeks Bay. This area is basin fill but contained no analytical data. Homewood was chosen because it represents the lowest nutrient concentrations in the region. The limited development in the area south of Meeks Bay constitutes using the lower nutrient concentrations.

The weighted concentration is then multiplied by the groundwater flux estimates calculated in Section 7.6. Table 7-14 summarizes the nutrient flux using this method. The wells used in this estimation are mostly located in the deep aquifer. This method could be discounting higher concentrations of nutrients that may be in the shallow aquifer. This approach also neglects the accumulation of nutrients as groundwater progresses downgradient through potential sources. Most of the wells are located either at the edge of developments or near the middle of the developed areas. No wells are located adjacent to the lake.

Although the wells in the Tahoe City area are placed such that they represent some of the land use types, there are still areas for which there is no data and no shallow monitoring results. To account for this, the dataset compiled for the entire basin was used to apply average nutrient concentrations within similar land use categories. Most of the developed area consists of residential (75%), commercial (15%) and recreational (10%) land use types. Using the averages established for these land use categories (see Section 3.2.1), the land use weighted averages were developed as shown in Table 7-14.

The land use weighted average approach for the Tahoe City/West Shore area is the most reasonable, as there is a limited monitoring network and mostly deep wells within the region. This method assumes that the land uses of the same category are consistent across the basin. Potential errors could be introduced by certain residential neighborhoods having manicured lawns versus those with natural yards. The results of the land use weighted nutrient estimate combined with the groundwater discharge estimate of 3.8×10^7 m^3/year (31,200 acre-feet/year) provide the most reasonable nutrient loading estimate to Lake Tahoe.

Table 7-14. Tahoe City/West Shore Average and Land Use Weighted Annual Nutrient Loading

Constituent	Groundwater Flux (m^3/year)	Average Concentration Method: Average Concentration (mg/L)	Average Concentration Method: Nutrient Loading (kg/yr)	Land Use Weighted Concentration Method: Land Use Weighted Average Concentration (mg/L)	Land Use Weighted Concentration Method: Nutrient Loading (kg/yr)
Ammonia + Organic	1.4E+07		1,400		3,500
	3.8E+07		3,900		9,800
	6.6E+07	0.10	6,700	0.256	17,000
Nitrate	1.4E+07		1,300		6,500
	3.8E+07		3,700		18,000
	6.6E+07	0.097	6,400	0.47	31,000
Total Nitrogen	1.4E+07		2,700		10,000
	3.8E+07		7,600		28,000
	6.6E+07	0.20	13,000	0.730	48,000
Orthophosphate	1.4E+07		1,000		1,100
	3.8E+07		2,800		3,100
	6.6E+07	0.073	4,900	0.082	5,400
Total Phosphorus	1.4E+07		1,500		1,600
	3.8E+07		4,300		4,400
	6.6E+07	0.11	7,500	0.11	7,600

Notes:
1. 1 m^3/year = 0.0008 acre-feet/year, 1 kg/yr = 2.2 lb/yr
2. Average nutrient concentrations are derived from those included in Table 7-10 -Table 7-13
3. All concentrations reported are dissolved.

7.8 Ambient Nutrient Loading

Ambient loading was calculated from the basin-wide data set for wells located in undeveloped areas. The ambient nutrient loading is calculated to estimate the amount of nutrients that would discharge into Lake Tahoe regardless of anthropogenic sources. The discharge rates which were determined to be the most reasonable estimates of groundwater discharge were used in calculating the ambient nutrient loading. Based on these estimates, the total dissolved nitrogen concentrations that may be entering the lake from natural processes is 10,000 kg/year (22,000 lbs/yr). The estimated ambient total dissolved phosphorus concentration entering the lake is 1,900 kg/year (4,200 lbs/yr). Table 7-15 summarizes the loading estimates.

Table 7-15. Tahoe City/West Shore Ambient Nutrient Loading Estimate

	Groundwater Discharge (m^3/year)	Ambient Total Nitrogen (mg/L)	Ambient Total Phosphorus (mg/L)	Ambient Nitrogen Nutrient Loading (kg/year)	Ambient Phosphorus Nutrient Loading (kg/year)
Incline Village	3.8E+07	0.27	0.049	10,000	1,900

Notes:

1. 1 m^3/year = 0.0008 acre-feet/year, 1 kg/yr = 2.2 lb/yr
2. Average nutrient concentrations derived from those included in Section 3.2.
3. All concentrations reported are dissolved.

7.9 Summary & Conclusions

The Tahoe City/West Shore region bounds Lake Tahoe with basin fill deposits continuously over a long distance. It also tends to have a relatively steep gradient which results in higher groundwater discharge estimates for the area. For these two reasons, this is one of the most important areas in the basin to understand.

There is a very limited monitoring well system in the Tahoe City/West Shore region. The wells are dispersed across the area, but are typically far from the lake and upgradient of the developed land uses. In addition, a majority of the wells are screened at depth, limiting the amount of shallow data to assess the nutrient concentrations in the shallow aquifer. This small network provides only a limited amount of data for land uses that are predominant in the remainder of the watershed. There is very limited data for residential or commercial areas which have a potential to be nutrient sources from fertilizer use, abandoned septic systems, etc. A monitoring network which is designed to monitor the predominant land uses with spatial variability would provide better estimates of nutrient loading.

Subsurface geology information is generally lacking in the Tahoe City/West Shore area. It is recommended that additional boreholes be drilled, including the collection of continuous core, or split-spoon sampling at regular intervals with borehole geophysics to tie in contacts, so that accurate determination of the stratigraphy can be made. A surface geophysical survey could then be run to extend the stratigraphic information parallel and perpendicular to the shoreline. To aid in the understanding of hydrologic conditions, piezometer wells should be located in nests to evaluate vertical components to ground water flow. The geometry of the sedimentary fill below this length of shoreline is significantly different from other portions of the basin, but the data defining these differences is sparse. Additional geology information would reduce errors in the loading estimate. Conducting pumping tests on the existing wells as well as performing additional studies would provide a better estimation of k values. This would also better define whether the aquifer has any significant aquitards.

A more comprehensive evaluation of the groundwater/stream interaction would provide better estimates of the area directly discharging to the lake versus the area discharging to streams. This is most important in the North Tahoe City, Ward Valley, and Meeks Bay subregions. A more complete groundwater level monitoring network would be required near gaged streams. Major faults may provide pathways for significant groundwater flow. A better understanding of the impacts the faults have on groundwater movement is another important factor.

To assist in determining the actual source(s) of nutrients, several methods could be used. The IKONOS data could be used to determine if any neighborhoods have a significant number of fertilized lawns. These areas could be targeted for additional monitoring. Historical record searches could be performed to locate and study the residual effects of septic systems. The infiltration basins of the region should also be monitored to determine their potential threat to elevated nutrient concentrations in groundwater.

Comparing the total groundwater nutrient loading (Table 7-14) to the ambient nutrient loading (Table 7-15), natural processes may make up to 36% of the nitrogen and 43% of the total dissolved phosphorus loading to the lake.

This region has the potential to discharge a significant amount of nutrients to the lake. Because of the lack of a regional monitoring network, there may be significant errors associated with these estimates. This is a justification for installing a more comprehensive monitoring network. This would reduce errors inherent in this method and provide additional confidence in the loading estimates.