6.0 TAHOE VISTA/KINGS BEACH NUTRIENT LOADING

6.1 Description of Study Area

The Tahoe Vista/Kings Beach area is located on the north shore of Lake Tahoe extending from the California/Nevada state line east to Dollar Point. Griff Creek drains the area into Agate Bay. The Tahoe Vista, Griff Creek, Kings Beach and East Stateline Point watersheds make up this region.

Human development is extensive near the lake. The land use includes residential, commercial and recreational. The primary forms of recreational land use include a golf course, regional park and State Recreation area.

6.2 History of Development (Lindstrom et al. 2000)

Settlements were established in Tahoe Vista and Kings Beach in the early 1860s. A logging camp and small mill community were established around 1864. During the late 1860s dairy and hay operations were conducted at locales on a small scale in North Tahoe. Hay and dairy enterprises were based in the meadows around Griff Creek near Tahoe Vista and Kings Beach.

Pine Grove Station was established by a wood contractor in Tahoe Vista in 1865. Tahoe Vista began to expand in the early 1900s with the establishment of the first casino/hotel in 1911 and the first subdivision in 1914. Wiggins Station was established in Kings Beach by a wood contractor as a logging camp and small mill community in the mid 1800s. By 1896, the Brockway Hot Springs Resort was developed. The 1920s brought the first subdivisions along with expansion of the resort to include a casino, club and golf course.

6.3 Local Geology

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. 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).

Geophysical surveys in the area indicate that basin-fill deposits overlying volcanic rock are less than 30 meters (100 feet) thick (Markiewicz 1992, p.21-27), but one driller's log for a well near Tahoe Vista, reports a clay and gravel contact at 27 meters (89 ft) and basalt at 60 meters (197 ft) bgs. Estimates of the thickness of basin-fill deposits along the eastern shore are limited but thickness probably extends to 61 meters (200 ft) thick (Thodal 1995, p. 14). The Dollar Point Fault, trending north-south, bounds the western side of the watershed area. As with most of the faults in the Lake Tahoe area, this is a steeply dipping normal fault.

The length of the shoreline representing groundwater recharge for the Kings Beach Watershed was measured from aerial photographs and a geologic map of California (Jennings 1977). The length of the shoreline representing groundwater recharge for the Kings Beach area was measured from the granitic outcropping, located at Brockway, just southeast of Kings Beach

to the outcropping of volcanic rock at Flick Point to the west. The length of shoreline between the two geologic units is approximately 6,000 meters (3.7 miles).

6.4 Previous Tahoe Vista/Kings Beach Area Investigations

No major investigations have been conducted in this area. Thodal's study included one public well just to the west of Tahoe Vista, but no wells within the basin fill area.

6.4.1 USGS, Brockway Golf Course & North Tahoe Public Utility District Water Quality Monitoring

There are eight wells located within the basin fill aquifer in Tahoe Vista/Kings Beach (Figure 6-1). Five of these wells are located on the Old Brockway Golf Course (149-152). No information is available regarding a fourth monitoring well at the golf course. One is located in North Tahoe Regional Park (145) and the other two are located in the southwestern portion of the basin fill aquifer (142-143). The golf course wells are used to monitor groundwater quality. The North Tahoe Regional Park well is a municipal supply well. The two wells located in the southwestern area are small provider drinking water wells. One additional well is located in the area outside of the basin fill aquifer (144). The well is a private drinking water well and has been used by the USGS for monitoring purposes.

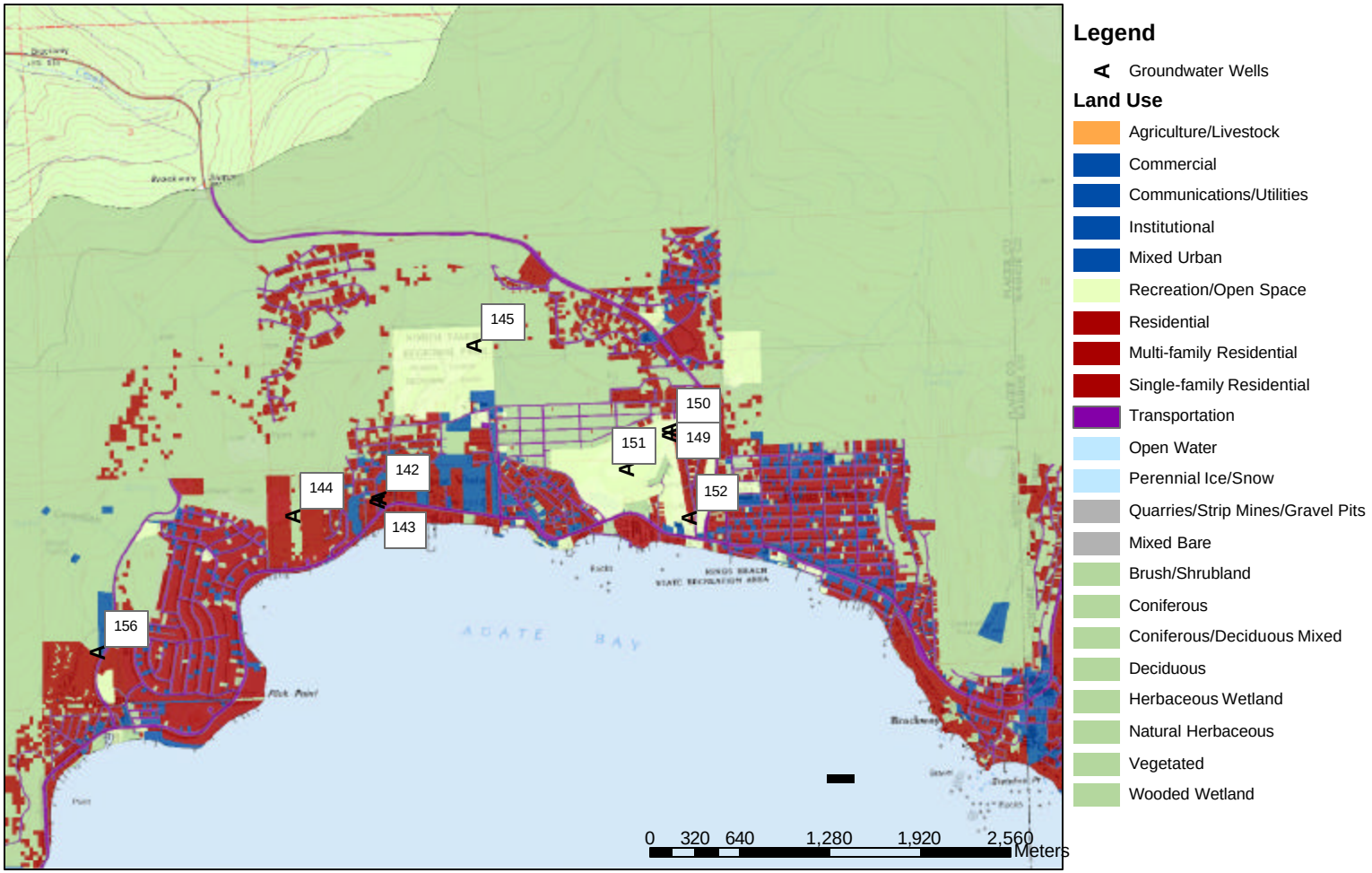
Table 6-1. Tahoe Vista/Kings Beach Area Well Construction Information

Site No.	Elevation, ft above msl	Depth of Well, meters
Tahoe Vista/Kings Beach		
142	6,260	--
143	6,260	--
145	6,450	268
149	6,280	--
150	--	--
151	6,250	--
152	6,245	--
Tahoe Vista Vicinity		
144	6,440	130

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, California DHS, and California DWR.
4. 1 meter = 3.2808 feet

Nutrient data has been collected for the Old Brockway Golf Course wells since 1989. Monitoring of well 144 began in 1990 and continues to be monitored. The California DHS retains monitoring data for the drinking water wells to monitor compliance with drinking water standards. See Section 6.5, Nutrient Concentrations for a detailed description of the nutrient data.

Figure 6-1. Tahoe Vista/Kings Beach 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.

Groundwater elevations have been recorded during each sampling event at the Brockway Golf Course. Groundwater elevation data was recorded only at the time of drilling for well 144. No groundwater elevation data is available for the remaining wells. See Table 6-2 for groundwater elevation data in the Tahoe Vista/Kings Beach area.

Table 6-2. Tahoe Vista/Kings Beach Groundwater Elevation Data (ft above msl)

	Well ID				
Date	144	149	151	152	Lake Elevation
Average Water Level	6,180.00	6,266.44	6,245.29	6,237.45	6,221.35
Minimum	--	6,261.60	6,244.00	6,232.80	6,219.42
Maximum	--	6,271.00	6,248.70	6,241.00	6,224.29

Notes:
1. Data was obtained from USGS.
2. Only one elevation was measured for well 144.

Well 144 is located outside of the basin fill aquifer. This well is constructed in fractured bedrock. The gradient between this well and the lake is negative, implying that the lake actually discharges to the groundwater in this area. The gradient within the basin fill aquifer averages 0.02 which corresponds to Thodal's average gradient for the basin (Thodal 1997).

6.5 Nutrient Concentrations

LRWQCB requires Old Brockway Golf Course to monitor groundwater to establish baseline conditions in early spring, monitor the effects of chemicals applied during the summer season and determine residual effects once the active season has ceased (LRWQCB 2000a). At least three groundwater samples are collected between March and November, the first sample occurring prior to any chemical application and one after cessation of chemical application but before winter. The golf course is required to sample groundwater for dissolved chemical constituents passing through a 0.45 micron filter. The nutrient constituents requiring analysis are dissolved Kjeldahl Nitrogen, dissolved nitrate plus nitrite, dissolved orthophosphorus and total dissolved phosphorus. No total dissolved phosphorus results were available.

The USGS has sampled well 144 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.

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. Data for the municipal well has been obtained beginning 1996. The small provider wells have data from 2002 only.

The average concentrations of each constituent are listed in Table 6-3.

Table 6-3. Tahoe Vista/Kings Beach Average Nutrient Concentration (mg/L)

	Well ID							
Constituent	144	149	150	151	152[a]	142	143	145
Land Use	Residential	Recreational	Recreational	Recreational	Recreational	Residential	Residential	Recreational
Ammonia + Organic	0.080	1.100	1.100	0.081	0.661	na	na	na
Nitrate	0.050	0.340	0.064	0.077	0.880	0.050	0.510	0.240
Total Nitrogen	0.130	1.400	1.100	0.160	1.500	na	na	na
Orthophosphate	0.036	0.061	0.079	0.035	0.130	na	na	na
Total Phosphorus	0.056	na	na	na	na	na	na	na
Top of Open Interval	335	Shallow	Shallow	Shallow	Shallow	--	--	240

Notes:

1. All concentrations reported are dissolved.
2. Data obtained from USGS, LRWQCB, and CA DHS
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 wells 142 and 143; 5 samples for well 145; 13 samples for well 144; 14-16 samples for well 151; 29-30 samples for well 150; 43-46 samples for well 152; and 44-47 samples for well 149.

6.5.1 Old Brockway Golf Course Data

Old Brockway Golf Course has five groundwater monitoring points at the site, four of which have groundwater monitoring data available. Upgradient monitoring well 4 has no data associated with it. Monitoring well 150 is considered an upgradient well. Monitoring wells 149, 151 and 152 are downgradient wells. In general, the concentration of all forms of nitrogen is higher in the downgradient well as compared to the upgradient well. The concentration of orthophosphate is at the detection limit in a majority of the samples for monitoring wells 149, 150, and 151. Monitoring well 152 consistently has orthophosphate concentrations above the detection limit.

Although total phosphorus was not measured in the golf course wells, an estimate is made as part of this evaluation. This estimate is based on the average percent organic phosphorus from the two wells in the vicinity is approximately 42% of the total phosphorus. This corresponds to Thodal's estimate of organic phosphorus percentage for the entire Tahoe Basin (Thodal 1997). This percentage was used to estimate the organic phosphorus and finally the total phosphorus estimates for the golf course monitoring wells.

The data shows that the groundwater entering the golf course is elevated in total nitrogen concentrations. The values are below the maximum concentration for discharge to land treatment systems (5 mg/L as N), but higher than the maximum concentration for discharge to surface waters (0.5 mg/L as N), as regulated by LRWQCB. The estimated total phosphorus concentration of groundwater entering the golf course is typically below the maximum concentration for discharge to land treatment systems (1 mg/L as N), and the maximum concentration for discharge to surface waters (0.5 mg/L as N), as regulated by LRWQCB. The land uses upgradient of the golf course primarily consist of single family and multi family residential. The potential sources of nutrients from the land use types are fertilizer, abandoned septic systems, urban runoff and active sewer lines.

The groundwater monitoring activities show that the concentration of nitrogen increases as it passes through the golf course. Monitoring well 152 is the only downgradient well that consistently shows higher estimated phosphorus concentrations. This well is not only downgradient from the golf course, but also a residential complex located within the boundary of the golf course. This indicates that the golf course and residential complex are contributing sources to the groundwater nutrient concentrations.

6.5.2 Drinking Water Wells

Wells 142 and 143 have only been sampled for nitrate and only one date has been recorded. Therefore, no evaluation of trends can be made for these wells. The well located within the Regional Park, 145, has only been sampled for nitrate. This well has consistently higher concentrations of nitrate each year. In addition, this well represents the deep water aquifer showing concentrations of nitrate approaching the maximum total nitrogen concentration for discharge to surface waters. This does not include organic nitrogen or ammonia, as no testing

has been conducted for those constituents. This deep water monitoring well should be evaluated yearly to determine if the increase in nitrogen concentration continues.

6.6 Groundwater Discharge

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

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 gradient, 0.02, between the monitoring well and lake was used in the estimate. The median hydraulic conductivity, 15 m/day (50 ft/day) as determined from the boring logs was used. The length of the basin fill aquifer is estimated at 6,000 meters (3.7 miles). The aquifer depth is 15 meters (50 feet).

The calculation yields an estimated discharge rate of 9.7×10^6 m^3/year (7,900 acre-ft/year).

The California Department of Water Resources (CA DWR) estimated that the length of shoreline intersecting basin fill deposits is approximately 4,000 meters (2.5 miles) (CADWR 2003a). CA DWR defined basin boundaries primarily using geologic contacts and hydrogeologic divides. Specifically the identification of the groundwater basins was initially based on the presence and aerial extent of unconsolidated alluvial sediments identified on 1:250,000 scale, geologic maps published by the California Department of Conservation, Division of Mines and Geology. The identified groundwater basin areas were then further evaluated through review of relevant geologic and hydrogeologic reports, and well completion reports to refine the basin boundaries (CADWR 2003b). Using this estimate, the groundwater discharge reduces to 6.4×10^6 m^3/year (5,200 acre-ft/year).

6.7 Nutrient Loading

The potential range of nutrient discharge from the Tahoe Vista/Kings Beach area occurring as direct groundwater inputs to Lake Tahoe was calculated by multiplying the estimates of annual groundwater discharge by concentrations of nutrients found in monitoring wells. Details of the methodology used are described in Section 3.2.

The average nutrient concentrations for all wells in the Tahoe Vista/Kings Beach area were multiplied by the groundwater flux estimates calculated in Section 6.6, Groundwater Discharge. Table 6-4 summarizes the nutrient flux using this method. The wells used in this estimation are mostly concentrated within a golf course. This does not represent a majority of the land use in the area and therefore is not representative. This approach also neglects the accumulation of nutrients as groundwater progresses downgradient through potential sources.

A more accurate method for this region is to multiply the average nutrient concentration in the downgradient well, 152, by the groundwater discharge estimates calculated. Table 6-4 summarizes the nutrient flux using this method. This method provides a reasonable estimation

of nutrient loading to Lake Tahoe. Although the downgradient well is located in a golf course, it does represent much of the land use in the Tahoe Vista/Kings Beach area. The golf course well is downgradient of residential and commercial land uses. This indicates that any contamination resulting from those land uses are intercepted by the well 152. This method may slightly overestimate the nutrient concentrations for the region as the wells also accumulate nitrogen and phosphorus from golf course activities that would be absent elsewhere in the region.

Although the wells in the Tahoe Vista/Kings Beach area are placed such that they represent the area more accurately than the Incline Village wells, there are still areas that are without data. To account for this, the dataset compiled for the entire basin was used to apply average nutrient concentrations within similar land use categories. A majority of this area consists of residential, recreational and commercial land use types. Each type represents approximately one-third of the area. Using the averages established for these land use categories (see Section 3.2.1) land use weighted average concentrations were developed.

The land use weighted average and discharge estimate using 6,000 meters (3.7 miles) of shoreline are used in the basin-wide estimate for overall nutrient loading to Lake Tahoe. The land use weighted average was chosen to best represent the nutrient concentrations that are likely in this region. The longer extent of basin fill aquifer is a more conservative approach to estimate the regional nutrient loading.

Table 6-4. Tahoe Vista/Kings Beach Average, Downgradient and Land Use Weighted Annual Nutrient Loading

		Average Concentration Method		Downgradient Concentration Method		Land Use Weighted Method	
Constituent	Groundwater Flux (m^3/year)	Average Concentration (mg/L)	Nutrient Loading (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading (kg/yr)	Land Use Weighted Average Concentration (mg/L)	Nutrient Loading (kg/yr)
Ammonia + Organic	9.7E+06	0.506	4,900	0.660	6,400	0.27	2,700
	6.4E+06		3,200		4,200		1,700
Nitrate	9.7E+06	0.250	2,400	0.880	8,600	0.70	6,800
	6.4E+06		1,600		5,600		4,500
Total Nitrogen	9.7E+06	0.750	7,300	1.5	15,000	0.97	9,400
	6.4E+06		4,800		9,900		6,200
Orthophosphate	9.7E+06	0.061	590	0.13	1,300	0.084	820
	6.4E+06		390		840		540
Total Phosphorus	9.7E+06	0.105	1,000	0.230	2,200	0.11	1,100
	6.4E+06		670		1,500		720

Notes:
1. Total Phosphorus concentrations for the average and downgradient concentration method are an estimation based on an assumed 42% content of organic phosphorus.
2. 1 m^3/year = 0.0008 acre-feet/year, 1 kg/yr = 2.2 lb/yr
3. Average nutrient concentrations are derived from those included in Table 6-3.
4. All concentrations reported are dissolved.

6.8 Ambient Nutrient Loading

Ambient loading was calculated from the basin-wide data set for wells located in a forested land use. 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 2,600 kg/year (5,700 lbs/yr). The estimated ambient total dissolved phosphorus concentration entering the lake is 480 kg/year (1,100 lbs/yr). Table 6-5 summarizes the loading estimates.

Table 6-5. Tahoe Vista/Kings Beach Ambient Nutrient Loading Estimate

	Groundwater Discharge (m^3/year)	Ambient Total Dissolved Nitrogen (mg/L)	Ambient Total Dissolved Phosphorus (mg/L)	Ambient Nitrogen Nutrient Loading (kg/year)	Ambient Phosphorus Nutrient Loading (kg/year)
Incline Village	9.7E+06	0.27	0.049	2,600	480

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.

6.9 Summary & Conclusions

The Tahoe Vista/Kings Beach area has only a limited amount of data for the region. The public water supply in this area is mostly taken from the lake, leaving only one municipal supply well in the area. A golf course is monitored in the basin, but as the only major source of data, this could be unduly showing high concentrations of nutrients in the area.

There is a very limited monitoring well system in the Tahoe Vista/Kings Beach area. The majority of wells used for monitoring are located in the eastern region. This small network provides only a limited amount of data for land uses that are predominant in the remainder of the watershed. A majority of the wells are currently located in recreational areas, specifically a golf course. There is very limited data for residential or commercial areas of basin fill deposits 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 information is generally lacking in the 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. Currently, a limited number of wells exist in this part of the basin. The geometry of the sedimentary fill below Tahoe Vista/Kings Beach is unknown. Additional geology information would reduce errors in the loading estimate. Conducting pumping tests on the existing wells as well as performing additional geophysical (or seismic) 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. A more complete groundwater level monitoring network would be required near gaged streams. A better understanding of the impacts the faults have on groundwater movement is another important factor.

A better definition of the actual source(s) of nutrients is needed. The IKONOS satellite imagery could be used to determine if any neighborhoods have a significant amount of fertilized lawns. The imagery can be processed to display areas with high nutrient content, both natural and fertilized area. These areas could then be targeted for additional monitoring. More detailed historical record searches could be performed to locate and study the residual effects of septic systems.

Another important source of nutrients could be the former treated wastewater pond located in the North Tahoe Regional Park. Additional data on the long term effects of the area should be undertaken to determine if this is a significant contributor of nutrients to the groundwater system.

The screen intervals of the wells should be determined. This will provide additional information regarding the portion of the aquifer which is being monitored by each well. This will aid in the design of any additional wells that would be useful to the monitoring of the area.

The groundwater discharge estimates ranged from 6.4×10^6 to $9.7 \times 10^6 m^3$/year (5,200 to 7,900 acre-ft/year). The range of values is due to uncertainty in the length of basin fill deposits bounding Lake Tahoe. A number of methods were used to provide a range of nutrient loading estimates for each region.

Comparing the total groundwater nutrient loading (Table 6-4) to the ambient nutrient loading (Table 6-5), natural processes may make up to 28% of the nitrogen and 44% of the total dissolved phosphorus loading to the lake.

This region has the potential to be discharging 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. A more extensive and representative monitoring network would provide additional information that could be used to better estimate the nutrient loading to Lake Tahoe. It could also be used to target the sources of nutrients which have the potential of contributing the most nutrients to the lake.