The area to the west of Taylor Creek and extending to Emerald Bay was not included in the model due to lack of data. The well in this area included only two groundwater level measurements. The gradients from these two measurements to the lake were 0.0018 and 0.018, averaging 0.0099. The land surface gradient in this area is similar to the average, 0.008. Using the range of gradients from 0.018 to 0.0018, a shoreline length of 1,900 meters (6,200 feet), average depth of aquifer of 15 meters (50 ft) and a hydraulic conductivity of 15 m/day (50 ft/day), the discharge from this area ranges from 2.5×10^5 to 2.8×10^6 m^3/year (200 to 2,300 acre-feet/year). The discharge estimate using the average hydraulic gradient is 1.6×10^6 m^3/year (1,300 acre-feet/year).

The California/Nevada border was the eastern boundary of the model therefore, the Stateline area discharge estimate was calculated. As the near shore topography is similar to that of South Lake Tahoe, an estimated hydraulic gradient of 0.0028 is reasonable. Using the gradient of 0.0028, a shoreline length of 2,400 meters (7,900 ft), average depth of aquifer of 15 meters (50 ft) and a hydraulic conductivity ranging from 15 to 25 m/day (50 to 82 ft/day), the discharge from this area ranges from 4.9×10^5 to 8.6×10^5 m^3/year (400 to 700 acre-feet/year).

Although the area from Taylor Creek to the California/Nevada state line was modeled for groundwater discharge, Darcy's Law was also applied in this subregion. The results of the Darcy's Law approach were developed to compare with the model results to determine if this method is reasonable for developing groundwater discharge rates in other regions. The shoreline lengths used were 3,100 meters (1.9 miles), 2,000 meters (1.2 miles), 3,300 meters (2.1 miles) and 2,300 meters (1.4 miles) for subregions 1 through 4, respectively. The depth of aquifer used in all subregions was 12 meters (39 feet). This depth was based on the finding that about 80% of the flow comes from the top 12 meters (39 feet) of fill. The hydraulic conductivity ranged from 15 m/day (50 ft/day) in subregion 1 to 21 m/day (70 ft/day) in subregion 2. The hydraulic gradient ranged from 0.0007 in subregion 3 to 0.005 in subregion 1. The groundwater discharge rates estimated using this method are 9.9×10^5 m^3/year (800 acre-feet/year), 2.5×10^5 m^3/year (200 acre-feet/year), 1.2×10^5 m^3/year (100 acre-feet/year), and 3.7×10^5 m^3/year (300 acre-feet/year) for subregions 1 through 4, respectively.

4.5 Nutrient Loading

The potential range of nutrient discharge via groundwater from the South Lake Tahoe/Stateline area to Lake Tahoe was calculated by multiplying the estimates of annual groundwater discharge for each subregion by concentrations of nutrients found in monitoring wells in the respective subregions. Details of the methodology used are described in Section 3.2.

4.5.1 Emerald Bay to Taylor Creek

This area only contains one well, 041, with analytical results for all nutrient forms of interest. Although this would normally be a constraint, the well is located in a significant location being close to the lake and within the predominant land use. For this reason, only one method of estimating loading was used, as it represents average, downgradient and land use weighted estimates. The average nutrient concentrations for well 041 are multiplied by the groundwater flux estimates calculated in Section 4.4. Table 4-12 summarizes the nutrient flux using this method.

The average concentrations, in conjunction with the discharge estimate using the average hydraulic gradient, 1.6x10^6 m^3/year (1,300 acre-feet/year), are the best representation of the average nutrient loading from the Emerald Bay to Taylor Creek subregion to Lake Tahoe.

Table 4-12. South Lake Tahoe Average Annual Nutrient Loading, Emerald Bay to Taylor Creek

Constituent	Groundwater Flux (m^3/year)	Average Concentration Method: Average Concentration (mg/L)	Average Concentration Method: Nutrient Loading Estimate (kg/yr)
Ammonia + Organic	2.8E+06		130
	1.6E+06		72
	2.5E+05	0.045	11
Nitrate	2.8E+06		140
	1.6E+06		82
	2.5E+05	0.051	13
Total Nitrogen	2.8E+06		270
	1.6E+06		150
	2.5E+05	0.096	24
Orthophosphate	2.8E+06		200
	1.6E+06		110
	2.5E+05	0.071	18
Total Phosphorus	2.8E+06		240
	1.6E+06		140
	2.5E+05	0.085	21

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 Table 4-3.
3. All concentrations reported are dissolved.
4. All groundwater flux estimates were developed using Darcy's Law.

4.5.2 Subregion 1

Both the average nutrient concentration and downgradient nutrient concentration methods were used for Subregion 1. The land use weighted method was not used as the wells in this subregion are located such that they represent the regional land use.

An average concentration for all nutrients of concern was determined for the subregion. The concentrations used to calculate the subregional averages are shown in Table 4-4. Wells 047 and 048 were averaged as one well since they are collocated. In addition, the same was done for wells 051, 052, 053, 054, 056 and 057. The average nutrient concentrations were multiplied by the groundwater flux estimates calculated in Section 4.4.

The wells in subregion 1 which best represent the downgradient concentrations are 043, 047, and 048. Again, wells 047 and 048 were combined as one for developing the average concentration. The average nutrient concentrations for these wells were multiplied by the groundwater discharge estimates calculated in Section 4.4. Table 4-13 summarizes the nutrient flux estimate using these methods.

The downgradient approach is the most reasonable estimate for the subregion. The downgradient wells represent the land uses of the subregion and would account for the accumulation or degradation of nutrients. The downgradient concentrations, in conjunction with the normal average year discharge rate, are the best representation of the average nutrient loading from subregion 1 to Lake Tahoe.

Table 4-13. South Lake Tahoe Average & Downgradient Annual Nutrient Loading, Subregion 1

			Average Concentration Method		Downgradient Concentration Method	
Constituent	Discharge Estimate Type	Groundwater Flux (m^3/year)	Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)
Ammonia + Organic	Normal Average	4.7E+05	0.490	230	0.72	340
	Maximum Average	6.8E+05		330		490
	Minimum Average	2.3E+05		110		170
	Darcy's Law	9.9E+05		480		710
Nitrate	Normal Average	4.7E+05	0.050	23	0.065	30
	Maximum Average	6.8E+05		34		44
	Minimum Average	2.3E+05		12		15
	Darcy's Law	9.9E+05		49		64
Total Nitrogen	Normal Average	4.7E+05	0.54	250	0.78	370
	Maximum Average	6.8E+05		370		530
	Minimum Average	2.3E+05		127		180
	Darcy's Law	9.9E+05		530		770
Orthophosphate	Normal Average	4.7E+05	0.044	21	0.033	15
	Maximum Average	6.8E+05		30		22
	Minimum Average	2.3E+05		10		8
	Darcy's Law	9.9E+05		43		33
Total Phosphorus	Normal Average	4.7E+05	0.048	22	0.06	28
	Maximum Average	6.8E+05		33		41
	Minimum Average	2.3E+05		11		14
	Darcy's Law	9.9E+05		47		59

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 Table 4-4.
3. All concentrations reported are dissolved.

4.5.3 Subregion 2

All three methods of estimation to determine nutrient concentrations are used in subregion 2. The wells are distributed throughout the area, so both the average and downgradient methods are applicable. The wells are not located in prime locations according to land use, therefore the land use weighted method of estimation is also applied in this subregion. This method uses characteristics of similar land use types basin-wide to better represent the concentrations of nutrients in groundwater. Table 4-14 shows the nutrient loading estimates for all methods.

The average nutrient concentrations were calculated for dissolved nitrate and total dissolved phosphorus using the average concentrations from the wells listed in Table 4-5. Only well 050 was monitored for ammonia + organic and orthophosphorus in this subregion. To establish a better estimate for these constituents as well as total dissolved nitrogen, the concentration for ammonia + organic was estimated using the nitrate concentrations as a basis. Nitrate represented 90% of the total nitrogen in well 050. Thodal (1997) estimated that the percentage of nitrate to total nitrogen was 85%. Orthophosphorus represented 61% of the total phosphorus in well 050. Thodal (1997) estimated that the percentage of orthophosphorus to total phosphorus was 55%. Thodal's estimates were based upon a larger data set and were used for the estimation in this subregion.

There are several sources of error in using the average nutrient loading method. The majority of wells used in this estimation are located a considerable distance from the lake (Figure 4-11), and do not take into account cumulative effects downgradient. The wells are clustered together and do not represent the distribution of land uses in the area.

Well 050 is the most downgradient well in this subregion. The average concentration for this well was used in the downgradient nutrient loading estimate. This method is not ideal as the downgradient well does not represent a majority of the land use. In addition, this well is deep (Table 4-5) and would not reveal the concentrations of nutrients in the shallow aquifer where they would be expected to be higher.

The land use weighted concentration method is more appropriate for this subregion. This method takes into account the major land uses of the area to estimate the average nutrient concentrations. The predominant land uses in this subregion are commercial and residential. They each account for approximately 50% of the land use in the subregion. A weighted average, using the values established in Section 3.2.1, was determined for each form of nitrogen and phosphorus. These weighted averages were used in conjunction with the discharge estimates to determine the estimated land use weighted nutrient loading for subregion 2.

The most reasonable estimate for this subregion uses the land use weighed concentrations and the normal average year discharge estimate. This method provides an estimation for subregion 2 which does not have an adequate monitoring network to evaluate the nutrients in the area.

Table 4-14. South Lake Tahoe Average , Downgradient & Land Use Weighted Annual Nutrient Loading, Subregion 2

Constituent	Discharge Estimate Type	Groundwater Flux (m^3/year)	Average Concentration Method: Average Concentration (mg/L)	Average Concentration Method: Nutrient Loading Estimate (kg/yr)	Downgradient Concentration Method: Downgradient Average Concentration (mg/L)	Downgradient Concentration Method: Nutrient Loading Estimate (kg/yr)	Land Use Weighted Method: Land Use Average Concentration (mg/L)	Land Use Weighted Method: Nutrient Loading Estimate (kg/yr)
Ammonia + Organic	Normal Average	1.2E+06	0.12	140	0.043	52	0.21	250
	Maximum Average	1.6E+06		180		69		340
	Minimum Average	7.2E+05		82		31		150
	Darcy's Law	2.5E+05		28		11		52
Nitrate	Normal Average	1.2E+06	0.680	820	0.37	450	0.440	530
	Maximum Average	1.6E+06		1,100		600		710
	Minimum Average	7.2E+05		490		270		310
	Darcy's Law	2.5E+05		170		92		110
Total Nitrogen	Normal Average	1.2E+06	0.79	960	0.42	510	0.65	790
	Maximum Average	1.6E+06		1,300		670		1,000
	Minimum Average	7.2E+05		570		300		470
	Darcy's Law	2.5E+05		200		100		160
Orthophosphate	Normal Average	1.2E+06	0.022	26	0.018	22	0.086	100
	Maximum Average	1.6E+06		35		29		140
	Minimum Average	7.2E+05		16		13		62
	Darcy's Law	2.5E+05		5		4		21
Total Phosphorus	Normal Average	1.2E+06	0.039	47	0.029	35	0.12	150
	Maximum Average	1.6E+06		63		47		190
	Minimum Average	7.2E+05		28		21		86
	Darcy's Law	2.5E+05		10		7		30

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 Table 4-5.
3. All concentrations reported are dissolved.

4.5.4 Subregion 3

All three methods of estimation to determine nutrient concentrations are used in Subregion 3. The wells are distributed throughout the area, so both the average and downgradient methods are applicable. The wells are not located in prime locations according to land use, therefore the land use weighted method of estimation is also applied in this subregion. This method uses characteristics of similar land use types basin-wide to better represent the concentrations of nutrients in groundwater. Table 4-15 shows the nutrient loading estimates for all methods.

The average nutrient concentrations were calculated for dissolved nitrate and total dissolved phosphorus using the average concentrations from the wells listed in Table 4-6. Only wells 045 and 049 were monitored for ammonia + organic and orthophosphorus in this subregion. To establish a better estimate for these constituents as well as total dissolved nitrogen, the concentration for ammonia + organic was estimated using the nitrate concentrations as a basis. Again, Thodal's estimates of 85% nitrate and 55% orthophosphorus were used in this subregion based upon a larger data set. The average concentration approach is not suited for this area as most of the wells are screened within the deep aquifer. This method neglects those concentrations found in the shallow aquifer and bias the estimates to lower concentrations. The potential accumulation of nutrients downgradient is not accounted for in the averaging method.

Well 039 is the most downgradient well in this subregion with nutrient concentrations reported. The downgradient approach is not the best method to use in this subregion. The well is located approximately 450 meters (1,500 ft) from the shore and does not represent downgradient concentrations. These well is deep, neglecting the shallow aquifer.

The land use weighted method is the most appropriate for the subregion. This takes into account the primary land use and provides an estimation over a range of aquifer depths. The predominant land uses in this subregion are ambient, residential and commercial representing approximately 50%, 33% and 17% of the land use in the subregion, respectively. A weighted average, using the values established in Section 3.2.1, was determined for each form of nitrogen and phosphorus. These weighted averages were used in conjunction with the discharge estimates to determine the estimated land use weighted nutrient loading for subregion 3.

The most reasonable estimate for this subregion uses the land use weighed concentrations and the normal average year discharge estimate. This method provides an estimation for subregion 3 which does not have an adequate monitoring network to evaluate the nutrients in the area.

Table 4-15. South Lake Tahoe Average, Downgradient & Land Use Weighted Annual Nutrient Loading, Subregion 3

			Average Concentration Method		Downgradient Concentration Method		Land Use Weighted Method	
Constituent	Discharge Estimate Type	Groundwater Flux (m^3/year)	Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Land Use Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)
Ammonia + Organic	Normal Average	4.9E+04	0.099	5	0.097	5	0.19	9
	Maximum Average	9.0E+04		9		9		17
	Minimum Average	1.2E+03		0		0		0
	Darcy's Law	1.2E+05		12		12		23
Nitrate	Normal Average	4.9E+04	0.35	17	0.550	27	0.260	13
	Maximum Average	9.0E+04		31		50		23
	Minimum Average	1.2E+03		0		1		0
	Darcy's Law	1.2E+05		43		68		32
Total Nitrogen	Normal Average	4.9E+04	0.44	22	0.65	32	0.450	22
	Maximum Average	9.0E+04		40		58		41
	Minimum Average	1.2E+03		1		1		1
	Darcy's Law	1.2E+05		55		80		56
Orthophosphate	Normal Average	4.9E+04	0.021	1	0.021	1	0.062	3
	Maximum Average	9.0E+04		2		2		6
	Minimum Average	1.2E+03		0		0		0
	Darcy's Law	1.2E+05		3		3		8
Total Phosphorus	Normal Average	4.9E+04	0.033	2	0.039	2	0.08	4
	Maximum Average	9.0E+04		3		3		7
	Minimum Average	1.2E+03		0		0		0
	Darcy's Law	1.2E+05		4		5		10

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 Table 4-6.
3. All concentrations reported are dissolved.

4.5.5 Subregion 4

All three methods of estimation to determine nutrient concentrations are used in Subregion 4. The wells are distributed throughout the area, so both the average and downgradient methods are applicable. The wells are not located in prime locations according to land use, therefore the land use weighted method of estimation is also applied in this subregion. This method uses characteristics of similar land use types basin-wide to better represent the concentrations of nutrients in groundwater. Table 4-16 shows the nutrient loading estimates for all methods.

An average concentration for all nutrients of concern was determined for the subregion. The concentrations used to calculate the subregional averages are shown in Table 4-7. The average nutrient concentrations were multiplied by the groundwater flux estimates calculated in Section 4.4. Many of the sampling points in this subregion are chosen to monitor specific nutrient sources. This increases the concentration for the subregion, as much of the other land uses are not represented.

The wells in subregion 4 which best represent the downgradient concentrations are 024, and 031. The average nutrient concentrations for these wells were multiplied by the groundwater discharge estimates calculated in Section 4.4. Table 4-13 summarizes the nutrient flux estimate using these methods. The downgradient wells are again designed to monitor specific sources. This may introduce errors when using this as an estimation for the entire subregion.

The land use weighted option is the most appropriate for this subregion. This method considers the type of land use in the subregion to apply average concentrations. The predominant land uses in this subregion are residential and commercial. Commercial and residential land uses represent approximately 25% and 75% of the land use in the subregion, respectively. A weighted average, using the values established in Section 3.2.1, was determined for each form of nitrogen and phosphorus. These weighted averages were used in conjunction with the discharge estimates to determine the estimated land use weighted nutrient loading for subregion 4.

The most reasonable estimate for this subregion uses the land use weighted concentrations and the normal average year discharge estimate. This method provides an estimation for subregion 4 which does not have an adequate monitoring network to evaluate the nutrients in the area. The land use weighted average and normal average year discharge provide the best estimation of nutrient loading for this subregion.

Table 4-16. South Lake Tahoe Average, Downgradient and Land Use Weighted Annual Nutrient Loading, Subregion 4

			Average Concentration Method		Downgradient Concentration Method		Land Use Weighted Method	
Constituent	Discharge Estimate Type	Groundwater Flux (m^3/year)	Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Land Use Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)
Ammonia + Organic	Normal Average	7.2E+05	0.54	380	0.36	260	0.23	170
	Maximum Average	8.6E+05		460		310		200
	Minimum Average	5.6E+05		300		200		130
	Darcy's Law	3.7E+05		200		130		86
Nitrate	Normal Average	7.2E+05	0.75	530	0.40	280	0.400	290
	Maximum Average	8.6E+05		650		340		350
	Minimum Average	5.6E+05		410		220		220
	Darcy's Law	3.7E+05		280		150		150
Total Nitrogen	Normal Average	7.2E+05	1.5	1,100	0.76	540	0.63	450
	Maximum Average	8.6E+05		1,300		650		550
	Minimum Average	5.6E+05		840		420		350
	Darcy's Law	3.7E+05		560		280		230
Orthophosphate	Normal Average	7.2E+05	0.081	58	0.066	47	0.08	60
	Maximum Average	8.6E+05		70		57		72
	Minimum Average	5.6E+05		45		37		46
	Darcy's Law	3.7E+05		30		24		31
Total Phosphorus	Normal Average	7.2E+05	0.052	37	0.12	85	0.12	83
	Maximum Average	8.6E+05		45		100		100
	Minimum Average	5.6E+05		29		66		65
	Darcy's Law	3.7E+05		19		44		43

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 Table 4-7.
3. All concentrations reported are dissolved.

4.5.6 Stateline

The Stateline area wells are dispersed throughout the area, providing a representative network. The wells are located in areas with a variety of land uses, and downgradient wells are present along the shoreline. For this reason, only the average and downgradient methods are applied. Table 4-17 shows the nutrient loading estimates for all methods.

An average concentration for all nutrients of concern was determined for the area. The concentrations used to calculate the subregional averages are shown in Table 4-8. The average nutrient concentrations were multiplied by the groundwater flux estimates calculated in Section 4.4.

The downgradient wells in this subregion are 003, 197, 199 and 200. The average nutrient concentrations for these wells were multiplied by the groundwater discharge estimates calculated in Section 4.4. The average nutrient concentrations for these wells were determined for use in estimating nutrient loading.

The downgradient approach is the most accurate in this subregion. The wells are positioned to monitor a variety of land uses and are close enough to the lake to show representative concentrations of nutrients that could be entering the lake. The downgradient nutrient concentrations and groundwater discharge rate of 8.6 x 10^5 m^3/year (700 acre-feet/year) are considered the most reasonable estimation of nutrient loading to Lake Tahoe from this area.

Table 4-17. Stateline Average & Downgradient Annual Nutrient Loading

		Average Concentration Method		Downgradient Concentration Method	
Constituent	Groundwater Flux (m^3/year)	Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading Estimate (kg/yr)
	4.9E+05		180		320
Ammonia + Organic	8.6E+05	0.370	320	0.64	550
	4.9E+05		480		54
Nitrate	8.6E+05	0.970	840	0.110	95
	4.9E+05		660		370
Total Nitrogen	8.6E+05	1.3	1,200	0.75	650
	4.9E+05		7		10
Orthophosphate	8.6E+05	0.015	13	0.020	17
	4.9E+05		11		17
Total Phosphorus	8.6E+05	0.023	20	0.034	30

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 Table 4-8.
3. All concentrations reported are dissolved.