4.4 Groundwater Discharge

A groundwater flow model was developed by the USACE Hydrologic Engineering Center. The model was broken down into four subregions based upon discharge estimates (Fenske 2003, Appendix B). Several different scenarios were modeled to show the change in discharge based upon climatic changes. The values used in this report are the normal average year, average spring and average fall. The normal average year is based upon taking the average of annually extrapolated spring 2002 (high discharge) conditions and fall 1996 (low discharge) conditions. The average spring discharge rates were used to estimate a maximum discharge rate for a year. In contrast, the average fall discharge rates were used to estimate the minimum groundwater discharge rate annually. This was done to provide a range of discharge that may be occurring in the South Lake Tahoe area. Modeling was also conducted to show a dry and wet year. See Appendix B for a more detailed discussion.

Table 4-9, Table 4-10, and Table 4-11 depict the total groundwater discharge rates for each area by model layer. The tables show that a majority of the groundwater discharge is from the top two layers of the model. This represents approximately the top 15 meters (50 feet) of the groundwater aquifer. Subregion 4 is the only area that shows an increase in flow in the bottom two layers (5 & 6). According to model results in Appendix B, the total simulated flux to the lake is relatively negligible below 46 meters (150 ft). This is due to the gently sloping lakebed surface, and impedance to vertical flow created by confining units. Figure 4-15, Figure 4-16, and Figure 4-17 depict the total groundwater discharge rates for each area.

Table 4-9. South Lake Tahoe Area Total Flux from Groundwater to Lake Tahoe by Layer and Subregion, Average Normal Year (Fenske 2003)

Layer	Midpoint of Layer Elevation, ft above msl	Total Flow into Lake, m^3/year			
		Subregion 1	Subregion 2	Subregion 3	Subregion 4
2	6,222	$4.0x10^5$	$1.2x10^6$	$4.4x10^4$	$4.7x10^5$
3	6,205	$5.8x10^4$	$1.2x10^4$	0	$7.2x10^4$
4	6,180	$1.2x10^3$	0	0	$1.2x10^4$
5	6,143	$1.2x10^3$	$1.2x10^3$	$1.2x10^3$	$8.0x10^4$
6	6,059	$7.4x10^3$	$6.2x10^3$	$3.7x10^3$	$8.9x10^4$
Total		$4.7x10^5$	$1.2x10^6$	$4.9x10^4$	$7.2x10^5$

Notes:
1. The average lake elevation, during a normal average year, is assumed to be 6225 ft MSL.
2. 1 m^3/year = 0.0008 acre-feet/year

Table 4-10. South Lake Tahoe Area Total Flux from Groundwater to Lake Tahoe by Layer and Subregion, Maximum Discharge (Fenske 2003)

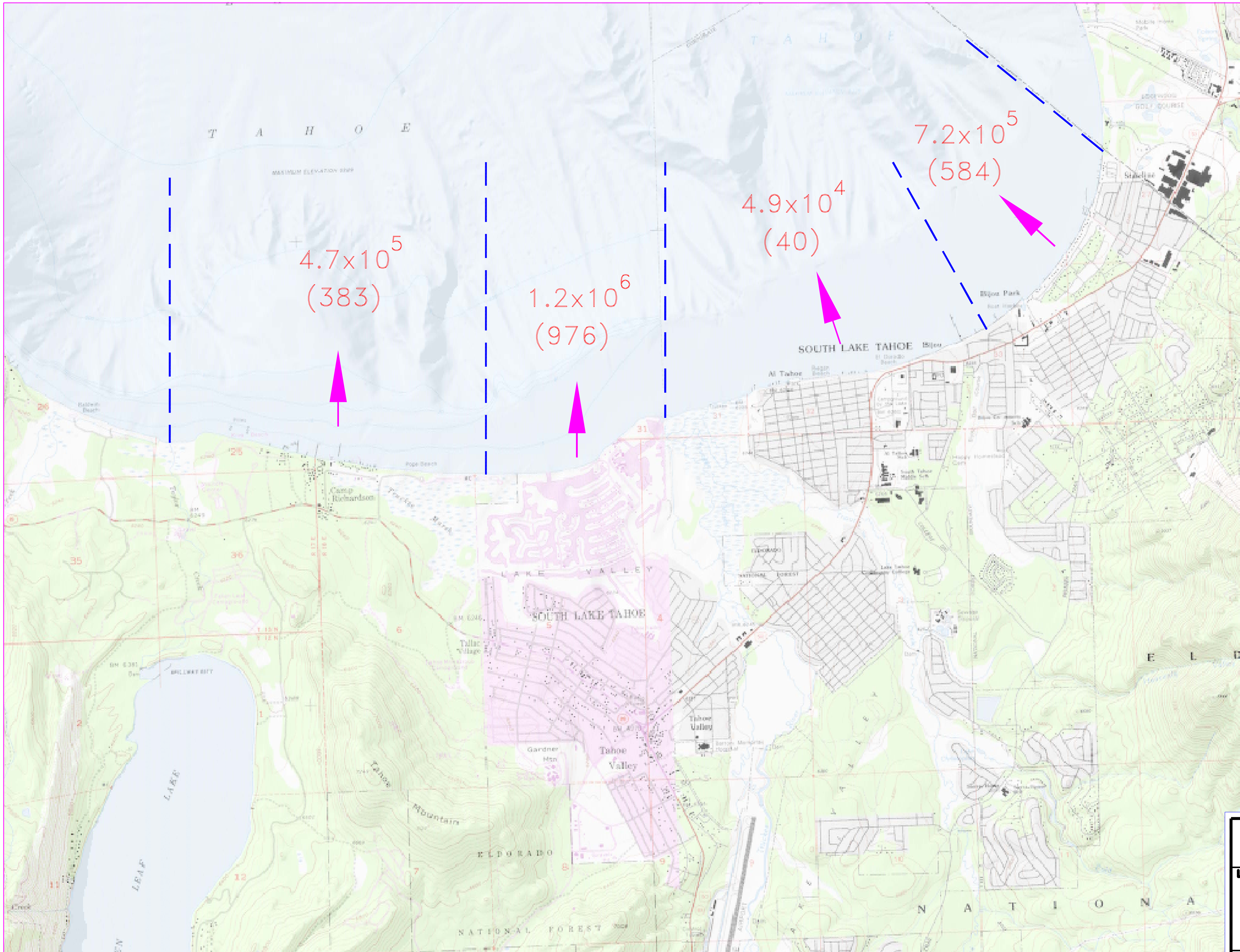
Layer	Midpoint of Layer Elevation, ft above msl	Total Flow into Lake, m^3/year			
		Subregion 1	Subregion 2	Subregion 3	Subregion 4
2	6,222	$5.7x10^5$	$1.6x10^6$	$8.3x10^4$	$5.6x10^5$
3	6,205	$9.0x10^4$	$1.7x10^4$	0	$8.5x10^4$
4	6,180	$1.2x10^3$	$1.2x10^3$	0	$1.5x10^4$
5	6,143	$2.5x10^3$	$1.2x10^3$	$2.5x10^3$	$9.7x10^4$
6	6,059	$1.1x10^4$	$1.1x10^4$	$6.2x10^3$	$1.0x10^5$
Total		$6.7x10^5$	$1.6x10^6$	$9.0x10^4$	$8.6x10^5$

1. 1 m^3/year = 0.0008 acre-feet/year

Table 4-11. South Lake Tahoe Area Total Flux from Groundwater to Lake Tahoe by Layer and Subregion, Minimum Discharge (Fenske 2003)

Layer	Midpoint of Layer Elevation, ft above msl	Total Flow into Lake, m^3/year			
		Subregion 1	Subregion 2	Subregion 3	Subregion 4
2	6,222	$2.1x10^5$	$7.0x10^5$	0	$3.6x10^5$
3	6,205	$1.9x10^4$	$7.4x10^3$	0	$5.6x10^4$
4	6,180	0	0	0	$9.9x10^3$
5	6,143	0	0	0	$5.9x10^4$
6	6,059	$3.7x10^3$	$1.2x10^3$	$1.2x10^3$	$6.9x10^4$
Total		$2.3x10^5$	$7.1x10^5$	$1.2x10^3$	$5.5x10^5$

1. 1 m^3/year = 0.0008 acre-feet/year



LEGEND:

7.2×10^5 (584) GROUNDWATER DISCHARGE CUBIC METERS/YEAR (ACRE FEET/YEAR)

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OCTOBER 2003

LAKE TAHOE — CALIFORNIA/NEVADA

SOUTH LAKE TAHOE AREA
TOTAL GROUNDWATER FLUX TO LAKE TAHOE

NORMAL YEAR– AVERAGE

SCALE: NOT TO SCALE — FIGURE: 4–15

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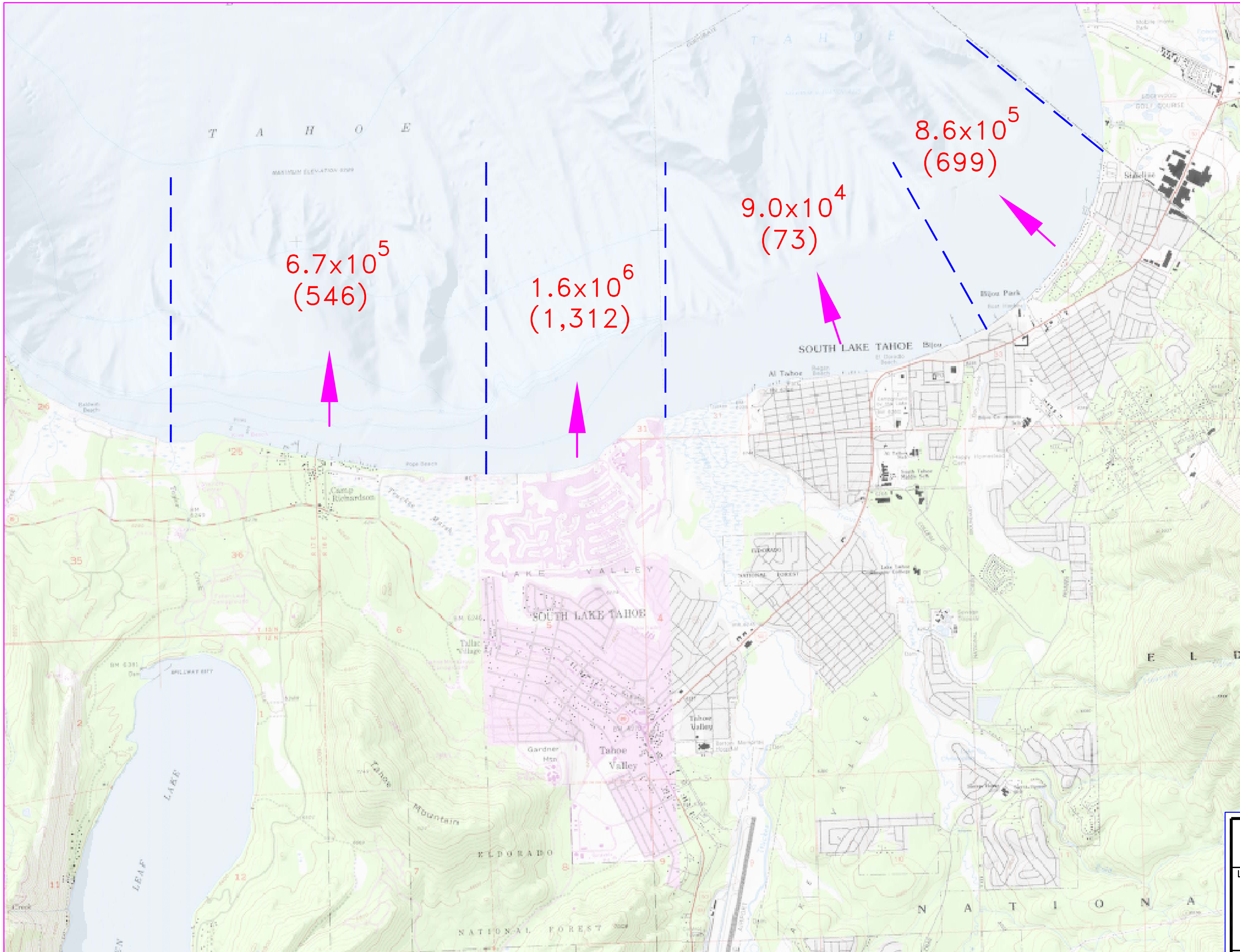

LEGEND:

6.7x10^5 (546) — GROUNDWATER DISCHARGE CUBIC METERS/YEAR (ACRE FEET/YEAR)

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LAKE TAHOE — CALIFORNIA/NEVADA

SOUTH LAKE TAHOE AREA
TOTAL GROUNDWATER FLUX TO
LAKE TAHOE

MAXIMUM DISCHARGE

SCALE: NOT TO SCALE — FIGURE: 4–16

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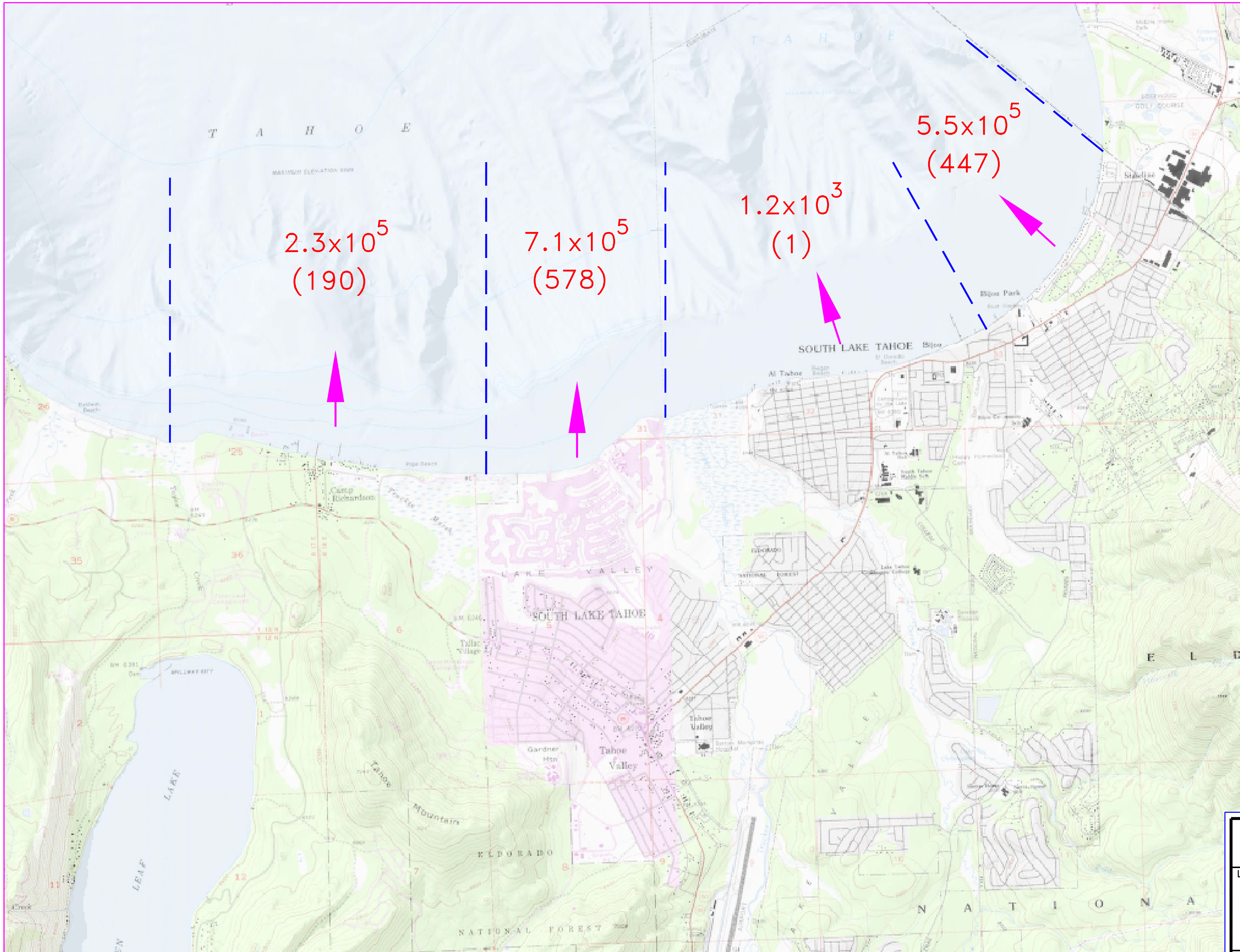

LEGEND:

2.3×10^5 (190) GROUNDWATER DISCHARGE CUBIC METERS/YEAR (ACRE FEET/YEAR)

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OCTOBER 2003

LAKE TAHOE CALIFORNIA/NEVADA

SOUTH LAKE TAHOE AREA
TOTAL GROUNDWATER FLUX TO LAKE TAHOE

MINIMUM DISCHARGE

SCALE: NOT TO SCALE

FIGURE: 4-17

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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 $2.5x10^5$ to $2.8x10^6$ m^3/year (200 to 2,300 acre-feet/year). The discharge estimate using the average hydraulic gradient is $1.6x10^6$ 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 $4.9x10^5$ to $8.6x10^5$ 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