2.0 PROBLEM STATEMENT

The process of sedimentation is the detachment, transport, and deposition of inorganic particles by water (Beschta 1996, 124). Although sediment is a necessary part of the watershed, excessive sediment can impair beneficial uses such as recreation, aquatic life habitat, and drinking water supply (USEPA 1999b). The transport of sediment particles in the water column and deposition of excessive sediments on lake and creek bottoms can reduce growth and survival rates of bottom-dwelling organisms, clog fish gills, and affect fish food sources and the ability of organisms to hide from prey. Changes in water temperature can also result, in turn affecting aquatic biota. Transport and build up of excess sediment can also change the habitat from more complex to less complex, leading to reduced biotic diversity (USEPA 1999b). Researchers have found reduced numbers and diversity of macroinvertebrates with turbidity values of 7-23 NTUs[8]. This reduction is most likely due to reduced periphyton[9] biomass resulting from light attenuation caused by the increase in turbidity (USEPA 2000, 33). Build up of excess sediment in certain areas can result in boat navigational hazards and limit water contact recreation activities.

While the term sediment refers to inorganic soil particles, organic particulate matter can also be a significant part of the total solids suspended in the water column, contributing to increased turbidity and reduced water clarity and light penetration, and to excessive sedimentation on lake and creek bottoms. Biological organisms contribute wastes that may settle on the lake bottom; dead and decaying organic matter also settles to the bottom. Organic particulate matter is also transported from the watershed with soil particles, particularly in streams draining forested watersheds or streams with high densities of riparian vegetation (Beschta 1996, 124).

Big Bear Lake and Rathbun Creek were placed on the Clean Water Act Section 303(d) list for sedimentation/siltation[10]. Excessive erosion and sediment transport in Rathbun Creek and the build-up of sediment in Big Bear Lake adversely affect the warm and cold freshwater habitat, recreational and municipal beneficial uses of these water bodies.

As described in Section 1.1, Rathbun Creek has been hydromodified and this has led to problems with stream channel stability. Bank erosion and stream bottom down cutting are significant problems in the creek that lead to sediment transport to the lake. Watershed sources also contribute sediment that is transported to the creek and thence Big Bear Lake. Aquatic habitat in Rathbun Creek is adversely affected by both the production and transport of sediment.

Over time, the capacity of Big Bear Lake has decreased due to erosion and transport of sediment from the watershed[11]. It is likely that watershed disturbances (e.g., conversion of forest land to ski resorts, urbanization, and road building) and changes in watershed hydrology led to increased erosion and transport of sediment to the lake. A recent hypothesis is that the changing lake levels contribute to the sedimentation problem in Big Bear Lake (Kirby 2005). Excessive sediment build up in Big Bear Lake, particularly at the mouths of the tributary creeks, has limited or restricted recreational access. Shallow areas at the mouths of the creeks and elsewhere in the lake allow for greater light penetration to the bottom, usually resulting in an increase in macrophyte biomass. In these shallow, littoral areas of Big Bear Lake, aquatic macrophytes are

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[8] Turbidity values are reported in NTUs. Turbidity is a measurement of how clear the water is - higher amount of total suspended solids, the higher the measured turbidity.
[9] Periphyton are organisms that grow on underwater surfaces.
[10] Siltation is the deposition of soil particles on lake or stream bottoms.
[11] Initial capacity (1912) of 85, 400 af. In 1977, storage capacity was 72,500 af (BBMWD 2002).

overabundant, especially the noxious aquatic plant, Eurasian watermilfoil[12]. Excessive macrophyte growth and the dominance of certain species severely impact the beneficial uses of the lake, including water contact recreation (REC1), non-contact water recreation (REC2), warm (WARM) and cold (COLD) freshwater habitat, wildlife habitat (WILD) and municipal and domestic supply (MUN)[13].

Sedimentation also contributes to the eutrophication problem in the lake since nutrients are sorbed to soil particles. Via sedimentation, nutrients are deposited on the lake bottom and may then become resuspended in the water column and available for plant growth (see also Big Bear Lake Nutrient TMDLs staff report, June 1, 2005).

Runoff from the watershed results in the addition of nitrogen and phosphorus to surface waters. Inorganic nitrogen is transported in surface water runoff in both dissolved and particulate forms. Phosphorus is transported to surface waters via eroded sediments. Phosphorus can become biologically unavailable as it sorbs to particles and the bottom substrate of lakes and reservoirs. However, as the bottom layer of a lake or reservoir becomes anoxic, phosphorus can desorb from sediments and recycle back into the water column. Also, bottom dwellers such as carp can disturb the bottom layer, causing phosphorus to be released from the sediments back into the water column. Algae, including both microscopic and attached forms, and bacteria, take up soluble reactive phosphorus (SRP), mainly as orthophosphate, and convert it to organic phosphorus. These algae and bacteria are in turn consumed by zooplankton, which excrete some of the organic phosphorus as SRP. Plants and animals then take in the SRP and the cycle begins again (USEPA 1999a, 2-4).

Phosphorus is deposited in lake bottom sediments via five different pathways: sedimentation of phosphorus minerals transported from the surrounding watershed; adsorption or precipitation of phosphorus with inorganic compounds; allochthonous[14] organic matter sedimentation of phosphorus; autochthonous[15] organic matter sedimentation of phosphorus; and, algal and macrophyte uptake of phosphorus from the water column and subsequent deposition to the sediments as detritus (Wetzel 2001, 245-246).

Because of the relationship between sediment and nutrient inputs to Big Bear Lake, the sediment TMDL for Big Bear Lake is linked to the nutrient TMDLs (see the Big Bear Lake Nutrient TMDLs staff report, June 1, 2005). By reducing sediment loads to the lake, nutrient loads are expected to be reduced as well. The Big Bear Lake nutrient TMDLs contain an in-depth discussion of eutrophication, nitrogen and phosphorus cycles, macrophytes and algae. This discussion is not repeated in this report (see the Big Bear Lake Nutrient TMDLs staff report, June 1, 2005).

The following sections (Sections 2.1-2.2) outline the applicable water quality standards and evaluate the data that were used to place Big Bear Lake and Rathbun Creek on the 1994 303(d) list for sedimentation/siltation. The specific justification used to place these waterbodies on the 303(d) list was not documented. The primary reasons for including Big Bear Lake and Rathbun

[12] Note that Eurasian watermilfoil was until recently the most dominant plant in Big Bear Lake. During 2002 and 2003, an aquatic herbicide was applied to Big Bear Lake, which resulted in the almost complete eradication of this noxious aquatic plant. Other plants may become nuisances if allowed to grow within recreational areas or become overabundant, reducing the diversity of plant species.
[13] Please refer to the Big Bear Lake Nutrient TMDLs staff report, June 1, 2005 for a description of macrophytes and the associated impacts on beneficial uses in Big Bear Lake.
[14] Organic matter created within the watershed and imported to the water body (Wetzel 2001, 49)
[15] Organic matter created within the water body (Wetzel 2001, 49)

Creek on the 303(d) list for sediment were (1) staff's best professional judgment that sediments provided a source of nutrients to the lake; (2) that Rathbun Creek was the largest contributor of sediment; and, (3) that the east end of the lake was becoming shallow, affecting recreational opportunities. Additional data that were collected after Big Bear Lake was placed on the 1994 303(d) list are also evaluated against the standards. Finally, a new set of data was collected beginning in 2001 as part of the TMDL Task Force monitoring. These data are also evaluated against the applicable water quality standards.

2.1 Applicable Water Quality Standards

The beneficial uses of Big Bear Lake as identified in the 1995 Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) are as follows:

- Municipal and Domestic Supply **(MUN)**
- Agricultural Supply **(AGR)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Warm Freshwater Habitat **(WARM)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**
- Rare, Threatened or Endangered Species **(RARE)**

The beneficial uses of Rathbun Creek as identified in the Basin Plan are as follows:

- Municipal and Domestic Supply **(MUN)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**

The following Basin Plan narrative and numeric water quality objectives for inland surface waters pertain to sedimentation/siltation impairment:

> Solids, Suspended and Settleable: "Inland surface waters shall not contain suspended or settleable solids in amounts which cause a nuisance or adversely affect beneficial uses as a result of controllable water quality factors."
>
> Turbidity: "Increases in turbidity which result from controllable water quality factors shall comply with the following:

Natural Turbidity	Maximum Increase
0-50 NTU	20%
50-100 NTU	10 NTU
Greater than 100 NTU	10%

All inland surface waters of the region shall be free of changes in turbidity which adversely affect beneficial uses."

No site-specific numeric sediment objectives have been established for Big Bear Lake or its tributaries.

2.2 Assessment of Existing Conditions Relative to Numeric and Narrative Water Quality Objectives

This section describes the conditions in the Big Bear Lake watershed that resulted in the inclusion of Big Bear Lake and Rathbun Creek on the 1994 303(d) list due to sedimentation/siltation. As stated previously, these listings resulted from the judgments that sediments were a likely contributor of nutrients, that Rathbun Creek was the largest contributor of sediment and that the east end of the lake was becoming shallow, in turn affecting recreation. Limited secchi disk transparency data were available for the 303(d) listing assessment (Table 2-1); no turbidity or total suspended solids (TSS) data were collected as part of the assessment, nor were any turbidity or TSS data available. Additional sediment data that were evaluated as part of the development of this TMDL report and problem statement were the data collected from 1994-2000 by the San Bernardino County Flood Control District (SBCFCD) (Table 2-2), data collected from 1997-2000 by the BBMWD (Table 2-3), data collected by the RWQCB in 1998 (Table 2-4), and data collected from 2001-2003 by the TMDL Task Force (Tables 2-5 and 2-6). Data collected included total suspended solids (TSS) measurements and secchi depth measurements. The Basin Plan does not specify objectives for secchi disk transparency[16], nor are there any numeric objectives for total suspended solids (TSS), only a narrative objective. In addition, there are no identified reference creeks or lakes within this watershed or similar watersheds with TSS measurements that could be used as a guide in determining impairment for Big Bear Lake and Rathbun Creek. Therefore, it is difficult to determine from these data the concentration at which TSS impacts beneficial uses in Big Bear Lake and in Rathbun Creek. Only with the identification and selection of a reference condition for lakes and creeks similar to the Big Bear Lake watershed and collection of this type of data over the long-term and under various hydrological periods can beneficial use impacts be tied with certainty to TSS measurements.

Big Bear Lake Data

Secchi disk transparency. The data used to place Big Bear Lake on the 1994 303(d) list due to sedimentation/siltation were collected as part of a Clean Water Act Section 314 grant (Clean Lakes Study) titled, "Investigation of Toxics and Nutrients in Big Bear Lake." (Courtier and Smythe 1994). The data were collected between April 1992 and April 1993 (Table 2-1).

Transparency is affected by algae and nonalgal turbidity[17]. Transparencies are greatest at the dam (Site #1), the deeper end of the lake, and gradually decrease from west to east (Site #4). The east end is shallower than the west end and is therefore more susceptible to sediment resuspension. The east end also contains a greater density of macrophytes. As macrophytes decay, organic matter is deposited on the lake bottom and can be resuspended. In addition, the prevailing wind is usually from the west. Due to these prevailing wind patterns, any matter on the lake tends to collect at the east end. Seasonal variations in secchi disk transparencies were also observed. The

[16] Secchi depth is a measure of the water's clarity. High readings mean greater clarity.
[17] Includes color and inorganic suspended solids.

deepest secchi values were seen in May and the shallowest values were generally observed in August. The shallow secchi depth readings probably correlate to increases in algal biomass during late summer, which can result in a reduction of water clarity. There were also differences in secchi values between 1992 and 1993; that is, secchi depths were greater in 1993 than in 1992. The improvement in water clarity can be attributed to the increase in lake levels in 1993. Lake levels were approximately 12 feet below full pool in 1992, whereas in 1993, lake levels were nearly at full pool due to significant amounts of precipitation received in the earlier part of the year (Figures 1-5 and 1-6).

Table 2-1. Secchi disk transparencies (feet) for Big Bear Lake (RWQCB: April 1992-April 1993)

	Near Dam Site No. 1	Metcalf Bay Site No. 2	Pine Knot Landing Site No. 3	East End Site No. 4
Average	6	8	6	4
Median	5	7	5	4
Number of samples	5	4	4	5
Max	11	10	10	6

Data collected in Big Bear Lake by the BBMWD from 1997-2000 were also evaluated (Table 2-2). Spatial and temporal differences were again observed in secchi disk transparencies. The west end station (Station 1) recorded deeper secchi disk measurements than did the east end station (Station 5). The deepest secchi disk measurements were recorded in June through July and the shallowest transparencies in late summer and early fall. These results are consistent with the data collected in 1992-1993, as discussed above.

Table 2-2. Secchi disk transparencies (feet) for Big Bear Lake (BBMWD:1997-2000)

	Site #1	Site #2	Site #3	Site #4	Site #5
Average	10	11	11	11	9
Median	10	11	10	10	9
Number of samples	114	110	112	111	112
Max	21	21	21	21	19

BBMWD's Sites #1 and #5 are equivalent to RWQCB's Sites #1 and #4. BBMWD's Sites #3 and # 4 are comparable to RWQCB's Sites # 2 and # 3; however, the RWQCB's sites are closer to the shoreline, while the BBMWD's sites are located in open water.

<u>TMDL Monitoring Program</u>

Starting in June 2001, a program of monthly sediment monitoring at four main lake stations and seven tributary stations was initiated as part of the Total Maximum Daily Load (TMDL) development process and is presently ongoing. Originally, ten lake stations were monitored but after February 2002, only **four** main lake stations (Dam, Gilner Point, Mid Lake Middle, and Stanfield Middle; hereinafter referred to as MWDL1, MWDL2, MWDL6, and MWDL9, respectively) were monitored due to limited funds (Figure 2-1). For this report, data from June 2001 through December 2003 are included in the analysis for these four main TMDL stations and data from June 2001 through February 2002 for the other six lake stations (Table 2-3). At all ten stations, a photic zone[18] composite water column sample and a discrete bottom water column sample[19] were analyzed for total suspended solids and volatile suspended solids (VSS). The VSS method is used to determine the relative proportion of the organic fraction within the total suspended solids concentration. This determination is important in this forest-dominated watershed, which would be expected to have a greater percentage of organic litter compared to other land uses. Secchi disk transparency was also recorded at each of the lake stations and is reported in Table 2-4.

Spatial as well as temporal differences in secchi disk transparencies were observed. Greater secchi disk transparencies were recorded at the deeper west end of the lake (MWDL1 and MWDL2) than at the bays and the east end of the lake (MWDL8, MWDL9 and MWDL10). The shallowest secchi disk transparencies were generally observed in late August and the beginning of September, while the greatest secchi disk transparencies were observed during the winter and early spring months. Other researchers (Irwin and Lemons 1974, 23) report similar findings, and the results are consistent with the 1992-93 RWQCB and 1997-2000 BBMWD studies. During the late summer, macrophytes start to decay and algal blooms occur. Both of these processes contribute significant amounts of detritus to the water column and contribute to the lowering of water clarity.

Because secchi disk transparency is affected by algae and/or nonalgal turbidity, it would be useful to determine which has the greater impact on turbidity. Even though turbidity was not measured, Walker (1996, 4-15) provides an equation to calculate nonalgal turbidity from secchi disk transparency and chlorophyll *a* measurements. The purpose of this equation is to determine whether turbidity is caused by algal response to nutrients or by allochthonous particulates. The equation is as follows:

$$(1/\text{secchi}) - (0.025 \times \text{chl } a) = \text{nonalgal turbidity}$$

secchi in meters; chlorophyll *a* in mg/m^3
Results <0.4: allochthonous particulates unimportant;high algal response to nutrients
Results >1 allochthonous particulates possibly important; low algal response to nutrients

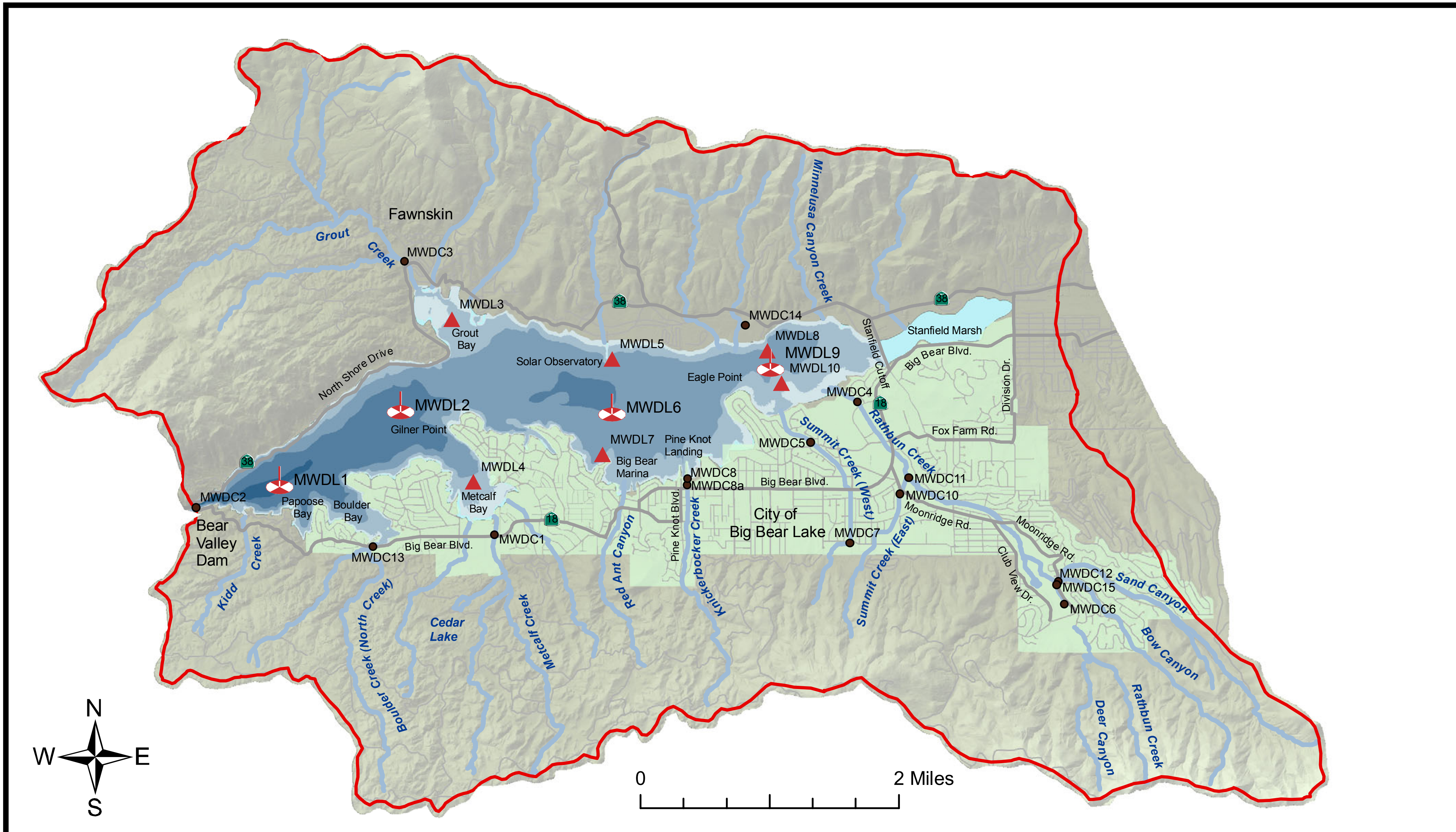
For each paired chlorophyll *a* and secchi disk transparency measurement, nonalgal turbidity was calculated and then an average nonalgal turbidity value was calculated for each main TMDL lake station (MWDL1, MWDL2, MWDL6, and MWDL9). Yearly and seasonal averages were calculated (Table 2-4). TMDL lake stations MWDL1, MWDL2 and MWDL6 all had the same nonalgal turbidity average value of 0.2, while station MWDL9 at the east end near Stanfield Marsh had an average nonalgal turbidity value of 0.3. In all instances, these numbers were less than 0.4, implying that the turbidity seen in the lake water column was caused by algae and not allochthonous particulates. There were temporal differences as well: at lake station MWDL9, a spring and winter average value of 0.5 was recorded, which is the highest for any station. It appears that this number might be related to snowmelt runoff and storm events, although no numbers were greater than 1.

[18] Photic zone is the zone to which light can penetrate the water column; for monitoring purposes, the photic zone was calculated as two times the secchi depth.
[19] The discrete bottom sample was collected approximately 0.5 meters above the lake bottom surface using a pump.

The USEPA developed a set of parameters (i.e., total P, chlorophyll *a*, secchi disk depth, and hypolimnetic oxygen percent of saturation) in the mid 1970s to characterize a lake's trophic status. A secchi disk depth of >4 meters (~13 feet) is representative of oligotrophic lakes, a secchi disk depth of <2 meters (~7 feet) characterizes eutrophic lakes, and mesotrophic lakes fall in between these numbers (Novotny and Olem 1994, 784). As shown in Table 2-3, the average secchi disk depth readings for all the Big Bear Lake stations are characteristic of a eutrophic lake. This confirms the findings of eutrophic status based on the other parameters (see Big Bear Lake Nutrient TMDLs staff report, June 1, 2005).

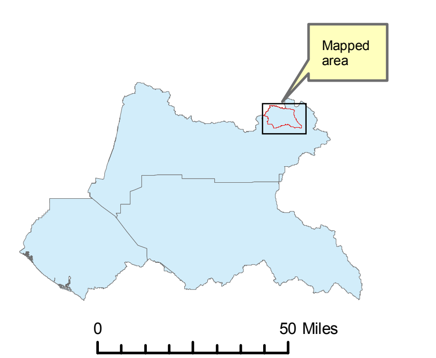
Spatial differences were observed in both TSS and VSS concentrations, with higher values seen in the bays and in the east end (MWDL9) (Figures 2-2 and 2-3). In addition, TSS and VSS concentrations in bottom water column samples were generally higher than the photic zone composite concentrations during most sampling events. TSS concentrations were most likely greater at the bottom and in the shallower waters of the bays and east end due to sediment resuspension. Temporal differences were observed in TSS and VSS concentrations for both the photic and bottom water column samples, although the differences in concentrations in the bottom water column samples were more extreme than those in the photic zone, especially for MWDL6 (Mid Lake) and MWDL9 (east end) probably caused by the increase in detritus from decaying macrophytes. Concentrations increased slightly during early spring (March) likely corresponding to snowmelt and runoff while during late summer/early fall concentrations increased significantly corresponding to increased phytoplankton biomass and detritus from decaying macrophytes.

Differences in the relative contribution of organic sources (VSS) to total suspended solids concentrations were observed between photic zone and bottom discrete samples. Ratios of VSS to TSS between MWDL1 and MWDL9 for both photic zone and bottom discrete concentrations were compared and for both stations, the photic zone samples contributed a greater percentage of organic sources (measured as VSS) than did the bottom discrete samples. This difference is likely due to the presence of phytoplankton within the photic zone. On average, the total suspended load consisted of 50% organic particulates (measured as VSS) for MWDL1 and 44% for MWDL9.



Water Boards
CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

Data Sources:
Tributaries (modified by RWQCB 8), Elevation - San Bernardino County, 2004
Watershed boundary - Hydmet, Inc., 2003
Lake bathymetry - ReMetrix, Inc., 2000
Monitoring Stations -RWQCB, 2002
Major roads - San Bernardino County, 2004
City of Big Bear Lake boundary - City of Big Bear Lake, 2002



Map Features

- Main TMDL Lake Monitoring Stations
- Other TMDL Lake Monitoring Stations
- Big Bear Lake Tributary Monitoring Stations
- Big Bear Lake watershed boundary
- Big Bear Lake Tributaries
- City of Big Bear Lake boundary
- Major roads
- Streets

Big Bear Lake Bathymetry

DEPTH

- 69 - 51 feet
- 50 - 36 feet
- 35 - 21 feet
- 20 - 9 feet
- 8 - 1 feet

Figure 2-1.
Big Bear Lake and
Tributary Monitoring Stations

D:GISDATA/BBL/BBL_3_sed.mxd

Map contact: Heather Boyd, CA Regional Water Quality Control Board, Santa Ana Region, June 2005

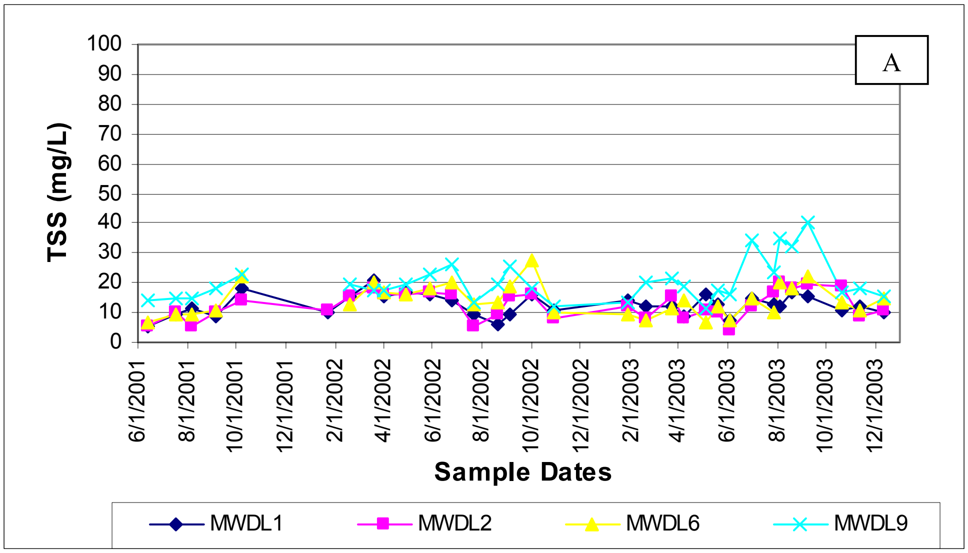
Table 2-3. Water Quality Data Summary for Big Bear Lake (June 2001-December 2003)

	Dam	Gilner Point	Mid Lake Middle	Stanfield Middle	Grout Bay	Metcalf Bay	Mid Lake North	Mid Lake South	Stanfield North	Stanfield South
Parameter Analyzed	MWDL1	MWDL2	MWDL6	MWDL9	MWDL3	MWDL4	MWDL5	MWDL7	MWDL8	MWDL10
Secchi Disk Transparency(feet)										
Average	7.5	7.0	5.9	3.7	2.5	4.7	5.3	5.4	3.5	4.5
Median	7.0	7.0	5.0	3.3	2.7	5.0	5.0	5.0	3.3	4.0
# of samples	43	43	42	42	8	8	8	8	8	8
Max	14.0	13.1	13.1	8.0	3.2	7.0	6.2	9.5	4.6	8.2
TSS (mg/L)										
Average	15.7	14.9	19.4	23.5	30.8	25.2	14.7	12.7	30.9	17.5
Median	13.8	13.0	15.2	19.4	29.6	21.6	14.8	12.2	16.9	15.8
# of samples	64	65	63	62	8	8	12	7	12	7
# of non-detects	0	0	0	0	0	0	0	0	0	0
Max	84.0	60.0	92.0	71.8	59.8	68.2	22.6	25.8	138.0	23.8
VSS (mg/L)										
Average	7.2*	7.0*	8.2*	9.9	13.4	10.4	6.8	6.6	9.9	8.6
Median	7.0*	6.7*	7.4*	8.4	13.1	10.5	6.5	6.0	7.9	8.6
# of samples	63	64	62	61	8	8	12	7	12	7
# of non-detects	2	3	2	0	0	0	0	0	0	0
Max	25.0	16.3	23.5	23.5	18.3	19.8	10.4	11.6	30.0	11.0

Note: Main TMDL stations 1, 2, 6, and 9 were sampled from June 2001-December 2003. Other stations were sampled from June 2001- February 2002.
*Estimated using both the robust probability plotting method and by the (parametric) maximum likelihood method adjusted for bias (Helsel and Cohn 1988)
TSS= total suspended solids
VSS=volatile suspended solids

Table 2-4. Nonalgal turbidity for Big Bear Lake (June 2001-Dec. 2003)

	# of samples	MWDL1	MWDL2	MWDL6	MWDL9
Overall Average	30	**0.2**	**0.2**	**0.2**	**0.3**
2001 average	5	0.2	0.2	0.1	0.2
2002 Average	12	0.2	0.2	0.2	0.3
2003 Average	13	0.2	0.2	0.2	0.3
Spring (March-May) Average	7	0.2	0.2	0.3	0.5
Summer (June-August) Average	11	0.2	0.2	0.2	0.1
Fall (September –November)Average	8	0.2	0.2	0.2	0.3
Winter (December –February)Average	4	0.0	0.0	0.1	0.5



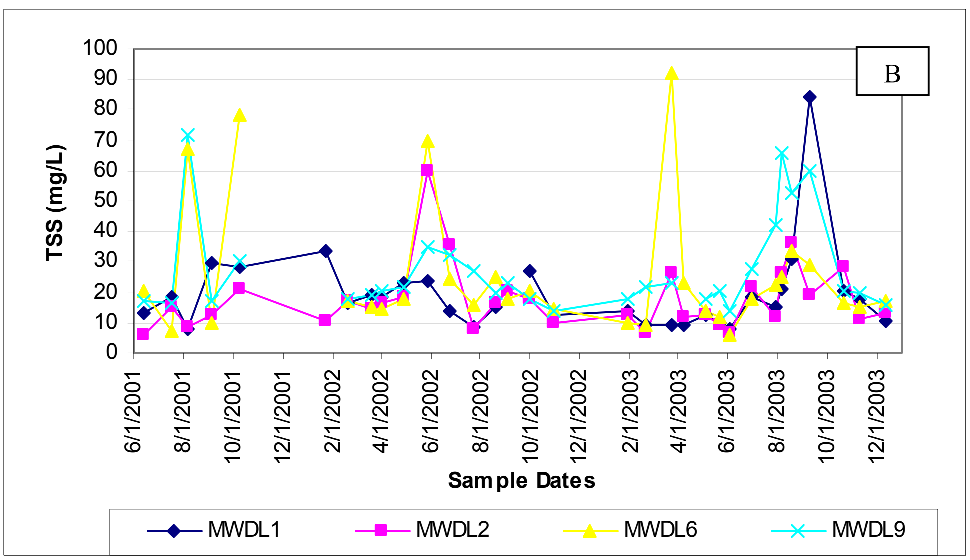


Figure 2-2. TOTAL SUSPENDED SOLIDS concentrations in the four main Big Bear Lake TMDL stations (A) photic composite and (B) bottom discrete.

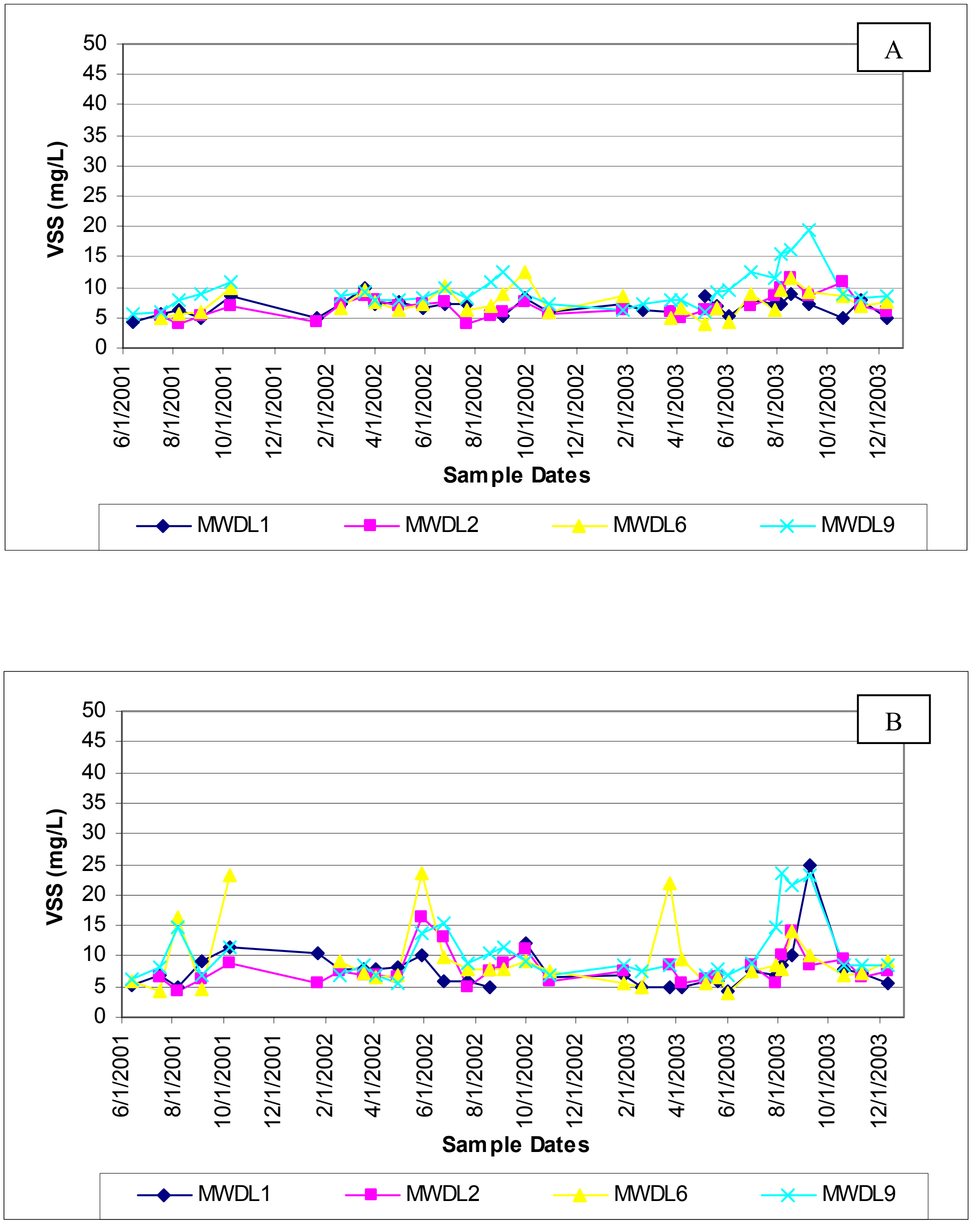


Figure 2-3. VOLATILE SUSPENDED SOLIDS concentrations in the four main Big Bear Lake TMDL stations (A) photic composite and (B) bottom discrete.

Rathbun Creek Data

Total Suspended Solids. As part of their National Pollutant Discharge Elimination System (NPDES) Stormwater Permit, SBCFCD monitored total suspended sediment (TSS) concentrations at two locations within Rathbun Creek: Rathbun Creek at Sandalwood Dr. (the mouth of Rathbun Creek) (Site #6), and Rathbun Creek at Bear Mountain Golf Course (downstream of the confluence with Sand Canyon Creek) (Site #7) from 1994 through 2000 (see Figure 1-3). First flush (sample collected during the first 30 minutes of the storm) and main program (sample collected the first two hours of the storm including the first flush) samples were collected. These "program" samples were collected as time-weighted composite samples (composited for discrete, equal-time intervals) (San Bernardino County Flood Control District 1998, 3-1, 3-3). The results are shown in Table 2-5. Maximum values for both the first flush and main program samples were recorded at Site #6, which is located near the mouth of Rathbun Creek. This makes sense as the bottom of the watershed is expected to receive sediment from the surrounding watershed and from the creek itself. However, Site #7 contributed a large amount of sediment during the first flush events. For both first flush and main program samples, the highest TSS values were obtained during the months of December and January. Note that there are no flow data available that correspond with these TSS data.

Table 2-5. Total suspended solids concentrations (mg/L) for Rathbun Creek (SBCFCD: 1994-2000)

	First Flush		Main Program	
	Rathbun Creek at Sandalwood Dr. Site #6	Rathbun Creek at Bear Mountain Golf Course Site #7	Rathbun Creek at Sandalwood Dr. Site #6	Rathbun Creek at Bear Mountain Golf Course Site #7
Average	275	245	358	224
Median	170	119	160	130
Number of samples	23	22	22	21
Max	2370	1820	2950	960

During March and April of 1998, Regional Board staff collected samples at several locations within Rathbun Creek (see Figure 1-3)[20]. One of the constituents measured was total suspended solids (TSS). The results are shown in Table 2-6. The values vary both spatially and temporally. The highest values were seen immediately below Bear Mountain, while lower values were seen farther down the creek. These data are different from those reported by the SBCFCD, which showed higher TSS concentrations at the mouth (Table 2-5). Differences could be attributed to different sampling methodologies, different flow events and to the unreliability of the TSS method in measuring suspended sediment concentration (Gray and Glysson, 2001). There are no flow data associated with these data.

[20] According to the Bear Valley Dam precipitation records, there was no rain during the sample collection dates (i.e., March 4, 1998 and April 28, 1998). For the March sampling date, precipitation had last occurred on Feb. 24, 1998 and for the April sampling date, precipitation had last occurred on April 15, 1998.

Table 2-6. Total suspended solids concentration (mg/L) for Rathbun Creek (RWQCB: March-April 1998)

	Below Bear Mtn.	Below Zoo	Below Parking Lot	At mouth
Average	129	22	34	11
Median	129	42	34	11
Number of samples	2	1	2	2
# of non-detects	0	1	0	0
Max	150	42	58	12

½ the detection limit used to calculate summary statistics for non-detects

TMDL Monitoring Program

Starting in June 2001, a program of monthly sediment monitoring at seven tributary stations was initiated as part of the nutrient and sediment TMDL development process and is presently ongoing (Figure 2-1). For this report, data from June 2001 through February 2003 are included in the analysis for these seven main tributary stations. Collected tributary data were sparse because little or no flows occurred in several of the creeks for much of the year. The installation of compound weirs and automatic samplers with bubble flow meters aided in the collection of storm event samples from a few tributaries. Samples were analyzed for TSS and VSS. Spatial differences were observed in TSS and VSS concentrations, with the highest values observed during storm events at sampling site MWDC4 (Mouth of Rathbun Creek)(Tables 2-7 and 2-8). The data might support temporal differences in TSS and VSS concentrations as well, but because not all tributaries were sampled during each event due to lack of flow, no conclusions to this effect can be made at this time. Ratios of VSS to TSS were evaluated and the contribution of organic sources (measured as VSS) varied with no apparent pattern.

Table 2-7. Total suspended solids concentration for Big Bear Lake tributaries (June 2001- February 2003)

	Sampling Station						
Parameter Analyzed	Metcalf Creek (MWDC1)	Bear Creek Outlet [(a)] (MWDC2)	Grout Creek (MWDC3)	Mouth Rathbun Creek (MWDC4)	SummitCR at Swan (MWDC5)	BMZoo on RC (MWDC6)	SummitPK West (MWDC7)
TSS (mg/L)-Grab sample							
Average	9.8	11.4		871.5	65.8	62.4	63.6
Median	9.4	9.5		871.5	14.4	64.1	63.6
# of samples	8	4		2	5	4	2
# of non-detects	0	0		0	0	0	0
Max	17.0	19.6		914.0	234.0	71.8	74.2
TSS (mg/L)-First flush sample							
Average	478.8		1,766.0	529	564.2		473.0
Median	20.6		1,766.0	472.5	564.2		473.0
# of samples	3		1	4	2		1
# of non-detects	0		0	0	0		0
Max	1,409.0		1,766.0	1,155.0	670.3		473.0
TSS (mg/L)-Flow composite sample							
Average	608.4		709.0	345.7	248.0		
Median	34.6		709.0	273.8	248.0		
# of samples	3		1	4	1		
# of non-detects	0		0	0	0		
Max	1,781.0		709.0	825.0	248.0		

Note: (a) represents lake water releases at the dam

Table 2-8. Volatile suspended solids concentration for Big Bear Lake tributaries (June 2001- February 2003)

	Sampling Station						
Parameter Analyzed	Metcalf Creek (MWDC1)	Bear Creek Outlet (a) (MWDC2)	Grout Creek (MWDC3)	Mouth Rathbun Creek (MWDC4)	SummitCR at Swan (MWDC5)	BMZoo on RC (MWDC6)	SummitPK West (MWDC7)
VSS (mg/L)-Grab sample							
Average	4.1*	4.5*		144.0	17.6	14.4	15.0
Median	4.6*	4.0*		144.0	7.2	14.5	15.0
# of samples	8	4		2	5	4	2
# of non-detects	2	1		0	0	0	0
Max	6.2	8.6		157.0	58.0	15.2	18.2
VSS (mg/L)-First flush sample							
Average	52.5		152.0	77	91.9		113.5
Median	6.6		152.0	73.0	91.9		113.5
# of samples	2		1	4	2		1
# of non-detects	1		0	0	0		0
Max	146.0		152.0	157.0	94.7		113.5
VSS (mg/L)-Flow composite sample							
Average	65.3		85.0	63.9	55.0		
Median	13.0		85.0	57.8	55.0		
# of samples	3		1	4	1		
# of non-detects	0		0	0	0		
Max	179.0		85.0	133.0	55.0		

Notes: (a) represents lake water releases at the dam
*Estimated using both the robust probability plotting method and by the (parametric) maximum likelihood method adjusted for bias (Helsel and Cohn 1988)
MWDC1 First flush, not enough data points to use Helsel and Cohn (1988) method, used ½ the detection limit to calculate average and median.