ANALYSIS OF FY09 GRANITE CREEK TURBIDITY, SEDIMENT (TSS) AND FLOW DATA AND EFFECTS ON SEDIMENT MODELS AND LOAD CALCULATIONS

June 30, 2009

Task 8 of the FY09 Granite Creek project workplan calls for a thorough analysis of turbidity and TSS data collected in FY09 for updating sediment load models and in-stream sediment load calculations developed in FY07. This ensures that estimates of monthly in-stream sediment loads (tons TSS/month) and load reductions use all available water quality information. The newly calculated FY09 sediment loads allow for comparing against prior years' sediment loads and quantifying load reductions over time in compliance with the 2002 TMDL.

Over the last several years, simultaneous collection of TSS and turbidity data, along with stream staff gage height correlated to a stage-discharge curve, has allowed for determining the instantaneous sediment-flow relationship for the creek and, with extrapolation, to monthly sediment loads. Sediment loads are directly proportional to flow rates. These analyses have provided quantifiable results on the effectiveness of sediment control BMPs in improving water quality of Granite Creek and a factual basis for recommending modifications to BMPs. The FY09 simultaneous data sets also allowed for updating mathematical equations on the relationship of TSS-to-turbidity and the relationship of TSS-to-flow rate.

Monthly sampling conducted at Station GC1 since September 2007 was changed to a random day of the month, independent of weather conditions, to avoid preferentially targeting high rainfall/high flow events. This more random method resulted in proportionally more low flows measured in 2007, 2008 and 2009 compared with the 2002-2007 period.

The Stepwise Process Used in FY09 Data Review

The FY07 comprehensive analysis of water quality data completed in June 2007 covered the period October 2002 through January 2007. The follow-up analysis completed in June 2008 addressed sixteen (16) additional monthly simultaneous TSS and turbidity data sets collected at Station GC1 at Granite Creek through May 2008. Stream gage height was also simultaneously documented, and later converted to flow rate (cfs) using the USGS stream rating table. The FY09 analysis is the third to be completed, and covers simultaneous TSS and turbidity data sets collected at Station GC1 from June 2008 through June 2009. *Table 1* includes a summary of all TSS, turbidity, gage height and flow rate data collected from June 2008 through June 2009. The reader is referred to the earlier reports for detailed data covering October 2002 through May 2008. Important excerpts and calculations from those reports are included in this 2009 analysis for continuity.

Prepared by Redburn Environmental & Regulatory Services for the City and Borough of Sitka and Alaska Department of Environmental Conservation using funding provided by ADEC and the Environmental Protection Agency through an ACWA community water quality grant awarded under the Clean Water Act.

The process used to analyze the 2008-2009 data was identical to that used in the prior 2007 and 2008 water quality analyses. A listing of sequential steps that needed to occur was prepared to guide the data analysis. Essential variables, parameters and relationships that needed examination were identified. As with the FY07/FY08 reports, data analysis focused on the monitoring results from Station GC1, the watershed integrator station at the Halibut Point Road bridge site. This station is the location of a USGS staff gage and the site of monthly monitoring of TSS and turbidity concentrations since October 2002.

In addition, comprehensive monitoring data collected throughout the watershed by the project consultant in FY09 were used to address time series of events over three day periods, and confirm source contributions of sediment within the watershed. These results are discussed in the section *FY09 Watershed-Wide Water Quality Data and General Observations.*

The steps in the analysis included:

- Tabulate all new turbidity and TSS data using the 14 simultaneously collected data sets from June 2008 through June 2009, and add to the previous 66 data sets.

- Complete a new linear regression analysis on all 80 simultaneously-collected TSS and turbidity data sets from October 2002 through June 2009 and generate an updated "y = mx + b" equation representing that relationship.

- Use the new TSS-turbidity mathematical equation to calculate the allowable "target" TSS concentration corresponding to 6.64 NTUs (= 5 NTUs above natural conditions). This TSS concentration is used to calculate the allowable load capacity (LC).

- Review new monthly flow rate data collected for June 2008 through June 2009 against the average monthly flows (AMF) calculated in June 2008 to see if any revisions to AMFs were warranted.

- Run linear regression analysis on the 14 simultaneous TSS and flow rate measurements collected from June 2008 through June 2009 and generate an equation reflecting the TSS-flow rate relationship for that period. This equation then generates a TSS value for a given flow rate value. Run a linear regression analysis on all 80 TSS and flow rate data sets and generate an updated equation covering the period October 2002 through June 2009.

- Using the new FY09 TSS: flow rate equation, calculate average monthly TSS concentrations for the entire period of record, October 2002 through June 2009.

- Calculate annual in-stream sediment load and load capacity for the period June 2008 through June 2009 to compare with previously estimated sediment loads (in tons TSS/year) for 2008 and 2007.

Table 1. Relationship of Total Suspended Solids (TSS), turbidity, and flow rate at Station GC1, Granite Creek, Alaska, from June 2008 through June 2009. [1]

Date	TSS (mg/l)	Mean turbidity (NTU)	Turbidity Replicates (NTU)	Flow rate (cfs)	USGS staff gage height (ft)	Comments and notes
6/11/08	0.1	0.37	0.39, 0.34	2.2	18.82	USGS installed permanent stream staff gage on November 8, 2002
7/09/08	0.6	1.25	1.30 1.20	14.0	19.21	
8/14/08	2.3	1.77	1.73, 1.80	2.4	18.84	
9/10/08	2.7	14.6	14.6, 14.7	80.1	19.65	
9/29/08	33	40.1	41.1, 39.1	58.3	19.56	
10/09/08	0.6	1.60	1.62, 1.58	5.2	19.00	
11/12/08	0.6	1.42	1.44, 1.41	1.4	18.73	
12/10/08	2.9	4.50	4.51, 4.49	7.7	19.08	
1/21/09	0.7	0.98	0.94, 1.01	8.1	19.09	
2/13/09	1.4	3.31	3.35, 3.27	2.2	18.82	
3/24/09	7.1	18.1	18.0, 18.2	1.2	18.69	
4/22/09	0.4	2.27	2.20, 2.35	1.8	18.78	
5/13/09	0.3	0.98	0.97, 0.99	2.6	18.86	
6/10/09	0.1	1.59	1.22, 1.95	1.5	18.74	

[1] Flow rates are derived from staff gage height readings converted using the USGS Stage discharge curve (SDC) and stream rating table.

1. TSS-to-turbidity relationship

Alaska water quality standards limit allowable turbidity to 5 NTUs above natural conditions to protect the drinking water use - the "default" designated use for Granite Creek. The turbidity criterion for the aquatic life use category may not exceed 25 NTUs above natural conditions.

The following assumptions were made in the TMDL and were upheld in analyses completed in 2007, 2008 and 2009.

1. Granite Creek has a natural background turbidity of *1.64 NTU*.
2. A turbidity of 1.64 NTU + 5 NTU = *6.64 NTU* as the target turbidity water quality standard

Another important conversion was necessary to allow for a quantitative calculation of sediment loading capacity for Granite Creek. The majority of water quality data collected from Granite Creek through 2002 was turbidity. Turbidity is an optical property and is a measure of the amount of light-scattering particles in the water. However, loading capacities are most often expressed as a mass per unit time. Not being a measure of the weight of particles in water, turbidity cannot be used *directly* to calculate pollutant loads (in tons of sediment) or load allocations. The TMDL required conversion of turbidity values to an equivalent TSS value to estimate sediment loads gravimetrically (by weight, in tons). Total suspended solids (TSS) was selected to represent sediment loads in Granite Creek.

History of the statistical relationship of TSS –to -turbidity

In 2002, regression analysis was completed on the data sets to establish the TSS-turbidity relationship. Sixteen data sets were plotted. The following equation described the relationship between TSS and turbidity in the original 2002 TMDL:

$$\text{TSS (mg/l)} = [1.075 \text{ (turbidity in NTUs)}] - 1.681$$

The correlation coefficient for the data was a highly significant 0.9676.

Validating this relationship was an important task in the comprehensive analysis completed in FY07. In June 2007, cumulative analysis was completed on 50 *simultaneously collected* TSS and turbidity data sets from October 2002 through January 2007. A new linear regression analysis was completed on the data collected from 2002 through early 2007. The following revised equation was generated:

$$\text{(2007 equation): TSS (mg/l)} = [1.2204 \text{ (turbidity in NTUs)}] - 2.934$$

The correlation coefficient for the new cumulative analysis was a highly significant 0.9780.

For the FY08 water quality analysis, 16 new data sets, along with the original 50 data sets, were run through linear regression analysis. The following equation was generated:

(2008 revised equation): TSS (mg/l) = [1.1727 (turbidity in NTUs)] – 2.8480

The correlation coefficient (r^2) for the new data analysis was a highly significant 0.9655.

For the FY09 water quality analysis, all 14 new data sets, together with the previous 66 data sets collected through May 2008, were run through linear regression analysis. The following new equation was generated:

(2009 revised equation): TSS (mg/l) = [1.1209 (turbidity in NTUs)] – 2.6648

The correlation coefficient (r^2) for the new data analysis is a highly significant 0.9563.

The addition of 14 FY09 TSS-turbidity data sets helps to strengthen the statistical relationship between TSS and turbidity. Importantly, the revised equation yields TSS values that deviate from the original equation by only 1% to 7% over the range of normally encountered turbidity levels. For example, using the original 2002 equation, a turbidity concentration of 10 NTUs represented a TSS equivalent of 9.27 mg/l. Using the 2009 equation, a 10 NTU turbidity level predicts a TSS level of 8.54 mg/l, a 7% change from the original estimate. At 30 NTUs, the comparison is 30.57 mg/l and 30.96 mg/l, for old and revised equations, respectively, a roughly 1% change from the original estimate. The new allowable target TSS concentration (equivalent to 6.64 NTUs) is 4.78 mg/l, compared to the 4.94 mg/l limit derived in 2008. The new "target" value for TSS is used in calculating the allowable monthly and annual sediment load capacity for Granite Creek, and represents a roughly 7.5% reduction in load capacity in tons TSS/year as compared with the 2007 estimate and a 3.2% reduction from 2008 load capacity estimates (see *Table 3*).

The bottom line is that the original regression equation was valid and acceptably accurate as confirmed from subsequent analysis of all 80 data sets collected from 2002 through June 2009. The revised equation, however, should be used for further analysis since it is based on a larger number of data points and, hence, is expected to be more accurate.

Confirming the close relationship between turbidity and TSS provides several benefits. First, water quality sampling could potentially rely on turbidity measurements alone, or a reduced number of TSS samples, in calculating TSS with a reasonable amount of accuracy. This is both cost-effective and provides real-time information without the need to await the results of laboratory analysis. Secondly, turbidity concentrations are more easily estimated and understood by gravel operators and other lease operators in conducting visual self-monitoring of the effects of their operations on water quality.

2. Sediment (TSS)-to-flow relationship

Of key importance in estimating monthly loading capacity and existing in-stream sediment loads in Granite Creek is creating a statistical model of the TSS-flow relationship. In 2002, data were insufficient to support a statistically significant regression equation. This was particularly true for higher flow-higher TSS conditions. Best available information was used.

In 2007, the cumulative analysis of TSS and flow data completed from October 2002 through January 2007 suggested that the original relationship of flow rate to average TSS concentration developed in 2002 for the TMDL was not entirely accurate for Granite Creek.

From October 2002 through January 2007, 50 sets of simultaneous TSS-flow measurements (flow rates converted from gage height elevations) were collected. These data allowed for developing a Granite Creek sediment-rating curve from actual stream data. Given the unique environmental characteristics of each stream, the slope and characteristics of a sediment-rating curve typically apply only to that stream. The relationship is exponential. Sediment loads tend to increase as a square of flow.

The most common statistical method of analyzing sediment – discharge data is a power function (regression analysis) that relates TSS to flow rate. Typically, a common logarithmic transformation of both TSS and discharge data is done prior to analysis. Logarithmic transformation makes it easier to evaluate the relationship between two variables by linearizing the relationship, normalizing distribution of highly skewed data, and stabilizing variance. By transforming both variables, the log-log association becomes linear when plotted. The USGS used this identical method to plot Granite Creek gage height data and discharge data on a log–log scale, generating the stage-discharge curve for Granite Creek in 2005.

For the 2007 analysis, the TSS-to-flow rate equation was:

$$\log(\text{TSS (mg/l)}) = 0.92489 * \log(\text{flow (cfs)}) - 1.1521$$

Statistical analysis of TSS-flow rate data from February 2007 through May 2008

In June 2008, an updated regression analysis was completed on all 16 TSS-flow rate data sets collected from February 2007 through May 2008. Common (base 10) logarithmic transformation was completed on all the data sets for Granite Creek. The transformed data were then run through linear regression analysis. The following equation was developed for the relationship of TSS and discharge rate in Granite Creek for February 2007 through May 2008.

$$\log(\text{TSS (mg/l)}) = 0.06196 * \log(\text{flow (cfs)}) - 0.03615$$

Regression analysis was also completed on all 66 TSS-flow rate data sets collected from October 2002 through May 2008. This allowed for calculating annual in-stream sediment load *using all project data*. The resulting June 2008 equation was:

$$\log(\text{TSS (mg/l)}) = 0.66258 * \log(\text{flow (cfs)}) - 0.67528$$

Statistical analysis of TSS-flow rate data from June 2008 through June 2009: an updated TSS – flow rate relationship

In June 2009, an identical regression analysis was completed on all 14 TSS-flow rate data sets collected from June 2008 through June 2009, together with the 66 prior data sets covering October 2002 through May 2008. *Table 1* includes all simultaneous TSS and flow data collected from June 2008 through June 2009. Common (base 10) logarithmic transformation was completed on all 80 data sets for Granite Creek. The transformed data were then run through linear regression analysis.

The following *FY09 updated equation* was developed for the relationship of TSS and discharge rate in Granite Creek for the period October 2002 through June 2008.

$$\text{(2009 revision) } \log(\text{TSS (mg/l)}) = 0.55867 * \log(\text{flow (cfs)}) - 0.46433$$

This equation represents the standard regression: $y = mx + b$

The “y” variable is TSS and the “x” variable is flow rate. The slope is “m’.
The y intercept on the graph is “b”.

The mean of all TSS measurements over this 7 year period was 1.34 mg/l and the mean discharge rate during the 7 year period was calculated at 11.42 cfs.

Recognizing that EPA and ADEC have formally adopted only the original 2002 load calculations, this revision is nonetheless more accurate in that it recalculates annual in-stream sediment loads and load capacity using all project data.

3. Average monthly flows, average monthly TSS concentrations, loading capacity and existing in-stream sediment loads

The fourteen monthly flow rate measurements recorded from June 2008 through June 2009 were compared against the average monthly flows (AMFs) calculated in 2007 using the original 208 data points. Given the relatively few number of flow observations (14), the new data did not meaningfully alter the mean monthly flow values calculated in both 2007 and in 2008. New AMFs were therefore not calculated. However, the flow data collected from February 2007 through June 2009 for the months of September through December measured much lower flows than the average monthly flows calculated in 2007, suggesting drier conditions.

To calculate monthly in-stream sediment loads, the average monthly flows listed in *Table 2* were converted to common logarithmic values and a logarithmic value for TSS was generated for that particular month using the 2009 updated TSS: flow rate equation above. The antilogarithm was then calculated from this value to yield the TSS concentration corresponding to the average monthly flow. This calculation was completed for all months, January through December. This calculation method was also used in both the June 2007 comprehensive analysis and the follow-up June 2008 analysis.

For example, January has an estimated average monthly flow of 44.5 cfs. Log transformation of 44.5 gives a value of 1.648. Using the 2009 updated TSS: flow equation, (0.55867) (1.648) - 0.46433 = 0.45636. The antilogarithm of 0.45636 is 2.86 mg/l TSS. This represents the newly-calculated average monthly TSS concentration for January during the period October 2002 through June 2009.

Using the 2009 regression equation found at the end of Section 2 above, the average monthly TSS concentrations calculated for each month using all 80 data sets from the period October 2002 through June 2009 were as follows:

January: 2.86 mg/l	July: 1.18 mg/l
February: 2.25 mg/l	August: 3.46 mg/l
March: 1.82 mg	September: 3.95 mg/l
April: 1.24 mg/l	October: 3.59 mg/l
May: 1.46 mg/l	November: 5.39 mg/l
June: 1.59 mg/l	December: 4.21 mg/l

Existing in-stream sediment loads *(Table 2)* for each month are then calculated by the following equation:

> Average monthly flow (cfs) * 0.0027 * average TSS concentration (mg/l) correlated to that monthly flow rate * number of days in the month = tons of sediment (TSS) for that month

Using this method, the monthly and annual existing in-stream sediment loads were then calculated (*Table 2*) using the revised equation. *The annual estimated in-stream sediment load, updated with June 2008 through June 2009 data, was calculated at 179.19 tons TSS/year. This value represents a reduction of 7.80 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 4.94 ton increase from the 174.25 tons TSS/year calculated for June 2008.*

Methods used to calculate annual in-stream sediment loads demonstrate that during the period June 2008 through June 2009, Granite Creek experienced an increased annual in-stream sediment load estimated at 4.94 tons TSS/year compared to the prior year's sediment load. Existing in-stream loads still remained below the five-year annual average in-stream sediment loads calculated in June 2007, at 179.19 tons TSS/year compared to 187.06 tons TSS/year, respectively. The month of November remains the only month in which the estimated in-stream sediment load exceeds the allowable sediment loading capacity for that month.

Table 2. Monthly existing (in-stream) suspended sediment loads in Granite Creek, updated with June 2008 – June 2009 data and compared with the 2008 and (2007) load estimates. Calculations were made using all 80 data sets.

Month	**Average Monthly Flow (cfs)**	**Existing In-Stream Suspended Sediment (TSS) Load (tons)[2] 2009 2008 (2007)**
January	44.5	10.65 9.72 (8.79)
February	29.0	4.93 4.32 (3.51)
March	19.8	3.02 2.54 (1.86)
April	9.9	0.99 0.77 (0.47)
May	13.4	1.64 1.32 (0.87)
June	15.5	2.00 1.63 (1.12)
July	9.1	0.90 0.69 (0.41)
August	62.4	18.07 17.08 (16.82)
September	79.5	25.44 24.73 (25.95)
October	66.7	20.04 19.04 (19.15)
November	138 [3]	60.25 61.82 (75.00)
December	88.7	31.26 30.59 (33.11)
Annual Total		**179.19 tons 174.25 tons (187.06 tons)**

[2] Tons of TSS/month = monthly average Q (cfs) * average TSS (mg/l) concentration corresponding to the average monthly flow (see text on using the TSS-flow regression equation) * 0.0027 * # of days in the month.

[3] November average includes 2 of the 3 highest flow rates recorded at Granite Creek from October 2002 through June 2009. Throwing out one or both of these flows (863 cfs and 1390 cfs) from the average calculation would result in significantly lower existing in-stream sediment load estimates for November. They are both left in here to provide a worst case scenario.

Monthly sediment load capacity (*Table 3*) is calculated by the following equation:

> Average monthly flow (cfs) * (4.78 mg/l TSS allowable target) * 0.0027 * number of days in the month = loading capacity in tons of sediment (TSS) for that month

The analysis of water quality data completed for February 2007 through May 2008 suggested a slight revision (4.5% reduction) of loading capacity (tons/year) was warranted. The allowable target TSS value was reduced slightly from 5.17 mg/l to 4.94 mg/l to reflect the results of the new TSS-to-turbidity regression equation.

In 2009, the allowable target TSS value was again revised to 4.78 mg/l based on the newly- calculated TSS: turbidity statistical relationship. *The FY09 estimated annual sediment load capacity is estimated at 226.39 tons TSS/year as compared to the 2007 estimate of 244.86 tons TSS/year and the 2008 estimate of 233.84 tons TSS/year*. Table 3 includes a comparison of monthly and annual loading capacities for 2009, 2008 and 2007.

Table 3. Monthly suspended sediment Loading Capacity (LC) for Granite Creek, showing both FY09 and FY08 revised load capacity and 2007 load estimates in ( ).

Month	**Average Monthly Flow (cfs)**	**Natural Background Load (tons)[4]**	**Loading Capacity TSS (tons)[5] 2009 2008 (2007)**
January	44.5	1.86	17.80 18.40 (19.26)
February	29.0	0.56	10.48 10.82 (11.33)
March	19.8	0.93	7.92 8.18 (8.57)
April	9.9	1.50	3.83 3.96 (4.15)
May	13.4	2.17	5.36 5.54 (5.80)
June	15.5	1.80	6.00 6.20 (6.49)
July	9.1	1.24	3.64 3.76 (3.94)
August	62.4	0.93	24.97 25.79 (27.00)
September	79.5	3.00	30.78 31.79 (33.29)
October	66.7	4.34	26.69 27.56 (28.86)
November	138	1.20	53.43 55.19 (57.79)
December	88.7	3.10	35.49 36.65 (38.38)
Annual Total		**22.63 tons**	**226.39 tons 233.84 tons (244.86 tons)**

[4] Natural background turbidity and sediment loads used in the original 2002 TMDL remain accurate and unchanged based on seven years of water quality data collection.

[5] FY09 monthly load capacity based on analysis of in-stream data. Includes natural background sediment load. Calculated as: (Monthly Q (cfs)) * (4.78 mg/liter TSS) * (0.0027) * (# days in month).

4. FY09 Watershed-Wide Water Quality Data and General Observations

Comprehensive water quality data collected throughout the watershed is valuable in identifying time series of events, BMP cause-and-effect relationships, and documents site-specific sources of turbidity and sediment. Eight permanent monitoring stations plus a number of opportunistic stations including drainage ditches, settling ponds, and road culvert discharges were monitored in FY09. Of immediate note is the rapidity with which runoff from unpaved roads, and associated turbidity spikes, will occur after heavy rains and truck traffic. Additionally, bedload resuspension and bank erosion during high creek flows are also known to contribute to elevated turbidity levels, although how much is not known precisely. Of equal note is the rapidity with which the system restores to normal with cessation of heavy rains. The exception is the residence time of turbidity levels in the CBS series of settling ponds receiving significant road runoff. Time series measurements over several days confirm that it typically takes 2 to 3 days for the ponds to "clear" to pre-heavy rain conditions. Ponds are working effectively the vast majority of time. Smaller ponds at the Tisher and Dormand McGraw leases experience periods where significant runoff exceeds their capacity to effectively treat turbidity, resulting in silty discharge from the ponds and into the tributaries. Retrofits are planned for both lease sites by the operators under their SWPPPs to increase volume and improve retention time.

A couple of observations have focused attention on the need for several new BMPs for FY10 and beyond. These are included in the updated Action Plan. The main culvert running under Granite Creek Road discharges ditchwater down the streambank into Granite Creek. During high flows, this discharge erodes the streambank and entrains sediment and turbidity. Higher turbidity levels were noted at the base of the streambank entering the creek compared to turbidity levels at the top of the streambank. Placing a series of small terraced, baffled settling ponds to slow water down and improve treatment of stormwater was examined in FY09 but rejected in lieu of focusing on improving retention and treatment in ponds and ditching leading to the culvert. Resuspension of turbidity/sediment in fast-flowing unvegetated drainage ditches during heavy rains was also observed over the last several years. Culverting, and other sediment control methods such as check dams and hydroseeding problematic ditches, are remedies to be examined.

The seeded and vegetated ditch running along Granite Creek Road below the Dormand McGraw scale area to the large culvert discharging under the road is working effectively, in combination with the installed check dams, to immediately reduce turbidity levels. For example, turbidity levels measured on October 10, 2007 in the ditch upgradient of the check dams and pond were on the order of 1000 NTU. The turbidity level measured from the culvert discharge after grass filtration/check dam/pond treatment was 108 NTUs, for a roughly ten-fold reduction in turbidity. Winter road maintenance tends to push gravel into the ditch, covering up some of the grass fringe. This drainage ditch was reseeded in June 2008 to reestablish grasses through its length and may be reseeded in the future as a maintenance BMP. The existing pond and segments of the drainage ditch need to be cleaned of sediment and the upper pond below the scales deepened and enlarged to provide improve stormwater retention and treatment. Flash flooding through the area can carry high sediment loads.

5. Conclusions and Recommendations

- *Granite Creek's annual in-stream sediment load calculated for June 2008 through June 2009 was slightly higher than the February 2007 – May 2008 period but remained lower than the five-year average annual sediment load calculated in 2007. The annual estimated in-stream sediment load, updated with June 2008 through June 2009 data, was calculated at 179.19 tons TSS/year. This value represents a reduction of 7.80 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 4.94 ton increase from the 174.25 tons TSS/year calculated for June 2008.*

- *The annual in-stream sediment load remains below the allowable annual sediment load capacity. November is the only monthly exception.*

- *An estimated 3.2% reduction in the annual allowable sediment load capacity was calculated in comparison to the load capacity calculated in 2008. This is due solely to the recalculated allowable target TSS limit of 4.78 mg/liter compared to the 4.94 mg/l limit used in the 2008 calculations*.

- *The TSS-to-turbidity mathematical relationship has been updated and improved with the addition of 14 new simultaneous data sets to the 66 data sets available in 2008. The 80 data sets were run through linear regression analysis and a new equation generated.*

- *Average monthly flows were not modified, as the meager data did not substantially change the average monthly flows calculated in 2007 and 2008.*

- *Updating and recalculating the TSS-to-flow rate relationship with each year's new data improves the statistical strength and validity of sediment load estimates, recognizing that the original 2002 TMDL loads are the formally prescribed loads.*

EPA and ADEC have formally adopted the 2002 TMDL in-stream sediment loads and load capacity as the regulatory benchmark against which recovery is evaluated. The load revisions proposed in 2007 were not adopted. Recognizing that formal revisions to the Granite Creek TMDL are not expected at this time, it is recommended that any future water quality analyses for purposes of clarifying/updating the TMDL annual load capacity and annual in-stream sediment loads be scheduled not more frequently than every three years. Given that Granite Creek's existing sediment load is considerably below the allowable load capacity on an annual basis, the recommended focus should be on ensuring that in-stream loads during November and other fall months (September through December) are reduced and remain below the allowable monthly load capacity for those months.