ANALYSIS OF FY10 GRANITE CREEK TURBIDITY, SEDIMENT (TSS) AND FLOW DATA AND EFFECTS ON SEDIMENT MODELS AND LOAD CALCULATIONS

June 30, 2010

Task 7 of the FY10 Granite Creek project workplan calls for a thorough analysis of turbidity and TSS data collected in FY10 for updating sediment load models and in-stream sediment load calculations developed annually in FY07, FY08 and FY09. This ensures that estimates of existing in-stream sediment loads (tons TSS/month and tons TSS/year) use all recently available water quality information. The newly calculated FY10 sediment loads allow for comparing against prior years' sediment loads and quantifying load reductions over time in compliance with the 2002 TMDL. Importantly, existing in-stream sediment loads must be below the allowable sediment stream load (the load capacity) in order to support delisting.

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 and annual 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 data also provides a basis for determining whether the TMDL has been met, i.e. when the in-stream sediment load is lower than the allowable sediment load. The FY10 simultaneous data sets provided seventeen (17) new data points 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 understandably resulted in proportionally more low flows measured in 2007, 2008, 2009 and 2010 compared with the 2002-2007 period which often targeted high flows.

The Stepwise Process Used in FY10 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. The FY09 analysis added another fourteen (14) data sets. Stream gage height was also simultaneously documented, and later converted to flow rate (cfs) using the USGS stream rating table. The FY10 analysis is the fourth to be completed since 2007, and includes simultaneous

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TSS and turbidity data sets collected at Station GC1 from July 2009 through June 2010. *Table 1* includes a summary of all TSS, turbidity, gage height and flow rate data collected from July 2009 through June 2010. The reader is referred to the earlier reports for detailed data covering October 2002 through June 2009. Important excerpts and calculations from those reports are included in this analysis for continuity.

The process used to analyze the 2009-2010 data was identical to that used in the prior 2007, 2008 and 2009 water quality analyses, with a few additional calculations made for comparative purposes. 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/FY09 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 FY10 were used to address time series of events over three day periods, and confirm source contributions of sediment within the watershed. The City and Borough of Sitka also completed comprehensive storm event monitoring in November 2009 to address these conditions. 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 17 simultaneously collected data sets from July 2009 through June 2010, and add to the previous 80 data sets collected since 2002.

- Complete a new linear regression analysis on all 97 simultaneously-collected TSS and turbidity data sets from October 2002 through June 2010 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 July 2009 through June 2010 against the average monthly flows (AMF) calculated in June 2009 to see if any revisions to AMFs were warranted. Particular attention was paid to November.

- Run linear regression analysis on the 17 simultaneous TSS and flow rate measurements collected from July 2009 through June 2010 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 97 TSS and flow rate data sets and generate an updated equation covering the period October 2002 through June 2010.

- Using the new FY10 TSS: flow rate equation, calculate average monthly in-stream TSS concentrations using data from the entire period of record, October 2002 through June 2010. Table 2 shows these results.

- For comparison, calculate annual in-stream sediment load and load capacity for the period July 2009 through June 2010 to compare with previously estimated annual in-stream sediment loads (in tons TSS/year).

Table 1. Relationship of Total Suspended Solids (TSS), turbidity, and flow rate at Station GC1, Granite Creek, Alaska, from July 2009 through June 2010. [1]

Date	**TSS (mg/l)**	**Mean turbidity (NTU)**	**Turbidity Replicates (NTU)**	**Flow rate (cfs)**	**USGS staff gage height (ft)**	**Comments and notes**
7/15/09	0.1	0.37	0.36, 0.38	0.74	18.54	USGS installed permanent stream staff gage on November 8, 2002
8/14/09	0.2	0.29	0.28, 0.30	0.65	18.50	
9/09/09	1.3	1.21	1.23, 1.19	1.5	18.74	
10/07/09	0.3	4.13	4.42, 3.83	5.2	19.00	
11/04/09	0.1	0.79	0.82, 0.76	4.3	18.96	
11/07/09	2.4	2.92	3.01, 2.82	58.3	19.56	Storm event
11/11/09	0.1	0.84	0.88, 0.81	2.2	18.82	
11/12/09	6.4	12.7	12.5, 12.9	58.3	19.56	Storm event[2]
11/18/09	0.27	0.96	0.97, 0.95	2.3	18.83	
11/25/09	4.6	7.72	7.66, 7.77	24.4	19.34	
12/14/09	0.1	0.53	0.53, 0.54	0.85	18.58	
1/14/10	0.75	1.49	1.45, 1.53	19.0	19.28	
2/10/10	0.2	0.45	0.42, 0.48	0.87	18.59	
3/03/10	1.2	2.74	2.64, 2.83	6.7	19.05	
4/29/10	0.1	0.45	0.42, 0.48	2.2	18.82	
5/12/10	0.7	0.86	0.87, 0.84	2.6	18.86	
6/08/10	0.2	1.72	1.39, 2.05	1.5	18.56	

[1] Flow rates are derived from staff gage height readings converted using the USGS stage discharge curve (SDC) and stream rating table.
[2] Sampling occurred during a storm event with over 2.5 inches of rain falling the previous 24 hours.

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, 2009 and 2010.

1. Granite Creek has an average 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

For the TMDL 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, as calculations for all in-stream sediment loads depend on it. In June 2007, cumulative analysis was completed on all 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 remained a highly significant 0.9780. Similar analyses were completed in each of FY08 and FY09.

For FY10, all 17 new data sets, together with the previous 80 data sets collected through June 2010, were run through linear regression analysis. The new FY10 equation generated was:

(2010 revised equation: TSS (mg/l) = [1.10886 (turbidity in NTUs)] – 2.41653

The correlation coefficient (r^2) for the new data analysis is a highly significant 0.95478.

The addition of 17 FY10 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 2% 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 2010 equation, a 10 NTU turbidity level predicts a TSS level of 8.67 mg/l, a 7% change from the original estimate. At 30 NTUs, the comparison is 30.57 mg/l and 30.90 mg/l. The new allowable target TSS concentration (equivalent to 6.64 NTUs) is 4.95 mg/l, compared to the 4.78 mg/l limit derived in 2009. The new "target" value for TSS is used in calculating the allowable monthly and annual sediment load capacity for Granite Creek in Table 3.

The bottom line is that the original regression equation was valid and acceptably accurate as confirmed from subsequent analysis of all 97 data sets collected from 2002 through June 2010. 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.

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.

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 at high flows. 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 (FY08) and June 2008 through June 2009 (FY09) were completed in identical fashion. The resulting equations are found in prior year's reports.

Statistical analysis of TSS-flow rate including data from July 2009 through June 2010: an updated TSS – flow rate relationship

In June 2010, regression analysis was completed using on all 17 TSS-flow rate data sets collected from July 2009 through June 2010, together with the 80 prior data sets covering October 2002 through June 2009. *Table 1* includes all simultaneous TSS and flow data collected from July 2009 through June 2010. Common (base 10) logarithmic transformation was completed on all 97 data sets for Granite Creek. The transformed data were then run through linear regression analysis.

The resulting equation used for generating the in-stream sediment loads in Table 2 was:

$$\log(\text{TSS (mg/l)}) = 0.65585 * \log(\text{flow (cfs)}) - 0.63218$$

The correlation coefficient for all logged data sets from 2002-2010 was 0.68739.

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 strength of the statistical relationship of TSS-to-flow has varied annually over the period 2002-2010. The relationship of TSS to low-to-moderate flow rates may be best represented by a linear equation, whereas high-to-extremely high flows appear best represented by an exponential equation.

For comparison and consistency with all prior year’s analyses, all monthly in-stream sediment loads and loading capacities were calculated using log transformed data and the resulting equation. To do otherwise would be comparing “apples and oranges” due to using different methods than those used in prior years. Tables 2 and 3 show the results with comparison to prior year’s load calculations.

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

The seventeen monthly flow rate measurements recorded from July 2009 through June 2010 were compared against the average monthly flows (AMFs) calculated in 2007 using the original 208 data points. Given the relatively few number of monthly flow observations (17), the new data did not meaningfully alter the mean monthly flow values calculated in 2007. Average recorded flows during FY10 were low, but the effect on recalculating AMFs would have an equal “lowering” effect on both in-stream loads and load capacity calculations. The effect of overall lower average monthly flows would be to lower equally the calculations for both load capacity and in-stream sediment loads. New AMFs were therefore not calculated, *with the exception of the AMF for November.* November is a focus of attention for sediment control, as previous analyses suggest it is the only month with an in-stream sediment load exceeding the allowable load capacity for the creek. Therefore, more flow measurements were recorded during November than in other months in recent years to get a more statistically accurate assessment of flow rate. Eight measured flows taken during 2008 through 2010 were added to the original 27 November flow measurements used to estimate the AMF at 135 cfs in 2002. The newly calculated AMF for November using the 35 observations is 110 cfs. This value was used in Tables 2 and 3.

It is worth noting that no November flows recorded over the last four years have exceeded 58.3 cfs. This suggest that several extremely high flows (863, 1390 cfs) measured in 2003 and 2005, respectively, have skewed the AMF higher than is supported by the vast majority (33 of 35 data points) of flow measurements in November. These high flows were not excluded from the calculation of November’s AMF in order to allow comparison with and be consistent with all prior year’s analyses, but excluding one or both of them would significantly lower the in-stream sediment load. For comparison in

Tables 2 and 3, the highest November flow rate recorded (1390 cfs) was excluded from the calculation of November's AMF and shown in **bold ( ).**

It is also important to note that the flow data collected from July 2009 through June 2010 for the months of October and December measured 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 2010 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 the June 2007 comprehensive analysis and all subsequent analyses**.**

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 2010 updated TSS: flow equation, (0.65585) (1.648) - 0.63218 = 0.44866. The antilogarithm of 0.44866 is 2.81 mg/l TSS. This represents the newly-calculated average monthly TSS concentration for January for the period October 2002 through June 2010.

Using the 2010 regression equation found at the bottom of page 6, the average monthly TSS concentrations calculated for each month using all 97 data sets from the period October 2002 through June 2010 were as follows:

January: 2.81 mg/l
February: 2.12 mg/l
March: 1.65 mg/l
April: 1.05 mg/l
May: 1.28 mg/l
June: 1.41 mg/l
July: 0.99 mg/l
August: 3.51 mg/l
September: 4.11 mg/l
October: 3.67 mg/l
November: 5.09 mg/l
December: 4.42 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 at the bottom of page 6. *The annual estimated in-stream sediment load, updated with the July 2009 through June 2010 data, was calculated at 166.15 tons TSS/year. This value represents a reduction of 20.91 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 13.04 ton decrease from the 179.19 tons TSS/year calculated for June 2009.*

Methods used to calculate annual in-stream sediment loads demonstrate that during the period July 2009 through June 2010, Granite Creek experienced a decrease in annual in-stream sediment load estimated at 13.04 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 166.15 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 very slightly exceeds the allowable sediment loading capacity for that month. Improved sediment controls have narrowed that deficit to 1.25 tons. *If the highest recorded November flow rate (1390 cfs) measured is removed from the average monthly flow calculations, the November in-stream load is far lower than the allowable sediment load for November.*

For purposes of comparison, the highest November flow rate (1390 cfs estimated in November 2005) was excluded from the 35 total flow observations for that month. November's in-stream sediment load and load capacity were recalculated and those values shown in **( )** in Tables 2 and 3. Using this method, the monthly in-stream sediment load for November is 23.44 tons compared to the allowable load capacity for November of 28.67 tons. *This recalculation to account or one outlier data point results in November's sediment loads complying with the load capacity for that month*. The rationale for deleting extreme "outlier" data points was further explored with the USGS to confirm that the practice is supported in calculations of AMF to avoid high bias when relatively few data points are available. USGS confirmed that, in cases where a stage discharge curve is based on relatively few high flow measurements, when the estimated flow rate using the stage discharge curve is greater than twice the highest directly measured stream flow, that estimated flow rate is suspect. The flow of 1390 cfs estimated in November 2005 was 15 times higher than the 90.2 cfs maximum measured flow rate that was used to develop the stage discharge curve for Granite Creek. It is accepted practice by professional hydrologists to question such flows as no calibration flows exist. This adds creedance to throwing out the 1390 cfs value in recalculating November's average monthly flow.

Table 2. Monthly existing (in-stream) suspended sediment loads in Granite Creek, updated with July 2009 – June 2010 data and compared with the 2009, 2008 and (2007) load estimates. Calculations were made using all 97 data sets from 2002-2010.

Month	Average Monthly Flow (cfs)	Existing In-Stream Suspended Sediment (TSS) Load (tons)[3] 2010 2009 2008 (2007)
January	44.5	10.47 10.65 9.72 (8.79)
February	29.0	4.65 4.93 4.32 (3.51)
March	19.8	2.73 3.02 2.54 (1.86)
April	9.9	0.84 0.99 0.77 (0.47)
May	13.4	1.44 1.64 1.32 (0.87)
June	15.5	1.82 2.00 1.63 (1.12)
July	9.1	0.75 0.90 0.69 (0.41)
August	62.4	18.33 18.07 17.08 (16.82)
September	79.5	26.47 25.44 24.73 (25.95)
October	66.7	20.49 20.04 19.04 (19.15)
November	110 [4] (72)[5]	45.35 **(23.44)** 60.25 61.82 (75.00)
December	88.7	32.81 31.26 30.59 (33.11)
Annual Total		**166.15 tons/ 179.19 tons/ 174.25 tons/ (187.06 tons) (144.24 tons)[6]**

[3] 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.

[4] Newly-calculated using additional flow data gathered from 2007-2010. November average includes 2 of the 3 highest flow rates recorded at Granite Creek from October 2002 through June 2010. 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.

[5] November average monthly flow calculated with highest recorded outlier flow (1390 cfs in Nov 2003) excluded from the 35 observations used to calculated AMF.

[6] Instream sediment load calculated using November AMF of 72 cfs.

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

> Average monthly flow (cfs) * (4.95 mg/l TSS allowable target) * 0.0027 * number of days in the month = loading capacity in tons of sediment (TSS) for that month

In FY10, the allowable target TSS value was 4.95 mg/l, based on the results of the newly-calculated TSS: turbidity statistical relationship using all project data from 2002-2010. This level corresponds to a turbidity allowable target level of 6.64 NTUs. This is a slight increase (3.5%) from the 4.78 mg/l target TSS concentration calculated in FY09 and results in slightly higher monthly and annual load capacity. *The FY10 estimated annual allowable sediment load capacity is estimated at 223.02 tons TSS/year as compared to the 2009 estimate of 226.39 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 2010 and prior years.

In summary, the annual in-stream sediment load (166.15 tons) is significantly below the allowable annual sediment load capacity (223.02 tons). This suggests compliance with the prescribed loads in the approved TMDL. For November, depending on whether an average monthly flow of 110 cfs (all flow data) or 72 cfs (one high flow excluded) is used, the in-stream sediment load is 1.25 tons above the allowable load capacity or 5.23 tons below the allowable load capacity, respectively.

Table 3. Monthly suspended sediment Loading Capacity (LC) for Granite Creek, showing 2010 and prior years' revised load capacity and 2007 load estimates in ( ).

Month	Average Monthly Flow (cfs)	Natural Background Load (tons)[7]	Loading Capacity TSS (tons)[8] 2010 2009 2008 (2007)
January	44.5	1.86	18.44 17.80 18.40 (19.26)
February	29.0	0.56	10.85 10.48 10.82 (11.33)
March	19.8	0.93	8.20 7.92 8.18 (8.57)
April	9.9	1.50	3.97 3.83 3.96 (4.15)
May	13.4	2.17	5.37 5.36 5.54 (5.80)
June	15.5	1.80	6.21 6.00 6.20 (6.49)
July	9.1	1.24	3.77 3.64 3.76 (3.94)
August	62.4	0.93	25.85 24.97 25.79 (27.00)
September	79.5	3.00	31.88 30.78 31.79 (33.29)
October	66.7	4.34	27.63 26.69 27.56 (28.86)
November	110 (72)	1.20	44.10 **(28.67)** 53.43 55.19 (57.79)
December	88.7	3.10	36.75 35.49 36.65 (38.38)
Annual Total		**22.63 tons**	**223.02 tons /226.39 tons/ 233.84 tons/ (207.59 tons) [9] (244.86 tons)**

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

[8] FY10 monthly load capacity based on analysis of in-stream data. Includes natural background sediment load. Calculated as: (Monthly Q (cfs)) * (4.95 mg/liter TSS) * (0.0027) * (# days in month).

[9] Instream sediment load calculated using November AMF of 72 cfs.

4. FY10 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 FY10. 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 very 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.

The City and Borough of Sitka completed comprehensive water quality monitoring at ten stations along Granite Creek during two separate storm events in November 2009. The purpose was to both isolate individual turbidity sources and also get more information on natural background conditions during storm events. The results indicated that natural background turbidity levels vary little from normal levels during such events.

Since October 2008, monthly turbidity monitoring at GC1 has shown only one instance where the 6.64 NTU target level was exceeded. The November 25, 2009 replicate turbidity levels recorded were 7.66/7.77 NTU. This information, coupled with sediment load calcuations, suggests a high level of compliance with both the TMDL and Alaska water quality standards for turbidity.

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 and again in FY10 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 rebuilding check dams and water diversion, are remedies to be examined.

Winter road sanding and maintenance pushes gravel into the Granite Creek roadside shoulder and ditch, smothering the grass fringe. This drainage ditch was reseeded in June 2008 to reestablish grasses through its length, but further seeding is not justified. The existing pond and segments of the drainage ditch need to be cleaned annually of sediment. The upper pond below the scales was deepened in July 2009 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 July 2009 through June 2010 was lower than the June 2008 – June 2009 period and remained much lower than the five-year average annual sediment load calculated in 2007. The annual estimated in-stream sediment load, updated with July 2009 through June 2010 data, was calculated at 166.15 tons TSS/year. This value represents a reduction of 20.91 tons TSS/year below the five-year average load of 187.06 tons TSS/year calculated in June 2007 and a 13.04 ton decrease from the 179.19 tons TSS/year calculated for June 2009.*

- *The annual in-stream sediment load remains below the allowable annual sediment load capacity.*

- *November's in-stream sediment load was reduced compared to 2009. At an AMF of 110 cfs, it is only slightly above the allowable load capacity for the month. At an AMF of 72 cfs, it is below the allowable load capacity. The AMF for November still seems artificially high when evaluating flow data over the last four years. Additional flow data collected in FY11 will be valuable in recalculating the AMF.*

- *An estimated 1.5% reduction in the annual allowable sediment load capacity was calculated in comparison to the load capacity calculated in 2009. This is due to the recalculated allowable target TSS limit of 4.95 mg/liter compared to the 4.78 mg/l limit used in the 2009 calculations and the recalculation of November's AMF using additional 2008-2010 flow data.*

- *The TSS-to-turbidity mathematical relationship has been updated and improved with the addition of 17 new simultaneous data sets to the 80 data sets available in 2009. The 97 data sets were run through linear regression analysis and a new equation generated.*

- *Average monthly flows were not modified, with the exception of November's, as the meager data did not substantially change the average monthly flows calculated in 2008 and 2009.*

- *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.*

- *Since October 2008, monthly turbidity monitoring at GC1 has shown only one instance where the 6.64 NTU target level was exceeded. The November 25, 2009 replicate turbidity levels recorded were 7.66/7.77 NTU. This information, coupled with sediment load calcuations, suggests a high level of compliance with both the TMDL and Alaska water quality standards for turbidity.*

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.