FEDERAL INTERAGENCY SEDIMENTATION PROJECT
PROPOSAL FORM

Proposal Title: **Digital Imaging for Particle Analysis and Characterization**
Project Chief: **Dan Gooding, Chief, Sediment Laboratory**
Project Chief Location: **USGS Cascades Volcano Observatory, Vancouver, WA**
Proposed Start Date: **November 2011**
Proposed End Date: **November 2012**

1. **Relation to FISP goals:**
The purpose of the proposed project is to expand the capabilities of the Digital Imaging for Particle Analysis and Characterization (DIPAC) instrument currently in development at the USGS Cascades Volcano Observatory Sediment Laboratory. The DIPAC uses optical imaging of particles as they are pumped through a flow cell to produce size distributions and concentration values for suspended sediment samples. The proposed project directly relates to two FISP funding goals for FY 2012.

First, further development of the DIPAC supports the goal of measuring temporal and spatial variation in SSC and grain size distribution. The DIPAC has proven itself capable of excellent repeatability for grain size distributions of extremely light (10-30mg) suspended sediment samples (Section 3). However, the current optics and lighting conditions do not allow accurate measurement of particles finer than 4µm, truncating a standard size distribution at 8µm. The proposed project seeks development funding to improve the optics and lighting, extending the measureable range down to 1-2µm so that accurate distributions for silt sized particles can also be reported. Because the DIPAC can handle such light samples, it is now possible for the CVO Sediment Lab to analyze the grain size distributions of suspended samples taken at very high spatial and temporal resolution. The proposed project will provide the necessary funds to finish the development of the lab version of the DIPAC so that full size distributions can be reported for a wider range of samples than previously available. Operational monitoring programs will realize an immediate benefit from the extension of the reporting range of the DIPAC down to the silt/clay range. Field personnel will be able to request size analysis for even very light suspended sediment samples, at a minimal cost.

Second, the proposed project supports the goal of comparing gravimetric and volumetric SSC. The DIPAC uses particle areas to estimate particle volumes, and then uses the particle density to generate an estimate of total particle mass in the analyzed sample volume. Improving the effective analytical range of the DIPAC will improve the accuracy of the DIPAC SSC measurement. While not critical for the success of the laboratory version of the DIPAC, improvements to the SSC measurement will provide a foundation for our goal of eventually developing of a field version of the DIPAC that will measure SSC and grain size in real time.

2. **Technical merit (Scientific merit):**
The proposed project significantly improves sediment analysis technology by expanding the availability of full particle size analysis for samples that previously had been too light to analyze. There is a need for an affordable instrument that can be used to measure the particle size distribution of low-concentration suspended sediment samples. Currently, most USGS sediment laboratories require 1.0-1.5 g of fine (<63um) material for a full size analysis; many suspended sediment samples do not contain this much material. Researchers respond to this limitation in two main ways. First, they may composite samples to achieve enough material for size analysis. Second, they may only measure size distribution for high concentration samples. By compositing they lose spatial and temporal resolution that could yield valuable information about the dynamics of the system. Additionally, compositing degrades the resolution of the concentration data, which normally would be available for very light samples but cannot be recovered at a high resolution when the samples are composited for size analysis. Limiting size analysis to only heavy (usually flood-stage) samples introduces uncertainty about sediment dynamics during lower concentration flows. Our proposed project addresses these issues by introducing a fully functional laboratory instrument for particle size analysis of very light samples.

CVO Sediment Laboratory personnel have considerable expertise in imaging particle size analysis. Gooding has published multiple papers on the technology used in the DIPAC (Gray et al 2003, Gray et al 2005, Gooding 2010).

3. **Technical context (Relevance and importance)**:
The proposed work is an extension of the existing work done by the CVO Sediment Laboratory to develop an instrument that uses digital image processing to analyze sediment grain size distributions. Testing has shown that the current instrument agrees well with the Sedigraph for particle diameters down to 6µm (Figure 1). For the 6µm and larger size ranges, the precision of the existing DIPAC is similar to the excellent precision attainable with the Sedigraph (<3%, Figure 2), with sample concentrations 1-2 orders of magnitude smaller (Figure 2). We seek funding to continue development, with the specific goal of extending the operational range of the instrument into the 1-2µm diameter range.

Achieving the measurement of sizes in the 1-2um range would represent an advance over existing sediment imaging systems. Other instruments based on the same measurement principle have achieved detection limits of 4µm (Benson and French, 2007), 7µm (Chakraborti et al, 2009), 10µm (Tysmans et al, 2006), 20µm (Lee et al, 2009), 30µm (Smith and Friedrichs, 2011), and 50µm (Verny et al, 2011). The main limitation on our current detection limit is the lighting. Inefficient fiber optic connectors and lossy condensing/diffusing lenses prevent us from gaining the highest efficiency possible with our current LED strobe lights. We plan to work with a consulting optical engineer to improve the object-side lenses and lighting, and if needed the image-side lenses, to achieve the desired brightness and magnification while maintaining the high speed strobing (6µs) required for crisp dynamic imaging of particles in suspension.

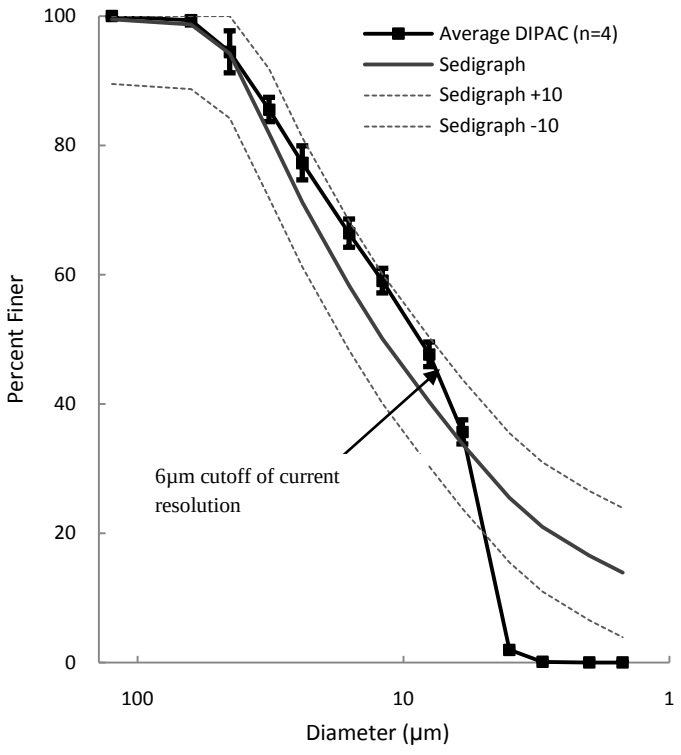

Figure 1: Agreement between DIPAC and sedigraph results for four separate 5ml subsamples of a suspension of AC spark plug dust fines. Bars indicate standard deviation of n=4 replicates. The DIPAC distribution agrees with the Sedigraph distribution down to 6µm diameter. The average mass of sediment in the subsamples is 0.0108g, the equivalent of 11 mg/L in a 1-L sample.

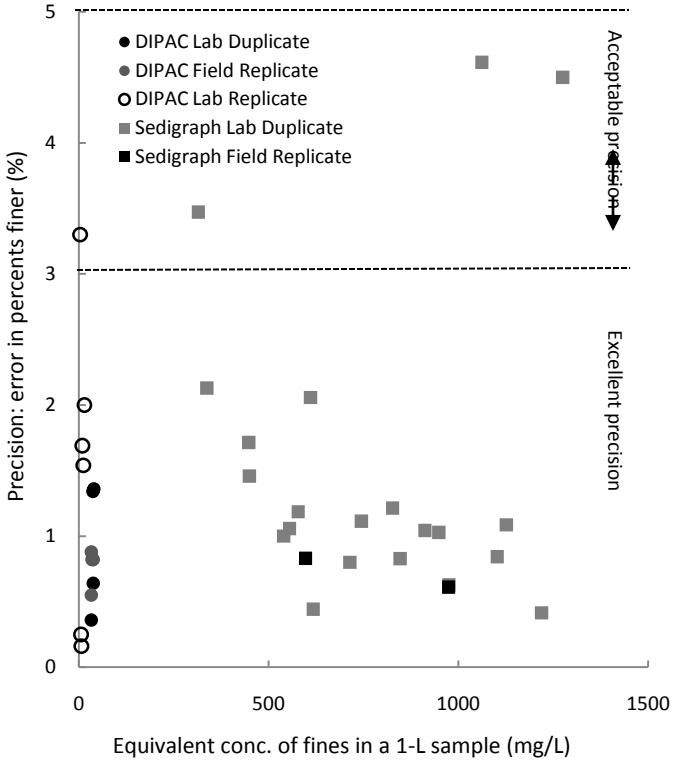

Figure 2: The precision attainable by the DIPAC and Sedigraph with different amounts of fine material in the sample. Lab duplicates are re-runs of the same material through the instrument two times. Field replicates are field samples taken within minutes of each other at the same location in a stream. Lab replicates are separate subsamples of the same field sample. The precision is expressed as the mean standard deviation of percents finer in the distribution of fines in the samples. Field samples and sedigraph samples are from the IL River, collected by Tim Straub, USGS, and analyzed for size at the CVO Sediment Laboratory in Summer 2011.

4. **Timeline, budget (Feasibility), and partners**:

Timeline:

Major Step	Allotted Time	Expected Outcome
Hire consulting optical engineer	Nov 2011-Dec 2011	
Work with engineer to re-design lighting and lenses	Dec 2011-March 2012	Diagram of lighting and lens system that will achieve desired resolution
Implement engineering solution to increase resolution	March 2012-May 2012	Laboratory instrument that can image particles from 63µm to 1-2µm range
Testing, validation, documentation	May 2012-Aug 2012	Publishable test data showing precision and accuracy of DIPAC
Complete report for publication and send out to review	Aug 2012-Nov 2012	Completed report presented to FISP Technical Committee 2012 meeting

Budget:

Item	Est. Cost
Optical Engineering of Lenses and lighting. (Contract labor)	$ 9,000
Machining (Contract labor)	$ 4,000
Parts (Calibration Targets, Lenses, LEDs, Electronic Components)	$ 1,000
Salary	$ 5,000
Publication	$ 3,000
TOTAL REQUESTED:	**$22,000**

References:

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