IMPLEMENTATION OF THE SEDIMENT IMPACT ASSESSMENT MODEL (SIAM) IN HEC-RAS

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Abstract: A sediment impact assessment model is being incorporated as part of the Hydrologic Engineering Center's River Analysis System (HEC-RAS) through a joint research and development effort between HEC and the U.S. Army Engineer Research and Development Center's (ERDC) Coastal and Hydraulics Laboratory (CHL). The sediment impact assessment model (SIAM) was initially developed through CHL research activities conducted with Colorado State University. The reach based sediment accounting model has been embedded in the Hydraulic Design module of HEC-RAS, and will provide users with an expedient means of determining average annual sediment impacts for stream networks. The stream network of HEC-RAS provides the conceptual framework for the application of SIAM, and the HEC-RAS user interface expedites data entry. HEC-RAS hydraulic and sediment transport calculations are coupled with user defined bed material and wash material descriptions, sediment sources, and flow duration information to compute reach averaged sediment supply, transport capacity, and local balance by grain size. Input data include bed material gradation, flow duration representative of an average annual hydrologic cycle, sediment properties, sediment source loading by grain size, and reach averaged hydraulic parameters. Results are reported by grain size and in total for each reach, and include local bed material balance, average annual sediment transport capacity, bed material and wash material supply, and local source supply. Use of the HEC-RAS interfaces to generate and execute SIAM runs will be discussed and illustrated.

INTRODUCTION

As water resource projects become more complex, there is a growing emphasis on the ability to implement effective regional sediment management. A common goal of many regional sediment management projects is the reduction of sediment loading from the watershed. This is often accomplished with rehabilitation features such as grade control structures, bank stabilization, drop pipes, dams, and land treatments. While these features are often implemented to reduce sediment yields to downstream areas, the spatial and temporal impacts of these features on the sediment regime of the system are far from straightforward, and often result in unexpected morphologic changes in the channel system. Therefore, the challenge in regional sediment management projects is to select the appropriate sediment management features that produce the desired reductions in sediment delivery while minimizing the disruption to the stability of the channel systems. In order to facilitate this decision-making process, ERDC and HEC are currently developing a Sediment Impact Assessment Model (SIAM), which provides for rapid assessment of the impact of sediment management activities on downstream sedimentation trends. SIAM is viewed as a screening tool for the assessment of multiple rehabilitation alternatives, particularly in the reconnaissance and feasibility phases of a project. It provides a framework to combine sediment sources and computed sediment transport capacities into a model that can evaluate sediment imbalances and downstream sediment yields for different alternatives. The development of SIAM includes the incorporation of the model into the Hydraulic Design module of HEC-RAS, which is an on-going task at the time of this writing. The implementation of SIAM into HEC-RAS will allow users to utilize the popular, widely used hydraulic modeling system for stream network development and data entry for SIAM applications. In addition, sediment impact assessments with SIAM can easily be conducted for systems where existing HEC-RAS models are available.

SIAM DESCRIPTION

SIAM was initially developed through CHL research activities conducted with Colorado State University on channel stability in small watersheds. The objective of model development was to create a tool that would combine sediment, hydrologic, and hydraulic information for a channel network and determine the average annual sediment budget for the system. In general, SIAM performs reach average sediment transport computations by grain size class, and integrates the computed transport rates with flow duration information to compute an average annual sediment transport capacity in tons per year. Computed average annual sediment transport capacity is compared with the average annual inflowing sediment load to evaluate sediment continuity for the reaches in the system. This provides the means to assess the potential impact of local alterations to the sediment regime on channel stability.

Model Computation Methodology: SIAM treats a stream network as a series of user defined sediment reaches. Sediment reaches are typically delineated based on observed locations of significant geomorphic change such as tributary locations, changes in channel gradient, plan form and geometry, and shifts in sediment composition. Computations of sediment supply and transport are conducted on a reach-by-reach basis and are representative of the average annual conditions for each reach.

In addition to reach-based computations, SIAM sediment computations are also conducted by grain size class. The sediment gradations are divided into fractions with a single representative grain diameter, and sediment transport and supply calculations are conducted independently for each fraction. This accounting by grain size allows the fate of specific size sediments to be observed throughout the system.

The grain size accounting also allows the tracking of wash material and bed material within the system. SIAM determines whether sediments within a system are wash material or bed material based on a user defined wash load threshold diameter. Changes in the wash load threshold diameter permit sediment that is wash material in one reach to transition into bed material in a downstream reach, and vice versa. The wash load threshold diameter is typically determined following Einstein (1950). The value of this model feature is illustrated by considering a channel where the upstream reach is very steep and the channel bed material is correspondingly very coarse, but the downstream reach is significantly less steep and the bed material is much finer. Coarse sands may be included in the wash material of the upstream reach due to a larger wash load threshold diameter. In the downstream reach that is less steep, the wash load threshold diameter is smaller, thus the coarse sand will transition into the bed material. The coarse sand load would have little morphological impact on stability of the upstream reach as wash material, but would have much more impact on the downstream reach as bed material. This demonstrates how modification of a sediment source by a given management practice could have little effect on channel stability in one reach but have significant effect on stability in reaches farther downstream.

Data Requirements: The SIAM process requires developing input records for each sediment reach that describe bed material composition, sediment properties, hydrology, hydraulics, and sediment loading from local sources (Figure 1). The bed material records define the percentage of sediment present in the channel bed for each grain size class. Sediment property records are used to set the threshold between wash material and bed material, and to select the sediment transport function. Hydrology records define the discharges and corresponding durations that are representative of an average annual hydrologic cycle. The hydrology records are populated with discharge values corresponding to each flow profile in the HEC-RAS model. Hydraulic records list the reach averaged HEC-RAS hydraulic parameters of depth, area, velocity, hydraulic radius, wetted perimeter, top width, friction slope and roughness for each flow profile. The local source records define the sediment sources and corresponding loadings from channel and watershed sources such as eroding channel banks, gullies, upland surface erosion, and point sources such as sand and gravel mining operations.

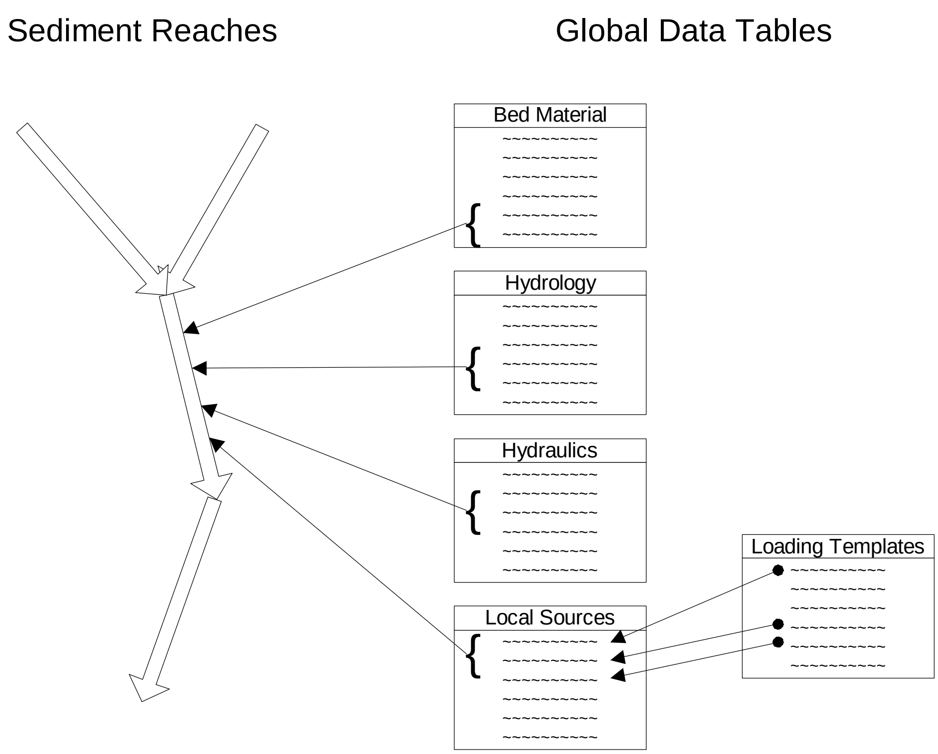


Figure 1 Input data requirements for SIAM

Model Output: The SIAM output consists of local bed material balance, average annual transport capacities, bed material and wash material supplies, and local sediment supply totals for each sediment reach. Local bed material balance is defined as the difference in the bed material supply and the average annual transport capacity for a sediment reach. A negative local balance indicates excess transport capacity and thus erosion potential for a reach, whereas a positive local balance indicates excess supply and potential for deposition. All output is listed by grain size class as well as total values for each sediment reach.

Capabilities and Limitations: SIAM provides sediment managers an intermediate assessment tool between qualitative evaluations and comprehensive mobile boundary numerical models. Funding constraints and limited resources often preclude the wide-scale use of complex numerical models in a study. With SIAM, users can rapidly evaluate the effectiveness of proposed sediment management techniques and identify which techniques may be candidates for more detailed investigation, thus providing cost savings to the project. Also, the data input structure of SIAM allows individual sediment sources to be easily entered and/or modified, allowing the user to quickly alter sediment loadings to reflect various sediment management techniques. The incorporation of SIAM into HEC-RAS makes the model available to the engineering community in a familiar format with continuing user support.

SIAM is not an event-based sediment routing model, which limits its applicability to investigations where average annual sediment budget calculations are sufficient. SIAM computations are based on annual flow duration, which makes modeling of individual events difficult. Channel geometry is not updated based on erosion or deposition, so the results are only indicative of a single channel configuration for the entire period of record being analyzed. Since SIAM is a reach-based model that uses reach-averaged parameters and produces reach-averaged results, information on specific locations of erosion/deposition cannot be determined.

INCORPORATING SIAM INTO HEC-RAS

Since SIAM directly utilizes HEC-RAS outputs it was advantageous to incorporate SIAM directly into the HEC-RAS framework. This enables a SIAM user to conduct the entire study in a single program, and utilize existing HEC-RAS models, which commonly exist, as a foundation for new SIAM evaluations. The combination of these programs also facilitates integrated output and results analysis capabilities.

SIAM Input: SIAM can be accessed through the "Hydraulic Design" menu in HEC-RAS versions 3.2 and later. The user interface populates the HEC-RAS schematic and provides a series of tabs under which the pertinent SIAM input data can be entered (Figure 2). Sediment reaches are specified and appropriate bed materials, sediment properties and sources are attributed to each sediment reach. Most of these data sets can have a one-to-one relationship with the reaches (e.g. each sediment reach has its own bed material gradation) or can be specified once and applied globally (e.g. a single sediment properties designation, including transport function and fall velocity method, is applied to all reaches).

The five major templates for input data are depicted in Figures 2 through 4. Each sediment reach must have a bed gradation to compute proportional grain fractions for transport capacity computations (Figure 2). HEC-RAS will populate the hydrology dialog (Figure 3a) with the flows corresponding to the sediment reach for each specified profile. The user then associates a duration with each profile to distribute this hydrologic record over a statistically average year.

Next a few basic sediment properties including a transport function are specified on the sediment properties tab (Figure 3b). The hydraulic tab is automatically populated by HEC-RAS (Figure 3c). A single set of hydraulic parameters is associated with each reach for each profile. HEC-RAS computes weighted averages of hydraulic parameters by prorating the value at each cross section by the length of the associated control volume as a percentage of the total reach length. Finally, users specify sediment sources (Figure 4). Annual load by grain size is entered for each source, which can then be associated with multiple sediment reaches and modified by means of a multiplier. Following complete specification of the input data, the "Compute" button will write a SIAM input file and launch the stand-alone program.

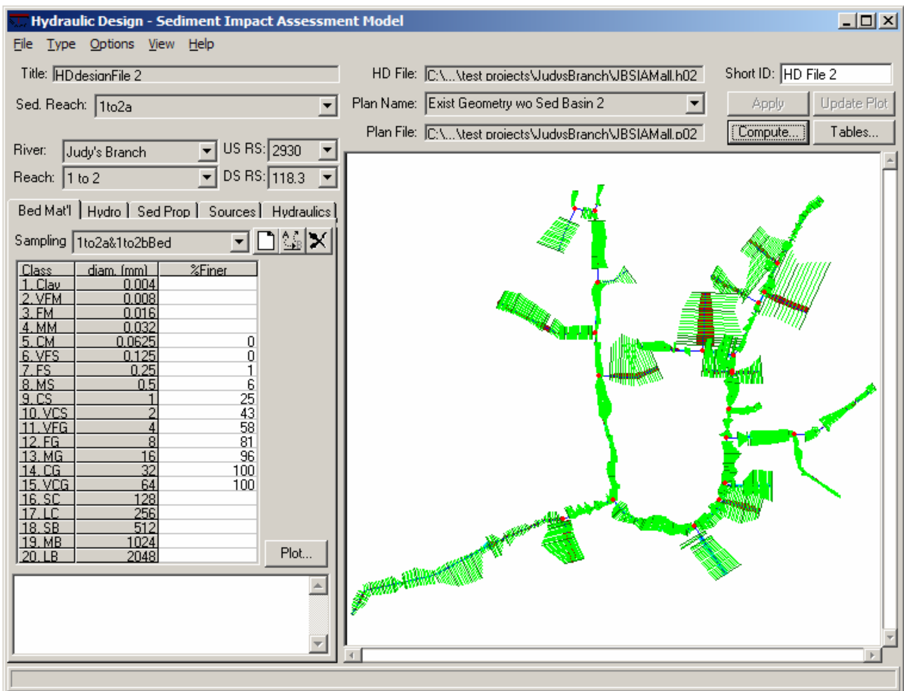
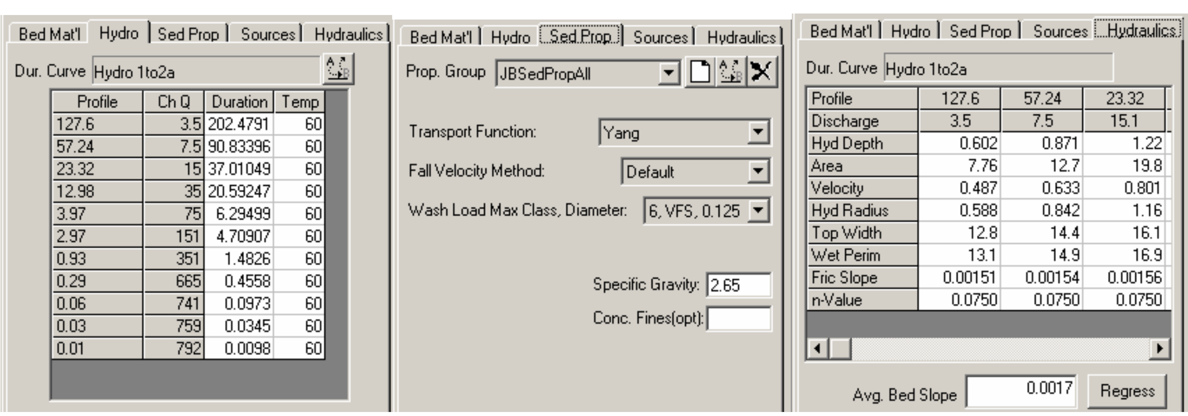


Figure 2 HEC-RAS interface for SIAM with the bed material input tab



(a) (b) (c)

Figure 3 SIAM data tabs in the HEC-RAS interface for (a) hydrology, (b) sediment properties and (c) hydraulics

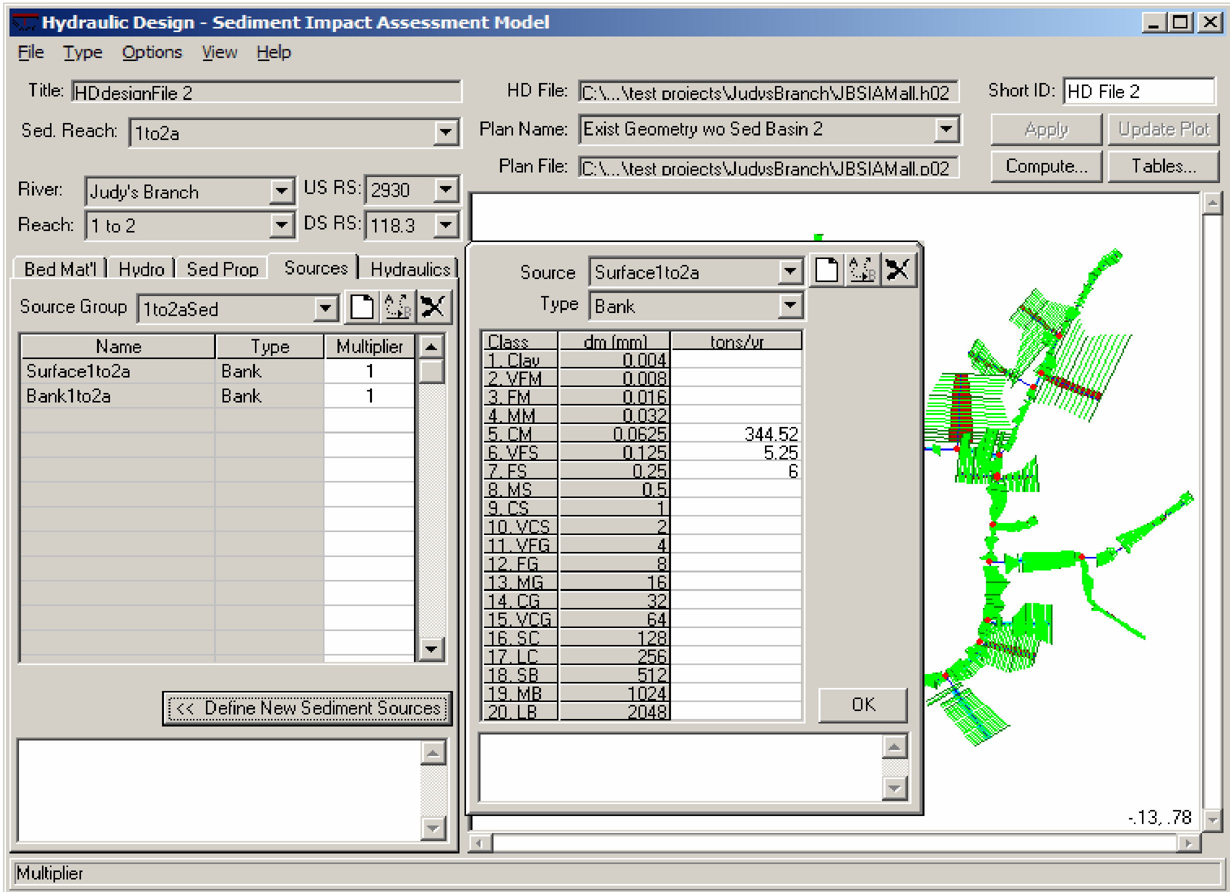


Figure 4 Source specification dialog and tab in the HEC-RAS interface for SIAM.

SIAM Output: SIAM currently generates a binary output file that HEC-RAS reads and makes available through several user output options. A range of tables and graphs are available for analysis of results following a computation. The primary SIAM output is "Local Balance" which reports magnitude of the average annual tendency of a reach to fill or scour. The local bed material balance plot for two alternatives, reported by reach, is depicted in Figure 5. HEC-RAS can also report SIAM output in graphical or tabular form by grain size as shown in Figure 6. Deficits and surpluses reported in tabular form are color coded to quickly identify expected aggradation or degradation, with any computed intervals falling within a user specified "equilibrium tolerance" reported in a third color (Figure 6). Since the local balance can be driven by reach length, a user can also select output by "Normalized Local Balance" which translates reach deficits or surpluses into tons/year/linear foot of channel. This output is more directly relatable to aggradation and degradation and allows more general comparison of impact between reaches. Other output options include grain-specific transport potentials, sediment source and supply information, and breakdowns of wash and bed material.

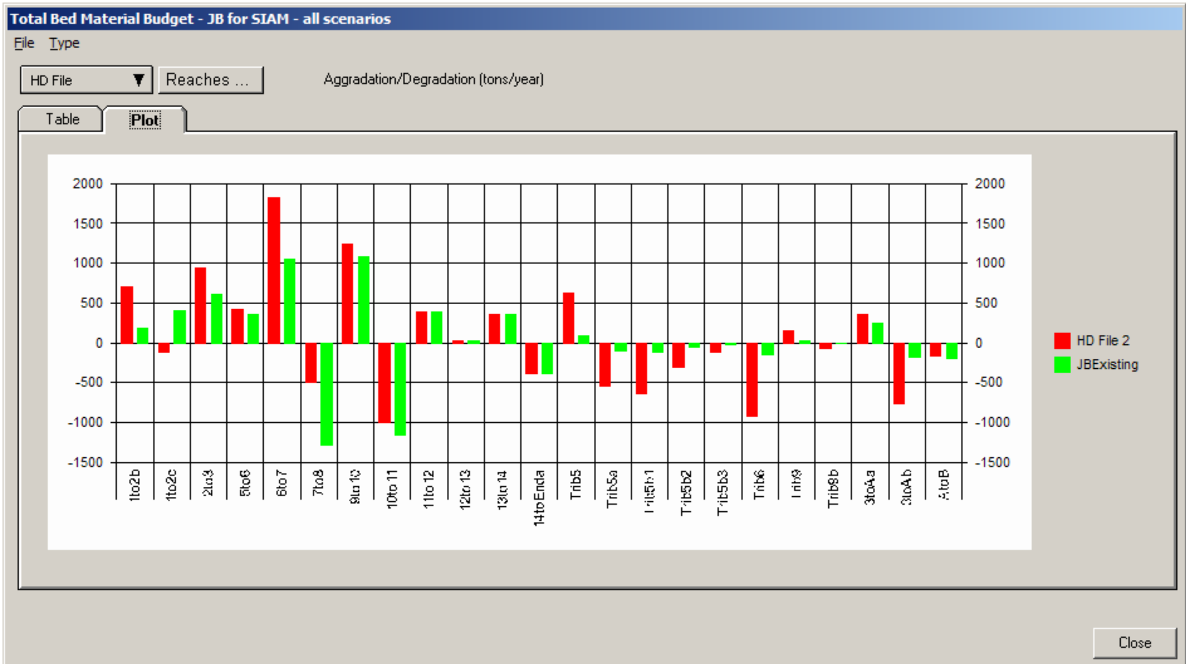
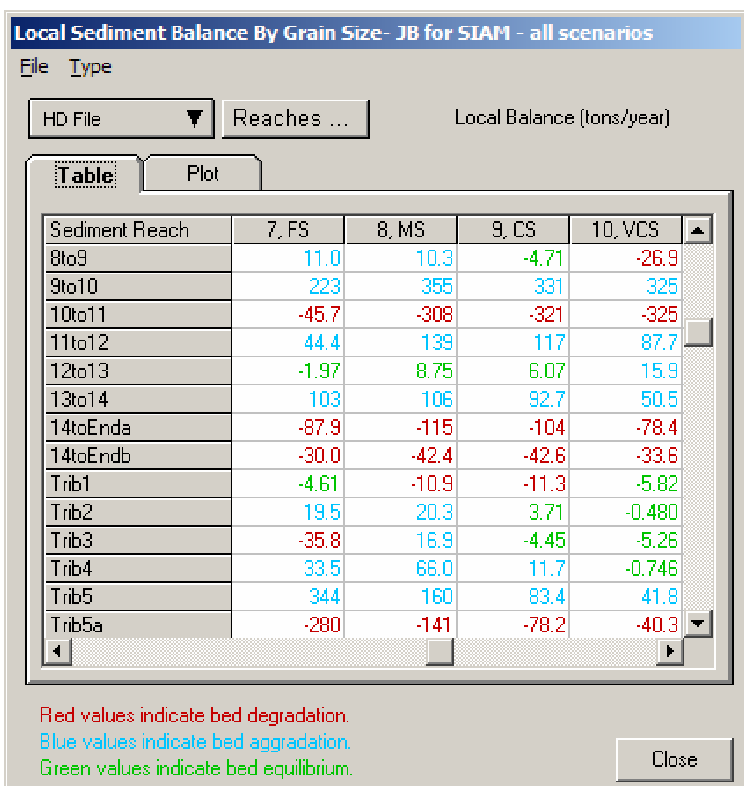


Figure 5 SIAM output plot of local bed material balance



Sediment Reach	7, FS	8, MS	9, CS	10, VCS
8to9	11.0	10.3	-4.71	-26.9
9to10	223	355	331	325
10to11	-45.7	-308	-321	-325
11to12	44.4	139	117	87.7
12to13	-1.97	8.75	6.07	15.9
13to14	103	106	92.7	50.5
14toEnda	-87.9	-115	-104	-78.4
14toEndb	-30.0	-42.4	-42.6	-33.6
Trib1	-4.61	-10.9	-11.3	-5.82
Trib2	19.5	20.3	3.71	-0.480
Trib3	-35.8	16.9	-4.45	-5.26
Trib4	33.5	66.0	11.7	-0.746
Trib5	344	160	83.4	41.8
Trib5a	-280	-141	-78.2	-40.3

Red values indicate bed degradation.
Blue values indicate bed aggradation.
Green values indicate bed equilibrium.
Close

Figure 6 SIAM output table of local balance by grain size

CONCLUSION

SIAM is being implemented into HEC-RAS with the aim of providing planners and designers an easily usable means of integrating sediment continuity concepts into stream rehabilitation and best management practices. It has the capability to be a very effective and easily applied tool for evaluating sediment management alternatives on a watershed scale where the application of complex numerical routing models may be impractical. The incorporation of SIAM into the proven and user-friendly environment of HEC-RAS greatly enhances the option for managers to address the impacts of sediment supply and transport in an expedient and cost effective manner.

REFERENCES

Einstein, H.A. (1950). "The bed-load function for sediment transport in open channel flows", U.S. Dept. of Agriculture, Soil Conservation Service, Technical Bulletin No. 1026.