DAM_Explorer: A Modeling Framework for Assessing the Physical Response of Streams to Dam Removal

June 2009

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Complexity

Environmental Value

Cost

PURPOSE

Dam removals and modifications are increasing areas of focus for US Army Corps of Engineers (USACE) Districts from several standpoints: design of restoration projects and quantifying potential environmental impacts (Operations, Continuing Authorities Projects, Support for Others, and General Investigations) and the evaluation of permit applications (Regulatory). Physical response of the reservoir bed and downstream channel boundary as well as multiple parameters of sediment dynamics are topics of central interest in dam removals and modifications. Knowledge of sediment behavior and geomorphic response of the system to the removal or modification alternatives is central to the decision process.

DAM_Explorer is a graphically rich, Windows-based program for analysis and presentation of three-dimensional physical responses. The Ecosystem Management and Restoration Research Program (EMRRP), a GI-funded technology transfer program administered by the Engineer Research and Development Center's Environmental Laboratory, supported the initial development of DAM_Explorer.

OVERVIEW

DAM_Explorer is a modeling framework for the assessment of sediment mobility and channel response in association with dam removal projects. The current version of the framework focuses on simulation of multidimensional sediment erosion, transport, and deposition. However, one of the explicit design goals for this effort was allowance for ready integration of additional modules in the future. Future modules could include the capacity to investigate staged reservoir drawdowns and incremental removals, various sediment management practices such as dredging, channel/floodplain interactions as influenced by revegetation, ice impacts, and bed material sorting. The framework supports deterministic analyses, but is best applied using parametric uncertainty analyses for stochastic representation of possible outcomes. A test case was created in this first stage as a basis for future testing and development of the modeling framework.

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PRODUCT CAPABILITIES

The DAM_Explorer tool is built on the EFDC_Explorer pre-post processor program for the Environmental Fluid Dynamics Code (EFDC). Currently, the DAM_Explorer tool provides a means to assess stage, bottom shear stresses, water column concentrations of suspended solids, noncohesive and cohesive sediment transport, downstream deposition patterns, bed/floodplain grain size changes over time, and reservoir sediment erosion patterns. The DAM_Explorer modeling framework includes the following pre- and post-processing visualization and animation capabilities:

General

- Graphical interface for the test case and EFDC sub-models:
    - Hydrodynamics
    - Various hydrologic regimes, including flood events
    - Density-dependent flow state variables: Salinity/temperature
    - Tracer behavior
    - Multidimensional sediment transport
    - Toxics
    - Water quality with sediment diagenesis
- Extensive visualization and point and click inquiries of input and output data.
- Extensive use of popup tips to help the user select the proper inputs.
- Extensive error and range checking for user inputs.
- Many functions work with calendar dates or Julian dates.
- Continuing support and development of the software and utilities.

Pre-Processor

- Model generation for Cartesian and curvilinear (i.e. riverine) grids.
- Initial conditions assignment.
- Boundary conditions assignment.
- Plan view and vertical profiles of model domain and parameters.

Post-Processor

- Animation of plan view and vertical profiles.
- Export of model results to third party commercial graphics packages.
- Calibration tools.

Figure 1 shows an example of the DAM_Explorer (DE) main form. DE includes the capability for specification of the dam cells and erodible sections. This utility provides the user with a simple method to assign EFDC cells that constitute the dam and erodible section. The user can manually assign the cells or use a polyline/polygon to define the dam location. Once the location cells are assigned, the user specifies the bottom elevation and how much sediment and/or dam material exists for those cells as an initial condition. Non-erodable surfaces can be simulated by specification of a zero (0) sediment thickness. Grain sizes of the dam sediments are assigned using the “Grain Size” button. The user must enter the mass fraction of each sediment class in the sediment deposits and river bed reach being modeled in EFDC. DE computes the d50 and displays it for information only.

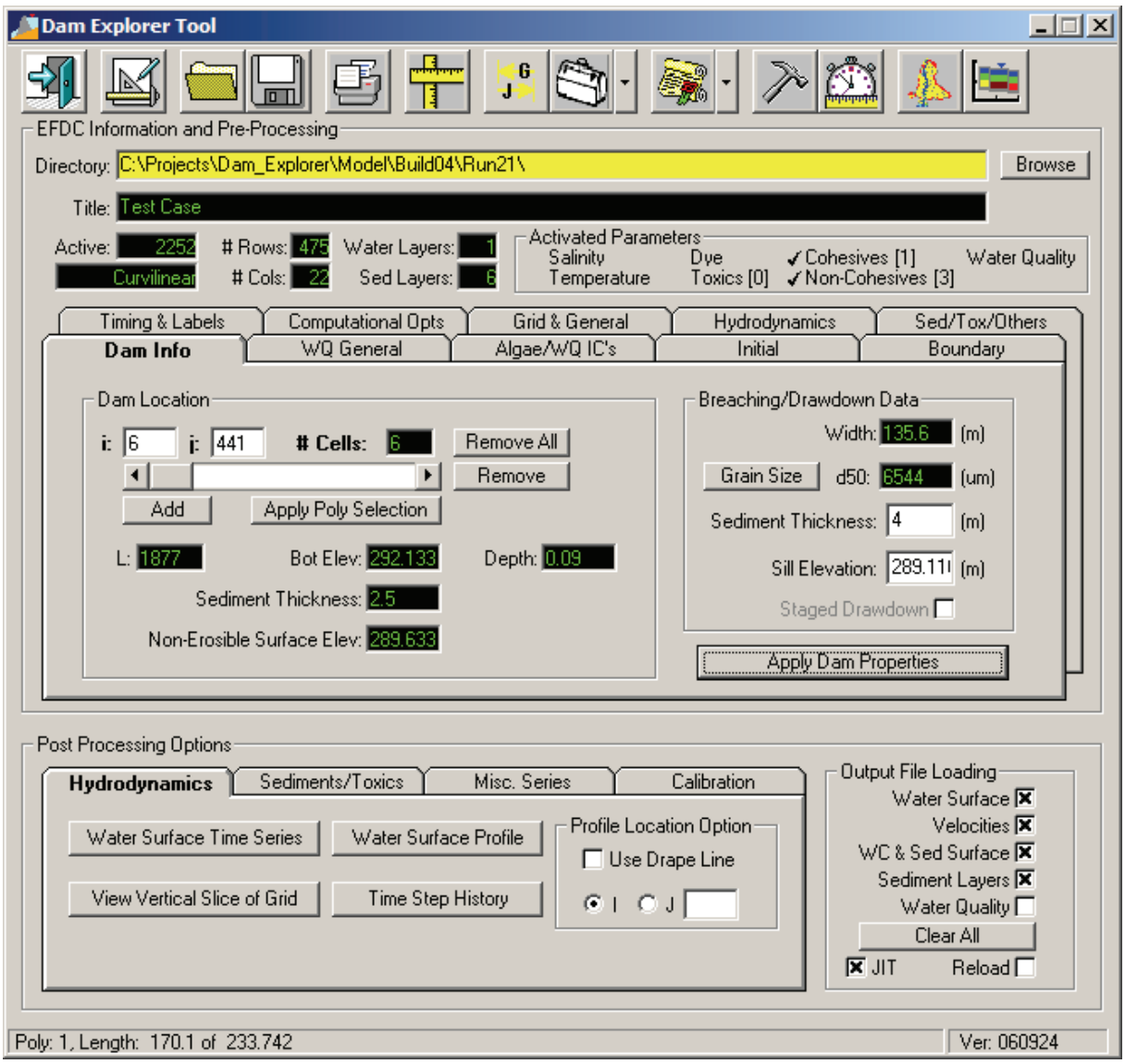

Figure 1. DAM_Explorer main data entry form

Once the cells are selected and the sediment and sill properties for the dam or breach are defined, the user must press the "Apply Dam Properties" button to assign the properties to the dam cells. The user can manually edit the cell properties later if needed.

A setup program included with the modeling framework provides a software utility that allows the user to build and analyze model results. The EFDC_Explorer Users Manual is provided in the setup program as guidance for much of the DAM_Explorer program. The setup program also installs the test case described in the following section.

TEST CASE DEVELOPMENT

A test case based on a mid-sized hypothetical dam was created as part of the development of the modeling framework. Figure 2 shows the plan view of the bottom elevations of the entire test case model domain. The test case includes an upstream reservoir, a section of river, and a second reservoir at the downstream boundary. The test case consists of 2252 active curvilinear cells. The modeled reach is approximately

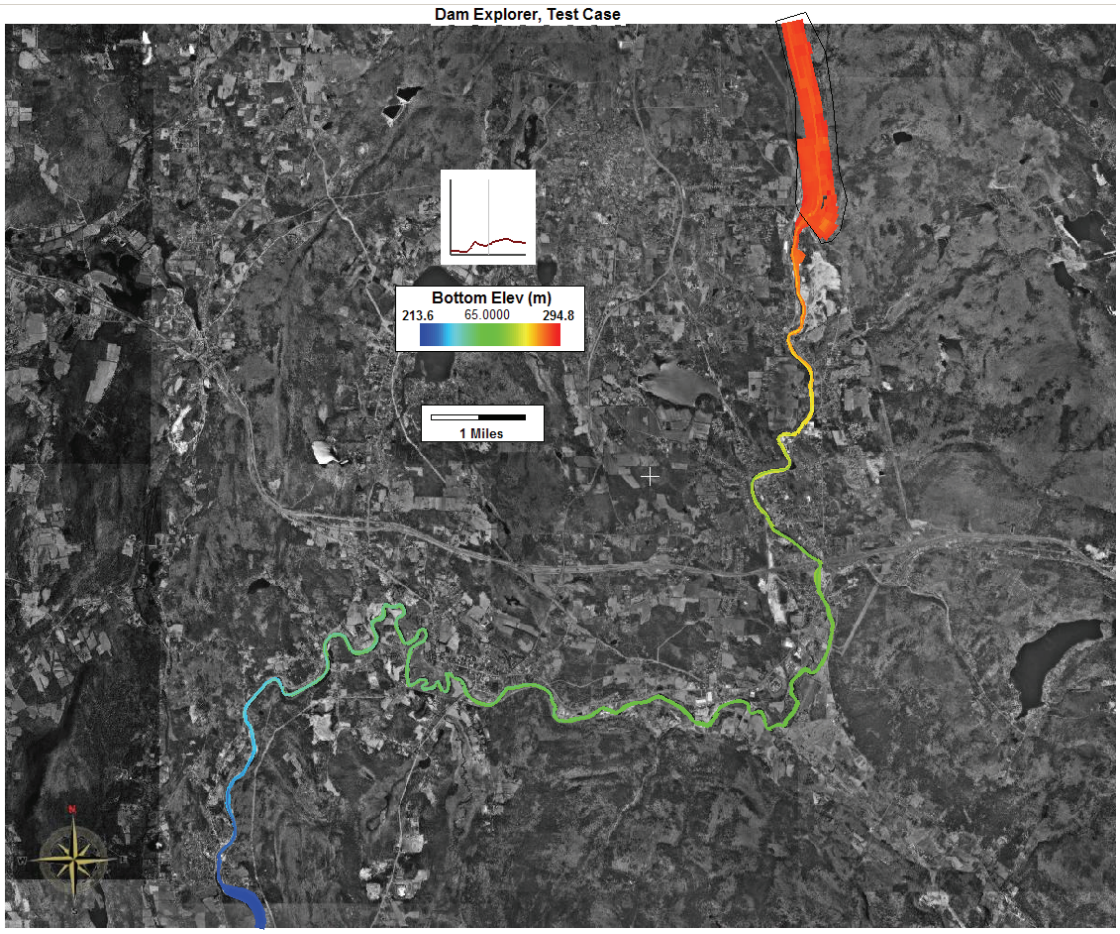

Figure 2. Test case domain showing bottom elevations of reservoir and downstream channel reach (N.B. intermediate figure in color legend represents Julian date of simulation)

36 kilometers long. The water column is presently represented by one layer.

The upstream boundary is represented as a flow boundary condition. The downstream boundary is an outlet control structure boundary. No tributary inflows were included in the test case.

Figure 3 shows a plan view of the sediment d50 initial conditions for the entire model domain, focusing on the river and near floodplain. Figure 3 shows the relatively fine sediments in the reservoir and occasional gravel beds in the river.

Figure 4 shows a vertical profile through the model domain prepared using the Dam_Explorer tool. The profile shows both the water column (above the black horizontal line, which represents the sediment/water interface) and the sediment bed. The software has various options available for longitudinal profile display. Figure 4 depicts Total Suspended Solids (TSS) (0 to 1000 mg/l) and the sediment bed computed d50's for each sediment layer below the sediment/water interface. This view, as is true with most of the visualizations within the framework, can be animated to view temporal durations of impacts and alterations.

Figure 5 displays scour and deposition patterns (including scouring of the reservoir sediment deposits) after an 82-day simulation that included several peak flow events.

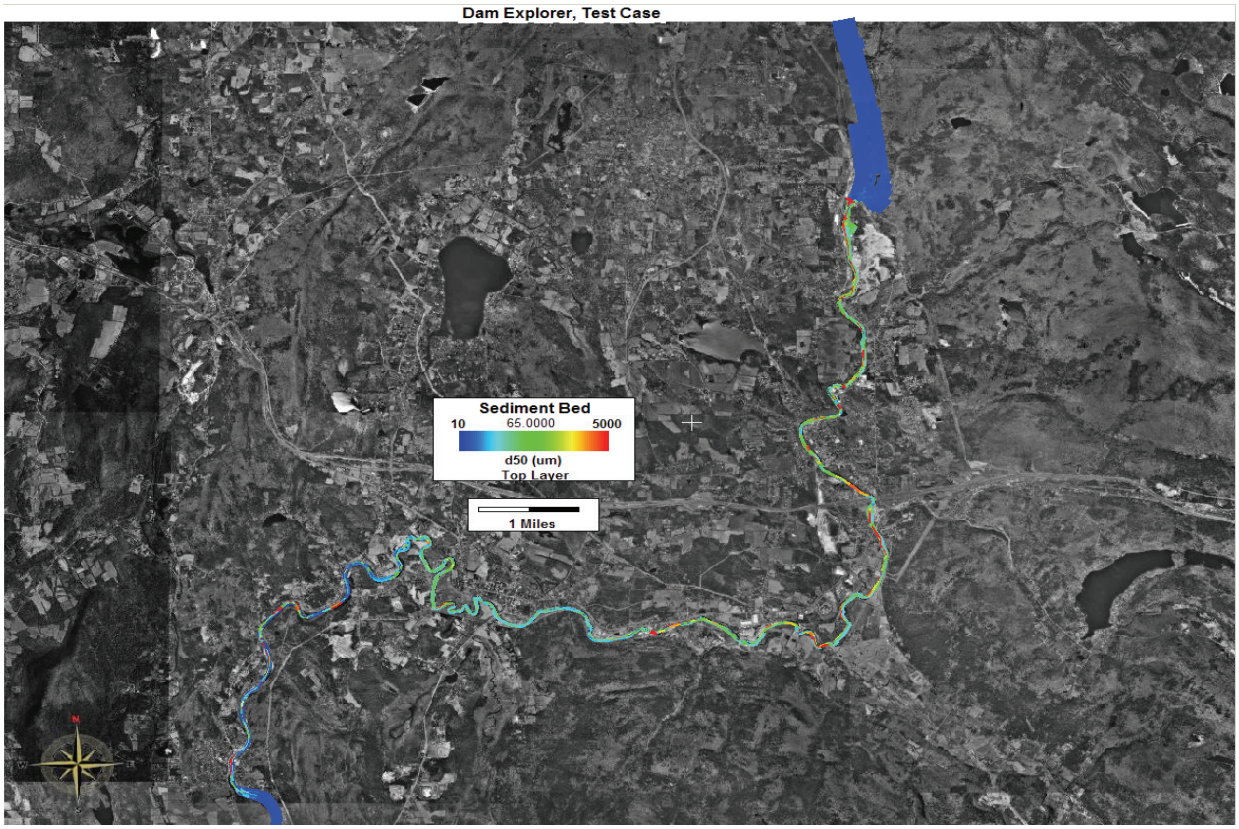

Figure 3. Plan view of sediment d50's pre-project (N.B. intermediate figure in color legend represents Julian date of simulation)

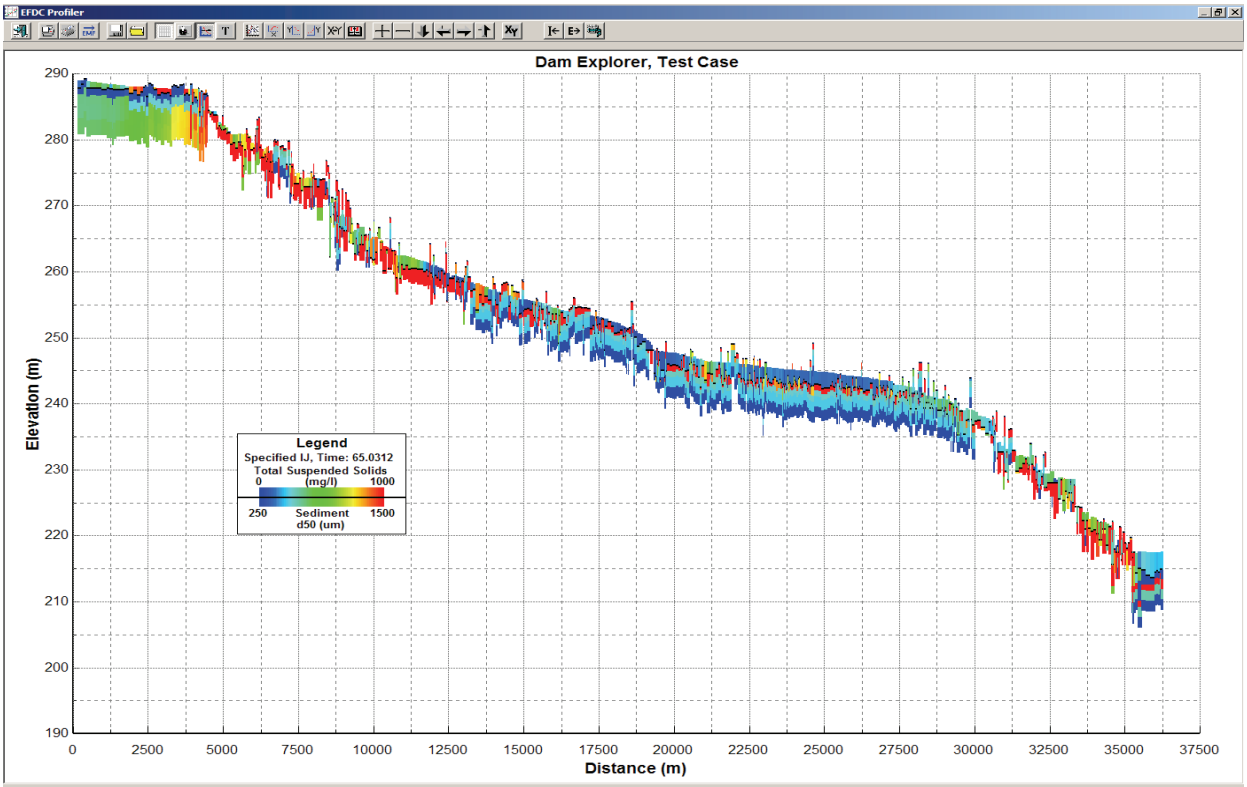

Figure 4. Water column TSS and river bed d50's downstream following breach

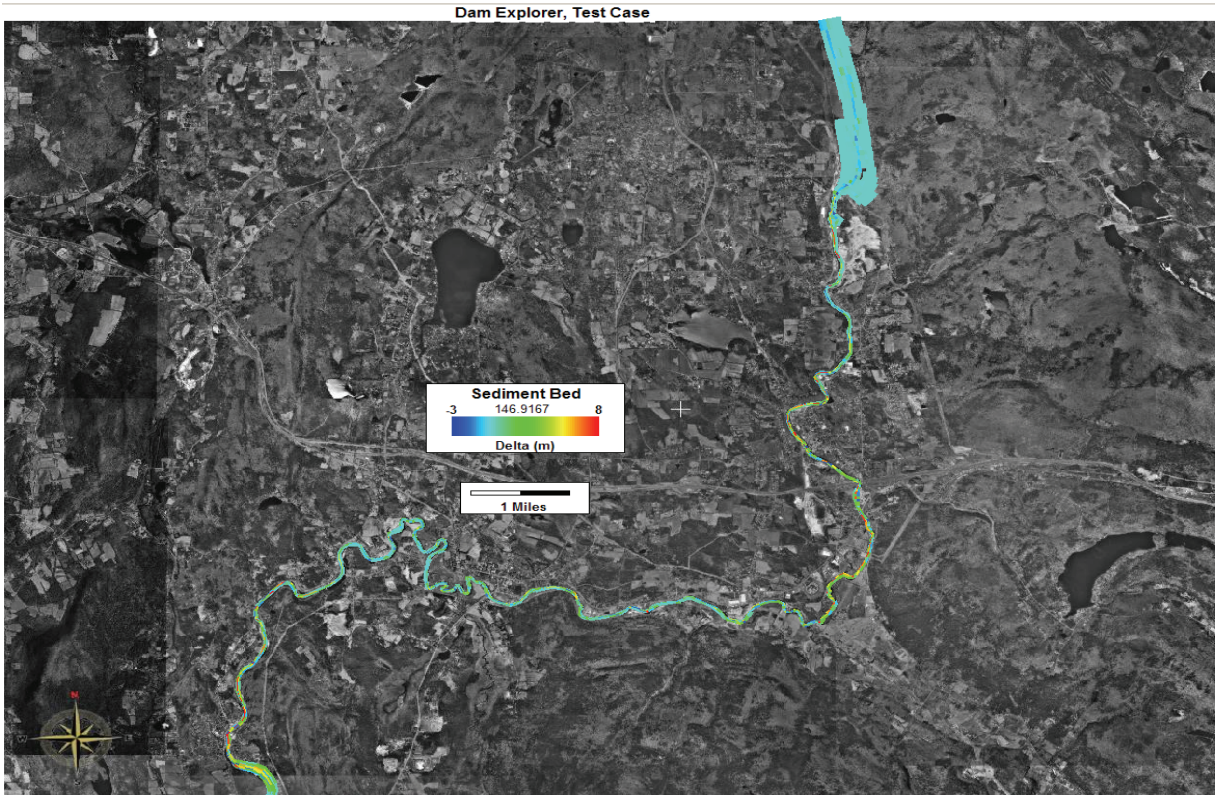

Figure 5. Scour and deposition patterns after 82 days with storm events (N.B. intermediate figure in color legend represents Julian date of simulation)

SUMMARY

Dam_Explorer offers Corps Districts and other users a valuable tool to test the effects of various physical site characteristics, removal choices, and hydrologic regimes on water quality and sediment dynamics following dam removals or major modifications. It includes 3-D functionality to assess spatially complex phenomena that are often of central interest to restoration and regulatory personnel and to visually communicate the outcomes of various removal scenarios to both technical and lay audiences. Assuming resources for further development, additional capacity to guide dam removal decisions (such as optimized physical and temporal increments for staged removals) is anticipated.

POINTS OF CONTACT

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This technical note should be cited as follows:

Conyngham, J., and C. Wallen. 2009. *DAM_Explorer: A modeling framework for assessing the physical response of streams to dam removal*. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-65. Vicksburg, MS: U.S. Army Engineer Research and Development Center http://el.erdc.usace.army.mil/emrrp/).