

---

# Flood Modeling Simulation Management

Alan K. Zundel  
*Brigham Young University*

---

## Introduction

Numerical simulations are an important component of flood studies. The amount of input data used for numerical simulations can be very large, both in the number of files and the amount of data required. This is particularly true if numerous simulations are created in order to study multiple scenarios. This paper describes an approach for sharing model data between simulations and a graphical user interface which has been created to manage the simulations and data sharing.

## TUFLOW Flood Study Data

TUFLOW (Syme, 1991 and WBM, 2005) is a finite difference based 1D/2D hydraulic model. It is ideal for flood studies because of its stability and flexibility. Two-dimensional computations are carried out on Cartesian grids. The model includes the capability to incorporate one-dimensional sections to represent open-channels, rectangular or circular pipes, weirs, or bridges. Boundary conditions can be applied to either the 1D and/or 2D portions of the model.

A TUFLOW simulation consists of all of the data for a single model run which includes 2D grid, 1D segments, boundary conditions and model parameters and options.

The 2D grid defines geometry and cell attributes used to do the 2D analysis in TUFLOW. The geometric definition includes the origin, rotation, grid size, cell sizes, and elevation data for the grid. The cell attributes define whether or not a cell is active, the material, and the initial water level for a cell.

The 1D segments include channel geometry and attributes for the 1D portions of the numeric domain. The geometry consists of the channel type: open-channel, rectangular or circular pipe, weir, or bridge; along with additional information dependant upon the channel type. Open-channels include cross-section information and upstream/downstream inverts, pipes include relevant sizes and invert data, etc. Attributes depend upon channel

type but may include: length, roughness values, channel storage information, flow direction (channels can be setup to flow in a single direction), and energy losses.

Boundary conditions are mechanisms for getting flow into/out of the model. Boundary conditions can be used to specify flow rate or water surface elevation along a model boundary. These can be specified through time or be defined using a relationship to other model parameters such as using a rating curve (water surface elevation/flow rate) to determine the water surface at a model boundary.

Model parameters and options include all of the settings used to control how the model behaves. This includes time controls (start, end, time step), output options, material properties, and computation settings (such as viscosity formulation, wet/dry options).

A flood study may include many simulations to evaluate different events, configurations, material properties, and model options. Different events generally mean different boundary conditions such as evaluating the 10-year, 20-year and 100-year events. Different configurations could be used to evaluate changes before/after a development or channel modification. Different material properties may be used for calibration/sensitivity analysis. Different model options may be used to evaluate their effects upon the model such as Smagorinsky computed viscosity values versus constant viscosity values.

The number of simulations in a study can become large quickly as simulations are created for every possible permutation of options. A study with four events, three configurations, three sets of material properties, and two model options generates 72 final simulations. This does not include intermediate runs generated when working towards the final solutions.

A simulation within a study often has much of the same data as other simulations within the study. For example, two simulations where the only difference is the event have all the same data except for the boundary condition definitions. This difference represents only a small portion of the model data. Simulations defined to evaluate flow conditions before/after installation of a structure such as a levy only differ in geometry around the structure. The balance of the elevation data is redundant. Redundant model data causes problems. First, redundant data requires increased disk storage space, coupled with increased time to store and backup this extra data. This represents lower efficiency. However, the major problem with redundant model data is maintaining the simulations. If there is a change to the base model elevations, each simulation needs to be altered with the new data. Updating all of the simulations is an error prone and time-consuming task. If errors are made, they can be difficult to find and give erroneous study results.

---

## Shared Components Strategy

TUFLOW allows all types of input data to be shared between simulations. Sharing data between simulations reduces the amount of data stored and provides easier maintenance since there are not duplicate items with the same data. The input data for TUFLOW resides in geographic information system (GIS) layers, command files, and csv files. Any number of these files can be used together to form a simulation. Each of these files can be shared between simulations. This paper refers to these a shared GIS layers, command files, or csv files as components.

Another important strength of TUFLOW is the ability to control the granularity of the shared data. For example, most models contain both an inflow and an outflow boundary. Whether both boundaries data are shared together or separately depends on the requirements and study area. If the boundary conditions change together based upon a certain event (10-year, 100-year, etc.), then they should be shared together. However, if the upstream boundary is a flow boundary for a watershed and the downstream boundary is the ocean, it may be beneficial to have each boundary specification shared independently. It may be desirable to match a 100-year inflow hydrograph with a 20 year peak tide as well as with a 50-year peak tide (or any number of similar arrangements). In TUFLOW, the modeller controls the granularity of the shared data can by grouping the data into the same component. Since TUFLOW allows multiple components that define the same kind of data, the modeller also chooses whether or not to group boundaries into the same or different components.

To further enhance the ability to share data, TUFLOW allows data to be overridden or replaced. For example, a GIS poly line can be used to define a levy which will replace the elevations that previously existed along the poly line. Not only is this a powerful approach for defining the elevations for a model, but using this approach allows more data sharing between simulations. A study for a proposed levy can share the base elevation data between all simulations and share proposed levy configurations among the appropriate simulations.

As with elevation data, all commands and attributes can be specified and then overridden later. This powerful feature enables a simulation to include everything from a previous simulation with some minor edits created by overwriting existing data. Model options are specified in TUFLOW using command files. Command files also read in other files including GIS layers, csv files, and other command files. The files read through a command file may be specific to the simulation or shared among multiple simulations. The ability to recursively read command files allows multiple components to be

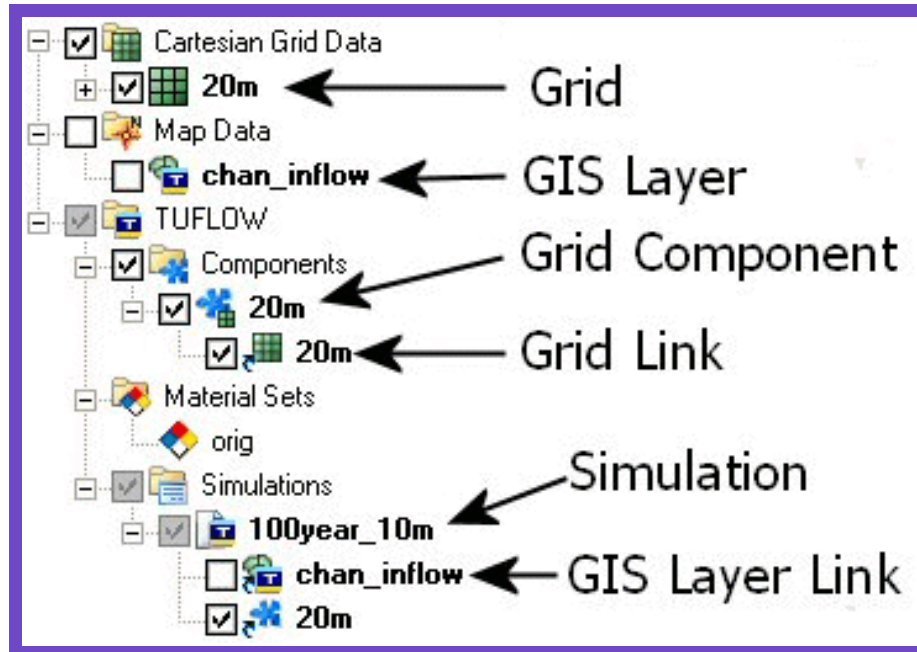
shared together using a shared command file. Each simulation has a root command file which reads in all of the simulation data (recursively as needed).

The ability to share model data using TUFLOW is extremely powerful. It makes it easier to build and maintain studies with large numbers of simulations and reduces the amount of data associated with a study. The difficulty with using this approach is that the modeller has to keep track of the individual components in a simulation. This approach can generate many files, each of which will be used by one or more simulations. It can be difficult to keep track of the simulations affected when changing individual files. In addition each link to a shared file has to be manually inserted into some command file. Generating and managing the command files can be time-consuming.

### **Graphical User Interface**

The simulation management paradigm used for TUFLOW input files is incredibly powerful but can be difficult to learn and manage. This is particularly true for a beginning user. A graphical user interface has been built into the Surface-water Modeling System (SMS) (Zundel, 2006) to more easily manage simulations. The graphical interface includes a graphical hierarchy or tree of the data loaded into the system. In the tree, each type of component (grids, GIS layers, etc.) has a unique icon and the types are grouped into folders. This allows components to be managed as objects which is far more intuitive than using command files.

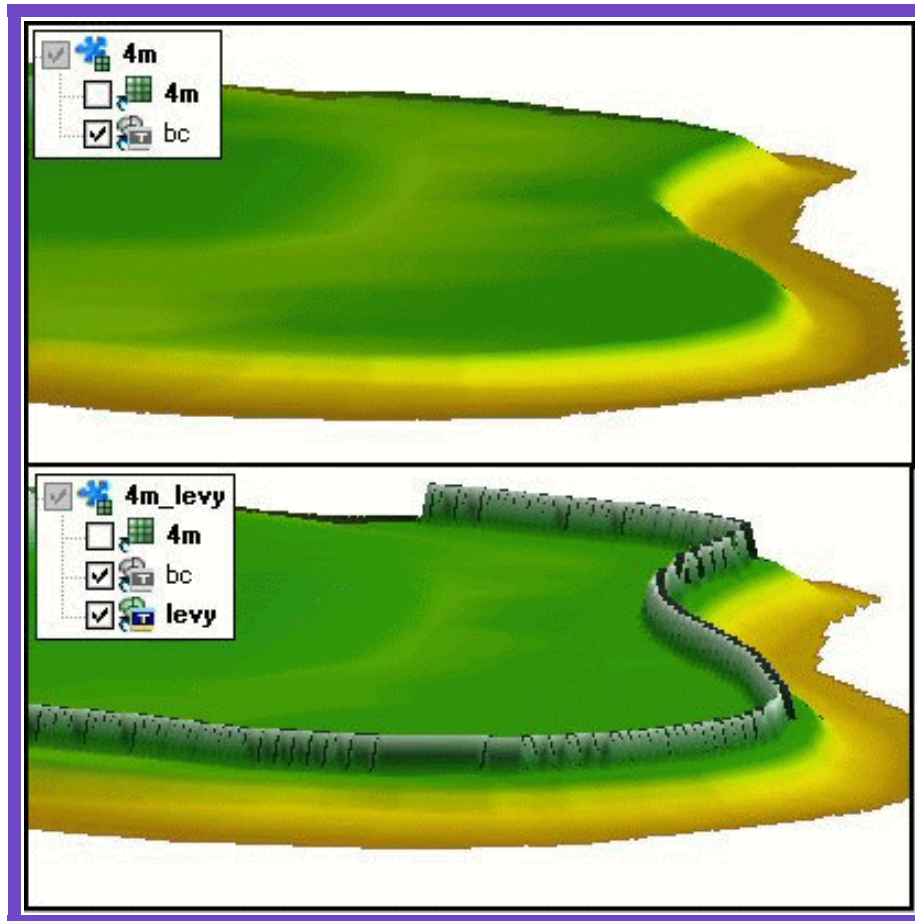
In the GUI, geometric components such as grids and GIS layers can be created and edited. These components then appear in the upper portion of the hierarchical tree (Figure 1). A TUFLOW project loaded into the system appears in the lower portion of the tree. The project includes material definitions sets, grid components, and simulations. A material set defines the roughness and hydrologic loss information for the materials used in the grid. Multiple material sets can be created and are useful for evaluating different seasons and for calibration or sensitivity analysis. Below each simulation the modeller adds links to GIS layers, and grid components that pertain to that simulation. A link to a component is created by dragging the component into the simulation where the link should be created. Links to components have an icon similar to the component icon but also includes an arrow similar to a shortcut symbol in Microsoft Windows. Each simulation also references one material set. Since more than one simulation may reference or include a link to a component, the tree helps manage the shared components.



*Figure 1. Components and Links as shown in the Graphical User Interface*

Any two-dimensional geometric information for a simulation must be included in a grid component. A grid contains an initial geometric definition of the 2D domain and cell attributes. Some GIS layers including 2D boundary conditions, elevation overrides, or cell attribute overrides apply directly to a grid. The grid and the layers which apply directly to the grid are grouped together using a grid component. These components appear in the “Components” folder in the project. A new component is created by clicking on the component node of the tree. The modeller then drags the grid and modifying GIS layers into the component to create links. These composite components can be dragged into the simulation to include them in that simulation.

Figure 2 illustrates using links to build grid components. The picture is divided into two parts which represent the elevation output from TUFLOW. The grid components are shown in the top left corner of each part of the image. The top grid component (4m) includes a link to the grid named “4m” and a link to the GIS layer “bc,” which provides boundary conditions (not shown in picture). The grid component named “4m\_levy” has links to the



*Figure 2. Grids Generated from Components with Shared Features*

same grid and to the GIS layer “bc” but also includes a link to a layer named “levy.” The levy layer includes the geometry definition of the levy which overrides the elevations in the base geometry. Both grid components reference the same grid definition and boundary definition. Therefore this data is only stored once, reducing disk space requirements. Further, any edits to either of these components automatically applies to both grid components. This greatly facilitates updating simulations and managing files.

Boundary conditions do not show up as components in the tree and are not shared with links. TUFLOW projects (groups of simulations) include a set of csv files which store the boundary condition curves used by the

simulations. Each curve is organized by a boundary condition and event name. In GIS boundary condition layers arcs or nodes define the location for the application of boundary condition curves. These geometric objects reference a boundary condition by name. A simulation stores the name of the event being used. When processing the input data, TUFLOW looks up boundary condition information by boundary condition name (from the GIS layer) and the event (from the simulation). When building a TUFLOW simulation outside of the GUI, the csv files must be setup by hand. In the GUI, the boundary condition curves are stored with the GIS objects and are used to generate the required csv files automatically making the specification of boundary conditions much easier.

When creating boundary conditions a definition is created for each event to be simulated. The event used for an individual simulation is selected when defining the model parameters for the simulation.

Shared components within the GUI derive the same benefits as models created outside the GUI such as input file sizes and maintainability. The GUI also addresses some of the deficiencies of building simulations outside the GUI. As mentioned earlier, when working outside of the GUI building and maintaining the necessary command files and links to shared files can be confusing and time consuming. It also tends to be problematic. The GUI makes building simulations and adding shared components very easy.

## Conclusions

Sharing components among simulations of a flood study make it easier to maintain models and decrease storage space. Using this approach inside of a graphical user interface maintains these advantages and makes it easier to build and maintain simulations than when working with raw input files.

The existing graphical user interface could be expanded to provide a more complete set of options for shared components. Specifically, the interface only supports a single type of composite component, namely the grid component. Additional, generic composite components would add support for more granular control of shared components. This provides sharing on multiple levels allowing related components to be grouped and shared between simulations. The interface also does not currently share model parameters between simulations. Perhaps a new type of object in the project would allow grouping of these types of parameters in a future version of the GUI.

**References**

Syme, W.J., 1991. "Dynamically Linked Two dimensional/One dimensional Hydrodynamic Modelling Program for Rivers, Estuaries and Coastal Waters." M.Eng.Sc. Thesis, University of Queensland.

WBM Pty Ltd. 2005. *TUFLOW Users Manual*. Australia: WBM Oceanics. Available at [http://www.tuflow.com/Downloads\\_TUFLOWManual.htm](http://www.tuflow.com/Downloads_TUFLOWManual.htm).

Zundel, A.K. 2006. *Surface-water Modeling System Reference Manual, Version 9.2*. Provo, UT: Environmental Modeling Research Laboratory, Brigham Young University.