ADVANCES
in Hydrologic Engineering

Spring 2015

Director's Comments

By Christopher N. Dunn, P.E., D.WRE

I recently participated in the Joint Federal Interagency Conference in Reno, NV and it was refreshing to hear about the innovative work that is being done not only by USACE (U.S. Army Corps of Engineers) but also by many of the other Federal agencies, academia and the profession as well. The conference, also called the SedHyd Conference, combines the Federal Interagency Sedimentation Conference with the Federal Interagency Hydrologic Modeling Conference. SedHyd only happens once every four to five years but the conference really should occur more frequently as it is a great place to share ideas and discuss potential collaboration. USACE had almost seventy participants at the Conference which is a significant increase from the attendance at many recent conferences. Maybe this is a sign that the conference approval process is improving? I was happy to be exposed to many technical topics. The presentations and discussions reminded me why I was so excited about civil engineering in the first place. If you didn't get a chance to participate in this conference, please consider participating in other conferences as they are a great way to rejuvenate your commitment to the profession, share your work, meet others and learn new things. Yes, I know it is

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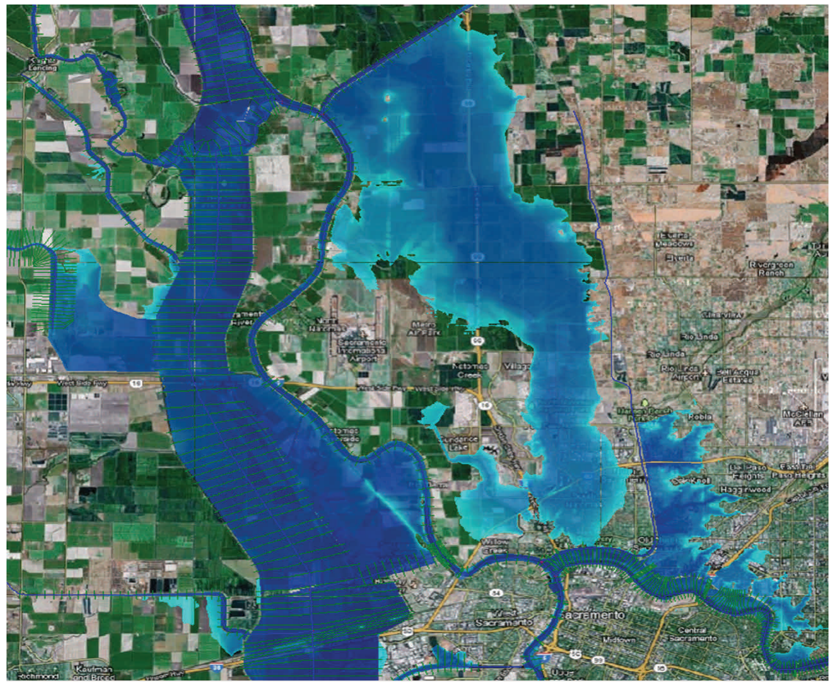
Combined One- and Two-Dimensional Hydraulic Modeling with HEC-RAS

By Gary Brunner, P.E., D. WRE



Combined One- & Two-Dimensional Hydraulic Modeling - HEC-RAS

The Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) is the most widely used river hydraulics software package in the world. Until recently, HEC-RAS was limited to one-dimensional river hydraulics computations. Over the past five years USACE (U.S. Army Corps of Engineers) has been performing dam and levee safety analyses that include detailed hydraulic modeling and risk and uncertainty analyses. Because of the dam and levee safety analysis needs, and the overall desire to improve the hydrodynamic modeling capabilities within HEC-RAS, HEC has developed and integrated two-dimensional hydrodynamics within the HEC-RAS unsteady flow computational engine. HEC-RAS now has the ability to perform one-dimensional hydrodynamic modeling; completely separate two-dimensional hydrodynamics; and integrated one- and two-dimensional hydrodynamic modeling.

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still difficult for Federal employees to obtain conference approval but as evidenced by my experience at the SedHyd conference, I believe you would find the effort of getting the conference approval worth it. The conference abstracts and papers from the SedHyd Conference should be available at the www.sedhyd.org website shortly.

It has been a while since HEC had a newsletter that focused on the enhancements and improvements to our software. Our last newsletter focused on our 50th Anniversary where we highlighted a few of the people that made HEC such a special place to work over the last fifty years. If you did not get a chance to read that newsletter, it is still available on our website. Our typical newsletter usually features current activities happening at HEC and this newsletter returns to that idea. Articles in this newsletter feature some of the groundbreaking work that HEC is doing in a number of fields. First, Gary Brunner has written an article about some of the new capabilities found in HEC-RAS (River Analysis System) with a focus on the combined one- and two-dimensional features. The article is quite detailed, with Gary discussing the way HEC-RAS can help the user model within one- and two-dimensions to increase detail but maintain efficiencies. We have provided some links within the newsletter so you can view some of the animations available within HEC-RAS. I've said it before but I'll say it again, I truly believe adding this capability in HEC-RAS will revolutionize how hydraulic modeling is performed by USACE and the profession. Gary provided a workshop and a demonstration during the SedHyd conference that described these HEC-RAS capabilities and many others.

Dr. Bill Scharffenberg provides an article on the need to estimate parameter uncertainty and how the user can estimate hydrologic uncertainty using HEC-HMS (Hydrologic Modeling System). For a number of years, HEC has been adding the capability to many of our tools to help the user estimate parameter uncertainty. While HEC-FDA (Flood Damage Reduction Analysis) has had the ability to use hydrologic, hydraulic and economic uncertainty estimates to develop the distribution of the mean Expected Annual Damage (among other metrics), HEC has never had the ability within our individual tools to estimate their parameter uncertainties. That is now changing. Soon you will be able to not estimate the most likely flow, stage or damage with our tools but you will also be able to develop the uncertainty bands about those most likely values. These capabilities will be available in not only HEC-HMS but also in software like HEC-RAS, HEC-FIA (Flood Impact Analyses), HEC-ResSim (Reservoir System Simulation) and others. Ultimately, you will be able to implement the parameter uncertainties in all these tools through HEC-WAT (Watershed Analysis Tool) which will integrate the estimation of uncertainties to address both knowledge uncertainty as well as natural variability. The ability to identify and estimate both was recommended by the National Research Council over a decade ago. When fully implemented, HEC-WAT will be the first piece of software to include this capability for watershed studies that also incorporate a systems approach.

This newsletter also includes articles written by Will Lehman and Woody Fields. Both of these articles discuss ways HEC has improved our ability to estimate consequences from flood events. Will's article introduces the National Structure Inventory (NSI) which is a database that improves upon the structure inventory data available through FEMA's (Federal Emergency Management Agency) HAZUS database. Using the NSI, USACE engineers, economists, and others will be able to greatly improve our estimates of flood risk through HEC-FIA, HEC-FDA, HEC-WAT, CWMS (Corps Water Management System) and HEC-LifeSim. Woody's article introduces HEC-LifeSim which is a relatively new tool within the HEC suite of software. Originally conceived through a collaborative process between the Institute for Water Resources (CEIWR) and Utah State University, HEC-LifeSim was built to estimate the potential loss of life from any flooding event. Woody has implemented many additional features to HEC-LifeSim and in recent years it has been used for many possible dam and levee failure alternatives. It too includes the capability to estimate uncertainty and is expected to be released by the end of the FY 2015.

A number of previous HEC newsletters have described CMWS and while the purpose of CWMS

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has not changed over the years, the basic framework that controls the software has. The CWMS framework is now the same framework that HEC-WAT was built around. Using the same framework for both of these tools helps to coordinate the two pieces of software and allows for easy conversion of real-time models, built for CWMS, into planning models using HEC-WAT. In this newsletter, Mr. Bill Charley introduces CWMS Version 3.0 and the advantages of using the new framework.

There are two separate articles about HEC's PROSPECT Training program. The first describes what is left of HEC's FY 2015 training program. HEC only has two courses left this year. We had to cancel a few classes this FY, and while we never like to cancel classes, if the number of prospective students is too low, the folks at Huntsville (CEHNC) who run the PROSPECT program encourage us to cancel the class. Of course, we attempt to solicit additional students but sometimes we still come up short. The second PROSPECT article (page 16) introduces the reader to our proposed FY 2016 training program. It is important to note that this list is just proposed at this point. There is no guarantee that HEC will actually present any of these classes. Whether we conduct these classes depends on how many people register for each of the classes. If the number of students is too small, we will have to cancel the class so if there are classes that whet your appetite, please sign up early. Later this summer, the USACE Learning Center will let us know how many people registered for each class and then we will post our FY 2016 PROSPECT program on the HEC website. Sign up early and sign up often.

One final article in the newsletter introduces you to one of the backbones of our office, Mr. Prasad Vemulapati. Prasad is one of those behind the scenes kind of guys who HEC relies on to perform the detailed programming that makes our software work. While he doesn't have the visibility of some at HEC, where would we be without people like Prasad? To read about Prasad's journey to HEC, please page through the newsletter.

I hope you enjoy the variety of articles in this newsletter and as always, if there is anything we can do for you, please do not hesitate to contact us.

Chris Dunn, P.E., D. WRE

PROSPECT Training Program

FY 2015 PROSPECT Training Program

By Penni Baker

The PROSPECT (Proponent-Sponsored Engineer Corps Training) program for FY 2015 is almost complete with only two courses left:

- Statistical Methods in Hydrology (spaces are available for this class - 058); 13-17 July 2015
- Advanced One- and Two-Dimensional Modeling with HEC-RAS (352); 3-7 August 2015

To register for HEC courses, please contact the appropriate party in your office or contact ULC, http://ulc.usace.army.mil. Registration is handled by Training and Operations (CEHR-P-RG). Course descriptions are provided at the ULC site (http://ulc.usace.army.mil/CrsSchedule.aspx). A short description along with a course agenda is also provided on HEC's web site (http://www.hec.usace.army.mil/training/list.aspx). To obtain enrollment information, please contact the USACE Learning Center. When doing so, please note the course number, name, data, and location, and contact:

USACE Learning Center
550 Sparkman Drive, NW
Huntsville, AL 35816-3416
Phone: (256) 895-7401
FAX: (256) 895-7469

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Two-Dimensional Modeling Capabilities

Two-dimensional flow areas have been added to HEC-RAS, so that users can easily combine one-and two-dimensional elements. The software allows for multiple two-dimensional flow areas, with flexible connections to one-dimensional elements, as well as directly connected boundary conditions. The software directly couples the one- and two-dimensional computations on a time step by time step basis, with options for iterating within a time step. This allows for more accurate hydraulic computations of flow transfers between one- and two-dimensional elements; faster computational speed than separately coupling one- and two-dimensional models; and, more accurate overbank flow, water surface elevations, and flow path computations. The two-dimensional modeling capabilities within HEC-RAS were built from the ground up to be directly integrated within the HEC-RAS unsteady flow engine. There are also several unique capabilities that have been developed that will allow modelers to develop accurate and efficient one- and two-dimensional models. The following are some of the HEC-RAS two-dimensional capabilities that are considered to be the most important.

Combined One- and Two-Dimensional Modeling. The ability to perform combined one- and two-dimensional modeling within the same unsteady flow model will allow users to work on larger river systems, utilizing one-dimensional modeling where appropriate (e.g., the main river system), and two-dimensional modeling in areas that require a higher level of hydrodynamic fidelity. A common example of this is utilizing the one-dimensional model elements for the river system, but modeling interior areas protected by levees with two-dimensional flow areas. The levees are modeled as lateral structures within HEC-RAS, and the software can be used to evaluate levee over topping and breaching.

Full Saint Venant or Diffusion Wave Equations. HEC-RAS solves either the full two-dimensional Saint Venant equations or the two-dimensional Diffusion Wave equations. The equation choice is user selectable, giving modelers more flexibility. In general, the two-dimensional Diffusion Wave equations allow the software to run faster, and have greater stability properties. While the two-dimensional Full Saint Venant equations are more applicable to a wider range of problems. Users can easily switch between equations and either choice can be evaluated for any given problem to determine whether the two-dimensional Full Saint Venant equations are warranted. In addition to mass conservation, the implementation of the two-dimensional momentum equation includes the following force terms: gravity; friction; hydrostatic pressure; acceleration; Eddy viscosity (turbulence modeling); and Coriolis effects. For details about the two-dimensional equations, please refer to the HEC-RAS Hydraulic Reference Manual (updated when Version 5.0 is released).

Implicit Finite Volume Solution Algorithm. The two-dimensional unsteady flow equation solver uses an Implicit Finite Volume algorithm. The implicit solution algorithm allows for larger computational time steps than explicit methods. The finite volume approach provides a measure of improved stability and robustness over traditional finite difference and finite element techniques. The wetting and drying of two-dimensional elements is very robust with the finite volume solution algorithm in HEC-RAS. Two-dimensional flow areas can start completely dry, and handle a sudden rush of water into the area. The software is very adept at modeling extreme events, such as dam and levee breaching scenarios. Additionally, the algorithm can handle subcritical, supercritical, and mixed flow regimes (flow passing through critical depth, such as a hydraulic jump). An example that demonstrates this capability is shown in Figure 1. This is Test No. 6B from a two-dimensional model test that was performed by the Environmental Agency in the United Kingdom. This model is an instantaneous dam break that includes a structure a short distance downstream of the breach. The flow quickly goes supercritical downstream of the breach, then goes through a hydraulic jump to subcritical flow due to the influence of the structure downstream.

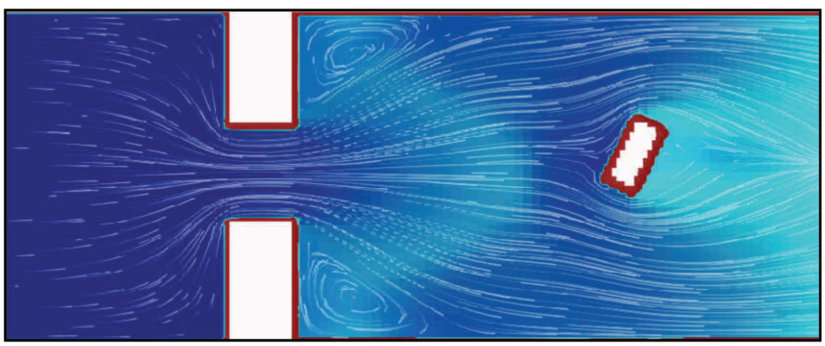

Figure 1. Instantaneous Dam Breach with Downstream Obstruction

Unstructured or Structured Computational Meshes. The software was designed to use structured or unstructured computational meshes. This means

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that computational cells can be triangles, squares, rectangles, or even five and six-sided elements (the model is limited to elements with up to eight sides). The mesh can be a mixture of cell shapes and sizes. The outer boundary of the computational mesh is defined with a polygon. The computational cells that form the outer boundary of the mesh can have very detailed multi-point lines that represent the outer face(s) of each cell. The user can define detailed break lines in the middle of the two-dimensional flow area, and the mesh generation tools will automatically develop a mesh that respects the break lines and aligns the cell faces along the break line.

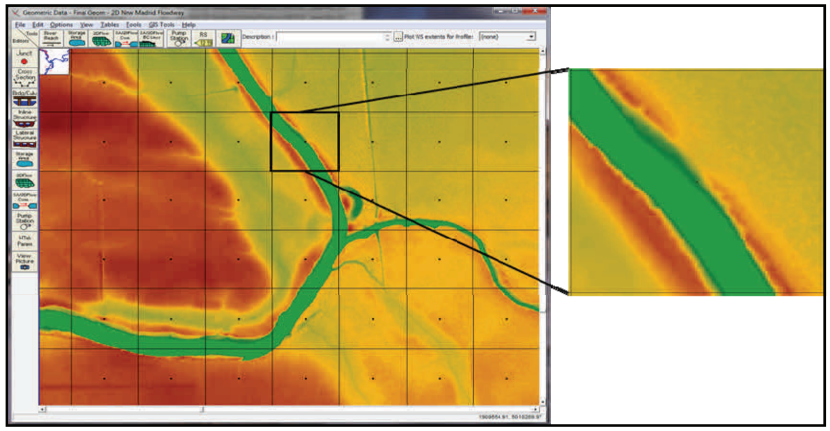

Figure 2. Computational Mesh with Detailed Sub-Grid Terrain Data

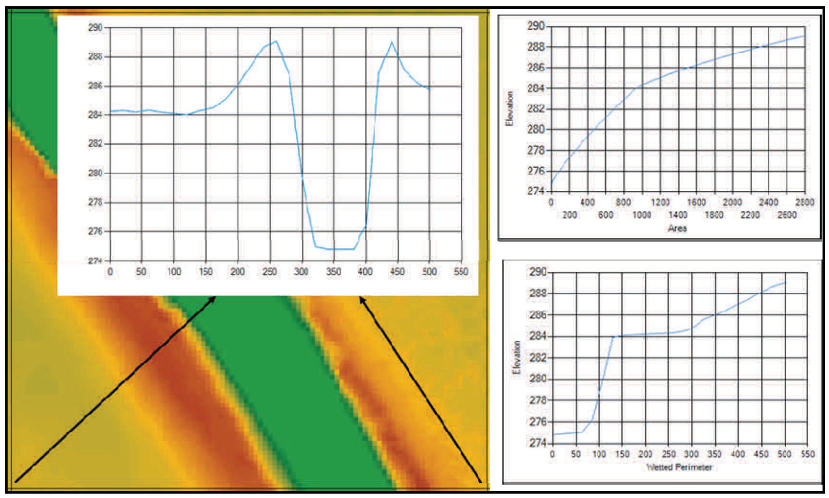

Figure 3. Example of how Cell Faces are Processed into Detailed Hydraulic Tables

Detailed Hydraulic Property Tables for Computational Cells and Cell Faces. Within HEC-RAS, computational cells do not have to be represented with one elevation, and cell faces are not a straight line, with a single elevation. Instead each cell and cell face is pre-processed in order to develop detailed hydraulic property tables based on the underlying terrain used in the modeling process. For example, consider a model built from a detailed terrain model (two foot grid-cell resolution) with a computation cell size of 200 by 200 feet, refer to Figure 2. The two-dimensional mesh pre-processor computes an elevation-volume relationship, based on the detailed terrain data (two foot grid), within each cell. Therefore, a cell can be partially wet with the correct water volume for the given WSEL (water surface elevation) based on the two foot grid data. Additionally, each computational cell face is evaluated similar to a cross section and is pre-processed into detailed hydraulic property tables (elevation versus wetted perimeter, area, roughness, etc.), as shown in Figure 3. The flow moving across the face (between cells) is based on the detailed terrain data. Use of the detailed terrain data, while not using one elevation per cell and cell face, allows the modeler to use larger computational cells, without losing too much of the details of the underlying terrain that govern the movement of the water. Additionally, the placement of cell faces along the top of controlling terrain features (roads, high ground, walls, etc.) can further improve the hydraulic calculations using fewer cells overall. The net effect of larger cells is less computations, which means much faster run times.

Pre-processing the cells and cell faces into hydraulic tables allows for water to move between cells based on the details of the underlying terrain, as it is represented by the cell faces and the volume contained within that cell. So the flow of water into, through, and out of a cell is controlled by the details of these face properties, and the cell elevation-volume relationship. The benefit of this approach is that the terrain has greater hydraulic details at the cell level versus other models that use a single elevation for each cell and face. With HEC-RAS, users can have much larger cells, but still retain great hydraulic detail within a cell. Additionally, HEC-RAS cells can be partially wet (i.e., water does not have to cover the entire cell, and can move through a portion of the cell). Therefore, a small channel that cuts through a cell, and is much smaller than the cell size, is still represented by the cell's elevation volume relationship, and the hydraulic properties of the cell faces. This means water can run through larger cells, but still be represented with its normal channel

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properties. An example of a small channel running through much larger grid cells is shown in Figure 4. The example shown in Figure 4 has several canals that are much smaller than the average cell size used to model the area (cell size was 500 by 500 feet, where the canals are less than 100 feet wide). However, as shown in Figure 4, flow is able to travel through the smaller canals based on the canal's hydraulic properties. Flow remains in the canals until the stage is higher than the bank elevation of the canal, then it spills out into the overbank areas.

Flow can move through a channel (As shown in Figure 4) in a one-dimensional type of mode, while flow in the overbank areas will be two-dimensional from cell to cell. If the user wants more detail within the channel, such as two-dimensional flow velocities and varying water surface elevations, then a cell size smaller than the channel is necessary to capture the two-dimensional effects within the channel itself. However, if there is a need to capture the two-dimensional flow effects on the floodplain, then this is a very viable option. The two-dimensional flow capabilities in HEC-RAS can be used in many ways. A mesh can be developed with very small cell sizes that can be used to model both channels and floodplains in great detail. A mesh with larger cell sizes, will provide less detail in the channel, but still have two-dimensional flow hydraulics in the floodplain. The level of detail used depends on the physical aspects of the system being modeled and the purpose of the study. Pre-processing the cells and faces into detailed hydraulic property tables is an advantage over two-dimensional models that use a single elevation for each cell (flat cells), and a single elevation for each face (flat or linear sloping faces).

Detailed Flood Mapping and Flood Animations. Mapping of the inundated area, as well as animations of the flooding can be completed through HEC-RAS using the RAS Mapper tool. The mapping of the two-dimensional flow areas is based on the detailed underlying terrain. This means that the wetted area will be based on the details of the underlying terrain, and not the computational mesh cell size. Computationally, cells can be partially wet/dry (this is how they are computed in the computational algorithm). Mapping will reflect those details, rather than being limited to showing a computational cell as either all wet or all dry. HEC-RAS Version 5.0 can produce spatial mapping of water surface elevations; water depths; velocities;

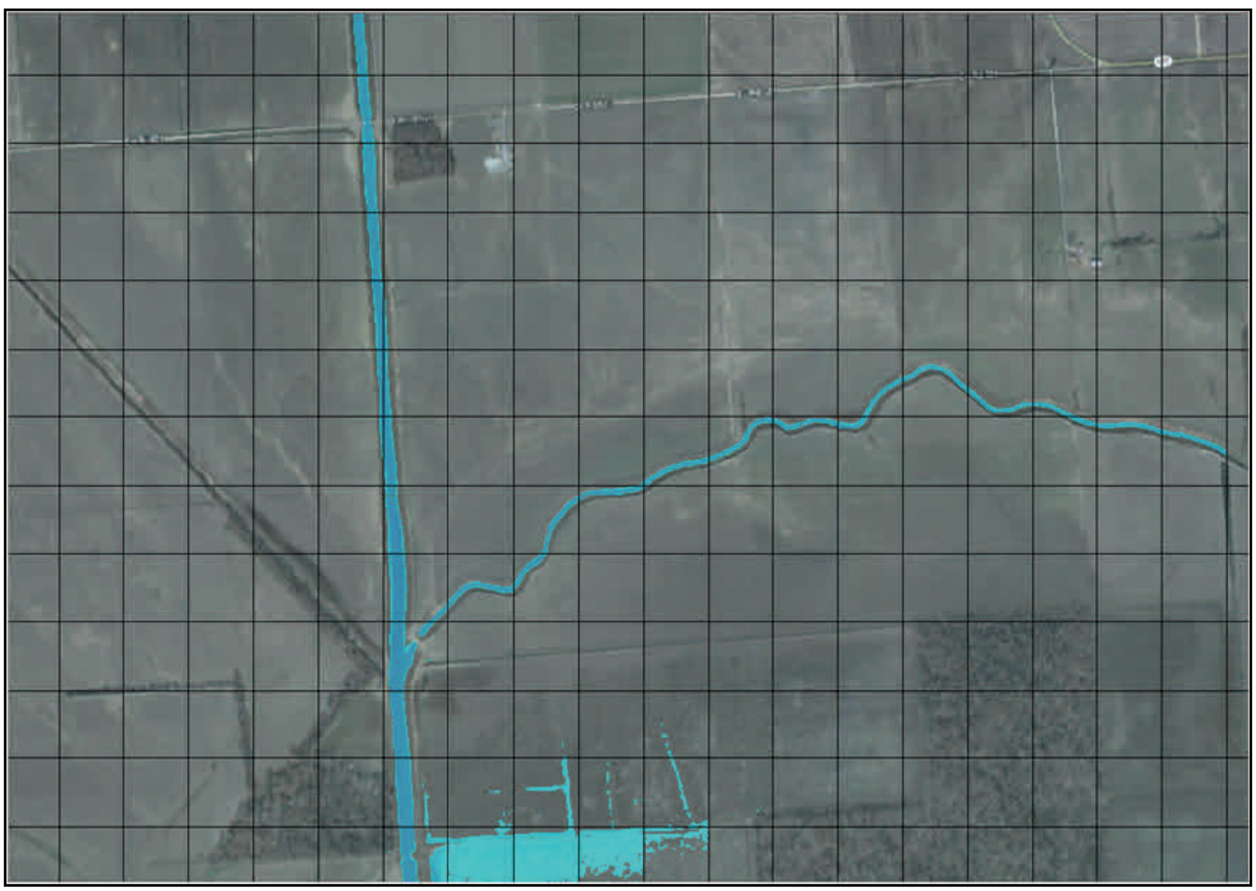

Figure 4. Example Showing the Benefits of Using the Detailed Sub-Terrain for the Cell and Face Hydraulic Properties

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flood arrival times; flood durations, and shear stress. Additionally, RAS Mapper has options to turn on particle tracing (shown in Figure 1) and velocity vector arrows for improved visualization of the water direction and magnitude.

Grid Resolution Testing

One of the major benefits of pre-processing the cells and cell faces based on the detailed underlying terrain, is that the user can use larger cells and still retain much of the underlying terrain properties. Using the detailed underlying geometry to build hydraulic property tables for the cells and the cell faces results in the user needing fewer cells to effectively produce similar hydraulic results. To test this theory, HEC-RAS was applied to several data sets and the computational grid size was varied. Results showed that many data sets can use larger cells, due to the fact that HEC-RAS computes a detailed elevation-volume curve for each cell from the underlying terrain data, and detailed hydraulic property curves for each cell face from the detailed terrain. There are obviously limits to cell size, even with this process, but this technique does allow for much larger cell sizes than models that treat every cell as a single averaged elevation, and every cell face as a line with either a single elevation, or even two elevations (one at each end of the line).

One data set that was used to test this approach for modeling the terrain is the White River at Muncie, Indiana. Muncie is protected by a levee. The HEC-RAS model of this area uses one-dimensional cross sections for the main river; a two-dimensional flow area for the area behind the levee; and lateral structures to represent the levee (Figure 5) The event used for this test was a hypothetical flood in which the levee is breached upstream, and flow goes into the interior area. There is enough flow getting into the interior area that it fills up the lower end of the two-dimensional flow area to an elevation that overtops the levee and flows back into the main river system. The model was run with four different grid resolutions: 25, 50, 100, and 200 foot grids. Nothing else was changed in the model other than the grid resolution.

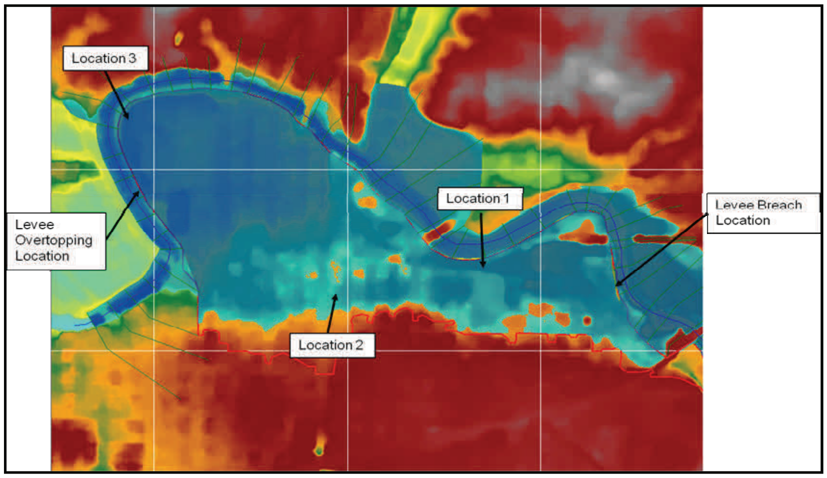

Figure 5. Example Maximum Inundation Map Showing the Five Evaluation Locations

From this analysis it was found that the 25, 50, and 100 foot grid resolution answers were about the same. The interior locations produce the same stage time series hydrographs with virtually the same magnitude and timing. However, the 200 foot grid resolution produced slightly different results in a few locations. The result of this experiment is that a 100 foot grid resolution produced almost the same results as a 25 foot grid resolution. Table 1 shows the number of cells required for each grid resolution model, as well as the computational time to run the simulation. The table shows computational times for each of the four grid resolutions run with the Full Saint Venant equations and with the Diffusion Wave equations. The flow and stage differences between the full equations and the diffusion wave solution were insignificant, so the full equations were not required to get adequate answers for the data set and event being modeled. This is by no means always the case, and the full equations solution should always be run in order to compare with the diffusion wave solution before making a final selection of the equations to use on any given problem. As shown in Table 1, the computational time varied from a high of fourteen minutes and 36 seconds for the 25 foot grid model with the full equations, to a low of four seconds for the 200 foot grid model with the diffusion wave equations. However, given the results of the 200 foot grid simulation, the model should not be used for this location and event. The lowest computational time for a reasonable resulting model is eight seconds from the 100 foot grid model with the diffusion wave equations. The answers from the 100 foot grid/diffusion wave model simulation are practically the same as the 25 foot/full equation model simulation, but the computation time is significantly less. The conclusion is that the 100 foot grid model with the diffusion wave equations could be used for evaluating any of the hypothetical events that would be required during a study of this area, thus saving tremendous amounts of compute time. While this data set is small, and so is the compute time, this same logic can be applied to much larger models where the compute time is significant. Therefore, HEC-RAS's ability to

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Table 1. Number of Cells and Computational Times for the Four Grid Resolutions

Test No.	Grid Size	No. of Cells	Time Step	HEC-RAS Diff Wave	Time Step	HEC-RAS Full Eqns.
1	25 feet	21,719	10 sec	3 min 1 sec	5 sec	14 min 35 sec
2	50 feet	5,379	15 sec	38 sec	6 sec	1 min 52 sec
3	100 feet	1,323	15 sec	8 sec	15 sec	12 sec
4	200 feet	321	15sec	4 sec	15 sec	5 sec

incorporate the details of the underlying terrain into the cell and cell face property tables will allow modelers to run large two-dimensional systems with much less compute time, but still retain very good hydraulic accuracy.

Conclusions

HEC has developed a completely new two-dimensional hydrodynamic modeling capability within the unsteady flow computational module of HEC-RAS. Users can now perform one-dimensional, two-dimensional, or combined one- and two-dimensional hydrodynamic modeling. The two-dimensional modeling capabilities within HEC-RAS have some unique aspects that allow for extremely flexible modeling of complex hydraulic systems. The two-dimensional modeling capabilities can handle subcritical, supercritical, and mixed flow regimes. Wetting and drying of cells is extremely robust, due to the implicit finite volume algorithm used. Additionally, HEC-RAS pre-processes computational cells and cell faces into detailed hydraulic property tables based on the underlying terrain. The property tables allow for a more accurate representation of the terrain and results in fewer cells being needed for accurate hydraulic results. Fewer cells equates to less computation time, which will allow users to model larger areas and longer simulation times.

Hydrology and Uncertainty

By William Scharffenberg, PhD.

The scientific principles of hydrology are well-established. Processes of precipitation, infiltration, surface runoff, channel flow, and the rest of the hydrologic cycle can all be described with mathematical equations. The parameters of some equations can be measured directly in the watershed while for other equations the parameters can be directly linked to something that can be measured. However, the process of determining the best parameter values can be challenging. In some cases the necessary measurements are missing and best estimates must be substituted. In other cases the link from what can be observed to the equation parameters is not very precise. The parameters become uncertain when we lack knowledge of the correct parameter values to use. The degree of uncertainty changes depending on the wealth of measurements and observations, and varies from one physical process to the next.

Three years of research and development has produced an initial capability to integrate uncertainty into the hydrologic simulation features of the Hydrologic Modeling System (HEC-HMS). The capability is called an *Uncertainty Analysis*. The heart of the *Uncertainty Analysis* is a Monte Carlo simulation that uses the existing components found in standard simulation runs. While it sounds complicated, a Monte Carlo simulation is simply repeating the same simulation thousands of times with different parameter values inserted into the model at each repetition. It is common to call each set of new parameter values and associated results a "realization." All of the realizations are tracked and statistically analyzed at the conclusion of the simulation.

The *Uncertainty Analysis* in HEC-HMS will allow the user to select which parameters will be sampled for each realization of the Monte Carlo simulation. Parameters can be selected from the canopy, surface, loss rate, transform, and baseflow methods in the subbasin and from the channel routing methods in the reach element. Parameters can also be selected from certain components of the reservoir element. There are three options for configuring the sampling of a selected parameter. First, a parameter can be sampled independently of all other parameters using an analytical probability distribution. The available choices for the probability distribution will include: beta, exponential, gamma, log-normal, normal, triangular, uniform, and Weibull. Second, a parameter can be sampled based on the starting month of the simulation with different probability distribution properties for each month of the year. Third, a parameter can be a linear function of another sampled parameter. The user must determine which parameters should be sampled and the best sampling approach for each one; generally these choices are guided by field data and calibration. One example of a parameter distribution is shown in Figure 6.

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The *Uncertainty Analysis* also includes simulation results. The sampled parameter values for each realization are stored for later analysis. Special output can be obtained at selected locations in the watershed. The time-series results from the selected locations are stored for each realization and can be processed after the simulation is complete. Flow and reservoir pool elevation receive additional attention. In addition to automatic calculation of the minimum, maximum, mean, and standard deviation in the time-series, summary statistics for peak flow, total volume, and maximum pool elevation are also stored for each realization.

One of the primary application areas for the new *Uncertainty Analysis* will be dam safety studies. A simple example was created to show how the peak pool elevation experienced during a Probable Maximum Flood (PMF) might be affected by uncertainty in the upstream watershed soil characteristics. The uncertainty in the soil properties was estimated using information from the watershed survey of which soil types were present in the watershed, combined with laboratory results for each identified soil type. The uncertainty in the soil properties resulted in different estimates of runoff volume for each realization in the Monte Carlo simulation. Each inflow volume resulted in a different peak pool elevation. The resulting distribution of the peak pool elevation for this example is shown in Figure 7. In this particular example the uncertainty in watershed properties did not translate into a significant uncertainty in the peak pool elevation. Differences in the amount of knowledge about the watershed properties, or differences in dam design could have led to a much different result.

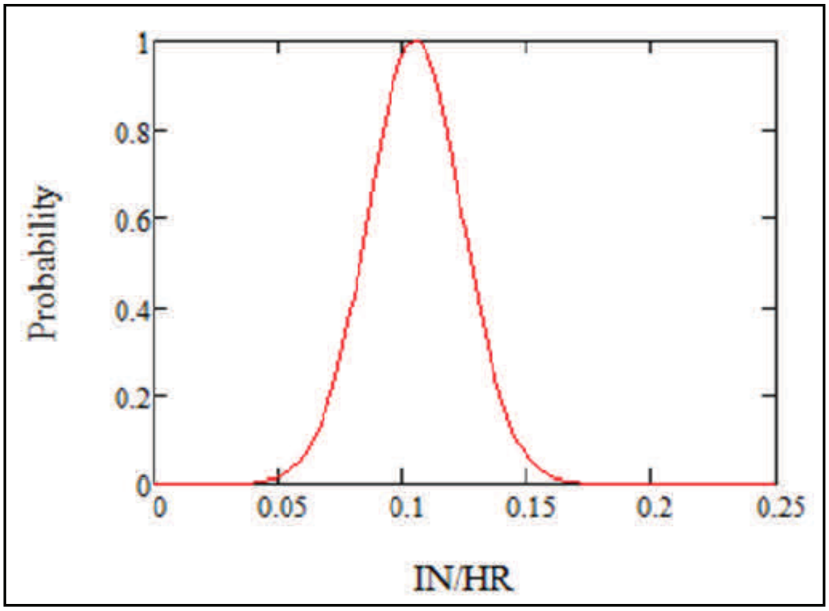

Figure 6. A Sample Probability Distribution for Saturated Hydraulic Conductivity in a Watershed Soil

The new *Uncertainty Analysis* in HEC-HMS will provide a major step forward in integrating hydrologic uncertainty into watershed studies; it will be part of HEC-HMS Version 4.1 currently anticipated for release in March 2015. The new *Uncertainty Analysis* will also be accessible within the Watershed Analysis Tool (HEC-WAT) Version 2.0, which will allow for integrated system analysis with meteorology, hydrology, reservoir operations, hydraulics, and consequences. More information about the *Uncertainty Analysis* will be available in the HEC-HMS User's Manual.

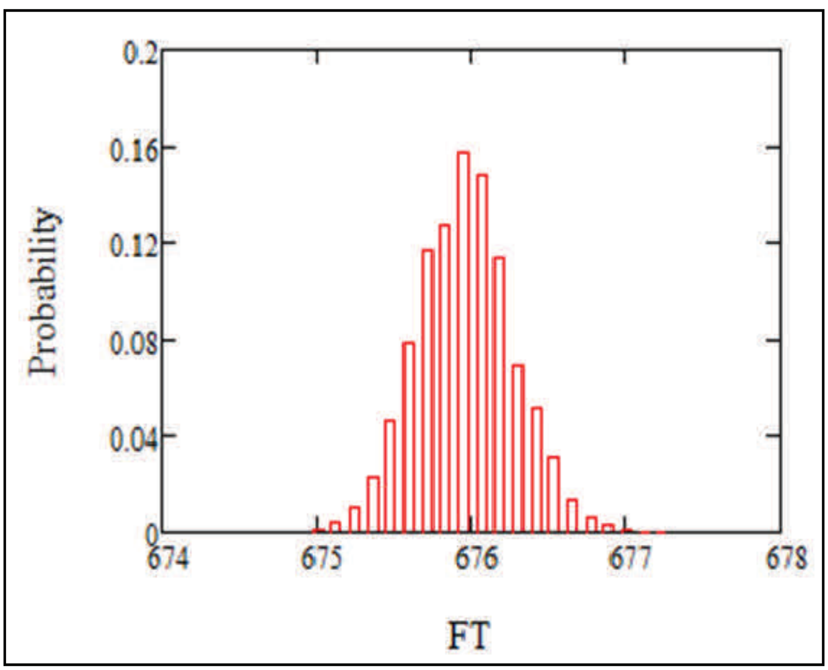

Figure 7. An Example Distribution for the Peak Pool Elevation During a Reservoir PMF Study

National Structure Inventory

By William Lehman

Over the last few years the Hydrologic Engineering Center (CEIWR-HEC) has been involved in supporting the Dam Safety, Levee Safety, and the National CWMS (Corps Water Management System) Implementation programs. Most of HEC's involvement has been centered on enhancing existing HEC software products; developing new tools as needed; and, providing training and support for these national efforts. A common hurdle shared by all these national scale programs is the evaluation of flood risk consequences, particularly the lack of a consistent building (structure) inventory database that meets the requirements for detailed consequence assessments. HEC-FIA (Flood Impact Analysis) and other USACE flood damage assessment software relies on detailed housing (structure) inventory data, with representations of buildings as individual structures. This level of detail is a large constraint when time is short, budgets are limited, and the scale is nationwide. The primary source of data that could be utilized nationally is FEMA's (Federal Emergency Management Agency) HAZUS database (a geographic information system (GIS) based on natural hazards in the United States). To utilize the HAZUS database in HEC-FIA, USACE's Modeling, Mapping, and Consequence Center (MMC) was manually preprocessing HAZUS data for each dam safety project, making improvements to the HAZUS data (which is described in this article), and utilizing the data in HEC-FIA. HEC-FIA converts the census block level data to a series of points, each representing a hypothetical structure, making it easier for users to adjust the structure point locations, or other attributes of the structures, in the inventory as a part of their quality assurance and quality control (QA/QC) process.

The idea for a National Structure Inventory (NSI) to address these needs (Figure 8) originated during a meeting with staff from the MMC about the National CWMS Implementation. Mr. Jason Sheely (MMC) suggested that a point-based structure inventory could be pre-generated nationally from FEMA's HAZUS database to eliminate a great deal of manual processing. Following the meeting with MMC staff, HEC embarked on developing a tool that would convert the entire HAZUS database into point-based records with a consistent methodology to improve the data as much as possible in a consistent reproducible way.

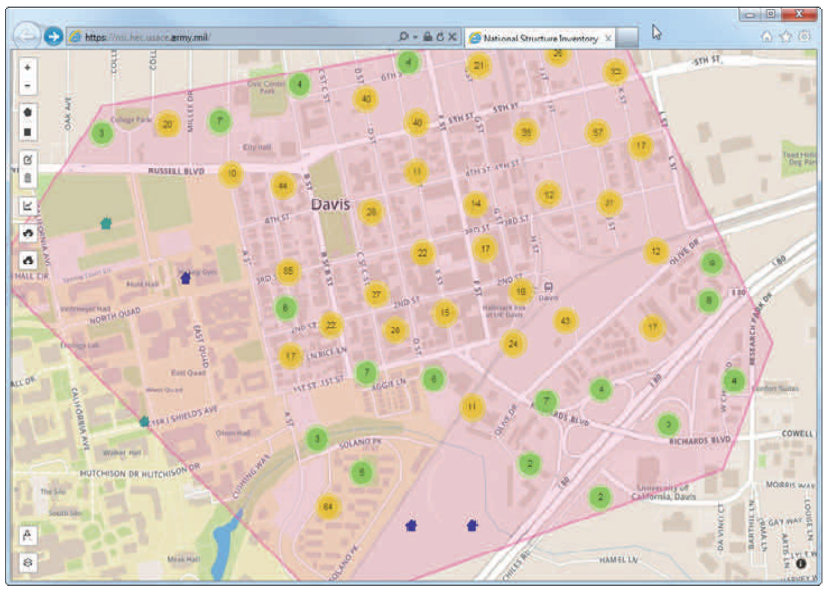

Figure 8. National Structure Inventory

Because the HAZUS database is not constructed for high resolution analysis, HAZUS has several known limitations. These limitations needed to be addressed when creating the NSI. Most of the issues resulted from processes that took statistical information and aggregated at a higher block group level, and then disaggregated the data down to census blocks. These issues cannot be completely fixed, but can be mitigated to some degree. A few of the larger issues that were addressed during the creation of the NSI were known population discordance between day and night estimates; over representation of the number of multifamily residences represented in the database (due to rounding errors); and, that structures are not uniformly distributed across the entire area of a rural census block. The HAZUS data is organized by census block, and does not contain specific point locations for a structure within each census block, so steps had to be taken to systematically locate the information within each census block in areas that are defined as urbanized. This process requires using the National Land Cover Land Use (NLCD) database, which identifies areas in the United States that are urbanized based on analysis of various forms of technology.

Following the creation of the enhanced dataset (which is based on the 2000 HAZUS database), HEC worked with personnel at USACE's Cold Regions Research and Engineering Laboratory (CRREL) to host the data on their servers to allow USACE-wide access to the NSI. Over the summer of 2012 a simple web service connection was set up by Mr. Will Breitkreutz (MMC) to allow USACE software developers to connect to the NSI

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National Structure Inventory (continued)

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database; retrieve structures from the NSI; and, convert data into their own formats. Figure 9 provides information on the NSI web service.

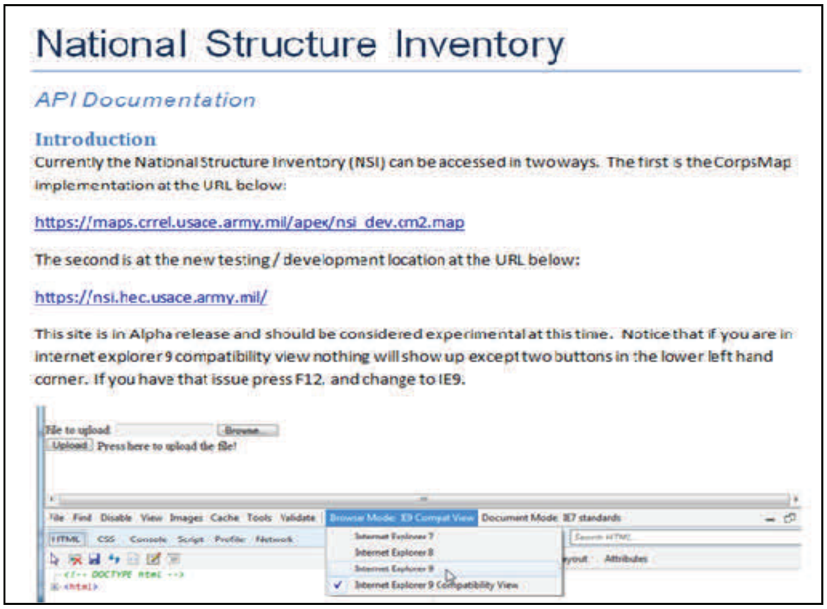

Figure 9. National Structure Inventory Web Service

The NSI web service connection is now used by HEC-FIA, IWR's (Institute for Water Resources) SimSuite, and is being incorporated into the workflow to support the Levee Screening Tool and the National Levee Database.

The NSI developers acknowledge that the base layer* of NSI is not high resolution data, but rather a consistent dataset, which also has a defined data structure. The consistency of the data resolution allows for comparison of USACE levees and dams in the screening level of the portfolio analysis using a standard dataset for consequences; and, the consistency of the data structure makes it easier to use the inventory data in many software applications.

Path Forward

The NSI base layer will be updated to reflect the 2010 HAZUS database and the new NLCD data. Additionally, a data structure for occupancy type information which describes the structure's susceptibility to flood damage will be created. After a regularization of the occupancy type information, a service where users can upload their own structure inventories will be stood up. This step will enable high resolution point based structure inventories to be uploaded and documented by the author of the data, and utilized by other users of the NSI data service.

In addition, FEMA recently approached USACE to partner on the NSI going forward. FEMA has expressed an interest in hosting the NSI web service which will allow acess to users outside of USACE. This partnership is perceived as a very important step in the development path and broader dissemination of NSI.

*NSI is intended to be a database that has many levels of structure inventories. All inventories will share the same database attributes, but some levels will be based on higher resolution datasets. USACE (in coordination with FEMA) has only created the base layer, and is working on methodologies to eventually allow users to upload higher resolution datasets.

HEC-LifeSim

By Woodrow Fields

The shift to a risk-based perspective continues to transform how the U.S. Army Corps of Engineers (USACE) tackles flood risk management challenges. Part of this paradigm shift is a focused consideration of human safety in decision making processes. Events like Hurricane Katrina, the Great Sendai Earthquake of Japan, Hurricane Sandy, and the 2004 Indian Ocean Tsunami have elevated concerns over life loss due to flooding. As creators and managers of water infrastructure, USACE has a responsibility to manage the associated risks to the public. Engineering Regulation 1105-2-101 includes human health as part of risk analysis for flood risk management studies. In addition, the primary objective of the USACE Dam and Levee Safety programs is to manage risk to the public from the infrastructure that is intended to keep them reasonably safe from flooding. The importance of human safety in risk analysis within the USACE has necessitated the development of methods and tools to estimate the potential life loss due to flooding.

One of the greatest challenges in estimating life loss from a dam or levee failure event has been an accurate simulation of how individuals evacuate when there is a threat. The life loss modeling tool HEC-LifeSim is USACE's most rigorous approach for estimating potential loss of life due to dam breach. The software provides a modular, spatially distributed, dynamic simulation system for estimating potential life loss resulting from catastrophic floods that explicitly considers the primary

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factors that contribute to life loss in a flood situation. HEC-LifeSim uses an agent-based approach to track individuals throughout the warning and evacuation process. The software also contains a traffic simulation engine to simulate the evacuation process for vehicles which allows them to interact with other vehicles and the hazard, and the evacuation engine offers an effective estimation of population re-distribution during the evacuation process. HEC-LifeSim was developed with an uncertainty sampling approach. By sampling uncertain parameters and running the model iteratively, HEC-LifeSim is capable of producing a distribution of results to better inform the risk assessment.

An important to note is that HEC-LifeSim is simulating the entire warning, mobilization, and evacuation process. The process can be illustrated by the following example. Let's consider a single family home with three individuals that is located in the study area for a given simulation. Once a flood warning is issued by emergency managers, it takes a certain amount of time before a resident in the home receives the warning. Once the warning is received and understood at the home, the family members will take a certain amount of time to gather their belongings and prepare for leaving their home. The family then leaves their home in a vehicle containing three individuals. On the road, there is interaction with both other vehicles on the road and flood waters. For example, the family may encounter a traffic jam at a freeway on-ramp and choose a different route out of the hazard area (see Figure 10). Or the family may choose to tough it out in the traffic jam, hoping that it will clear up. If the family reaches a road that is currently flooded they turn around and go in a different direction. If the family gets caught on a flooded road, the survival of each family member is dependent

Figure 10. Traffic Jam Caused by Evacuation from Hurricane Bret (1999)

on their state (e.g., age) and the hydraulic conditions at their location. All of these interactions are simulated during an HEC-LifeSim model iteration. Because warning times and individual's behaviors are sampled from a range of possibilities, the same family may take longer to get warned or choose to remain in their home during the next model iteration.

Simulation results for existing conditions and alternatives can be visualized using HEC-LifeSim animation capabilities (see Figure 11). In an HEC-LifeSim results animation, structures and cars caught (inundated) by floodwaters are red. Yellow structures indicate that a warning was received but the individuals inside haven't started evacuating yet, and brown structures indicate that a warning has not been received yet. Blue cars represent individuals mobilizing on roads, and are tracked throughout the study area based on traffic simulation algorithms.

By tracking individuals and their movements, HEC-LifeSim can tell us where individuals are most at risk of losing their lives, whether it is on roads or in structures. The software can also pinpoint the locations of greatest potential life loss which is useful when developing alternative project formulations. For example, a simulation may show that life loss on a particular road is significant. HEC-LifeSim allows for a detailed analysis of a range of alternatives based on both structural and nonstructural measures for reducing potential life loss. Nonstructural measures to reduce life loss could include raising or closing at risk road embankments and increasing road capacities to reduce congestion. A nonstructural alternative could also consist of increasing the warning time through better warning issuance and community awareness.

HEC-LifeSim Version 1.0 is currently in alpha development, and a final version is expected to be released by the end of fiscal year 2015.

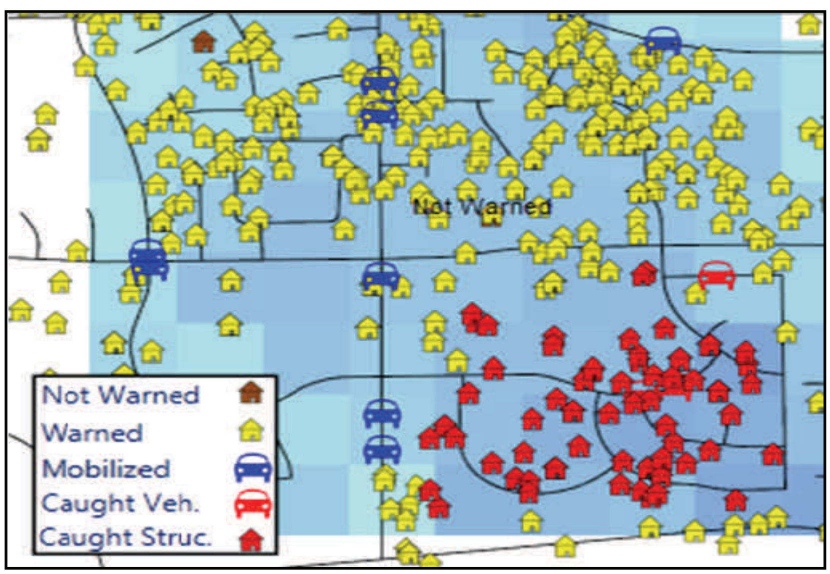

Figure 11. HEC-LifeSim Simulation Animation

CWMS Version 3.0, Field Testing Phase

By William Charley, P.E.

The Hydrologic Engineering Center (CEIWR-HEC) has been working with USACE field offices beta testing CWMS (Corps Water Management System) Version 3.0, in preparation for a Spring 2015 release. CWMS is a comprehensive data acquisition and hydrologic modeling system for short-term decision support of water control operations in real time. The software encompasses data collection, validation and transformation, data storage, visualization, real time model simulation for decision-making support, and data dissemination. In its USACE implementation, CWMS uses an Oracle® database and Sun Solaris® workstations for data processes and storage, with a client application (the Control and Visualization Interface, CAVI) that integrates hydrologic models on a local workstation.

CWMS provides support for operational decision making by forecast simulation modeling using any combination of the following models. Rainfall-runoff modeling with HEC-HMS based on gaged or radar-based precipitation, Quantitative Precipitation Forecasts (QPF) and other future precipitation scenarios provides forecasts of uncontrolled flows into and downstream of reservoirs. Simulation of reservoir operations with either HEC-ResSim or CADSWES's RiverWare provides operational decision information for the engineer. The river hydraulics program HEC-RAS computes river stages and water surface profiles for these scenarios. An inundation boundary and depth map of water in the flood plain can be calculated from the HEC-RAS results using RAS Mapper. The impacts of different flow alternatives are computed by HEC-FIA. The user-configurable sequence of modeling software allows engineers to evaluate operational decisions for reservoirs and other control structures, and view and compare hydraulic and economic impacts for various "what if?" scenarios.

Version 3.0 contains a major overhaul of the CWMS CAVI, graphical user interface (GUI) and the "framework" (the framework is the underlying code that controls the basic user interface for the program). The framework (Figure 12) is now the same framework being used by the Watershed Analysis Tool (HEC-WAT) and several other HEC software applications. CWMS Version 3.0 moves the model computations from the Sun® server to the local workstation. Running the models locally on the workstation provides several advantages over running the software applications on the server:

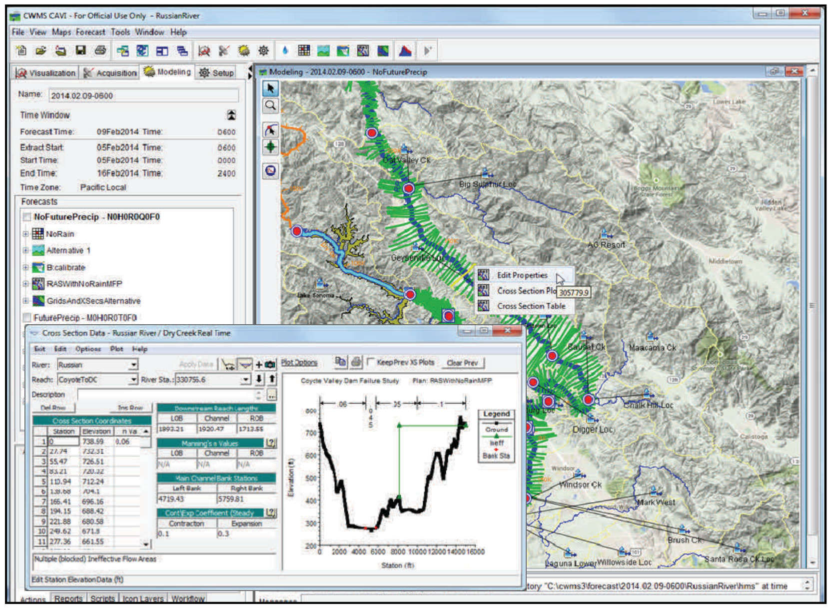

Figure 12. CWMS Version 3.0 - Framework

- Direct interaction with the individual software applications. In earlier versions of CWMS, users interacted with CWMS dialogs that sent data to the server, and the models used that in computations. In Version 3.0, the individual software application's GUI is used instead of a surrogate, which allows the models to verify and use parameters when entered. Plots and dialogs are generated by the individual software application itself, not an interface built for the CAVI.
- Access to new capabilities that would not be on the server. Several new capabilities in Version 3.0 require direct interaction on the local workstation, including:
  - Soil moisture calibration using the HEC-HMS graphical calibration tool. Users can move a slider bar for soil moisture and other parameters and see the resulting plot right then.
  - Real-time inundation mapping using the RAS Mapper tool (Figure 13) provided in HEC-RAS. (HEC-RAS is a Window-based product). RAS Mapper can produce a inundation map on the local workstation from flows computed during a CWMS forecast run.
- In previous versions of CWMS, the individual software applications were compiled

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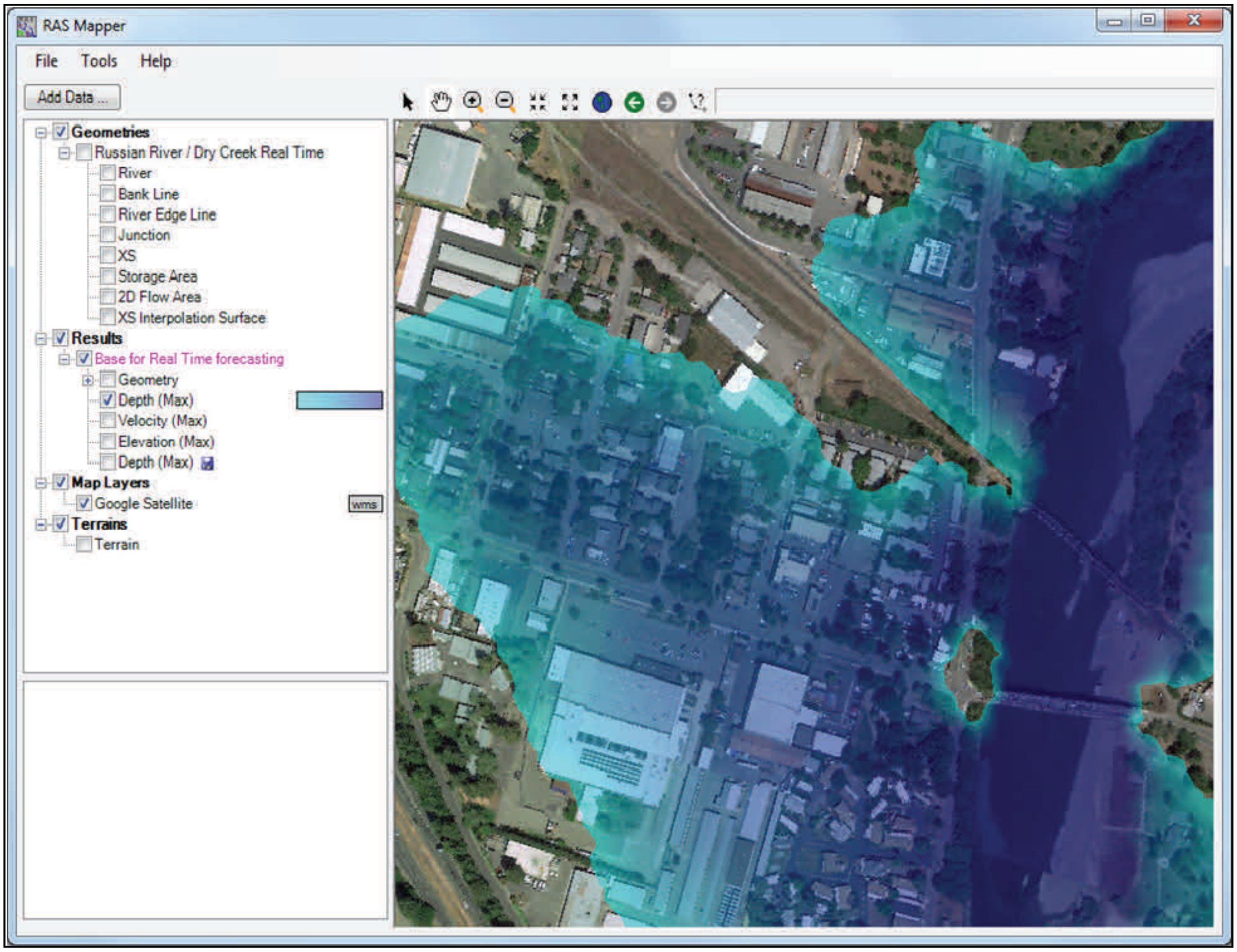

Figure 13. RAS Mapper Tool from HEC-RAS

with the CAVI; a new version of a software application required an update of the CAVI. With CWMS Version 3.0, a standard API (Application Public Interface) was established so that new versions of a software application could be added, as long as the API was honored. Also, because of this API, a different software application can be added to the program sequence without any changes to the CAVI.

- The speed and cost of local workstations has become advantageous compared to Sun® server workstations over the years. Running more complex models used to take significantly more time on local workstations compared to servers; now that trend has reversed.

- Remote access is less server dependent. Since less data needs to be sent from the server to the local workstation, a slow connection would not hamper running the CAVI as much. If server side access was lost, a user could continue to use the CAVI, limited to the data they had.

The CAVI and the models share a common geo-referenced "Desktop Pane" that can have an Internet map background, such as Google® or Bing®. Each model registers and draws geo-referenced model objects on the map panel, such as a reach, cross-section, subbasin, junction, etc. When a user selects one of those objects, the CAVI sends a message to the model and the model displays the dialog box associated with that object. For example, by selecting one of the green cross section lines on the map, the user can bring up the HEC-RAS Geometry Editor for that cross section.

CWMS uses "common computation points" (CCPs), locations where models hand off data to each other (shown as red dots in Figure 14). When a user right-clicks on a CCP, a shortcut menu is displayed which provides a list of the available model elements at that location. Thus, the user can edit individual model parameters for that location, or view results from that location.

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CWMS Version 3.0, Testing Phase (continued)

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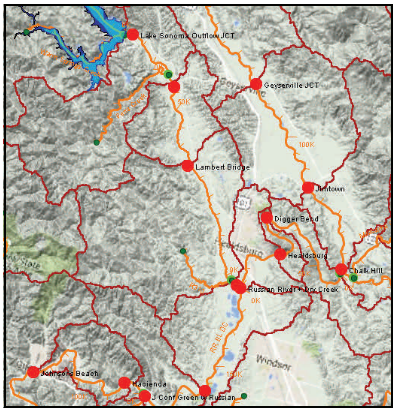

Figure 14. CCPs

The CAVI has an "Actions/Reports" panel. From this panel, when a model is selected, that model displays a list of commands (buttons) that can performed by that model in that state, such as compute, set loss rates, change routing coefficients, etc. Selecting a command brings up the appropriate software application editor or performs a action. Similarly, the Reports panel displays a list of commands for reports (plots, tables) from each of the software applications, which are displayed when selected.

The integration with HEC-RAS and RAS Mapper provides a mechanism for computing flood inundation maps in real-time using forecasted flows from HEC-HMS and HEC-ResSim. The maps will display flood depths and boundaries based on various rainfall scenarios and/or reservoir operations or other alternatives that can affect stages and flow. The maps are overlaid on a Internet map background (chosen by the user) or a geo-referenced photo, allowing the user to zoom in and see detailed depths. RAS Mapper can write selected maps in a Google® format that can be placed on a server and seen in the field on an iPad or smart phone.

Work on CWMS Version 3.0 began several years ago. Alpha testing (in-house) testing occurred during the Summer of 2014, beta (field) testing began Fall 2014. Because server-side modifications were not implemented until field testing began, several key components were found to be missing and had to be completed prior to full field testing. CWMS Version 3.0 is expected to be released to all USACE offices in Spring 2015.

HEC Staff

Prasad Vemulapati is a Computer Scientist, working for the Water Management Systems Division, Hydrologic Engineering Center (CEIWR-HEC). Mr. Vemulapati came to HEC in 2010 and immediately began working on the CWMS (Corps Water Management System) software.

He was born and raised in the southern part of India, not far from the city of Madras (or Chennai as it is called now). Mr. Vemulapati earned a Bachelor's degree in Aerospace Engineering from the Indian Institute of Technology, Madras, India, in 1988. A Master's degree in Computer Science and Engineering was completed from the Indian Institute of Technology in 1989. He became a naturalized US citizen in June 2005.

Mr. Vemulapati came to the United States (U.S.) and began working at the State University of New York, in Buffalo, New York. He began working as a research scientist, with his first assignment being the development of software that would recognize handwriting on postal envelopes. Other work that Mr. Vemulapati was involved with included: designing and developing several real time software/hardware systems that have been used to read IRS (U.S. Internal Revenue Service) tax forms; and, United States, United Kingdom, and Australian handwritten postal addresses and handwritten forms. Most of these applications were based on pattern recognition techniques (such as neural networks, Bayesian classifiers) and were developed in C/C++. Mr. Vemulapati began working on JAVA application development starting in early 2000 with the design and development of an Image Evaluation System for the U.S. Postal Service (USPS). This system was a custom built application that was used by USPS to measure improvements in their address recognition systems.

Mr. Vemulapati joined HEC in 2010 while HEC was on the cusp of releasing the CWMS Version 2.0 software. From the start, the CWMS Version 2.0 deployment kept him busy. After the initial CWMS Version 2.0 deployment, he was actively involved in testing and providing several CWMS and CCP (CWMS Computational Processor) software and schema updates to the field. Apart from testing and providing CWMS software releases, Mr. Vemulapati is also involved in JAVA/ and database development (PL/SQL,SQL). This development improves or adds new functionality to various CWMS components such as the CAVI, Server Admin, CWMSVue, and the CWMS database API. Some of his most

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recent projects include setting up a National CWMS Database by streaming CWMS data from all of the field offices to the National CWMS Database at the CPC and to setup/test database/replication features for the National CWMS Pilot project.

HEC is very pleased to have Mr. Prasad Vemulapati as part of the software development team working on the CWMS software. He brings a wealth of knowledge and HEC looks forward to a long and successful stay.

FY 2016 Proposed PROSPECT Training Program

By Penni Baker

CEIWR-HEC has submitted our proposed FY 2016 PROSPECT training program to the USACE Learning Center (ULC). The ULC is located in Huntsville, Alabama and will start conducting a survey in a couple of months which will help decide which courses will be taught during FY 2016. Only courses that have enough subscriptions will be taught. Therefore, it is very important that you complete the survey for each course you wish to attend. For your review and use, CEIWR-HEC has provided the proposed FY 2016 course schedule (see the table below). If you are interested in one or more of the courses, please let the training program in your District/Division know so that they can report your interest to the ULC.

To register for our courses, please contact the appropriate party in your office or contact ULC, http://ulc.usace.army.mil. Registration is handled by Training and Operations (CEHR-P-RG). Course descriptions are provided at the ULC site (http://ulc.usace.army.mil/CrsSchedule.aspx). A short description along with a course agenda is also provided on HEC's web site (http://www.hec.usace.army.mil/training/list.aspx). To obtain enrollment information, please contact the USACE Learning Center. When doing so, please note the course number, name, data, and location, and contact:

USACE Learning Center
550 Sparkman Drive, NW
Huntsville, AL 35816-3416
Phone: (256) 895-7401
FAX: (256) 895-7469

CEIWR-HEC's FY 2016 Proposed PROSPECT Training Program

Course	Course Title	
114	Steady Flow with HEC-RAS	2 - 6 November 2015
164	Water and the Watershed	16-20 November 2015
122	Sediment Transport Analysis with HEC-RAS	30 November - 4 December 2015
178	Hydrologic Modeling with HEC-HMS	7 - 11 December 2015
155	CWMS Modeling for Real-Time Water Management	11 - 15 January 2016
188	Unsteady Flow Analysis with HEC-RAS	25 - 29 January 2016
098	Reservoir System Analysis with HEC-ResSim	8 - 12 February 2016
209	Risk Analysis for Flood Risk Management	22 - 26 February 2016
320	H&H for Dam Safety Studies	7 - 11 March 2016
161*	Hydrologic Analysis for Ecosystem Restoration	4 - 9 April 2016
369	Advanced Applications of HEC-HMS	18 - 23 April 2016
152	Water Data Management with HEC-DSSVue	2 - 6 May 2016
219	Hydrologic Engineering Applications for GIS	16 - 20 May 2016
60**	Consequence Estimation with HEC-FIA	13 - 17 June 2016
352	Advanced 1D/2D Modeling with HEC-RAS	11 - 15 July 2016
123	Flood Frequency Analysis	1 - 5 August 2016

*In the FY2016 Purple Book there is an error on the date for Course Number 161 (Hydrologic Analysis for Ecosystem Restoration). The date should be 4 - 9 April 2016 (CEIWR-HEC has requested that ULC correct the FY2016 Purple Book).

**In the FY2016 Purple Book there is an error on the date for Course Number 60 (Consequence Estimation with HEC-FIA). The date should be 13 - 17 Jun 2016 (CEIWR-HEC has requested that ULC correct the FY2016 Purple Book).