The Future of Risk Assessment
H&H tools for the 21st Century

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The Problem

1. Modeling software has caught up with CPU power!

2. Exponential power of PC’s over the last 20 years now causing engineers serious grief

3. From hours of time spent on creating and editing HEC-2 input files to days waiting on HEC-RAS 2D model to complete!

Hydraulic Modeling in Action
Runtime from 1D to 2D

1. Runtime from 1D to 2D increased drastically.
2. Instead of minutes, we are talking about hours to days!
3. And it doesn’t scale linearly!
4. We found there was no way to make a good guess on how long a model would take.
   - You can’t solve a problem if you don’t quantify it!

How do you quantify such nebulous problem?

Every model is unique – cell sizes, rain on grid, time steps, simulation times, what matrix solver is it using, what kind of PC are you using!

But there are some common traits that every model shares.

Solution: A unitless value that takes into account the primary variables.

Enter the MCU

Millions of Computational Units

- (grid size) x (runtime) x (time step)

A unique way to compare a variety of models and get a handle on what makes them the same, and what makes them different.
MCU Chart

Ran one model 50 different ways
Changing only one variable at a time (grid size, time step, or computational method)

*It doesn’t scale linearly!*

More MCU’s = More run time
Runtime/min = 71*MCU’s - 0.334

As my old boss used to say:
SO WHAT?

We’ve now quantified the problem, the longer the model runs the more time it’s going to take to get to a solution.

Well duh! It still doesn’t solve our scheduling problem if we have 2 weeks to get a model out… but will take 3 weeks to get them all done!
Flood Manager

What is Flood Manager?

1. Model Process Automation
2. Quality Analysis
3. Model Management & Visualization

Flood Manager Benefits

1. Aligns to program needs for accommodating a consistent, cloud-based modeling environment, georeferenced
2. Cloud-based parallel processing = speed = cost savings
3. Available on-demand, at scale from anywhere
4. Metadata driven model management and storage
5. Reduced project delivery time (emails users when done)
6. Identify global errors with consistent Quality Control
Wait a Second...

This is all well and good, offloading your local PC to run these models, and being able to use a PC that we don't normally have access too is great. BUT a 32 core PC is still going to take 12hrs to run my frequency storm! What if I've got 9 more 12 hrs runs to do!

That's still going to be 120hrs of model time!!!

That's still 5 days.
Stepping on the accelerator

Our team knew that we could leverage all this computing power...

if we could just figure it out...

it was missing one key ingredient...

The Minions!

1. We hired the Minions from Universal Pictures
   (they work for bananas)

2. We had some legal issues....
   • Had to call it...“Run Plans in Parallel”

Parallel Computing in Action

Let's take the USACE Project Orange for an example:

• A model that covers 4,654 acres
  • 238K mesh (average 50ft grid cell)
  • Rain on grid
  • 3 second time step
  • 48hr simulation time

13,421 MCUs

Estimate for 8 core CPU using RAS 5.07...75hrs!
Parallel Computing in Action

13,421 MCU’s runtime using RAS 6.1:
- 12 Core CPU Workstation, 32GB RAM, SSD Windows 10
  - Runtime: 8hrs 2 min * 6 storms * 2 conditions (base/future)
  - 12 plans * 8hrs 2 min * 6 storms * 2 conditions
- 32 Core Flood Manager tool:
  - Runtime: 6hrs 18 min * 6 storms * 2 conditions
  - 12 plans parallel * 6hrs 18 min (splitting and recombining models)
  - Time savings of 3.5 days!

Caveats
1. It’s not all sunshine and puppies with the Cloud!
2. You still have to upload and download models after each run
   - Our Orange output model was 32 GB, when completed!
3. Computation penalty when running on the Cloud.
4. We found it to be about a 30% reduction in run times compared to a comparable desktop PC.

Parallel Computing Solution
1. Employing the “minions” (I mean parallel runs) adds some computational time to account for the model plans to be split apart and recombined.
2. Not the best solution for small models but can be a real time/budget/schedule saver when these models push beyond 2+ hours to run.
Flood Manager in Action

Flood Manager is a digital solution for 2D base level engineering workflow for each of these clients:

- Iowa Department of Natural Resources
- Texas Water Development Board
- Kansas Department of Natural Resources
The Future

1. Coastal modeling with ADCIRC to run on Azure High-Performance Computing platform.
2. New modeling types including ModFlow & Mike
3. Virtual Desktop to reduce need for upload/download
4. Map interfaces to instantly visualize models
5. Automated data post-processing
6. Training MACHINE LEARNING services from model runs
Flood Predictor Process

1. Engineering Features
2. Machine Learning
3. Visualization
4. Performance

Engineering Features: Data Harvesting
- USGS: Digital Elevation model
- WILD: Land Use

Engineering Features: Data Derivatives
- Topographic Wetness Index
- Accumulation
- Stream Distance
Flow or Runoff

\[ \log \left( \frac{\text{Flow or Runoff}}{H_D} \right) = 1.49 + 0.35 \times \frac{H}{S} \]

Fig. 1. Example of a hydraulic cross section with the description of the parameters $H$ and $S$.

Engineering Features: Dimensionless Indices

- Velocity
- Manning's Equation
- Cross-sectional area

Topographic Wetness Index
- Stream distance
- Height Above Nearest Drainage

Engineering Features (Training Sites)
- Flood Predictor Flood Index
- Flood Probability
- FEMA Floodplains
- Flood Predictor Engine
- Flood Prediction
- Maintained and updated regularly

Engineering Features (Prediction Site)
- User Defined Hydrologic Condition
- Processing Time
- 1-3 Hours
- 2-20 Minutes

Flood Predictor
- Flood Index
- Engine
Lake Champlain and Saranac Watersheds, Clinton County, New York (Riverine Site)

2021 Preliminary FEMA 1% Annual Chance Floodplain Flood Predictor Output, 1% Annual Chance Floodplain Flood Predictor Output, Probability of Flooding

PASSAIC RIVER WATERSHED, PASSAIC NEW JERSEY (Flash Flooding Site)

HEC-RAS 2D 1% Annual Chance Floodplain Flood Predictor Output, 1% Annual Chance Floodplain

CONFIDENCE

Current Global Flood Predictor F1-Score is 0.78

Flood Predictor output correlation with FEMA floodplain
Historic Rainfall

Waverly TN Case Study

Waverly, Tennessee August 2021 Flash Flood Event
(Prediction Site)
Flood Predictor Benefits

1. Scalable, high resolution flood risk data for the nation
2. High resolution floodplains and Annual Exceedance Probability (AEP) data can be created in minutes
3. Can be applied to create hazard and risk information for unmapped areas
4. Leverages existing publicly available FEMA engineering data.
5. Ready for planning purposes “What-if” analysis (climate change scenarios, storm forecasting, etc.)

Flood Predictor Models & Roadmap

Currently supported:
- Riverine, flash & combined flood risk

Upcoming:
- Coastal (storm surge) flooding.
- Weather forecast integration.
- Watershed moisture status (real-time) for runoff potential
- Depth and velocity estimates.

Questions, Answers & Next Steps