



Rain-on-Grid Modeling in Mountainous Terrain: A Case Study at Five Chilean Mining Sites

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What I will be presenting:

This study includes Probably Maximum Flood and flood-frequency analyses at five mineral mining sites in Chile, most of which contain tailings dams. Located in northern Chile in the Atacama Desert, the driest nonpolar desert in the world, the topographic setting at these sites is especially unique. Vegetation is sparse, and much of the terrain directly surrounding the sites is steep and mountainous. To investigate flood hazard impacts, a 2-dimensional (2D) rain-on-grid hydraulic model was developed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS). However, due to the remoteness of these sites outside of the United States, common national data sources used to collect data for hydraulic models were not available, and global data sources were not of similar quality (e.g., the highest resolution DEM publicly available for Chile was 12.5 m). This presentation aims to discuss the challenges and solutions associated with performing rain-on-grid models in mountainous areas with relatively limited data. Major findings included how to minimize the impacts of these challenges, with approaches such as maximizing the use of breaklines along steep features, time step management to account for varying velocities in such terrain, suggested cell sizes, and the use of the diffusion wave (DWE) versus shallow water equations (SWE).

What the audience will learn:

Some of the primary problems encountered due to the limited data and unique terrain included: how the DWE is generally more stable than the SWE, but neglects acceleration and may not capture rapid changes in runoff; how using a coarse DEM flattens and blocks small flow paths formed by high peaks and narrow valleys, causing artificially retained patches of water; how flattened terrain creates inaccurate velocities and inundation extents; and how the rendering of results cell-to-cell can produce unrealistic results in highly-variable terrain. The audience will not only see examples of these challenges as they appear in this model but will also learn about the driving processes in HEC-RAS that lead to such issues. This presentation will discuss various steps, successful and not successful, taken to approach these challenges (discussed above as major findings). With a stronger understanding of the driving causes of unrealistic model results in regions similar to northern Chile, audience members will be better equipped to apply and adapt the presented approaches to their own similar scenarios, whether it be for stormwater management, watershed analyses, dam breach studies, or other unique engineering projects.



Beyond the Barrel: Leveraging 2D Hydraulic Modeling to Optimize Culvert Design and Evaluate Downstream Impacts

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Highlights

- Accurate delineation of overland flow paths through urban infrastructure
- High-resolution flood extent definition along property boundaries and critical assets
- Downstream impacts analysis and legal/regulatory ramifications

Introduction

In Pennsylvania (PA), New Jersey (NJ), and other states with highly developed urban watersheds, aging drainage systems are increasingly being pushed beyond their original design capacity. The reality of aging infrastructure, undersized conveyance systems, and increasingly evolving rainfall patterns are combining to expose vulnerabilities which directly impact public safety. These conditions present an all too common but complex challenge: how to effectively retrofit or replace aging stormwater infrastructure within urbanized, constrained environments while minimizing unintended downstream consequences. Traditional one-dimensional (1D) hydraulic analyses provide a limited representation of these scenarios, particularly where flow paths become multidirectional during overtopping events. As a result, one-dimensional methods often fall short in capturing the full extent of flood behavior, associated risks, and potential downstream impacts. This case study demonstrates how two-dimensional (2D) hydraulic modeling can be leveraged to more accurately characterize existing hydraulic behavior, inform conveyance system design, and evaluate downstream impacts across a range of storm events. By moving beyond conventional one-dimensional approaches, the analysis identifies solutions that not only address localized flooding at urbanized roadway crossings but also improve overall floodplain performance while avoiding unintended adverse impacts. The study highlights how 2D modeling techniques support more resilient infrastructure, strengthen stormwater management decision-making, and provide practical guidance for practitioners, demonstrating the importance of accounting for potential downstream impacts when developing and evaluating design alternatives.

Background and Methodology

Case Study Background

This case study examines a roadway crossing where a small, unnamed fluvial tributary is conveyed through an existing 36-inch reinforced concrete pipe (RCP) culvert approximately 90 feet in length. The contributing watershed is highly urbanized, consisting of a mix of commercial development and residential land use, resulting in increased runoff volumes and low infiltration rates. Upstream of the 36-inch crossing is a 5-foot by 4-foot box culvert, and just downstream is a bridge with a 4-foot by 22-foot opening. While these adjacent structures have been upsized over time through various projects throughout the years, the 36-inch pipe has remained in place, creating a localized bottleneck where flows tend to back up, pond and cause flooding. Field observations and prior analysis indicate that the structure begins to overtop the roadway crossing at rainfall depths exceeding approximately two inches, which is below the historical 1-year storm threshold. This behavior causes flooding along the roadway corridor toward a nearby intersection, where floodwaters expand laterally and begin to encroach upon adjacent commercial properties upstream and downstream of the culvert crossing. These impacts become more pronounced during larger storm events, where the extent and depth of flooding increase, posing serious public safety risks. Collaboration with local stakeholders and the public has also played a crucial role in the evaluation process. Videos provided by the public which document the flooding conditions at the crossing were used to support the 2D modeling analysis and verify model results.



Hydraulic Modeling Methodology

A two-dimensional hydraulic model was developed for this case study using Aquaveo's SMS/SRH-2D software. The model was constructed to simulate both in-channel and overland flow, allowing for a more comprehensive representation of flow paths, floodplain storage, and hydraulic interaction between structures. The modeled reach extends approximately 500 feet upstream and 1700 feet downstream of the roadway crossing, capturing the full extent of the floodplain limits. Model inflows were based on project-specific hydrographs developed using standard NRCS methodology for the 2-, 5-, 10-, and 100-year storm events. This approach allowed for a dynamic evaluation of system response across a range of storm magnitudes. The existing condition was modeled to use as a baseline comparison against four (4) proposed box culvert alternatives. Alternatives were evaluated based on key hydraulic parameters including water surface elevations (WSE), flow velocities, and floodplain extents, as shown in Figure 1.



Figure 1. Existing (blue) vs. Proposed (red) Conditions 2-Year Storm Floodplain Extents

Regulatory Context and Impact Considerations

In New Jersey, floodplain design is governed by the Flood Hazard Area Control Act Rules (FHACA), which establishes criteria for allowable increases in WSE associated with proposed culvert development. For the purpose of this case study, the primary regulatory consideration is the allowable increase in flood elevations within regulated flood hazard areas, typically evaluated through defined maximum allowable rises. While the FHACA regulations provide a clear framework for WSE increases, guidance related to the evaluation and interpretation of downstream impacts remains less explicitly defined, particularly for complex flood plain hydraulics where lateral increases in flooding extents occur, particularly in highly developed areas. Therefore, it remains the responsibility of engineers to evaluate these potential impacts as part of the design process, consistent with our broader obligation to protect public safety.

Key Findings

- Two-dimensional hydraulic modeling is highly effective for evaluating complex floodplain behavior and capturing downstream impacts that are often not represented in conventional one-dimensional analyses, enabling more informed and resilient design of flood-prone infrastructure.
- Hydraulic evaluation should extend beyond localized compliance checks to consider system-wide performance, including flow redistribution, floodplain connectivity, and off-site impacts across multiple storm events.
- The findings emphasize the responsibility of engineers to evaluate potential offsite impacts that may extend beyond traditional regulatory review frameworks, as the foremost commitment of engineers is to protect public safety.

Recommendations

- Design of hydraulic structures should incorporate 2D modeling as standard practice for complex floodplains, particularly where 1D methods may not fully capture multi-directional flow distribution or downstream impacts.
- Conveyance improvements should be evaluated collaboratively in a system-wide context, ensuring that proposed structures address both local performance and offsite hydraulic conditions across a variety of storm events.



Comparison of 1D, 2D, and 3D Model for Labyrinth Spillway Design

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What I will be presenting:

A dam rehabilitation design was conducted on a high hazard dam in Massachusetts. Part of the design consisted of designing a new spillway chute with a labyrinth weir. During the design, a 1-dimensional (1D) and 2-dimensional (2D) hydraulics model was constructed using Hydrologic Engineering Center's River Analysis System (HEC-RAS) while a 3-dimensional (3D) computational fluid dynamics (CFD) model was constructed using the SimFlow graphical user interface, which utilizes the CFD simulation software OpenFOAM. The models were used to guide the sizing of the spillway chute and labyrinth weir to contain design inflows and meet design requirements. This presentation will aim to highlight the similarities and differences in results from each modeling method, along with the computational demand and/or limitations.

What the audience will learn:

Each design has its own sensitivity to the array of results that a model can produce. A 1D, 2D, and 3D CFD model can be beneficial during different design scenarios, and this presentation will help highlight the capability of each modeling method. Some factors that can be considered when choosing a modeling method to use can include (but is not limited to) result outputs, computation time, and modeling effort. The type of results that each modeling method can produce, along with the computation time, and modeling effort for each method for the design of the spillway chute and labyrinth weir will be compared. The pros and cons of each modeling method will be highlighted along with examples of when each one can be beneficial or even compliment the other. Although this spillway is more large scale when compared to traditional stormwater measures, the engineering and modeling techniques can be applied to other open water spillway or weir designs that contain similar hydraulic features.



LEGACY IN THE FLOW: FORENSIC HYDRAULICS FOR CLOMR DESIGN AT HISTORIC URBAN BRIDGES

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What I will be presenting:

This presentation summarizes the development of a FEMA-compliant Conditional Letter of Map Revision (CLOMR) model to support stream restoration within the Tacony–Frankford Creek watershed in Philadelphia. The project area extends from downstream of Roosevelt Boulevard to approximately 500 feet downstream of Whitaker Avenue and is located within one of the city’s most densely urbanized watersheds. Two major legacy bridges—the 12-lane Roosevelt Boulevard concrete arch bridge and the Whitaker Avenue steel arch bridge—serve as dominant hydraulic controls within the study reach.

The project required development of a new HEC-RAS model using limited effective model data, as the available FEMA regulatory information was derived from legacy HEC-2 analyses last updated in the 1970s. No effective HEC-RAS model existed for the project reach at the time of design. To address these constraints, the modeling effort relied on extensive historical record retrieval, including Right-To-Know and record retention requests, to reconstruct bridge geometry and hydraulic parameters from mid-century as-built drawings.

The presentation walks through the technical decisions required to build these historic bridges in HEC-RAS, including defining deck and roadway geometry, pier configurations, skew angles, ineffective flow areas, and contraction and expansion coefficients, while meeting FEMA regulatory review criteria for CLOMR approval.

What the audience will learn:

Audience members will learn how legacy infrastructure and incomplete regulatory datasets can complicate CLOMR development in urban environments, and how these challenges can be addressed through a structured, defensible modeling approach. The session highlights how historic bridge geometry—particularly low chords, piers, skew, and ineffective flow areas—can significantly influence floodway and floodplain results when modeled in HEC-RAS.

Attendees will gain insight into transitioning legacy HEC-2 data into a modern HEC-RAS framework when effective models are unavailable, including strategies for validating assumptions against FEMA expectations. The presentation emphasizes practical techniques for incorporating historical as-built drawings into model inputs, selecting reasonable Manning’s roughness values, and applying appropriate contraction and expansion coefficients for constrained urban channels.

A key takeaway is the importance of documentation and transparency when using engineering judgment to fill data gaps. By walking through the regulatory review questions FEMA applies to CLOMR submittals, the presentation provides a clear framework for managing uncertainty, maintaining compliance, and supporting restoration and infrastructure improvement projects in legacy-rich urban watersheds.

