Module 01: Introduction to Computational Hydraulics

Unit 01: Overview

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National Programme for Technology Enhanced Learning (NPTEL)

Learning Objectives

- To define computational hydraulics

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- To define computational hydraulics
- To recognize the differences between physical experiment and computational approach.

Introduction

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- *Computational Hydraulics* is the **art** of representing *complex* ODEs/PDEs in the form of algebraic equations.
- Overall aim of *Computational Hydraulics* is to reduce the experimental (physical) cost by solving the algebraic equations.

Solution Methods

Solution Methods for ODEs/PDEs

- Analytical (closed form)

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- Numerical (approximate form)

What is Computational Hydraulics?

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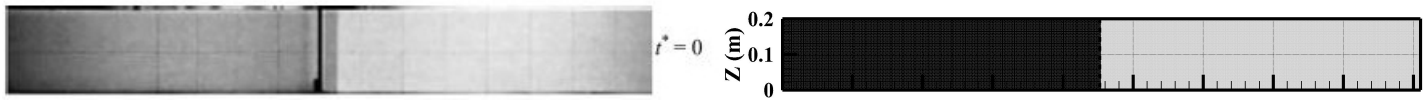
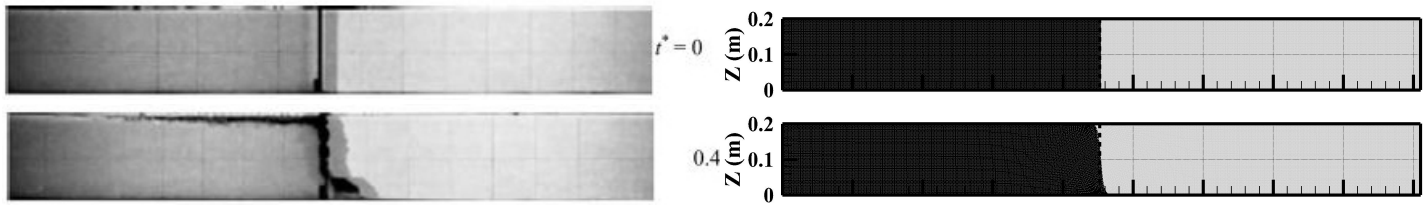
Objective

Computational hydraulics empowers scientists/engineers to perform numerical experiments in a "*virtual laboratory*" before experimenting physically.

Experiments vs. Simulations



Experiments vs. Simulations



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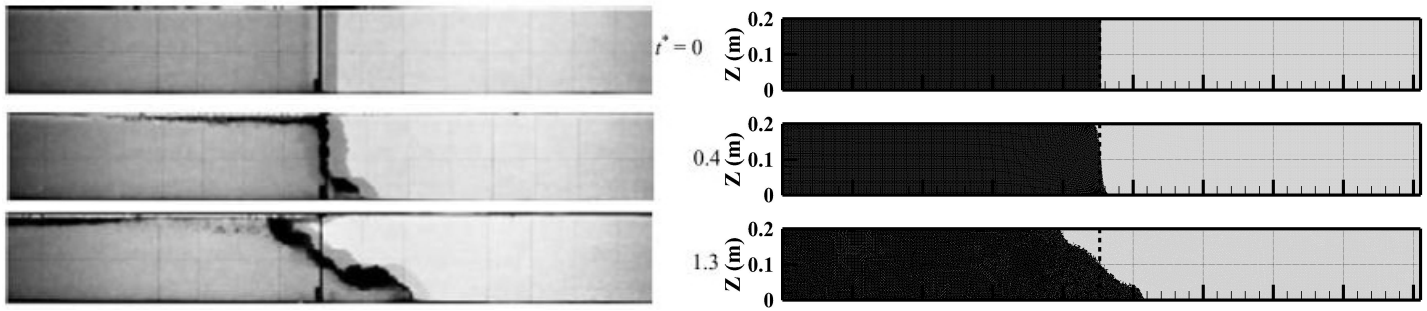

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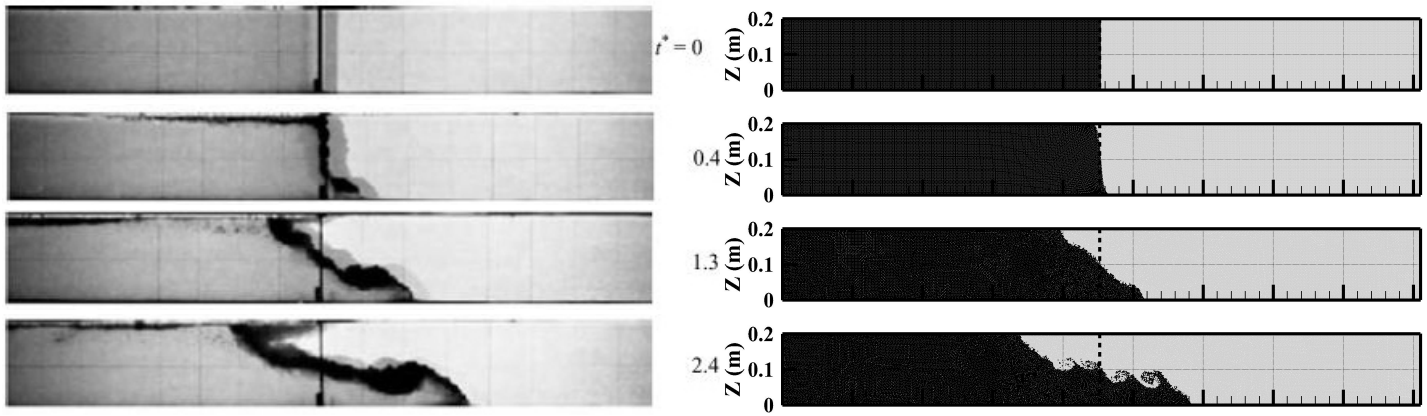

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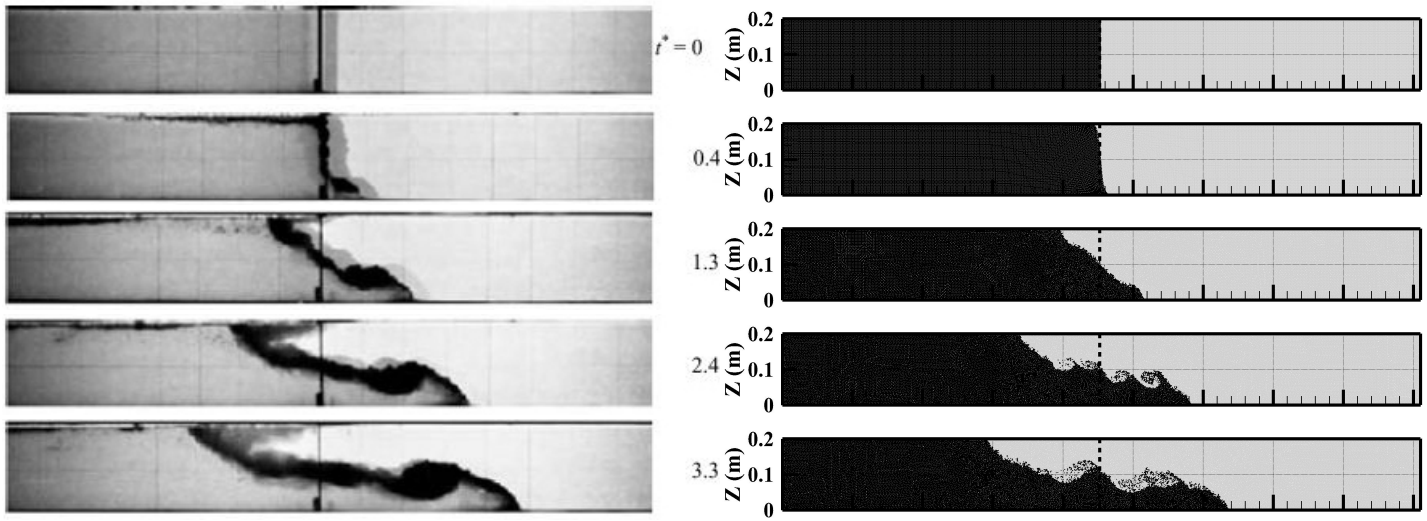

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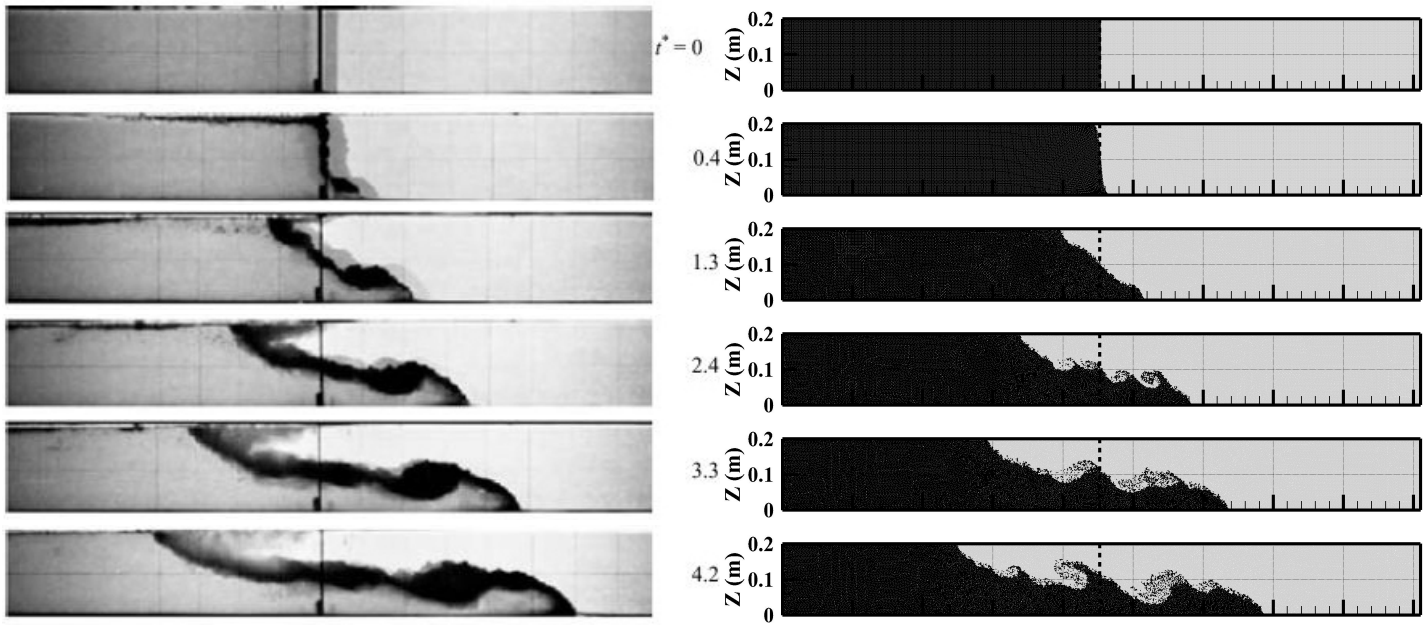

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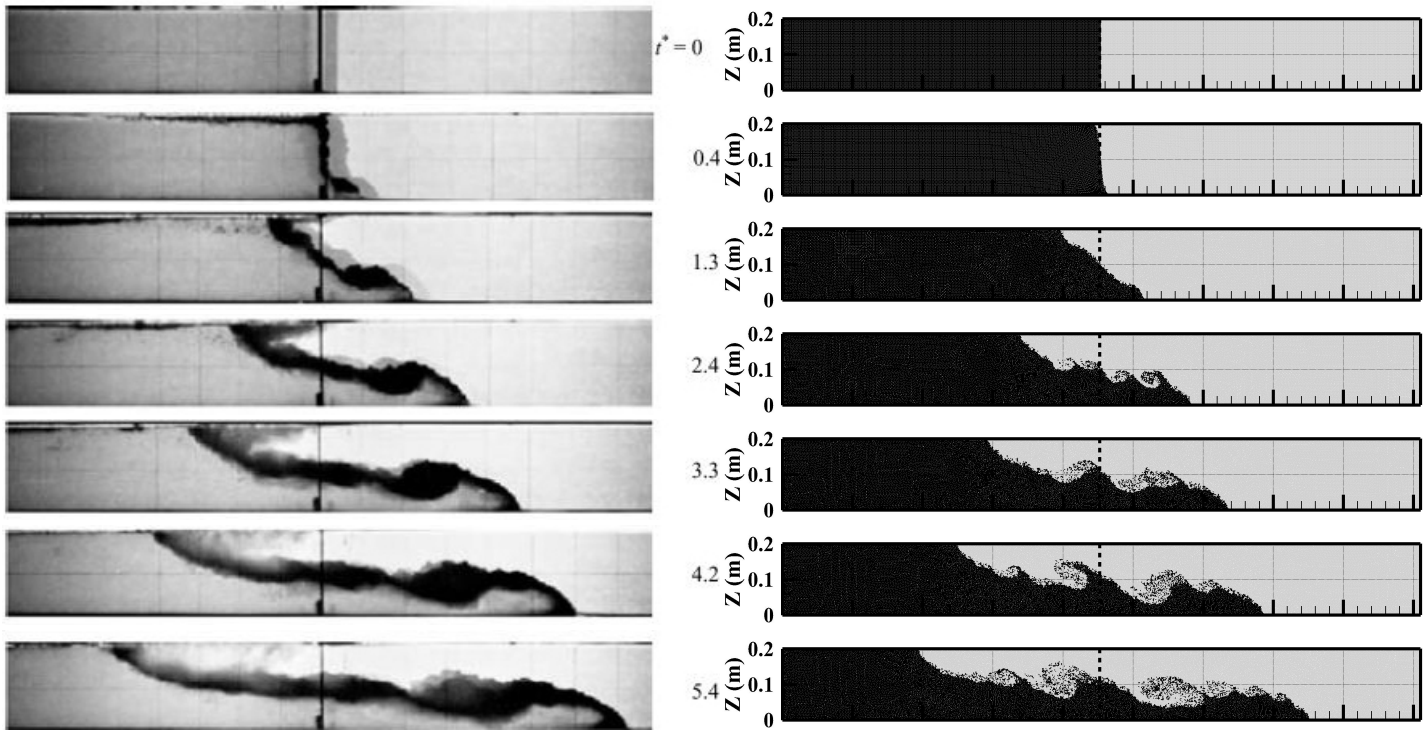

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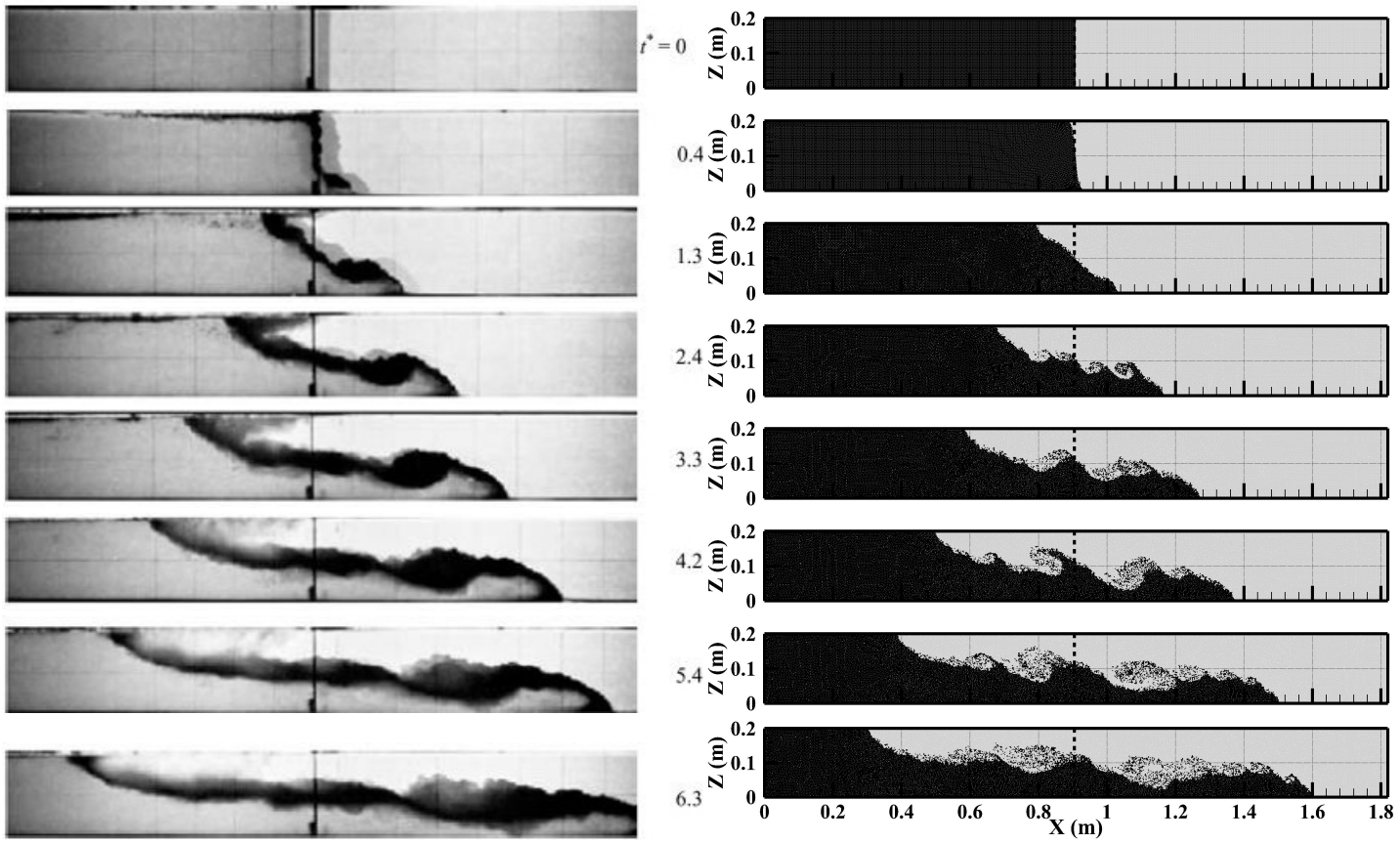

Figure: Comparison of Experimental (Lowe et al., 2005) and Numerical (Pahar and Dhar, 2016) Lock-exchange Flow

Experiments vs. Simulations

Experiments	Simulations
Information about physical phenomena on representative spatiotemporal observation points depending on techno-economic feasibility.	Prediction about physical phenomena on discretized nodes depending on techno-economic feasibility.

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Information about physical phenomena on representative spatiotemporal observation points depending on techno-economic feasibility.	Prediction about physical phenomena on discretized nodes depending on techno-economic feasibility.
Measurement error is important.	Conceptualization (mathematical description of physical phenomena) and numerical errors are important.

Types of Fluid Flows/Movements

Fluid flows/movements in hydraulic systems include

- Groundwater movement and contaminant transport in aquifers

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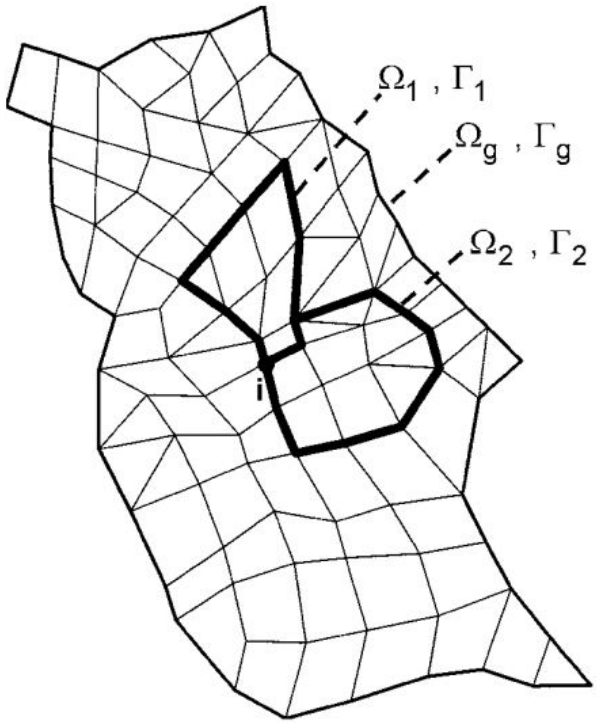
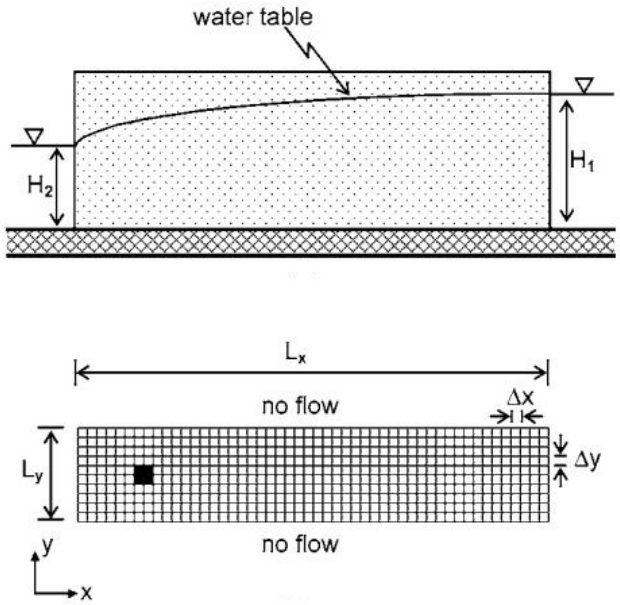
- Interaction between surface water and groundwater flows

Groundwater Movement in Aquifers

Variable: h(x,y,t)



(a) Descriptive schematics of discretizations of global domain and two subdomains (Dogrul and Kadir, 2006)



(b) cross section of heterogeneous aquifer between two lakes and simulation grids (Dogrul and Kadir, 2006)

Contaminant Transport

Variables: h(x,y,t), C(x,y,t)

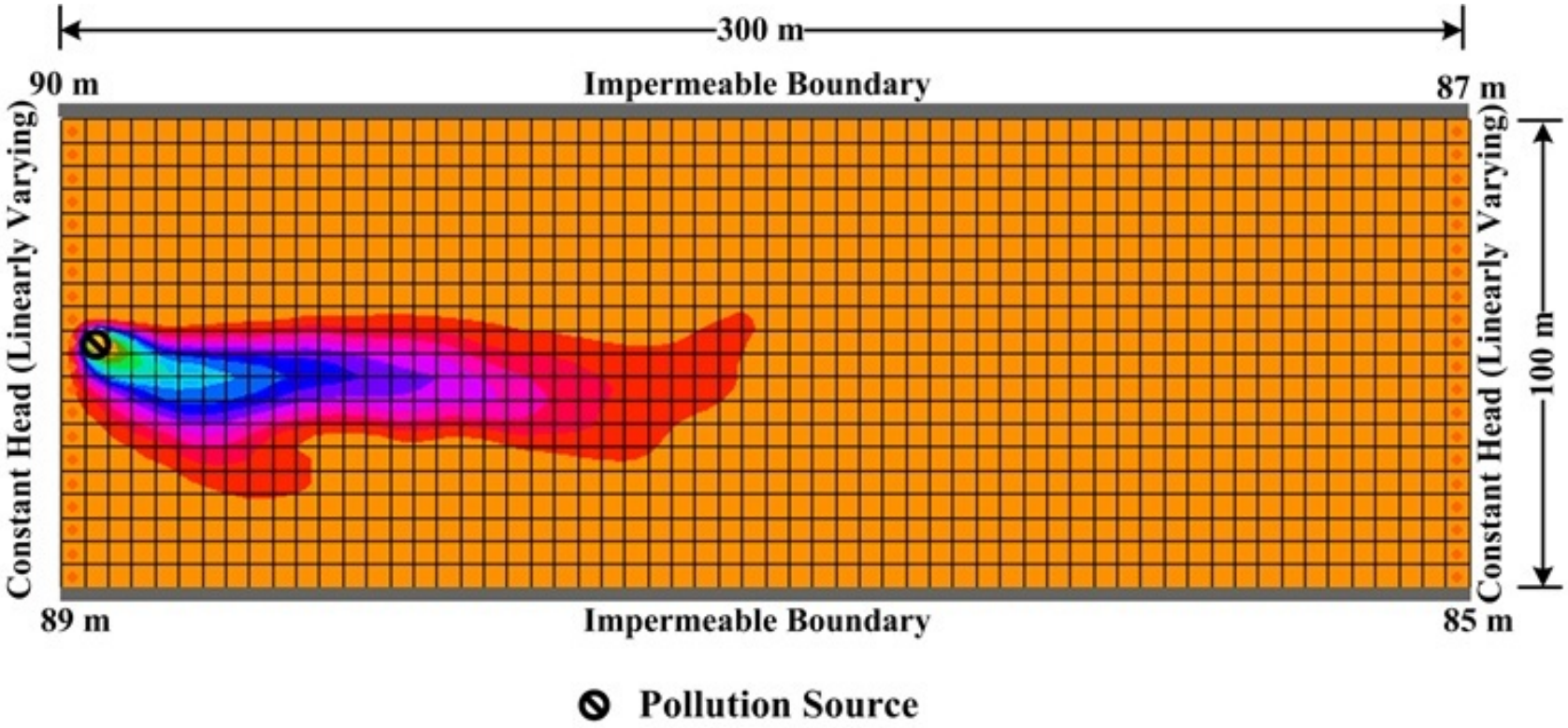


Figure: Contaminant Transport in Aquifer (Dhar and Patil, 2012)

Channel Networks

Variables: Q(x,t), h(x,t)

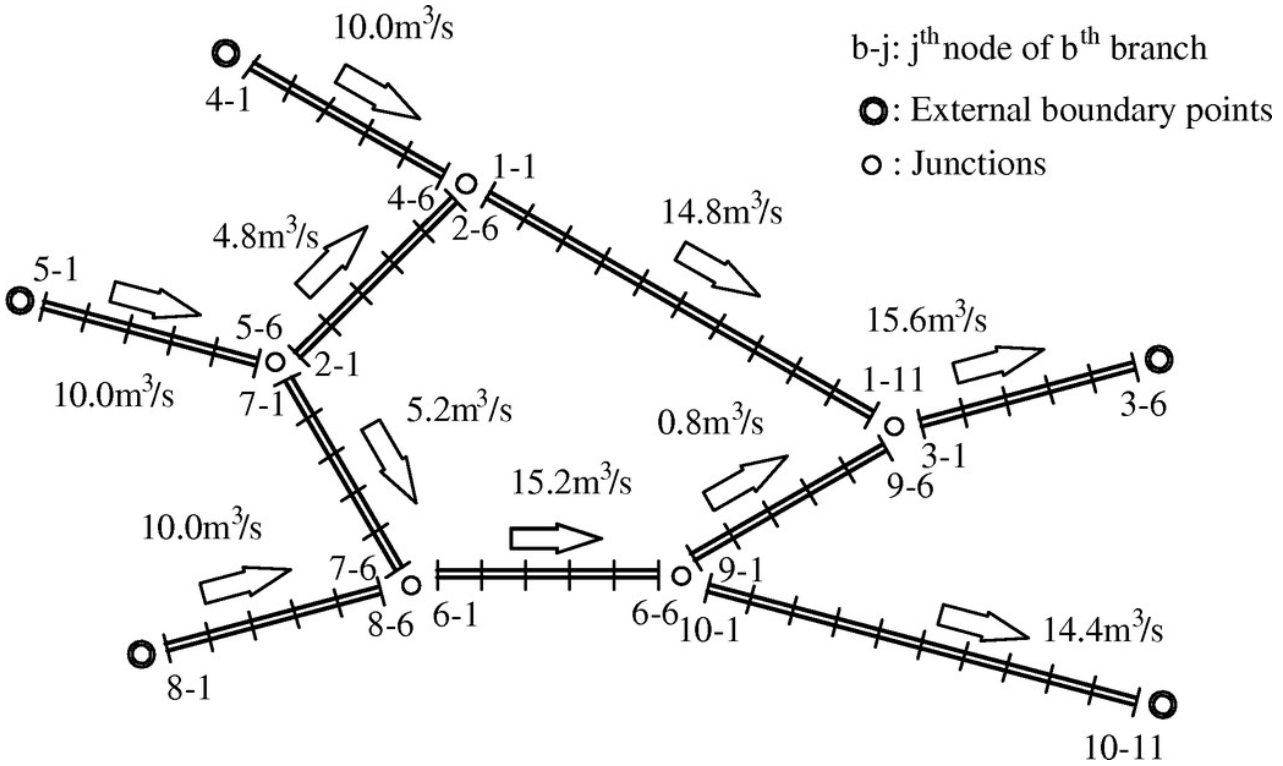


Figure: Typical channel network system (Garg and Sen, 2002)

Surface Flooding

Variable: h(x,y,t)

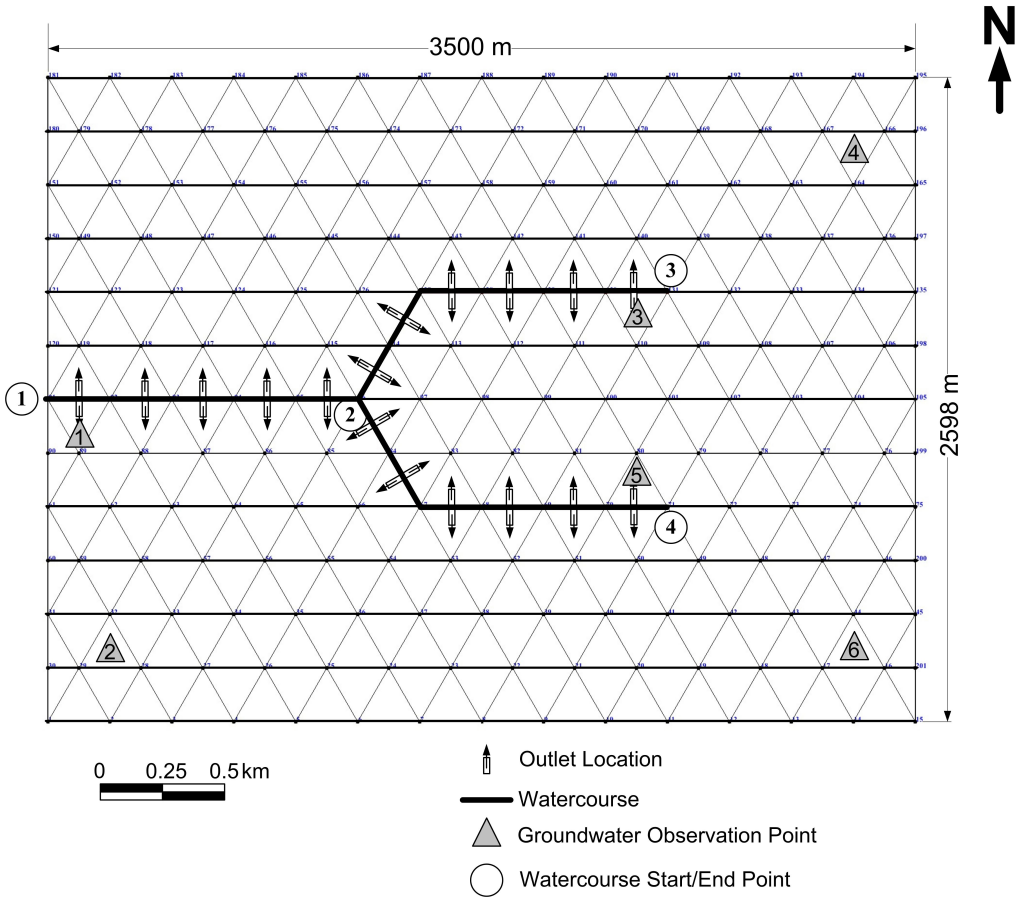
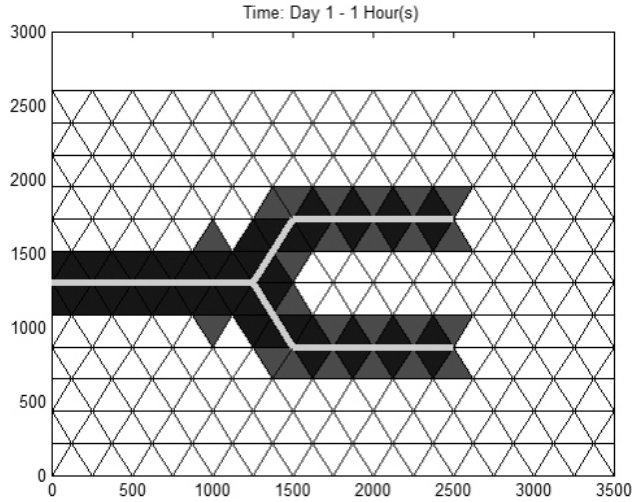


Figure: Initial Condition (Biswas, 2016)

Surface Flooding



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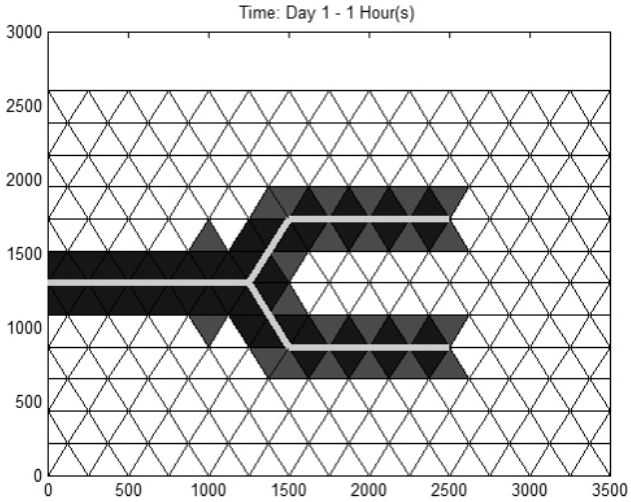

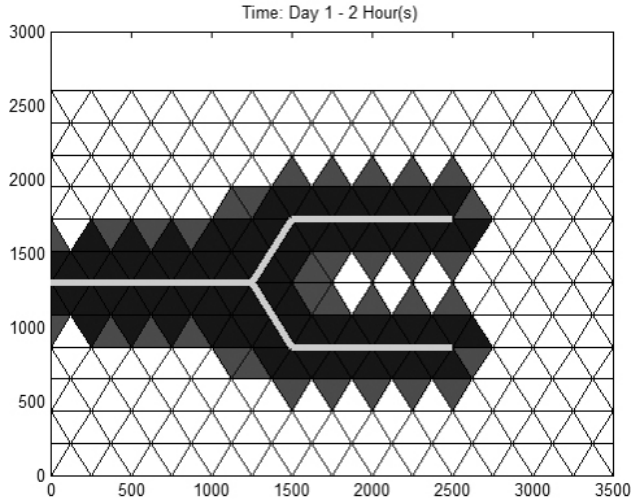

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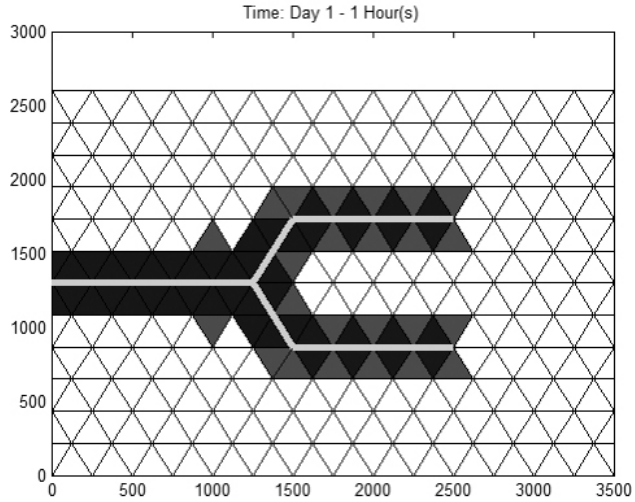

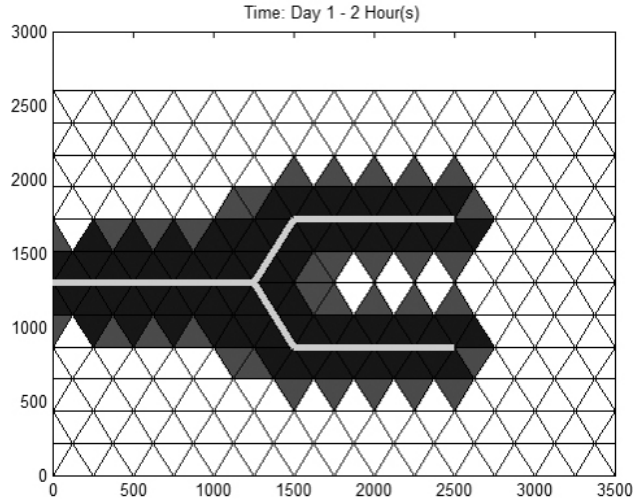

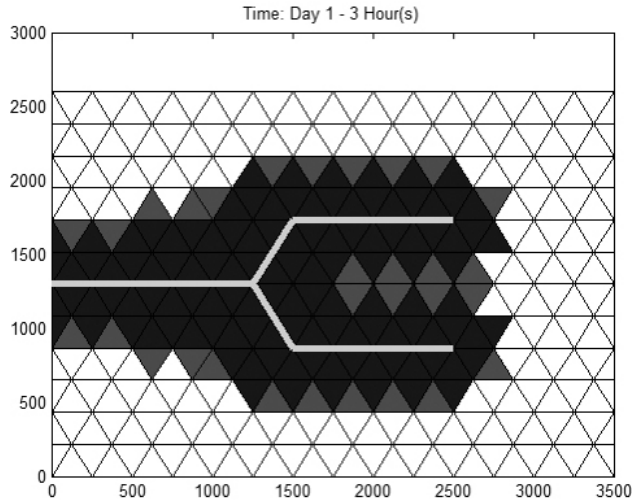

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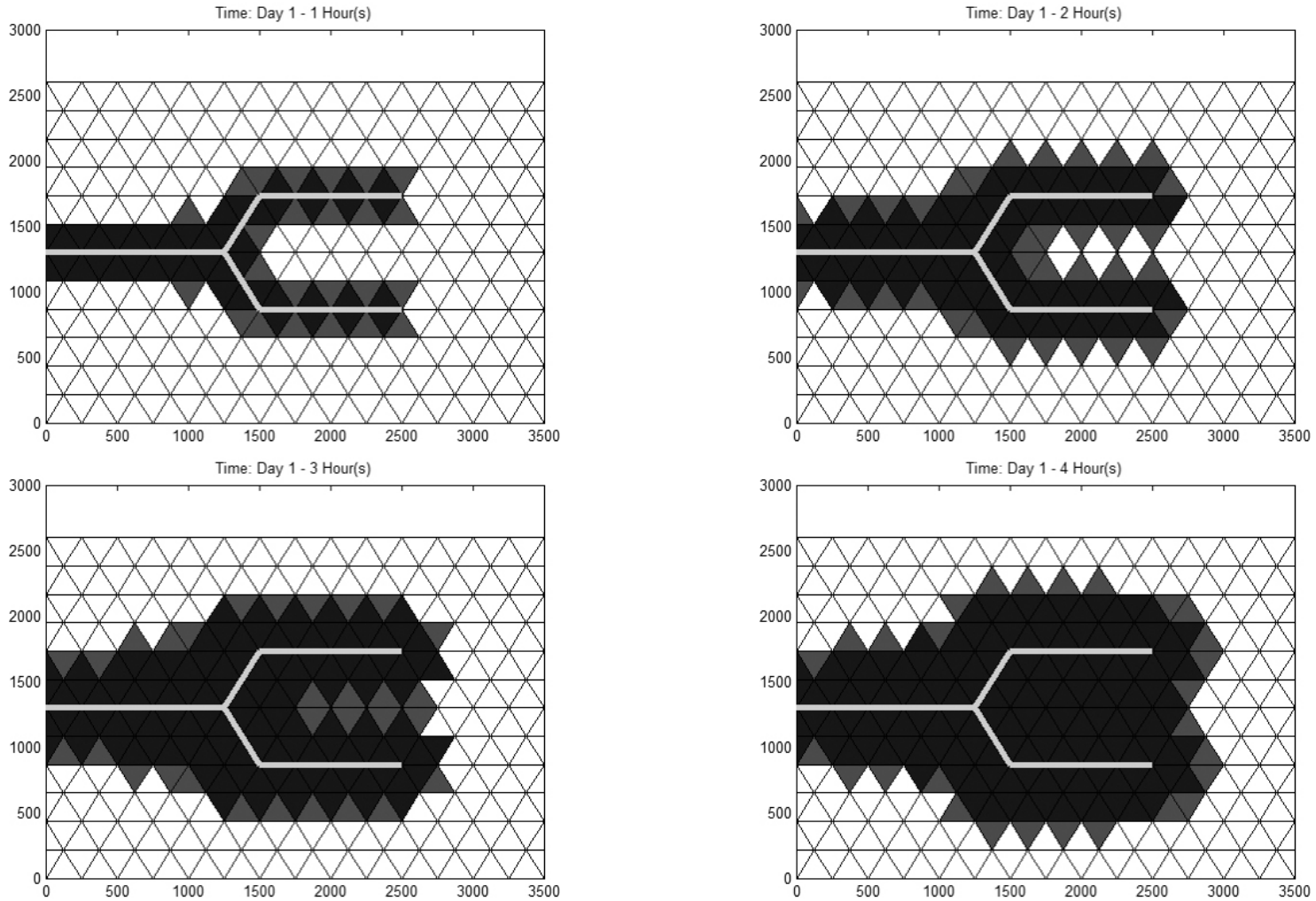


Figure: Surface flooding (Biswas, 2016)

Open Channel Flow
Hydraulic jump

Variables: u(x,z,t), w(x,z,t)

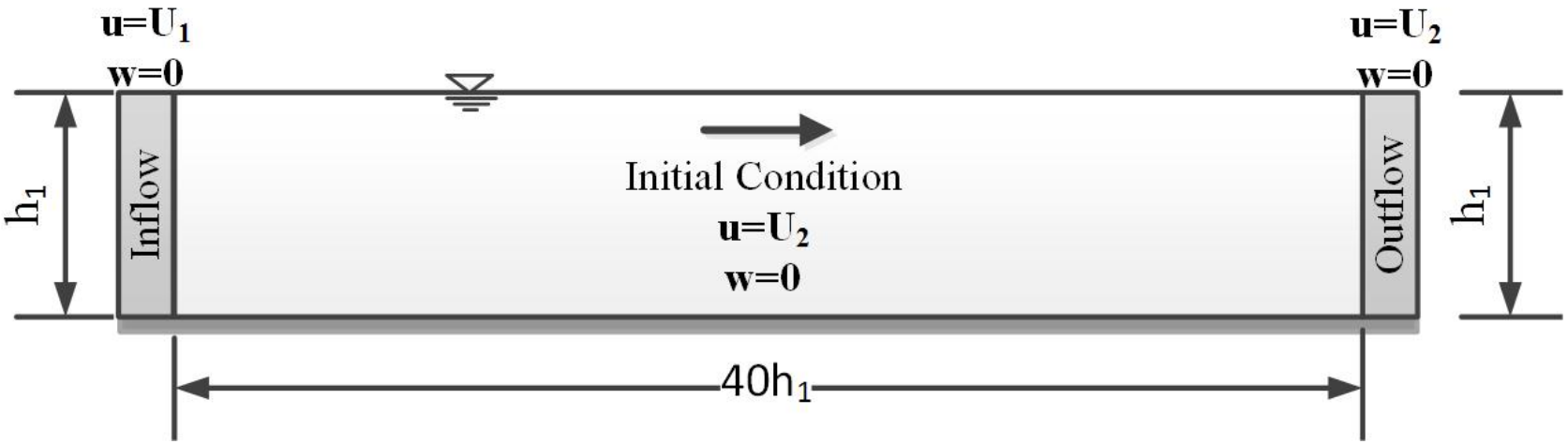
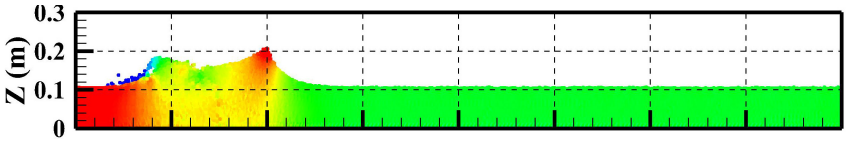


Figure: Initial condition of hydraulic jump (Pahar and Dhar, 2017)

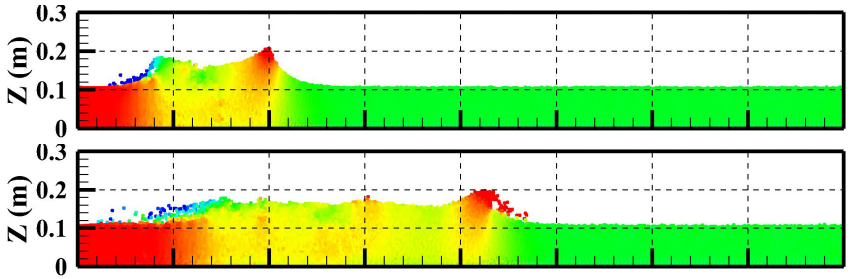
Open Channel Flow

Hydraulic jump



Open Channel Flow

Hydraulic jump



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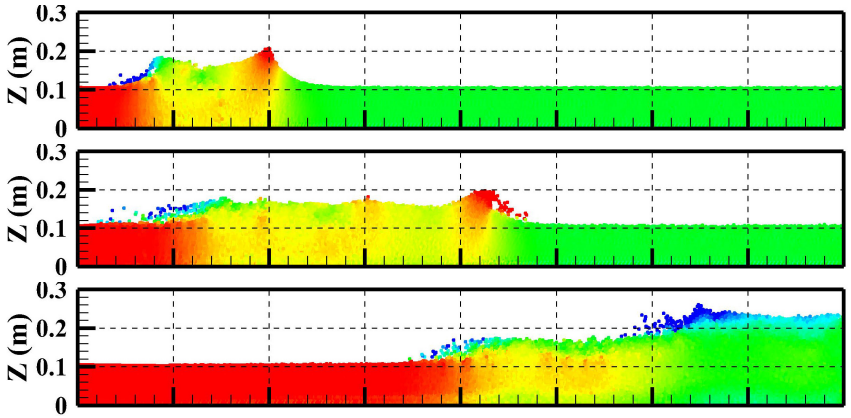

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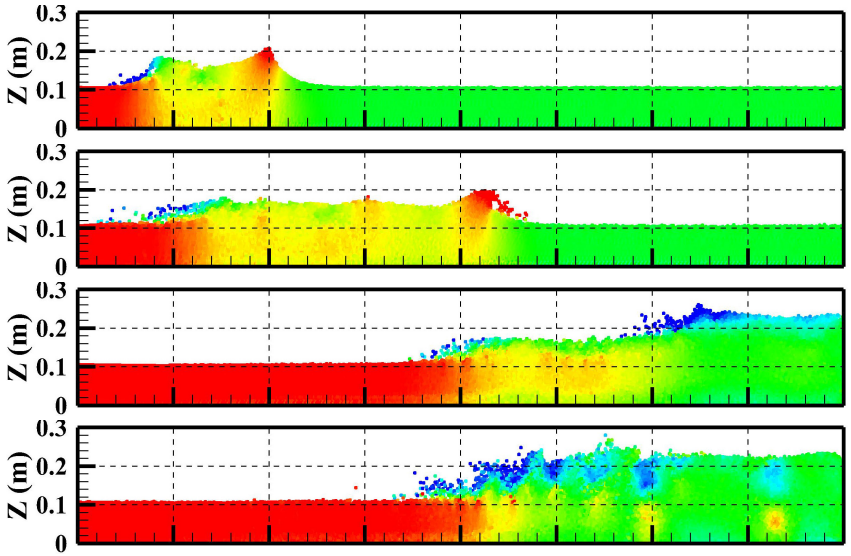

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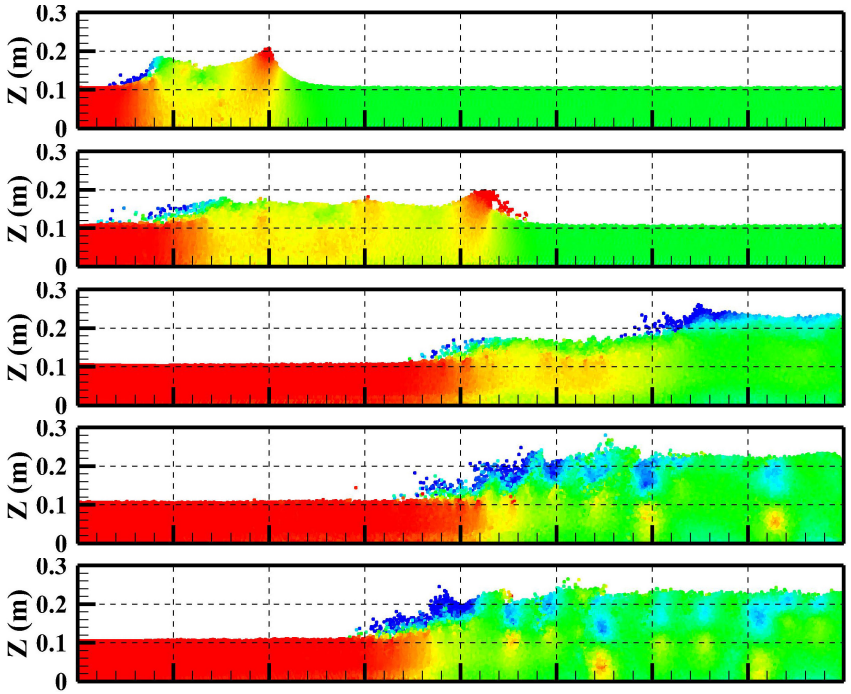

Open Channel Flow

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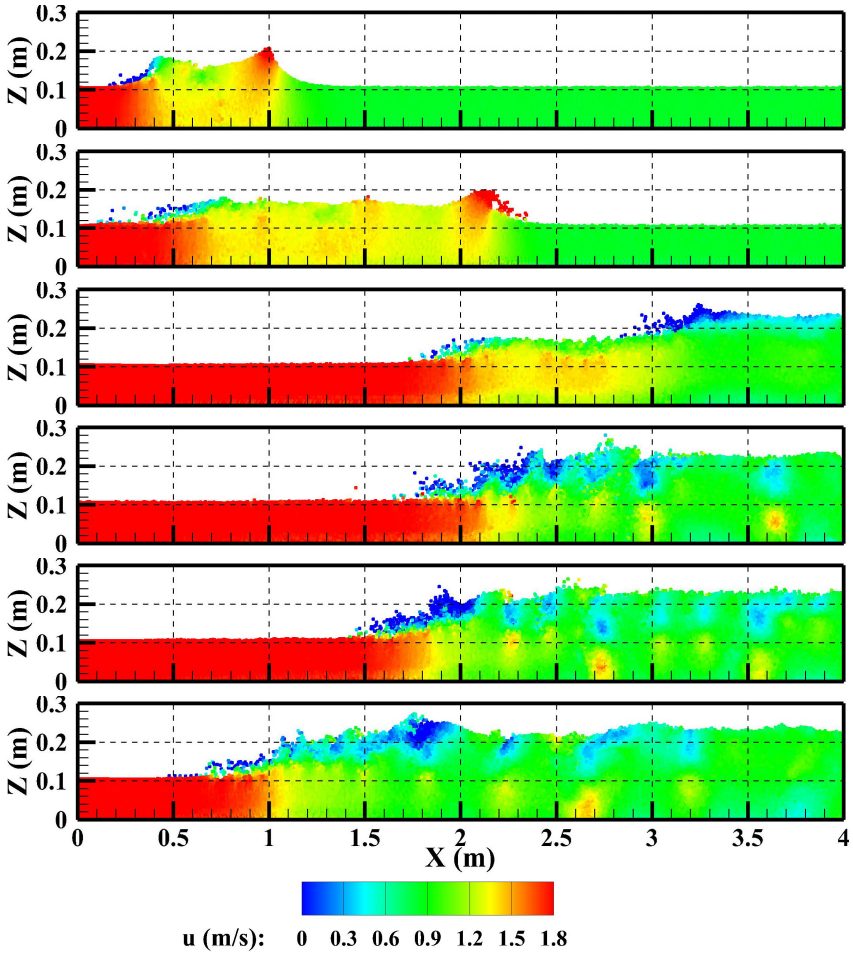


Figure: Velocity evolutions of hydraulic jump (Pahar and Dhar, 2017)

Pressurized Conduits

Variables: H(x,t), Q(x,t)

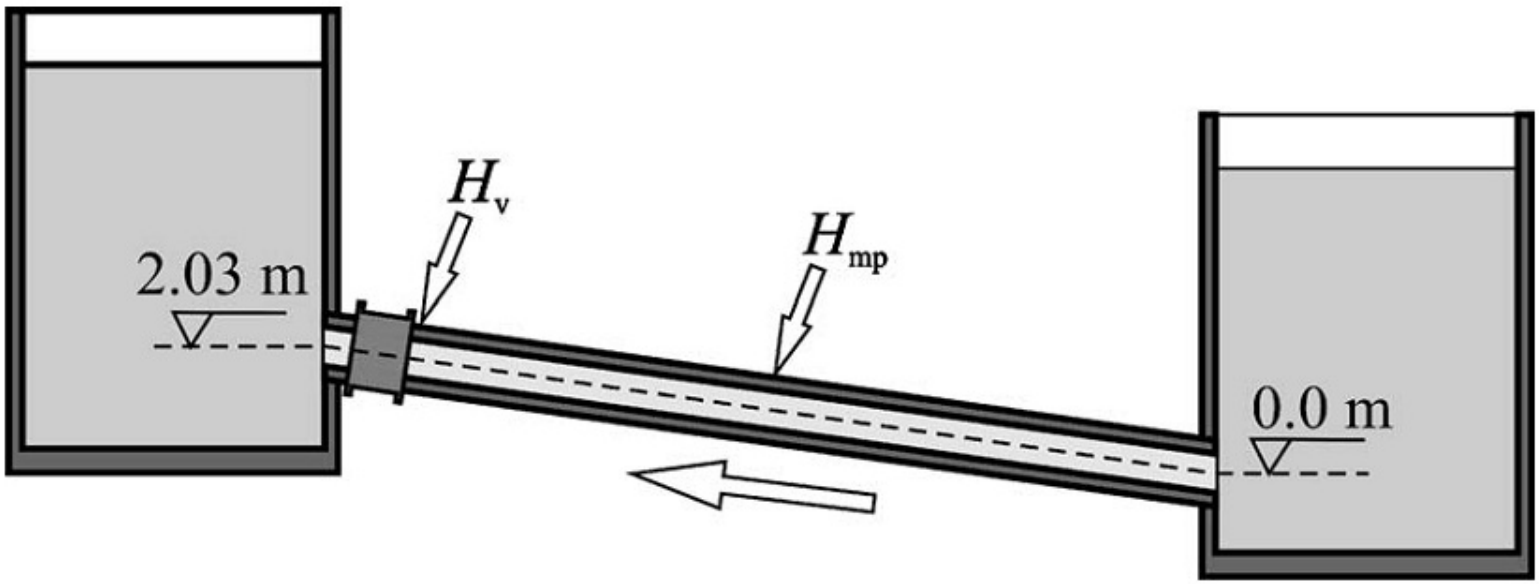


Figure: Connection between two reservoirs (Skific et al., 2010)

Pressurized Conduits

Variables: p(x,t), q(x,t)

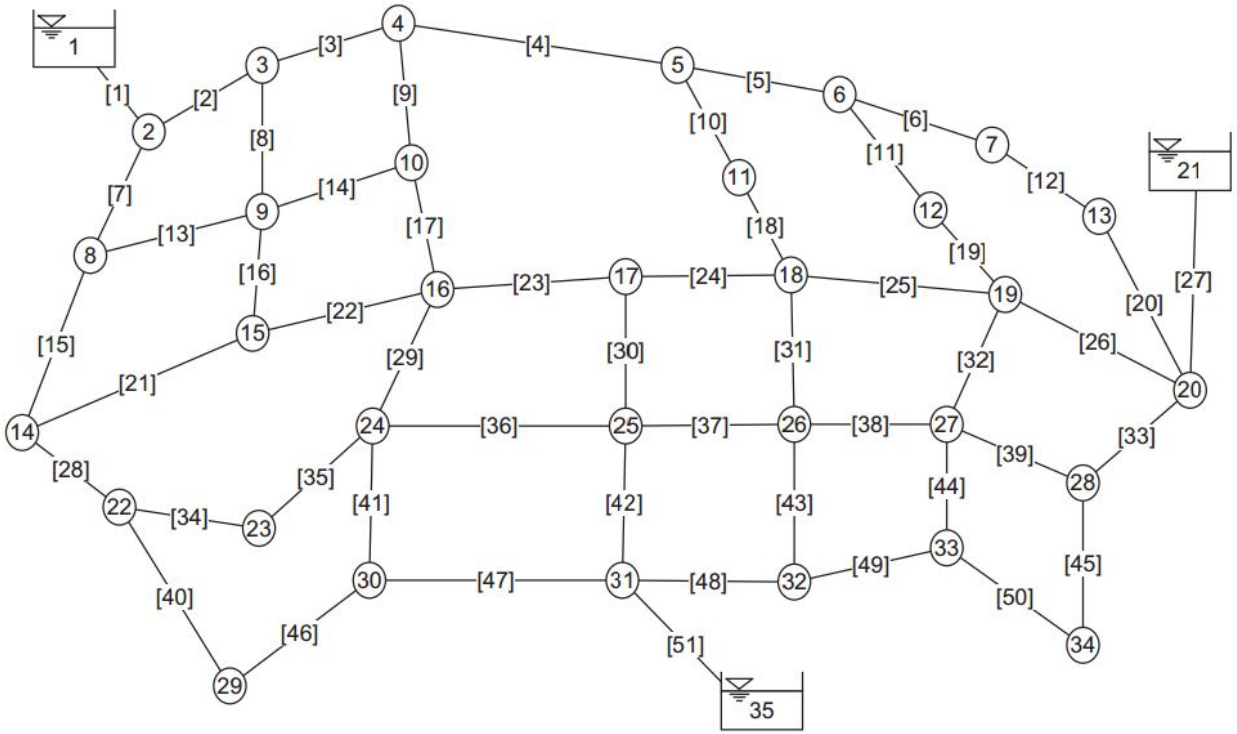


Figure: Pipe Networks (Zecchin et al., 2009)

Surface water-groundwater interaction

Variables: $\zeta^s(x,t)$, $p^s(x,t)$, $\zeta^g(x,t)$, $p^g(x,t)$,

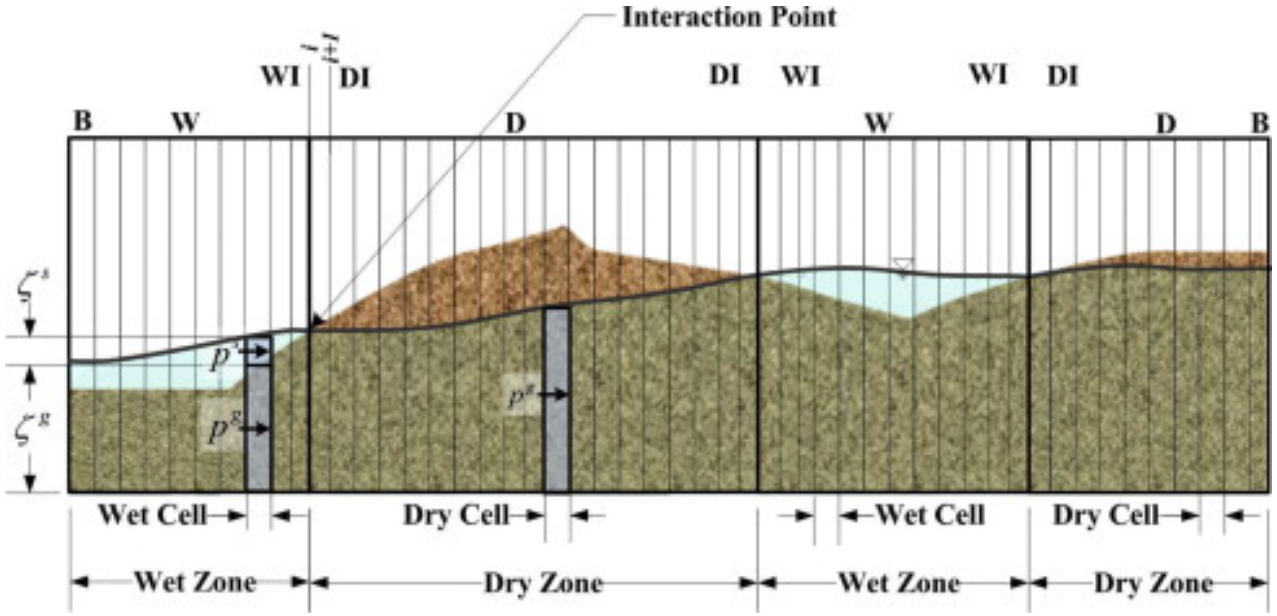
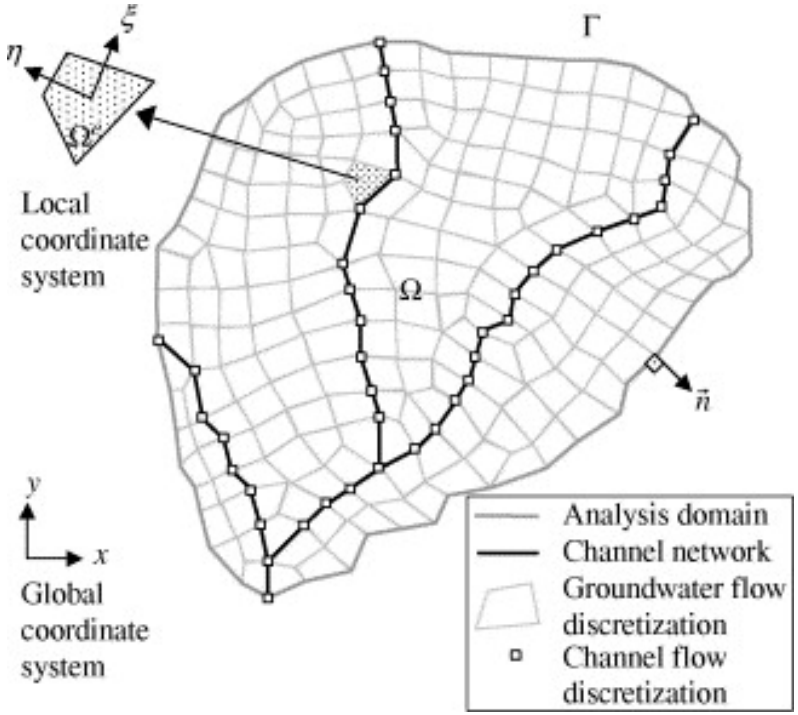


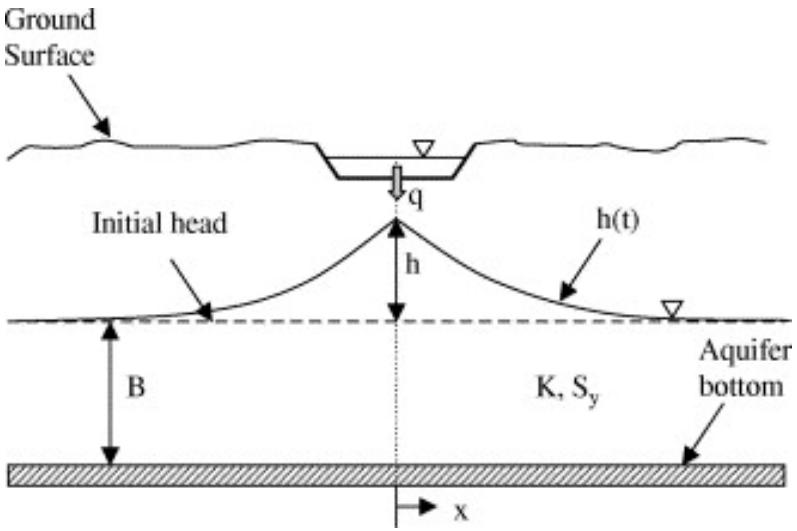
Figure: Conceptual representation of dry cell-wet cell theory (Pahar and Dhar, 2014)

Surface water-groundwater interaction

Variables: $h_s(x,t)$, $Q(x,t)$, $h_g(x,y,t)$



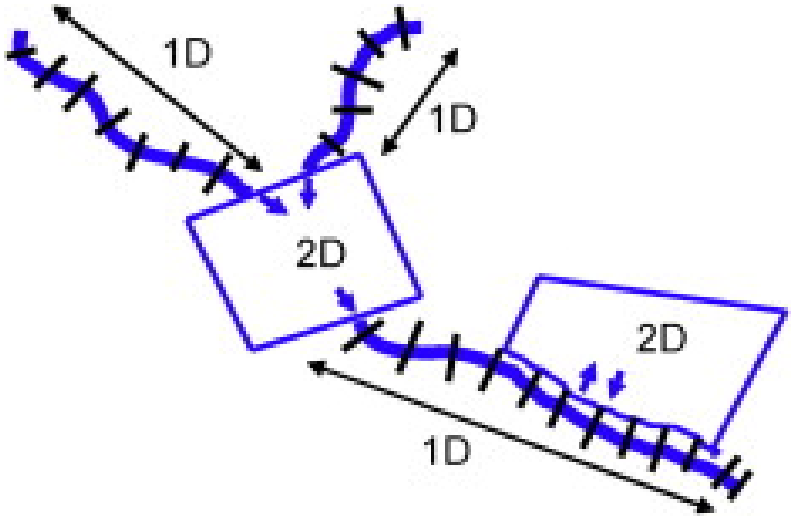
(a) Coupled modeling domain (Gunduz and Aral, 2005)



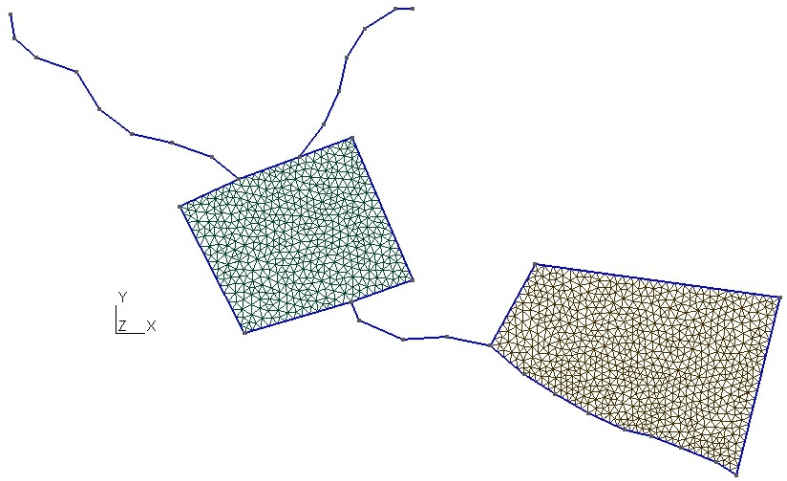
(b) Stream aquifer interaction (Gunduz and Aral, 2005)

1D-2D integrated system

Variables: $h_c(x,t)$, $Q_c(x,t)$, $h_f(x,y,t)$, $u_f(x,y,t)$, $v_f(x,y,t)$



(a) Integrated 1D-2D simulations with lateral and flow direction connections (Blade et al., 2012)



(b) Discretization of computational domain

Steps

- Problem definition

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- Conceptualization in terms of mathematical governing equations

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- Domain representation in terms of discrete nodes/cells

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- Discretization of governing equations
- Representation in terms of algebraic equations

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- Representation in terms of algebraic equations
- Solution of algebraic equations

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- Postprocessing obtained solution results

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- Problem definition
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- Domain representation in terms of discrete nodes/cells
- Discretization of governing equations
- Representation in terms of algebraic equations
- Solution of algebraic equations
- Postprocessing obtained solution results
- Verification with experimental/analytical results.

Thank You

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