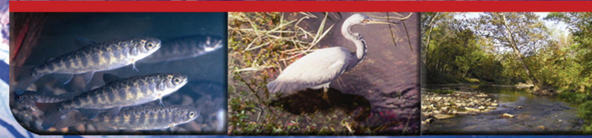

System-Wide Water
SWWRP
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ADaptive Hydrology/Hydraulics (ADH)

Description: ADaptive Hydrology/Hydraulics (ADH) is a modular, parallel, adaptive finite element model for one-, two-, and three-dimensional flow and transport. ADH simulates groundwater flow, internal flow, and open channel flow. The specifics of each flow type are described as follows:

- **Groundwater flow:** The groundwater simulation includes 3-D, variably-saturated groundwater flow and constituent transport. The groundwater flow may be coupled to 2-D diffusive wave or dynamic wave surface water flow. Groundwater flow also is coupled loosely to 3-D, subsurface heat transport.
- **Internal flow:** The internal flow capability represents 3-D Navier-Stokes flow. This module is nonhydrostatic and includes a k-ε turbulence model.
- **Open channel flow:** There are two approaches for open channel flow: nonhydrostatic and hydrostatic pressure methods. The nonhydrostatic pressure module is the same as that used for internal flow and is 3-D. The free surface is updated dynamically. This module is more appropriate for domains near structures where the vertical inertial terms are significant. The shallow-water equations represent the hydrostatic approach. This includes 2-D and 3-D with variable density flow (baroclinic). The 2-D module includes that capability for wetting-drying, dam-break, supercritical, and subcritical flow. The 2-D shallow-water module includes sediment transport and bed change. The 2-D module can include the long-wave vessel effects. ADH has also been linked to Cold Regions Research and Engineering Laboratory (CRREL) discrete element model to drive simulations of ice and debris.

Key features common to the flow types include:

- The ability to automatically refine or coarsen the mesh during the simulation, resulting in more accurate solutions, and more stable, less expensive simulations.
- The ability to run on any number of processors and machines ranging from a standard PC to the high-end supercomputers.
- The modular style that allows additional physical processes to be added with ease.
- An extended continuous finite element approach that conserves mass locally without the expense of a discontinuous method.

Application: Among 3-D Navier-Stokes applications are the Little Goose, Ice Harbor, and Lower Monumental Dams and forebays on the Snake River. These flow fields were developed to drive the Numerical Fish Surrogate simulator to represent juvenile salmon migration. Various components of other hydraulic structures have also been modeled to provide design and/or forensic information on flow conditions associated with various normal and extreme conditions.

The shallow-water module has been used in overtopping and channel at the confluence of the Arkansas, White, and Mississippi Rivers. Other locations include Point Au Chene, San Diego Bay Pools 5 and 8 on the Mississippi River, and various lock approaches in Research and Development (R&D) programs.

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The groundwater model is being used to simulate groundwater flow and contaminant transport at Pueblo Chemical Depot, Pueblo, Colorado, and to simulate detailed soil moisture and temperature distributions in multiple R&D programs.

Benefits: The general features in ADH that substantially benefit the modeler are:

- **Adaption:** The user needs to only generate a mesh of good enough quality to capture the geometry of the problem. ADH can automatically refine beyond this to provide accurate hydrodynamics and transport
- **Portability:** ADH can run efficiently on a wide variety of platforms. These include Windows, Unix and Linux machines. Single processor machines to distributed memory supercomputers.

ADH improves the computational efficiency of coupled surface water-groundwater interaction simulation. Coupled 3-D groundwater and 2-D surface water provide:

- diffusive wave and full shallow-water equations
- flux-based communication which avoids switching flux/head boundary
- dual-valued nodes on ground surface
- solves and maintains reasonable sized for linear systems
- potential for different time advancement for hydrologic components

The ADH Navier-Stokes module has been linked to the Numerical Fish Surrogate to predict fish migration. It can provide accurate hydrodynamics as well as accelerations.

The shallow-water module includes:

- density coupled (salinity and temperature)
- sediment transport
- vessel effects
- overtopping and wetting-drying regions
- links to the CRREL discrete element model for ice and debris simulation

Future Capabilities: Over the next four years, the groundwater model will be extended to permit two-phase, air-water modeling with air-phase transport. The ADH 3-D Navier-Stokes portion will include another solver to be able to simulate wave breaking, overtopping and vessel effects using level-set technology. The shallow-water module will include the capability to have regions of 2-D and 3-D within the same domain. Eventually, an overall domain will include regions that are nonhydrostatic, hydrostatic, and groundwater.

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