Hydrodynamic

An easy-to-use hydrodynamic simulation software package can give reliable forecasts about the consequences of building dikes and embankments

DESCRIBED as a reliable way forecast the consequences of different activities, such as dredging or building dikes, bridges, piers, and embankments, AquaDyn is a powerful and easy-to-use hydrodynamic simulation software package for water resources engineering studies, risk assessment, and impact studies. It allows the complete description and analysis of two-dimensional hydrodynamic conditions (e.g., flow rates, water levels, concentration of diffused particles or heat) of open channels such as rivers, lakes, and estuaries.

The software can be used to model steady and unsteady flows in supercritical, as well as, subcritical conditions. Therefore, this permits the study of the effects of weirs, contractions, dam break, and tidal waves. It can also be used to study the protection of fish habitats and to perform water quality assessments. As an example, engineers, specialists, and decision-makers may use the specialised modules of the simulation package to predict impacts on water flow conditions caused by engineering projects. Similarly, AquaDyn can predict impacts on pollution concentration downstream of a projected industrial plant.

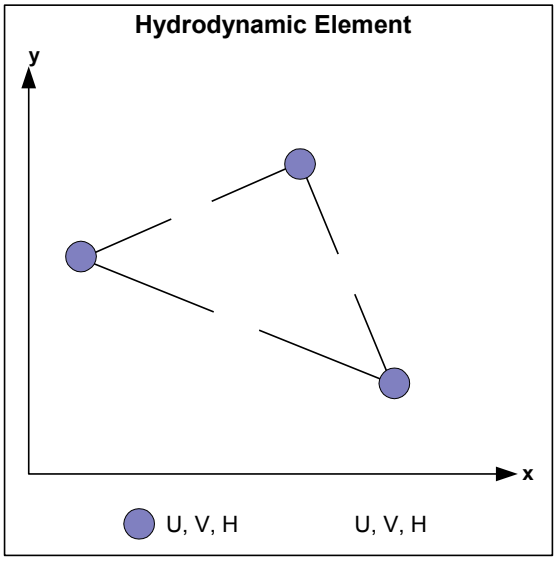
AquaDyn is based on the Synexus Global Simulation System. This is a powerful development environment designed to help engineers and scientists to simulate environmental phenomena and engineering problems. The system is an easy-to-use, flexible and efficient tool offering powerful control over all simulation parameters and visualisation of results. Its particular strength is that it allows for multiple studies (each complete study is contained within one compact file) and analyses "what if…" scenarios rapidly.

Simulation results can be exchanged among users through e-mail, which enhances tremendously the diffusion of information and technical support. The Simulation System interacts with AquaDyn in a client-server relationship. Other client applications like Microsoft Excel or a Microsoft Visual Basic application can be used to control AquaDyn using its application programming language (API). This last feature is useful to couple AquaDyn to a real-time monitoring and forecasting system. Forecasting water levels at specific locations allows AquaDyn to forecast floods, critical discharge rates, water quality thresholds, etc., at any point of the river.

Hydro-Québec of Canada established the idea for the AquaDyn model and the software programming, architecture and interface design were developed by Synexus Global. The first version of AquaDyn was developed in 1991 and was used for internal studies at Hydro-Québec. AquaDyn became a commercial product in 1994, has evolved, and its latest version is presently used in more than 20 countries.

GOVERNING EQUATIONS

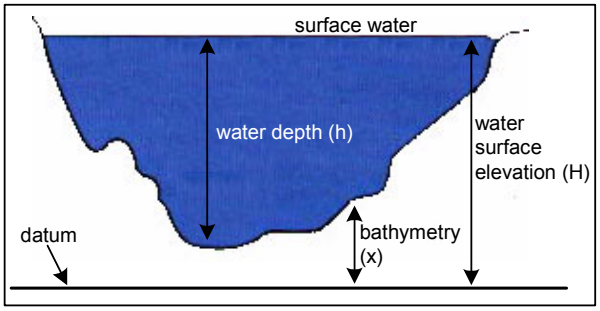
The numerical model used by AquaDyn for surface water modelling software is a two-dimensional depth-averaged representation of the hydrodynamic and transport flow (the particle transport or heat diffusion) in an open channel. The mathematical equations are based on the non-linear St. Venant equations. AquaDyn solves the equation using a triangular finite-element Galerkin method (using 3,6,6 degrees of freedom for the water level (H) and the two horizontal velocities (U, V) respectively.)



Above: Numerical Integration Method

It is therefore possible to simulate open channel flow over a domain of an arbitrary complex shape. The resolution of the non-linear equation is done with the Residual Newton-Raphson. Finally, a Crank-Nicholson time discretisation for time dependant problems is used (unsteady regime.)

The equation takes into consideration the water bed topology (bathymetry), water bed friction with the Manning equation, the wind influence modelled as surface dragging force, Coriolis effect due to the rotation of the earth and the turbulent viscosity (enables simulation of vortex flow). Moreover, the transport equation allows for heat exchange with air, particle decay in a steady or unsteady hydrodynamic flow. AquaDyn handles the dry element to simulate water propagation over a flood plain.



Above: General Schematic of Water Flow

Several convenient boundary conditions can be imposed at the boundary of the simulation region (impose water level, tangential and normal velocity, water flow, pollutant concentration, sink and source concentration flow within element. These boundary conditions can be time dependent to simulate tidal flow in estuaries.

AquaDyn is robust and convergence is easily obtained in most hydrodynamic regimes with an initial default condition. It can perform sensitivity analysis by beginning a new simulation from a previously obtained solution leading to rapid convergence (within three iterations) permitting rapid studies of multiple scenarios.

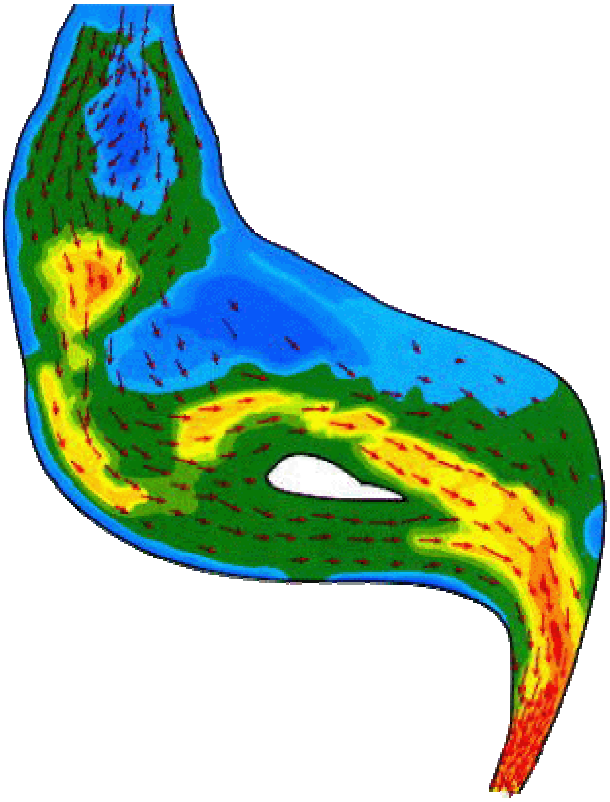
During the last ten years, AquaDyn has been used in numerous engineering projects, by Civil Engineers, Environmentalists, and Researchers. An example of some projects is given below.

Complex Flood Plain Flow

This study shows the flow pattern of a 2km-river section of Ste-Marguerite River in the province of Québec. This river section is characterised by a complex flood plain topography, which includes flood plain embankments, a channel bifurcation, and an island. The river flow is torrential upstream followed with a hydraulic jump to bring the river to a fluvial regime in the central part.

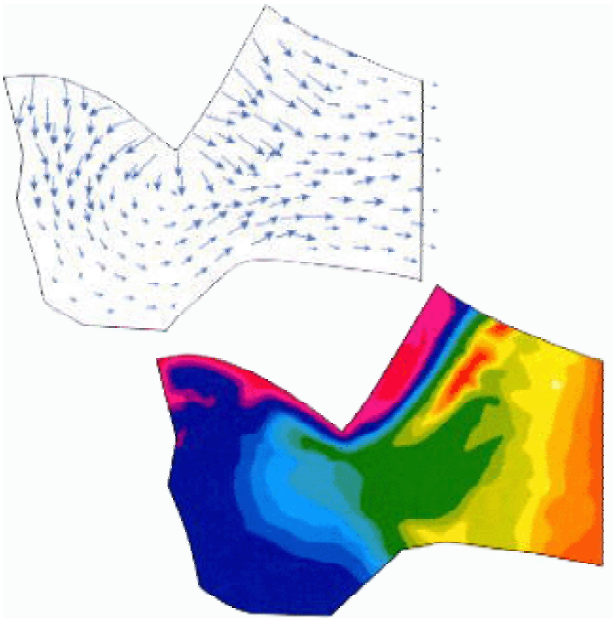
Finally, in the lower part the flow becomes torrential where the river width decreases significantly.

This study demonstrates the flow pattern of water running over a V-shaped weir gate and continuing towards the right. The water drops by 2m (from pink to blue region), followed by a hydraulic jump on the right (after the blue region, the green-red-green.) The arrow field clearly indicates the direction of the flow.



Key: Speed arrow field and bed elevation are shown in colour (blue for swallow or dry region up to Red for the depth region). Results obtained from Softkit-CERCA, Canada.

Below: Flow Over V-shape Weir Gate



Partial Dam Break

This example is taken from Synexus Global Canada and illustrates a partial dam break for a reservoir located on the left side. Initially the reservoir level is at 10m and downstream of the dam at 5m. At 7.2secs, after the breach, the water level has decreased in the reservoir (negative wave propagating towards the left) and the water level downstream increases rapidly.

DETAILED RIVER ROUTING

AquaDyn is part of Synexus Global's product suite to provide large-scale, multi-purpose water resource utilisation solutions. For example, Vista Decision Support System is used to study and/or plan water releases from reservoirs, hydroelectric generation, and water supply scenarios. The results from these model applications include water level trajectories, and time series of discharges into and out of regulating reservoirs. These variables are used as boundary conditions for AquaDyn, to study detailed two-dimensional patterns in reservoirs or river reaches, and associated temperature variations, or conservative water quality variations over time.

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System Requirements…

AquaDyn and the Simulation System run on Microsoft Windows and the following hardware requirements are recommended:

- Pentium II (666 MHz) and up,
- 128 Mb RAM (more for running large simulations involving thousands of elements),
- Microsoft Windows 95, 98, NT4, NT5, 2000, or XP,
- 100 MB of free hard disk space (15 Mb for the installation and 85 Mb for swap-space when required).

AquaDyn can be obtained from the following:

- www.synexusglobal.com,
- directly from www.technum.com,
- in England from www.geomen.co.uk.

Readers may be interested to know that a full copy of AquaDyn can be downloaded free of charge for a trial period.