Report for Student Collaboration for Gathering and Dissemination of GIS-based Hydrology and Hydraulic Modeling Tools

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The project was initiated by U.S. Bureau of Reclamation in the context of increasing applications of Geographic Information System (GIS) and satellite remote sensing data and techniques to the field of hydrology and hydraulics. GIS is becoming the most common spatial platform to pre- and post-process information for water related modeling, and to share data and information. A variety of federal and non-federal entities are interested in developing tools and methods for taking advantage of GIS, particularly the non-proprietary data and applications, to address water-related problems. To this end, the objective of this project was to gather and disseminate GIS-based hydrology and hydraulic modeling tools, providing information on how to access the data and applications, and how to receive training and support.

Gathering and dissemination of the inventory of GIS-based applications were conducted primarily on the basis of an established web site at Texas A&M University (http://hydrologicmodels.tamu.edu/) and relevant questionnaires. The web site contains a list of questionnaires of a variety of hydrologic and hydraulic models, which has been established between the Bureau of Reclamation and Texas A&M University under the supervision of Dr. Vijay P. Singh and is aware well by the hydrologic and hydraulic community.

The project has been conducting from June 1, 2009 by Di Long, a Ph.D. student from Department of Biological & Agricultural Engineering at Texas A&M University under the direction of Dr. Vijay Singh. Enclosed is a summary of what we have done for this project and of updates for the established web site. Further suggestions on refining the web site and extending the project are also given.

1. Organization of Existing Hydrologic and Hydraulic Questionnaires

The watershed models are of different types since they have been developed for different uses and purposes (Singh and Frevert, 2002). Nevertheless, many of them share some structural similarities because their underlying assumptions are similar, and some of the models are distinctly different. Singh (1995) classified models based on (1) process description, (2) time scale, (3) space scale, (4) techniques of solution, (5) land use, and (6) model use. ASCE (1996) reviewed and categorized flood analysis models into (1) event-based precipitation-runoff models, (2) continuous precipitation-runoff models, (3) steady flow routing models, (4) unsteady-flow flood routing models, (5) reservoir regulation models, and (6) flood frequency analysis models. Wurbs (1998) highlighted the availability and role of generalized computer modeling packages and outlined the institutional setting within which the models are disseminated throughout the water community. Generalized water resources models were classified into (1) watershed models, (2) river hydraulics models, (3) river and reservoir water quality models, (4) reservoir/river system operation models, (5) ground water models, (6) water distribution system hydraulic models, and (7) demand forecasting models. Todini (1988) classified hydrologic models according to the degree of priori knowledge that can be introduced at
the model specification stage into four groups: (1) purely stochastic models, (2) lumped integral models, (3) distributed integral models, and (4) distributed differential models.

There are totally 93 hydrologic and hydraulic models being investigated for the web site model inventory. The first version questionnaires were sent to modelers in the year 1999, 2007 and 2008, respectively. Such questionnaires that are currently listed on our web site are the latest ones for the three surveys conducted. All these models were attempted to be grouped into partially overlapped 7 categories by comprehensively and synthetically taking the physical basis, structure, techniques and purposes of models into considerations. There are: Precipitation-Runoff Models (54), Hydraulic Models (11), River and Watershed Management Models (9), GIS Application in Hydrology and Hydraulics (13), Regional and Global Hydrology Models (2), Stochastic Models (2), and Parameter Analysis Model (2), respectively. The Precipitation-Runoff models were further categorized into 5 groups. There are Distributed Models (17), Lumped and Parametric Models (20), Environmental Models (12), Monthly Water Balance models (3), and Real Time Flow Forecasting Model (2). It is apparent that for effectively disseminating information about the GIS-based hydrologic and hydraulic models, they were listed as a major independent category of the inventory. Inevitably, one model could be placed in multiple categories. For example, the Soil and Water Assessment Tool (SWAT) is listed in both categories of the Precipitation-Runoff Model and GIS Application in Hydrology and Hydraulics.

2. Completion of a questionnaire survey on GIS-based hydrologic and hydraulic models

We received 13 questionnaires (the second version questionnaire) about GIS-based hydrologic and hydraulic models. The questionnaire constitutes questions about: (1) Brief description; (2) Platform/operating system; (3) Web-based or desktop application; (4) Data requirement; (5) Data format and compatibility; (6) Will the application import and export data files? (7) Is the application flexible to couple with external programs and user created executables? (8) Are system and user documentation available? (9) Are example applications available? (10) Does the application require prior installation of ESRI software? (11) If so, which products? (12) Is there a user group or hotline-type support? The 12 questions portray basic information on the techniques and software of the GIS-based models for the public users, providing the potential users with basic information to facilitate selection and further investigation of a GIS-based model.


3. Completion of a new questionnaire survey for hydrologic and hydraulic models on the aspects of GIS and remote sensing data and techniques

We designed the third version questionnaire for further gathering information on application of GIS and satellite data and techniques in a spectrum of hydrologic modeling and applications and updated such information for our web site. In addition to describing
the computer system, operating system, programming language and software dependencies involved in the second version questionnaire, the new questionnaire attempts to describe a GIS-based model from a hydrologic or hydraulic perspective. The new questionnaire contains items like model type, model objective, model structure or mathematical basis, model parameter, spatial scale employed in the model, temporal scale employed in the model, input data requirement, input data format, model output, output data format, parameter estimation or model calibration, model testing and verification, model sensitivity, model reliability and model application or case studies. This would provide the users with more detailed information on practical applications. The third version questionnaire is shown at the end of the report.

The questionnaire survey was carried out on December 21, 2009, with disseminating to more than 30 institutes, organizations and developers. We have received 16 feedbacks until now and uploaded them to our web site. This questionnaires cover a more broad range of hydrologic and hydraulic models as well as more detailed and wide descriptions about GIS applications in these models.

4. Investigation of newly developed hydrologic and hydraulic models and their integrated applications of GIS techniques

We searched for newly developed GIS-based hydrologic and hydraulic as well as those models relevant to GIS applications through literature database like ISI Web of Knowledge, Scopus and Engineering, Village and Google Scholar, and continuously disseminated questionnaires to modelers.

5. Completion of a conference paper

We collaborated with the Hydrologic and Hydraulic GIS Applications Workgroup for a conference paper on ‘Federal Interagency Hydrology and Hydraulics GIS Applications Workgroup’ submitted to the Joint Federal Interagency Conferences 2010, Las Vegas, Nevada to be held on June 27 to July 1, 2010.

6. Suggestions and Recommendations

It is suggested that the model inventory could be systematically updated every two or three years. Traditional and newly developed models are increasingly making use of GIS and satellite data and techniques for simulation. The newer use and integration of GIS techniques require a timely update for the model inventory. Dissemination of the web site could be realized through the modelers’ Email list established and suggesting them to circulate amongst their colleagues and students. In addition, we may take opportunities to attend hydrologic modeling and water resources related conferences to let people know our web site. To this end, the incoming Joint Federal Interagency Conferences 2010 is a great opportunity. As a complement for the update of the model inventory, we may upload the questionnaires on our web site and modelers can download them to update models’ information in terms of their needs at anytime.

Continued gathering and disseminating questionnaires about the latest survey has not been completely finished; there are still certain Email addresses of modelers needed to be corrected and searched for to get into contact. A comprehensive and systematic
contrast and comparison of all hydrologic and hydraulic models being investigated on the utilization of GIS-based techniques is desired for providing the users with more meaningful information and reference for selection and application of models in their own research. The research is suggested to be extended by Sep 1, 2010.

References
The Texas A&M University and U.S. Bureau of Reclamation Hydrologic Modeling Inventory (HMI) Questionnaire

December 19, 2009

This document is the Texas A&M University (TAMU)-U.S. Bureau of Reclamation (USBR) Hydrologic Modeling Inventory (HMI) Questionnaire. Your response to this questionnaire will provide the basis for the HMI on-line database accessed through the HMI Web page. Modelers can interactively obtain information about your model through this Web-enabled model inventory complete with search capabilities. The information you provide will hopefully foster wider interest in your model. A designated contact will be explicitly acknowledged and posted within the HMI Web page database.

Given more and more applications of GIS and remote sensing techniques to hydrologic modeling, water resources and watershed management, the Subcommittee on Hydrology has recently set up a workgroup to organize and publicize information on GIS applications in the fields of hydrology and hydraulics. This scope has been expanded to include related water quality, watershed management, and ecological sciences GIS applications. This work is intended to make information on GIS applications in hydrology and hydraulics more generally available. This questionnaire is also designed to gather limited but key information about a particular GIS application in order for a potential user to decide if the application fits his/her computer system, data requirements, and physical system to be modeled.

These applications should be public domain and supported by user documentation. Availability on the Web is not necessary if the application can be distributed on CD ROM or through e-mail requests. If a short abstract, fact sheet, or technical paper is available on the application, please attach a copy. Please respond this email before 22 January, 2010.

Name of Model, Date, Version Number:

Contact (with e-mail, web site, and/or phone number):

Brief Description:

Model Type:

Model Objective(s):

Model Structure or Mathematical Basis:

Spatial Scale Employed in the Model:

Temporal Scale Employed in the Model:

Input Data Requirement:

Model Output:

Input Data Format:

Output Data Format:
Parameter Estimation/Model Calibration:

Model Testing and Verification:

Model Sensitivity:

Model Reliability:

Model Application/Case Studies:

Platform/Operating System:

Programming language and software:

Web-based or desk-top application?

Is the application flexible to couple with external programs and user created executables?

Are system and user documentation available? (Web site)

Are example applications available? (Web site)

Is there a user group or hotline-type support? (Website)

Other Comments:

Please return the questionnaire to Di Long at descartes66@tamu.edu or Dr. Vijay P. Singh, Texas A&M University, Office: (979)-845-7028, E-mail: vsingh@tamu.edu. Address: Scoates Hall 321, Texas A&M University, College Station, TX, 77843-2117
Guidelines for Responding to the Texas A&M University and U.S. Bureau of Reclamation Hydrologic Modeling Inventory (HMI) Questionnaire

Introduction to Model Questionnaire

This document provides guidelines for completion of the Texas A&M University (TAMU)-U.S. Bureau of Reclamation (USBR) Hydrologic Modeling Inventory (HMI) Questionnaire. Your response to this questionnaire will provide the basis for the HMI on-line database accessed through the HMI Web page. Modelers can interactively obtain information about your model through this Web-enabled model inventory complete with search capabilities. The information you provide will hopefully foster wider interest in your model. A designated contact will be explicitly acknowledged and posted within the HMI Web page database.

Please find attached a sample response form. You mail reply by E-mail, Fax, US Post. If you are not able to complete the questionnaire, please forward suitable documents that will permit completion of the questionnaire for your model. Models have recently been summarized in the literature by Wurbs (1998), Ahuja, et al (1995), and Barton (1993). The organization of the modeling questionnaire is based on characterization of past model developments by Singh (1995) and Singh & Frevert (2002a, b, 2006).

Please see our web page: [http://hydrologicmodels.tamu.edu](http://hydrologicmodels.tamu.edu) for more details about our approach to developing this inventory system.

Questionnaire Response Guidance:

The elements of the questionnaire will include the following topics to be filled out by the model developer/support group:

Name of Model, Date, Version Number:
Contact (with e-mail, web site, and/or phone number):
Brief Description:
Model Type:
Model Objective(s):
Model Structure or Mathematical Basis:
Spatial Scale Employed in the Model:
Temporal Scale Employed in the Model:
Input Data Requirement:
Model Output:
Input Data Format:
Output Data Format:
Parameter Estimation/Model Calibration:
Model Testing and Verification:
Model Sensitivity:
Model Reliability:
Model Application/Case Studies:
Platform/Operating System:
Programming language and software:
Web-based or desk-top application?
Is the application flexible to couple with external programs and user created executables?
Are system and user documentation available?  (Web site)
Are example applications available? (Web site)
Is there a user group or hotline-type support? (Website)
Other Comments:

Name of Model, Date, Version Number
Format:  Text title (Acronym)
Limit to one phrase

For Example:
  Flood Hydrograph Package (HEC-1)
  The HEC Hydrologic Modeling System (HEC-HMS)
  The GIS Weasel, 4/2008, v 1.0

Contact (with e-mail, web site, and/or phone number)
Provide the Agency and Office contacts information, including voice telephone, fax and e-mail and (optionally) web URL.

Model Type
This section states the type of model developed. For example, hydrologic models can be classified as event-based precipitation-runoff models, continuous precipitation runoff models, snowmelt runoff models, steady-flow flood routing models, unsteady-flow flood routing models, reservoir regulation models, flood frequency models, etc.

For Example:
  The HEC-1 model is an event-based precipitation –runoff simulation model.

Model Objective(s)
Describe purpose of the model.

For Example:
  The purpose of HEC-1 is the simulation of hydrologic processes for designing flood damage reduction projects.

Model Structure or Mathematical Basis
Describe the following items:
  1. The type of the basins for which the model has been developed.
     For example: The basins may be rural, urban, agricultural, mountainous, etc.
  2. The size of the basins for which the model applies.
     For example: The basins may be small, medium, or large.
3. The nature of simulation that the model undertakes. For example: The simulation may be **event-based** or **continuous**.

4. Components of the hydrologic cycle represented in model formulation. For example: Precipitation, infiltration, evaporation, interception, detention storage, overland flow, channel flow.

5. The underlying hypotheses (or the type of equations employed) that form the basis of the modeling approach to each component process, including:

- Precipitation (Rain, snow, etc.)
- Infiltration
- Evaporation
- Interception
- Detention storage
- Overland flow
- Channel flow
- Groundwater flow
- Snow melt runoff

Mathematical formulation of the model components:

*For example:* Lumped, Distributed, Deterministic, or Probabilistic

For your assistance, the following list of terms is offered to assist you in providing the requested information about the model structure. This list is only illustrative and not intended to be exhaustive, please make any substitutions needed for your model:

<table>
<thead>
<tr>
<th><strong>Precipitation</strong></th>
<th><strong>Infiltration</strong></th>
<th><strong>Evaporation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean areal precipitation is estimated using the arithmetic mean, Theissen polygon, or isohyetal method.</td>
<td>The rate of infiltration is determined by the Green-Ampt, Horton, Phillip, or Smith equation.</td>
<td>Evapotranspiration is estimated using Penman, Penman-Monteith, Jensen-Hayes, Blaney-Criddle or Hargreve method.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Interception</strong></th>
<th><strong>Detention storage</strong></th>
<th><strong>Overland flow</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The amount of interception is estimated as a fraction of the total precipitation amount or using an negative exponential equation.</td>
<td>The detention storage is estimated using either an exponential function or a power function or is taken as a constant of the precipitation amount.</td>
<td>The overland flow is determined using the kinematic wave theory or the linear reservoir theory.</td>
</tr>
</tbody>
</table>
### Channel flow
Flow routing in channels is computed by linear channel theory (e.g. Muskingum method, etc.), kinematic wave theory, diffusion wave theory, or dynamic wave theory.

### Groundwater flow
The base flow is estimated using the linear reservoir theory or Boussinesq theory.

### Snow melt runoff
Snow melt runoff routing is performed using empirical methods, linear reservoir theory or kinematic wave theory.

## Spatial Scale Employed in the Model
This section describes the spatial representation used in the model. For example, the watershed can be treated as a single unit or as a network of sub-watersheds.

**For Example:**
*In HEC-1 the watershed is decomposed into a network of homogeneous sub-watersheds, each having individualized parameters and processes.*

## Temporal Scale Employed in the Model
This section describes whether the model is an “event based” model or a daily, weekly, monthly, yearly model.

**For Example:**
The HEC-1 model is an event-based model, simulating the rainfall-runoff relationship for an individual rainfall event.

## Input Data Requirements
This section describes the data required for application of the model (which follows from the model structure). The data may pertain to the following elements as needed by the model:

- Watershed characteristics data (topographic map, drainage area, channel lengths, drainage areas of channels, slope, etc.)
- Climate data (rainfall intensity in time, temperature [daily, max, min, etc.], humidity, vapor pressure, wind velocity, etc.)
- Stream flow data (measured discharge in regular time steps)
- Soils data (type, structure. Texture, infiltration characteristics)
- Land use data (cropping patterns, vegetation, percent imperviousness, etc.)

## Model Output
This section describes the type of output the model produces.

**For Example:**
HEC-1 produces runoff water discharge output with user specified time intervals (minutes/hours).

## Input Data format
This section describes the format of input for each category, Raster data? Vector data? Like DEM in ESRI GRID, TIFF/GeoTIFF, etc. Land use in ESRI GRID, Arcview
2009 HMI Questionnaire

Shapefile, ESRI Arcinfo Coverage, etc., Precipitation, temperatures, wind velocity in TXT, ASCII, etc.

Output Data format
This section provides the format of output data, like streamflows in ASCII, distribution of pollution load in ESRI GRID, etc.

Parameter Estimation / Model Calibration
This section describes the parameters to be estimated and the calibration algorithm used to pursue calibration.

For Example:
HEC-1 can have parameters estimated by the user or HEC-1 can be instructed to use an automated parameter search algorithm.

Model Testing & Verification
This section describes whether the model has been tested and verified extensively using split sampling data and split sampling watershed techniques, involving other watersheds than calibration watersheds. Are test data sets available to the user for modeling use training and model operation confirmation?

For Example:
HEC-1 has been extensively tested using data and watersheds other than those used in calibration / parameter estimation of HEC-1 as described in the user manual, as evidenced by the wide spread use of the model in the consulting community.

Model Sensitivity
This section describes the sensitivity of the model to its parameters and its components. Has a sensitivity analysis been performed for the model and shared to the general user community?

For Example:
1) In HEC-1 the importance of evapotranspiration is considered inconsequential and is therefore not included in the model, for HEC-1 is an “event based” model and evapotranspiration is inconsequential during rainfall.
2) In HEC-1 the basin lag parameter is one of the most important parameters when using the unit hydrograph method for rain excess-runoff simulation.

Model Reliability
This section describes the confidence in the model results. Consider a) the repeatability of the model, b) accuracy of output as compared with real observations, and c) the Probability of obtaining consistently accurate model predictions.

For Example:
HEC-1 is widely accepted in the public and consulting community as a hydrograph simulation package and is considered to predict within XXX percent accuracy.
2009 HMI Questionnaire

Model Application/Case Studies
This section describes where the model is / has been typically applied. How does the user community apply the model to real world problem settings?

For Example:
HEC-1 has been applied to design and planning of a wide range of civil works involving flood prediction, flood protection, urban drainage, dam safety and breach evaluation, flood damage reduction, among others.

Platform/Operating System
This section describes the type of computer / operating system, memory and disk storage for operating the model.

For Example:
HEC-1 is available on 486 PC running DOS (DOS under Win3.1, Win95, WinNT) XXXX Meg. Memory and YYYYY Meg. Disk space. Anywhere ArcInfo Workstation runs: Windows and a handful of Unix flavors.

Programming Language and Software
This section provides what kind of programming language the software system uses and what kind of relevant software are required to drive the model

For Example:
The GIS Weasel software system uses a GIS-based graphical user interface (GUI), the C programming language, and external scripting languages. The software will run on any computing platform where ArcInfo Workstation (version 8.0.2 or later) and the GRID extension are accessible. The user controls the processing of the GIS Weasel by interacting with menus, maps, and tables.

Other Comments
This section provides information and experiences that should be available for the reader of the modeling inventory not contained in previous categories in a limited free form text.

For Example:
HEC-1 has been employed in US, other developed countries, and developing countries. Third party instruction (public and private) for specific application of the model is readily available to the professional community.