Trends in Integrated Hydrologic Modeling

by

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Presentation Outline

- Perspective on Integration and Modeling
- Evolution of Integrated Modeling
- Examples from Recent and Ongoing Work
- Ideas for Future
- Conclusions
The purpose of a model is to support resource management decisions. All other truths on this subject are merely derivative.
Integration is an overused word..

- Integrated Groundwater Surface water Model (IGSM)
- Integrated Hydrogeologic Modeling System (InHMS)
- Integrated Watershed Management
- Integrated Regional Water Management Plan (Proposition 50)

..........
Dimensions of Integration

- Integration across various dimensions of water – Surface water, Groundwater, Water Quality
- Integration across natural resources – land and environmental process, terrestrial and aquatic systems
- Integration across social and economic development
An Example ...
Purpose of a Model Did Not Change …
But the Use of a Model Changed …

\[
\begin{align*}
\text{started as a scientific tool to understand} \\
\text{physical relationships} \\
\text{now used for multiple purposes} \\
\text{from scientific analysis to resolve political and legal conflicts}
\end{align*}
\]
Resource Management Conflicts...

SCIENTIFIC FACTS
things that are known to be true

PUBLIC VALUES
things that are regarded as desirable
Problem Domain and Solution Needs ...

FACTS

VALUES

POLITICAL

COMPUTATIONAL

CULTURAL

LEGAL
Model is asked to do all this..

FACTS

POLITICAL
- increase credibility
- foster collaboration
- provide transparency

COMPUTATIONAL
- provide ease of use
- integrate information
- enable rapid analysis

CULTURAL
- support multiple viewpoints
- foster communication
- enhance understanding

LEGAL
- provide documentation
- facilitate traceability
- enable verification

VALUES

On top of that we have …

} more theories
} more digital data
} faster computers
} more numerical algorithms
} GIS
} more public scrutiny

} … But less time
Integration is needed ….

“California has an urgent need to develop an integrated set of analytical tools and supporting data to strategically evaluate the wide range of options available for water management problems in California.”

CWEMF Strategic Analysis Framework Initiative
Different Levels of Integration …

- **Component Integration**
  - Physical System modeled as a whole (SW, GW, Land Use …)

- **Process Integration**
  - Automation of data exchange among models

- **Database Integration**
  - Integration of models with databases; shared databases

- **User Interface Integration**
  - Single interface to analyze model input/output
Component Integration
IGSM, MIKESHE

Evapotranspiration

Rain

Direct Runoff

Consumptive Use Model

Infiltration

Soil Moisture Storage

Accretion to Soil Moisture

Surface Return Flow

Irrigation Water

Surface Water Diversion

Recharge through unsaturated zone

Groundwater Pumping

Baseflow/Stream Seepage Loss

Groundwater Storage

Stream System

Operations Models

MODFLOW
| Output of one model is the input of next |
| Users handle the interfacing and data transfer |
| No feed back |
Process Integration

Traditional Approach: 2 Weeks

- Operations Model (PROSIM)
  - Cut & Paste
  - Temperature Model
    - Cut & Paste
    - Fish Mortality Model
      - Post-Processing

Integrated Approach: 1 Day

- Operations Model (PROSIM)
  - Menu Driven Automated Processing and Visualization
  - Temperature Model
    - Menu Driven Automated Processing and Visualization
  - Fish Mortality Model
    - Menu Driven Automated Processing and Visualization
Data and User Interface Integration
Single Model

- Address a single issue
- Self-contained
- No Linking
Integrated Models with feedback loops
Mostly designed to run on a single machine and not via networks/internet

Data and User Interface Integration
Multiple Models
This was all past ..
What about Future ...
Integrated Hydrologic Modeling
Ideas for Future

} Super Modeling
  - One big model/interface that includes many models and all data
  - Limited to the models within the Super Model

} Modular and Plug & Play Modeling
  - Any number of models/modules could be added to the big model
  - Interfaces could talk to each other & link to models and data

} Cross Domain Modeling
  - Models in each domain should be capable of transferring data and/or being employed by models in other domains
  - Modular and expandable
Integrated Databases

- Shared data source
- Links to integrated models
- Links to other databases
- Distributed computing
- Web enablement
Integrated Interfaces

- GIS Based
- Web Based
- Links to models and databases
- Single Graphical User Interface
Memorandum of Understanding (MOU) among eight Federal Agencies in 2001

- Cooperation in R&D of multimedia environmental models, software, and databases
- Pursue common technology
- Protocols for linking disparate databases and models under a common model-data framework.
EU Water Framework Directive

- Adopted in 2000
- Focus is Integrated River Basin Management
- Open Modeling Interface (OpenMI) that will simplify the linking of hydrology related models.
Analogous to plug and play peripherals
Everglades Restoration
Search for a Supermodel

} Driver
  | Integrated Watershed Management

} Supermodel or Assortment of Models?
  | Both approaches are pursued simultaneously
  | Tradeoffs between scale and level of detail
  | Dangers of oversimplification
  | Balance between complexity and over-parameterization
Hydrosphere
Fully Integrated Surface/Subsurface, WQ, and Sedmentation

\begin{itemize}
  \item \textbf{Driver}
    \begin{itemize}
      \item Watershed Analysis
    \end{itemize}
  \item \textbf{Supermodel of Watershed?}
    \begin{itemize}
      \item One system of equations for surface, tile-drain, and subsurface
      \item Advective-dispersive transport
      \item Temperature, DO, BOD and Erosion/ Sedimentation
    \end{itemize}
\end{itemize}
USGS & Bureau of Reclamation Cooperative Effort to Develop Database Centered DSS

- Combine USGS Modular Modeling System (MMS) and BOR RiverWare Tools
- Watershed and River System Management Program (WARSMP)
Snake River DSS
Conceptual Architecture
Decision Support System
Tampa Bay, Florida

Field Data Collection
- SCADA
- Manual
- Laboratory System
- Other Sources

Enterprise Database Management System

Data Collection Systems and Database

DSS Manager
- OROP Production Schedule
- Data Analysis & Evaluation
- Reporting
- Queries
- Model Simulations

Models and Analytical Tools
- OROP
  - IHM Hydrologic Model
  - Demand Forecasting
  - Surface Water Models
  - Trade-off Analysis Model

User Secure Access Modes
DSS Development Costs

- **Snake River, Idaho**
  - Multiple Phases (completed) – $4 million

- **Tampa Bay, Florida**
  - Phase I – Needs Assessment and Implementation Plan ($970,000 - 9 months)
  - Phase II (Ongoing) – Database re-design, DSS manager application development, SCADA improvements ($16 million – multi-year)

- **Colorado River, Colorado**
  - Multiple Phases (ongoing) – $20 million
Integration is said easier than done

At a conceptual level, integration receives considerable support

At a working level, there are numerous difficulties

- Lack of ease of use
- Lack of visible progress
- Lack of immediate utility
- Changing technology
- Institutional issues
- Costs – development and maintenance
Change of Approach is Needed

- Design
- Development
- Implementation
Integration Challenges - Design

What We Have

- Lots of Data, Models, and Maps
- Lots of ways to look into those

What We Need

- Data Access & Visualization
- Rapid Comparative Analysis
- On the Fly Analysis & Synthesis
- Adhoc Queries
- Drill-down to more details

What Matters

4 Ease of Use
4 Time Efficiency
4 Presentable to Managers/Stakeholders
4 Flexibility
Integration Challenges - Architecture

Institutional Setting
- Data centralization may not be a choice
- Data replication is costly
- Organizational change

Diverse Data & Models
- Data universe is unknown
- Data standardization takes too long
- Rigid data rules make the software brittle
- Changing models, analytical tools

New Science
1. New knowledge, new data, new models
2. Resource interrelationships unfolding
Successful Development Approach

- Open Architecture
- No dependency on a single database or model
- Mix of data centralization and distributed computing
- No dependency on proprietary technology
- Evolutionary, flexible, and adaptable
- Easy Maintenance
Successful Implementation Approach

Close Association With Client, TAC, Member Agencies, Technical Specialists, Managers and Decision-Makers

4 DMS Configuration
4 User Involvement
4 Prioritize Data and Features

Deploy Selected Modules (GW)

Add More Modules (SW data, TMDL, others)

Add More Modules

User Feedback

Incremental Delivery
Integrated Information Environment (IIE)
A modular software architecture

Data Management Environment (DME)
- Groundwater Quality
- Groundwater Levels
- POTW Discharge
- Surface Water Quality
- Streamflow
- Additional Future Data

Geographic Information Management Environment (GME)
- Maps
- DEM
- Graphs
- Satellite

Model Management Environment (MME)
- IGSM2
- MODFLOW
- Qual II-E
- Spreadsheet Models
- Statistical Models
- Economic Models
- Planning Models
- Other Models
CALFED Integration and Visualization System
CALFED Integration and Visualization System
Summary

} Supermodeling
    | Oversimplified or overly complex
    | Cost – time and money

} Plug and Plays Models
    | Consistency of chosen models
    | More contentions

} Cross Domain Modeling
    | Flexible and adaptable
    | Needs successful integration approach
Conclusions

- Integration is a necessity
- Integration “always” is not a good approach
- Define scope and scale of integration first
- Avoid proprietary tools
- Serve users – not technology
- Deliver incrementally
We need a purpose-driven approach

The purpose of a model is to support resource management decisions. All other truths on this subject are merely derivative.
Questions?