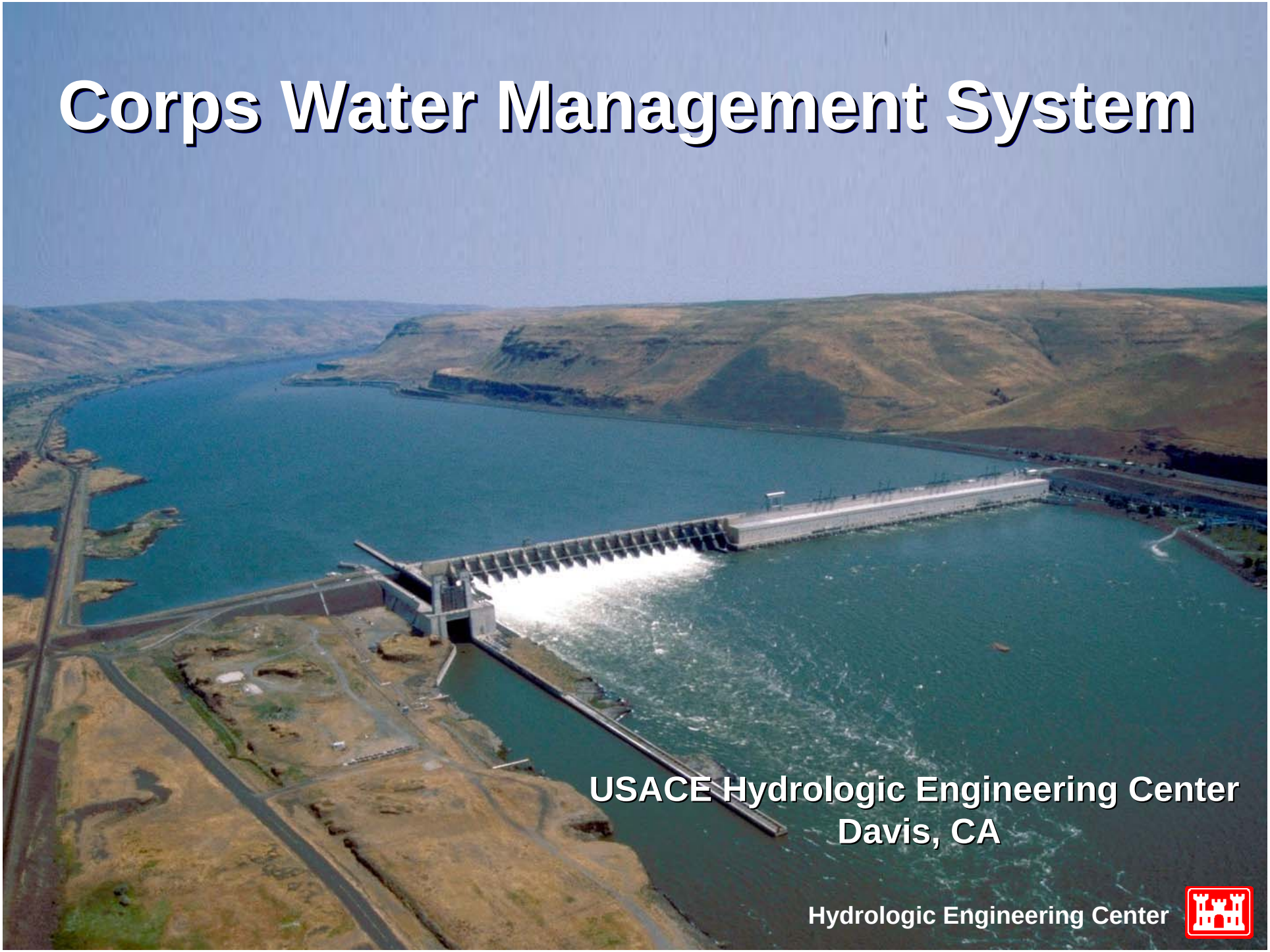
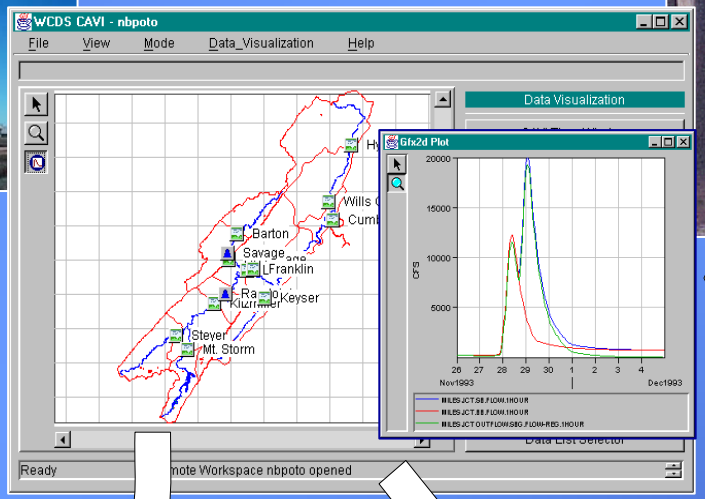
Corps Water Management System

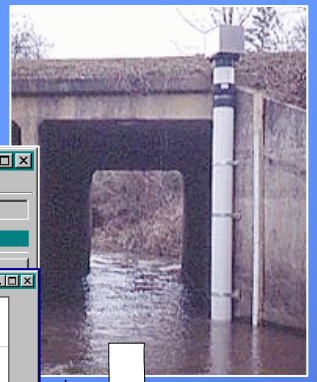


USACE Hydrologic Engineering Center
Davis, CA

Water Control Mission

- **Real-Time Decision Support for Water Management**
- **700+ Multipurpose Reservoirs and Flow Control Structures, Thousands of Miles of Levees**
- **Expanded Corporate Web-Based Information**

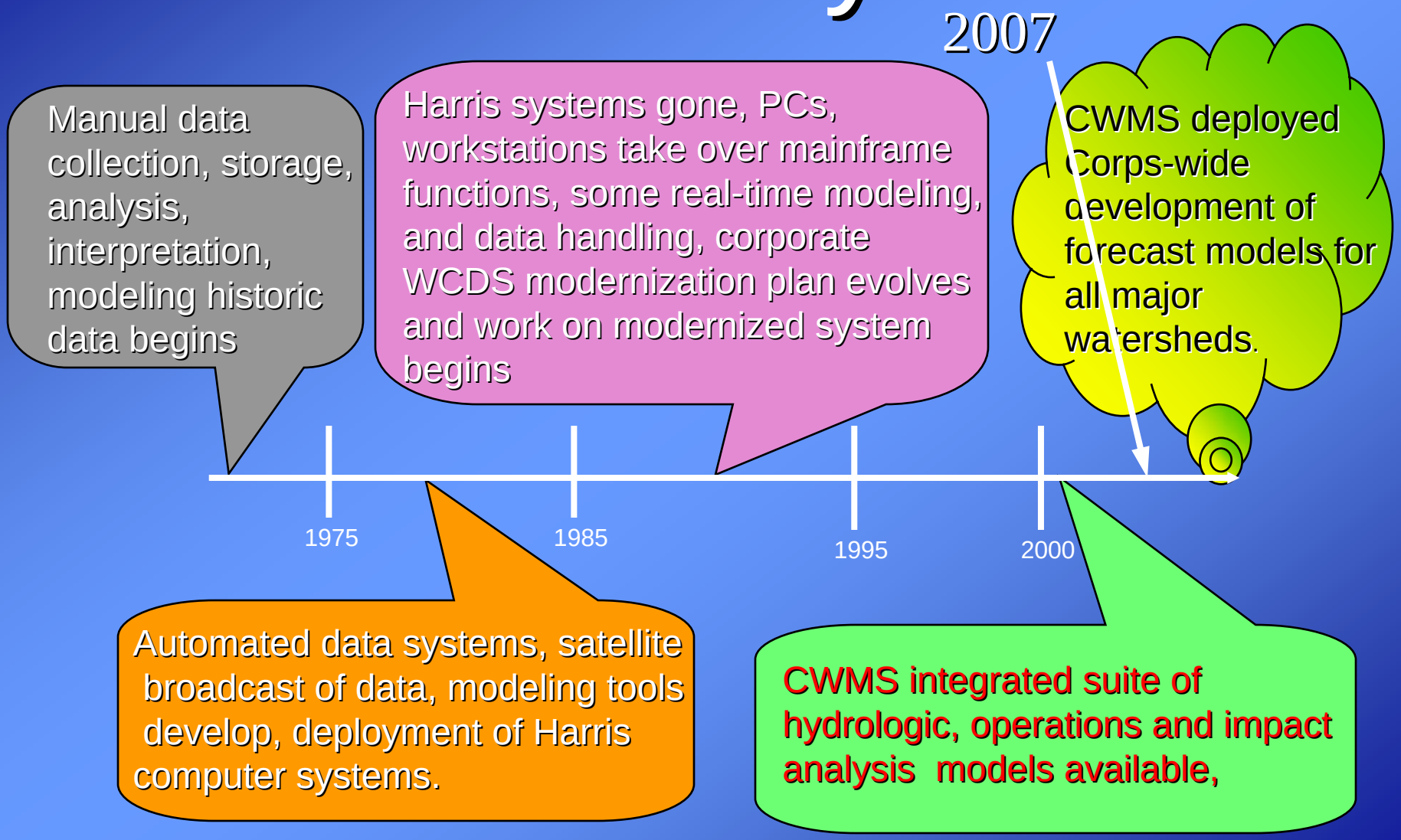




CWMS

An integrated system of hardware, software, and communication resources supporting Corps' real-time water control mission

History


2007
Manual data collection, storage, analysis, interpretation, modeling historic data begins
Harris systems gone, PCs, workstations take over mainframe functions, some real-time modeling, and data handling, corporate WCDS modernization plan evolves and work on modernized system begins
CWMS deployed Corps-wide development of forecast models for all major watersheds.
1975
1985
1995
2000
Automated data systems, satellite broadcast of data, modeling tools develop, deployment of Harris computer systems.
CWMS integrated suite of hydrologic, operations and impact analysis models available,

CWMS Modernization Project

- Hardware/Software Modernization - 1991.
- Hardware Modernization Completed; SUN Workstations.
- Software Development 1997 - 2001. Fixed schedule and budgeted project – PRIP funded.
  - Test Installations - 3 versions; 1999 - 2001.
- CWMS Deployment V 1.0 - July 2001 - December 2002 <18 Months>.
- CWMS Software Update to V1.4 Dec 2005
- CWMS Software Update to V1.5 Feb 2007
- Version 2.0 Target date Spring 2008

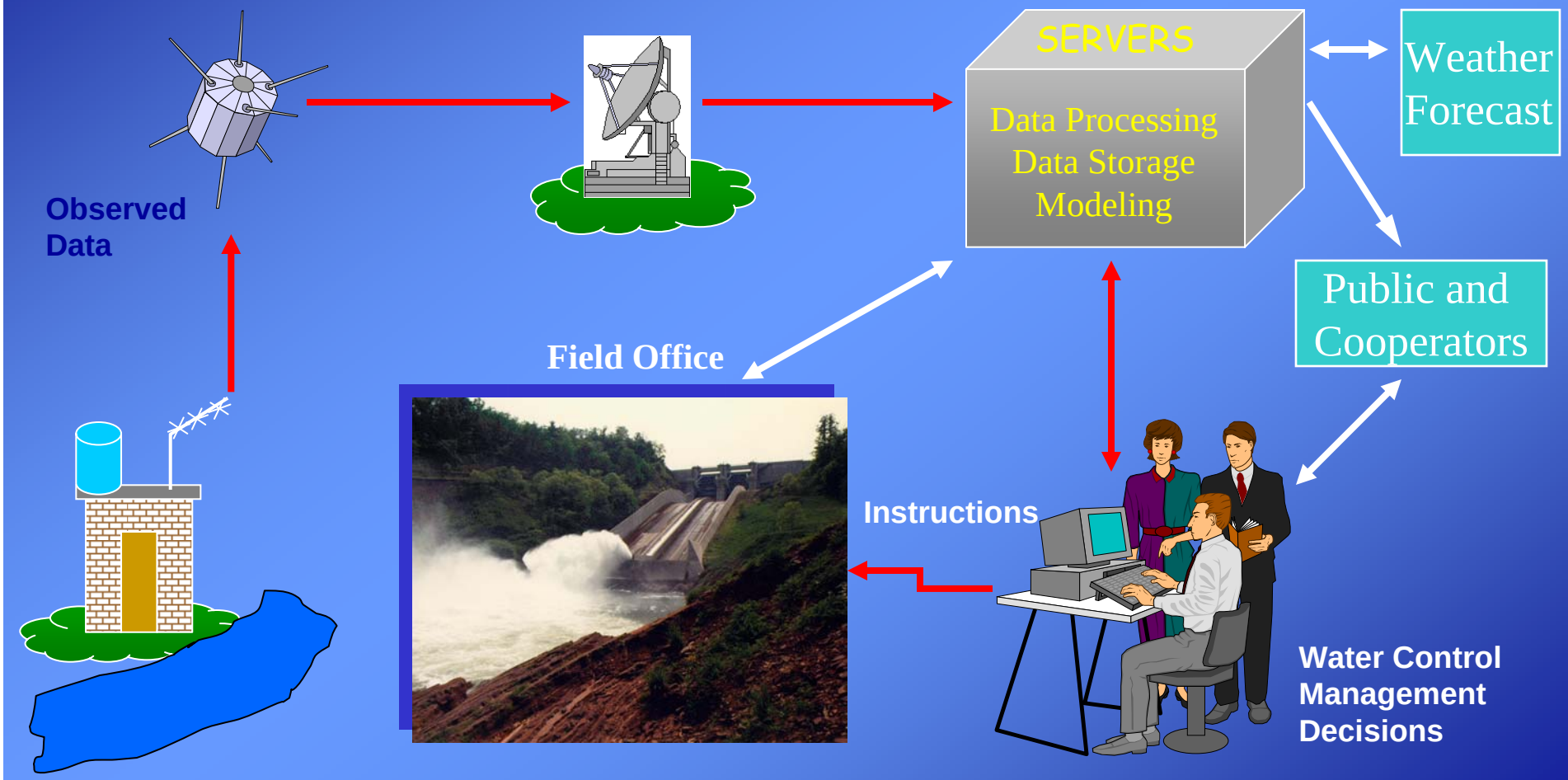
CWMS Management Team

- Program Manager: Jerry Webb, CECW-EW - Overall Direction and Program Management
- Advisory Group (AG): MSC Level Advisory Body for PM on Policies and Major Issues
- CWMS Users Representative Group (CURG): User Representative From Each District and MSC, Identify System Requirements, Future Direction, on-going System issues.

CWMS Enterprise Management

- Enterprise management plan document, Aug 02 - https://cwms.hec.usace.army.mil/cwcinfo/documents/CWMSEnterpriseManagementPlan.V1.1.pdf
  - Plan assures corporate CWMS resources are available at all offices of the Corps and are applied in a consistent and effective manner.
  - Management of the CWMS is a cooperative effort between the Water Management and Information Management communities.
- Configuration Control Board (CCB) reports to PM and is enterprise management body, includes:
  - CWMS Advisory Group (AG)
    - MSC (Division/Region) Water Management representatives
    - System Developer
    - CURG Chairman
    - CEIM Representatives
  - Information Assurance Security Officer

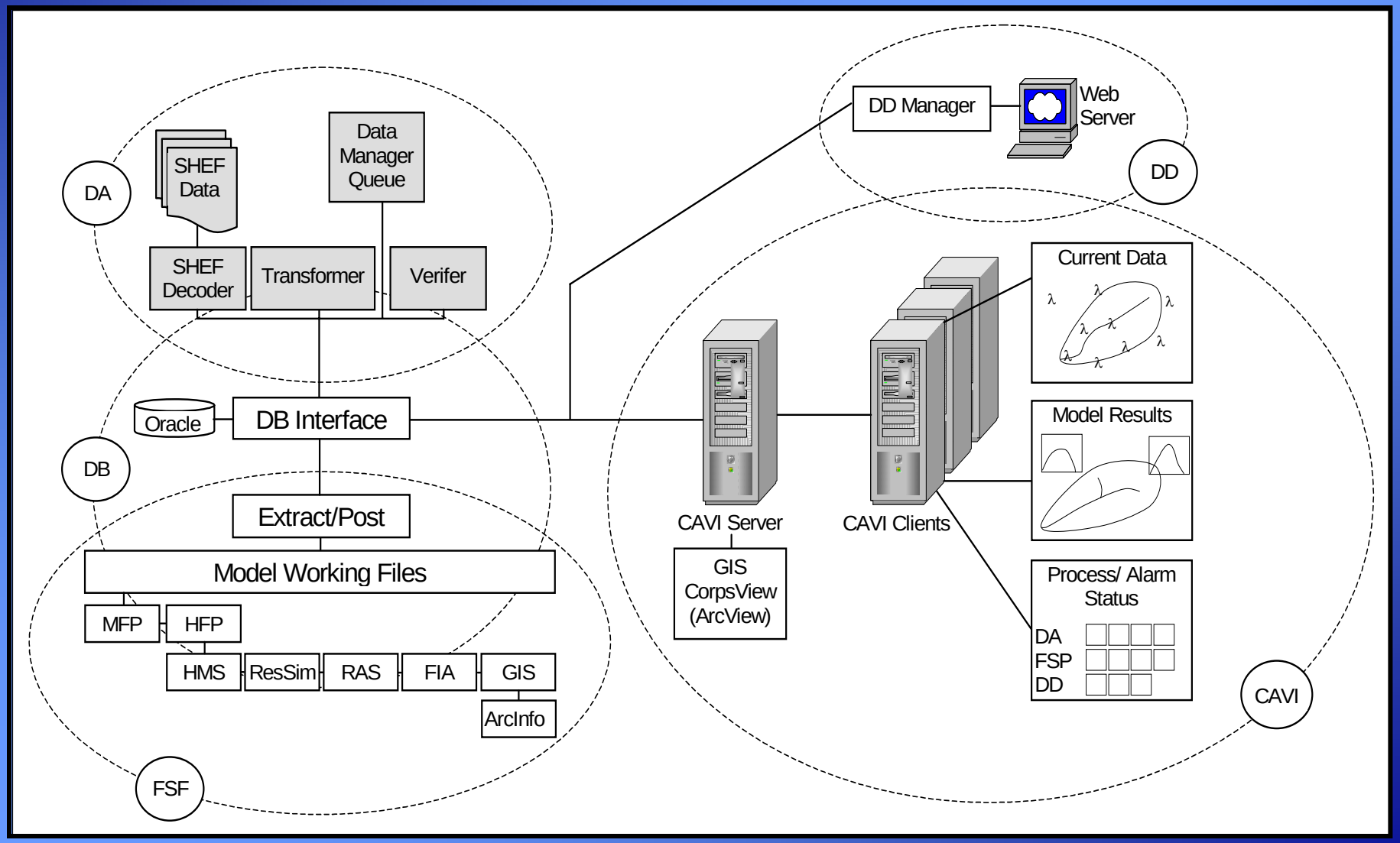
CWMS Software Integrates the Processing from Data to Water Management Decisions



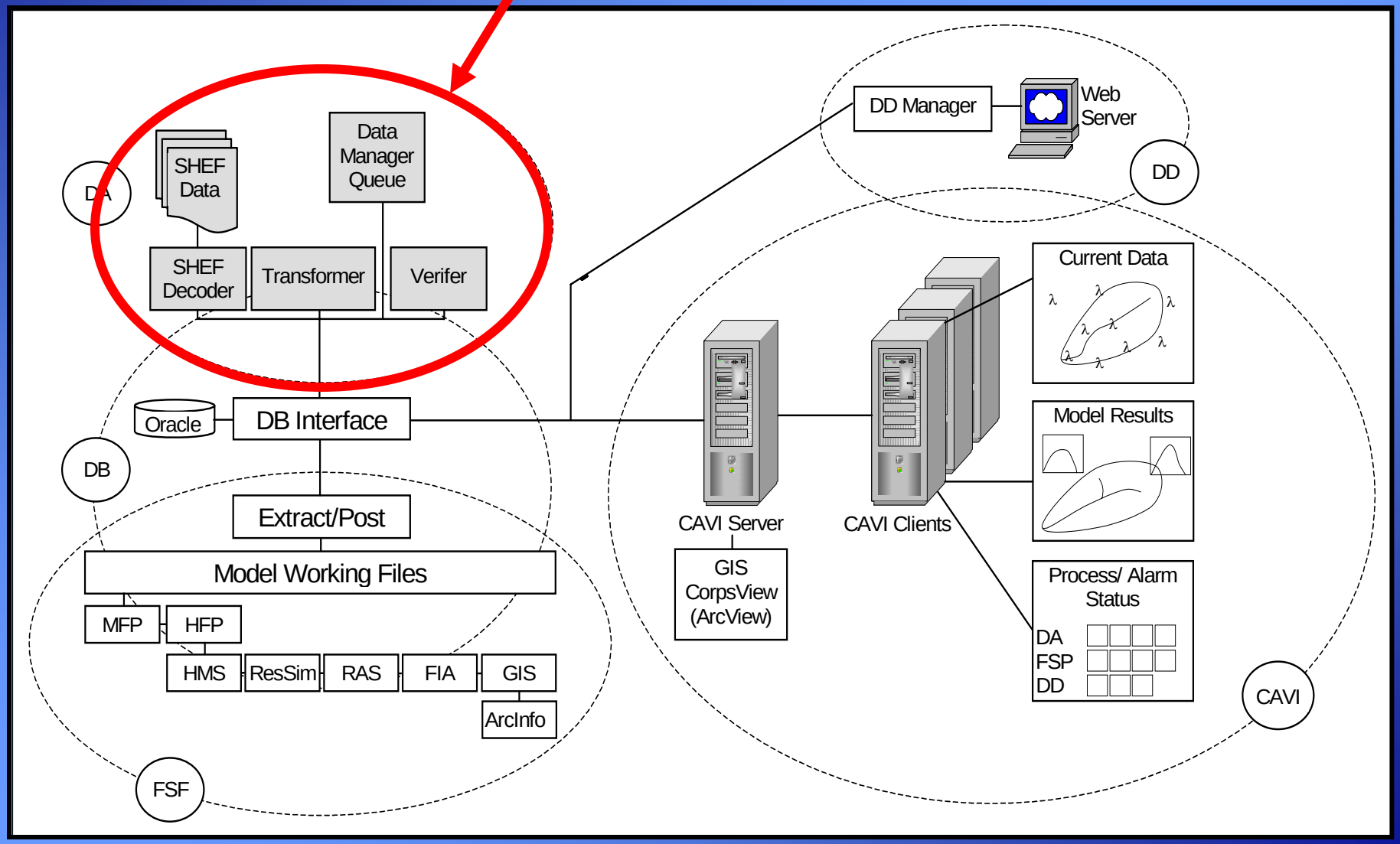
CWMS - Major Components

- Database
  - Stores hydromet data in Oracle DBMS
  - Manages retrieval and display of same
- Data Acquisition (Observations)
  - Collects real-time data from data streams
  - Decodes, validates, and transforms the raw data
- Modeling (Forecasts)
  - Manages model configurations for watersheds
  - Runs models for operational forecasts

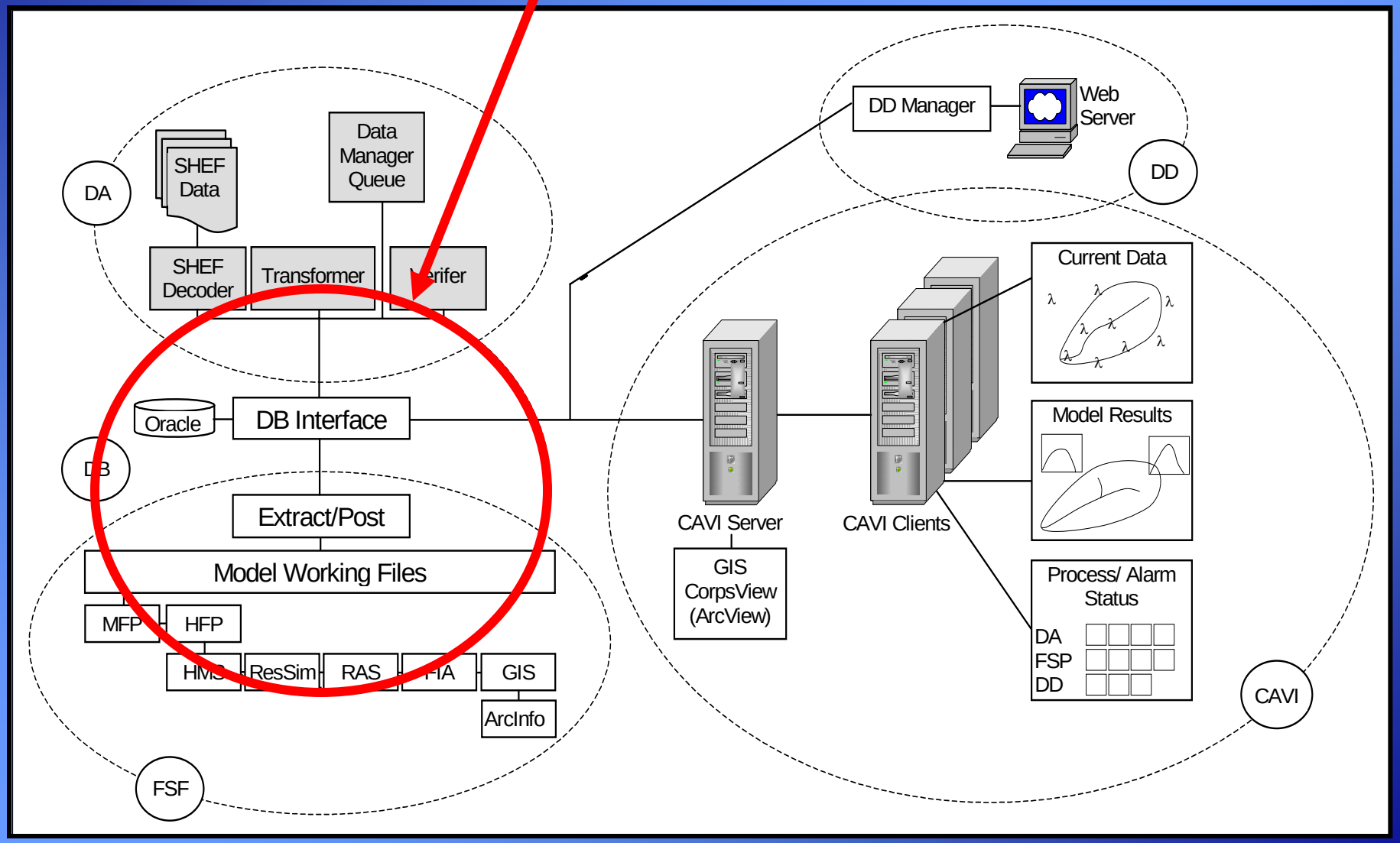
CWMS System Components



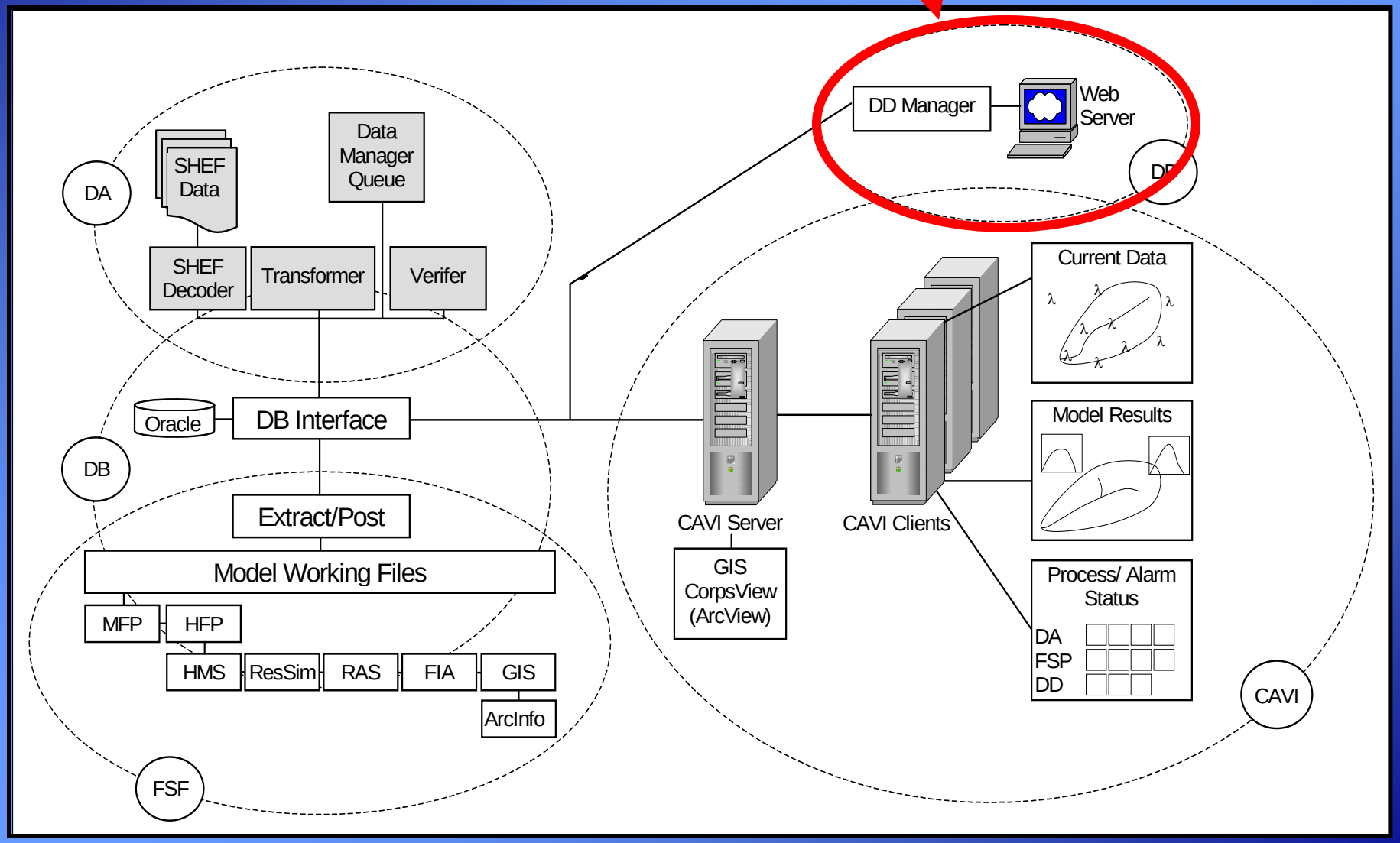
Data Acquisition



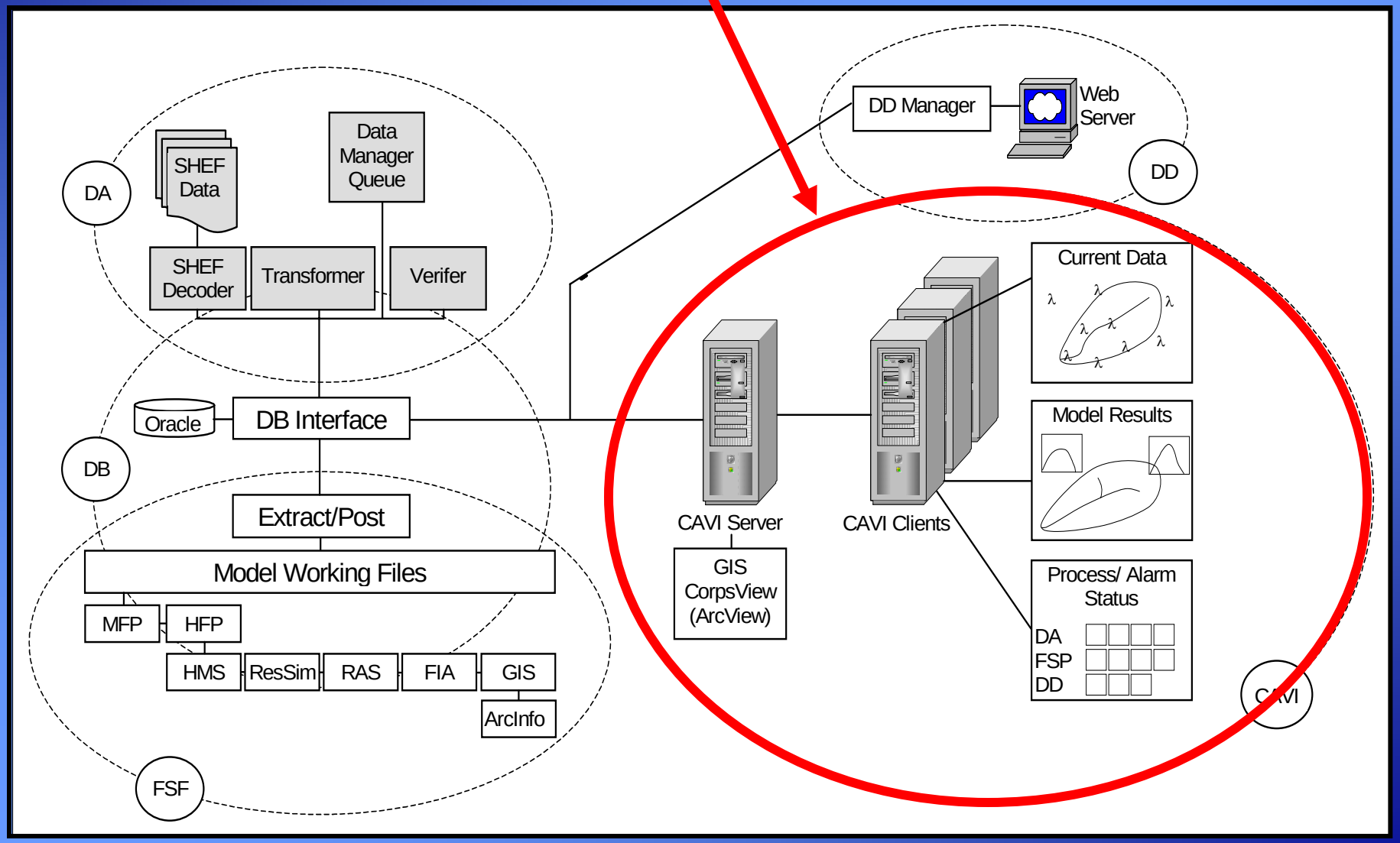
Database Services



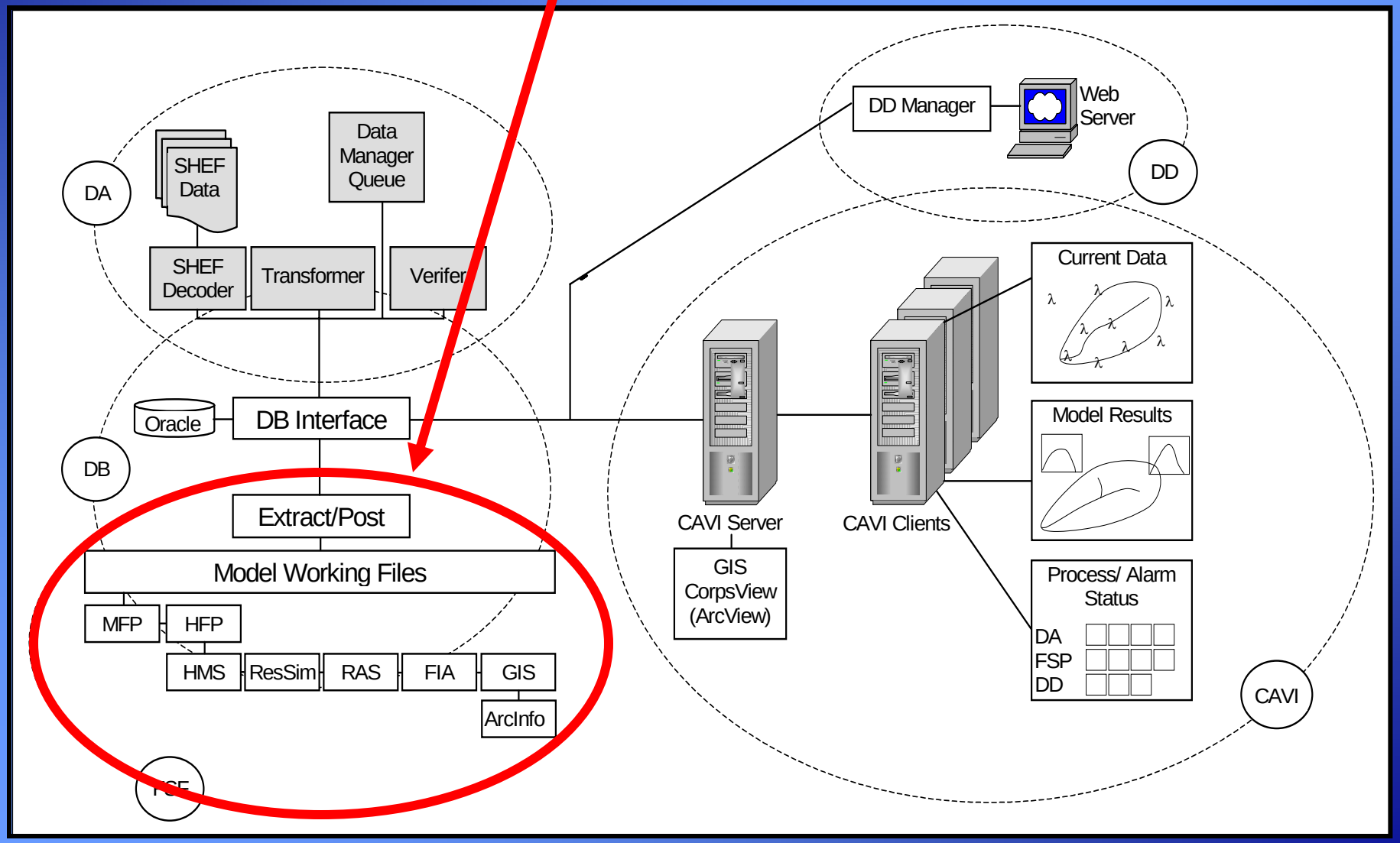
Data Dissemination



User Control and Visualization



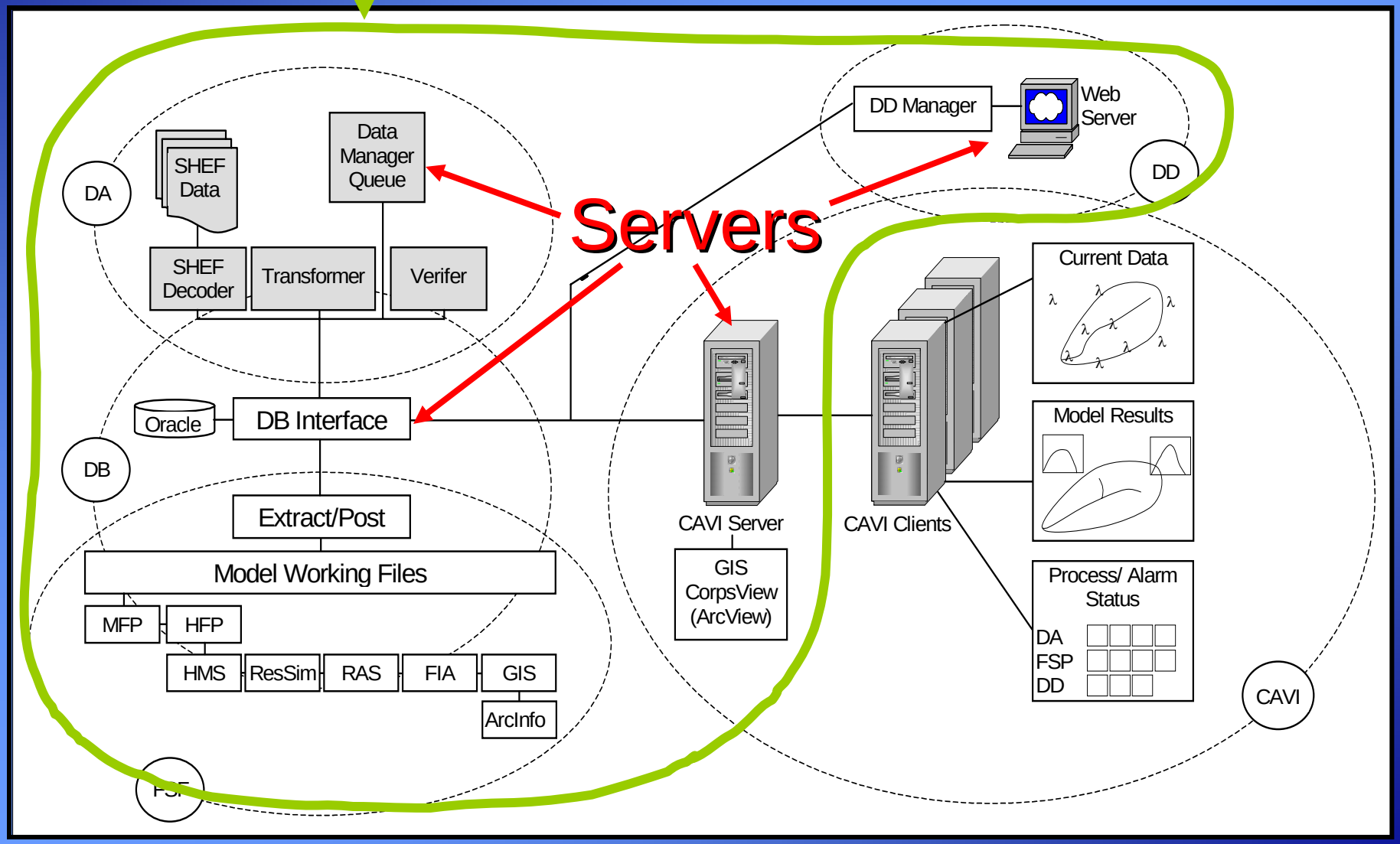
Simulation Modeling



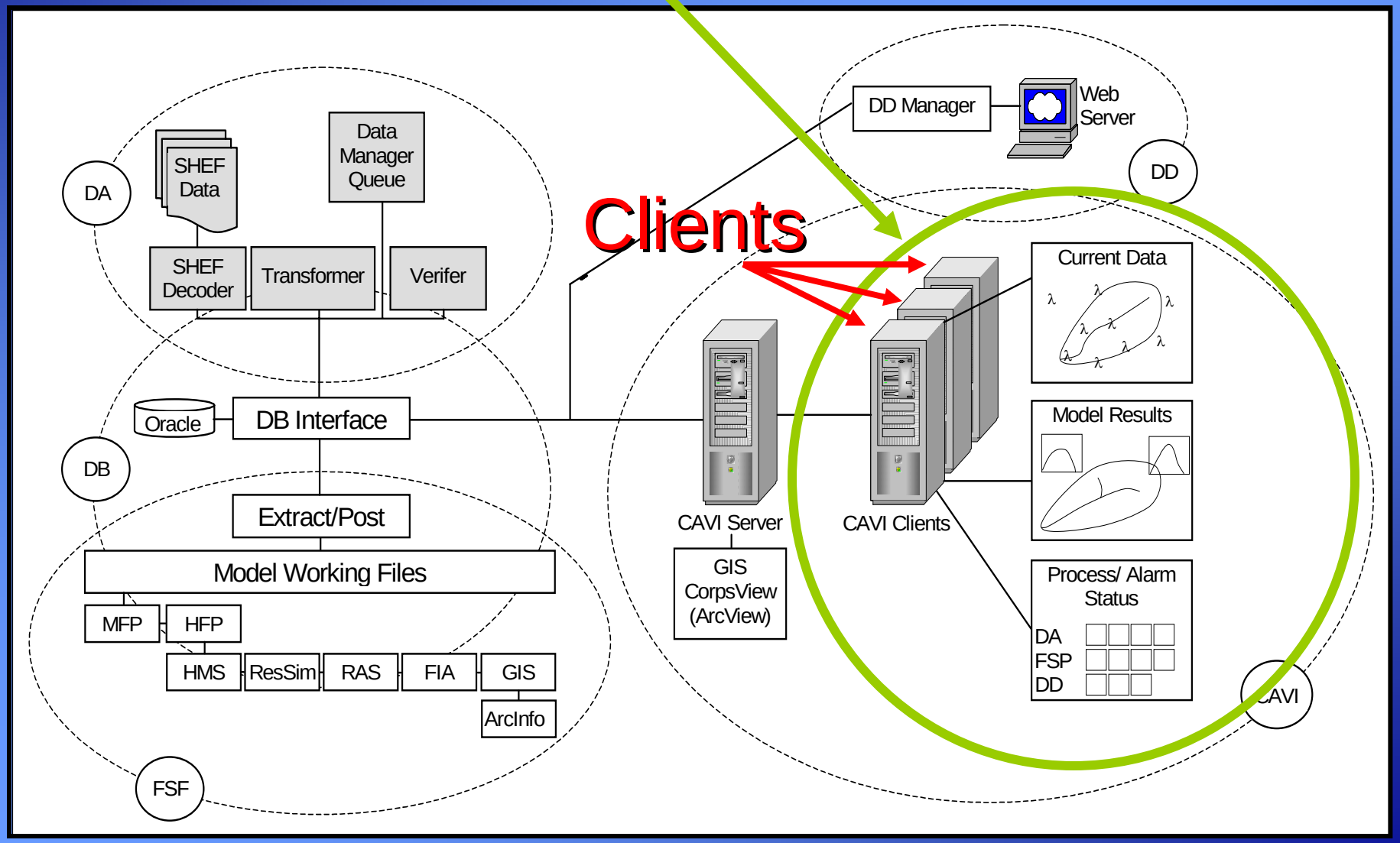
CWMS Client-Server Architecture

- CWMS Client
  - Principle user interface to the CWMS software
    - Retrieves hydromet data for plotting and editing
    - Graphic displays: map backgrounds, GUI, plots…
    - Retrieves model parameters for editing
    - Conveys model control requests to servers
- CWMS Server
  - Provides the system resources to:
    - Support multi-client access to models and database
    - Manages hydromet data for clients
    - Manages model parameters and state information
    - Performs model runs

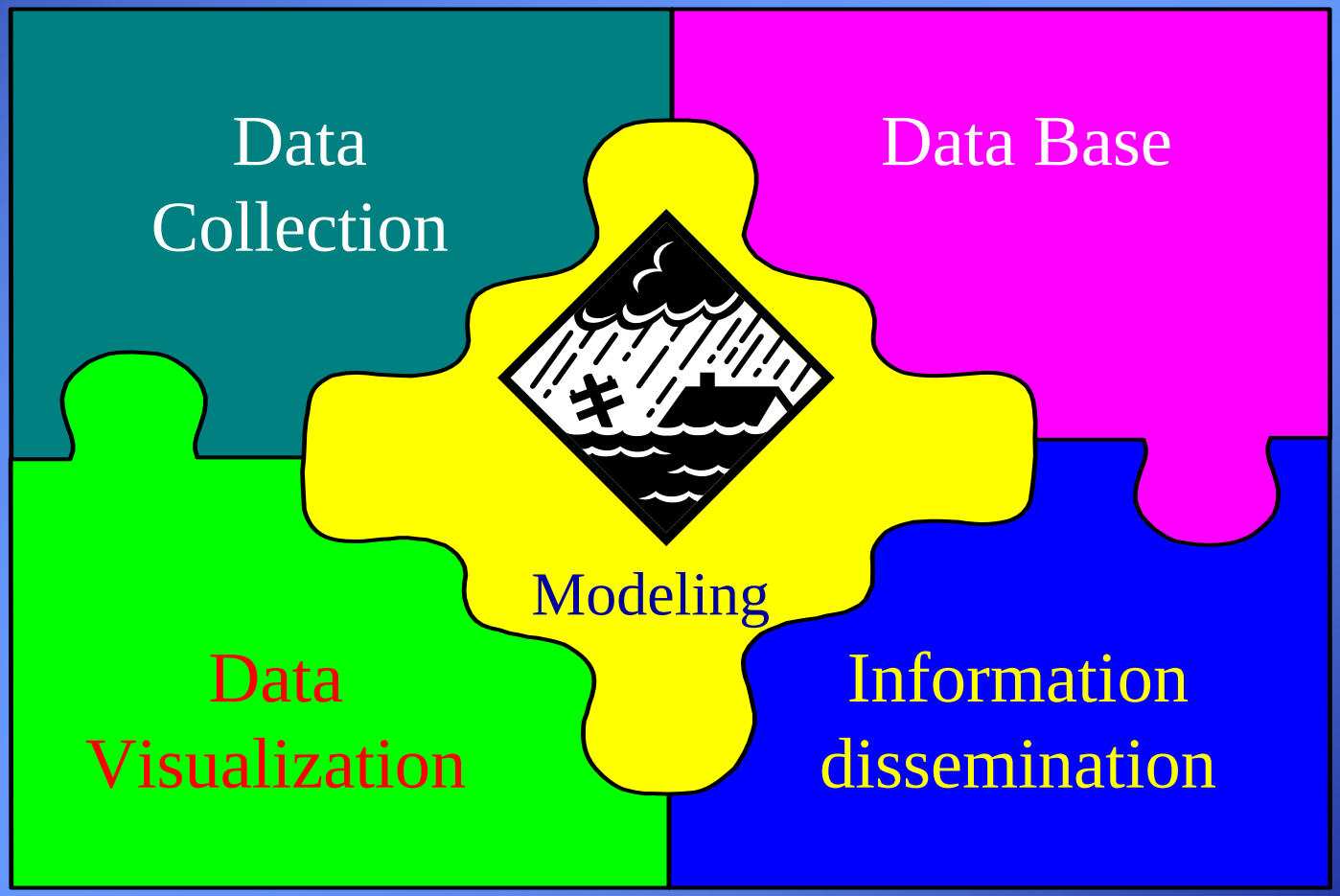
Components on Central Computers



Components on User PC

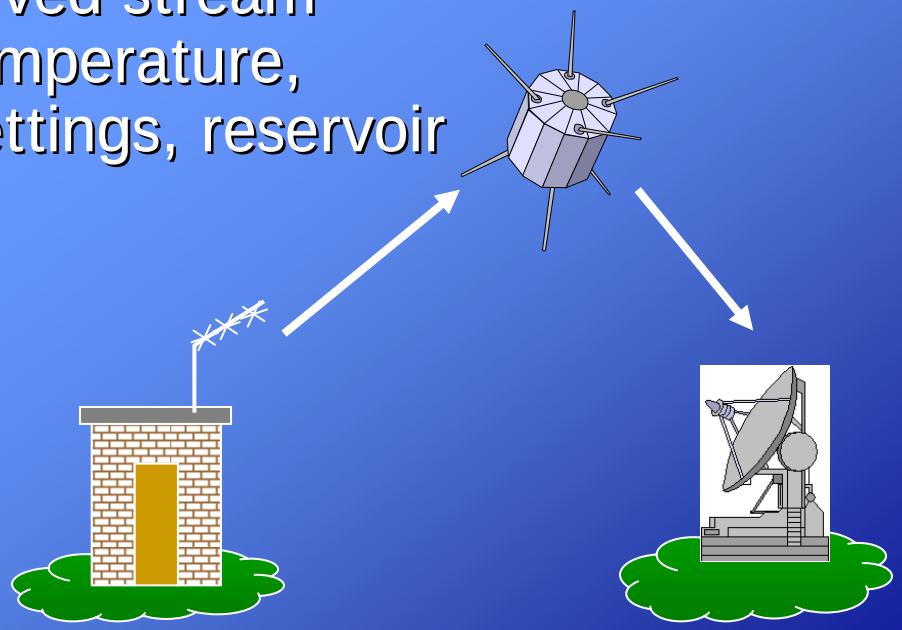


CWMS Components

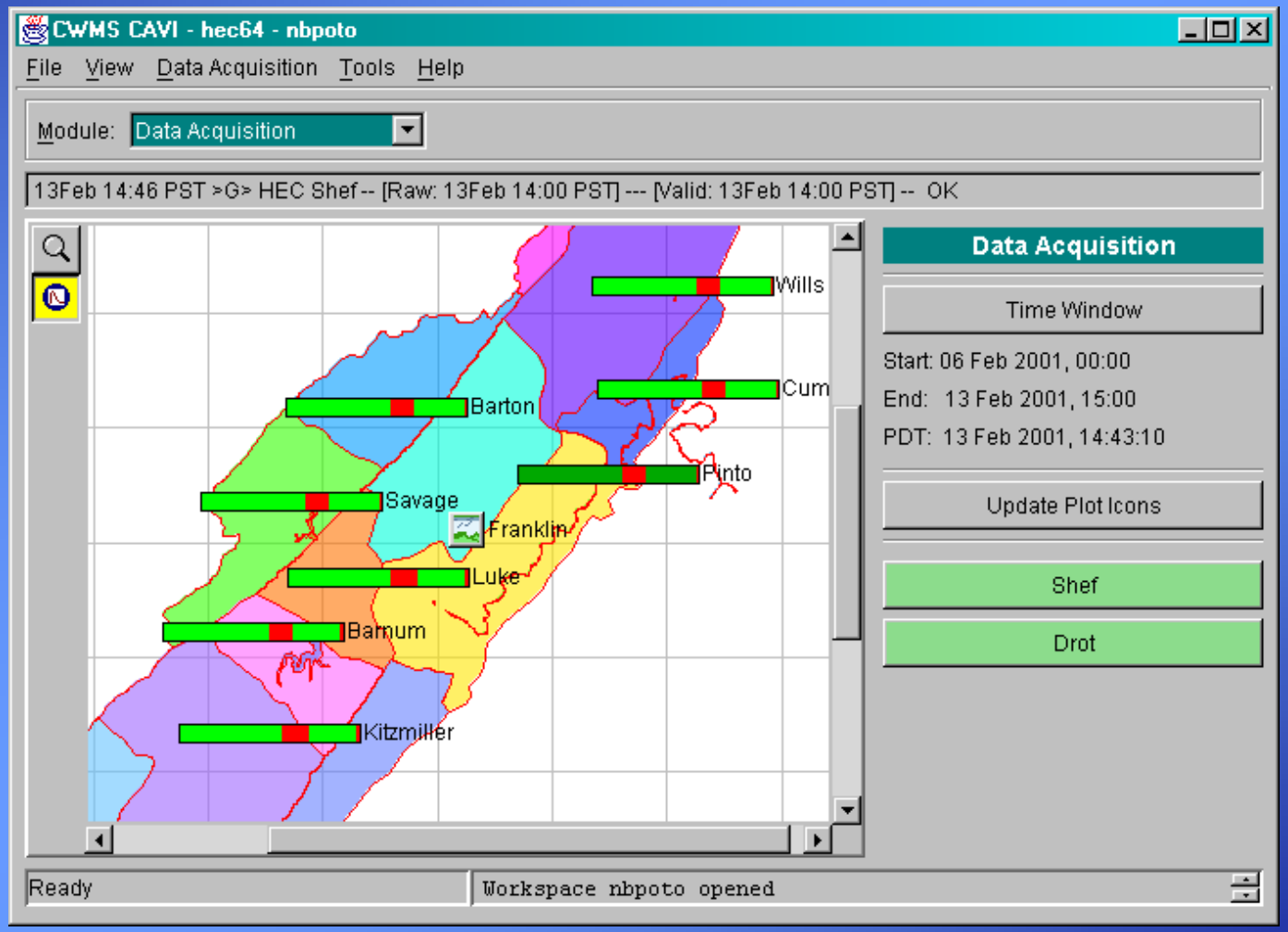


Data Acquisition

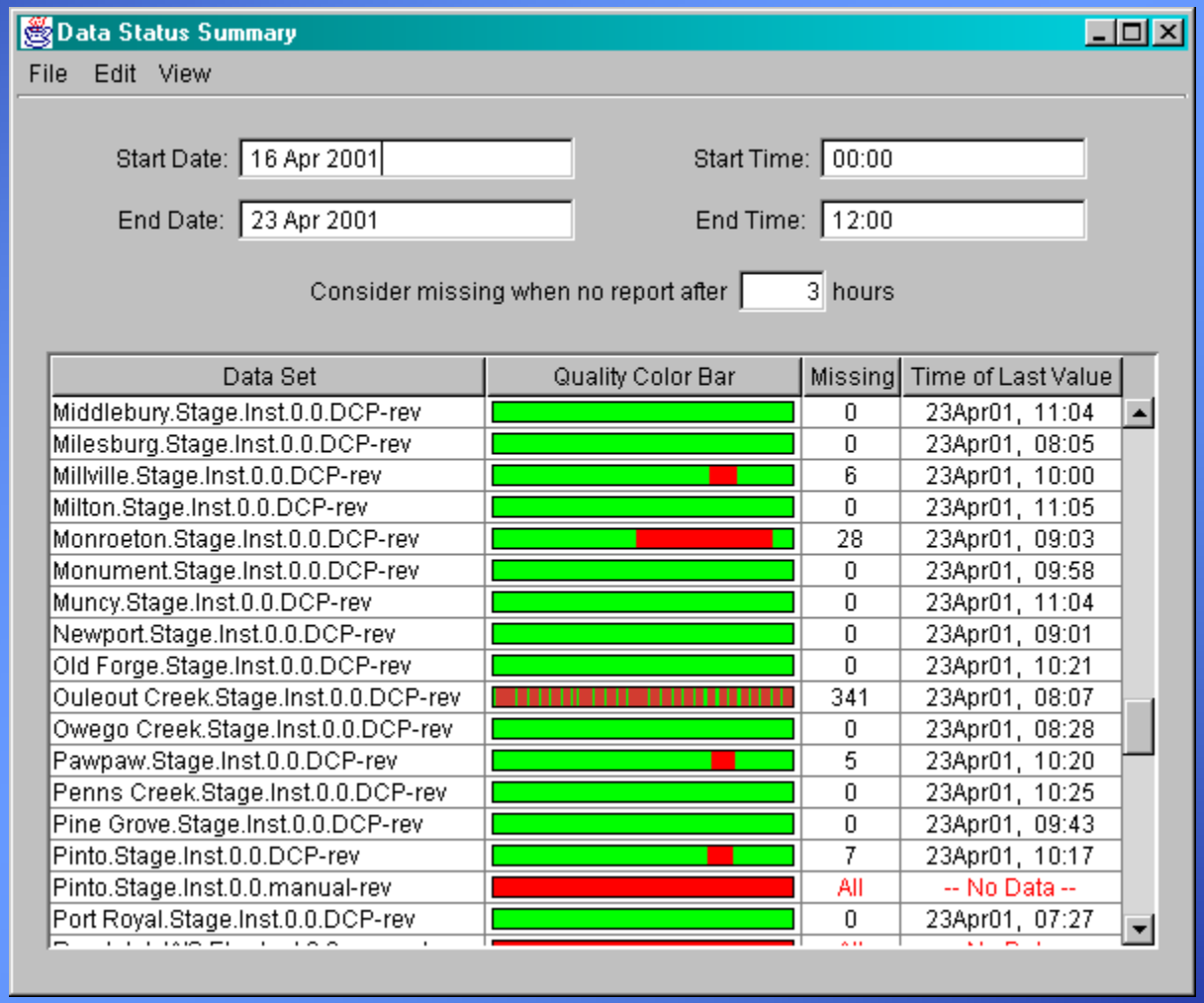
- Collect:
  - Static data: physical data for model development
  - Real-time data: observed stream flow, precipitation, temperature, water quality, gate settings, reservoir levels, etc.
- Decode
- Validate
- Transform



Data Acquisition Module

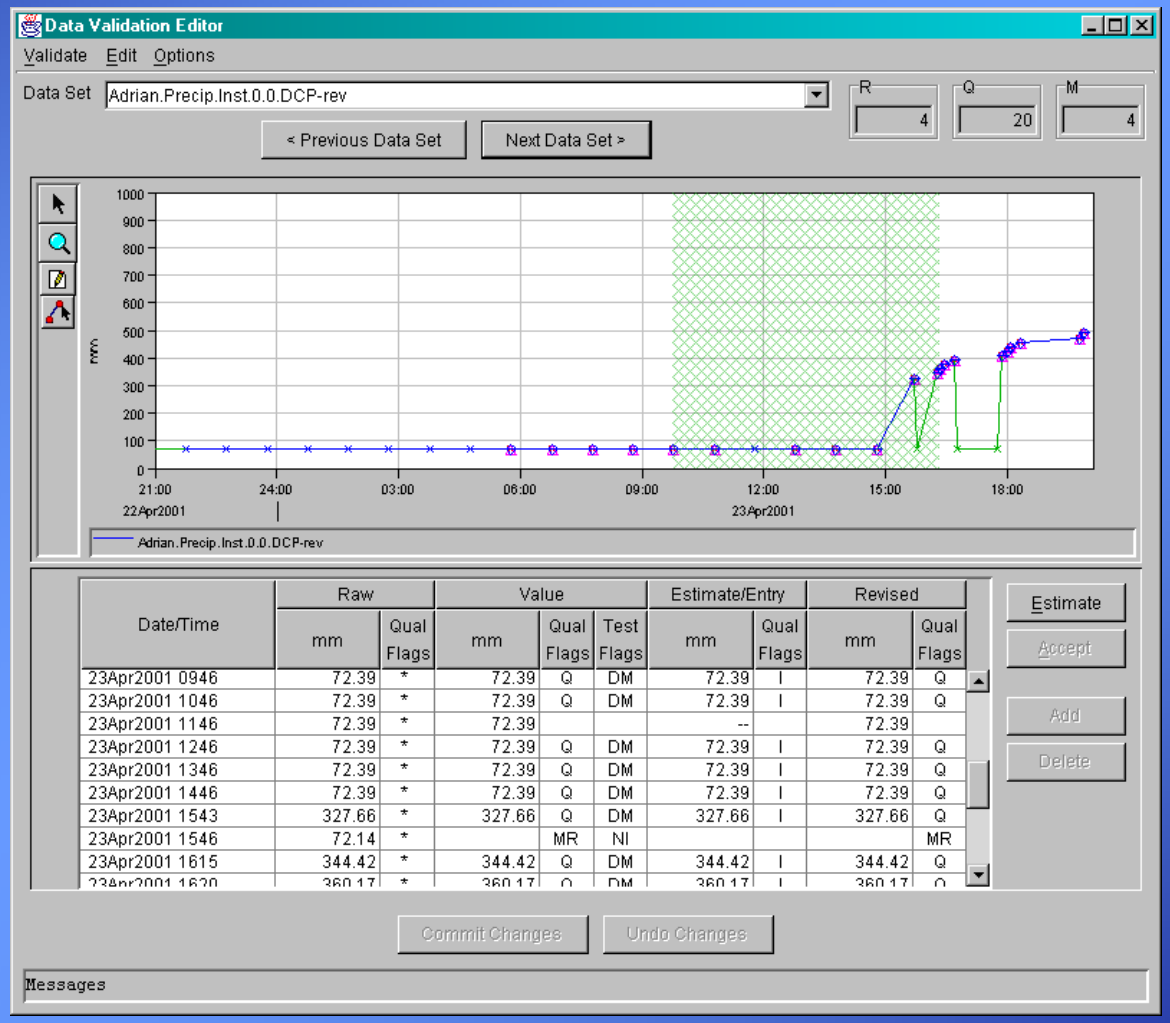


Data Status Summary Table



Data Set	Quality Color Bar	Missing	Time of Last Value
Middlebury.Stage.Inst.0.0.DCP-rev		0	23Apr01, 11:04
Milesburg.Stage.Inst.0.0.DCP-rev		0	23Apr01, 08:05
Millville.Stage.Inst.0.0.DCP-rev		6	23Apr01, 10:00
Milton.Stage.Inst.0.0.DCP-rev		0	23Apr01, 11:05
Monroeton.Stage.Inst.0.0.DCP-rev		28	23Apr01, 09:03
Monument.Stage.Inst.0.0.DCP-rev		0	23Apr01, 09:58
Muncy.Stage.Inst.0.0.DCP-rev		0	23Apr01, 11:04
Newport.Stage.Inst.0.0.DCP-rev		0	23Apr01, 09:01
Old Forge.Stage.Inst.0.0.DCP-rev		0	23Apr01, 10:21
Ouleout Creek.Stage.Inst.0.0.DCP-rev		341	23Apr01, 08:07
Owego Creek.Stage.Inst.0.0.DCP-rev		0	23Apr01, 08:28
Pawpaw.Stage.Inst.0.0.DCP-rev		5	23Apr01, 10:20
Penns Creek.Stage.Inst.0.0.DCP-rev		0	23Apr01, 10:25
Pine Grove.Stage.Inst.0.0.DCP-rev		0	23Apr01, 09:43
Pinto.Stage.Inst.0.0.DCP-rev		7	23Apr01, 10:17
Pinto.Stage.Inst.0.0.manual-rev		All	-- No Data --
Port Royal.Stage.Inst.0.0.DCP-rev		0	23Apr01, 07:27

Data Validation Editor



Date/Time	Raw		Value			Estimate/Entry		Revised	
	mm	Qual Flags	mm	Qual Flags	Test Flags	mm	Qual Flags	mm	Qual Flags
23Apr2001 0946	72.39	*	72.39	Q	DM	72.39	I	72.39	Q
23Apr2001 1046	72.39	*	72.39	Q	DM	72.39	I	72.39	Q
23Apr2001 1146	72.39	*	72.39			--		72.39	
23Apr2001 1246	72.39	*	72.39	Q	DM	72.39	I	72.39	Q
23Apr2001 1346	72.39	*	72.39	Q	DM	72.39	I	72.39	Q
23Apr2001 1446	72.39	*	72.39	Q	DM	72.39	I	72.39	Q
23Apr2001 1543	327.66	*	327.66	Q	DM	327.66	I	327.66	Q
23Apr2001 1546	72.14	*		MR	NI				MR
23Apr2001 1615	344.42	*	344.42	Q	DM	344.42	I	344.42	Q
23Apr2001 1620	360.17	*	360.17	Q	DM	360.17	I	360.17	Q

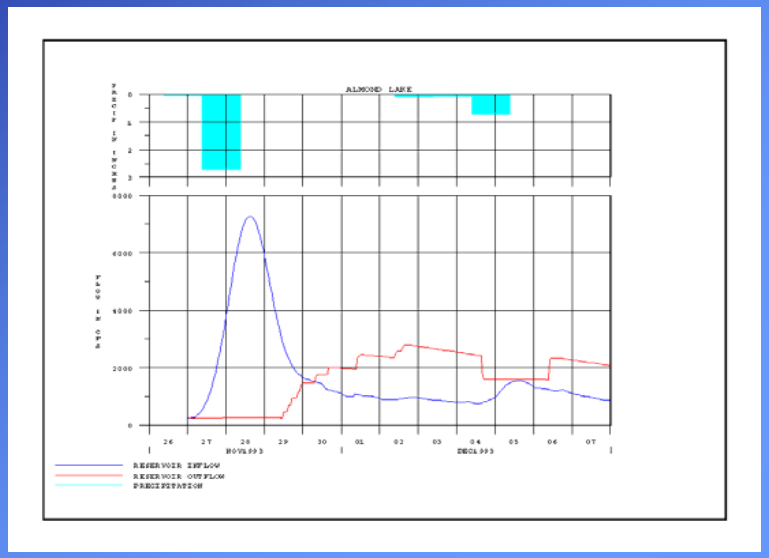
Data Storage

- ORACLE is CWMS record database
- HEC-DSS is the modeling database
- Interfaces with other databases
- Accessible by multiple users
- Modeling
  - Extracts data to HEC-DSS for analyses
  - Posts results for decision-making

Data Dissemination

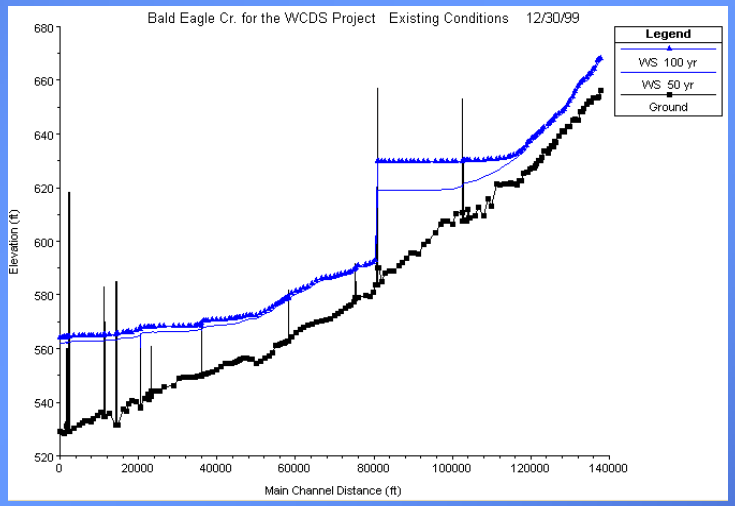
- Common information source
- Data & information placed on WEB-based platform
  - Available to Corps users & outside interests
  - Real-time availability

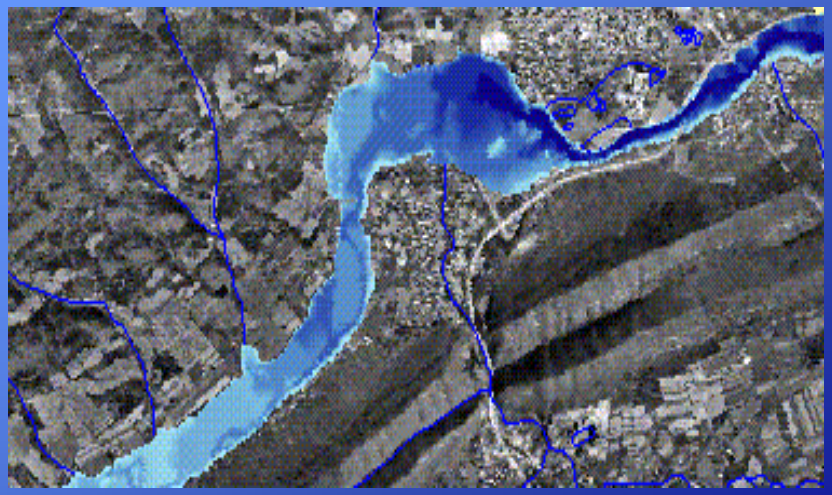
Data Visualization



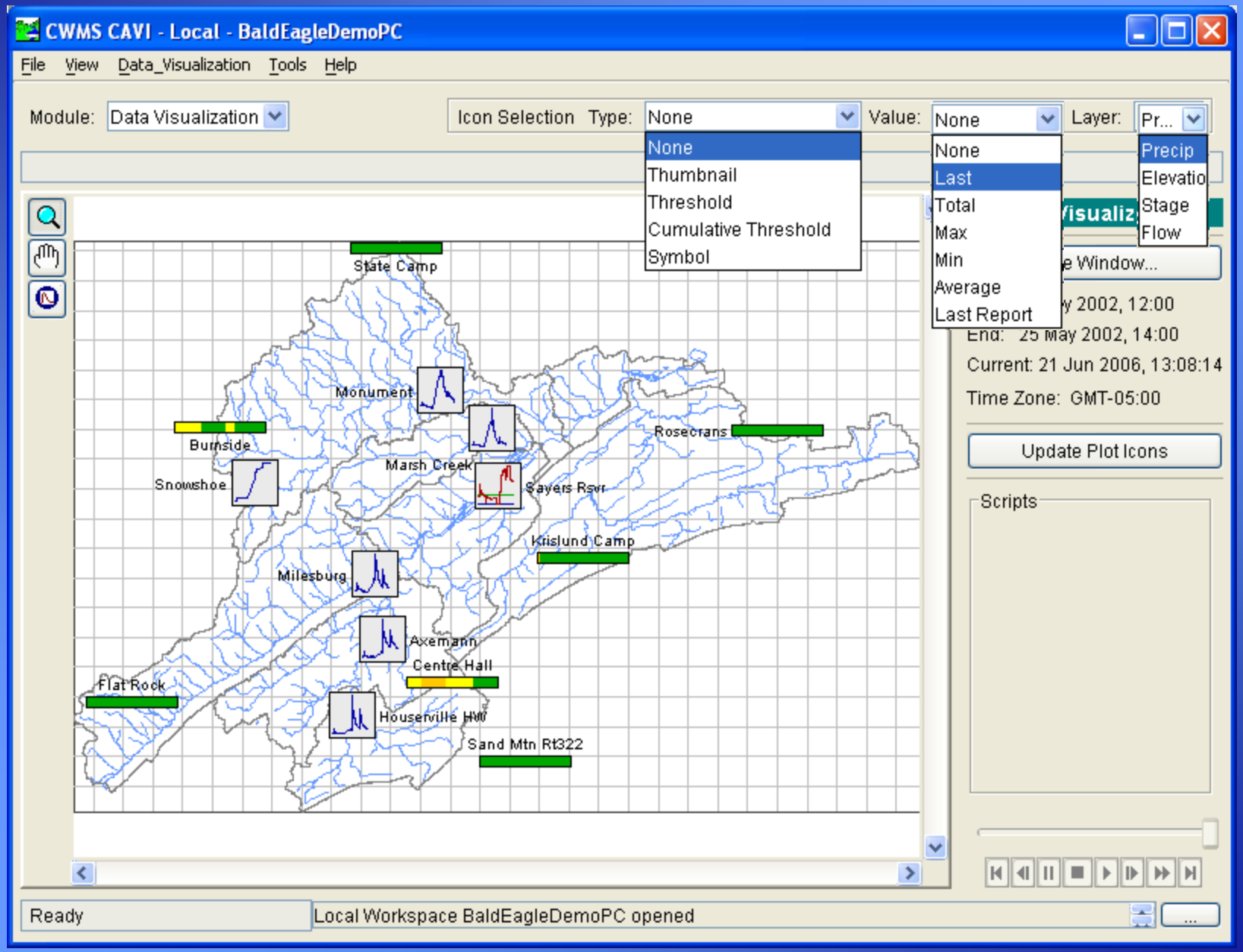
Impact Action Report

Impact Area	Stage	Impact	Action	Time	Time
				5BGEN.frun	8BGEN.frun
Cottage Area	556.0	Flood Warning Stage	Initiate Reconnaissance and ...	12Nov99 03:00	12Nov99 03:00
	558.0	Flood Stage	Full Alert, Warn of Potential E...	12Nov99 04:00	12Nov99 04:00
	560.0	Damage to Infrastructure, La...	Close Life Lines, Roads/ Loc...	12Nov99 05:00	12Nov99 05:00
	561.0	Egress Begins to be a Probl...	Evacuate Residences, Perfor...	12Nov99 05:00	12Nov99 05:00
	567.0	All Cottage Area Buildings Fl...	Continue Survellance		12Nov99 09:00
Lock Haven	535.2	Zero stage reading	None	09Nov99 24:00	09Nov99 24:00
	540.1	Flap gates of interior drains ...	Check drains to ensure oper...	11Nov99 22:00	11Nov99 23:00
	543.2	Elevation of Grant Street Dam	None	11Nov99 23:00	11Nov99 24:00
	545.0	Handrails at Summer Beach ...	Remove handrails & close G...	11Nov99 24:00	12Nov99 01:00
	549.0	Grant Street Dam platform el...	None	12Nov99 01:00	12Nov99 02:00
	553.0	Flood Warning Stage	Begin levee patrol	12Nov99 02:00	12Nov99 02:00
	556.2	Flood Stage	River overtops bank	12Nov99 03:00	12Nov99 03:00
	556.3	Bath house floor elevation	Close bath house	12Nov99 03:00	12Nov99 03:00
	557.2		Prepare to close Closure Str...	12Nov99 03:00	12Nov99 03:00
	559.1		Close Closure Structure No. 3	12Nov99 04:00	12Nov99 03:00
	559.2		Prepare to close Closure Str...	12Nov99 04:00	12Nov99 03:00
	561.0		Close Closure Structure No. 2	12Nov99 05:00	12Nov99 04:00
	564.0		Prepare to close Closure Str...	12Nov99 07:00	12Nov99 05:00
	565.0	Base elevation of Closure Str...	None	12Nov99 09:00	12Nov99 06:00
	566.0		Close Closure Strcutures No...		12Nov99 07:00
	567.0	Evacuation Alert Stage	Prepare for Lock Haven evac...		12Nov99 07:00
	572.0	Danger Stage	Evacuation of Lock Haven		12Nov99 13:00

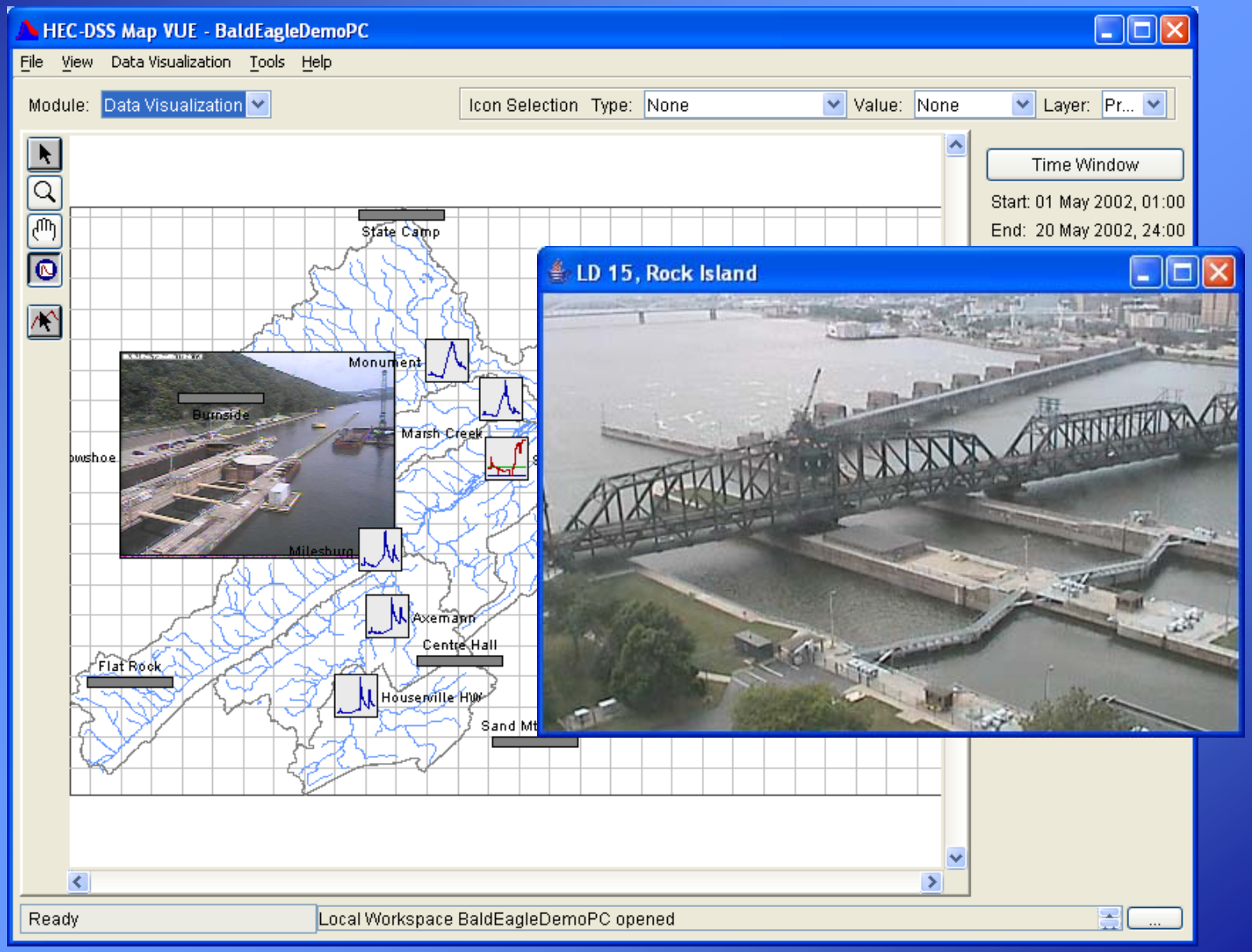




Data Visualization



Time Series Icon Video (Webcam - updating)



Data Dissemination

Hunt Dist Corps of Eng Water Contrl: Lake Sumry - Netscape

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Bookmarks Location: http://www.lrh-wc.usace.army.mil/wc/summary.html What's Related

Instant Message Internet Lookup New&Cool

US Army Corps of Engineers
Huntington District
WATER CONTROL

Lake Page

Lake Summary Report

Includes all Huntington District Reservoir Projects

All time references are Eastern Standard Time (EST). All data is preliminary. Please see disclaimer prior to use.

LAKE SUMMARY

	12 JUN 00			
BASIN	LAKE PROJECT	LAKE LEVEL	24HR CHANGE	24H PREC
MUSKINGUM	ATWOOD	928.09	0.11	
	BEACH CITY	948.86	0.01	
	BOLIVAR	899.24	0.28	
	CHARLES MILL	997.21	-0.07	

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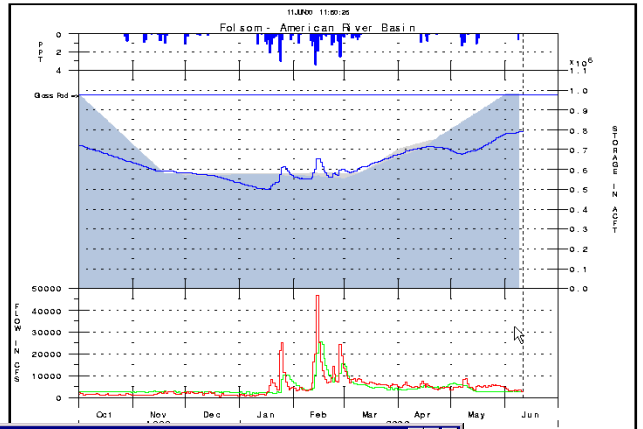

JPEG image 1000x1000 pixels - Netscape

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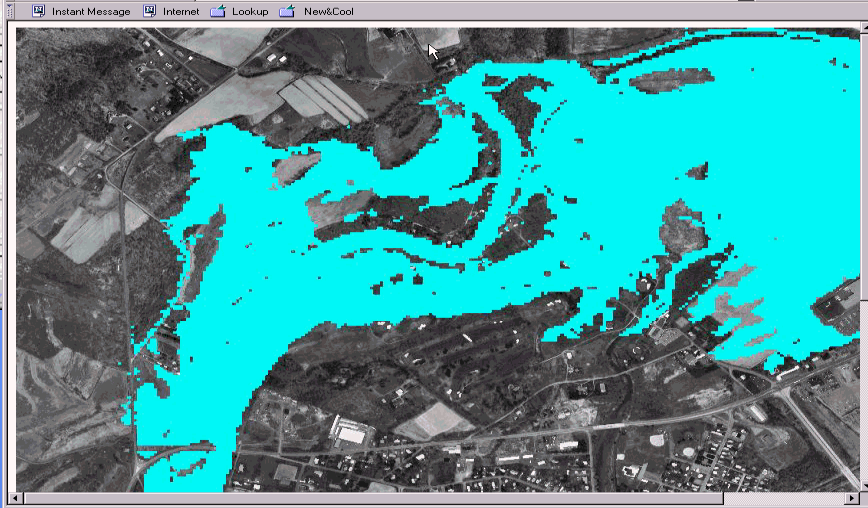

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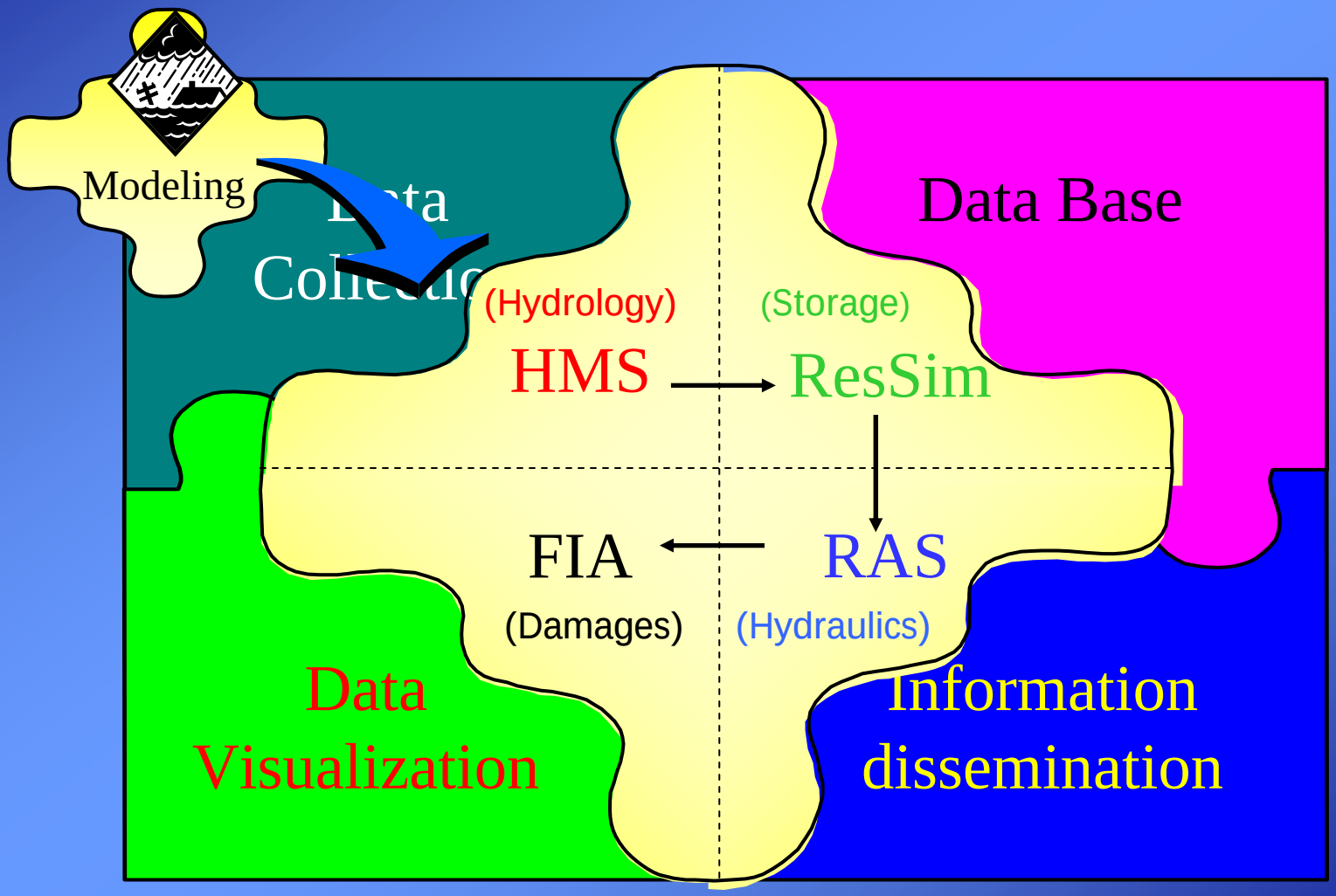
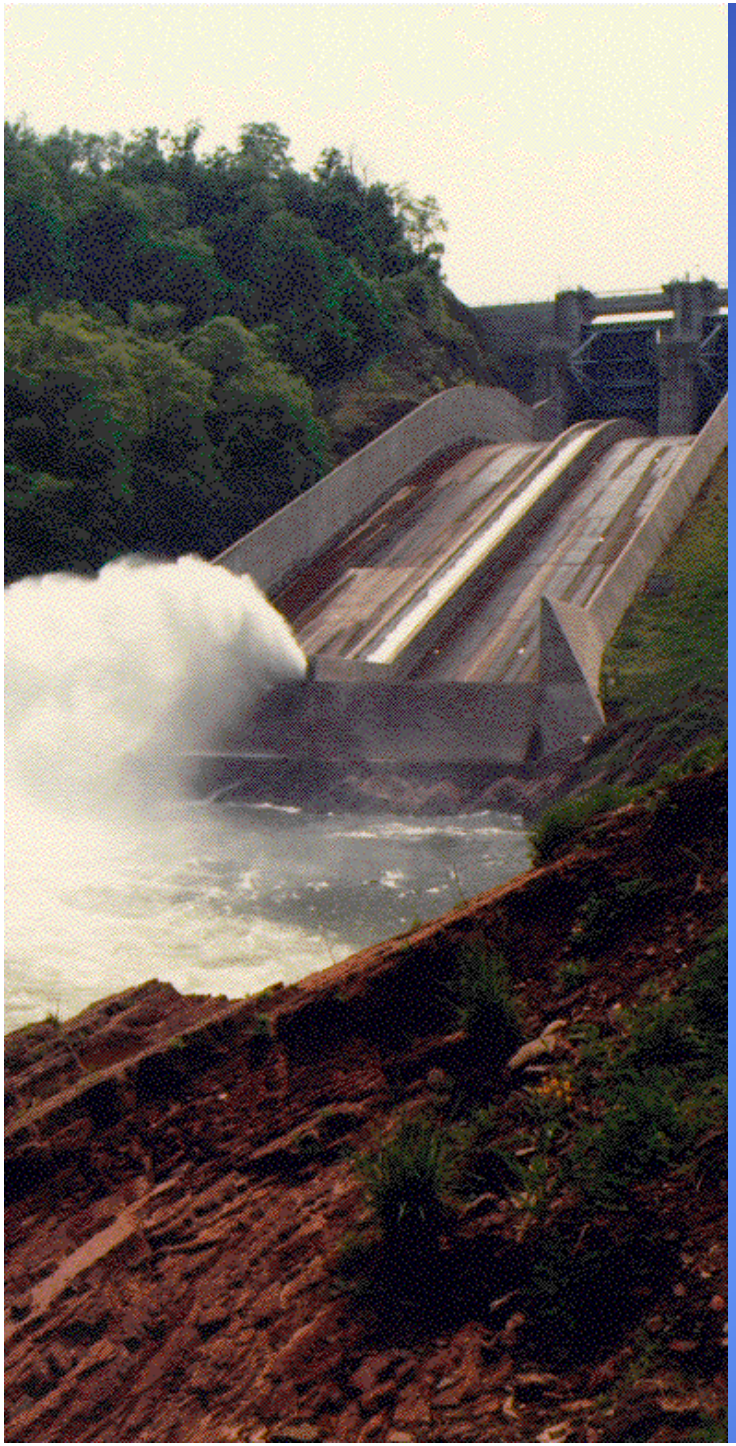
Real-Time Simulation Modeling for Decision Support

Watershed Modeling





Modeling for Decision Support

- Hydrologic / hydraulic simulation models for short-term forecasts and event scenarios
- Discrete models developed outside CWMS and then linked together
- Spatially distributed models
- Typically use one week of observed data and evaluate results two weeks into the future
- Evaluate a variety of scenarios:
  - Future precipitation amounts and timing
  - Reservoir operations
  - Levee failures

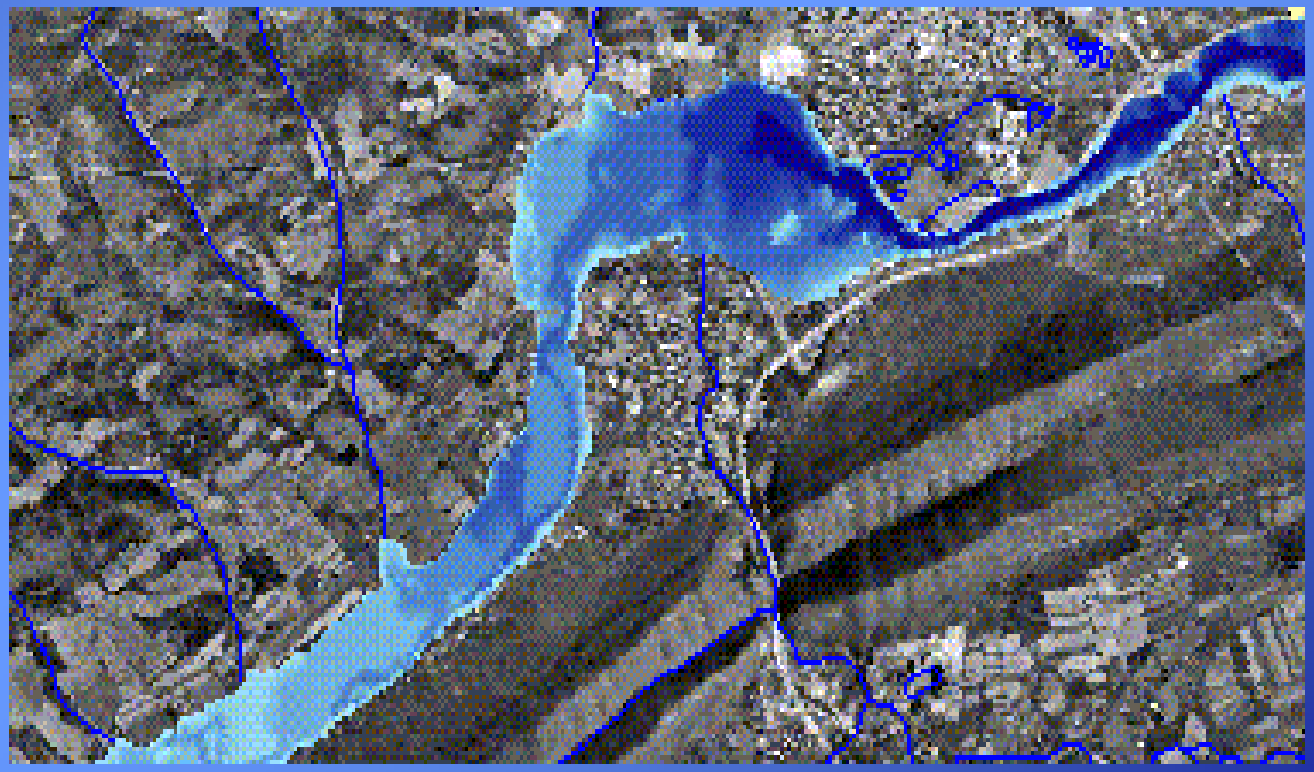
Model Results

Tabular Information

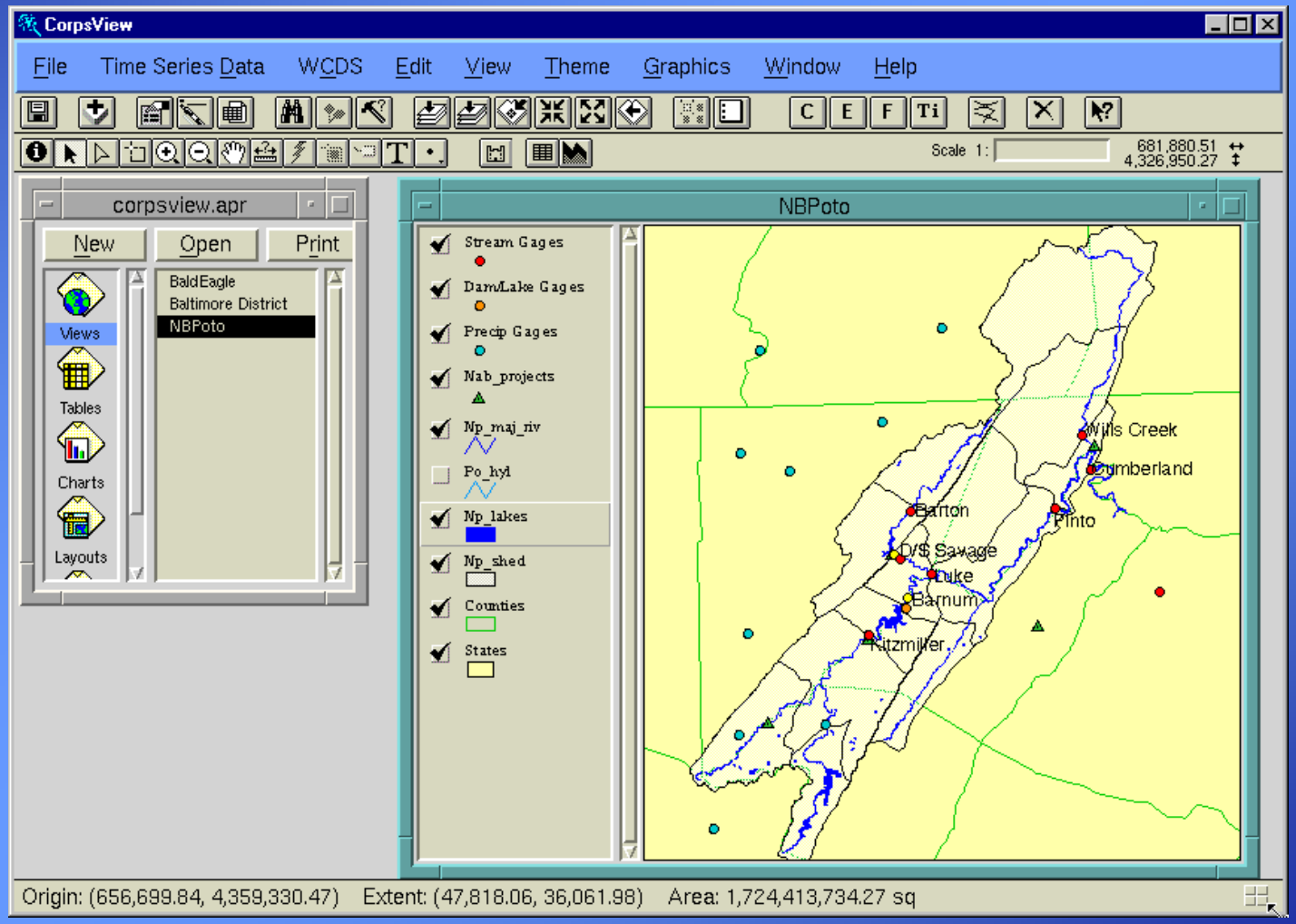
Impact Area	Stage (ft)	Impact	Action	Time	
				Initial Forecast	Modified Releases
Cottage Area	556.0	Flood Warning Stage	Initiate reconnaissance and alert appropriate p	22Mar2002 0600	22Mar2002 0600
	558.0	Flood Stage	Full alert, warn of potential evacuation.	22Mar2002 0700	22Mar2002 0700
	560.0	Damage to infrastructure, landscape, etc.	Close life lines & roads to everyone but local tr	22Mar2002 0900	22Mar2002 0900
	561.0	Egress begins to be a problem.	Evacuate residences & perform surveillance.	22Mar2002 1000	22Mar2002 1000
				Max Flood Stage - 25Mar2002, 07:00 562.63 ft	Max Flood Stage - 25Mar2002, 07:00 562.63 ft
Lock Haven	535.2	Zero stage reading		19Mar2002 1000	19Mar2002 1300
	540.1	Flap gates of interior drains under water	Check drains to ensure operation	21Mar2002 2300	21Mar2002 2300
	543.2	Elevation of Grant Street Dam		22Mar2002 0100	22Mar2002 0100
	545.0	Handrails at Summer Beach nearing inun	Remove handrails & close Grant Street Dam p	22Mar2002 0200	22Mar2002 0200
	549.0	Grant Street Dam platform elevation		22Mar2002 0400	22Mar2002 0400
	553.0	Flood Warning Stage	Begin levee patrol	22Mar2002 0600	22Mar2002 0500
	556.2	Flood Stage	River overtops bank	22Mar2002 0900	22Mar2002 0700
	556.3	Bath house floor elevation	Close bath house	22Mar2002 0900	22Mar2002 0700
	557.2		Prepare to close Closure Structure No. 3	22Mar2002 1000	22Mar2002 0700
	559.1		Close Closure Structure No. 3	22Mar2002 0800	22Mar2002 0800
	559.2		Prepare to close Closure Structure No. 2, notif	22Mar2002 0800	22Mar2002 0800
	561.0		Close Closure Structure No. 2	22Mar2002 1000	22Mar2002 1000
				Max Flood Stage - 25Mar2002, 07:00 562.07 ft	Max Flood Stage - 25Mar2002, 07:00 562.07 ft

Inundation Mapping

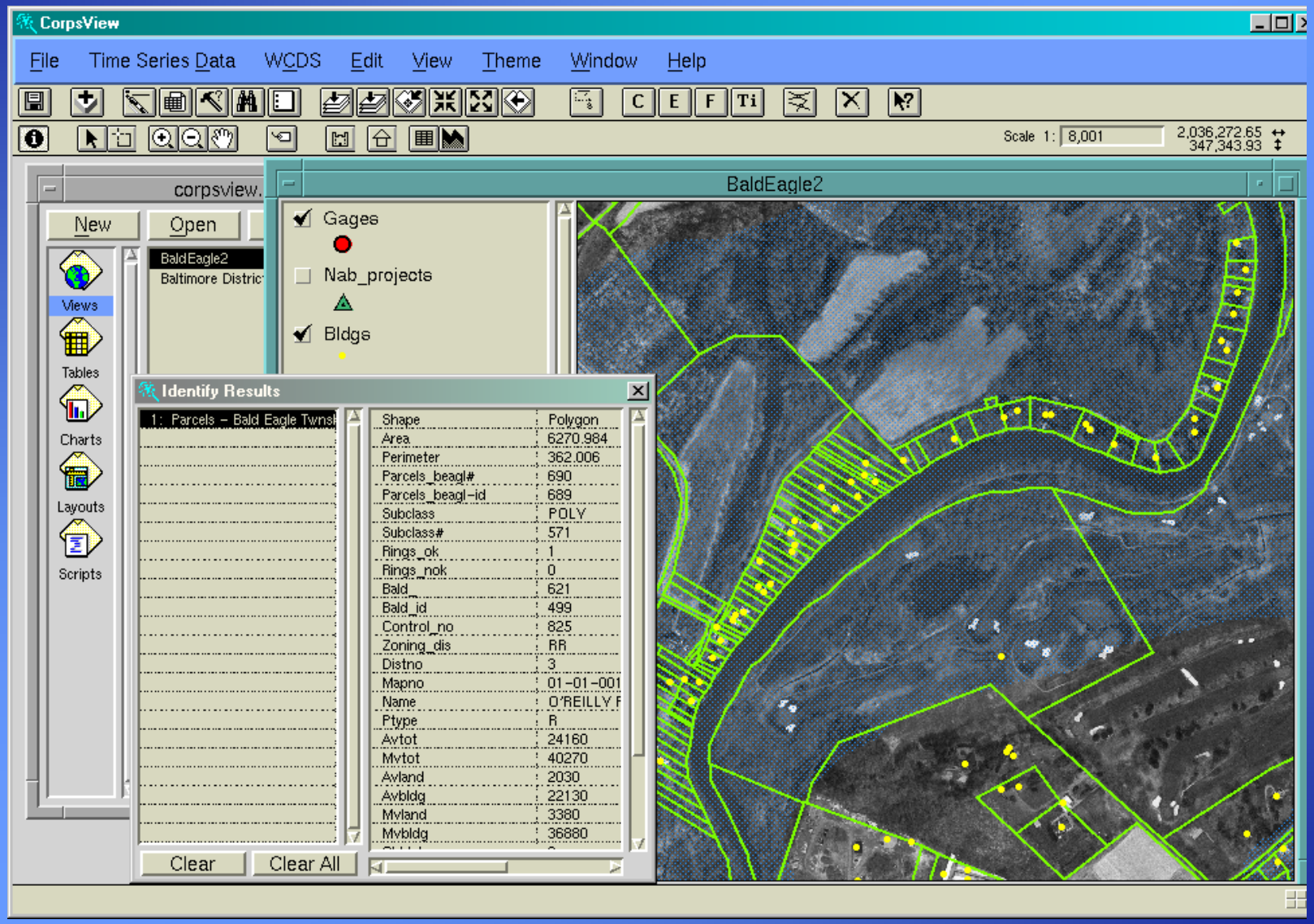
Delineates geographic extent of flooding using model results & topography



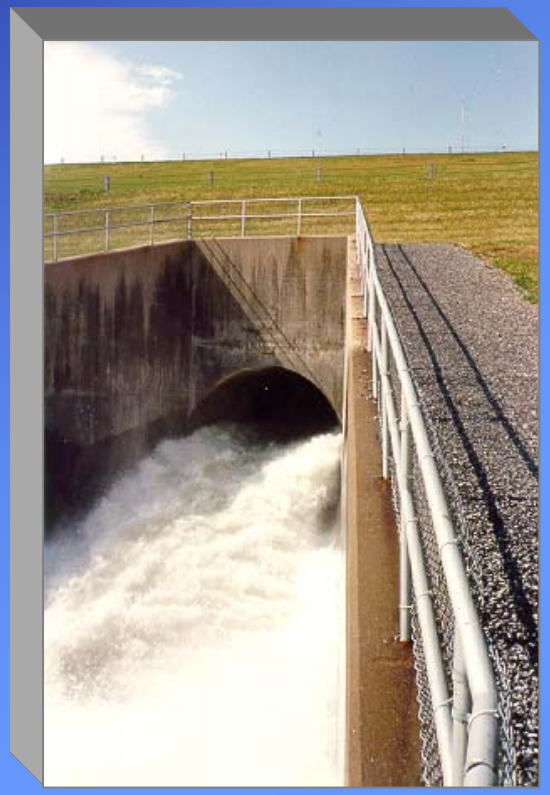
CorpsView Displays



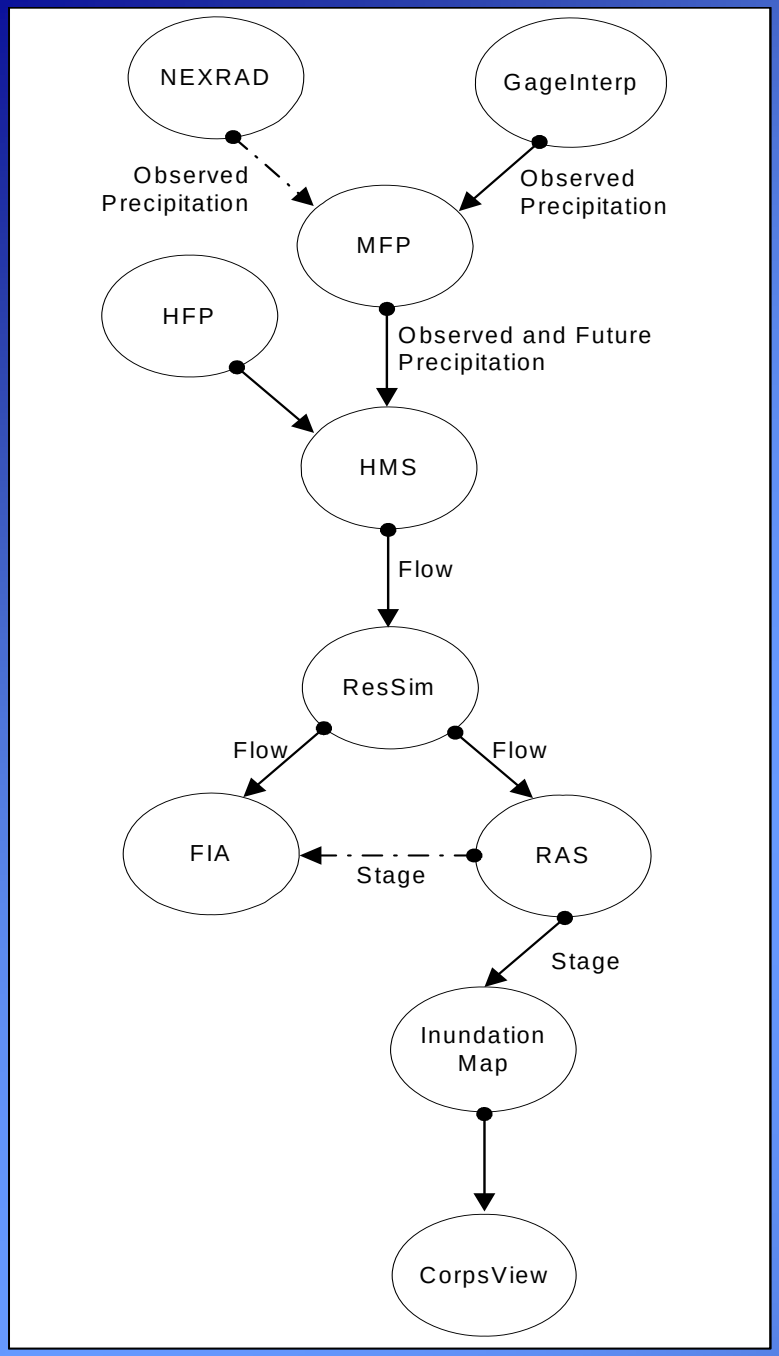
CorpsView - Site Information



The Modeling Process



1) Check status & currency of real-time data
2) Select a forecast time
3) Adjust model parameters
4) Perform model computations
5) View results
6) Modify model parameters as necessary
7) Re-compute simulation

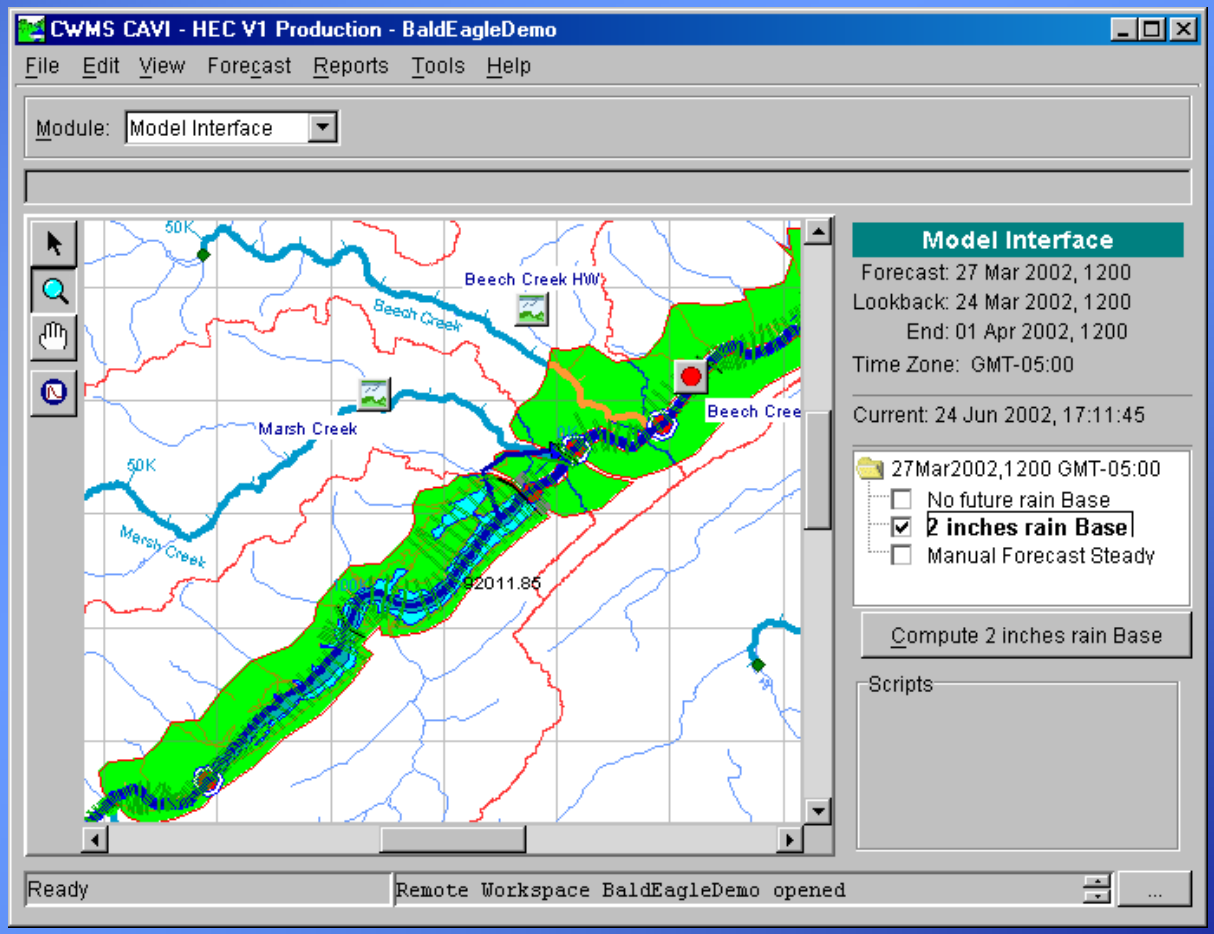


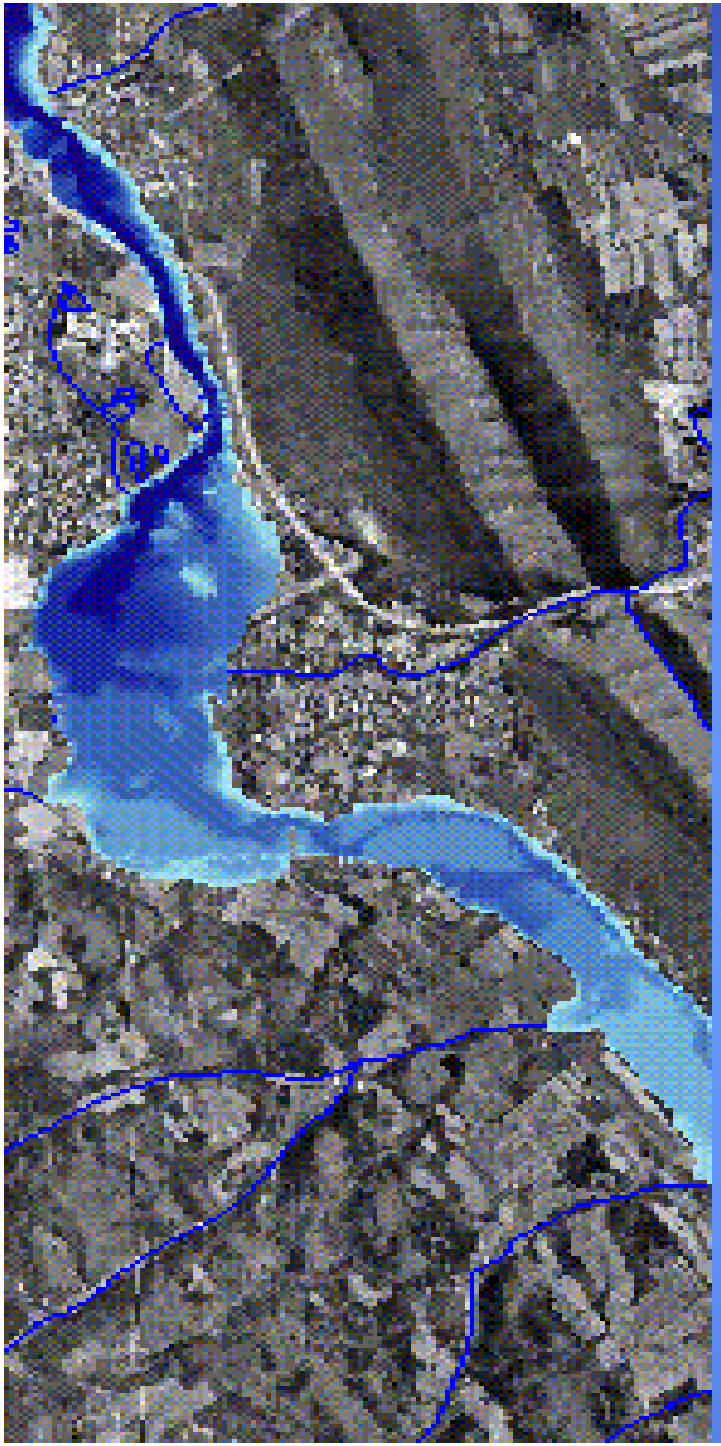
CWMS Model Linking

- HEC-HMS computes forecasted flows from
  - Observed precipitation from NEXRAD and rain gages
  - Future precipitation forecasts and scenarios
  - Observed flow
- ResSim simulates reservoir operations and downstream flows from HEC-HMS flows.
- HEC-RAS computes stages and inundation areas from ResSim flows.
- FIA computes damages and impacts from HEC-RAS stages or ResSim flows.
- Inundation areas and depths are displayed in CorpsView, an extension to ARC.

CAVI Model Interface and Control

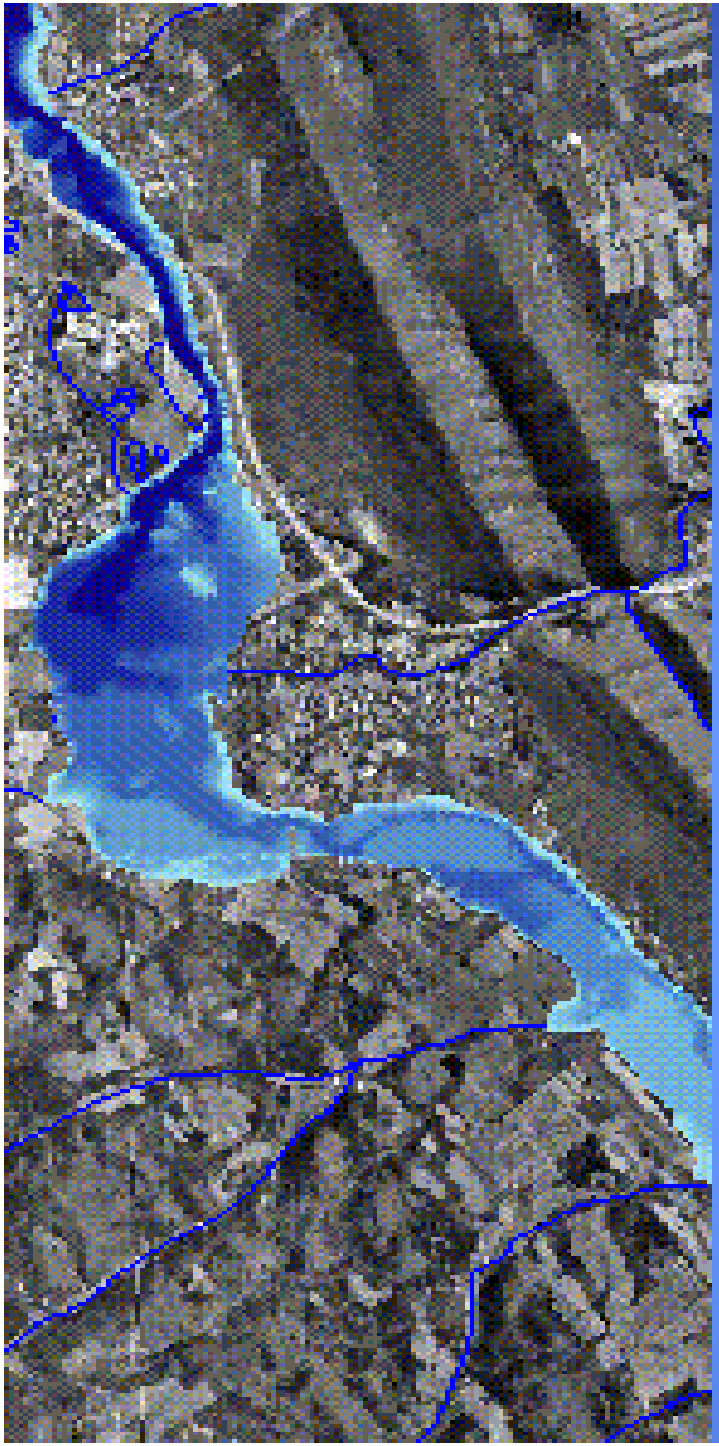
- Executes and controls various models
- Set model parameters
- Visualize Results
- Generate and Compare Alternatives





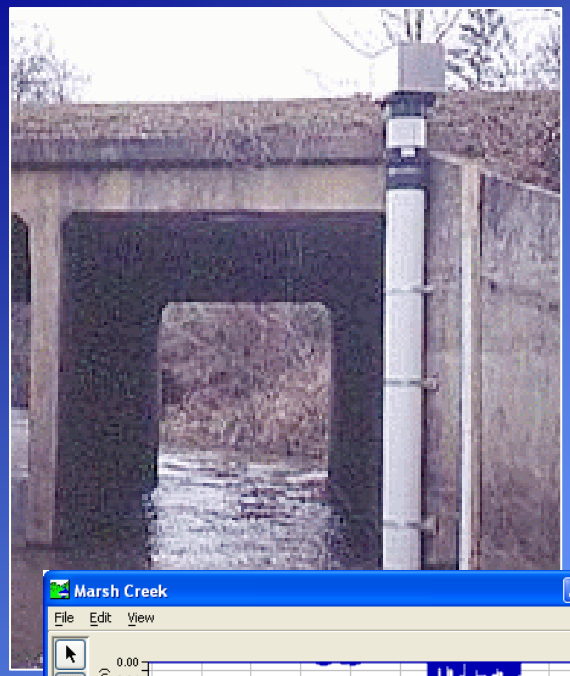
CWMS Simulation Modeling

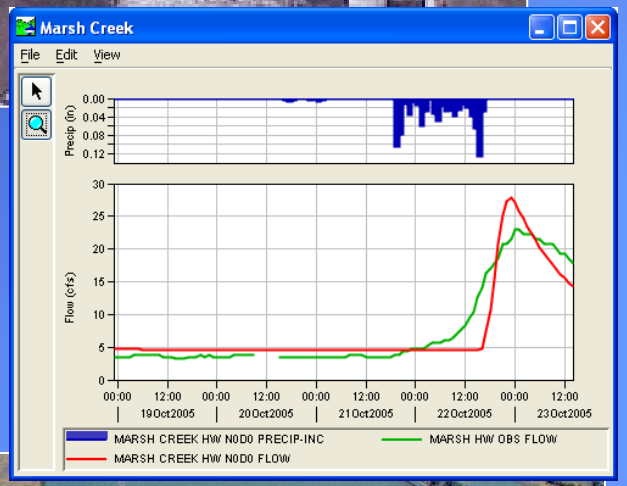
- Modeling programs exchange time-series and curve data through HEC-DSS
- Model representations are sent to the CAVI client from the CWMS server
- Model parameters are modified in the CAVI Model Interface and sent back to the server
- Models are executed on the server
  - Allows several users to access models and view results at the same time
  - Consistent and central storage area
- Results and “alternatives” are view and compared on multiple CAVI clients

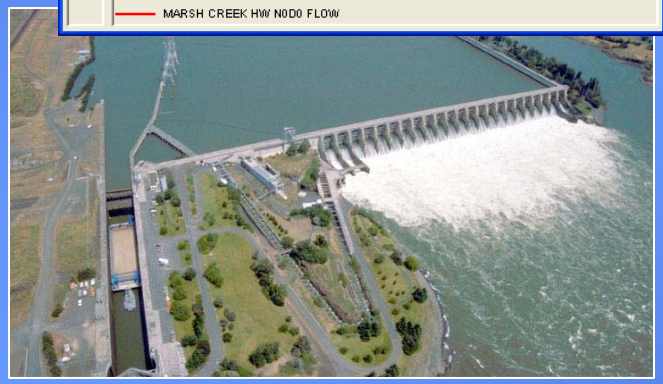


CWMS Simulation Modeling

- User selects a “forecast time”
  - Typically a couple of hours old
  - All data is known up to that time
  - All data is simulated after that
- A working directory is created on the server
- All data and model input files are copied into that directory
- Multiple users can share and run models from this directory
- Alternatives and “What if” scenarios are created here
- The models can be rerun and evaluated at a later time from this directory

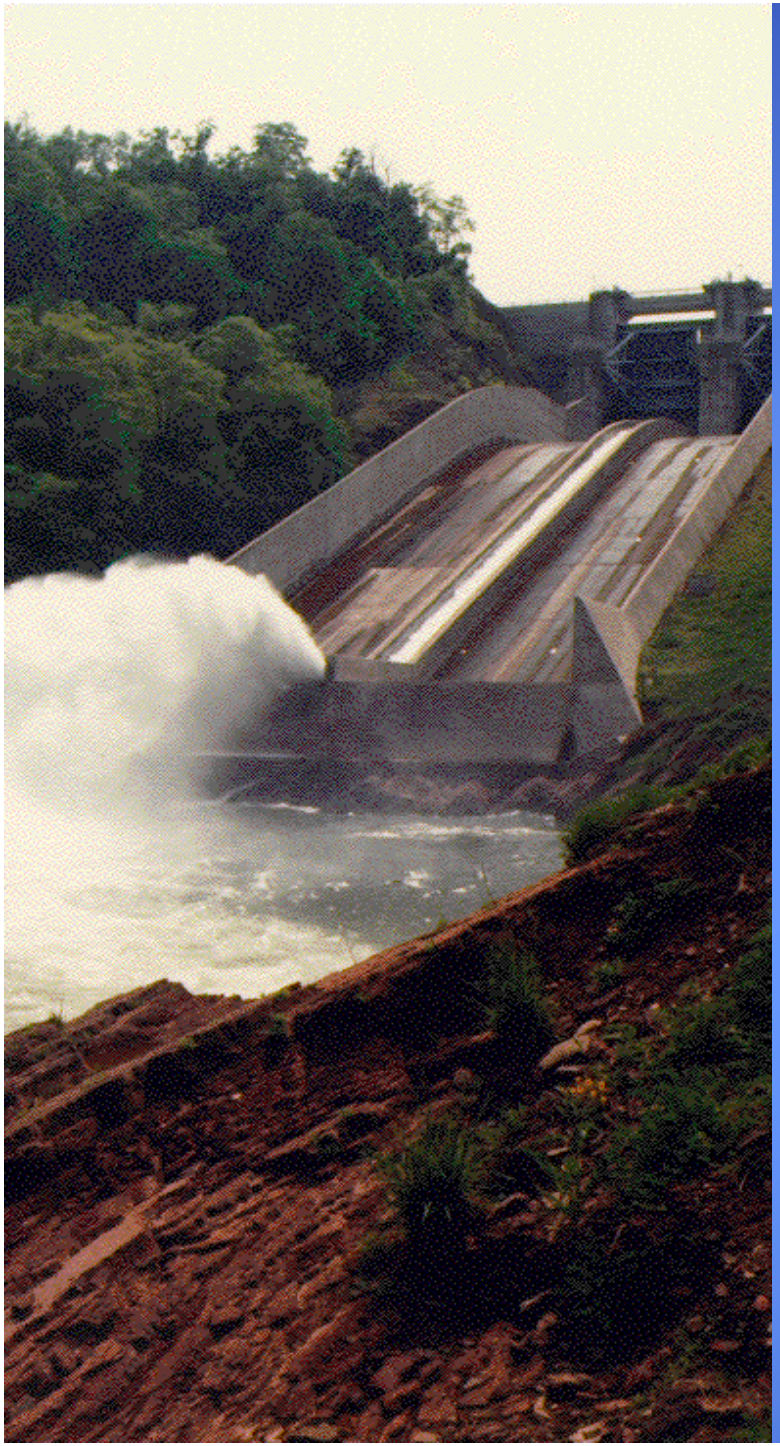






Calibration

- HEC-HMS is calibrated for the observed time window, adjusting
  - Soil moisture parameters
  - Base flow
  - Routing coefficients
- Computed verses observed hydrographs are compared for gaged headwater subbasins
- Calibration parameters are generalized to adjacent areas that do not have gages for calibration



Reservoir Operation Simulation

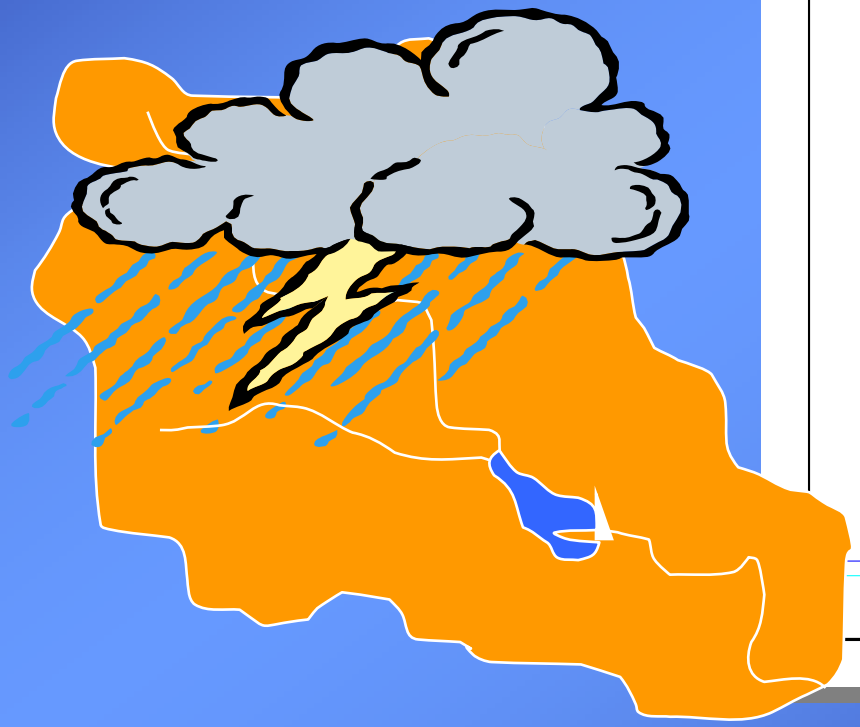
- HEC-HMS is then executed with likely precipitation scenarios
- HEC-ResSim simulates reservoir operations and computes downstream hydrographs
- The impact of the hydrographs are evaluated with HEC-RAS and HEC-FIA
- Releases may be overridden or rule sets modified to improve operations

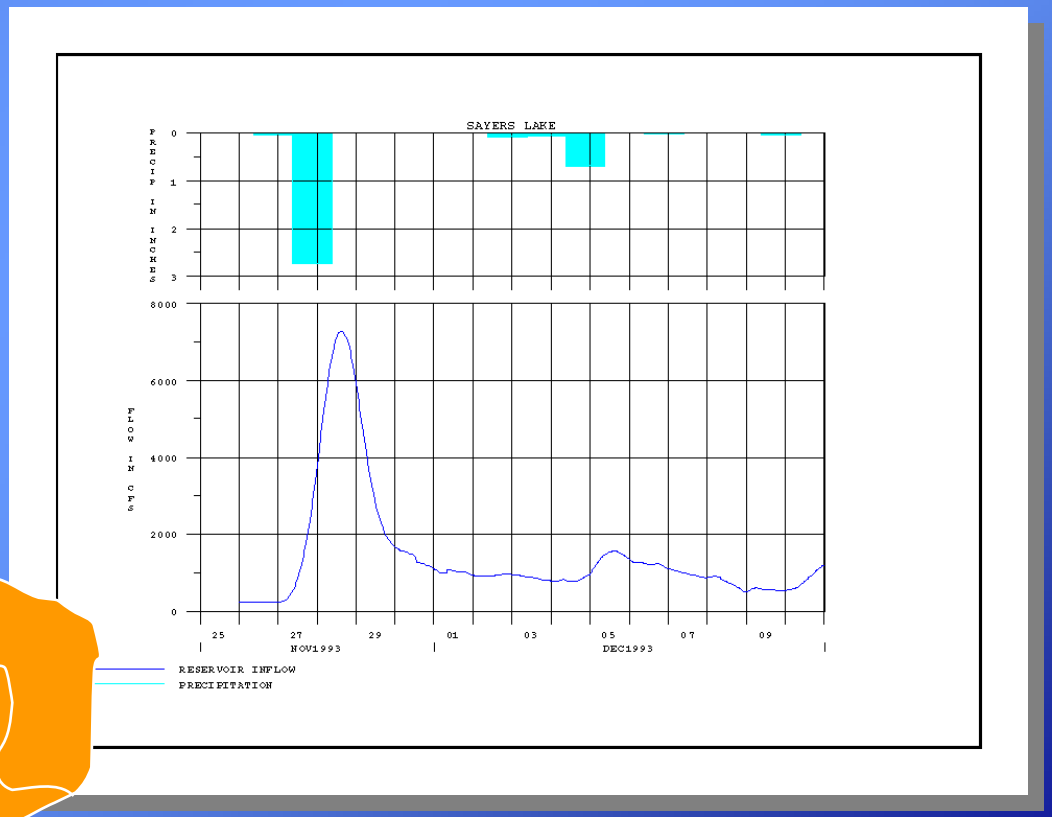
Precipitation Analysis

- Precipitation processed on a grid basis.
- Observed data from NEXRAD or interpolated from gages.
- Future Precipitation Scenarios:
  - NWS Quantitative Precipitation Forecasts (QPF)
  - Multiples of the QPF
  - Manual-entry or standard scenarios (What if?)
    - Timing
    - Location (watershed “zones”)

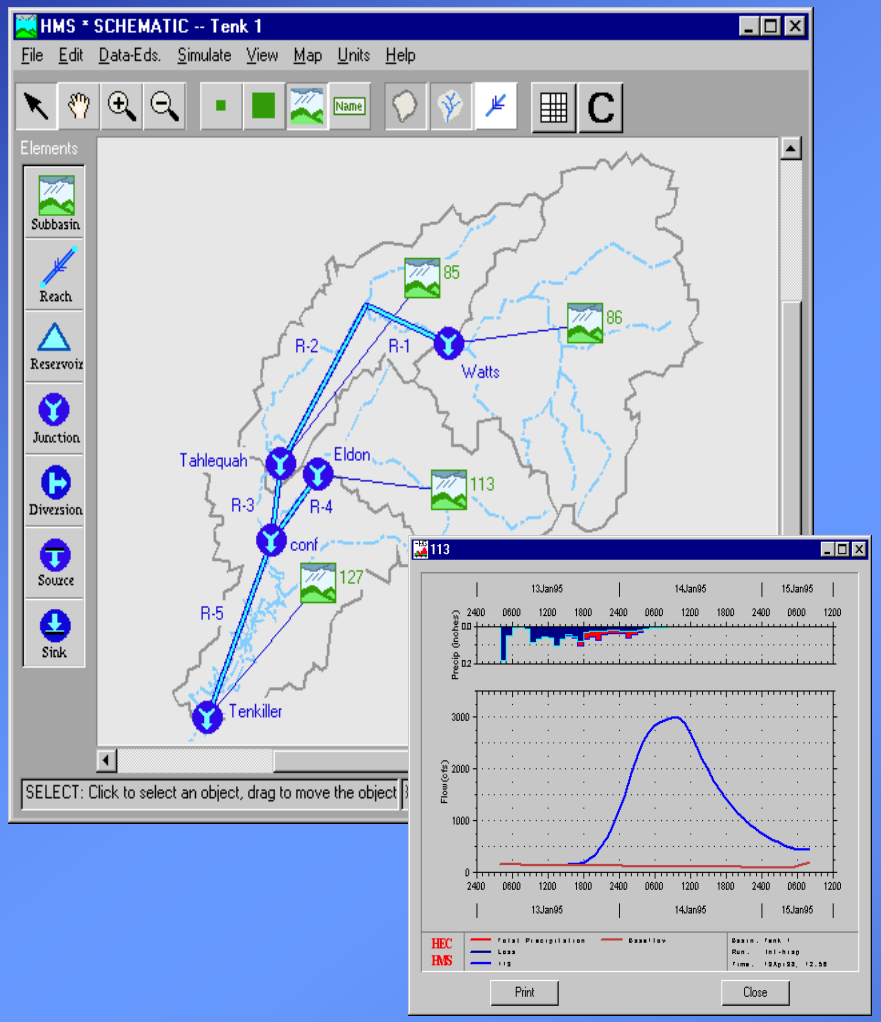
HEC-HMS
Hydrologic Modeling System

Computes runoff from observed & forecasted precipitation



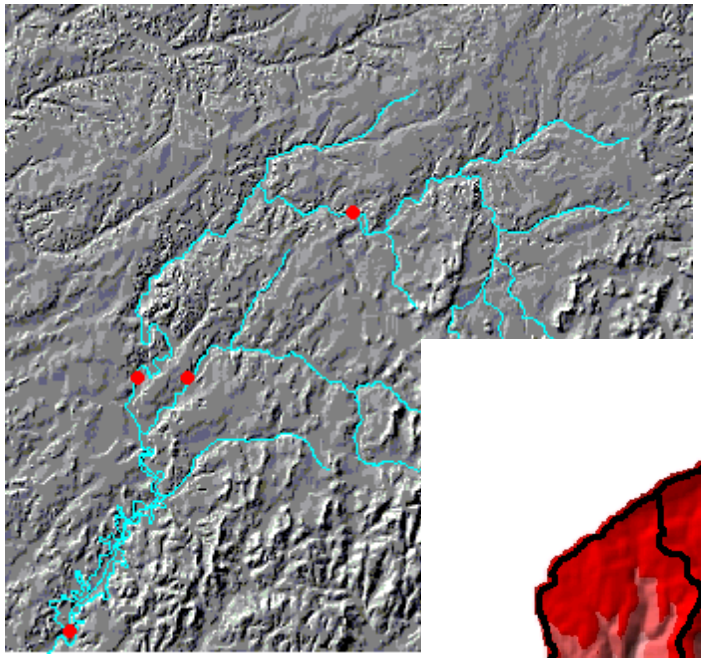


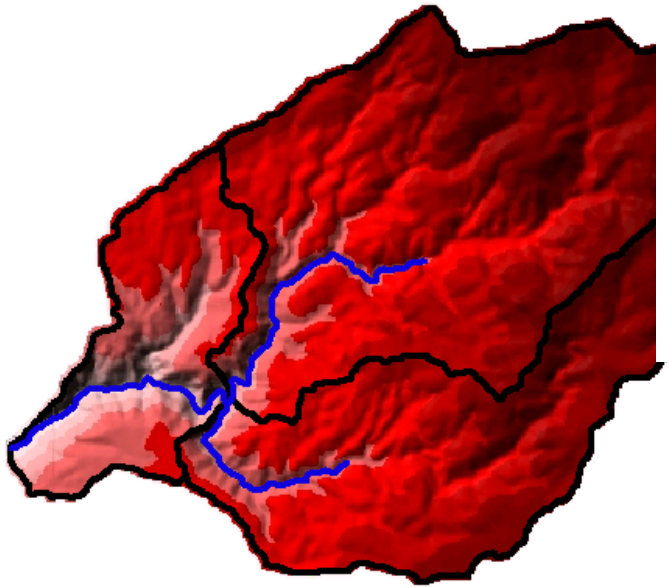
Hydrologic Modeling (HEC-HMS)

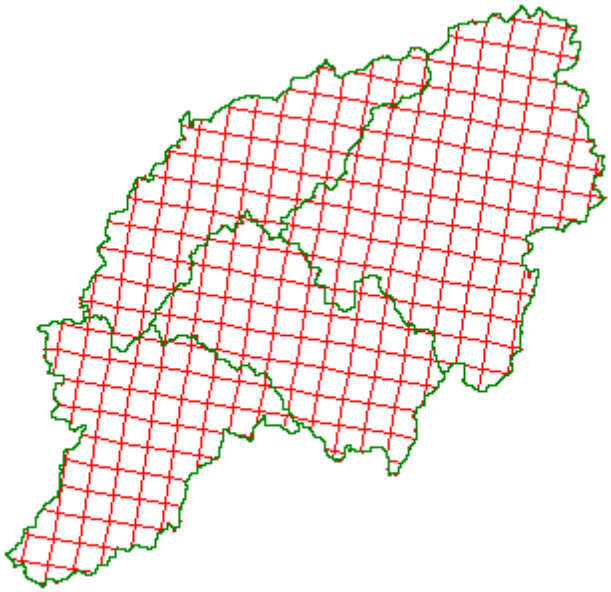


- Computes runoff from observed data and future precipitation scenarios
- "Event-oriented" model
- ModClark model for rainfall/runoff transform from distributed data
  - Grid cell sizes are approximately 2 km x 2 km
  - Excess rainfall is lagged by grid cell translation times, routed through linear reservoirs, then combined at subbasin outlets.
- Soil moisture conditions calibrated prior to modeling runs

Gridded Runoff Analysis







HEC-HMS
Input & Output

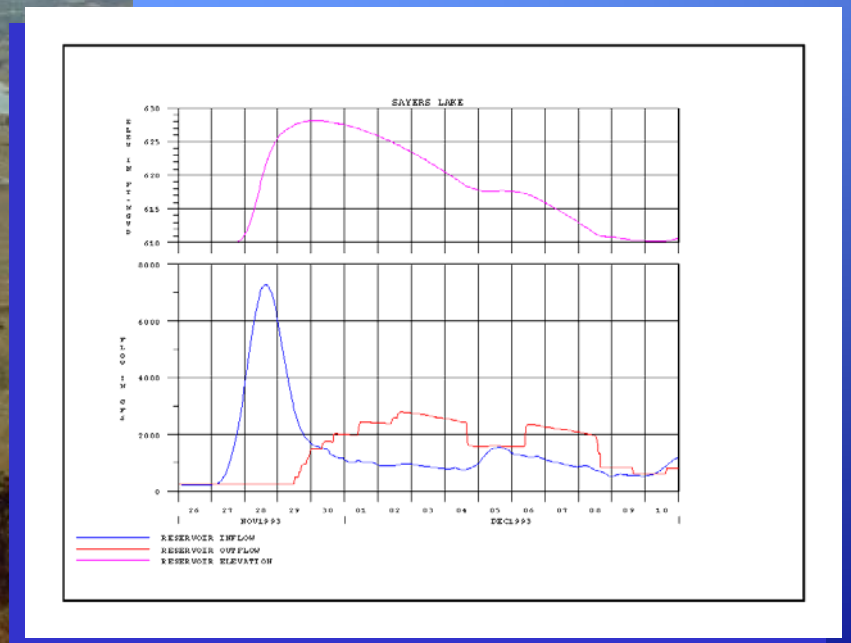
- Precipitation amounts
- Timing & distribution
- Basin hydrologic parameters

➔ Streamflow hydrographs

HEC-ResSim

Reservoir Simulation System

Simulates reservoir regulation using inflow hydrographs & project characteristics



Reservoir Operations HEC-ResSim

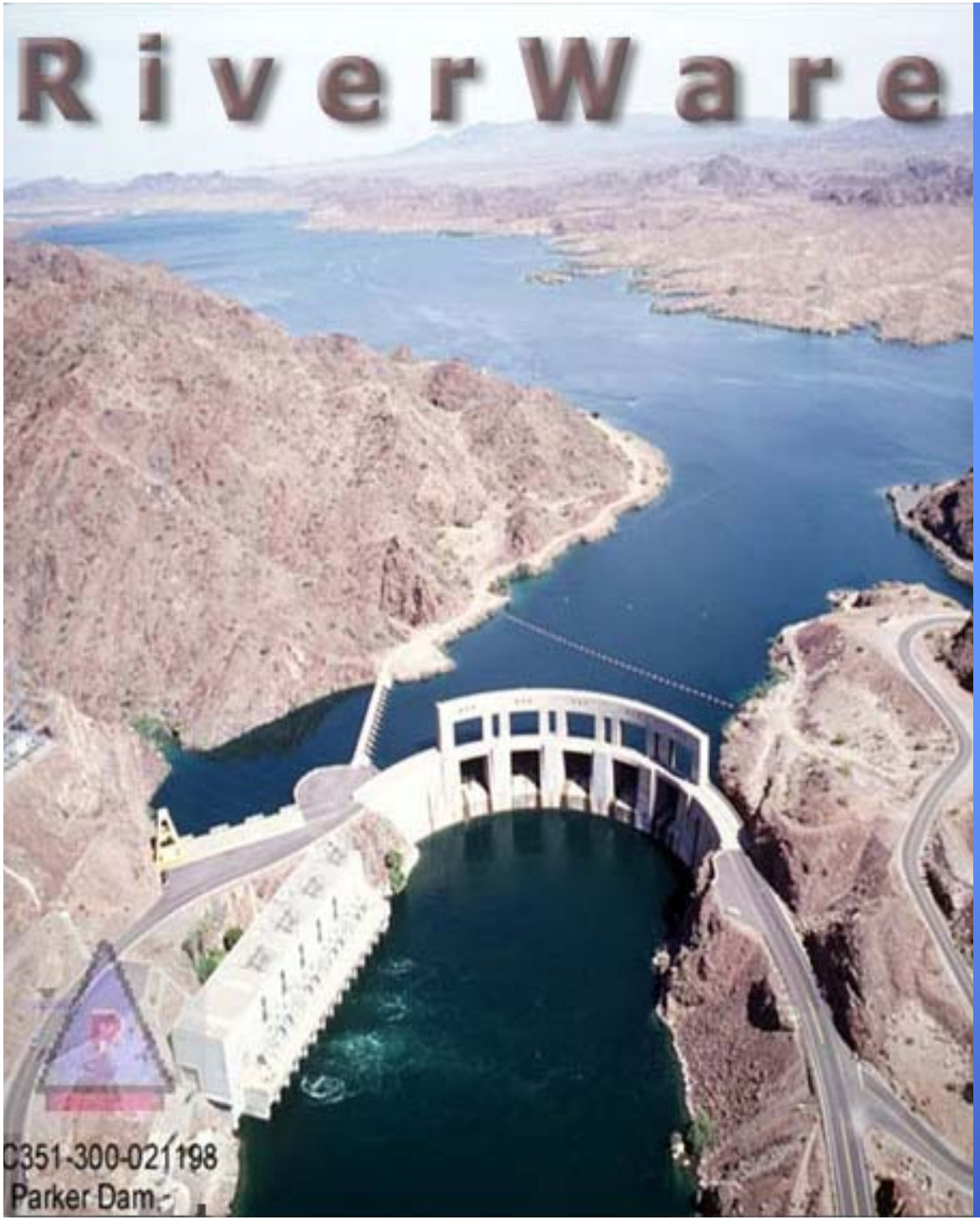
- Simulates operations through user-defined operating rules and scheduled releases
- Uses reservoir inflow and downstream local hydrographs computed by HEC-HMS
- Manually set release “overrides”
- Automatically generates downstream hydrographs for a “no reservoir” condition for project benefit analysis

HEC-ResSim Input & Output

- Inflow hydrographs
- Reservoir characteristics
- Regulation rules & constraints

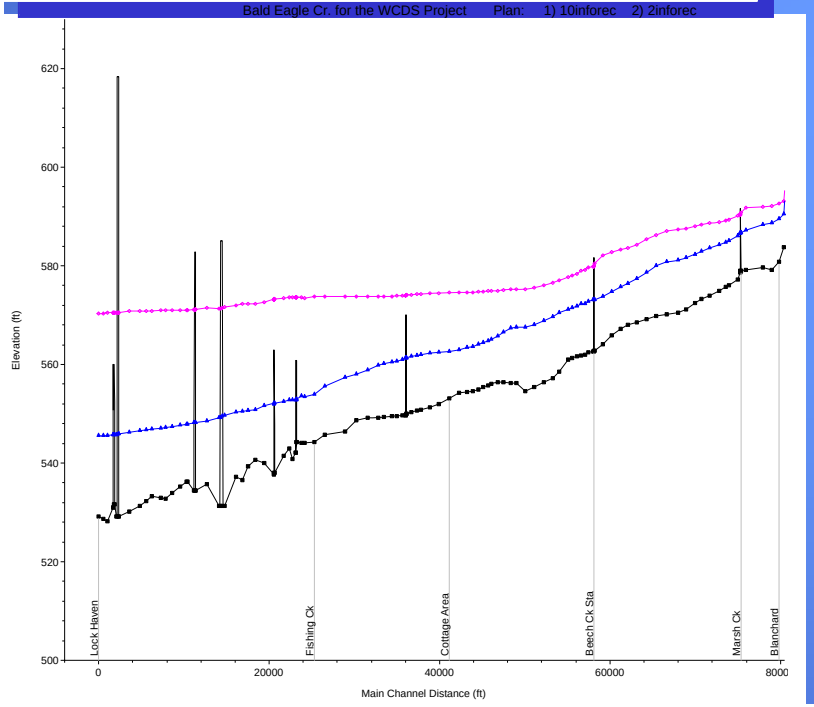
➔ Reservoir storage, release, & spillway flow

➔ Downstream hydrographs (with & without regulation)



Reservoir Operations with RiverWare

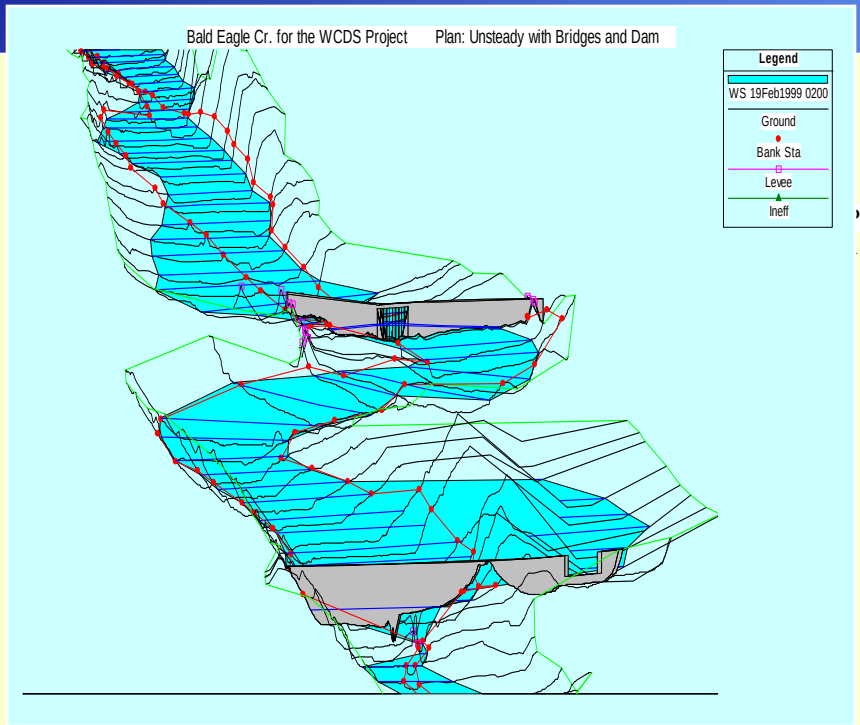
- Use with or in place of ResSim
- Tightly integrated into CWMS
- Uses HEC-DSS for time-series data

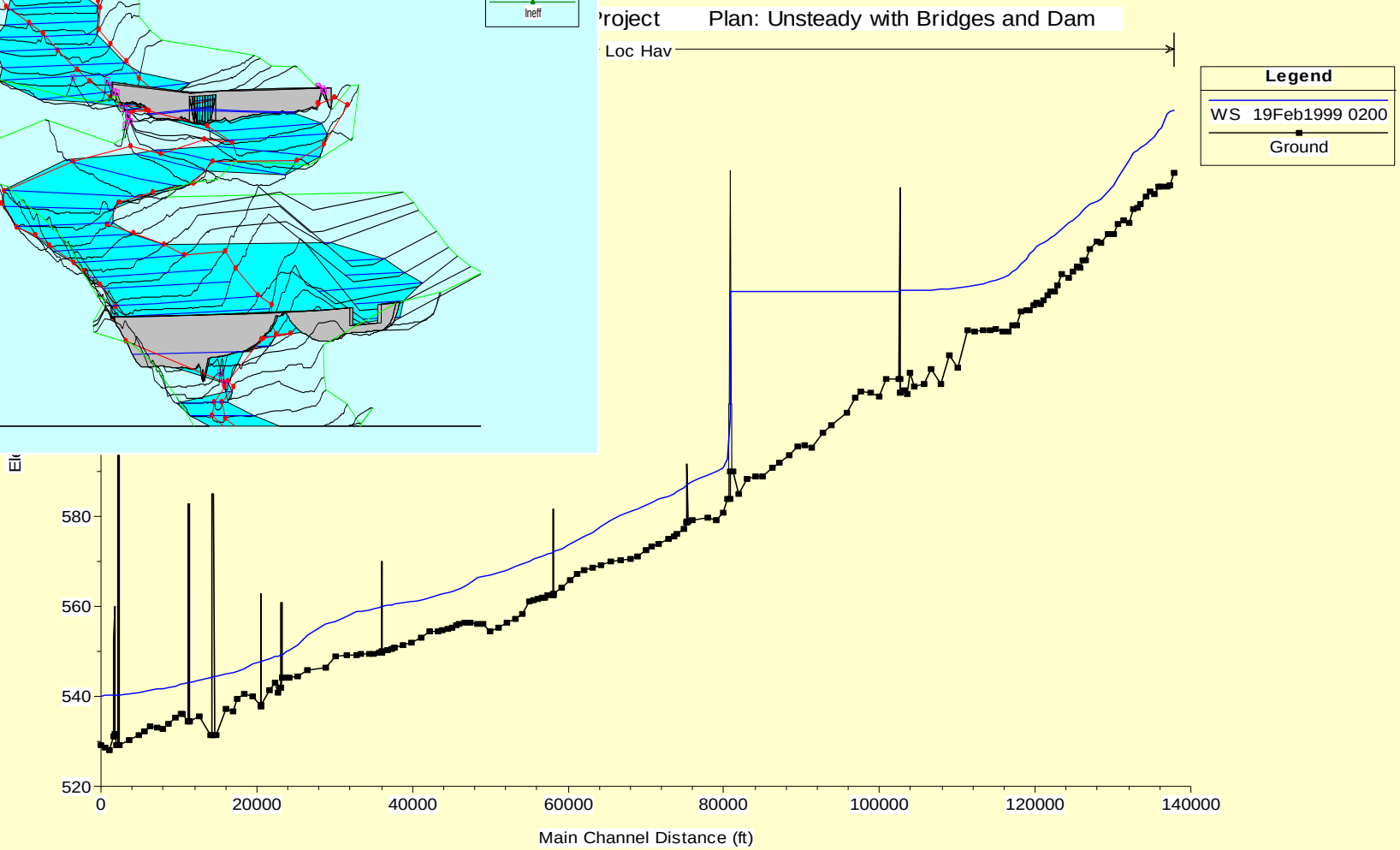


River Hydraulics HEC-RAS

- Analyzes river hydraulics to compute water depth, velocity, & inundation boundaries
- Computes water surface profiles and stage hydrographs from HEC-ResSim hydrographs
- Steady-flow or unsteady-flow analysis.
- Channel friction adjusted through CWMS interface
- Used in conjunction with Arc, inundation boundaries and depth maps are computed then viewed with CorpsView, an extension to Arc

River Profile Modeling



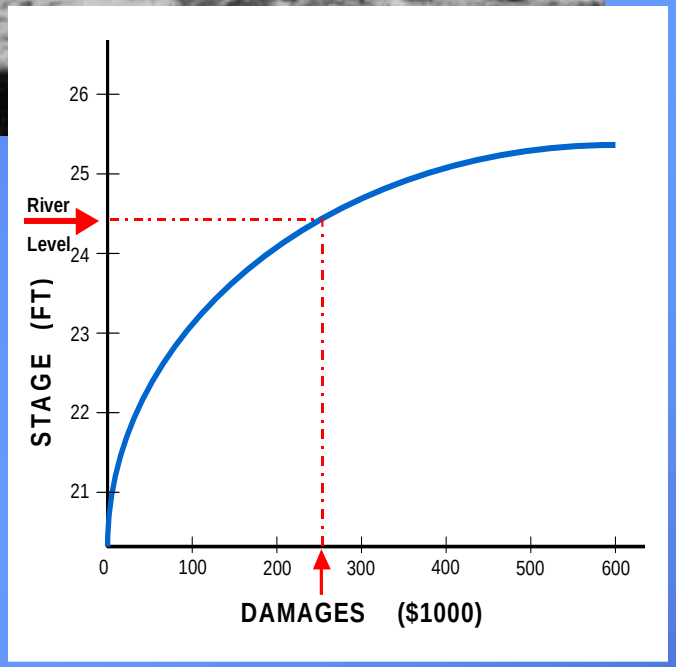


HEC-RAS
Input & Output

- Streamflow hydrographs
- Channel hydraulic characteristics

➔ Water surface elevations & profiles

➔ Inundation boundaries



Economic / Impact Analysis (HEC-FIA)

- Computes agricultural and urban damages and project benefits by “impact area”
- Computes damages and benefits between different scenarios, and with and without project conditions
- “Action tables” provide a list and time of actions to take during an event, based on forecasted stages

Impact Action Table

Impact Area	Stage (ft)	Impact		Time	
				Initial Forecast	Modified Releases
Cottage Area	556.0	Flood Warning Stage	Initiate reconnaissance and alert appropriate p	22Mar2002 0600	22Mar2002 0600
	558.0	Flood Stage	Full alert, warn of potential evacuation.	22Mar2002 0700	22Mar2002 0700
	560.0	Damage to infrastructure, landscape, etc.	Close life lines & roads to everyone but local tr	22Mar2002 0900	22Mar2002 0900
	561.0	Egress begins to be a problem.	Evacuate residences & perform surveillance.	22Mar2002 1000	22Mar2002 1000
				Max Flood Stage - 25Mar2002, 07:00 562.63 ft	Max Flood Stage - 25Mar2002, 07:00 562.63 ft
Lock Haven	535.2	Zero stage reading		19Mar2002 1000	19Mar2002 1300
	540.1	Flap gates of interior drains under water	Check drains to ensure operation	21Mar2002 2300	21Mar2002 2300
	543.2	Elevation of Grant Street Dam		22Mar2002 0100	22Mar2002 0100
	545.0	Handrails at Summer Beach nearing inun	Remove handrails & close Grant Street Dam p	22Mar2002 0200	22Mar2002 0200
	549.0	Grant Street Dam platform elevation		22Mar2002 0400	22Mar2002 0400
	553.0	Flood Warning Stage	Begin levee patrol	22Mar2002 0600	22Mar2002 0500
	556.2	Flood Stage	River overtops bank	22Mar2002 0900	22Mar2002 0700
	556.3	Bath house floor elevation	Close bath house	22Mar2002 0900	22Mar2002 0700
	557.2		Prepare to close Closure Structure No. 3	22Mar2002 1000	22Mar2002 0700
	559.1		Close Closure Structure No. 3	22Mar2002 0800	22Mar2002 0800
	559.2		Prepare to close Closure Structure No. 2, notif	22Mar2002 0800	22Mar2002 0800
	561.0		Close Closure Structure No. 2	22Mar2002 1000	22Mar2002 1000
				Max Flood Stage - 25Mar2002, 07:00 562.07 ft	Max Flood Stage - 25Mar2002, 07:00 562.07 ft
Sayers Lake Area	586.0	Streambed	None	19Mar2002 1300	19Mar2002 1300
	590.0	Gate Sill	None	19Mar2002 1300	19Mar2002 1300
	610.0	Late Winter Conservation Pool	None	19Mar2002 1300	19Mar2002 1300
	625.0	Mid winter Conservation Pool	None	22Mar2002 1000	22Mar2002 1000
	630.0	Summer Recreation Pool	None	22Mar2002 1600	22Mar2002 1600
	631.0	Marina and Launch Ramps	Lift gangplanks connecting marina and launch	22Mar2002 1800	22Mar2002 1800
	633.0	Marina and Launch Ramps	None	22Mar2002 2200	22Mar2002 2200
	634.5	Entrance to Parking @ Winter Lot	Close road to winter parking lot	23Mar2002 0200	23Mar2002 0300
	635.0	Invert, Howard flap gates for interior drain	Begin monitoring Howard interior drainage area	23Mar2002 0400	23Mar2002 0500
	636.0	Top Well # 3 Pump Station at Green Brid	Close road to pump station at Green Bridge	23Mar2002 0900	23Mar2002 1400
	636.1	Low Pt. Sycamore Loop Road	Close Sycamore Loop Road	23Mar2002 1000	23Mar2002 1500
	636.6	Low Pt. Winter Boat Storage Area	Move boats from winter storage area	23Mar2002 1400	
	637	Floor of Restroom-W Hunter Run Launch	Close restroom at Hunter Run	23Mar2002 1700	
	637.4	Low Pt. Road at Hunter Run Launch	Close road below Hunter Run parking lot	23Mar2002 2200	
	637.5	Parking Lot Entrance @ Bald Eagle Laun	Close road to Bald Eagle launch area	24Mar2002 0000	
	637.7	Entrance to Main Marina	Close main marina	24Mar2002 0300	
				Max Flood Stage - 25Mar2002, 07:00 647.86 ft	Max Flood Stage - 25Mar2002, 07:00 636.41 ft

HEC-FIA
Input & Output

- Stage hydrographs
- Geographic & economic information

- Damage
- Benefits
- Timetable for emergency actions

HEC-RTS

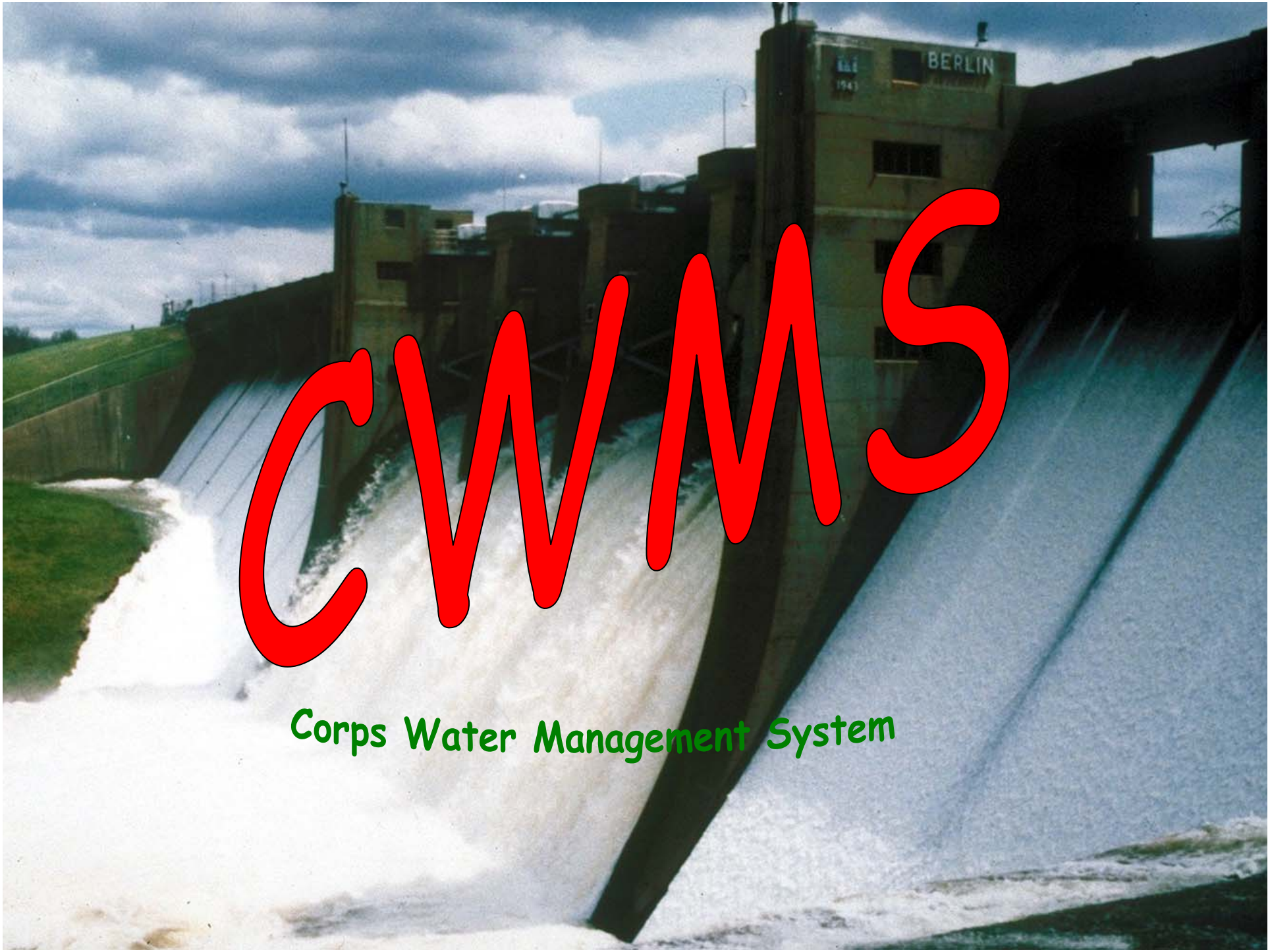
- Public Release of the CWMS model integration components for real-time decision support.
- PC-based (not client-server)
- Direct access to HEC-HMS, HEC-RAS and HEC-GeoRas
- Can Run RirverWare in addtion to ResSim
- No data acquisition / verification processing capabilities

Potential Future of Modeling for CWMS

- Running models both on the PC and on the server
  - Faster
  - Direct access to model programs
  - More control
- Integration with the server and caching (ala "CAVI-lite")
- Multi-user access is where the work is needed
  - Important consideration, especially during an event

Summary

- Comprehensive, integrated system for real-time water control decision support
- Complete data retrieval / verification / database system
- Full range of hydrologic / hydraulic modeling software to evaluate operational decisions and compare the impact of various “what if?” scenarios
- Client / Server architecture, with full set of visualization tools to evaluate data and model results



CWMS

Corps Water Management System