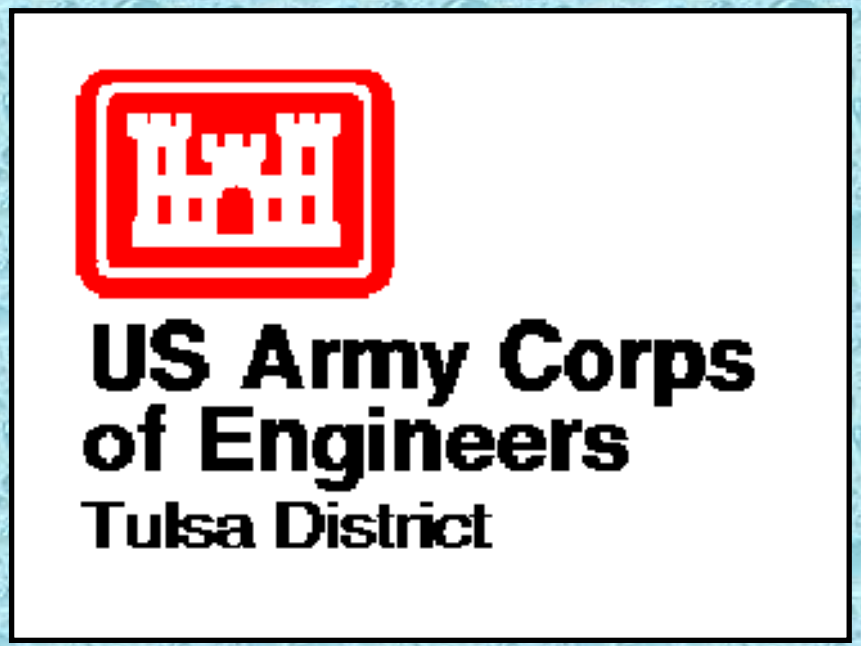
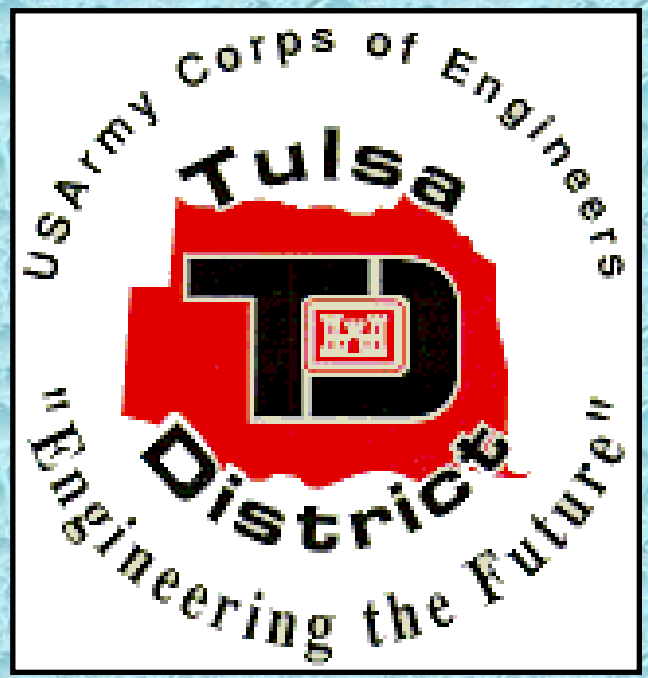
RIVERWARE FLOOD CONTROL METHODS ARKANSAS RIVER BASIN



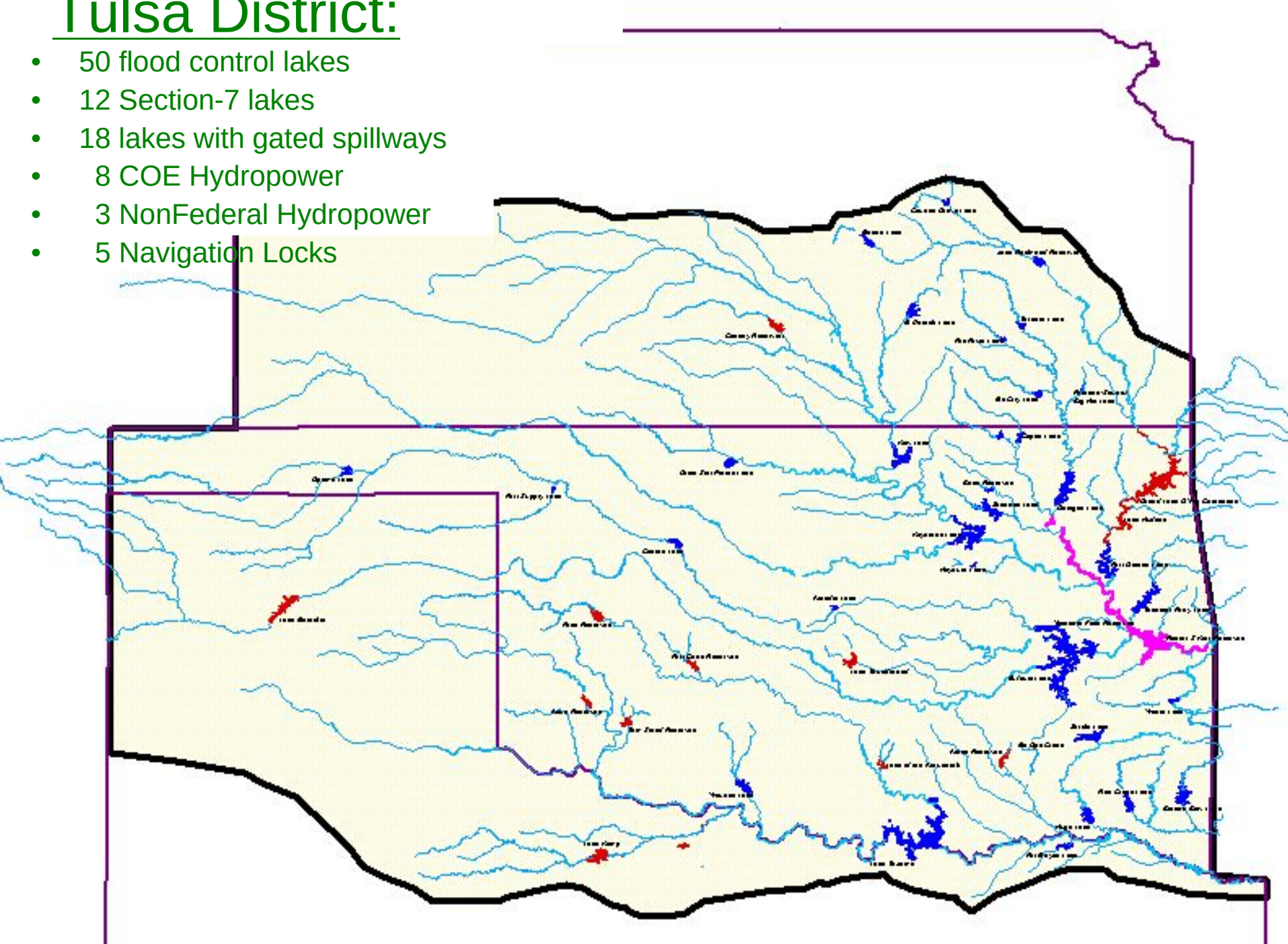


TODAY'S DISCUSION

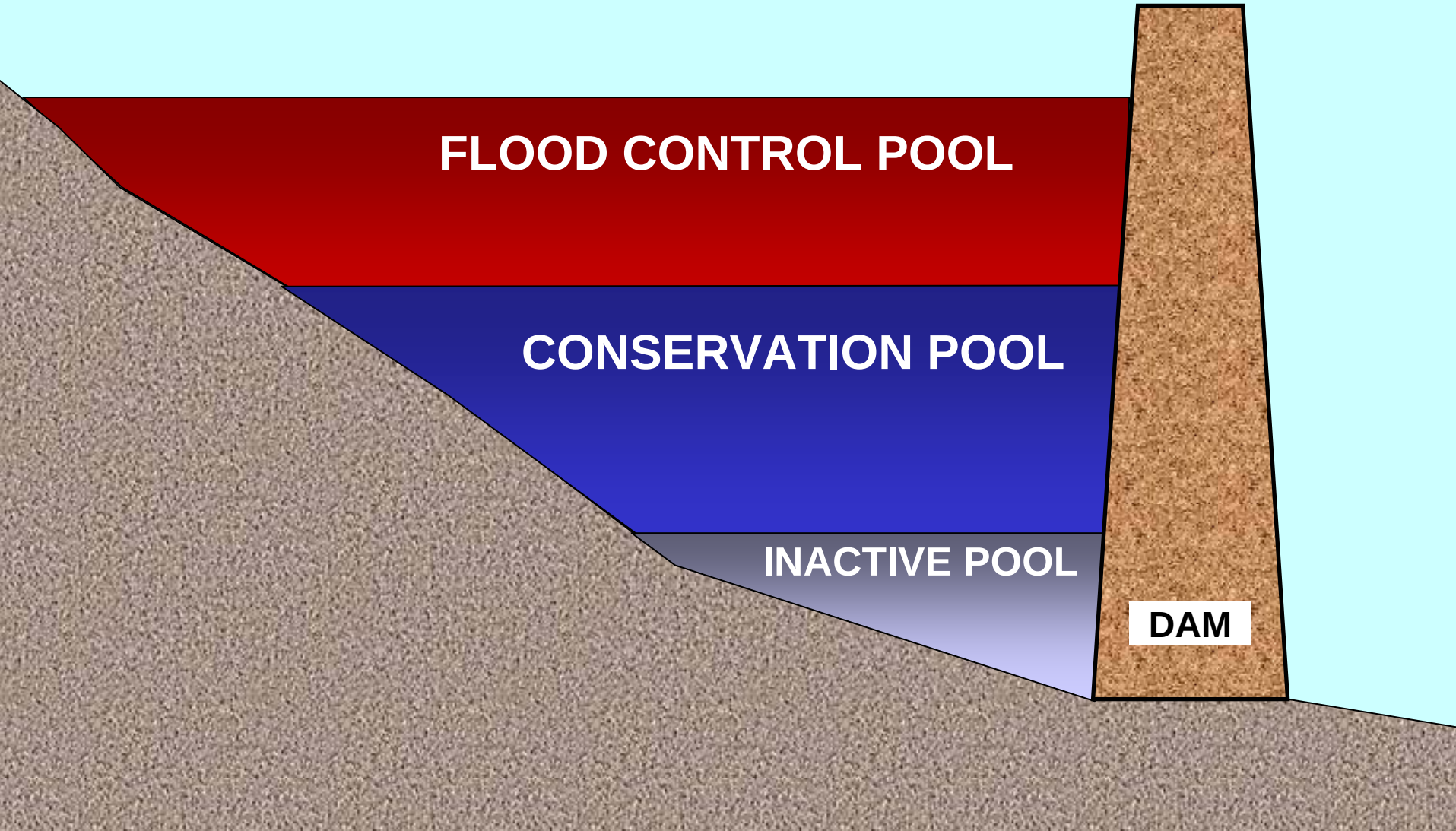
- System/Project Features: Arkansas River
- Need for period of record (POR) basin simulation model
- Transition to RiverWare, brief history
- New flood control methods in RiverWare
- Future work

Tulsa District:

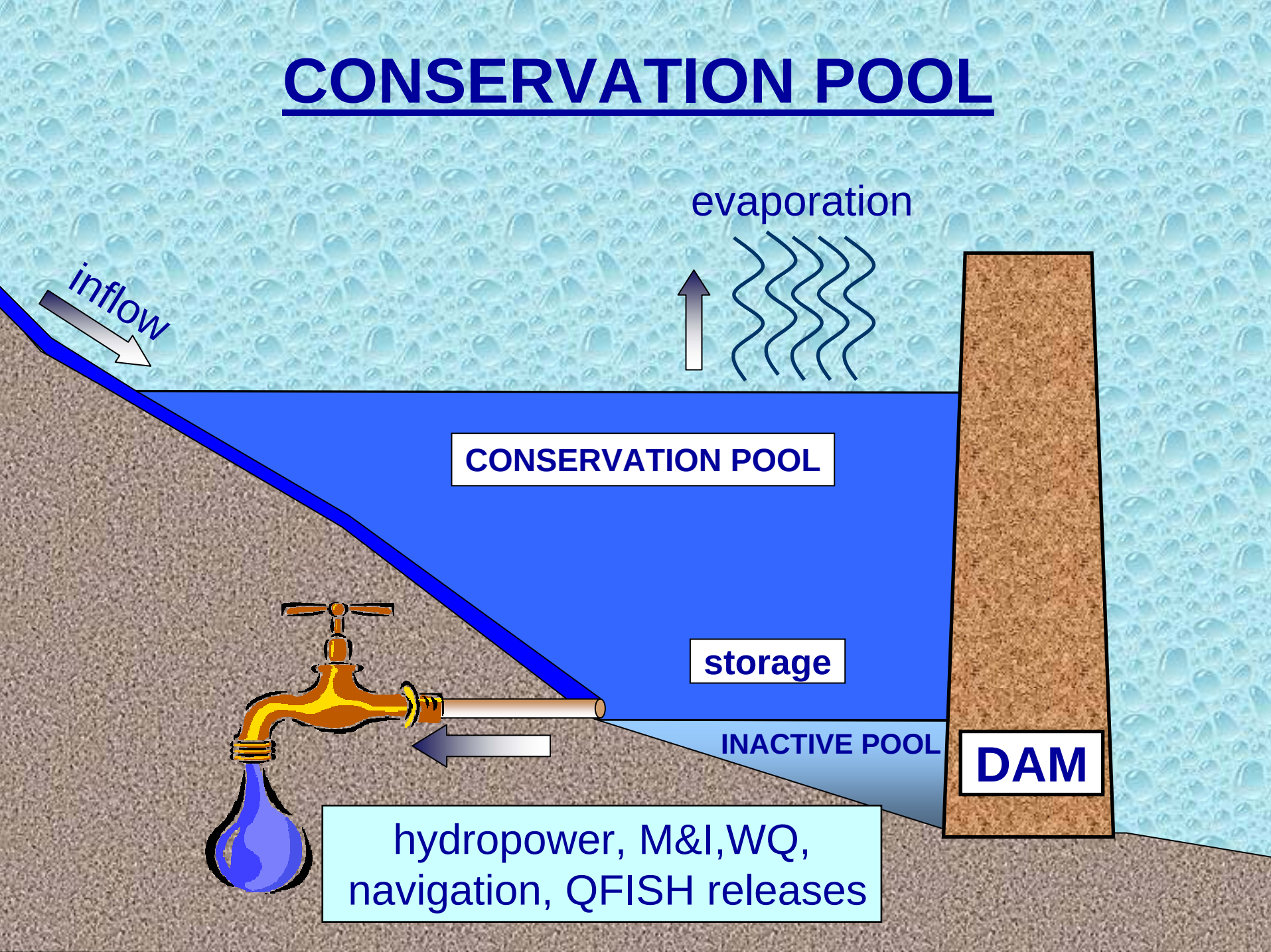
- 50 flood control lakes
- 12 Section-7 lakes
- 18 lakes with gated spillways
- 8 COE Hydropower
- 3 NonFederal Hydropower
- 5 Navigation Locks



STORAGE DIVISIONS



CONSERVATION POOL

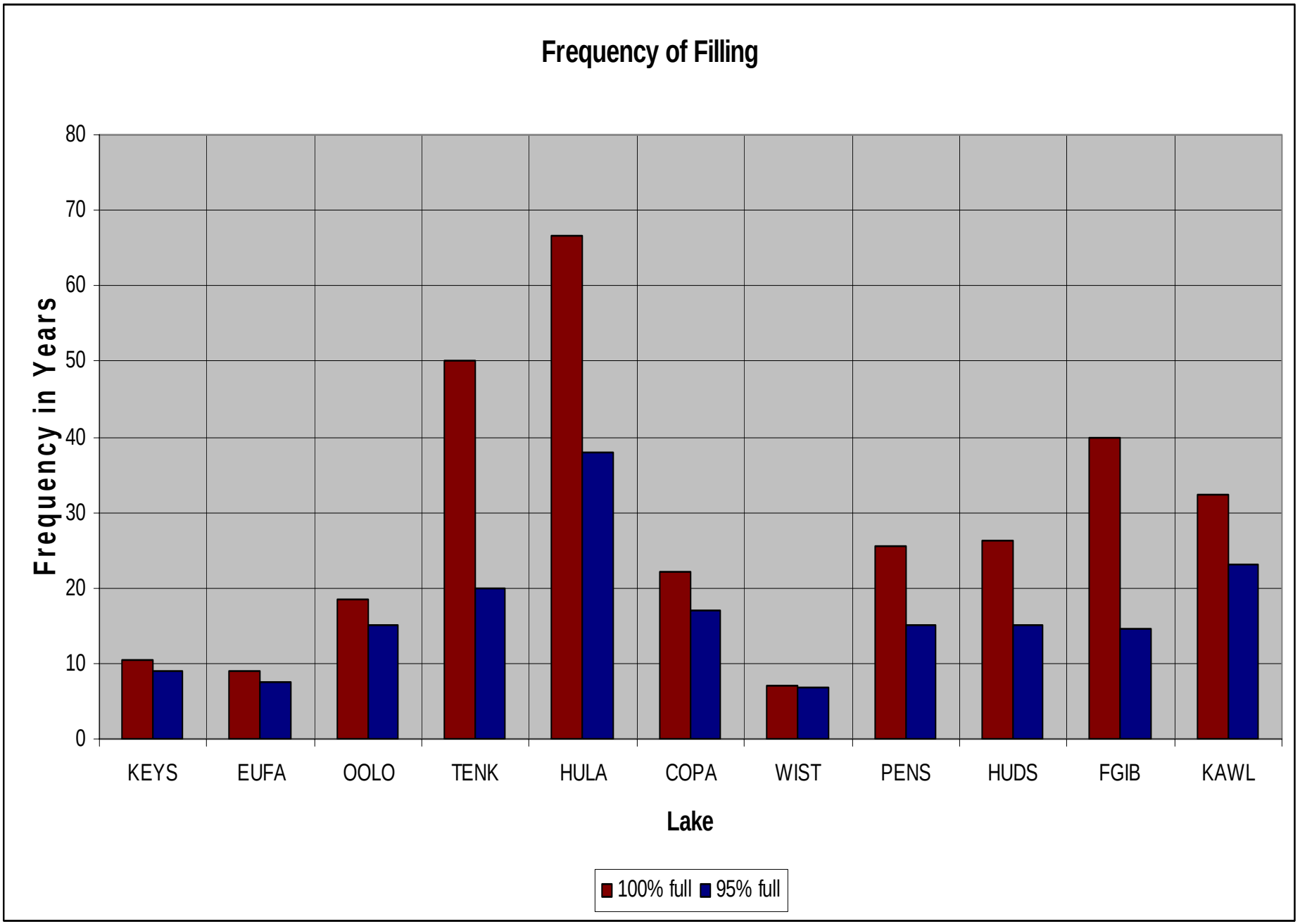


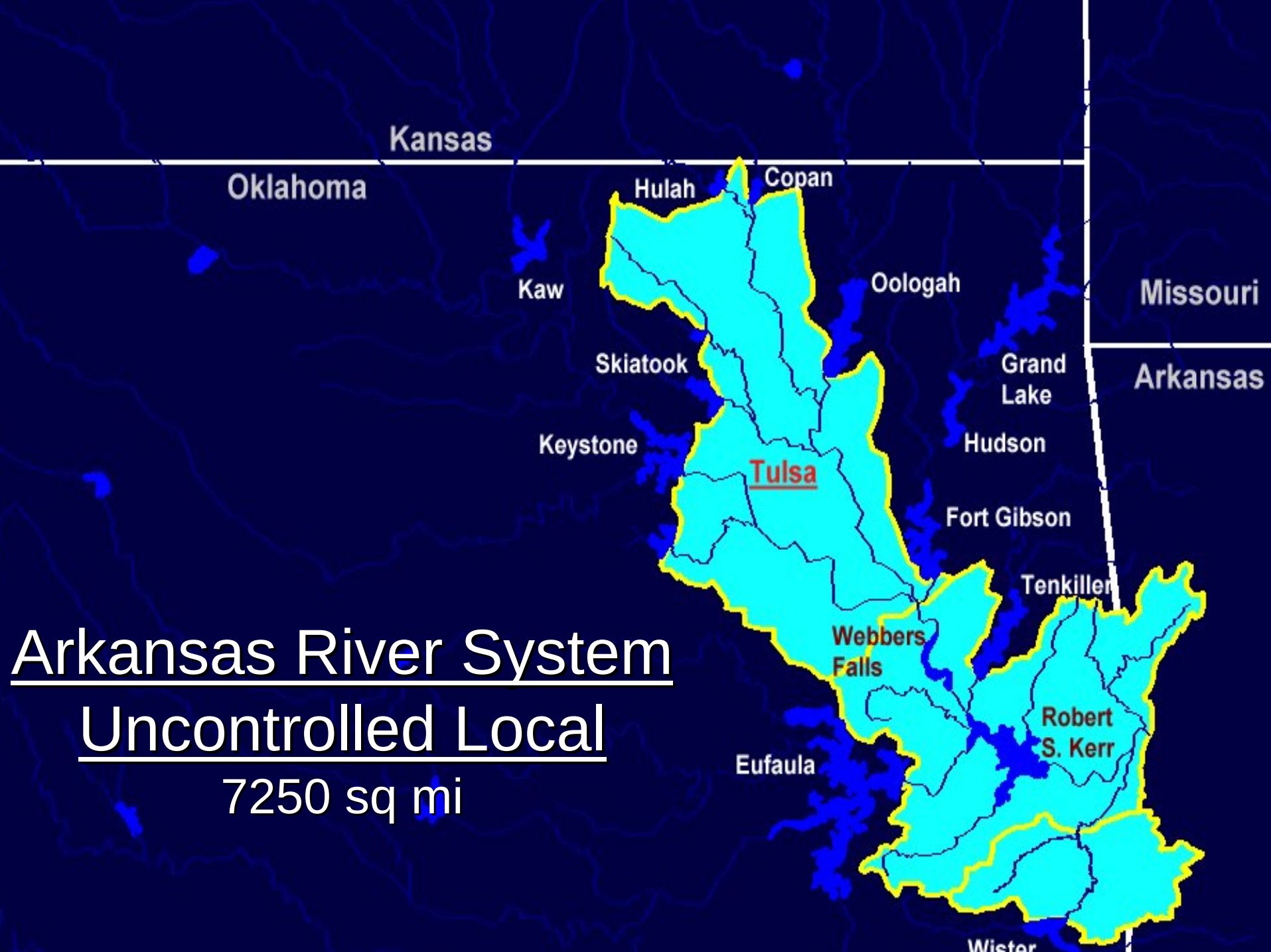
ORIGIN OF INFLOW

- Seasonal Rainfall - Spring/Fall
- Frontal Systems
- Remnants of Tropical Systems
- Snow Pack Insignificant

RUNOFF

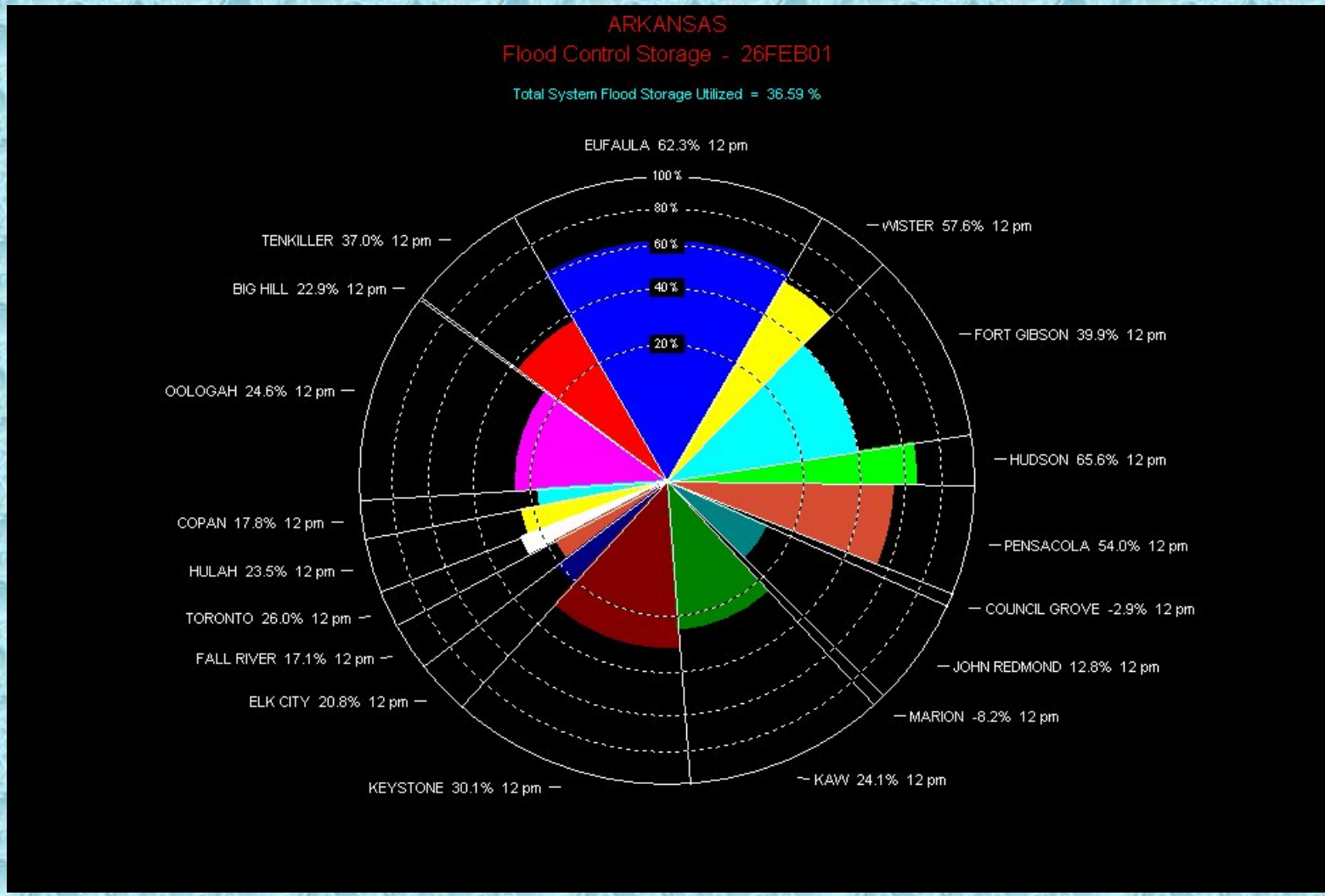
- Few Hours to Several Days
- Single to Multiple Events


Frequency of Filling
Frequency in Years
80
70
60
50
40
30
20
10
0
KEYS
EUFA
OOLO
TENK
HULA
COPA
WIST
PENS
HUDS
FGIB
KAWL
Lake
100% full
95% full



Arkansas River System
Uncontrolled Local
7250 sq mi

ARKANSAS RIVER BASIN: PROJECT FLOOD CONTOL %



NEED FOR POR SIMULATION & PLANNING MODEL

- Statistical Analysis
- Alternative operations
- Reallocation of storages
- Recreation Investment
- M&I Dependability
- Hydropower
- Navigation
- Environmental Issues

EXISTING POR SIMULATION MODEL - SUPER

- Southwest Division COE Districts have been using a system planning model for 30 years - “Super”. Development/Expert (Ronald L. Hula) SWD Corps, Retired.
- “Super Program” application has been accepted by SWPA/DOE, State Water Distr’s, navigation, others.
- Districts have limited ability to use/revise program.
- Retiree is temporarily on contract.

GOAL OF FLOOD CONTROL OPERATION

Surcharge Operation: Prevent overtopping and loss of control

Drain flood pool quickly as possible without causing downstream flooding, if possible

Give priority to reservoirs based on their “fullness”

Leave sets of reservoirs controlled by a KEY control point as balanced as possible

Flooding at control point does occur as a result of:

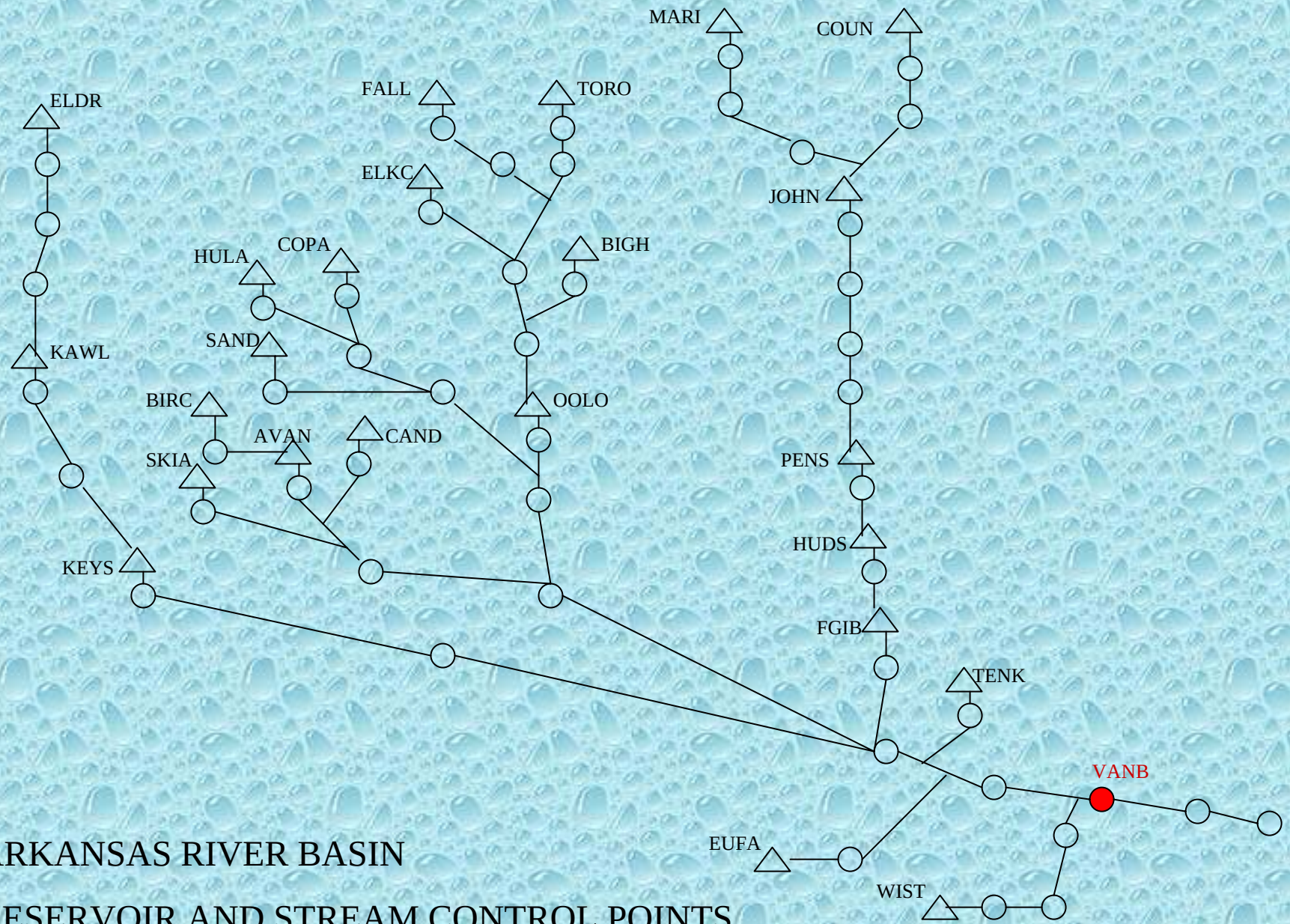
- Surcharge releases
- Local runoff added to prior releases
- Convergence

TRANSITION FROM SUPER TO RIVERWARE

- 1999 - Southwest Division lead effort to investigate existing simulation models.
- 1999 - 2000: Determination that RiverWare has potential to meet SWD COE needs. Simulation and Rules Training
- Spring 2000: Preliminary RiverWare investigation/evaluation
- 2001 - 2004: Flood control logic transferred from old Super program to RiverWare by CADWES with new methods
- Currently Using old program with assistance of author
- Developing RiverWare models

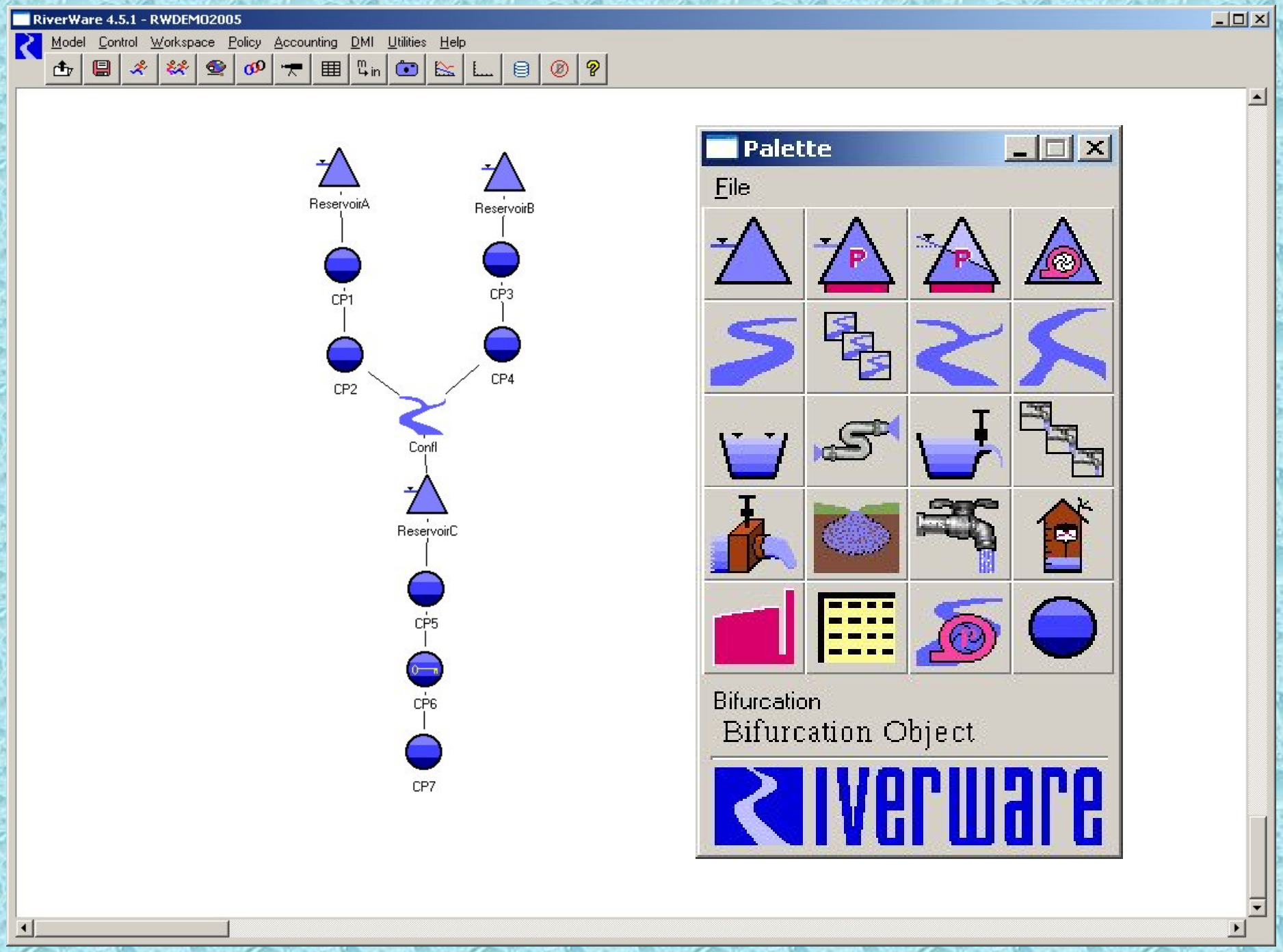
SIMULATION WITH RIVERWARE:

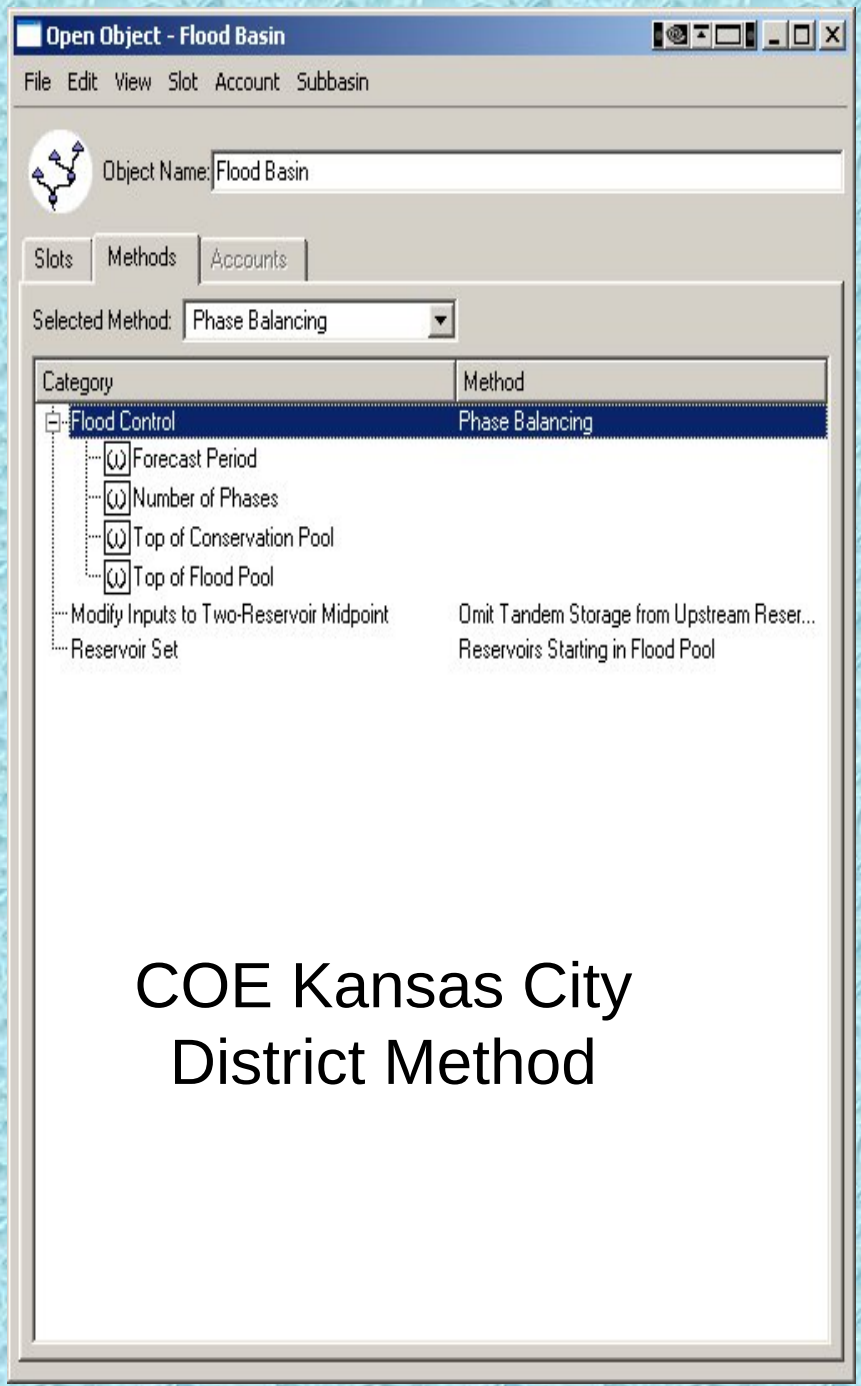
- Sub-Basin Configuration: Pre-Defined Rules of Operation/Simulation
- Reservoir Object: Balance Level Definition
- Control Point Object: Local Flow With Forecast, Regulation Method, List of Regulating Reservoirs
- Key Control Point Definition
- Stream Routing
- Evacuate Flood Control Storage In A Way To Achieve System Balance

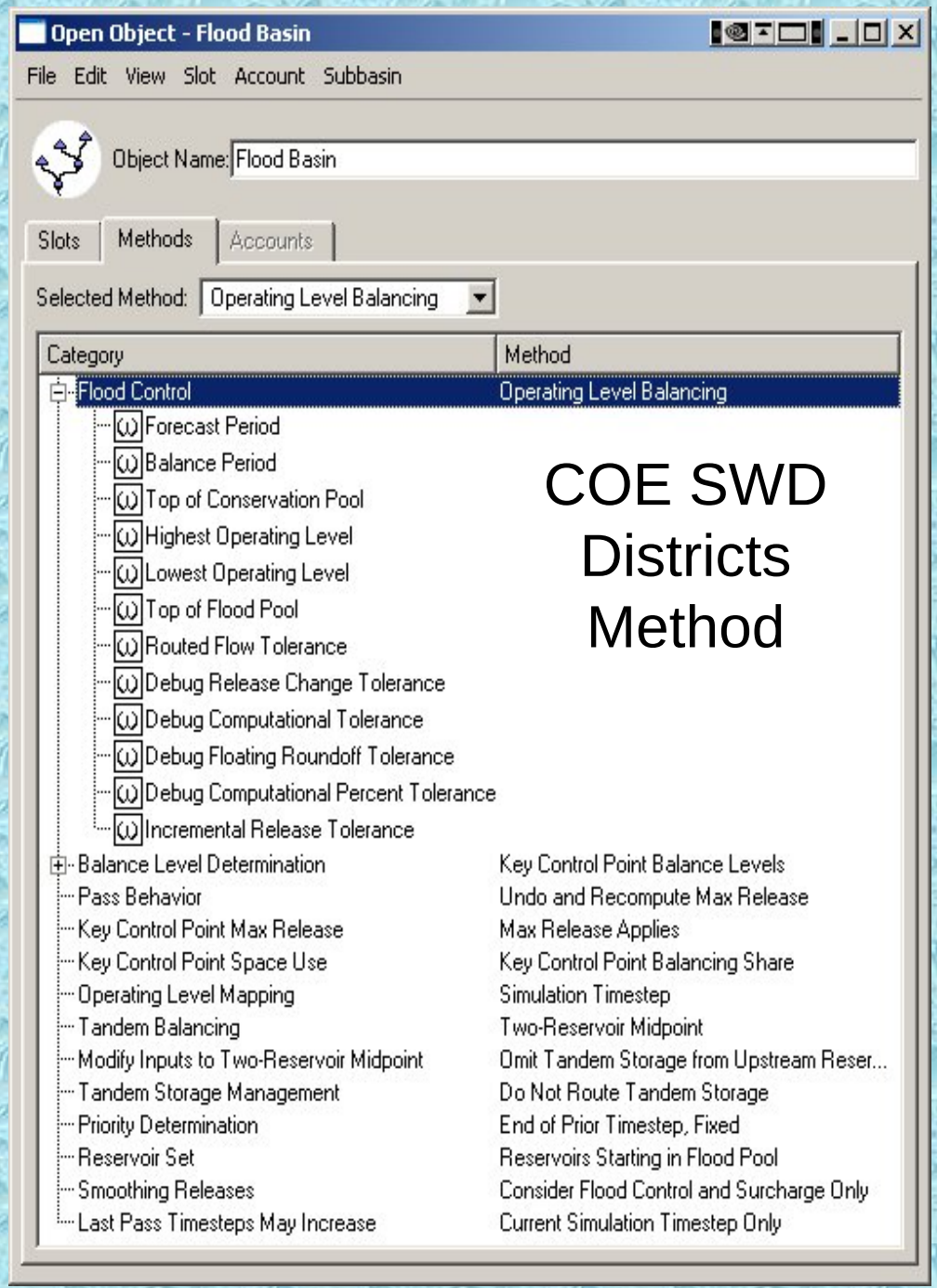


ARKANSAS RIVER BASIN

RESERVOIR AND STREAM CONTROL POINTS


RiverWare 4.5.1 - RWDEMO2005
Model Control Workspace Policy Accounting DMI Utilities Help
ReservoirA
ReservoirB
CP1
CP3
CP2
CP4
Confl
ReservoirC
CP5
CP6
CP7
Palette
File
Bifurcation
Bifurcation Object
RiverWare


Open Object - Flood Basin
File Edit View Slot Account Subbasin
Object Name: Flood Basin
Slots Methods Accounts
Selected Method: Phase Balancing
Category Method
Flood Control Phase Balancing
Forecast Period
Number of Phases
Top of Conservation Pool
Top of Flood Pool
Modify Inputs to Two-Reservoir Midpoint Omit Tandem Storage from Upstream Reser...
Reservoir Set Reservoirs Starting in Flood Pool
COE Kansas City District Method


Open Object - Flood Basin
File Edit View Slot Account Subbasin
Object Name: Flood Basin
Slots Methods Accounts
Selected Method: Operating Level Balancing
Category Method
Flood Control Operating Level Balancing
Forecast Period
Balance Period
Top of Conservation Pool
Highest Operating Level
Lowest Operating Level
Top of Flood Pool
Routed Flow Tolerance
Debug Release Change Tolerance
Debug Computational Tolerance
Debug Floating Roundoff Tolerance
Debug Computational Percent Tolerance
Incremental Release Tolerance
Balance Level Determination Key Control Point Balance Levels
Pass Behavior Undo and Recompute Max Release
Key Control Point Max Release Max Release Applies
Key Control Point Space Use Key Control Point Balancing Share
Operating Level Mapping Simulation Timestep
Tandem Balancing Two-Reservoir Midpoint
Modify Inputs to Two-Reservoir Midpoint Omit Tandem Storage from Upstream Reser...
Tandem Storage Management Do Not Route Tandem Storage
Priority Determination End of Prior Timestep, Fixed
Reservoir Set Reservoirs Starting in Flood Pool
Smoothing Releases Consider Flood Control and Surcharge Only
Last Pass Timesteps May Increase Current Simulation Timestep Only
COE SWD Districts Method

RiverWare 4.5.1 - RWDEMO2005

Model Control Workspace Policy Accounting DMI Utilities Help

Inflow = Upstream routed releases

Total Inflow = Inflow + Deterministic Local + Diversion Return + Canal

Outflow = Surcharge Release + Flood Control Release + Turbine

Inflow = Upstream Routed Release

Outflow = Step Response Routing Method

Inflow = Upstream routed releases

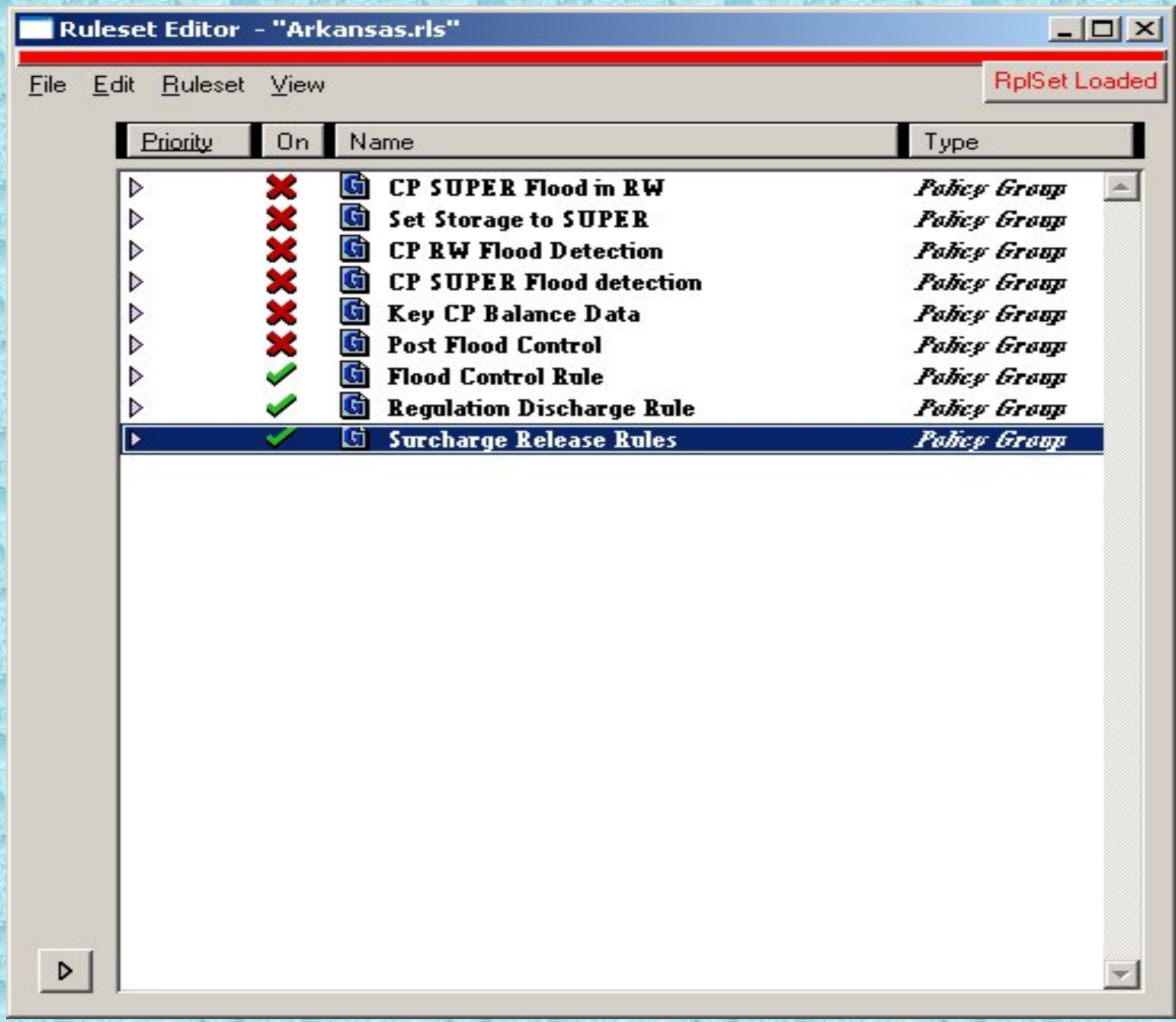
Total Inflow = Inflow + Deterministic Local + Local Peaking

Total Discharge = Total Inflow + Diversion

Inflow = Outflow

16 BALANCE LEVELS

1 Zero storage
2 Bottom conservation
3 Bottom power pool
4 50% conservation
5 100% conservation pool
6-8 Typically not used
9 10% Flood control
10 30% Flood control
11 50% Flood control
12 70% Flood control
13 90% Flood control
14 100% Flood control
15 Top surcharge
16 Top of dam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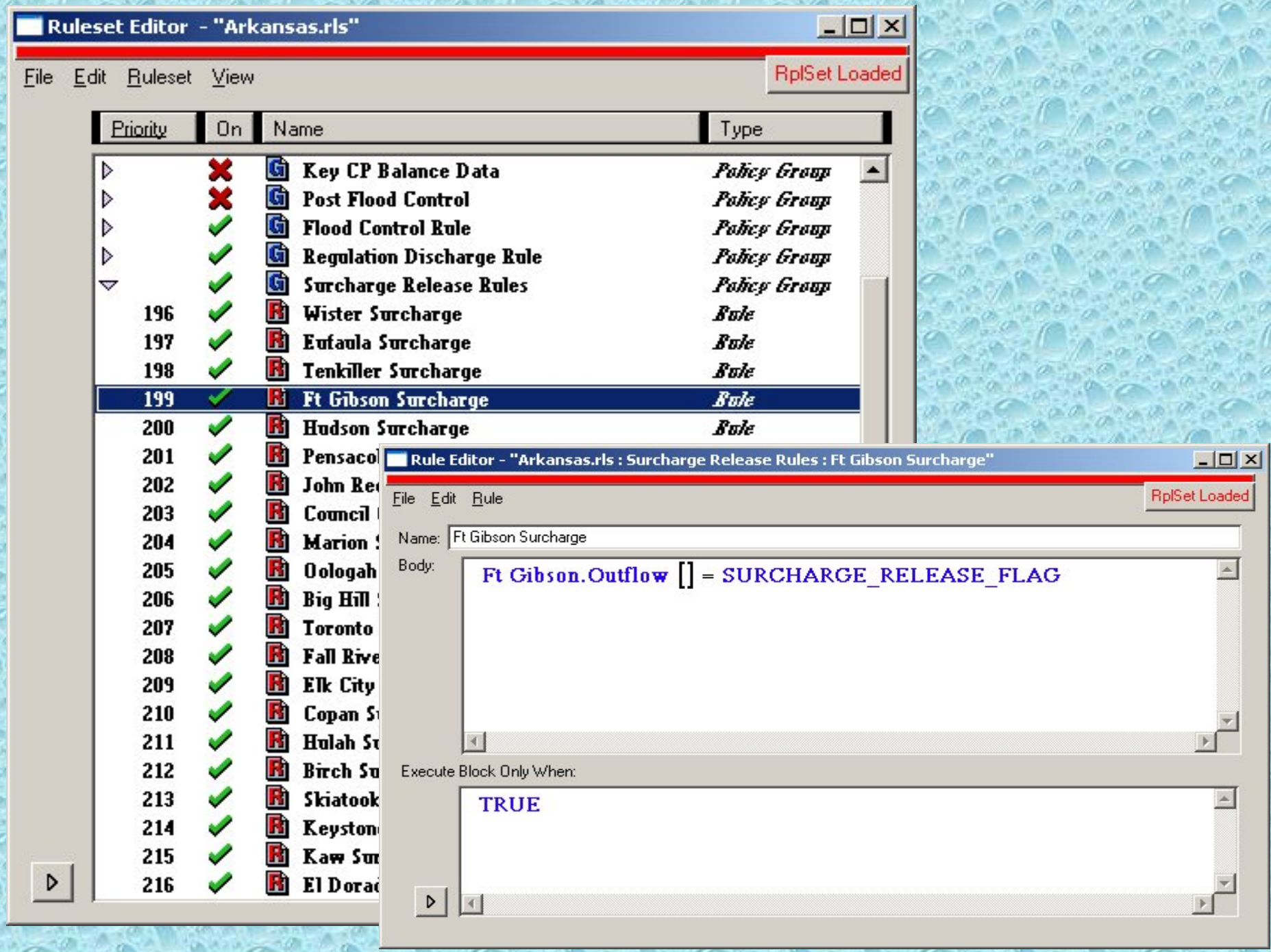
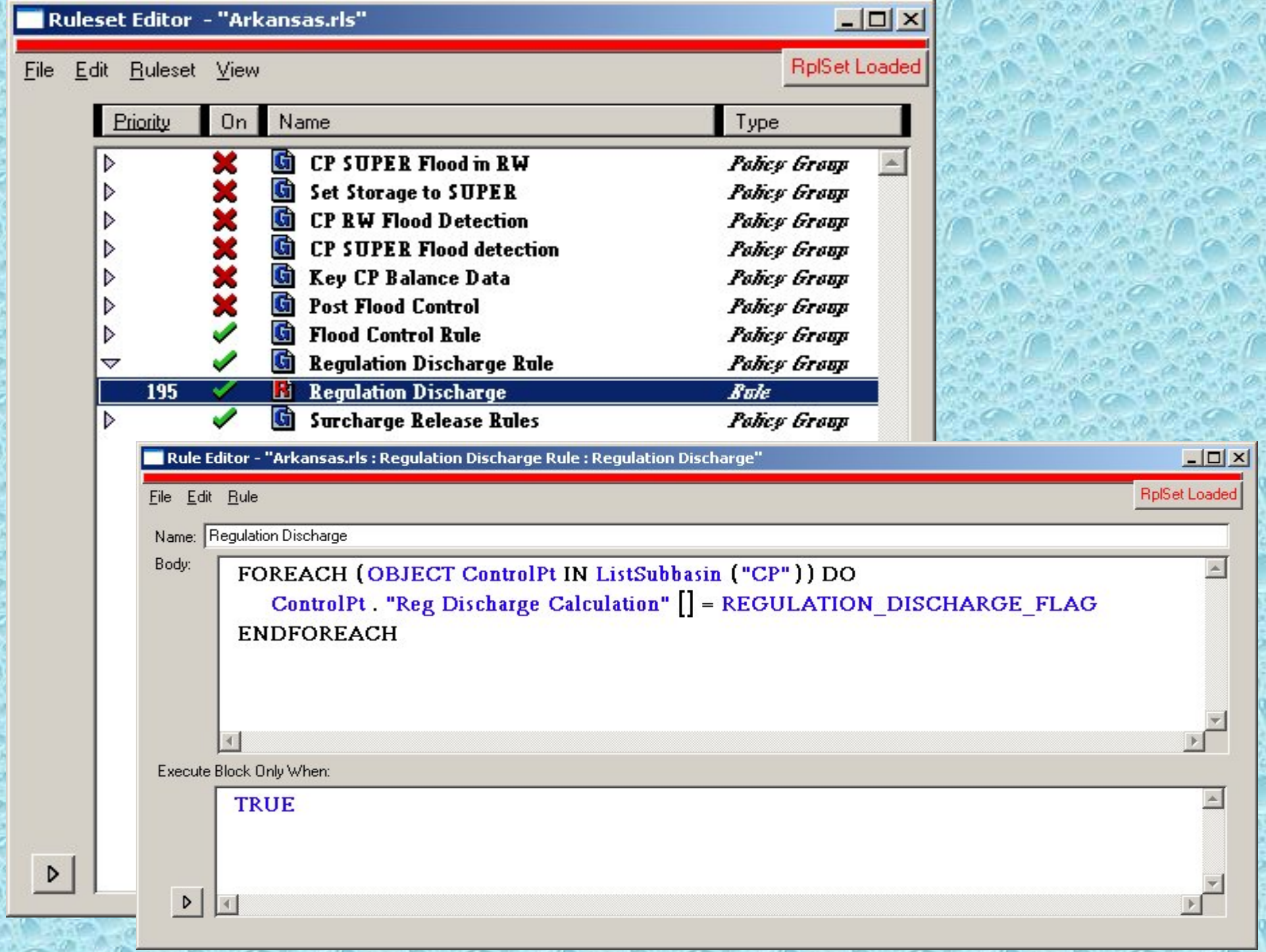
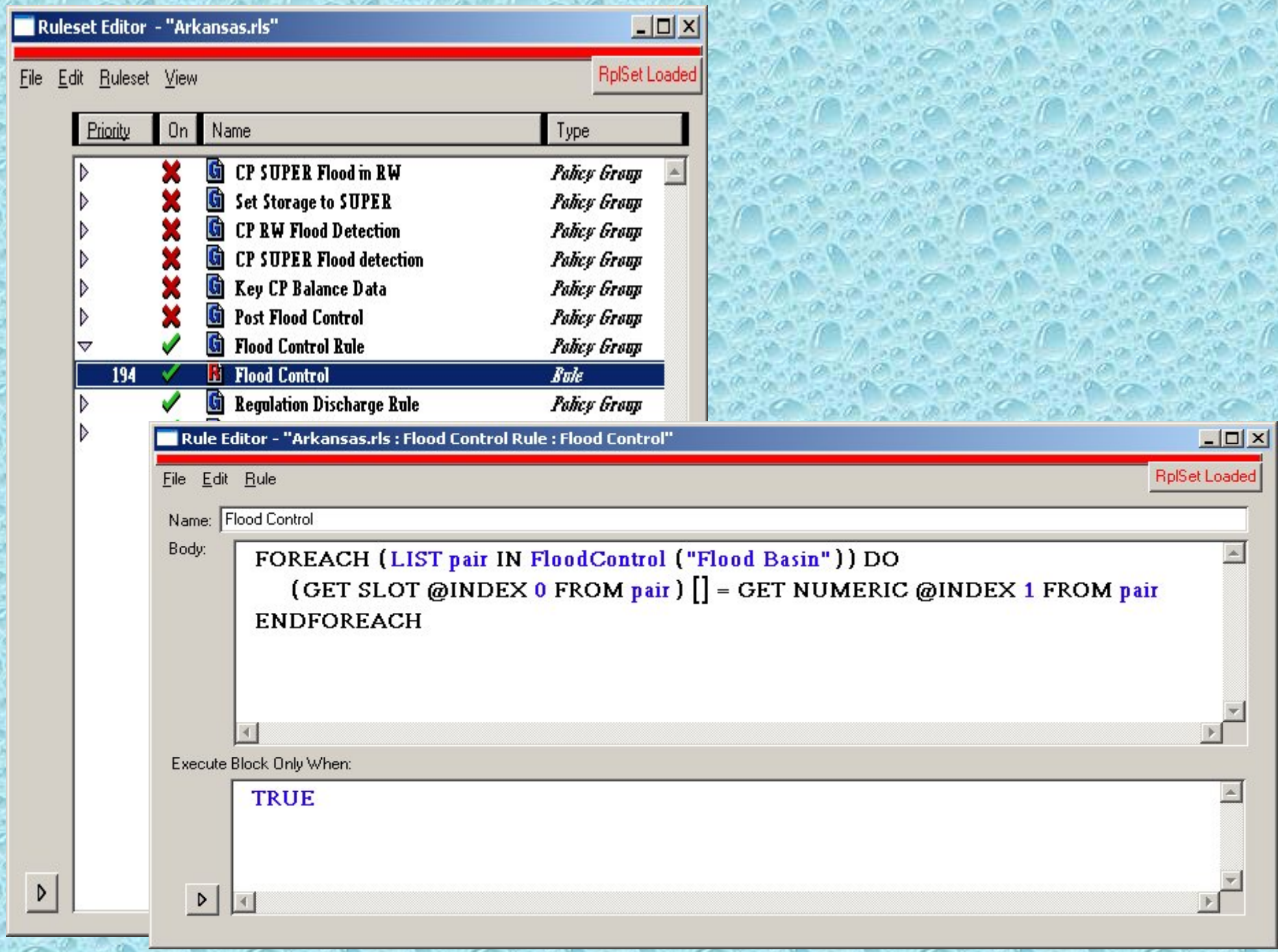
File
Edit
Ruleset
View
RplSet Loaded
Priority
On
Name
Type
CP SUPER Flood in RW
Policy Group
Set Storage to SUPER
Policy Group
CP RW Flood Detection
Policy Group
CP SUPER Flood detection
Policy Group
Key CP Balance Data
Policy Group
Post Flood Control
Policy Group
Flood Control Rule
Policy Group
Regulation Discharge Rule
Policy Group
Surcharge Release Rules
Policy Group


Ruleset Editor - "Arkansas.rls"
File Edit Ruleset View
RplSet Loaded
Priority
On
Name
Type
Key CP Balance Data
Post Flood Control
Flood Control Rule
Regulation Discharge Rule
Surcharge Release Rules
Policy Group
196 Wister Surcharge
197 Eufaula Surcharge
198 Tenkiller Surcharge
199 Ft Gibson Surcharge
200 Hudson Surcharge
Rule
Rule Editor - "Arkansas.rls : Surcharge Release Rules : Ft Gibson Surcharge"
File Edit Rule
RplSet Loaded
Name: Ft Gibson Surcharge
Body:
Ft Gibson.Outflow [] = SURCHARGE_RELEASE_FLAG
Execute Block Only When:
TRUE


Ruleset Editor - "Arkansas.rls"
File Edit Ruleset View
RplSet Loaded
Priority
On
Name
Type
CP SUPER Flood in RW
Set Storage to SUPER
CP RW Flood Detection
CP SUPER Flood detection
Key CP Balance Data
Post Flood Control
Flood Control Rule
Regulation Discharge Rule
195
Regulation Discharge
Surcharge Release Rules
Policy Group
Rule
Rule Editor - "Arkansas.rls : Regulation Discharge Rule : Regulation Discharge"
File Edit Rule
RplSet Loaded
Name: Regulation Discharge
Body:
FOREACH (OBJECT ControlPt IN ListSubbasin ("CP")) DO
ControlPt . "Reg Discharge Calculation" [] = REGULATION_DISCHARGE_FLAG
ENDFOREACH
Execute Block Only When:
TRUE

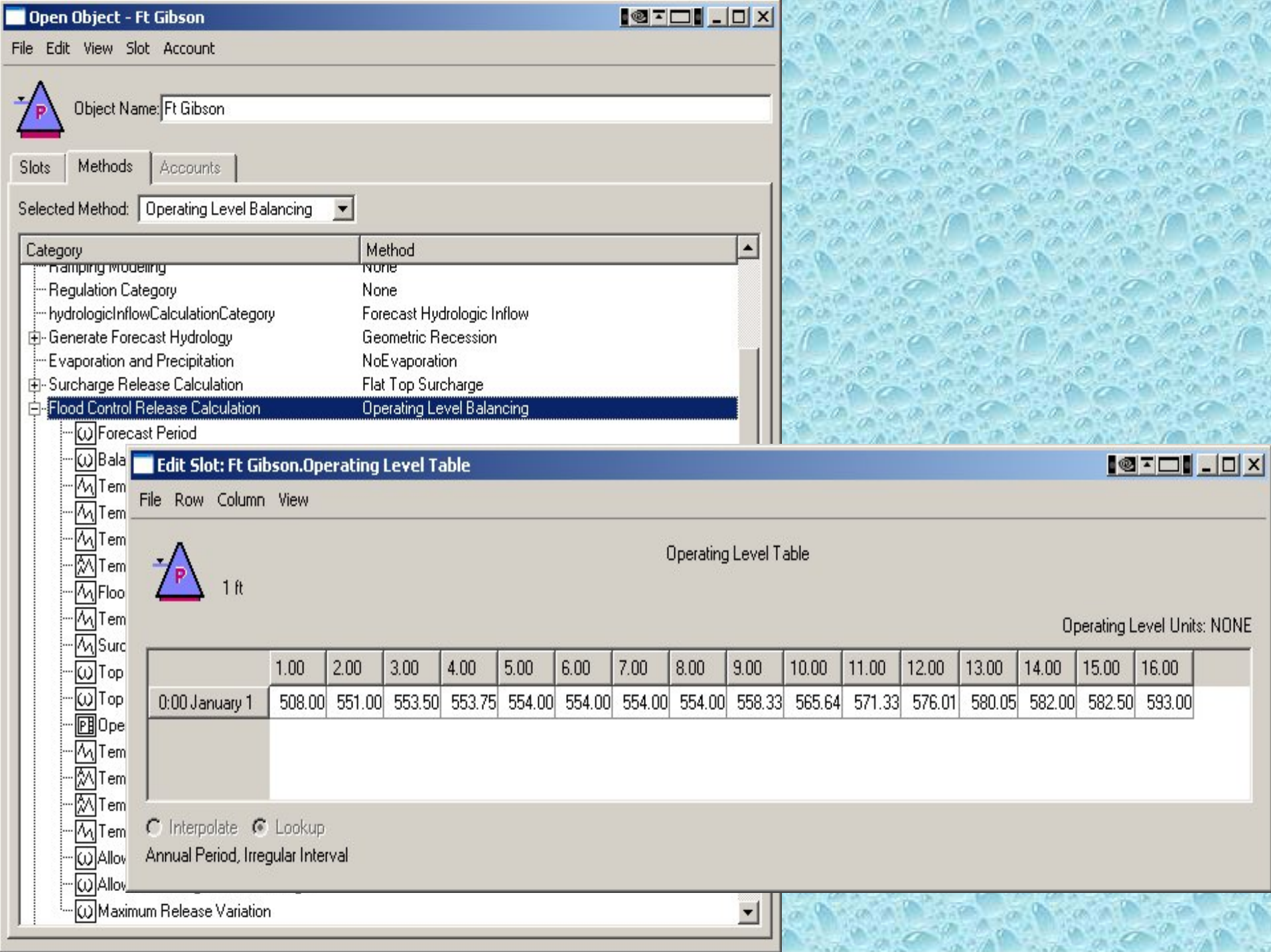

Ruleset Editor - "Arkansas.rls"
File Edit Ruleset View
RplSet Loaded
Priority
On
Name
Type
CP SUPER Flood in RW
Policy Group
Set Storage to SUPER
Policy Group
CP RW Flood Detection
Policy Group
CP SUPER Flood detection
Policy Group
Key CP Balance Data
Policy Group
Post Flood Control
Policy Group
Flood Control Rule
Policy Group
194
Flood Control
Rule
Regulation Discharge Rule
Policy Group
Rule Editor - "Arkansas.rls : Flood Control Rule : Flood Control"
File Edit Rule
RplSet Loaded
Name: Flood Control
Body:
FOREACH (LIST pair IN FloodControl ("Flood Basin")) DO
(GET SLOT @INDEX 0 FROM pair) [] = GET NUMERIC @INDEX 1 FROM pair
ENDFOREACH
Execute Block Only When:
TRUE

Edit John Redmond::Rating Curves

File Edit View

Value:

	Storage	Induced Surcharge Curve	Free-Flow Rating Curve
	acre-ft	cfs	cfs
0	0.00	0.00	0.00
1	9980.00	0.00	130.00
2	50501.00	0.00	25000.00
3	148016.00	0.00	104000.00
4	209187.00	0.00	152500.00
5	303252.00	0.00	225000.00
6	443981.00	0.00	327500.00
7	574918.00	12000.00	428000.00
8	610768.00	20000.00	450000.00
9	646617.00	50000.00	472000.00
10	682467.00	95000.00	495000.00
11	718317.00	180000.00	518000.00
12	736242.00	260000.00	530000.00
13	746997.00	380000.00	537000.00
14	750581.00	540000.00	540000.00


Open Object - Ft Gibson
File Edit View Slot Account
Object Name: Ft Gibson
Slots Methods Accounts
Selected Method: Operating Level Balancing
Category
Method
Regulation Category
None
hydrologicInflowCalculationCategory
Forecast Hydrologic Inflow
Generate Forecast Hydrology
Geometric Recession
Evaporation and Precipitation
NoEvaporation
Surcharge Release Calculation
Flat Top Surcharge
Flood Control Release Calculation
Operating Level Balancing
Forecast Period
Maximum Release Variation
Edit Slot: Ft Gibson.Operating Level Table
File Row Column View
1 ft
Operating Level Table
Operating Level Units: NONE
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00
0:00 January 1
508.00 551.00 553.50 553.75 554.00 554.00 554.00 554.00 558.33 565.64 571.33 576.01 580.05 582.00 582.50 593.00
Interpolate
Lookup
Annual Period, Irregular Interval

Edit Slot: Kaw.Operating Level Table

File Row Column View

1 ft

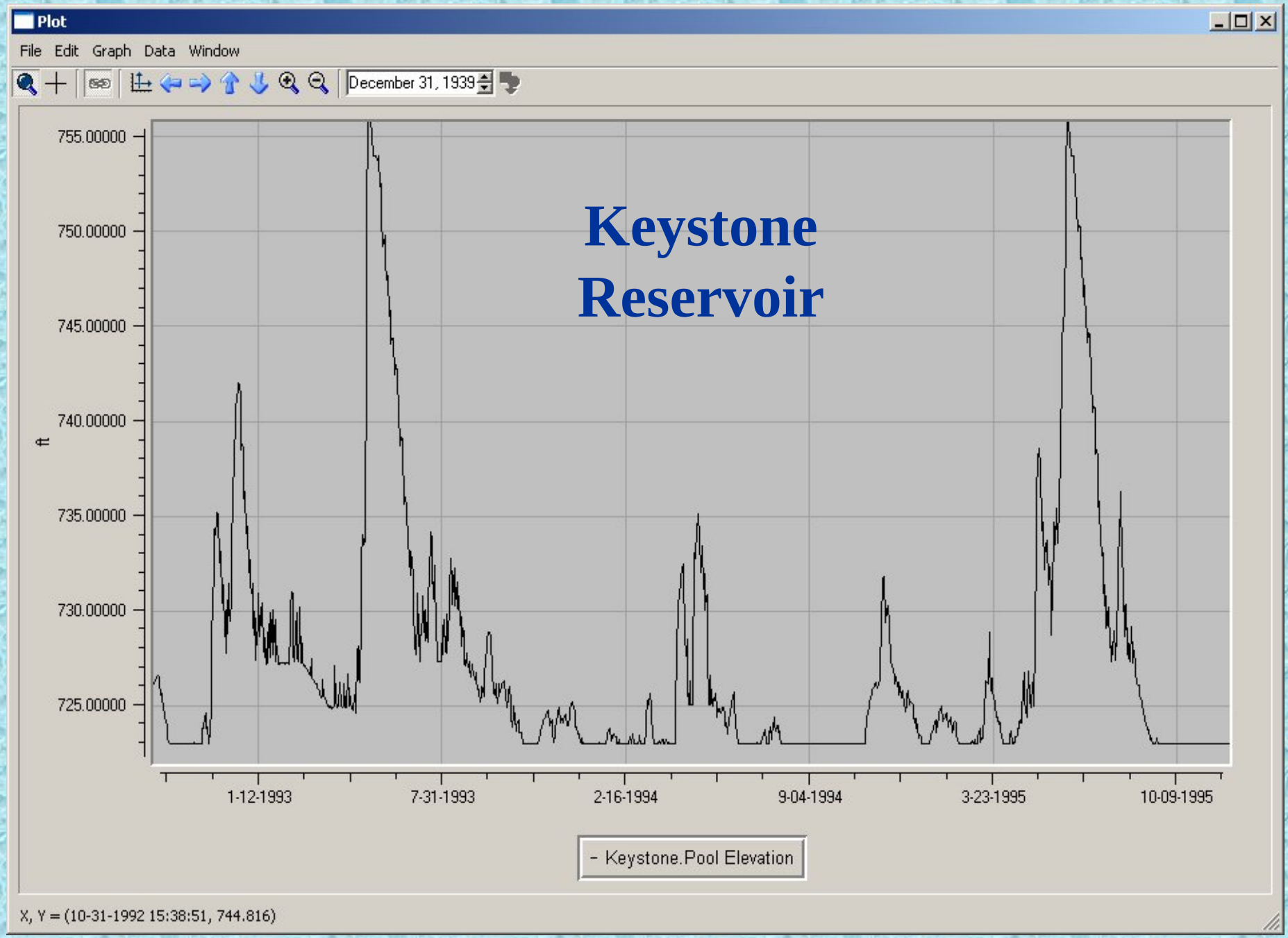
Operating Level Table

Operating Level Units: NONE

	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
0:00 January 2	936.30	978.00	978.00	998.53	1010.00	1010.00	1010.00	1017.05	1020.27	1023.25	1030.55	1036.48	1042.02	1044.50	1047.50	1058.00
0:00 January 11	936.30	978.00	978.00	998.53	1010.00	1010.00	1010.00	1017.05	1020.27	1023.25	1030.55	1036.48	1042.02	1044.50	1047.50	1058.00
0:00 January 21	936.30	978.00	978.00	996.55	1007.50	1007.50	1007.50	1015.29	1018.72	1022.10	1029.86	1036.09	1041.91	1044.50	1047.50	1058.00
0:00 March 2	936.30	978.00	978.00	996.55	1007.50	1007.50	1007.50	1015.29	1018.72	1022.10	1029.86	1036.09	1041.91	1044.50	1047.50	1058.00
0:00 April 21	936.30	978.00	978.00	998.53	1010.00	1010.00	1010.00	1017.05	1020.27	1023.25	1030.55	1036.48	1042.02	1044.50	1047.50	1058.00
0:00 July 26	936.30	978.00	978.00	998.53	1010.00	1010.00	1010.00	1017.05	1020.27	1023.25	1030.55	1036.48	1042.02	1044.50	1047.50	1058.00
0:00 August 6	936.30	978.00	978.00	997.32	1008.50	1008.50	1008.50	1015.98	1019.36	1022.55	1030.15	1036.24	1041.95	1044.50	1047.50	1058.00
0:00 September 16	936.30	978.00	978.00	997.32	1008.50	1008.50	1008.50	1015.98	1019.36	1022.55	1030.15	1036.24	1041.95	1044.50	1047.50	1058.00
0:00 November 16	936.30	978.00	978.00	998.53	1010.00	1010.00	1010.00	1017.05	1020.27	1023.25	1030.55	1036.48	1042.02	1044.50	1047.50	1058.00

(•) Interpolate ( ) Lookup

Annual Period, Irregular Interval


Plot
File Edit Graph Data Window
December 31, 1939
Keystone
Reservoir
755.00000
750.00000
745.00000
740.00000
735.00000
730.00000
725.00000
ft
1-12-1993
7-31-1993
2-16-1994
9-04-1994
3-23-1995
10-09-1995
- Keystone.Pool Elevation
X, Y = (10-31-1992 15:38:51, 744.816)

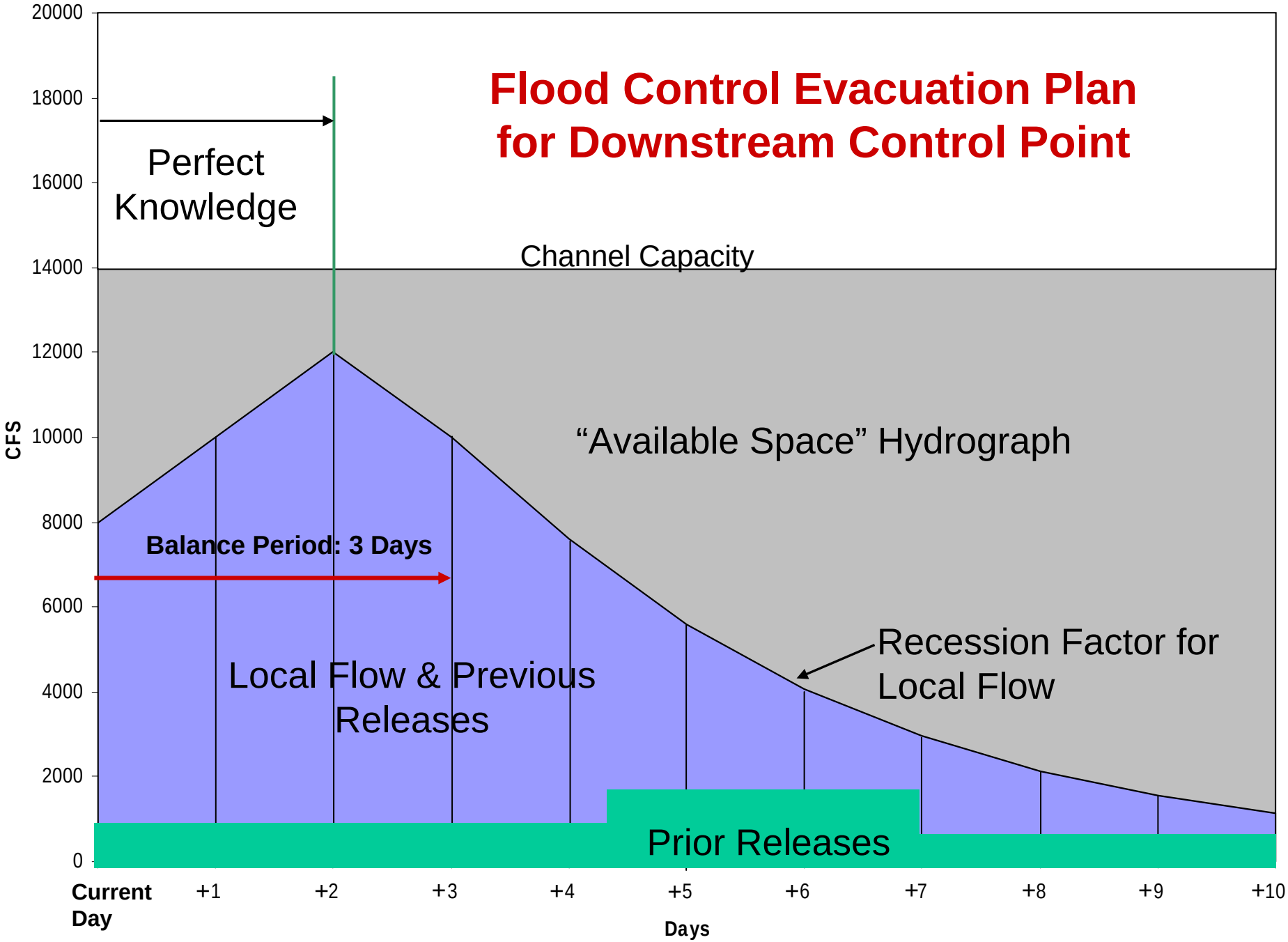
CONTROL POINT OBJECT

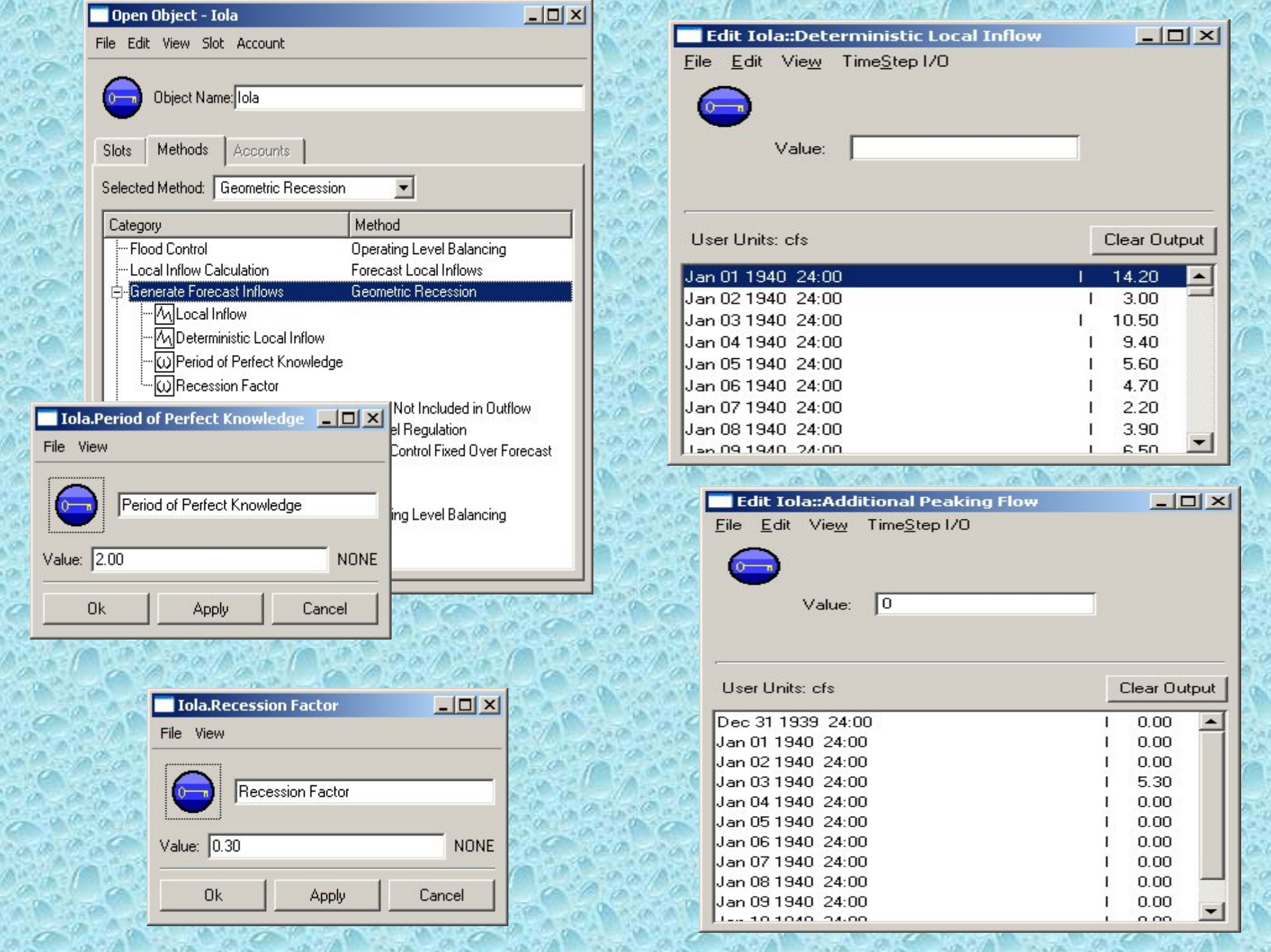
- Uncontrolled local flow
- Routed upstream releases
- Regulation method (Key Control Point)
- Space hydrograph for releases

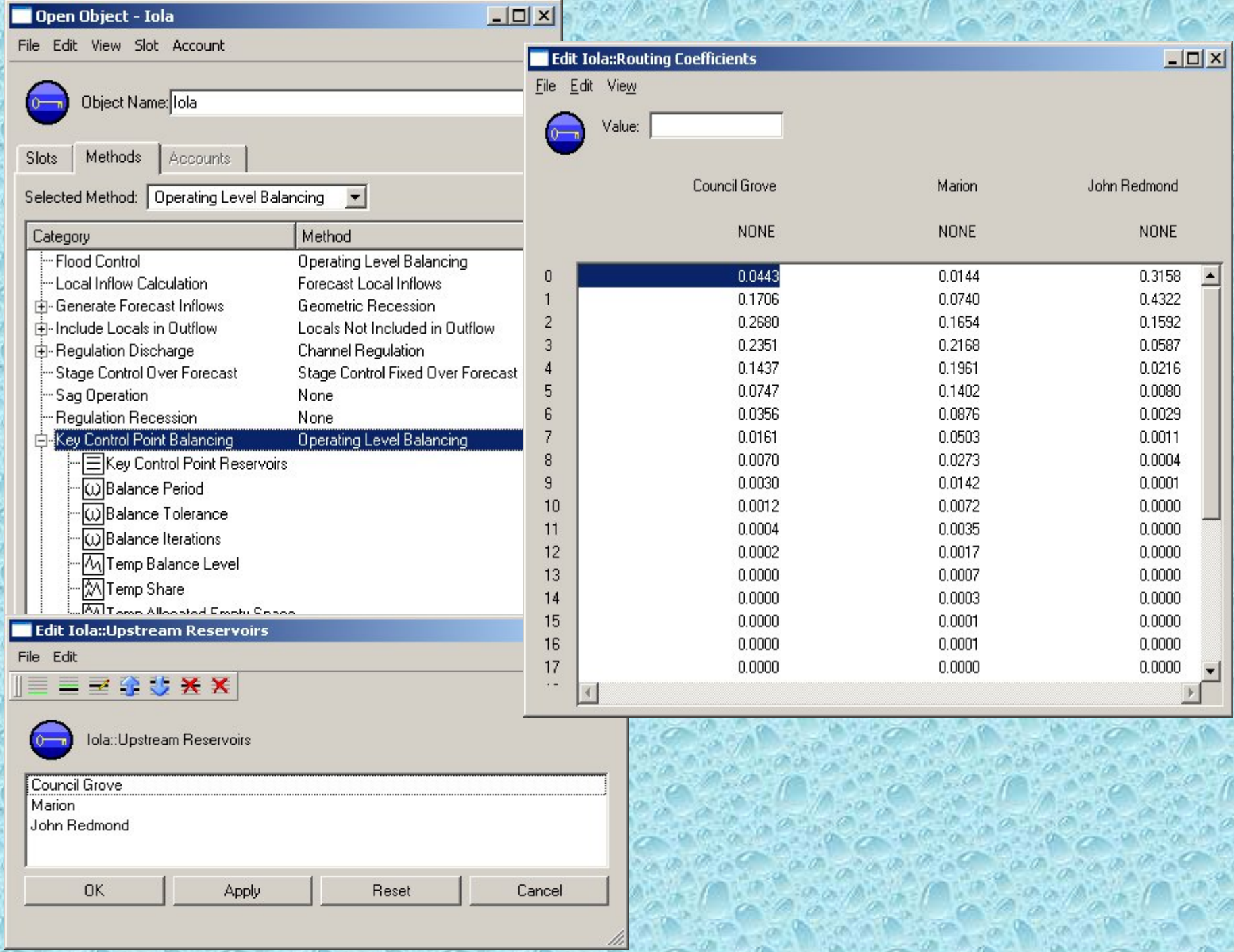
CONTROL POINT REGULATION METHODS

1. Channel regulation
2. Current level regulation
3. Future level regulation
4. System percent full regulation

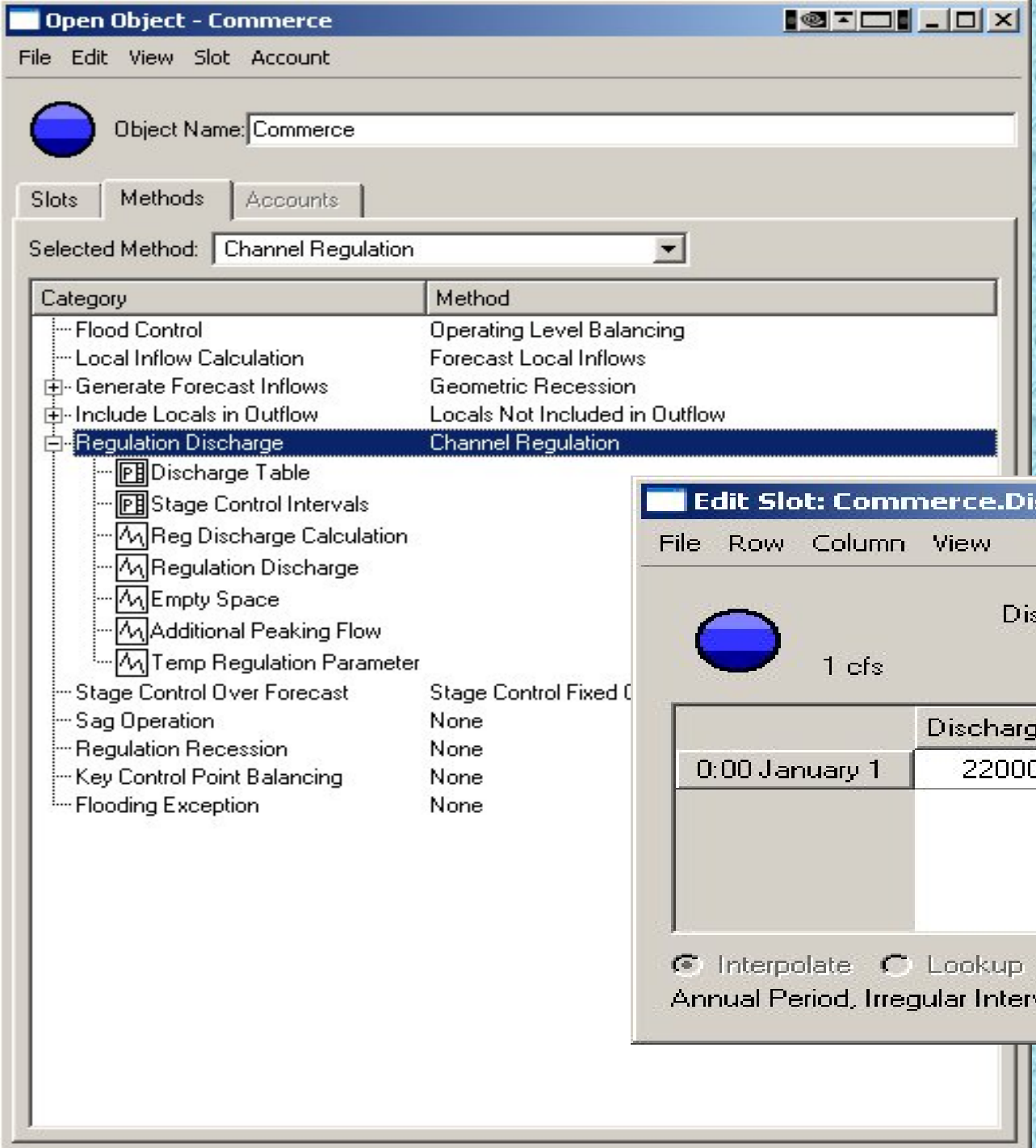
Misc applications: Stage control
Sag operation
Flood exception
Regulation recession


Flood Control Evacuation Plan
for Downstream Control Point
Perfect
Knowledge
Channel Capacity
"Available Space" Hydrograph
Balance Period: 3 Days
Local Flow & Previous
Releases
Recession Factor for
Local Flow
Prior Releases
CFS
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Current
Day
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
Days

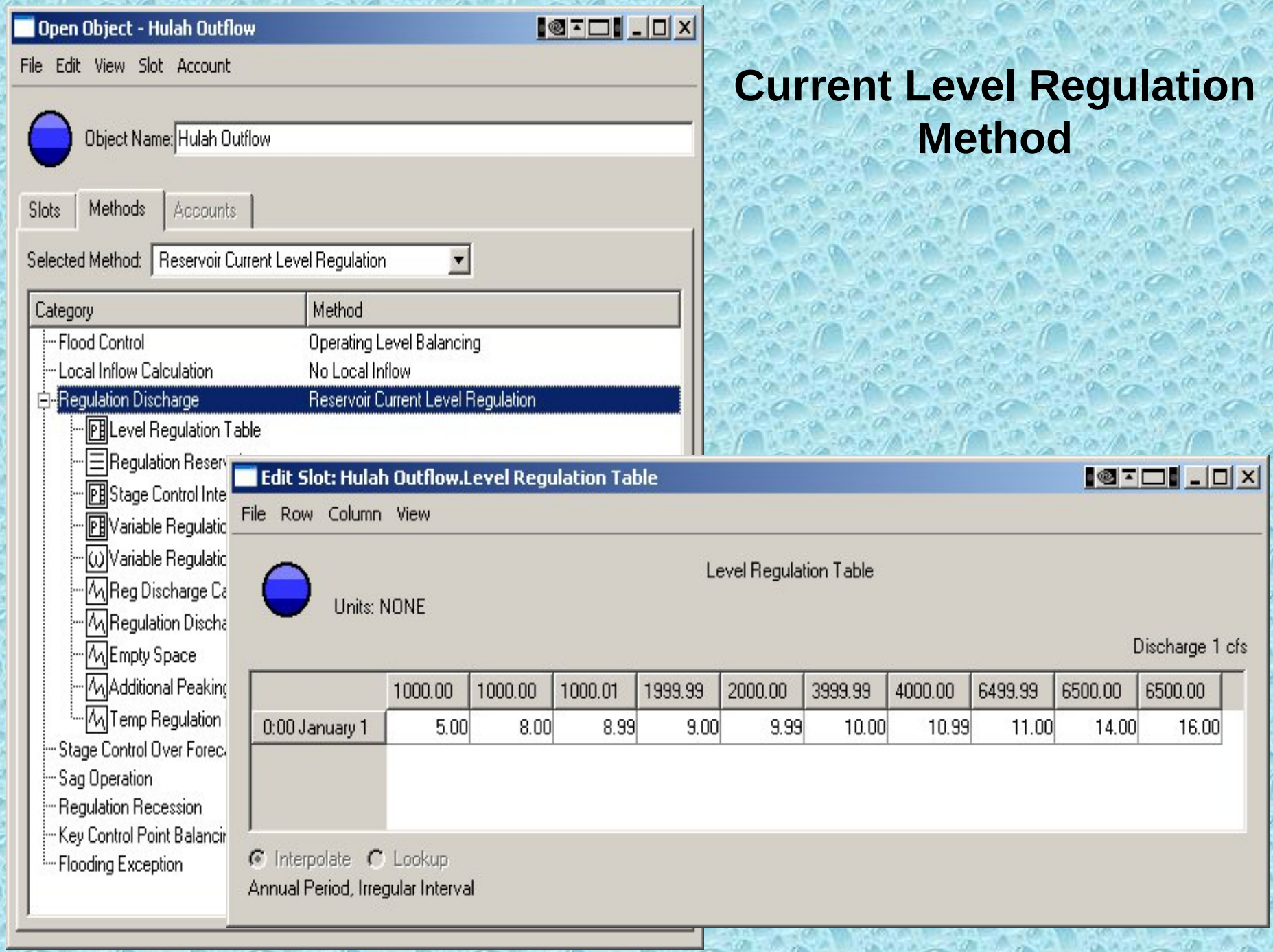

Open Object - Iola
File Edit View Slot Account
Object Name: Iola
Slots Methods Accounts
Selected Method: Geometric Recession
Category
Method
Flood Control
Operating Level Balancing
Local Inflow Calculation
Forecast Local Inflows
Generate Forecast Inflows
Geometric Recession
Local Inflow
Deterministic Local Inflow
Period of Perfect Knowledge
Recession Factor
Not Included in Outflow
el Regulation
Control Fixed Over Forecast
ing Level Balancing
Iola.Period of Perfect Knowledge
File View
Period of Perfect Knowledge
Value: 2.00
NONE
Ok
Apply
Cancel
Iola.Recession Factor
File View
Recession Factor
Value: 0.30
NONE
Ok
Apply
Cancel
Edit Iola::Deterministic Local Inflow
File Edit View TimeStep I/O
Value:
User Units: cfs
Clear Output
Jan 01 1940 24:00 I 14.20
Jan 02 1940 24:00 I 3.00
Jan 03 1940 24:00 I 10.50
Jan 04 1940 24:00 I 9.40
Jan 05 1940 24:00 I 5.60
Jan 06 1940 24:00 I 4.70
Jan 07 1940 24:00 I 2.20
Jan 08 1940 24:00 I 3.90
Edit Iola::Additional Peaking Flow
File Edit View TimeStep I/O
Value: 0
User Units: cfs
Clear Output
Dec 31 1939 24:00 I 0.00
Jan 01 1940 24:00 I 0.00
Jan 02 1940 24:00 I 0.00
Jan 03 1940 24:00 I 5.30
Jan 04 1940 24:00 I 0.00
Jan 05 1940 24:00 I 0.00
Jan 06 1940 24:00 I 0.00
Jan 07 1940 24:00 I 0.00
Jan 08 1940 24:00 I 0.00
Jan 09 1940 24:00 I 0.00


Open Object - Iola
File Edit View Slot Account
Object Name: Iola
Slots Methods Accounts
Selected Method: Operating Level Balancing
Category
Method
Flood Control
Operating Level Balancing
Local Inflow Calculation
Forecast Local Inflows
Generate Forecast Inflows
Geometric Recession
Include Locals in Outflow
Locals Not Included in Outflow
Regulation Discharge
Channel Regulation
Stage Control Over Forecast
Stage Control Fixed Over Forecast
Sag Operation
None
Regulation Recession
None
Key Control Point Balancing
Operating Level Balancing
Key Control Point Reservoirs
Balance Period
Balance Tolerance
Balance Iterations
Temp Balance Level
Temp Share
Edit Iola::Routing Coefficients
File Edit View
Value:
Council Grove
Marion
John Redmond
NONE
NONE
NONE
0 0.0443 0.0144 0.3158
1 0.1706 0.0740 0.4322
2 0.2680 0.1654 0.1592
3 0.2351 0.2168 0.0587
4 0.1437 0.1961 0.0216
5 0.0747 0.1402 0.0080
6 0.0356 0.0876 0.0029
7 0.0161 0.0503 0.0011
8 0.0070 0.0273 0.0004
9 0.0030 0.0142 0.0001
10 0.0012 0.0072 0.0000
11 0.0004 0.0035 0.0000
12 0.0002 0.0017 0.0000
13 0.0000 0.0007 0.0000
14 0.0000 0.0003 0.0000
15 0.0000 0.0001 0.0000
16 0.0000 0.0001 0.0000
17 0.0000 0.0000 0.0000
Edit Iola::Upstream Reservoirs
File Edit
Iola::Upstream Reservoirs
Council Grove
Marion
John Redmond
OK
Apply
Reset
Cancel

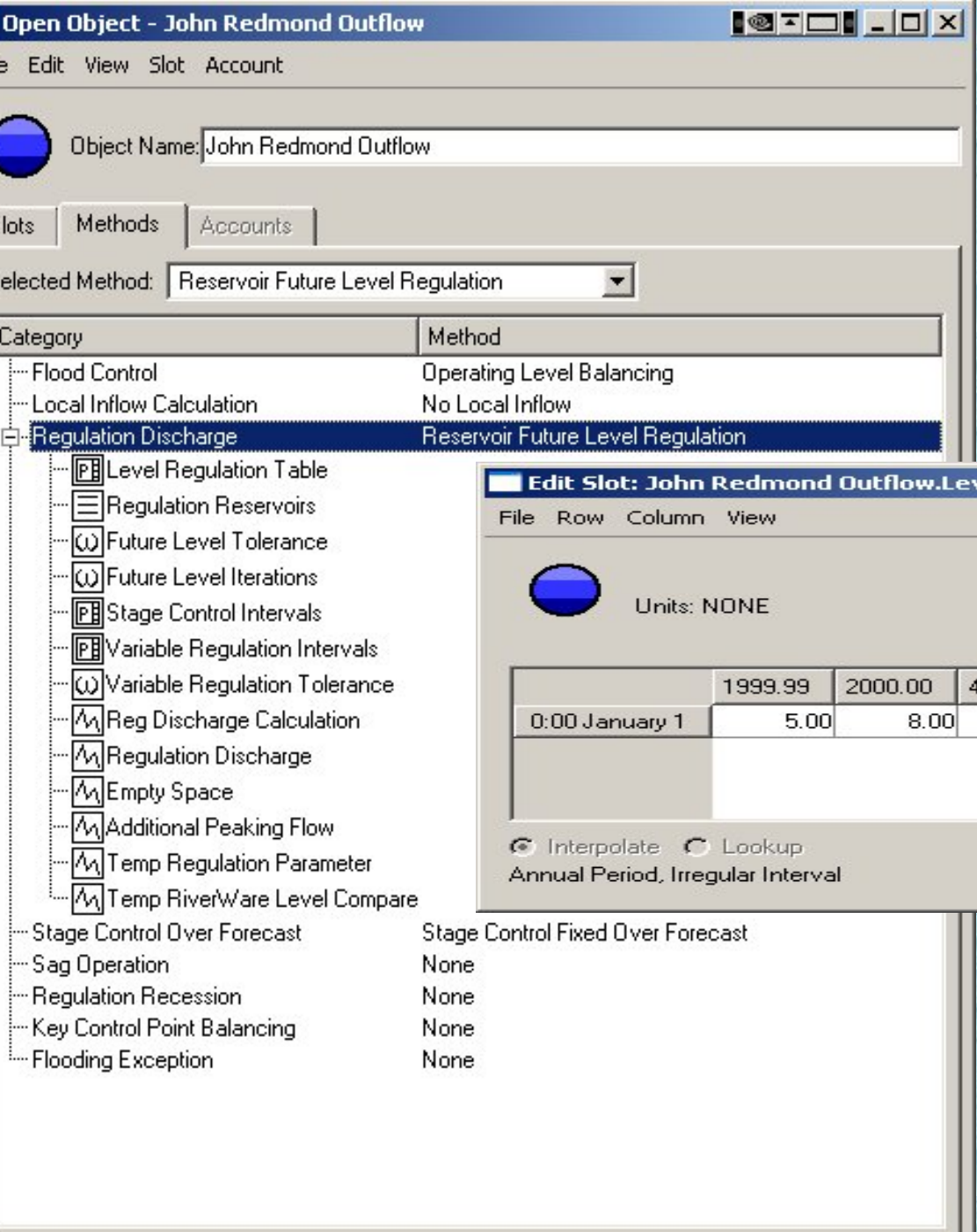
Channel Regulation Method

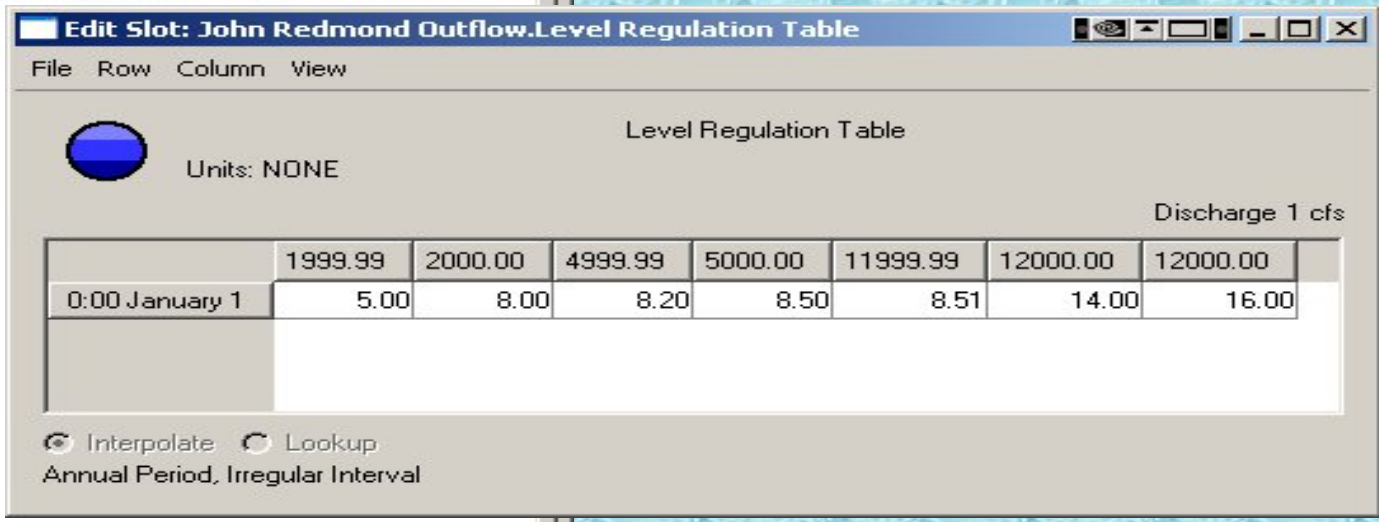


Current Level Regulation Method



Future Level Regulation Method





Edit Slot: Van Buren.Percent Full Regulation Table

File Row Column View

Units: NONE

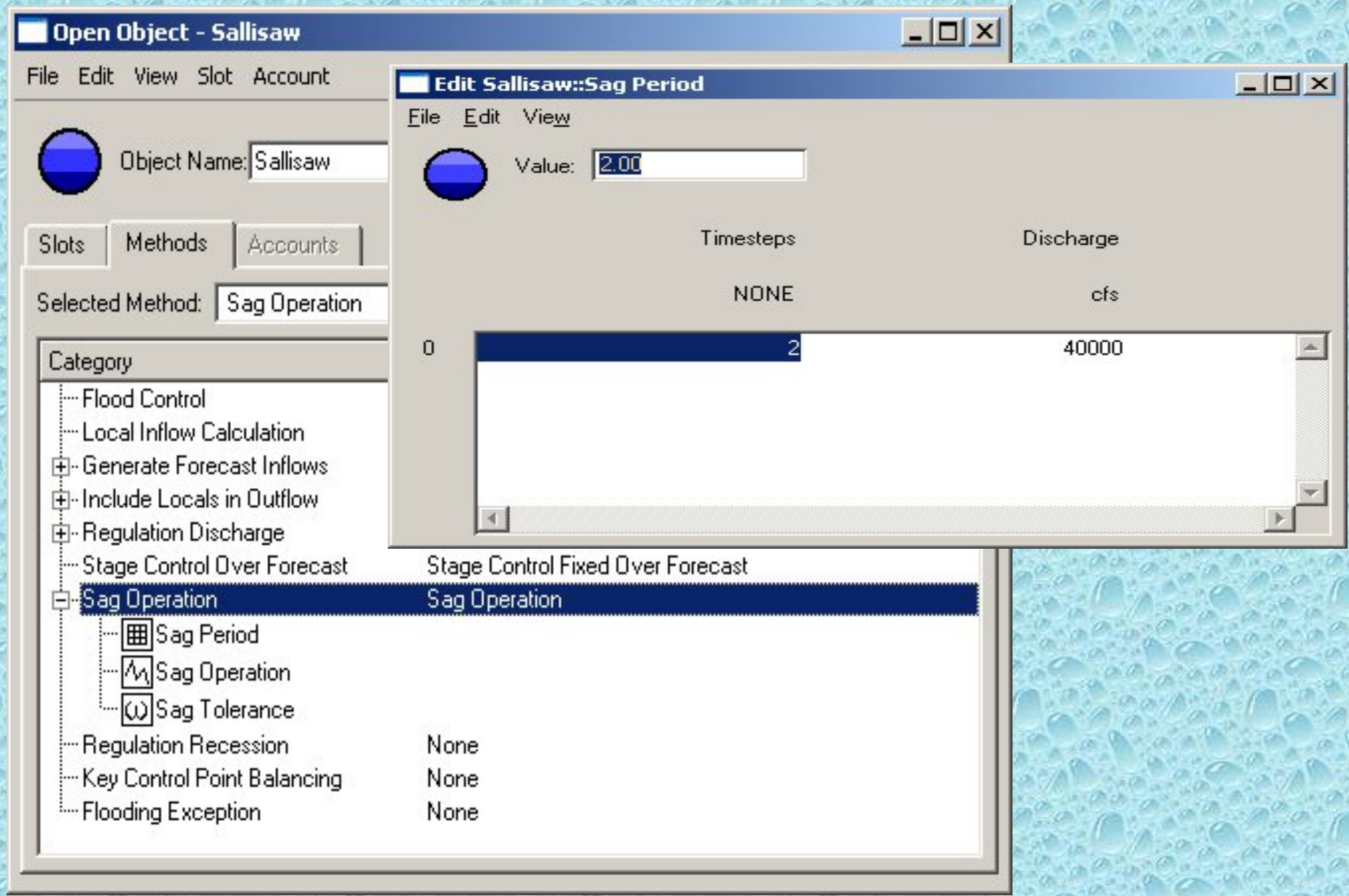
Percent Full Regulation Table

Discharge 1 cfs

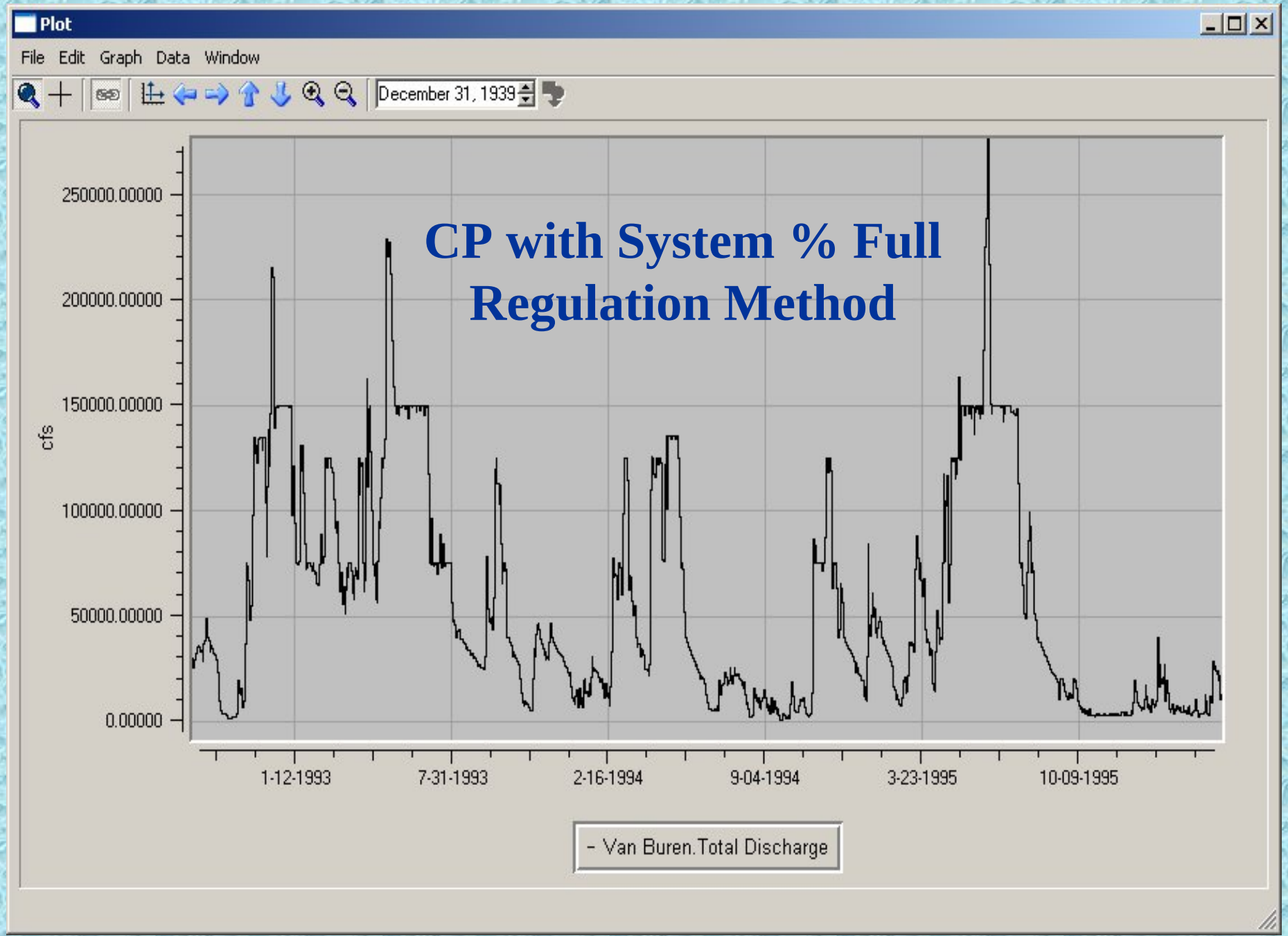
	20000.00	40000.00	75000.00	75000.01	125000.00	125000.01	150000.00	150000.00
0:00 January 2	0.00	0.07	0.09	0.18	0.19	0.40	0.40	1.00
0:00 February 16	0.00	0.07	0.09	0.18	0.19	0.40	0.40	1.00
0:00 March 2	0.00	0.03	0.05	0.10	0.11	0.40	0.40	1.00
0:00 May 16	0.00	0.03	0.05	0.10	0.11	0.40	0.40	1.00
0:00 June 16	0.00	0.11	0.13	0.18	0.19	0.40	0.40	1.00
0:00 September 16	0.00	0.11	0.13	0.18	0.19	0.40	0.40	1.00
0:00 October 2	0.00	0.07	0.09	0.18	0.19	0.50	0.50	1.00
0:00 November 2	0.00	0.07	0.09	0.18	0.19	0.50	0.50	1.00
0:00 December 2	0.00	0.07	0.09	0.18	0.19	0.50	0.50	1.00
0:00 December 16	0.00	0.07	0.09	0.18	0.19	0.40	0.40	1.00

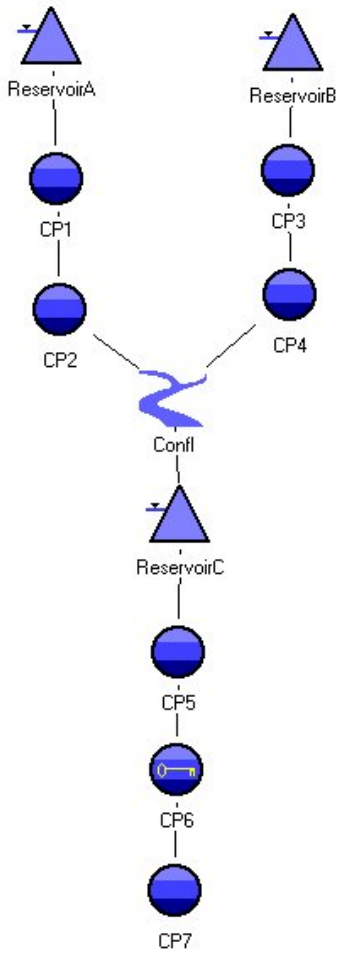
(•) Interpolate ( ) Lookup

Annual Period, Irregular Interval



Sag Regulation Method


Plot
File Edit Graph Data Window
December 31, 1939
CP with System % Full Regulation Method
250000.00000
200000.00000
150000.00000
100000.00000
50000.00000
0.00000
cfs
1-12-1993
7-31-1993
2-16-1994
9-04-1994
3-23-1995
10-09-1995
- Van Buren.Total Discharge



TANDEM SOLVING

Balancing

Fillup

Pass through

RECENT EFFORTS BY CADSWES

- Completion of flood control logic & methods
- Scope DMI & RW integration into HEC-CWMS
- Assessment of COE hydropower approach
- Critical dependable pool and stream yield analysis using RW Batch Mode with RCL
- Multi-cycle periodic slot
- Flood control user guide

FLOOD CONTROL TESTING BY CADSWES

- RiverWare test results are very close to Super
- RiverWare generally releases more than Super
- Super storage slightly greater than RiverWare, total system difference very small
- Differences in flood control releases on one reservoir are made up for in another reservoir, total balance level very close
- Balance achieved by RiverWare is neither better nor worse on average than Super
- 61-year daily POR flood control run takes 2.6 hrs on Pentium 4 (4.3GHz with 1G RAM): 21 Reservoirs, 50 CP's

16 BALANCE LEVELS

1 Zero storage
2 Bottom conservation
3 Bottom power pool
4 50% conservation
5 100% conservation pool

6-8 Typically not used

9 10% Flood control
10 30% Flood control
11 50% Flood control
12 70% Flood control
13 90% Flood control
14 100% Flood control
15 Top surcharge
16 Top of dam

CORPS USE WITH RIVERWARE

- Super to RW by Tulsa, Ft Worth, & Little Rock COE Distr's
- HEC-CWMS
- Real time evacuation of flood storage - TAPER program used in Tulsa
- Water supply accounting
- Other COE Districts?

CORPS RIVERWARE BASINS

- Arkansas River
- Red River
- White River
- Brazos River
- Trinity River

- Others: Kansas River, Upper Rio Grande

FUTURE WORK WITH CADSWES

- Balance Depletion Method of conservation pools
- DSS, Database, and DMI functionality
- RiverWare interaction with HEC-CWMS
- Performance issues
- Corps Hydropower and QFISH methods
- Statistical post processing analysis on Slots
- Input comparison tool

SUPER

R.I.P

RIVERWARE FLOOD CONTROL METHODS

Questions? Discussion?