

RECLAMATION

Managing Water in the West

WRIMS – Water Resources Integrated Modeling System

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U.S. Bureau of Reclamation

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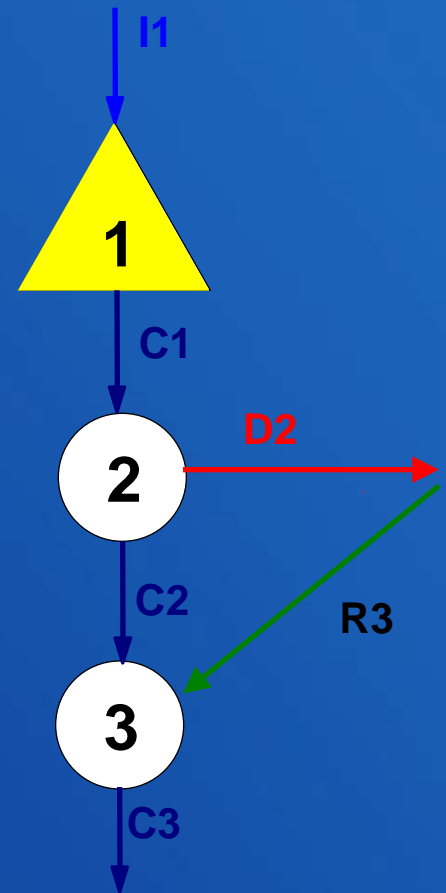
U.S. Department of the Interior
Bureau of Reclamation

WRIMS Overview

- WRIMS is a general purpose water resources management tool for modeling surface water and/or groundwater allocations
- Water Resources Integrated Modeling System
- Developed and maintained by the California Department of Water Resources
- CVP/SWP Planning Modeling
- Klamath Project Planning Modeling

WRIMS Basics

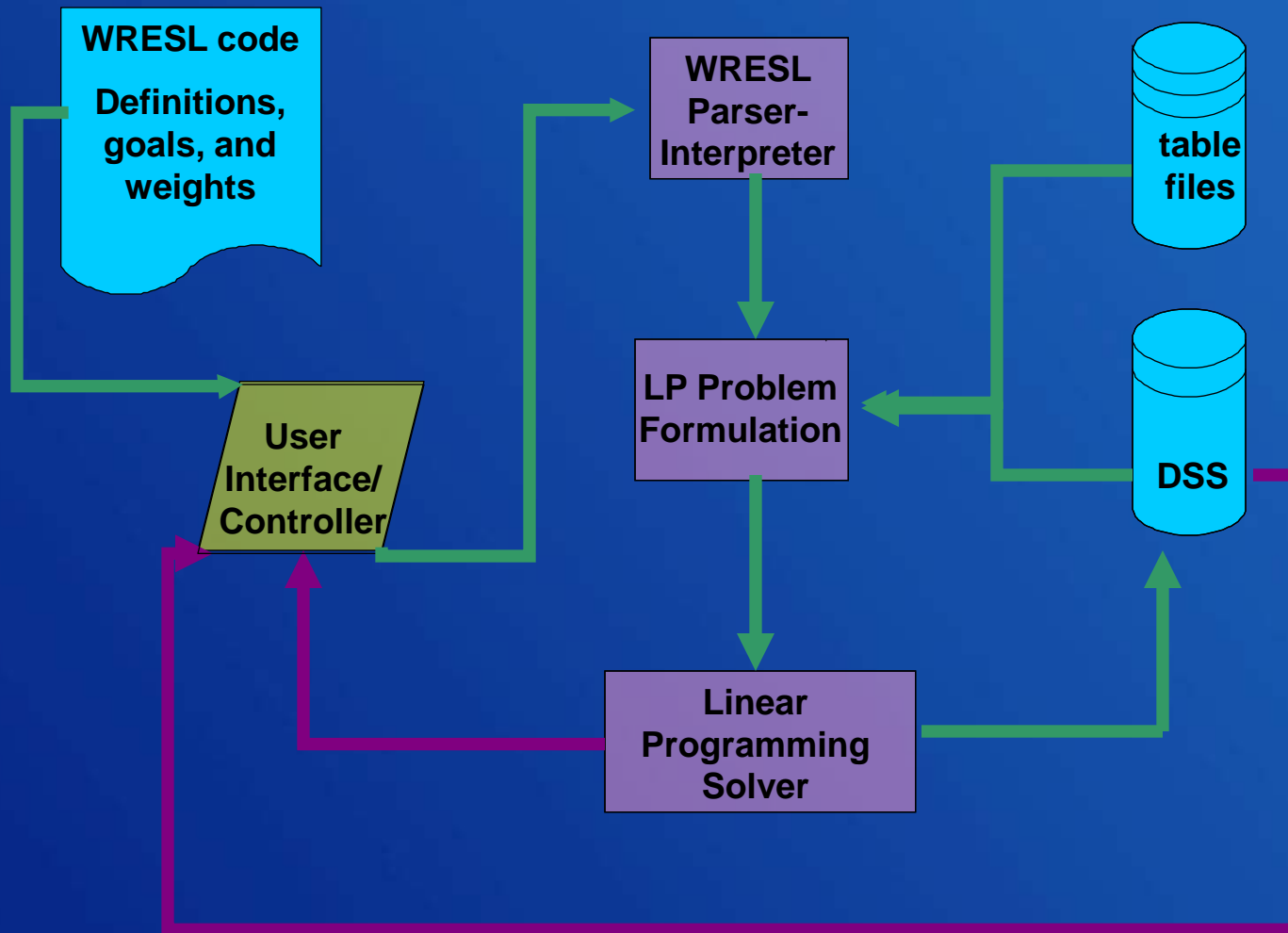
- Physical river system represented as a network of nodes (reservoirs, diversion points) and arcs (river channels, canals)
- Describe what the problem is, not how to solve it



WRIMS Basics

- Water Resources Engineering Simulation Language (**wresl**) Code
 - Define variables, Write goals/constraints
 - “English-like” syntax
- Input
 - Time series inputs – HEC-DSS (monthly, daily)
 - Parameter/Function inputs – ascii tables
- Output
 - HEC-DSS

WRIMS Components and Structure

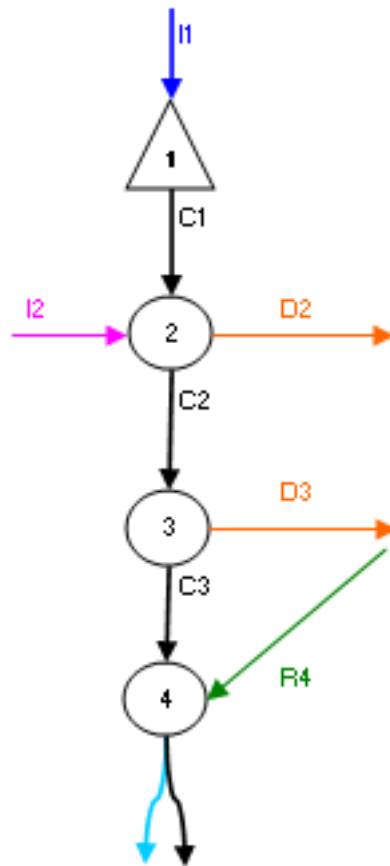


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WRESL Basics – Three Elements

- **Definitions**
 - **State Variables** – Input data (time series or lookup) or values calculated from input data
 - **Decision Variables** – Storage, Flows, Diversions, or other values calculated at run time
- **Goals / Constraints** – describe physical and institutional limits on operations;
hard or soft, constant or conditional
- **Weights** – prioritize flows, deliveries, storage

Optimization Problem



$$C4 = C4_MIF + C4_EXC$$

Connectivity

$$I1 + S1(-1) = S1_1 + S1_2 + S1_3 + E1 + C1$$

$$C1 + I2 = D2 + C2$$

$$C2 = D3 + C3$$

$$C3 + R4 = C4$$

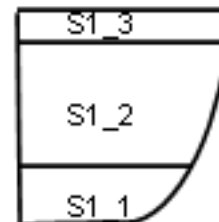
Storage Zones

$$S1 = S1_1 + S1_2 + S1_3$$

$$S1_1 < 150$$

$$S1_2 < 300$$

$$S1_3 < 50$$



50 taf Flood Space

300 taf Conservation Pool

150 taf Minimum Storage

Operation Constraints

$C1 < \text{release capacity}$

$D2 < \text{constant demand}$

$R3 = \text{factor} * D2$

$D3 < \text{time series demand}$

$C4_MIF < \text{minimum flow}$

Weights

S1_1	2000
S1_2	1000
S1_3	-10000
D2	1100
D3	1050
C4_MIF	1200

Sorted Weights

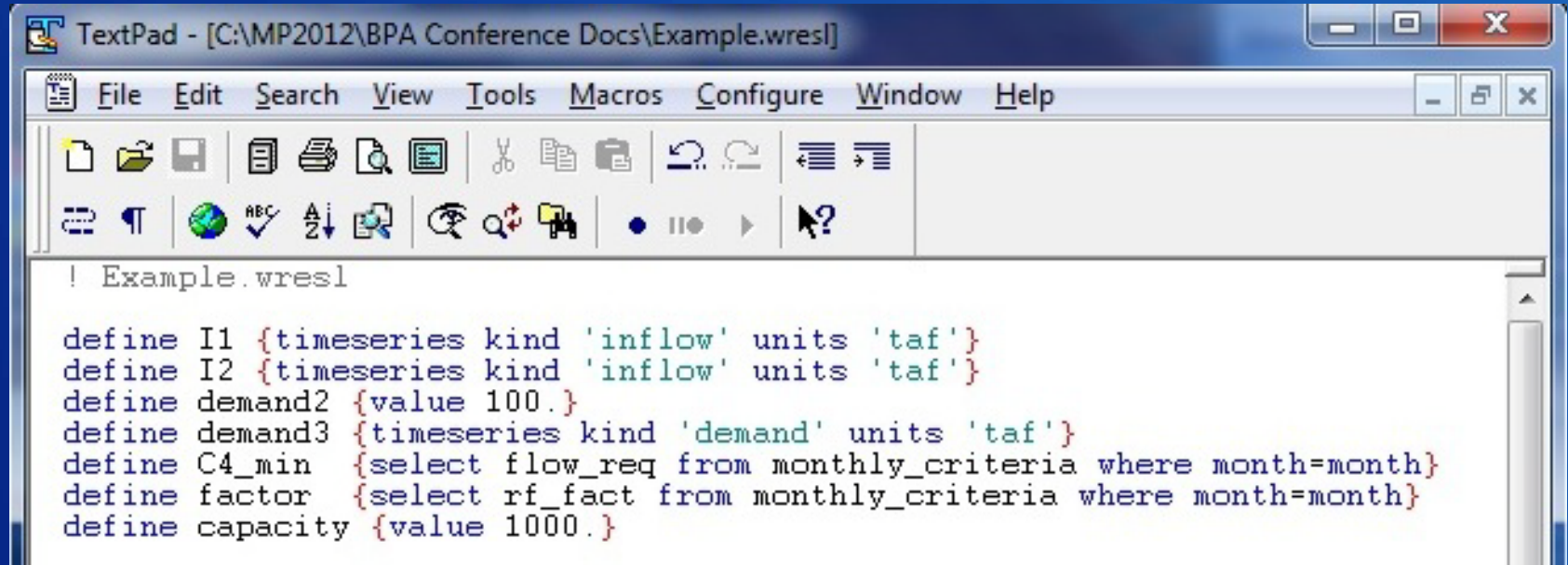
S1_1	2000
C4_MIF	1200
D2	1100
D3	1050
S1_2	1000
S1_3	-10000

Objective Function:

$$\text{Max } Z = 2000 * S1_1 + 1000 * S1_2 - 10000 * S1_3 + 1100 * D2 + 1050 * D3 + 1200 * C4_MIF$$

WRIMS Example

- Define Inputs



The screenshot shows a TextPad window titled "TextPad - [C:\MP2012\BPA Conference Docs\Example.wresl]". The window contains the following code:

```
! Example.wresl

define I1 {timeseries kind 'inflow' units 'taf'}
define I2 {timeseries kind 'inflow' units 'taf'}
define demand2 {value 100.}
define demand3 {timeseries kind 'demand' units 'taf'}
define C4_min {select flow_req from monthly_criteria where month=month}
define factor {select rf_fact from monthly_criteria where month=month}
define capacity {value 1000.}
```


WRIMS Example

- Define Decision Variables

```
define S1 {std kind 'storage' units 'taf'}
define S1_1 {std kind 'storage-level' units 'taf'}
define S1_2 {std kind 'storage-level' units 'taf'}
define S1_3 {std kind 'storage-level' units 'taf'}
goal totS4 {S4 = S4_1 + S4_2 + S4_3}
define C1 {std kind 'channel' units 'cfs'}
define C2 {std kind 'channel' units 'cfs'}
define C3 {std kind 'channel' units 'cfs'}
define C4 {std kind 'channel' units 'cfs'}
define C4_MIF {std kind 'flow-minimum' units 'cfs'}
define C4_EXC {std kind 'flow-excess' units 'cfs'}
goal totC4 {C4 = C4_MIF + C4_EXC}

define D1 {std kind 'diversion' units 'cfs'}
define D2 {std kind 'diversion' units 'cfs'}
define R4 {std kind 'return' units 'cfs'}
```

WRIMS Example

- Write Constraints and Goals
- Weight Decision Variables

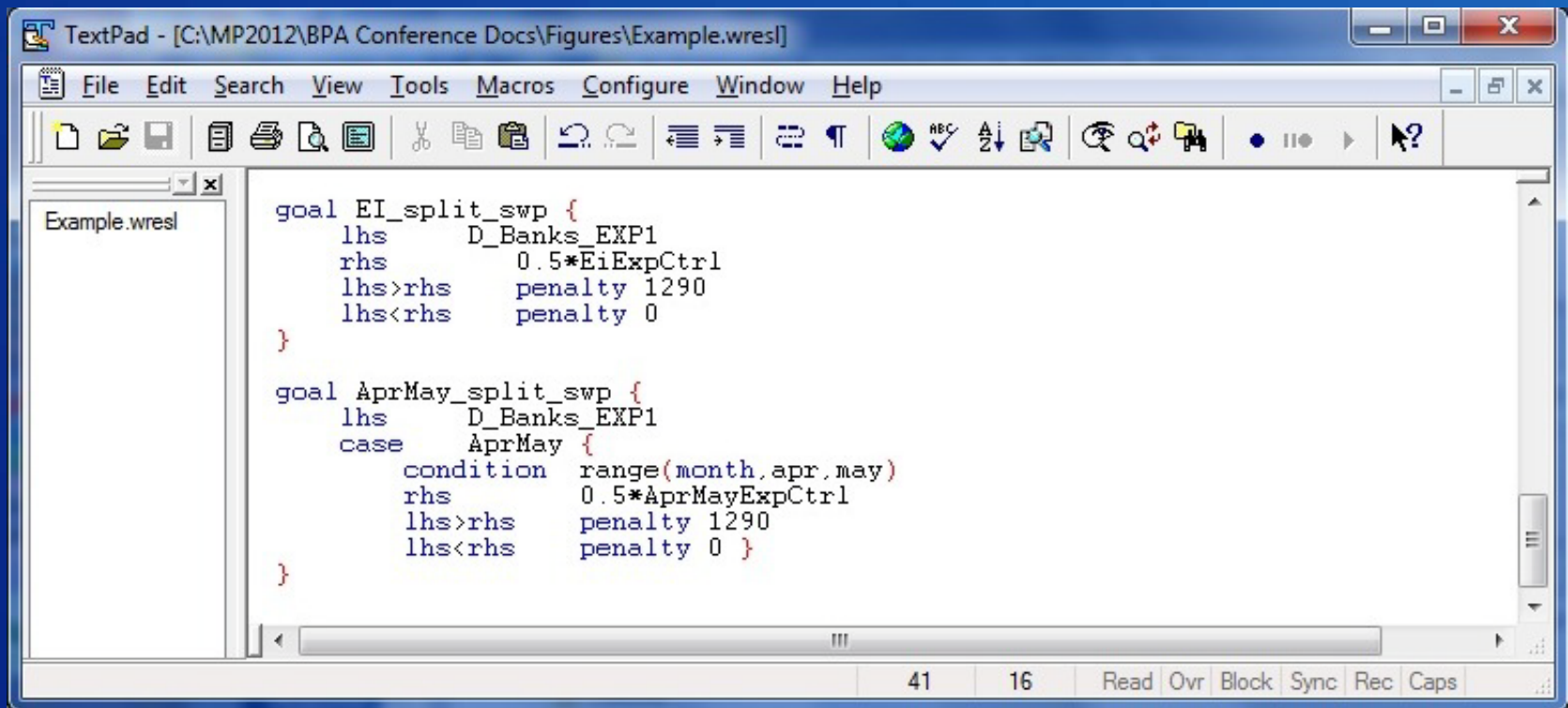
```
goal continuity1 {I1 - C1 - E1 = S1*taf_cfs - S1(-1)*taf_cfs}
goal continuity2 {C1 + I2 - D2 - C2 = 0.}

goal LimitRelease {C1 < capacity}
goal meetD2       {D2 < demand2}
goal meetD3       {D3 < demand3}
goal setD3Return  {R4 = D3 * factor}
goal MeetMinFlow  {C4_MIF < C4_min}

Objective obj = {
[S1_1, 2000*taf_cfs],
[C4_MIF, 1200],
[D2, 1100],
[D3, 1050],
[S1_2, 1000*taf_cfs],
[C4_EXC, -100],
[S1_3, -1000*taf_cfs]
}
```

WRIMS Example

- Soft Constraints – slack and surplus penalties



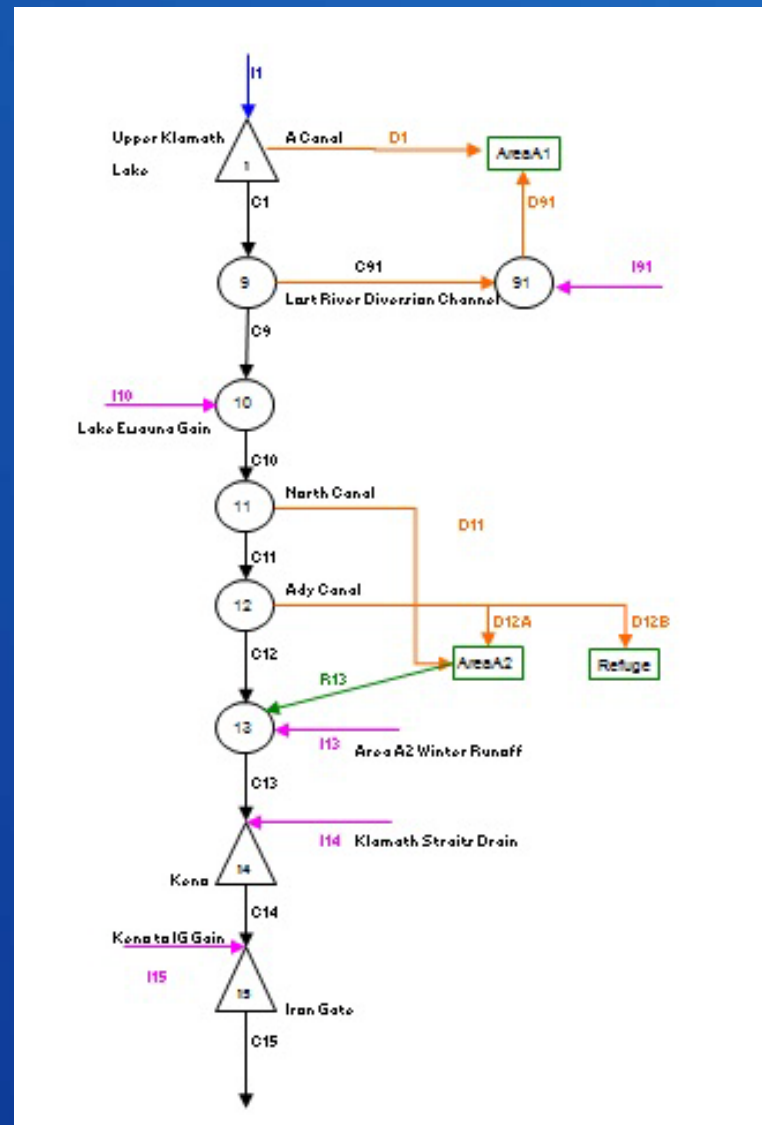
The screenshot shows a TextPad window titled "TextPad - [C:\MP2012\BPA Conference Docs\Figures\Example.wresl]". The window contains the following code:

```
goal EI_split_swp {
  lhs      D_Banks_EXP1
  rhs      0.5*EiExpCtrl
  lhs>rhs  penalty 1290
  lhs<rhs  penalty 0
}

goal AprMay_split_swp {
  lhs      D_Banks_EXP1
  case     AprMay {
    condition range(month, apr, may)
    rhs     0.5*AprMayExpCtrl
    lhs>rhs penalty 1290
    lhs<rhs penalty 0 }
}
```

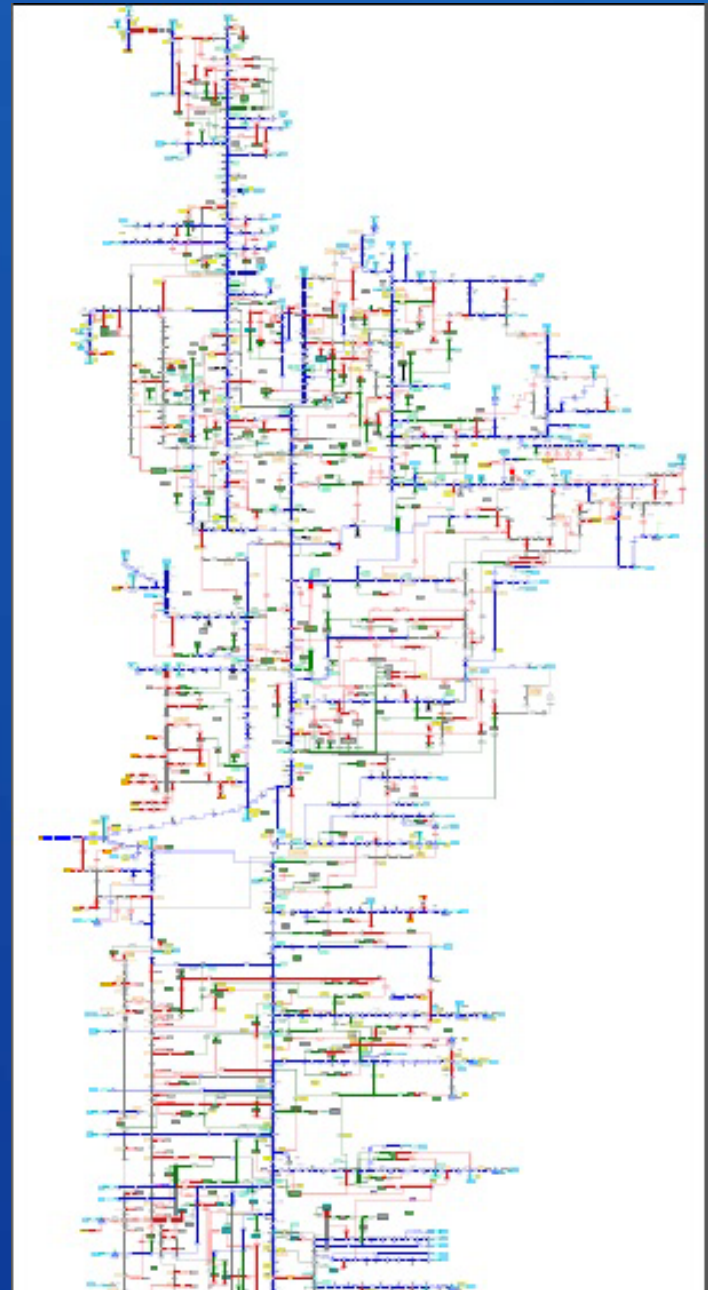
The status bar at the bottom of the window shows "41" and "16" on the left, and "Read Ovr Block Sync Rec Caps" on the right.

WRIMS Example



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WRIMS Example



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WRIMS Solution

- **XA LP/MILP Solver – Sunset Software**
 - \$1250
 - Hardware license
- Maximize objective function value while meeting user specified constraints
- Integer variables allow dynamic switches
- **Solution vs. optimization**
- Debugging is an acquired skill

WRIMS Software

- **Conditional or multiple solutions within each time step allow for layering of constraints**
- **Can incorporate external functions or dll's**
- **Position analysis capabilities enable use of ensemble input data sets**
- **Flow routing using arc “storage”**
- **Mixed timestep simulations – look-ahead forecasting and routing applications**

WRIMS User Experience

- **Problems are hard; models should help**
- **WRIMS development done in text files**
 - custom, readable, searchable, “story-line”, text highlights
- **GUI facilitates running the model**
- **GUI enables basic results processing – variable lists, time series, plots, tables**

WRIMS Look and Feel

WRIMS - Study Output

General System Lookup Options Sensitivity Run/Result

Study Name: PA2013

Author: K White and N Parker

Date: Thu Feb 09 09:51:21 MST 2012

Description: Proposed Action for 2013 consultation - Allocation with Max protect

WRESL File: C:\k\math\FY12\PA\Studies\DTs10b\run\man.wresl

SV File: C:\k\math\FY12\PA\Studies\DTs10b\dss\dailyPA_sv.dss

SV File A Part: CalSim SV File F Part: KBPM

DV File: C:\k\math\FY12\PA\Studies\DTs10b\dss\dailyPA_DV.DSS

Init File: C:\k\math\FY12\PA\Studies\DTs10b\dss\dailyPA_init.dss

Init File F Part: KBPM

Time Step: IDAY Number of Time Steps: 11322

Start Date: 1980 Year OCT Month 1 Day

Stop Date: 2011 Year SEP Month 30 Day

Sim Option: SLP # Sequences: 1

Status: Done.

WRIMS - Study Output

Message Panel

Project Name: [Empty]

Base Files [X] DV: C:\MP2012\CalSimIII\CS3_BO_version95B\conv\DSS SV: [Empty]

Comp Files 1 [] DV: [Empty] SV: [Empty]

Comp Files 2 [] DV: [Empty] SV: [Empty]

Comp Files 3 [] DV: [Empty] SV: [Empty]

Mode: Base Co... Diff View: Plot Table Mon... TW: OCT1921 - SEP2003 Units: TAF CFS

General Dts Tree

Filter

TYPE A B C D E

DVAR S_SHSTA

Filter Retrieve

No.	A PART	B PART	C PART	D PART	E PART
1	CALSIM	S_SHSTA	STORAGE	31OCT1921 2400 - 30S...	1MON

Graph

Graph Display

Zoom Out Paging

Graph (CALSIM)

TAF

19211926193119

WRIMS - Study Output

Message Panel

Project Name: [Empty]

Base Files [X] DV: C:\MP2012\CalSimIII\CS3_BO_version95B\conv\DSS SV: [Empty]

Comp Files 1 [] DV: [Empty] SV: [Empty]

Comp Files 2 [] DV: [Empty] SV: [Empty]

Comp Files 3 [] DV: [Empty] SV: [Empty]

Mode: Base Co... Diff View: Plot Table Mon... TW: OCT1921 - SEP2003 Units: TAF CFS

General Dts Tree

Dts Directory

- Storage.MTS

Derived Time Series: STORAGE.MTS

Derived Time Series	Dvar/Svar	B part	C part
DVAR	S_TRNTY	STORAGE	
DVAR	S_SHSTA	STORAGE	
DVAR	S_FOLSM	STORAGE	
DVAR	S_OROVL	STORAGE	

Add Insert Delete Open

Status: Done.

MONTHLY REPORT

File

STUDI: CALSIM30_06 FILE: C:\MP2012\CalSimIII\CS3_BO_version95B\conv\DSS\Version95B_88yr_011312_WRIMS\2

Data: /CALSIM/S_SHSTA/STORAGE/01JAN1920/1MON/CALSIM30_06/

Units: TAF

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1922	2601	2591	2735	2865	3192	3534	4096	4543	4321	3896	3577	3400
1923	3250	3159	3268	3471	3611	3723	4122	4008	3728	3257	2973	2959
1924	2908	2818	2812	2836	3002	2958	2893	2585	2225	1648	1367	1180
1925	1181	1325	1443	1676	2952	3329	3973	4211	4040	3477	3169	3075
1926	3025	2974	3011	3005	3868	4073	4403	4258	3865	3189	2609	2469
1927	2400	2892	3337	3668	3462	4132	4552	4552	4343	3845	3506	2958
1928	2950	2932	3053	3287	3797	3965	4552	4548	4159	3531	3200	2824

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