AUTOMATED PARAMETER ESTIMATION AND MODEL CALIBRATION IN RIVERWARE

John Craven, **Nick Mander**, John Carron,
Hydros Consulting Inc.
February 3, 2015

Hydros
Consulting

Outline

- Motivation
- Interfacing PEST with RiverWare
- Examples
  - ***Single Objective Calibration***: Hourly routing model
  - ***Multi-Objective Optimization***: Monthly operational model
- Summary

Motivation:
RiverWare models may be highly parameterized

- Models may represent multiple physical processes and/or policies
- Parameters may be **uncertain**, difficult to measure, or altogether **unknown**
  - Reach routing parameters
  - Policy parameters
  - Water user min./max. efficiency
  - Reach gain/loss coefficients
  - Canal seepage
  - Groundwater object parameters (hydraulic conductivity, conductance, specific yield, etc.)
  - …and many more…

Motivation

- “Traditional” approach → Hand-calibration
  - **Time consuming**, lots of clicking
  - Difficult to understand overall system response without in-depth analysis
- Automated calibration
  - Can quickly see system response through multi-objective problem formulation – ***Time Saving!***

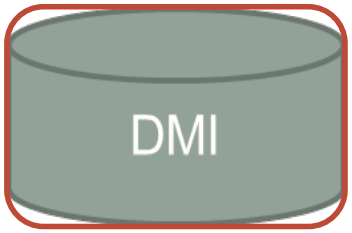
PEST: Overview
Parameter ***EST***imation[1]

- Open-source parameter estimation software package
  - **Model independent**
- Widely used in surface and groundwater modeling
- Multiple search algorithms available (GML and SCE-UA)
- Will work with ***ANY*** model that can be executed through the command line
  - Your “model” can be a script that calls the actual “model”
  - Input/Output read/written by PEST must be text (may require pre-/post-processing)
- 1) www.pesthomepage.com

Interfacing with RiverWare

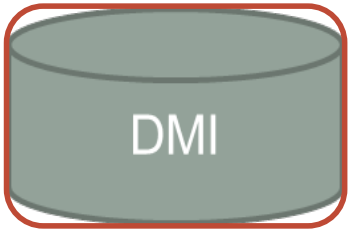
1) Generate new parameters, evaluate obj. function, Evaluate stopping criteria

2) Load model Rules,etc., Invoke DMI



3) Load parameters generated by PEST

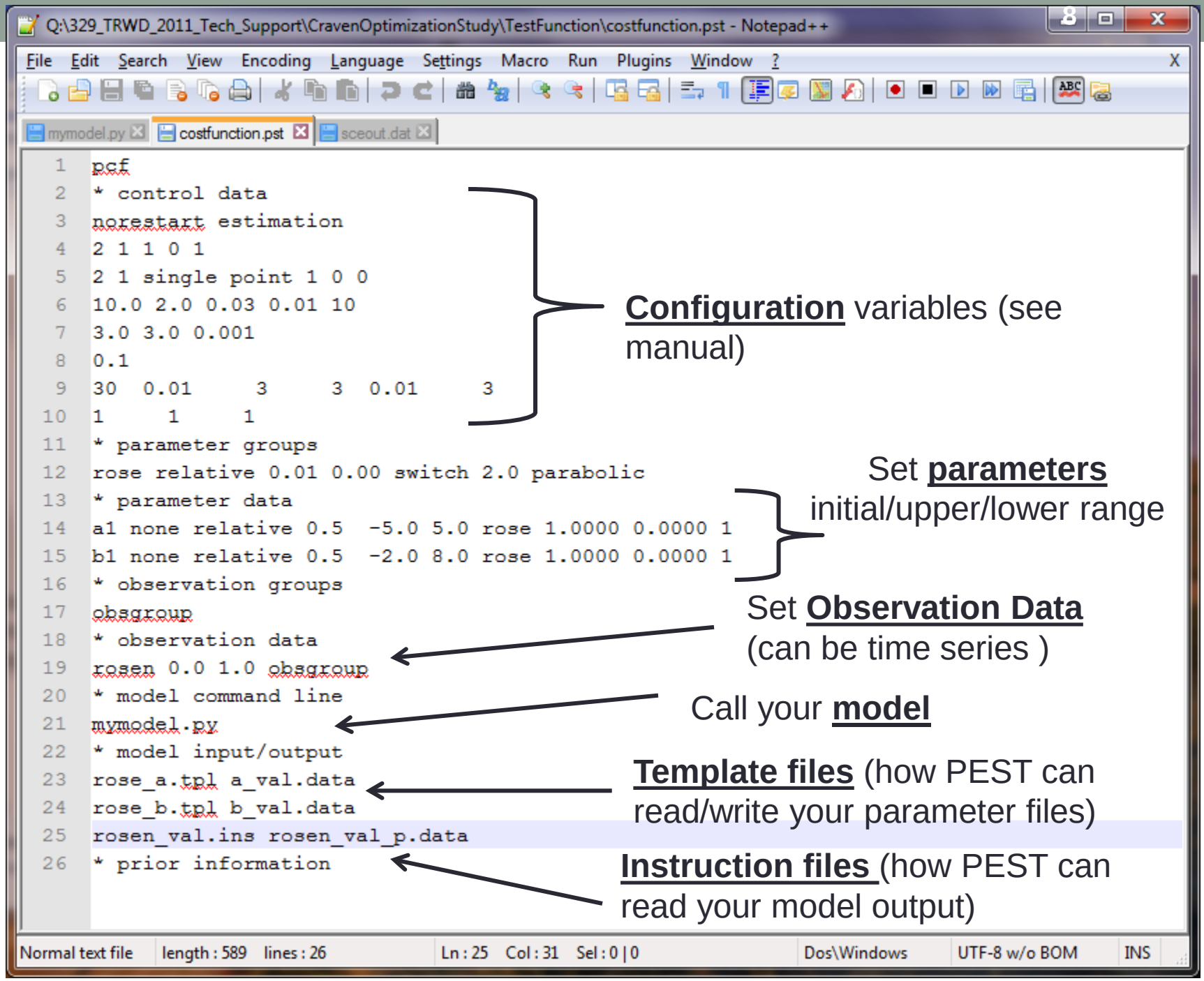
4) Run the model!



5) Generate output through the DMI; Evaluate

Interfacing with RiverWare: Main components of PEST

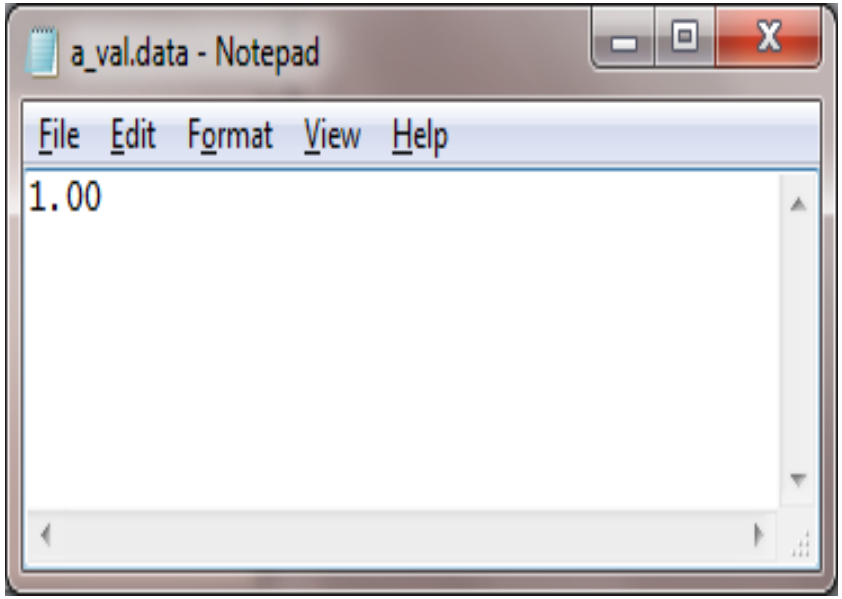
- **Control file:** configuration, set parameters, observations
- **Template file(s):** tell PEST how to generate parameter files used by your model (RiverWare)
- **Instruction file(s):** tell PEST how to understand the output generated by your model

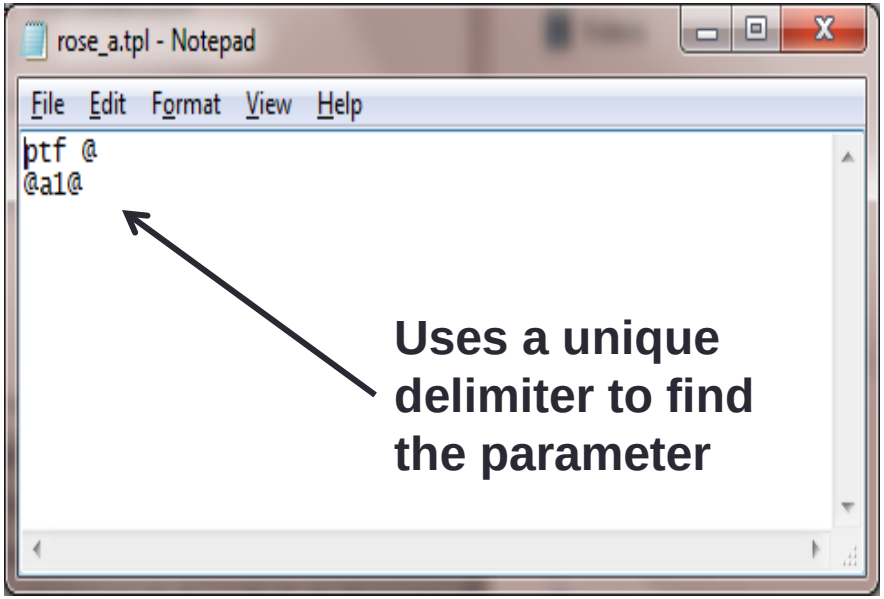

Q:\329_TRWD_2011_Tech_Support\CravenOptimizationStudy\TestFunction\costfunction.pst - Notepad++
File Edit Search View Encoding Language Settings Macro Run Plugins Window ?
mymodel.py
costfunction.pst
sceout.dat
pcf
* control data
norestart estimation
2 1 1 0 1
2 1 single point 1 0 0
10.0 2.0 0.03 0.01 10
3.0 3.0 0.001
0.1
30 0.01 3 3 0.01 3
1 1 1
* parameter groups
rose relative 0.01 0.00 switch 2.0 parabolic
* parameter data
a1 none relative 0.5 -5.0 5.0 rose 1.0000 0.0000 1
b1 none relative 0.5 -2.0 8.0 rose 1.0000 0.0000 1
* observation groups
obsgroup
* observation data
rosen 0.0 1.0 obsgroup
* model command line
mymodel.py
* model input/output
rose_a.tpl a_val.data
rose_b.tpl b_val.data
rosen_val.ins rosen_val_p.data
* prior information
Normal text file length : 589 lines : 26 Ln : 25 Col : 31 Sel : 0 | 0 Dos\Windows UTF-8 w/o BOM INS
Configuration variables (see manual)
Set parameters initial/upper/lower range
Set Observation Data (can be time series)
Call your model
Template files (how PEST can read/write your parameter files)
Instruction files (how PEST can read your model output)

Interfacing with RiverWare: How PEST can read/write your model parameters/output

Model Parameter File → PEST Template File

Tells PEST how to write your parameter files



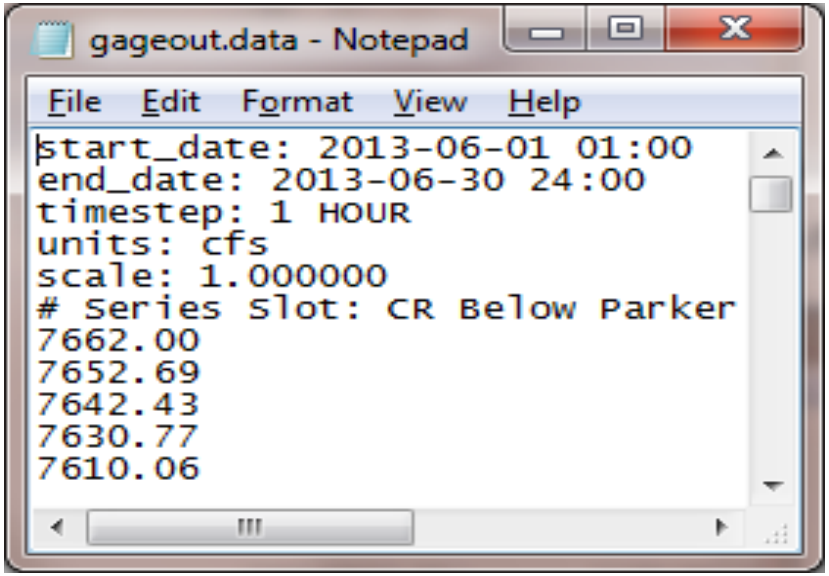


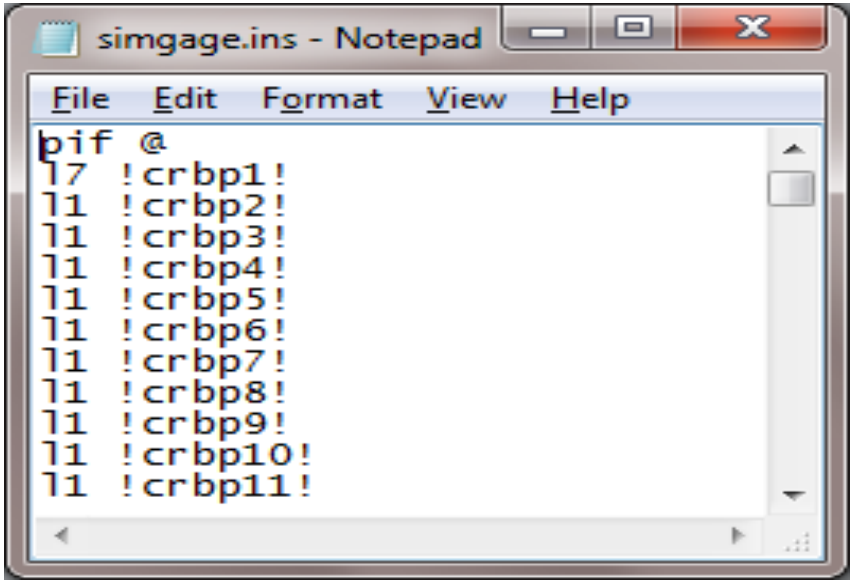
RiverWare ***PEST***

Interfacing with RiverWare: How PEST can read/write your model parameters/output

Model OUTPUT File → PEST Instruction File

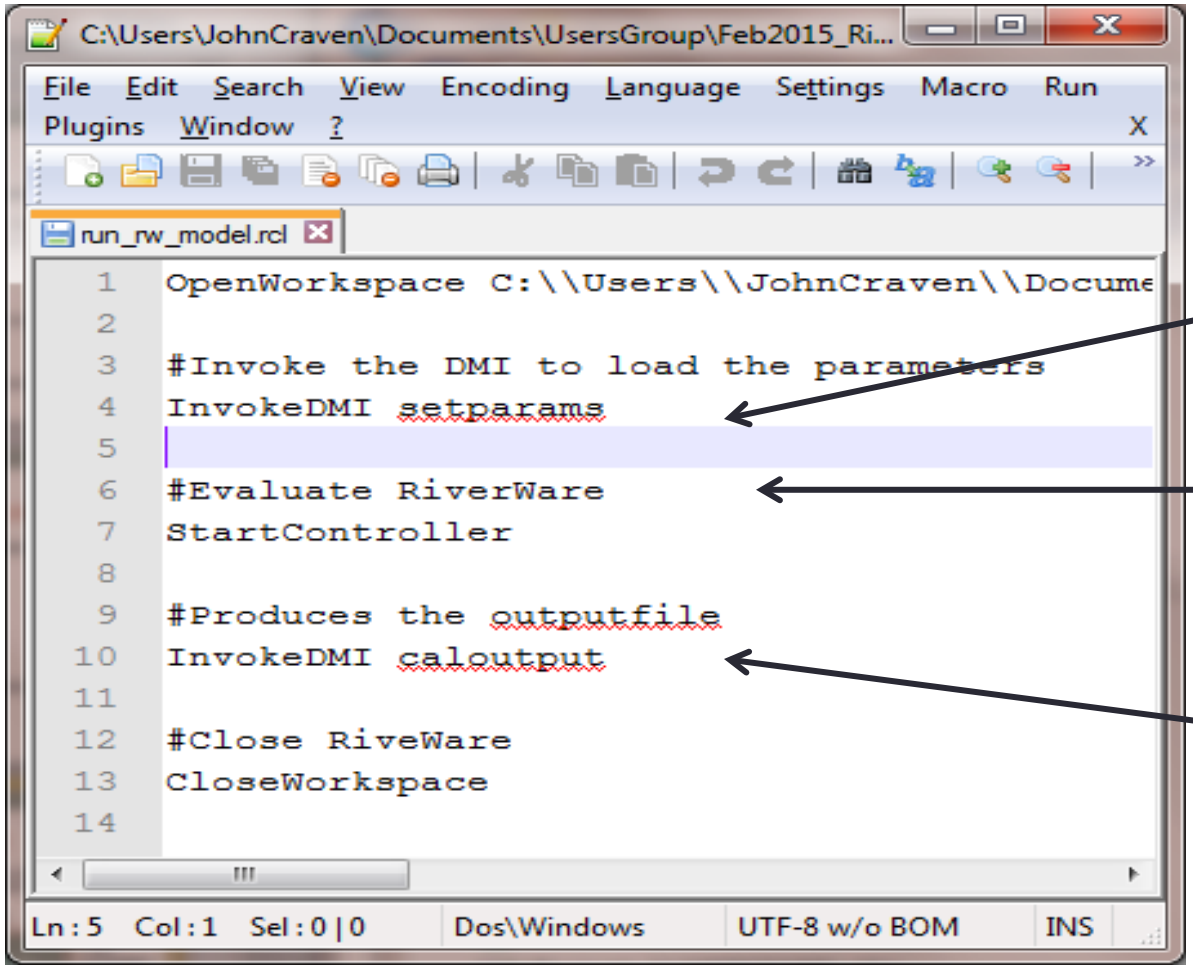
Tells PEST how to read your output





RiverWare ***PEST***

Interfacing with RiverWare



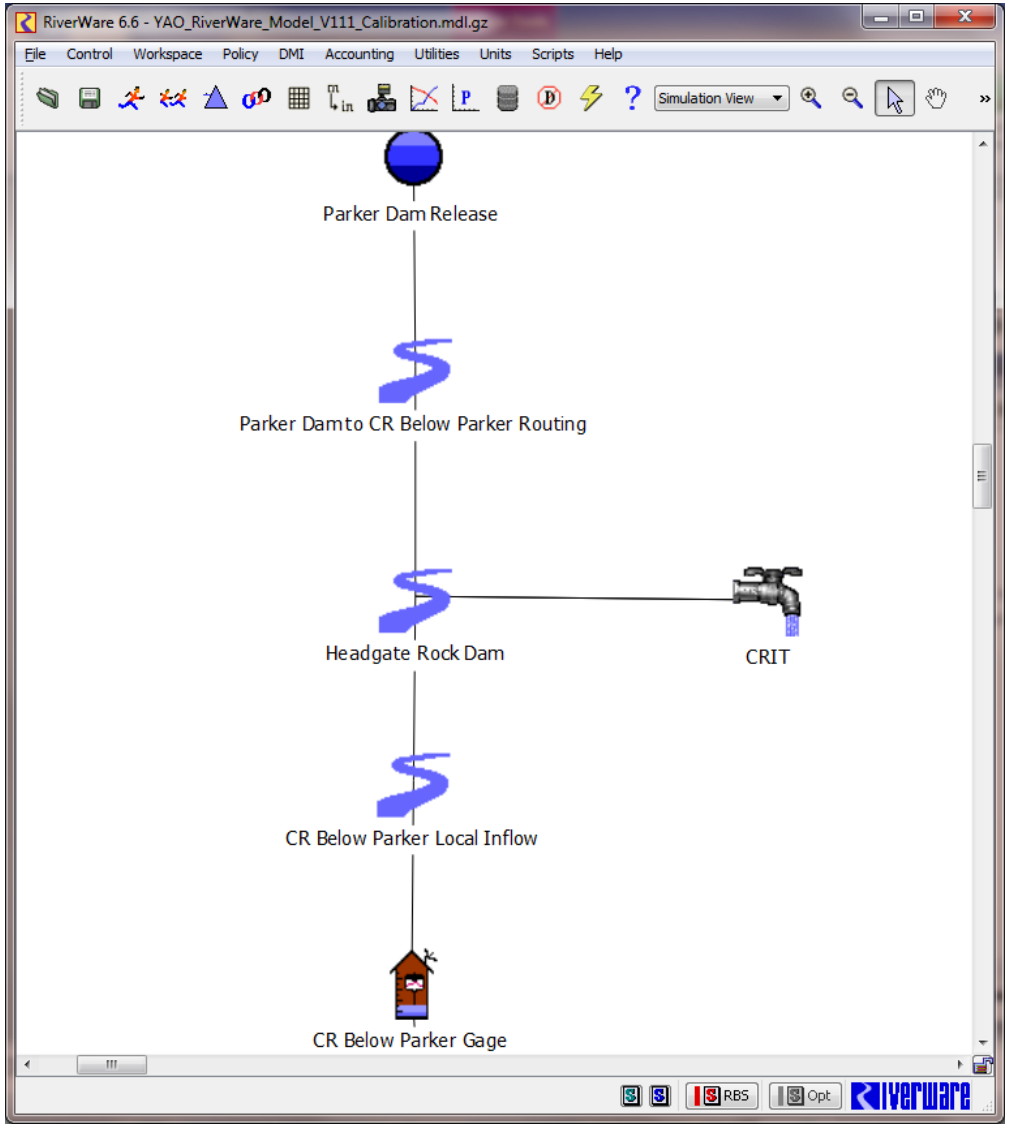
Load the parameters (DMI) generated by PEST, etc.

Run the model

Produce output through DMI to be evaluated

Single Objective Example: Routing Model

- Minimize Sum of the Squared Errors
  - Obs. v. Simulated
- Hourly model
- Kinematic-Improved reach routing method
- 3 Parameters
  - Manning's Roughness N
  - Reach Length
  - Bottom Width



Single Objective Example: Routing Model

1) Define objective function → here minimize sum of squared errors

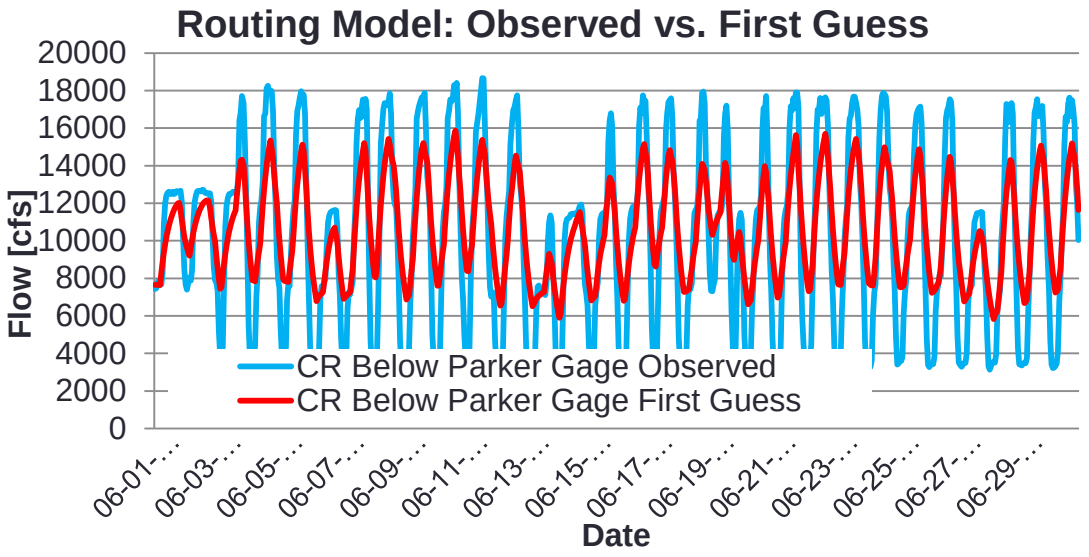
2) First guess
   - Estimate length and width from survey data/GIS
   - Look up a Manning's N value from literature

3) Parameter bounds
   - Estimate parameter bounds, literature, available data

4) Build PEST files
   - Control/Template file(s)/Instruction file(s)

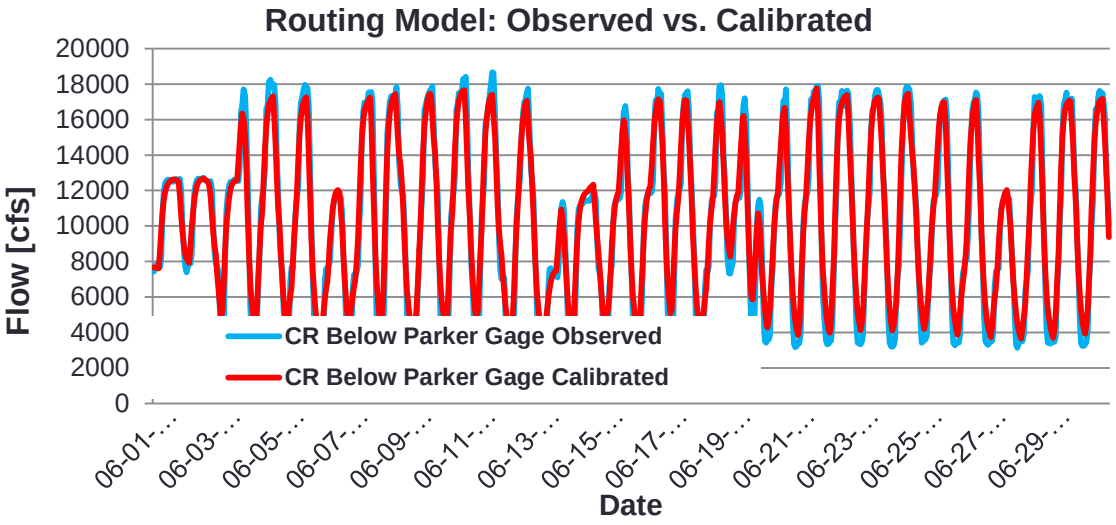
5) Build RCL Script and Input/Output DMI

Single Objective Example: Routing Model



$R^2 = 0.83$

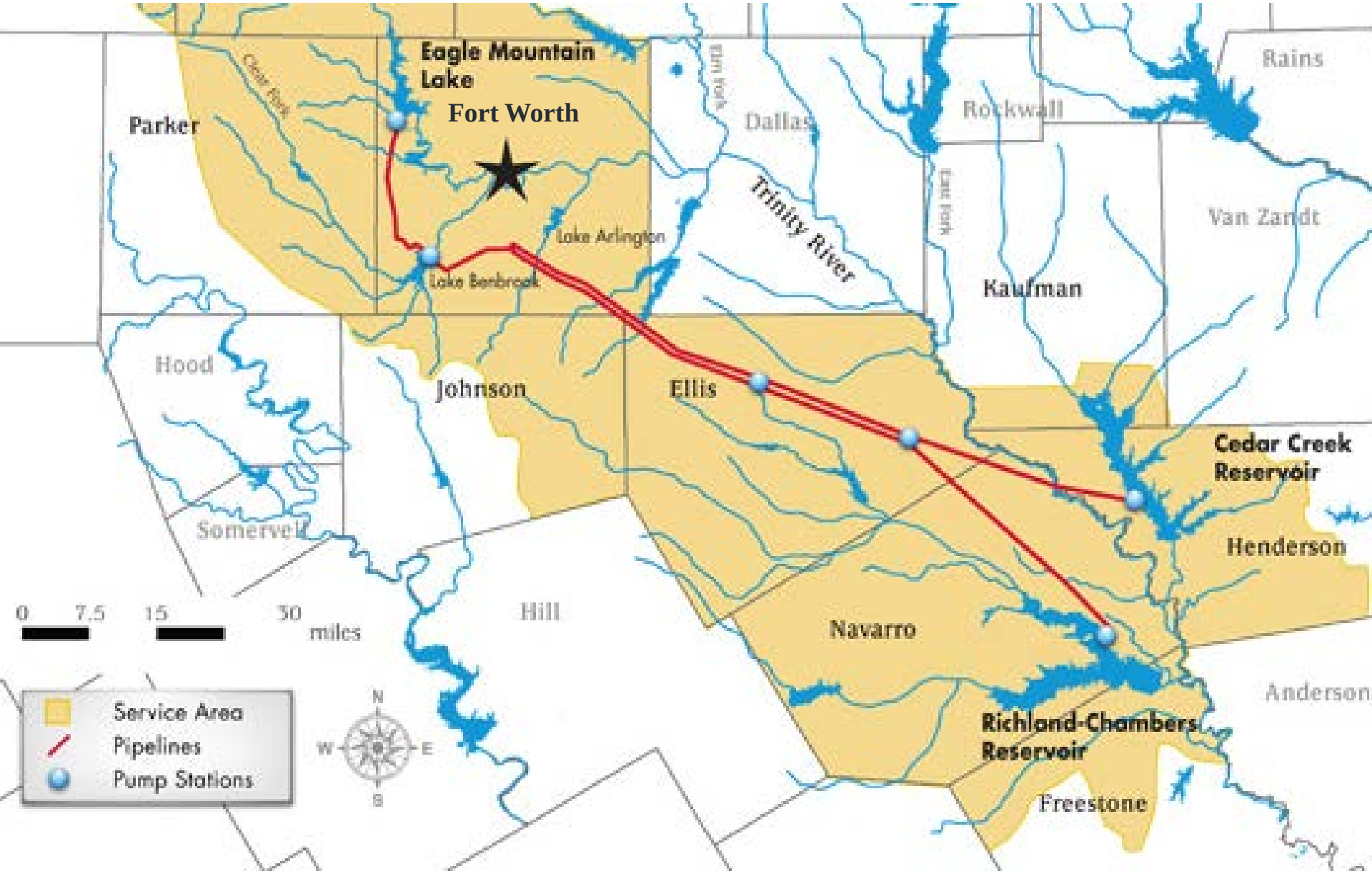
- Calibration on 1 month (hourly)
- Model run: ~2 seconds
- Total time: ~10 minutes (300 runs)

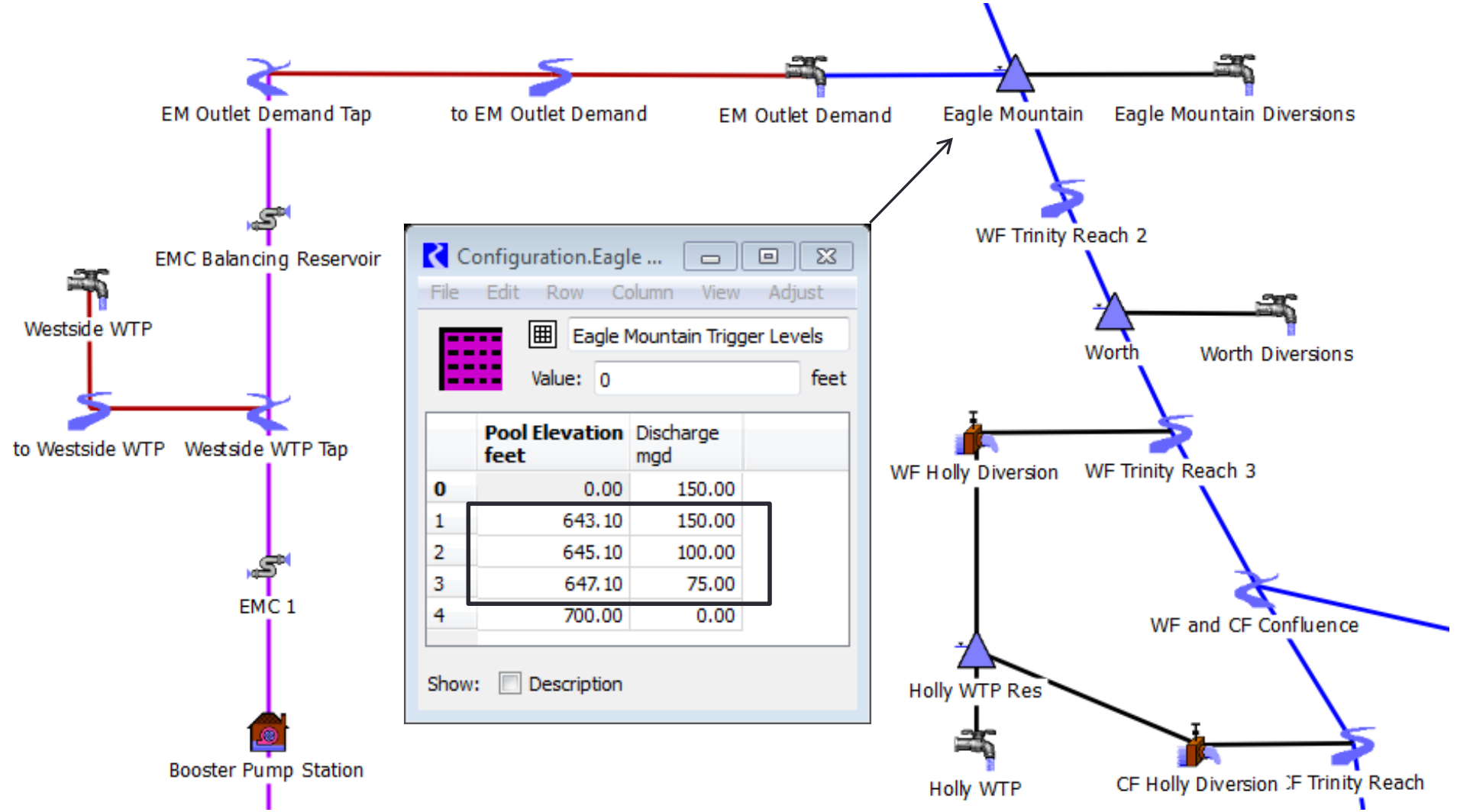


$R^2 = 0.97$

- Multiple reaches
- Benefits:
  - Let calibration loop over all reaches
  - No intervention req. beside set-up (1-2 hours)

Example: TRWD monthly longterm planning model




EM Outlet Demand Tap
to EM Outlet Demand
EM Outlet Demand
Eagle Mountain
Eagle Mountain Diversions
EMC Balancing Reservoir
WF Trinity Reach 2
Westside WTP
Worth
Worth Diversions
to Westside WTP
Westside WTP Tap
WF Holly Diversion
WF Trinity Reach 3
EMC 1
WF and CF Confluence
Holly WTP Res
Booster Pump Station
Holly WTP
CF Holly Diversion
CF Trinity Reach
Configuration.Eagle ...
File Edit Row Column View Adjust
Eagle Mountain Trigger Levels
Value: 0
feet
Pool Elevation feet
Discharge mgd
0 0.00 150.00
1 643.10 150.00
2 645.10 100.00
3 647.10 75.00
4 700.00 0.00
Show: Description

Example: Operations Model "Optimization" Objective Function Components[1]

- # of months that system spills
- Total volume spilled

- # of months Eagle Mountain Pipeline is over 50 MGD

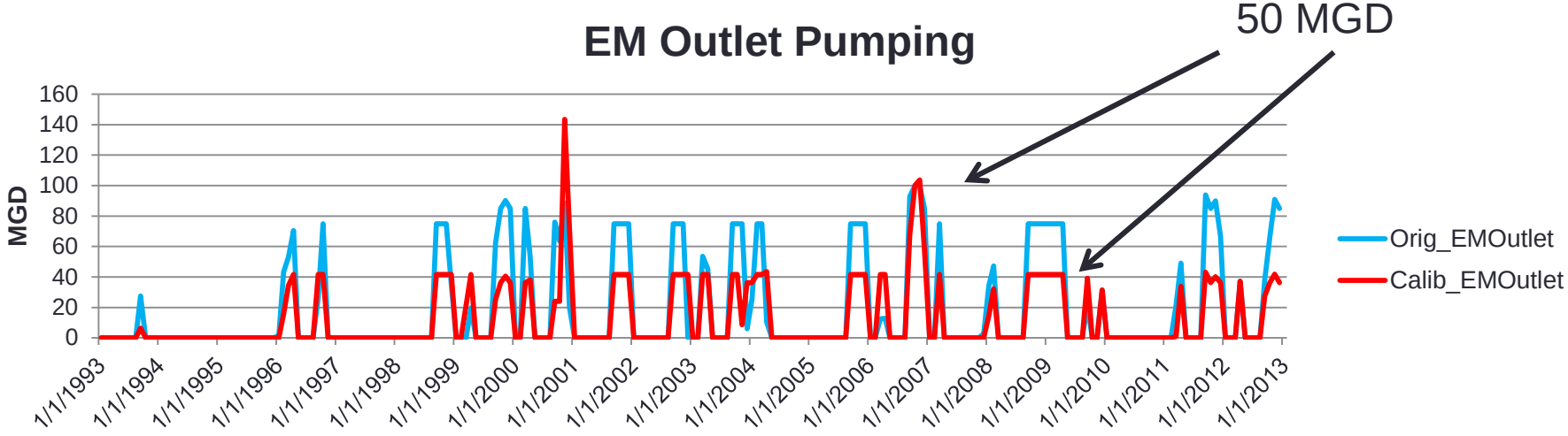
- Total East Texas Pumping volume
- Total volume of East Texas Pumping above 211 MGD

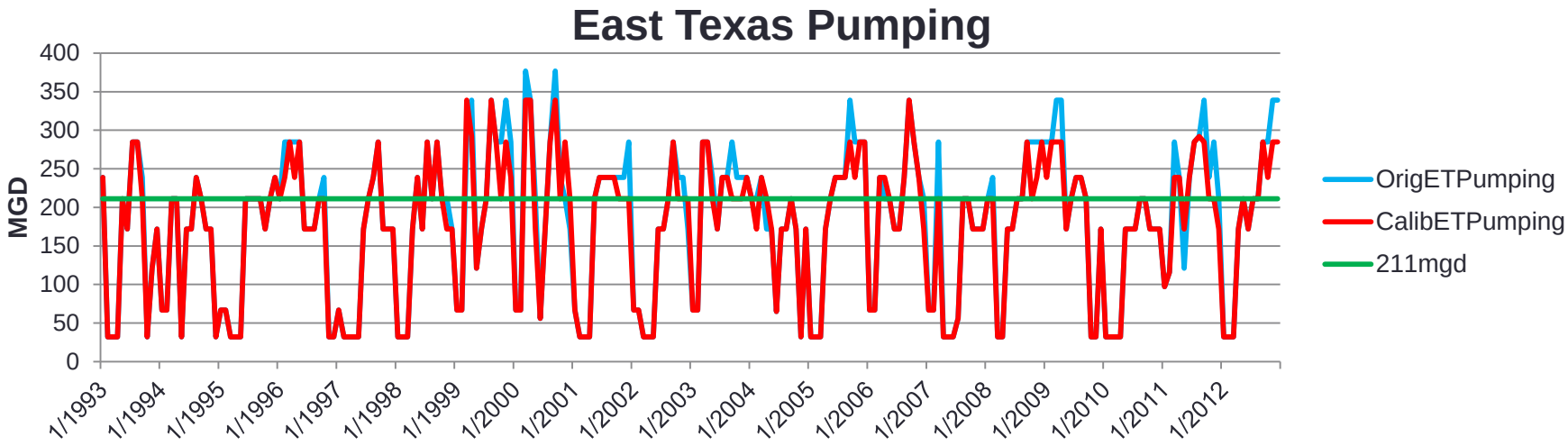
- East Texas Pumping
  - Total Variance
  - Summer Variance (June – September)
  - Variance calculated over the past 11 months

1) R. Smith 2014 - CADSWES

Results

Calibrated model rarely pumps > 50 MGD





Results

- 6 Parameters
- 8 piece objective function
- Convergence ~9 hours

Objective	Baseline	Calibrated	Difference
# of months system spill	94	94	0
Total Volume Spilled [af]	3,026,389	2,914,218	-3.8%
# of Months EM Pumping > 50 MGD	52	6	-760%
Total East Texas Pumping [af]	85,517	82,502	-3.7%
Total Volume of East Texas Pumping > 211 MGD [af]	23,115	18,246	-21%
East Texas Pumping Total Variance	8,886	7,721	-13%
Average Summer Variance	2,573	2,187	-18%
Average 11 month moving variance	8,778	7,140	-23%

- Pumping variance reduced
- Eagle Mountain Pumping > 50 MGD *significantly* reduced
- No adverse impacts on the system
  - Optimized policy parameters plugged into daily forecasting model

Summary

- Fully automated calibration/parameter estimation is possible
  - Works well with single or multi-objective problems
- Allows modeler to explore influence of parameters, parameter ranges, and system response quantitatively
- Time savings!
- Challenges
  - Need good estimates of parameter range
  - Still need parameters that make sense!
  - What is/isn't included in your objective function matters!
  - Weighting of objective function components is fairly subjective

References

- PEST http://www.pesthomepage.org/
- Duan et al. 1991,1992, 1993, 1994
- R. Smith 2014

- Thanks to Laura Blaylock at TRWD