South Platte Decision Support System

a joint effort by CWCB and DWR

Alluvial Groundwater Model Calibration Results

Peer Review Committee Meeting 6

August 16, 2011

Introductions

Meeting Purpose

- Update PRC on Alluvial Groundwater Model Calibration Results
- Feedback from PRC

Presentation Outline

- Goals and Potential Applications of Model
- Background
- Calibrated Model Presentation
- Conclusions and Next Steps
- Discussion

Alluvial Groundwater Model: Goals and Potential Applications

Goals:

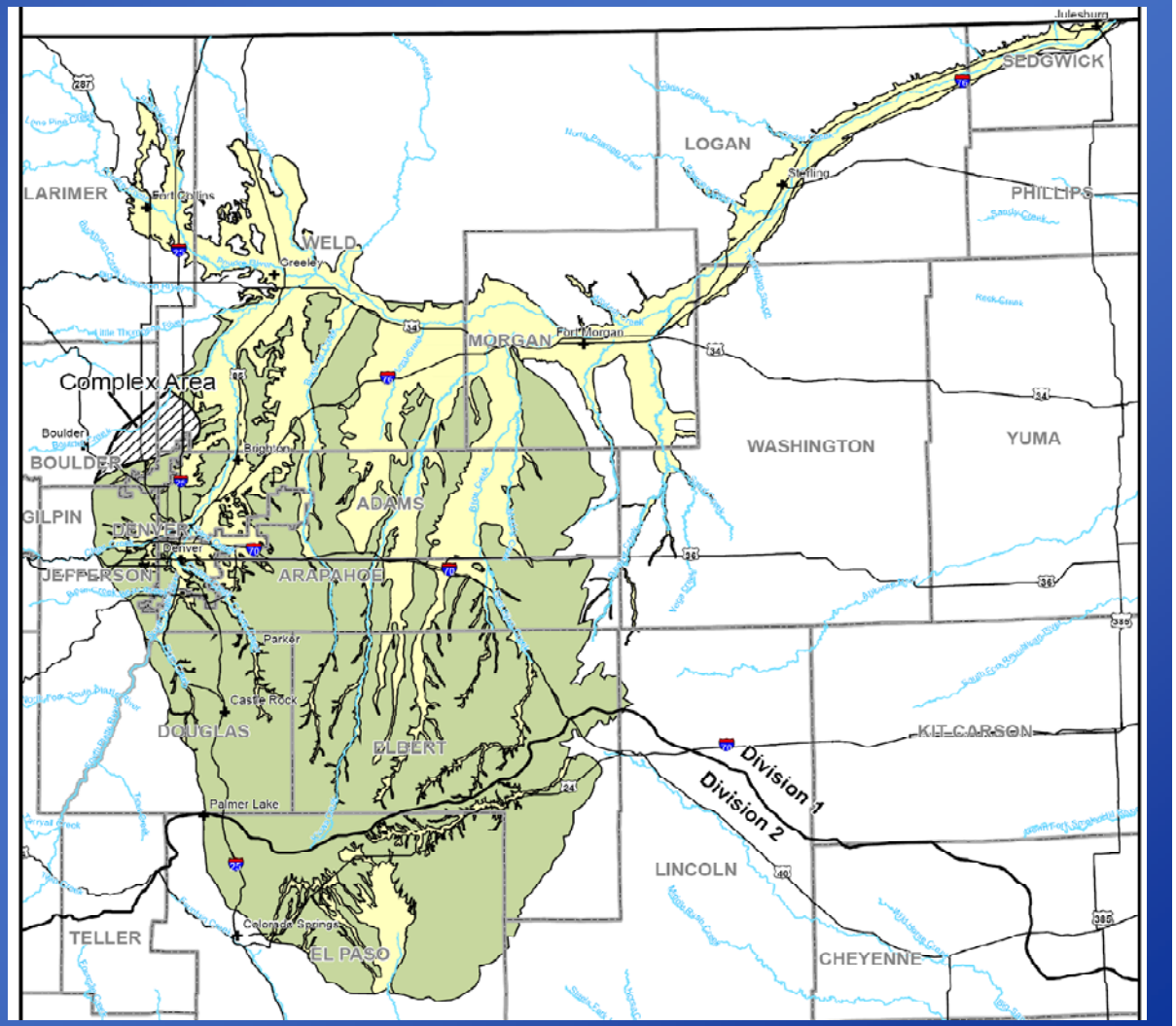
- Enhance understanding of regional groundwater flow in the study area
- Develop a tool to assist in planning and evaluation of regional water resources

Potential Applications:

- Effects of pumping and recharge at a regional scale
- Effects of changes in irrigation practices at a regional scale
- Other regional scale analyses
- Basis for local scale analyses

Background

- SPDSS Process
- Development of Stress Inputs



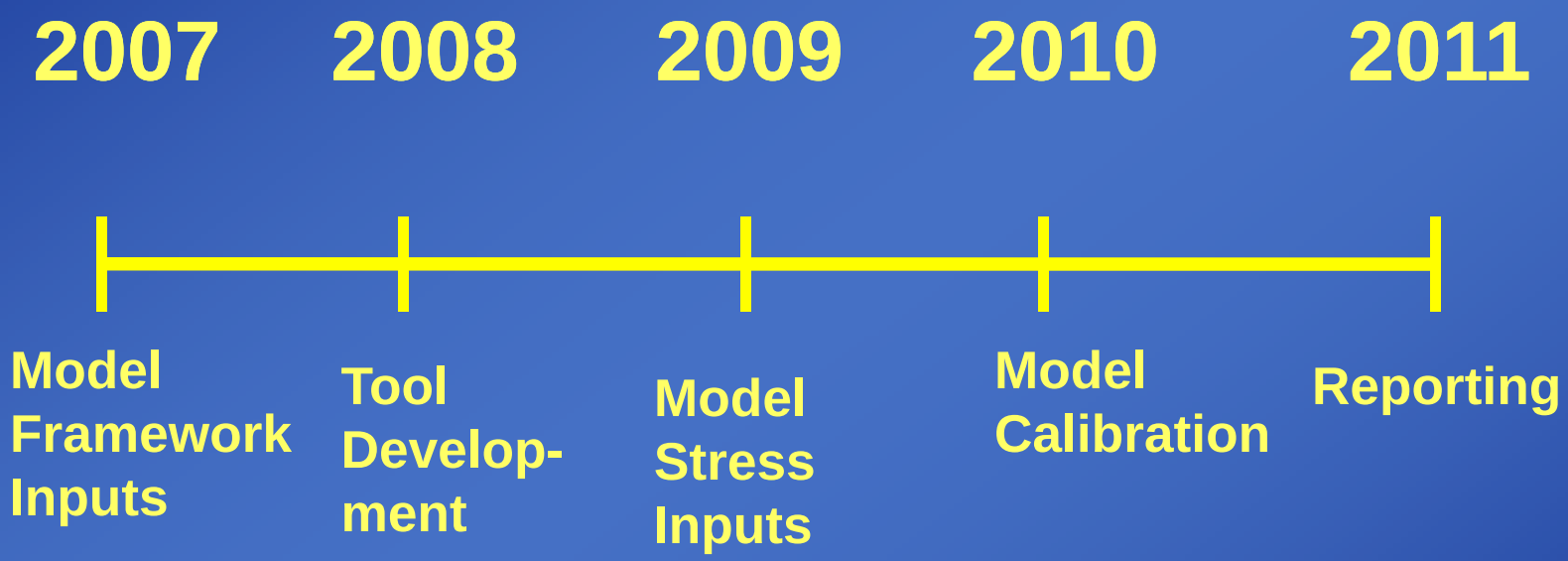
SPDSS Modeling Process

- Use data from earlier SPDSS tasks to develop inputs
- Use Data Centered tools developed under the RGDSS & SPDSS to develop the model input files
- Incorporate other information provided by SPDSS contractors
  - agricultural pumping
  - recharge
  - groundwater evapotranspiration
- Use relevant data from HydroBase
- Run and calibrate the model

SPDSS Documentation

- Technical Memoranda
  - Municipal & Industrial Pumping (Task 41.3)
  - Aquifer Configuration (Task 42.3)
  - Aquifer Properties (Task 43.3)
  - Water Levels (Task 44.3)
  - Stream Gain/Loss (Task 46.2)
  - Calibration Targets & Approach (Task 48.2)
  - Historic Consumptive Use (LRE, 2008)
  - Model Stress Inputs (Pending)
  - Modeling Report (Pending)
- Available via CDSS website (cdss.state.co.us)

SPDSS Modeling Process (cont'd)



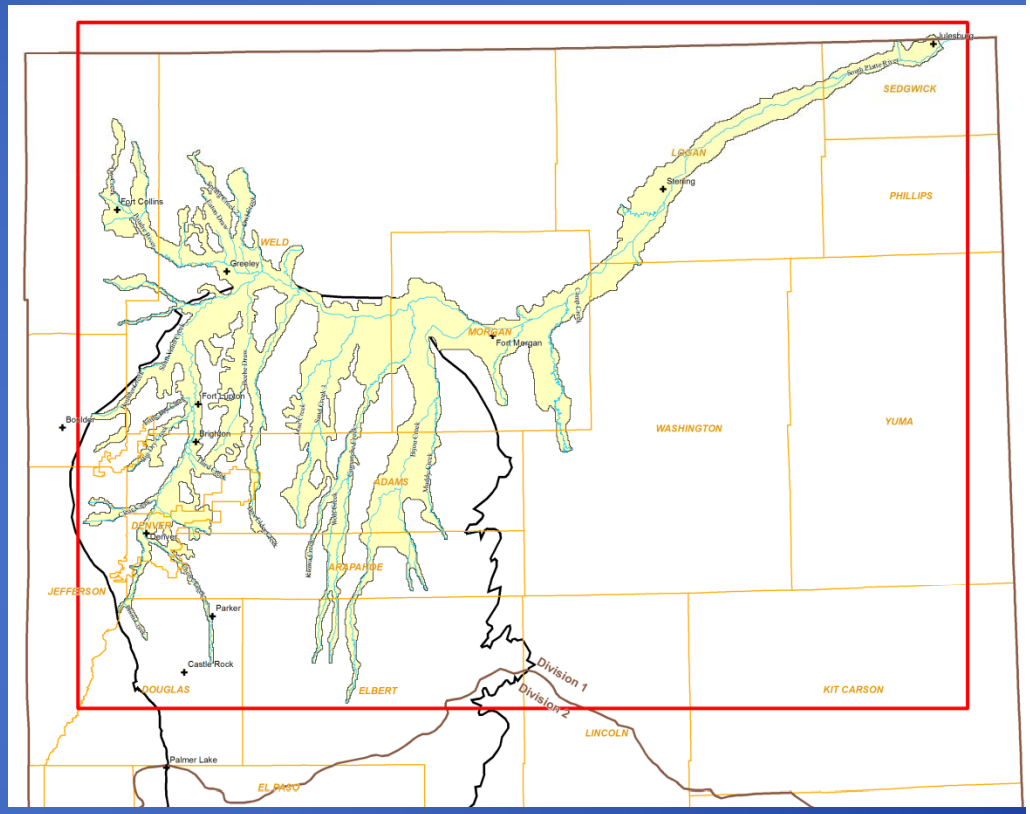
Model Description

Alluvial Model Domain

- 1,000 ft uniform grid spacing (cell size ~ 23 acres)
- One layer model
- Active domain defined by saturated thickness >10 ft
- Active area 2500 sq. miles

Model Time Period

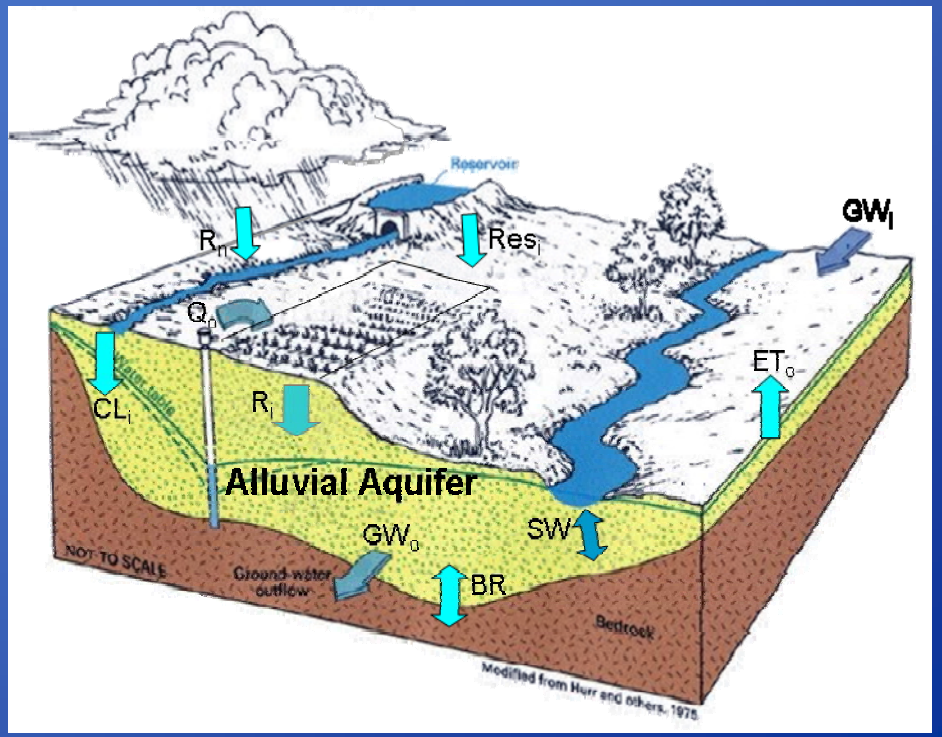
- Simulation Period is 1950 – 2006
- Monthly Stress Periods



SPDSS Alluvial Aquifer Model Area and Active Domain

Simulated Flows (model stresses)

- Stress Inputs from StateCU
  - Irrigation-based recharge
  - Canal seepage
  - Precipitation-based recharge
  - Agricultural pumping
  - Groundwater evapotranspiration
- Other Stress Inputs
  - Recharge areas and wells
  - M&I pumping
  - Lateral boundary inflows
  - Stream flows and diversions
  - Bedrock aquifer flux
  - Reservoir seepage
  - Alluvial groundwater inflow



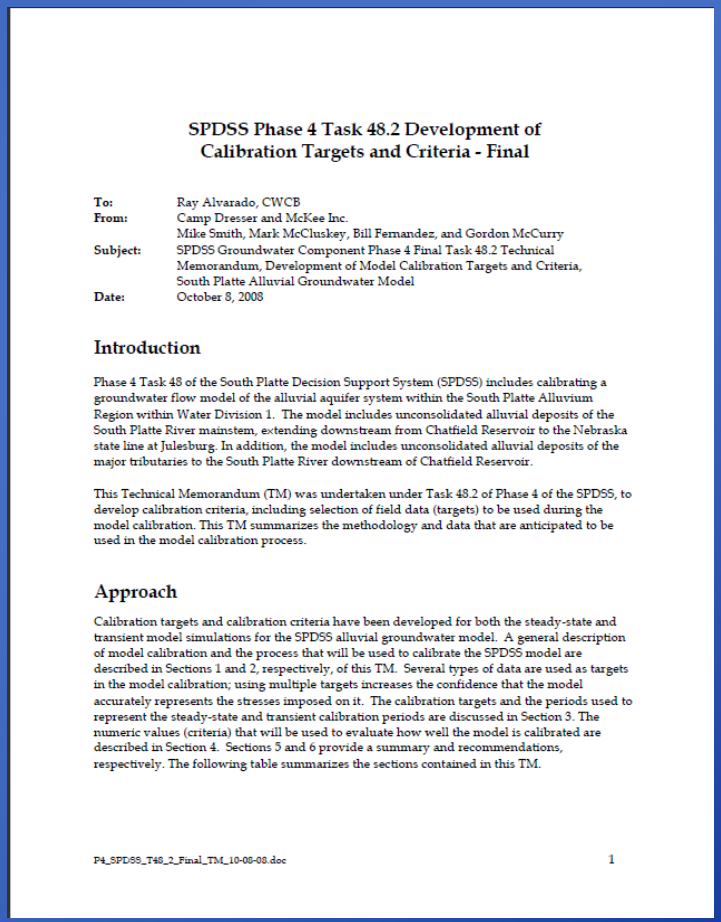
Model Implementation

- **MODFLOW Package (& System Components Simulated)**
  - **ETS (GW Evapotranspiration)**
  - **RCH (Precip., Irrigation & Canal-based Recharge, Reservoir Seepage, Recharge Areas)**
  - **WEL (Bedrock Fluxes, Well Production, Alluvial Underflow, Lateral Boundary Inflow)**
  - **SFR2 (Stream Flow, Stream-Groundwater Interaction)**
- **Using SPDSS data centered tools to develop inputs**
- **Using MODFLOW2000 (V 1.18) with double precision**

Model Calibration – Overview

- Calibration Approach
- Calibration Targets
- Calibration Parameters

Documented in Task 48.2 Development of Calibration Targets and Criteria



SPDSS Phase 4 Task 48.2 Development of Calibration Targets and Criteria - Final

To: Ray Alvarado, CWCB
From: Camp Dresser and McKee Inc.
Mike Smith, Mark McCluskey, Bill Fernandez, and Gordon McCurry
Subject: SPDSS Groundwater Component Phase 4 Final Task 48.2 Technical Memorandum, Development of Model Calibration Targets and Criteria, South Platte Alluvial Groundwater Model
Date: October 8, 2008

Introduction

Phase 4 Task 48 of the South Platte Decision Support System (SPDSS) includes calibrating a groundwater flow model of the alluvial aquifer system within the South Platte Alluvium Region within Water Division 1. The model includes unconsolidated alluvial deposits of the South Platte River mainstem, extending downstream from Chatfield Reservoir to the Nebraska state line at Julesburg. In addition, the model includes unconsolidated alluvial deposits of the major tributaries to the South Platte River downstream of Chatfield Reservoir.

This Technical Memorandum (TM) was undertaken under Task 48.2 of Phase 4 of the SPDSS, to develop calibration criteria, including selection of field data (targets) to be used during the model calibration. This TM summarizes the methodology and data that are anticipated to be used in the model calibration process.

Approach

Calibration targets and calibration criteria have been developed for both the steady-state and transient model simulations for the SPDSS alluvial groundwater model. A general description of model calibration and the process that will be used to calibrate the SPDSS model are described in Sections 1 and 2, respectively, of this TM. Several types of data are used as targets in the model calibration; using multiple targets increases the confidence that the model accurately represents the stresses imposed on it. The calibration targets and the periods used to represent the steady-state and transient calibration periods are discussed in Section 3. The numeric values (criteria) that will be used to evaluate how well the model is calibrated are described in Section 4. Sections 5 and 6 provide a summary and recommendations, respectively. The following table summarizes the sections contained in this TM.

P4_SPDSS_T48_2_Final_TM_10-08-08.doc 1

Calibration Approach

- Develop model input files
- Develop a stable model
- Develop Objective Function and Weighting Factors for PEST and heuristic methods
- Run Steady-state & Transient models
- Evaluate Model Calibration

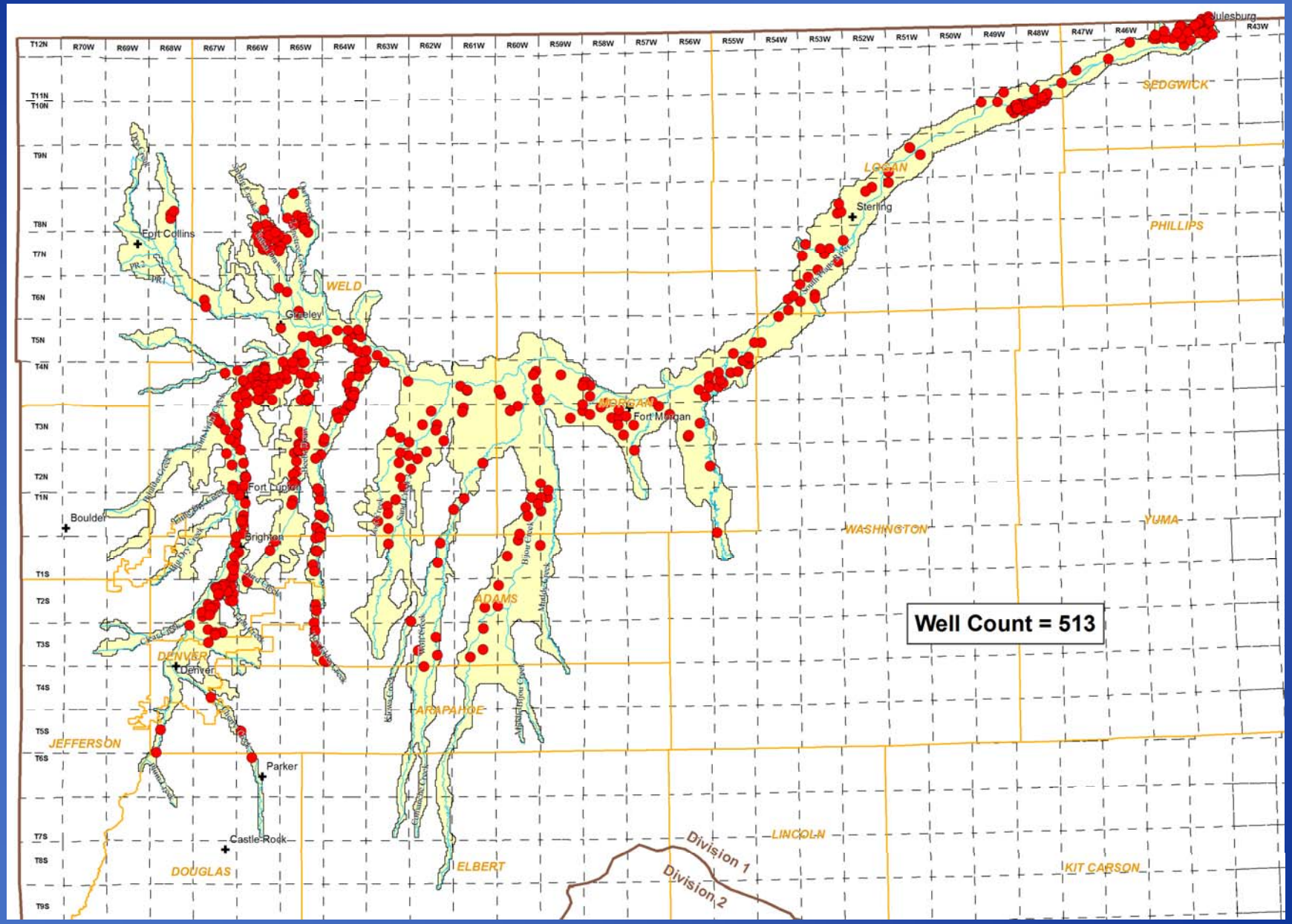
Model Calibration Periods

- Steady-state period (1991 - 1994)
  - Steady alluvial water table (min. change in storage)
  - Minimal change in number of new wells (Q >50 gpm)
  - Adequate number of water level measurements
- Transient Calibration (1999 - 2005)
  - Climate variability
  - Adequate number of water level measurements
  - Seasonal water level data
- Validation Period (1950 - 2006)

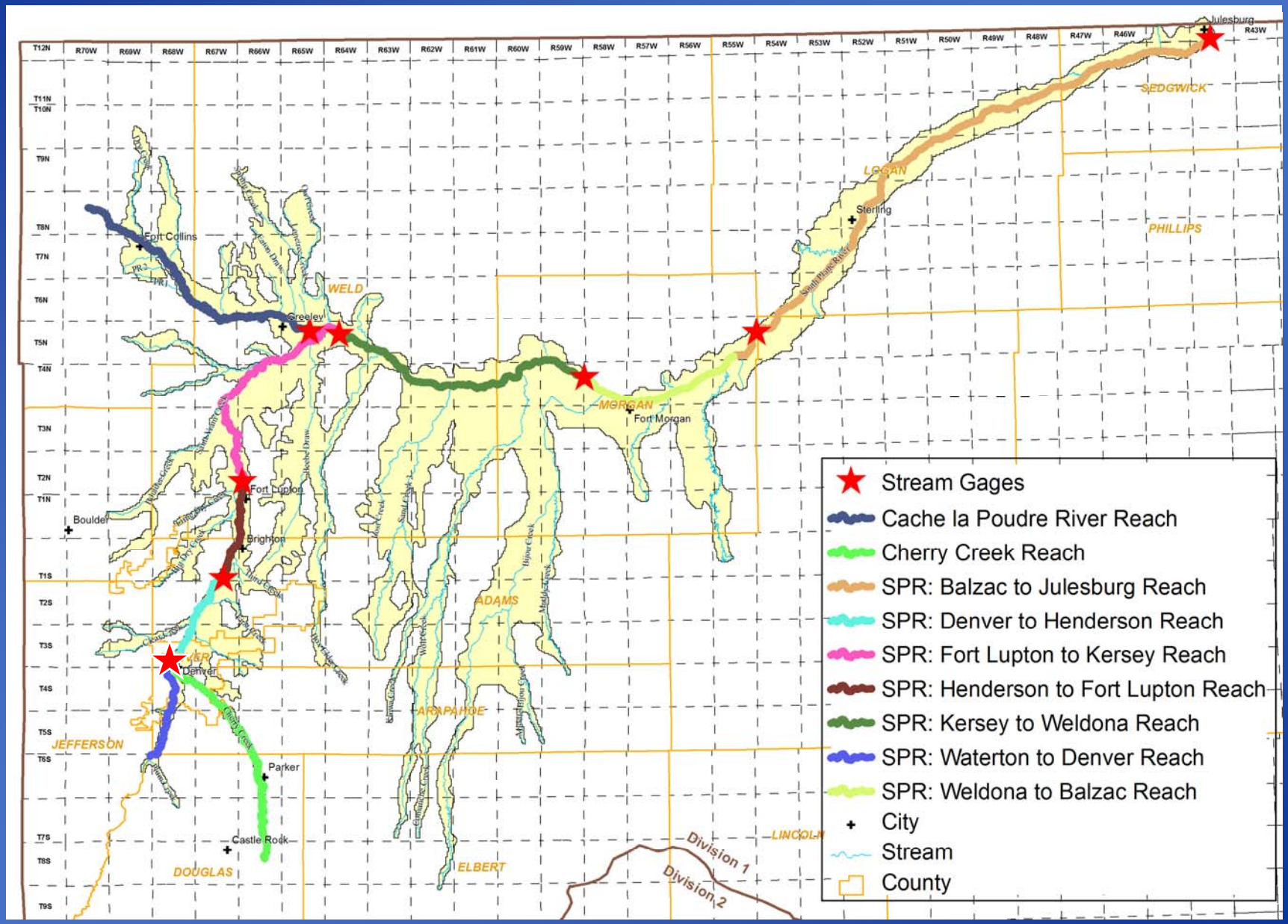
Calibration Targets

- Primary Targets
  - Head (groundwater levels)
  - Streamflow
- Secondary Targets
  - Stream gain/loss
  - Diversion amounts
  - ET extent
  - Wet/dry cells
  - General shape of water table surface

Transient Head Targets (1999-2005)



Streamflow Gages & Gain/Loss Reaches



Candidate Calibration Parameters

- Aquifer hydraulic conductivity (K)
- Streambed vertical hydraulic conductivity
- Recharge
- Well pumping
- Lateral boundary inflows
- Specific yield (Sy)

Break

(10 Minutes)

Calibration Parameters

- Aquifer hydraulic conductivity (K)
  - 100 to 800 ft/day
- Streambed vertical hydraulic conductivity
  - 0.1 to 10 ft/day
- Recharge
  - Not Changed
- Well pumping
  - Reduction in selected areas to 70 to 80% of original pumping rates
- Lateral boundary inflows
  - Not changed
- Specific yield (Sy)
  - 0.2

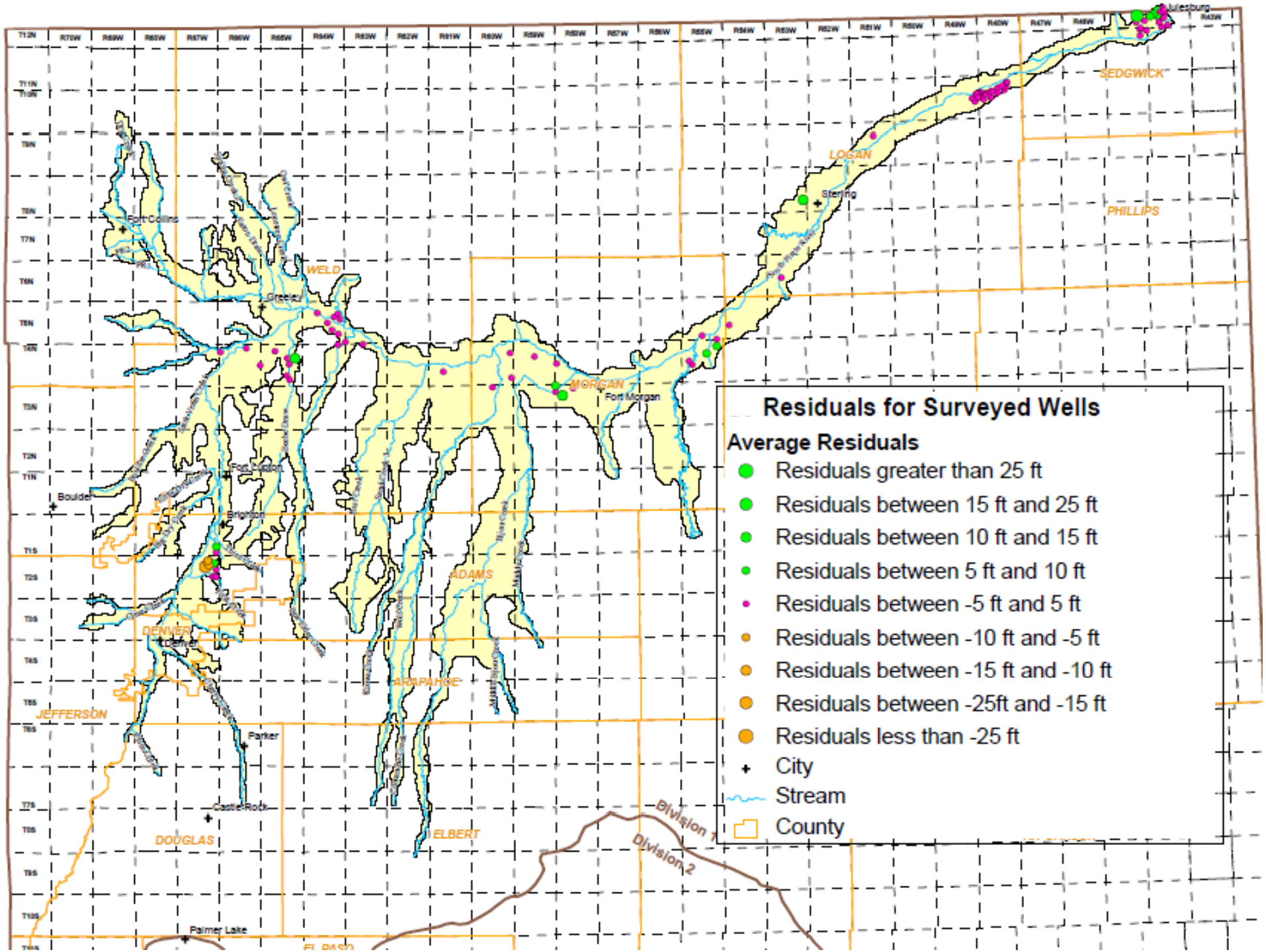
SPDSS Hydraulic Conductivity

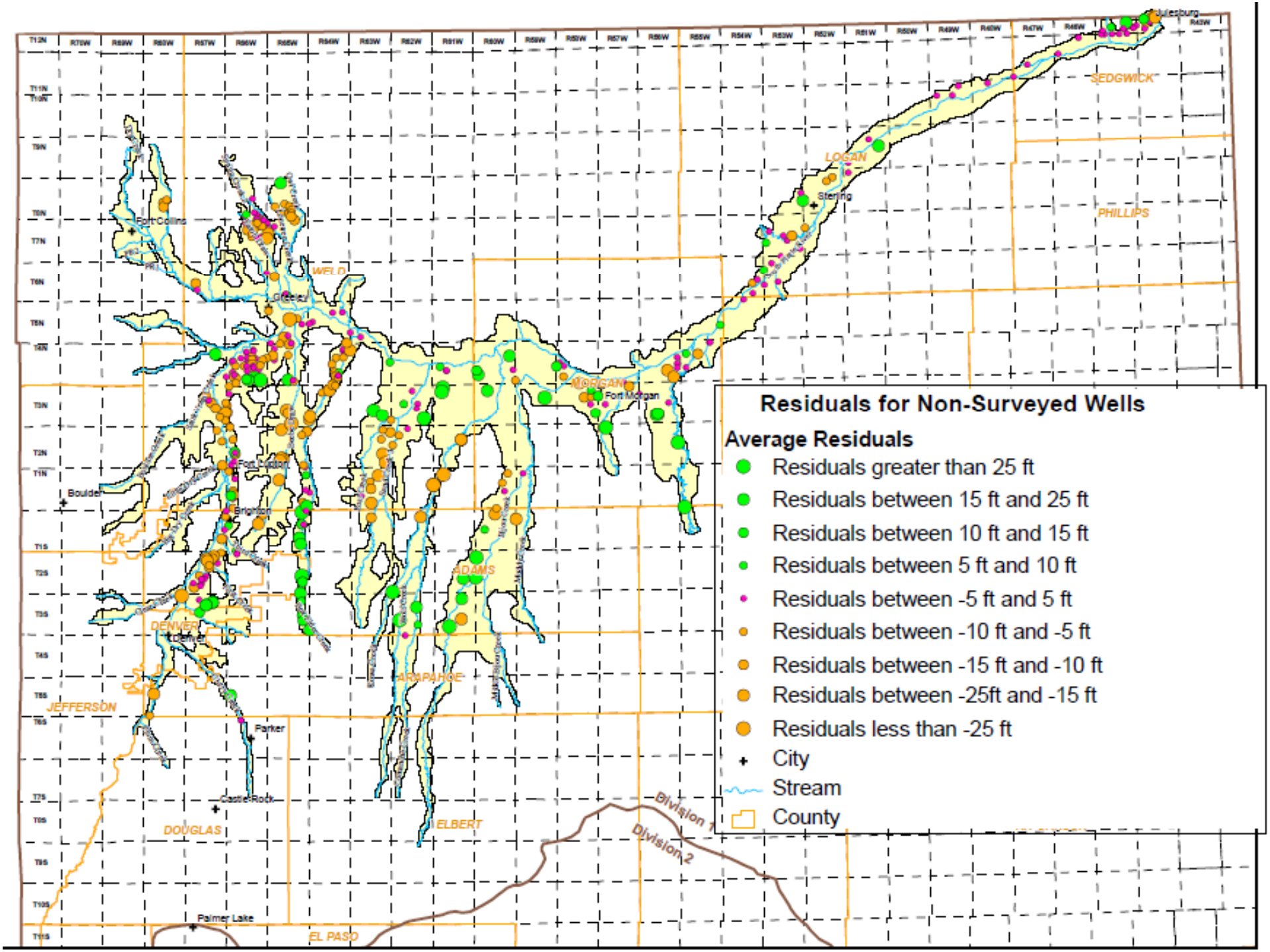
Model Calibration Results

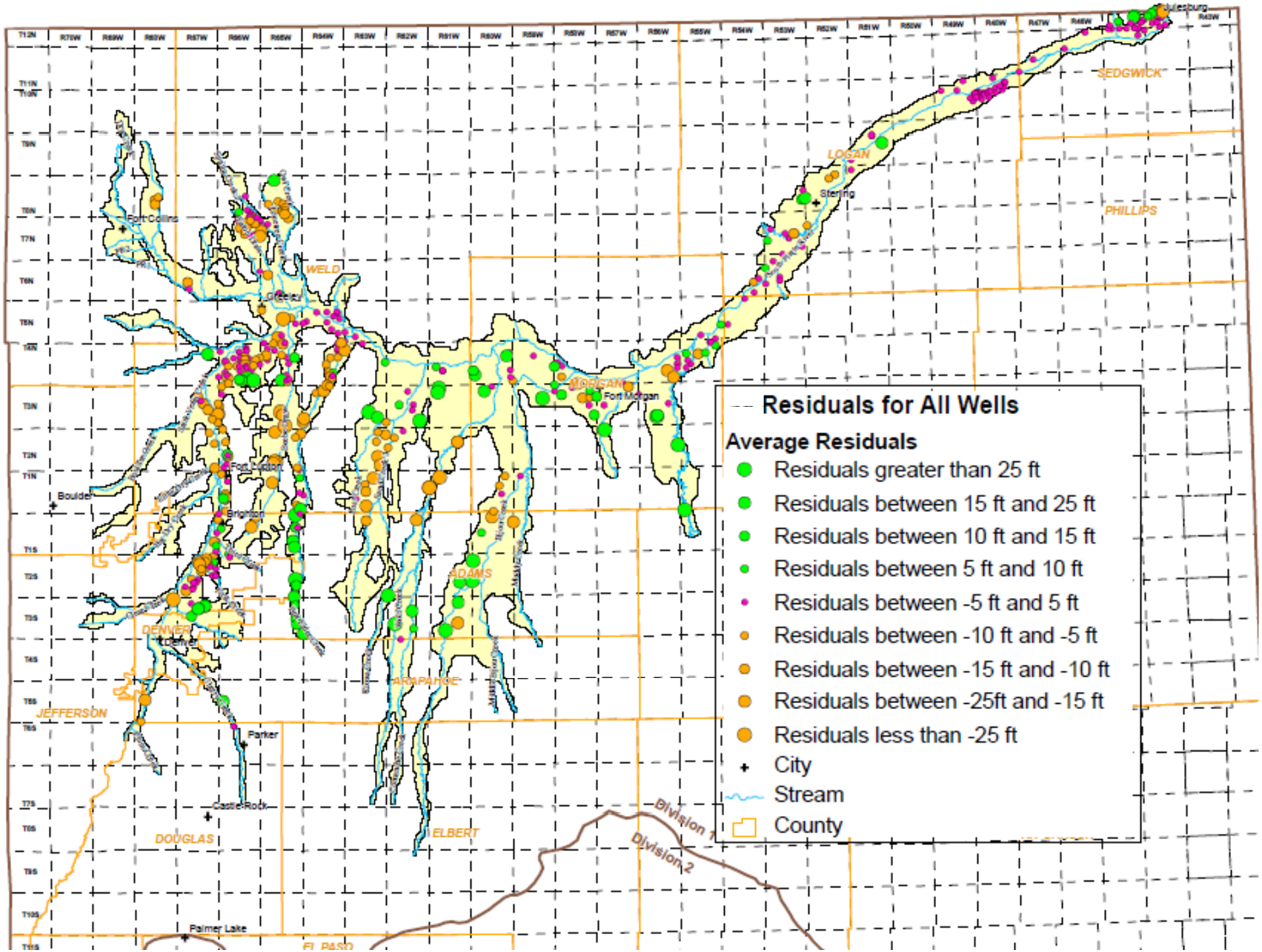
- Head targets
  - Absolute heads
  - Change in heads (delta heads)
  - Hydrographs
- Streamflow targets
- Stream gain/loss
- Diversions
- Phreatophyte Evapotranspiration

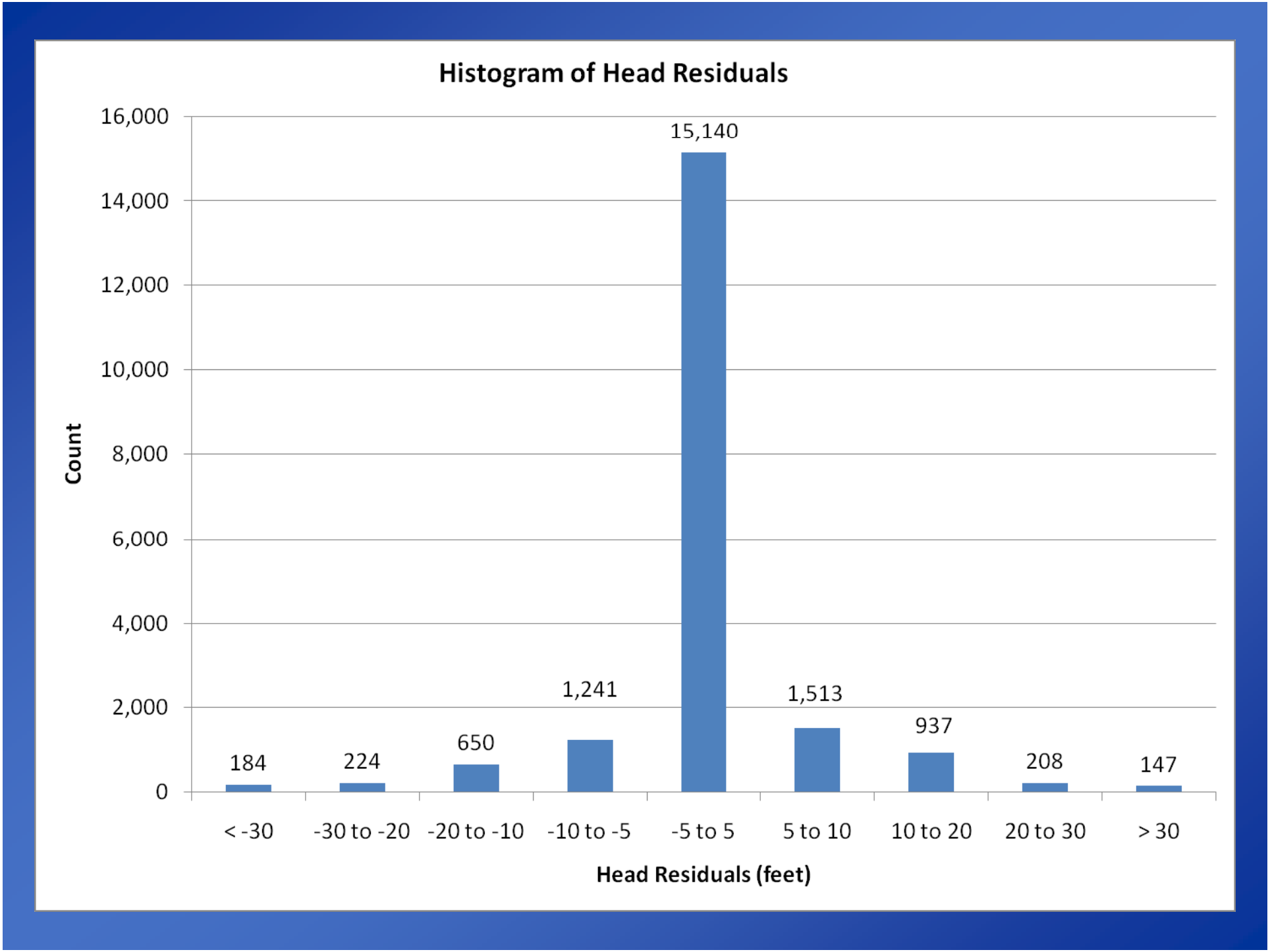
Head Targets

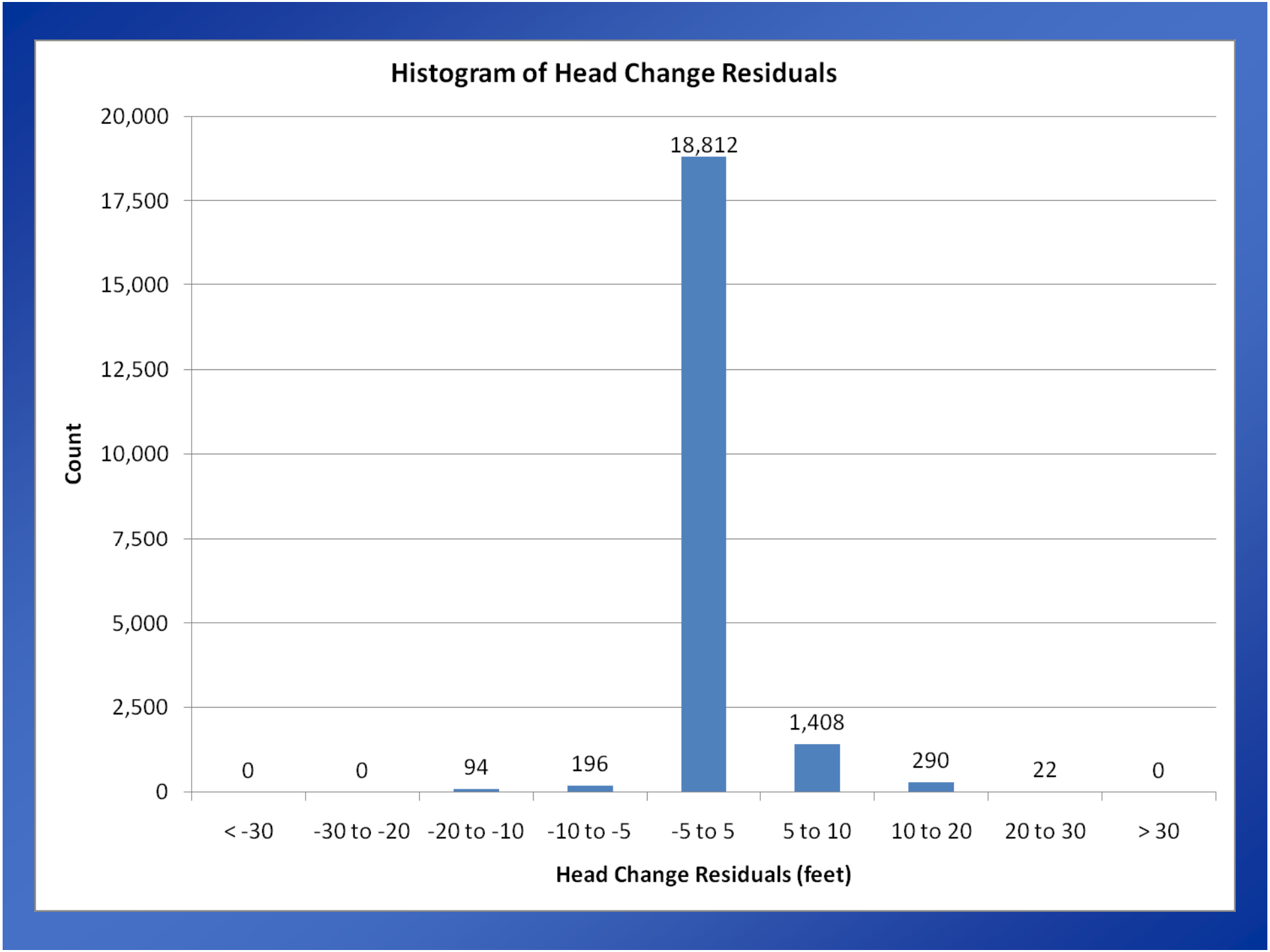
- The calibration run results showing the mean residual head differences are shown for:
  - surveyed wells
  - non-surveyed wells and
  - all wells
- Use of the average provides a measure of total error to help identify areas for refinement

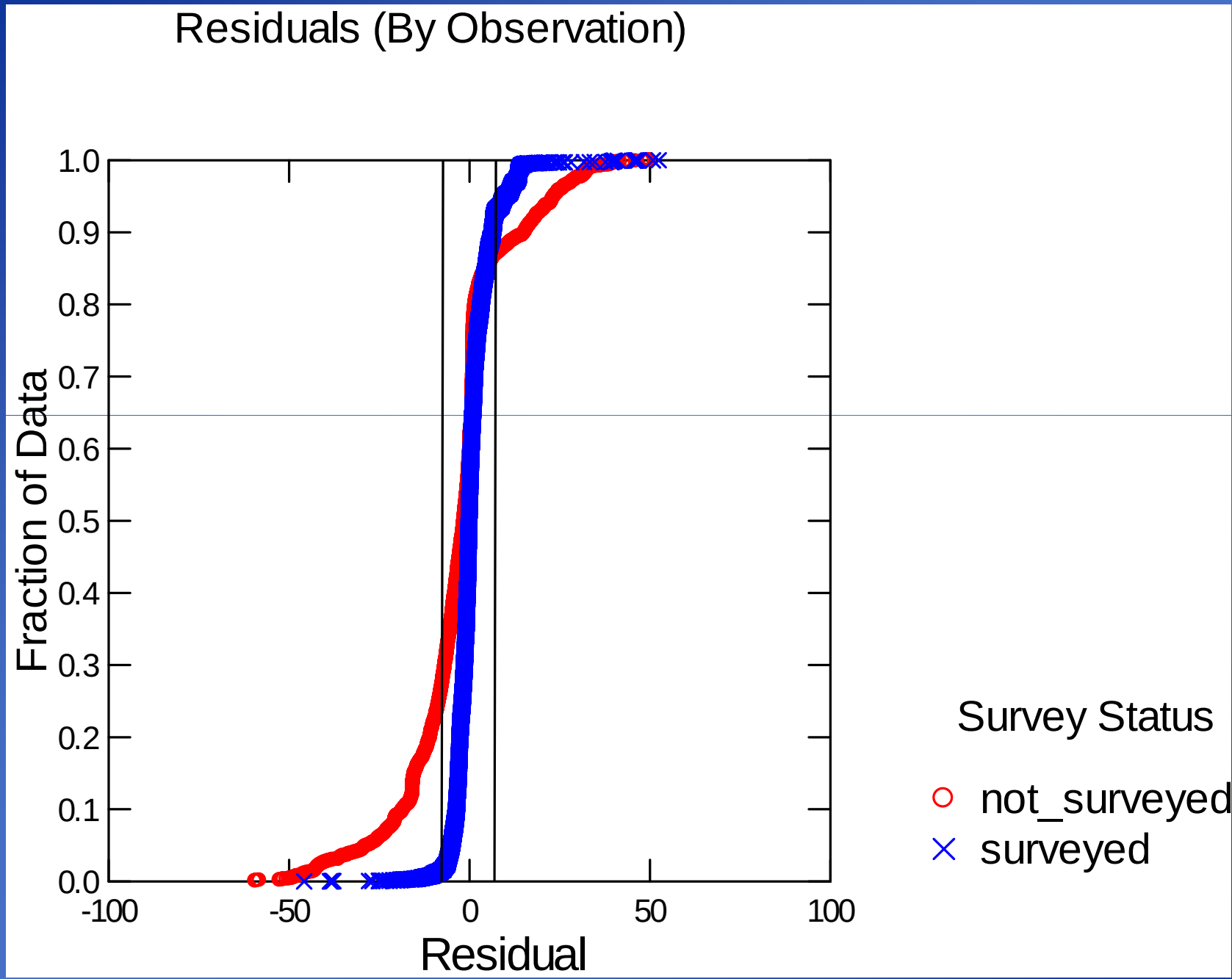

Residuals for Surveyed Wells
Average Residuals
Residuals greater than 25 ft
Residuals between 15 ft and 25 ft
Residuals between 10 ft and 15 ft
Residuals between 5 ft and 10 ft
Residuals between -5 ft and 5 ft
Residuals between -10 ft and -5 ft
Residuals between -15 ft and -10 ft
Residuals between -25ft and -15 ft
Residuals less than -25 ft
City
Stream
County
SEDGWICK
LOGAN
PHILLIPS
WELD
MORGAN
ADAMS
ARAPAHOE
DENVER
JEFFERSON
DOUGLAS
ELBERT
Fort Collins
Greeley
Sterling
Fort Morgan
Boulder
Brighton
Parker
Castle Rock
Palmer Lake
Division 1
Division 2


Residuals for Non-Surveyed Wells
Average Residuals
Residuals greater than 25 ft
Residuals between 15 ft and 25 ft
Residuals between 10 ft and 15 ft
Residuals between 5 ft and 10 ft
Residuals between -5 ft and 5 ft
Residuals between -10 ft and -5 ft
Residuals between -15 ft and -10 ft
Residuals between -25ft and -15 ft
Residuals less than -25 ft
City
Stream
County
SEDGWICK
PHILLIPS
LOGAN
Sterling
WELD
Greeley
Fort Collins
MORGAN
Fort Morgan
Fort Lupton
Boulder
Brighton
ADAMS
DENVER
Denver
ARAPAHOE
JEFFERSON
Parker
Castle Rock
DOUGLAS
ELBERT
Palmer Lake
EL PASO
Division 1
Division 2

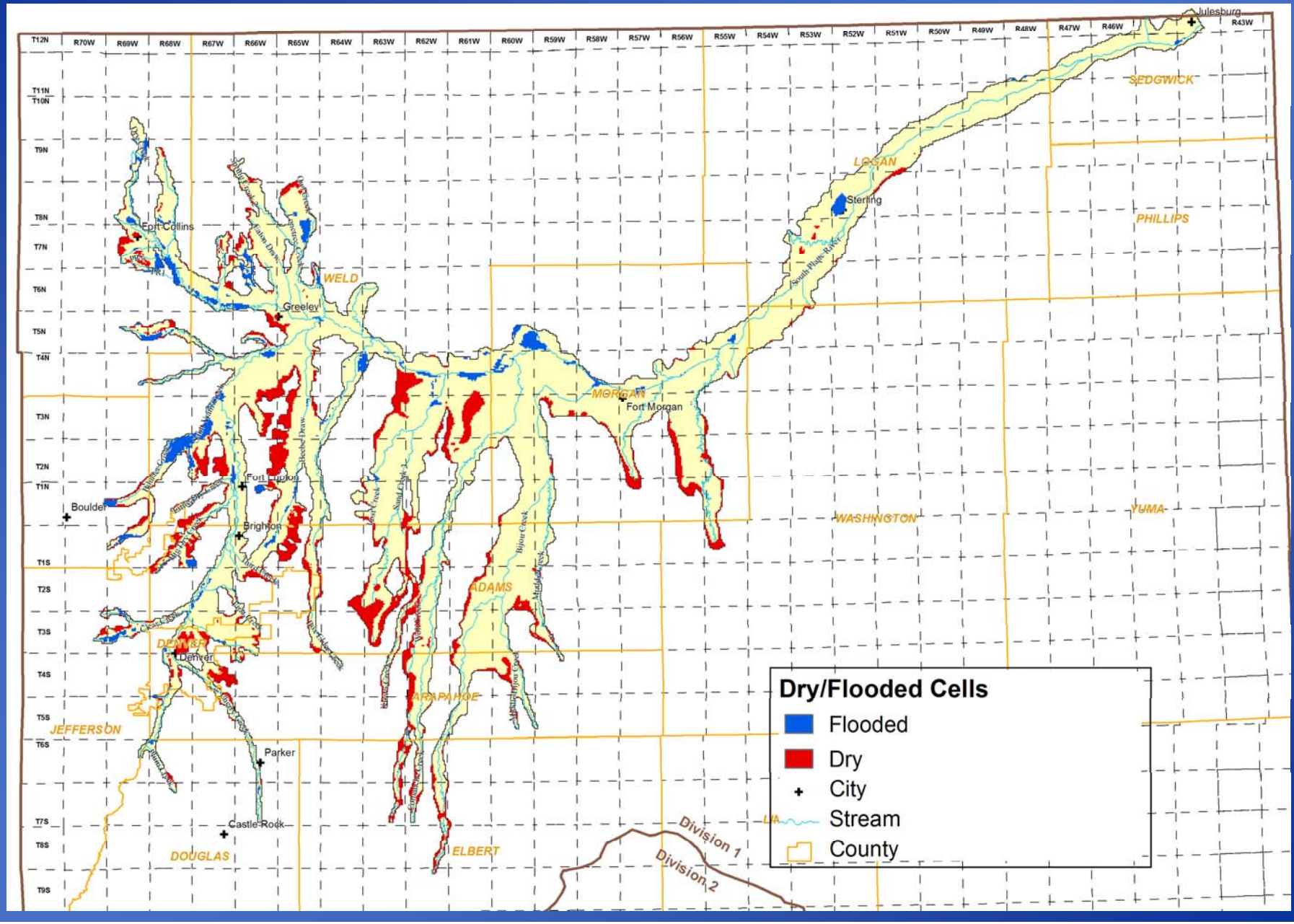

Residuals for All Wells
Average Residuals
Residuals greater than 25 ft
Residuals between 15 ft and 25 ft
Residuals between 10 ft and 15 ft
Residuals between 5 ft and 10 ft
Residuals between -5 ft and 5 ft
Residuals between -10 ft and -5 ft
Residuals between -15 ft and -10 ft
Residuals between -25ft and -15 ft
Residuals less than -25 ft
City
Stream
County
SEDGWICK
LOGAN
PHILLIPS
MORGAN
WELD
ADAMS
ARAPAHOE
DENVER
JEFFERSON
DOUGLAS
ELBERT
EL PASO
Fort Collins
Greeley
Sterling
Fort Morgan
Boulder
Brighton
Parker
Castle Rock
Palmer Lake
Division 1
Division 2


Histogram of Head Residuals
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Count
184
224
650
1,241
15,140
1,513
937
208
147
< -30
-30 to -20
-20 to -10
-10 to -5
-5 to 5
5 to 10
10 to 20
20 to 30
> 30
Head Residuals (feet)

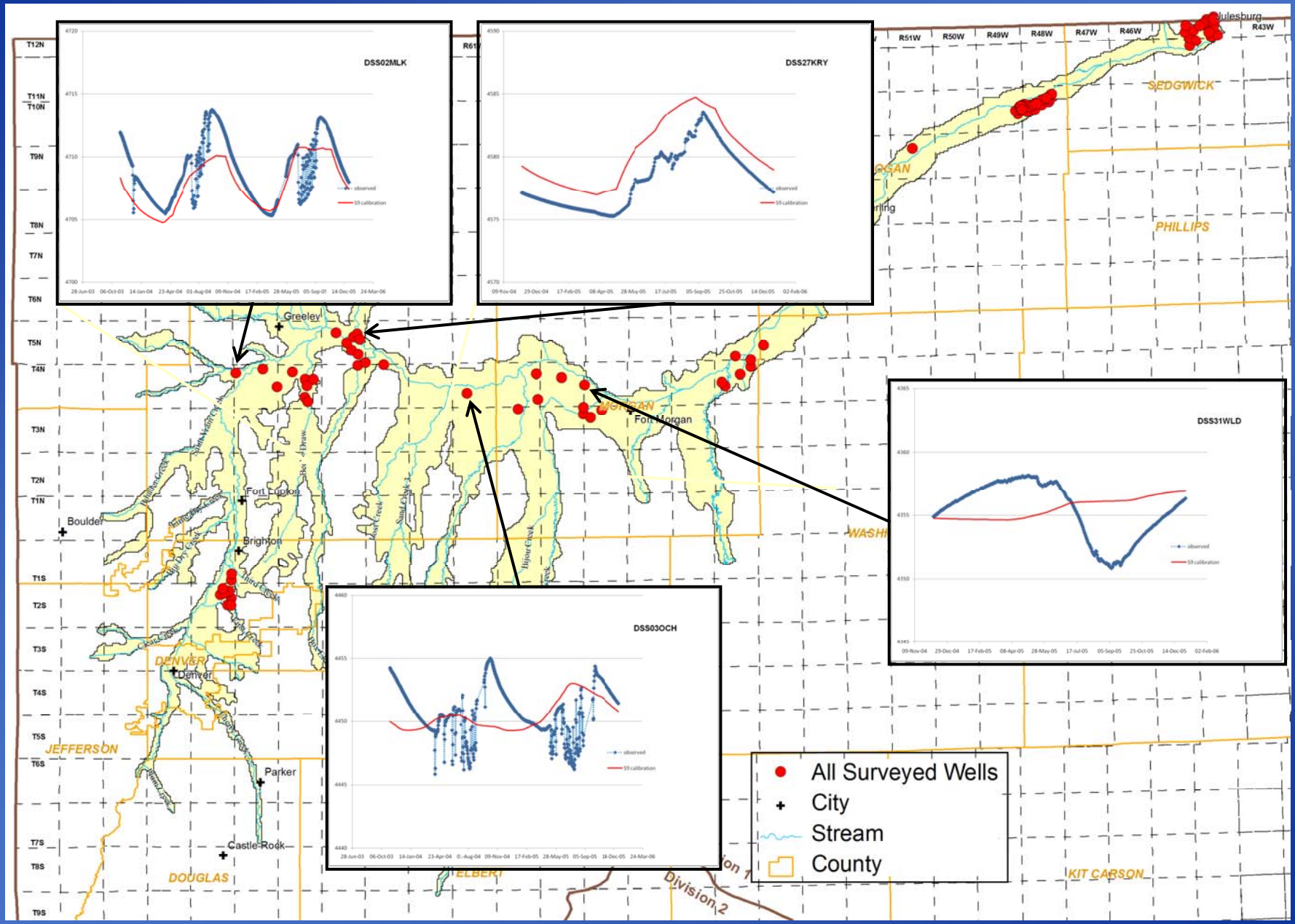

Histogram of Head Change Residuals
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
Count
18,812
1,408
0
0
94
196
290
22
0
< -30
-30 to -20
-20 to -10
-10 to -5
-5 to 5
5 to 10
10 to 20
20 to 30
> 30
Head Change Residuals (feet)


Residuals (By Observation)
Fraction of Data
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-100
-50
0
50
100
Residual
Survey Status
not_surveyed
surveyed

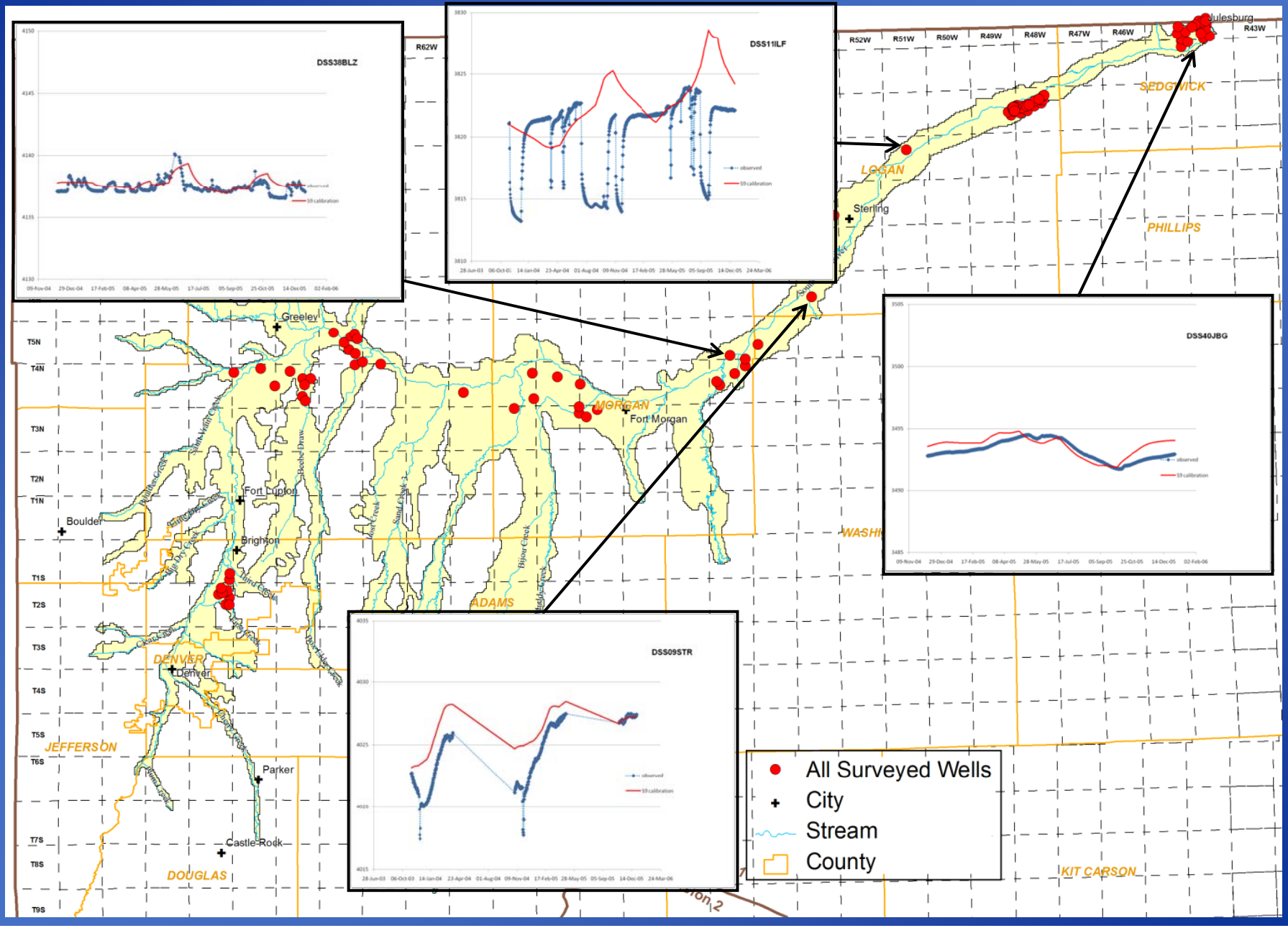
Dry and Flooded Cells



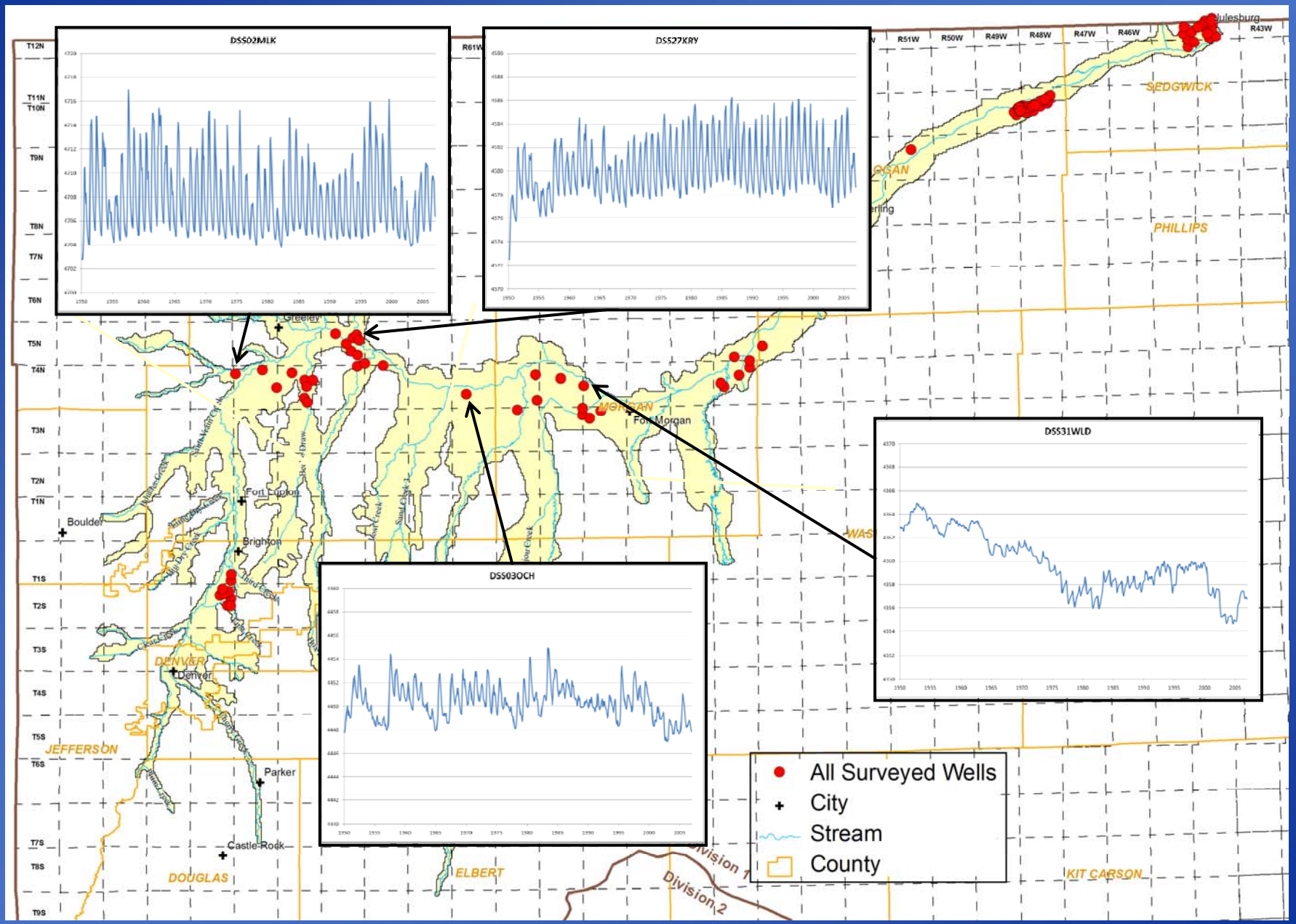
Hydrographs (1999 – 2005)



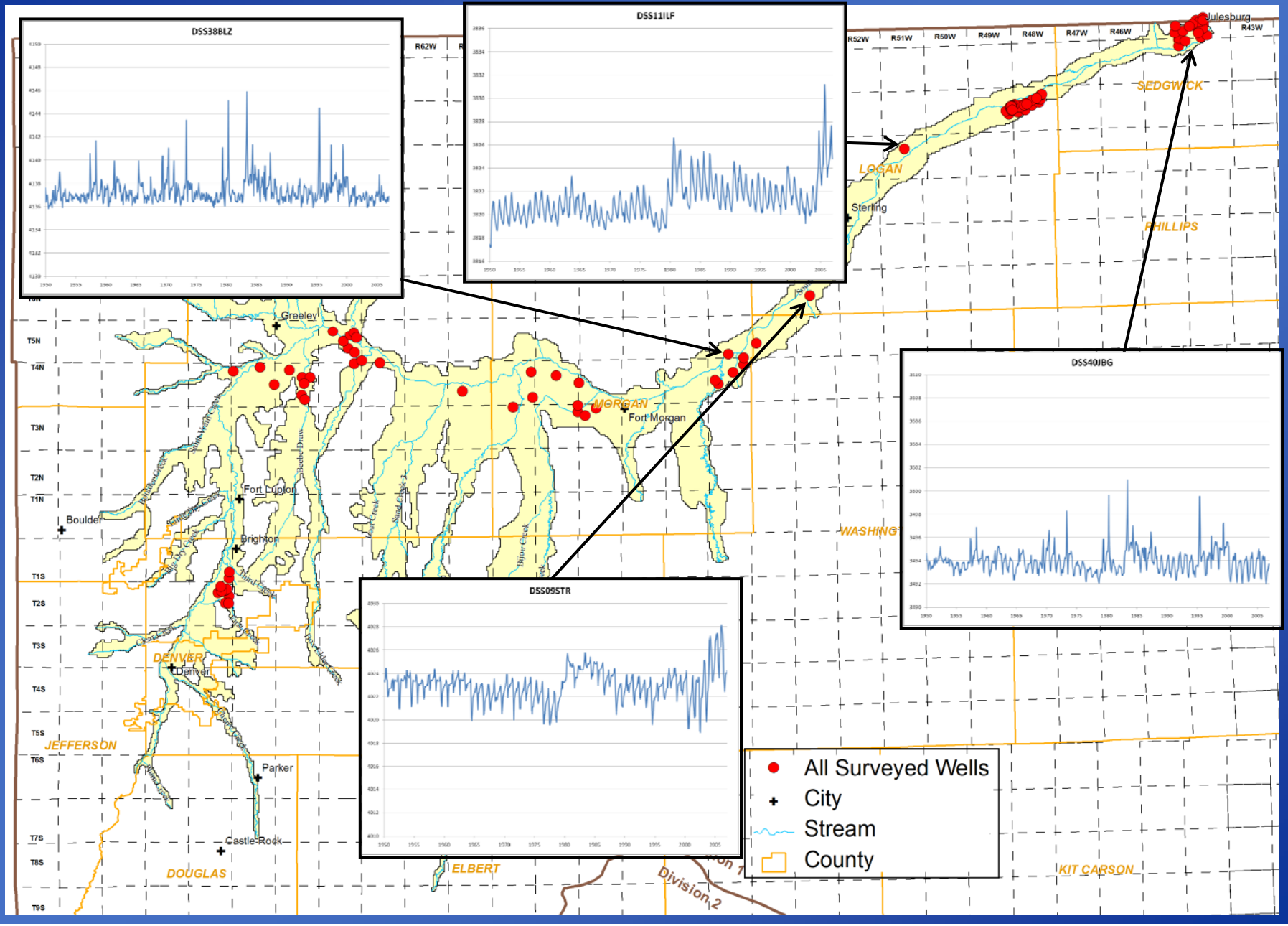
Hydrographs (1999 – 2005)



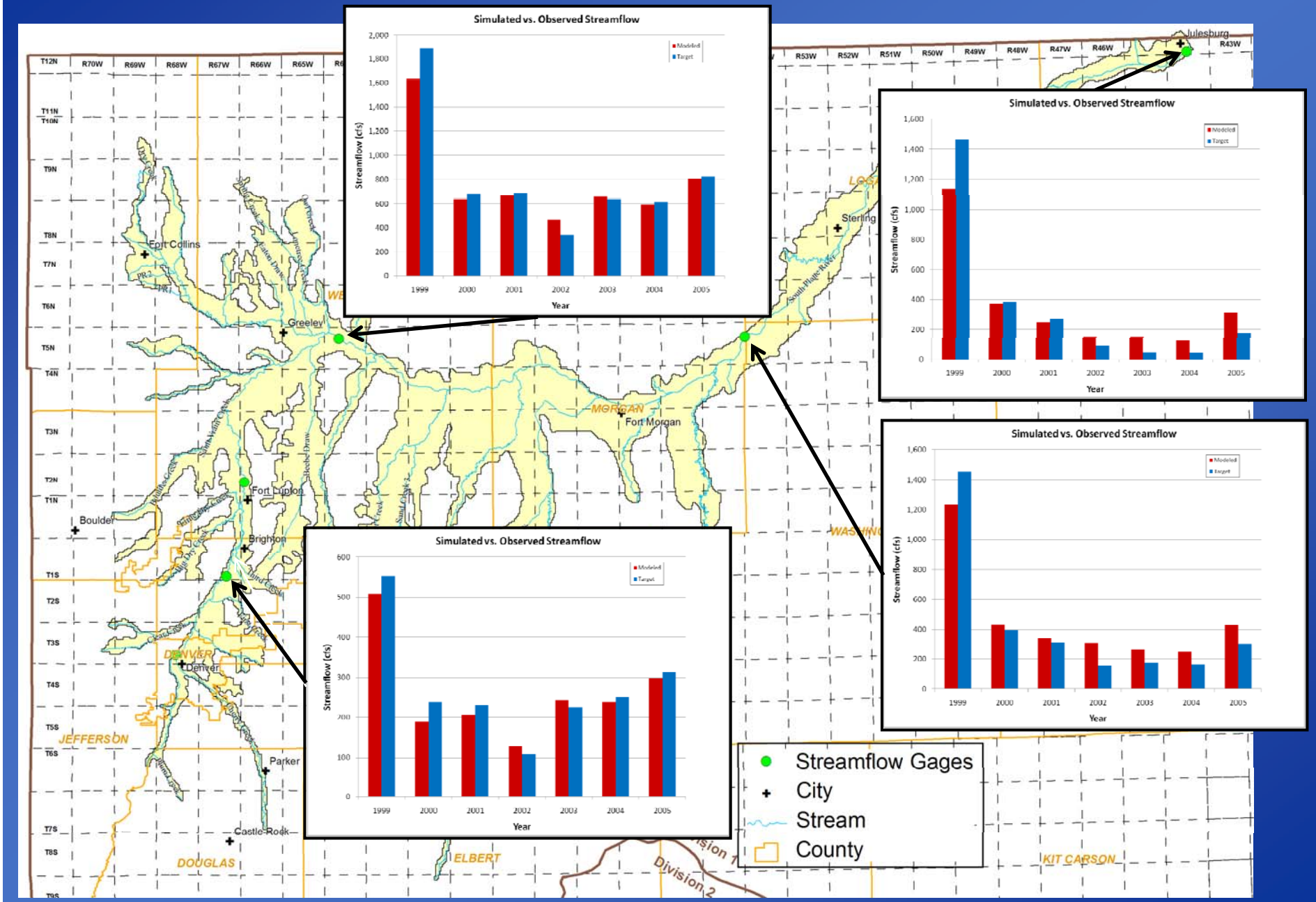
Hydrographs – (1950 – 2006)

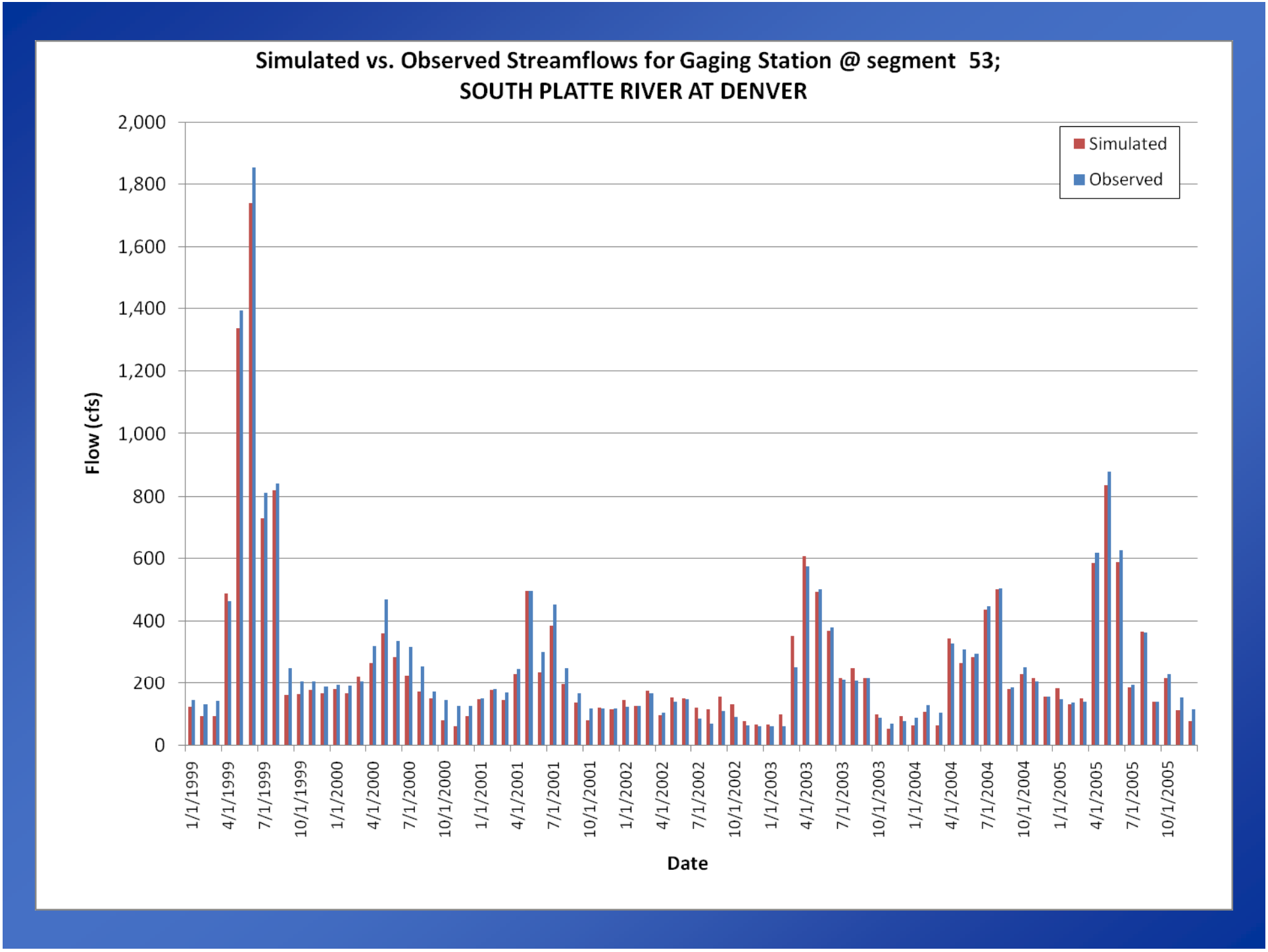


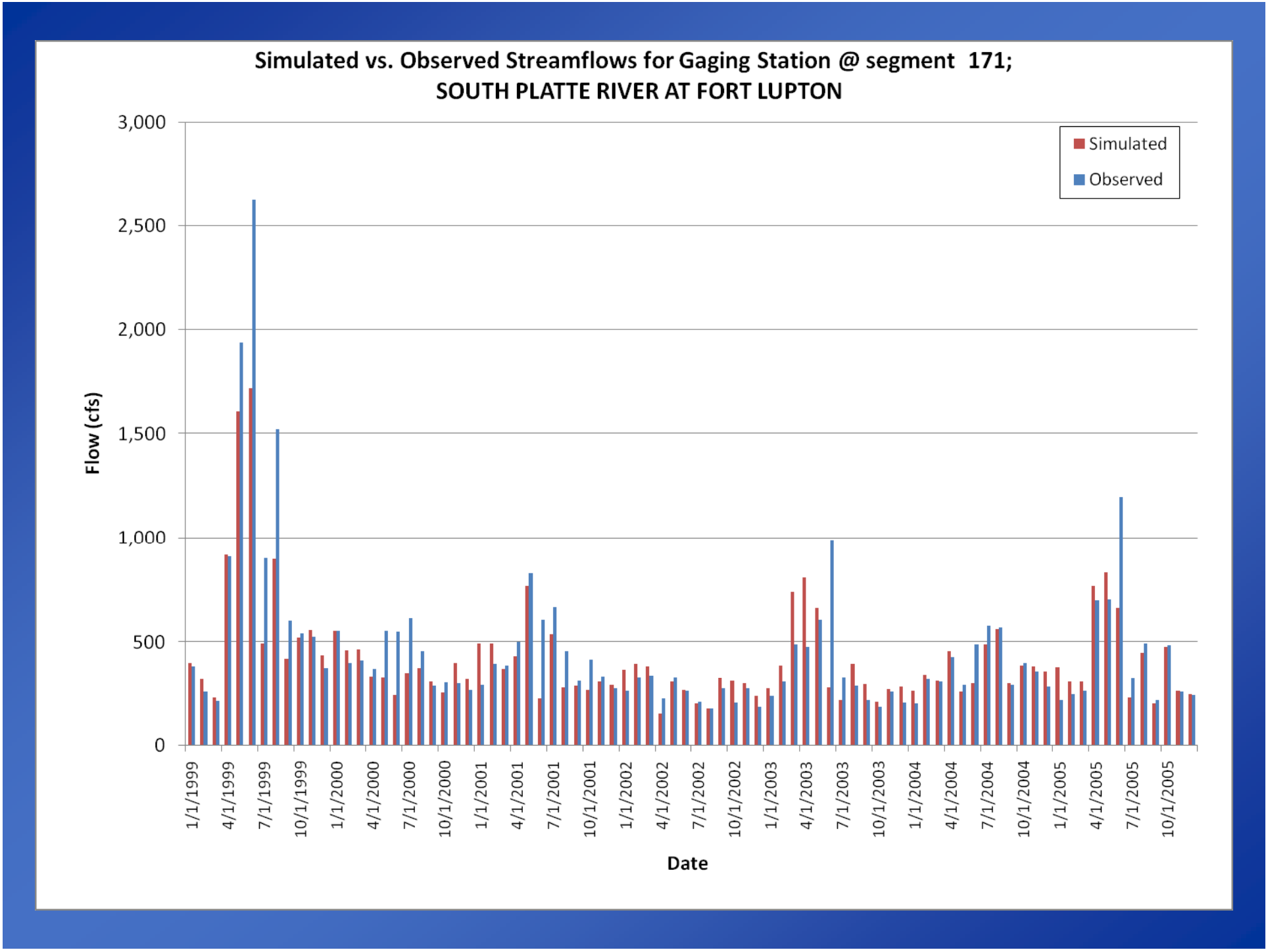
Hydrographs – (1950 – 2006)

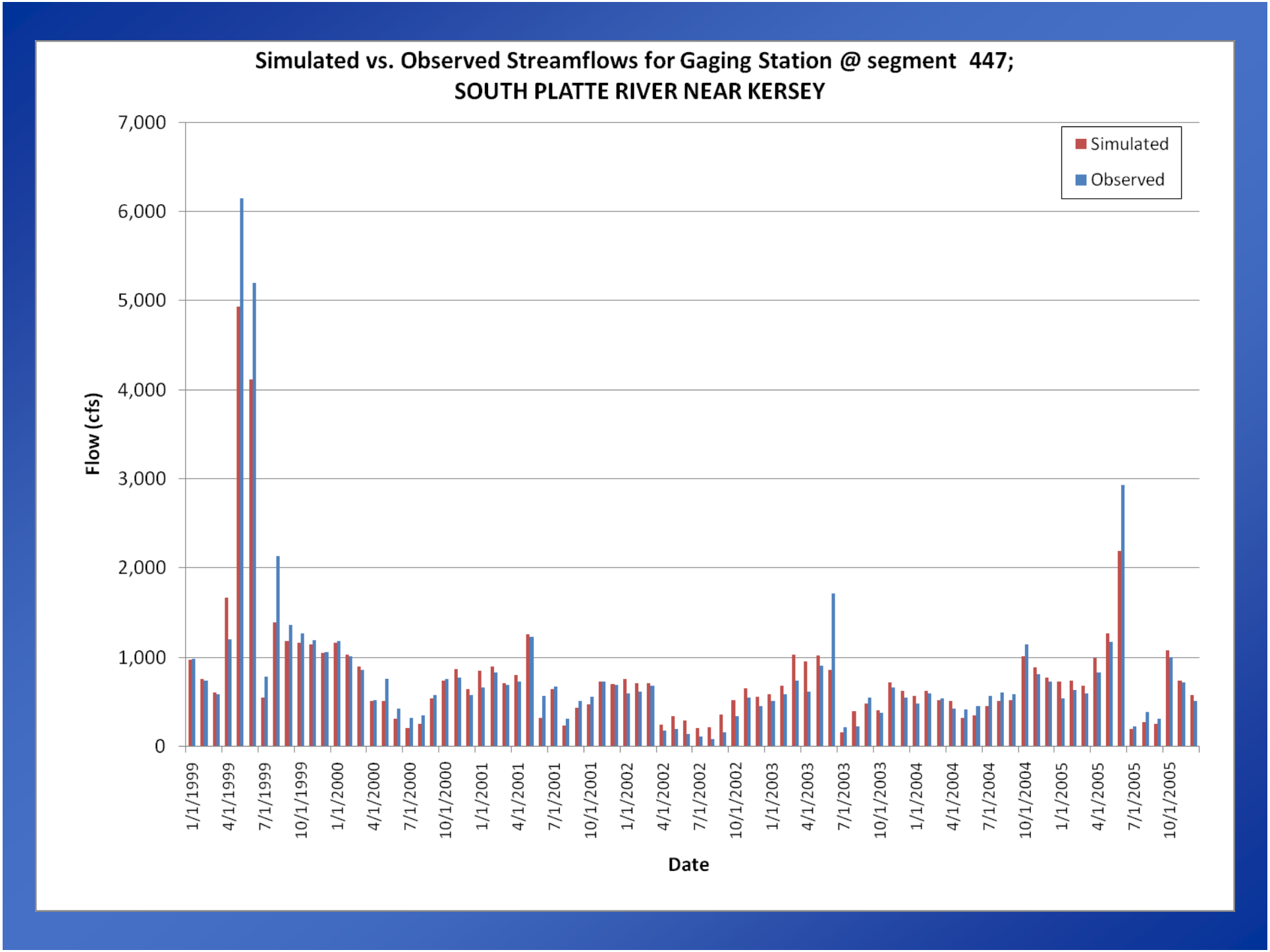


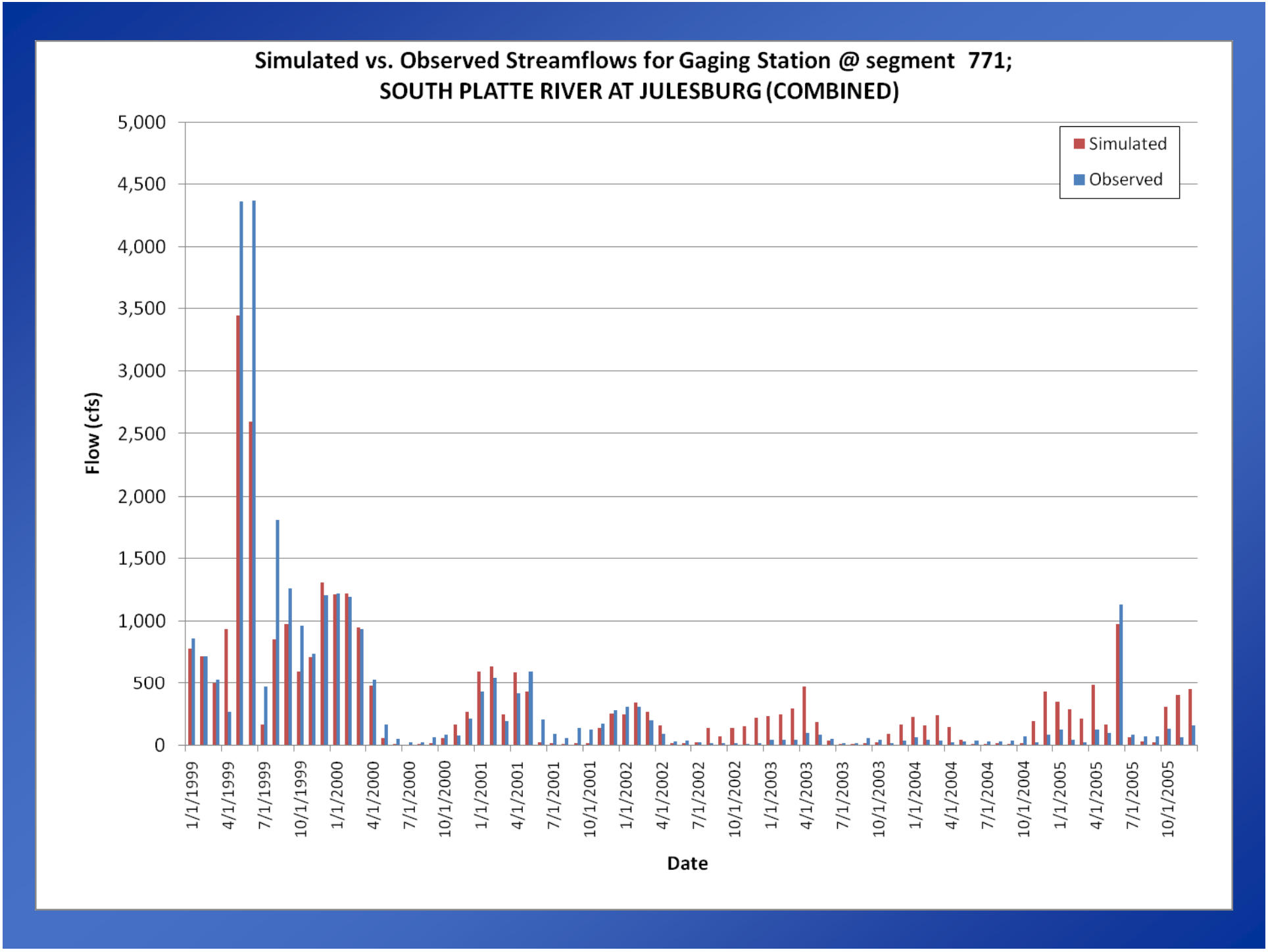
Streamflow


Simulated vs. Observed Streamflow
Streamflow (cfs)
Year
Modeled
Target
Simulated vs. Observed Streamflow
Streamflow (cfs)
Year
Modeled
Target
Simulated vs. Observed Streamflow
Streamflow (cfs)
Year
Modeled
Target
Simulated vs. Observed Streamflow
Streamflow (cfs)
Year
Modeled
Target
Streamflow Gages
City
Stream
County
Julesburg
Sterling
Fort Collins
Greeley
Fort Morgan
Fort Lupton
Boulder
Brighton
Denver
Parker
Castle Rock
MORGAN
WASHINGTON
JEFFERSON
DENVER
DOUGLAS
ELBERT
KIT CARSON
Division 1
Division 2

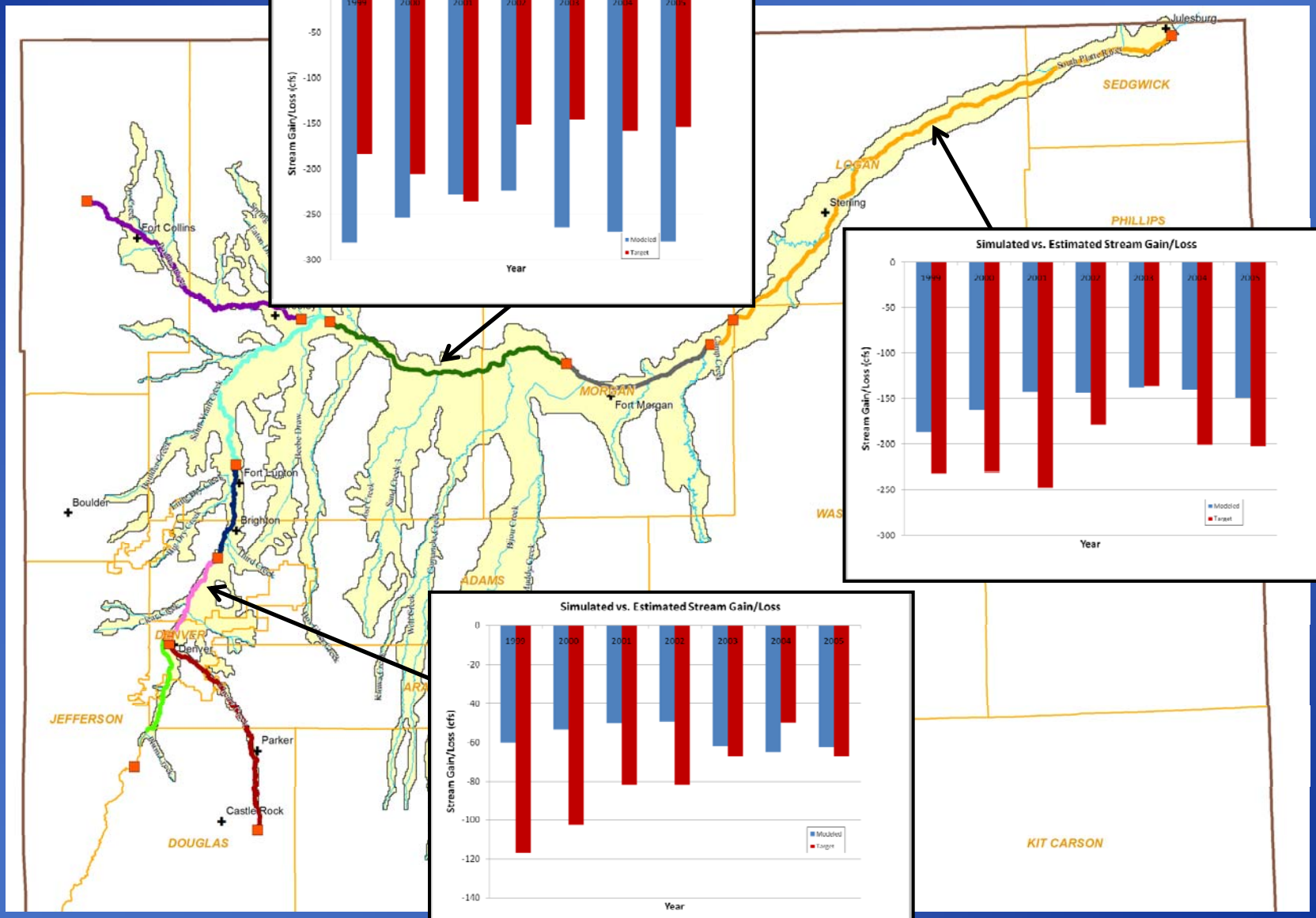

Simulated vs. Observed Streamflows for Gaging Station @ segment 53;
SOUTH PLATTE RIVER AT DENVER
Simulated
Observed
Flow (cfs)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1/1/1999
4/1/1999
7/1/1999
10/1/1999
1/1/2000
4/1/2000
7/1/2000
10/1/2000
1/1/2001
4/1/2001
7/1/2001
10/1/2001
1/1/2002
4/1/2002
7/1/2002
10/1/2002
1/1/2003
4/1/2003
7/1/2003
10/1/2003
1/1/2004
4/1/2004
7/1/2004
10/1/2004
1/1/2005
4/1/2005
7/1/2005
10/1/2005
Date


Simulated vs. Observed Streamflows for Gaging Station @ segment 171;
SOUTH PLATTE RIVER AT FORT LUPTON
Simulated
Observed
Flow (cfs)
3,000
2,500
2,000
1,500
1,000
500
0
1/1/1999
4/1/1999
7/1/1999
10/1/1999
1/1/2000
4/1/2000
7/1/2000
10/1/2000
1/1/2001
4/1/2001
7/1/2001
10/1/2001
1/1/2002
4/1/2002
7/1/2002
10/1/2002
1/1/2003
4/1/2003
7/1/2003
10/1/2003
1/1/2004
4/1/2004
7/1/2004
10/1/2004
1/1/2005
4/1/2005
7/1/2005
10/1/2005
Date

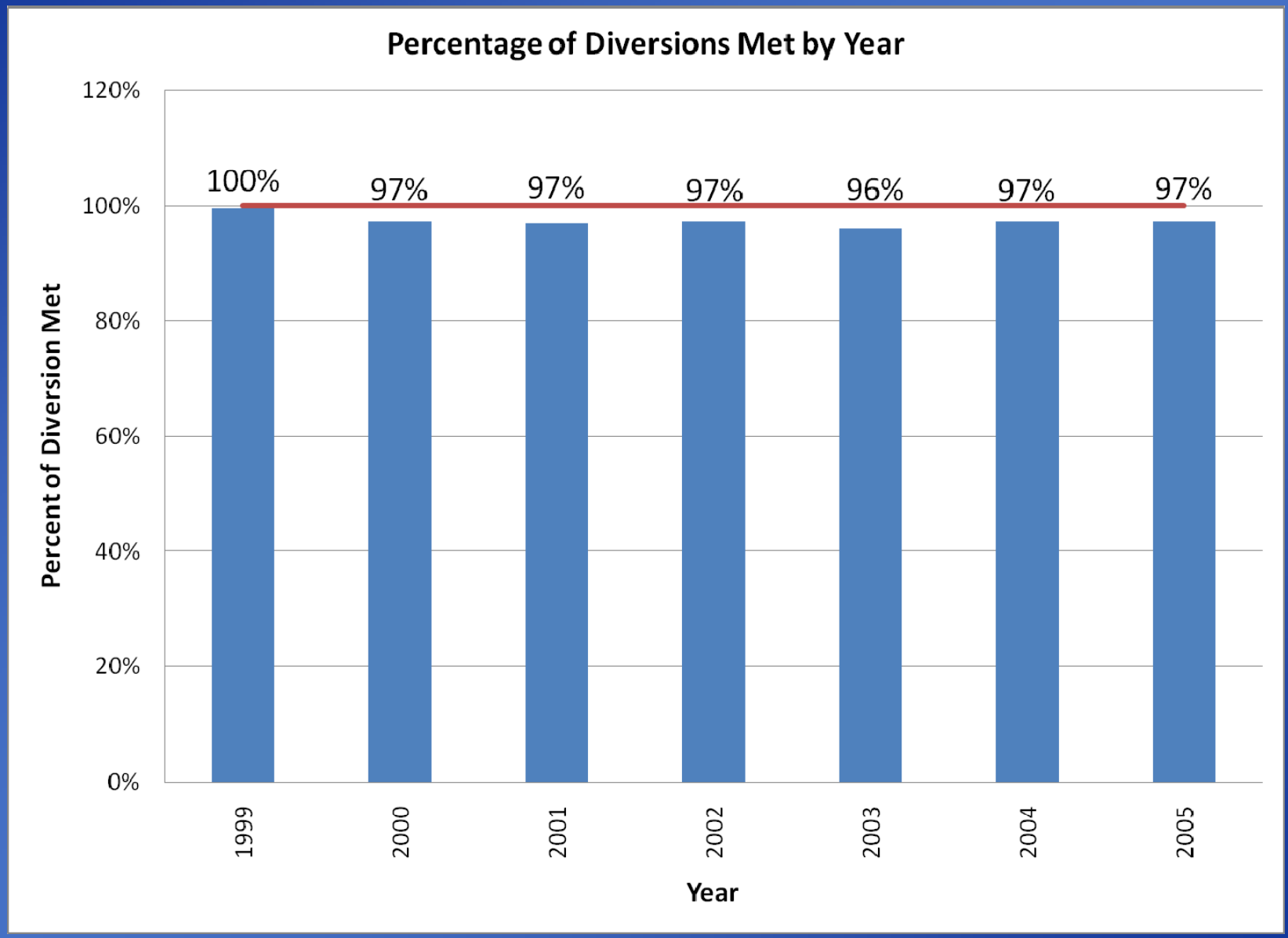

Simulated vs. Observed Streamflows for Gaging Station @ segment 447;
SOUTH PLATTE RIVER NEAR KERSEY
Simulated
Observed
Flow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1/1/1999
4/1/1999
7/1/1999
10/1/1999
1/1/2000
4/1/2000
7/1/2000
10/1/2000
1/1/2001
4/1/2001
7/1/2001
10/1/2001
1/1/2002
4/1/2002
7/1/2002
10/1/2002
1/1/2003
4/1/2003
7/1/2003
10/1/2003
1/1/2004
4/1/2004
7/1/2004
10/1/2004
1/1/2005
4/1/2005
7/1/2005
10/1/2005
Date


Simulated vs. Observed Streamflows for Gaging Station @ segment 771;
SOUTH PLATTE RIVER AT JULESBURG (COMBINED)
Simulated
Observed
Flow (cfs)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1/1/1999
4/1/1999
7/1/1999
10/1/1999
1/1/2000
4/1/2000
7/1/2000
10/1/2000
1/1/2001
4/1/2001
7/1/2001
10/1/2001
1/1/2002
4/1/2002
7/1/2002
10/1/2002
1/1/2003
4/1/2003
7/1/2003
10/1/2003
1/1/2004
4/1/2004
7/1/2004
10/1/2004
1/1/2005
4/1/2005
7/1/2005
10/1/2005
Date

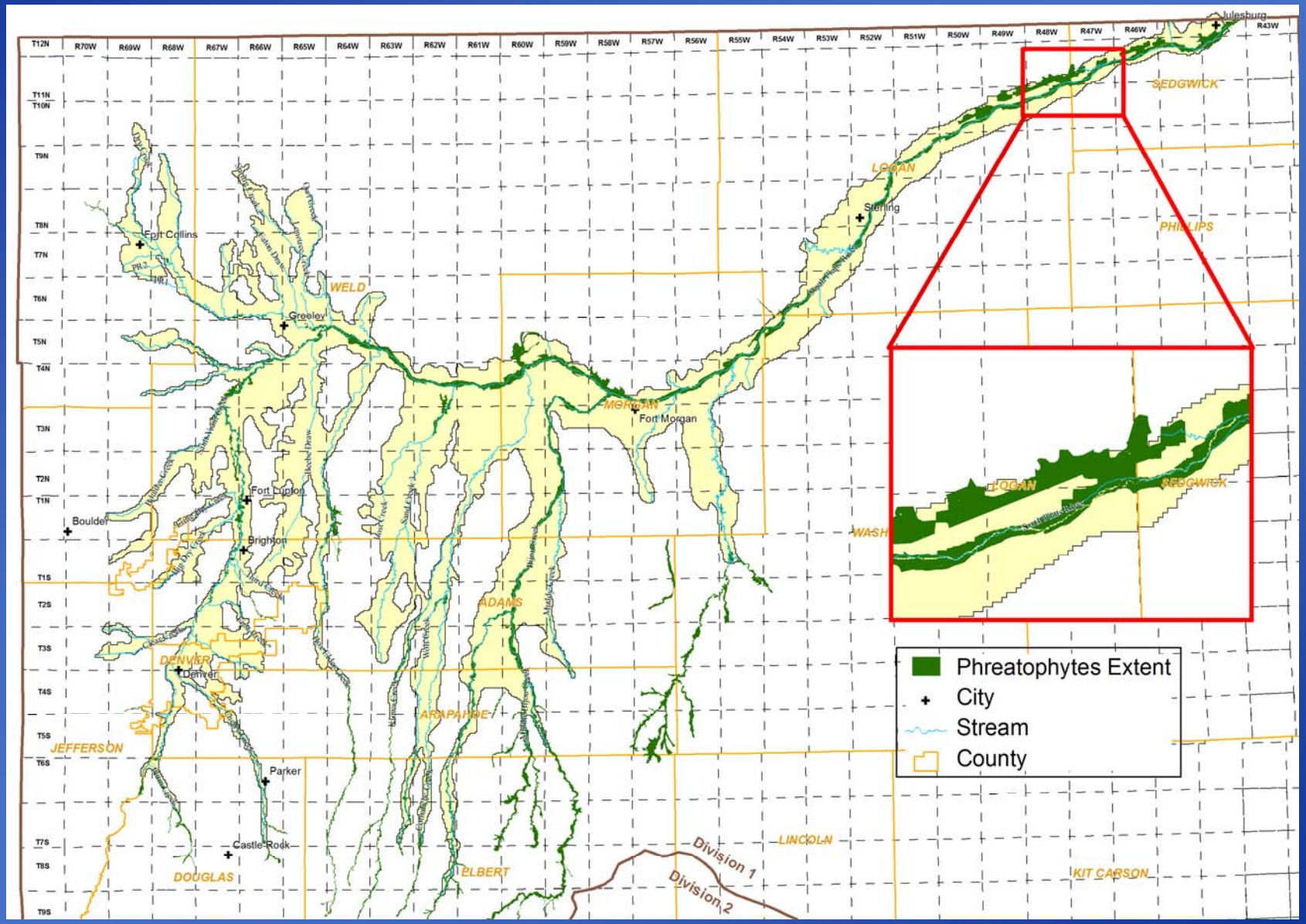
Stream Gain/Loss



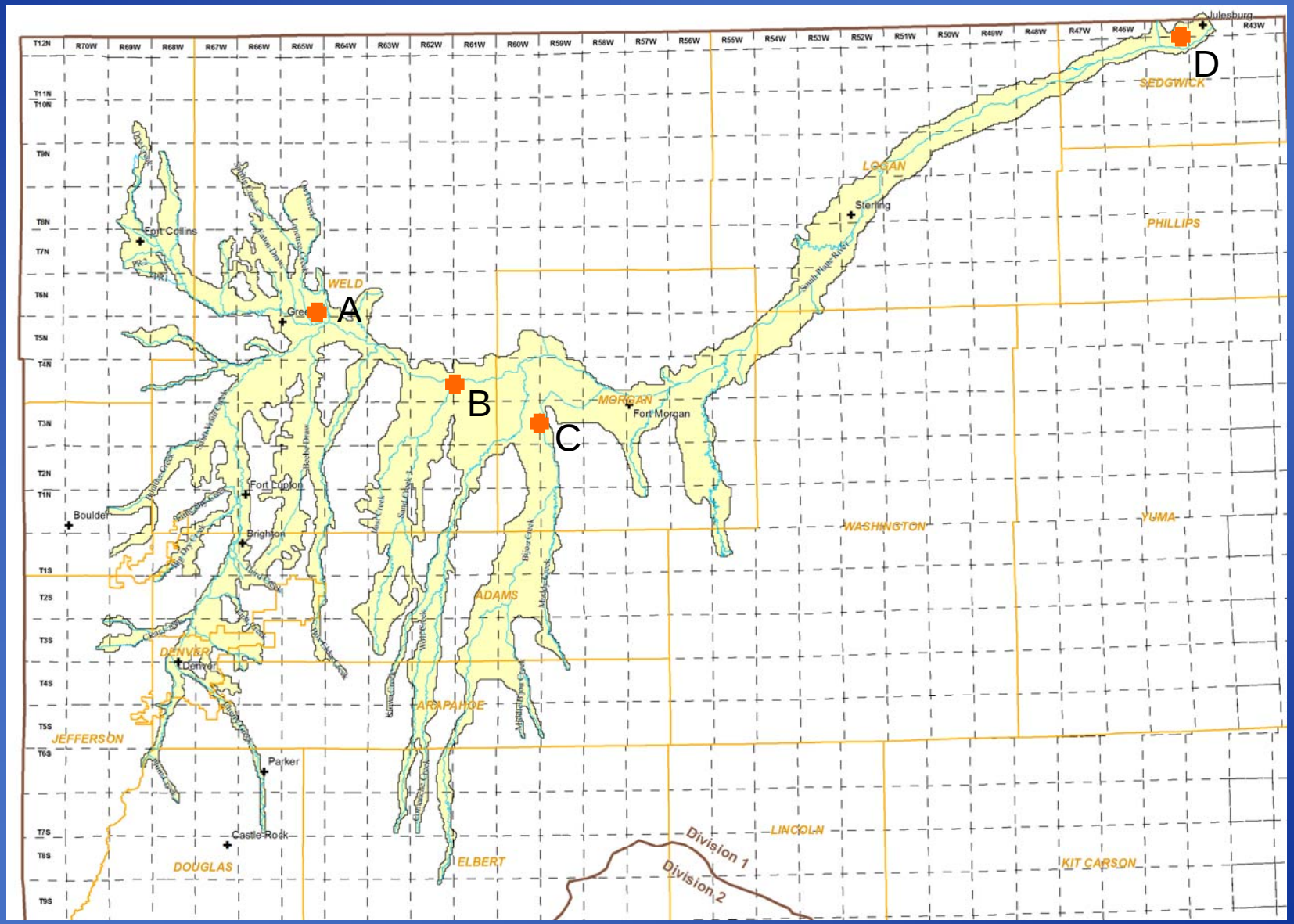
Diversions

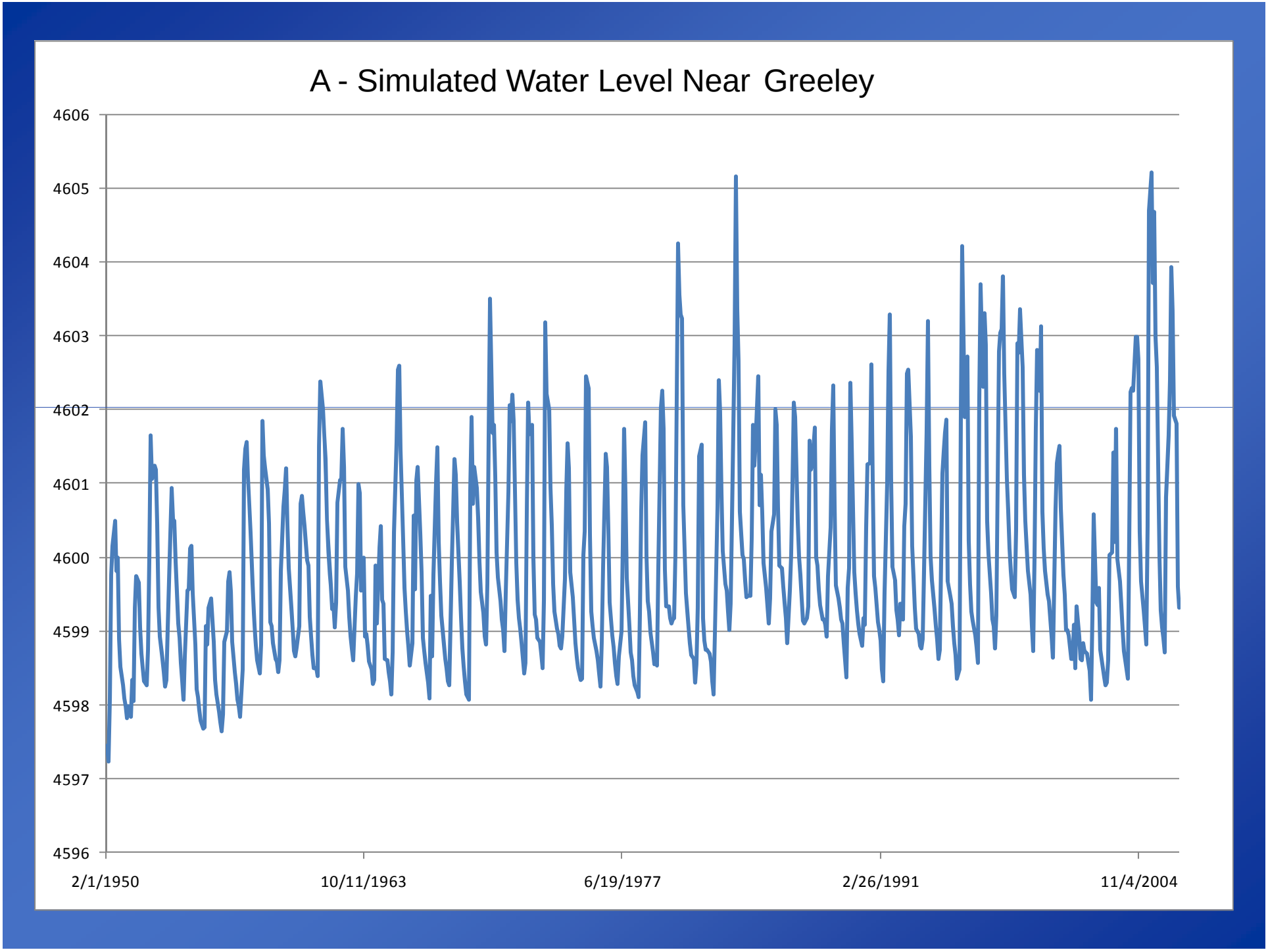

Percentage of Diversions Met by Year
120%
100%
80%
60%
40%
20%
0%
Percent of Diversion Met
100%
97%
97%
97%
96%
97%
97%
1999
2000
2001
2002
2003
2004
2005
Year

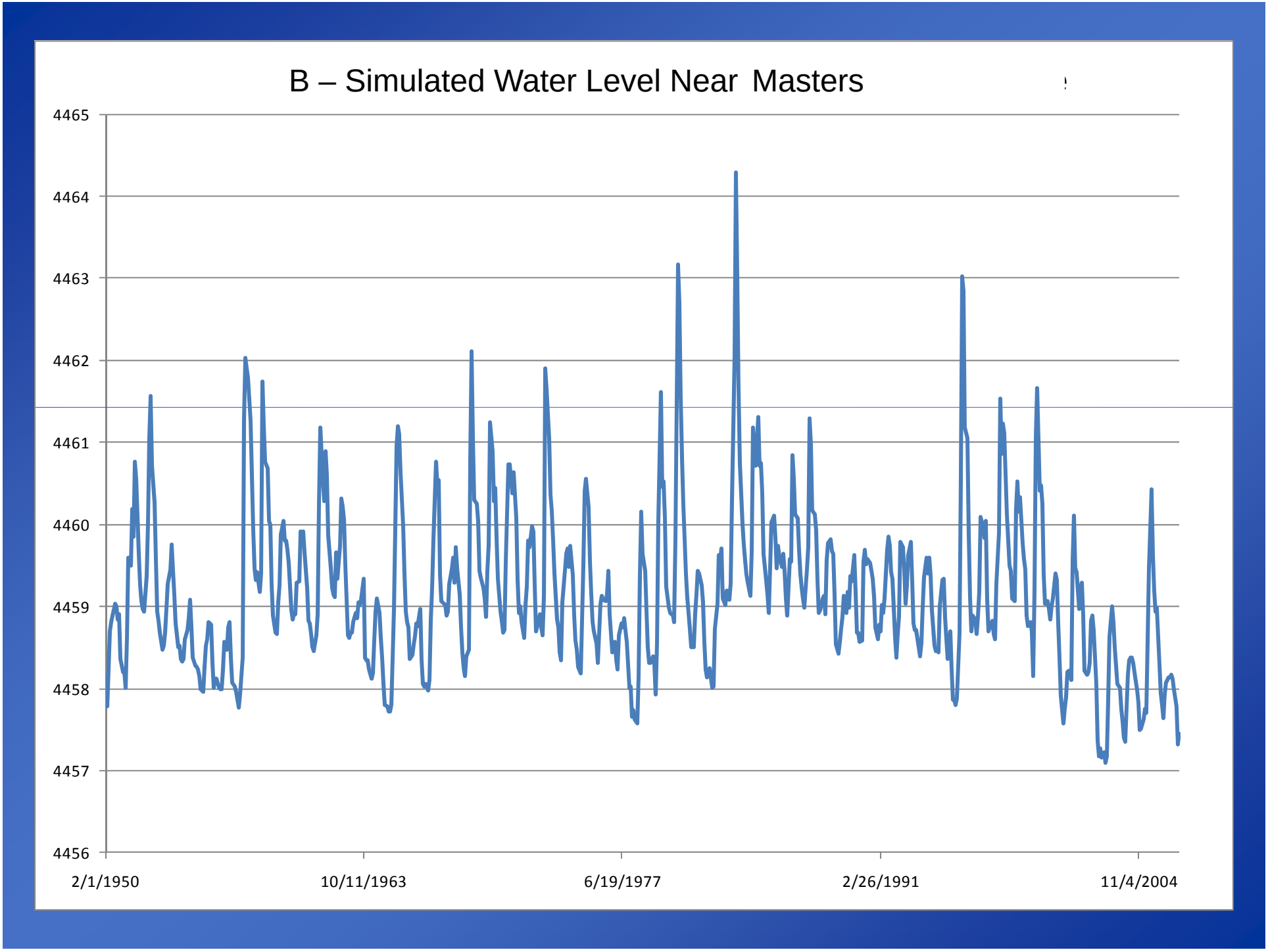
Phreatophyte Extent

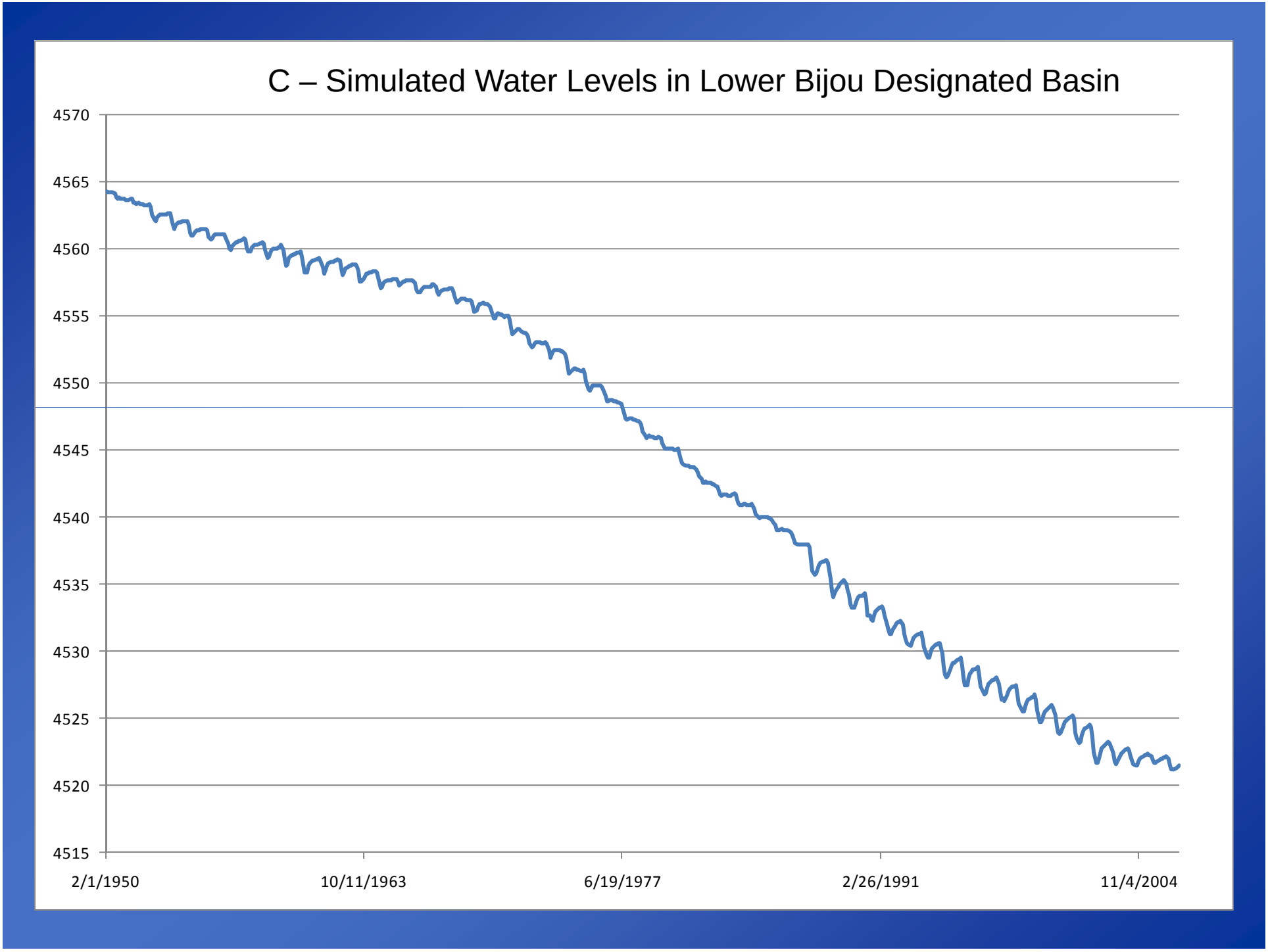


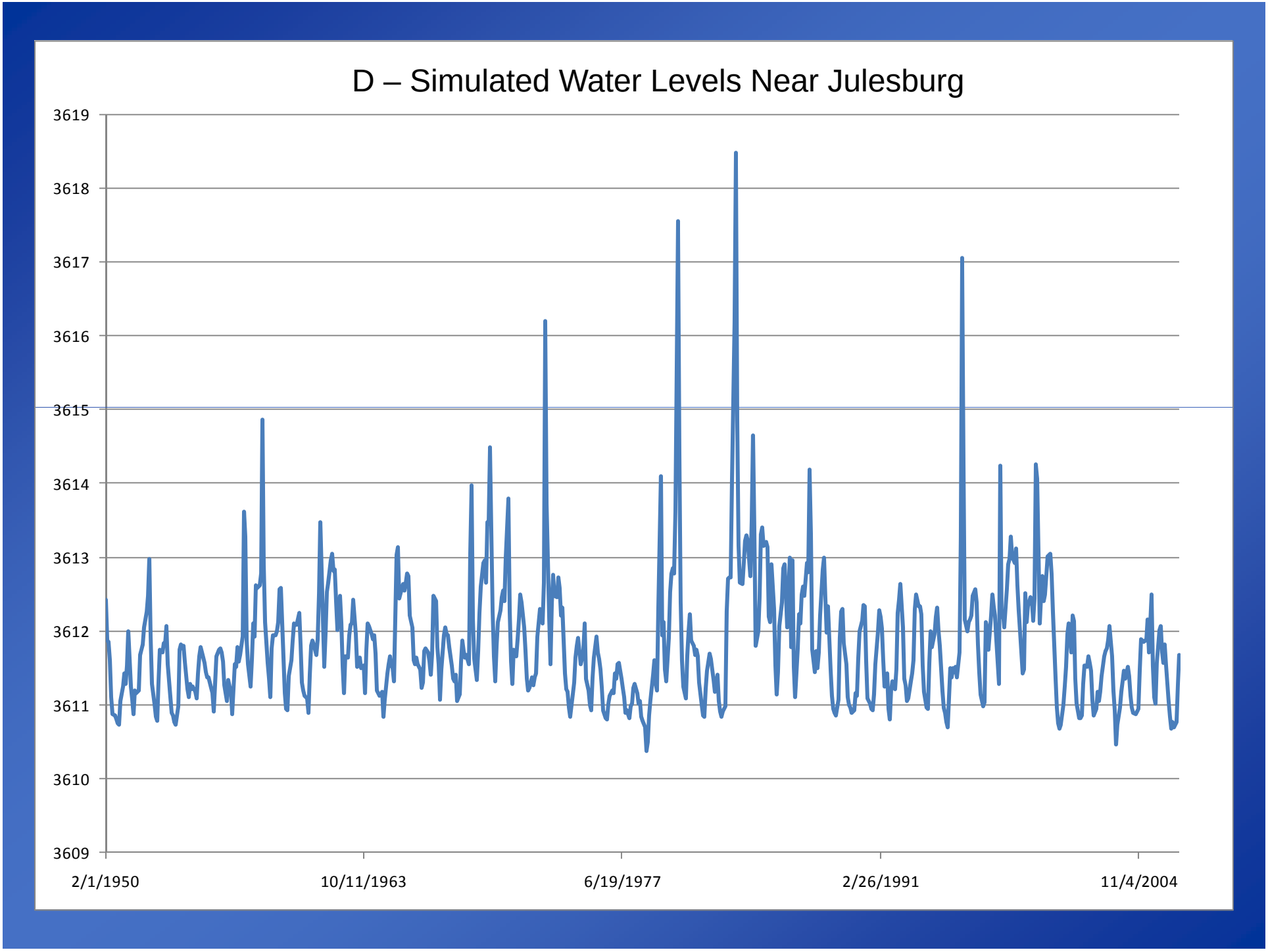
Location of Simulated Hydrographs (Validation Period 1950-2006)




A - Simulated Water Level Near Greeley
4606
4605
4604
4603
4602
4601
4600
4599
4598
4597
4596
2/1/1950
10/11/1963
6/19/1977
2/26/1991
11/4/2004


B – Simulated Water Level Near Masters
4465
4464
4463
4462
4461
4460
4459
4458
4457
4456
2/1/1950
10/11/1963
6/19/1977
2/26/1991
11/4/2004


C – Simulated Water Levels in Lower Bijou Designated Basin
4570
4565
4560
4555
4550
4545
4540
4535
4530
4525
4520
4515
2/1/1950
10/11/1963
6/19/1977
2/26/1991
11/4/2004


D – Simulated Water Levels Near Julesburg
3619
3618
3617
3616
3615
3614
3613
3612
3611
3610
3609
2/1/1950
10/11/1963
6/19/1977
2/26/1991
11/4/2004

Transient Calibration Summary (1999-2005)

Criteria	Model Results %	Calibration Target
Cumulative % mass balance	0.01%	Minimize
Head residuals (all) +/- 5 ft	75%	75%
Head residuals (all) +/- 10 ft	88%	
Head residuals (surveyed) +/- 5 ft	83%	75%
Head residuals (surveyed) +/- 10 ft	95%	
Delta head residuals +/- 5 ft	90%	75%
Delta head residuals +/- 10 ft	98%	
Annual Streamflow +/- 25%	89%	80%
Annual Streamflow +/- 40%	95%	
# of flooded cells	3%	Minimize
# of dry cells	12%	Minimize
% diversions met	97%	90%

Conclusions

- Developed a database that can be used as a source of information for other groundwater studies
- Developed data centered tools to facilitate future model updates
- Calibrated an alluvial groundwater model of the South Platte Alluvium which can be used for water resource planning at a regional scale
- Developed a model that can be used as a *basis* for localized modeling of specific tributaries or sections of the South Platte alluvium

Did We Meet Our Goals?

- Enhanced Understanding of Regional Groundwater Flow in the Study Area
- Developed a Tool to Assist in Planning and Evaluation of Regional Water Resources

Next Steps – To be completed in 2011

- Modeling Report
- Model and Data Availability

Discussion – Questions and Comments

For Further Information and Comment:

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