ERDC/CHL CR-10-1

Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Urban Flood Damage Reduction and Channel Restoration Development and Demonstration Program for Arid and Semi-Arid Regions (UFDP)
Southwest Urban Flood Damage Program (SWDP)

State of Flood Related Modeling Along Middle Rio Grande: Report Documentary 2007-2008 Work

Julie Coonrod

July 2010

Photo courtesy of Kelly Issacson

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State of Flood Related Modeling Along Middle Rio Grande: Report Documenting 2007-2008 Work

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Final report

Approved for public release; distribution is unlimited.

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Abstract: To best determine the current state of flood related modeling along the Middle Rio Grande, two tasks were accomplished. The first task included creating a catalog of reports and studies that have dealt with flood related issues. This catalog is organized in a spreadsheet and references 203 reports and papers. The second task involved organizing and hosting a Rio Grande Seminar at the University of New Mexico. The seminar provided a multi-disciplinary collaborative forum.

Contents

Figures and Tables

Figures

Tables

Preface

The University of New Mexico (UNM) is conducting this study under the direction of the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center (ERDC), Technical Programs Office. Funding was provided by the Urban Flood Damage Reduction and Channel Restoration Development and Demonstration Program for Arid and Semi-Arid Regions (UFDP) and the Southwest Urban Flood Damage Program (SWDP) of the USACE General Investigations Research and Development Program. Authorization of the U.S. Army Corps of Engineers to conduct research and development is codified in 10 U.S.C. 2358.

Work was performed under the general supervision of Dr. Lisa Hubbard, UFDF and SWDP Program Manager, CHL; Dr. Jack Davis, Technical Director for Flood and Coastal Storm Damage Reduction; William R. Curtis, Program Manager for Flood and Coastal Storm Damage Reduction Research and Development Program; Dr. William D. Martin, Director CHL, and Jose Sanchez, Deputy Director, CHL. This report was prepared by Dr. Julie Coonrod of the University of New Mexico, and a technical review was conducted by Steve Boberg, U.S. Army Engineer District, Albuquerque, and Meg M. Jonas and Dr. Lisa Hubbard both of CHL. J. Holley Messing, Coastal Engineering Branch, CHL, completed final formatting of the draft report.

COL Gary E. Johnston was Commander and Executive Director of ERDC. Dr. Jeffery P. Holland was Director.

1 Introduction

This report submitted by the University of New Mexico represents the beginning of a collaborative effort between the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers (USACE), the Desert Research Institute, Sandia National Laboratories, and the University of New Mexico to research urban flood reduction and ecologic enhancement issues along the Middle Rio Grande. This particular project is aimed at collaboration initiation and data collection. Collaboration initiation and data collection go hand in hand as both items require contacting agencies and stakeholders involved in modeling the Middle Rio Grande.

2 Data Collection

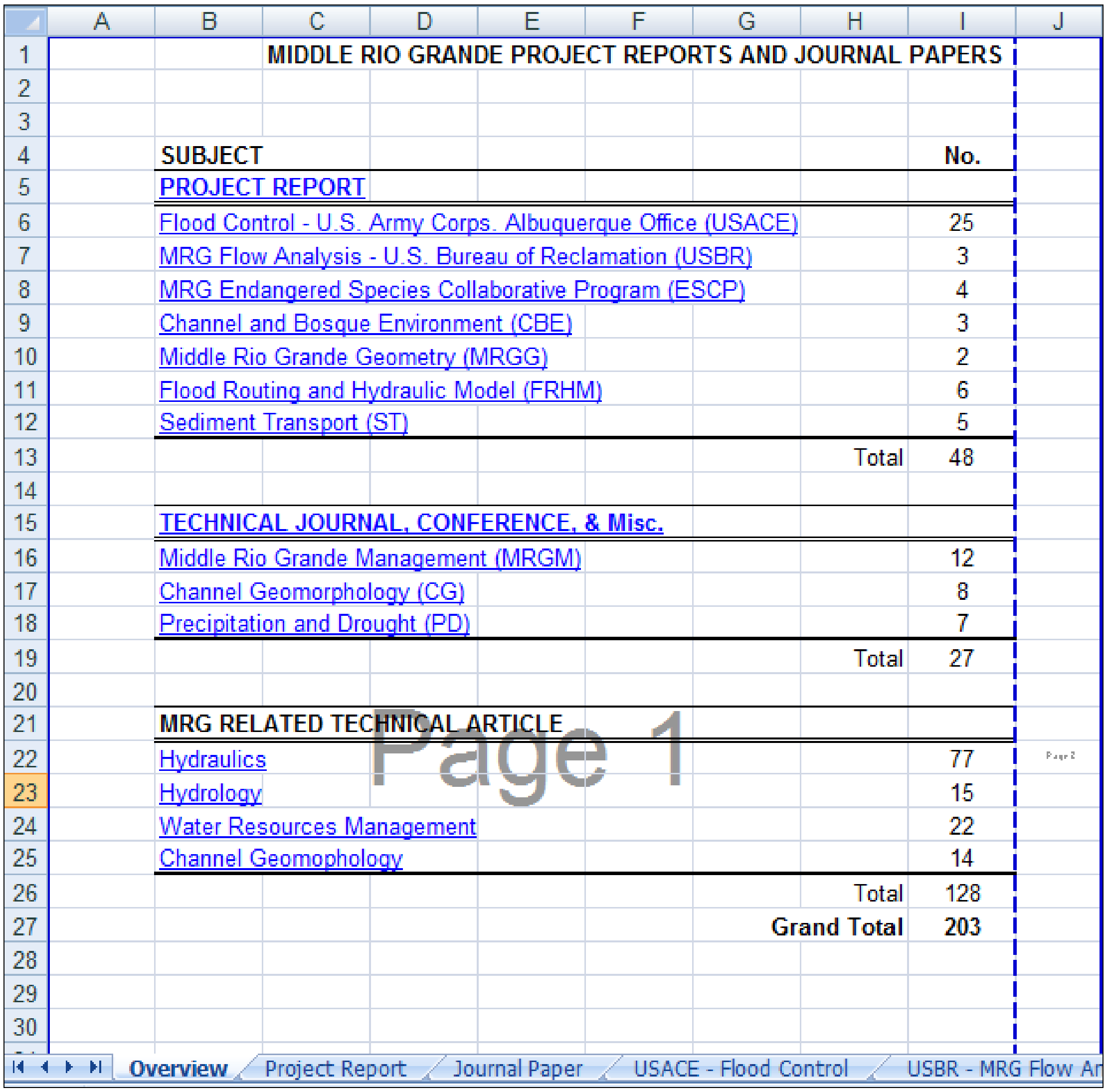
A number of Federal, state, and local governmental agencies are actively participating in studies related to sediment transport and flood control along the Middle Rio Grande. Some of these studies may be highlighted at a local meeting; however, many of these studies result in reports that are not well circulated. For example, the two dimensional (2D) flood routing model FLO-2D was used to model the entire Middle Rio Grande from Cochiti Dam to Elephant Butte. The results of this model have been presented at Bosque Initiative meetings. FLO-2D was applied again to the river to assist the Save Our Bosque Task Force in their restoration planning through the Socorro reach. Results of FLO-2D through the Albuquerque stretch were presented at a 10 February 2006 meeting at the Albuquerque District, USACE. This model used updated cross sections and additional high-flow calibration data. Each of these studies had different objectives; nonetheless, the river was modeled and flood surface elevations were calculated for different flow rates.

One purpose of this project is to determine the current state of knowledge of flooding issues associated with the Middle Rio Grande. Thus, an inventory of hydrologic, hydraulic, and sediment transport models that have been used for the Middle Rio Grande has been conducted. A total of 203 reports and papers are included in a catalog that is in spreadsheet form. The first worksheet of the spreadsheet is an overview as shown in Figure 1. The overview places reports in different categories.

The spreadsheet contains links that allows the user to easily navigate through the reports that might be relevant to his/her research. For example, if the user clicks the *Sediment Transport (ST)* link on the Overview worksheet, the user will be redirected to the Sediment Transport worksheet as shown in Figure 2.

Individual worksheets include titles, authors, for whom the report was prepared, date, and a link to an abstract. The abstracts are linked to a worksheet containing abstracts for all of the reports. Figure 3 shows an example of a link to an abstract. By clicking the *ST-2* link in the Sediment Transport worksheet (Figure 2), the user is directed to the Abstracts worksheet with the appropriate abstract selected (Figure 3). In some instances, the abstract was provided by the report. In other instances, the abstract was developed as part of this project.

The spreadsheet is currently available for downloading at www.unm.edu/~jcoonrod. It is also available in Appendix A of this report.



MIDDLE RIO GRANDE PROJECT REPORTS AND JOURNAL PAPERS

SUBJECT	No.
PROJECT REPORT	
Flood Control - U.S. Army Corps. Albuquerque Office (USACE)	25
MRG Flow Analysis - U.S. Bureau of Reclamation (USBR)	3
MRG Endangered Species Collaborative Program (ESCP)	4
Channel and Bosque Environment (CBE)	3
Middle Rio Grande Geometry (MRGG)	2
Flood Routing and Hydraulic Model (FRHM)	6
Sediment Transport (ST)	5
Total	48
TECHNICAL JOURNAL, CONFERENCE, & Misc.	
Middle Rio Grande Management (MRGM)	12
Channel Geomorphology (CG)	8
Precipitation and Drought (PD)	7
Total	27
MRG RELATED TECHNICAL ARTICLE	
Hydraulics	77
Hydrology	15
Water Resources Management	22
Channel Geomophology	14
Total	128
Grand Total	**203**

Figure 1. Catalog of reports in spreadsheet format.

	A	B	C	D	E
1	**Title**	**Prepared By**	**Prepared For**	**Abstract**	**Date**
2	Sediment Transport Modeling of the Rio Grande San Antonio to Elephant Butte R	Bureau of Reclamation, Sediment	Bureau of Reclmation	ST-1	Sep-03
3	Sediment Plug Computer Modeling Study, Tiffany Junction Reach, Middle Rio Gra	Craig Boroughs to the Technical S	Bureau of Reclmation, Alb	ST-2	Oct-05
4	Elephant Butte Temporary Channel 2005 Sediment Transport Modeling, Middle Ri	Kent L. Collins, Bureau of Reclam	Bureau of Reclmation, Alb	ST-3	May-06
5	Sediment Erosion Analysis of San Acacia Diversion Dam Removal Alternative - Fi	Blair Greimann, Bureau of Reclam	Bureau of Reclamation, A	ST-4	Aug-05
6	Prediction of River Bed Armoring and Sorting, Middle Rio Grande Project	Blair Greimann and Travis Bauer, I	Bureau of Reclamation, A	ST-5	Jan-06

MRG Endangered Species | **Sediment Transport** | Middle Rio Grande Geometry | Channel and Bosque Environme

Figure 2. Sediment Transport worksheet.

	A	B
1	**Code**	**Abstract**
2	FRHM-1	[Summarized by UFDP] The Middle Rio Grande FLO-2D model has been evolving since 1997 through its application to a number of flood projects. The d
3	FRHM-5	[Summarized by UFDP] Geomorphic analyses indicate that the general trends of the Bernalillo Bridge reach include a decrease in width, width-depth rat
4	CBE-3	[Summarized by UFDP] In the first years of the 1990s, United States Senator Pete Domenici's Rio Grande Bosque Conservation Committee brought fed
5	CBE-1	[Summarized by UFDP] There is a plan to develop a Rio Grande minnow sanctuary in the Albuquerque area. This analysis was intended to provide inforr
6	ST-2	[Summarized by Author] There are several documented cases of sediment plug development in alluvial rivers, but little is known about the specific proce

Hydraulics | Hydrology | Water Resources Management | Channel Geomorphology | **Abstracts**

Figure 3. Abstracts worksheet.

3 Collaboration Initiation

To help determine the current state of knowledge of flooding issues associated with the Middle Rio Grande, we held a seminar class during the fall, 2006, semester which focused on the Rio Grande (Table 1). The seminar afforded us the opportunity to invite outside speakers as well as provided a collaborative forum for the different Rio Grande projects taking place at UNM.

Table 1. Rio Grande Seminar Schedule, Fall, 2006.

22 August	Julie Coonrod, UNM Civil Engineering	An introduction to the Middle Rio Grande and the Urban Flood Demonstration Program.
29 August	James Cleverly, UNM Biology	Evapotranspiration: long-term studies of ecohydrology and biometeorology along the Middle Rio Grande.
5 September	Dianne McDonnell, UNM and ReSpec	Scaling Riparian Evapotranspiration to Canopies along the Middle Rio Grande Corridor in Central New Mexico.
12 September	Aaron Byrd, ERDC	A system-wide approach to watershed management.
19 September	Rolf Schmidt-Peterson, ISC	River System Overview and Role of Interstate System Commission.
26 September	Paul Tashjian, USF&WS	Physical Habitat of the Middle Rio Grande (historic vs. current).
3 October	Nabil Shafike, ISC	Modeling Framework for the Middle Rio Grande Basin
10 October	Mike Harvey, Mussetter Engineering, Inc.	Alluvial Bar Morphology and Dynamics in the Middle Rio Grande: Application to Habitat Restoration for the Rio Grande Silvery Minnow.
17 October	Susan Kelly, UNM Utton Center	Legal / Transboundary Issues.
24 October	Stuart Bunn, Griffith University, Brisbane, Australia	Making the connection between healthy waterways and healthy catchments, Southeast Queensland, Australia.
Please note the Fall 2006 UNM Water Forum will meet in the Student Union Building (Lobo A & B) on 31 October.		
31 October	Water Forum at SUB April Sanders , COE	Middle Rio Grande Endangered Species Act Collaborative Program.
7 November	Fred Phillips, NMT	Salt of the Earth: Salinization of the Rio Grande.
14 November	Brief student presentations	Graduate Research Topic.
21 November	Scott Collins, Sevilleta LTER	Sevilleta LTER: Presses and pulses in aridland ecosystems.
28 November	Janie Chermak, UNM Economics	Economics & Water in the Middle Rio Grande.
5 December	Jesse Roberts, SNL	Sediment Transport Modeling in the Albuquerque Reach.
12 December	Finals week	

The Rio Grande Seminar was cross-listed in the Departments of Civil Engineering and Biology and held once-a-week on Tuesdays at 12:30. Twenty students registered for the course. Additional faculty, students, and stakeholders attended the seminar on a regular basis such that attendance was typically about 30 people. Fifteen speakers participated in the seminar including Urban Flood Demonstration Program collaborators Aaron Byrd (ERDC) and Jesse Roberts (Sandia National Laboratory). A Web site was established to help keep stakeholders informed of the speakers. In most instances, the slides presented by the speakers have been posted on the Web site http://www.unm.edu/~jcoonrod/ rgseminar/). They are also available on a CD which accompanies this report.

In addition to the weekly speakers, we had 1 week where each student registered for the course was asked to make a brief presentation of their graduate research. The purpose of having each student present their research was to spur more collaboration where appropriate and to educate each other on the Rio Grande related research taking place on campus.

Some of the slides contained in these presentations provide additional information on the state of modeling in the Middle Rio Grande. In some instances, this is information that is not yet available in report format.

Additional seminar talks were held during 2007 and 2008 on a sporadic basis.

4 Conclusions

The Rio Grande Seminar was a successful collaborative forum that served many students and researchers. Holding such a seminar every several years would continue to foster education, collaboration, and new ideas. The organization of reports and studies that have been done on the Rio Grande will prove useful to various entities. Both the seminar and the spreadsheet of reports are linked from Julie Coonrod's Web page www.unm.edu/~jcoonrod. The spreadsheet of reports are available as Appendix A of this report and the seminar is on an accompanying CD attached to this report.

Appendix A: Middle Rio Grand Project Reports and Journal Papers

Project Report

Flood Control - U.S. Army Corps, Albuquerque Office (USACE)

Title	Prepared By
San Acacia Levee Project	U.S. Army Corps of Engineers
Middle Rio Grande Flow Frequency	U.S. Army Corps of Engineers
Cochiti Dam Revised PMF, 100-Years, Volume I and II	U.S. Army Corps of Engineers
Water Control Manual, Cochiti Lake Rio Grande Basin, New Mexico	U.S. Army Corps of Engineers
Rio Grande Floodway Truth or Consequences Unit, NM - General Design Memo No. 1	U.S. Army Corps of Engineers
Galisteo Dam, Initial Reservoir Filling/Flood Emergency Plan	U.S. Army Corps of Engineers
Cochiti Dam Spillway DSA Program FDM Studies - Hydraulic Design	U.S. Army Corps of Engineers
Cochiti Lake NM Revised PMF	U.S. Army Corps of Engineers
Truth or Consequences Flood Warning	U.S. Army Corps of Engineers
Belen LRR	U.S. Army Corps of Engineers
Middle Rio Grande LRR - Mountain View East, Isleta West	U.S. Army Corps of Engineers
Middle Rio Grande Flood Protection Project - Bernalillo to Belen, Corrales Planning Branch, District Review of Corrales LRR	U.S. Army Corps of Engineers
New Mexico Statewide Inventory of Flood Protection Needs	U.S. Army Corps of Engineers
Determination and Evaluation of Flood Protection Alternatives for Middle Rio Grande Floodway	A.M. Kinney, Inc.
Middle Rio Grande Flood Protection Study, Interior Drainage	U.S. Army Corps of Engineers
Rio Grande Bernalillo to Belen	U.S. Army Corps of Engineers
Proposed Alternation for Flood Control, Las Cruces Feasibility Study	U.S. Army Corps of Engineers
Las Cruces Flood Control Project Local Protection Phase I	U.S. Army Corps of Engineers
Las Cruces Local Flood Control Project - Rio Grande and Tributaries	U.S. Army Corps of Engineers
Las Cruces Design Manual No. 3 Initial Reservoir Filling Plan Flood Plan	U.S. Army Corps of Engineers
General Reevaluation Report Alamogordo Flood Control Project	U.S. Army Corps of Engineers
Middle Rio Grande Flood Protection Bernalillo to Belen	U.S. Army Corps of Engineers
Las Cruces Flood Control Project Local Protection Phase II	U.S. Army Corps of Engineers
Las Cruces, New Mexico Local Flood Protection Project	U.S. Army Corps of Engineers
Rio Grande and Tributaries, Las Cruces, New Mexico Report on Review Survey for Flood Control	U.S. Army Corps of Engineers

MRG Flow Analysis - U.S. Bureau of Reclamation (USBR)

Title	Prepared By
Calendar Year 2007 Report to the Rio Grande Compact Commission	U.S. Bureau of Reclamation
Middle Rio Grande Peak Flow Frequency Study Transforming Unregulated and Multistation Adjusted Frequency Curves to Regulated Conditions	Technical Service Center, Flood Hydrology Group, U.S. Bureau of Reclamation
Middle Rio Grande Peak Flow Frequency Analysis, New Mexico, Influence of Tributary Flows and Major Flood Control Structures	U.S. Bureau of Reclamation

MRG Endangered Species Collaborative Program (ESCP)

Title	Prepared By
Study and Preliminary Design Development of a Fish Passage Facility for San Acacia Diversion Dam	U.S. Army Corps of Engineers
Evaluation of Bar Morphology, Distribution and Dynamics as Indices of Fluvial Processes in the Middle Rio Grande, New Mexico	Mussetter Engineering, Inc.
Evaluating Hydrologic Effects of Water Acquisitions on the Middle Rio Grande	Benjamin L. Harding, P.E. and James T. McCord, Hydrosphere Resource Consultants
Water Management Decision-Support System for Middle Rio Grande Irrigation	Ramchand Oad, Colorado State University and Deborah Hathaway, Dagmar Llewellyn and Rick Young, S.S. Papadopulos & Associates, Inc.

Channel and Bosque Environment (CBE)

Title	Prepared By
Rio Grande Silvery Minnow Sanctuary Proposed Site, 1-D HEC-RAS Model of Area of Interest	Jonathan Acbuchon and Kristi Smith, Bureau of Reclamation
Aquatic Habitat and Hydraulic Modeling Study for the Upper Rio Grande Water Operations Model	Bohannan Huston, Mussetter Engineering, Inc., and Miller Ecological Consultants, Inc.
Middle Rio Grande Ecosystem Bosque Biological Management Plan	

Middle Rio Grande Geometry (MRGG)

Title	Prepared By
2002 Cross Section Geometry and Validation Middle Rio Grande Project, NM, Upper Colorado Region	Christopher Holmquist-Johnson and Paula Maker, Sedimentation and River Hydraulics Group, U.S. Bureau of Reclamation
2007 Geomorphic Summary of the Middle Rio Grande Verlarde to Caballo	Tamara Massong, Paula Marker, and Travis Bauer

Flood Routing and Hydraulic Model (FRHM)

Title	Prepared By
Development of Middle Rio Grande FLO-2D Flood Routing Model, Cochiti Dam to Elephant Butte Reservoir	Tetra Tech., Inc., Surface Water Group, Albuquerque, NM
Hydraulic Modeling on the Middle Rio Grande, Rio Puerco Reach, NM	Gigi Richard, Claudia Leon, and Pierre Julien, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO
Effect of Bendway Weir Characteristics on Resulting Flow Conditions, Volume I Technical Report	Jamis D. Darrow, Christopher I. Thornton, Steven R. Abt, Chad M. Lipscomb, Chester C. Watson, and Michael D. Robeson, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO
Effect of Bendway Weir Characteristics on Resulting Flow Conditions, Volume II Technical Report	Jamis D. Darrow, Christopher I. Thornton, Steven R. Abt, Chad M. Lipscomb, Chester C. Watson, and Michael D. Robeson, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO
Bernalillo Bridge Reach Highway 44 Bridge to Corrales Flood Channel Outfall Hydraulic Modeling Analysis 1962-2001	Mike Sixta, Jason Albert, Claudia Leon, and Pierre Y. Julien, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO
Riparian Groundwater Models for the Middle Rio Grande: ESA Collaborative Program FY04	S.S. Papadopulos & Associates, Inc., and New Mexico Interstate Stream Commission

Sediment Transport (ST)

Title	Prepared By
Sediment Transport Modeling of the Rio Grande San Antonio to Elephant Butte Reservoir to Evaluate Various Temporary Channel Design Configurations	U.S. Bureau of Reclamation, Sedimentation & River Hydraulics
Sediment Plug Computer Modeling Study, Tiffany Junction Reach, Middle Rio Grande Project, Upper Colorado Region	Craig Boroughs to the Technical Services Division
Elephant Butte Temporary Channel 2005 Sediment Transport Modeling, Middle Rio Grande, NM	Kent L. Collins, U.S. Bureau of Reclamation, Sedimentation & River Hydraulics
Sediment Erosion Analysis of San Acacia Diversion Dam Removal Alternative - Final Report	Blair Greimann, U.S. Bureau of Reclamation, Sedimentation and River Hydraulics
Prediction of River Bed Armoring and Sorting, Middle Rio Grande Project	Blair Greimann and Travis Bauer, U.S. Bureau of Reclamation, Sedimentation and River Hydraulics

Technical Journal, Conference, and Miscellaneous

Middle Rio Grand Management

Title	Author
Economic impact of alternative policy responses to prolonged and severe drought in the Rio Grande Basin	Jonathan Acbuchon and Kristi Smith, U.S. Bureau of Recalmation
Managing Irrigation for Better River Ecosystems—A Case Study of the Middle Rio Grande	Ramchand Oad and Rachel Kullman
Summary of the Middle Rio Grande Regional Water Plan 2000-2050	The Middle Rio Grande Water Assembly & The Mid-Region Council of Governments
Integrated Economic, Hydrologic, and Institutional Analysis of Policy Responses to Mitigate Drought Impacts in Rio Grande Basin	Frank A. Ward; James F. Booker; and Ari M. Michelsen
Market Prices for Water in the Semiarid West of the United States	David S. Brookshire and Bonnie Colby
Western Municipal Water Conservation Policy: The Case of Disaggregated Demand	Stuart Burness, Janie Chermak, and Kate Krause
Influence of Flooding, Sediment, and Hydrology on Soil Development in the Middle Rio Grande Floodplain, New Mexico	Nicole M. Bailey
An Economic Model for the Rio Grande Drainage Basin, New Mexico	James Frederic Roach
Economic Impact of the Conversion of Water from Irrigation to Municipal and Industrial Use in the Rio Grande Basin of New Mexico	Edwin A. Lewis
Environmental Implications of Surface Water Resource Development in the Middle Rio Grande Drainage, New Mexico	Richard A. Wortman
Does an Interstate Compact Preclude Interstate Water Rights Transfers?: A Rio Grande Case Study	Michael C. Pease
Hydraulic Modeling Study to Determine Diversion Structure Impacts: Rio Grande at Albuquerque, New Mexico	Jungseok Ho

Channel Geomorphology (CG)

Title	Author
Metrics for Assessing the Downstream Effects of Dams	John C. Schmidt and Peter R. Wilcock
Case Study: Modeling the Lateral Mobility of the Rio Grande Below Cochiti Dam, New Mexico	Gigi A. Richard, Pierre Y. Julien, and Drew C. Baird
Analyzing Changes in River Channel Morphology Using GIS for Rio Grande Silvery Minnow Habitat Assessment	Michael Porter and Tamara Massong
Using Hydraulic Modeling to Assist in Rio Grande Restoration	Carolyn Donnelly
A River in Transition: Geomorphic and Bed Sediment Response to Cochiti Dam on the Middle Rio Grande, Bernalillo to Albuquerque, New Mexico	Richard M. Ortiz
Development of Design Criteria for Deep Foundations Within the Rio Grande Channel Alluvium	Bob Meyers
Biogeochemistry of the Middle Rio Grande Bosque: Links Among Surface Water, Groundwater, and Sediments	Susan E. Block
Ecological Restoration: Examples from the Middle Rio Grande	Heather L. Bateman

Precipitation and Drought (PD)

Title	Author
Fractional snow cover in the Colorado and Rio Grande basins, 1995–2002	R. C. Bales, K. A. Dressler, B. Imam, S. R. Fassnacht, and D. Lampkin
Changes in U.S. Streamflow and Western U.S. Snowpack	Ajay Kalra, Thomas C. Piechota, Rob Davies, and Glenn A. Tootle
Climatic Change and U.S. Water Resources: From Modeled Watershed Impacts to National Estimates	Brian H. Hurd, Mac Callaway, Joel Smith, and Paul Kirshen
Integrated Frequency Analysis of Extreme Flood Peaks and Flood Volumes Using the Regionalized Quantities of Rainfall Depths as Auxiliary Variables	Wilson Fernandes and Mauro Naghettini
A Historical Study of Floods Prior to 1892 in the Rio Grande Watershed, New Mexico	Rufus H. Carter
Scaling Riparian Evapotranspiration to Canopies Along the Middle Rio Grande Corridor in Central New Mexico	Dianne Elaine McDonnell
Comparison of Remote Sensing Methods to Estimate Evapotranspiration, Middle Rio Grande Riparian Corridor, New Mexico	Alandren Etlantus

MRG Related Technical Article

Hydraulics

Title	Author
3D Numerical Modeling of Flow and Sediment Transport in Laboratory Channel Bends	A. Khosronejad, C. D. Rennie, S. A. A. Salehi Neyshabouri, and R. D. Townsend
A Two-Fraction Model for the Transport of Sand/Gravel Mixtures	Peter R. Wilcock and Stephen T. Kenworthy
A Unifying Framework for Particle Entrainment	S. E. Coleman and V. I. Nikora
Adding Radar Rainfall and Calibration to the TR-20 Watershed Model to Improve Dam Removal Flood Analysis	T. Endreny and M. Higgins
Automated Grain Size Measurements from Airborne Remote Sensing for Long Profile Measurements of Fluvial Grain Sizes	Patrice E. Carbonneau and Normand Bergeron
Applicability Criteria of the Variable Parameter Muskingum Stage and Discharge Routing Methods	Muthiah Perumal and Bhabagrahi Sahoo
Approach to Separate Sand from Gravel for Bed-Load Transport Calculations in Streams with Bimodal Sediment	Jaber H. Almedeij, Panayiotis Diplas, and Fawzia Al-Ruwaih
Bed-Material Load Computations for Nonuniform Sediments	Baosheng Wu, Albert Molinas, and Pierre Y. Julien
Best Hydraulic Section of a Composite Channel	Abdulrahman Abdulrahman
Determination of Boundary Shear Stress and Reynolds Shear Stress in Smooth Rectangular Channel Flows	Shu-Qing Yang and John A. McCorquodale
Aspect Ratio to Maximize Sediment Transport in Rigid Bank Channels	Guoliang Yu and Graeme Smart
Channel Bed Evolution and Sediment Transport Under Declining Sand Inputs	Karen B. Gran, David R. Montgomery, and Diane G. Sutherland
Channel-Forming Discharge Selection in River Restoration Design	Martin W. Doyle, Doug Shields, Karin F. Boyd, Peter B. Skidmore, and DeWitt Dominick
Characteristics of Loose Rough Boundary Streams at Near-Threshold	Subhasish Dey and Rajkumar V. Raikar
Influence of Coherent Flow Structures on the Dynamics of Suspended Sediment Transport in Open-Channel Flow	M. Cellino and U. Lemmin
Coupling Bank Stability and Bed Deformation Models to Predict Equilibrium Bed Topography in River Bends	Ebrahim Amiri-Tokaldany, Stephen E. Darby, and Paul Tosswell
Critical Shear Stress of Bimodal Sediment in Sand-Gravel Rivers	Matthieu de Linares and Philippe Belleudy
Design of Hydraulically Efficient Power-Law Channels with Freeboard	Arif A. Anwar and Derek Clarke
Discharge and Suspended Sediment Transport during Deconstruction of a Low-Head Dam	Tim Granata, Fang Cheng, and Matthew Nechvatal
Characteristics of Turbulent Unidirectional Flow Over Rough Beds: Double-Averaging Perspective with Particular Focus on Sand Dunes and Gravel Beds	S. R. McLean and V. I. Nikora
Downstream Hydraulic Geometry of Alluvial Channels	Jong-Seok Lee and Pierre Y. Julien

Title	Author
Dunes, Turbulent Eddies, and Interfacial Exchange with Permeable Sediments	M. Bayani Cardenas and John L. Wilson
Effect of Seepage-Induced Nonhydrostatic Pressure Distribution on Bed-Load Transport and Bed Morphodynamics	Simona Francalanci, Gary Parker, and Luca Solari
Effect of Instream Wood on Vertical Water Flux in Low-Energy Sand Bed Flume Experiments	Michael Mutz, Edda Kalbus, and Stefan Meinecke
Effect of Suspended Load on Sandbar Instability	B. Federici and G. Seminara
Effects of River Flow Scaling Properties on Riparian Width and Vegetation Biomass	R. Muneepeerakul, A. Rinaldo, and I. Rodriguez-Iturbe
Effects of Vegetation on Braided Stream Pattern and Dynamics	Tom J. Coulthard
Engineering Design Standards and Liability for Stream Channel Restoration	Louise O. Slate, F. Douglas Shields, Jr., John S. Schwartz, and Donald D. Carpenter
Equivalent Roughness Height for Plane Bed under Steady Flow	Benoît Camenen, Atilla Bayram, and Magnus Larson
Estimating Shear Stress From Moving Boat Acoustic Doppler Velocity Measurements in a Large Gravel Bed River	Louise C. Sime, Robert I. Ferguson, and Michael Church
Estimation of Average Stream Velocity	Michael G. Waldon
Exponential Formula for Bedload Transport	Nian-Sheng Cheng
Extension of Preissmann Scheme to Two-Dimensional Flows	Maurizio Venutelli
Flow Resistance Law in Channels with Flexible Submerged Vegetation	F. G. Carollo, V. Ferro, and D. Termini
Formulas for Sediment Porosity and Settling Velocity	Weiming Wu and Sam S. Y. Wang
Hydraulic Performance of a Morphology-Based Stream Channel Design	Sean M. Smith and Karen L. Prestegaard
Data Interpretation for In Situ Measurements of Cohesive Sediment Erosion	J. Aberle, V. Nikora, and R. Walters
Comparison of Methods for Predicting Incipient Motion for Sand Beds	Nick A. Marsh, Andrew W. Western, and Rodger B. Grayson
Influence of Bed Material Size Heterogeneity on Bedload Transport Uncertainty	Li Chen and Mark C. Stone
Influence of Cohesion on the Incipient Motion Condition of Sediment Mixtures	Umesh C. Kothyari and Rajesh Kumar Jain
On Interfacial Instability as a Cause of Transverse Subcritical Bed Forms	Jeremy G. Venditti, Michael Church, and Sean J. Bennett
Kinematic and Diffusion Waves: Analytical and Numerical Solutions to Overland and Channel Flow	Cevza Melek Kazezyılmaz-Alhan, and Miguel A. Medina Jr.
Kinematic Wave Model for Transient Bed Profiles in Alluvial Channels Under Nonequilibrium Conditions	Gokmen Tayfur and Vijay P. Singh
Lodging Velocity for an Emergent Aquatic Plant in Open Channels	Jennifer G. Duan, Brian Barkdoll, and Richard French
On the Long-Term Behavior of Meandering Rivers	C. Camporeale, P. Perona, A. Porporato, and L. Ridolfi

Title	Author
Identification of Manning's Roughness Coefficients in Shallow Water Flows	Yan Ding, Yafei Jia, and Sam S. Y. Wang
Formula for Sediment Transport in Rivers, Estuaries, and Coastal Waters	Shu-Qing Yang
Modeling Suspended Sediment Discharge from the Waipaoa River System, New Zealand: The Last 3000 Years	A. J. Kettner, B. Gomez, and J. P. M. Syvitski
Modeling the Evolution of Incised Streams: I. Model Formulation and Validation of Flow and Streambed Evolution Components	Eddy J. Langendoen and Carlos V. Alonso
Modeling the Influence of River Rehabilitation Scenarios on Bed Material Sediment Flux in a Large River Over Decadal Timescales	Michael Bliss Singer and Thomas Dunne
Sand Transport in Nile River, Egypt	S. Abdel-Fattah, A. Amin, and L. C. Van Rijn
Modeling Noncohesive Suspended Sediment Transport in Stream Channels Using an Ensemble-Averaged Conservation Equation	S. Sharma and M. L. Kavvas
Numerical Simulation of Relatively Wide, Shallow Channels with Erodible Banks	Chang-Lae Jang and Yasuyuki Shimizu
Numerical and Experimental Study of Dividing Open-Channel Flows	A. S. Ramamurthy, Junying Qu, and Diep Vo
Performance of Bed-Load Transport Equations Relative to Geomorphic Significance: Predicting Effective Discharge and Its Transport Rate	Jeffrey J. Barry, John M. Buffington, Peter Goodwin, John G. King, and William W. Emmett
Performances of Hydraulics and Bedload Sediment Flushing in Rigid Channel Using Surge Flows	Guoliang Yu and Soon-Keat Tan
Predicting Incipient Motion, Including the Effect of Turbulent Pressure Fluctuations in the Bed	Stefan Vollmer and Maarten G. Kleinhans
Reynolds Stress and Bed Shear in Nonuniform Unsteady Open-Channel Flow	Subhasish Dey and Martin F. Lambert
Effect of Sampling Time on Measured Gravel Bed Load Transport Rates in a Coarse-Bedded Stream	Kristin Bunte and Steven R. Abt
Effect on Flow Structure of Sand Deposition on a Gravel Bed: Results from a Two-Dimensional Flume Experiment	Gregory H. Sambrook Smith and Andrew P. Nicholas
Scour Around Bankline and Setback Abutments in Compound Channels	Terry W. Sturm
Role of Resistance Coefficient in Seasonal Adjustments in Alluvial Rivers	S. V. Chitale
Secondary Current Effects on Cohesive River Bank Erosion	Athanasios N. Papanicolaou, Mohamed Elhakeem, and Robert Hilldale
Sediment Budget of the Yangtze River	Zhao-Yin Wang, Yitian Li, and Yiping He
Flume Investigations into the Influence of Shear Stress History on a Graded Sediment Bed	Heather Monteith and Gareth Pender
Stress History Effects on Graded Bed Stability	Heather Haynes and Gareth Pender

Title	Author
Structure and Hydraulics of Natural Woody Debris Jams	R. B. Manners, M. W. Doyle, and M. J. Small
Suspended Sediment Concentration Profiles in Nonuniform Flows: Is the Classical Perturbative Approach Suitable for Depth-Averaged Closures?	Marco Toffolon and Gianluca Vignoli
The Unified Gravel-Sand (TUGS) Model: Simulating Sediment Transport and Gravel/Sand Grain Size Distributions in Gravel-Bedded Rivers	Yantao Cui
Influence of Turbulence on Bed Load Sediment Transport	B. Mutlu Sumer, Lloyd H. C. Chua, N.-S. Cheng, and Jørgen Fredsøe
Turbulent Flow Friction Factor Calculation Using a Mathematically Exact Alternative to the Colebrook–White Equation	Jagadeesh R. Sonnad and Chetan T. Goudar
Two-Phase Versus Mixed-Flow Perspective on Suspended Sediment Transport in Turbulent Channel Flows	M. Muste, K. Yu, I. Fujita, and R. Ettema
Modeling of Vegetation-Erosion Dynamics in Watershed Systems	Z.-Y. Wang, G. H. Huang, G. Q. Wang, and J. Gao
Velocity Distribution in the Roughness Layer of Rough-Bed Flows	Vladimir Nikora, Katinka Koll, Ian McEwan, Stephen McLean, and Andreas Dittrich
Velocity Distributions in Spatially Varied Flow with Increasing Discharge	Mehdi H. Khiadani, Jaya Kandasamy, and Simon Beecham
Vertical Dispersion of Fine and Coarse Sediments in Turbulent Open-Channel Flows	Xudong Fu, Guangqian Wang, and Xuejun Shao
Wash Load and Bed-Material Load Transport in the Yellow River	Chih Ted Yang and Francisco J. M. Simões

Hydrology

Title	Author
A Methodology for Discharge Estimation and Rating Curve Development at Ungauged River Sites	Muthiah Perumal, Tommaso Moramarco, Bhabagrahi Sahoo, and Silvia Barbetta
Area and Width Functions of River Networks: New Results on Multifractal Properties	Bruno Lashermes and Efi Foufoula-Georgiou
Case Study of Tribal Drought Planning: The Hualapai Tribe	Cody L. Knutson, Michael J. Hayes, and Mark D. Svoboda
Climate Change, Urbanization, and Optimal Long-Term Floodplain Protection	Tingju Zhu, Jay R. Lund, Marion W. Jenkins, Guilherme F. Marques, and Randall S. Ritzema
Hydrologic and Economic Implications of Climate Change for Typical River Basins of the Agricultural Midwestern United States	Hua Xie, J. Wayland Ehear, and Hyunhee An
Integrated Frequency Analysis of Extreme Flood Peaks and Flood Volumes Using the Regionalized Quantiles of Rainfall Depths as Auxiliary Variables	Wilson Fernandes and Mauro Naghettini
Comparison of Kinematic-Wave and Nonlinear Reservoir Routing of Urban Watershed Runoff	Yiying Xiong and Charles S. Melching
Kinematic Wave Parameters for Trapezoidal and Rectangular Channels	Tommy S. W. Wong, and M. C. Zhou
Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America	Richard Seager, Mingfang Ting, Isaac Held, Yochanan Kushnir, Jian Lu, Gabriel Vecchi, Huei-Ping Huang, Nili Harnik, Ants Leetmaa, Ngar-Cheung Lau, Cuihua Li, Jennifer Velez, Naomi Naik
Parameter Estimation for Muskingum Models	Amlan Das
Parameter Estimation for the Nonlinear Muskingum Model Using the BFGS Technique	Zong Woo Geem
Patterns of Predictability in Hydrological Threshold Systems	E. Zehe, H. Elsenbeer, F. Lindenmaier, K. Schulz, and G. Blo¨schl
Pesticide Runoff Loads from Lawns and Golf Courses	Douglas A. Haith and Matthew W. Duffany
Relations Among Storage, Yield, and Instream Flow	Richard M. Vogel, Jack Sieber, Stacey A. Archfield, Mark P. Smith, Colin D. Apse, and Annette Huber-Lee
Stream Gains and Losses Across a Mountain-to-Valley Transition: Impacts on Watershed Hydrology and Stream Water Chemistry	Timothy P. Covino and Brian L. McGlynn

Water Resources Management

Title	Author
A Stochastic Approach to Analyze Trade-Offs and Risks Associated with Large-Scale Water Resources Systems	A. Tilmant and R. Kelman
Better Management of Renewable Resources Can Avert a World Crisis	George H. Hargreaves and Daniele Zaccaria
Coping with Global Warming and Climate Change	Peter Rogers
The Economic Value of Stream Restoration	Alan Collins, Randy Rosenberger, and Jerald Fletcher
Estimating Resilience for Water Resources Systems	Yi Li and Barbara J. Lence
Estimating the Performance of International Regulatory Regimes: Methodology and Empirical Application to International Water Management in the Naryn/Syr Darya Basin	Tobias Siegfried and Thomas Bernauer
Managing the Water Program	Donald J. Brady
No River Left Behind: A Call for Regulation in a Deregulating and Misregulating Era	J. Wayland Eheart
Objectives of Public Participation: Which Actors Should be Involved in the Decision Making for River Restorations?	Berit Junker, Mattias Buchecker, and Ulrike Mu ller-Bo¨ker
Optimal Design of Parabolic Canal Section	Bhagu R. Chahar
River Restoration	Ellen Wohl, Paul L. Angermeier, Brian Bledsoe, G. Mathias Kondolf, Larry MacDonnell, David M. Merritt, Margaret A. Palmer, N. LeRoy Poff, and David Tarboton
River Restoration Using a Geomorphic Approach for Natural Channel Design	David L. Rosgen
Role of a Central Administrator in Managing Water Resources: The Case of the Israeli Water Commissioner	Eran Feitelson, Itay Fischhendler, and Paul Kay
Sediment Transport and Channel Adjustments Associated with Dam Removal: Field Observations	Fang Cheng and Tim Granata
Strategic Decision Support for Resolving Conflict over Water Sharing Among Countries Along the Syr Darya River in the Aral Sea Basin	K. D. W. Nandalal and K. W. Hipel
Triple Dividends of Water Consumption Charges in South Africa	Anthony Letsoalo, James Blignaut, Theuns de Wet, Martin de Wit, Sebastiaan Hess, Richard S. J. Tol, and Jan van Heerden
Effects of Design Practice for Flood Control and Best Management Practices on the Flow-Frequency Curve	Seth M. Nehrke and Larry A. Roesner
Short-Term Forecasting for Urban Water Consumption	Alaa H. Aly and Nisai Wanakule
‘‘Virtual water’’: An Unfolding Concept in Integrated Water Resources Management	Hong Yang and Alexander Zehnder
Stochastic Model to Evaluate Residential Water Demands	Vicente Juan Garcı´a, Rafael Garcı´a-Bartual, Enrique Cabrera, Francisco Arregui, and Jorge Garcı´a-Serra
Water Management Applications of Climate-Based Hydrologic Forecasts: Case Study of the Truckee-Carson River Basin	Katrina Grantz, Balaji Rajagopalan, Edith Zagona, and Martyn Clark
Water Use Regimes: Characterizing Direct Human Interaction with Hydrologic Systems	Peter K. Weiskel, Richard M. Vogel, Peter A. Steeves, Philip J. Zarriello, Leslie A. DeSimone, and Kernell G. Ries III

Channel Geomorphology

Title	Author
A Parameterization of Flow Separation Over Subaqueous Dunes	Andries J. Paarlberg, C. Marjolein Dohmen-Janssen, Suzanne J. M. H. Hulscher, and Paul Termes
Analysis of Flow Competence in an Alluvial Gravel Bed Stream, Dupuyer Creek, Montana	Andrew C. Whitaker and Donald F. Potts
Analytical Approach to Calculate Rate of Bank Erosion	Jennifer G. Duan
Case Study: Application of the HEC-6 Model for the Main Stem of the Kankakee River in Illinois	Nani G. Bhowmik, D.WRE, Christina Tsai, Paminder Parmar, and Misganaw Demissie
Channel-Reach Morphology Dependence on Energy, Scale, and Hydroclimatic Processes with Implications for Prediction Using Geospatial Data	Alejandro N. Flores, Brian P. Bledsoe, Christopher O. Cuhaciyan, and Ellen E. Wohl
Evaluation of an Experimental LiDAR for Surveying a Shallow, Braided, Sand-Bedded River	Paul J. Kinzel, C. Wayne Wright, Jonathan M. Nelson, and Aaron R. Burman
Geospatial Representation of River Channels	Venkatesh M. Merwade, David R. Maidment, and Ben R. Hodges
Metrics for Assessing the Downstream Effects of Dams	John C. Schmidt and Peter R. Wilcock
Parameter Estimation for Flow in Open-Channel Networks	Amlan Das
Estimating the Mechanical Effects of Riparian Vegetation on Stream Bank Stability Using a Fiber Bundle Model	Natasha Pollen and Andrew Simon
River Bifurcations: Experimental Observations on Equilibrium Configurations	W. Bertoldi and M. Tubino
Significance of the Riparian Vegetation Dynamics on Meandering River Morphodynamics	E. Perucca, C. Camporeale, and L. Ridolfi
A Unified Model for Subaqueous Bed Form Dynamics	Douglas J. Jerolmack and David Mohrig
Why Some Alluvial Rivers Develop an Anabranching Pattern	He Qing Huang and Gerald C. Nanson

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Julie Coonrod

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Rio Grande Seminar presentations on CD attached to report

14. ABSTRACT
To best determine the current state of flood related modeling along the Middle Rio Grande, two tasks were accomplished. The first task included creating a catalog of reports and studies that have dealt with flood related issues. This catalog is organized in a spreadsheet and references 203 reports and papers. The second task involved organizing and hosting a Rio Grande Seminar at the University of New Mexico. The seminar provided a multi-disciplinary collaborative forum.

15. SUBJECT TERMS

Middle Rio Grande	Data collection	Desert Research Institute
Collaboration initiation	Sediment transport	Sandia National Laboratories
	University of New Mexico	Urban flood reduction

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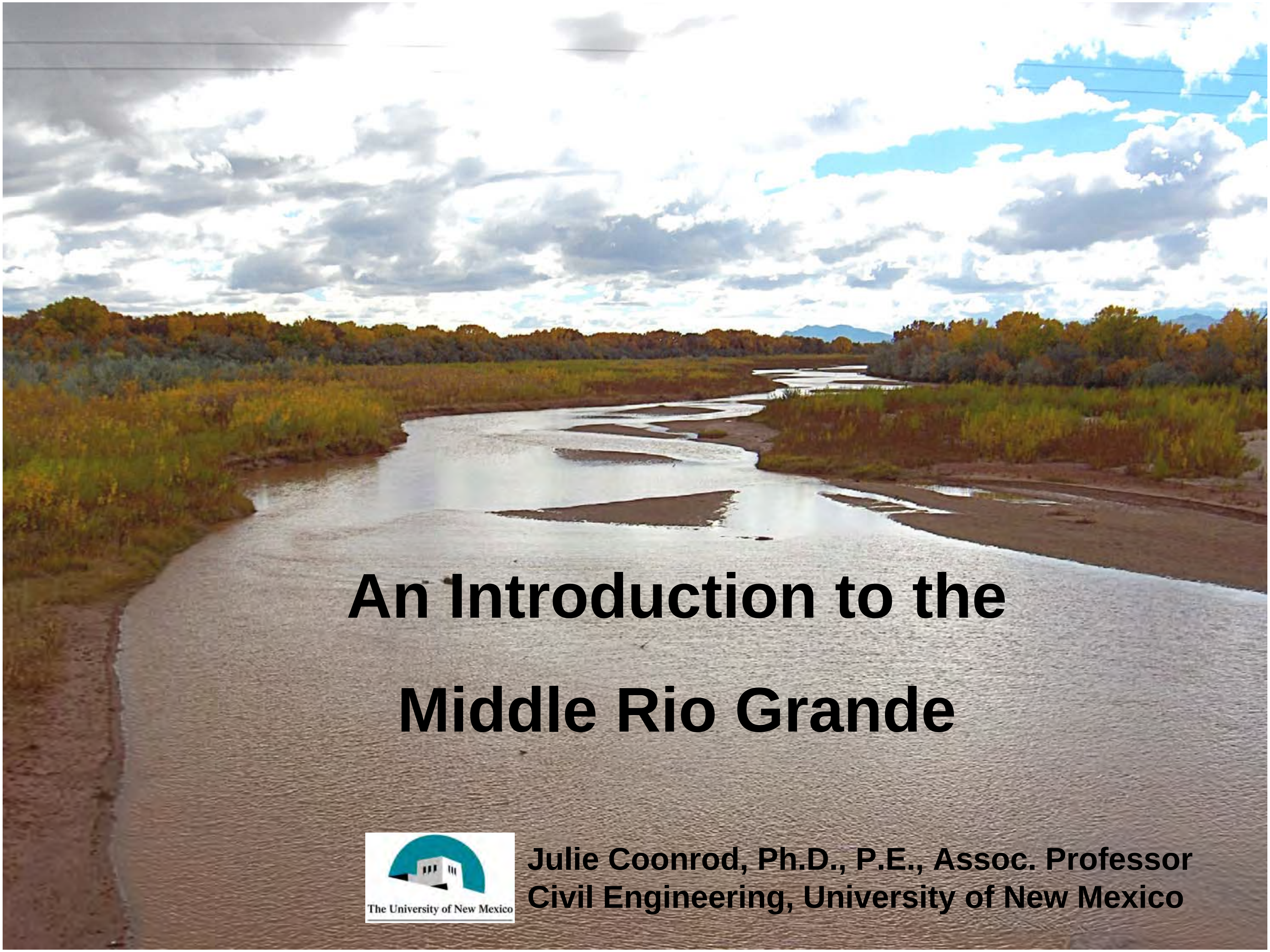
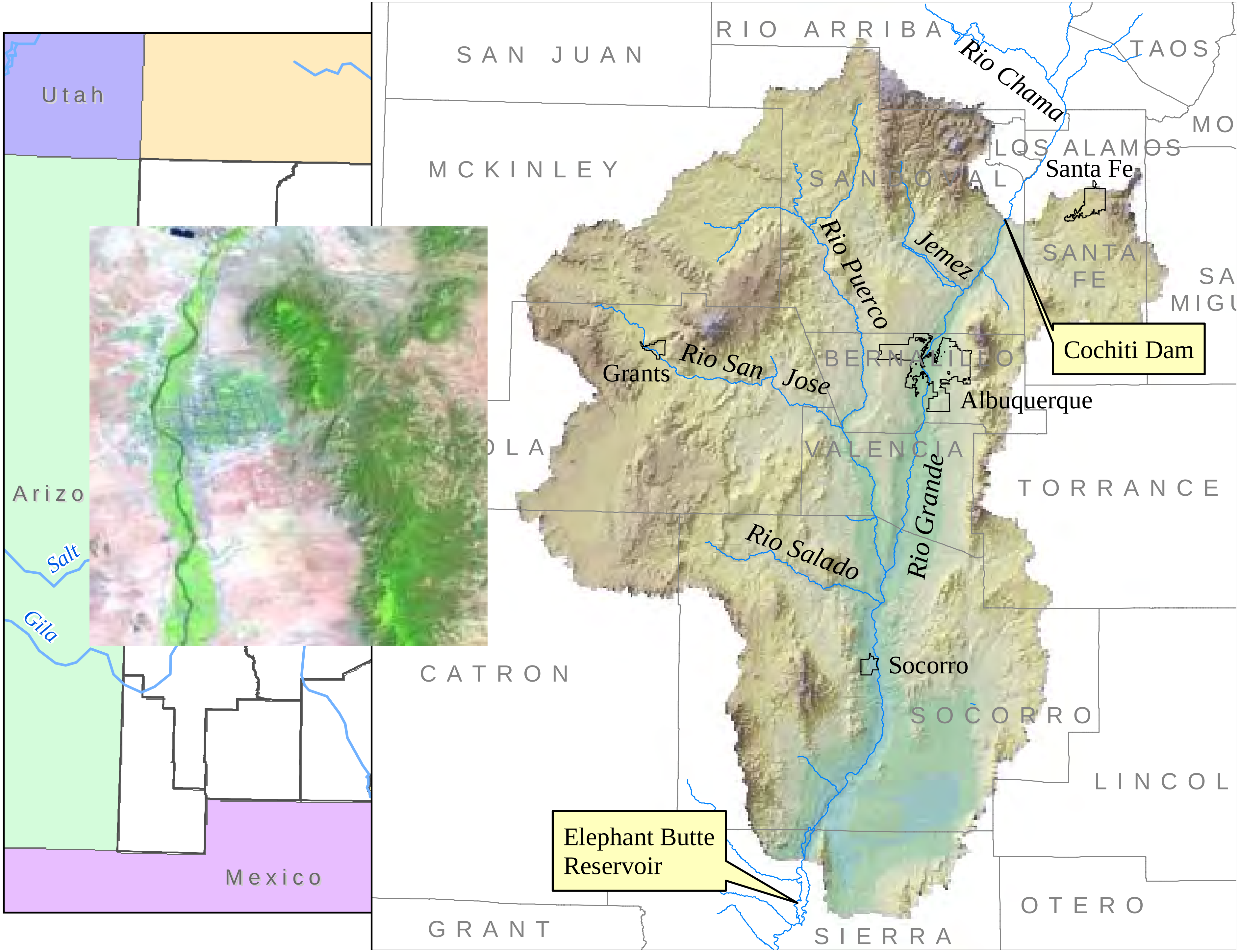
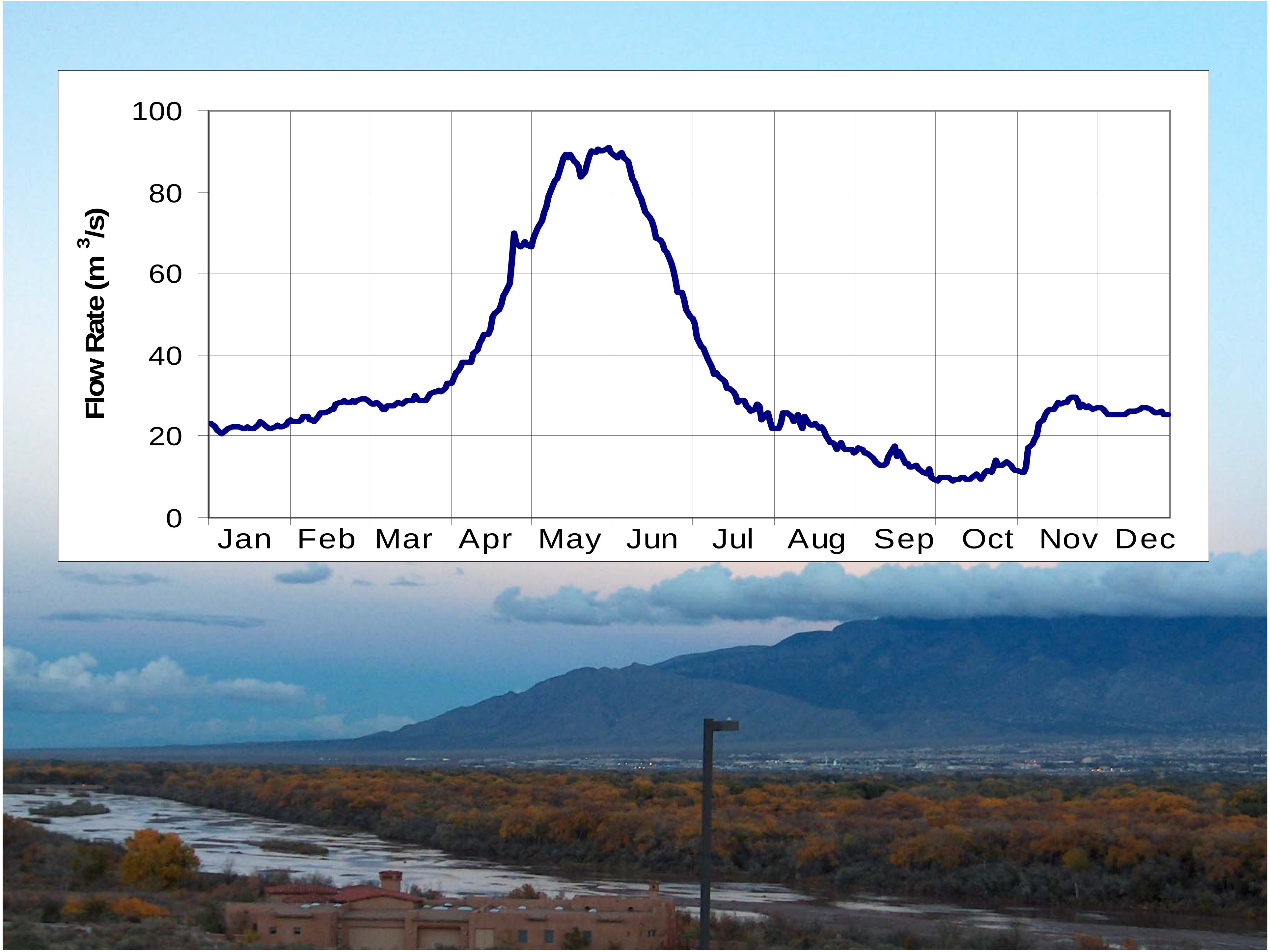


An Introduction to the Middle Rio Grande

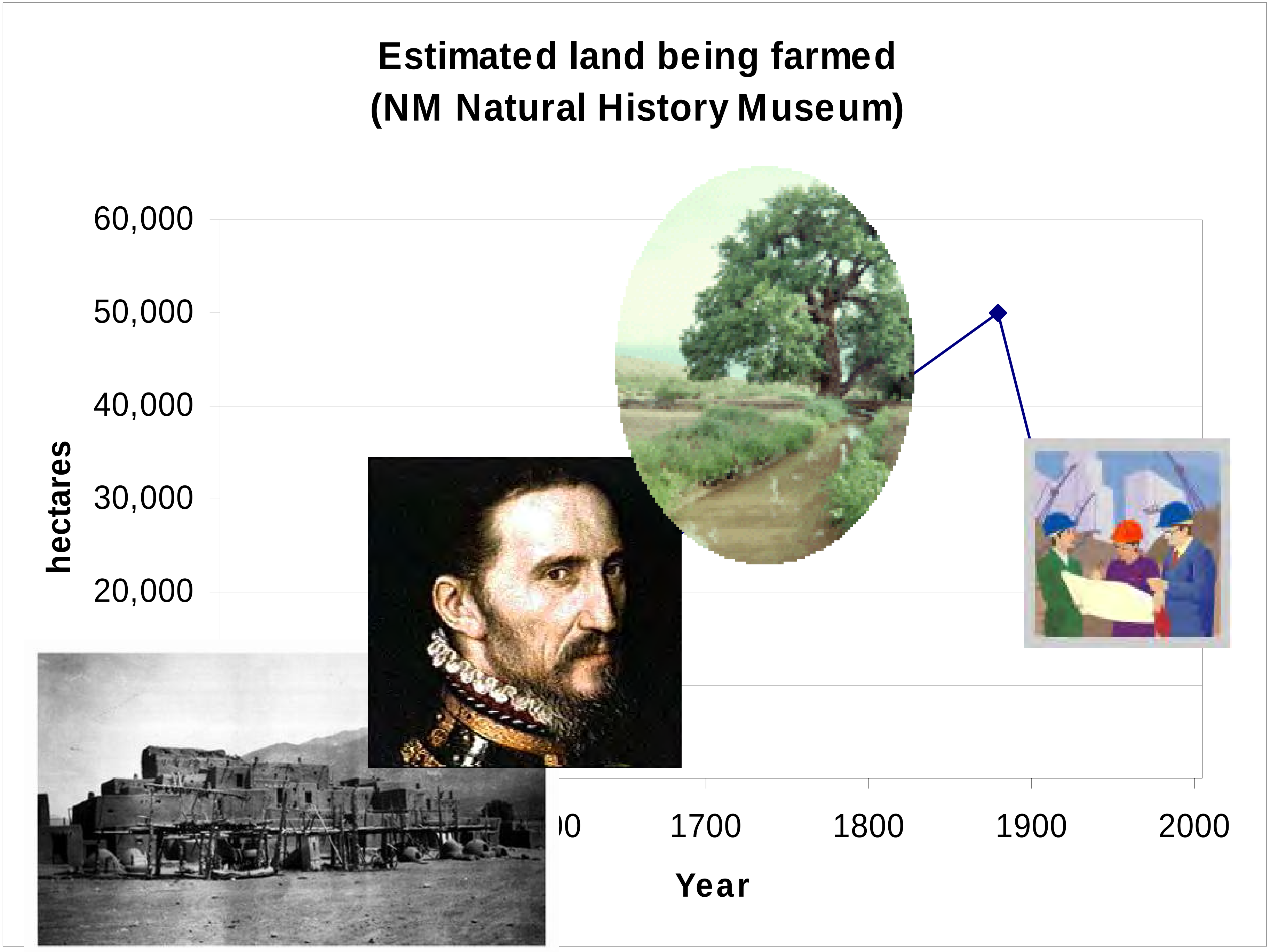
The University of New Mexico
Julie Coonrod, Ph.D., P.E., Assoc. Professor
Civil Engineering, University of New Mexico



Utah
Arizo
Salt
Gila
Mexico
SAN JUAN
RIO ARRIBA
Rio Chama
TAOS
MCKINLEY
LOS ALAMOS
MO
Santa Fe
SANDOVAL
Rio Puerco
Jemez
SANTA FE
SA MIGU
Cochiti Dam
Grants
Rio San Jose
BERNALILLO
Albuquerque
VALENCIA
TORRANCE
Rio Grande
Rio Salado
CATRON
Socorro
SOCORRO
LINCOL
Elephant Butte Reservoir
OTERO
GRANT
SIERRA

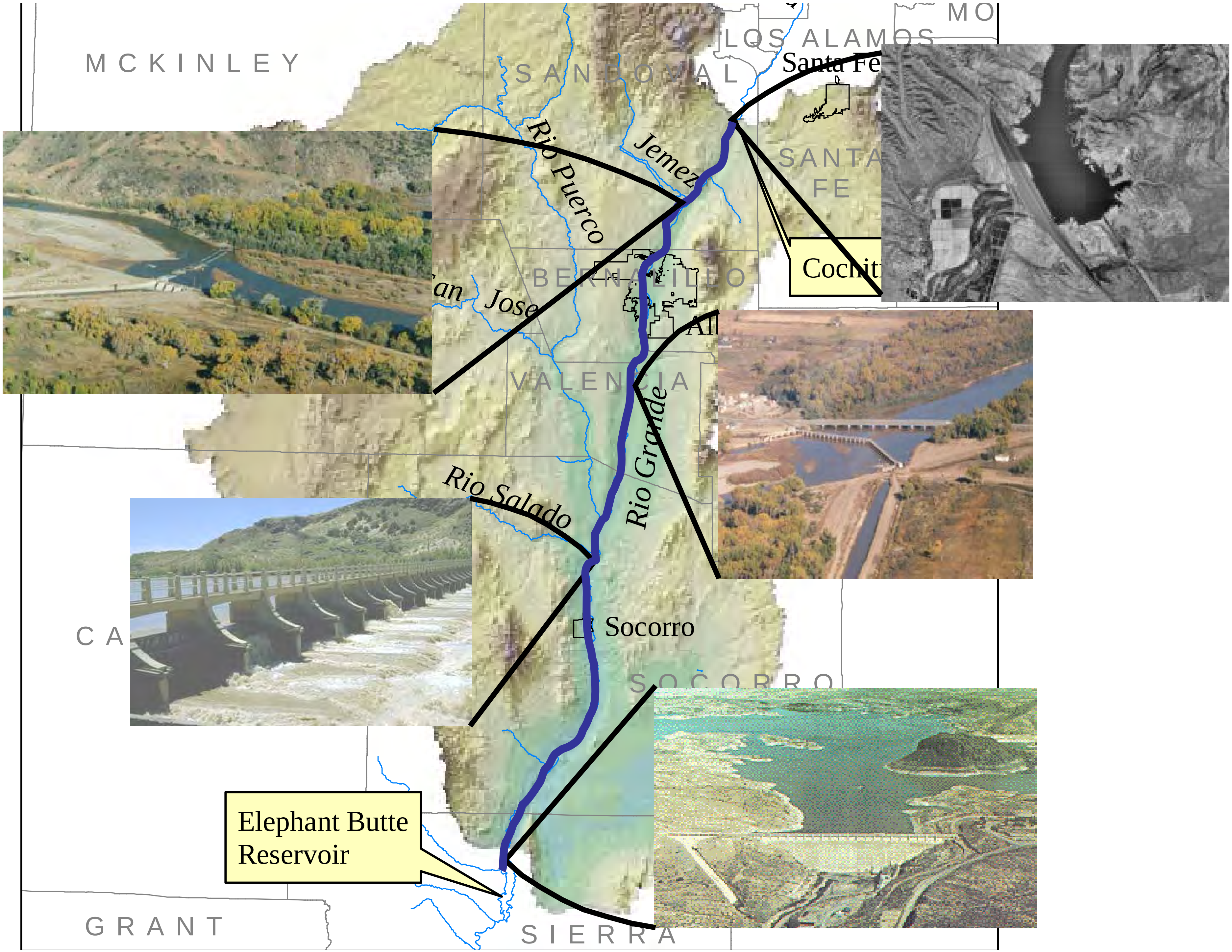


Flow Rate (m 3/s)
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



Estimated land being farmed
(NM Natural History Museum)
60,000
50,000
40,000
30,000
20,000
hectares
)0
1700
1800
1900
2000
Year


Jetty jacks



MCKINLEY
SANDOVAL
LOS ALAMOS
MO
Santa Fe
SANTA FE
Rio Puerco
Jemez
Cochiti
BERNALILLO
Jose
VALENCIA
Rio Grande
Rio Salado
CA
Socorro
SOCORRO
Elephant Butte Reservoir
GRANT
SIERRA

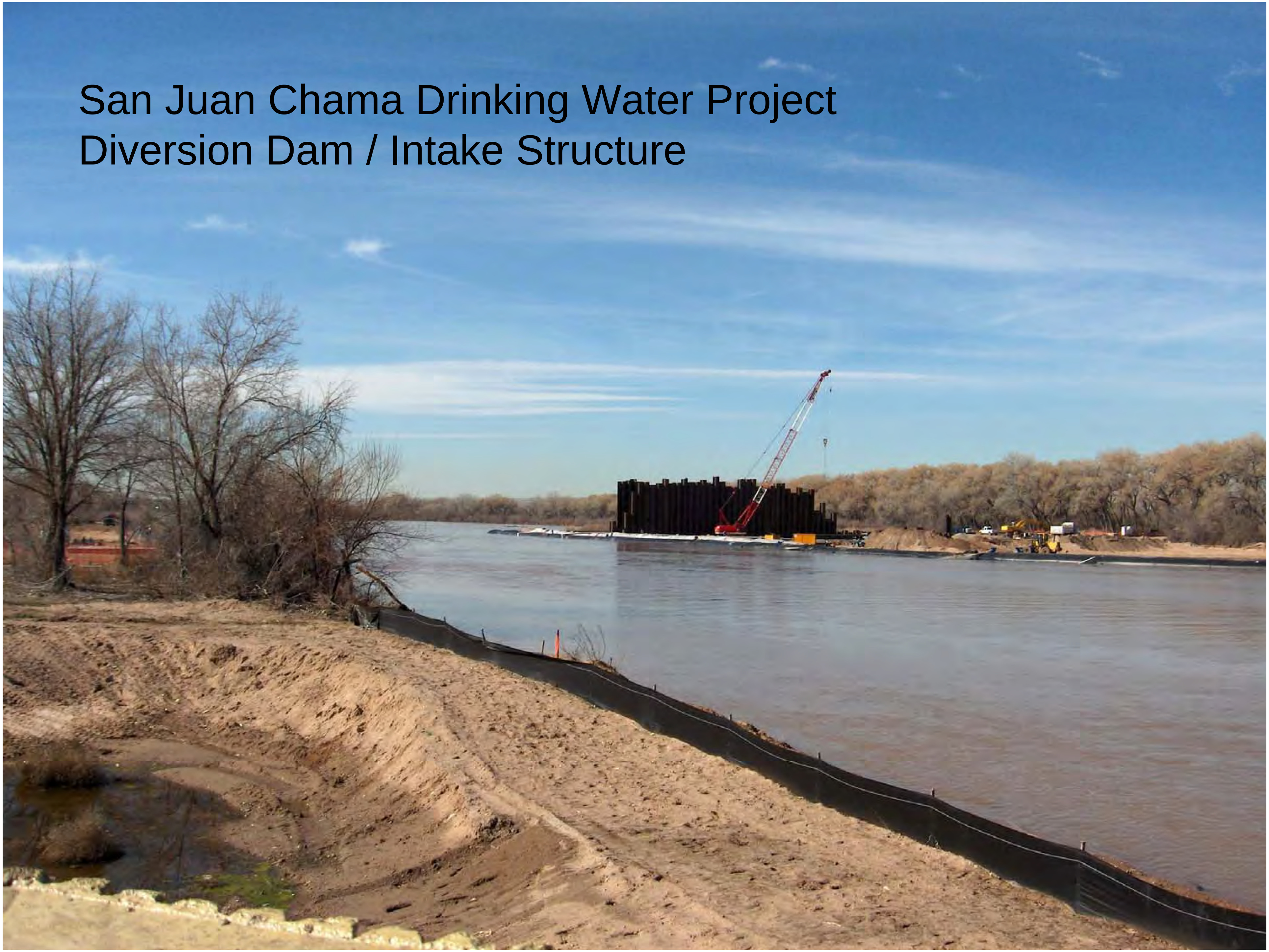
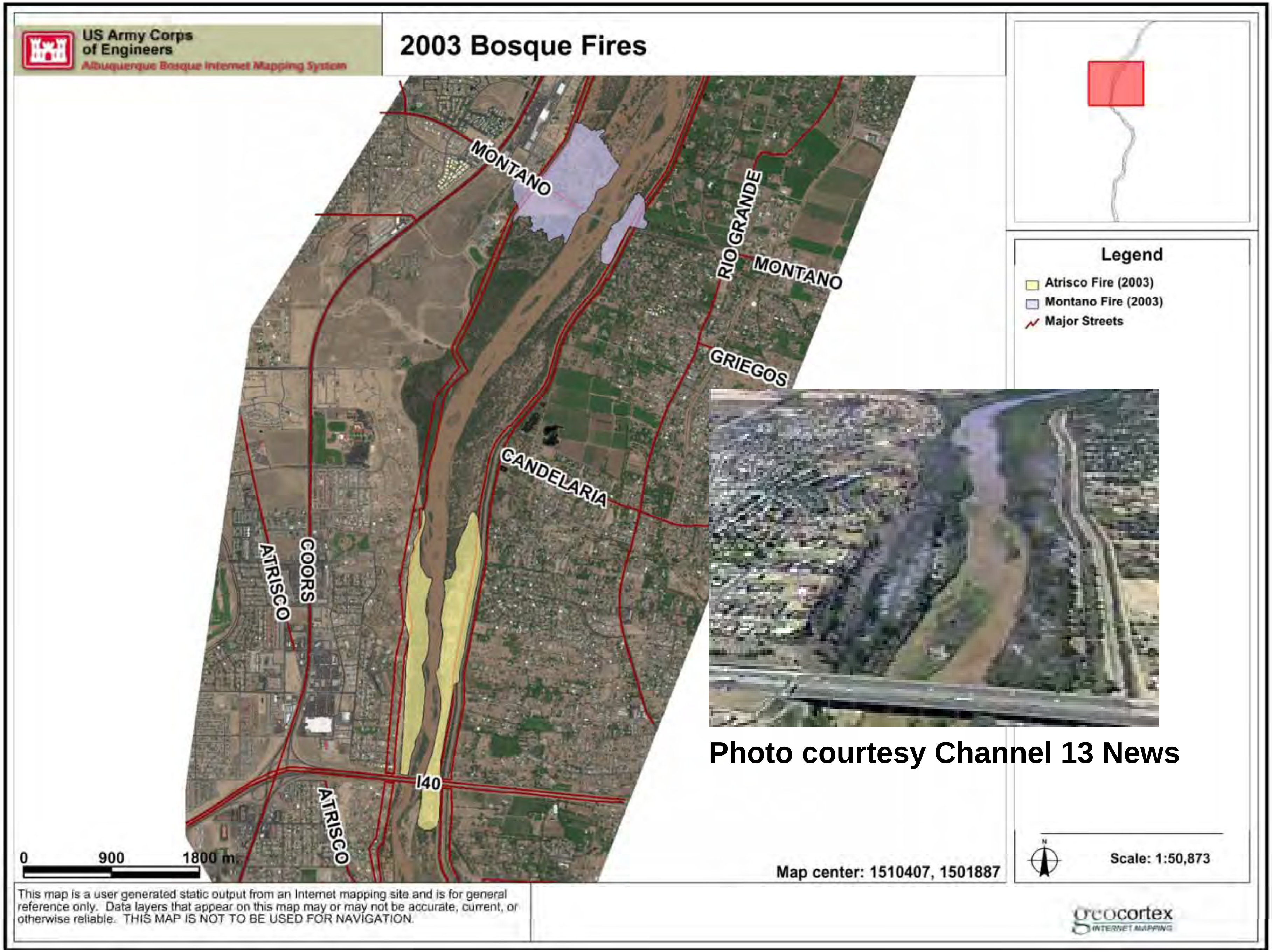

San Juan Chama Drinking Water Project
Diversion Dam / Intake Structure


Photo by Steven Gonzales

To “restore” can mean to put a system into a more natural state than it is currently.

remove exotic vegetation
re-introduce native species
provide habitat for threatened or endangered species
provide recreational opportunities
re-connect a river and its floodplain
remove dams, diversions, and other flow barriers
provide water quality
import fish and/or wildlife

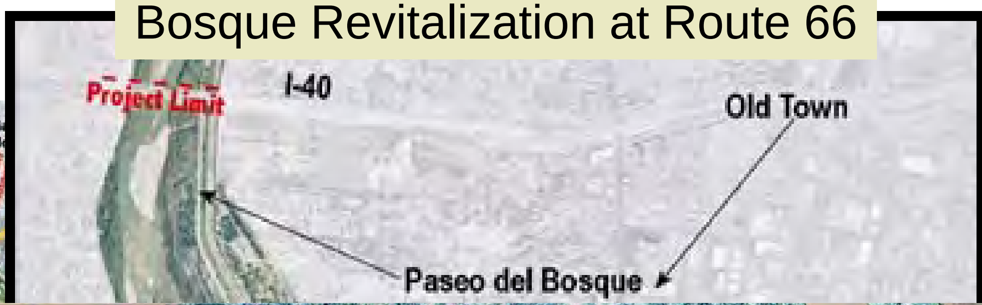

US Army Corps of Engineers
Albuquerque Bosque Internet Mapping System
2003 Bosque Fires
MONTANO
RIO GRANDE
MONTANO
GRIEGOS
CANDELARIA
ATRISCO
COORS
I40
ATRISCO
Legend
Atrisco Fire (2003)
Montano Fire (2003)
Major Streets
Photo courtesy Channel 13 News
0 900 1800 m.
Map center: 1510407, 1501887
Scale: 1:50,873
This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.
geocortex INTERNET MAPPING

Albuquerque Bosque Restoration Projects

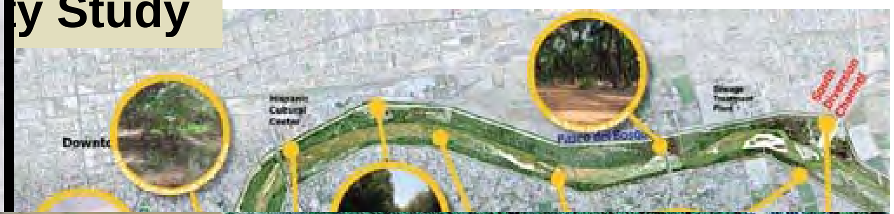
US Army Corps of Engineers

www.bosquerevive.com

Bosque Revitalization at Route 66

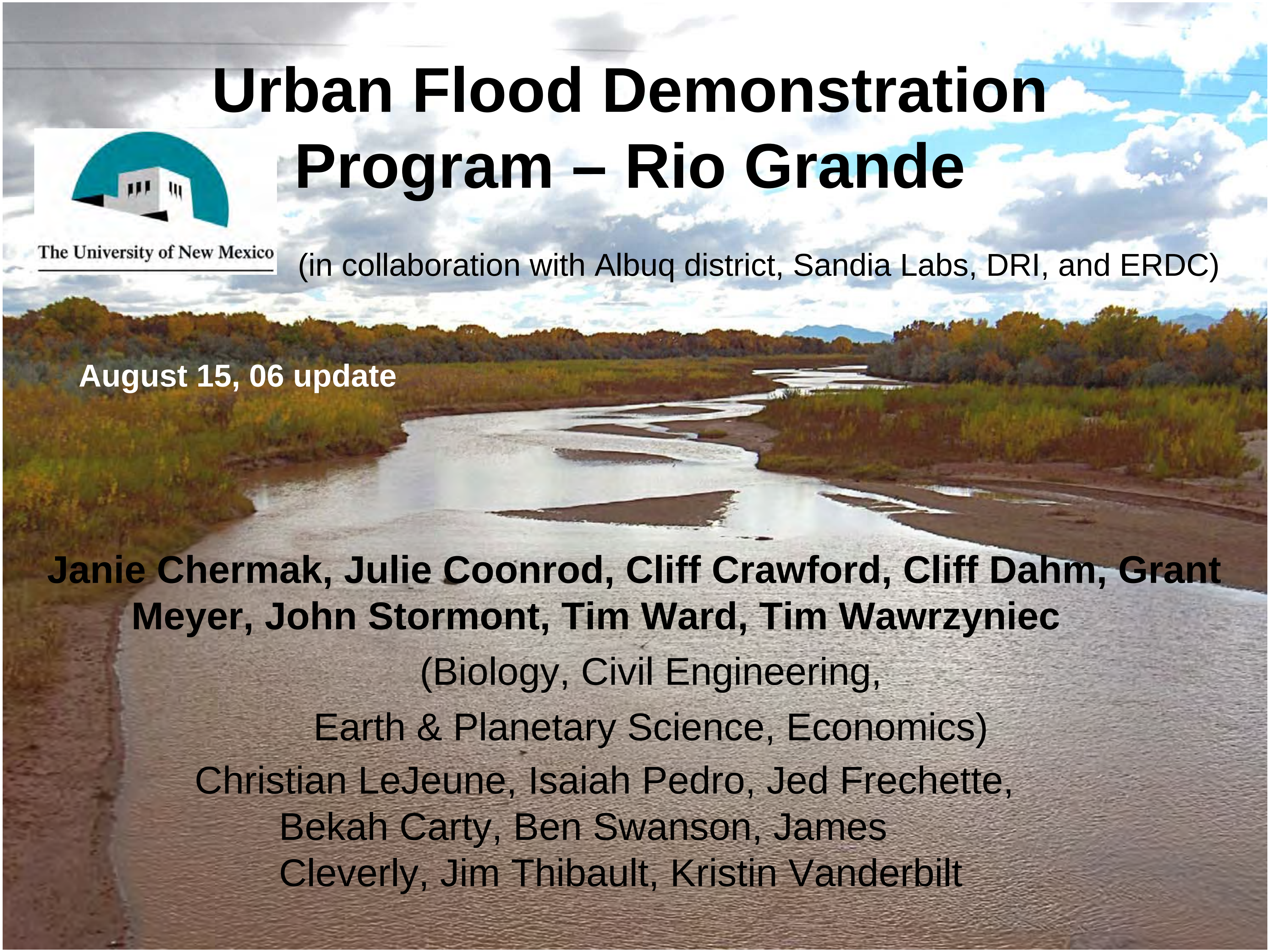


…y Study



Tingley Pond Habitat Restoration and Improvements


Successes:
Endangered species populations increased
Public awareness increased
Fire threat reduced
Challenges:
Sustainability
More water demands
Conflicting opinions/priorities



Urban Flood Demonstration Program – Rio Grande

The University of New Mexico

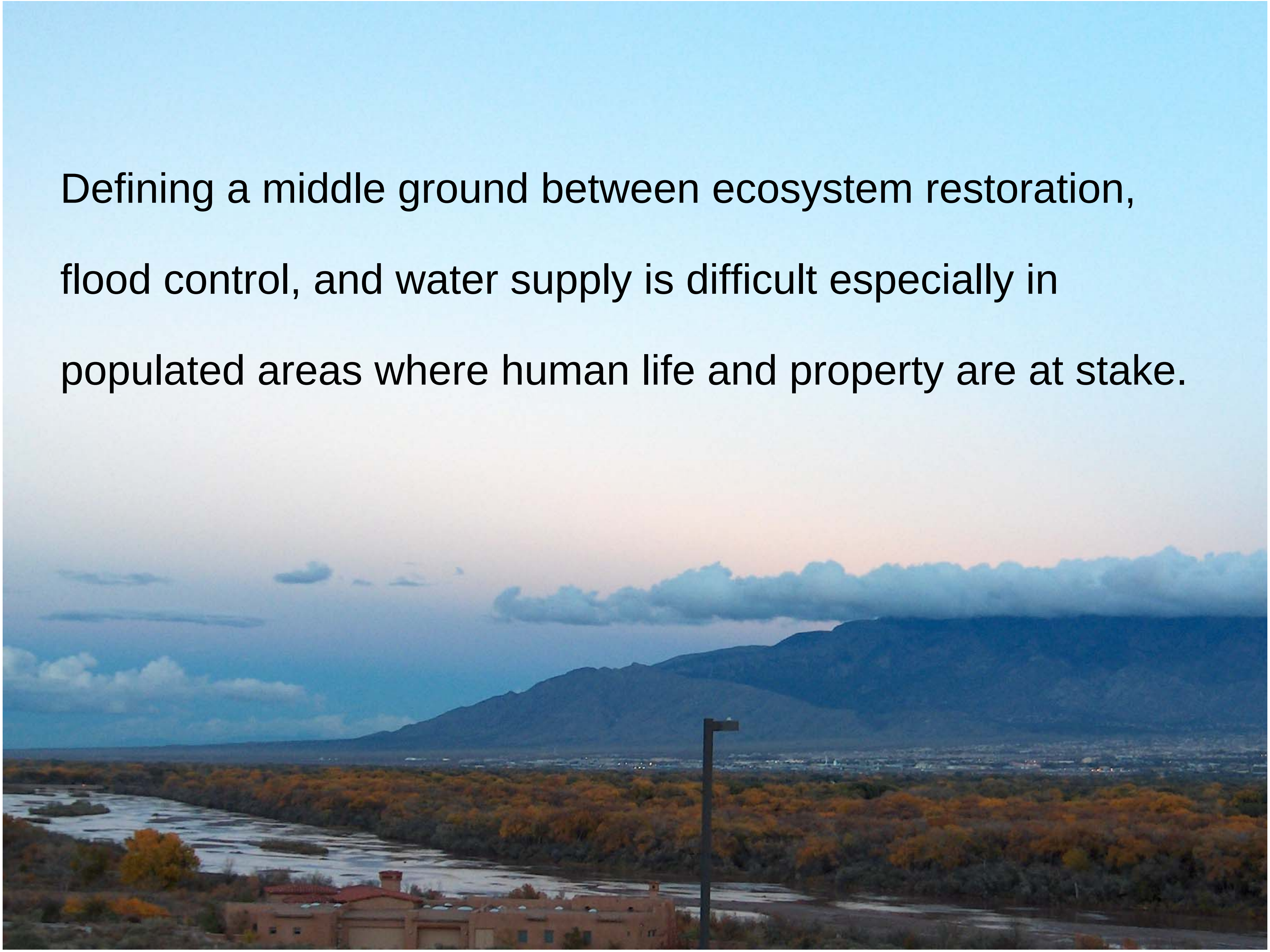
(in collaboration with Albuq district, Sandia Labs, DRI, and ERDC)

August 15, 06 update

Janie Chermak, Julie Coonrod, Cliff Crawford, Cliff Dahm, Grant Meyer, John Stormont, Tim Ward, Tim Wawrzyniec

(Biology, Civil Engineering, Earth & Planetary Science, Economics)

Christian LeJeune, Isaiah Pedro, Jed Frechette, Bekah Carty, Ben Swanson, James Cleverly, Jim Thibault, Kristin Vanderbilt


Defining a middle ground between ecosystem restoration,
flood control, and water supply is difficult especially in
populated areas where human life and property are at stake.

Where is the common ground?

Flood Control	'Restoration'
freeboard	overbank
ba	bility
m	ency of
c	lled
no extr	ents

Use of floodplain

Better understanding role of vegetation along banks and current role (if any) of jetty jacks

What flood frequencies can the current system handle?
How is sediment moved at those frequencies?

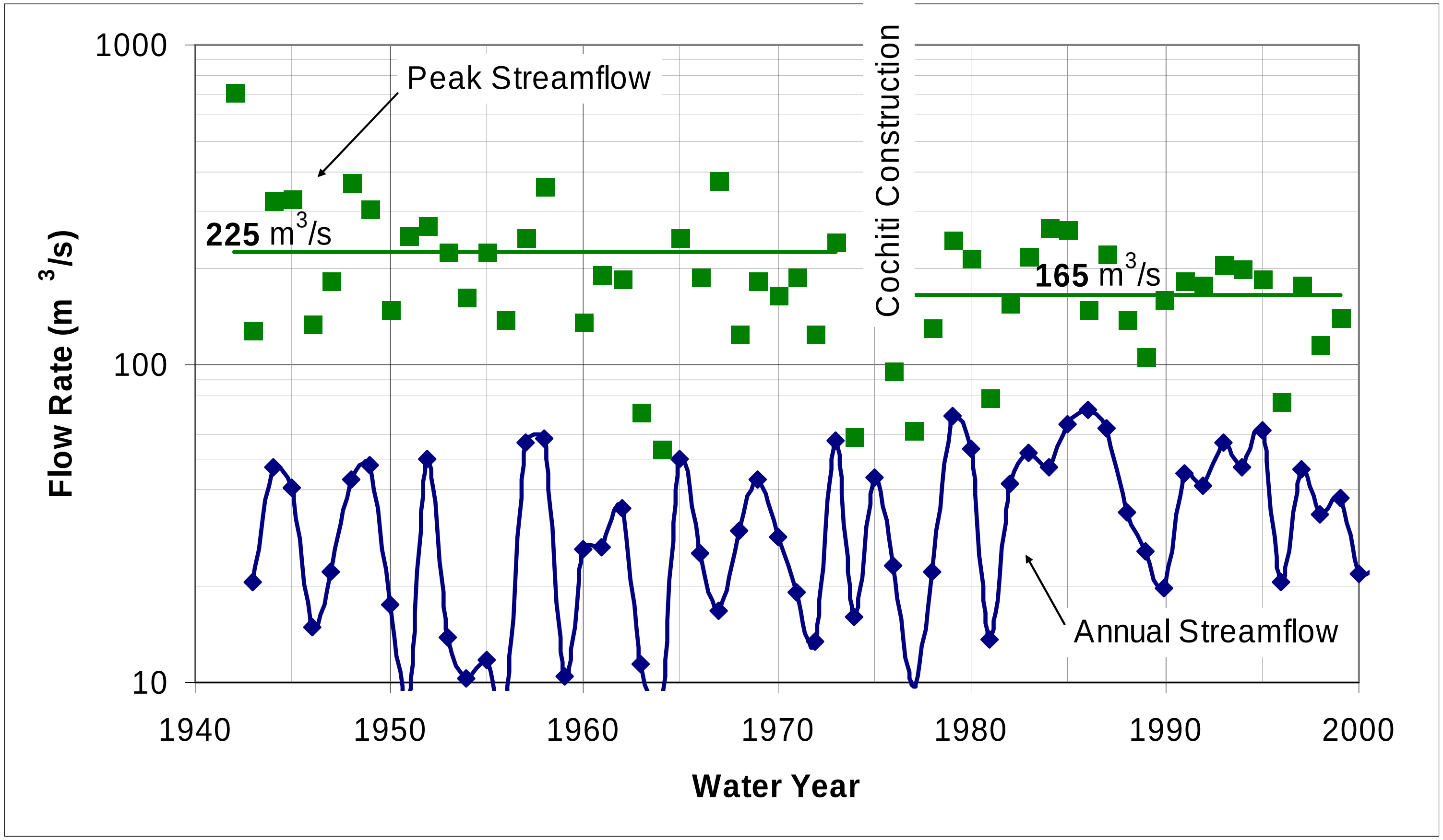
Control where human life is at stake is necessary

Engineer "extreme" events back into the system

All while water deliveries are met.

Albuquerque river system

- •Cochiti Dam in 1970's
- •River continues to incise (resulting in less overbanking even when higher flows exist)
- •Channel bottom becoming more coarse



FY06 UNM projects

16. State of flood related modeling
17. Investigating groundwater/surface water interaction between Alameda and Paseo del Norte bridges
18. ET, water tables, diel fluctuations, flow fields and riparian zone restoration
20. Bank erosion monitoring
21. Coupling of hydrologic/hydraulic models and aerial photos through time

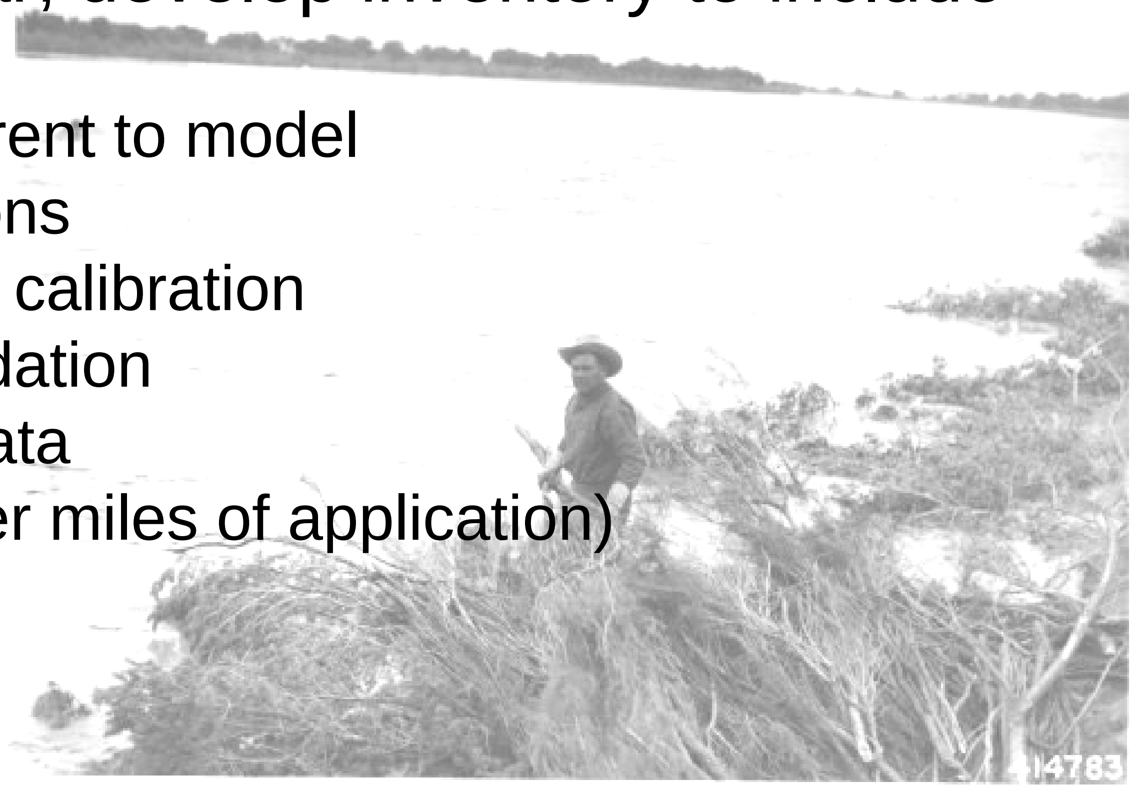
State of flood related modeling

Location: Middle Rio Grande

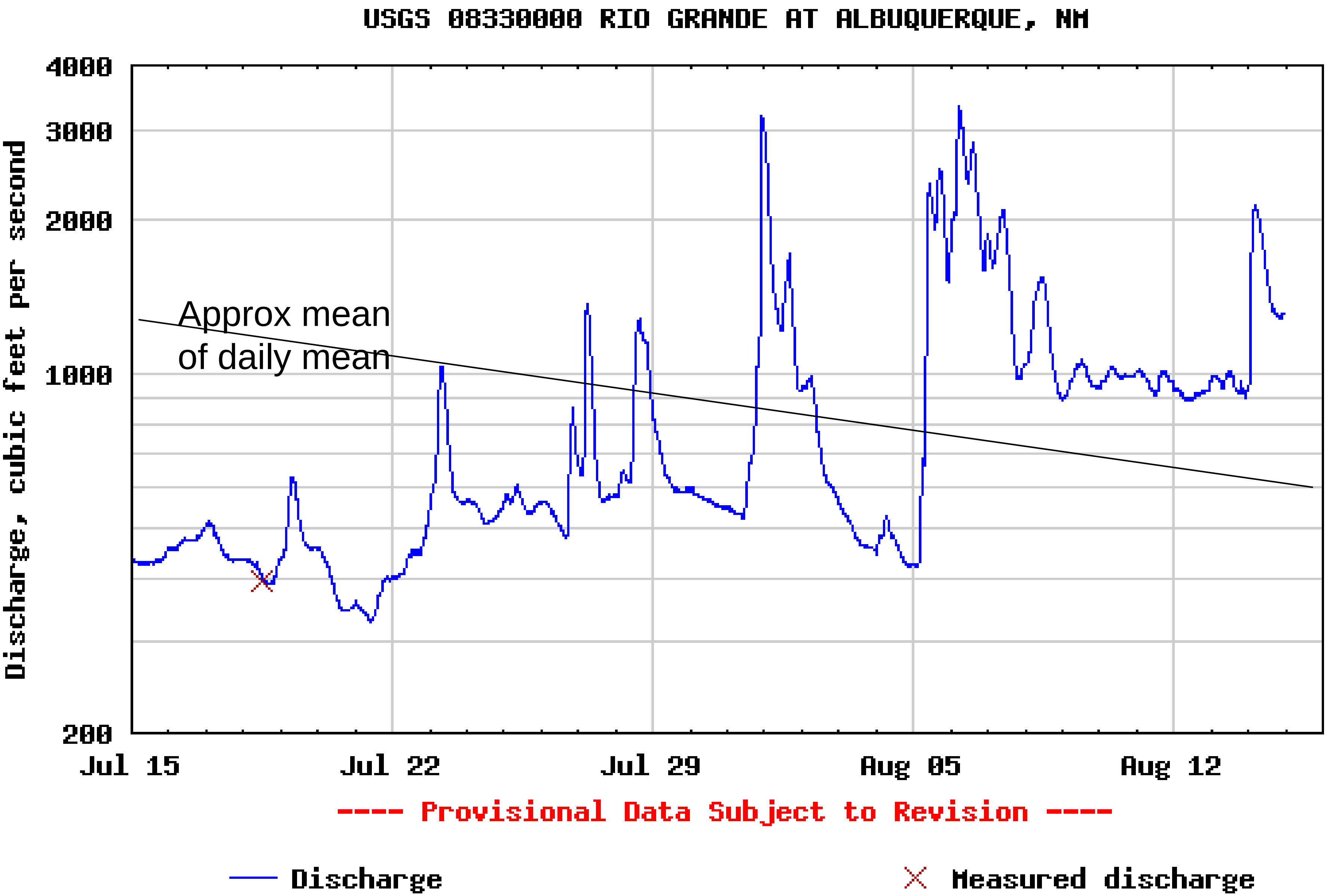
Purpose: Identify issues and needs

Methods: Literature review, stakeholder interviews, seminar, develop inventory to include

- Model used
- Assumptions inherent to model
- Governing equations
- Variables used for calibration
- Data used for validation
- Ranges of input data
- Spatial extent (river miles of application)




Greatest focus to date: field work!


USGS 08330000 RIO GRANDE AT ALBUQUERQUE, NM
Discharge, cubic feet per second
4000
3000
2000
1000
200
Jul 15
Jul 22
Jul 29
Aug 05
Aug 12
Approx mean of daily mean
---- Provisional Data Subject to Revision ----
Discharge
Measured discharge

Investigating groundwater/surface water interaction between the Alameda and Paseo del Norte bridges

Location characteristics: downstream of urban outfall, new diversion dam, Calabacillas outfall

Purpose: adaptive bosque management, bank storage, provide validation/calibration for Sandia, ERDC & DRI models

Monitor ground water levels

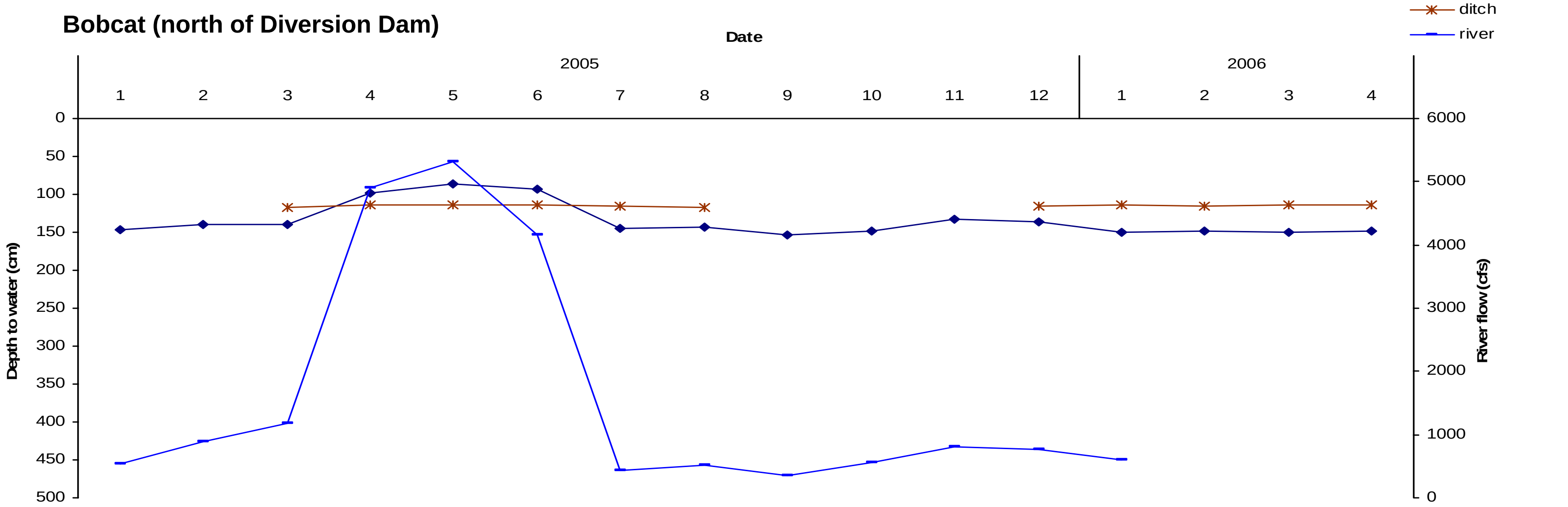
Continue monitoring 6 wells with pressure transducers and conduct manual measurements of existing wells.

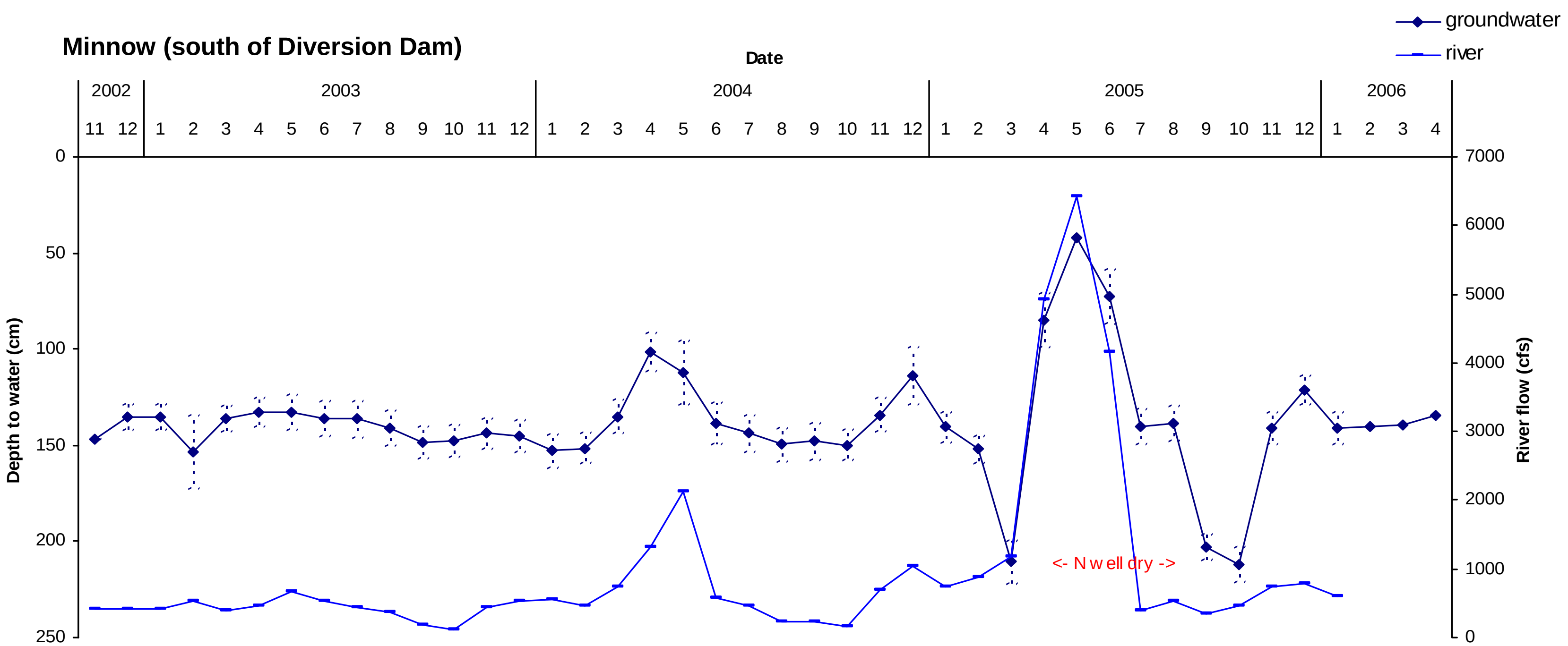
Instrument an additional 12 wells for continuous ground water levels using pressure transducers.

Christian LeJeune Measuring Water Depth Using a Well Beeper

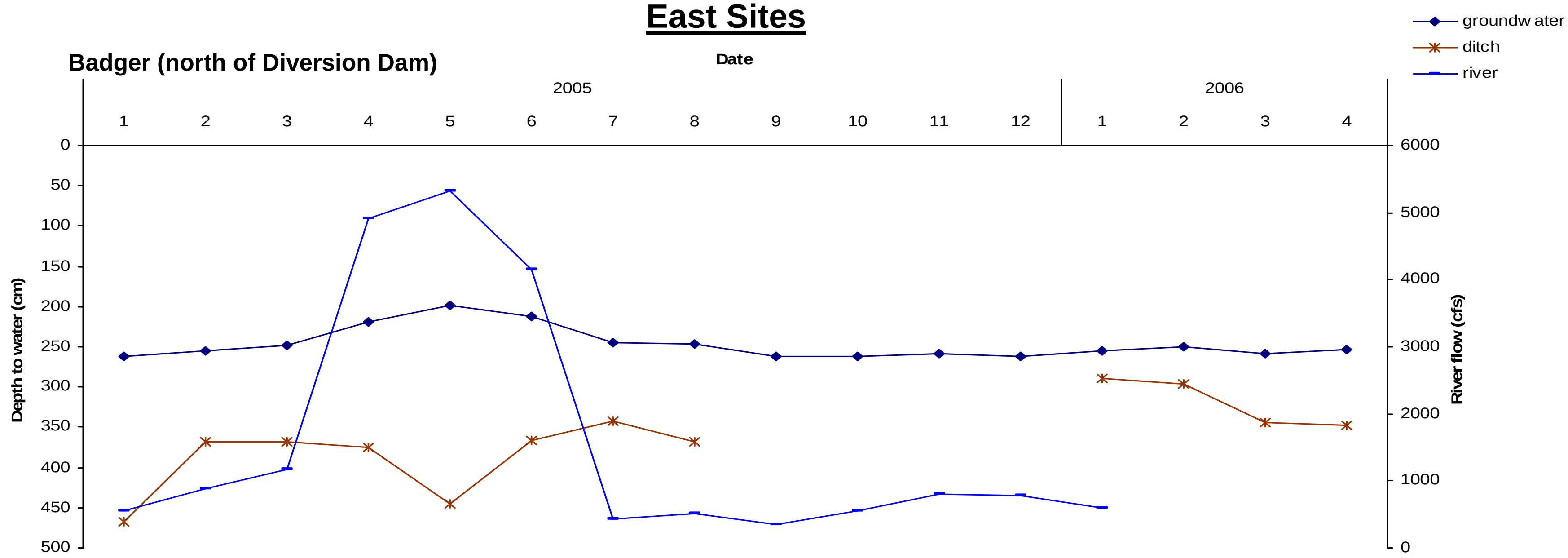
Status: pressure transducers ordered.

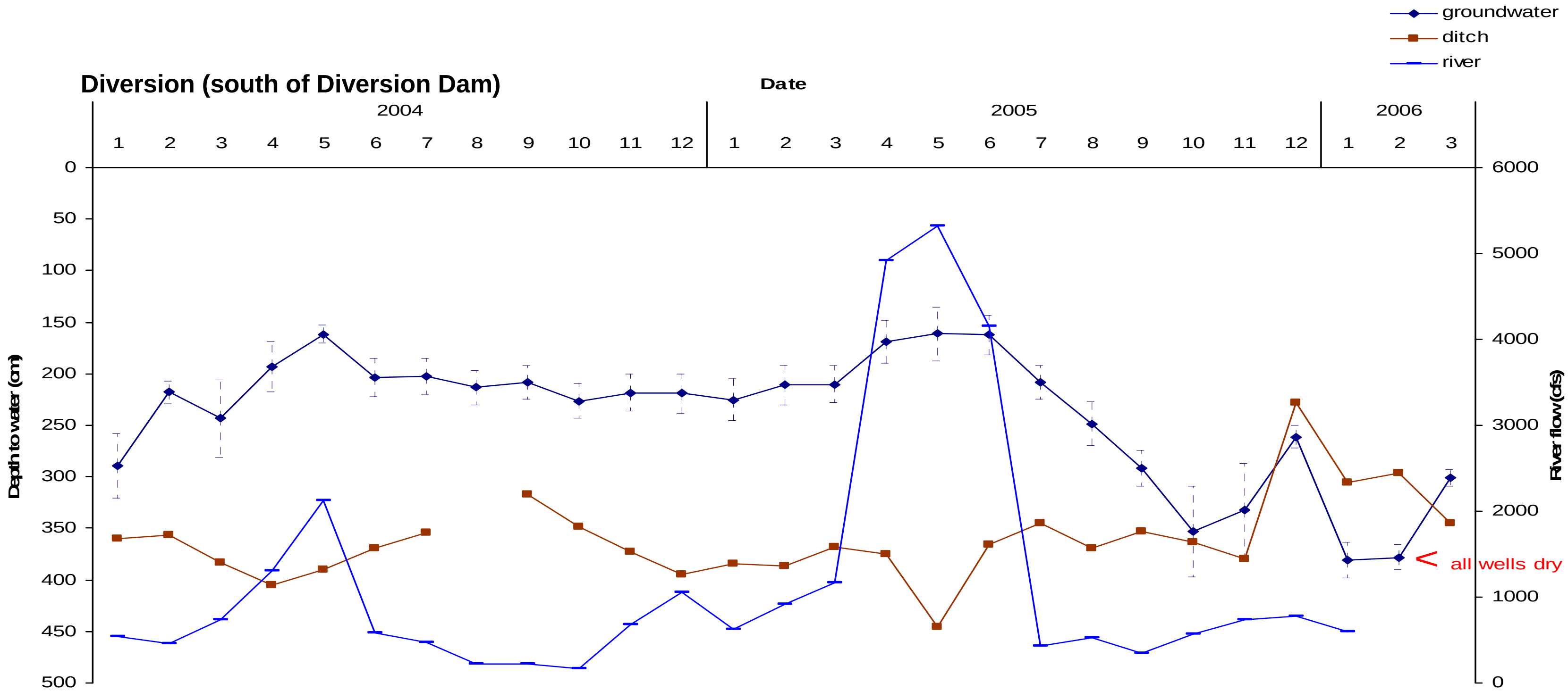
West Sites


Bobcat (north of Diversion Dam)
Date
2005
2006
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
Depth to water (cm)
River flow (cfs)
0 50 100 150 200 250 300 350 400 450 500
6000 5000 4000 3000 2000 1000 0
groundw ater
ditch
river


Minnow (south of Diversion Dam)
Date
2002
2003
2004
2005
2006
11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
Depth to water (cm)
River flow (cfs)
0 50 100 150 200 250
7000 6000 5000 4000 3000 2000 1000 0
<- N w ell dry ->
groundwater
river

East Sites


Badger (north of Diversion Dam)
Date
2005
2006
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
Depth to water (cm)
River flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
6000
5000
4000
3000
2000
1000
0
groundwater
ditch
river


Diversion (south of Diversion Dam)
Date
2004
2005
2006
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
Depth to water (cm)
River flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
6000
5000
4000
3000
2000
1000
0
groundwater
ditch
river
< all wells dry

Riparian soil characterization

Intensely sample soils between surface and ground water

Classify soils, and measure their hydraulic properties, e.g.,

•Hydraulic conductivity

•Unsaturated parameters

•Water-holding capacity

Status: 8 of 20 boring for samples completed.

Isaiah Pedro Using Auger to
Drill Coring Sample

Placing Coring Sample
on Table for Testing

I. Pedro and C. LeJeune Field
Classifying Coring Sample

Soil samples brought to laboratory for
hydraulic properties testing.

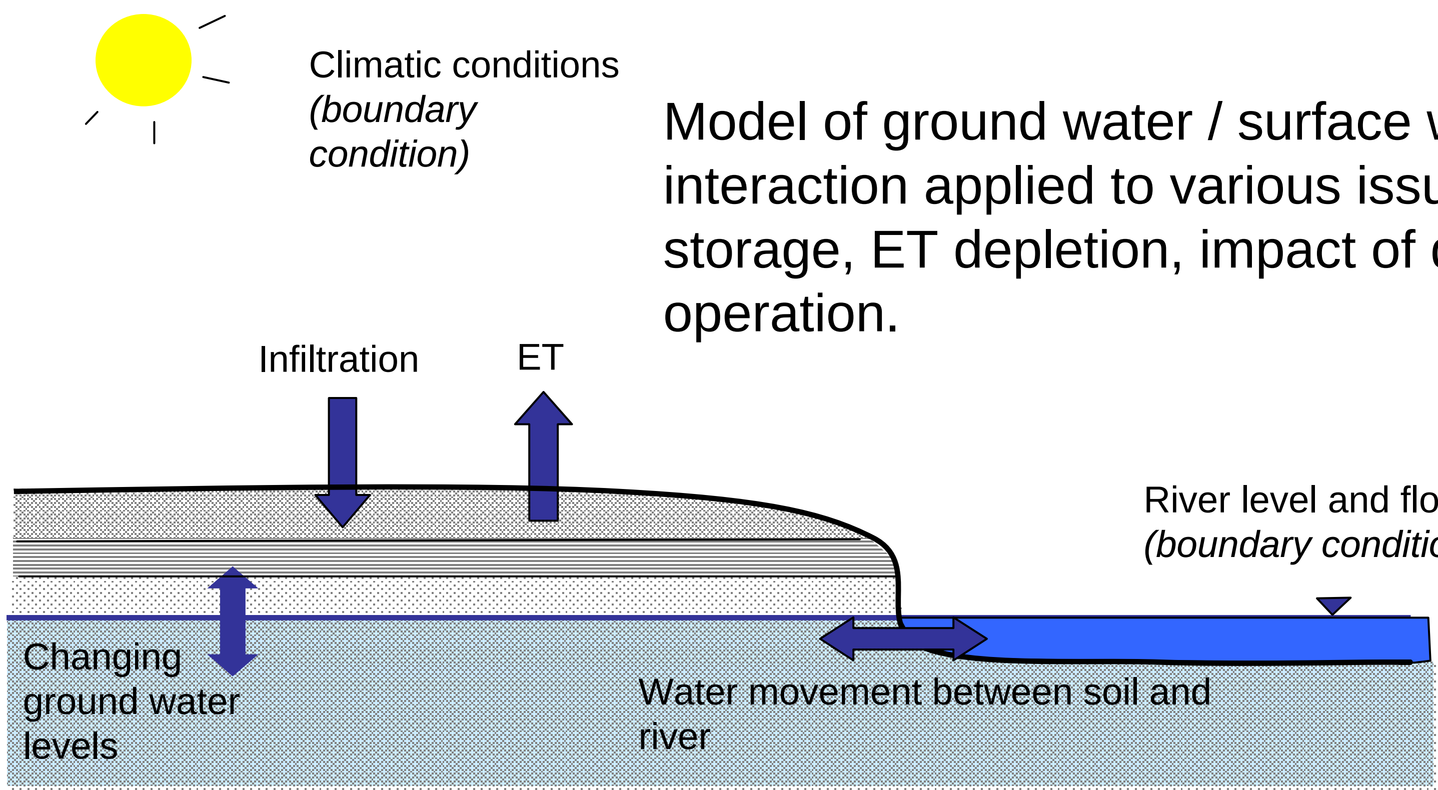
Monitor bosque ecology

Vegetation Plot Within Well Area

Model of ground water / surface water interaction
measurements and monitoring data used as input

Data base available to all, including river levels and flows, ground water levels, soil types and properties, and ecological response.

Model of ground water / surface water interaction applied to various issues, e.g.: bank storage, ET depletion, impact of dam operation.



ET, water tables, diel fluctuations, flow fields, and riparian zone restoration

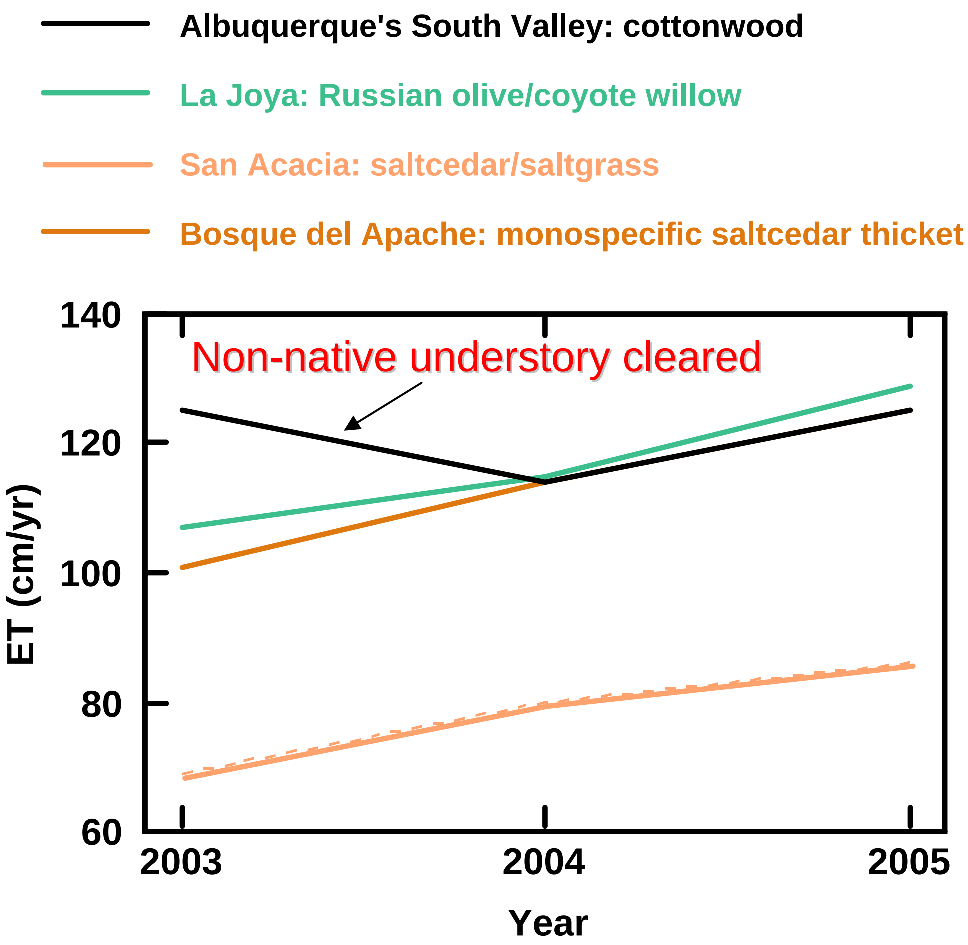
Location: Middle Rio Grande

Purpose: Restoration and flooding effects on ET and alluvial groundwater dynamics

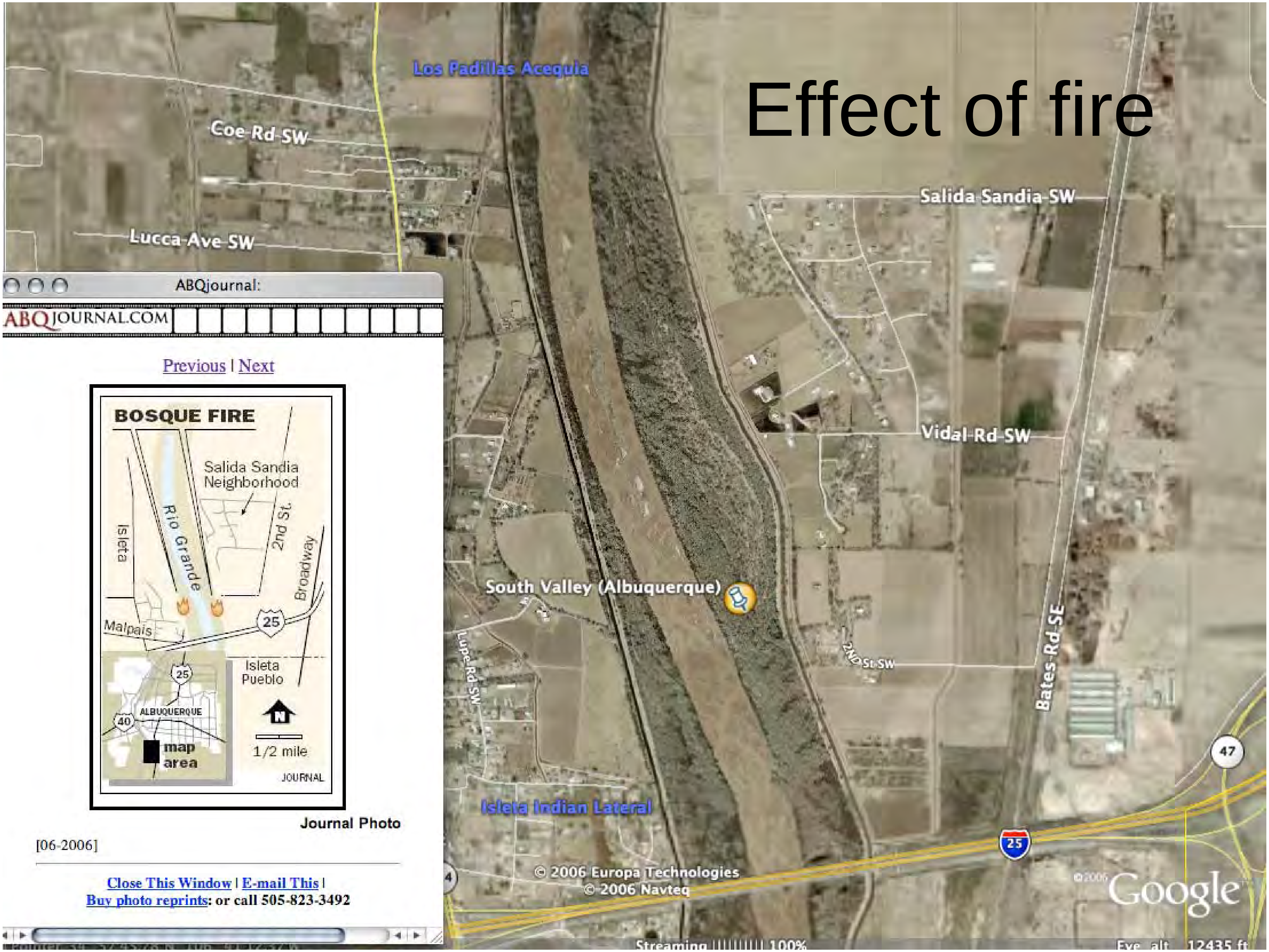
Methods: 3-D eddy covariance towers, groundwater wells, compare diel groundwater fluctuations to measured ET

Restoration water salvage

- Understory Russian olive and saltcedar removed from South Valley Albuquerque cottonwood forest between 2003 and 2004 growing seasons
- First year reduction in ET of 9% while other sites increasing by 12% (total = -21% or -26 cm/yr)
- Second year increase matched increase at other sites: 0 cm/yr



Effect of fire



Bank Erosion Monitoring

Location: Calabacillas outfall

Purpose: determine river response to tree removal, evaluate bank stability

Methods: monitor bank stability with erosion pins and LiDAR

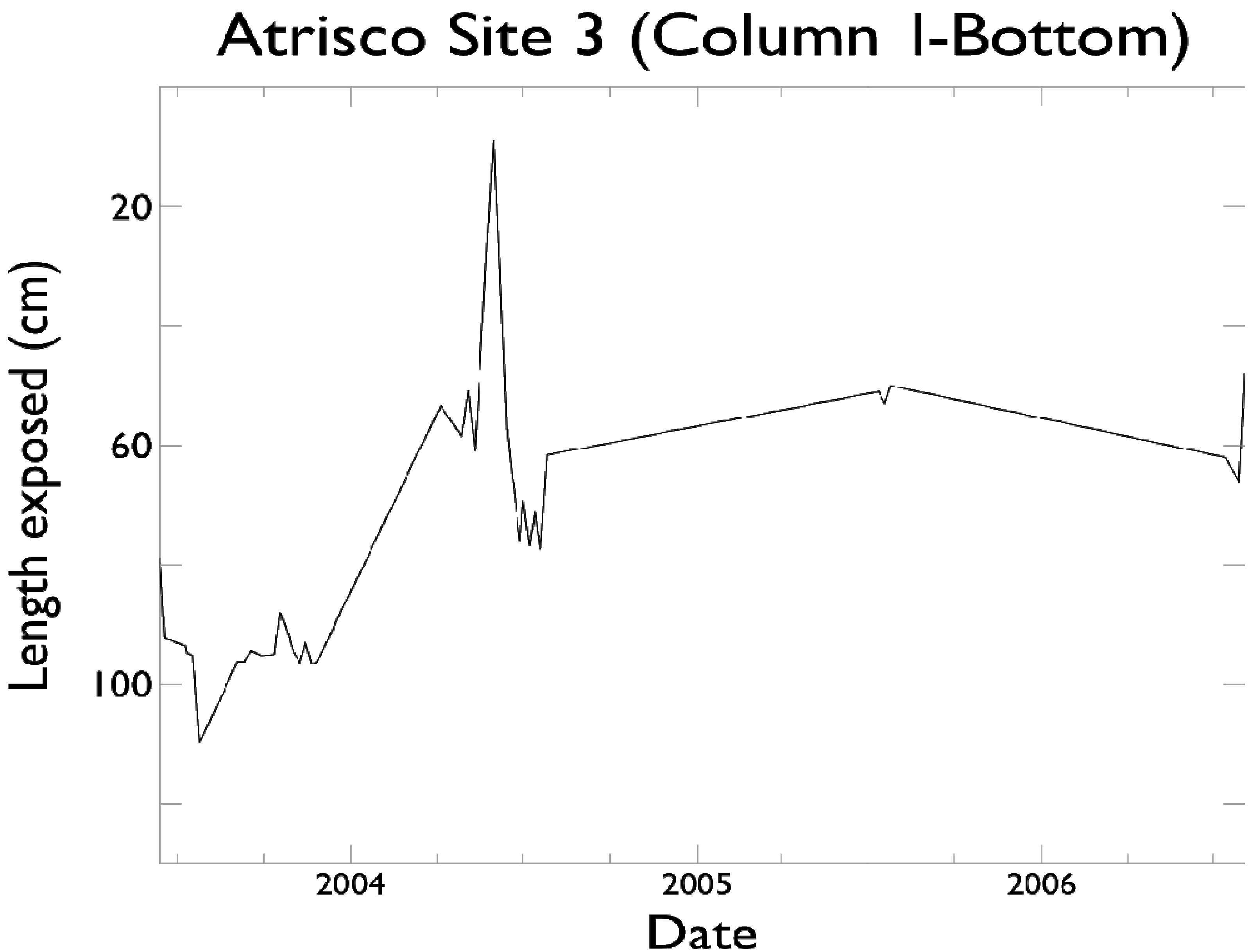
Erosion pins

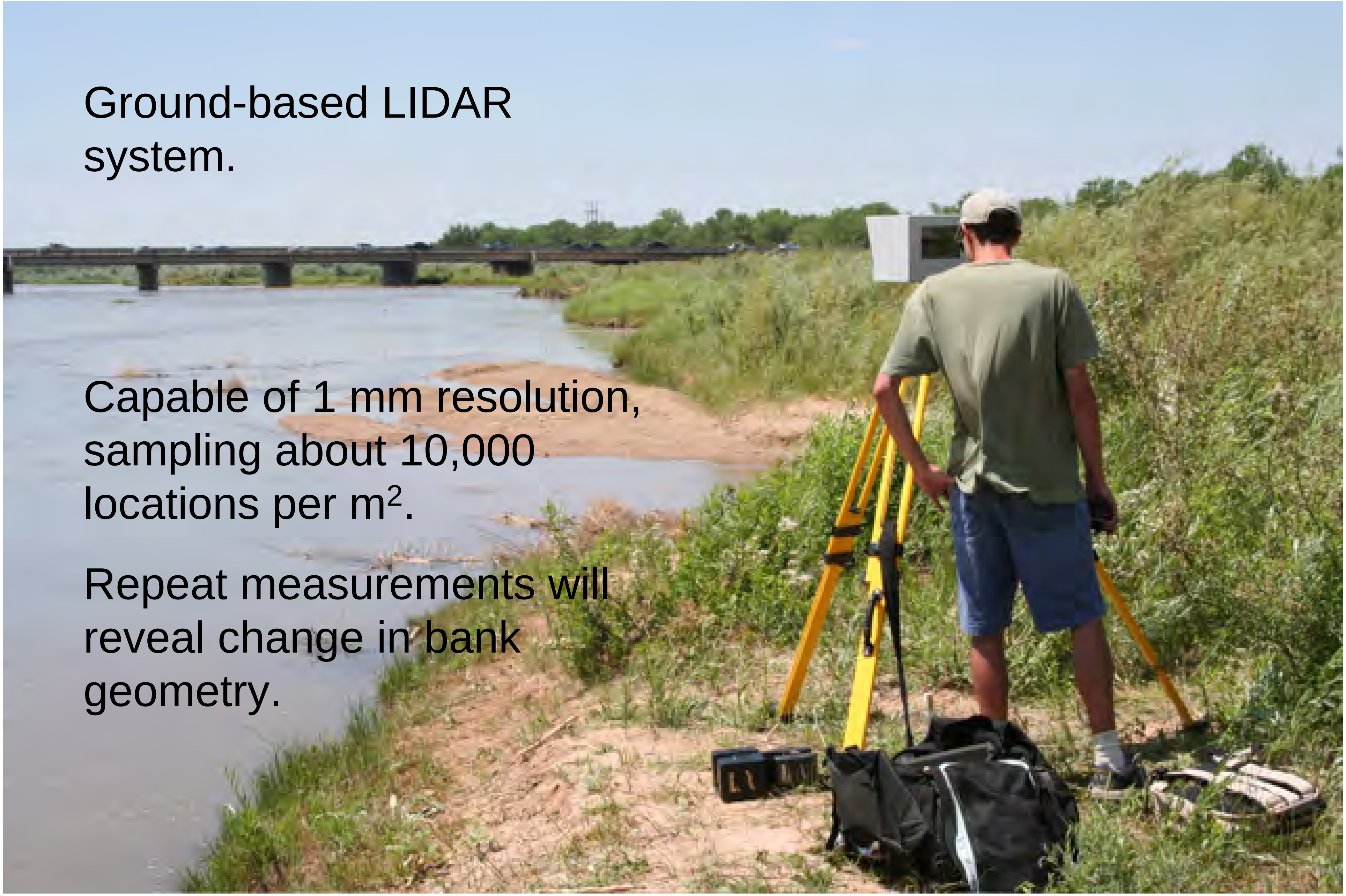
Located in sets above and below typical water surfaces.

First sets installed near Central Bridge in 2000, and periodically monitored.

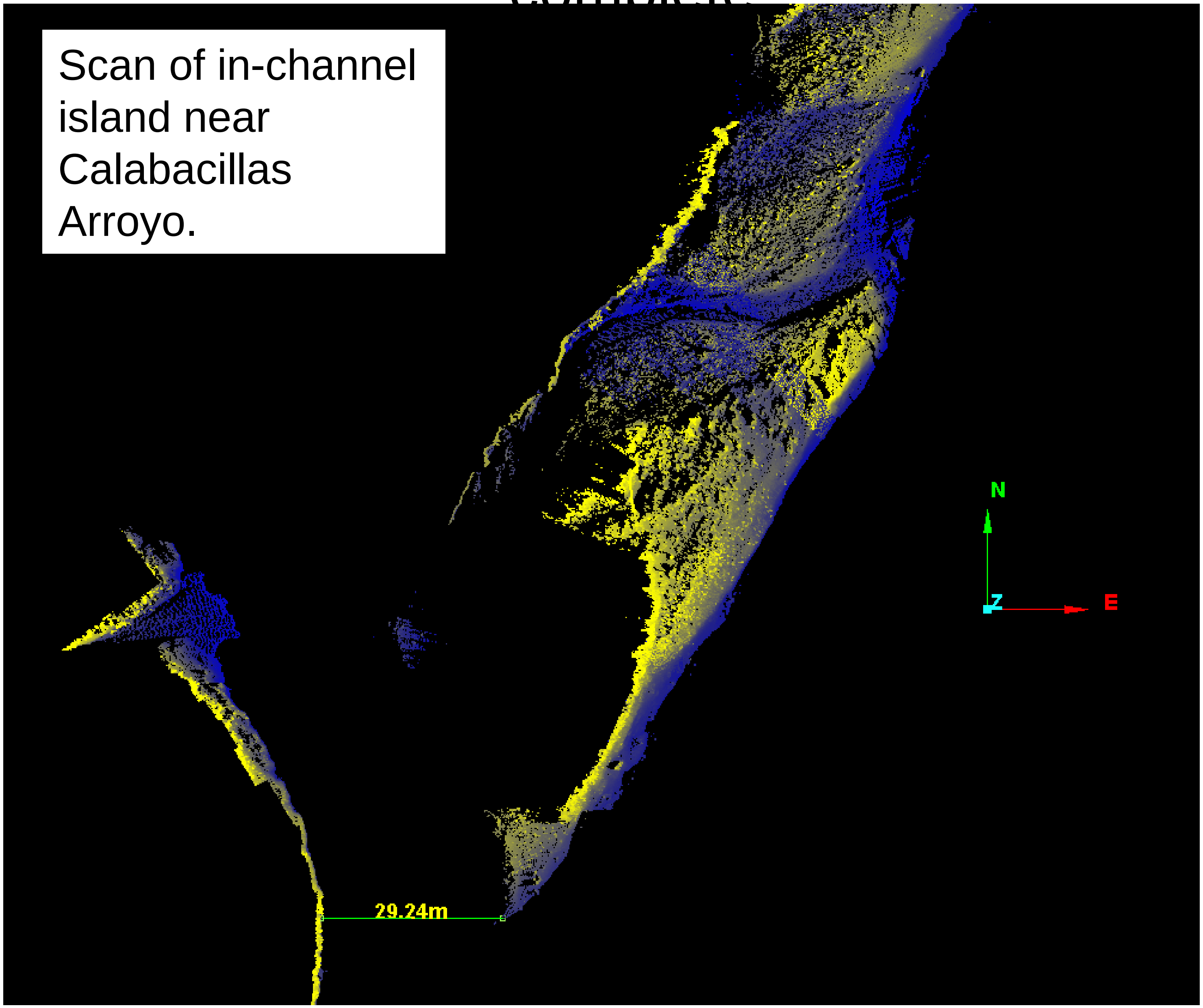
Second set installed near diversion dam and Calabacillas Arroyo in 2006.

Simple, manual measurement method.


Atrisco Site 3 (Column 1-Bottom)
Length exposed (cm)
20
60
100
2004
2005
2006
Date


Ground-based LIDAR system.
Capable of 1 mm resolution, sampling about 10,000 locations per m^2.
Repeat measurements will reveal change in bank geometry.

Initial scans of 1 km of bank near diversion dam complete




Calabacillas Arroyo
CW20

Coupling of hydrologic/hydraulic models and aerial photos through time

Location: Albuquerque reach

Purpose: track movement of sediment through the system over time

Methods: acquire aerial photos, develop algorithm to measure river widths and sandbar widths, identify areas of sediment movement and compare with the hydrologic record

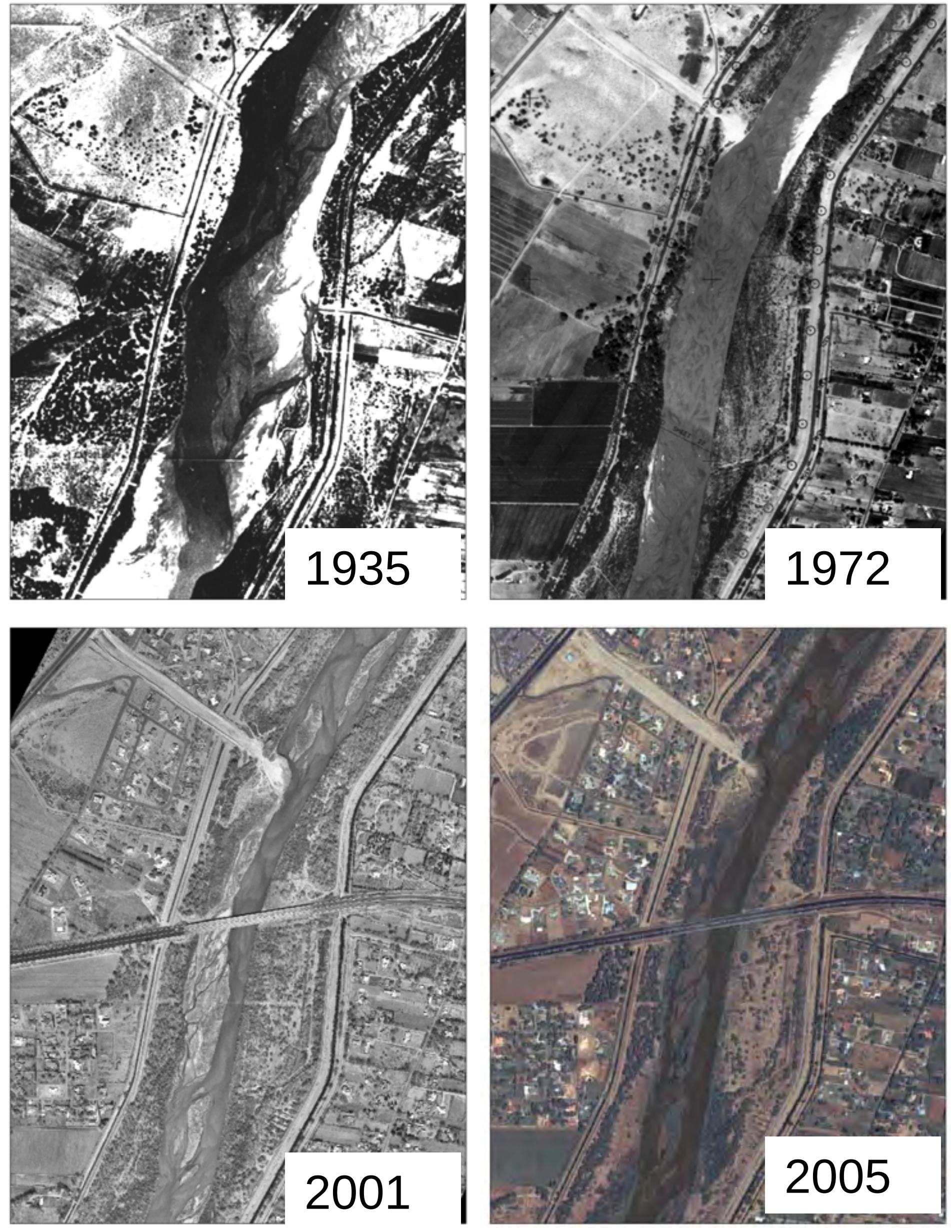
Aerial Photography

Available Photos (obtained)

Year	From
1935	USBR/USACE
1949	USBR/USACE
1972	USBR/USACE
1984	USBR/USACE
1996	Bernalillo Co.
1999	Bernalillo Co.
2001	USBR
2002	Bernalillo Co.
2004	Bernalillo Co.
2004	USACE - Quickbird
2005	USACE - Quickbird
2006	USBR

Database Development:

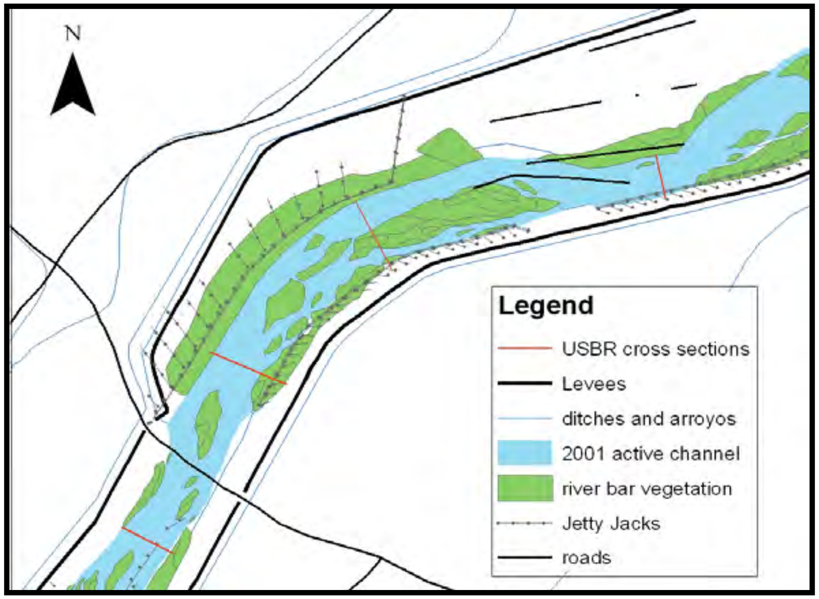
Photo date
Avg Daily Discharge
Photo Resolution



Build GIS Database

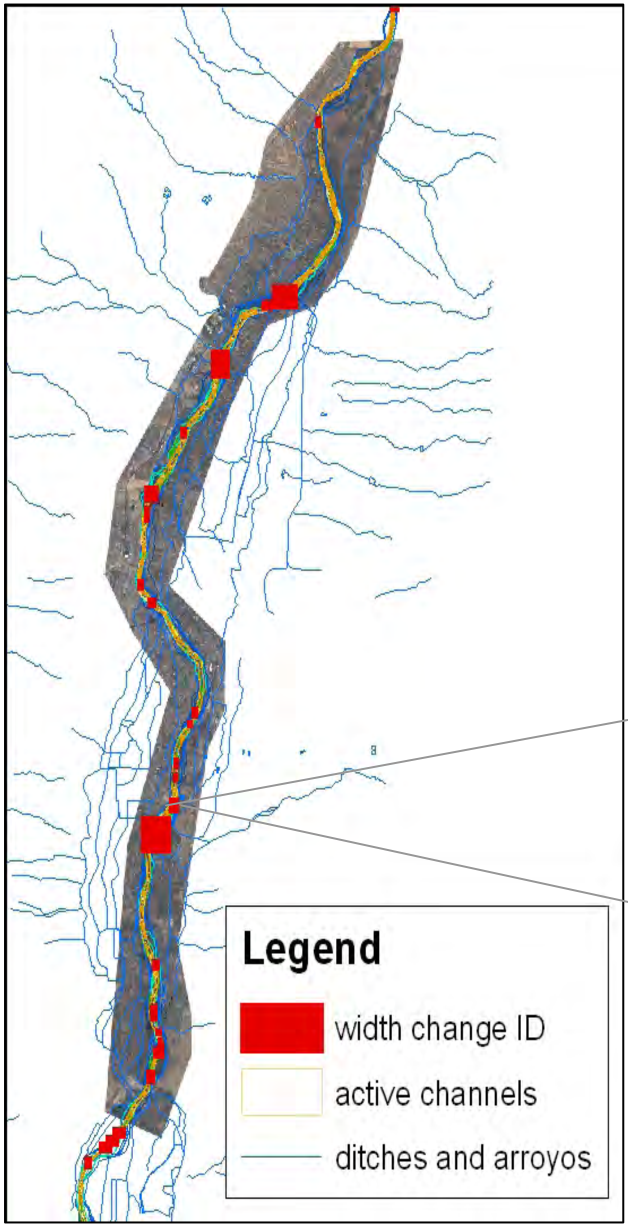
Data	Contents	Obtained from
Historic Active Channel	Channels and Vegetated Islands	USBR (Oliver 2004)
Ecology Data	Vegetation and Terraces	USBR/USACE
Infrastructure Data	Jetty Jack Lines, Levees, Temp Bridges, etc.	USACE
Elevations	2ft Contours for Bosque, DEMs	USACE
Cross Sections	Cross Section Lines and Profile Data	USBR
General	Roads, Hydro, Orthophotos, Topos, Etc	RGIS and Bernalillo Co.

For use in this or other UFDP projects –
gw/sw interaction, bank erosion, etc.



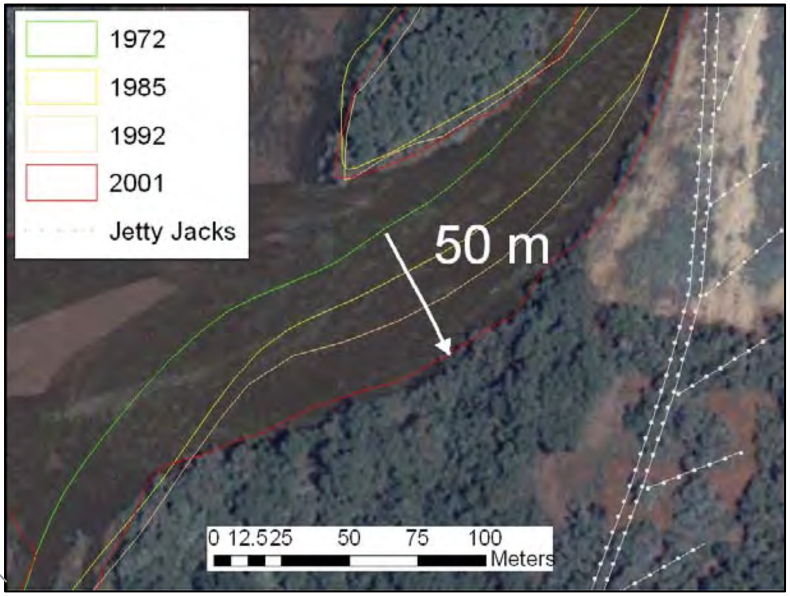
Rio Grande Above Alameda Blvd Bridge

Measure changes in channel and sandbar widths



- Bank erosion and channel change identified using historical channels (1935 to 2002 – Oliver 2004 data USBR).
- Banks are being digitized from more recent photos (2004, 2006).
- USBR (Massong 2005) observed little erosion after 2005 high flows.

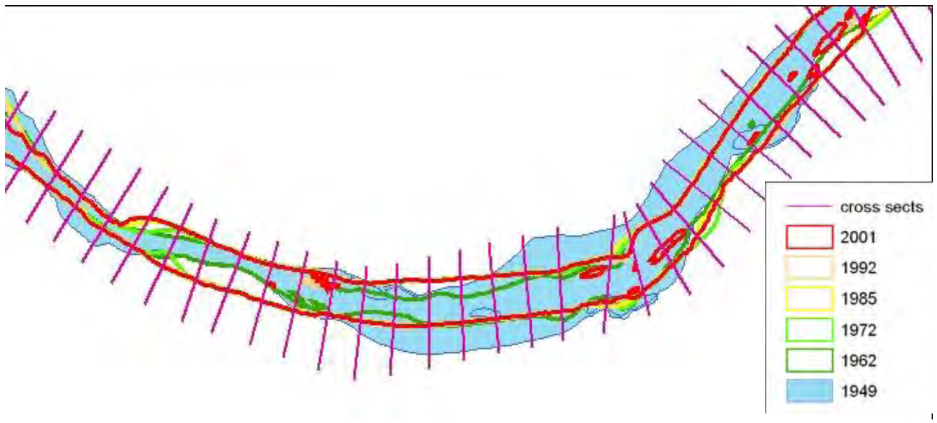
Rio Grande Above Arroyo Tijeras



Channel, Island, and Bar Measurements

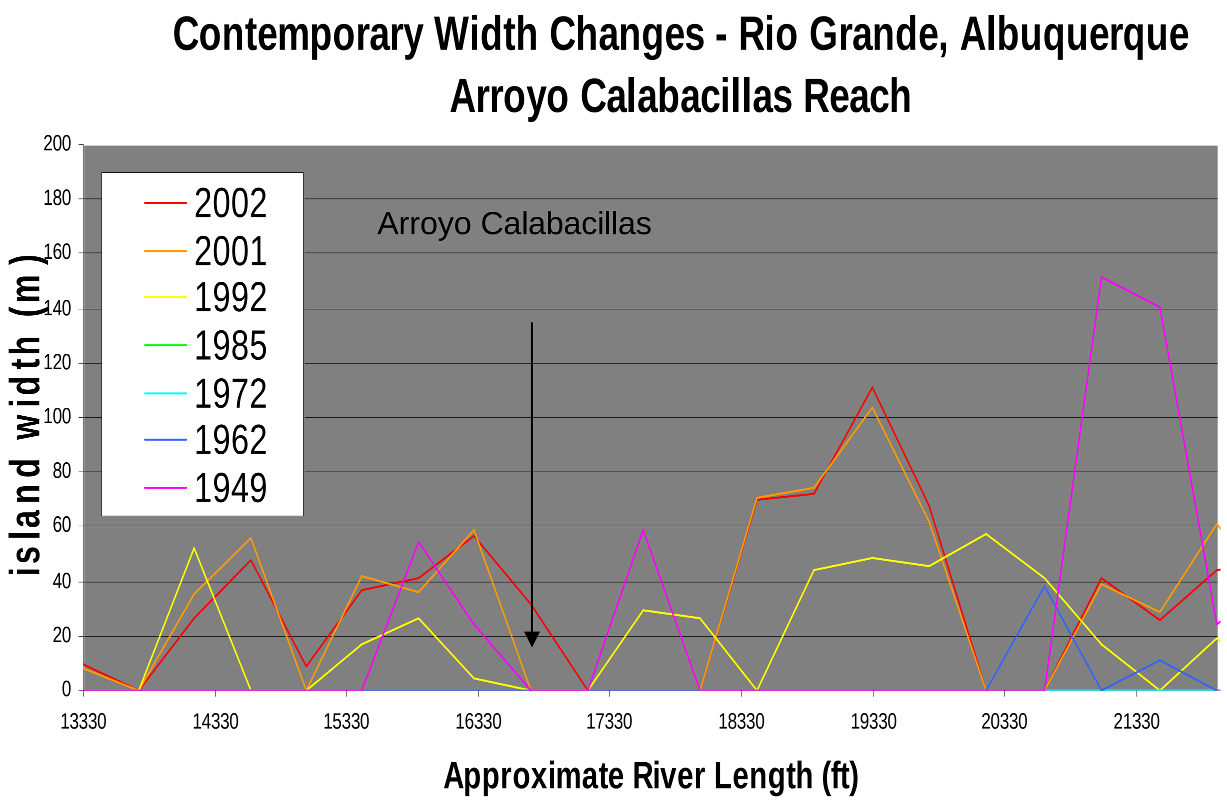
Developing GIS Methodology

- Digitize active channel, islands, and sandbars
- Produce cross sections orthogonal to bank centerline (used Oliver 2004 channels and cross sections).



•Use above channel features to “clip” cross sections

•“Measure” new cross section lengths (Xtools)



Similar method used in Makar et al. 2006

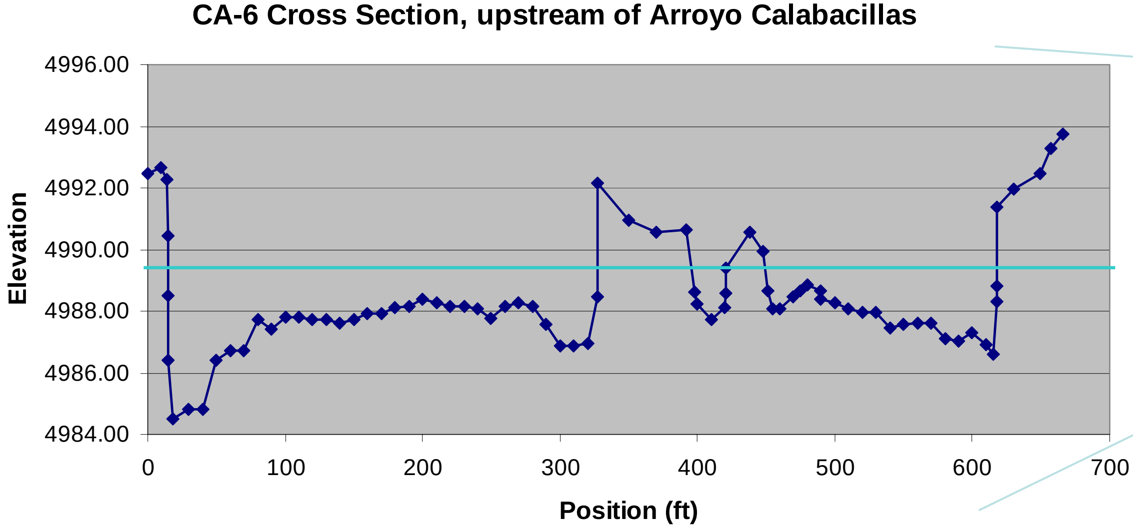
Measuring Water Depths from Air Photos

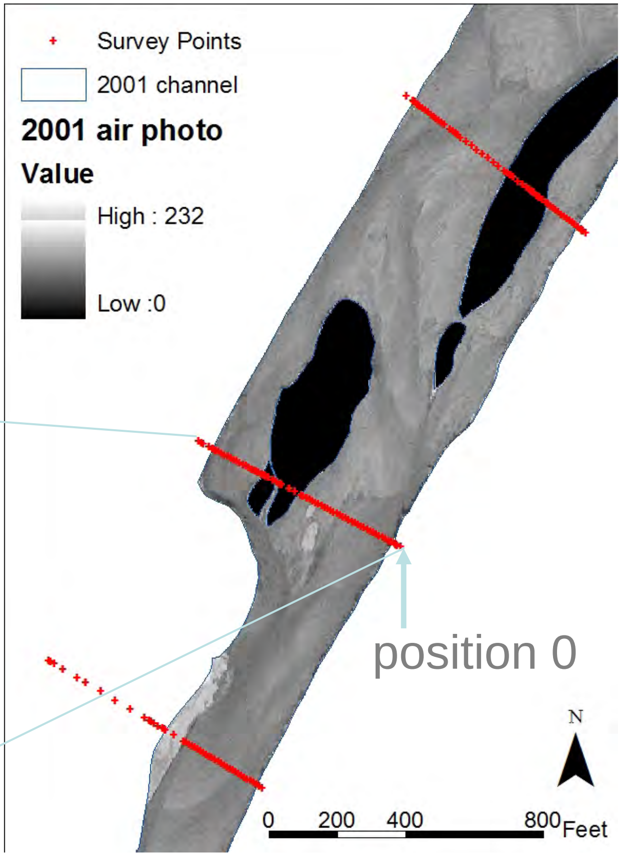
Use regression between cross section depths and photo reflectance to predict depths

Jordan and Fonstad, 2005 - Brazos River, TX

Winterbottom and Gilvear, 1997 – UK rivers

- -Use Depths to track bar movement
- -Use depths in conjuction with other measured variables (slope, roughness, etc) to calculate shear stress, stream power.
- -Use above with vegetation, bank heights, bank material, etc. to predict bank erosion





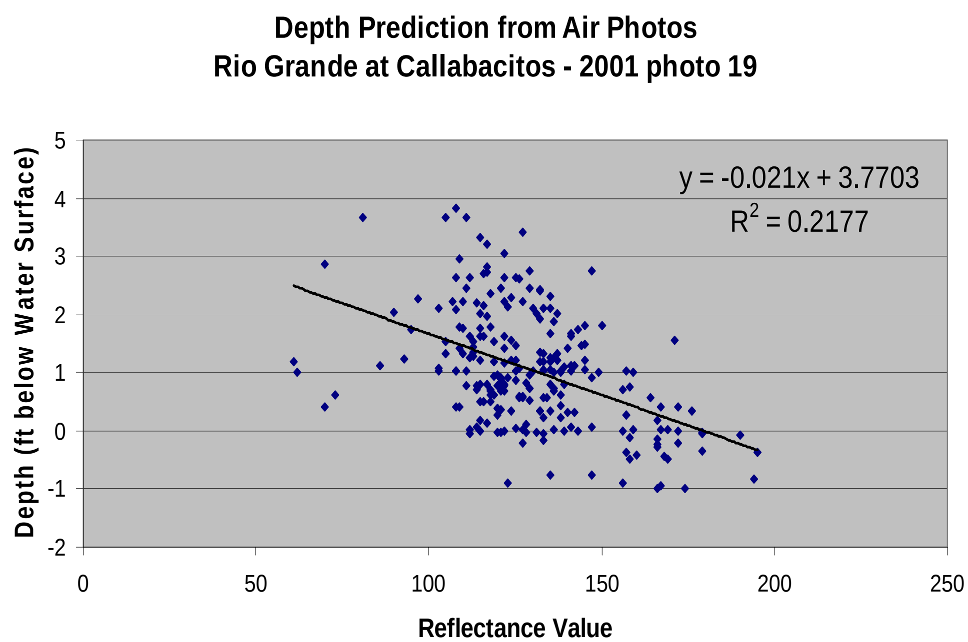
Depths from 2001 Air Photos – Initial Results

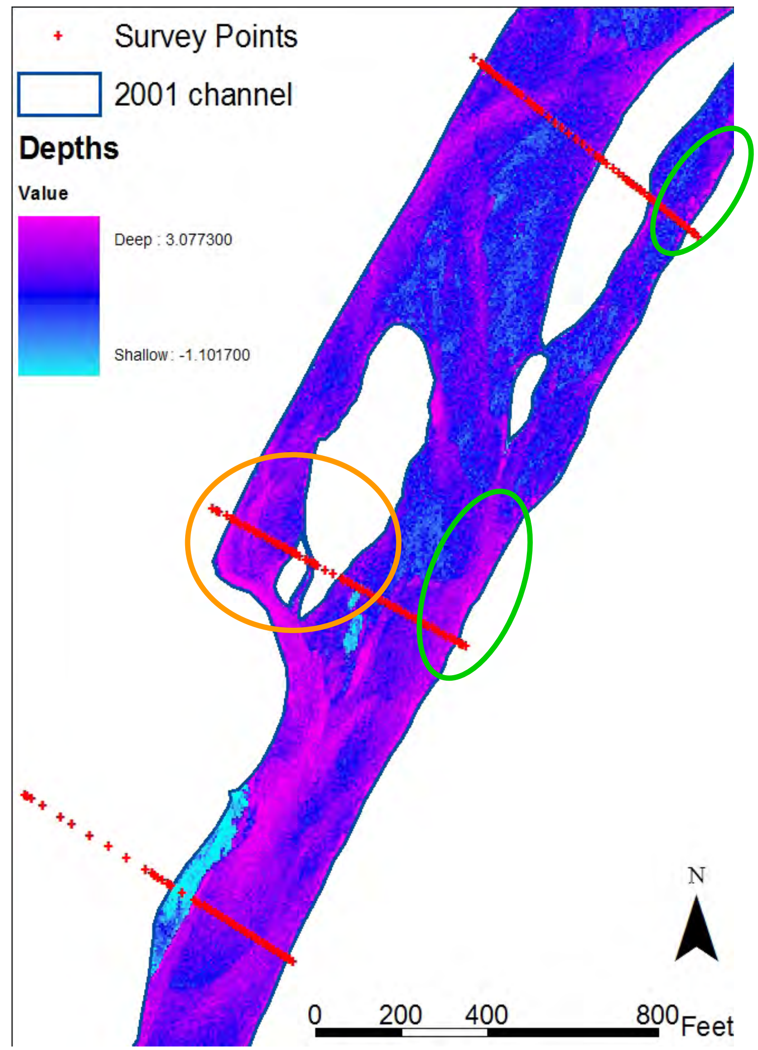
Poor Relationship

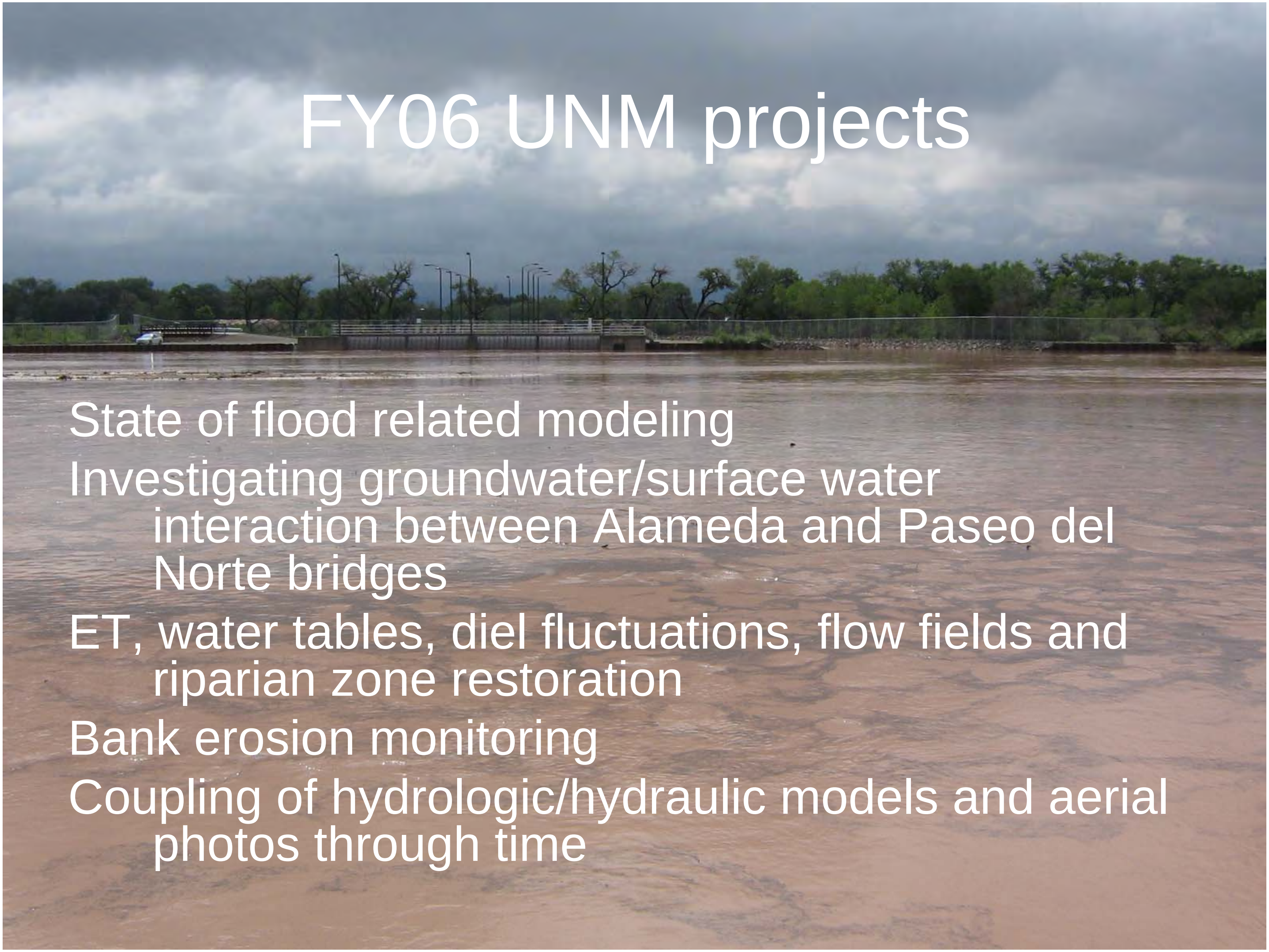
R^2 from 0.11 to .42 for 2001 photos - 0.69 and 0.55 for other studies

Issues

- Multiple channels
- Overhanging vegetation and shadows
- Turbidity
- Variable bottom cover
- Sun Glint
- Others







FY06 UNM projects

- State of flood related modeling
- Investigating groundwater/surface water interaction between Alameda and Paseo del Norte bridges
- ET, water tables, diel fluctuations, flow fields and riparian zone restoration
- Bank erosion monitoring
- Coupling of hydrologic/hydraulic models and aerial photos through time

Rio Grande Seminar

- Provides regular forum for inter-disciplinary discussion
- Speakers from ERDC, NMSEO, NMF&WS, Sandia Labs, UNM, and others

www.unm.edu/~jcoonrod/rgseminar

Making the connection between healthy waterways and healthy catchments

Stuart Bunn
Australian Rivers Institute
Griffith University

Eva Abal, Bill Dennison, Paul Greenfield & Di Tarte

Moreton Bay Waterways and Catchments Partnership

HEALTHY WATERWAYS
Because we're all in the same boat

Outline

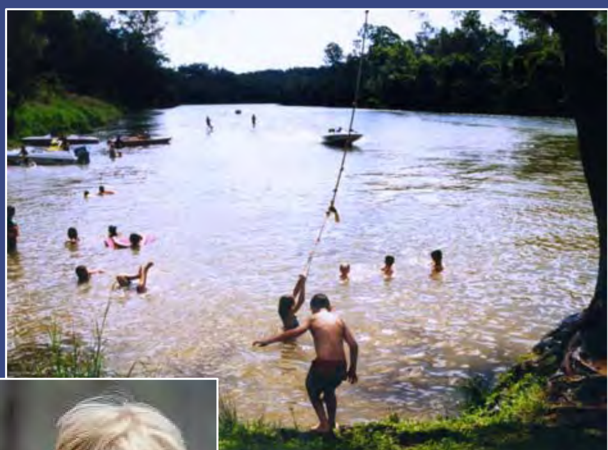
- Background to the study region: Moreton Bay catchment in eastern Australia - rapidly expanding population
- Development of partnership (science, managers, policy makers) to deal with issues affecting coastal waterways
- Development of science and monitoring program
- Communication with stakeholders
- Implementation of actions

Background to the study region

- 15 major catchments
- 22,672 km^2
- 19 local government areas
- Population 2.5 m
- Fastest growing region in Australia

Importance of the region's waterways:

- High conservation significance (Ramsar)
- Major commercial and recreational fisheries
- Water supply (urban and rural)
- Recreation & transport



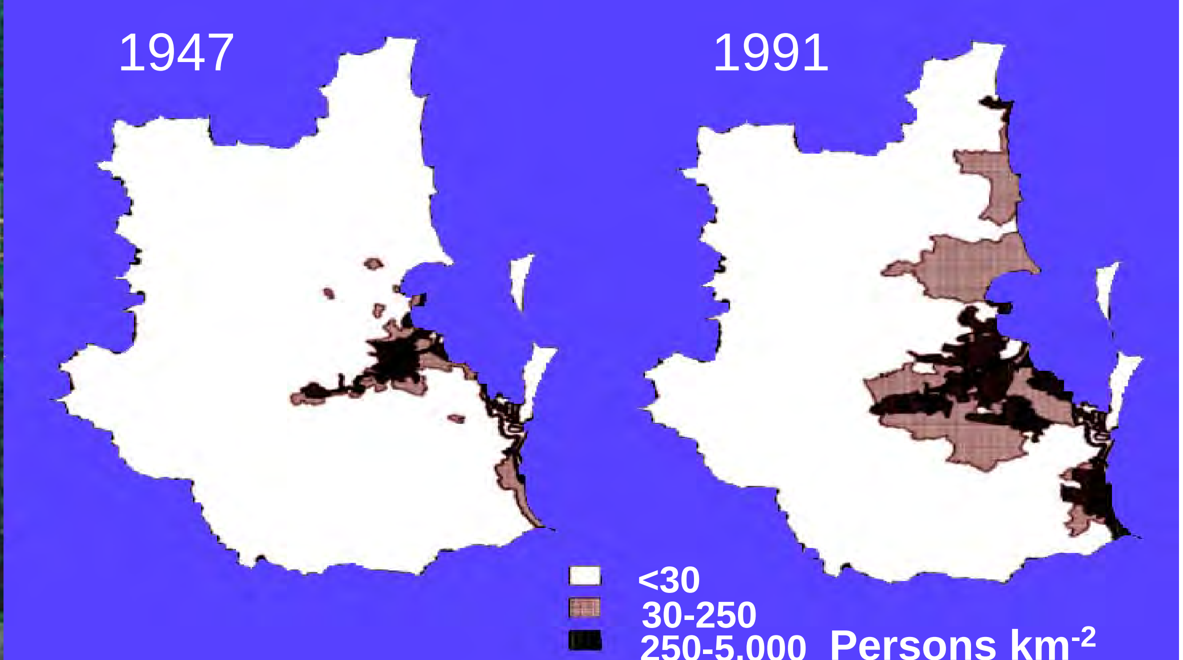




The human footprint:

Since European settlement:

- 20% of original vegetation remains - less adjacent to streams
- Altered hydrology - dams & weirs
- Declining water quality (nutrients & sediment)
- Declines in aquatic diversity



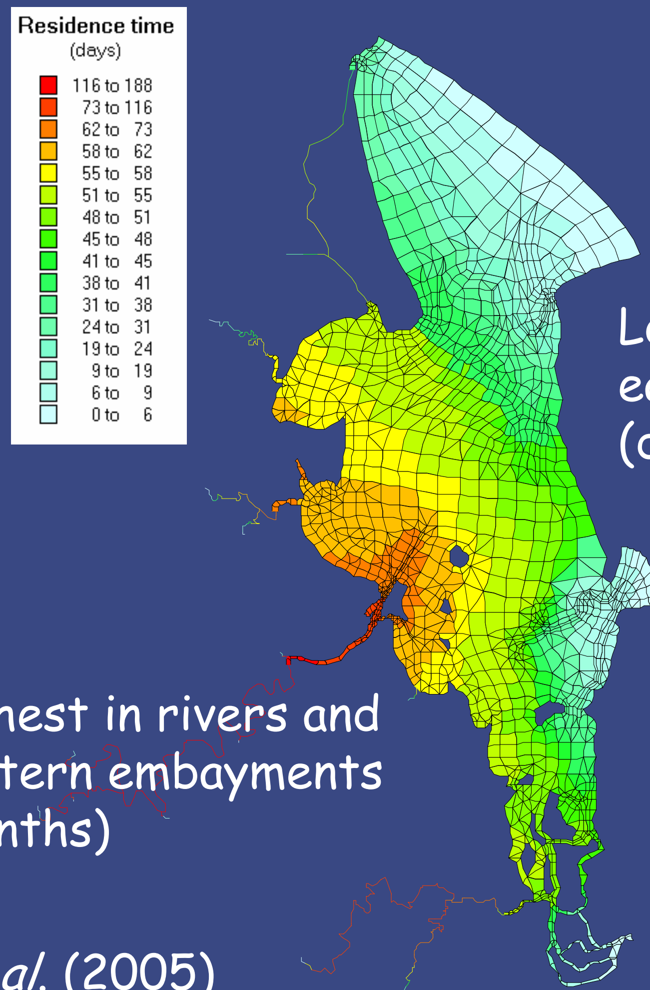
Catchments drain into Moreton Bay

Catchment to Bay Ratio:

14:1

Brisbane River

Residence Time



Lowest in eastern Bay (days)

Highest in rivers and western embayments (months)

Abal *et al.* (2005)

Key drivers for change

- Fast growing population
- Security of water supply (quantity and quality)
- Concerns about industry viability - tourism, fishing and agriculture.
- Increasing community expectations about improving water quality and ecosystem health

Recognition - cheaper to protect than to restore ...

Formation of the Partnership

3 levels of government

- Local councils (6; 19)
- State Government agencies (6)
- plus Federal funding

Strong research support

- 3 Universities
- CSIRO
- 3 Cooperative Research Centres

Community & industry advisory groups (>40)

- indigenous
- conservation
- catchment & landcare
- commercial industry
- rural industry

Developing a common vision:

"South-east Queensland's catchments and waterways will, by 2020, be **healthy living ecosystems** supporting the **livelihoods and lifestyles** of people in South-east Queensland and will be **managed in collaboration** between community, government and industry."

Achieving the vision:

Set values that reflect the vision

- numerous workshops with stakeholders

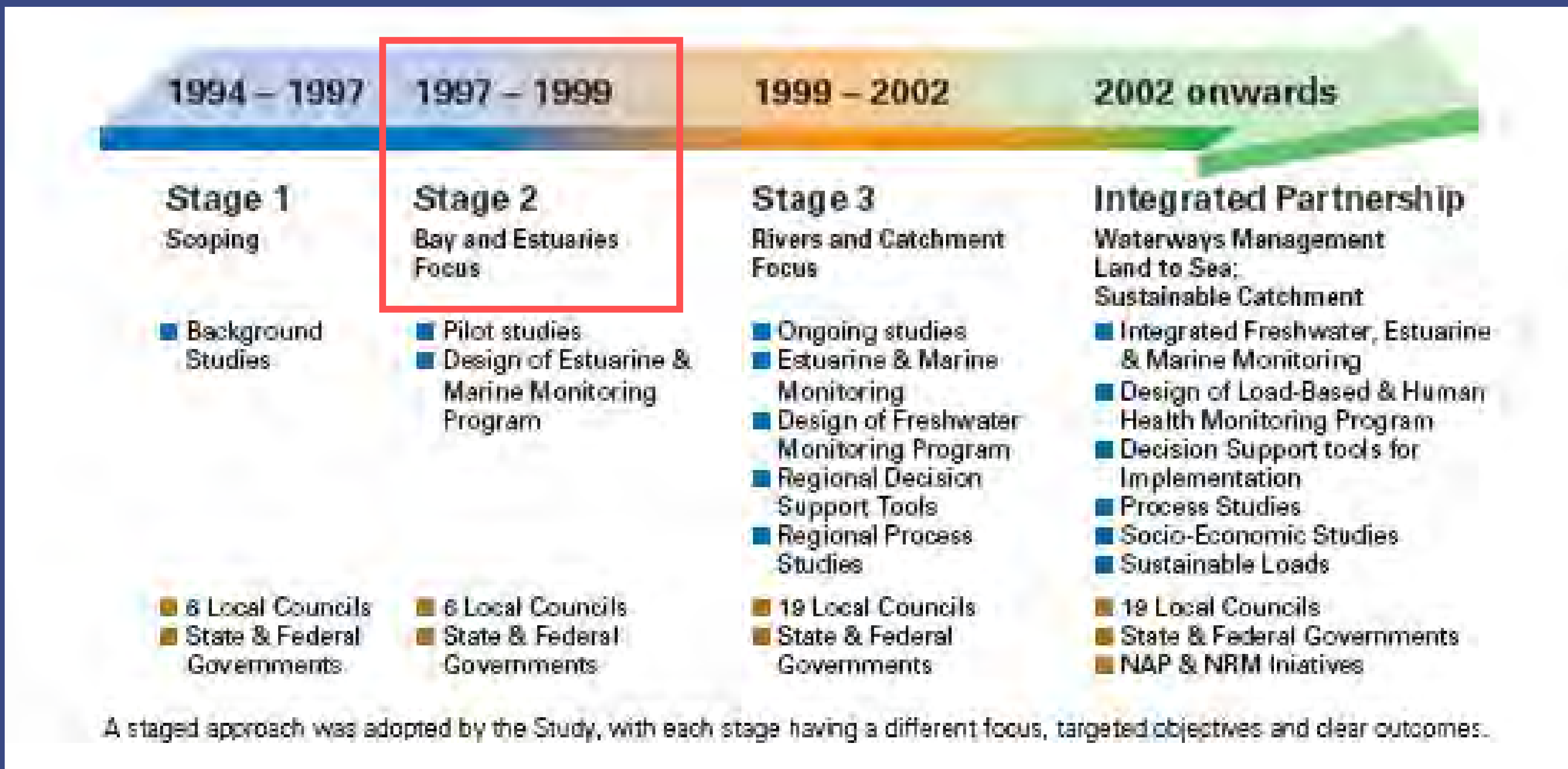
Measurable water quality or ecosystem health objectives that protect the values

- underpinned by sound science

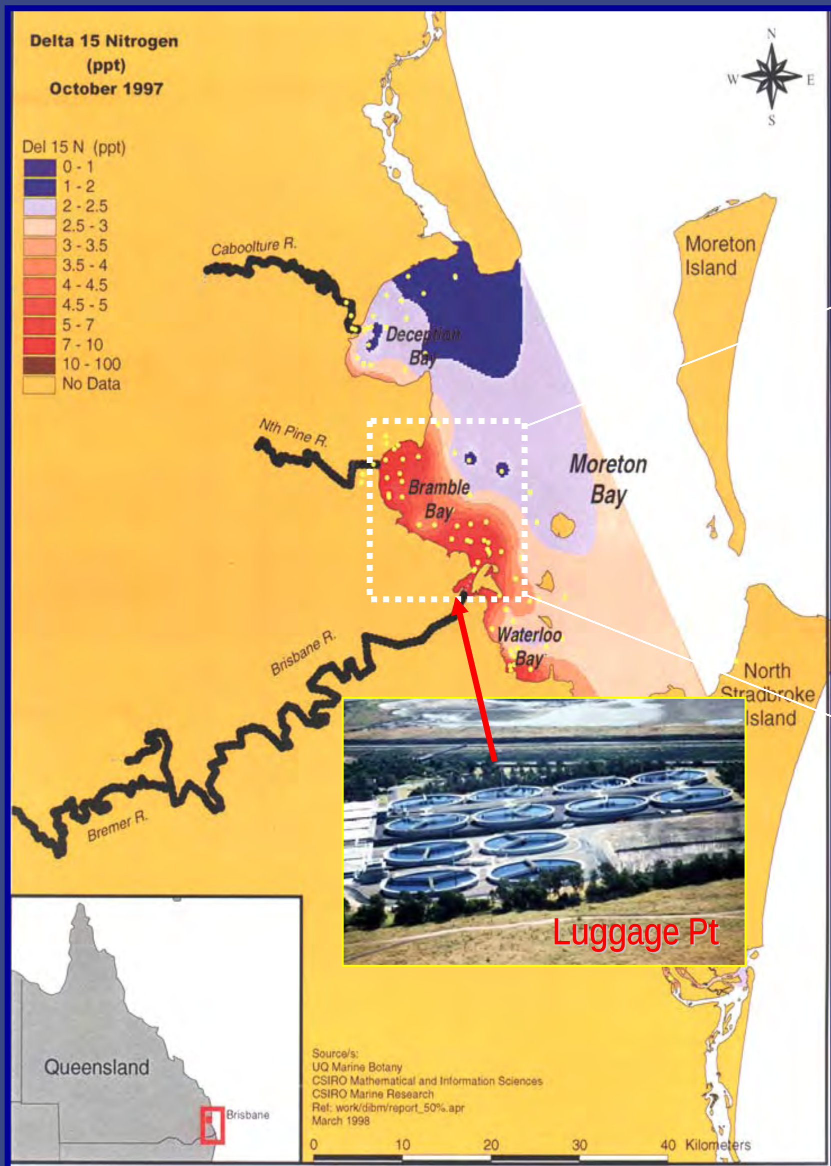
Management actions to achieve these objectives

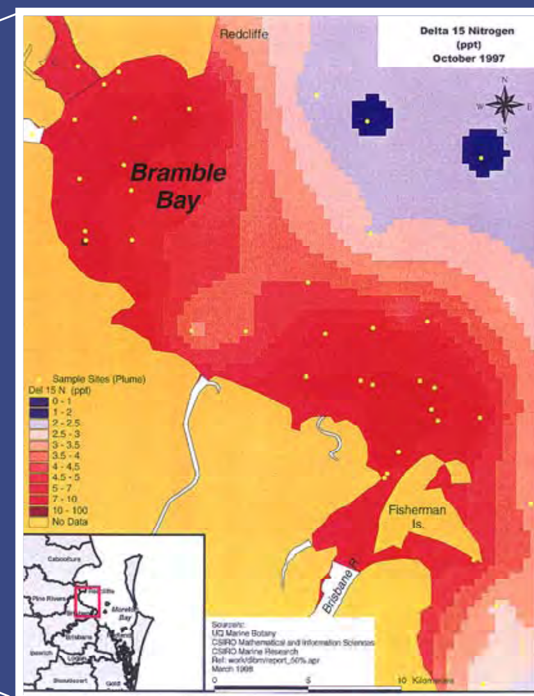
- working with policy makers

A staged approach: Stage 2- Moreton Bay



Sewage Plume Mapping (using $\delta^{15}N$)

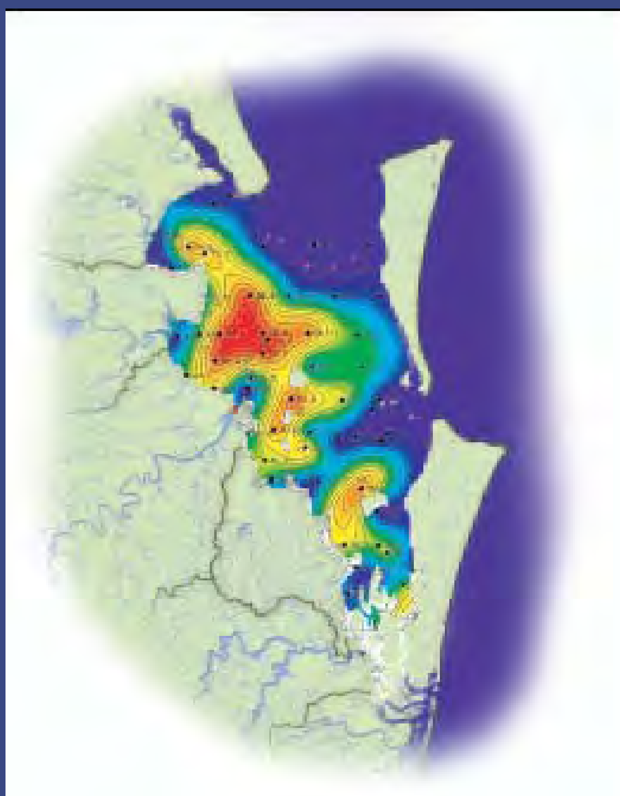




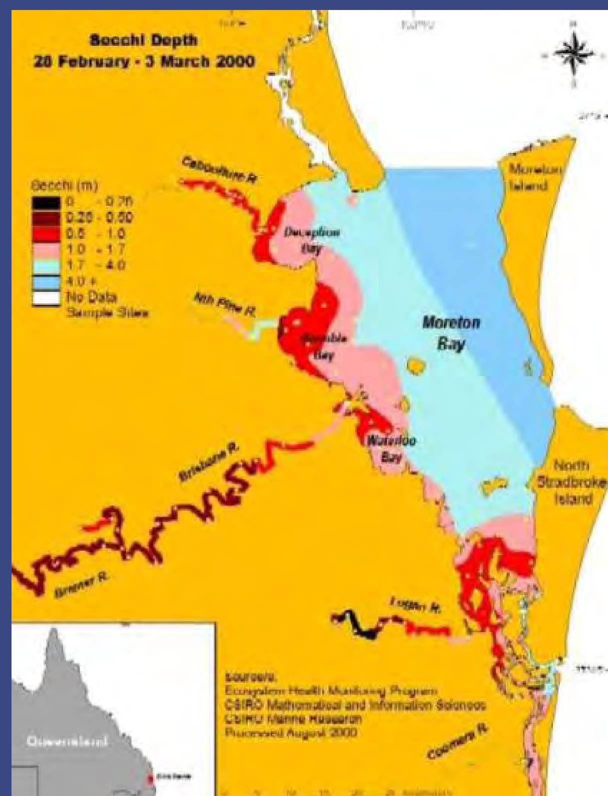
Marine Botany, University of Queensland
CSIRO Mathematical and Information Sciences
CSIRO Marine Research

Sediments in Moreton Bay and seagrass loss

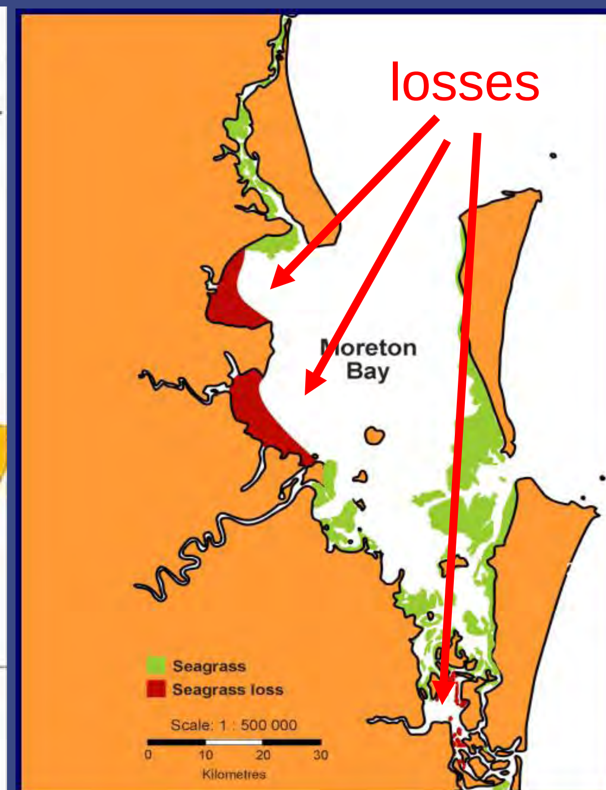
Sediments in the Bay



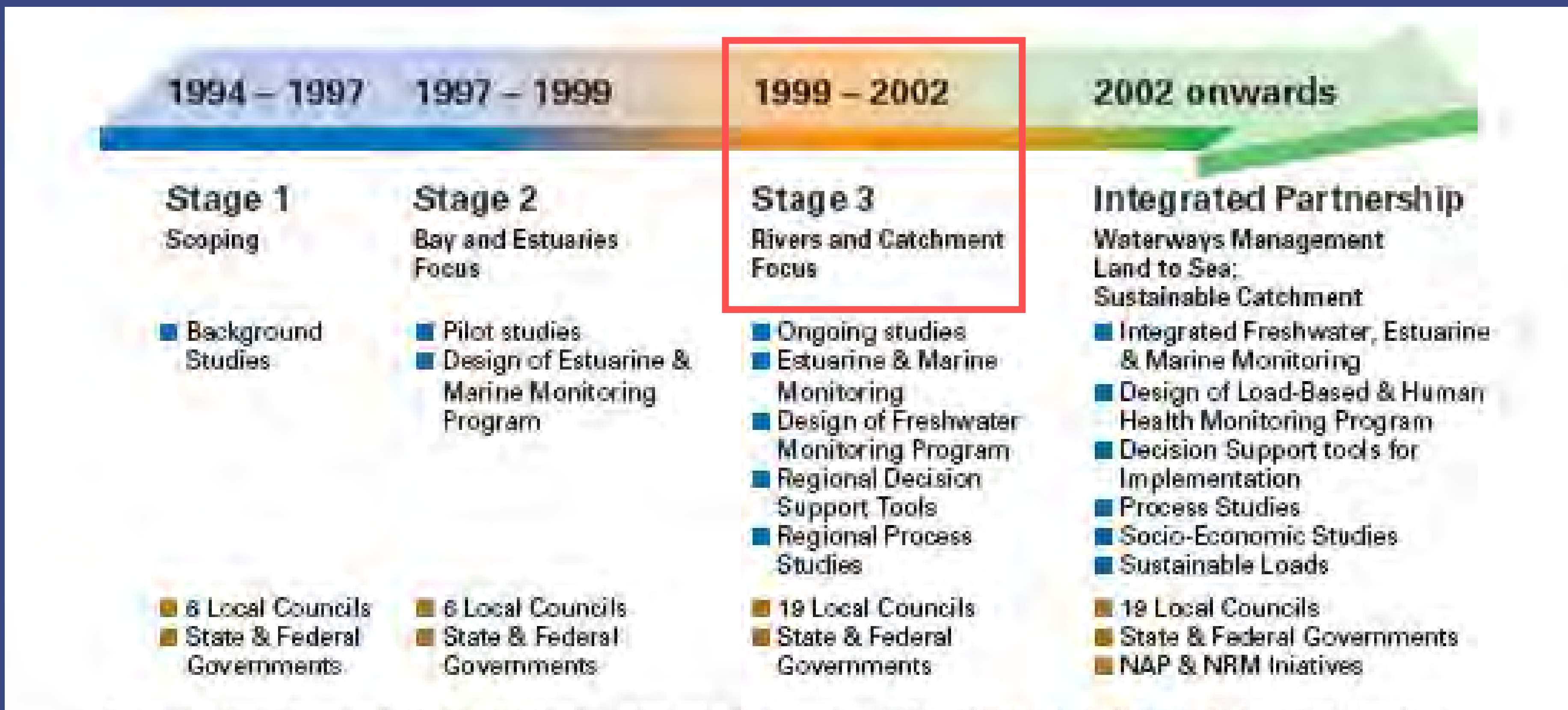
Turbidity



Seagrass distribution

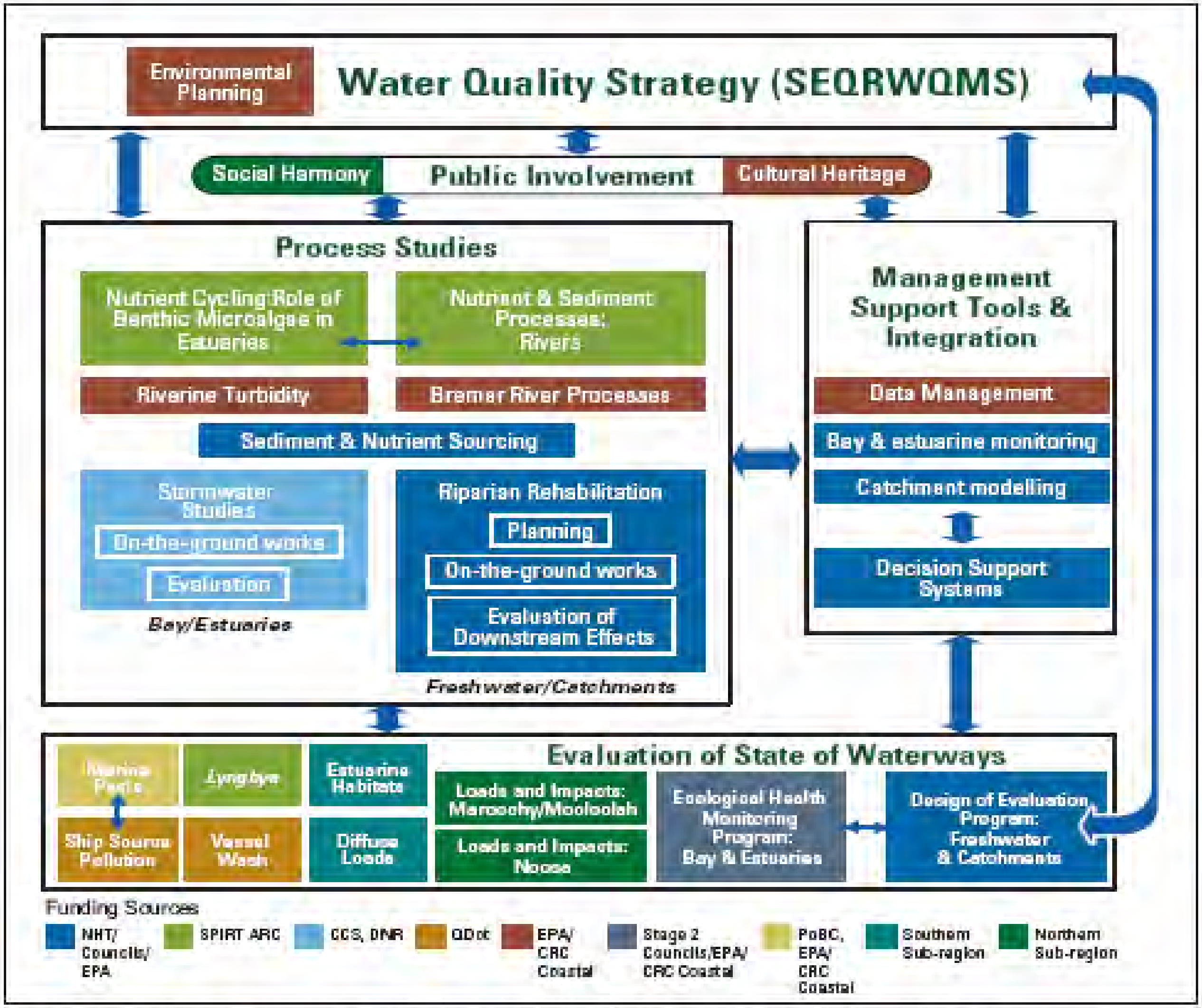


A staged approach: Stage 3- catchments



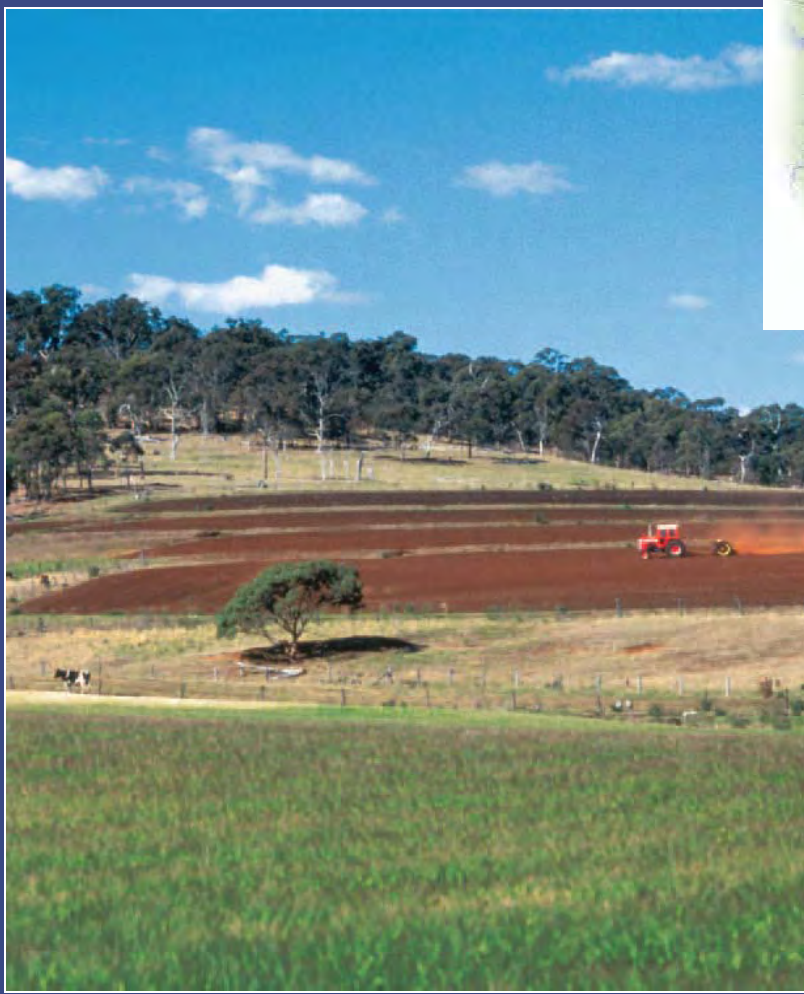
A staged approach was adopted by the Study, with each stage having a different focus, targeted objectives and clear outcomes.

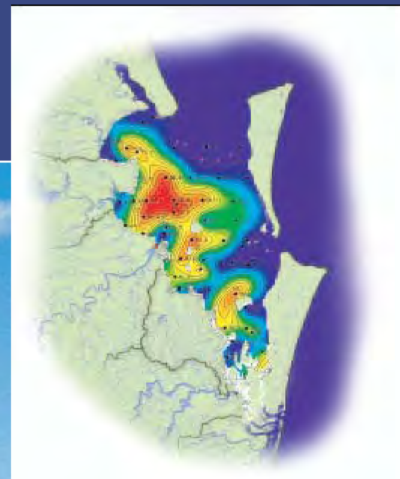
Stage 3 Scientific Tasks



Stage 3 task architecture, showing the integration and linkages of tasks aimed at providing input into the development of the SEQ Regional Water Quality Management Strategy.

Sources of sediment in Moreton Bay

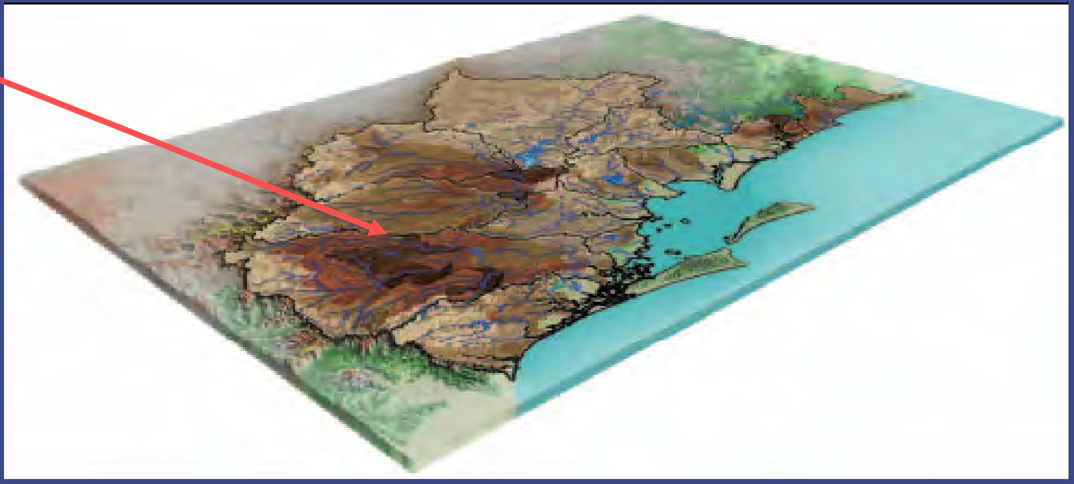


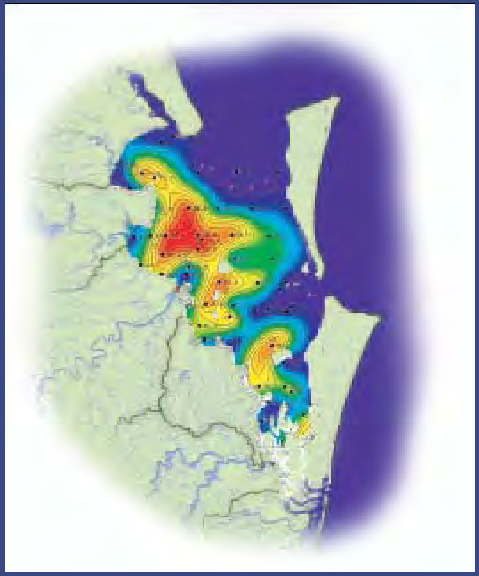


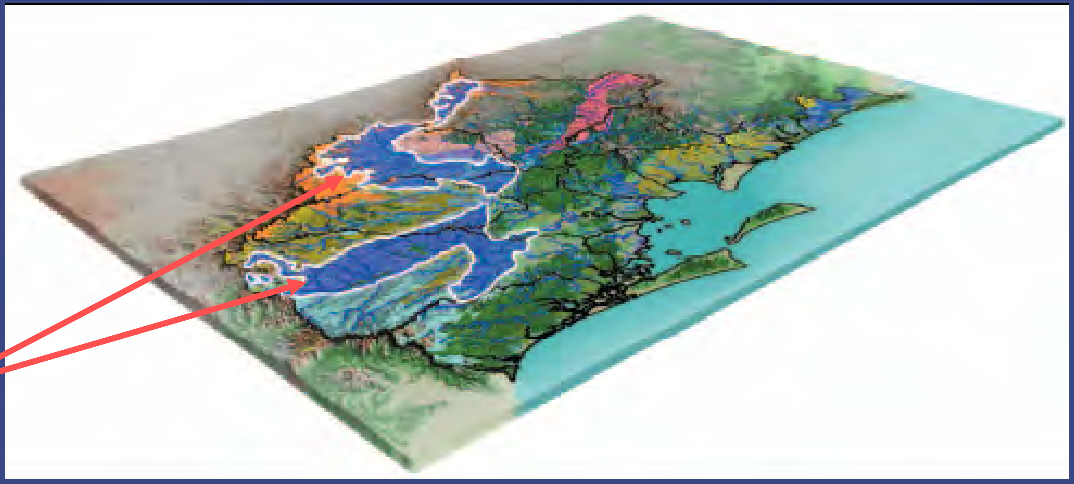
- Where does it come from?
- What are the processes that generate it?

Source of sediment in Moreton Bay

Modelling suggests 70% sediment in Bay comes from <30% catchment area







Tracer study confirms that most sediment comes from soils on Marburg formation rocks

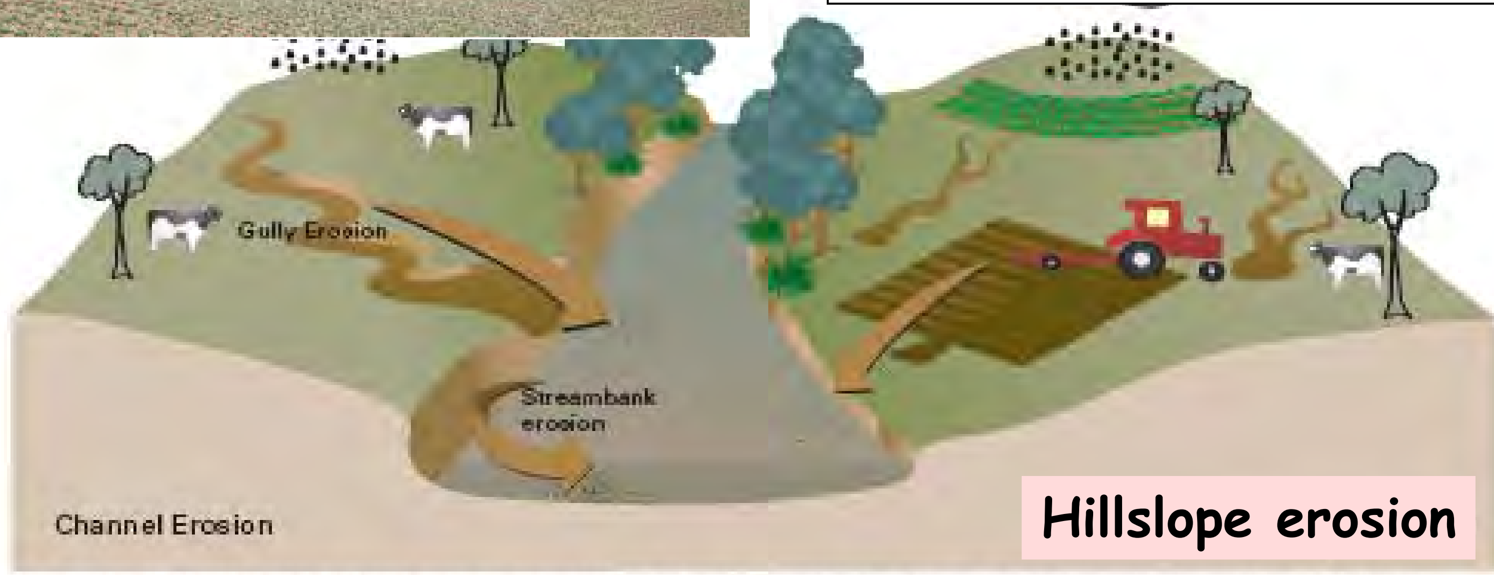
Caitcheon & Howes (2005)

Dominant processes generating sediment?

Hillslope erosion

Key issue in steeper pasture and intensively cropped floodplain

Solutions:
- promote ground cover
- maintain soil structure
- trap eroded sediments



Hillslope erosion

Illustration of channel and hillslope erosion processes. Channel erosion includes gully and streambank erosion and hillslope erosion includes sheetwash and rill (shallow [<20 cm] channel) erosion.

Dominant processes generating sediment?

Channel erosion

Promoted by high stream energy, riparian vegetation clearing, and floodplain degradation

Solutions:
- protect riparian vegetation
- re-establish riparian vegetation
- control stock access

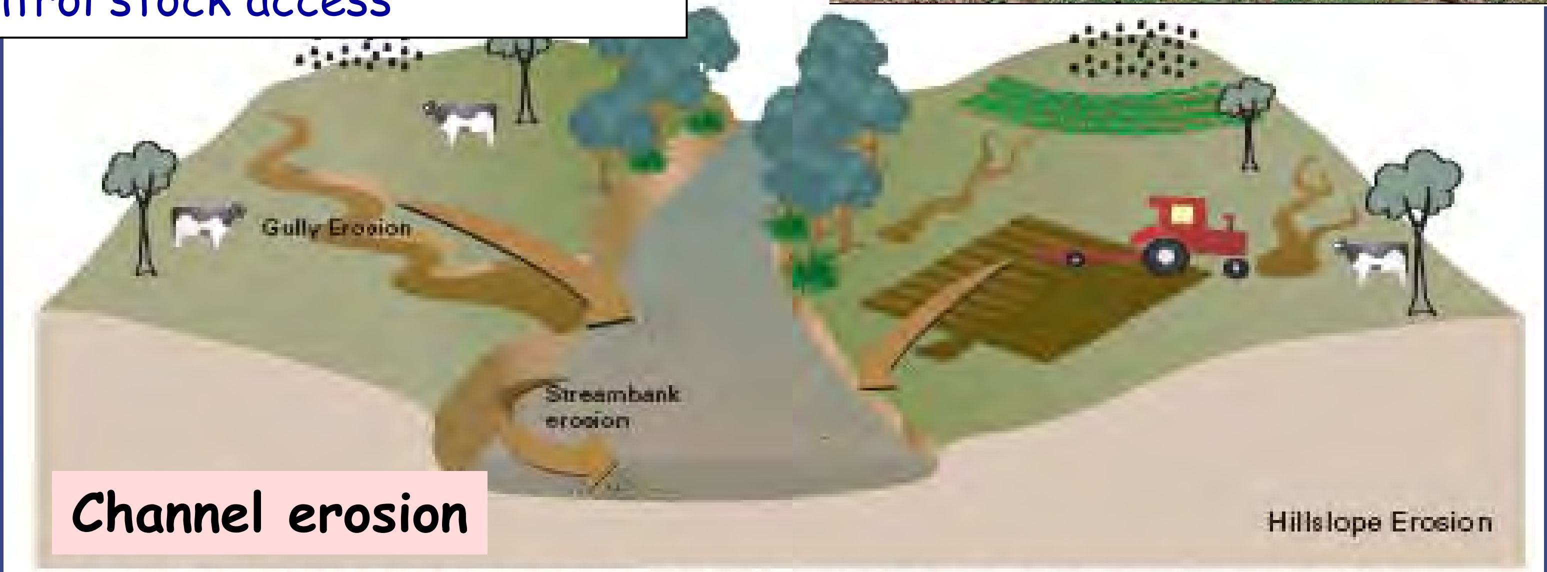
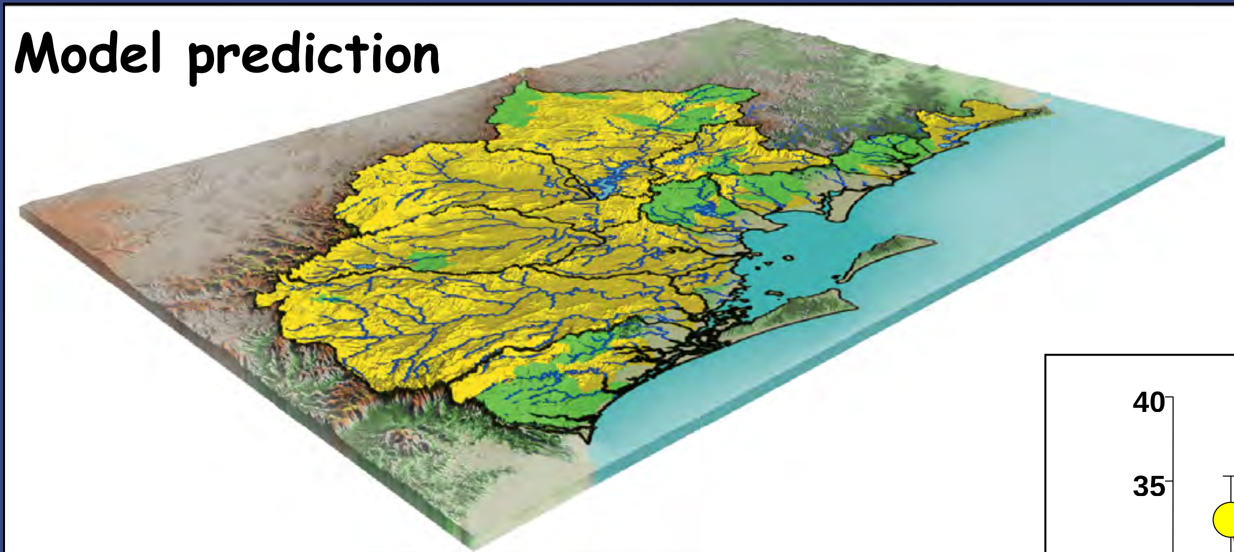
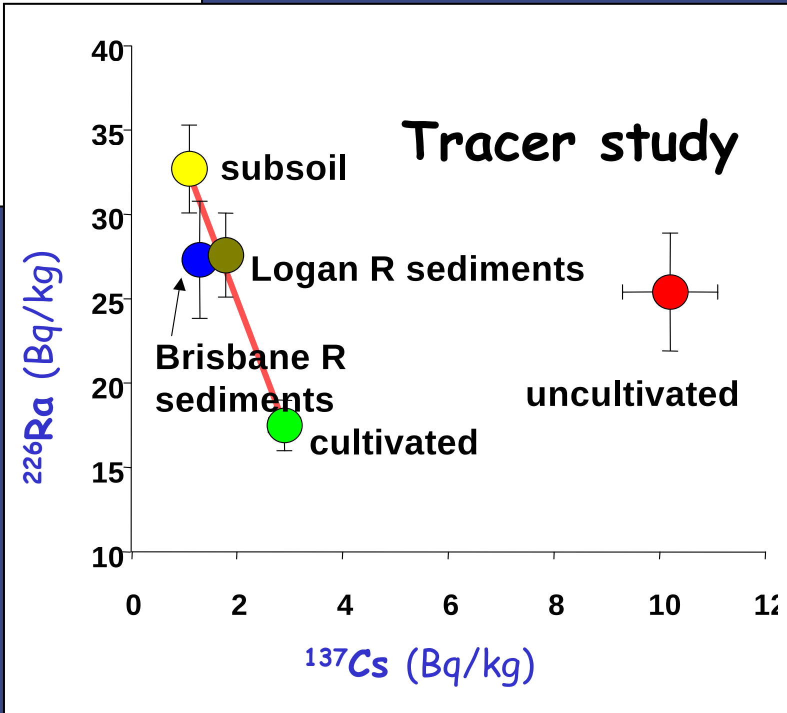


Illustration of channel and hillslope erosion processes. Channel erosion includes gully and streambank erosion and hillslope erosion includes sheetwash and rill (shallow [<20 cm] channel) erosion.

Channel erosion dominates in the region



Hillslope:channel erosion ratio
- 0-1 (channel erosion dominates)
- 1-10 (hillslope erosion dominates)



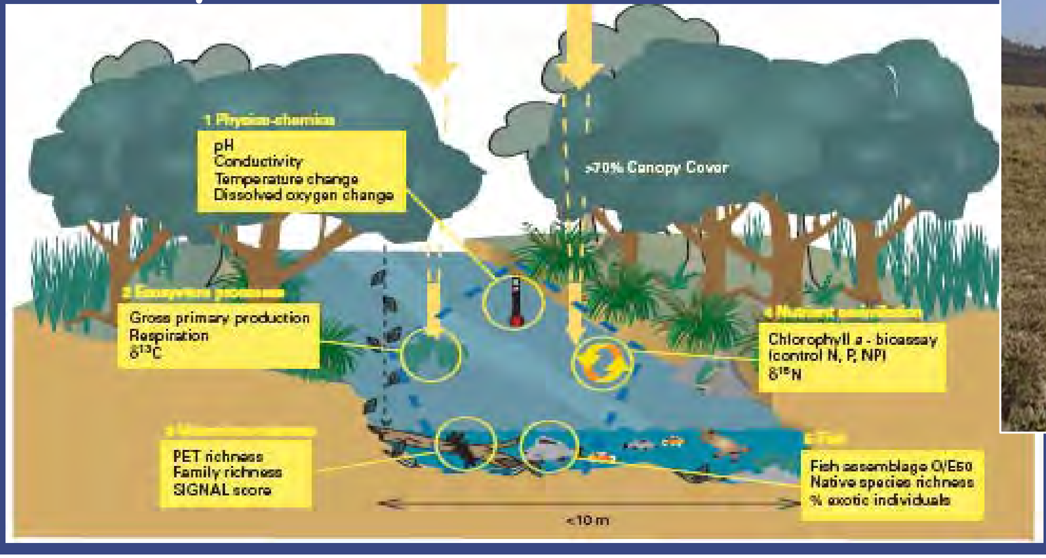
- Channel erosion is source of most sediments delivered to the lower Brisbane & Logan Rivers
- Other source is cultivated surface soils

Caitcheon & Howes (2005)

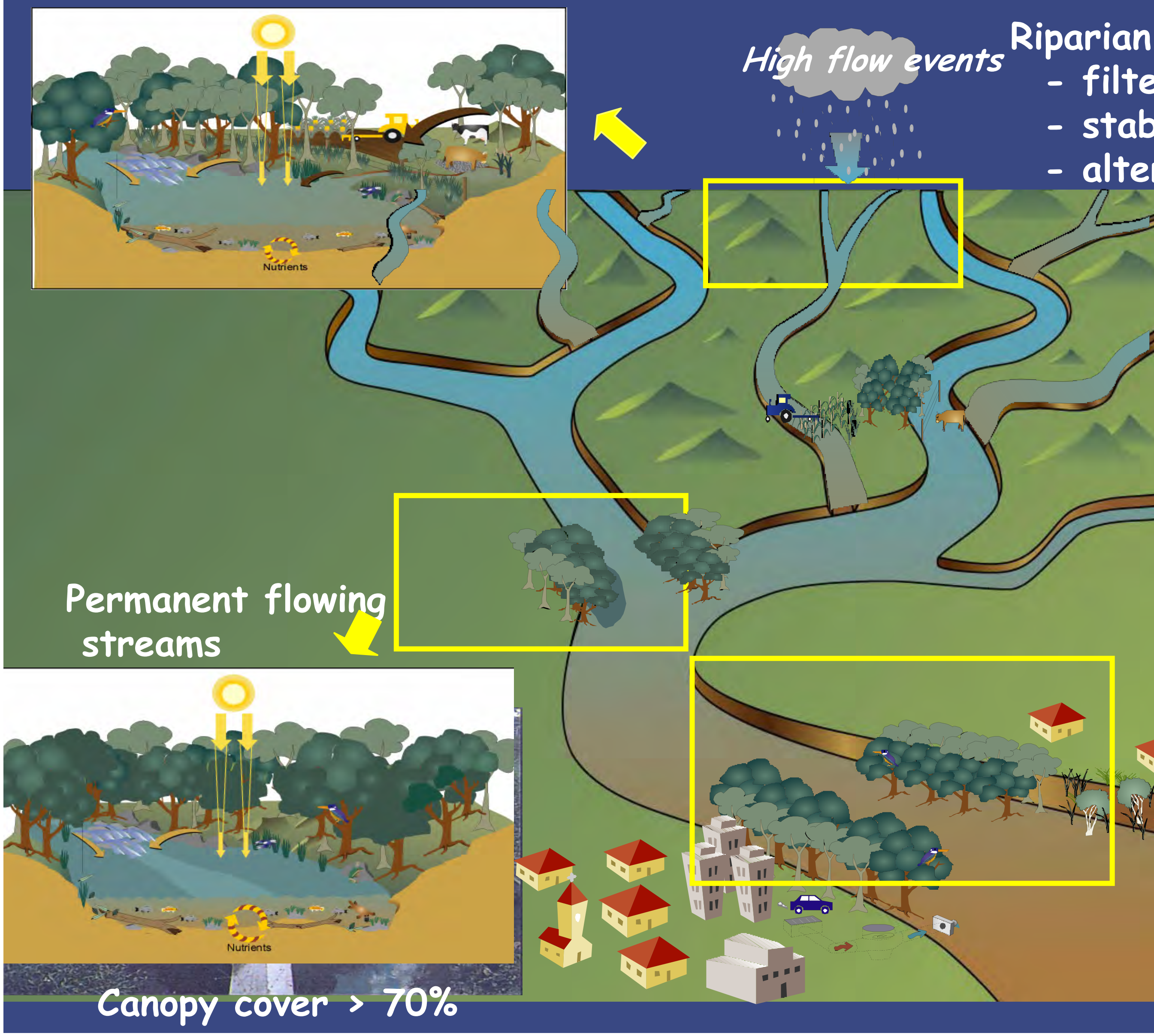
Degraded riparian lands

About 50% of the 48,000 km of streams in SEQ has poor riparian condition

Riparian condition also has a large influence on stream ecosystem health



Recommendations for riparian management



Riparian rehab. for:
- filtering sediments & nutrients
- stabilisation
- altering water flows

Streams are dry most times of the year

Riparian rehab. for:
- stream health
- stabilisation
- wildlife corridor
- habitat protection

Riparian rehab. for:
- stabilisation
- wildlife corridor
- habitat protection

SQIDS/Wetland

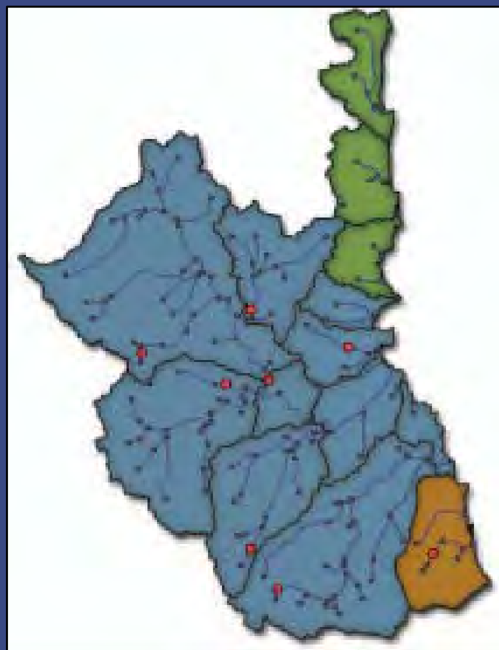
Using Decision Support Software

EMSS

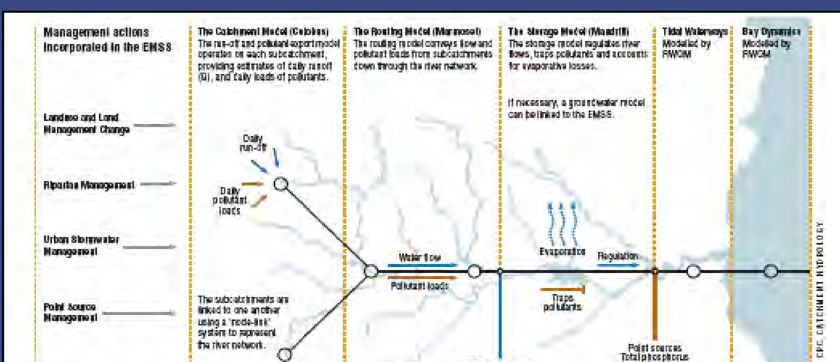
- Synthesise process understanding of the system (links catchment to water)
- Facilitates decision making process to select actions to best protect waterways

Using Decision Support Software

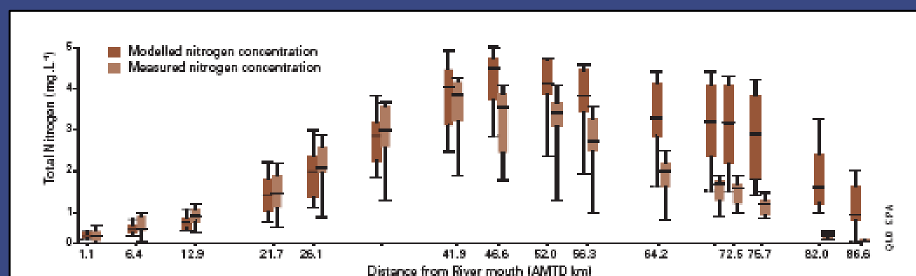
EMSS



Receiving Water Quality Model



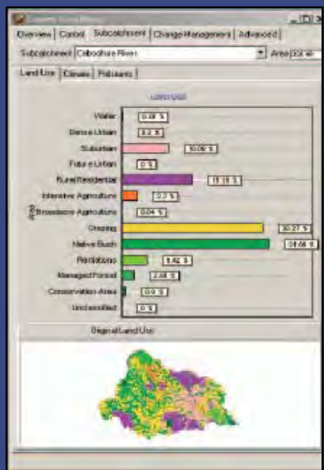
The three linked sub-models comprising EMSS.

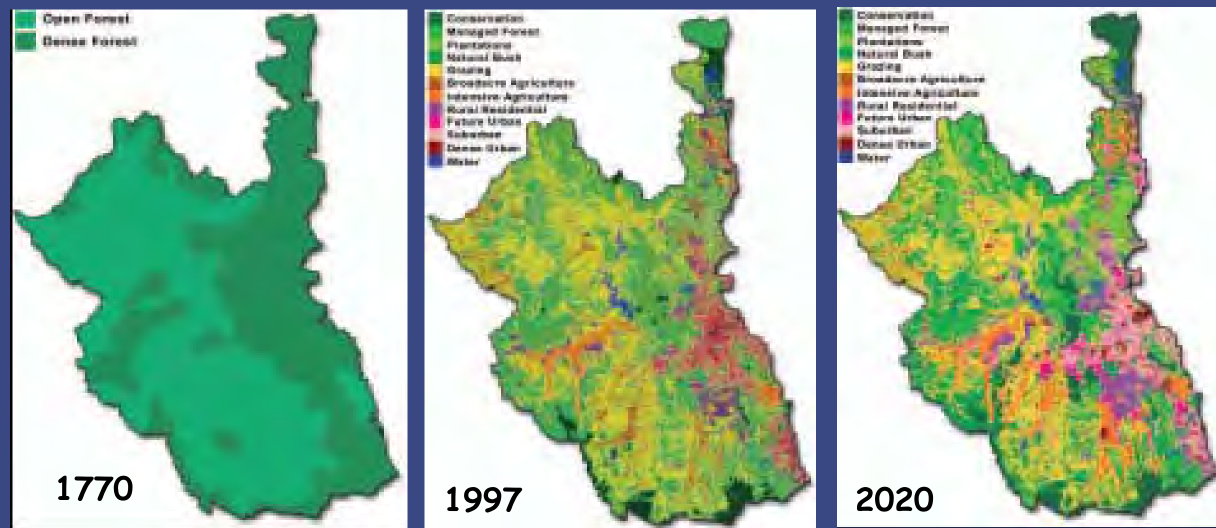


Example of Receiving Water Quality Model Calibration – Brisbane River.

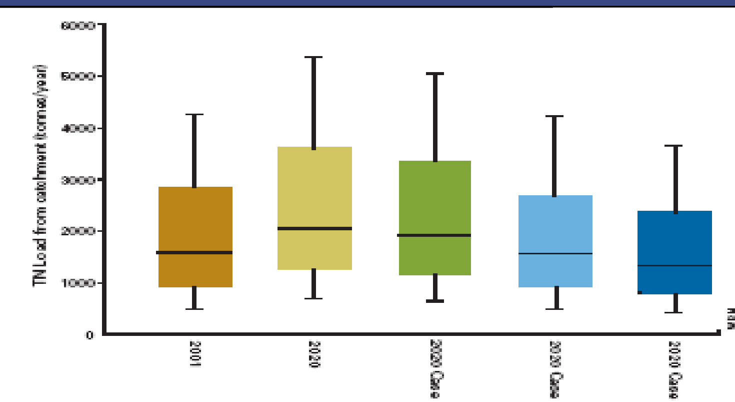
Vertessey & McAlister (2005)

Scenario testing





Past Present Future



Predicted total N load to Moreton Bay

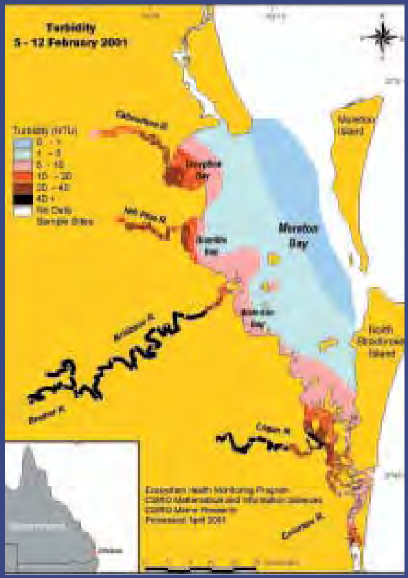
- Current TN loads
- 2020 "do nothing" scenario
- 2020 achieve objectives for future urban land
- 2020 achieve objectives for future urban land + SQID retrofit
- 2020 achieve objectives for future urban land + SQID retrofit + riparian management

Vertessey & McAlister (2005)

Ecosystem Health Monitoring Program

Assess effectiveness of environmental protection measures (e.g. stormwater controls, STP upgrades, riparian vegetation)

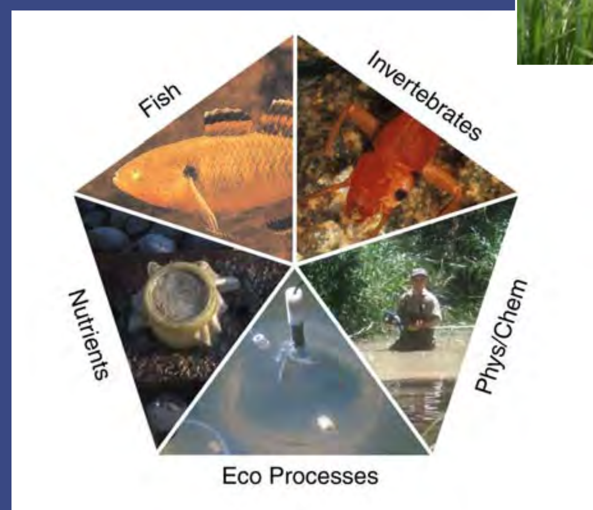
Estuarine and marine EHMP
- Designed stage 2
- Implemented Stage 3



260 sites (sampled monthly)

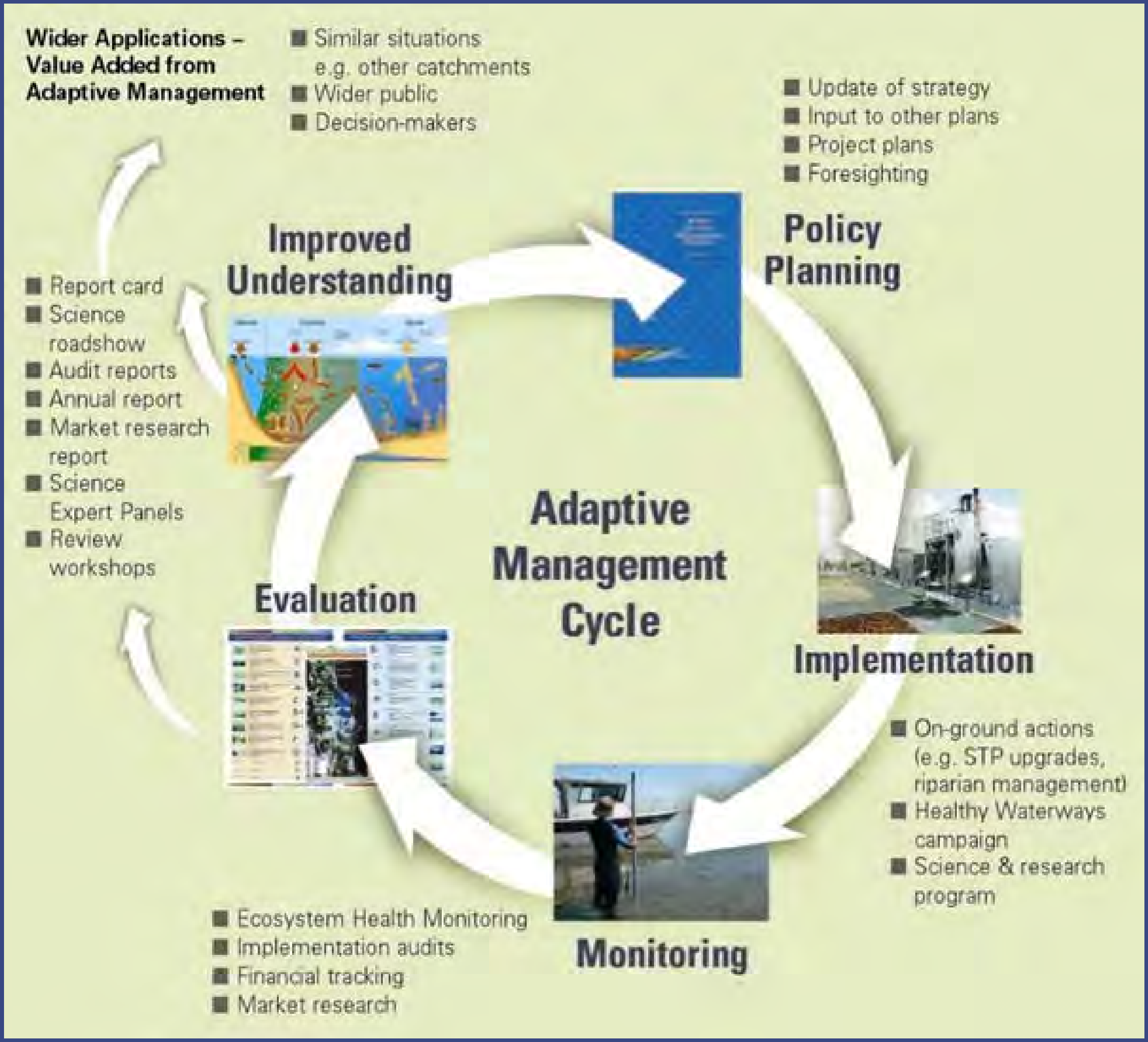
Ecosystem Health Monitoring Program

Freshwater EHMP
- Designed stage 3 ; Implemented 2002



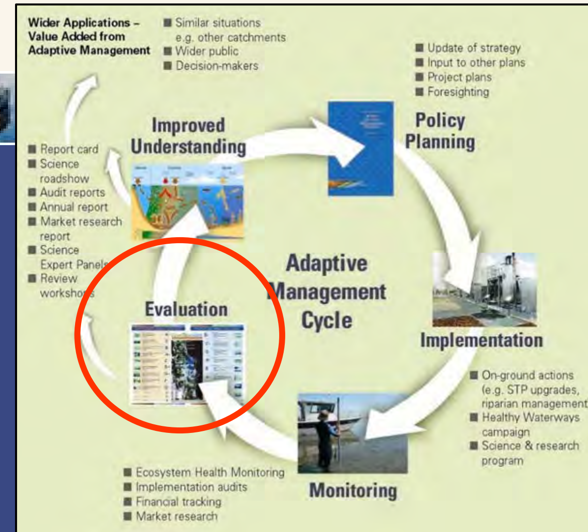
120 freshwater sites
(sampled 2x/yr)

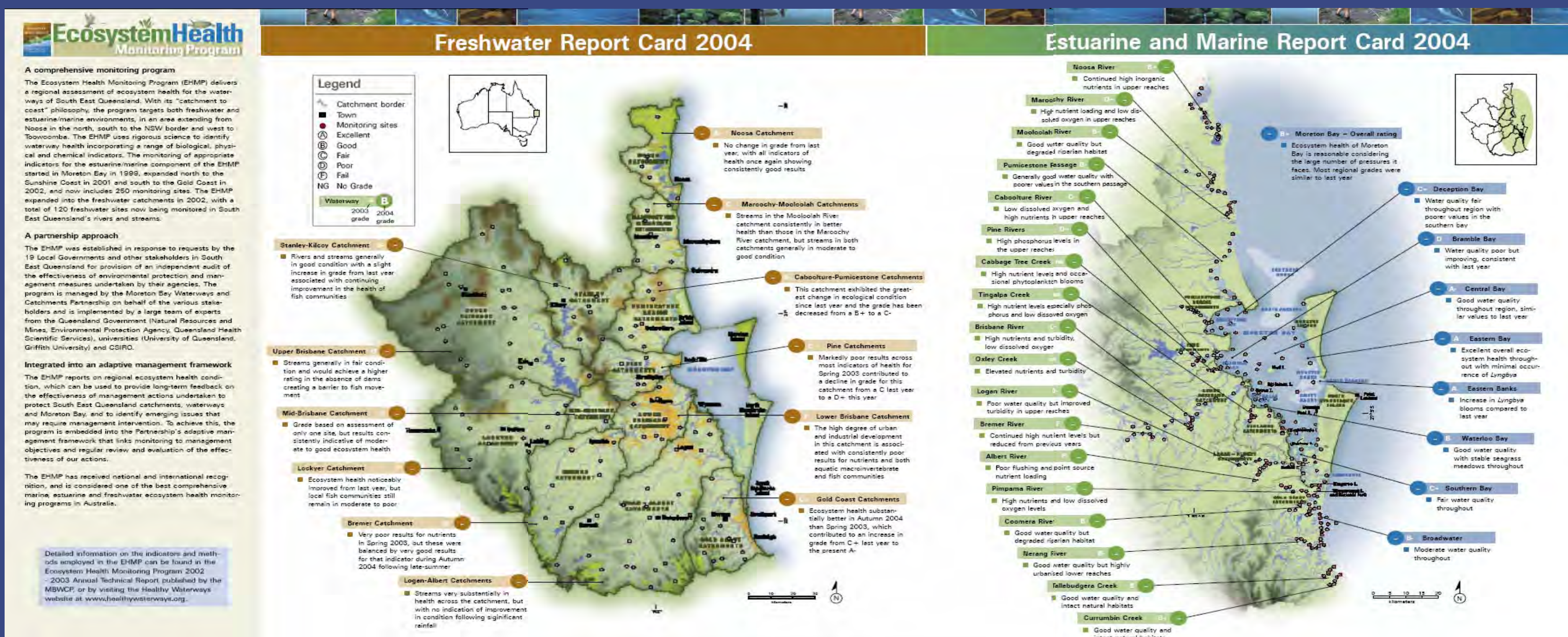
Adaptive management framework



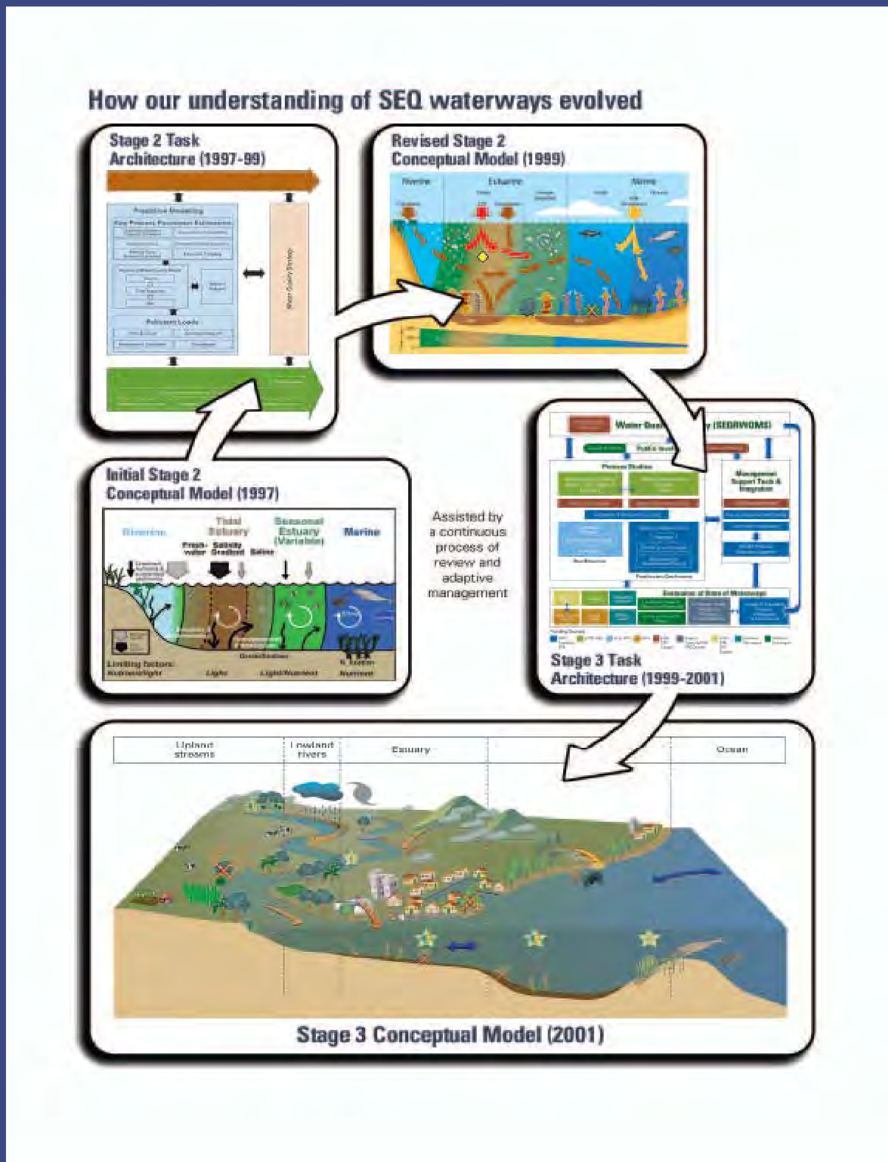
- ongoing knowledge acquisition
- critical role of monitoring
- continuous improvement in the identification and implementation of management.
- effective communication of knowledge for policy/planning

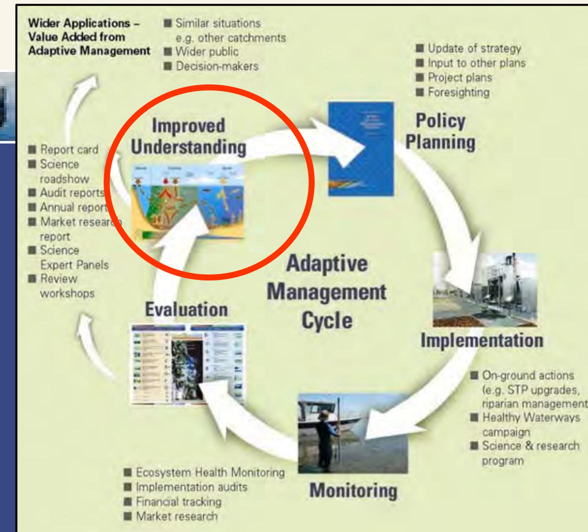
Report cards on progress





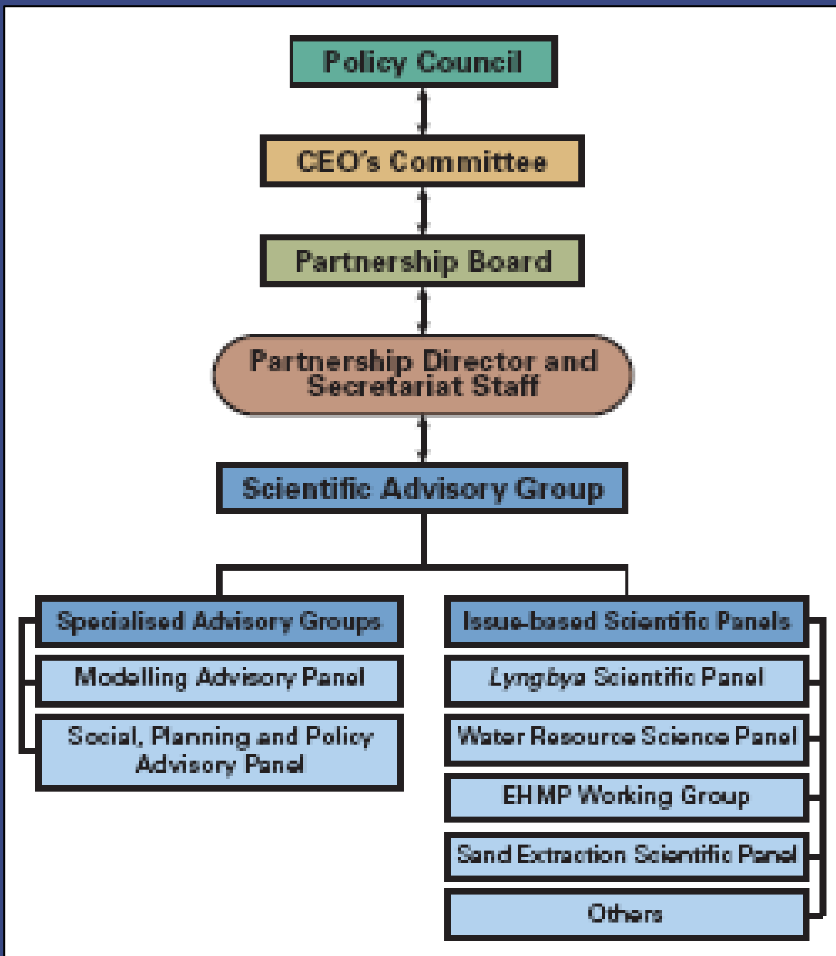
Improvement of understanding



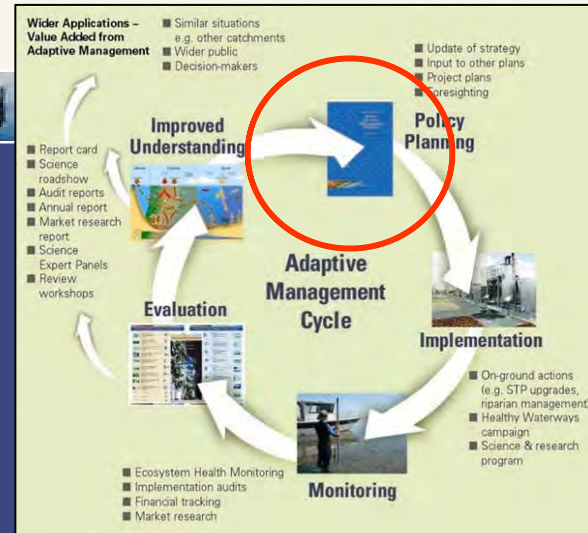


Continual refinement and testing of conceptual models

Links to policy

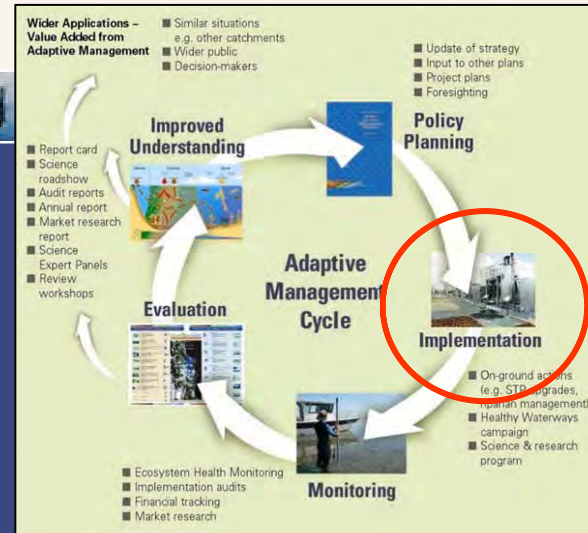


Links between the Partnership Scientific Advisory Group and the policy-setting and decision making components of the Partnership.



Strong link between science and policy makers

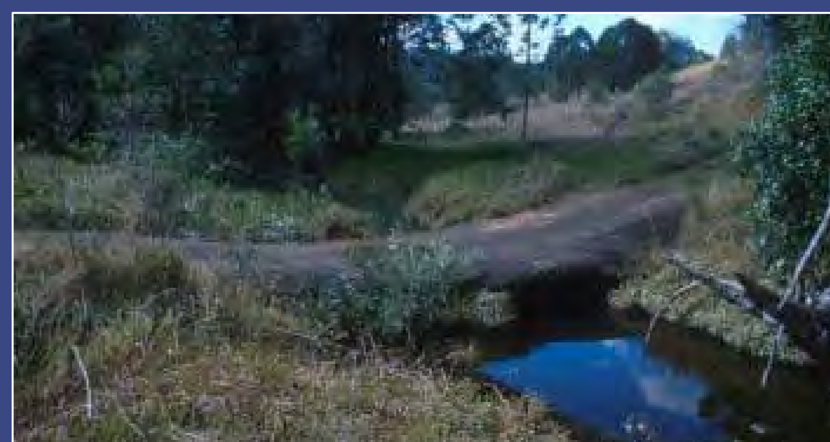
Targeted management actions



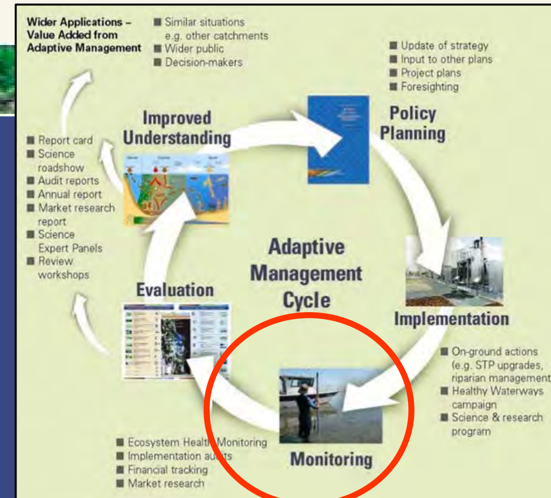
Sewage Treatment Plant upgrades

Stormwater Quality Improvement Devices

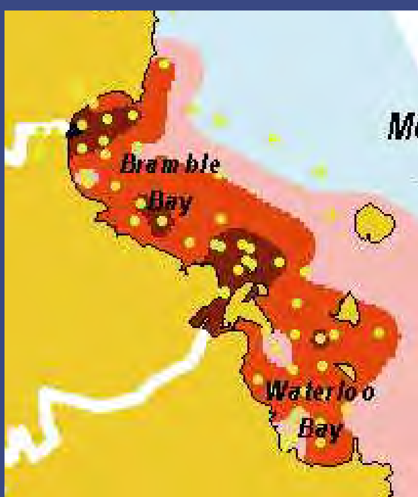
Riparian Rehabilitation



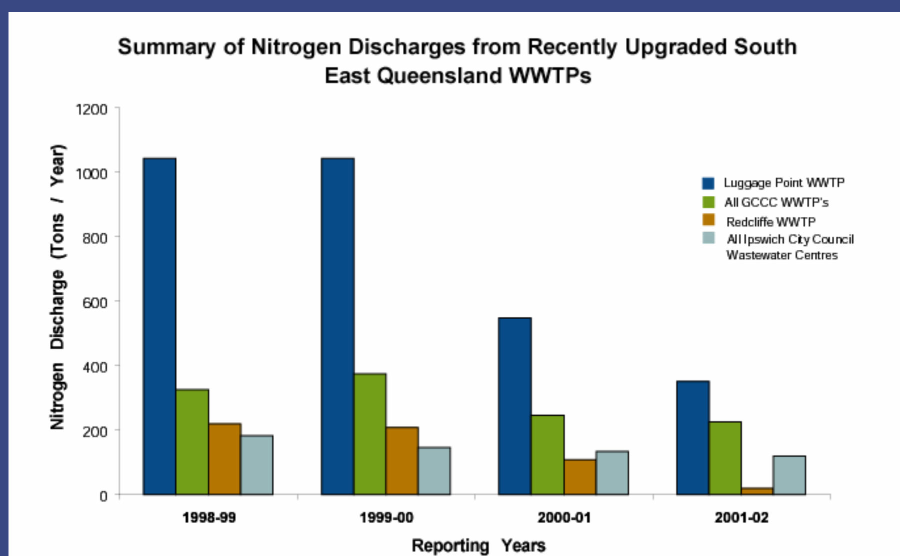
Effectiveness of management actions

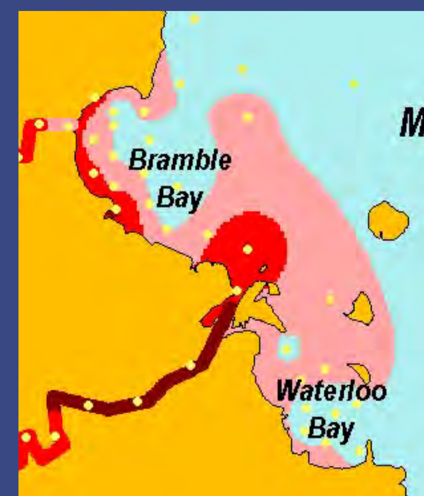


~$500M commitment by local government to reduce wastewater



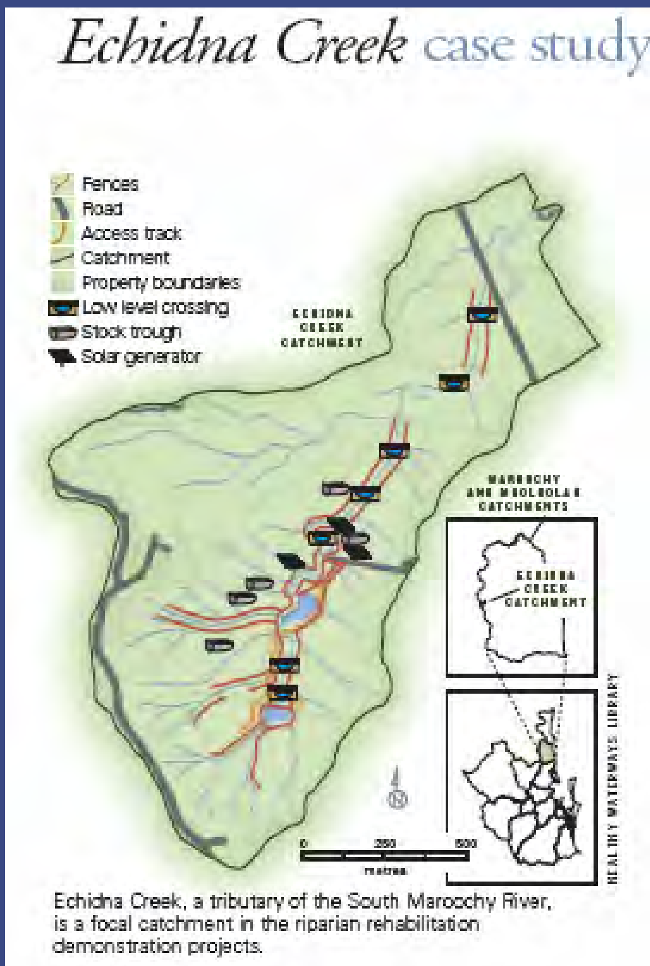
$\delta^{15}N$ Sewage Plume 1998 (summer)



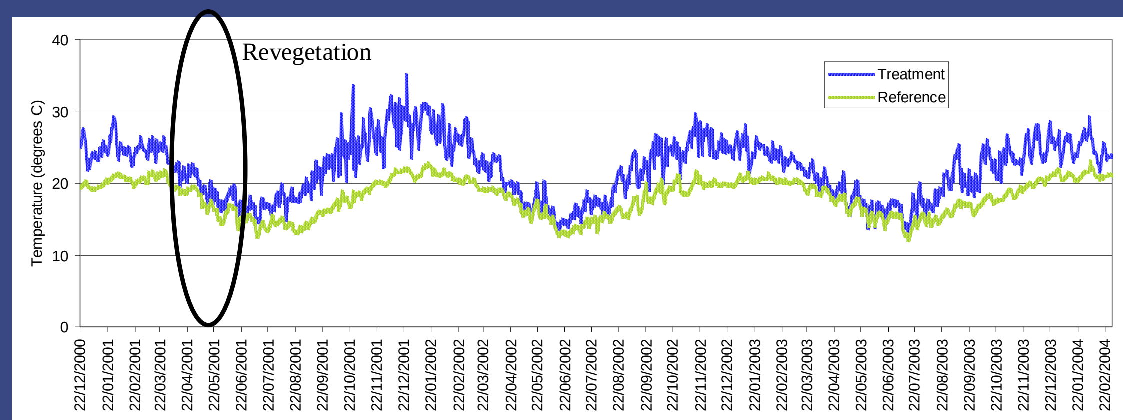


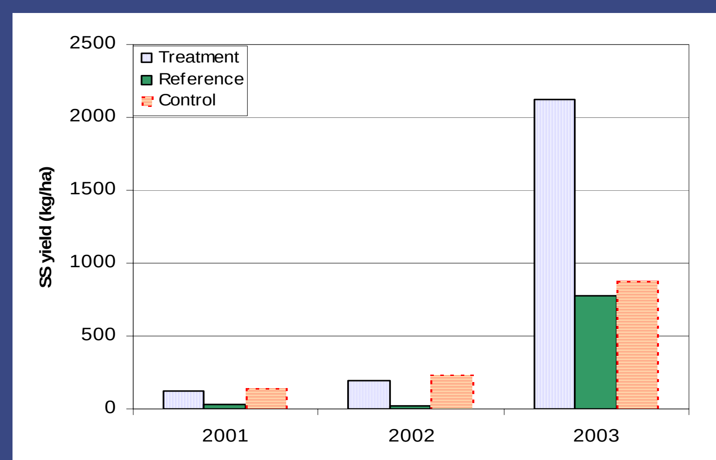
$\delta^{15}N$ Sewage Plume 2001 (summer)

Riparian rehabilitation experiments



temperature regimes





sediment yield

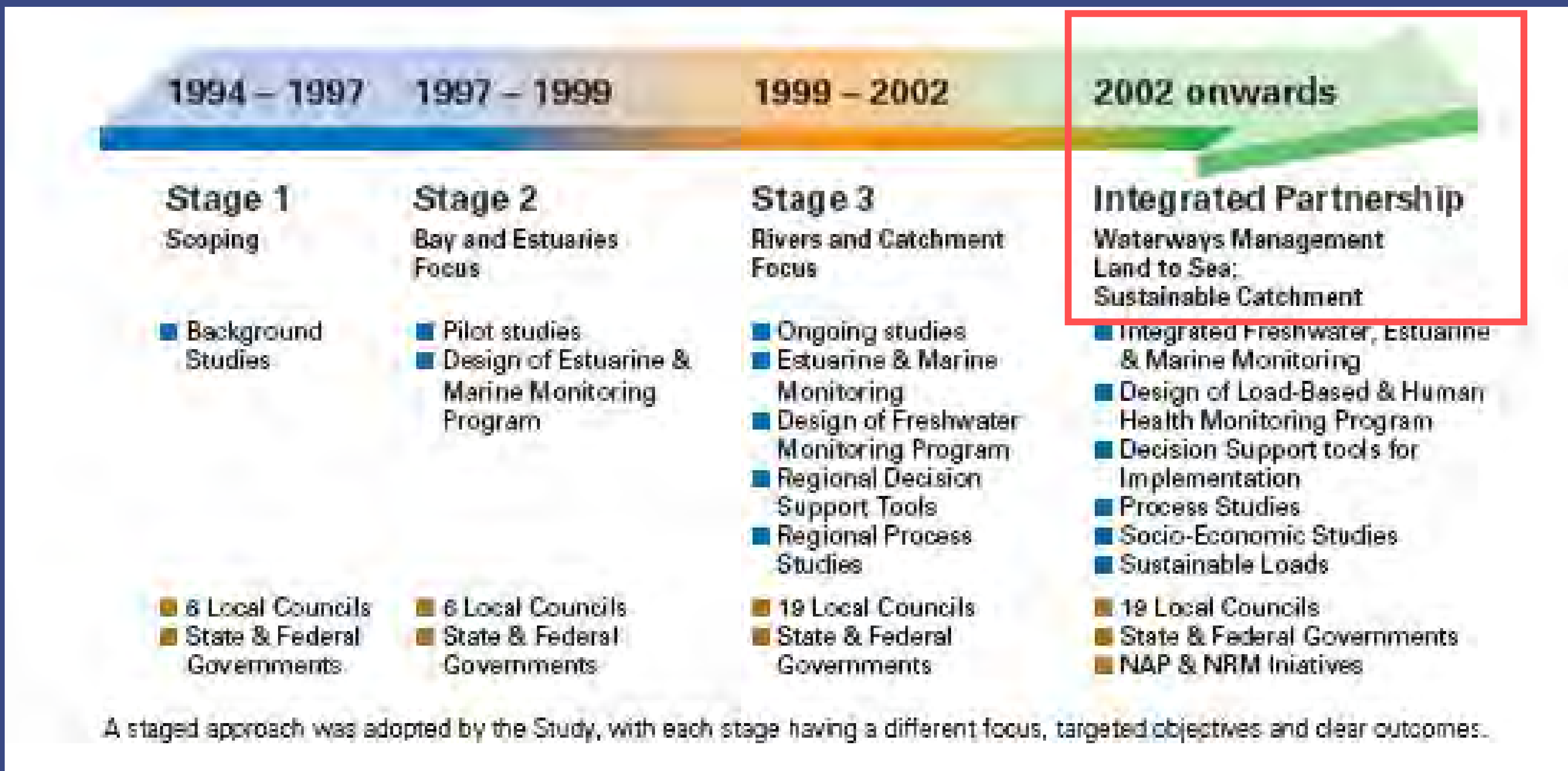

November 2001


February 2003

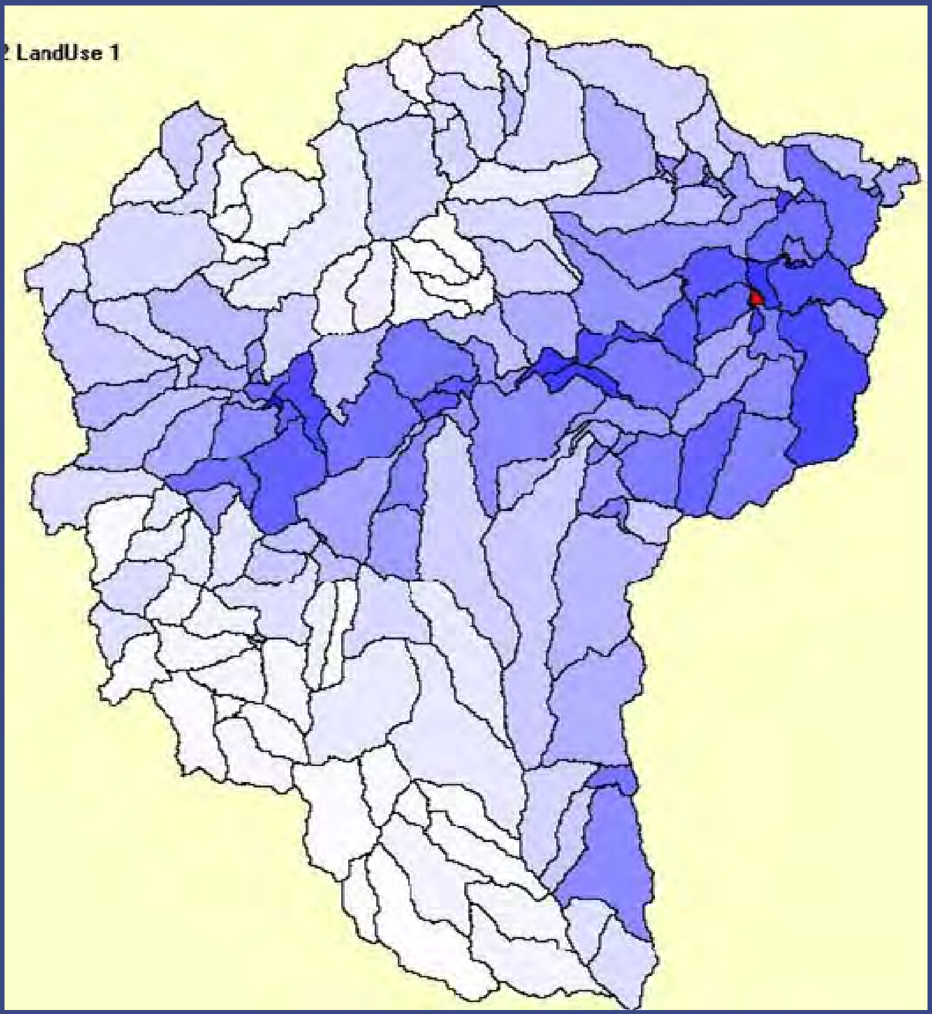

March 2004

The future


HEALTHY WATERWAYS

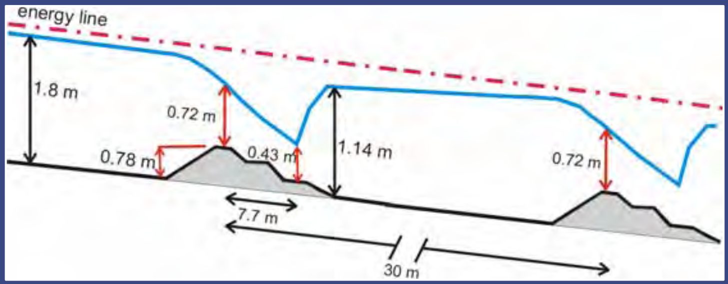

1994 – 1997
1997 – 1999
1999 – 2002
2002 onwards
Stage 1
Scoping
Stage 2
Bay and Estuaries Focus
Stage 3
Rivers and Catchment Focus
Integrated Partnership
Waterways Management
Land to Sea;
Sustainable Catchment
Background Studies
Pilot studies
Design of Estuarine & Marine Monitoring Program
Ongoing studies
Estuarine & Marine Monitoring
Design of Freshwater Monitoring Program
Regional Decision Support Tools
Regional Process Studies
Integrated Freshwater, Estuarine & Marine Monitoring
Design of Load-Based & Human Health Monitoring Program
Decision Support tools for Implementation
Process Studies
Socio-Economic Studies
Sustainable Loads
6 Local Councils
State & Federal Governments
6 Local Councils
State & Federal Governments
19 Local Councils
State & Federal Governments
19 Local Councils
State & Federal Governments
NAP & NRM Iniatives
A staged approach was adopted by the Study, with each stage having a different focus, targeted objectives and clear outcomes.

Subcatchment scale – 'priorities'



Ex. Lockyer Scoping Study
We can identify the areas which are exporting more sediment

What restoration is required?



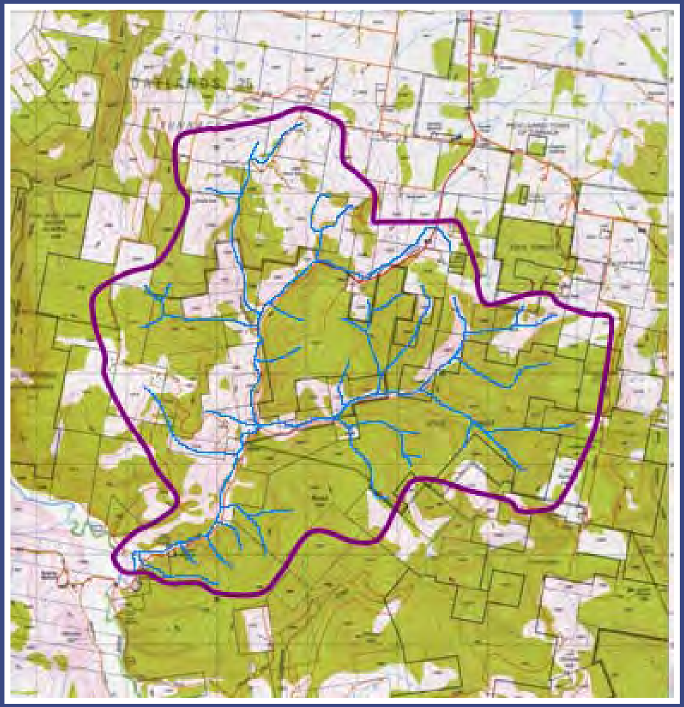
channel/bank restoration?

gully stabilization?

riparian revegetation?

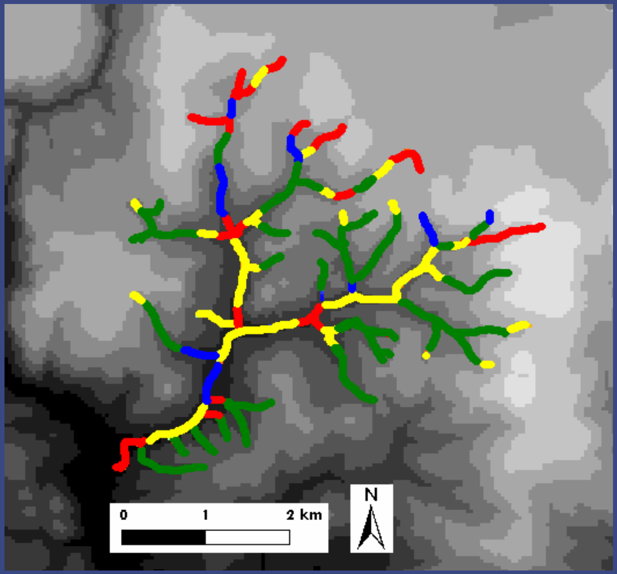
Also can provide this advice now

Where in the landscape?



are there priority areas?

- eg high sediment yield
- eg low riparian shade



What is the optimum size and spatial arrangement of restoration?

- eg one large continuous section or several small ones?

Cannot fully answer this

Summary - Key lessons

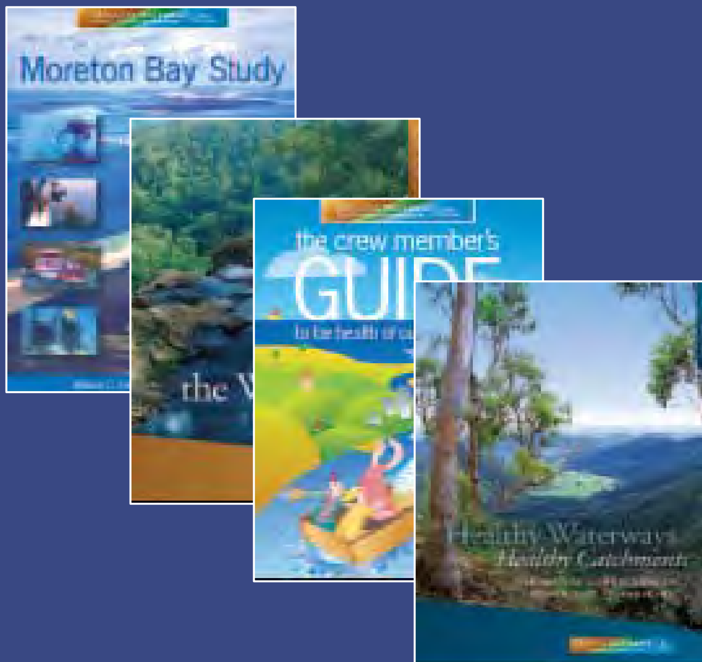
Common Vision

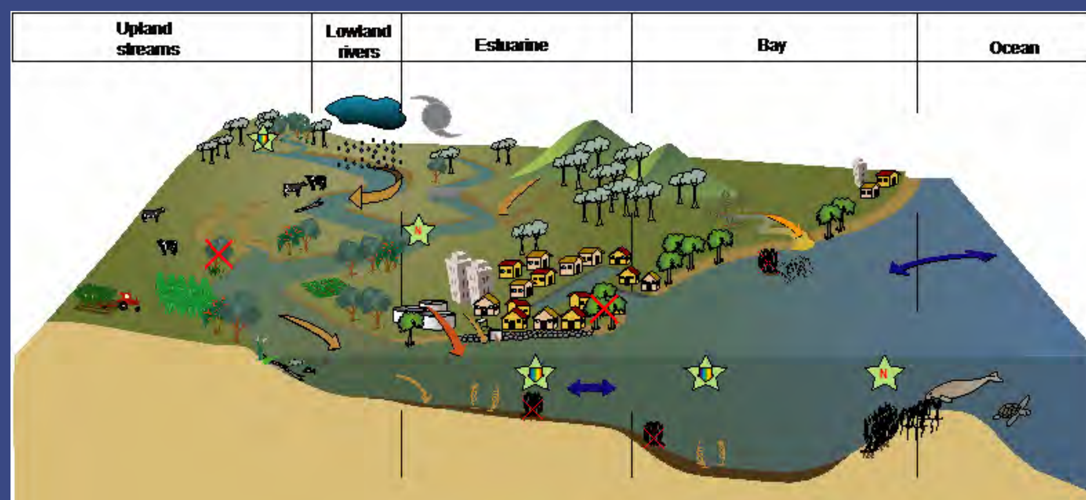
Committed Individuals

HEALTHY WATERWAYS

Because we're all in the same boat

Defensible science and effective communication





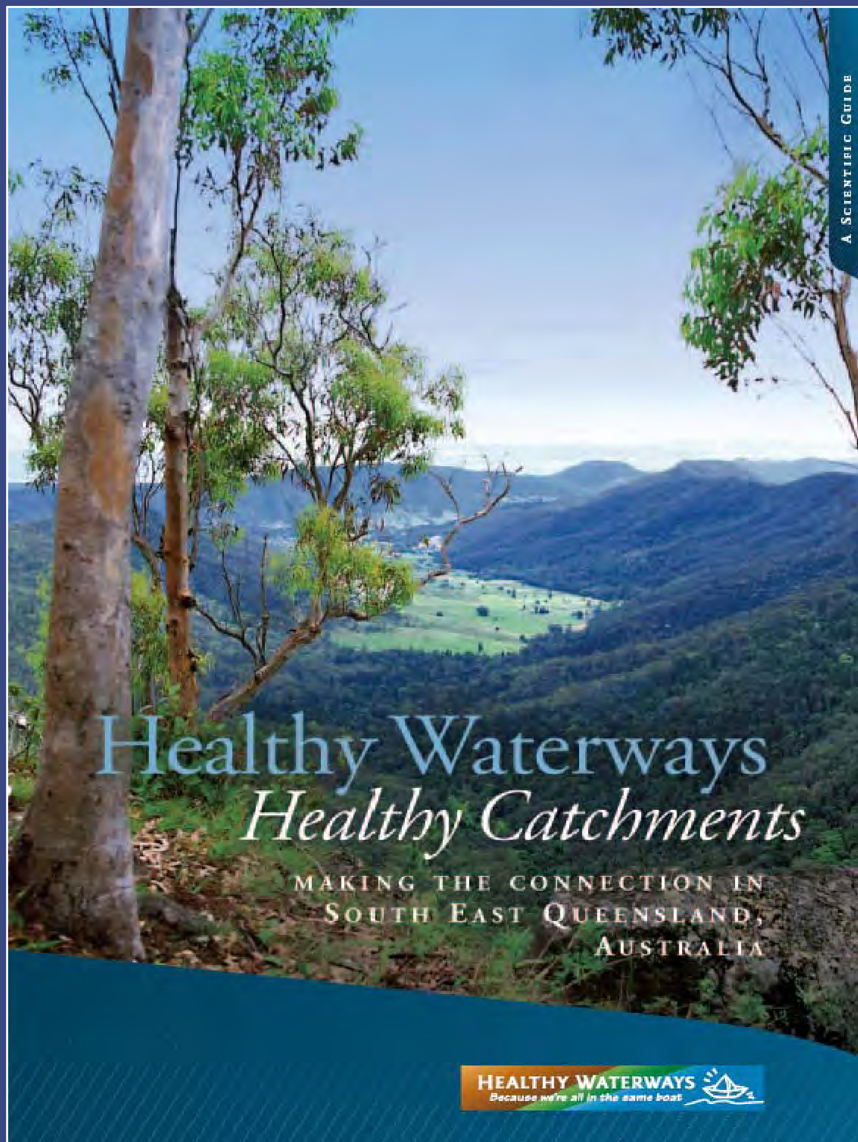
Science involvement in cultural celebration

Annual Riverfestival and International Riversymposium

'Managing rivers with climate change and expanding populations'
4th – 7th September 2006

www.riversymposium.com

Science book - 2005



Thankyou

HEALTHY WATERWAYS

Because we're all in the same boat

http://www.healthywaterways.org

Economics and Water in the Middle Rio Grande

Janie M. Chermak
Associate Professor of Economics
University of New Mexico

Presented in the Rio Grande Seminar
University of New Mexico
November 28, 2006

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Components of Water Resource Management

- Economic Agents; Consumers, Suppliers

  Irrigators, urban centers, species, recreational

- Natural Physical Constraints; Climate

  Precipitation, river and groundwater systems. vegetation

- Manmade Constraints; Physical, Institutional

  Storage, conveyance systems, International, national, state and local institutions: property rights and agreements

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Water Management Policy

"The traditional engineering emphasis in water supply has tended to relegate pricing to a minor role in water policy decision making…. the public has had difficulty in recognizing that water service, even though a necessity, does not have sacred qualities that preclude it from being subjected to economic analysis."

Mellendorf (1983)

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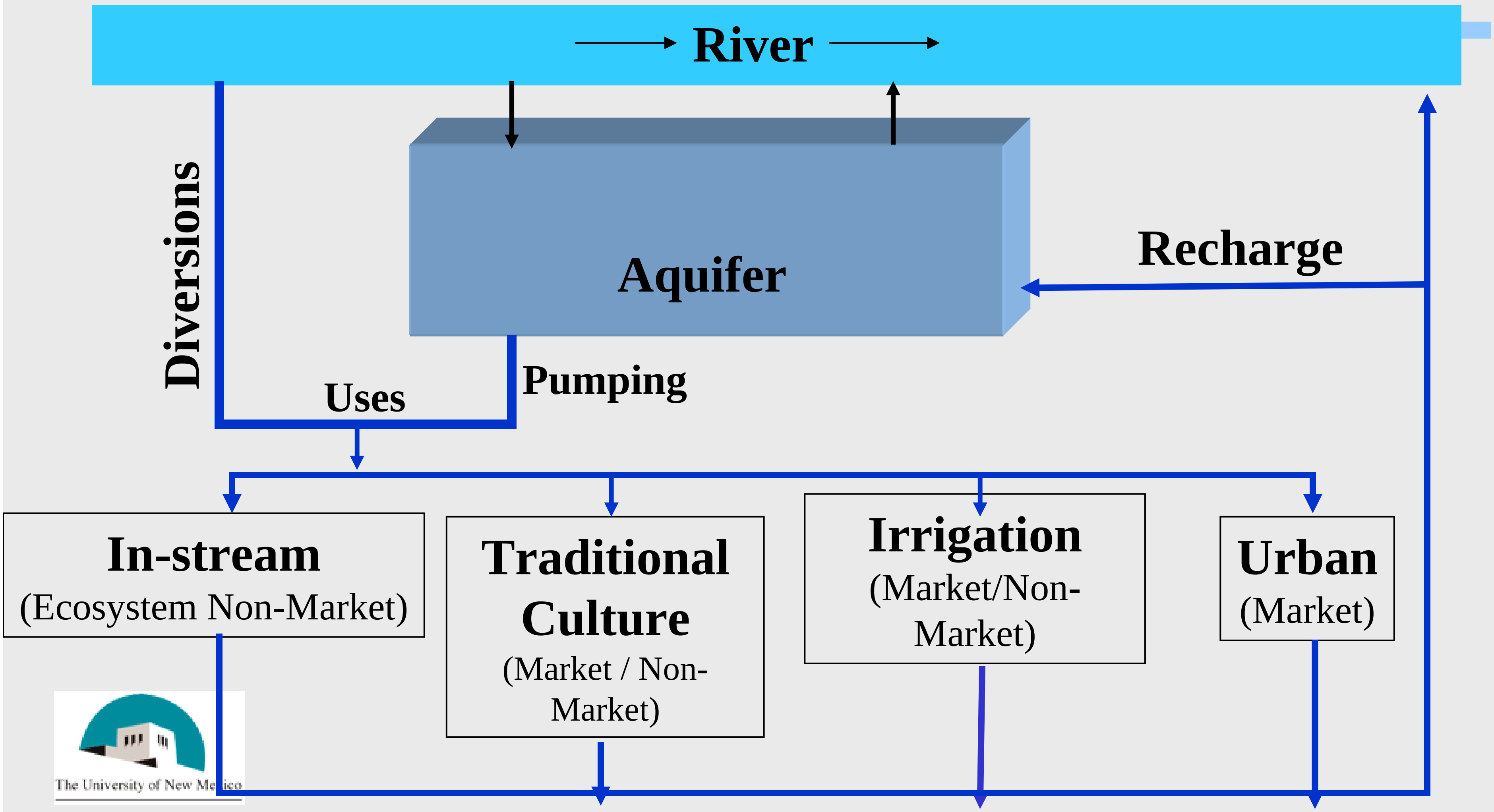
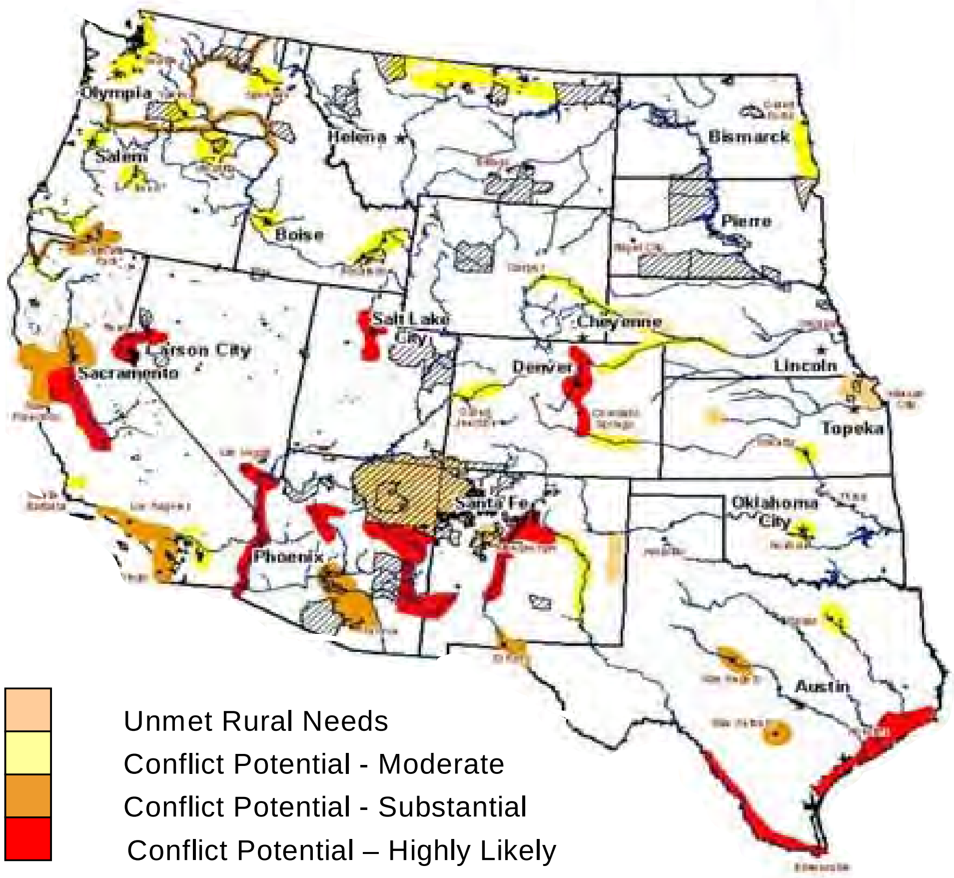
Where Does Economics Fit In?



Water in the West: Potential Areas of Conflict

DOI (2003)



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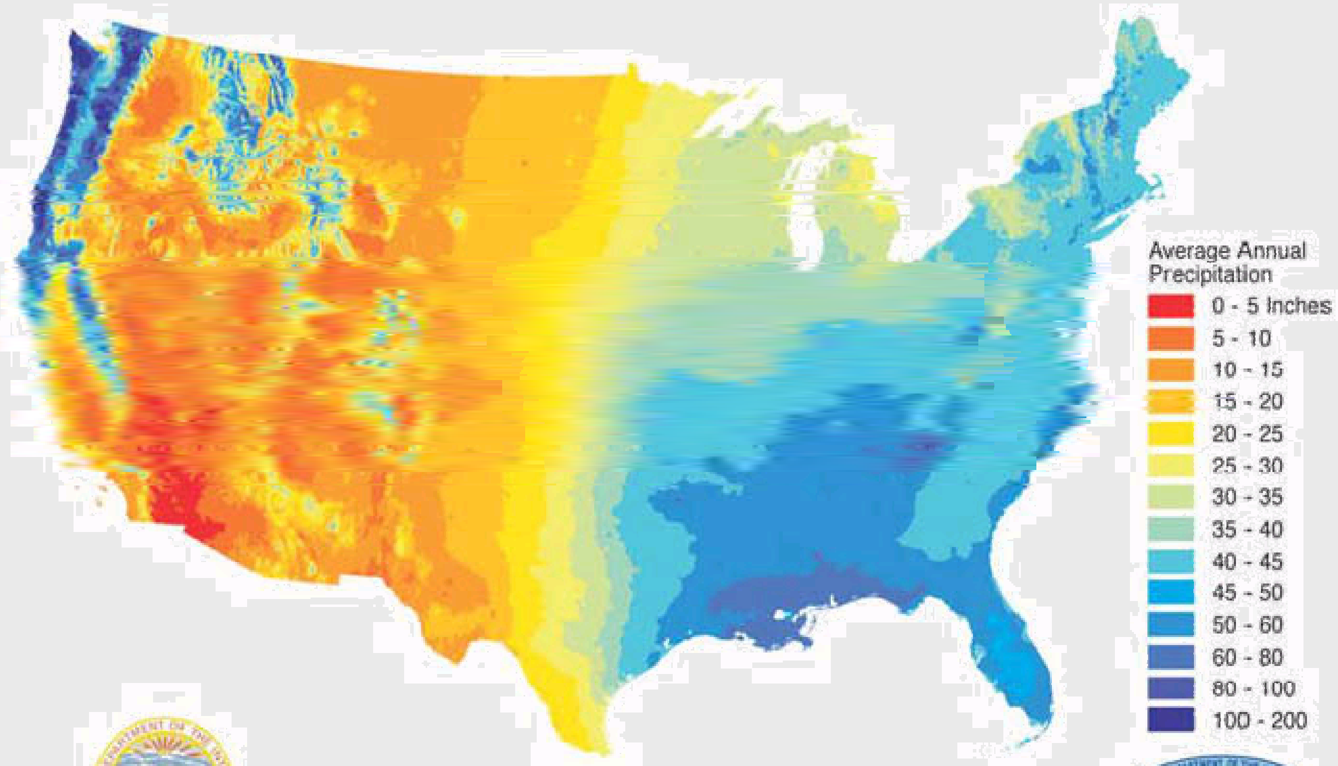
Why?

Southwest Characterized by:

Low Precipitation



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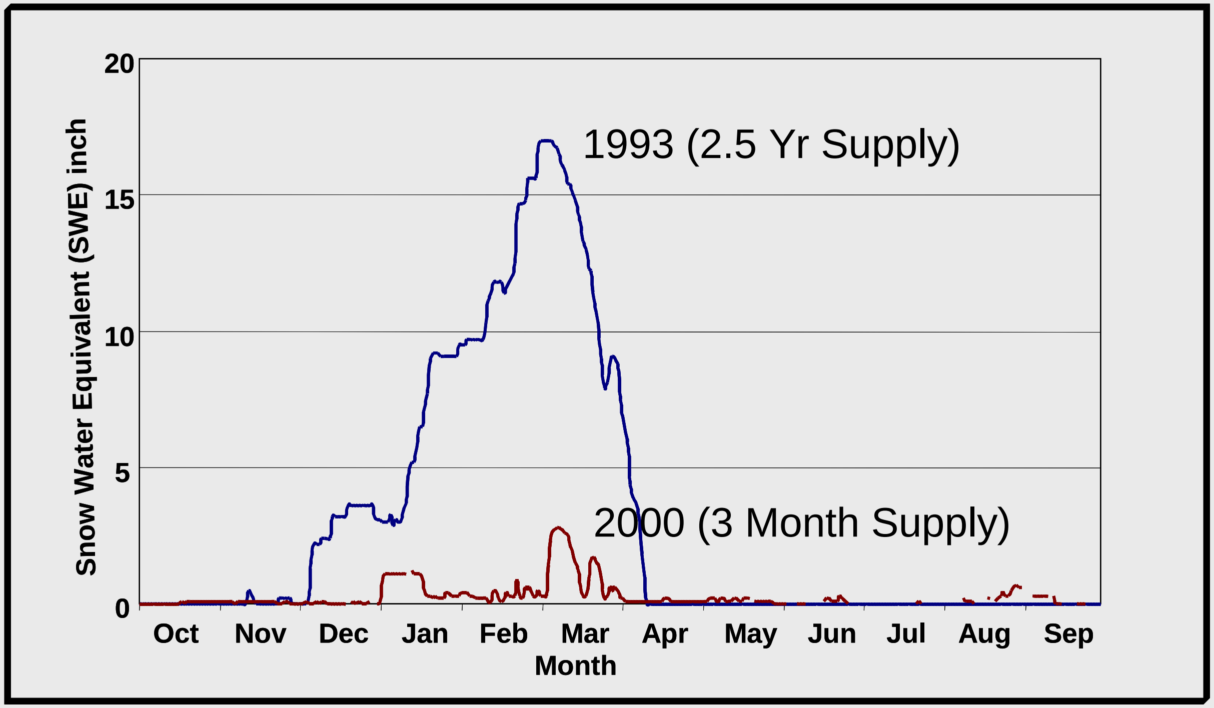
Source: USDA-NRCS: http://www.ftw.nrcs.usda.gov/prism.html

Southwest Characterized by:

Erratic Precipitation



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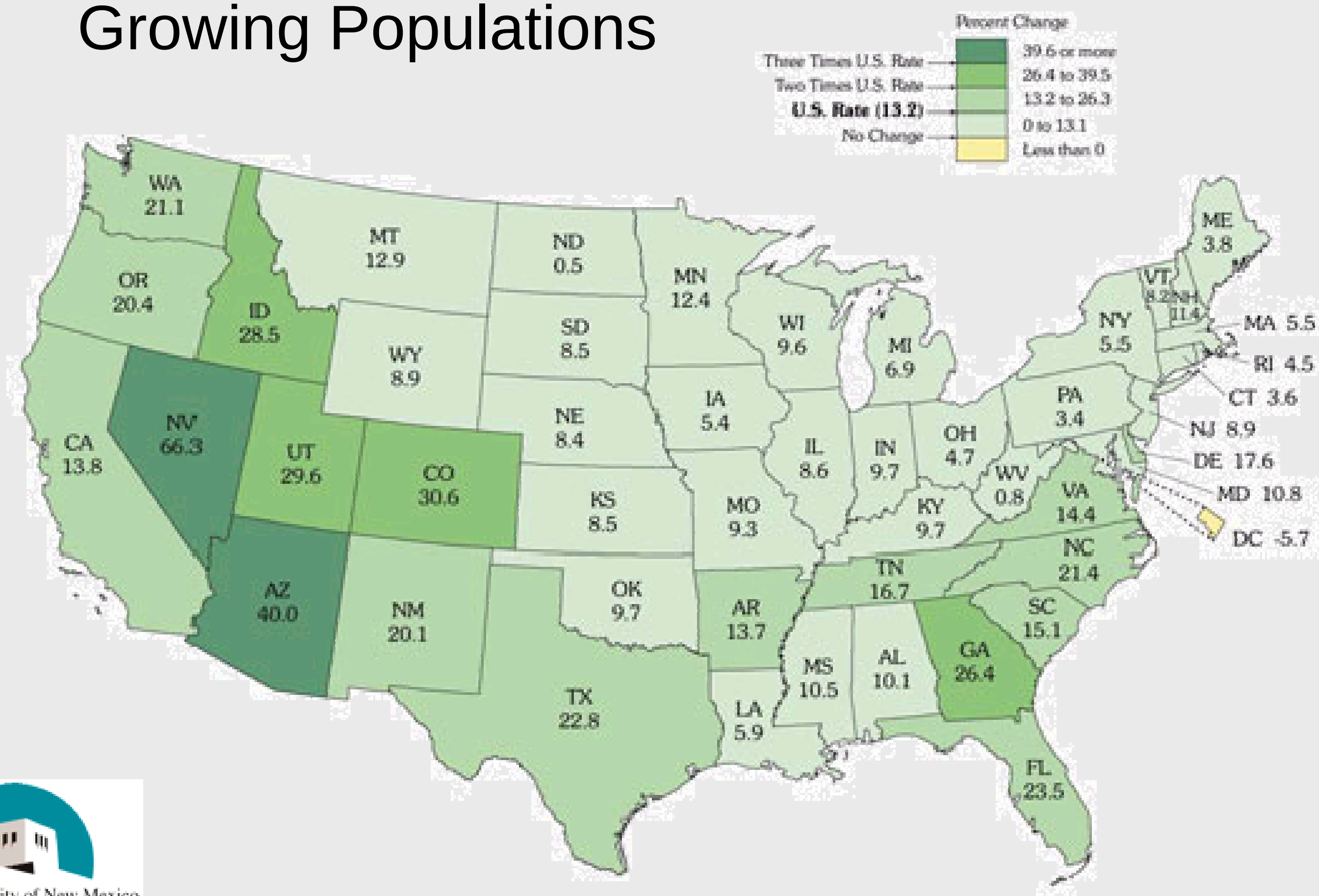
Southwest Characterized by:

Growing Populations



- Darker areas denote faster growth rates.

- Nevada (66%) and Arizona (40%) lead the nation.

- Intermountain states average about 30%.

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Increased Competing Uses

- Agricultural
- In-stream
- Urban
- Native American

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Agriculture

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Agriculture

- Profit Maximizer

$$\max_{\mathbf{x},w} \pi = Pq(\mathbf{x}, w) - C(q(\mathbf{x}, w))$$

$$s.t. \quad w \leq \bar{w}$$

- Water is an Input into Production of Crops

- Cost of Water?

- Value of Product?

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Cropping Patterns[1]

CROP	PERCENTAGE OF TOTAL ACRES PLANTED
Alfalfa	53%
Pasture Grass	35%
Corn	4%
Grain	4%
Miscellaneous Vegetables[2]	3%
Chile Peppers	1%

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[1] Chermak et al (Sandia National Laboratories Draft Report 2006).
[2] Includes miscellaneous vegetables (1.9%), grapes (0.1%), melons (0.1%), miscellaneous fruit (0.5%), nursery stock (0.45%), and tree fruit (0.02%).

Crop Information[1]

Crop	Valencia Farm ($ per acre)	Socorro Farm ($ per acre)	Value
Alfalfa (3.5 ton/ac)	$413.60	$541.25	$112-150 per ton
Pasture Grass	---	$238.45	$90-128 per ton
Corn (180 bu/ac)	---	$514.20	$2.50-$3.20 per bushel
Grain		$424.60	$2.70-$3.30 per bushel
Chiles	$2209.90	$1906.72	$24.70-$30.30 per 100 weight

Yield depends on ET or water applied

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[1] From Sandia Draft Report. (Based on NMSU Extension Service Information)

In Stream Values

In-Stream Flow Values

- Non-use: $25 per year per NM household. (Berrens et al 1996).
- Shoreline:$0.02 - $0.10 per cfs: decreases with increasing cfs. (Daubert and Young 1981)
- Birding: $65/day for change from intermittent to perennial, $97 to maintain prime perennial flows (Crandall et al 1992)

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Example: Value of Birding

Value/visitor		$32 ($2003)	$65 (marginal value $2003)
	Avg. monthly visits (1999-2003)	Low-Flow value	Intermittent to perennial
January	19,998	$838,694	$1,703,596
February	19,546	$819,737	$1,665,090
March	11,110	$465,950	$946,461
April	8,878	$372,324	$756,283
May	6,065	$254,381	$516,712
June	4,074	$170,846	$347,030
July	3,838	$160,981	$326,993
August	3,663	$153,634	$312,068
September	4,829	$202,527	$411,383
October	9,972	$418,206	$849,481
November	30,890	$1,295,501	$2,631,486
December	15,390	$645,444	$1,311,058

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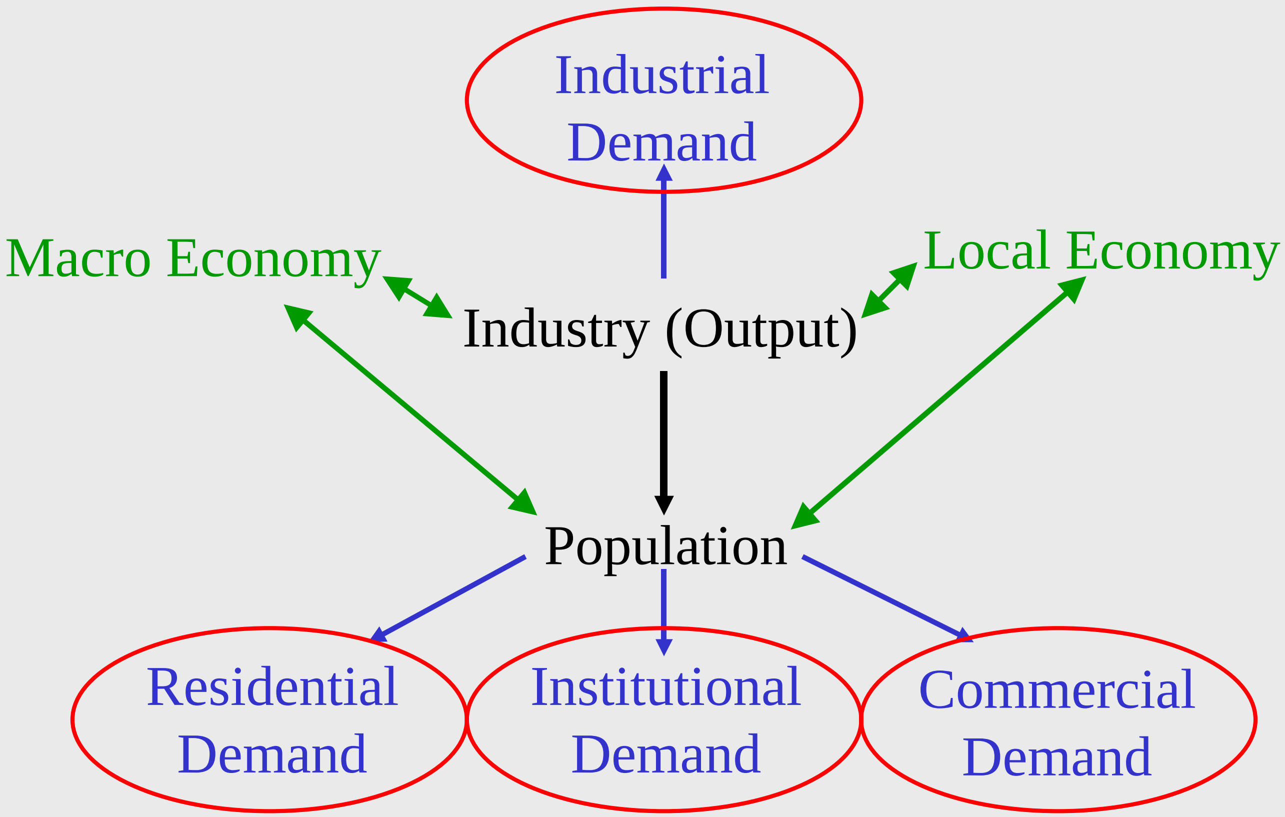
Urban

Interactions in NM Economy



Urban

- Residential
- Commercial
- Industrial
- Institutional

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Commercial, Industrial, Institutional

$$\max_{\mathbf{x},w} \pi = Pq(\mathbf{x}, w) - C(q(\mathbf{x}, w))$$

$$s.t. \;\; w \leq \overline{w}$$

Production not well studied: water use as a function of employees. May not the as bad an estimate as one might think…

What percentage of Albuquerque's water use is from commercial, industrial, and institutional?

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For a $1 Million Dollar Primary Impact

Activity	Econ. Impact	Employ	Water Use (Mil Gal)	$/Gallon
Copper Mining	1.96	11	8237	0.24
Manufacturing	2.15	21	10481	0.21
Electronics	1.7	20	1790	0.95
Grains	2.02	9	20333	0.10
Golf (amusement/Rec Services)	1.54	23	2637	0.58
Electric Utility	1.67	7	2239	0.75
Dairy	2.7	13	12885	0.21
Semiconductors	1.77	13	8452	0.21
Mattresses and Bedsprings	2.28	20	11093	0.21

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It May Not be Economic Growth

and its impact on water, but the impact of economic growth on population growth.

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Urban Populations (2000)

- Otowi-Cochiti: 62,200
- Cochiti-San Felipe: 0
- San Felipe-Albuquerque: 393,300
- Albuquerque-Bernardo: 147,200
- Bernardo-San Acacia: 300
- San Acacia-San Marcial: 10,300
- San Marcial-Elephant Butte: 0
- TOTAL: 613,400

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Population Growth (2005-2030) BBER Projections

- NM: 33%
- Bernalillo: 27%
- Dona Ana: 45%
- Santa Fe: 57%
- San Juan: 27%
- Sierra 50%
- Valencia: 68%
- Sandoval: 82%

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From: http://www.unm.edu/~bber/demo/table1.htm (Last accessed 10-17-05)

It May Not be Economic Growth

and its impact on water, but the impact of economic growth on population growth.

And, all consuming households are not created equal…

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Do “Conservation-built” Homes Help?

Consider the following consumer who lives in a house that is equipped with many water savings devices, such as;

Low-flow showerheads
Ultra-low flush toilets
Drip irrigation system

How does this family use water? Are they conservation minded?

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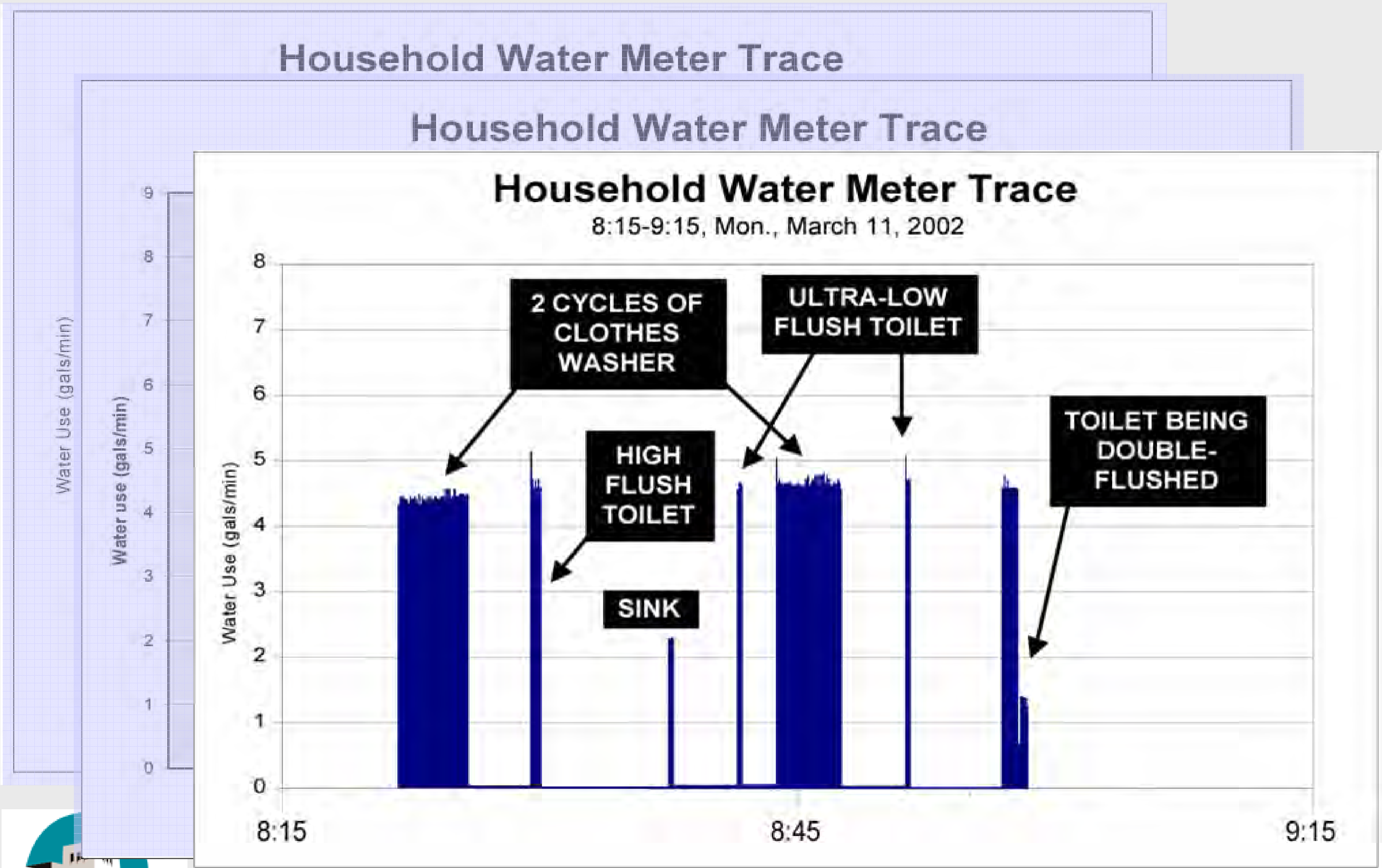
From: Woodard (2002)

Water Meter Traces Reveal Water Use



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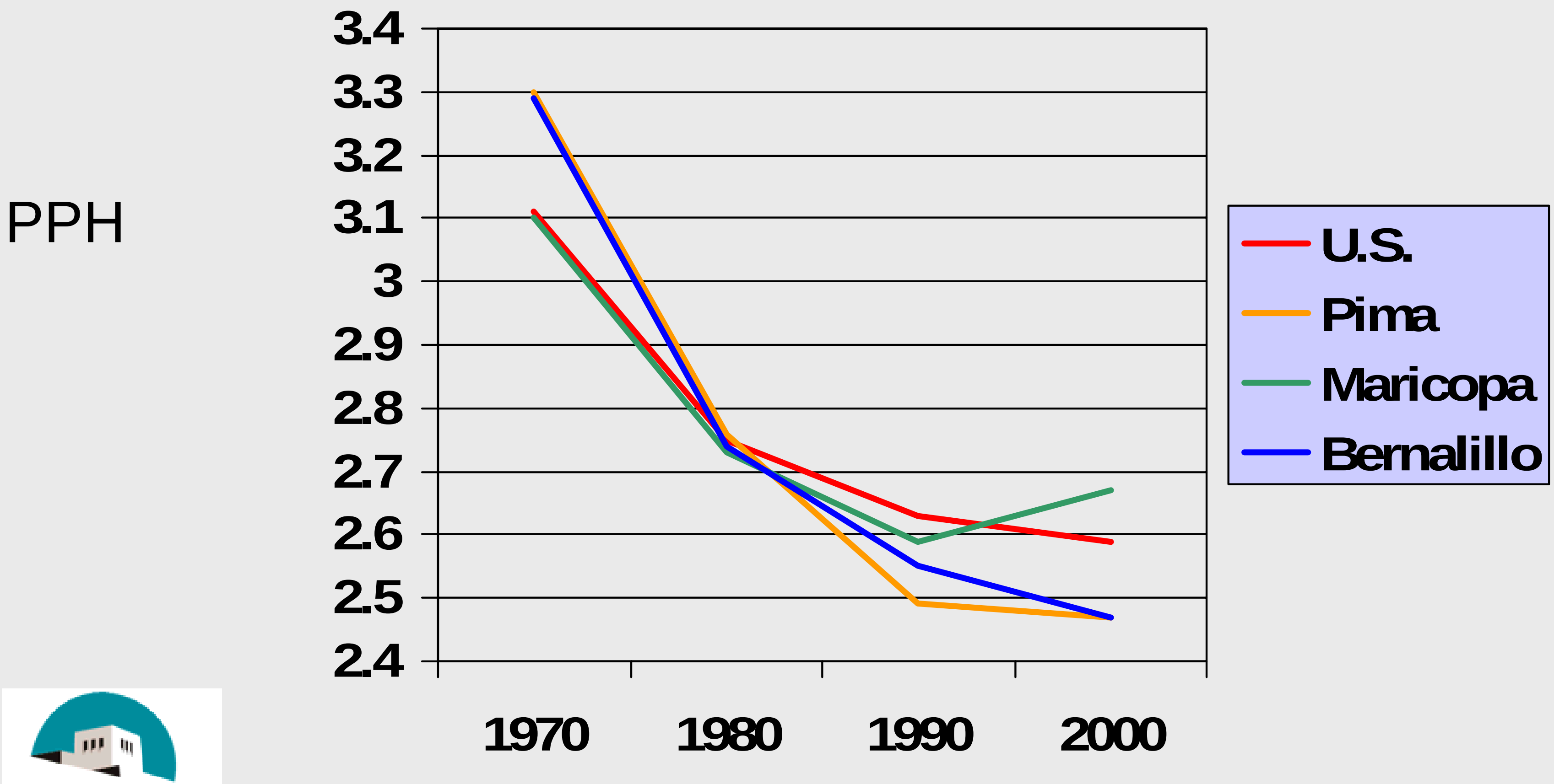
From: Woodard (2002)

Trends: Persons per Household (PPH)



*From: Woodard (2002)

Impact on Housing Demand

Housing Demand Impact from:

Area	% from Pop Growth	% from PPH Drop
USA	50	50
Albuquerque, NM	57	43
Tucson, AZ	69	31
Phoenix, AZ	81	19

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From: Woodard (2002)

Does Homeownership and Type Matter?*

Outdoor demand is a function of housing type. Residents of Single Family Residences use more water outdoors than residents of townhouses and condos, which in turn use more water than residents of apartments and mobile homes.

Owner-occupied homes are associated with greater outdoor water demand.

Changes in the housing stock mix are increasing outdoor water demand.

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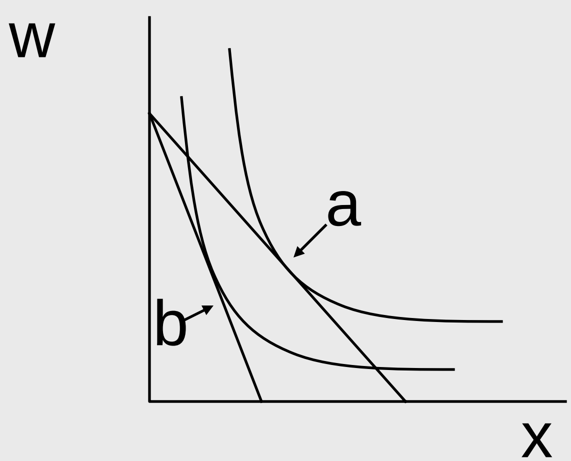
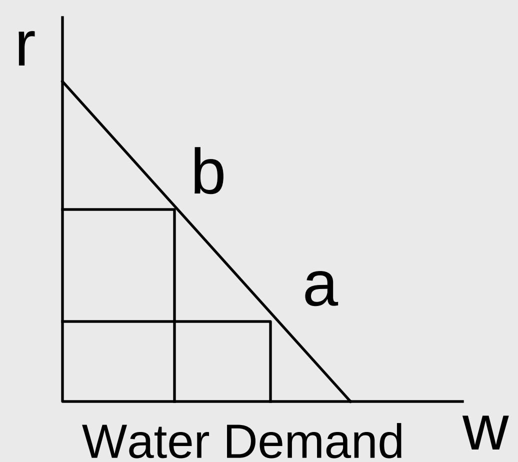
From: Woodard (2002)

Demand?

$$\max_{\mathbf{x},w} U = u(\mathbf{x}, w; \beta)$$

$$s.t. \;\; \mathbf{px} + rw \le E$$





Factors that Impact Demand[1]

- Price (-)
- Income (+)
- Education (-)
- Gender: Male (+)
- Native (+)
- Home Ownership (-)
- Protestant (+)
- Non-denominational (+)
- DNR religion (+)
- Republican (-)
- Other Political Affiliation (-)
- Geographic Location (-)
- Temperature (+)

Consumers are not heterogeneous: one size pricing does not fit all…

1 Krause et al 2002.

How Do Water Prices Fit In?

- Historic Realities
- Current Trends
- Future Directions

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Conventional Wisdom

Residential consumers do not vary responsive to price, therefore price is not an effective management tool.

Based on?

Data

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Empirical Evidence?

- Majority of empirical studies find residential consumers unresponsive to price changes

- Brookshire, et al (2002), Espey et al (2000)

Why?

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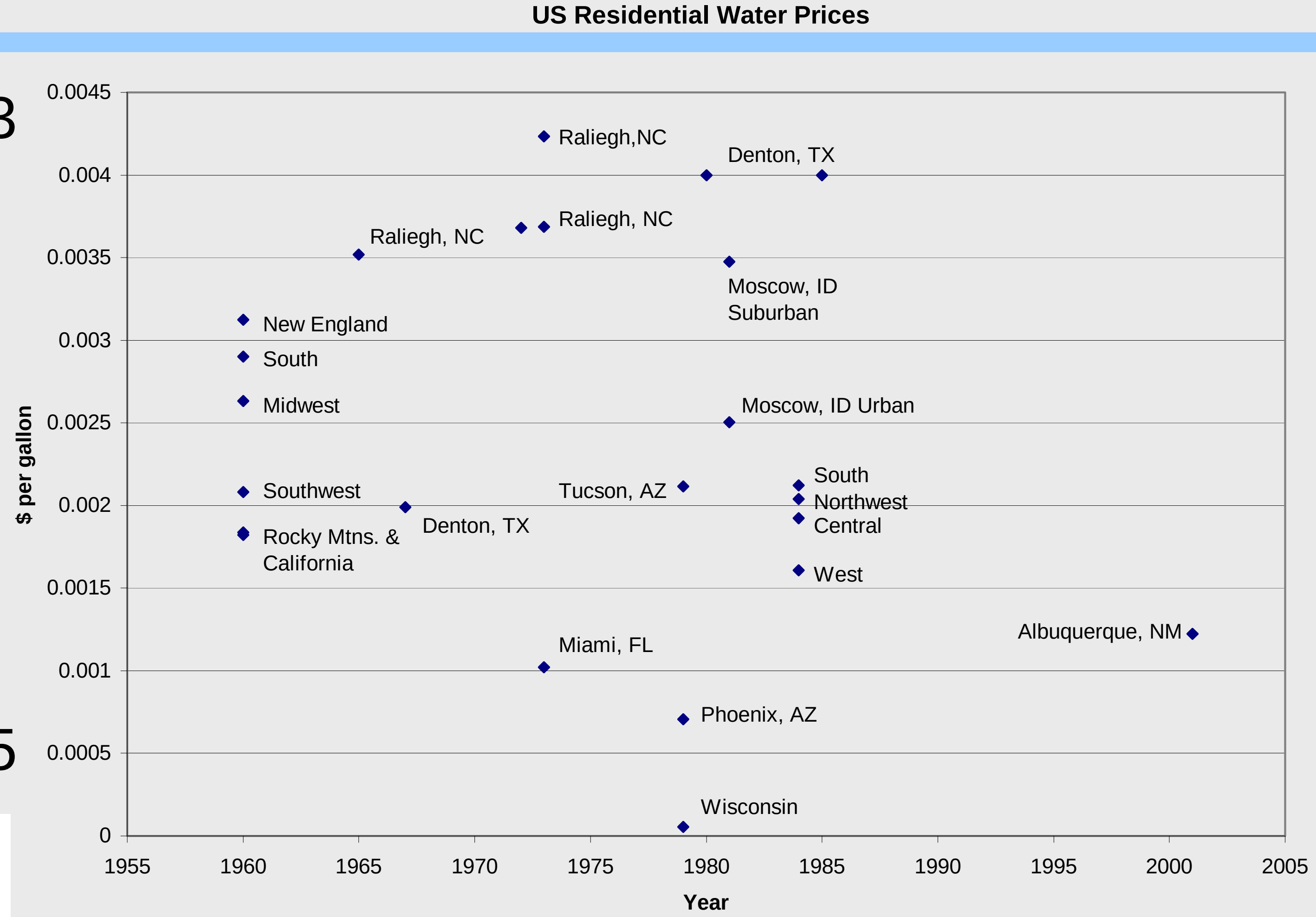
Historical Pricing in US

$0.0043

$0.0005



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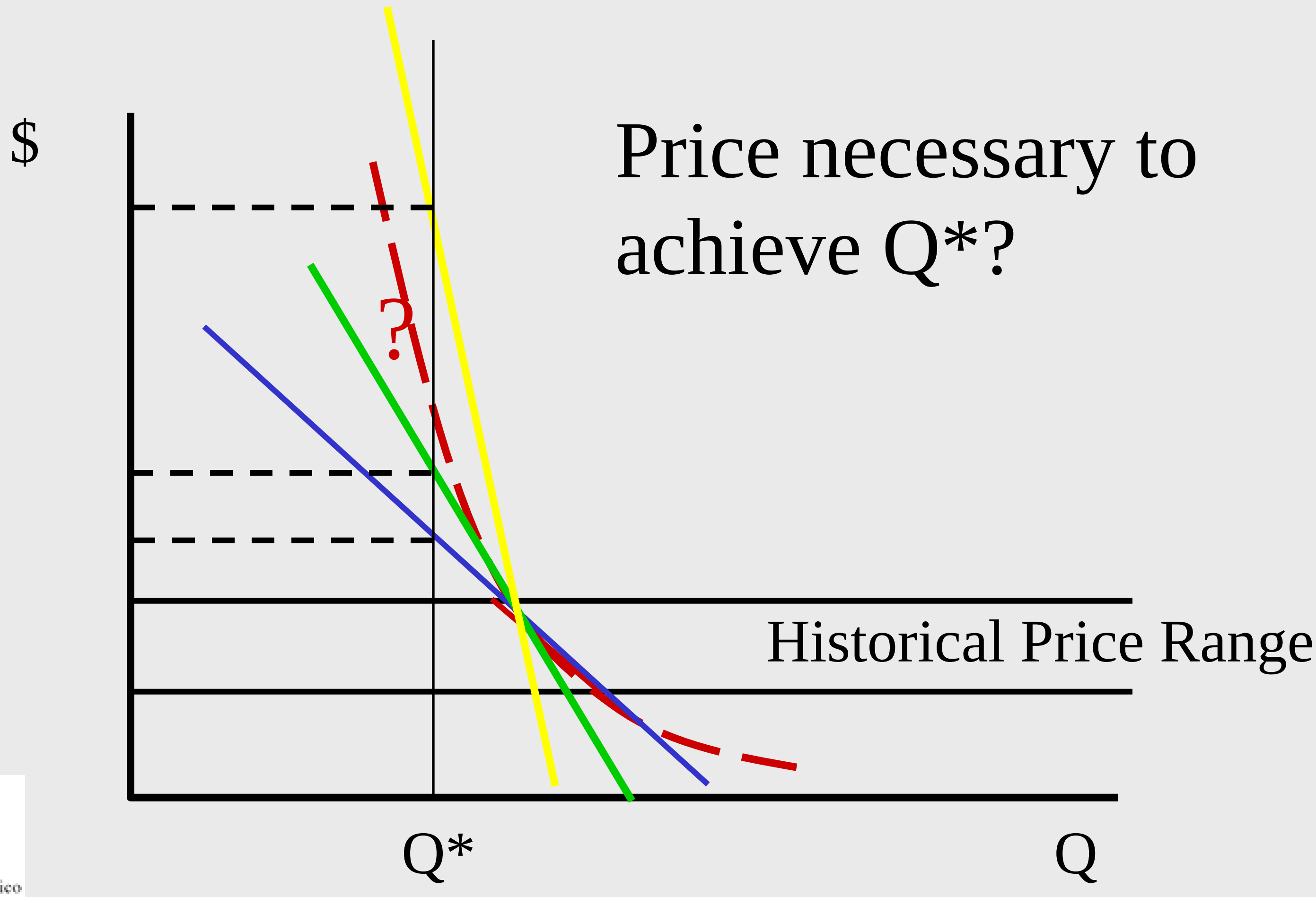
Problem with Historical Prices



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Current Pricing Trends

- Base (Fixed) Charge
- Commodity Charge
- Block Rate Structure
- Summer Surcharge
- Drought Policies

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SW Pricing Examples (2005 info)

Location	Base	Commodity (1000 gallons)	Comments
Albuquerque	$4.60	$1.65	Surcharge
Santa Fe	$14.50	$5.32-$15.32	Surcharge+ Block Rate
T or C	$8.15	$1.75	Block Rate
Denver	$3.41	$1.63	Block Rate
Fort Collins	$12.72	$1.78	Block Rate
Tucson	$5.35	$1.03	Block Rate
Tucson	$11.96	$1.98	Block Rate
Phoenix	$5.16	$1.93	Uniform
Las Vegas	$3.72	$1.05	Block Rate
Los Angeles	None	$2.46 (tier 1) $2.56 (tier 2)	Block Rate, by tier by month

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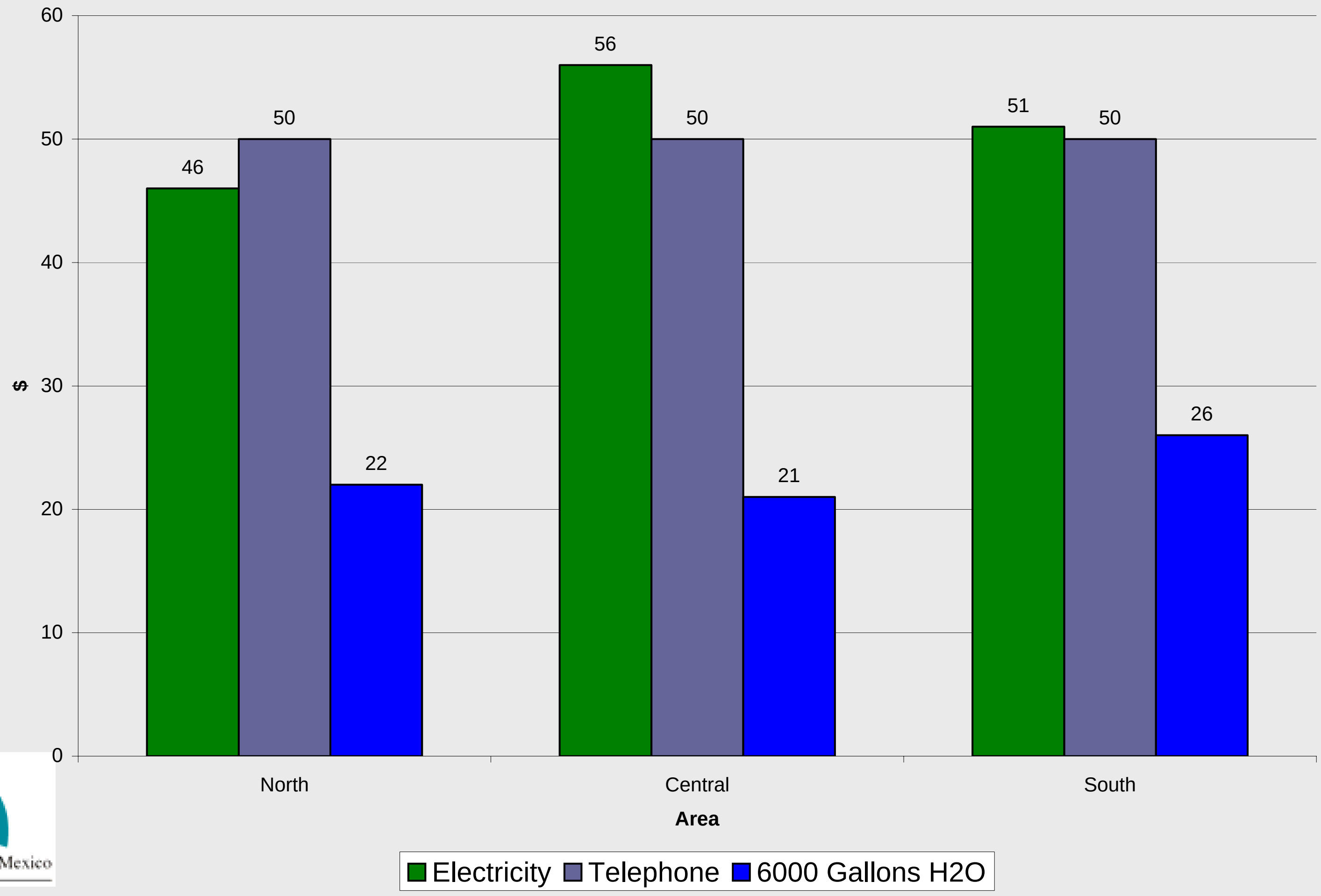
Average Monthly Utility Expenditures



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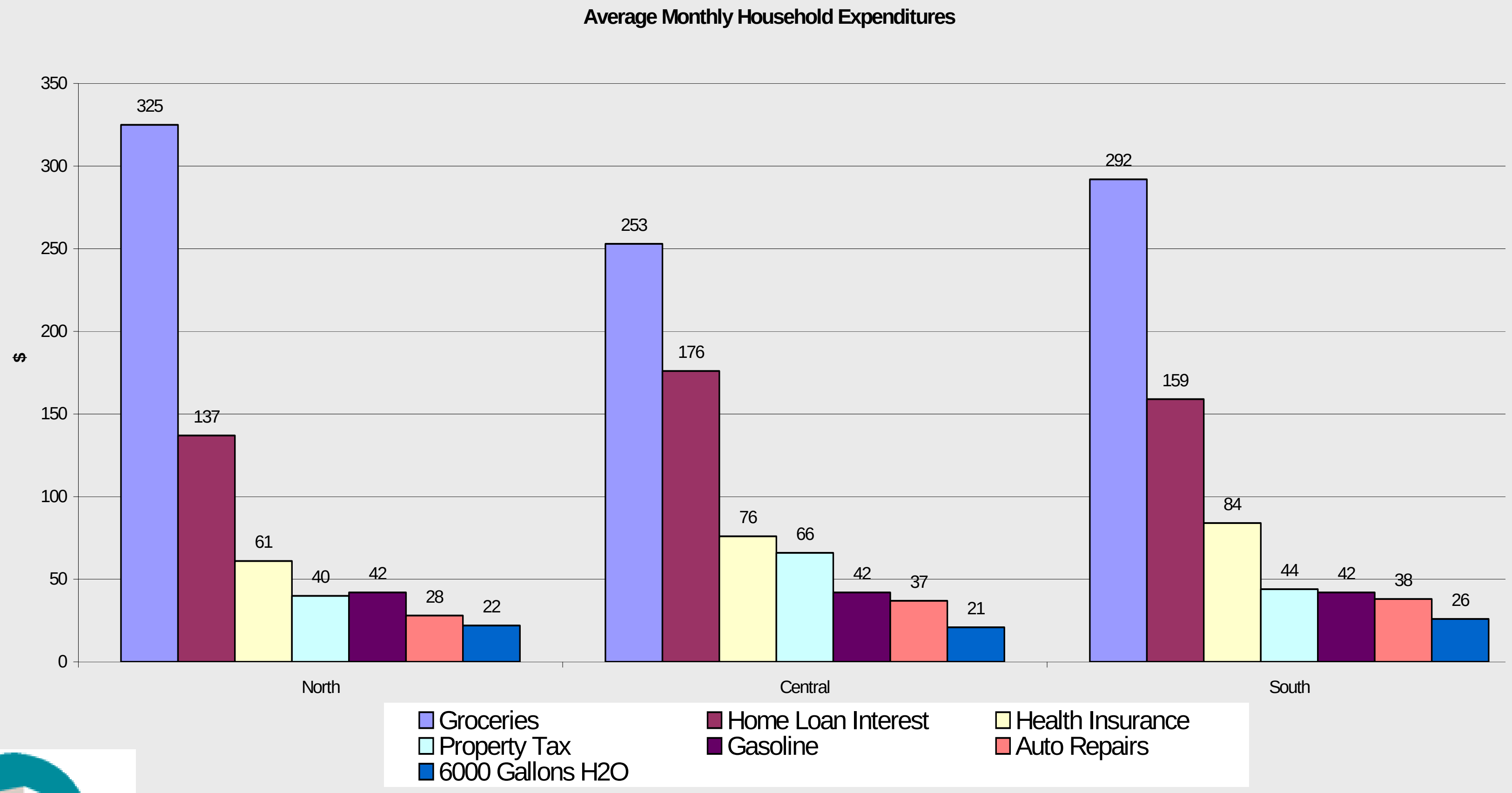
Average Monthly Household Necessities Expenditures for a Family of Four



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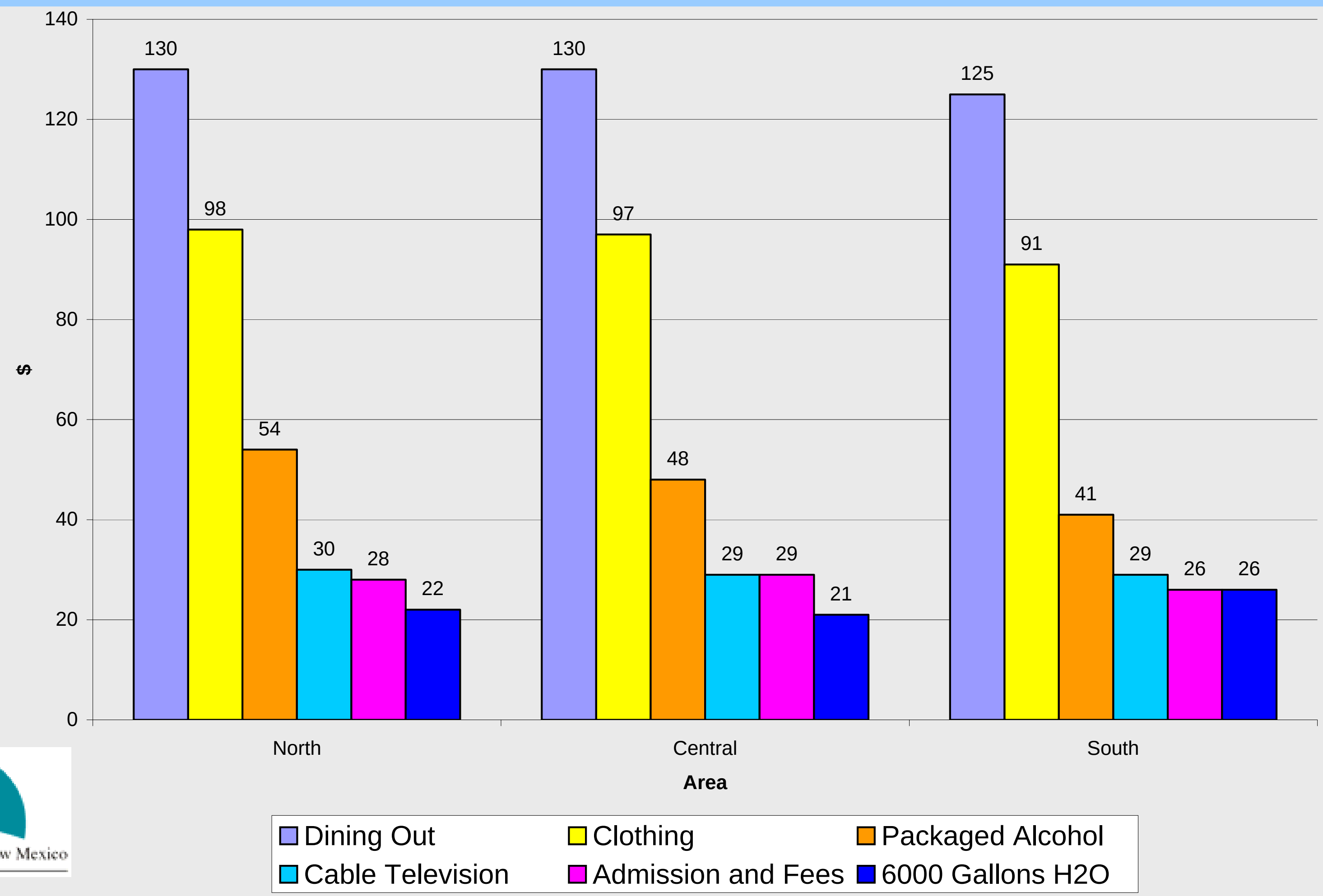
Monthly Discretionary Goods Expenditures



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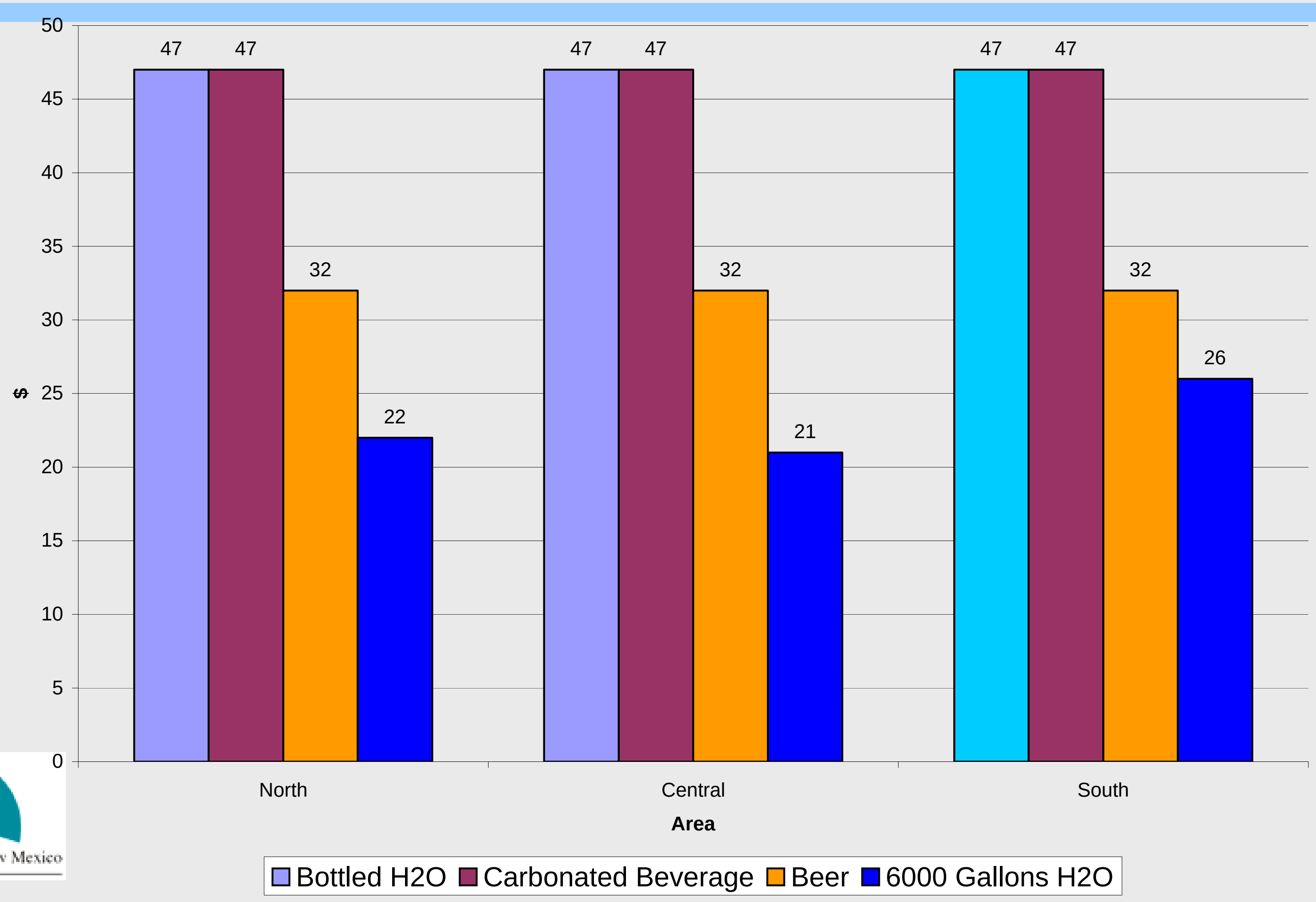
Average Monthly Expenditures of Select Beverages



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Signals and Incentives Given?

- Water is relatively cheap
- Delivery of water is the only thing of value
- Water is abundant

But we still need to trade-off between uses, because there isn't enough water….

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How do We Make Trade-offs?

- Market versus Non-Market
- Agriculture versus Urban Development
- How much and at what price?

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Mechanisms

Markets: voluntary

Forbearance: coordinated or negotiated

Legislated: required

Oversight

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COMPETITIVE MARKET EXAMPLE

- Perfect Information
- No Market Power
- Homogeneous Product
- No Market Externalities
- Full Water Allocations

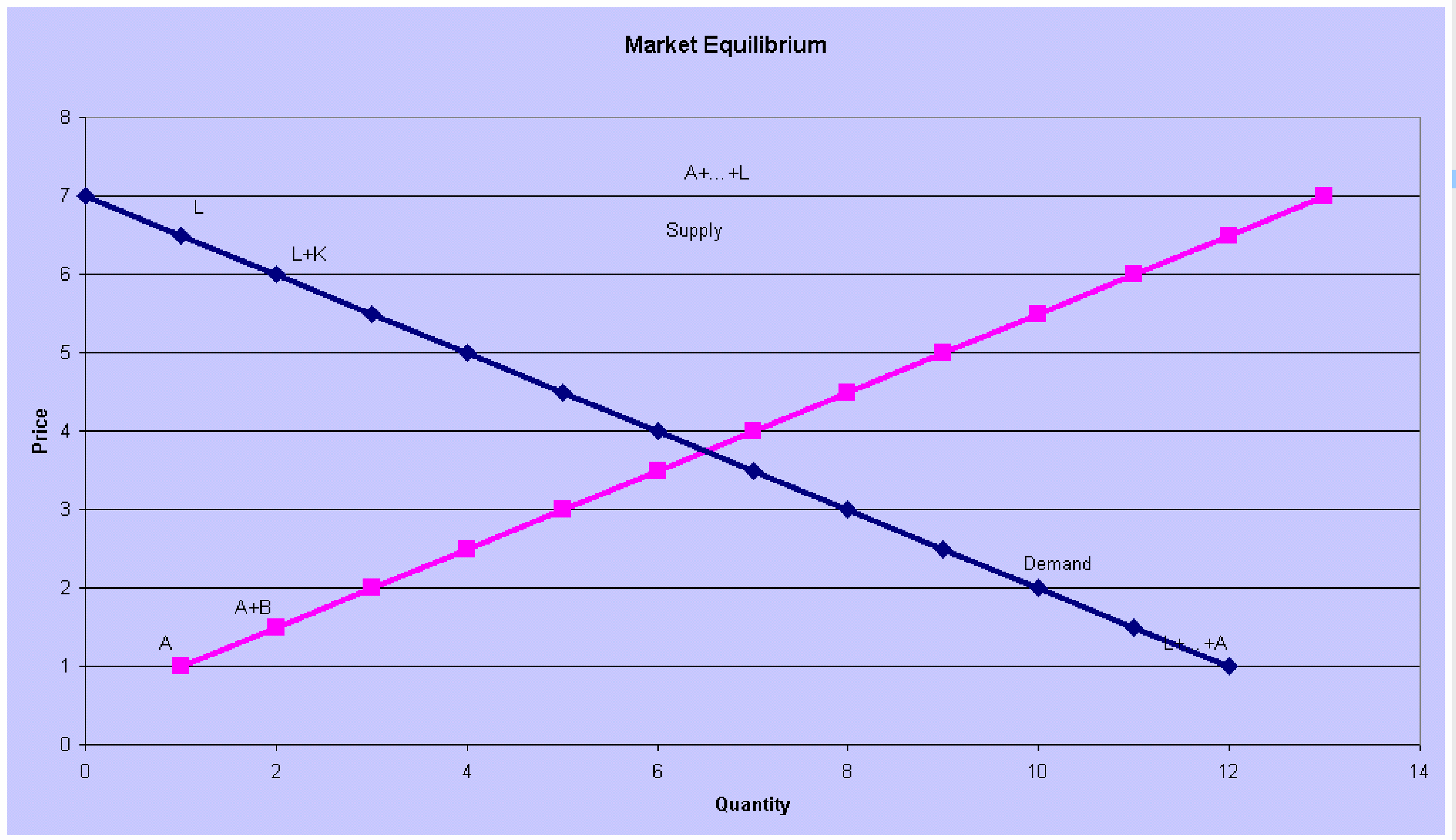
EXAMPLE: PARAMETER VALUES

- Resource: Q=12
- N=12
- MNB Vary Across the Agents
- Optimal Use Level for Each Agent is 2 Units
- Endowment to Each Agent is 1 Unit

INITIAL CONDITIONS

AGENT	$\bar{q}_{it}$	q_{it}^*	VMP	SUPPLY	DEMAND
A	1	2	1	1	12
B	1	2	1.5	2	11
C	1	2	2	3	10
D	1	2	2.5	4	9
E	1	2	3	5	8
F	1	2	3.5	6	7
G	1	2	4	7	6
H	1	2	4.5	8	5
I	1	2	5	9	4
J	1	2	5.5	10	3
K	1	2	6	11	2
L	1	2	6.5	12	1

INITIAL CONDITIONS EQUILIBRIUM



RELAX 100% DELIVERY ASSUMPTION

- Reduce Q_t By 33% (q_{it}=0, for 4 Agents)
- Scenario 1: Junior Priority Rights are high value
- Scenario 2: Junior Priority Rights are low value
- Scenario 3: Junior Property Rights are mid value

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SCENARIO 1: SUPPLY REDUCTION
Jr. Rights, Highest Value

AGENT	Priority	$\bar{q}_{it}$	VMP	SUPPLY	DEMAND
A	1	1	1	1	16
B	2	1	1.5	2	15
C	3	1	2	3	14
D	4	1	2.5	4	13
E	5	1	3	5	12
F	6	1	3.5	6	11
G	7	1	4	7	10
H	8	1	4.5	8	9
I	9	0	5	8	8
J	10	0	5.5	8	6
K	11	0	6	8	4
L	12	0	6.5	8	2

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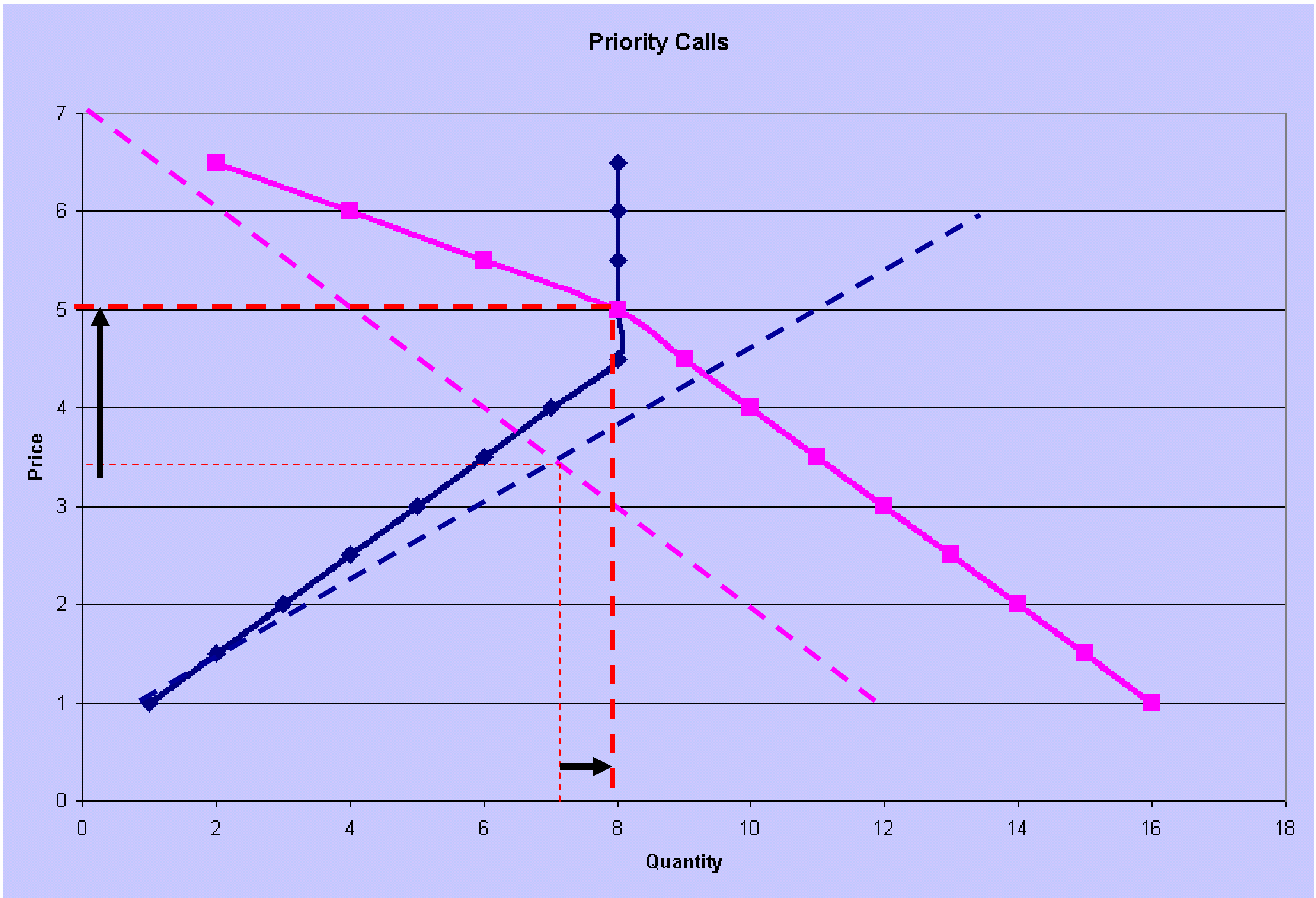
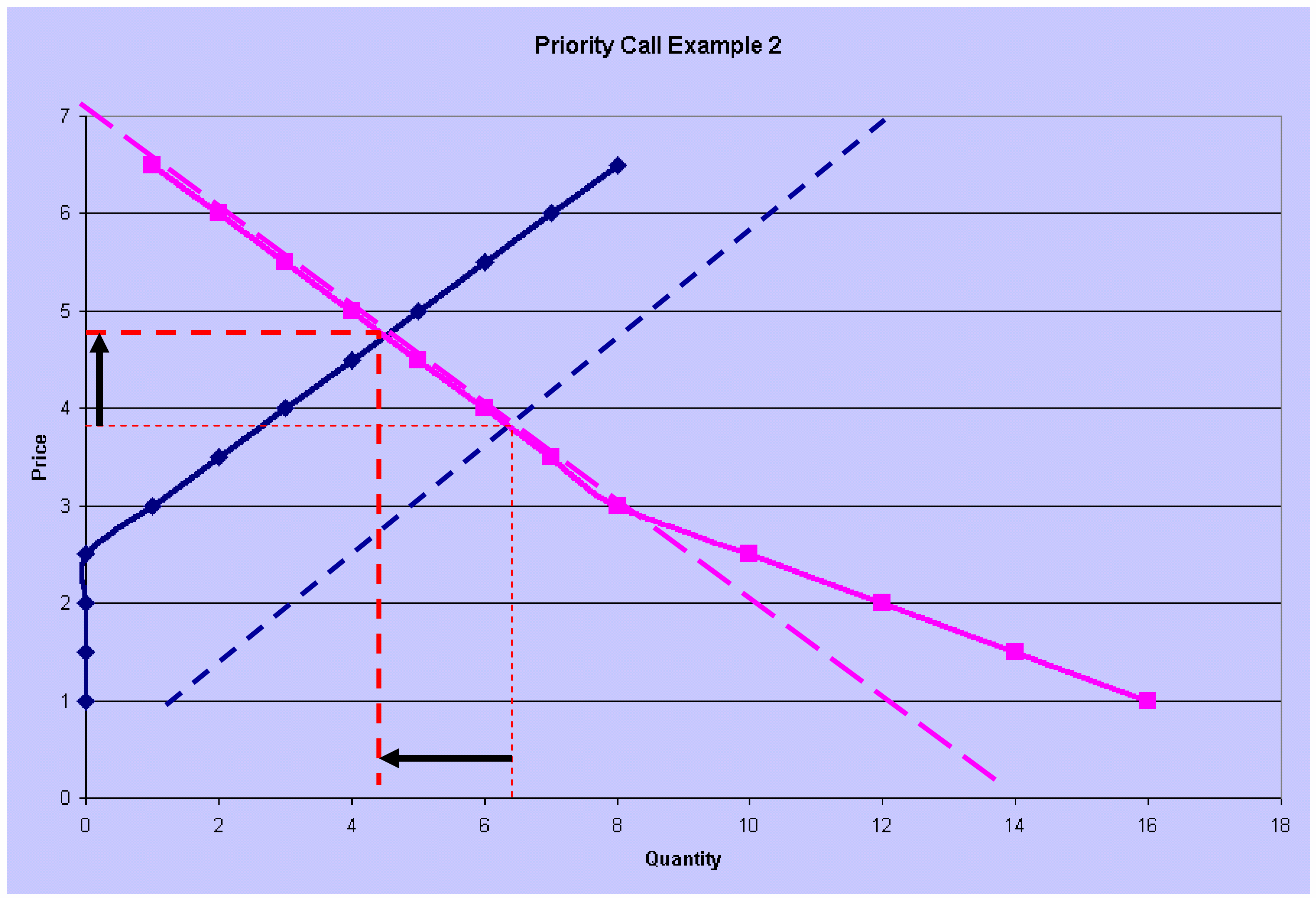
SUPPLY REDUCTION (Jr. Rights Highest Value)



SCENARIO 2: SUPPLY REDUCTION
Jr. Rights Lowest Value

AGENT	Priority	$\bar{q}_{it}$	VMP	SUPPLY	DEMAND
A	12	0	1	0	16
B	11	0	1.5	0	14
C	10	0	2	0	12
D	9	0	2.5	0	10
E	8	1	3	1	8
F	7	1	3.5	2	7
G	6	1	4	3	6
H	5	1	4.5	4	5
I	4	1	5	5	4
J	3	1	5.5	6	3
K	2	1	6	7	2
L	1	1	6.5	8	1

SUPPLY REDUCTION (Jr. Rights Lowest Value)



SCENARIO 3: SUPPLY REDUCTION
Jr. Rights Mid-Values

AGENT	Priority	$\bar{q}_{it}$	VMP	SUPPLY	DEMAND
A	8	1	1	1	16
B	7	1	1.5	2	15
C	6	1	2	3	14
D	5	1	2.5	4	13
E	12	0	3	4	12
F	11	0	3.5	4	10
G	10	0	4	4	8
H	9	0	4.5	4	6
I	4	1	5	5	4
J	3	1	5.5	6	3
K	2	1	6	7	2
L	1	1	6.5	8	1

Tl New Mexico

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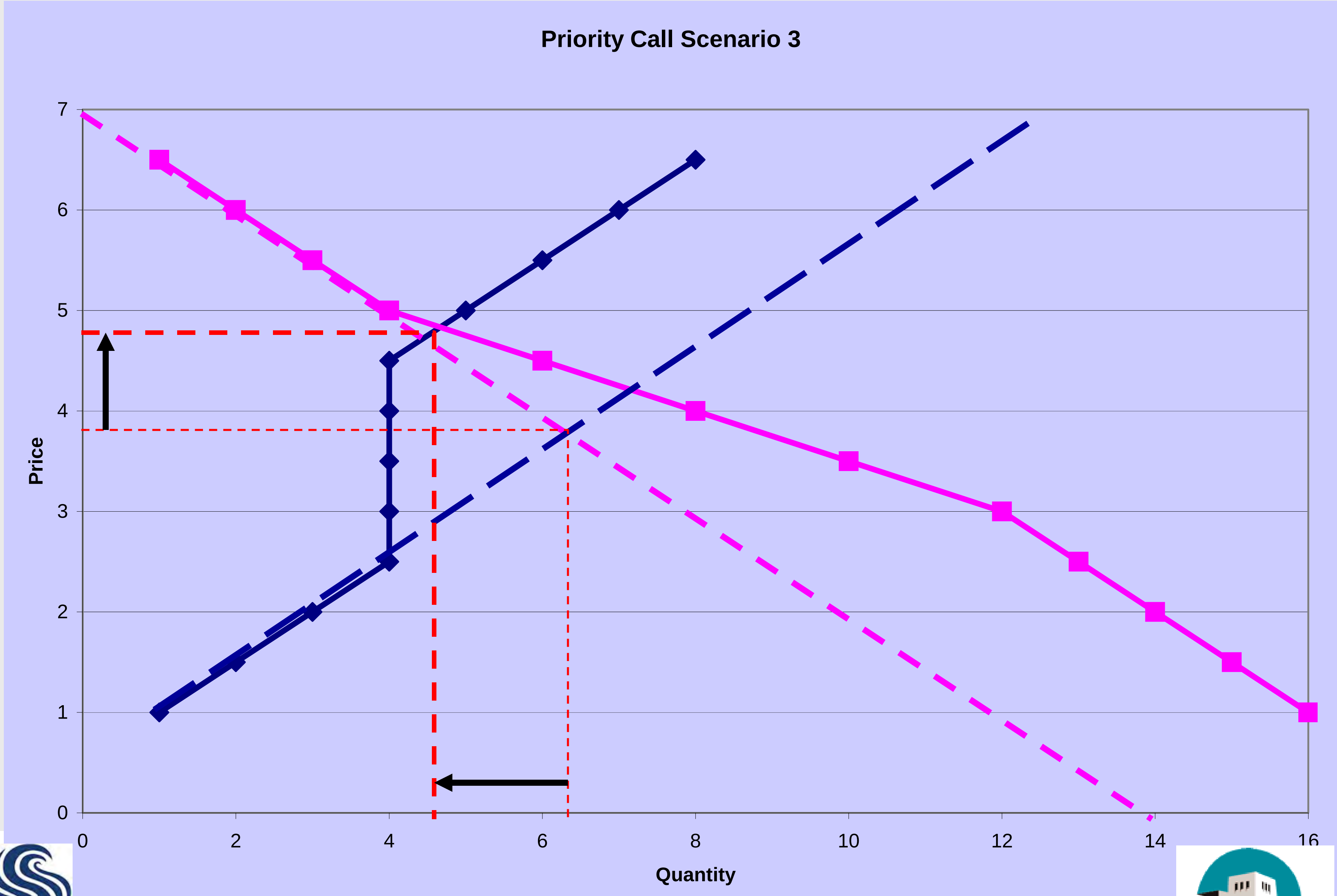
SUPPLY REDUCTION (Jr. Rights Mid-Values)



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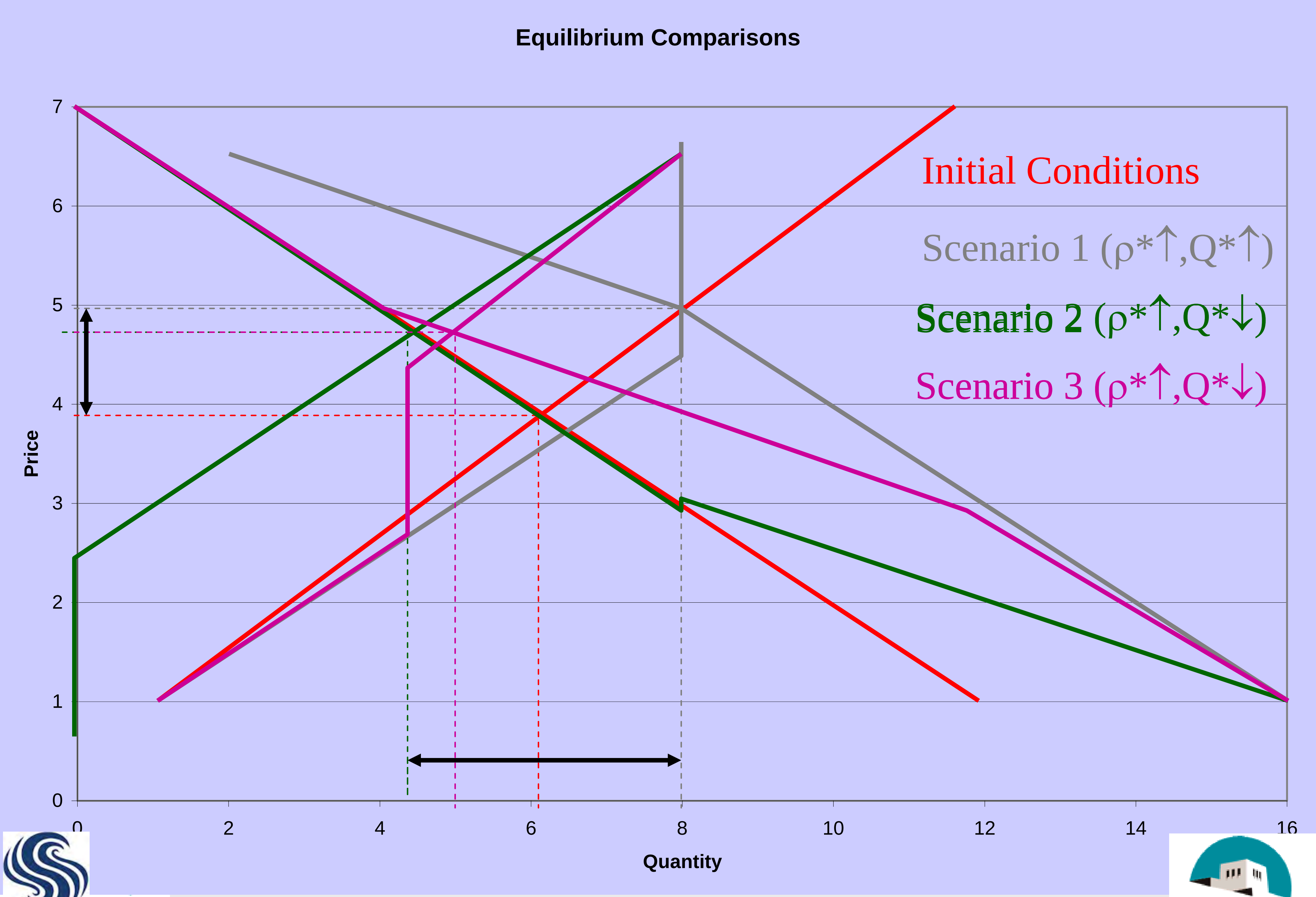
SUPPLY REDUCTION EQUILIBRIUM COMPARISONS



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Forbearance

What is the objective?
- Storage
- In-stream flow
- Additional alternative uses

What are the rules?
- Individual choice
- Lateral choice
- Some other group level?

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Legislative or Regulatory

Cost?

Implementation Strategy?

Oversight?

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The Important Starting Questions May Be:

What is the objective?

What is the time frame?

What are the appropriate incentives?

What are the tradeoffs?

How do we implement?

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What are the interactions between the physical and behavioral aspects of the problem?

Economics for the sake of economics, will fair no better than engineering for the sake of engineering

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Components of Water Resource Management

- Economic Agents; Consumers, Suppliers

  Irrigators, urban centers, species, recreational

- Natural Physical Constraints; Climate

  Precipitation, river and groundwater systems. vegetation

- Manmade Constraints; Physical, Institutional

  Storage, conveyance systems, International, national, state and local institutions: property rights and agreements

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Evapotranspiration: long-term studies of ecohydrology and biometeorology along the Middle Rio Grande

James Cleverly

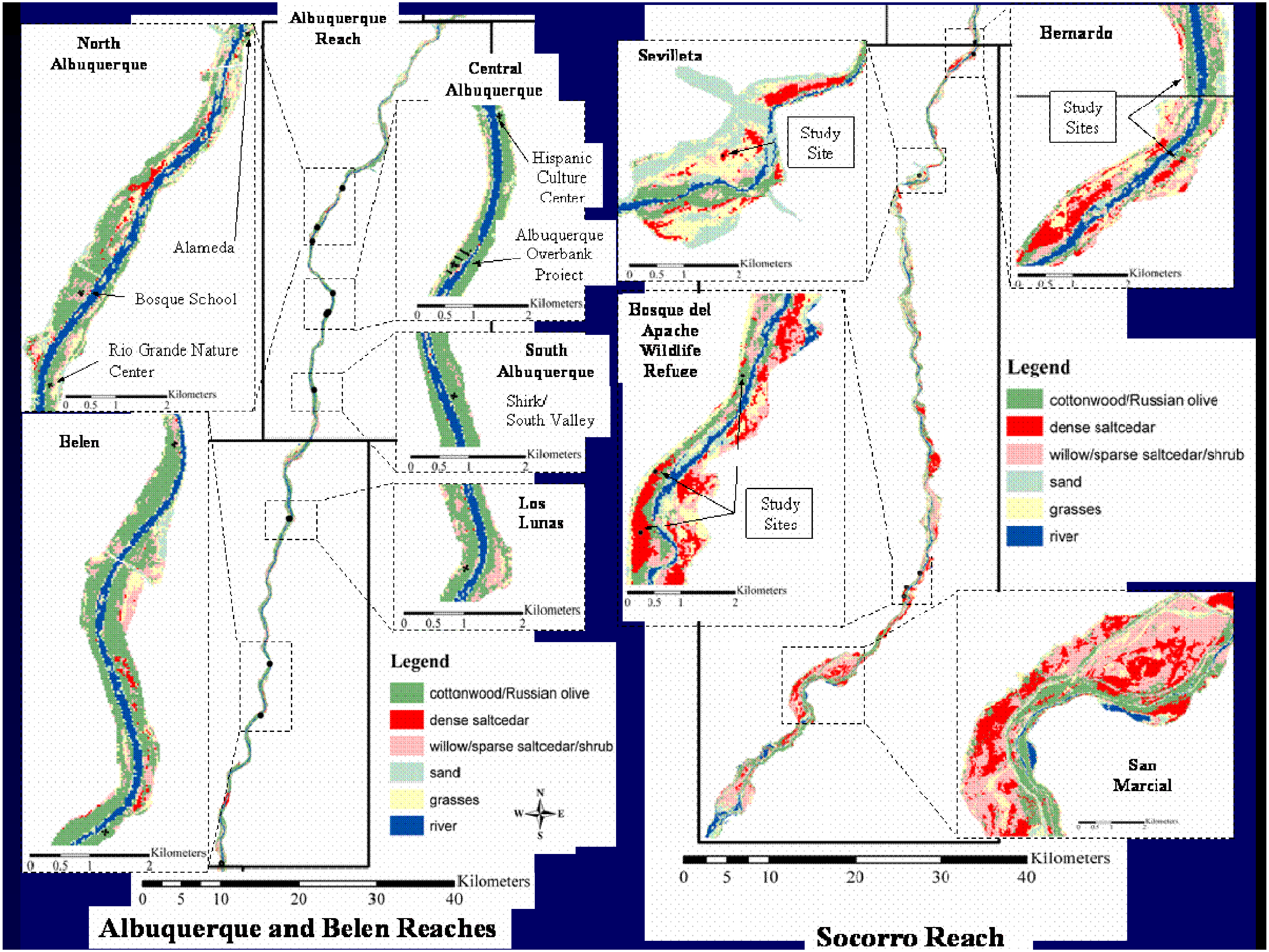
Co-Investigators: Cliff Dahm, Julie Coonrod, James Thibault, Stephen Teet

Acknowledgements

- NASA award NAG5-6999
- Bosque Initiative/Bosque Improvement Grant
- Interstate Stream Commission
- US Bureau of Reclamation/Endangered Species Workgroup
- US Army Corps of Engineers
- US Fish and Wildlife Service/Bosque del Apache NWR
- NM House Bill 2
- NSF/EPSCoR RII-2
- UNM Hydrogeoecology
- UNM Sevilleta LTER
- NM ET Workgroup
- NM Bosque Hydrology Group
- City of Albuquerque Open Spaces Division
- Middle Rio Grande Conservancy District
- NM State Land Office
- Bosque del Apache NWR
- Sevilleta NWR
- Rio Grande Nature Center

Major Basin Characteristics

- 320 km of riverine corridor
- 1672.9 m elevation in the north (Otowi) to 1262.2 m elevation in the south (Elephant Butte)
- 39,220 km^2 drainage
- Discharge gauge records from 1895 (Otowi) and 1915 (Elephant Butte)
- Major Biotic Communities: Great Basin grassland, semi-desert grassland, Chihuahuan desert scrub
- 20 — 31 cm annual precipitation (from north to south)



North Albuquerque
Alameda
Bosque School
Rio Grande Nature Center
Albuquerque Reach
Central Albuquerque
Hispanic Culture Center
Albuquerque Overbank Project
South Albuquerque
Shirk/ South Valley
Los Lunas
Belen
Legend
cottonwood/Russian olive
dense saltcedar
willow/sparse saltcedar/shrub
sand
grasses
river
Kilometers
0 5 10 20 30 40
Albuquerque and Belen Reaches
Sevilleta
Study Site
Bernardo
Study Sites
Bosque del Apache Wildlife Refuge
Study Sites
San Marcial
Socorro Reach

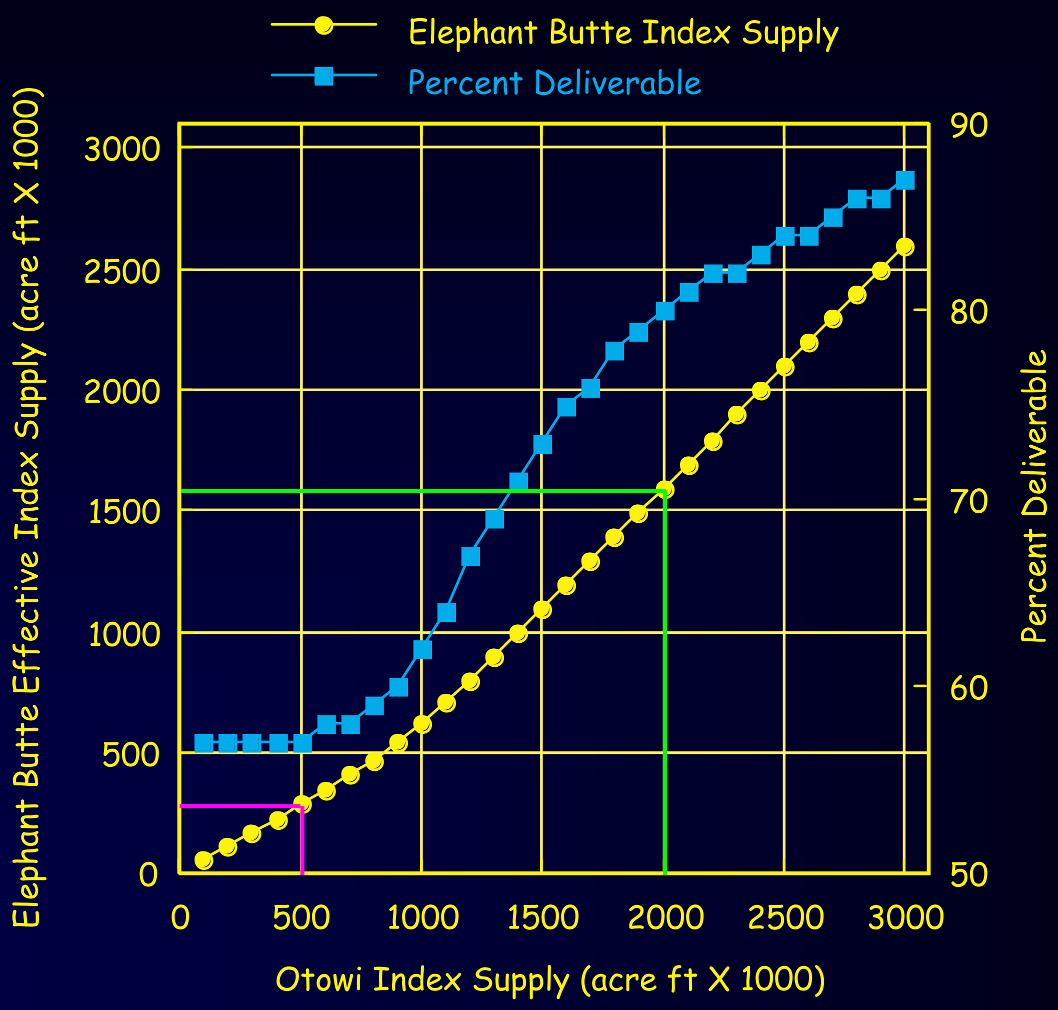
Water Budget:

A summary that shows the balance in a hydrologic system between water supplies (inflow) to the system and water losses (outflow) from the system

‖

Depletions are the difference between inflow at Otowi and outflow at Elephant Butte

NM Legal Obligation



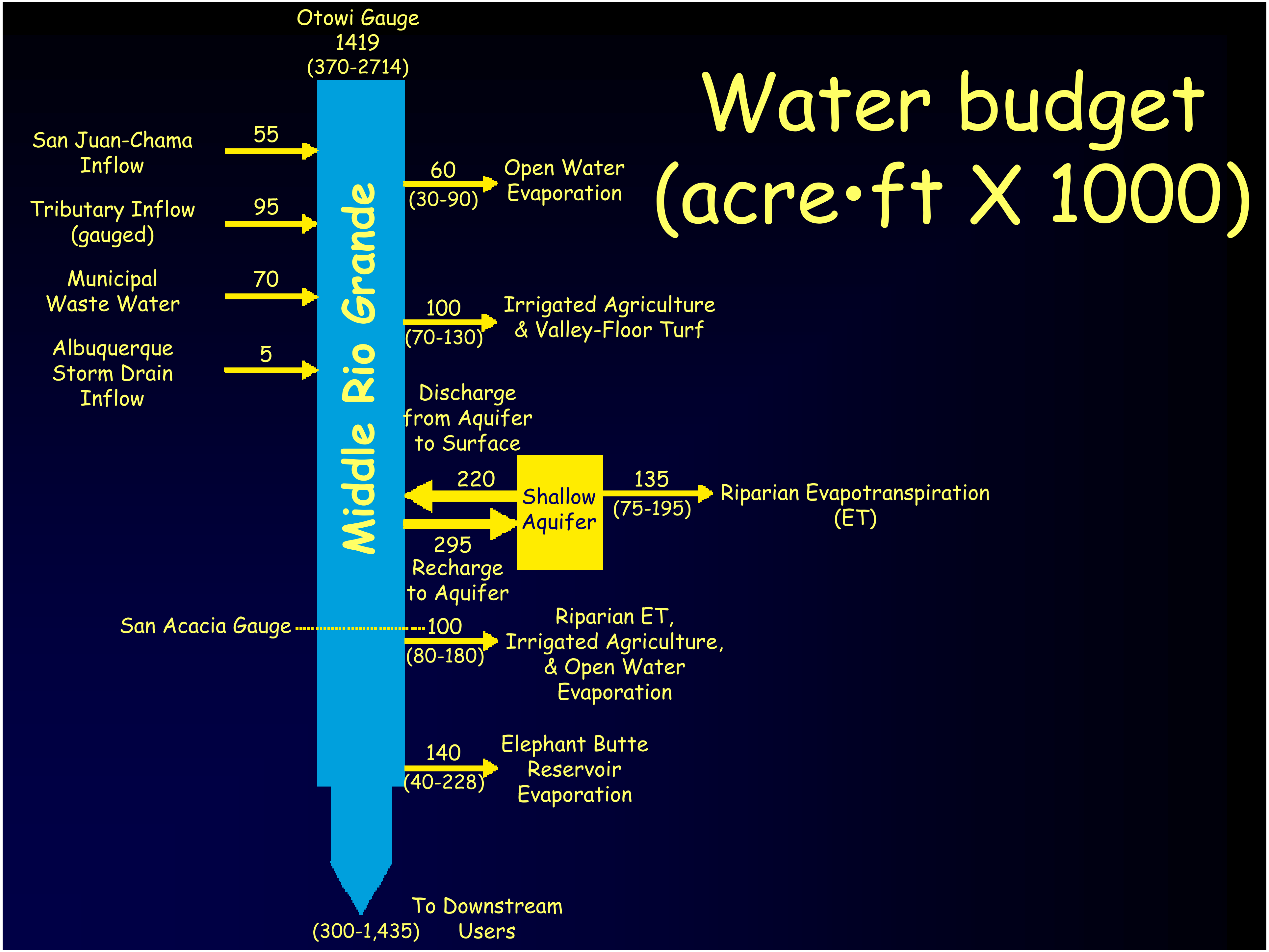
http://www.fws.gov/southwest/mrgbi/Resources/RG_Compact/rg_compact.pdf

Major Depletions

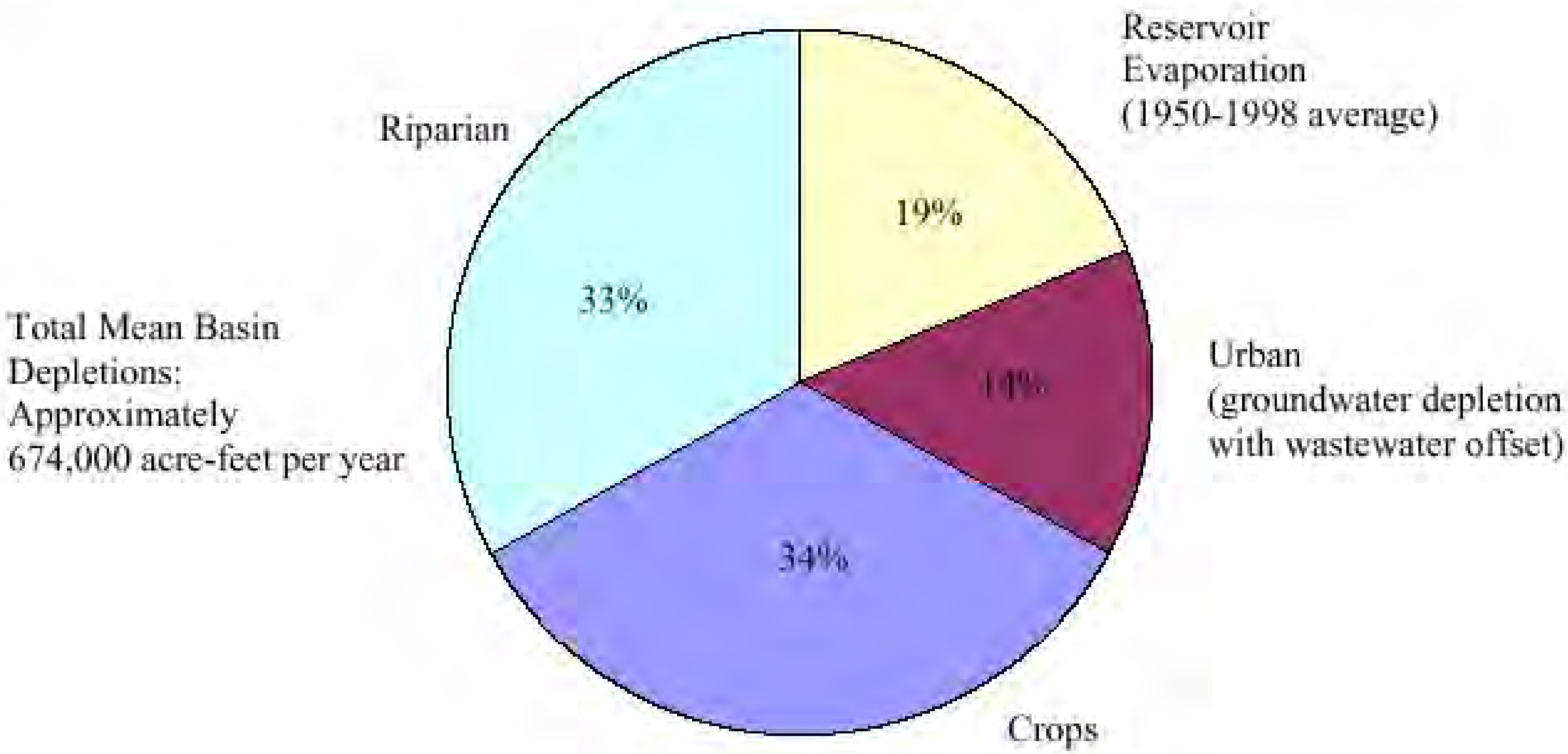
- Evaporation
- Transpiration
- Agriculture
- Urban Use
- Groundwater Recharge

Major Depletions

- Evapo-transpiration
- Agriculture
- Urban Use
- Groundwater Recharge


Water budget
(acre•ft X 1000)
Otowi Gauge
1419
(370-2714)
Middle Rio Grande
San Juan-Chama Inflow
55
Tributary Inflow (gauged)
95
Municipal Waste Water
70
Albuquerque Storm Drain Inflow
5
60
(30-90)
Open Water Evaporation
100
(70-130)
Irrigated Agriculture & Valley-Floor Turf
Discharge from Aquifer to Surface
220
Shallow Aquifer
135
(75-195)
Riparian Evapotranspiration (ET)
295
Recharge to Aquifer
San Acacia Gauge
100
(80-180)
Riparian ET, Irrigated Agriculture, & Open Water Evaporation
140
(40-228)
Elephant Butte Reservoir Evaporation
(300-1,435)
To Downstream Users

b) Mean total Middle Rio Grande depletions (including depletion from groundwater storage),under present land use and groundwater development conditions



Populus deltoides ssp. *wislizenii*
(cottonwood)

Dominant Riparian Vegetation

Interflood Interval	Saltcedar	Cottonwood
Short	connected non-native	connected native
Long	disconnected non-native	disconnected native

Molles *et al*. 1998

Tamarix ramosissima
(saltcedar)

Native | Exotic

Populus deltoides ssp. *wislizenii* (Rio Grande Cottonwood)

Elæagnus angustifolia (Russian Olive)

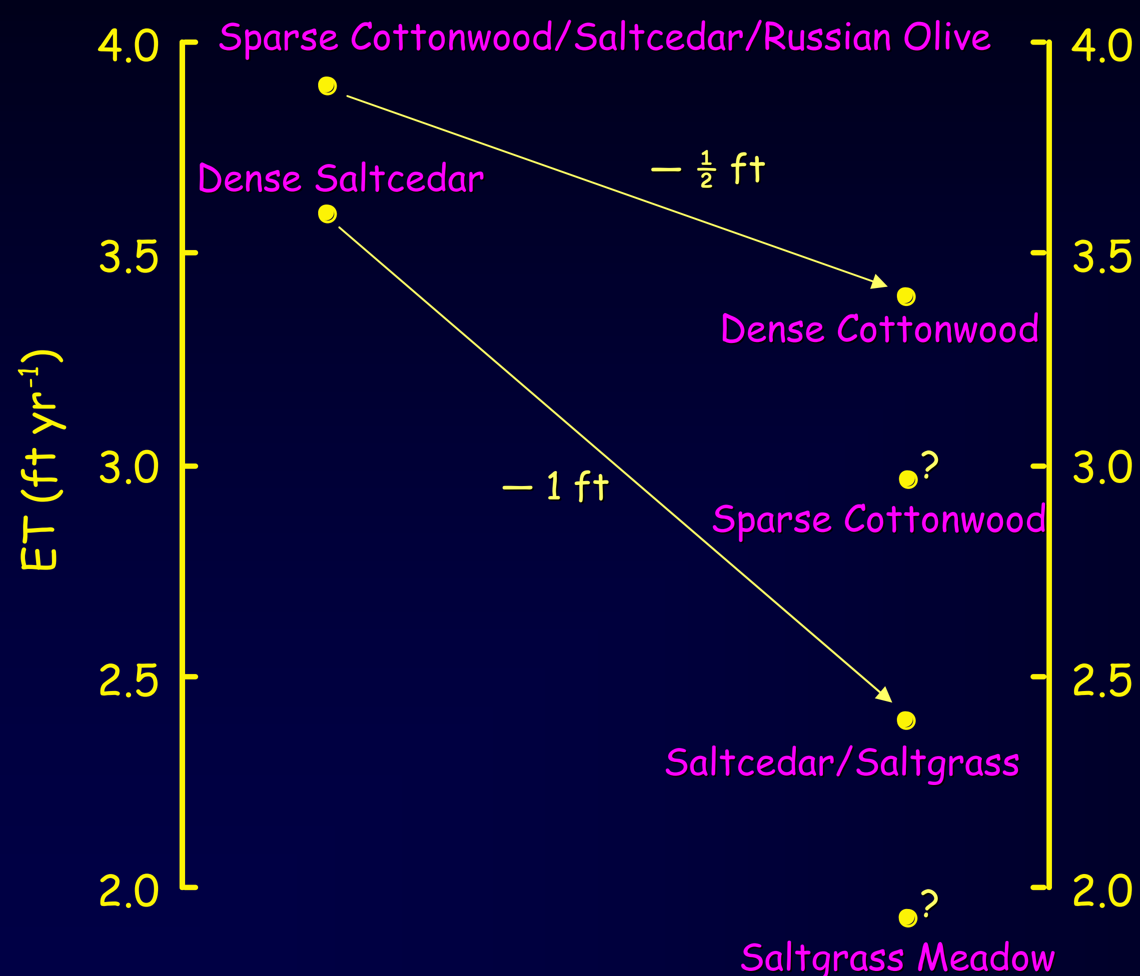
Tamarix chinensis (Saltcedar)

EPSCoR New Mexico

Restoration hypotheses

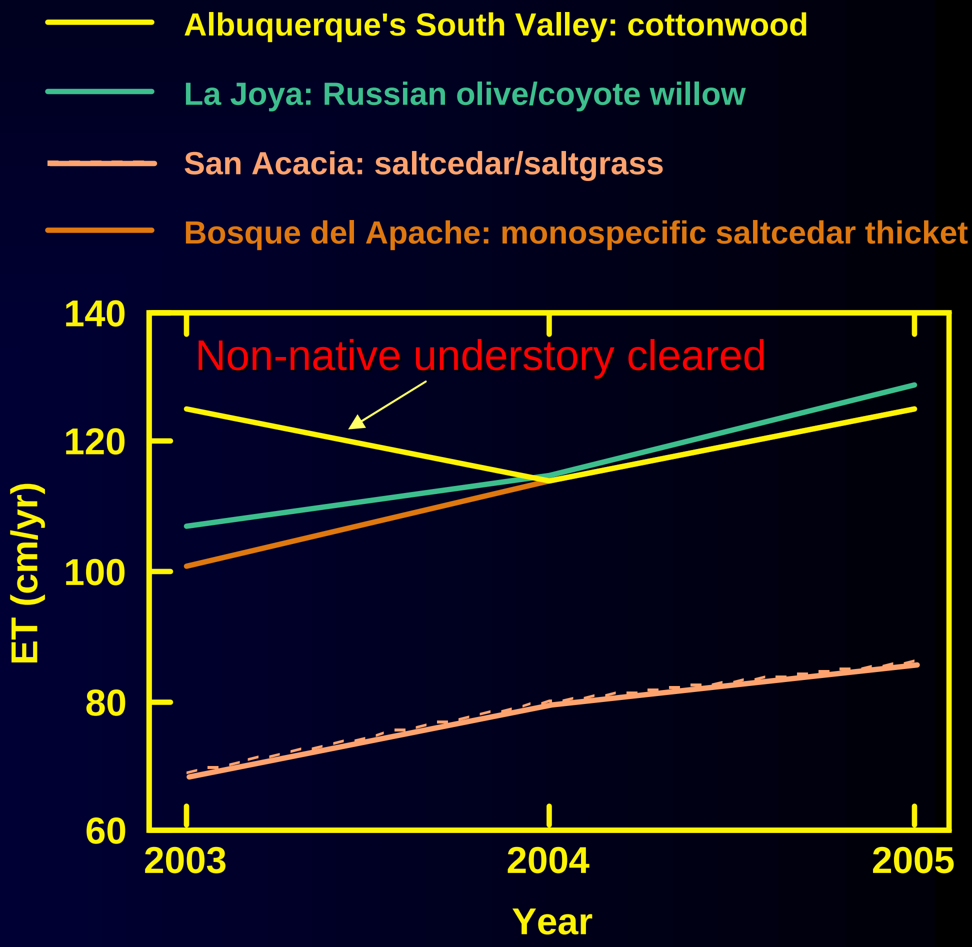
- Saltcedar removal from Cottonwood forests is predicted to be associated with a water savings
- High water usage when saltcedar develops high LAI

Restoration – comparative

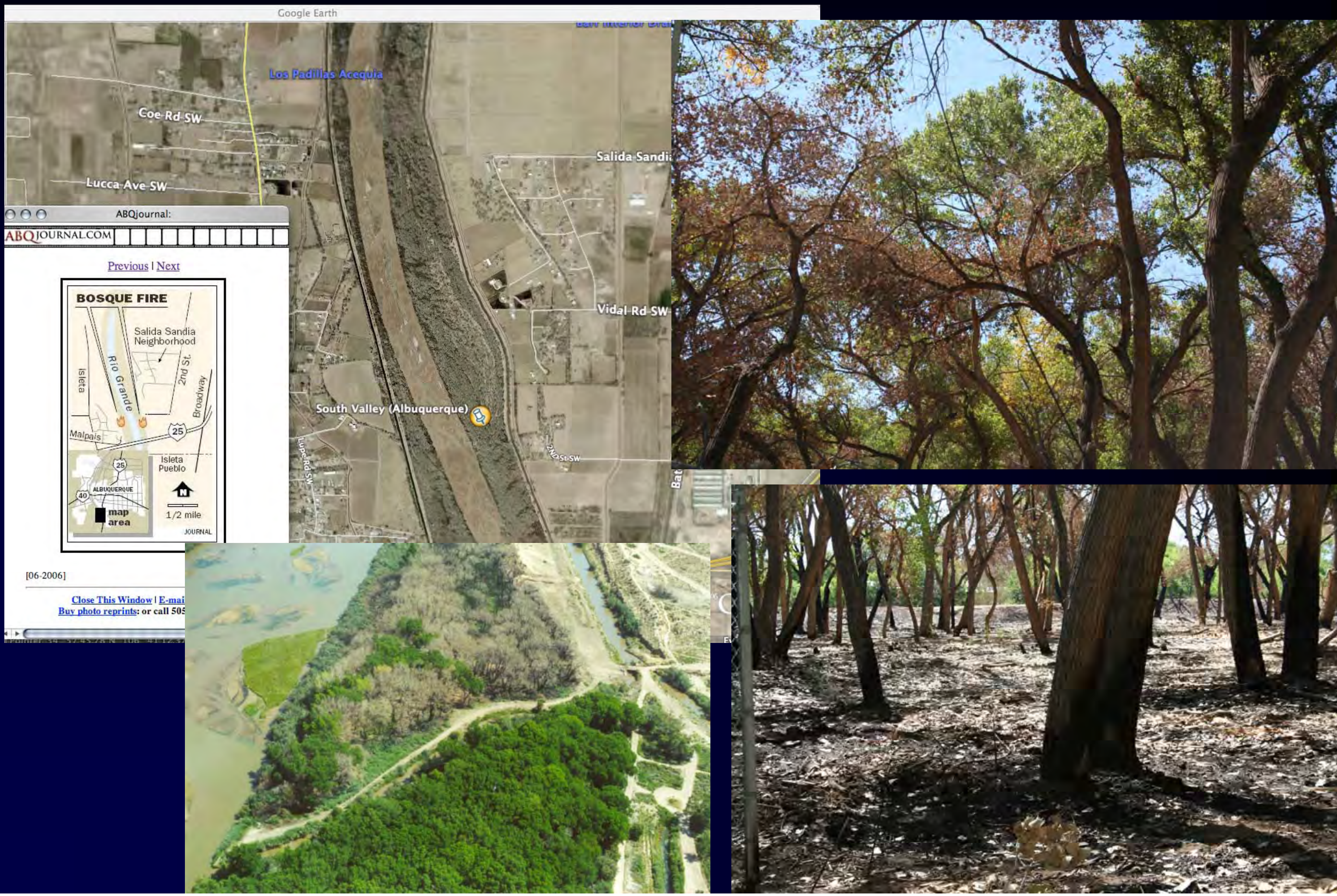


Restoration water salvage

- Understory Russian olive and saltcedar removed from South Valley Albuquerque cottonwood forest between 2003 and 2004 growing seasons
- First year reduction in ET of 9% while other sites increasing by 12% (total = -21% or -26 cm/yr)
- Second year increase matched increase at other sites: 0 cm/yr



Bosque Fire


Google Earth
Los Padillas Acequia
Coe Rd SW
Lucca Ave SW
Salida Sandi
Vidal Rd SW
South Valley (Albuquerque)
ABQjournal:
ABQJOURNAL.COM
Previous | Next
BOSQUE FIRE
Salida Sandia Neighborhood
Rio Grande
Isleta
2nd St.
Broadway
Malpais
25
Isleta Pueblo
ALBUQUERQUE
40
map area
1/2 mile
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Short Interflood Interval < 2yrs
(flood site)

Long interflood interval > 10yrs
(nonflood site)

Ecohydrology

- Parameterization of the interactions between terrestrial ecosystems and the water cycle
- Key papers:

Newman, B.D. et al., 2006. The ecohydrology of arid and semiarid environments: a scientific vision. Water Resources Research.

Pataki, D.E., Bush, S.E., Gardner, P., Solomon, D.K. and Ehleringer, J.R., 2005. Ecohydrology in a Colorado River riparian forest: Implications for the decline of Populus fremontii. Ecological Applications, 15(3): 1009-1018.

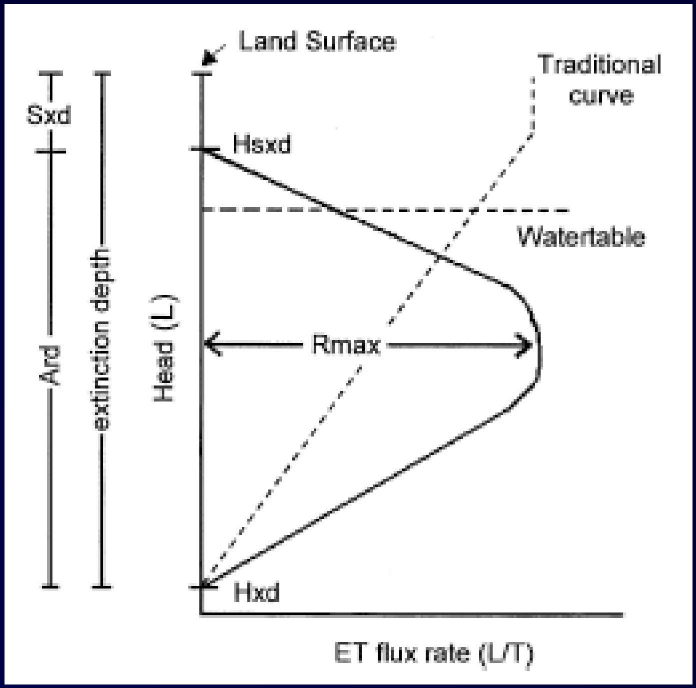
Huxman, T.E. et al., 2005. Ecohydrological implications of woody plant encroachment. Ecology, 86(2): 308-319.

Wilcox, B.P. and Newman, B.D., 2005. Ecohydrology of semiarid landscapes. Ecology, 86(2): 275-276.

Cleverly, J.R., Dahm, C.N., Thibault, J.R., McDonnell, D.E. and Coonrod, J.E.A., 2006. Riparian ecohydrology: regulation of water flux from the ground to the atmosphere in the Middle Rio Grande, New Mexico. Hydrological Processes.

Ecohydrology Parameters

- ET:PPT
- T:ET
- GW (MODFLOW)



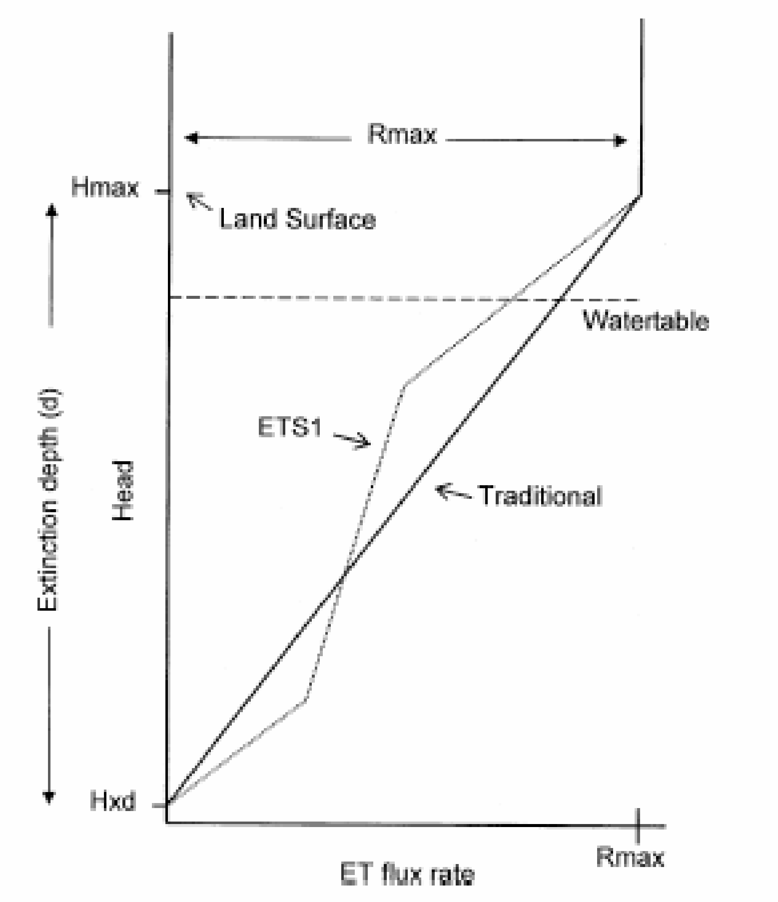


Fig. 1. Traditional linear (MODFLOW 96) and ETS1 segmented function (MODFLOW 2000) ET curves. Hxd, extinction depth elevation; *d*, extinction depth; Rmax, maximum ET rate; Hmax, maximum ET surface elevation.

Populus deltoides ssp. *wislizenii*
(Rio Grande Cottonwood, native)

- Strongly dependent upon groundwater:
  - $ET_{surface}$ ≈ 3 m, $ET_{extinction}$ ≈ 5 m (Horton 2001)
  - Only cottonwoods growing along ephemeral streams have shown uptake of soil water/precipitation (Stromberg & Pattern 1996, Snyder & Williams 2000)
  - Crown dieback occurred during the drought at locations with a deep water table

Elæagnus angustifolia
(Russian Olive, non-native)

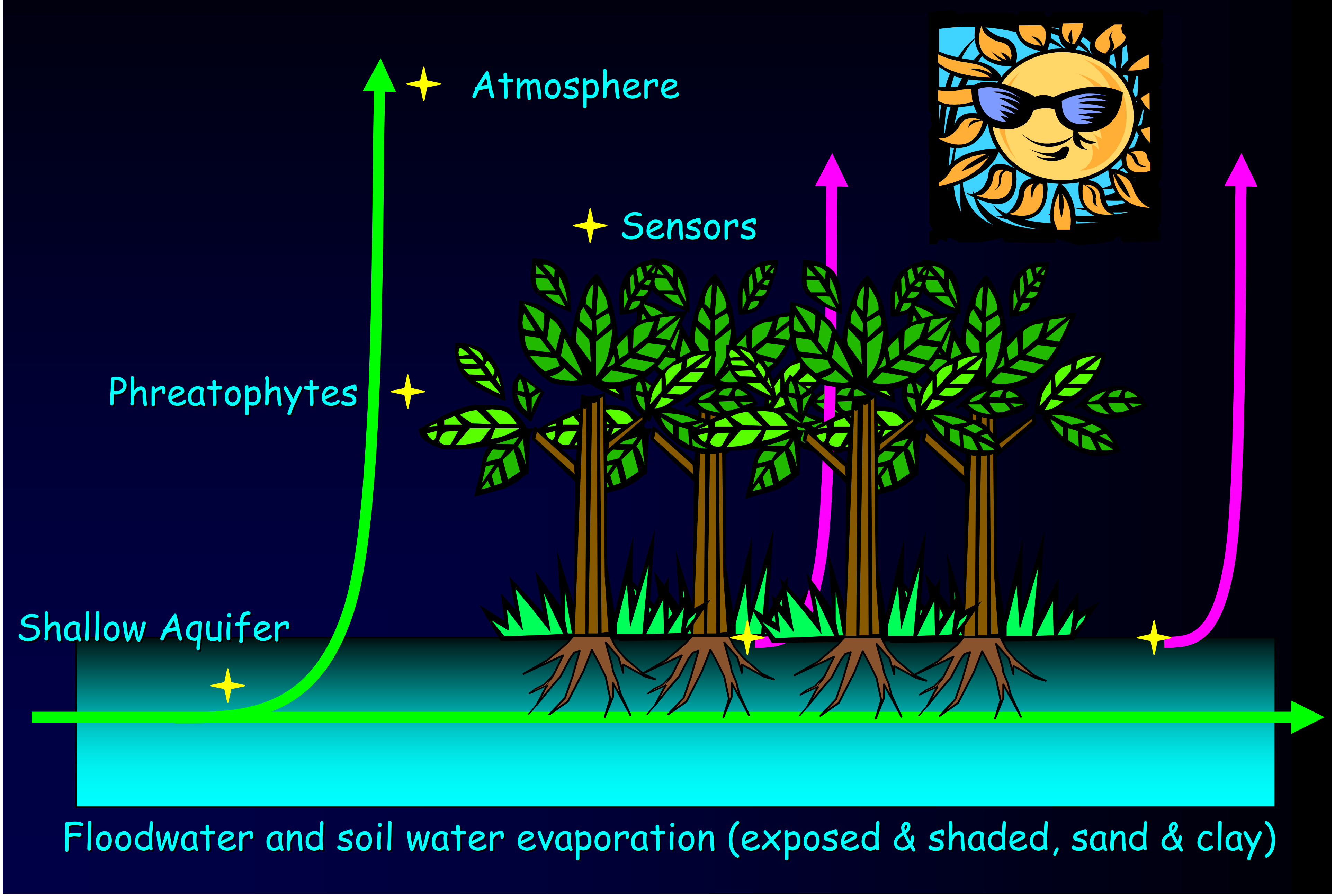
- Relationship with groundwater?:

- $ET_{surface}$ & $ET_{extinction}$ unknown
- Found in a wide range of habitats (Katz & Shafroth 2003)
- Seldom found in a monoculture along the MRG
- Water use typically equivalent to monospecific saltcedar & native cottonwood forest

Tamarix chinensis
(Saltcedar, non-native)

- Relationship with groundwater?:
  - $ET_{surface}$ deeper than 10-m (Horton 2001) or 25-m (Gries et al 2003)
  - $ET_{extinction}$ undefined
  - Known facultative phreatophyte with hydraulic properties similar to other xeroriparian spp. (Busch et al 1995; Pockman & Sperry 2000)
  - Variations in transpiration explained solely by fluctuations in leaf-to-air VPD
  - Found preferentially in habitats with variable water table depth (Lite & Stromberg 2005)

Evapotranspiration



Reference Evapotranspiration

- Semi-empirical formulations
  - Measurements of associated conditions; e.g., Radiation
  - Blaney-Criddle, Jensen-Haise, Priestley-Taylor, Aerodynamic, Penman, Penman-Monteith
  - SCS, FAO, Grass standard
  - Crop/calibration coefficient:

$$ET_a = k \cdot ET_0$$

- Energy Balance
  - Bowen ratio, OPEC

Temperature: Blaney-Criddle-SCS 1950

$$u = k_t k_c \ddot{A}$$

k_t: monthly consumptive use coefficient for temperature; $k_t = 0.0173T_a - 0.314$, °F

k_c: monthly crop coefficient

f: monthly consumptive use factor;

$$\ddot{A} = \frac{T_a p}{100}$$

p: mean monthly percentage of annual daytime hours

Combination: Penman

$$ET_0 = \frac{\Delta}{\Delta + \gamma} R_n + \frac{\gamma}{\Delta + \gamma} E_A$$

Δ: slope of the saturation water vapor curve at a given temperature

R_n: net radiation (downwelling solar+thermal radiation less upwelling)

E_A: drying function (wind and humidity)

γ: psychrometric coefficient;

$$\gamma = \frac{C_P P}{\varepsilon \lambda_v}$$

Combination: Penman-Monteith 1965

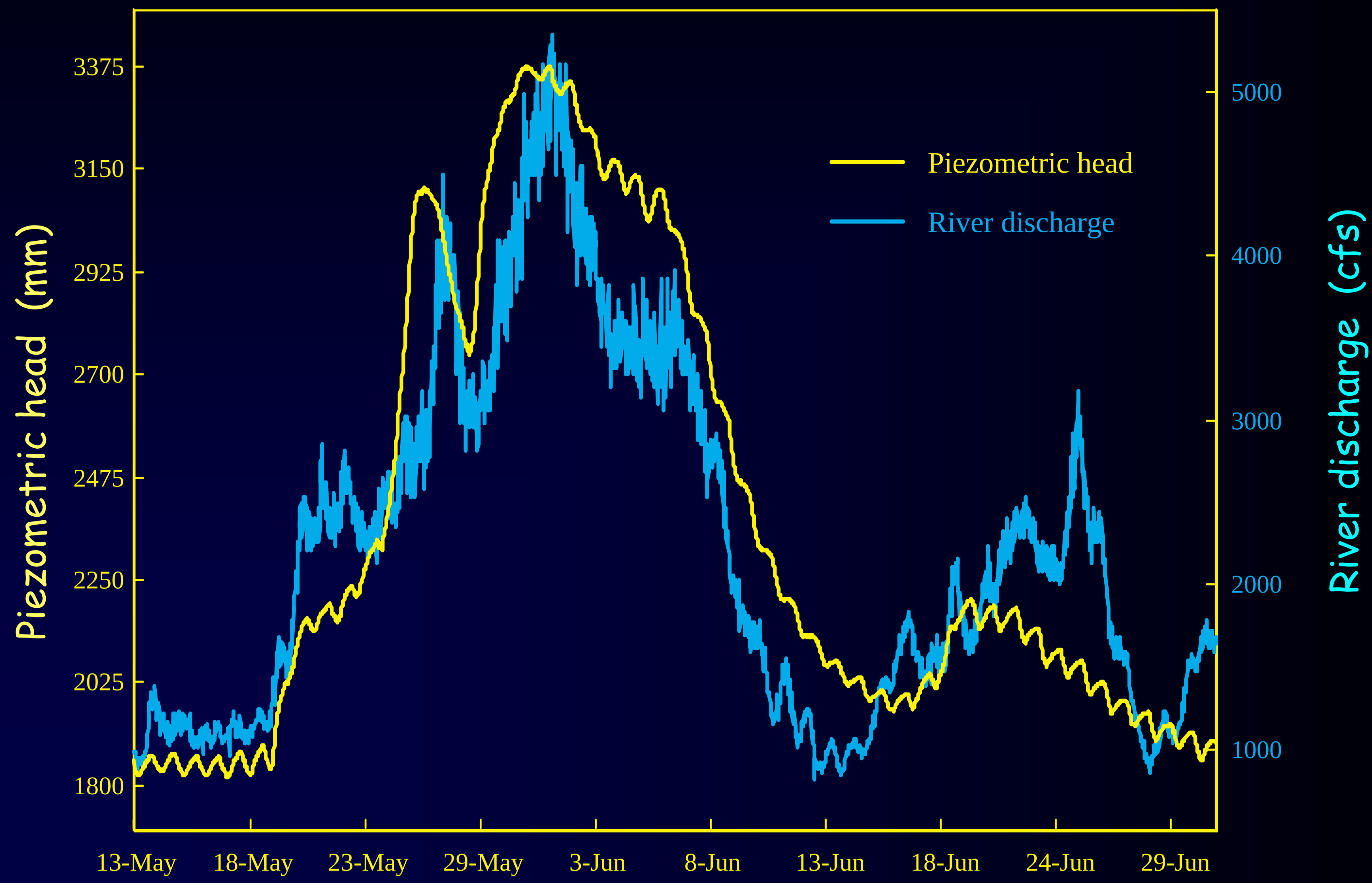
$$\gamma^* = \gamma\left[1 + \frac{r_c}{r_a}\right]$$

r_c: canopy resistance (stomatal resistance, LAI)

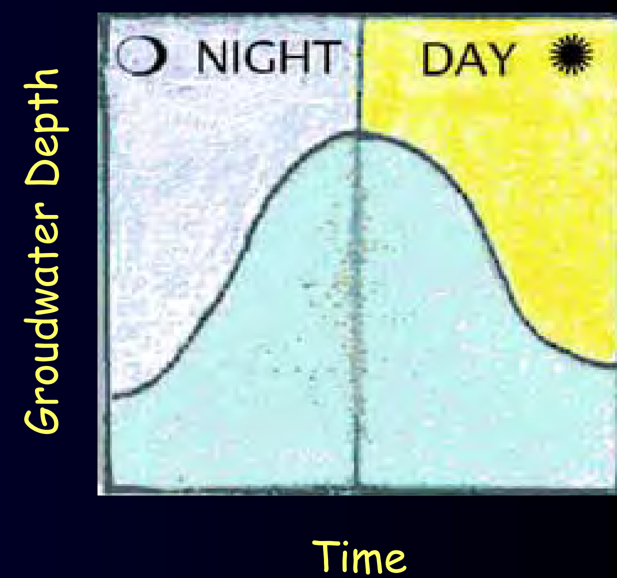
r_a: aerodynamic resistance;

$$r_a = \frac{\ln\left[\frac{z_w - d}{z_{0m}}\right]\ln\left[\frac{z_p - d}{z_{0v}}\right]}{(0.41)^2 u}$$

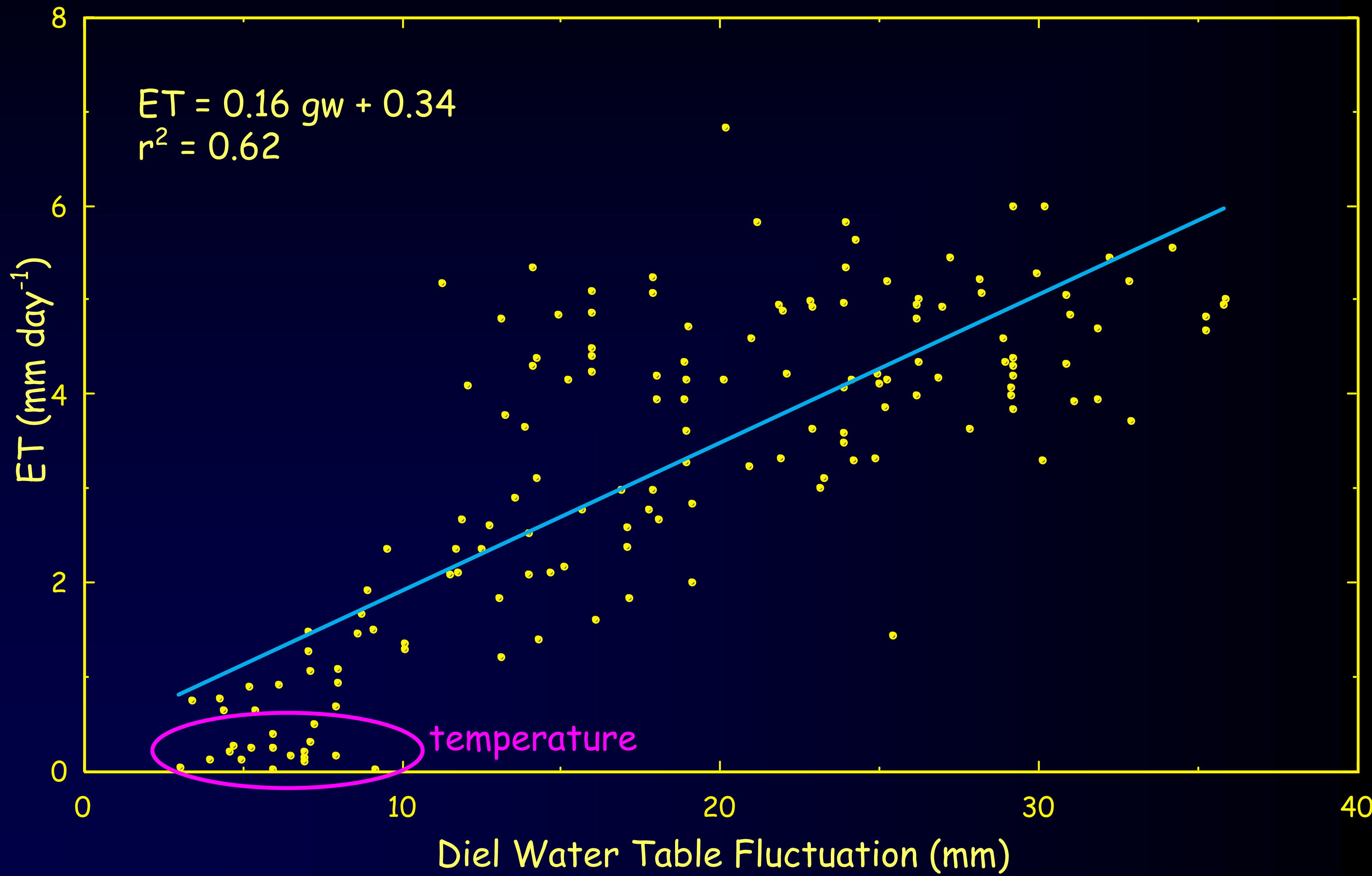
Hydrology


Piezometric head
River discharge
Piezometric head (mm)
River discharge (cfs)
3375
3150
2925
2700
2475
2250
2025
1800
5000
4000
3000
2000
1000
13-May
18-May
23-May
29-May
3-Jun
8-Jun
13-Jun
18-Jun
24-Jun
29-Jun

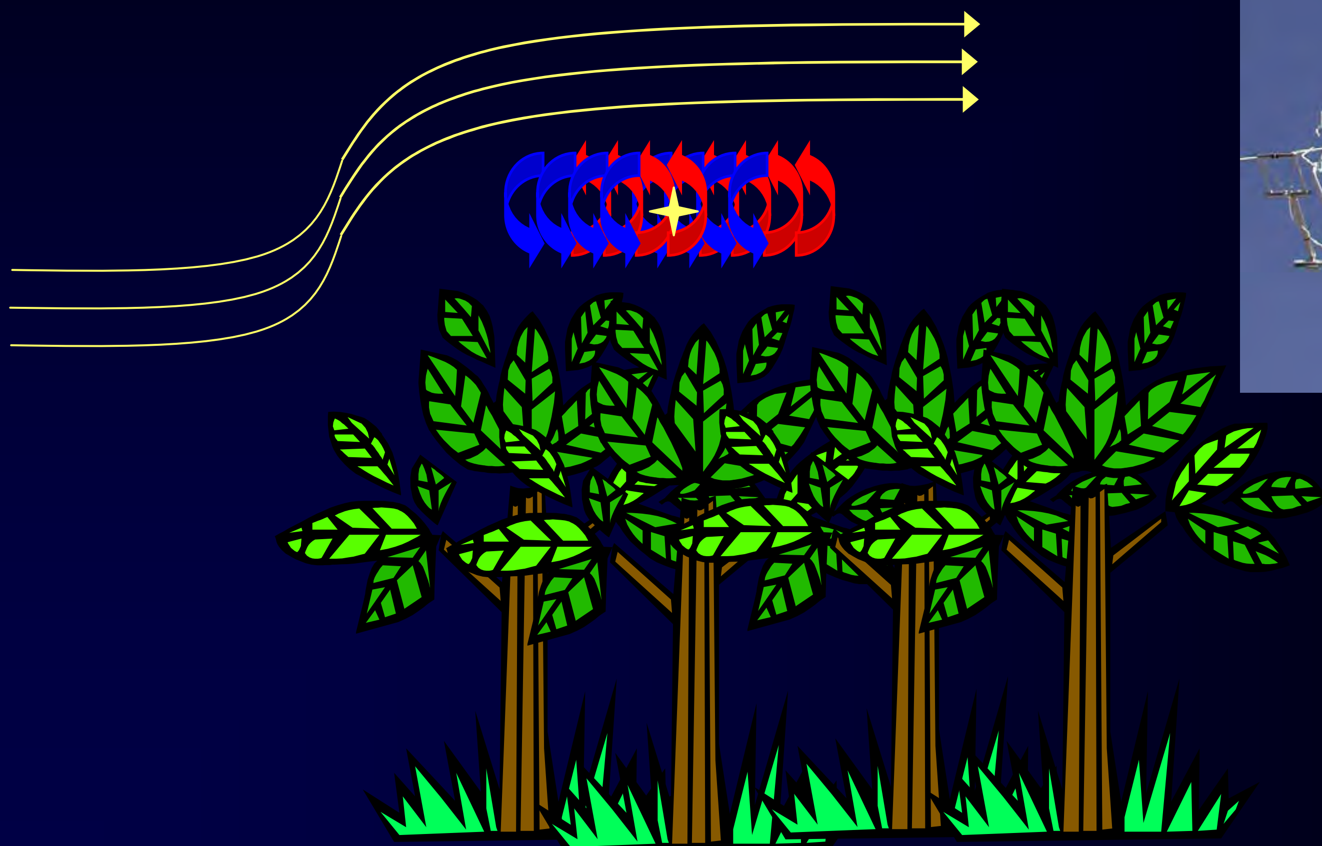
Diel GW fluctuations



Diel Groundwater – ET



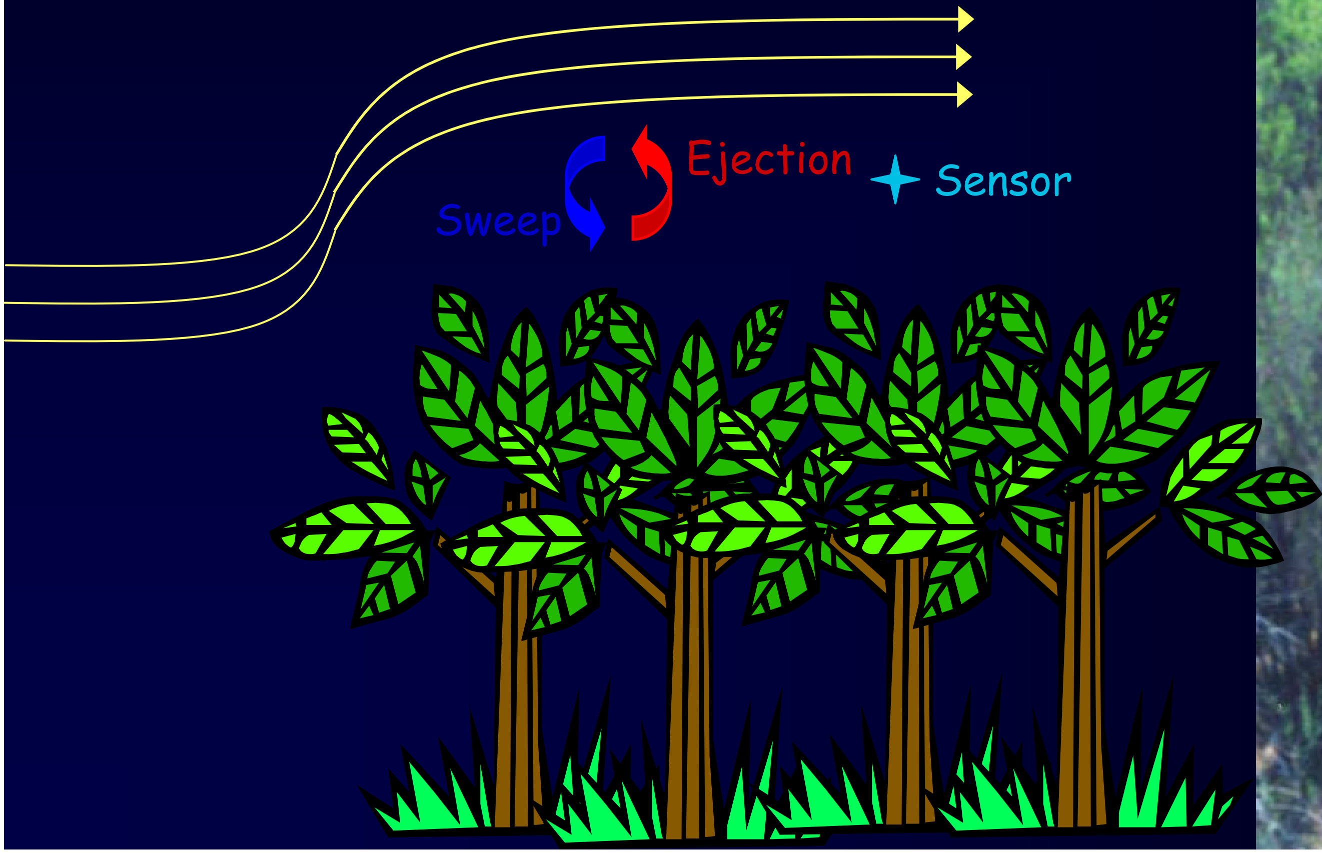
Surface Layer



3-D Eddy Covariance

Video: P Sprott

- Direct measurement of ET
- Self-test for accuracy
- Consistent with the application of atmospheric physics



Energy and Water Fluxes

- Core Measurements: 3-D Eddy Covariance
  - Sonic anemometer
  - Hygrometer/IR Gas Analyzer
  - Temperature-Relative Humidity
  - Net Radiation
  - Ground heat flux
  - Soil temperature
  - Soil water content
  - Barometric pressure
  - Precipitation
  - Cellular/WiFi communications

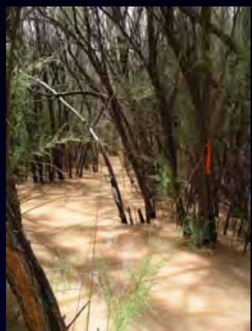
$$R_n + G + LE + H = 0$$

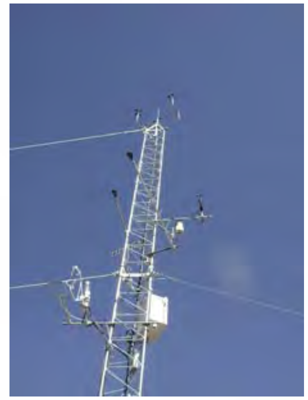
$$\lambda\ Cov(wq) = \lambda\ \overline{w'q'} = LE$$

$$\rho\ c_p\ Cov(wT) = \rho\ c_p\ \overline{w'T'} = H$$

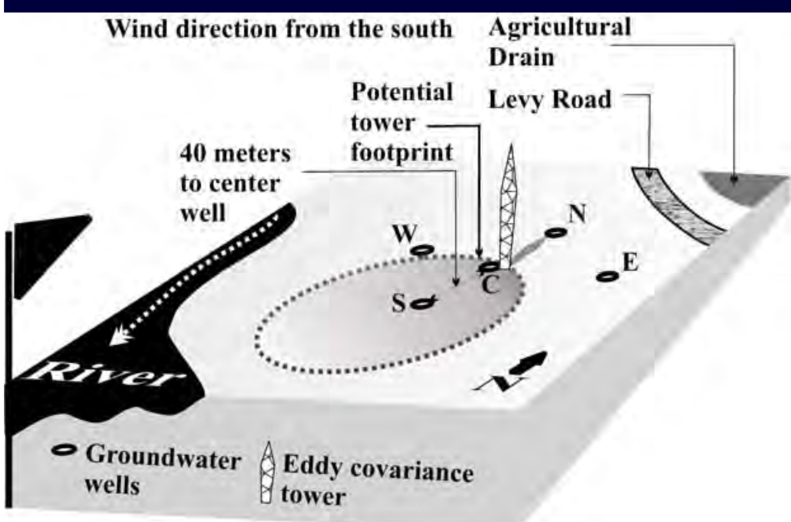
EPSCoR New Mexico

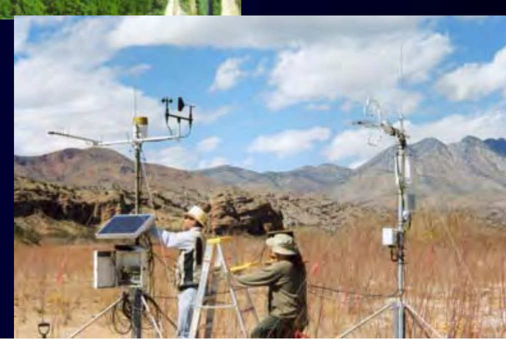
NSF



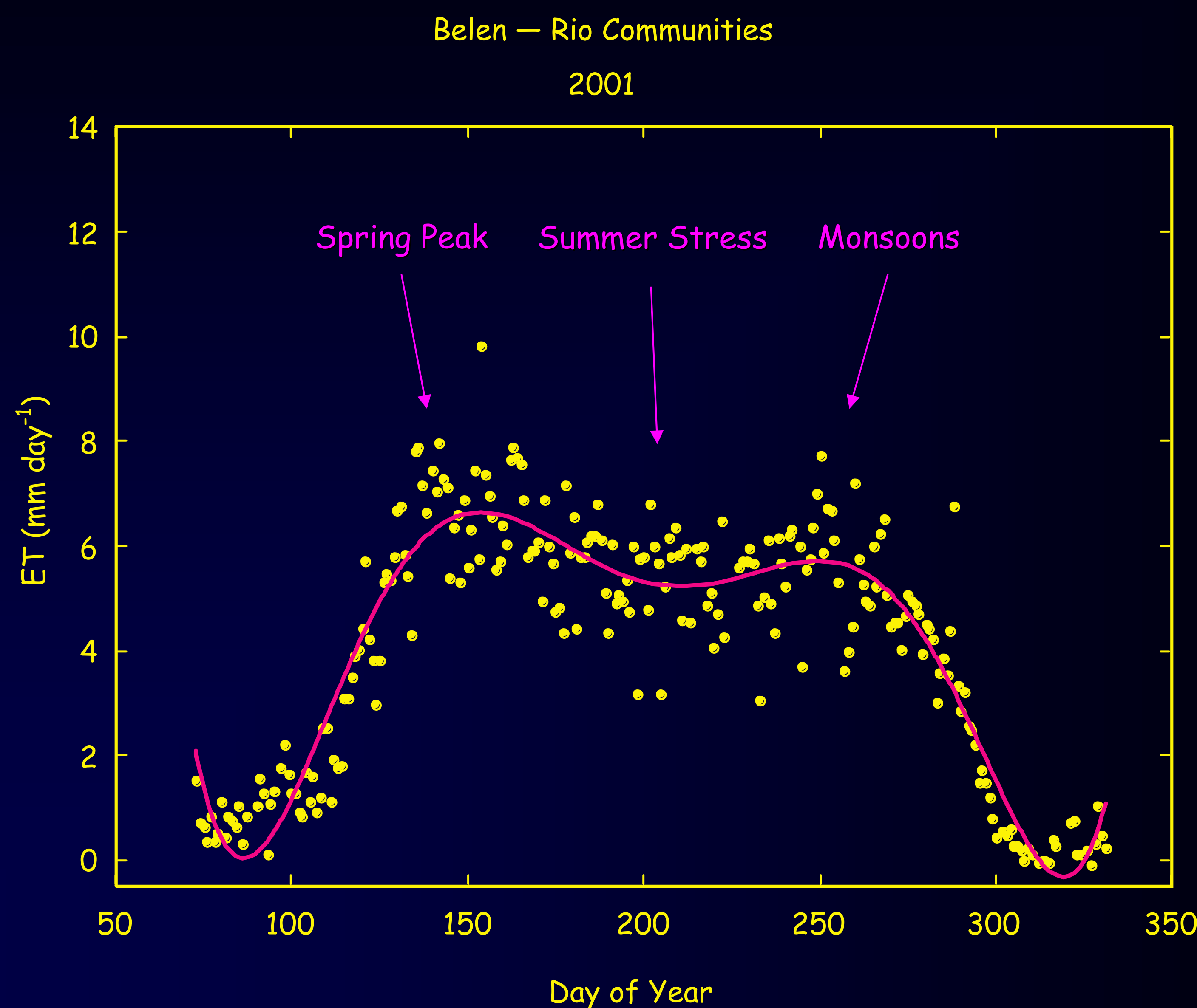



Rio Chama
Rio Grande
Jemez River
Rio Puerco
Albuquerque's South Valley
Cottonwood + Saltcedar/Russian olive understory
Understory removed 2004 / Partially burned 2006
New Site:
Rio Salado
Bare Soil
Rio Salado
Belen near Rio Communities
Cottonwood, mostly native understory
Site decommissioned 2004 following vandalism
La Joya State Game Refuge
Russian olive/coyote willow
established in 2003
Sevilleta National Wildlife Refuge
Saltcedar/Saltgrass
New Site:
San Acacia village
Alfalfa
Bosque del Apache National Wildlife Refuge
Dense monospecific saltcedar
Elephant Butte Reservoir


Wind direction from the south
Agricultural Drain
Potential tower footprint
Levy Road
40 meters to center well
W
N
E
S
C
River
N
Groundwater wells
Eddy covariance tower

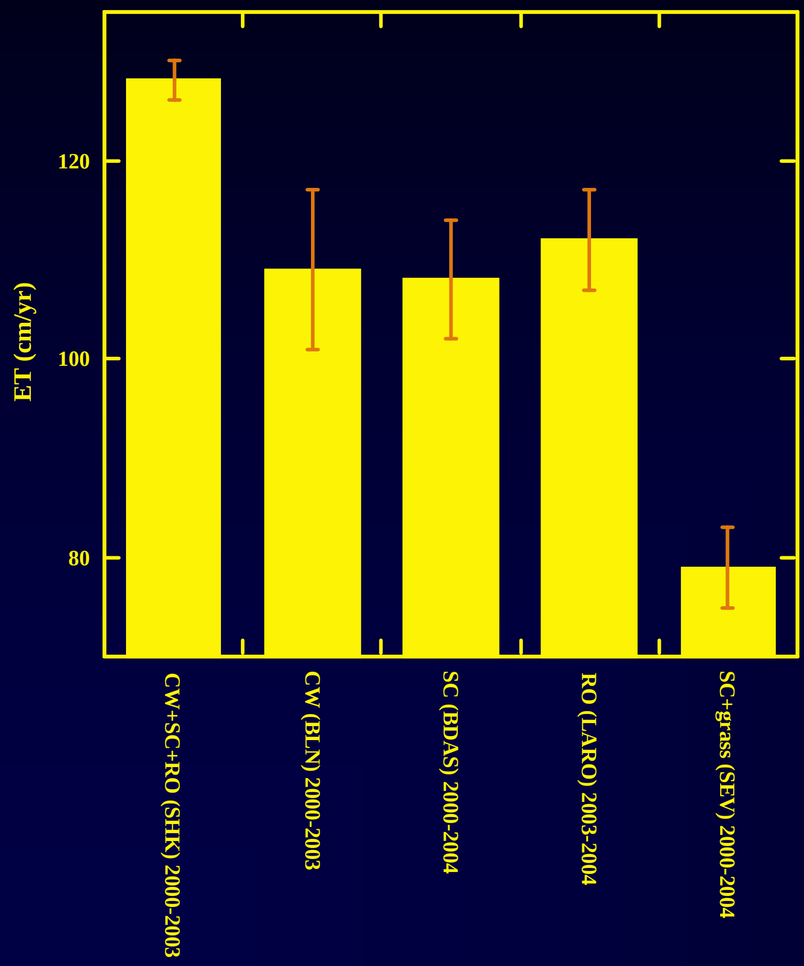


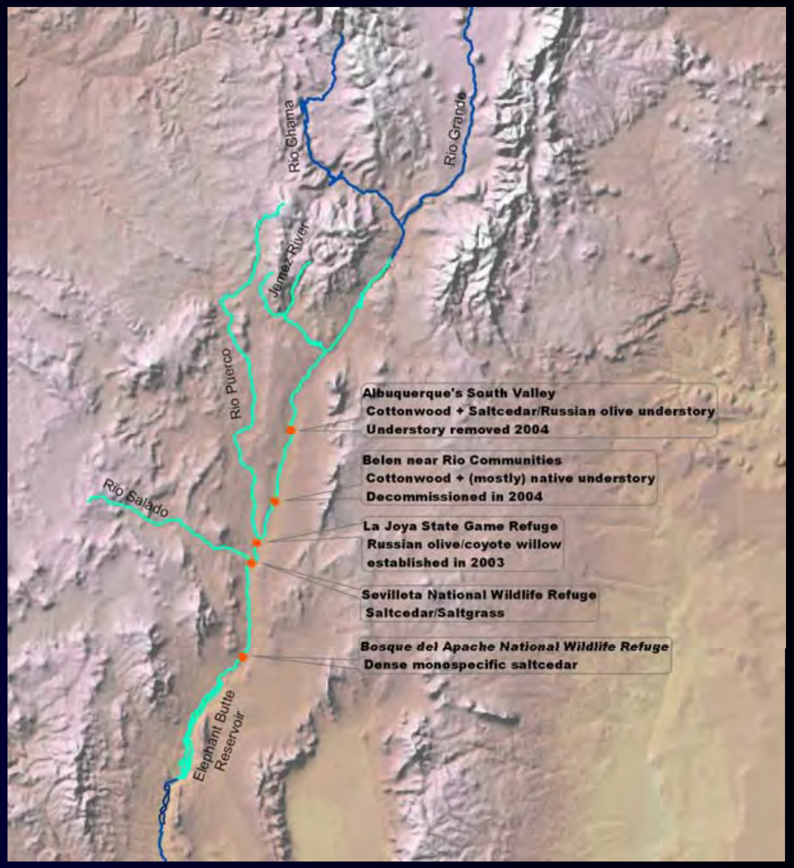
Seasonal ET



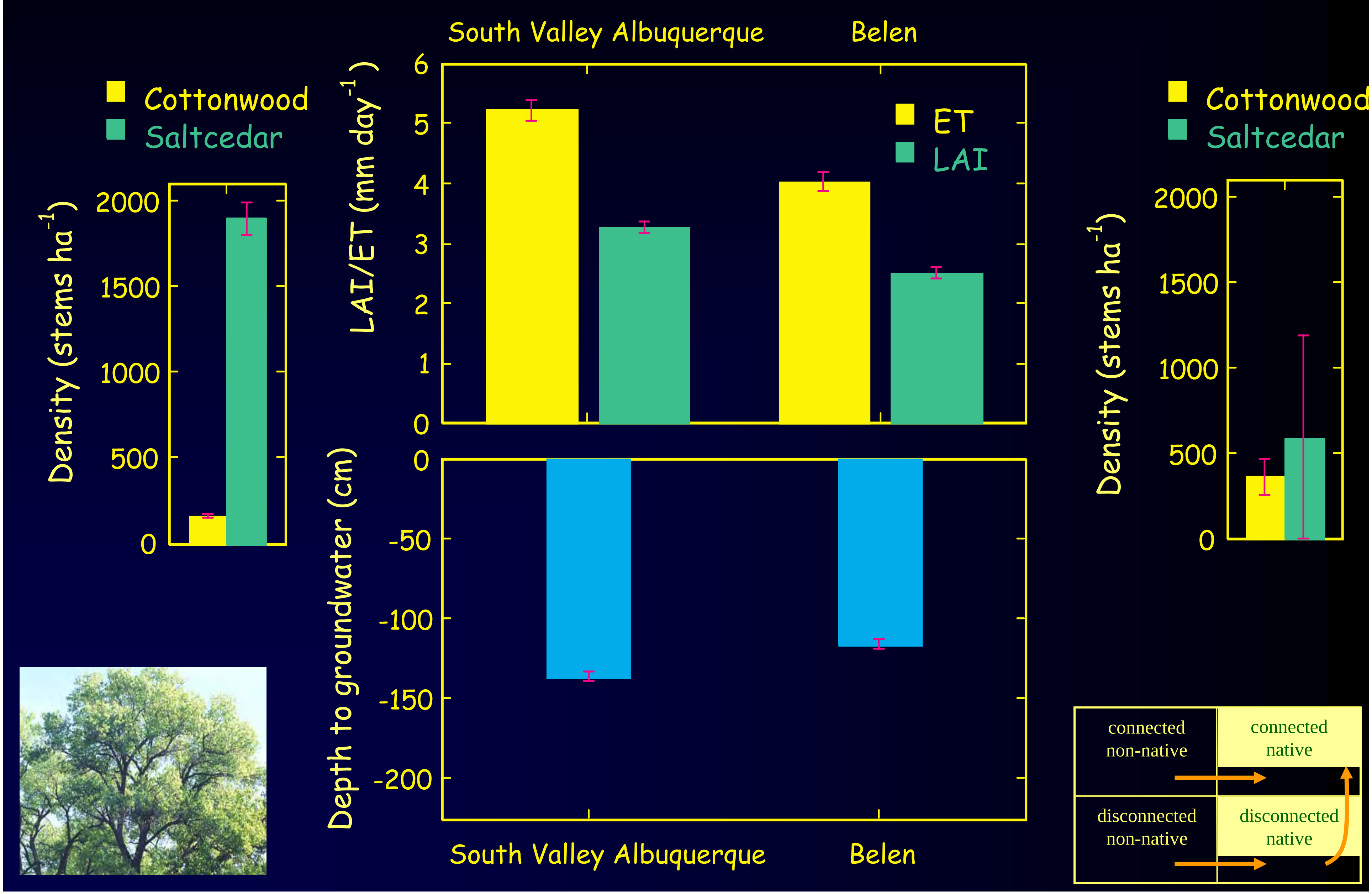
Belen — Rio Communities
2001
Spring Peak
Summer Stress
Monsoons
ET (mm day-1)
Day of Year
0
2
4
6
8
10
12
14
50
100
150
200
250
300
350

Average evapotranspiration

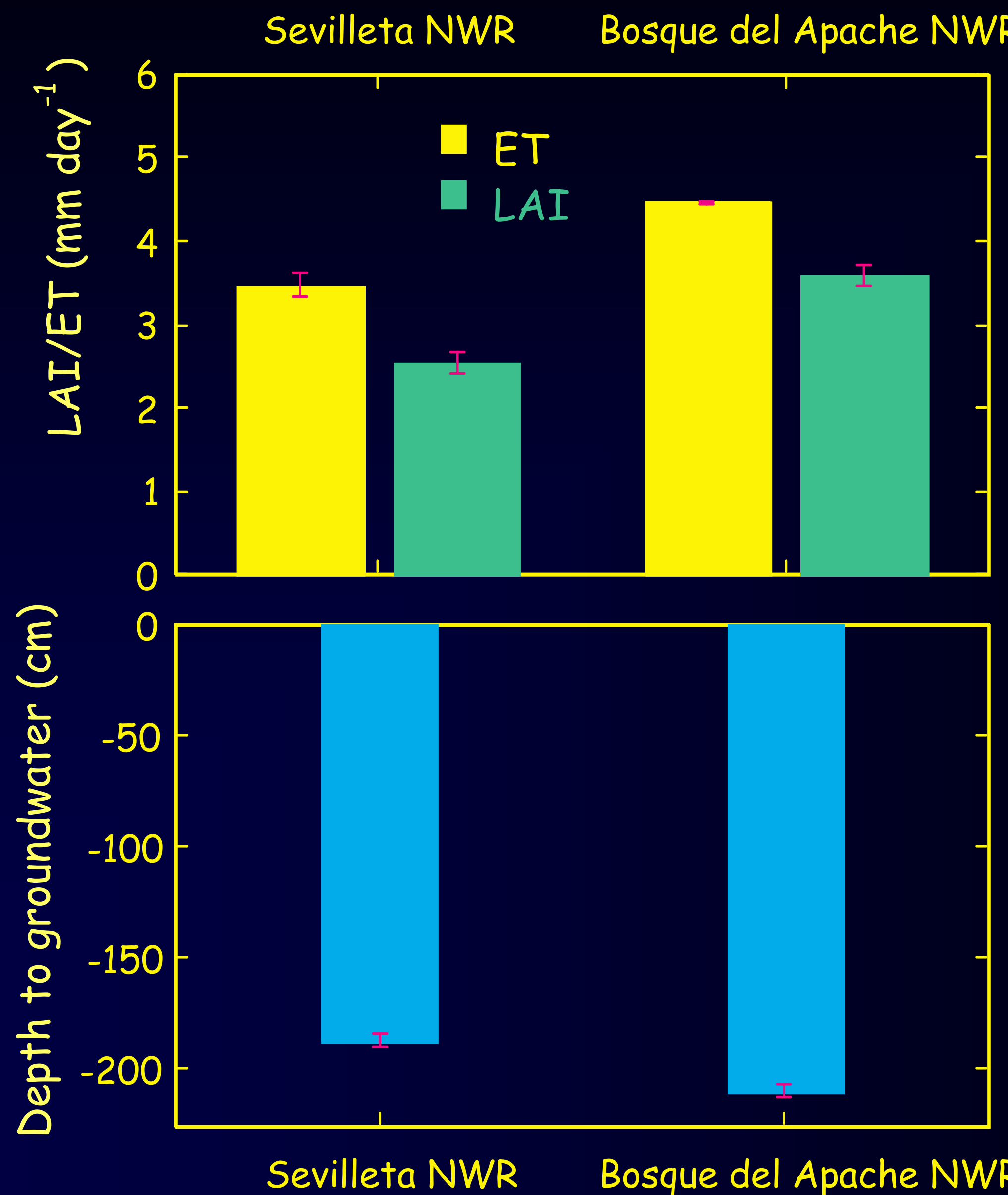


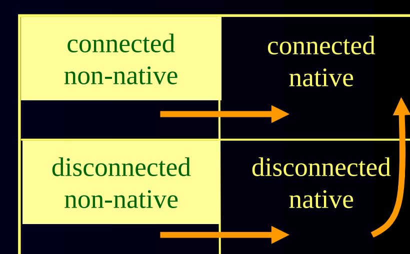


Cottonwood Mixed Communities

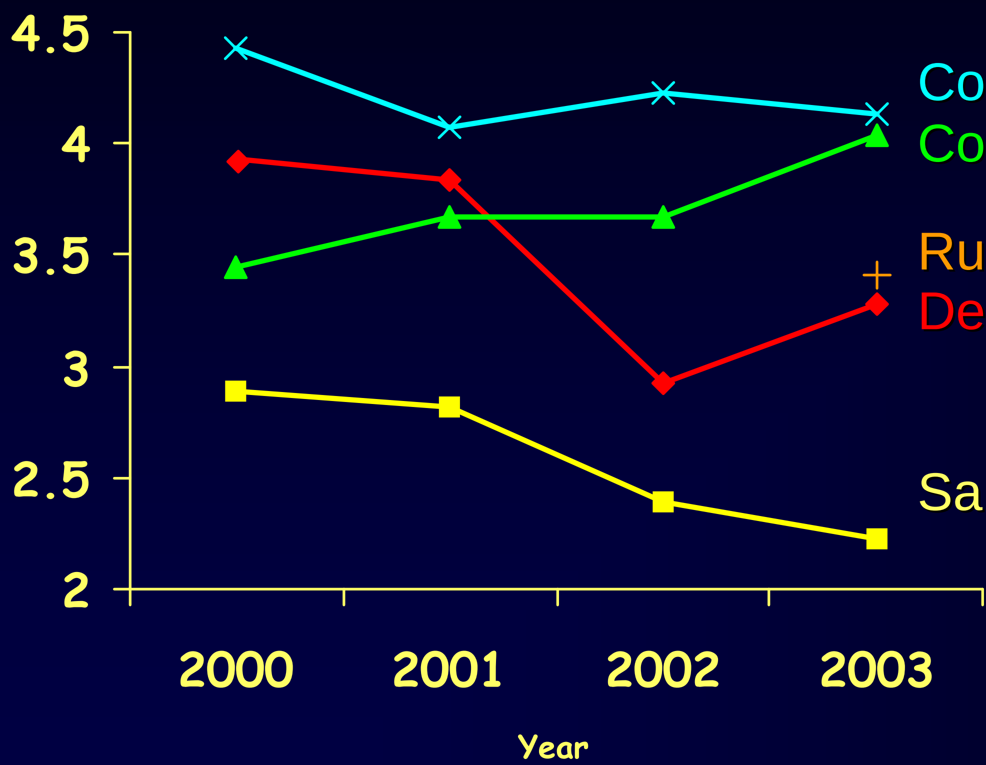


Saltcedar Communities





Annual ET

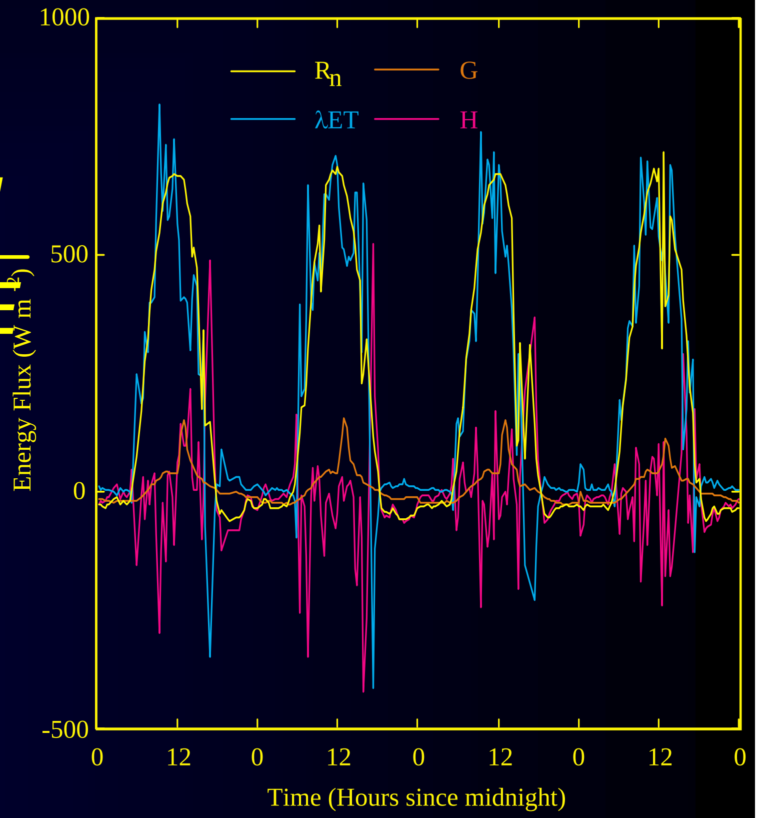


- Site location
- Drought
- Vapor Pressure Deficit
- Groundwater

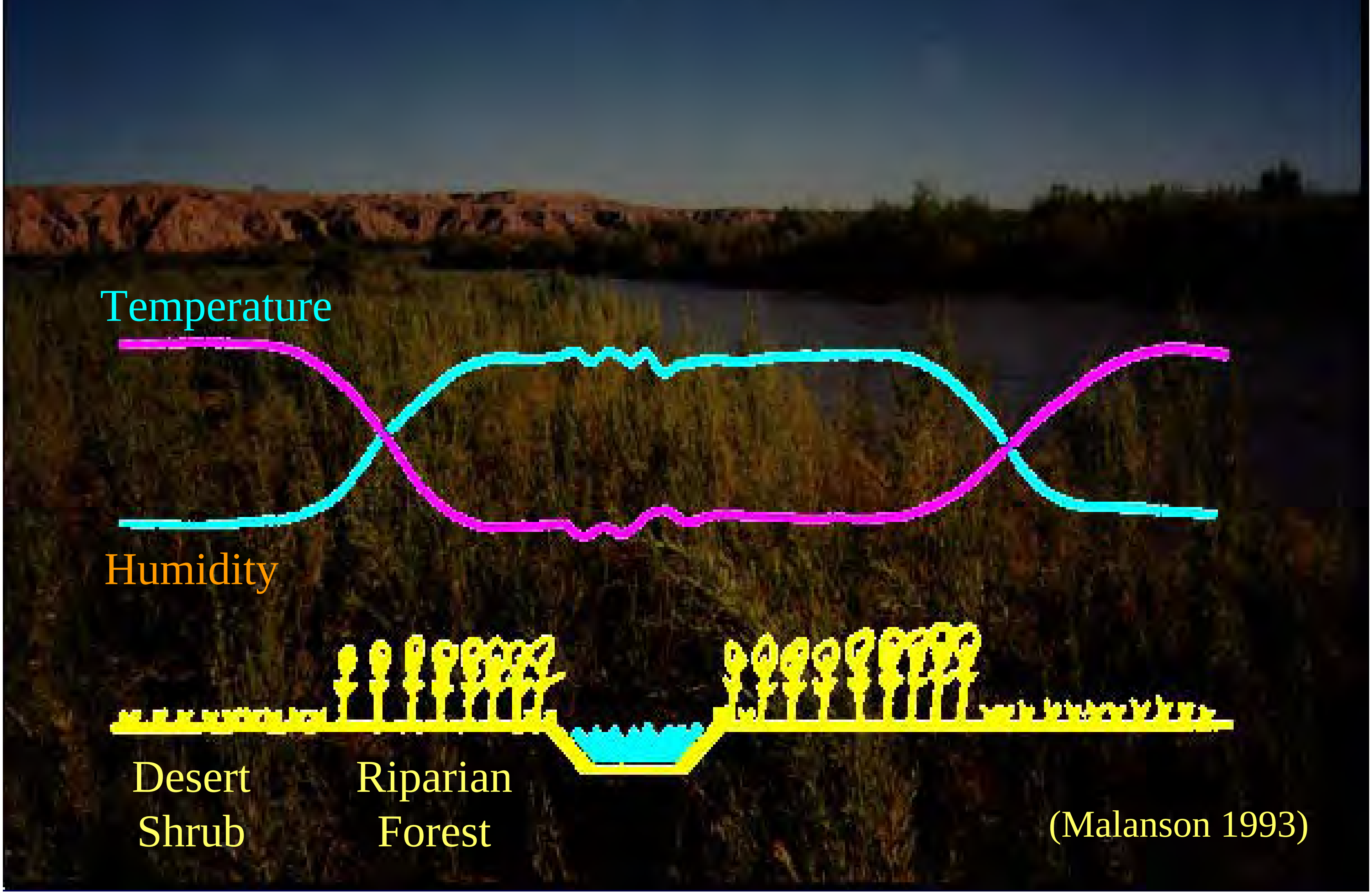
Bowen Ratio Energy Balance

$$\beta = \frac{PC_P\left(T_2 - T_1\right)}{\lambda_v \varepsilon\left(e_2 - e_1\right)} = \frac{H}{LE}$$

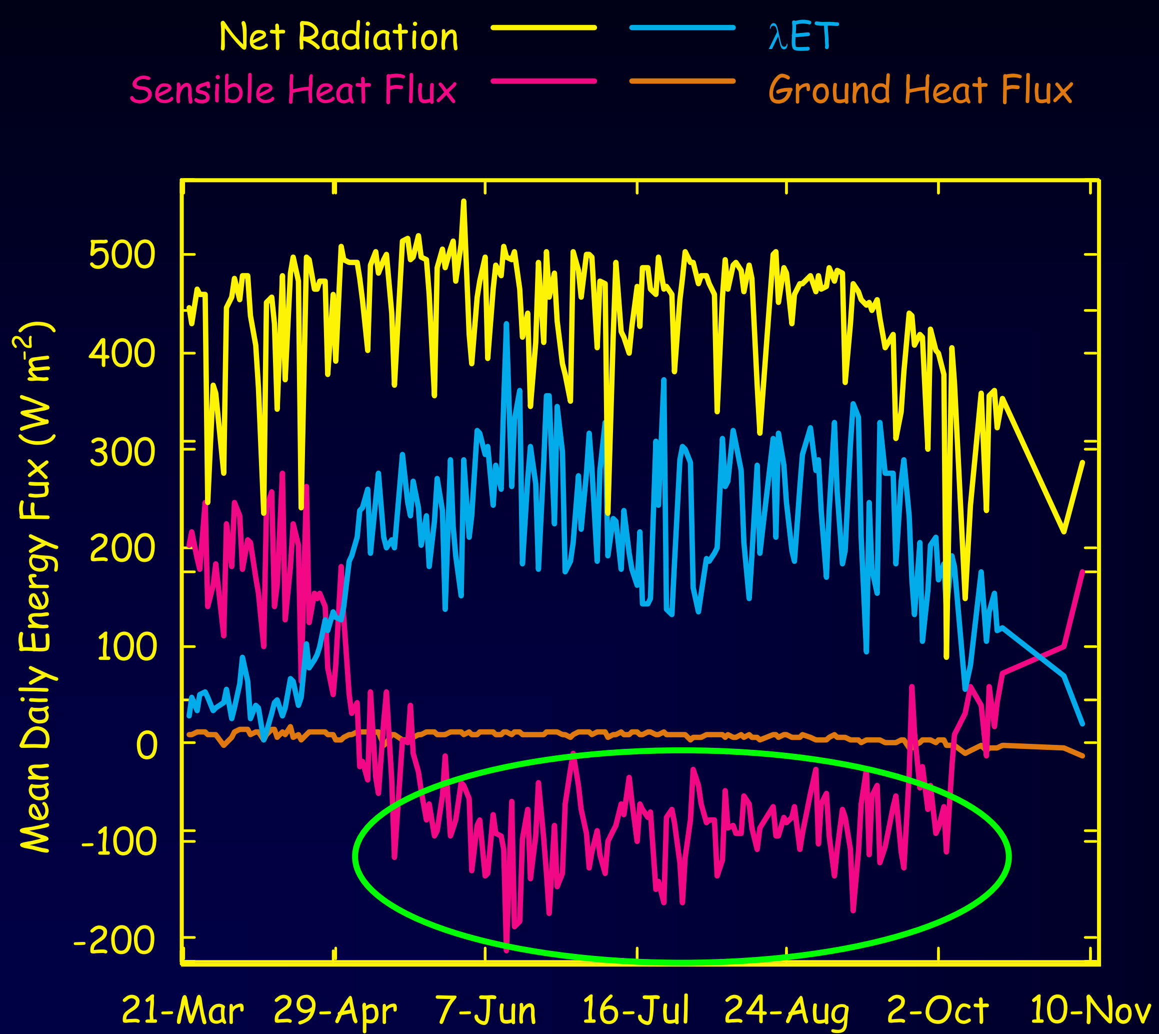
$$R_n = G + H + LE + S$$



Desert floodplain ecosystems



Sensible Heat Advection



- - H indicative of sensible heat input from adjacent desert
- + H observed over saltcedar towers (2000) and Sevilleta saltcedar tower (1999, 2000, & 2001)
- Cottonwood: 25-30 m
- Saltcedar: 4-6 m

Time lag

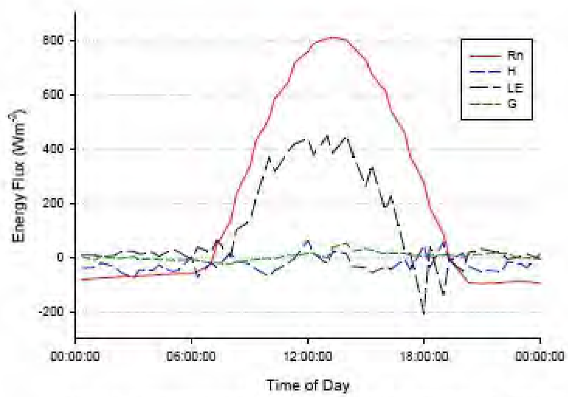


Figure 1: Comparison of energy fluxes on a sunny day, June 22, 2003, at the Belen site, dominated by *P. deltoides* with a native understory.

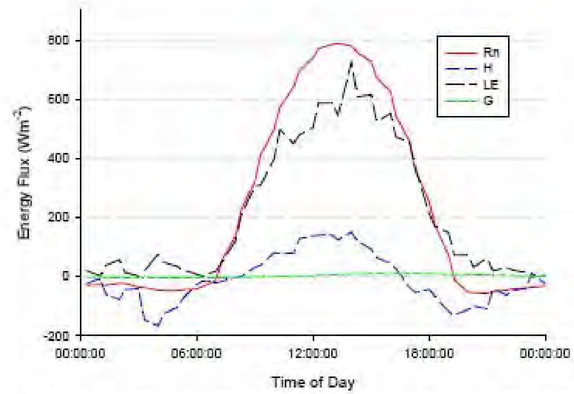


Figure 2: Comparison of energy fluxes on a sunny day, August 8, 2004, at the Bosque del apache site, a monospecific stand of the invasive species *T. ramosissima.*

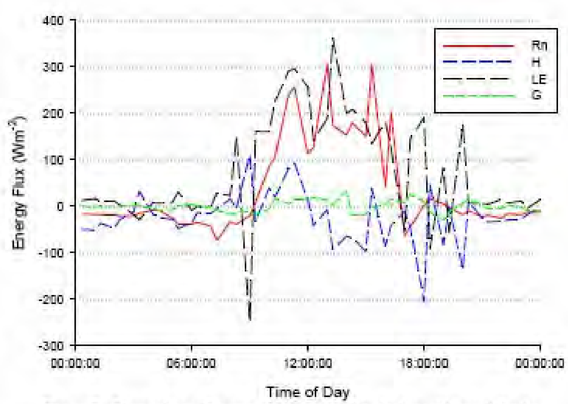


Figure 3: Comparison of energy fluxes on a cloudy day with precipitation, August 15, 2003, at the Belen site.

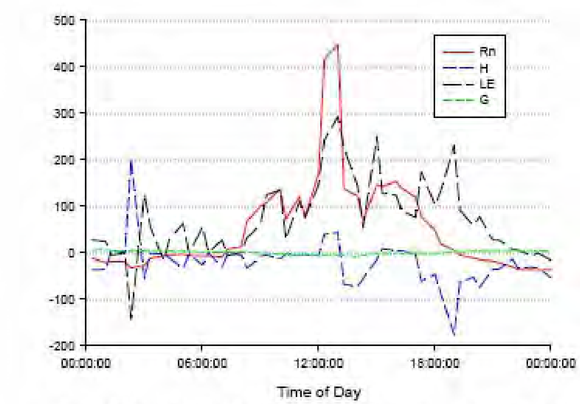


Figure 4: Comparison of energy fluxes on a cloudy day with precipitation, September 4, 2004, at the Bosque del Apache site.

Closure error

$$R_n = G + H + LE + closure$$

$$frac_{closure} = \frac{|H| + |LE|}{R_n - G}$$

Table 4. Summary of energy balance closure error using uncorrected and corrected fluxes.

Site	$frac_{closure}$ uncorrected	$frac_{closure}$ corrected
2000:		
Albuquerque	0.89 ± 0.01	0.88 ± 0.01
Belen—Rio Communities	0.81 ± 0.01	0.74 ± 0.01
Sevilleta NWR	0.86 ± 0.01	0.86 ± 0.01
Bosque del Apache NWR	0.82 ± 0.01	0.82 ± 0.01
2001:		
Albuquerque	0.86 ± 0.01	0.85 ± 0.01
Belen—Rio Communities	0.81 ± 0.02	0.76 ± 0.02
Sevilleta NWR	0.83 ± 0.01	0.84 ± 0.01
Bosque del Apache NWR	0.87 ± 0.01	0.89 ± 0.01
2002:		
Albuquerque	0.92 ± 0.01	0.90 ± 0.01
Belen—Rio Communities	0.91 ± 0.02	0.85 ± 0.02
Sevilleta NWR	0.81 ± 0.01	0.81 ± 0.01
Bosque del Apache NWR	0.87 ± 0.01	0.88 ± 0.01
2003:		
Albuquerque	0.86 ± 0.01	0.86 ± 0.01
Belen—Rio Communities	0.80 ± 0.02	0.75 ± 0.02
Sevilleta NWR	0.84 ± 0.01	0.83 ± 0.005
Bosque del Apache NWR	0.80 ± 0.01	0.82 ± 0.01

What is the upper limit?

550 W/m² for 12 hrs/day, 250 days/yr:
7.96 acre-ft/acre = ~ 432 gallons/(plant-yr)

Advection

150 W/m² for 12 hrs/day, 250 days/yr:
2.17 acre-ft/acre = ~ 118 gallons/(plant-yr)

6000 plants/acre at Bosque del Apache

Photo: bhg.fws.gov

Time Series

(with John Preuger, Larry Hipps, Bill Eichinger, & Dan Cooper)

Wavelets:

q', T', w'

- Continuous 1-D wavelet transformation*

Wavelet Half Planes: Covariance

$\overline{w'T'}, \overline{w'q'}, \overline{T'q'}$

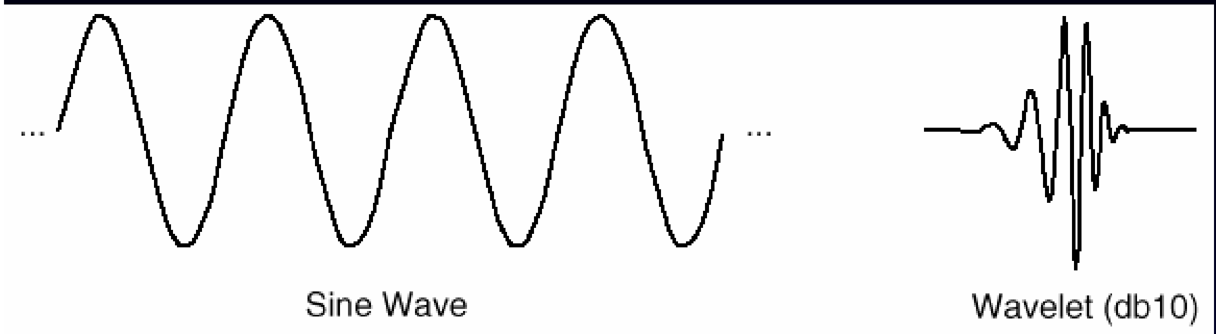
- Discrete 1-D wavelet transformation** (WaveletTransform[data, d1, 16])
- Array multiplication of coefficients**
- Synthesize new signal** (InverseWaveletTransform[wtdata, d1])
- Continuous 1-D wavelet transformation*

* Matlab

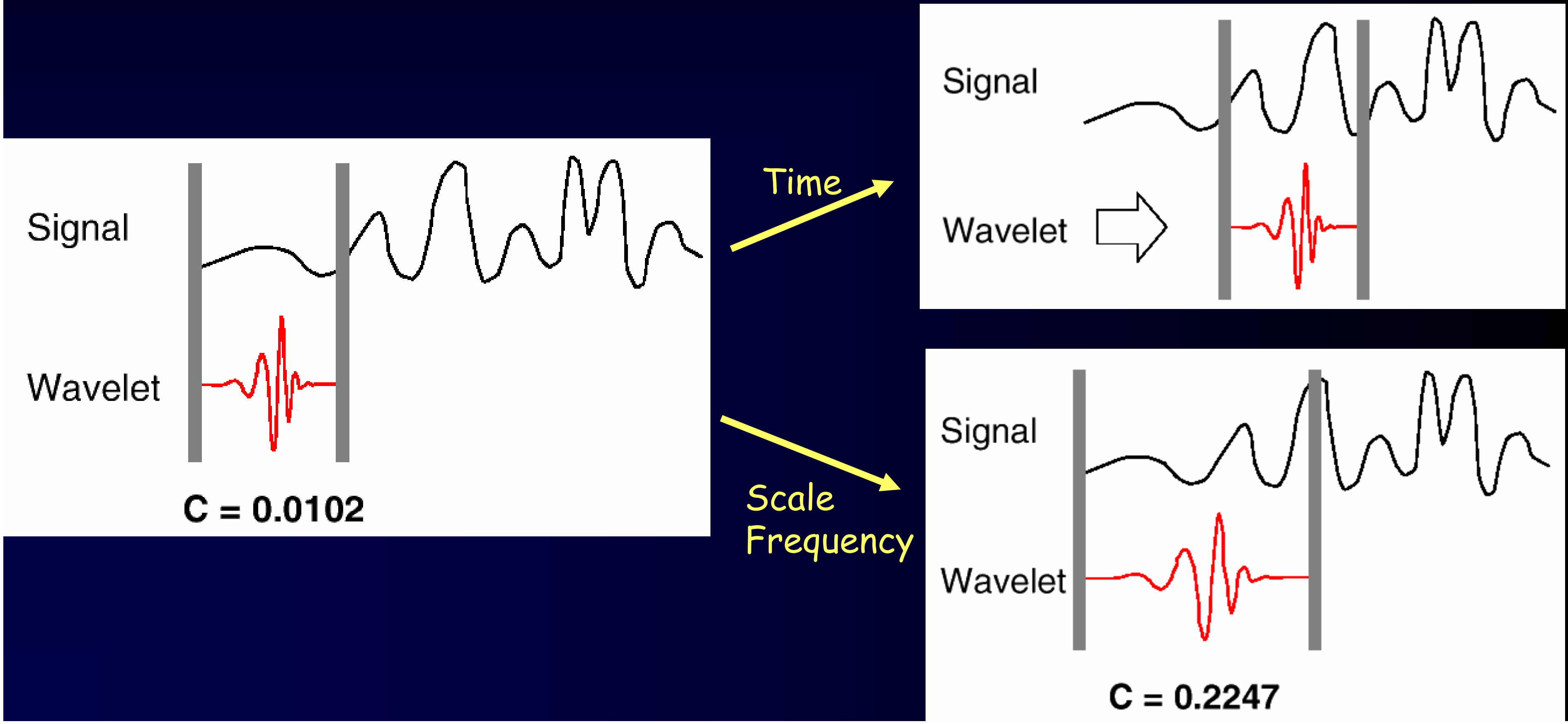
** Matlab (up to 2^{12}), Mathematica (full analysis, 2^{16})

(Scanlon & Albertson In Review)

Wavelets

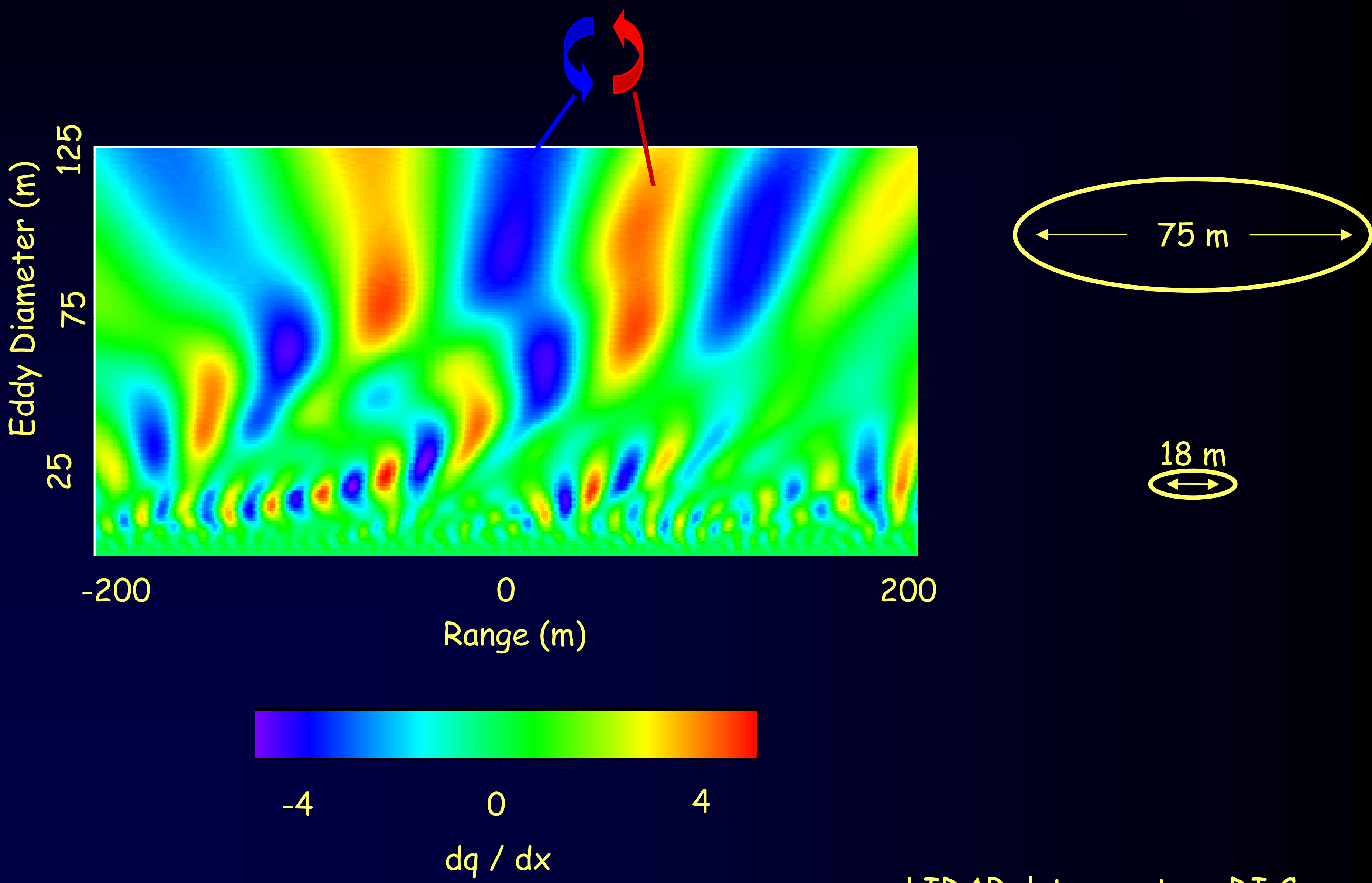


...
...
Sine Wave
Wavelet (db10)



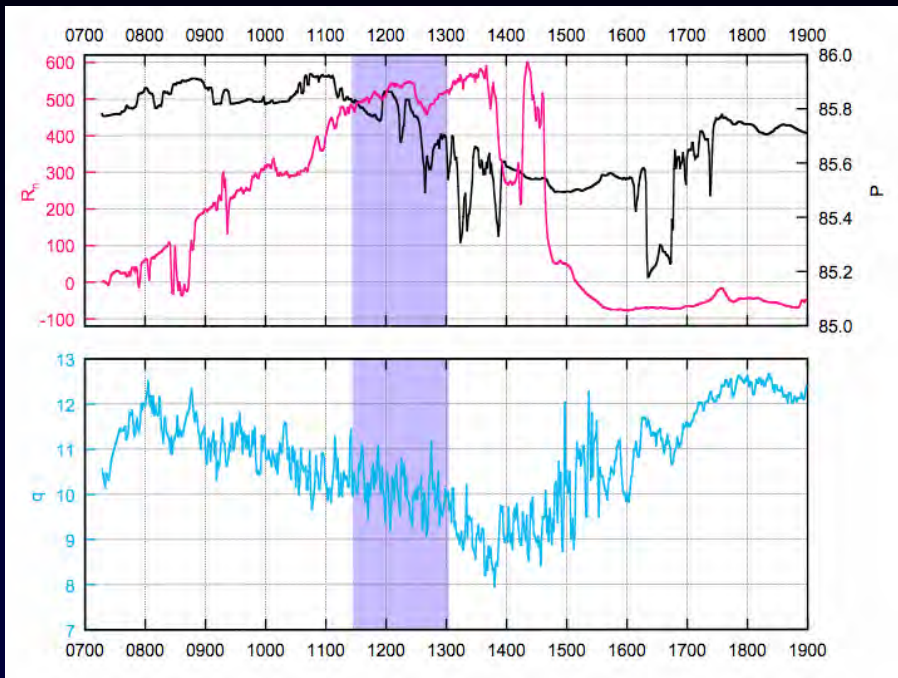
Signal
Wavelet
C = 0.0102
Time
Signal
Wavelet
Scale
Frequency
Signal
Wavelet
C = 0.2247

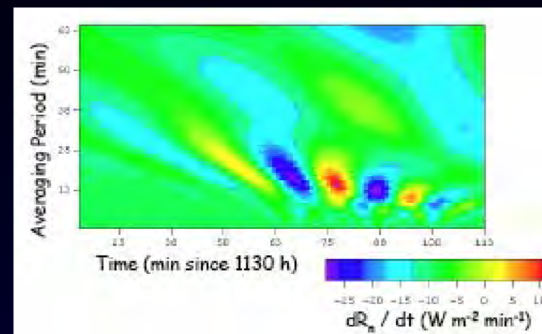
Space Series & Eddy Size

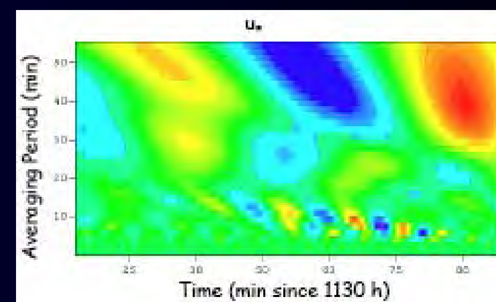


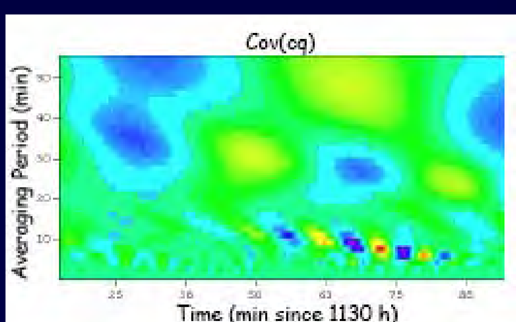
LIDAR data courtesy DI Cooper

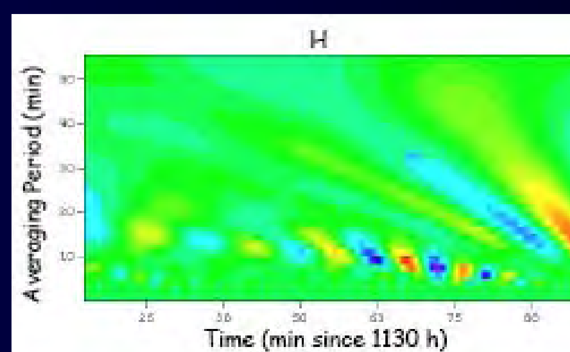
Monsoon dynamics

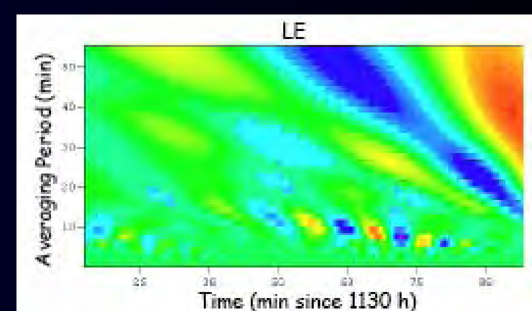




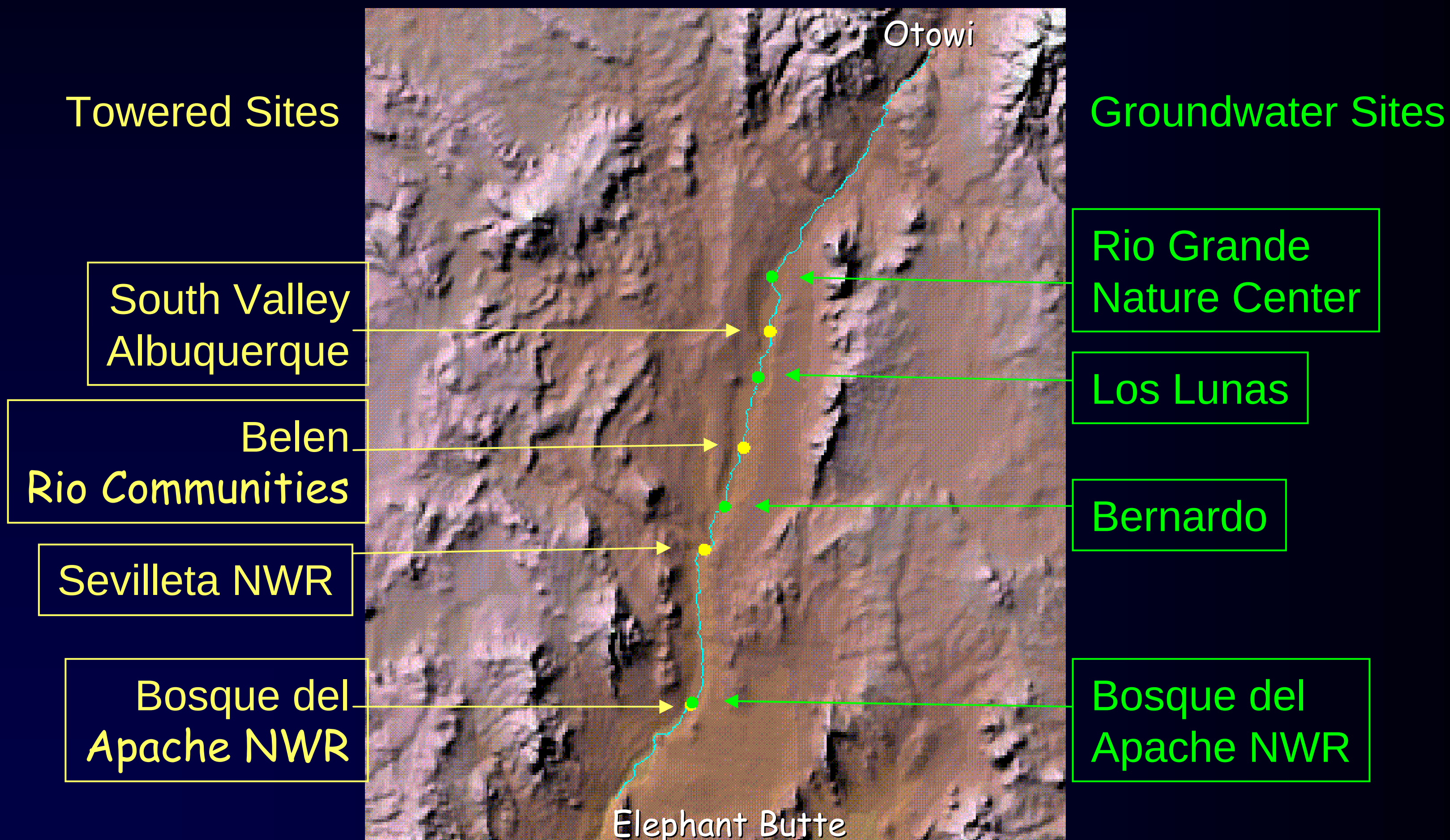






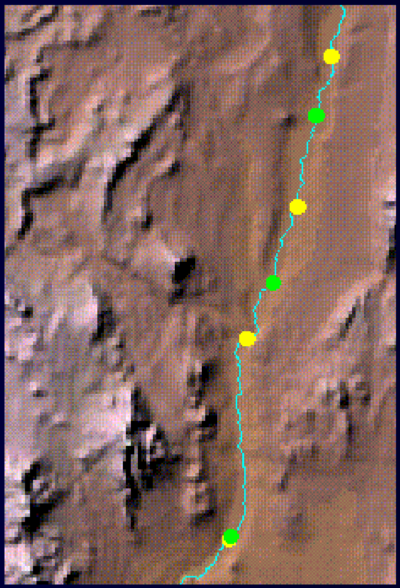


Basin Topography



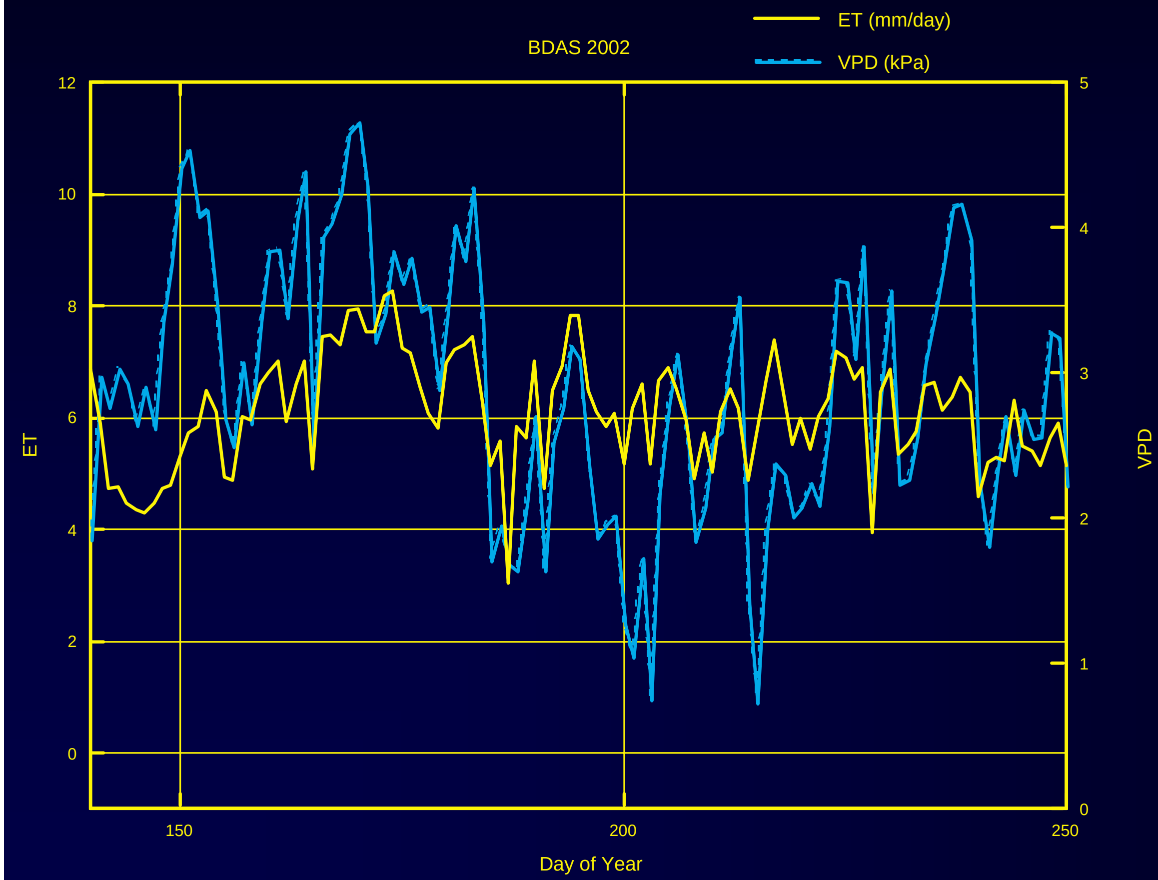
Topography

Site	Temp C	Valley width m	Angle	Distance km	Nearest Arroyo
Albuquerque	20.3 (11.7, 27.7)	2600 Š 5100	0.0 Š 2.3	16.5	60 , 4000 m, upstream, E
Belen Ń R io Communities	20.5 (11.0, 28.6)	3300 Š 4000	1.0 Š 1.6	20.0 (37.0)[b]	30 , 24000 m, downstream, W[c]
Sevilleta NWR	20.7 (8.5, 30.3)	400 Š 4000 (6500)[a]	2.0 Š 13.2	27.2	90 Š 180 onsite, W[d]
Bosque del Apache NWR	20.1 (7.8, 30.6)	3000 Š 5000	2.0 Š 8.7	39.2	80 , 23600 m, downstream, W[e]



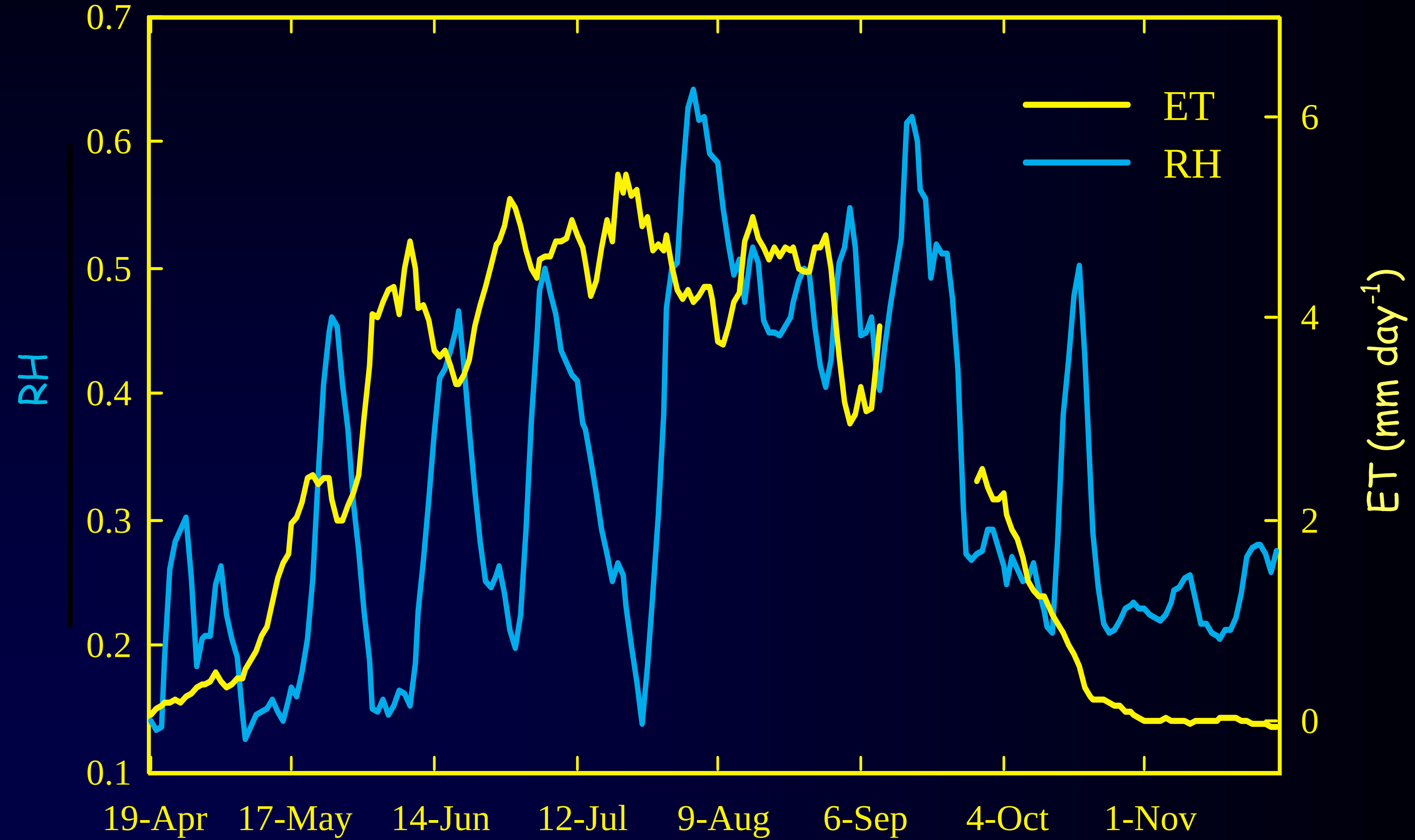
Vapor Pressure Deficit

$VPD = e_{air} - e_{leaf\text{-}saturated}$



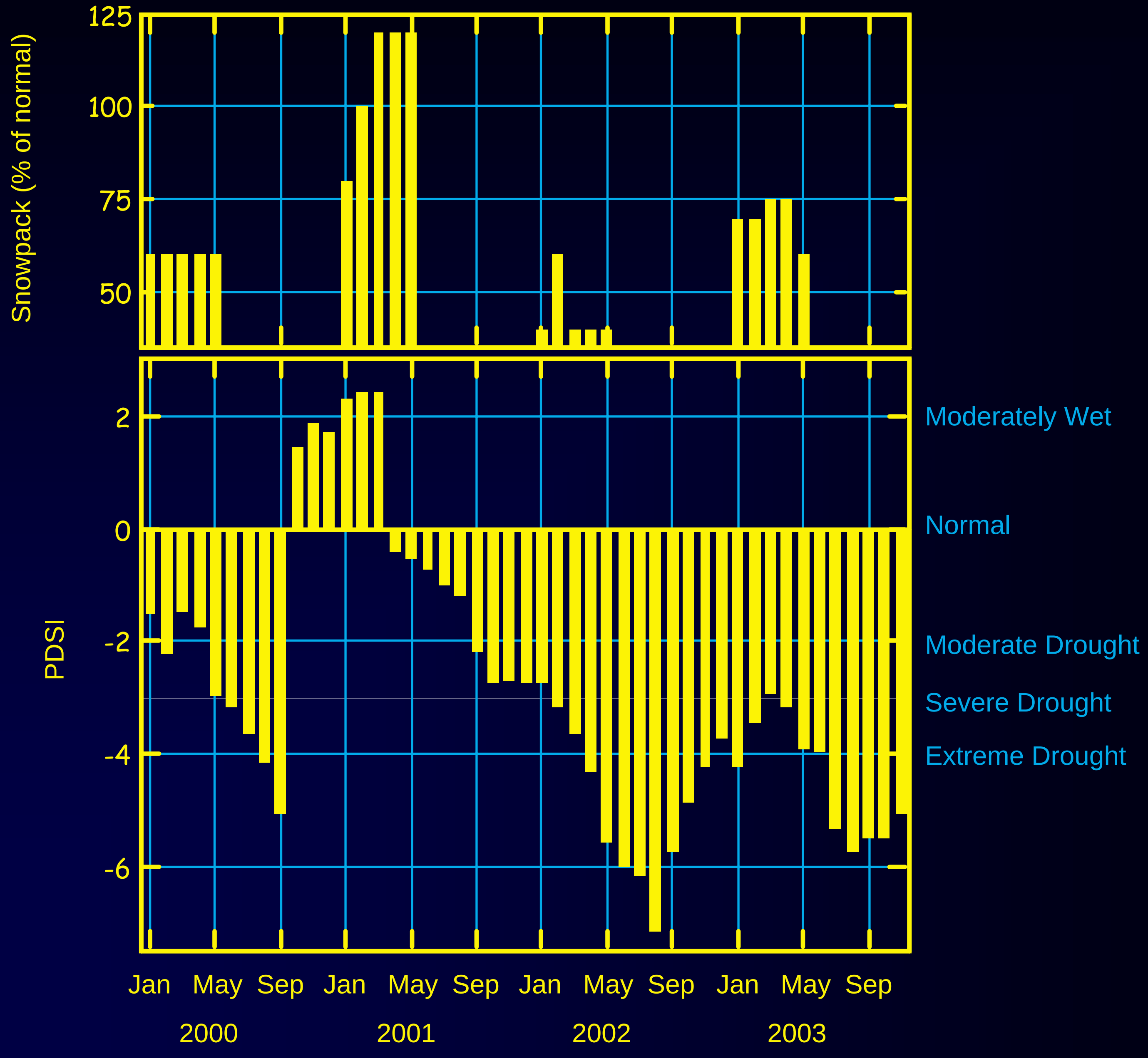
Factor	Coefficient ± se	F	p
Albuquerque and Belen ŃŹRio Communities, *Populus deltoides*			
Model:	**0.54**	**110.8**	**< 0.0001**
Energy Balance:			
H	-0.008 ± 0.002	19.2	< 0.0001
R_n	0.02 ± 0.0008	388.1	< 0.0001
Aerodynamics:			
v	-0.1 ± 0.06	5.8	0.02
v X u	-0.09 ± 0.02	16.2	< 0.0001
Sevilleta and Bosque del Apache NWRs, *Tamarix chinensis*			
Model:	**0.66**	**77.7**	**< 0.0001**
Energy Balance:			
R_n	0.005 ± 0.0005	83.7	< 0.0001
Aerodynamics:			
u	0.08 ± 0.03	7.5	0.007
u_*	1.2 ± 0.3	12.9	0.0004
q_*	-4.2 ± 0.6	50.2	< 0.0001
u_* X q_*	11.8 ± 4.3	7.4	0.007
Surface Scalars and Interaction Effects:			
VPD	0.5 ± 0.07	43.0	< 0.0001
T_{max} X T_{min}	-0.01 ± 0.003	9.8	0.002
PPT X H	-0.003 ± 0.0005	24.3	< 0.0001
R_n X PPT	0.001 ± 0.0003	18.4	< 0.0001

Atmospheric Humidity



(Cleverly et al, In Review)

Drought in the Rio Grande Basin



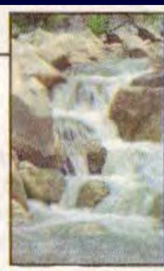
Water Controversies

Overdrawn *at the* Riverbank

Drought compounds problems along Rio Grande as water users demand more and more

Running low

First in a five-part series



The Rio Grande is being stretched to the limit by growing demands for its water

How Do You Stretch a River?

Rio Grande Domesticated for Human Needs

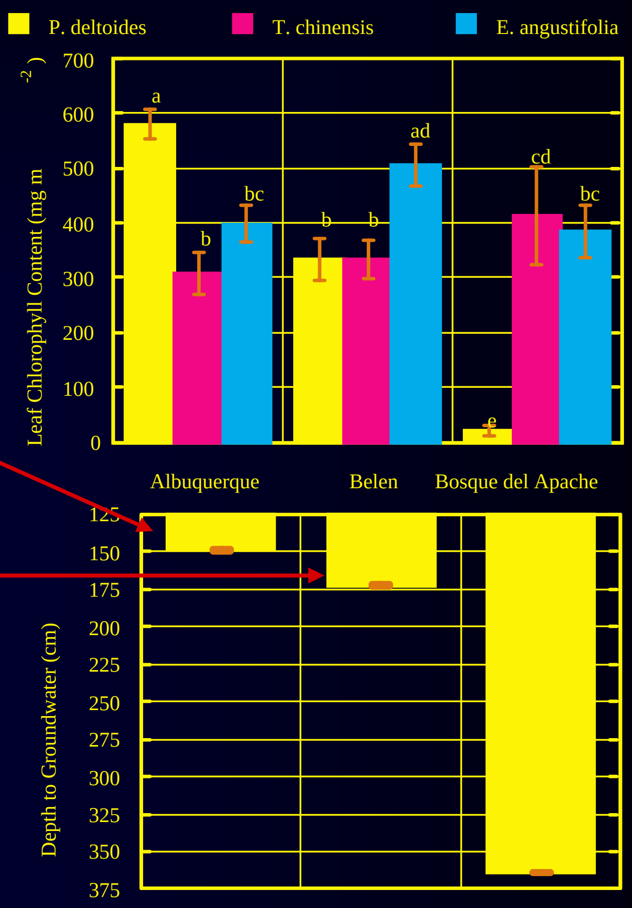
Cottonwoods Take Back Bosque From Cedars

Crown dieback

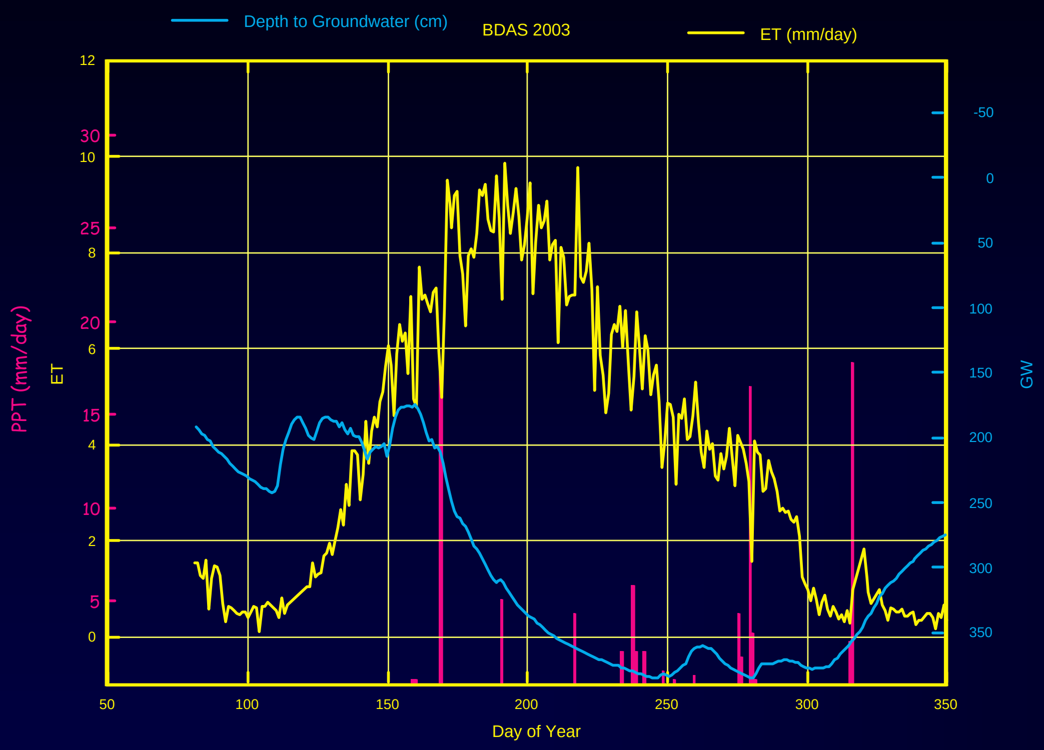
Water table maintained by:

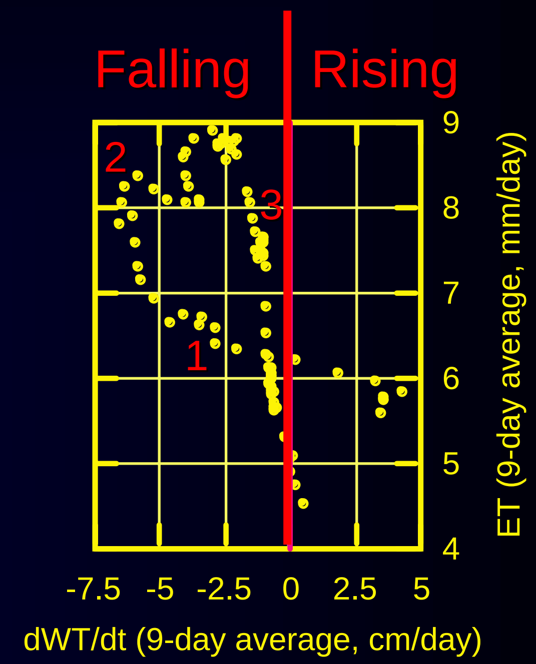
Wastewater treatment

Irrigation return



Groundwater recession





1 Draining begins, soil too saturated for taproot elongation, uptake continues at original capillary fringe

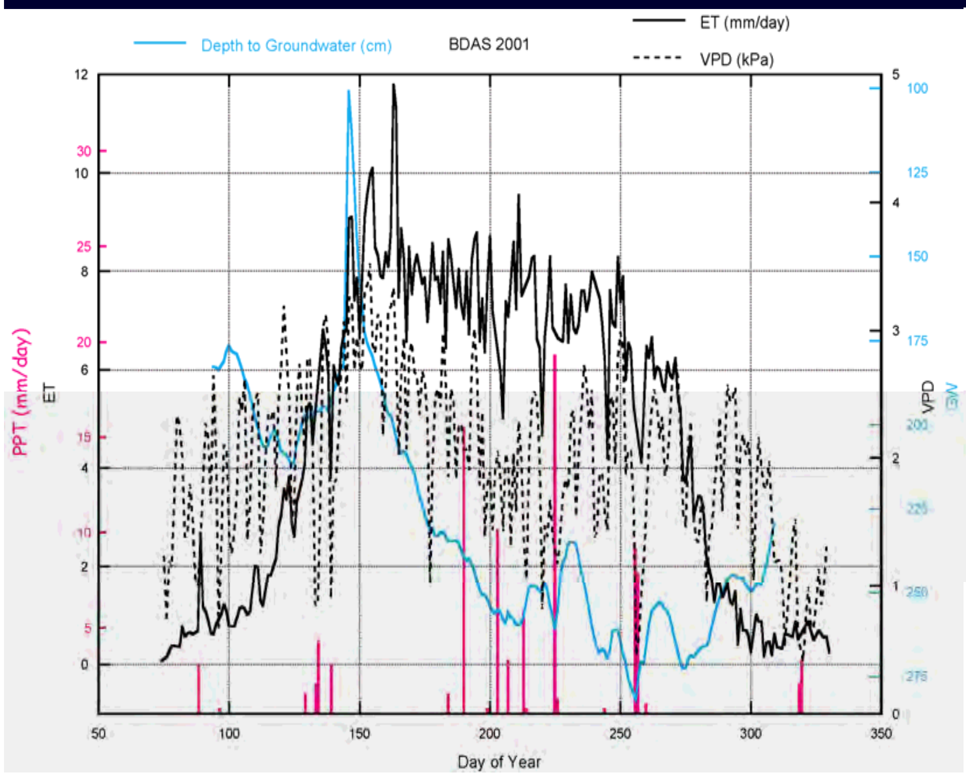
2 Taproot growth exploits deeper water table, uptake continues at or near original capillary fringe

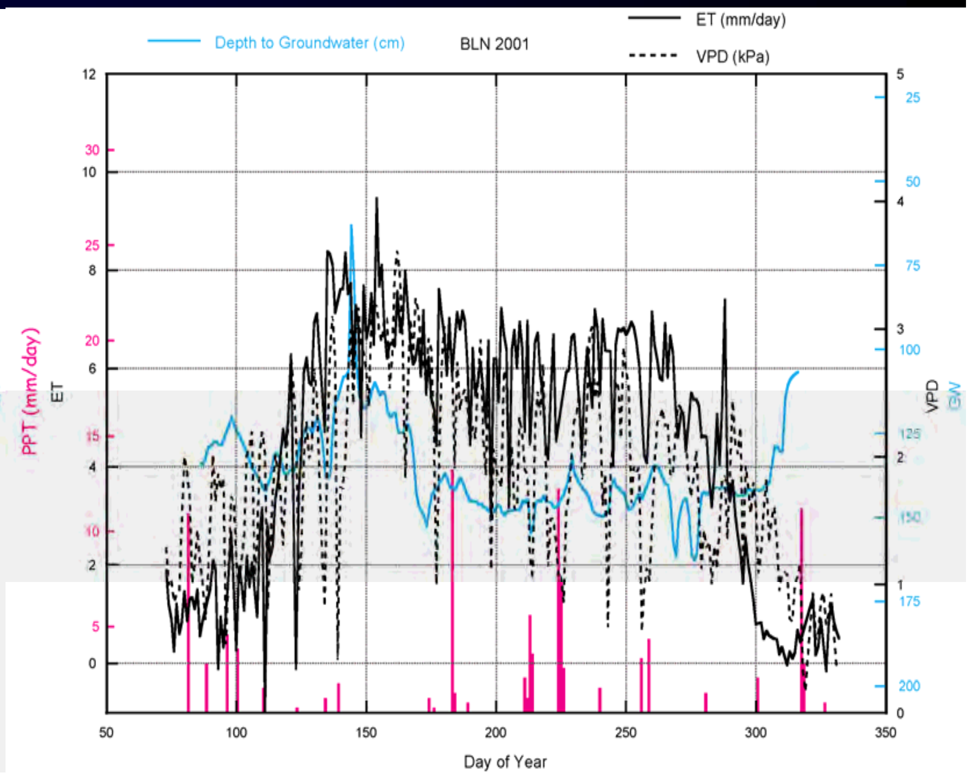
3 Uptake continues at deeper water table, uptake at original water table curtailed by soil drying

Flooding 2001
(1-day inundation initiated by US ACoE)

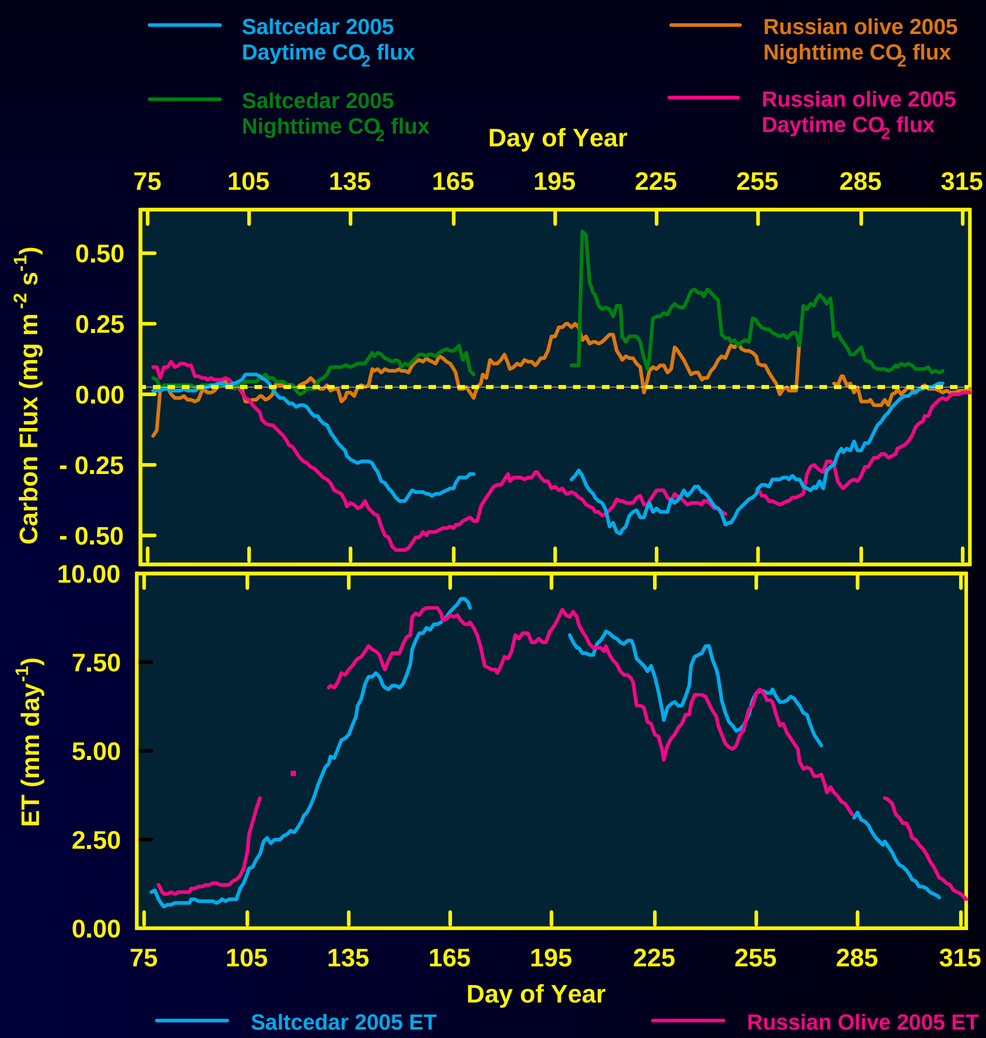
Dense saltcedar
Clay soil (R. Puerco)
Perched floodwater

Cottonwood
+ (mostly) native understory
Loamy-sand soil
Partially inundated site
(microtopography)





Flooding



Saltcedar 2005
Daytime CO_2 flux
Saltcedar 2005
Nighttime CO_2 flux
Russian olive 2005
Nighttime CO_2 flux
Russian olive 2005
Daytime CO_2 flux
Day of Year
75 105 135 165 195 225 255 285 315
Carbon Flux (mg m^{-2} s^{-1})
0.50
0.25
0.00
- 0.25
- 0.50
10.00
7.50
5.00
2.50
0.00
ET (mm day^{-1})
75 105 135 165 195 225 255 285 315
Day of Year
Saltcedar 2005 ET
Russian Olive 2005 ET

Factors Influencing ET

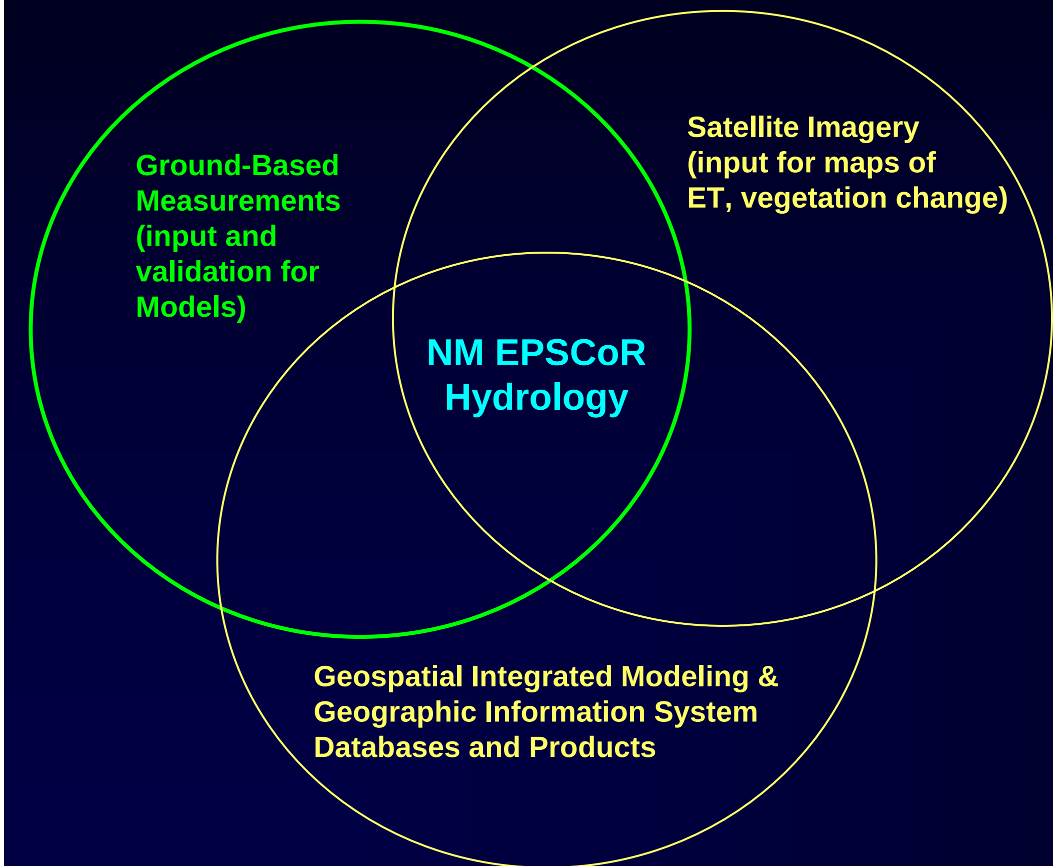
- Leaf Area Index
  - Chloride, Nitrate, Water Table depth
- Drought & Groundwater Decline/Dynamics
- Flooding
- Topography
  - Cold air drainage (Katabatic winds)
    - Temperature, Season Length, & Sensible heat advection
- Vapor Pressure Deficit
- Precipitation
- Energy balance
- Turbulence

New Mexico EPSCoR: a Statewide Ecohydrology and Flux Network Within a Semi-arid Region

<u>James Cleverly</u>*, *Robert Bowman, Clifford Dahm, Julie Allred Coonrod, Zohrab Samani, James Thibault, and James Gosz*

***UNM Hydrogeoecology, http://sevilleta.unm.edu/~cleverly**

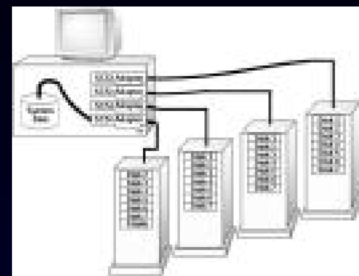
EPSCoR: Experimental Program to Stimulate Competitive Research



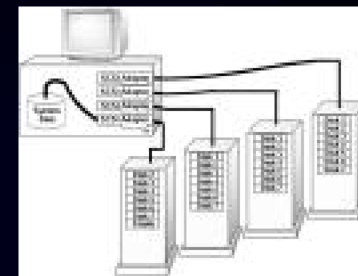
- Ground-based measurements: Fluxnet+ NM
- Remote sensing: scaling, statewide ET maps, and model input
- Geospatial integrated modeling: distributed hydrological processes, computation, and data products

NM EPSCoR

daily

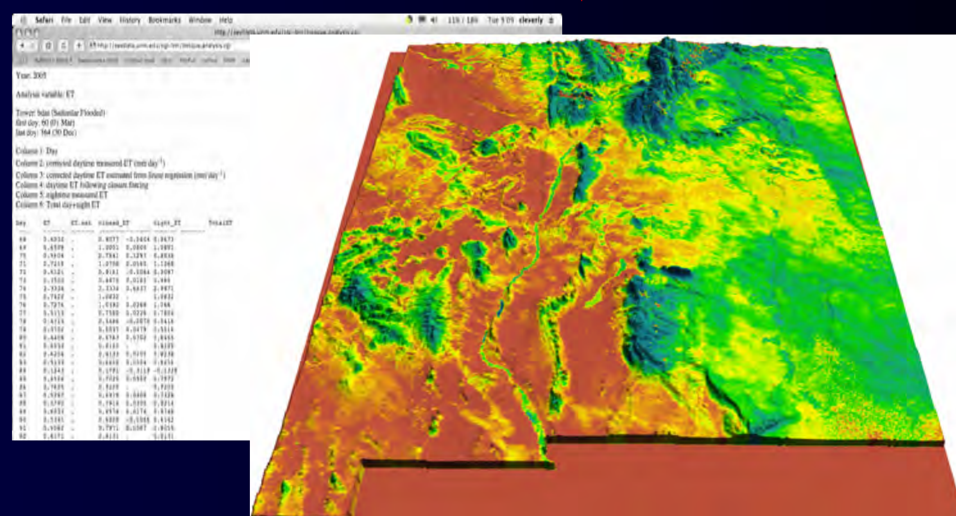


LambdaRail



UNM GigaPOP
Flux corrections
RS Imagery
Data Distribution

NMT GigaPOP
Hydrologic Model
Data Archive



EPSCoR New Mexico

NSF

NM-EPSCoR FluxNet

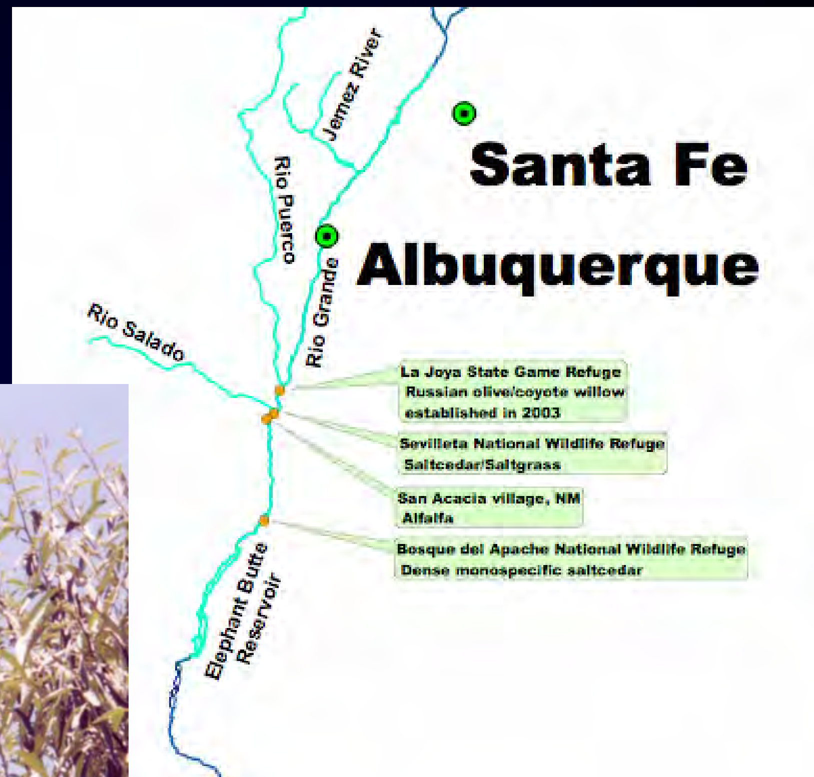
Founding Nodes

- Riparian and Middle valley — UNM
- Arid upland — UNM-Litvak
- Mesilla valley — NMSU-Bawazir

Extended network

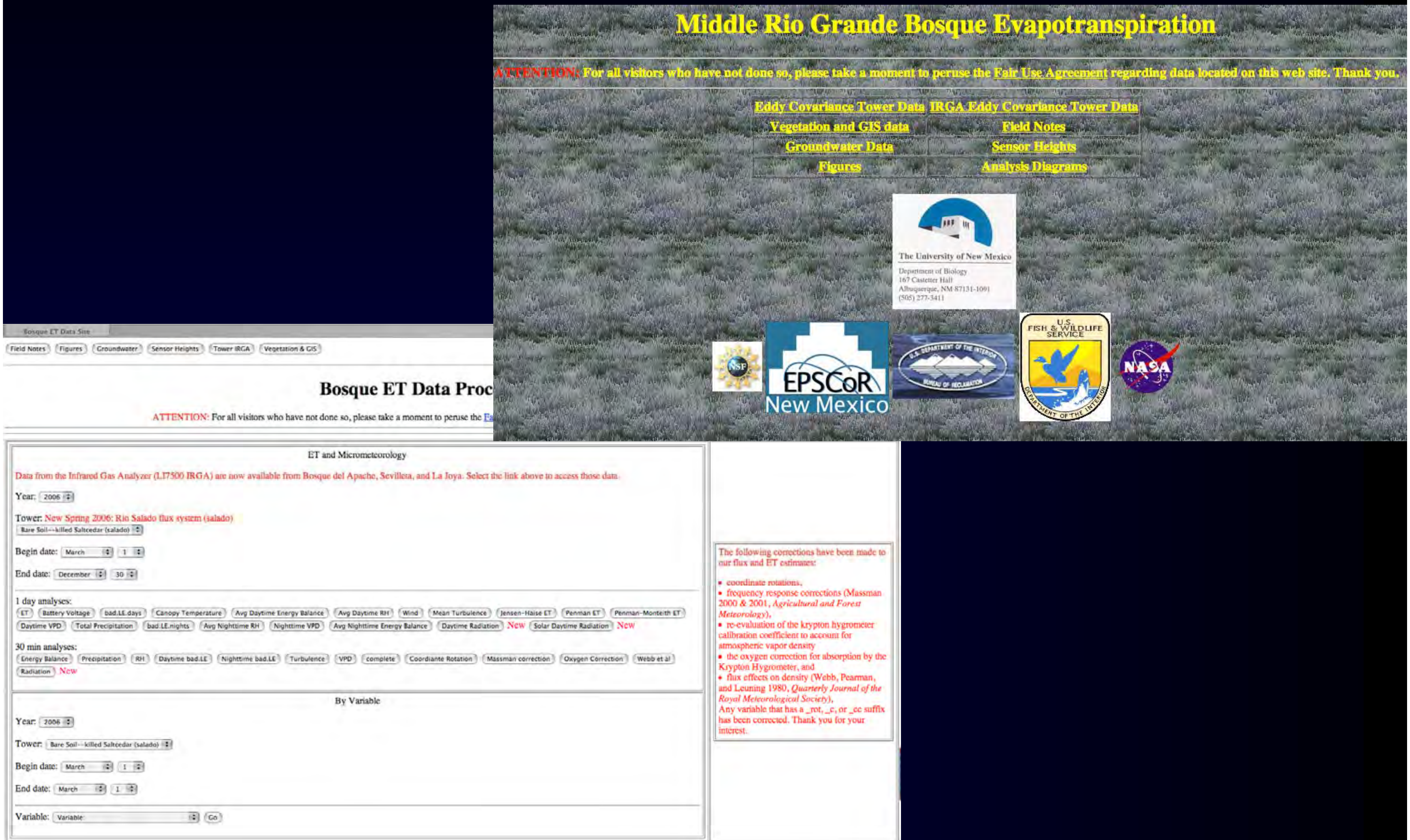
- Albuquerque — NMT-Kleissl
- Arid lowland — USDA/ARS-Rango
- High elevation conifer — UA-Brooks

AmeriFlux



http://public.ornl.gov/ameriflux/

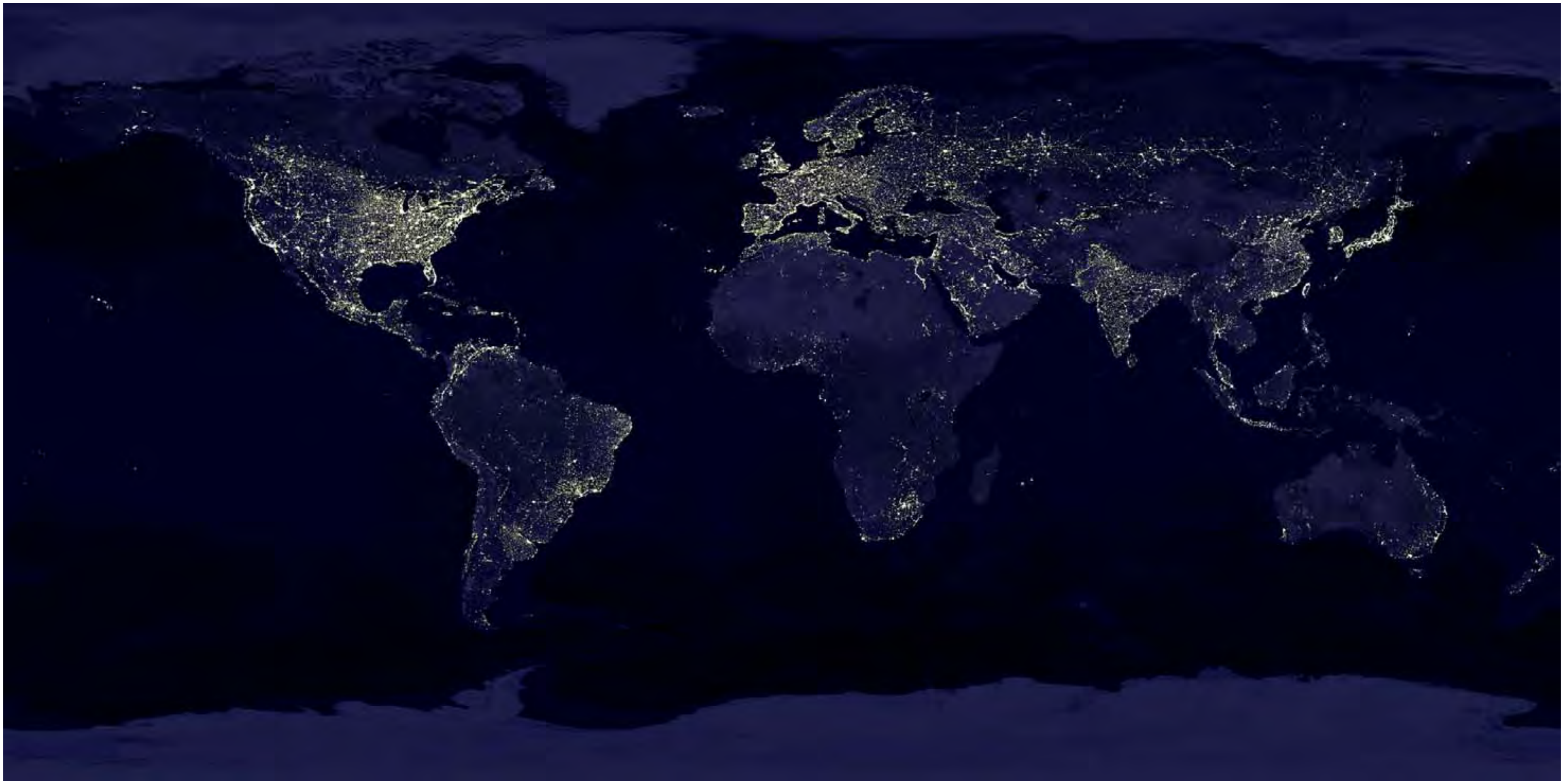
UNM Bosque ET web



http://bosque.unm.edu/~cleverly/bosque/index.html

Integrated Science for Society and the Environment

Scott Collins, Ali Whitmer, Barbara Benson, Dan Childers



http://intranet.lternet.edu/planning/

A DECADE OF SYNTHESIS:
GOALS OF THE LTER PLANNING PROCESS (from the proposal):

This proposal describes an ambitious **planning activity to develop a new LTER science agenda that when implemented will use the Network to its maximum potential and take LTER science to a higher level of research collaboration, synthesis and integration.**

- **Objective 1: establish activities that will lead to multi-site, highly collaborative, integrated research initiatives that explicitly include synthesis components coupled with novel training opportunities in graduate and undergraduate education.**

- **Objective 2: evaluate LTER Network governance structure and further stimulate the culture of collaboration within the LTER Network.**

- **Objective 3: envision and develop education and training activities that will infuse LTER science into the K-12 science curriculum.**

Build on the strengths of the existing LTER Network:

- Research on
  - climate variability and climate change
  - biogeochemical cycles
  - biotic structure and dynamics

- Experience Integrating Ecology, Geosciences and Social Sciences

- Well Defined Organizational Structure

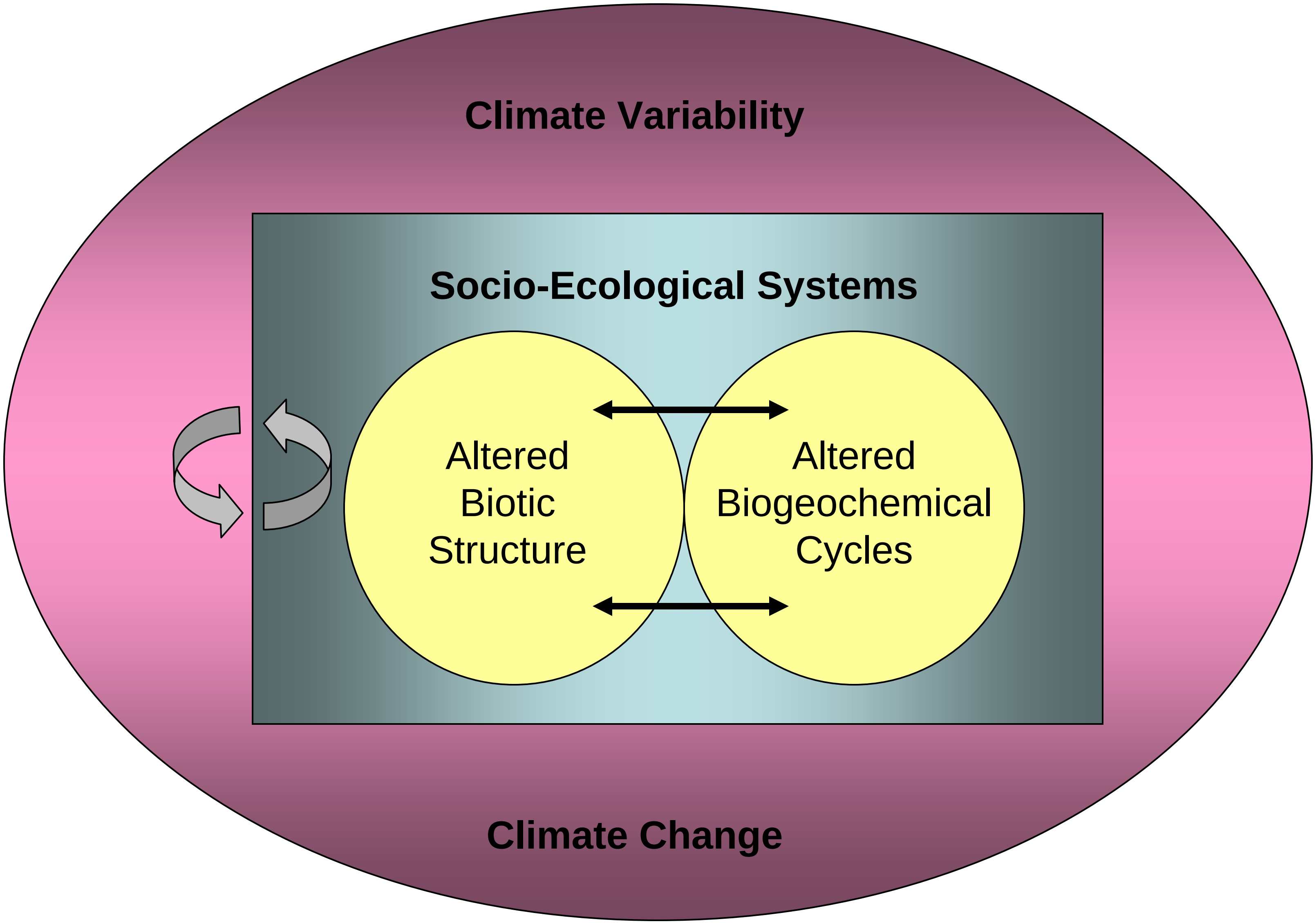
- Common Network-level Goals

- Cyberinfrastructure and Information Management

- Strong Graduate and Undergraduate Education

- Schoolyard LTER

Hierarchical structure of the LTER Planning Framework

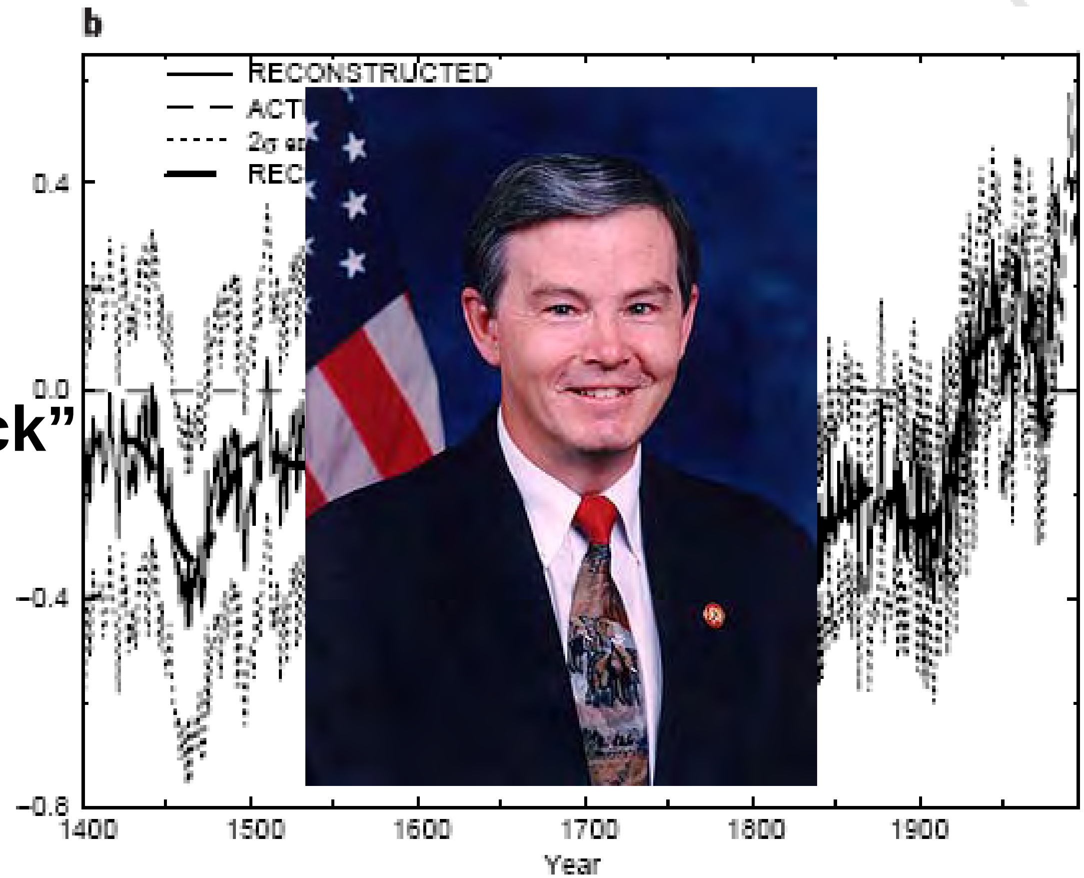


LTER has a strong history of research in these areas

Global-scale temperature patterns and climate forcing over the past six centuries

Michael E. Mann*, Raymond S. Bradley* & Malcolm K. Hughes†

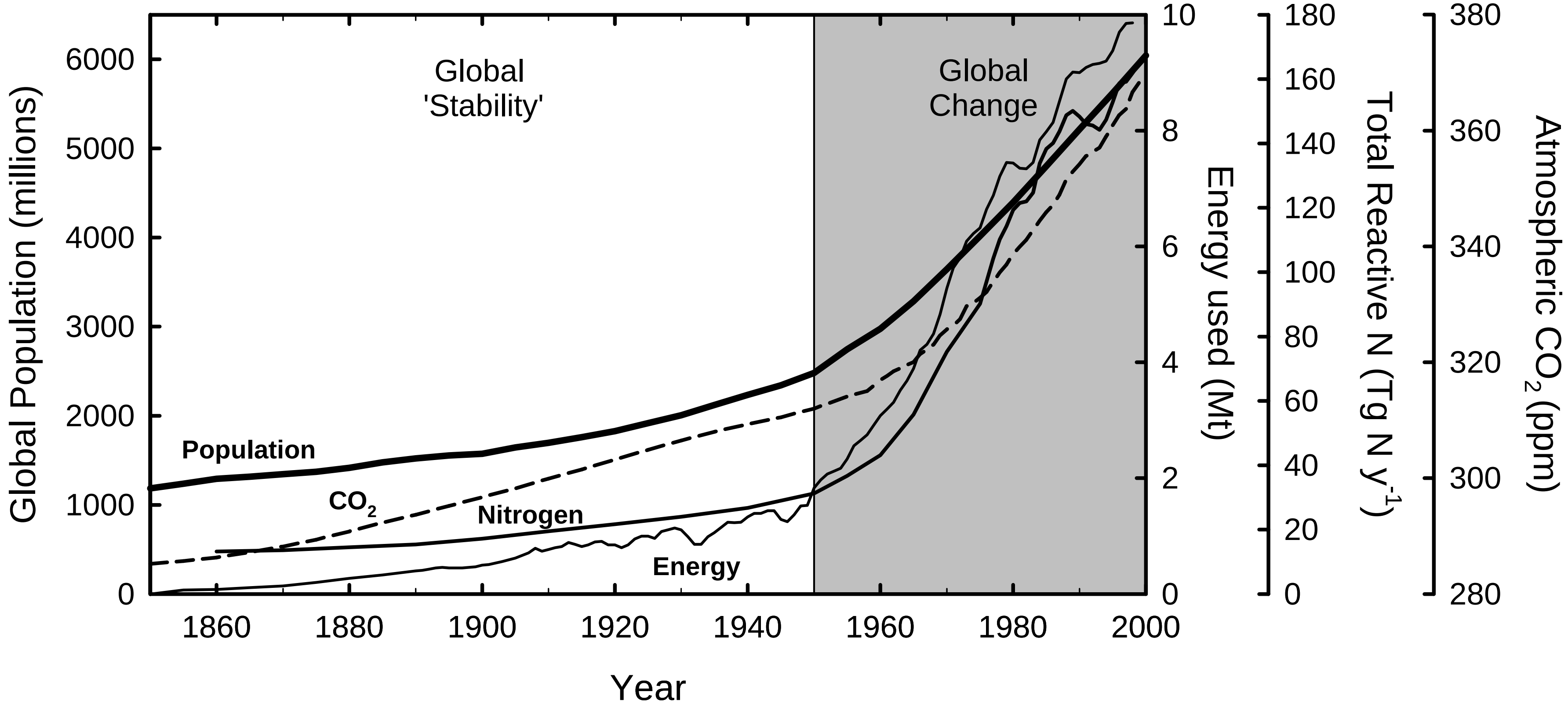
* *Department of Geosciences, University of Massachusetts, Amherst, Massachusetts 01003-5820, USA*
† *Laboratory of Tree Ring Research, University of Arizona, Tucson, Arizona 85721, USA*



"Hockey Stick"

Mann et al. 1998
Nature

Hockey Team

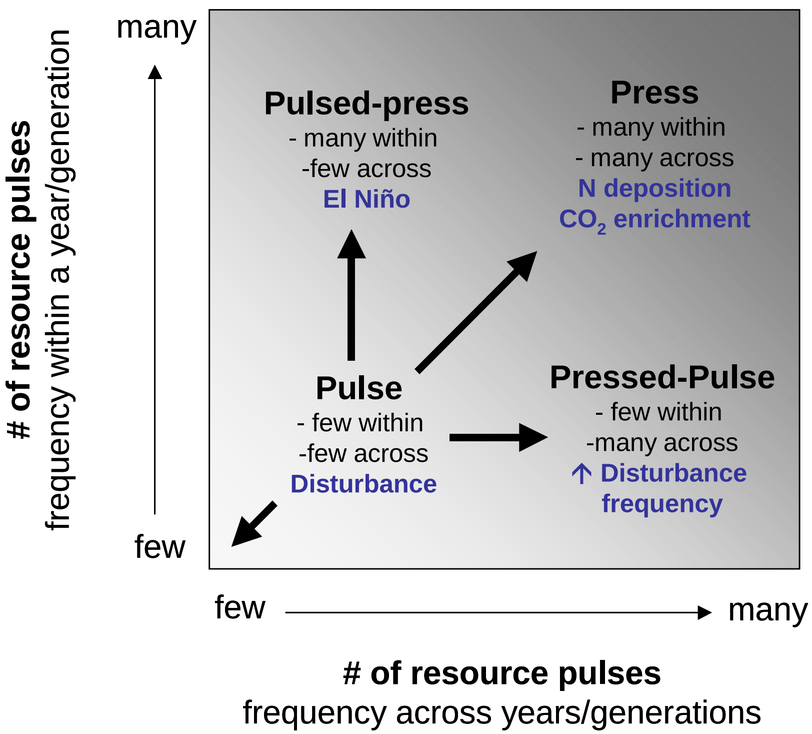


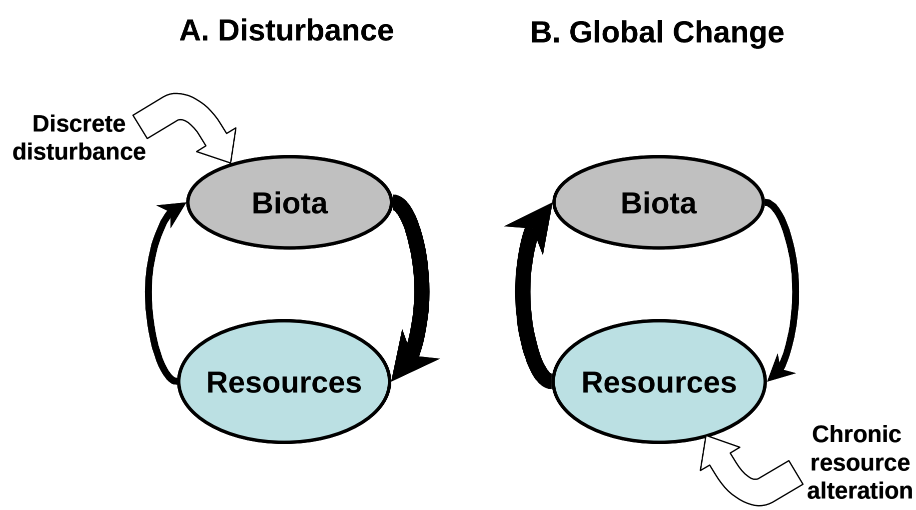
Global 'Stability'
Global Change
Population
CO_2
Nitrogen
Energy
Global Population (millions)
0
1000
2000
3000
4000
5000
6000
1860
1880
1900
1920
1940
1960
1980
2000
Year
Energy used (Mt)
0
2
4
6
8
10
Total Reactive N (Tg N y^{-1})
0
20
40
60
80
100
120
140
160
180
Atmospheric CO_2 (ppm)
280
300
320
340
360
380

Press factor – variable or driver that is applied continuously at rates ranging from low to high (e.g., atmospheric nitrogen deposition, elevated CO2). Includes changes in rates (increases, decreases) relative to some historical baseline.

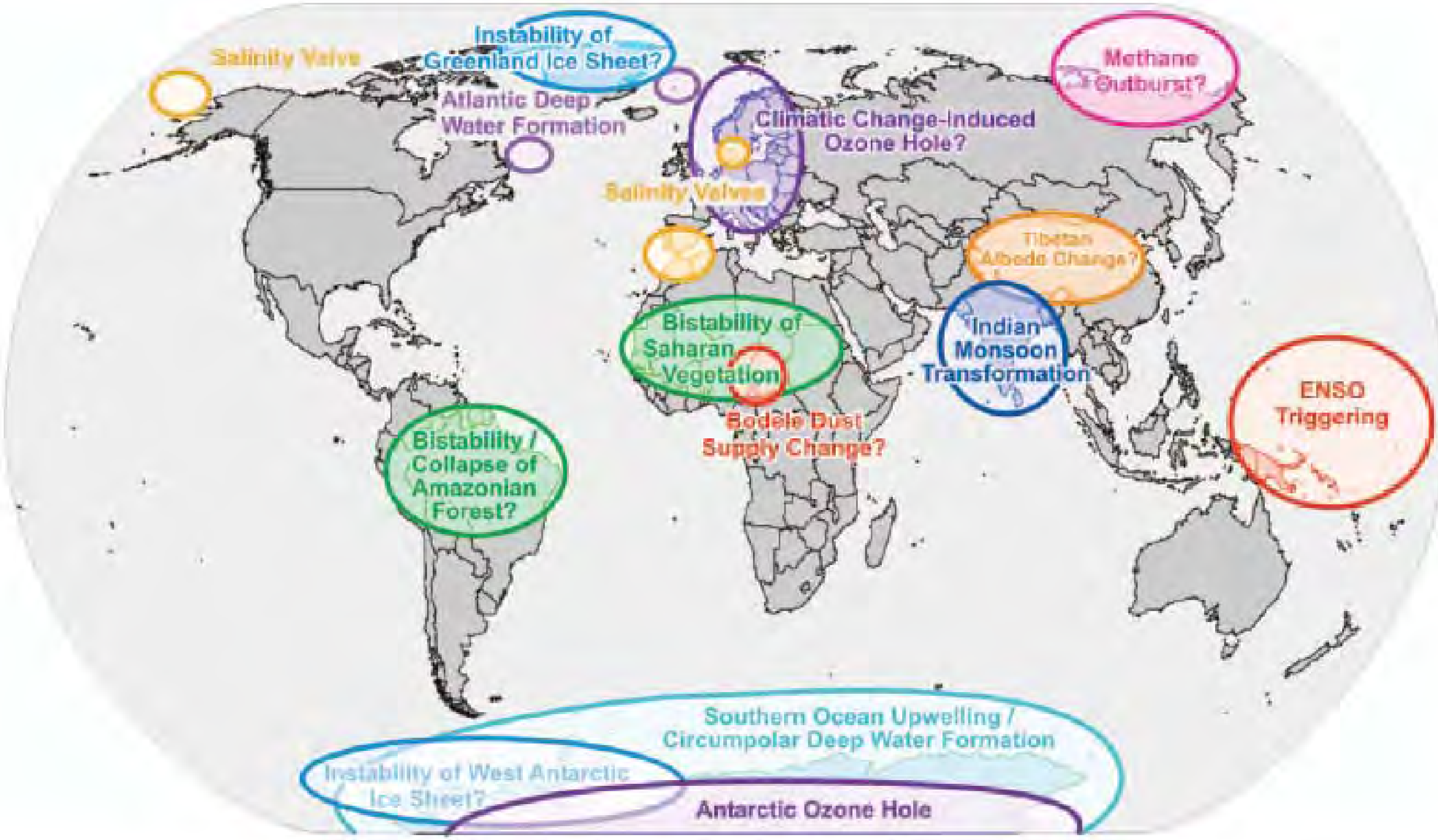
Pulse factor – variable or driver that is applied once or at periodic intervals (e.g., fire, extreme climatic events). Includes changes in the size, magnitude and frequency at which pulses occur.

Concept from Bender et al. 1984. Perturbation experiments in community ecology: Theory and practice. Ecology 65(1):1-13.





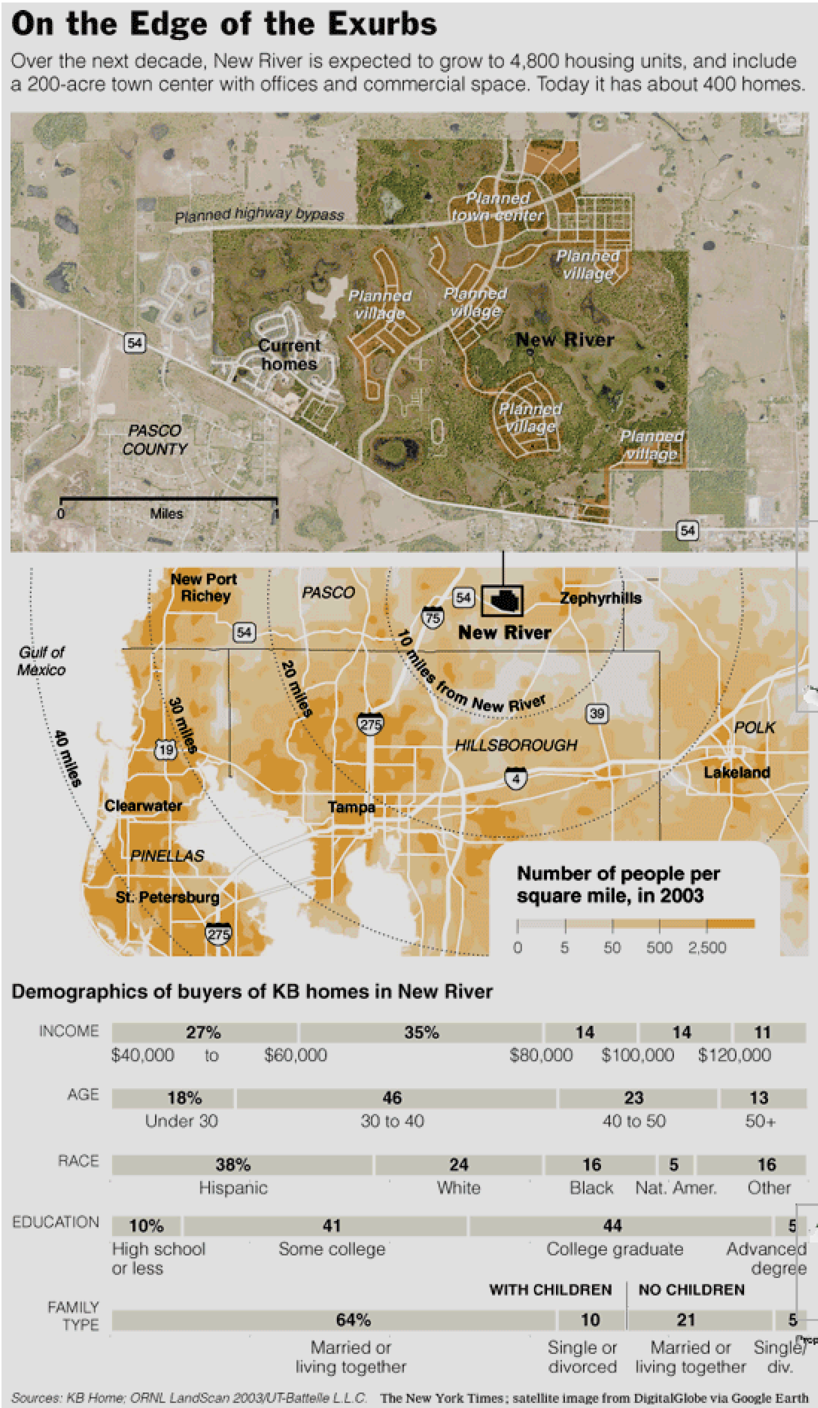
Global Change Tipping Points



Global Climate Change Tipping Points produced by climatologist Hans Joachim Schellnhuber and published in Nature (Kemp 2005).

Ecosystem Tipping Points

CHALLENGE: Identify causes and consequences of ecosystem tipping points in North America



Main drivers:

Human Population Change

Human Consumption

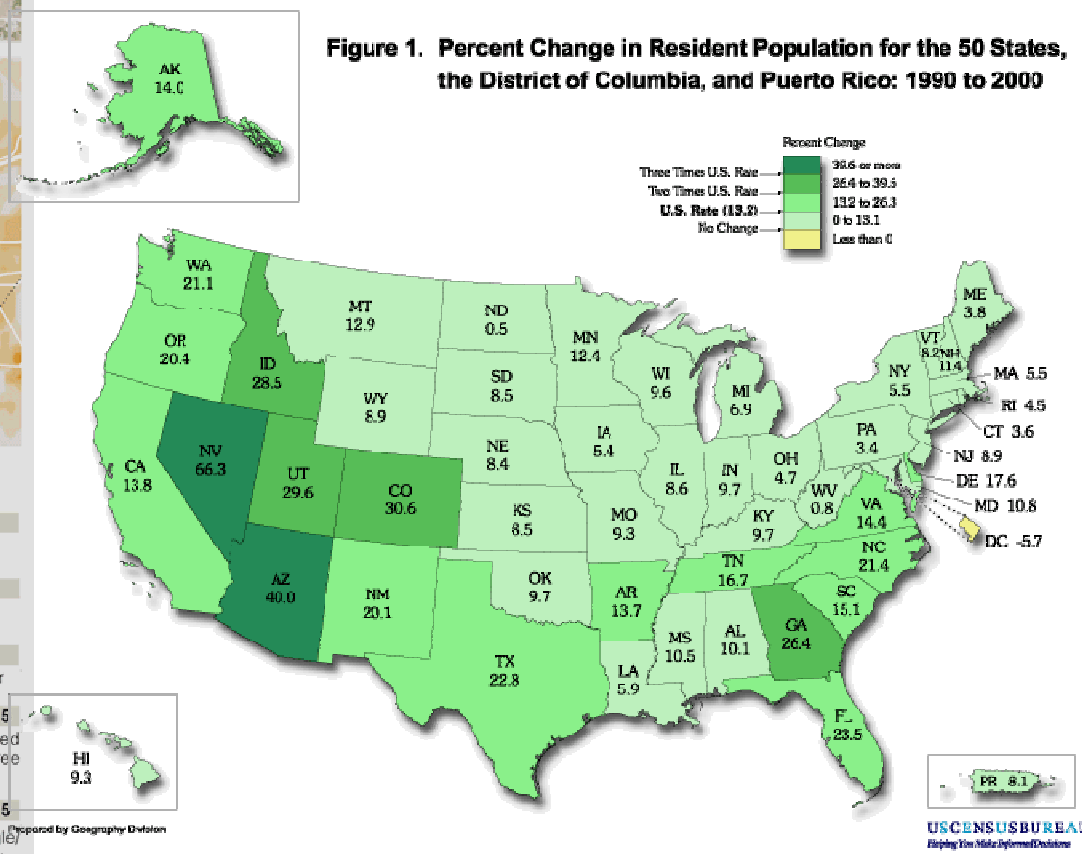
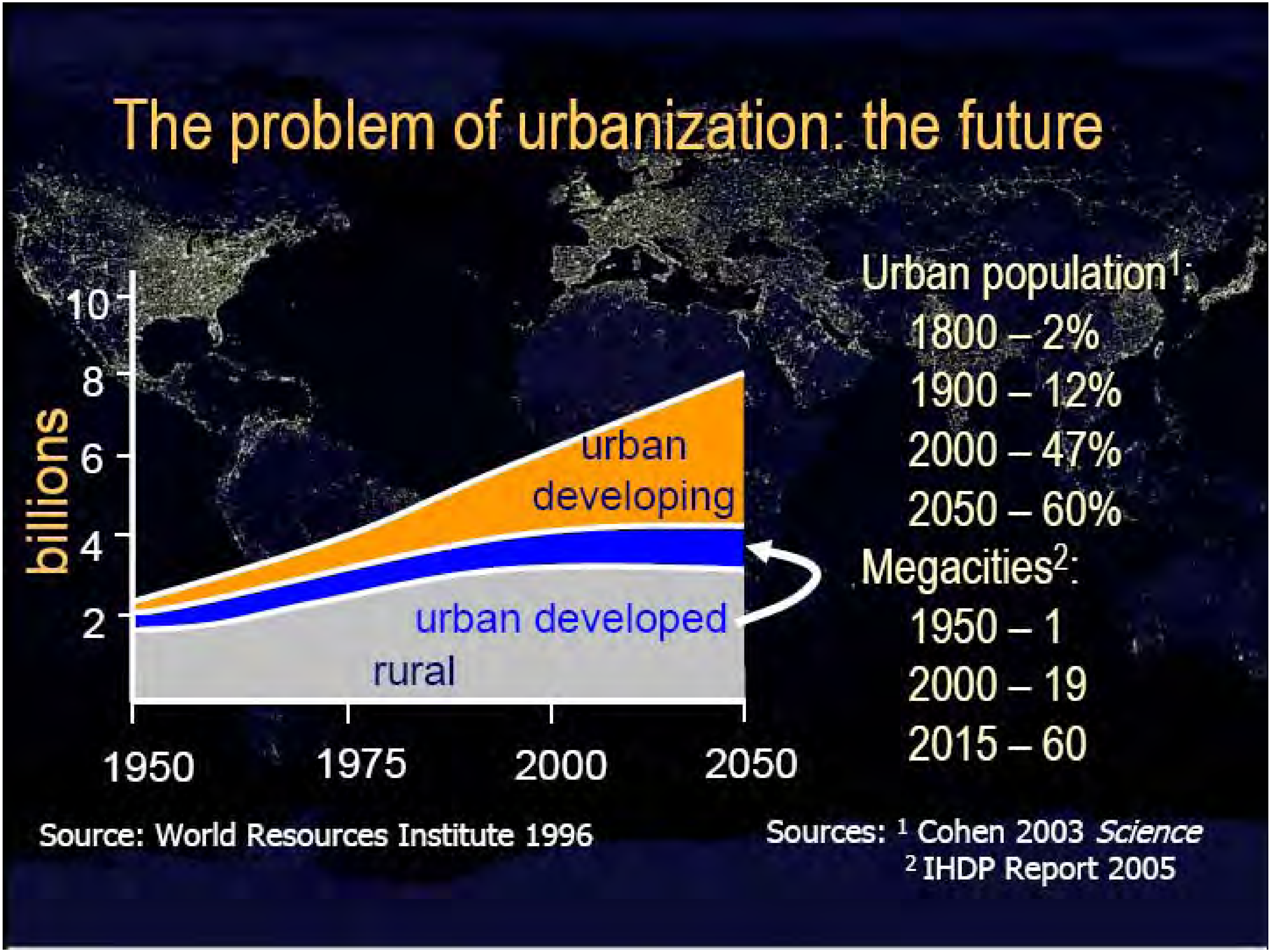
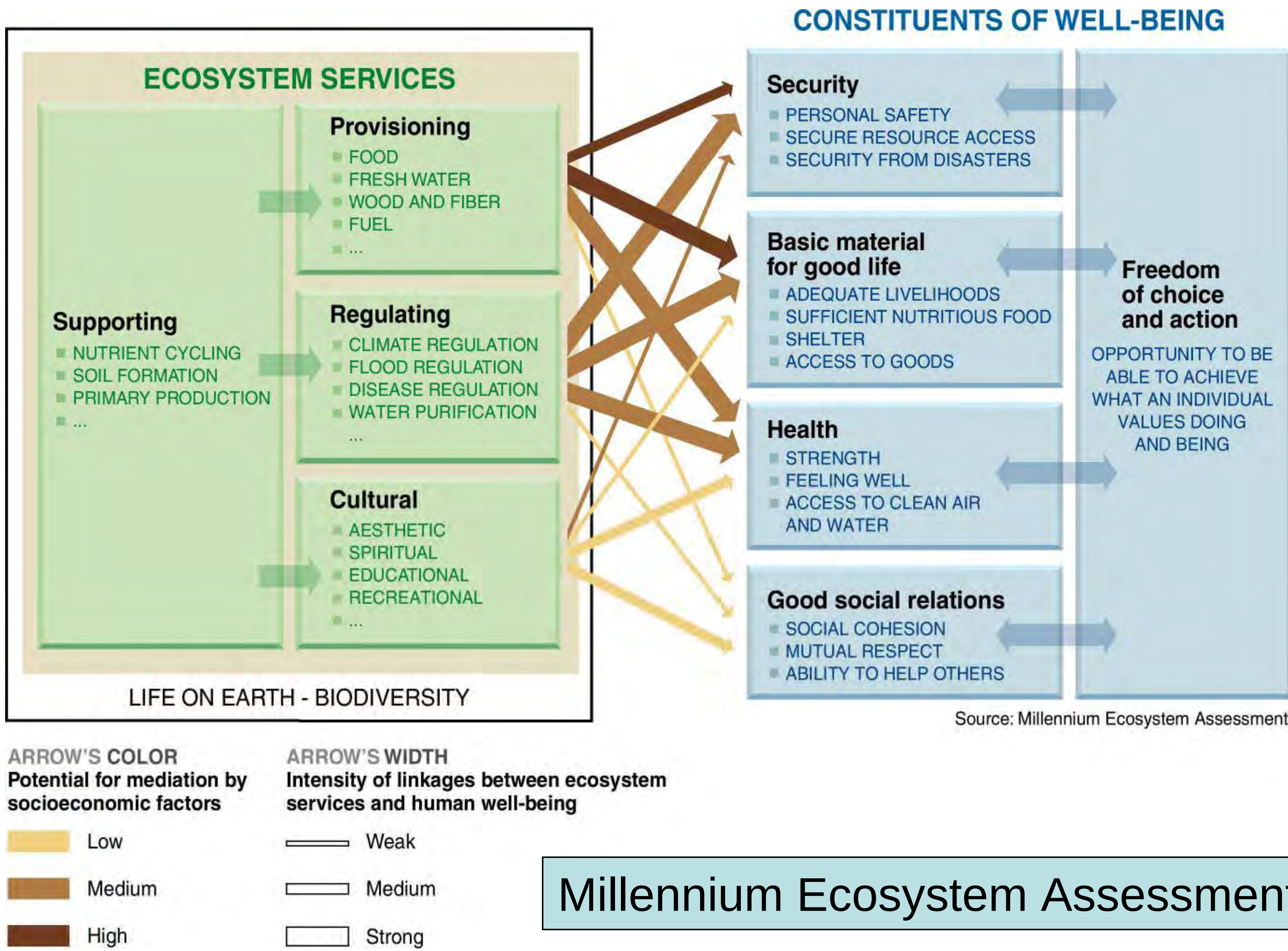


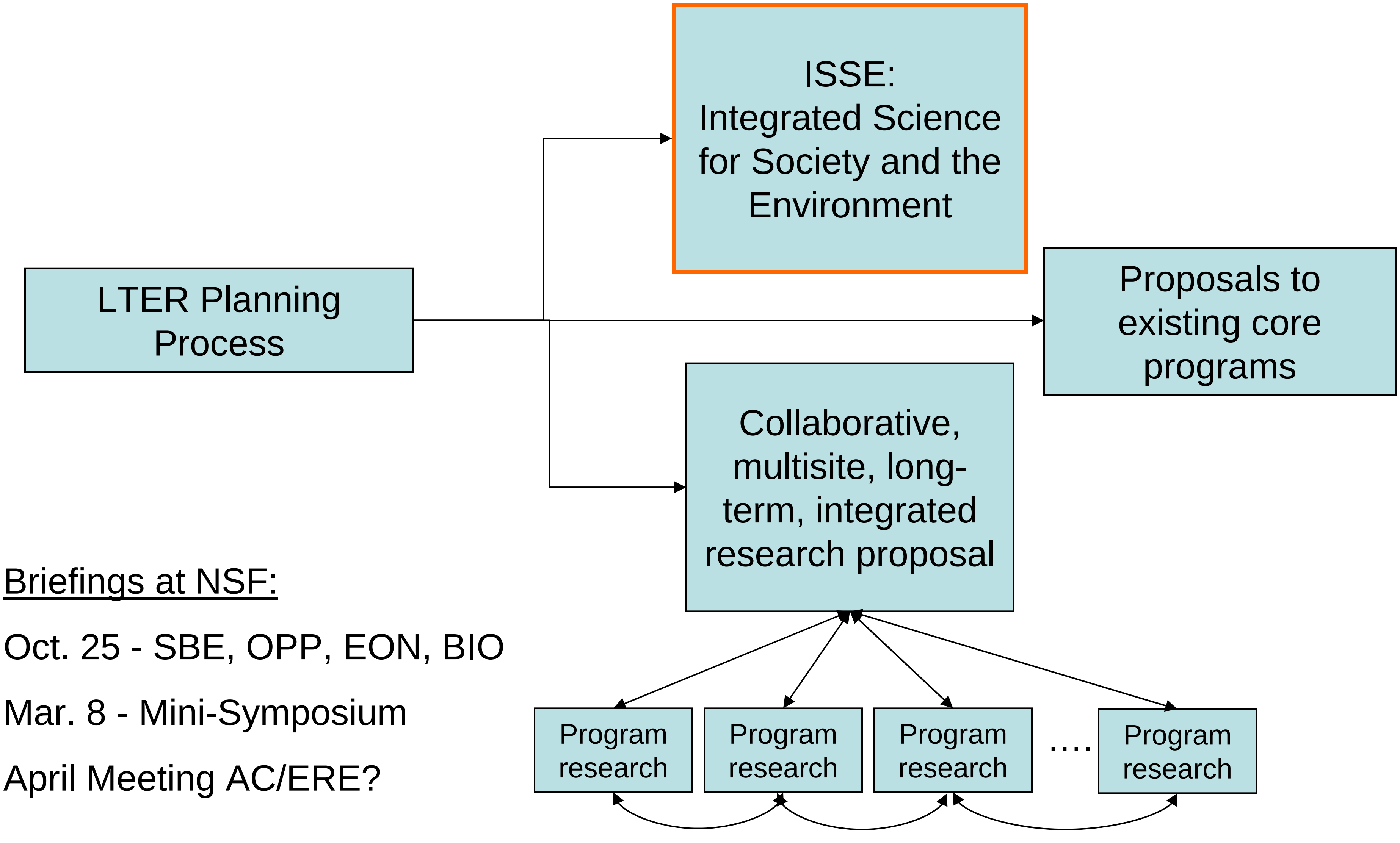
Figure 1. Percent Change in Resident Population for the 50 States, the District of Columbia, and Puerto Rico: 1990 to 2000


The problem of urbanization: the future
billions
10
8
6
4
2
urban
developing
urban developed
rural
1950
1975
2000
2050
Urban population[1]:
1800 – 2%
1900 – 12%
2000 – 47%
2050 – 60%
Megacities[2]:
1950 – 1
2000 – 19
2015 – 60
Source: World Resources Institute 1996
Sources: [1] Cohen 2003 *Science*
[2] IHDP Report 2005



Millennium Ecosystem Assessment

Outcomes of the Planning Process



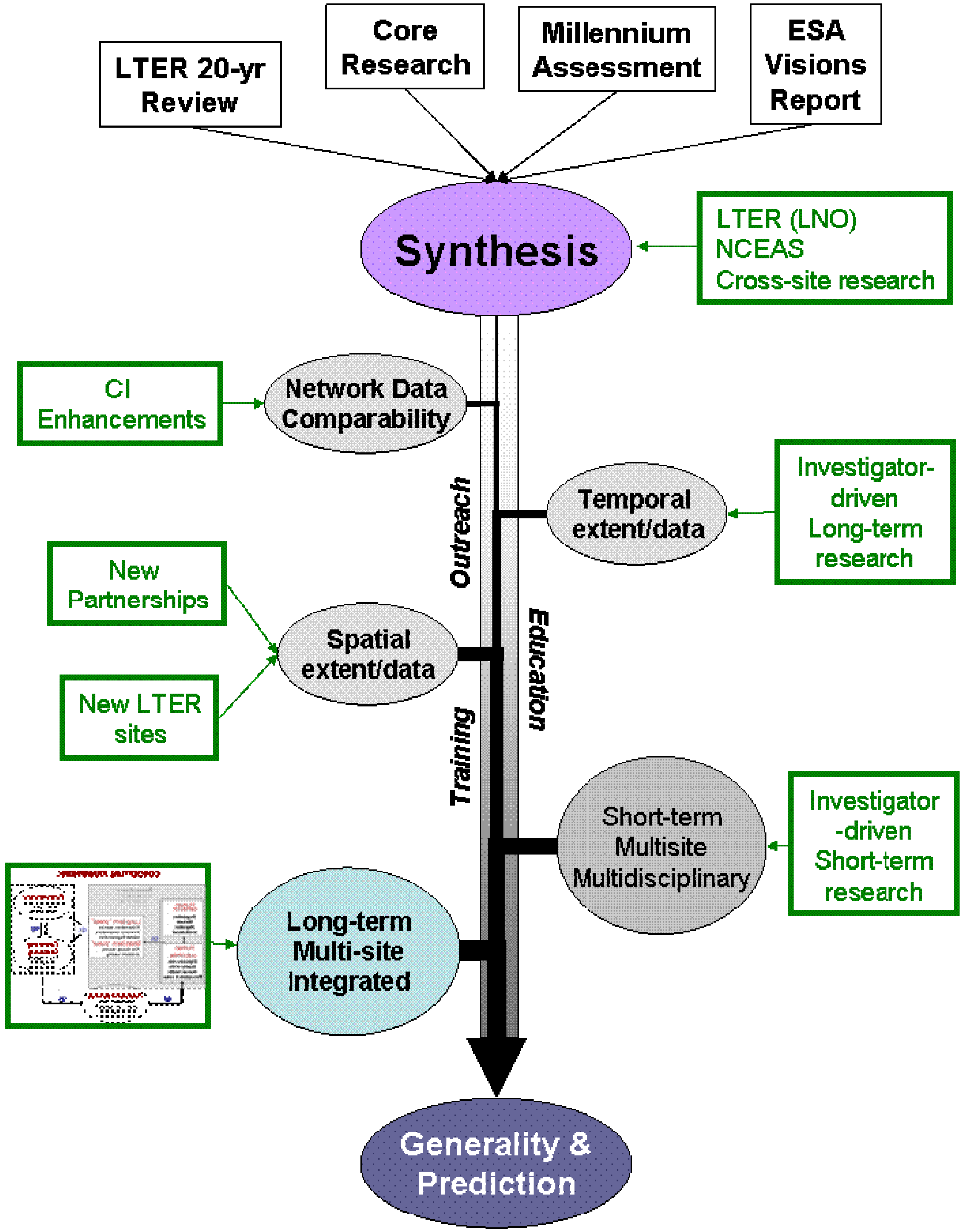
Briefings at NSF:

Oct. 25 - SBE, OPP, EON, BIO

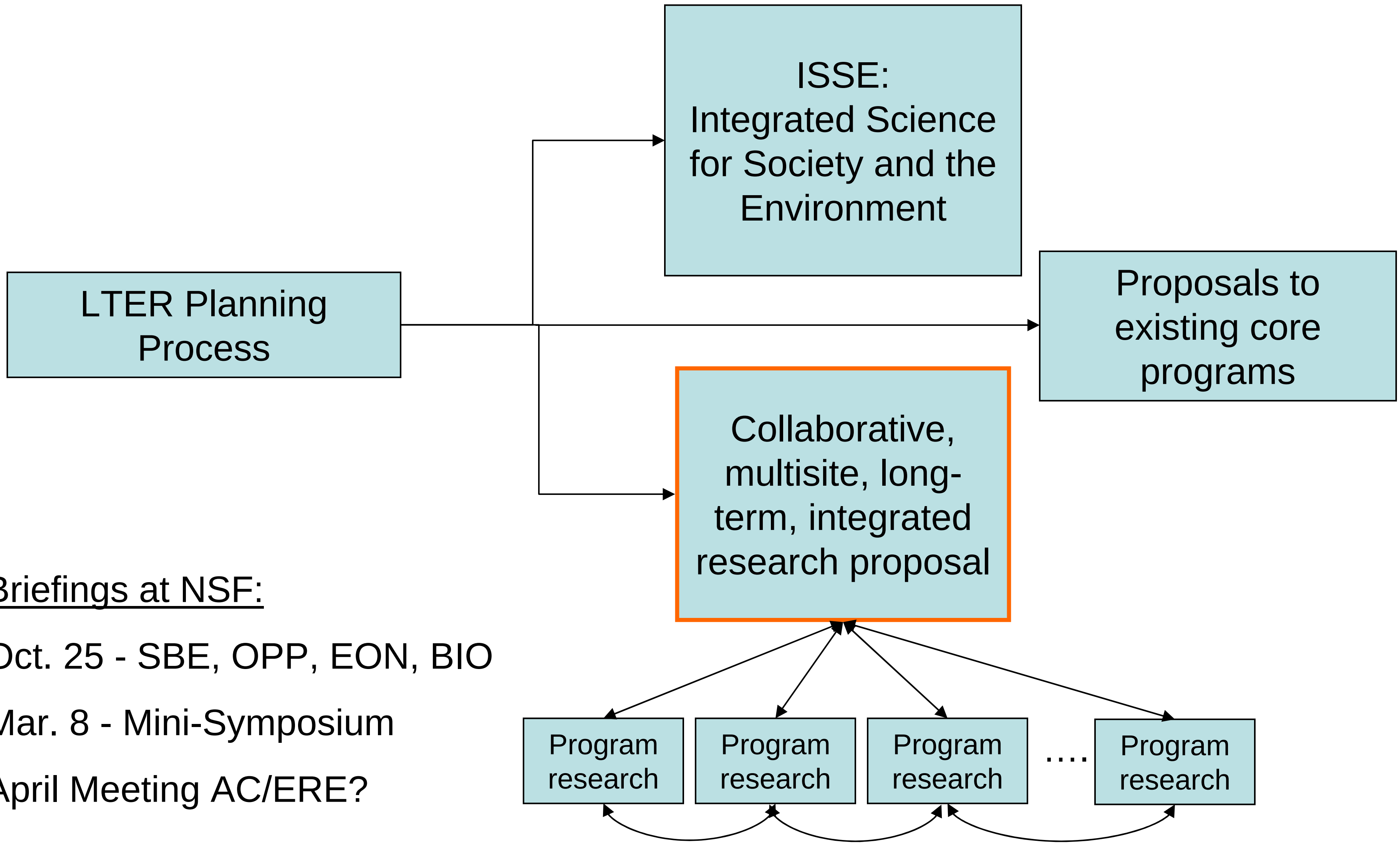
Mar. 8 - Mini-Symposium

April Meeting AC/ERE?

Integrated Science for Society and the Environment: a broadly based funding initiative



Outcomes of the Planning Process



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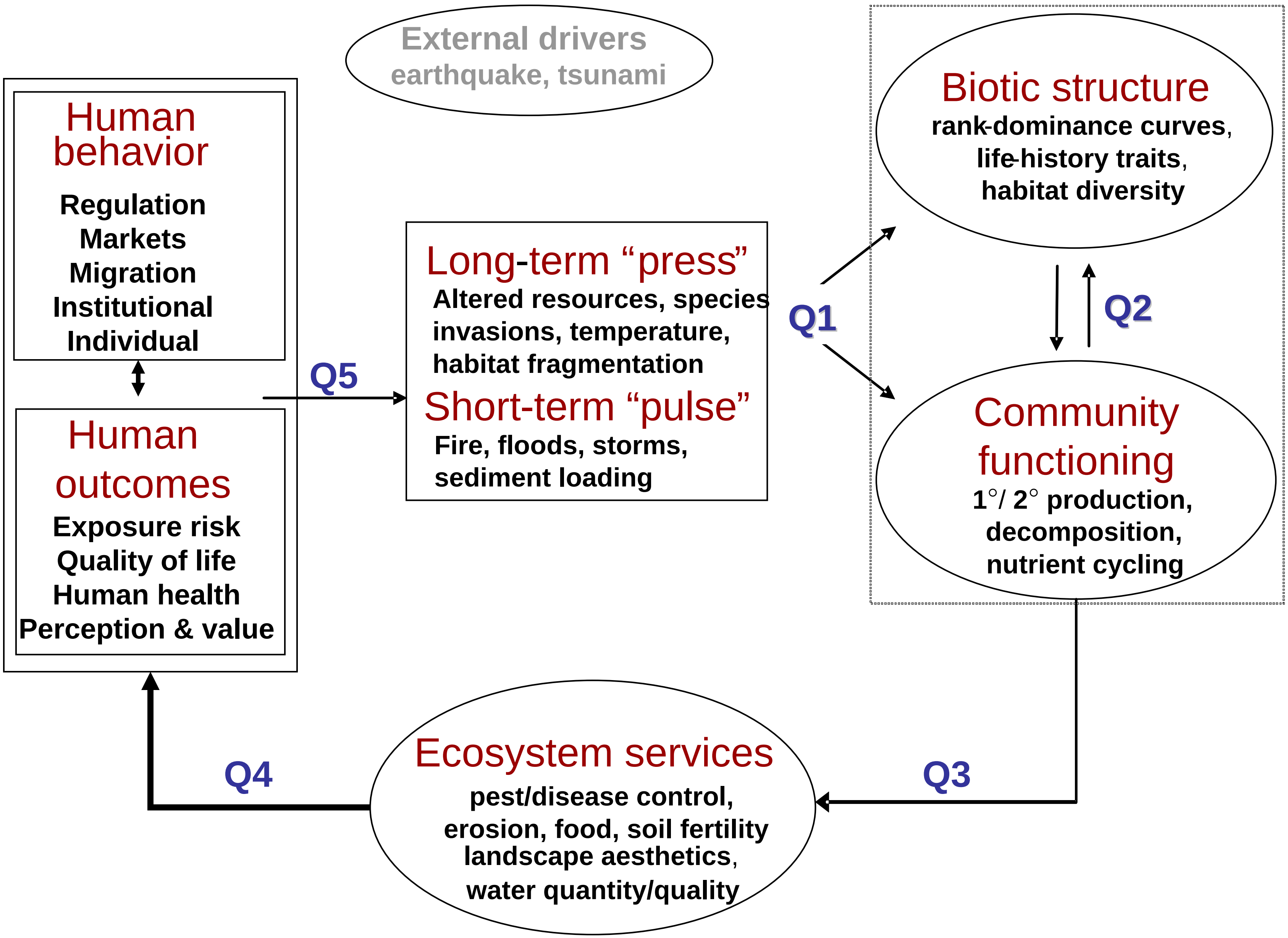
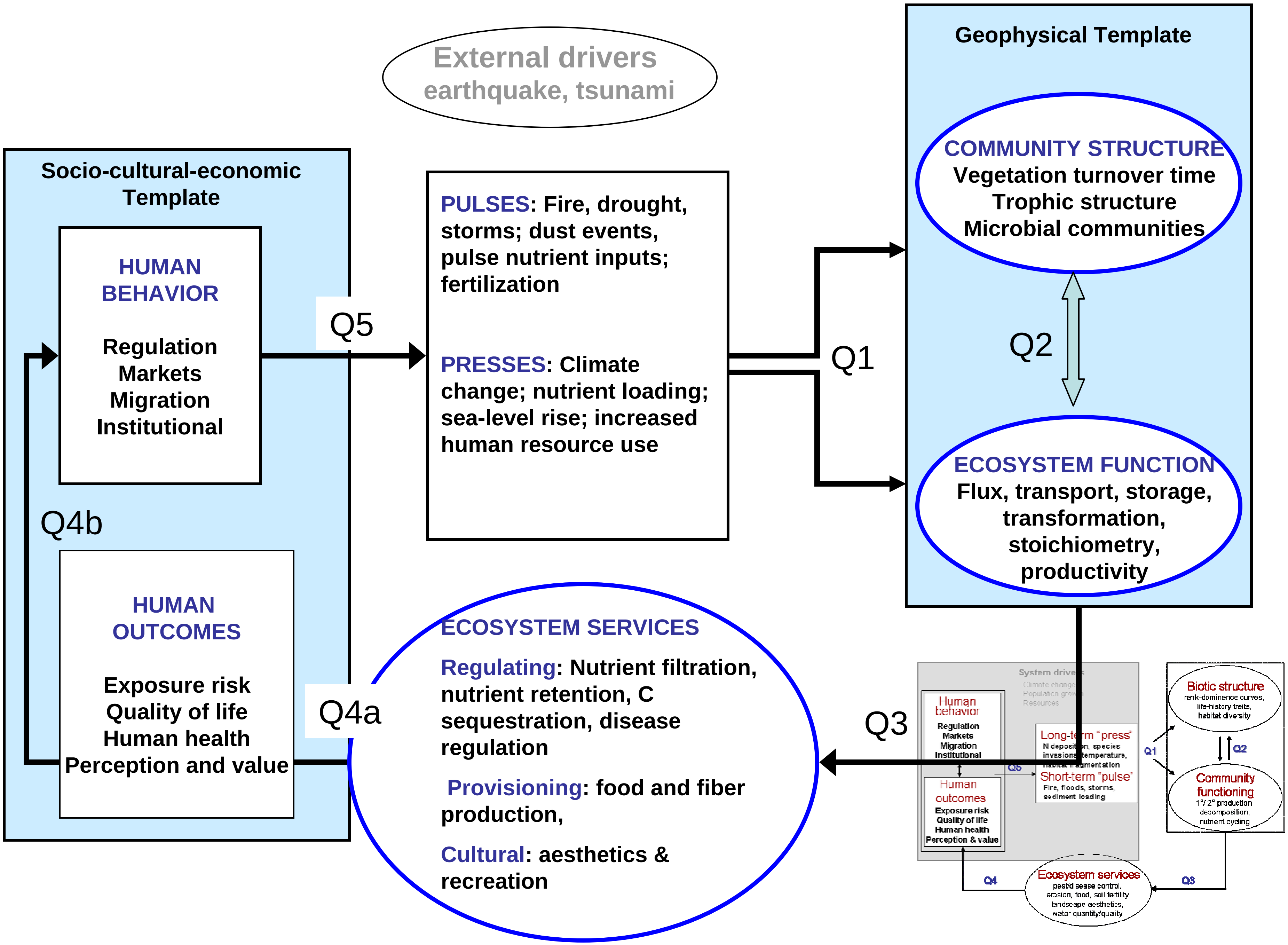
CONCEPTUAL FRAMEWORK

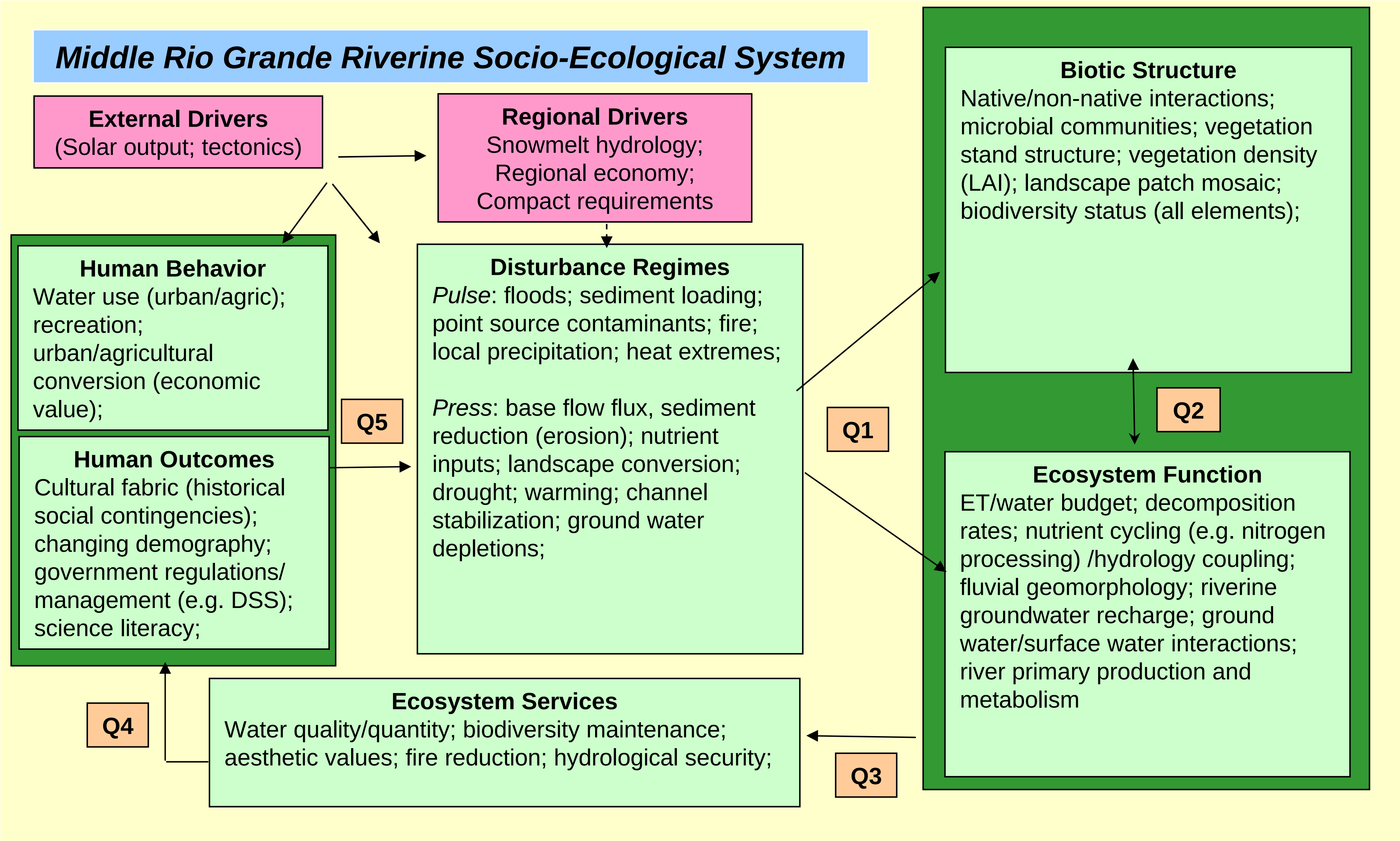


Framework Questions

- **Q1:** How do long-term press disturbances and short-term pulse disturbances ***interact*** to alter ecosystem structure and function?
- **Q2:** How can biotic structure be both a ***cause and consequence*** of ecological fluxes of energy & matter?
- **Q3:** How do altered ecosystem dynamics affect ecosystem services?
- **Q4:** How do changes in vital ecosystem services ***feed back*** to alter human behavior?
- **Q5:** Which human actions influence the frequency, magnitude, or form of press and pulse disturbance regimes across ecosystems, and how do these change across ecosystem types?

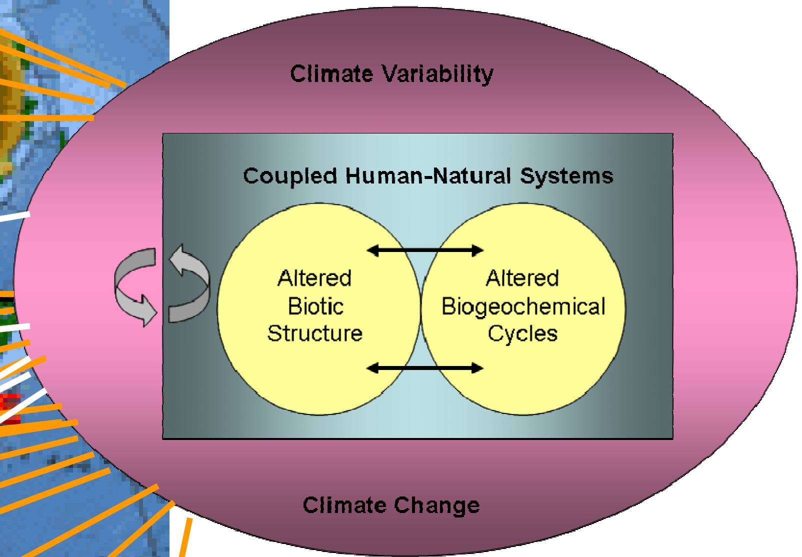


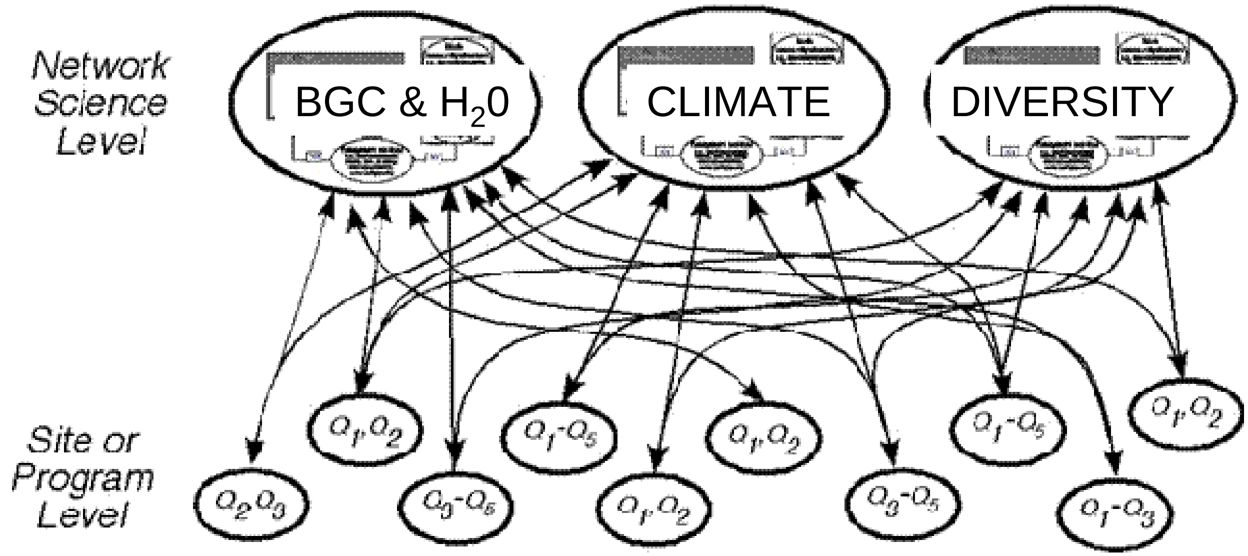
External drivers
earthquake, tsunami
Socio-cultural-economic Template
HUMAN BEHAVIOR
Regulation
Markets
Migration
Institutional
Q5
PULSES: Fire, drought, storms; dust events, pulse nutrient inputs; fertilization
PRESSES: Climate change; nutrient loading; sea-level rise; increased human resource use
Q1
Geophysical Template
COMMUNITY STRUCTURE
Vegetation turnover time
Trophic structure
Microbial communities
Q2
ECOSYSTEM FUNCTION
Flux, transport, storage, transformation, stoichiometry, productivity
Q4b
HUMAN OUTCOMES
Exposure risk
Quality of life
Human health
Perception and value
Q4a
ECOSYSTEM SERVICES
Regulating: Nutrient filtration, nutrient retention, C sequestration, disease regulation
Provisioning: food and fiber production,
Cultural: aesthetics & recreation
Q3
Human behavior
Regulation
Markets
Migration
Institutional
Human outcomes
Exposure risk
Quality of life
Human health
Perception & value
Short-term "pulse"
Fire, floods, storms, sediment loading
Biotic structure
rank-dominance curves, life-history traits, habitat diversity
Q1
Q2
Community functioning
decomposition, nutrient cycling
Ecosystem services
pest/disease control, erosion, food, soil fertility, landscape aesthetics, water quantity/quality
Q4
Q3



Q1: How do long-term flow regulation and short-term flow variability (floods, droughts, and river drying) interact to alter the Rio Grande riverine corridor?
Q2: How are feedbacks between water availability, decomposition, nutrient cycling, and fluvial geomorphology (ecosystem processes) and vegetation structure, patch dynamics, biodiversity, and microbial communities (biotic structure) affected by flow regulation and flow variability?
Q3: How do changing river and riparian ecosystems affect the regional water budget, channel characteristics, water quality, fire regime, and biodiversity?
Q4: How does the human population along the Middle Rio Grande respond to decreased water availability and quality, increased fire frequency, biodiversity losses, non-native species, and competing water demands?
Q5: How do humans decisions and actions affect flow characteristics of the managed riverine corridor and responses to floods, fire, drought, and drying?

US Long-term Ecological Research Network (LTER)





Resource and Amenity-Based Migration and Land Use Dynamics

1. human settlement and development patterns in relation to natural resources and aesthetic and biodiversity amenities.

2. evolution of human attitudes and values as both ecosystems and human communities change over time.

3. experimental market ecology to examine institutional structures that affect ecosystems over time.

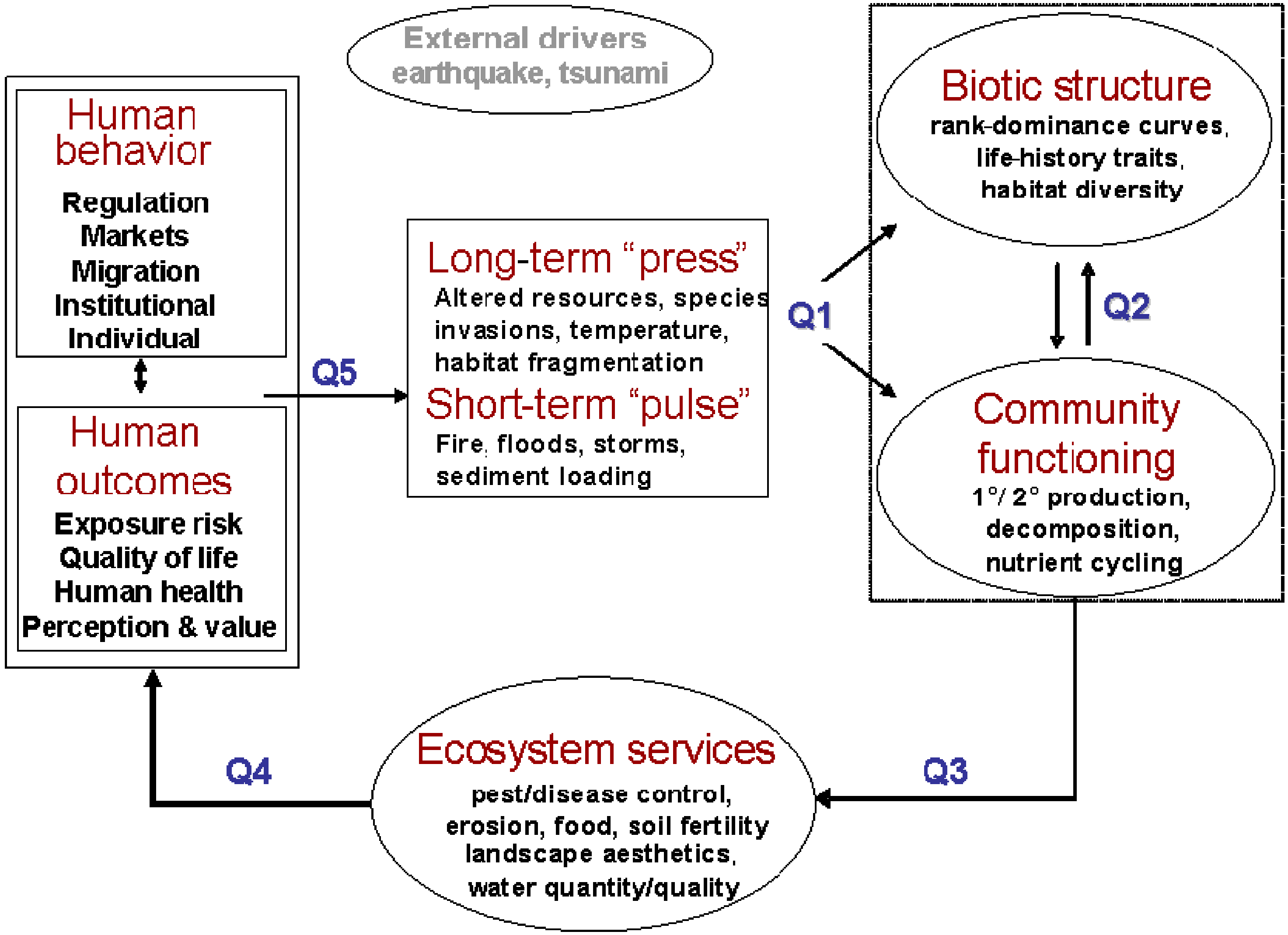
Overarching Question:

How do changing climate, biogeochemical cycles, and biotic structure affect ecosystem services and dynamics with feedbacks to human behavior?

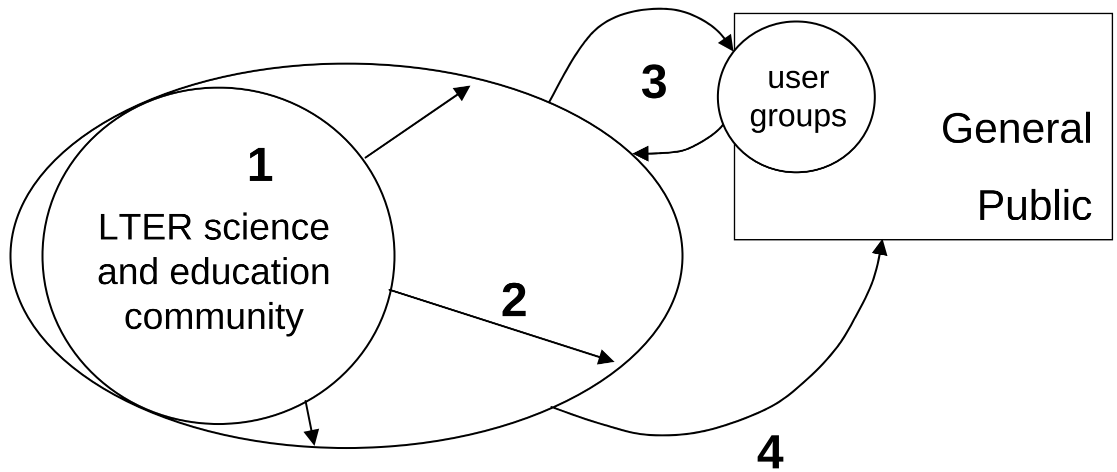
Important attributes of this research:

- Multivariate
  - Expansion beyond univariate-based understanding to studying interactive effects of multiple stressors: we can model and manipulate these at multiple sites over long time frames and identify commonalities in ecosystem responses.
- Interdisciplinary
  - People are typically viewed as drivers of change, but only infrequently as response variables - we will develop reciprocal models of causality that explicitly incorporate human behavior as both a cause and consequence of ecosystem change.
- Cross-site and cross-habitat
  - multiple sites will allow us to identify the most important underlying processes through a combination of observation, modeling and experimentation

Integrating Research and Education



Addressing these questions will require a new interdisciplinary research approach. This new approach can be effective only if its implications are understood by citizens, educators, and policymakers.



1. Support the future vitality of the LTER research and education program by assuring it has the human capital needed for success.

2. Expand our community to reflect the diversity of our society and to include a broader range of skills, expertise, and disciplines.

3. Communicate with and bring user perspectives into our community.

4. Improve environmental literacy through formal and informal education systems.

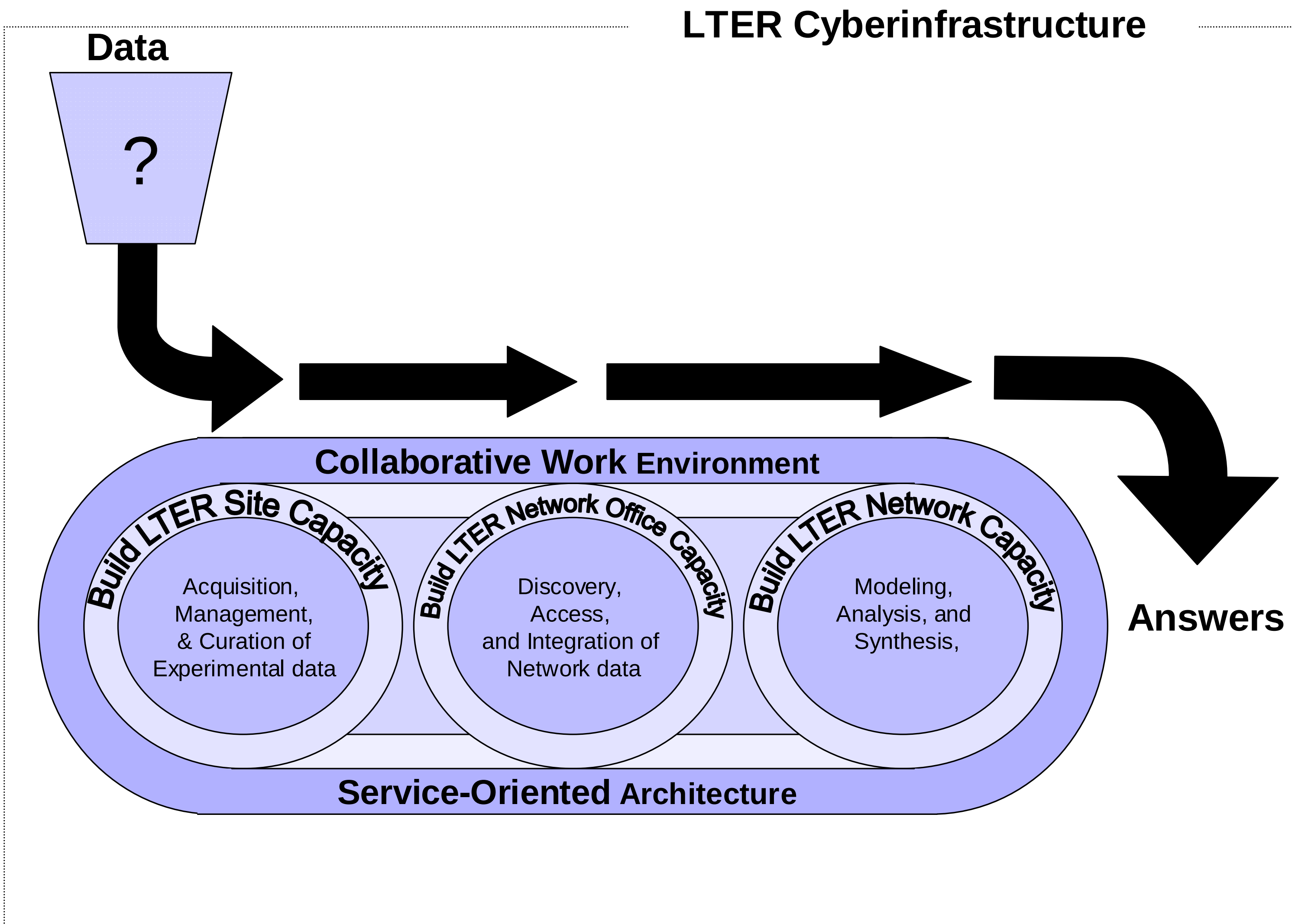
Cyberinfrastructure Planning within the LTER Network Planning Grant

Barbara Benson
James Brunt
Don Henshaw
John Porter
John Vande Castle

Goals: Cyberinfrastructure (CI) Planning

- engage computer and information scientists to address the new integrative challenges presented by the expanding spatial, temporal and interdisciplinary scope of LTER network science
- provide cross-fertilization between LTER CI planning and that of other concurrent efforts within and beyond the ecological science community

LTER Cyberinfrastructure Strategic Plan



http://intranet.lternet.edu/planning/files/5/53/CI_Strategic_Plan_2.3.pdf

September 15, 2006

Integrating CI into socio-ecological research requires a program of workforce training and education

RECENT STEPS:

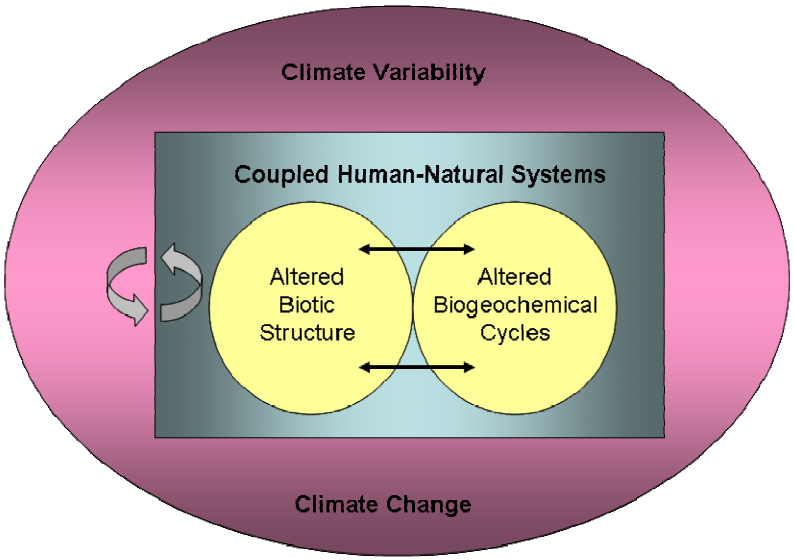
•Program Representatives meeting in Aug 2006
  presented site ideas
  began integration of multi-site research

•Submit revised initiatives document for comment

•Society Endorsement of ISSE

•All Scientist Meeting
  flesh out proposal
  multi-site integration, phase II
  Begin transition to LTER SC

•STFAC meeting Oct 2006
•SC Meeting May 2007
•Proposal July 2007



GOAL during the All Scientists Meeting: Continue to develop detailed multi-site research plan

Program Reps meeting:

- Feedback from sites
- Coordinate activities during ASM

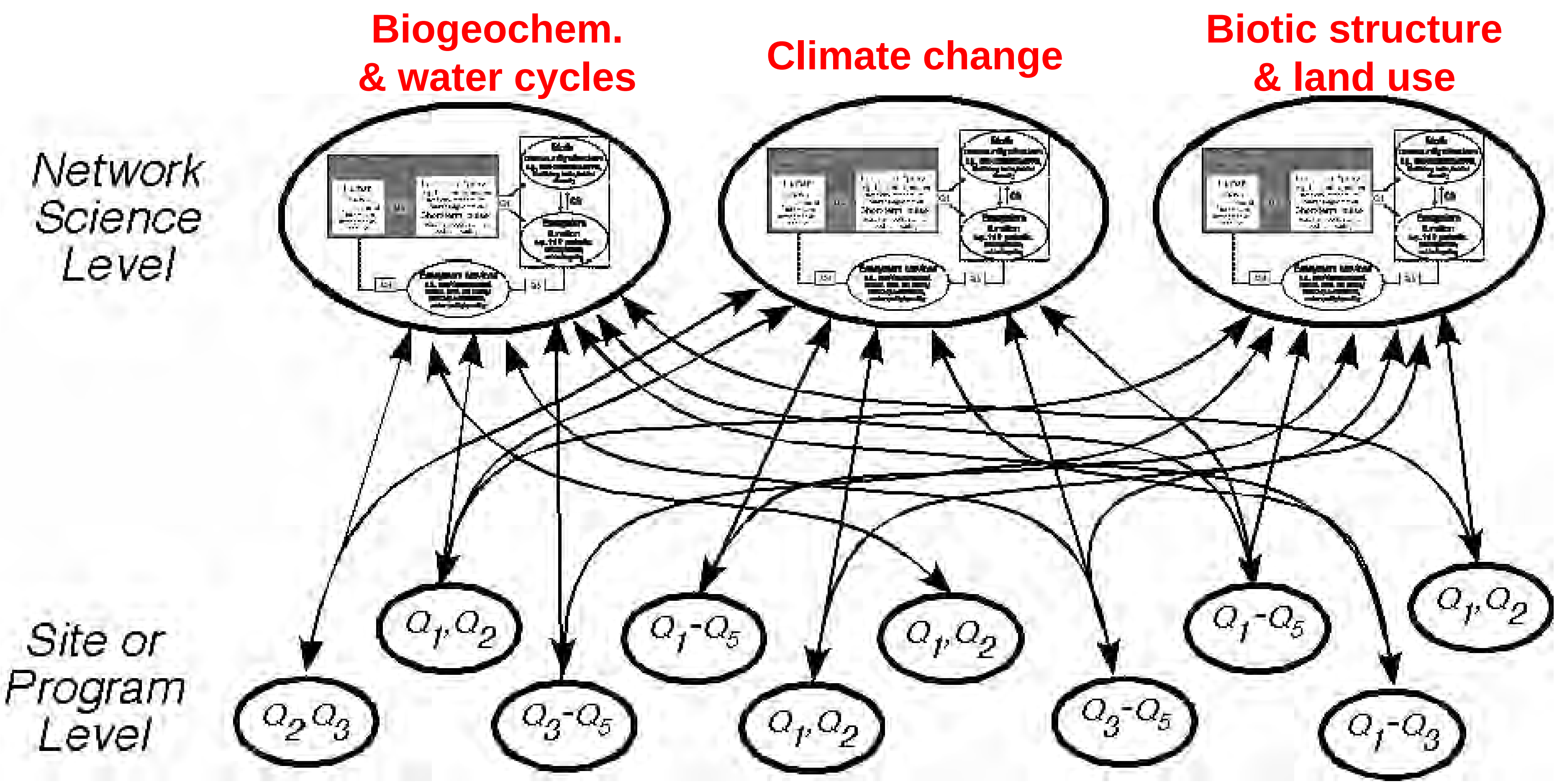
“Topical Question” Workshops: Bring your ideas

- Social science (Thursday 1:30-3:00PM)
- Altered biogeochemical and water cycles (Friday 9:30 AM -12:00 PM)
- Climate change and variability (Friday 3:30 - 5:30 PM)
- Altered biotic structure (Saturday 9:30 AM -12:00 PM)

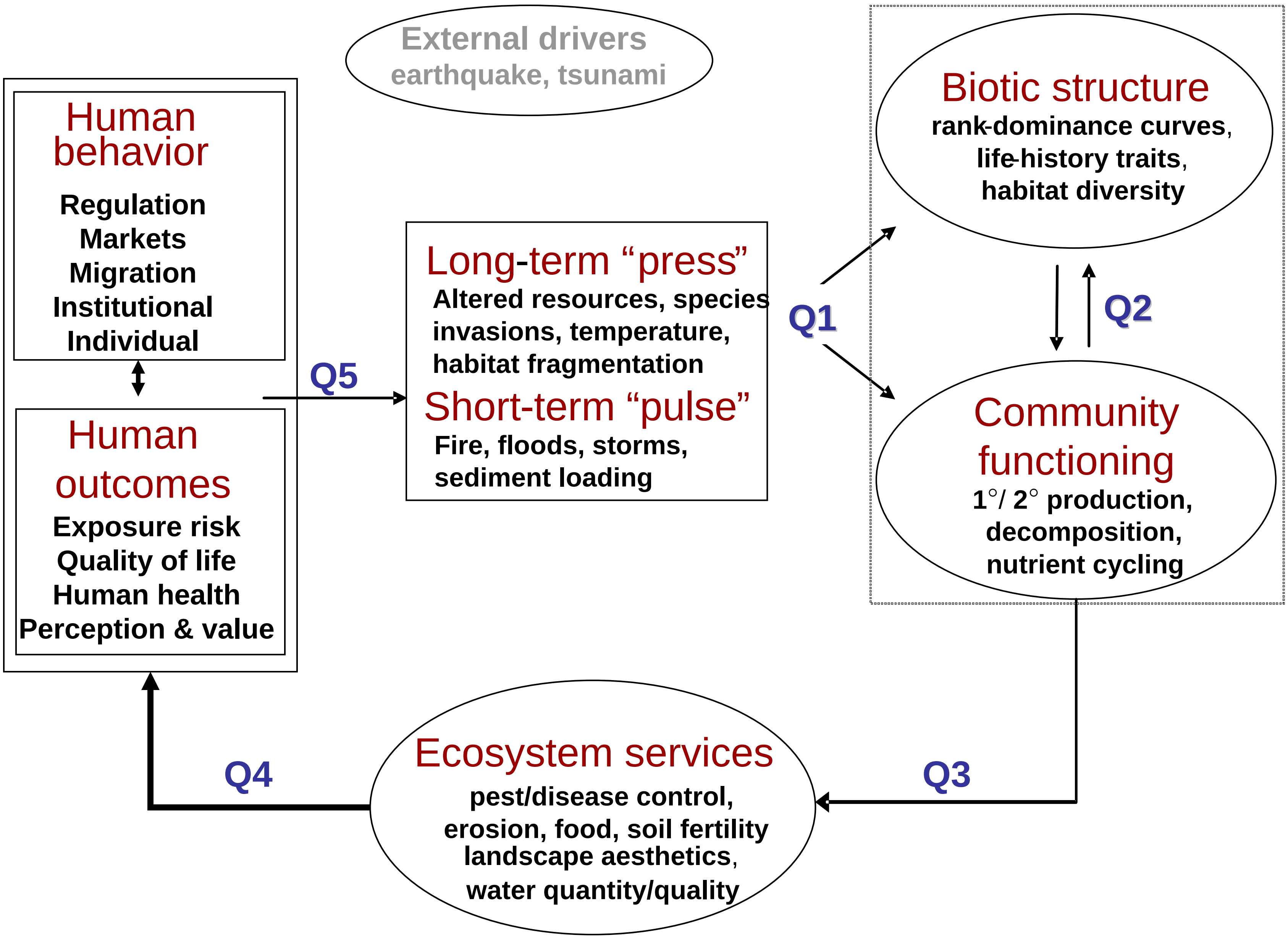
Synthesis Workshops:

- Altered biogeochemical and water cycles synthesis (Friday 3:30 – 5:30)
- Climate change and variability (Saturday 9:30 AM – 12:00 PM)
- Altered biotic structure (Saturday 2:00 – 5:30 PM)

Moving to the next hierarchical level of science, education, CI, and social influence



CONCEPTUAL FRAMEWORK



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Alluvial Bar Morphology and Dynamics in the Middle Rio Grande: Application to Habitat Restoration for the Rio Grande Silvery Minnow

Mike Harvey

Mussetter Engineering, Inc.

WORK CONDUCTED FOR:

- **New Mexico Interstate Stream Commission**
- **Middle Rio Grande ESA Collaborative Program**

WHAT IS A BAR ?

?

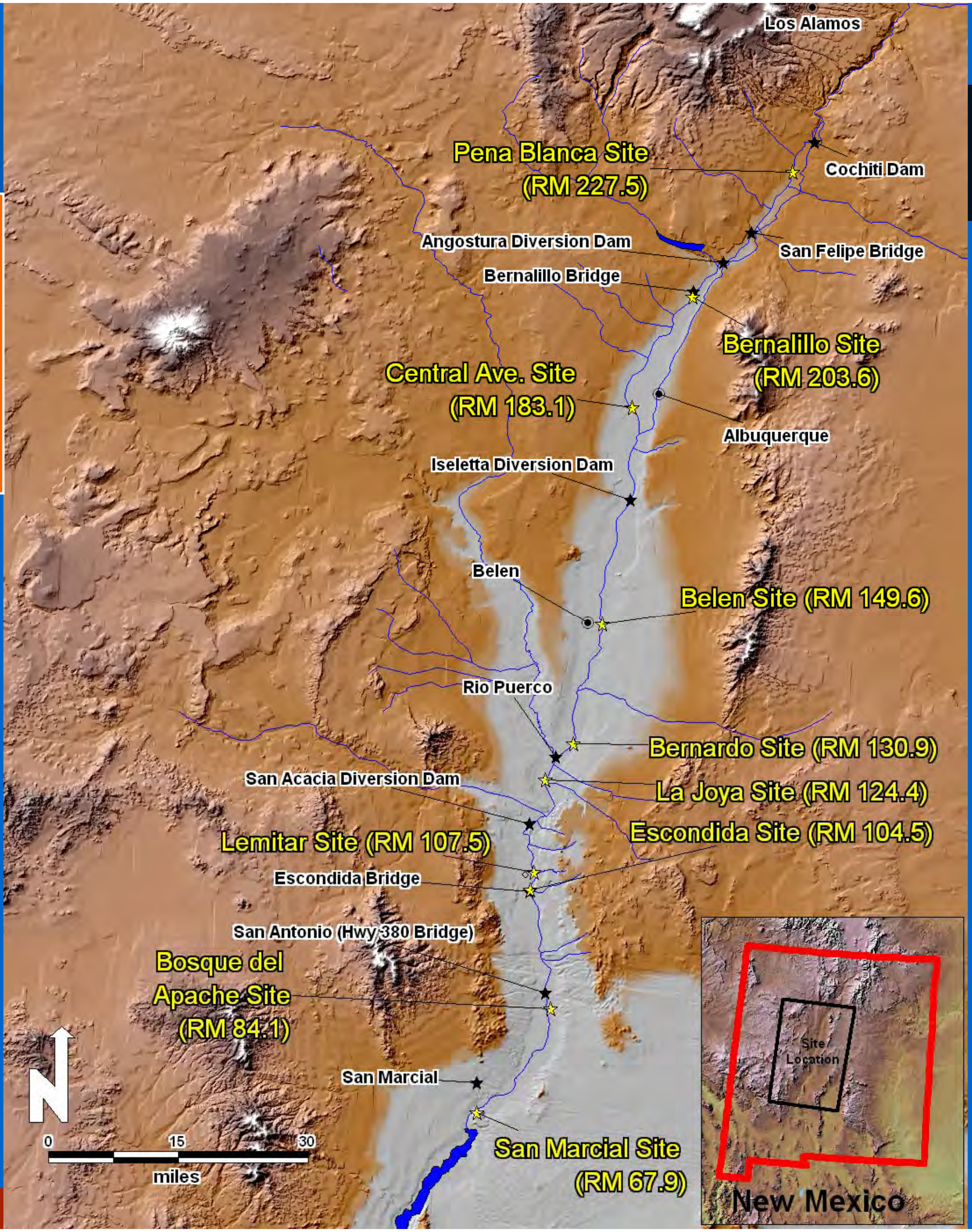
"Discrete alluvial feature formed by deposition and modified by erosion"

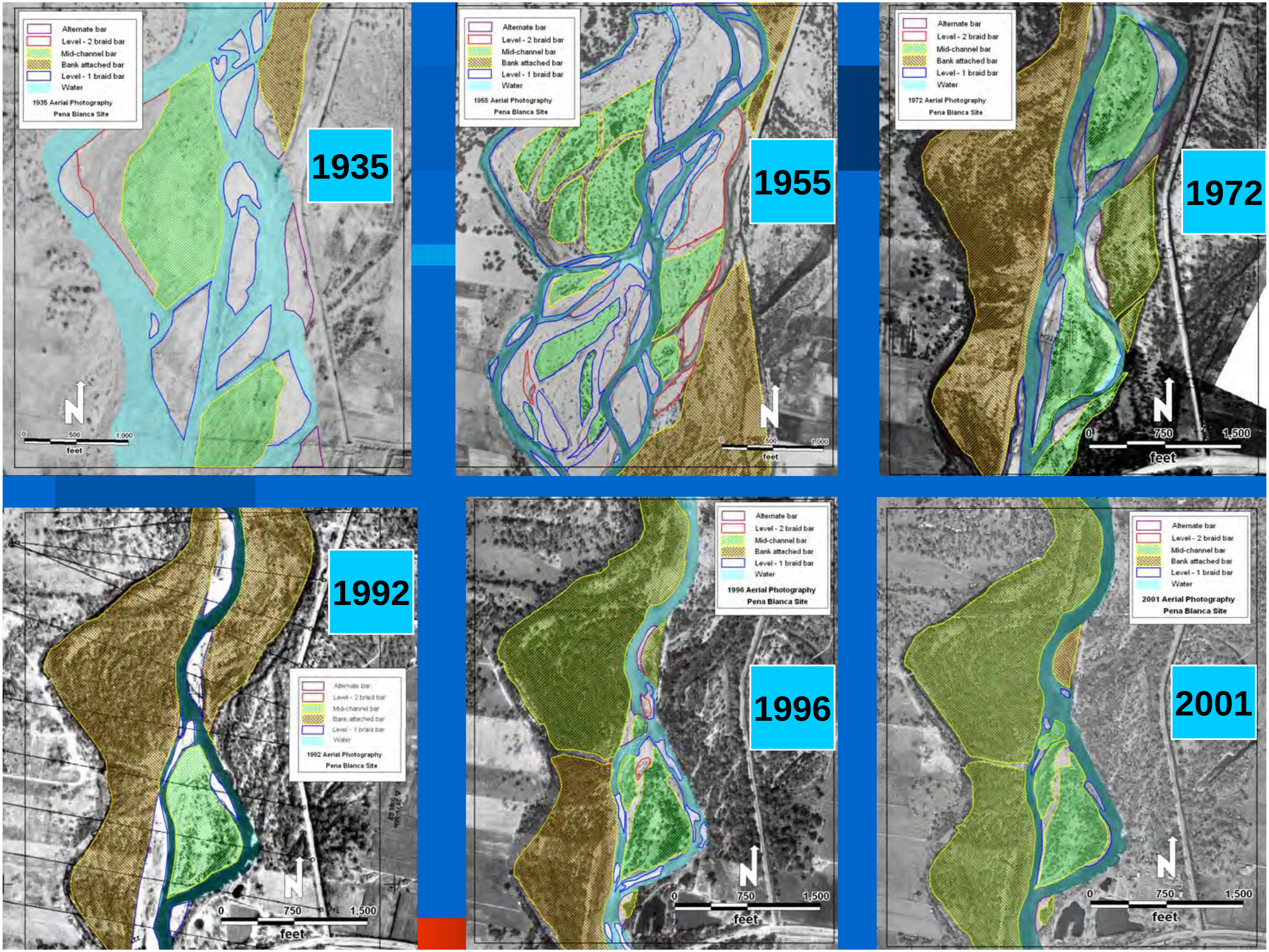
– Can be mid-channel or bank-attached
– Can be subaerial or subaqueous
– Can be stationary or mobile
– Can be vegetated or unvegetated

PROJECT OBJECTIVES

- Evaluate bar changes over time in response to changes in flow, sediment supply and channel morphology
- Develop a bar classification
- Relate fluvial processes to bar types
- Apply results to river/habitat restoration

9 STUDY SITES





Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
1935 Aerial Photography
Pena Blanca Site
1935
0 500 1,000
feet
Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
1955 Aerial Photography
Pena Blanca Site
1955
0 500 1,000
feet
Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
1972 Aerial Photography
Pena Blanca Site
1972
0 750 1,500
feet
1992
Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
1992 Aerial Photography
Pena Blanca Site
0 750 1,500
feet
Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
1996 Aerial Photography
Pena Blanca Site
1996
0 750 1,500
feet
Alternate bar
Level - 2 braid bar
Mid-channel bar
Bank attached bar
Level - 1 braid bar
Water
2001 Aerial Photography
Pena Blanca Site
2001
0 750 1,500
feet

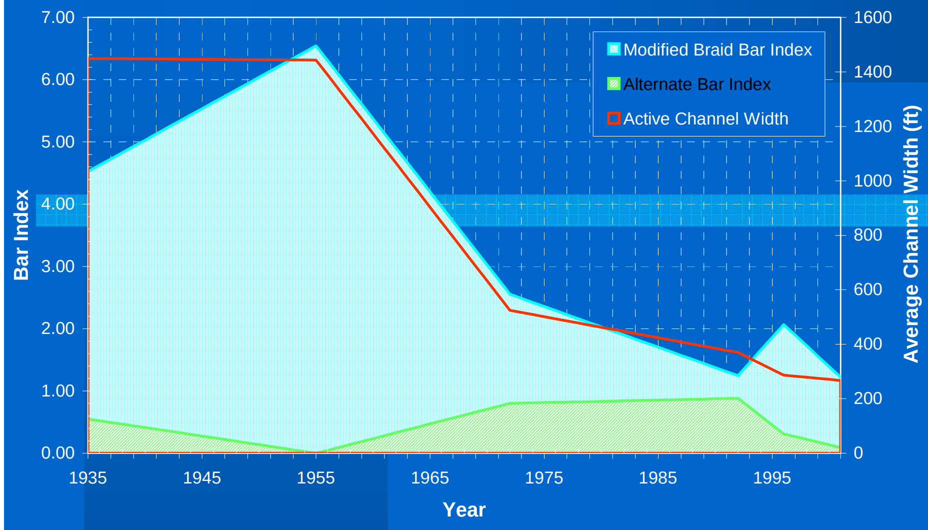
Modified Braiding Index (Germanoski, 1989)

$$MBI = \frac{2(\sum L_{BraidBar})}{L_{Channel}} + \frac{n_{bars}}{L_{Channel}}$$

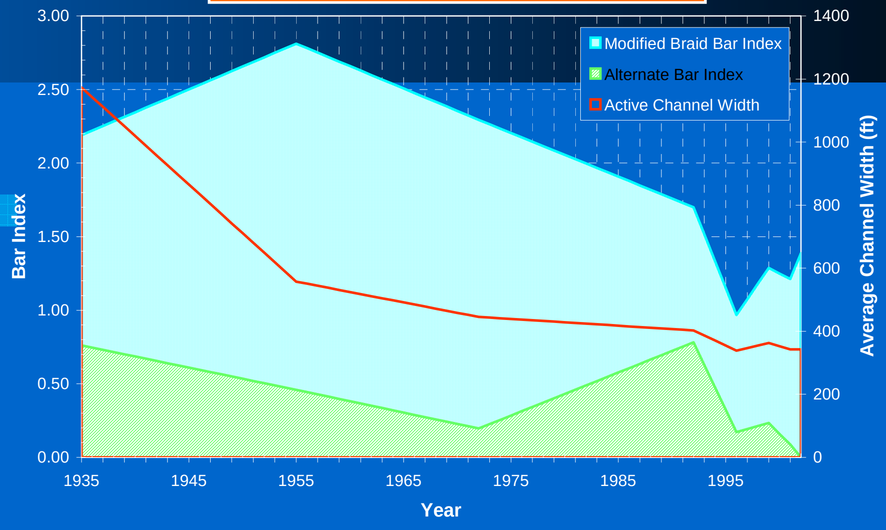
EXPECTED MBI RESPONSES (Germanoski and Schumm, 1993; Germanoski and Harvey, 1993)

- **If D_{50} increases, and there is sediment supply: > MBI**
- **If D_{50} increases, and there is no sediment supply: < MBI**
- **If the bed aggrades: > MBI**
- **If the bed degrades: < MBI**

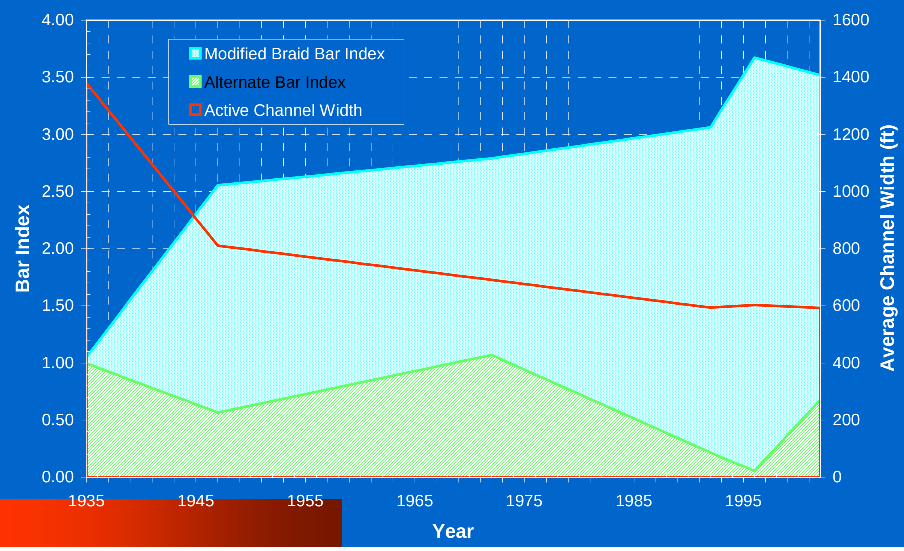
Pena Blanca



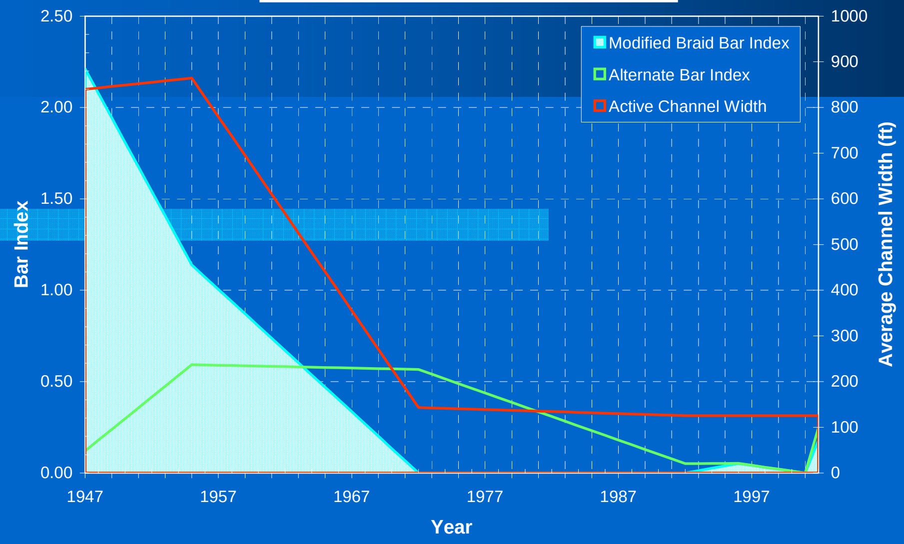
Central Avenue



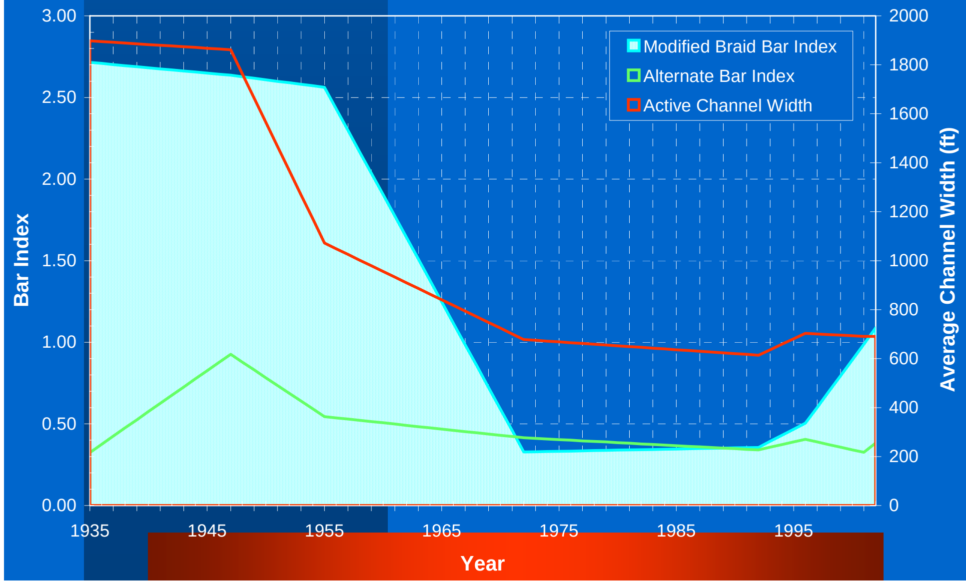
Bernardo



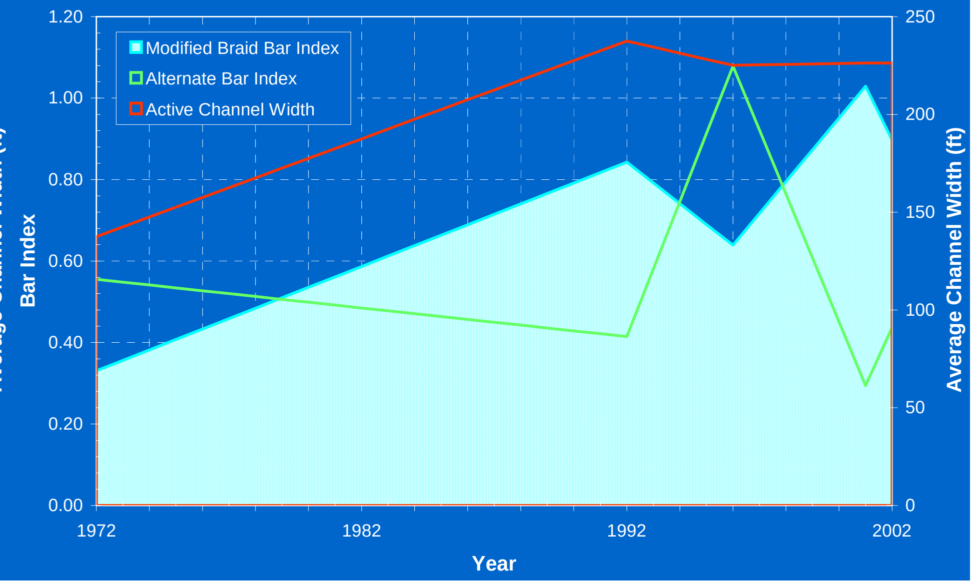
Escondida



Bosque del Apache



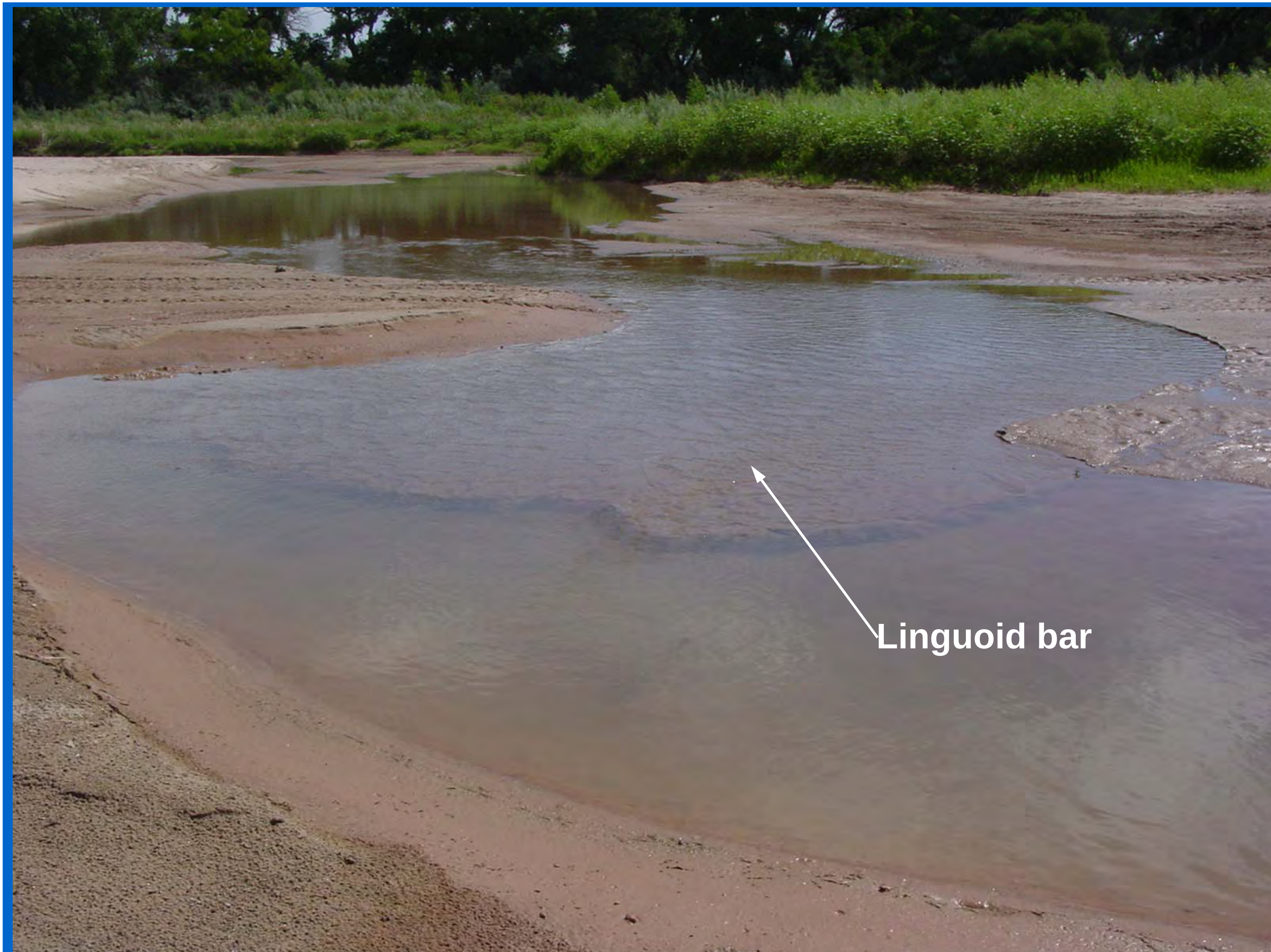
San Marcial



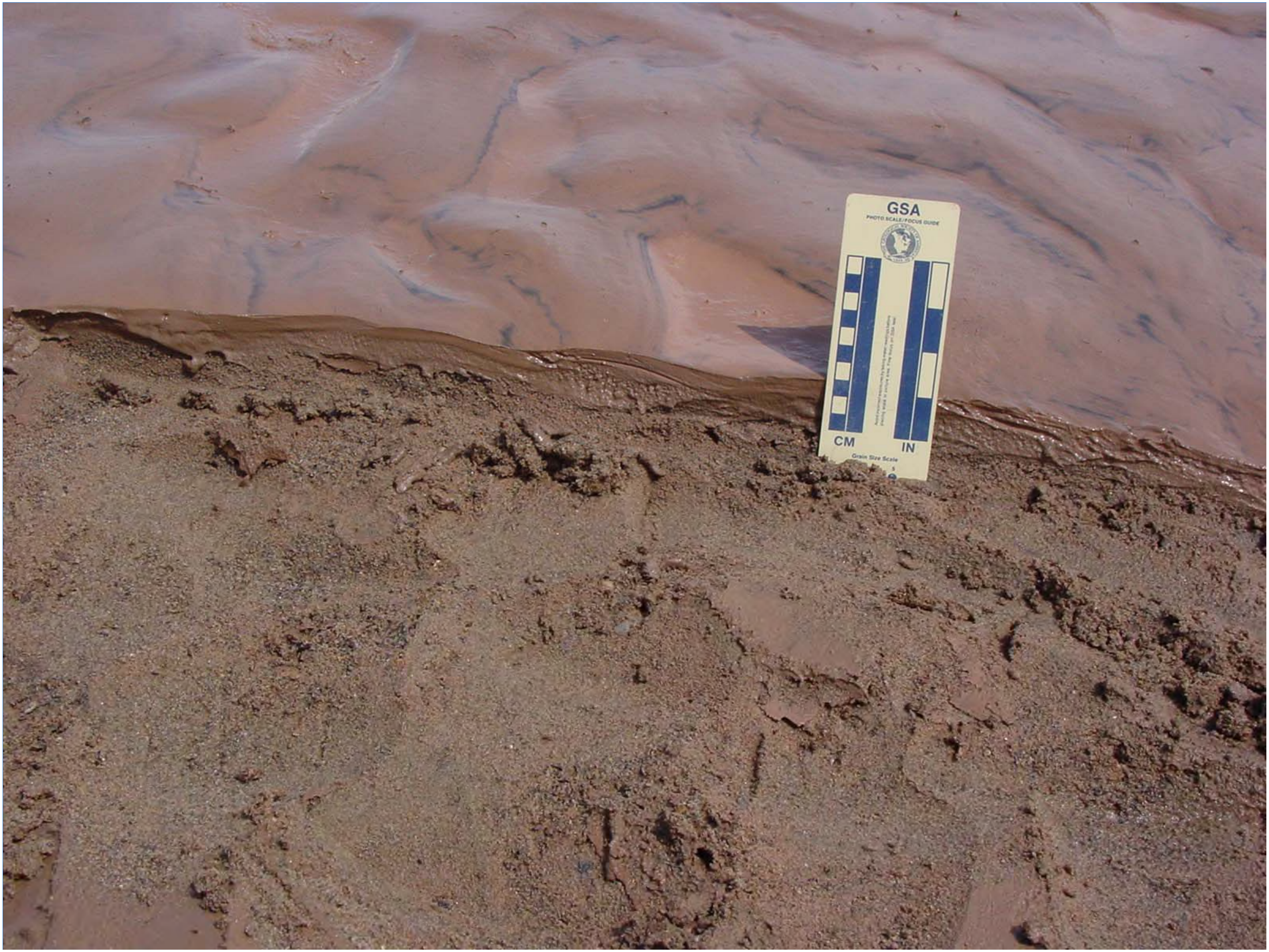
Hierarchical Bar Classification for the Middle Rio Grande

Bar Type	Location	Elevation	Subaqueous or Subaerial	Perennial Vegetation
Linguoid	Mid-channel	Bed	Subaqueous	No
Braid	Mid-channel	Level-1,2	Subaerial	No
Alternate	Bank-attached	Level-1	Subaerial	No
Mid-channel	Mid-channel	Level-1,2	Subaerial	Yes
Bank-attached	Bank-attached	Level-1,2	Subaerial	Yes

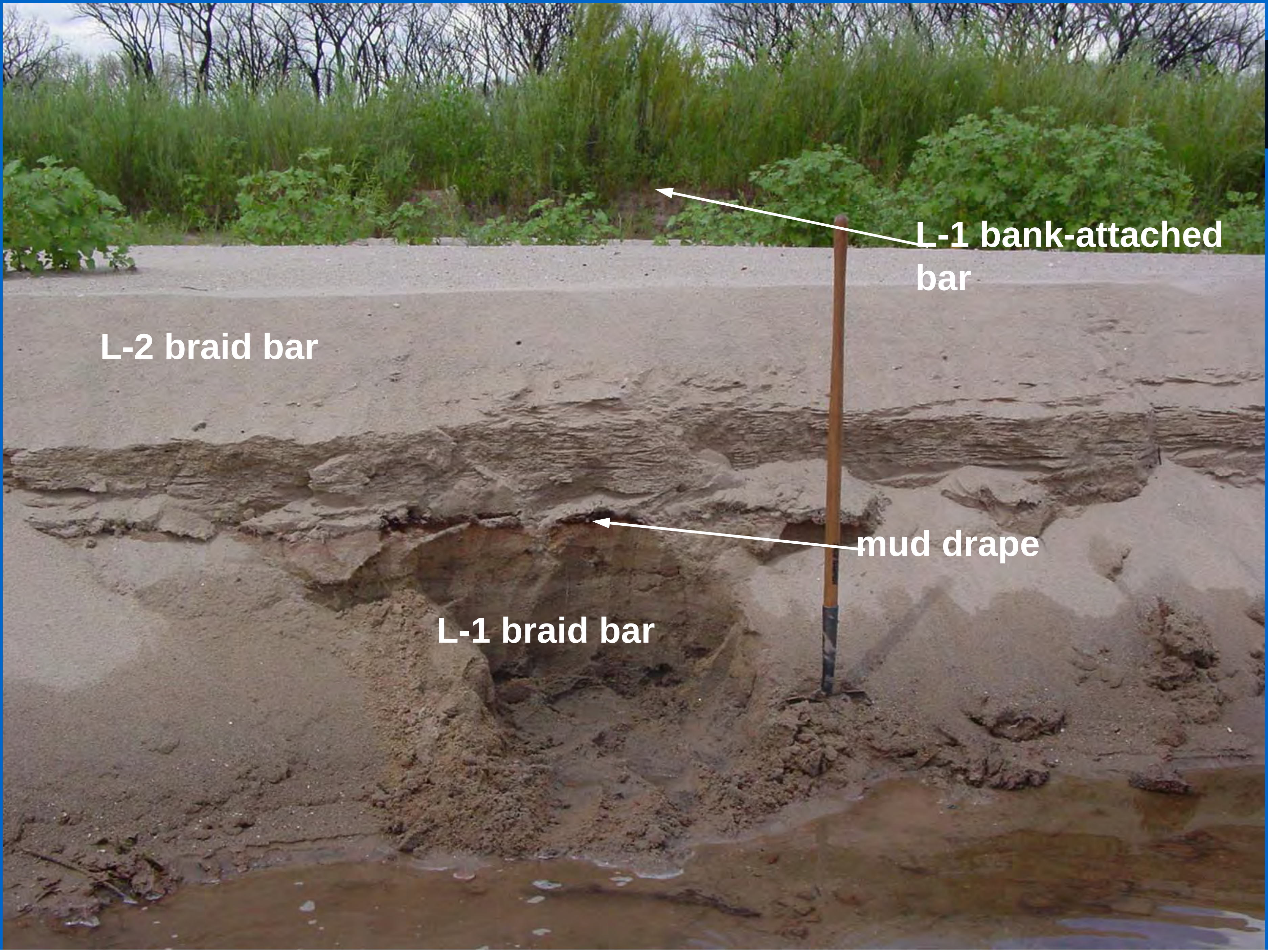
MEI

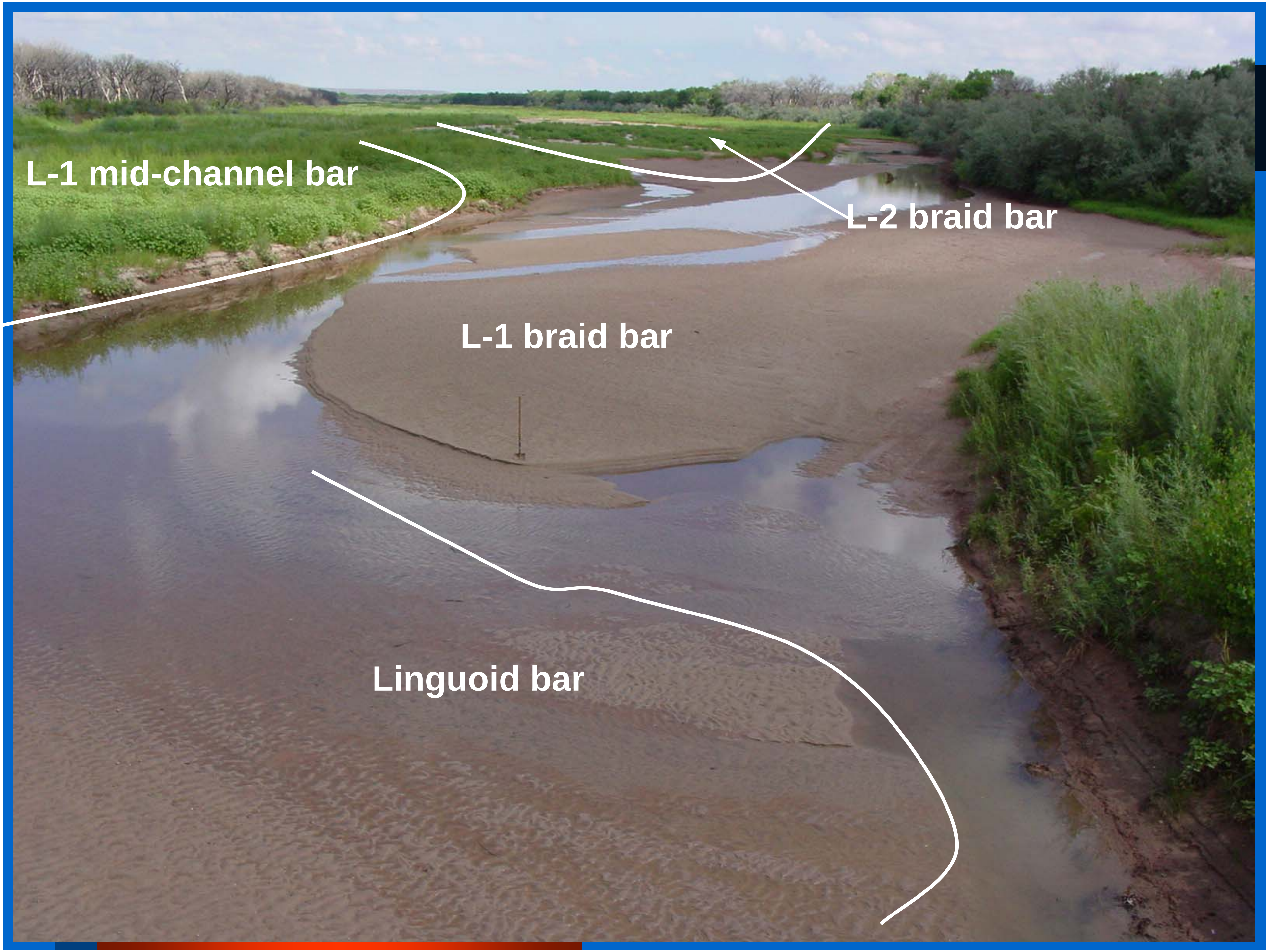

Linguoid bar

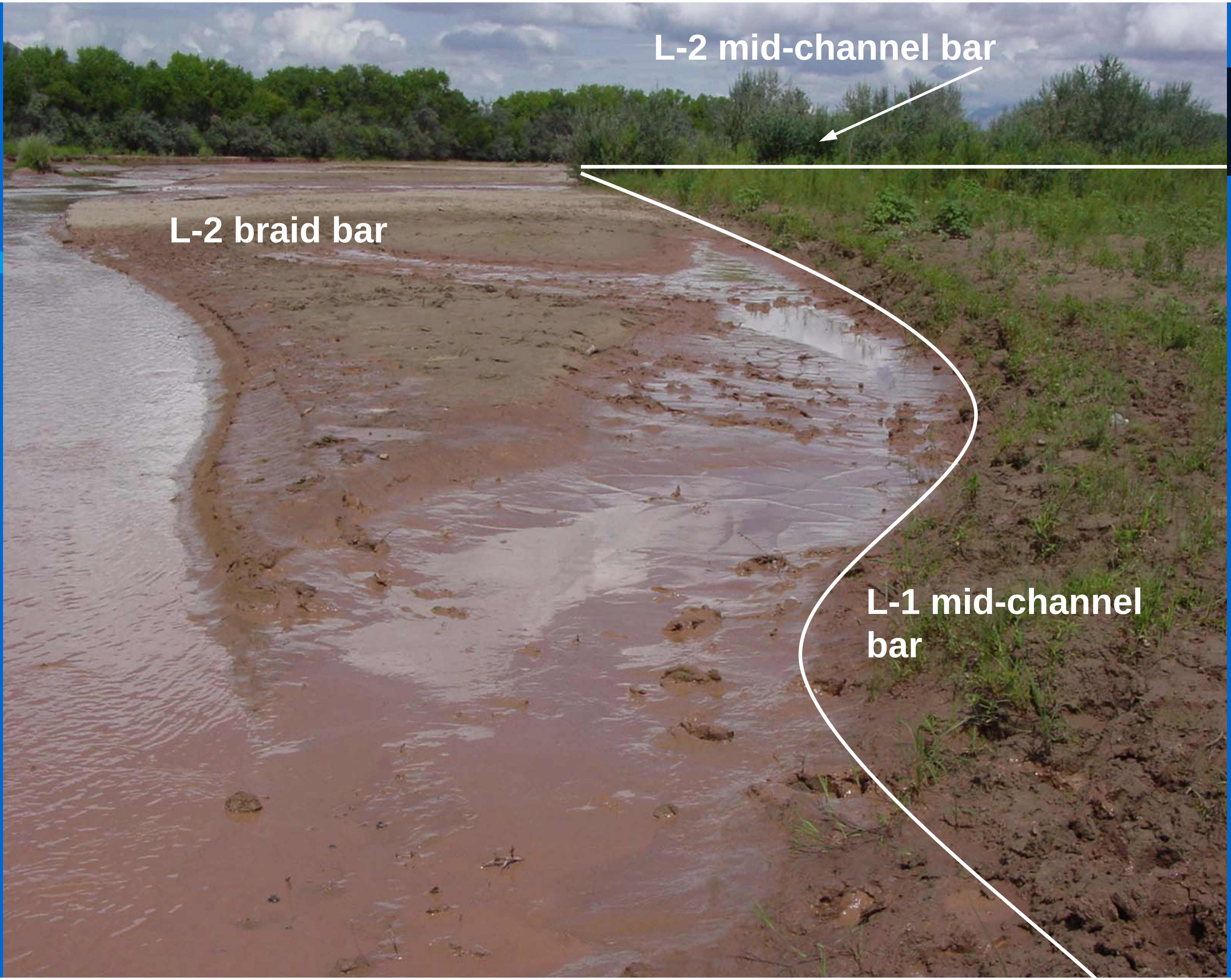

L-1 braid bars



GSA
PHOTO SCALE/FOCUS GUIDE
CM
IN
Grain Size Scale


L-1 bank-attached bar
L-2 braid bar
mud drape
L-1 braid bar


L-1 mid-channel bar
L-2 braid bar
L-1 braid bar
Linguoid bar

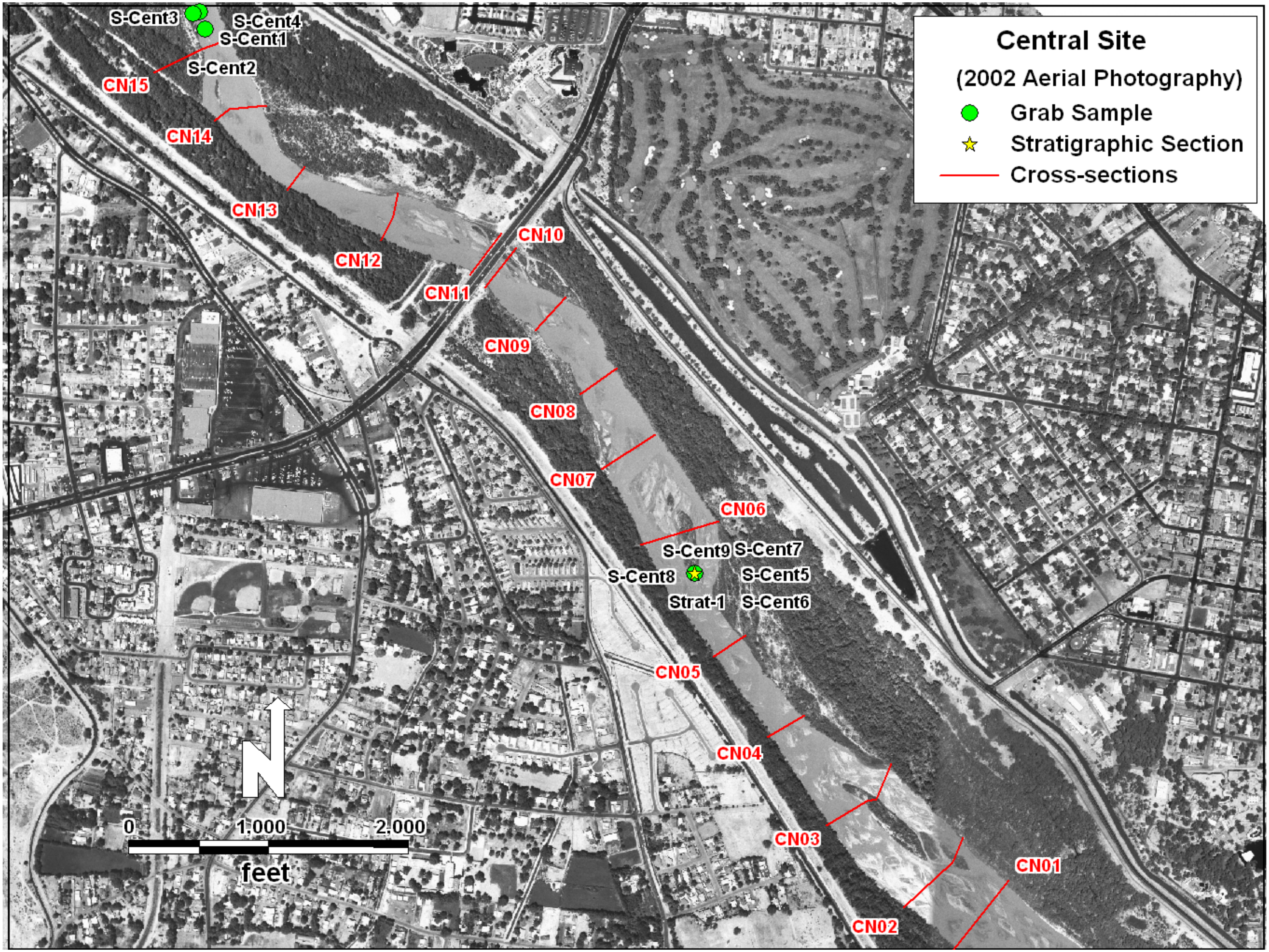

L-2 mid-channel bar
L-2 braid bar
L-1 mid-channel
bar


L-2 mid-channel bar


L-2 bank-attached bar
L-1 bank-attached bar

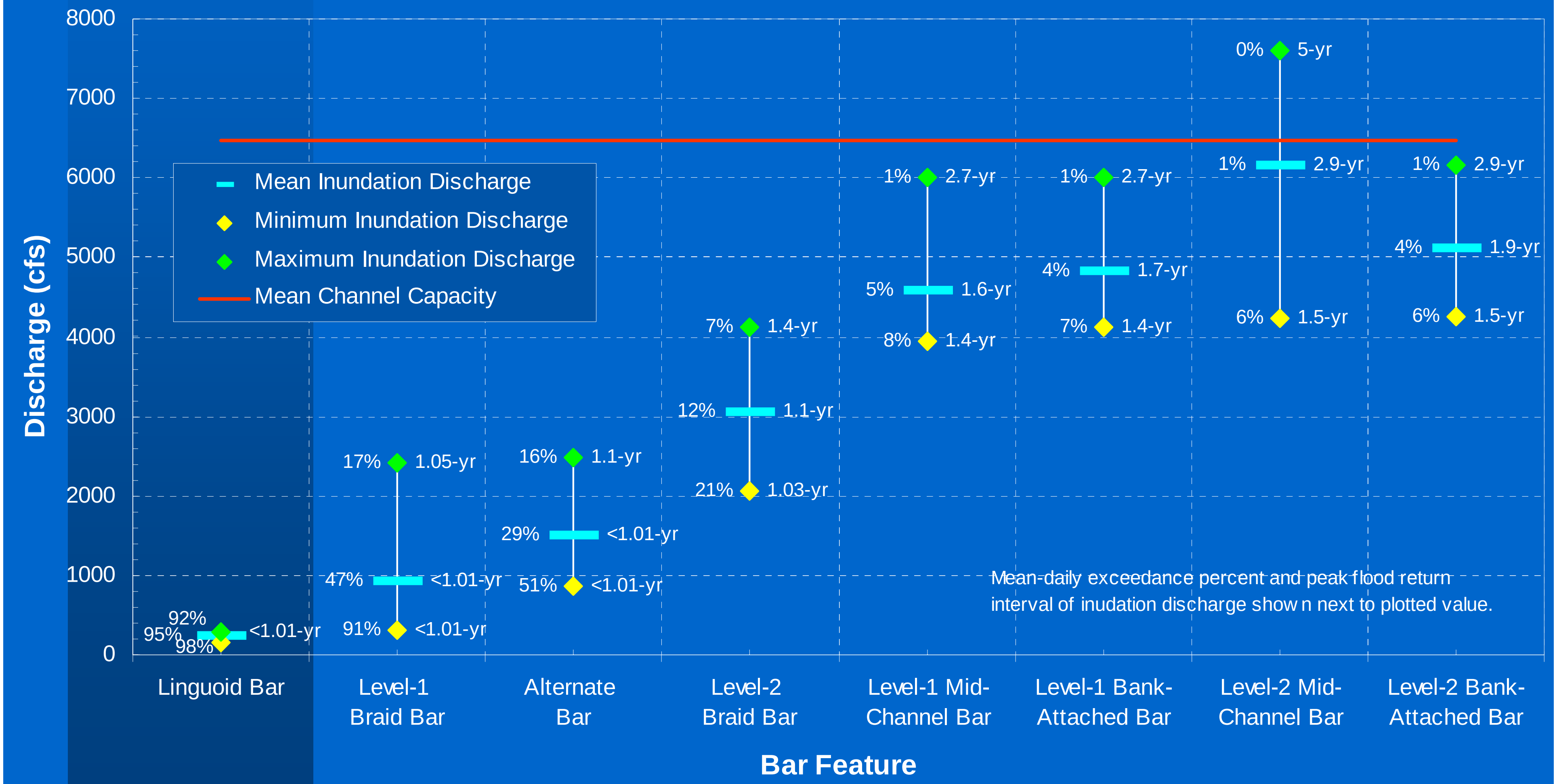
HYDRAULIC ANALYSIS

- **One-dimensional HEC-RAS models**
  - **Fixed-bed analysis**
  - **Calibrated to gauged flow at time of survey and 2005 peak flow (Tetra Tech. (2005)**


Central Site
(2002 Aerial Photography)
Grab Sample
Stratigraphic Section
Cross-sections
S-Cent3
S-Cent4
S-Cent1
S-Cent2
CN15
CN14
CN13
CN12
CN11
CN10
CN09
CN08
CN07
CN06
S-Cent9
S-Cent7
S-Cent8
S-Cent5
Strat-1
S-Cent6
CN05
CN04
CN03
CN02
CN01
0
1,000
2,000
feet

Central Site

Bar Inundation Analysis



BAR INUNDATION FREQUENCY & DURATION

Table ES-1. Summary of frequency and duration of inundation of the classified bar types at sites without excessive aggradation or degradation.*

Bar Type	Inundation Recurrence Interval	Days per Year of Inundation	Percent of Year Inundated
Level 1 braid bars	< 1 year	290	80%
Alternate bars	< 1 year	290	80%
Level 2 braid bars	< 1 year	146	<40%
Level 1 mid-channel bars	1.5 years	90	25%
Level 1 bank-attached bars	1.5 years	90	25%
Level 2 mid-channel bars	2 years	36	<10%
Level 2 bank-attached bars	2 years	36	<10%

*excluding the Pena Blanca, Bernalillo, Escondida and San Marcial sites.

BARS AND SHEAR STRESS

Table ES-2: Comparison of maximum in-channel shear stresses to the prevalence of bars in the sand-bed sites.

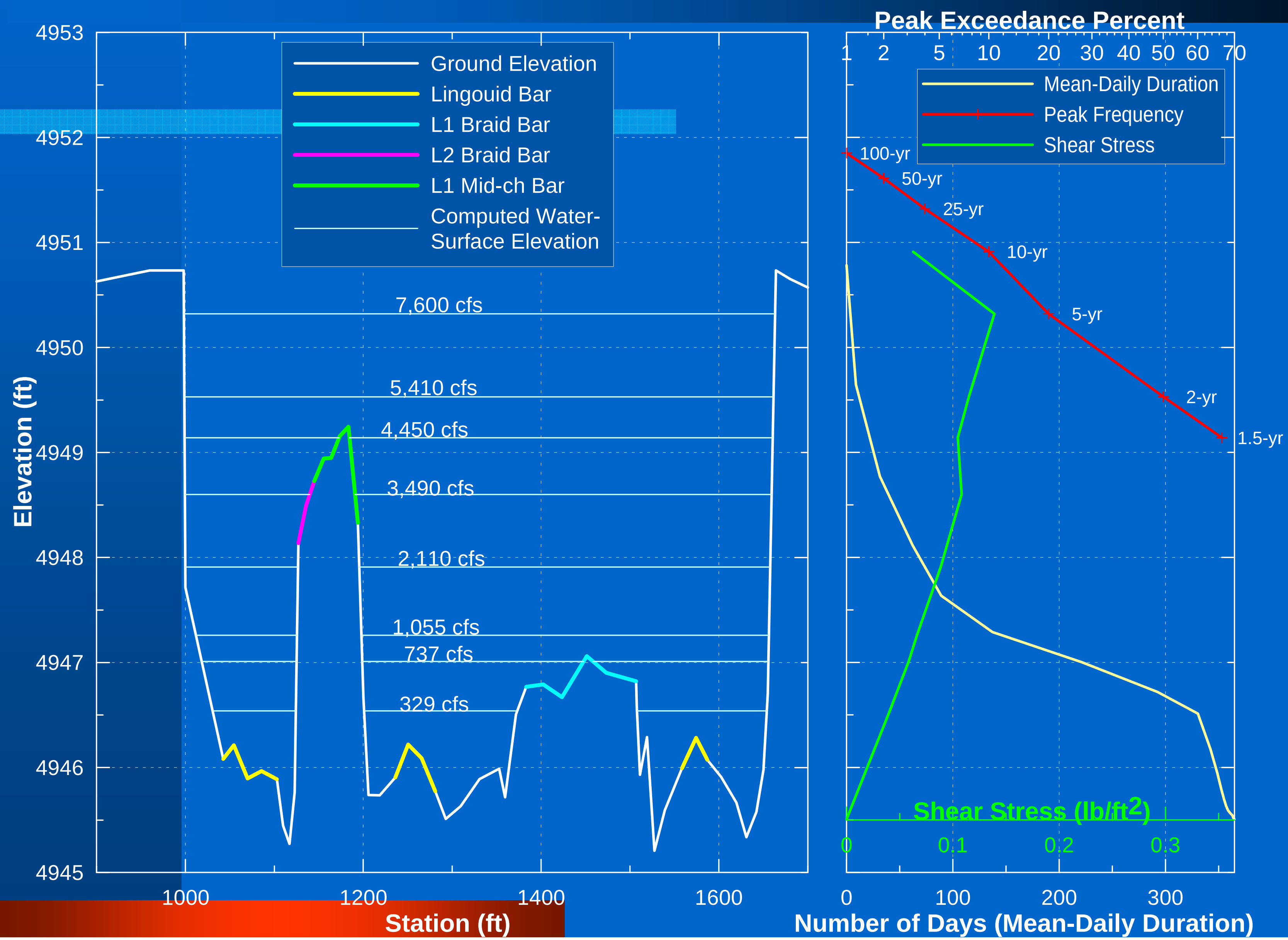
Site Names	Maximum In-Channel Shear Stresses (lb/ft^2)	Prevalence of Active Bars
Central Avenue	<0.1	moderate to high number of active bars
Bosque del Apache, San Marcial	0.1	high number of active bars
Bernardo, La Joya, Lemitar	0.12 - 0.15	active bars are present
Belen	0.2	moderate number of active bars
Escondida	0.3	virtually no active bars

BARS AND VEGETATION

- **Shear stress limit for vegetation establishment ~ < 1 psf**
- **Shear stress limit for vegetation removal ~ > 6 psf**


9 4 2005

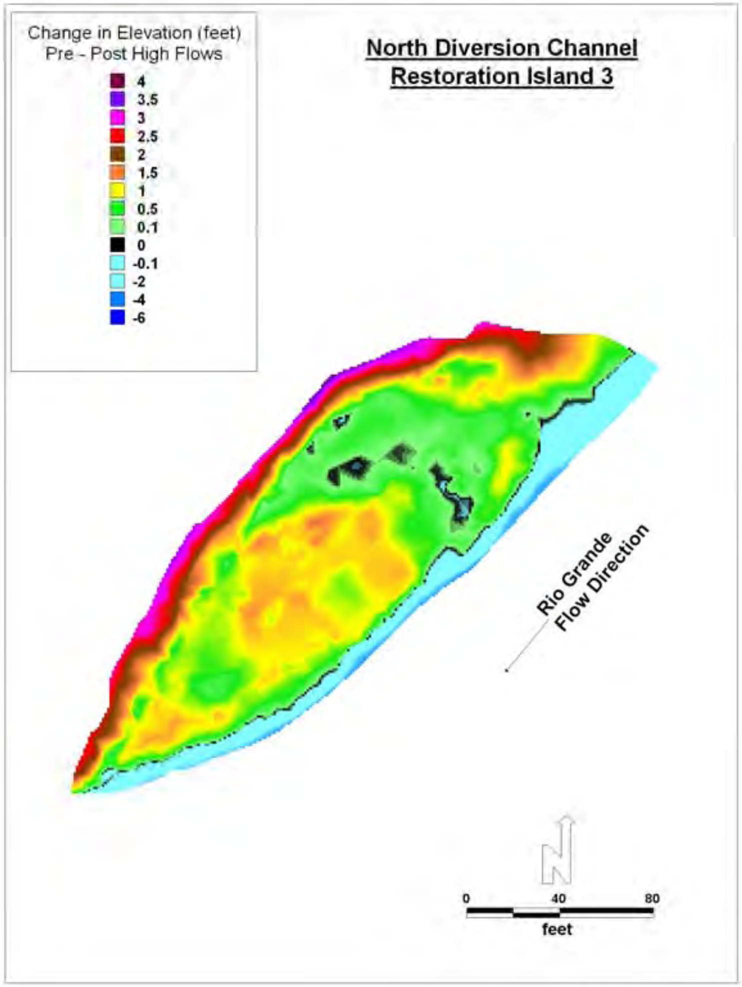
Central Site – Cross Section 2



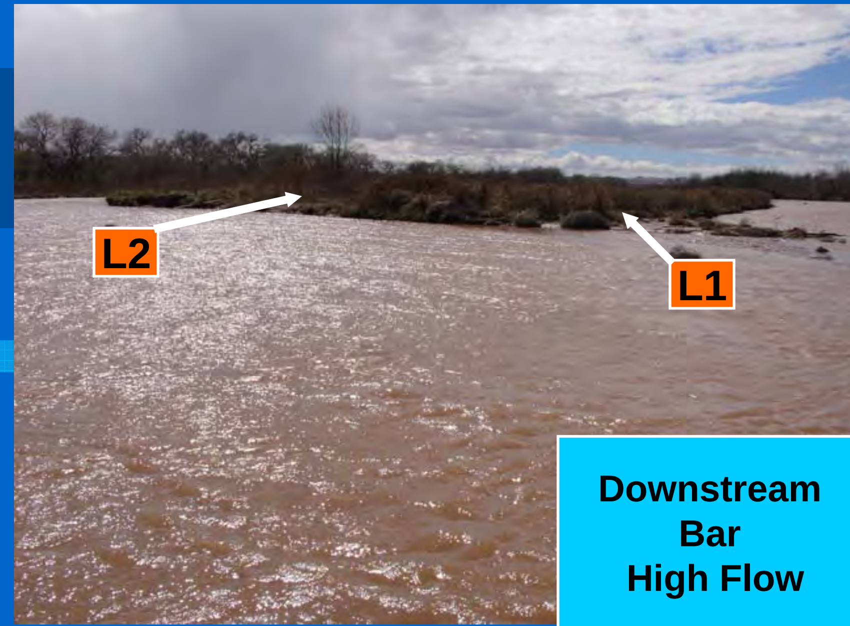
BARS AND DEPOSITION

- Based on surveys of L1 and L2 bars in Albuquerque Reach, pre- and post-2005 high flows
- Comparison based on 0.5 ft contour-interval topographic mapping

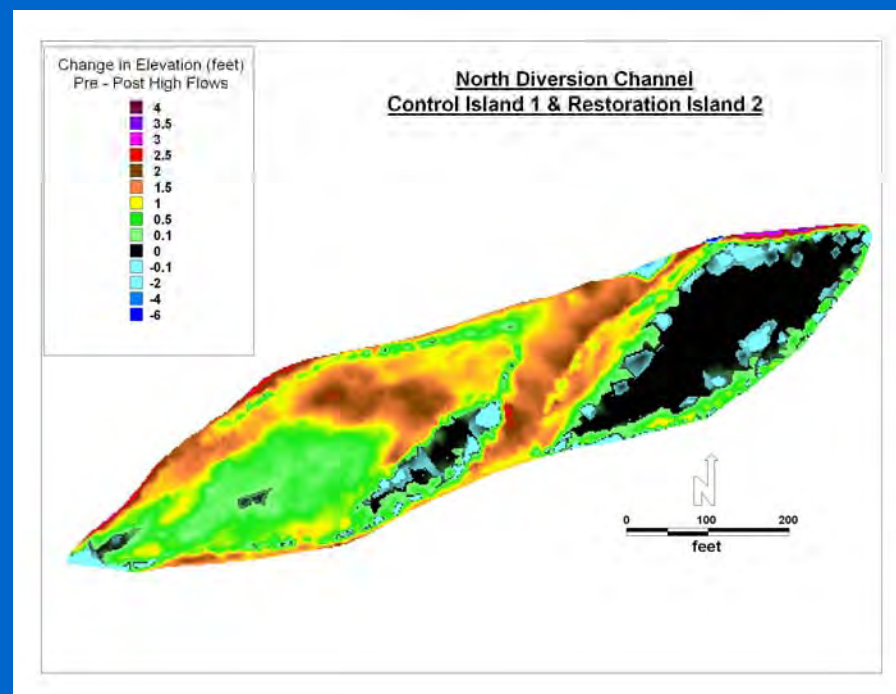
POST-HIGH FLOW SEDIMENT DEPOSITION 2005




L1
L2
Upstream
Bar
High Flow


L2
L1
Downstream
Bar
High Flow


L1
Upstream
Bar
Low Flow


Change in Elevation (feet)
Pre - Post High Flows
4
3.5
3
2.5
2
1.5
1
0.5
0.1
0
-0.1
-2
-4
-6
North Diversion Channel
Control Island 1 & Restoration Island 2
0
100
200
feet

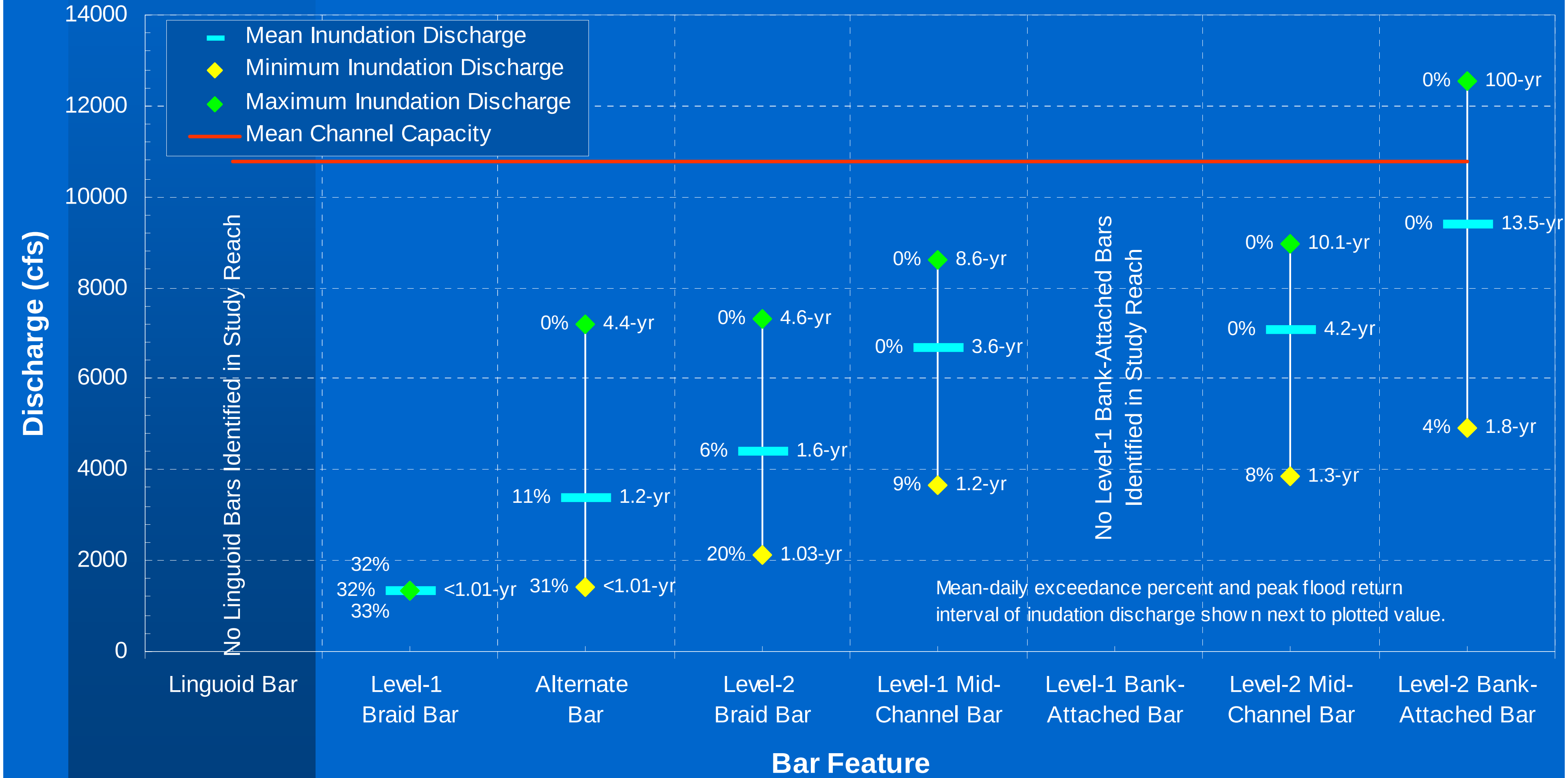
BARS AND DEGRADATION

- **Degradation causes hydrologic abandonment of bars**
- **If restoration is being considered is the bed currently stable?**
- **If degradation continues, restoration will be compromised**

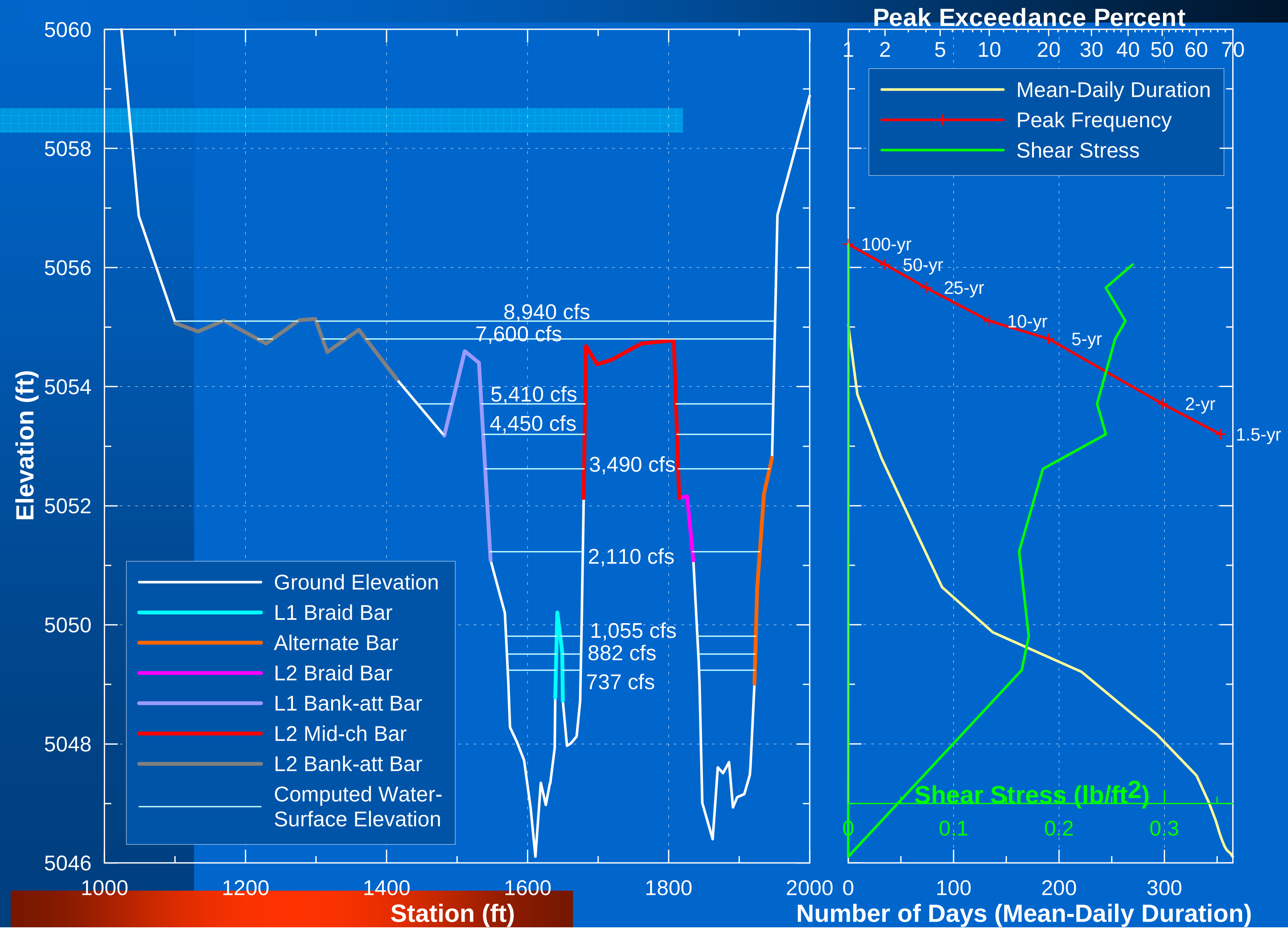

Abandoned L-2
mid-channel bar

Bernalillo Site

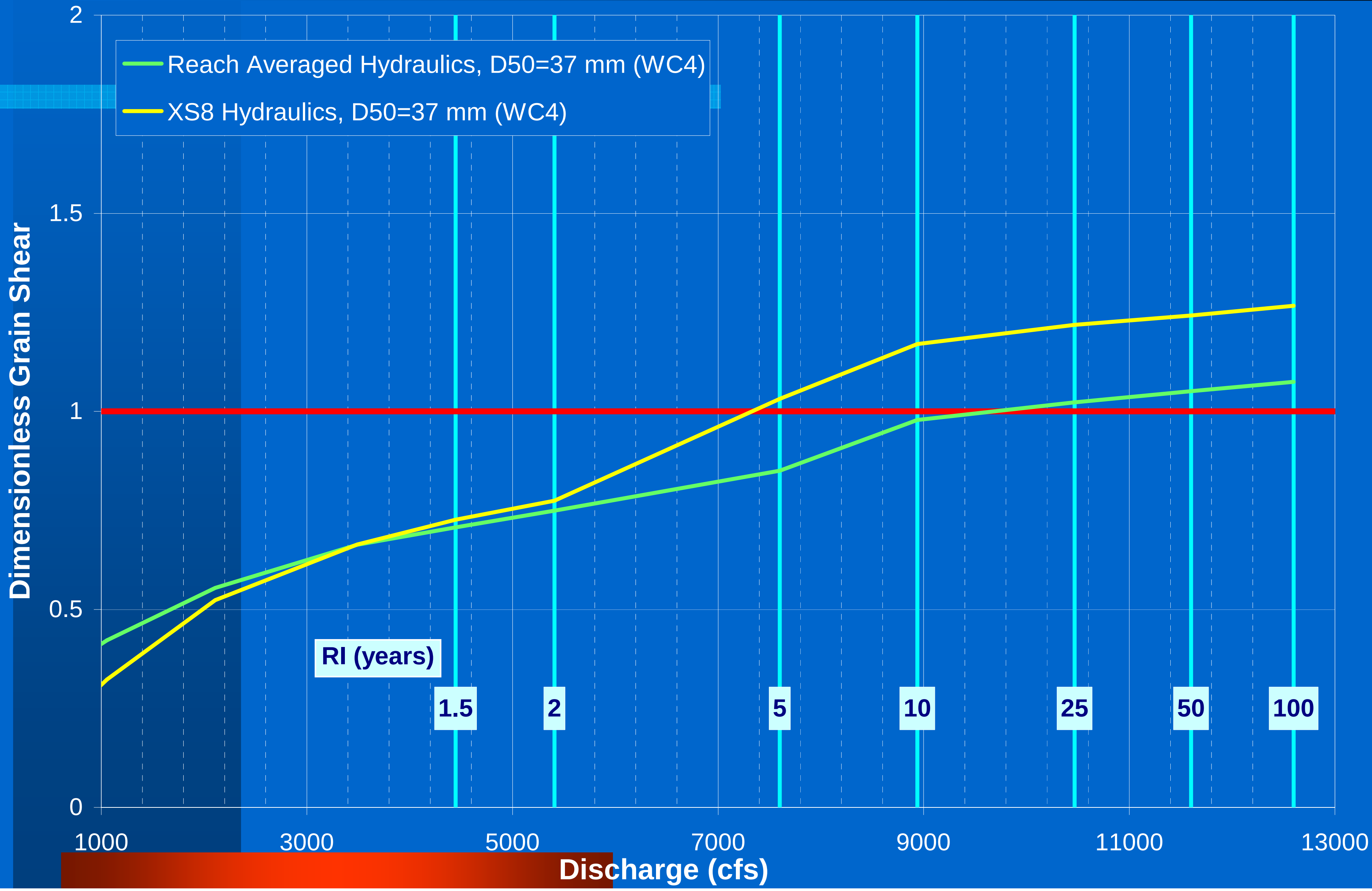
Bar Inundation Analysis



Bernalillo Site – Cross Section 10



Bernalillo Site



CONCLUSIONS

- **Bar indices reflect changes in flow, sediment supply and channel morphology**
- **Bar classification is a communication tool, and provides first-cut hydraulic assessments**

CONCLUSIONS

- **Active braid bars require average shear stresses < 0.2 psf**
- **Inundation of bars leads to vertical growth and reduced frequency and duration of inundation**
- **Degradation will adversely affect restoration efforts, so vertical stability must be assessed**

APPLICATION TO RESTORATION


Bridge Blvd.

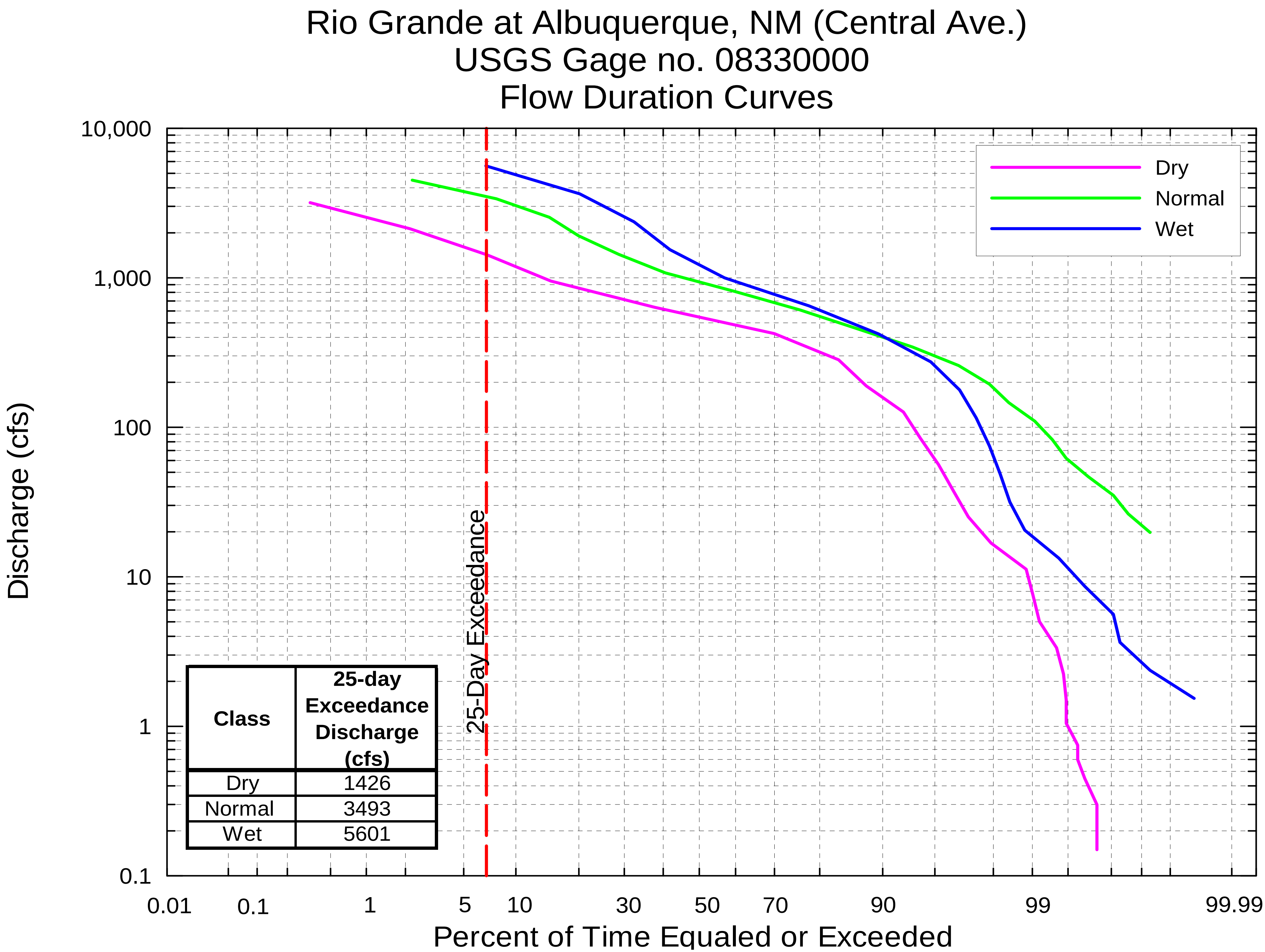
RIO GRANDE SILVERY MINNOW

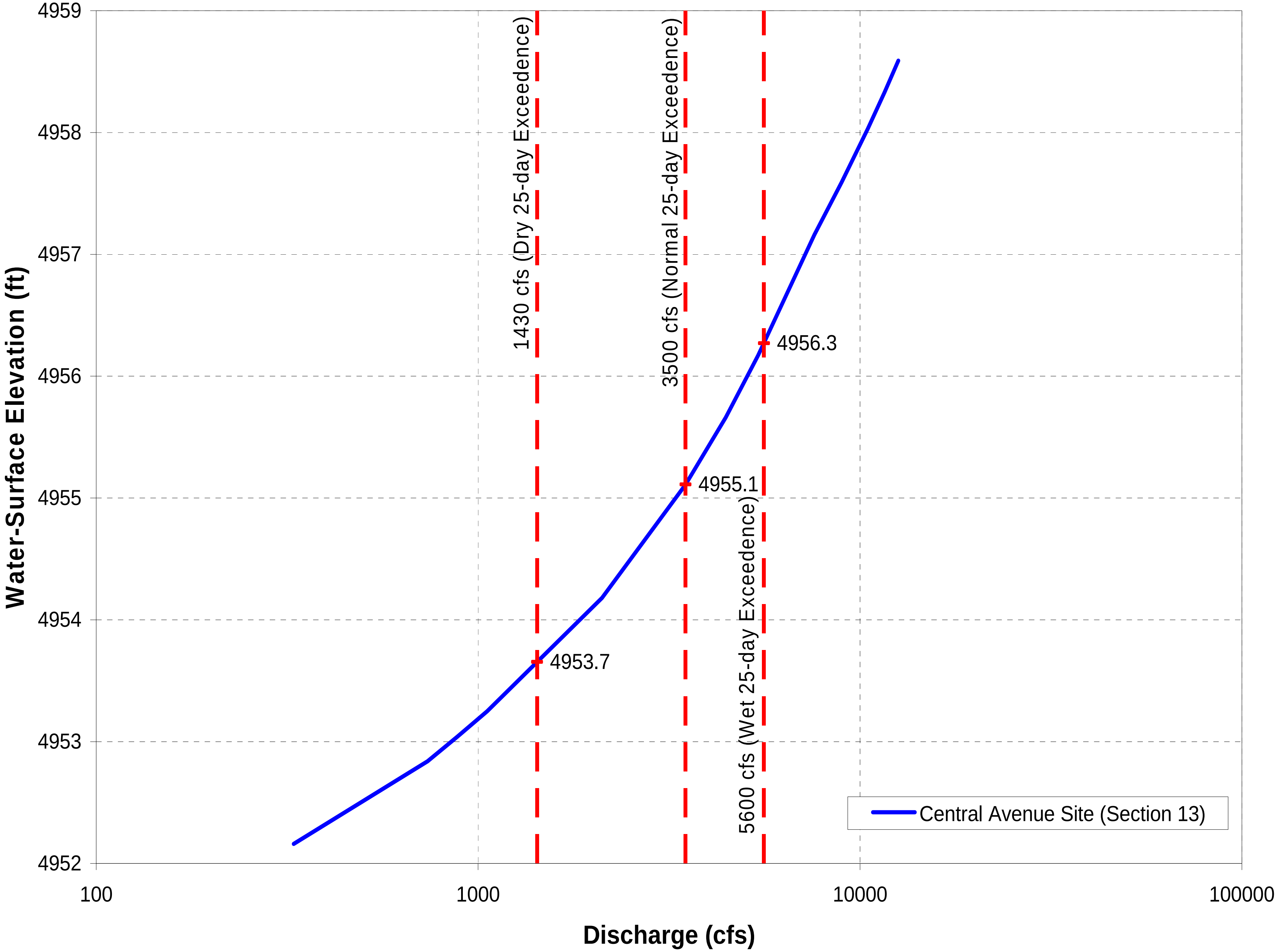
TARGETED LIFE STAGES:
-EGGS
- LARVAE
- JUVENILES

PHYSICAL NEEDS
-LOW VELOCITY
-SHALLOW DEPTH

BIOLOGICAL TARGET
25 DAYS INUNDATION
(~ 7 % EXCEEDENCE)

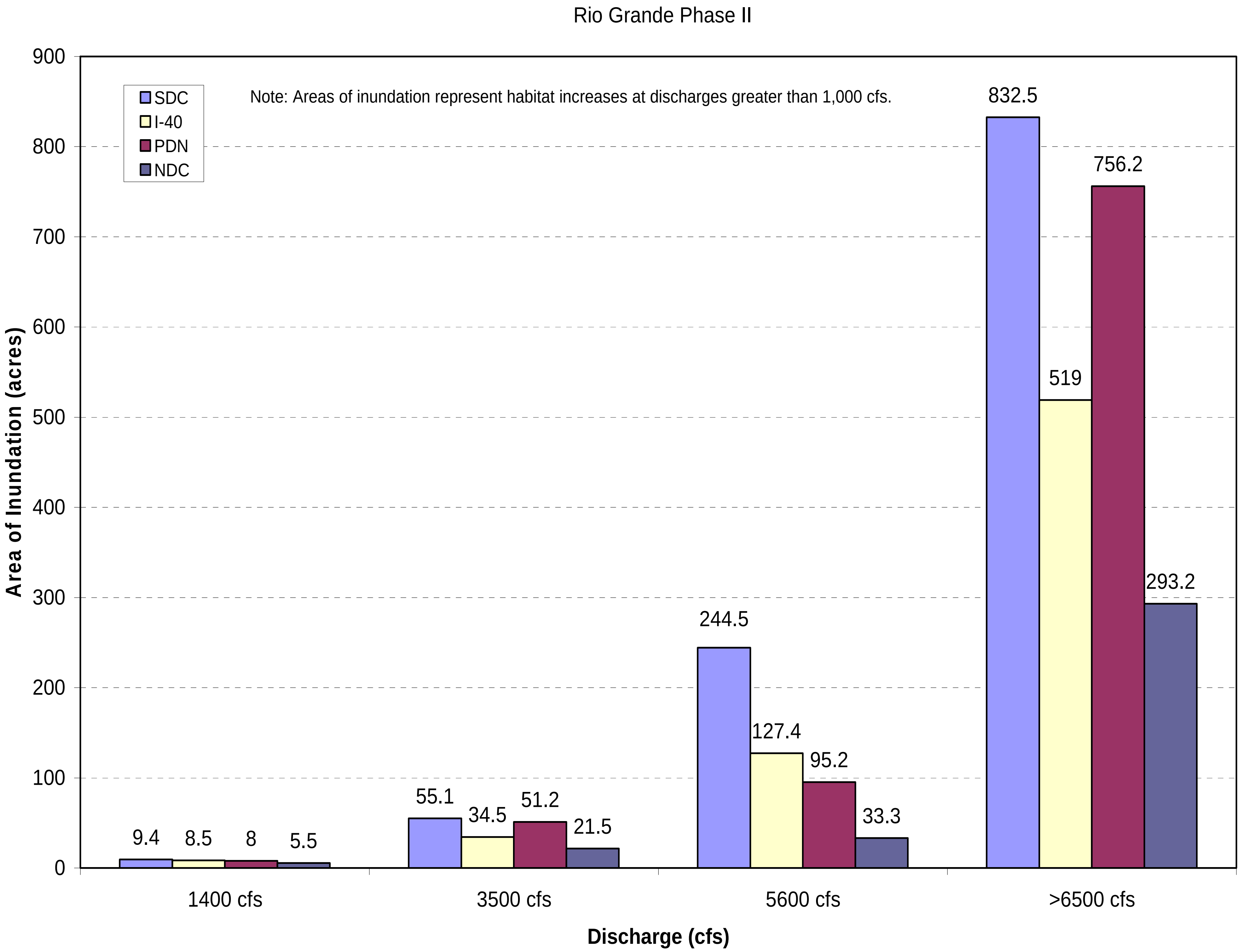
POST-COCHITI (1974 -2005)
Flow Duration Curve:
~ 4000 CFS


Rio Grande at Albuquerque, NM (Central Ave.)
USGS Gage no. 08330000
Flow Duration Curves
Discharge (cfs)
10,000
1,000
100
10
1
0.1
0.01
0.1
1
5
10
30
50
70
90
99
99.99
Percent of Time Equaled or Exceeded
Dry
Normal
Wet
25-Day Exceedance
Class
25-day Exceedance Discharge (cfs)
Dry
1426
Normal
3493
Wet
5601

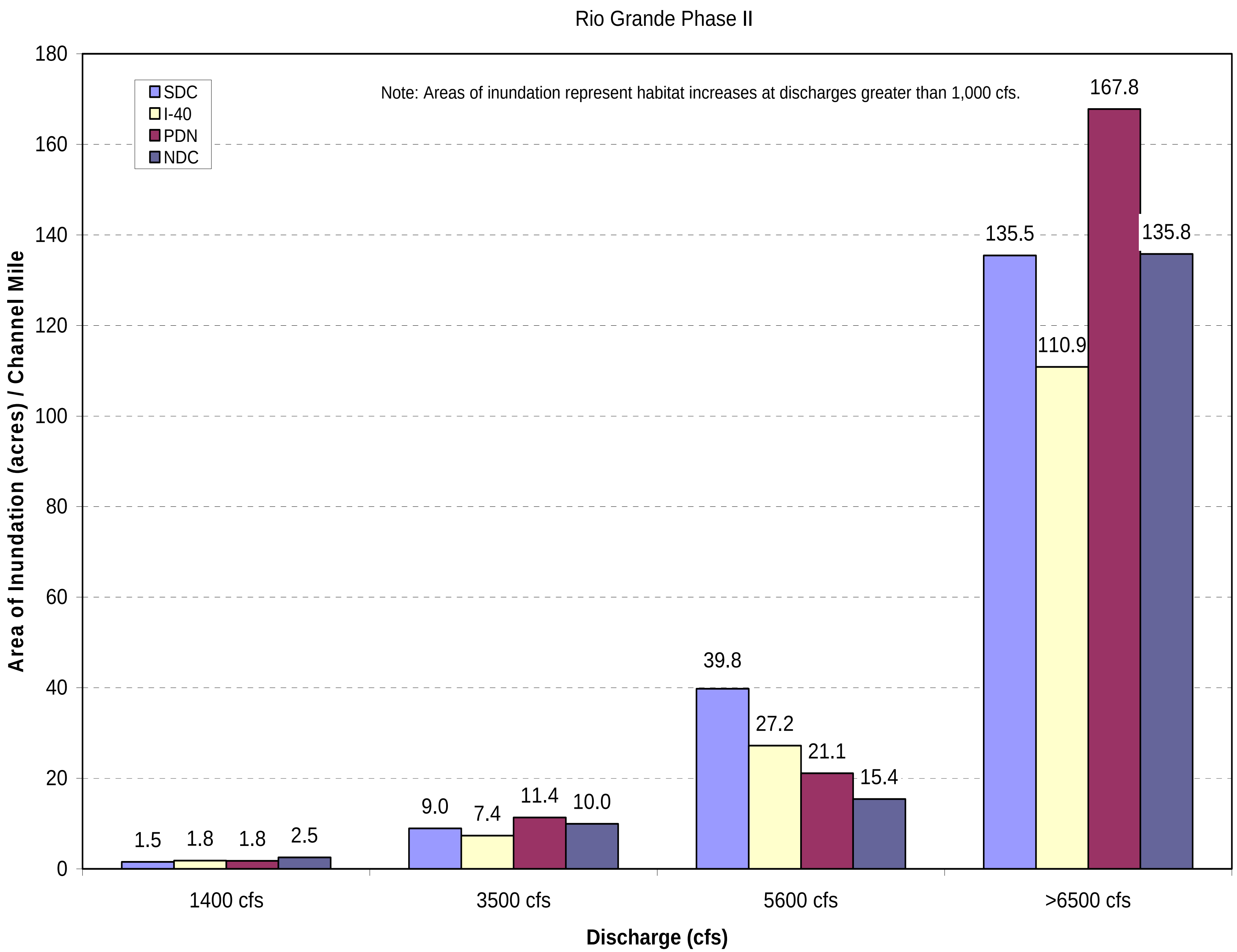


Water-Surface Elevation (ft)
4959
4958
4957
4956
4955
4954
4953
4952
100
1000
10000
100000
Discharge (cfs)
1430 cfs (Dry 25-day Exceedence)
3500 cfs (Normal 25-day Exceedence)
5600 cfs (Wet 25-day Exceedence)
4956.3
4955.1
4953.7
Central Avenue Site (Section 13)

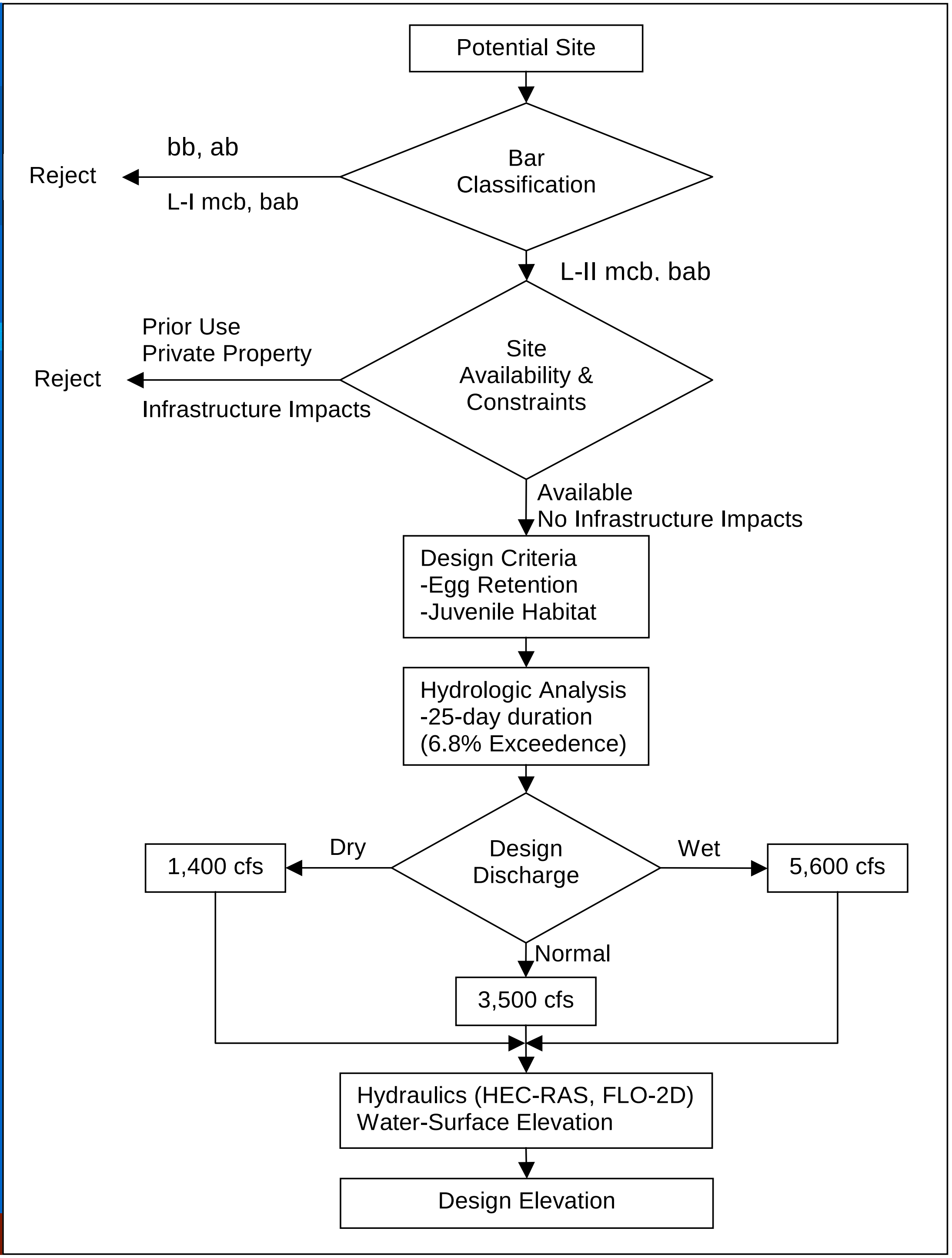

Bridge Blvd.

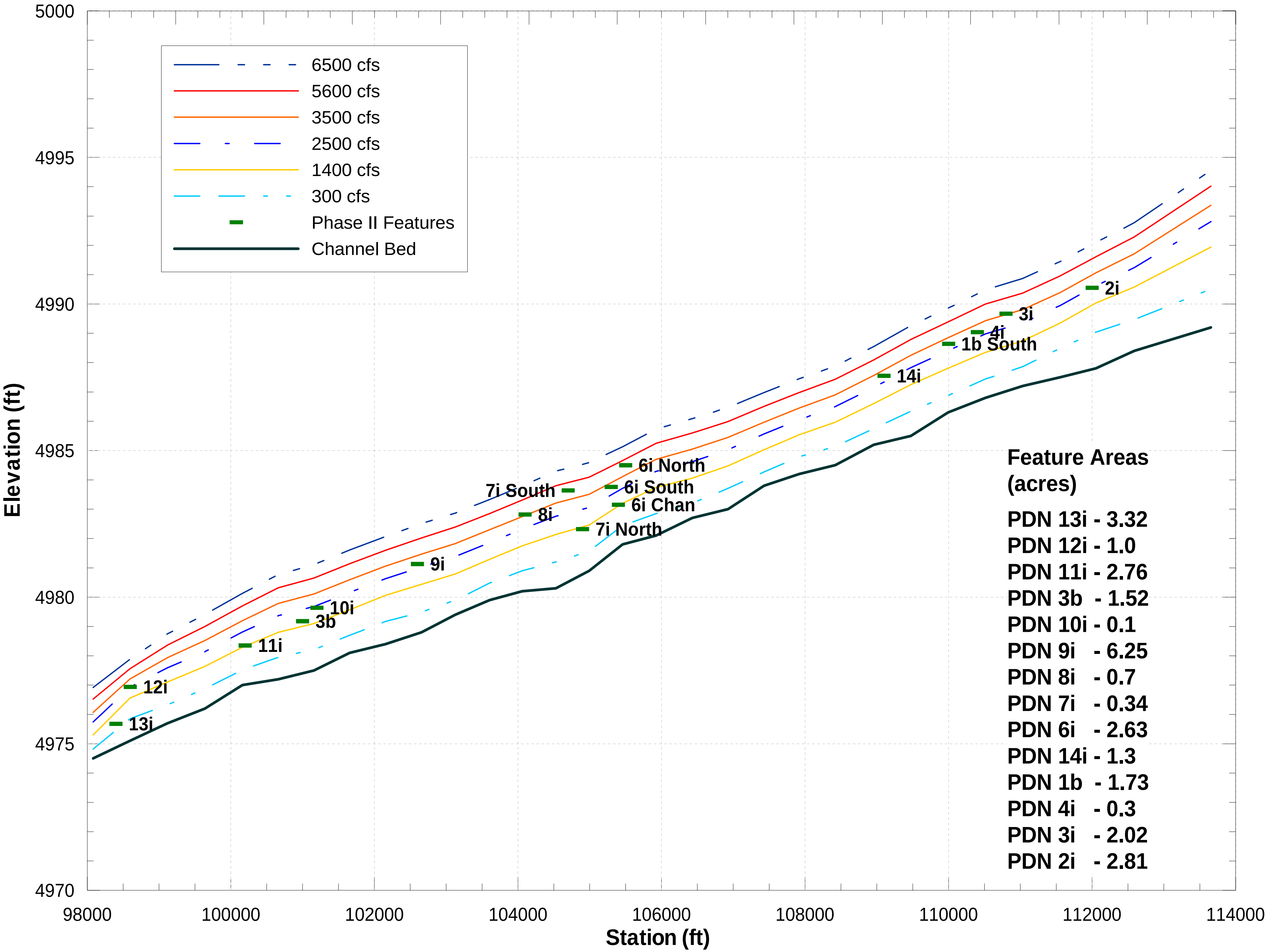


Rio Grande Phase II
SDC
I-40
PDN
NDC
Note: Areas of inundation represent habitat increases at discharges greater than 1,000 cfs.
Area of Inundation (acres)
900
800
700
600
500
400
300
200
100
0
9.4
8.5
8
5.5
55.1
34.5
51.2
21.5
244.5
127.4
95.2
33.3
832.5
519
756.2
293.2
1400 cfs
3500 cfs
5600 cfs
>6500 cfs
Discharge (cfs)


Rio Grande Phase II
Note: Areas of inundation represent habitat increases at discharges greater than 1,000 cfs.
SDC
I-40
PDN
NDC
Area of Inundation (acres) / Channel Mile
Discharge (cfs)
0
20
40
60
80
100
120
140
160
180
1400 cfs
3500 cfs
5600 cfs
>6500 cfs
1.5
1.8
1.8
2.5
9.0
7.4
11.4
10.0
39.8
27.2
21.1
15.4
135.5
110.9
167.8
135.8

SITE SELECTION SCREENING TOOL




6500 cfs
5600 cfs
3500 cfs
2500 cfs
1400 cfs
300 cfs
Phase II Features
Channel Bed
Elevation (ft)
Station (ft)
5000
4995
4990
4985
4980
4975
4970
98000
100000
102000
104000
106000
108000
110000
112000
114000
13i
12i
11i
3b
10i
9i
8i
7i South
7i North
6i North
6i South
6i Chan
14i
1b South
4i
3i
2i
Feature Areas
(acres)
PDN 13i - 3.32
PDN 12i - 1.0
PDN 11i - 2.76
PDN 3b - 1.52
PDN 10i - 0.1
PDN 9i - 6.25
PDN 8i - 0.7
PDN 7i - 0.34
PDN 6i - 2.63
PDN 14i - 1.3
PDN 1b - 1.73
PDN 4i - 0.3
PDN 3i - 2.02
PDN 2i - 2.81

Microsoft Excel - Habitat Selection Tool Version 2 8-30-06(BCM).xls

SDC

Stage differences (for reference)

SDC SITE	Station (ft)	Average Elevation (ft)	Existing Overtopping Discharge (cfs)	Existing Area (ac)	1400 to 2500 cfs	2500 to 3500 cfs	3500 to 5600 cfs
9i	17100	4903.13	2,920	1.98	0.69	0.54	0.68
8i	21200	4906.98	4,687	0.33	0.54	0.42	0.54
6i	23100	4908.58	4,686	2.03	0.61	0.45	0.59
5i Main	23600	4909.13	4,637	0.93	0.59	0.44	0.58
4i Main	24100	4909.81	4,981	1.73	0.57	0.43	0.56
3i	24800	4910.4	4,467	0.84	0.56	0.43	0.56
5b	26000	4911.49	4,428	1.70	0.64	0.47	0.60
4b South	26200	4912.06	5,670	0.33	0.67	0.50	0.63
4b North	26400	4912.87	6,795	0.67	0.67	0.50	0.64
1i	28800	4914.09	4,655	0.70	0.55	0.45	0.61
3b	32800	4917.64	3,872	3.27	0.70	0.53	0.67
1b	38200	4921.79	3,187	0.32	0.75	0.56	0.70
			TOTAL	14.81			

SDC SITE	Total Percent Area	Excavation Volume (yd^3)
9i	0	0
8i	100	612
6i	100	5,194
5i Main	100	1,408
4i Main	100	4,466
3i	100	1,508
5b	85.8	3,073
4b South	100	634
4b North	100	1,939
1i	100	1,489
3b	18.7	3,181
1b	100	1,686
	Total	25,189

		AREA 1						AREA 2					
SDC SITE	Safety Factor (ft)	Target Discharge 1	Design Depth (ft)	X - Grade	Percent of Area	Cut (ft)	New Innundation Q (cfs)	Target Discharge 2	Design Depth (ft)	X - Grade	Percent of Area	Cut (ft)	New Innundation Q (cfs)
9i	0	3500	0.5	YES	0	0.20	2920	2500	0.25	YES	0	0.49	2920
8i	0	3500	0.5	YES	49.9	0.93	2327	1400	0.25	NO	50.1	1.64	1001
6i	0	3500	0.5	NO	24.2	0.97	2404	1400	0.25	NO	75.8	1.78	1043
5i Main	0	3500	0.5	NO	100	0.94	2388	1400	0.25	NO	0	1.73	4637
4i Main	0	3500	0.5	NO	26.9	1.06	2362	1400	0.25	NO	73.1	1.81	1006
3i	0	3500	0.5	NO	30.4	0.87	2359	3500	0.25	NO	27.1	0.62	2911
5b	0	3500	0.5	NO	70.7	0.88	2447	Bed	0	NO	15.1	3.28	Bed
4b South	0	3500	0.5	NO	100	1.19	2493	1400	0.25	NO	0	2.10	5670
4b North	0	3500	0.5	NO	100	1.79	2500	1400	0.25	NO	0	2.71	6795
1i	0	3500	0.5	NO	55.9	0.98	2398	1400	0.25	NO	44.1	1.73	976
3b	0	Bed	0	NO	0	3.23	3872	Bed	0	NO	18.7	3.23	Bed
1b	0	Bed	0	NO	100	3.32	Bed	1400	0.25	NO	0	1.39	3187

UPDATE SUMMARY TABLE

Summary

Design Discharge (cfs)	Existing Area (acres)	Existing Area (%)	Post-Mod Area (acres)	Post-Mod Area (%)
< 1400	0	0.00%	1.18	7.99%
1400	0.00	0.00%	3.86	26.04%
2500	2.29	15.47%	1.98	13.34%
3500	11.52	77.78%	7.79	52.63%
5600	1.00	6.75%	0.00	0.00%

Warning	Problem
Warning	Excavation Volume is negative
Warning	Feature is being cut to an elevation below the bed
Warning	Target Discharge is set to Bed, design depth should be zero.

SUMMARY

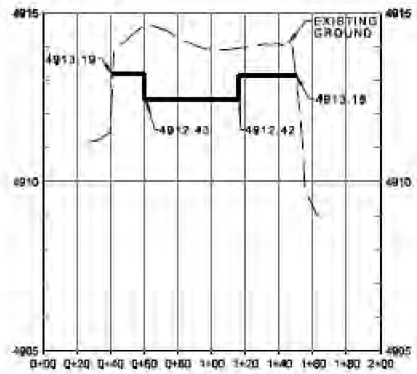
SDC	Total Excavation Volume (yd^3)			25,189
Design Discharge (cfs)	Existing Area (acres)	Existing Area (%)	Post-Mod Area (acres)	Post-Mod Area (%)
< 1400	0.00	0.0%	1.18	8.0%
1400	0.00	0.0%	3.86	26.0%
2500	2.29	15.5%	1.98	13.3%
3500	11.52	77.8%	7.79	52.6%
5600	1.00	6.8%	0.00	0.0%

PDN	Total Excavation Volume (yd^3)			16,475
Design Discharge (cfs)	Existing Area (acres)	Existing Area (%)	Post-Mod Area (acres)	Post-Mod Area (%)
< 1400	3.32	13.8%	3.65	15.1%
1400	4.25	17.6%	9.74	40.4%
2500	12.32	51.1%	5.69	23.6%
3500	4.20	17.4%	5.01	20.8%
5600	0.00	0.0%	0.00	0.0%

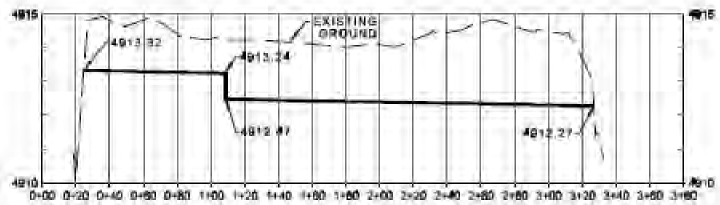
I-40	Total Excavation Volume (yd^3)			62,500
Design Discharge (cfs)	Existing Area (acres)	Existing Area (%)	Post-Mod Area (acres)	Post-Mod Area (%)
< 1400	1.04	4.1%	1.99	7.7%
1400	0.58	2.2%	5.99	23.3%
2500	0.00	0.0%	2.98	11.6%
3500	15.57	60.6%	11.19	43.5%
5600	8.52	33.1%	3.55	13.8%

	Yards
Grand Total	104,164

B
3500 CFS
NO CROSS-GRADING
A'
1400 CFS
NO CROSS-GRADING
A
RIO GRANDE
B'
PLAN VIEW
NEW MEXICO INTERSTATE STREAM COMMISSION
RIO GRANDE
BAR RESTORATION
PHASE II
SITE - SDC-1
Mussetter
Engineering
Inc.



CROSS SECTION A-A'
HORIZ: 1"=100'
VERT: 1"=5'



CROSS SECTION B-B'
HORIZ: 1"=100'
VERT: 1"=5'

NEW MEXICO INTERSTATE STREAM COMMISSION

RIO GRANDE BAR RESTORATION PHASE II

SITE - SDC-11

Mussetter Engineering Inc.

1730 South College Ave. Suite 100 Fort Collins, Colorado 80525 (970) 224-4612

JOB NO: 08-11

TAKE HOME MESSAGES

- **Restoration requires a clear understanding of river dynamics and biological objectives.**
- **Must be able to translate biological objectives into physical parameters to provide a basis of design.**
- **Bar classification provides a first-cut tool for relating fluvial process to habitat requirements and initial site selection.**

Sources of Salinity to the Rio Grande

Fred M. Phillips, James Hogan, Heather Lacey, Elizabeth Bastien, & Suzanne Mills

New Mexico Tech & SAHRA

Coauthors

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Suzanne

James

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

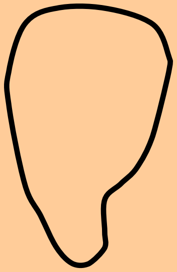
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Heather and Liz

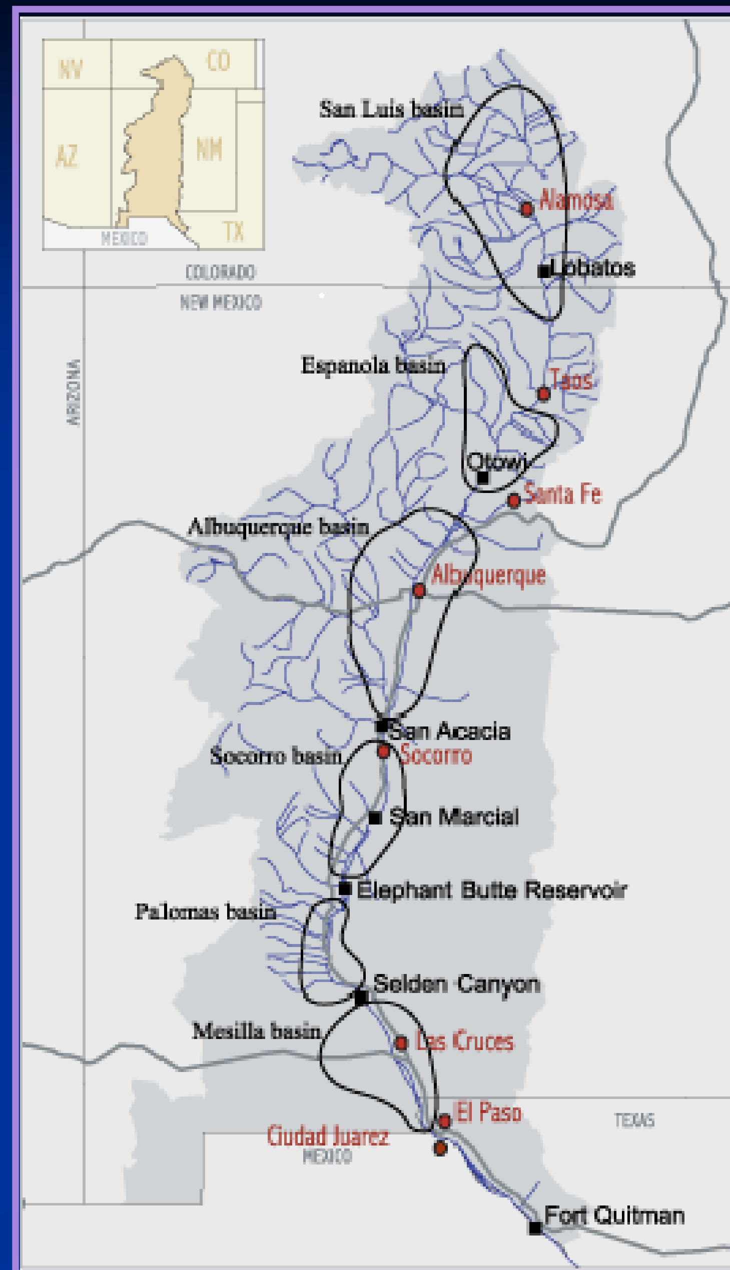
Center for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA)

This research was funded by SAHRA under the Science & Technology Center Program of the U.S. National Science Foundation

Rio Grande basin



= sedimentary basin

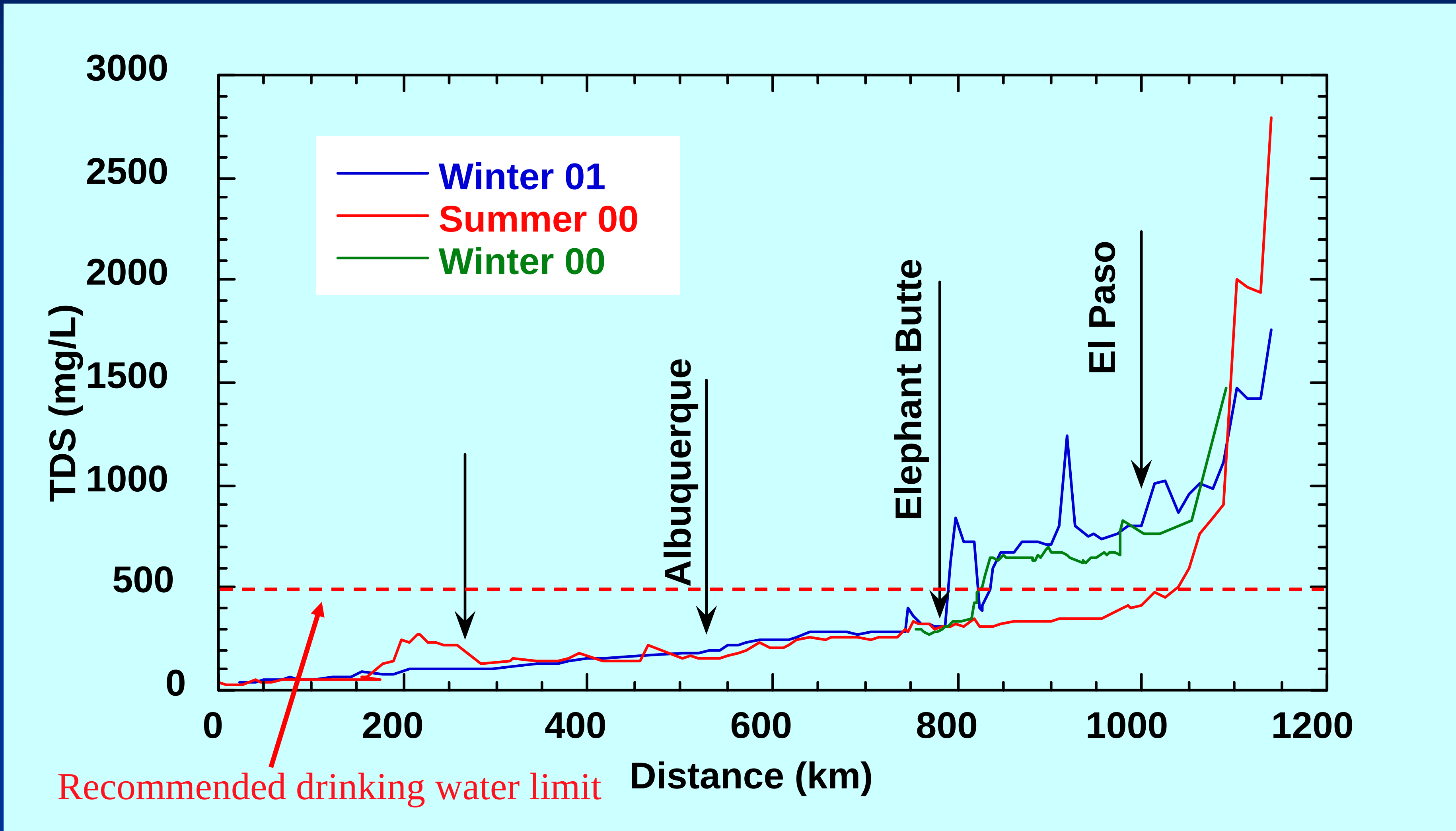


- Basin Area - 32,210 mi^2
- Precipitation - 6 to >50 in.
- Population - 1,072,000 (1990)
- Irrigation - 914,000 acres

Facts about Rio Grande

- Current mean annual discharge at Otawi Bridge (northern New Mexico) is 49 $m^3 s^{-1}$
- Natural discharge (without ag diversions) at this point would have been ~70 $m^3 s^{-1}$
- TDS at headwaters is ~40 $mg L^{-1}$
- TDS at El Paso averages ~750 $mg L^{-1}$
- TDS at Fort Quitman is >2,000

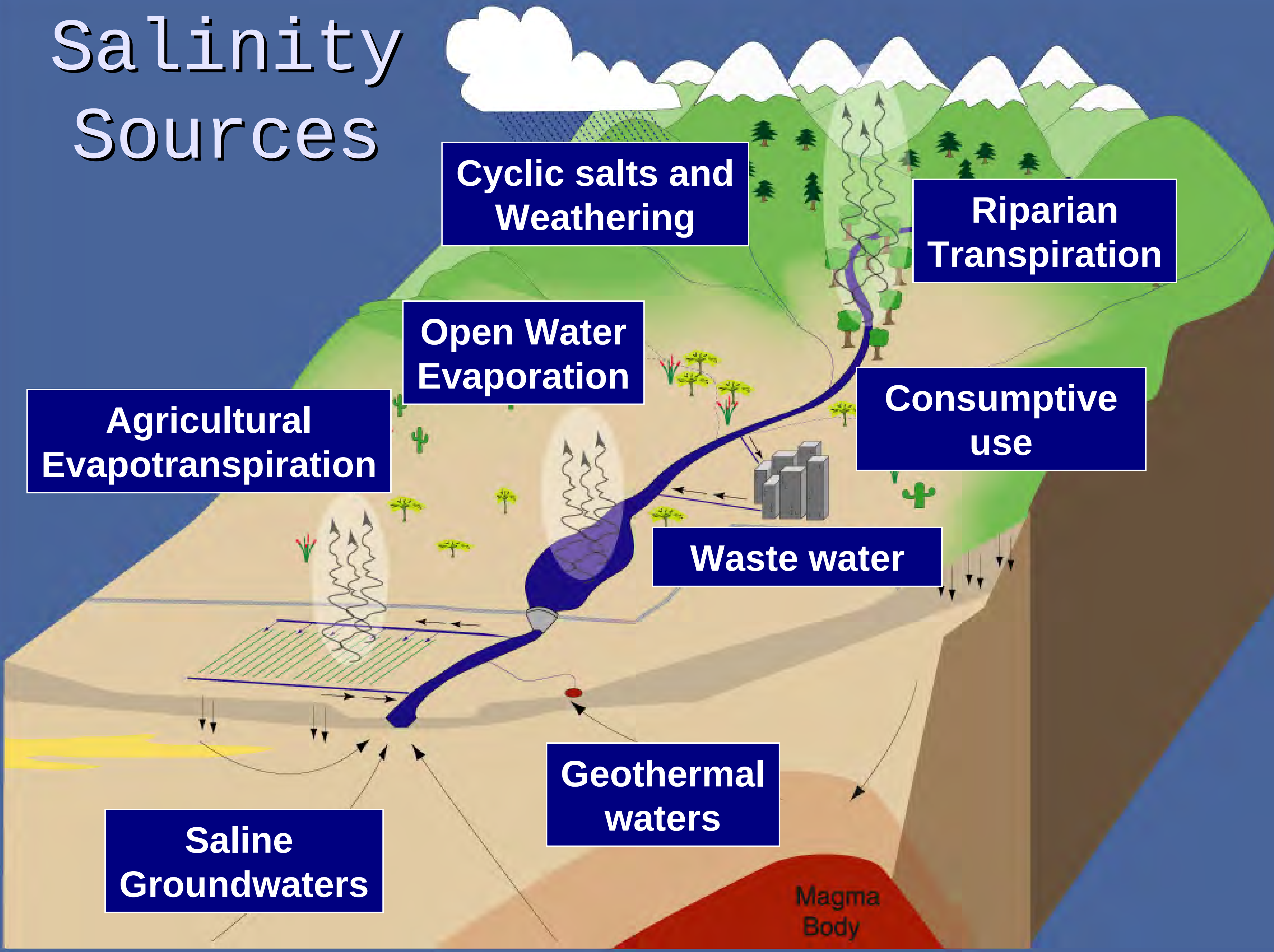
TDS of the Rio Grande



Questions we will try to answer

- Where is the salt coming from?
- What is the salt budget of the river?
- What are the controls on salt and water dynamics in the river system?
- How is the river responding to prolonged drought?

Salinity Sources



Where is the salt coming from?

- There are no known evaporite deposits under the Rio Grande rift
- There are a few moderately saline hot springs, but salt output is small
- River water is consumed by three major irrigation districts along the course of

What have previous investigators said?

Hypothesis 1: Effects of evapotranspiration

J.B. Lippincott (1939): "The increase in salinity of the waters of the Rio Grande [is] due to their use and re-use [for irrigation] in its long drainage basin..."

Hypothesis 1: Effects of evapotranspiration

Trock et al. (1978) "The deterioration in the water quality of the Rio Grande ... is due principally to the concentrating effect of irrigation."

Hypothesis 2: Groundwater displacement

Wilcox (1957): "There is a relatively large increase in the tonnage of both sodium and chloride from the upper to the lower stations... [that can be] attributed to the displacement of salty groundwater in the course of irrigation and drainage operations."

Hypothesis 3: "Continental solute erosion"

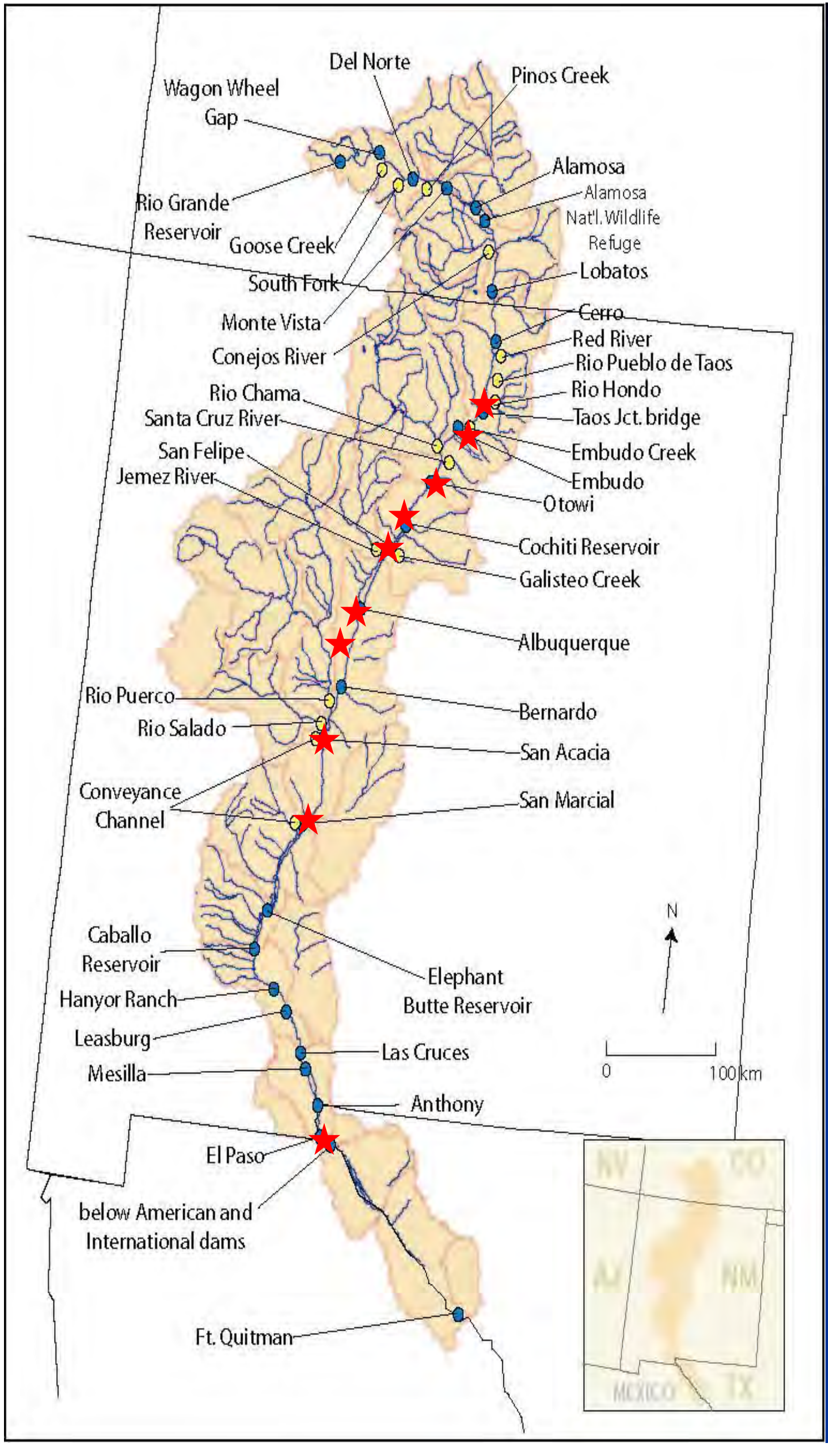
van Denburgh and Feth (1965): Noted that only 4.2% of the chloride burden of the Rio Grande originated from atmospheric deposition over the catchment and attributed the remainder to"continental solute erosion".

How to Quantify Sources and Causes of Salinization?

- Traditional approach: Measure discharge and salt concentrations at gaging stations and compute salt burden
- Alternative Approach: Measure environmental tracers at high spatial resolution and employ dynamic simulation to interpret results

Potential Tracers

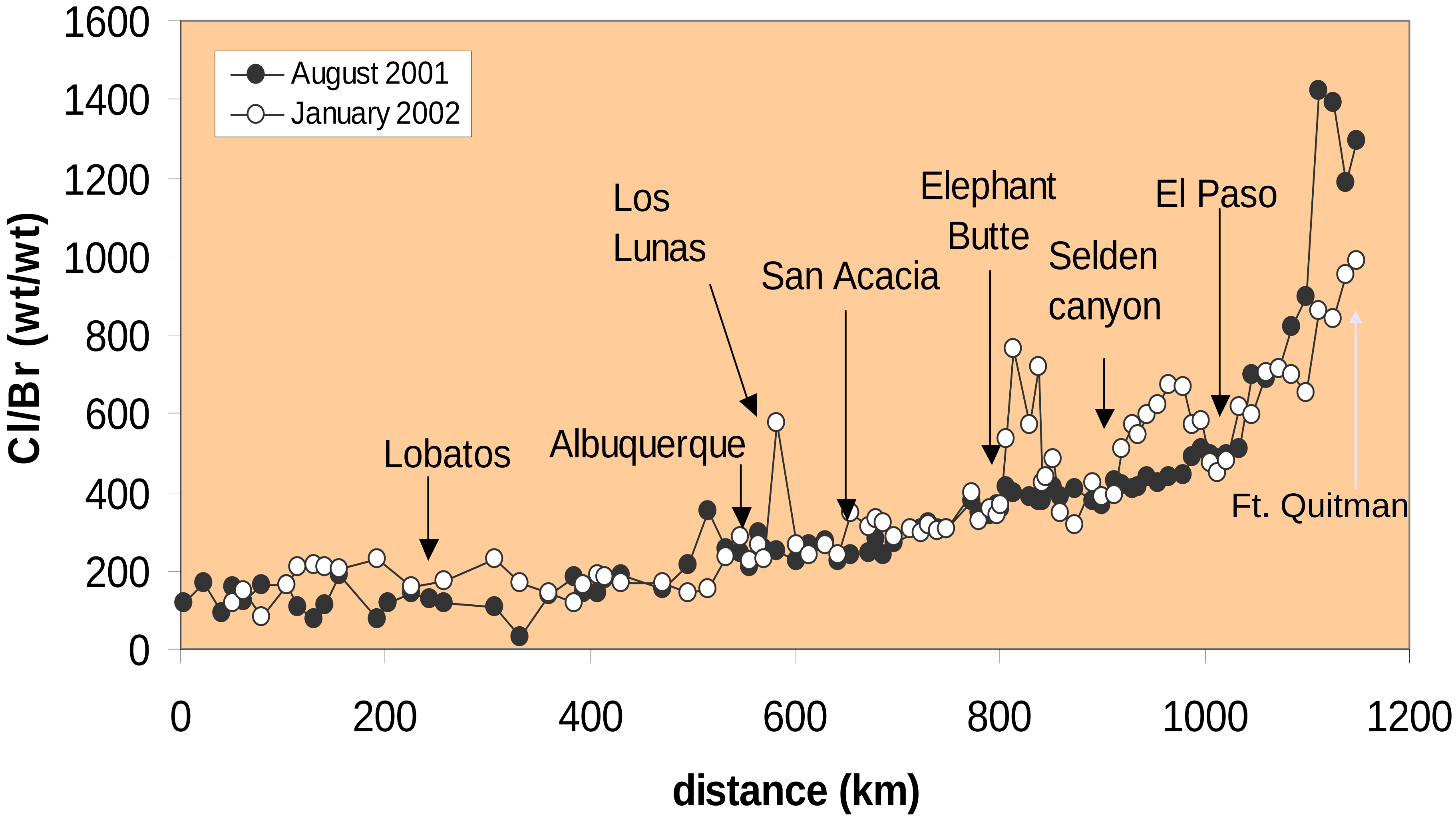
- Cl
- Cl/Br
- ^{36}Cl
- $\delta^{37}Cl$
- $\delta^{18}O$ and $\delta^{2}H$
- $^{87}Sr/^{86}Sr$
- $^{234}U/^{238}U$



Sampling locations along the Rio Grande

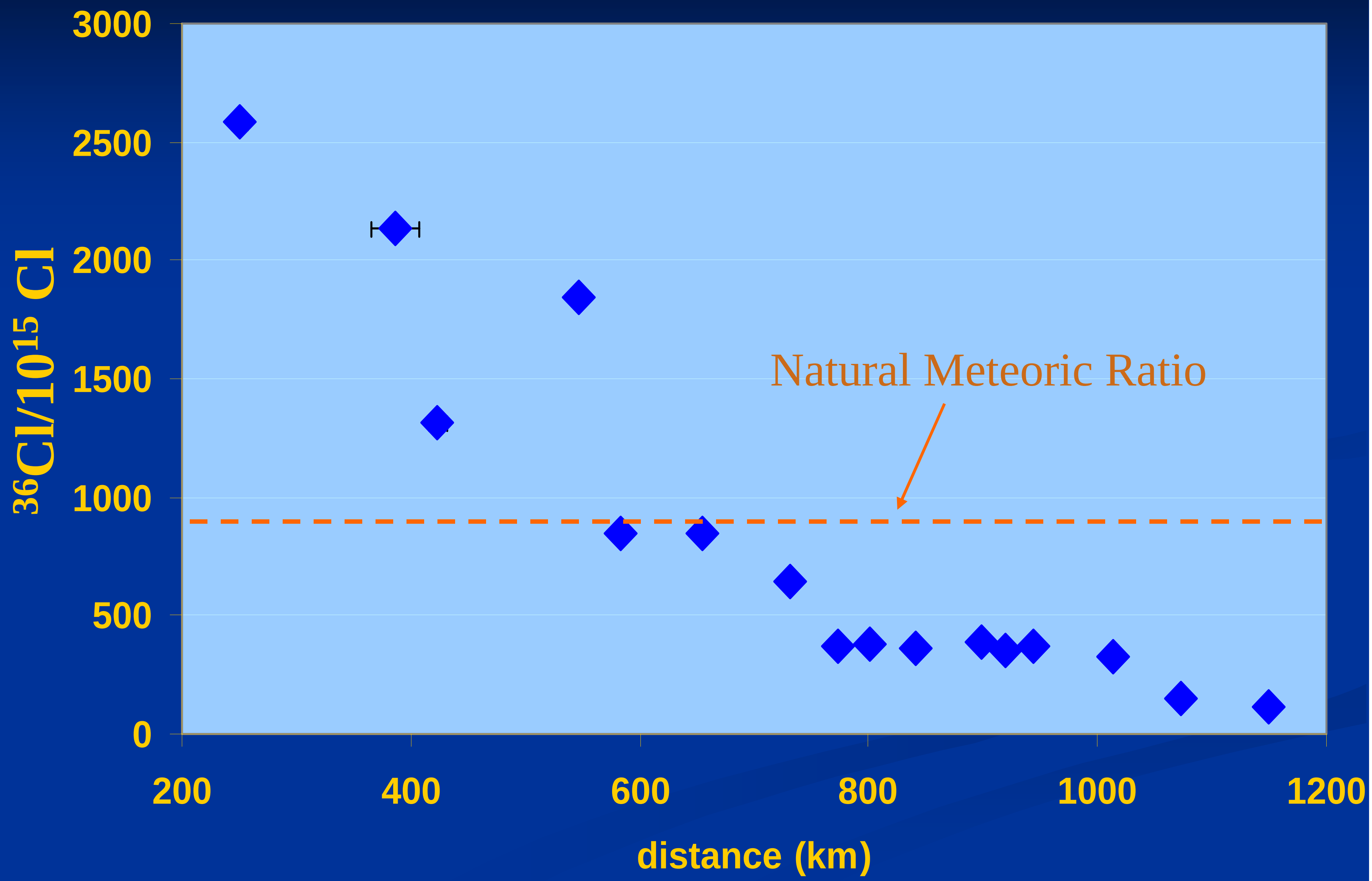
Chloride/Bromide Data

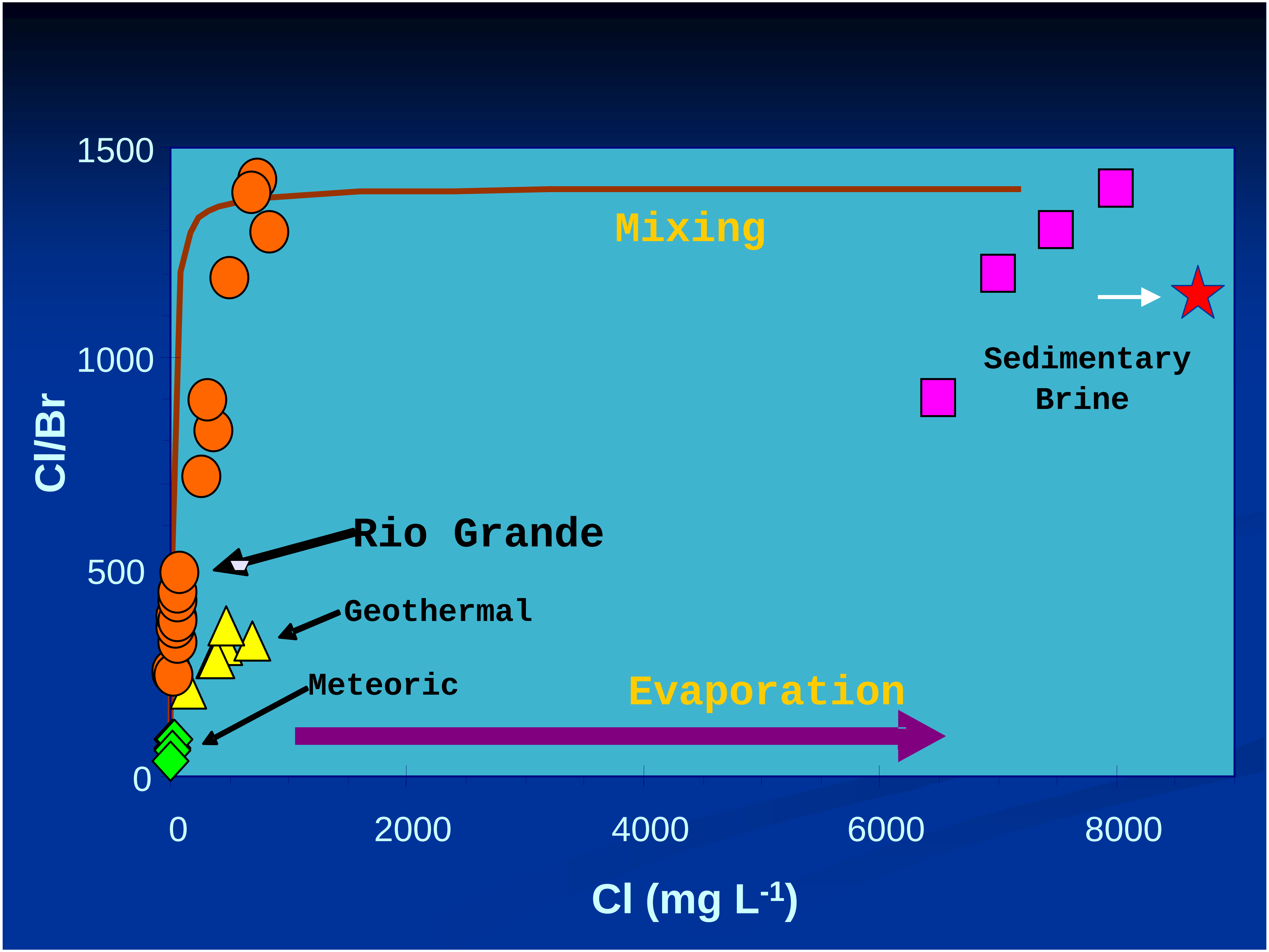
Patterns of Salt Addition cont'd: Cl/Br in the Rio Grande

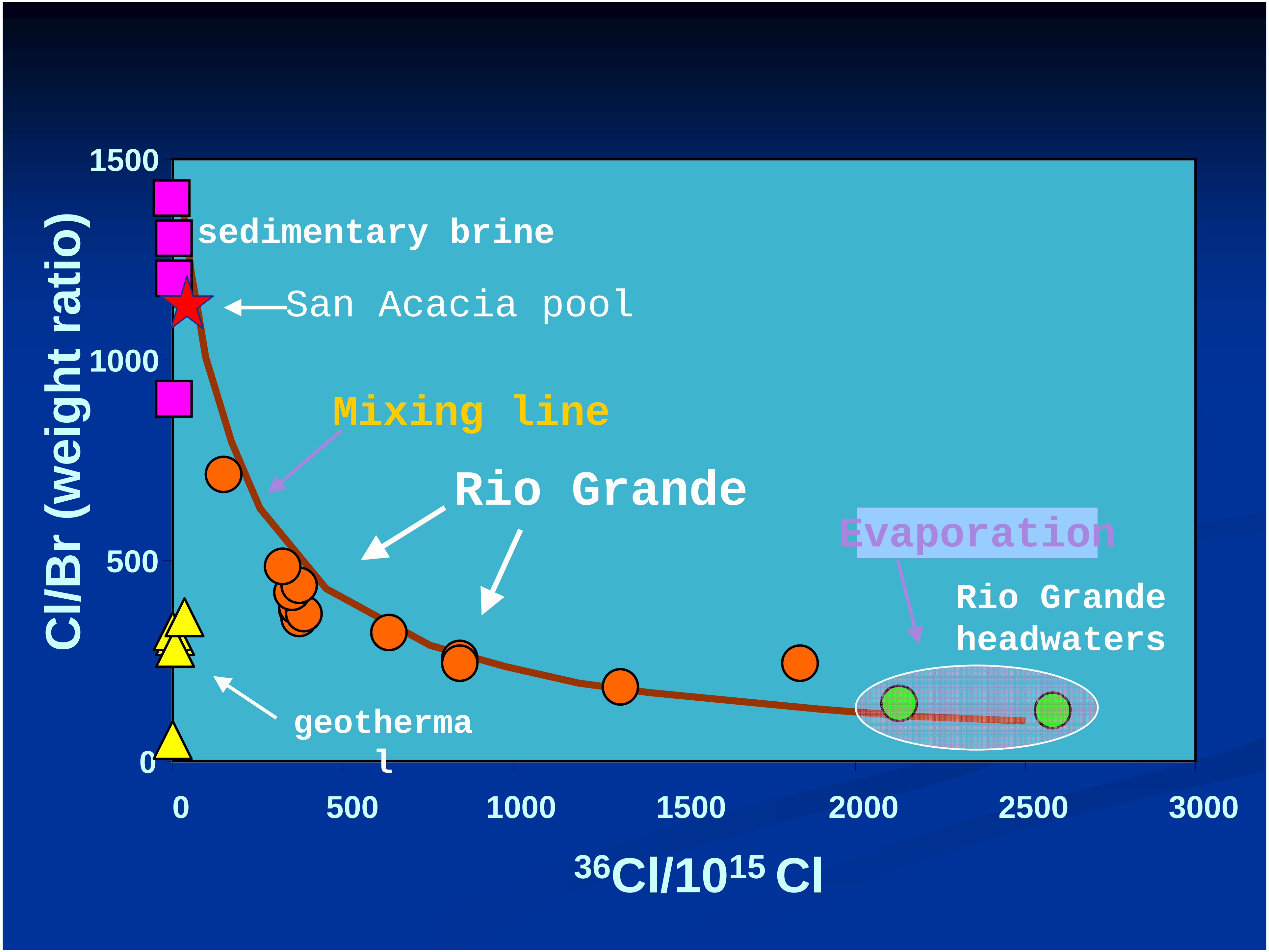


Chlorine-36 Data

^{36}Cl vs. flow distance




1500
1000
500
0
Cl/Br
0
2000
4000
6000
8000
Cl (mg L-1)
Mixing
Sedimentary
Brine
Rio Grande
Geothermal
Meteoric
Evaporation



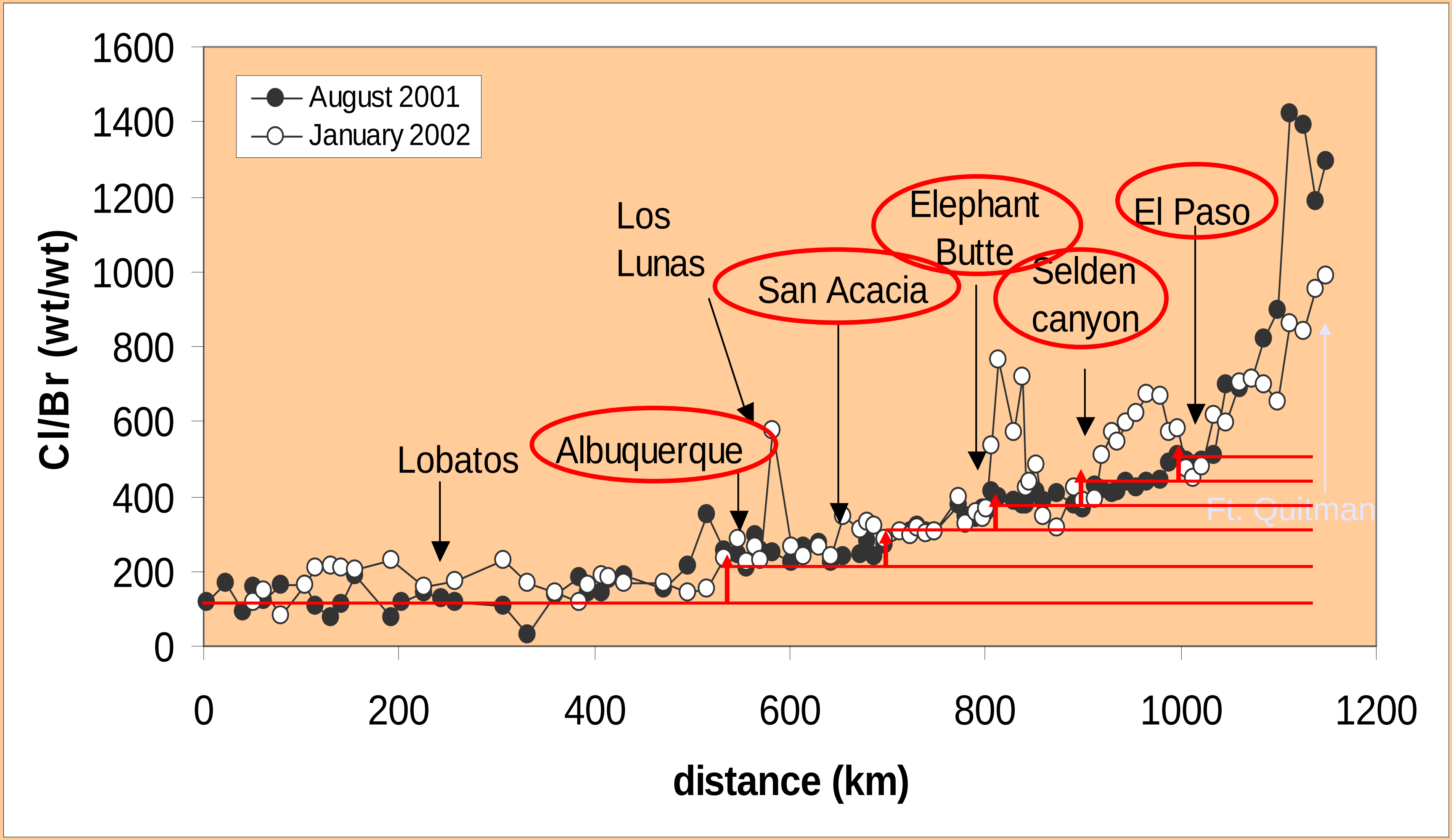
Cl/Br (weight ratio)
1500
1000
500
0
sedimentary brine
San Acacia pool
Mixing line
Rio Grande
Evaporation
Rio Grande
headwaters
geotherma
l
0
500
1000
1500
2000
2500
3000
$^{36}Cl/10^{15}$ Cl

Result from tracer work

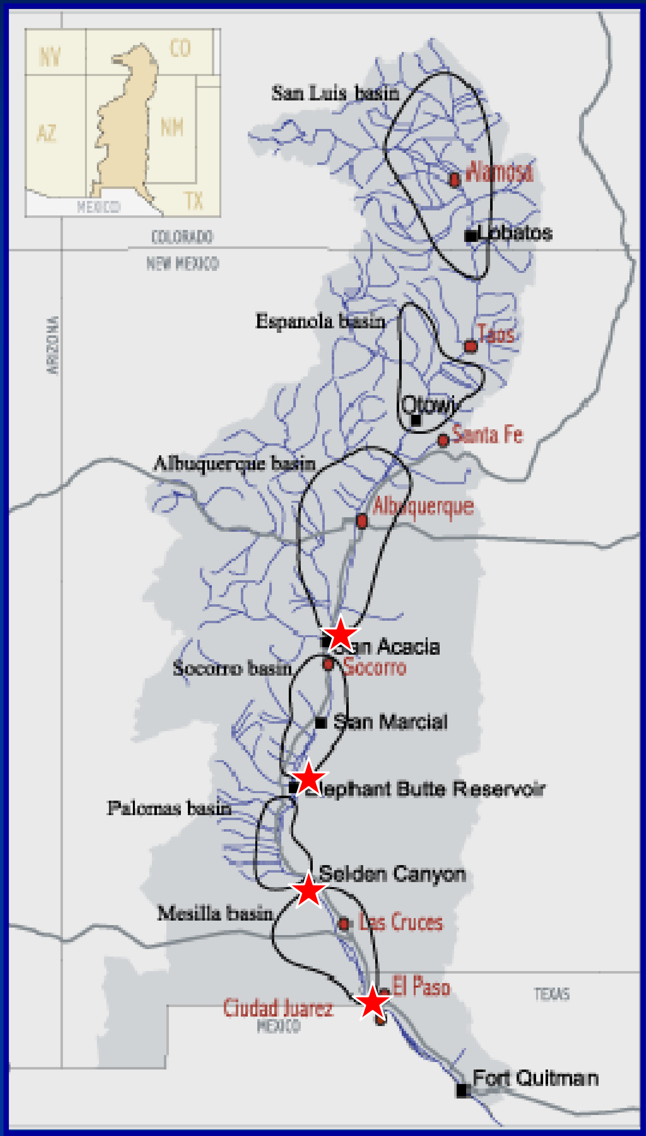
A large part of the salinization of the Rio Grande is due to seepage of deep, sedimentary-origin brines

Where are these brines entering the Rio Grande?

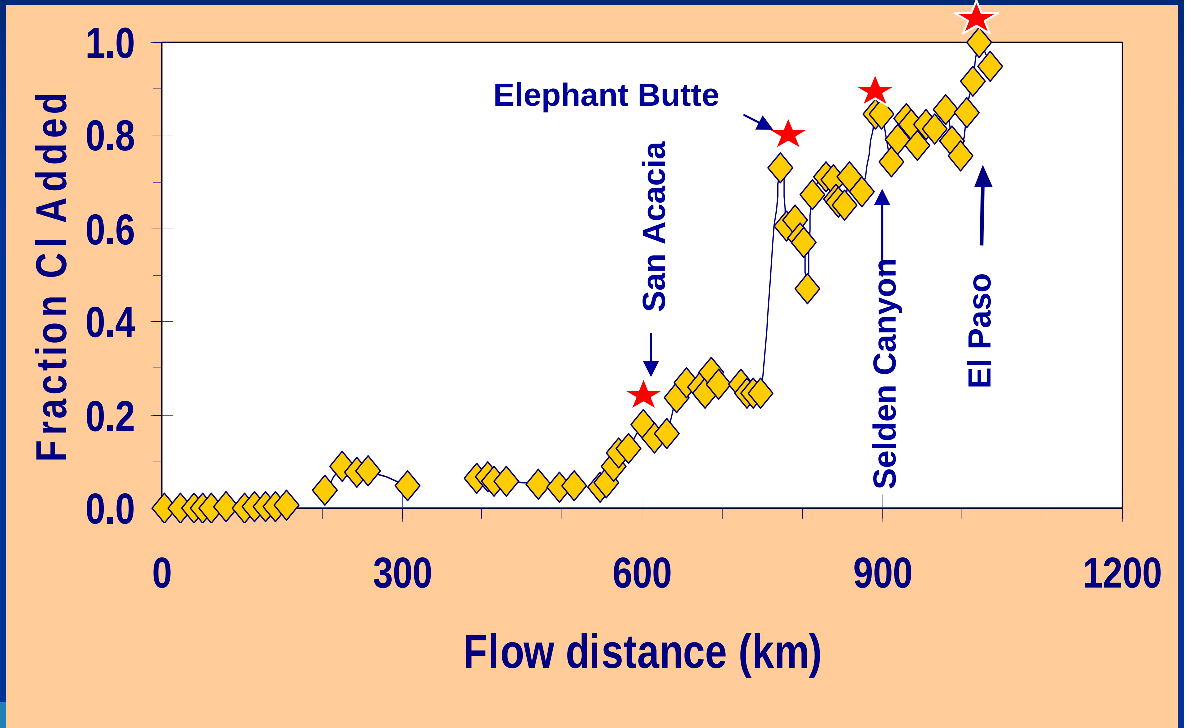
Patterns of Salt Addition cont'd: Cl/Br in the Rio Grande



Points of Salt Addition

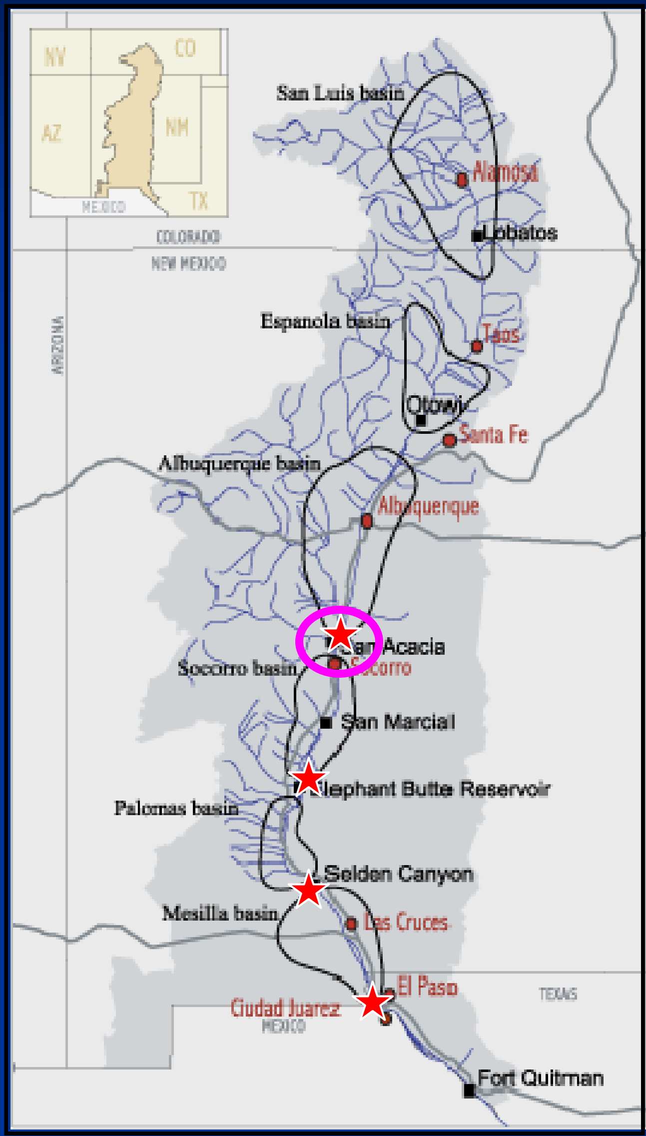


Fraction Cl Added vs. flow distance

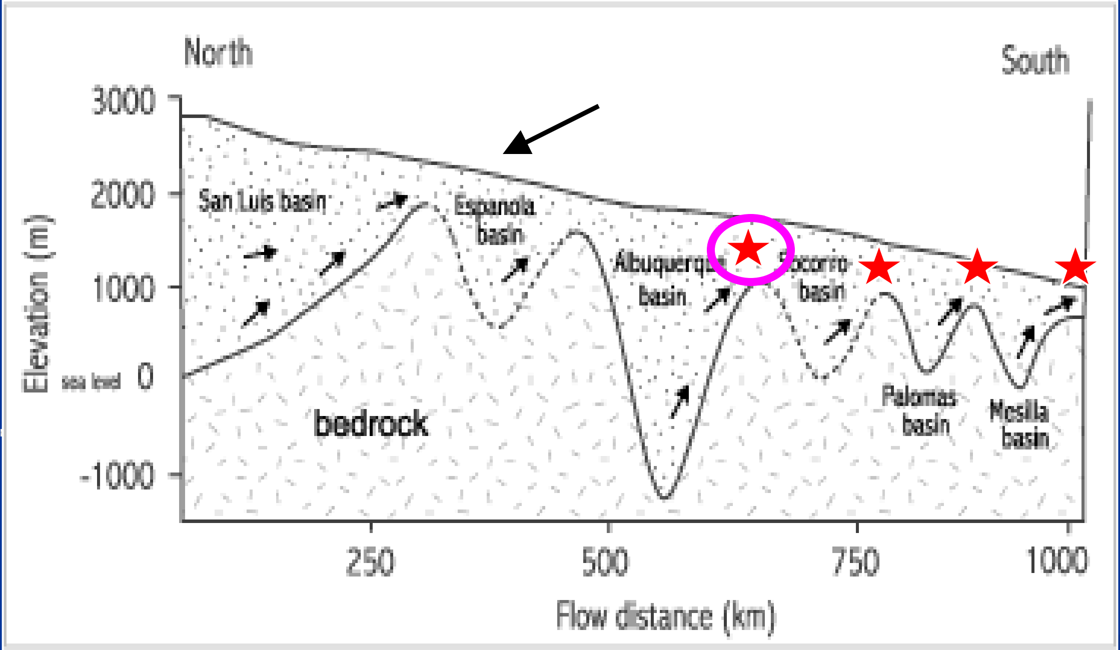


★ = basin terminus

Basin Groundwater Systems



Schematic Hydrogeologic Cross-Section, Parallel to River Path



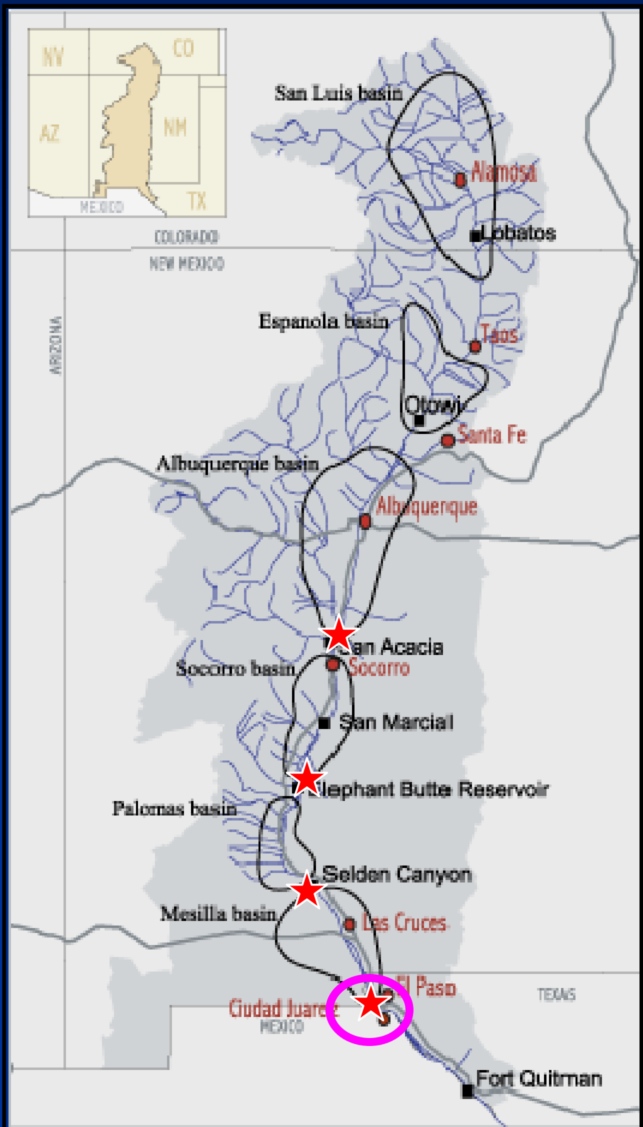
★ = basin terminus

Saline input: San Acacia pool

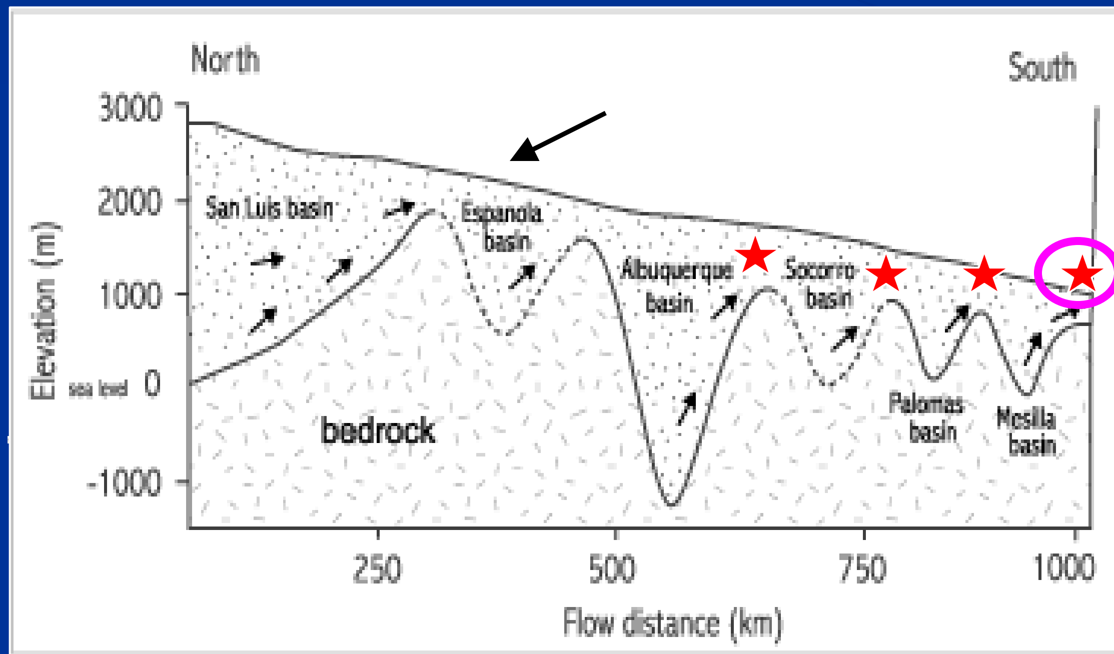
[Cl^-] = 32,300 mg L^{-1}

salt-encrusted tree stumps

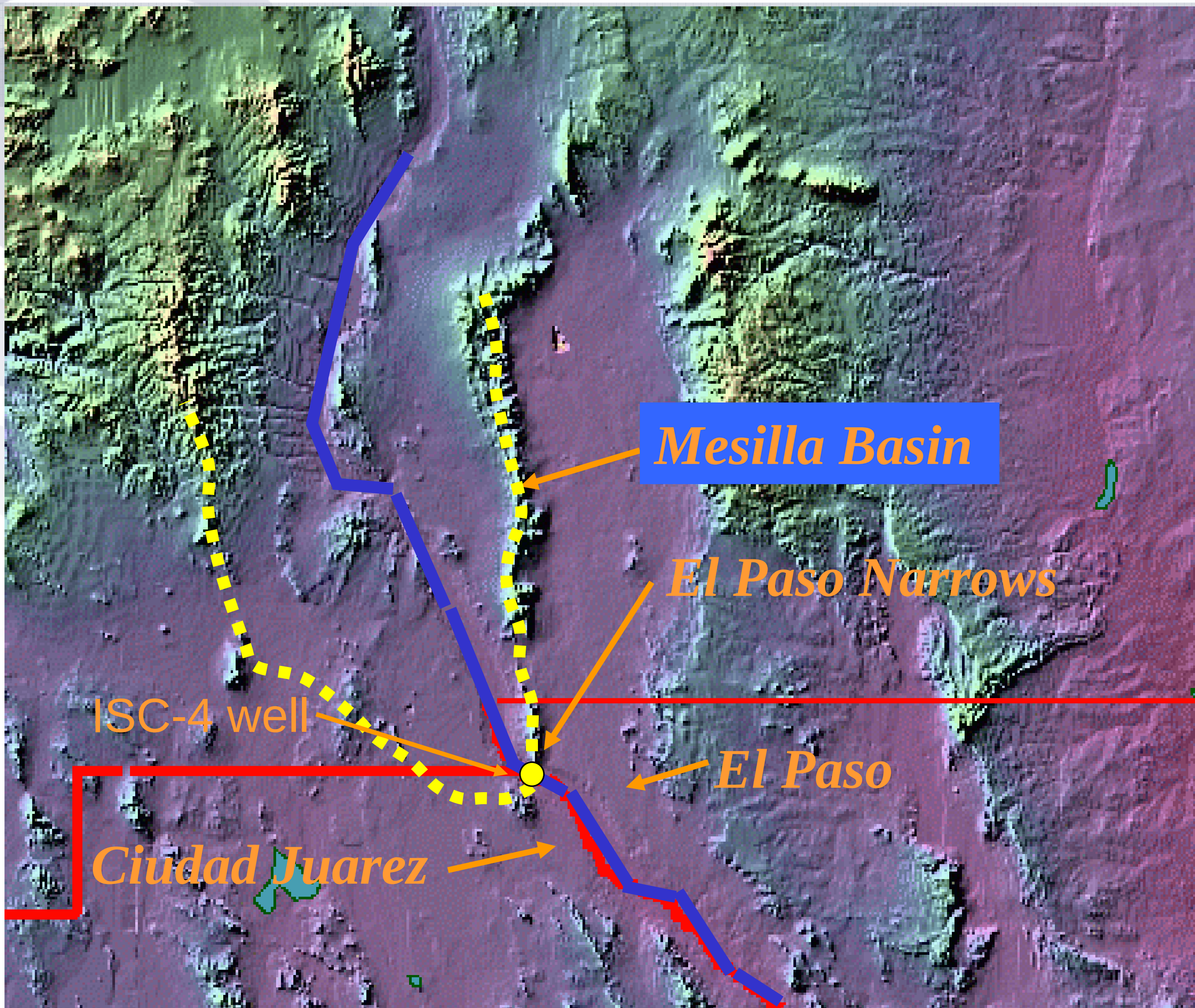
Basin Groundwater Systems



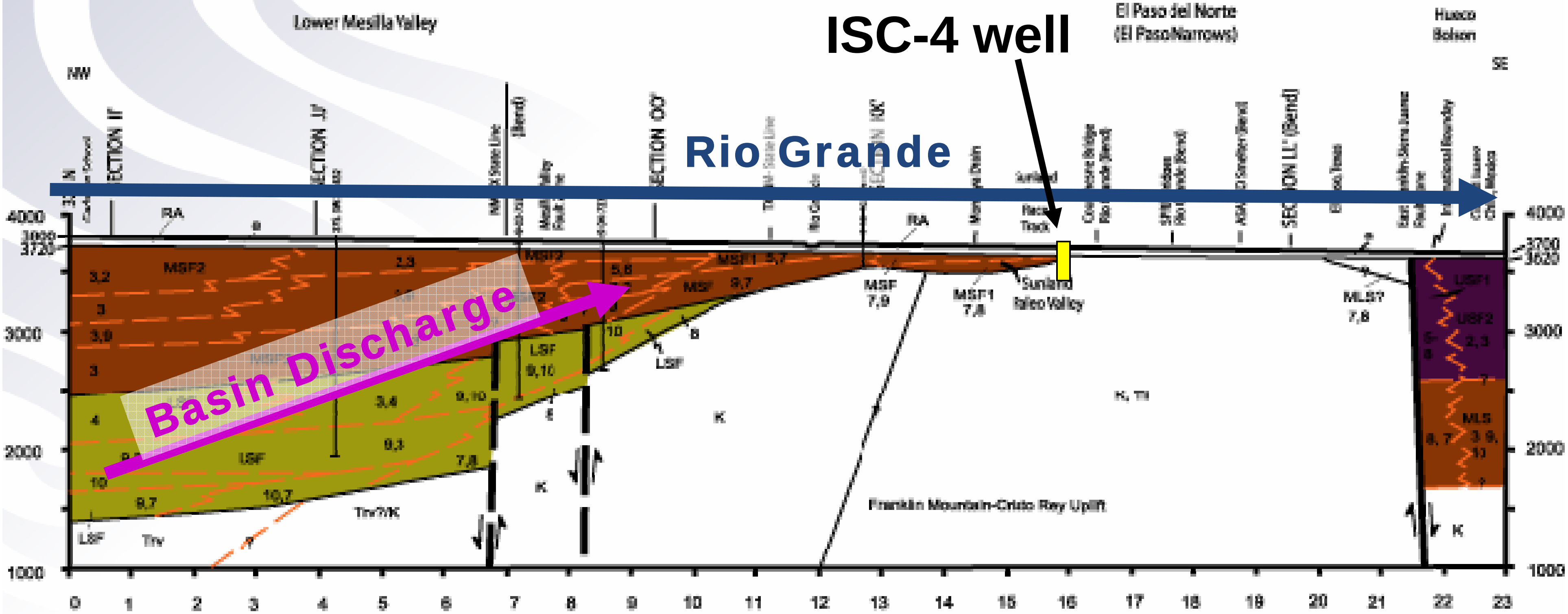
Schematic Hydrogeologic Cross-Section, Parallel to River Path



★ = basin terminus

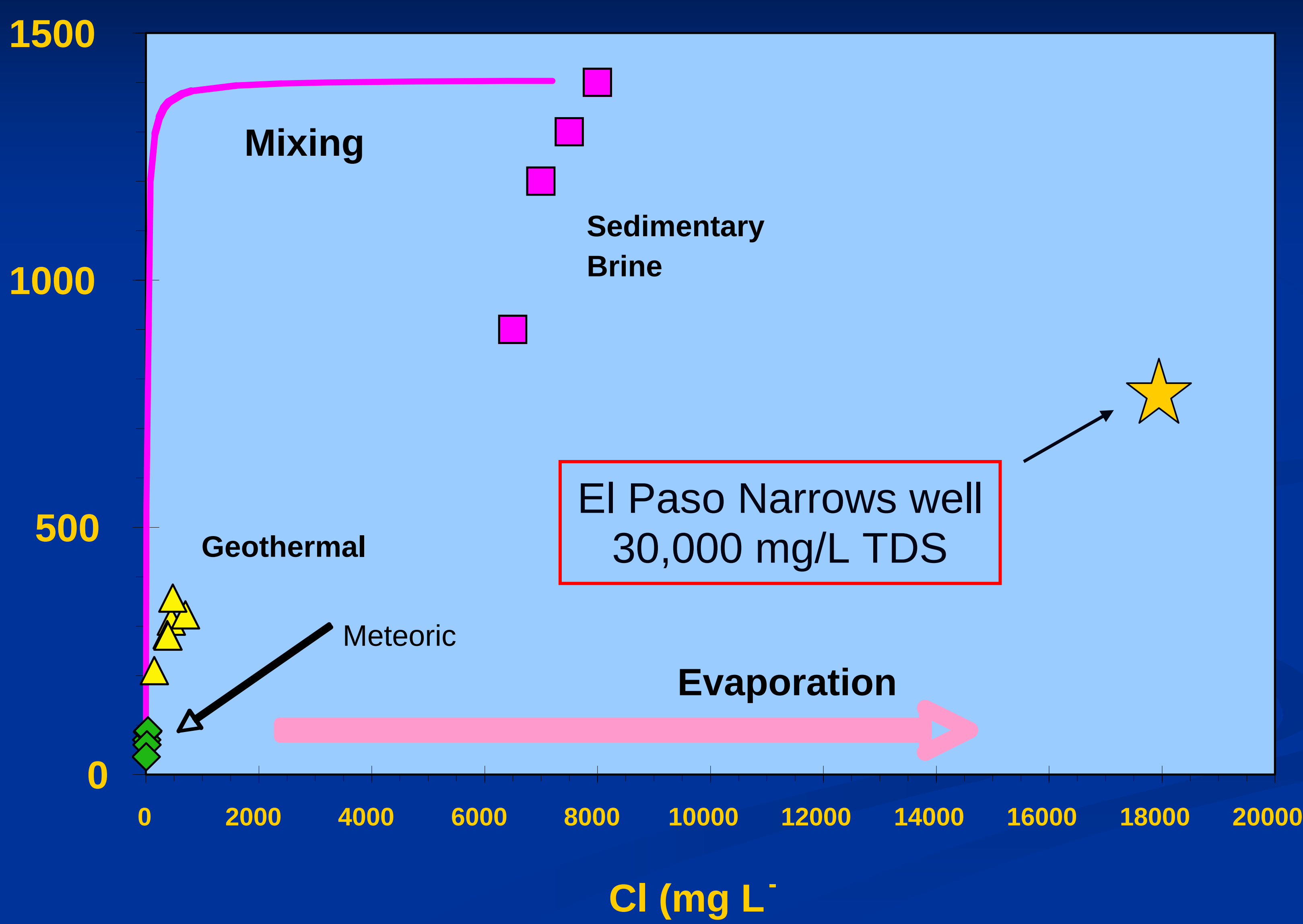

Mesilla Basin
El Paso Narrows
ISC-4 well
El Paso
Ciudad Juarez

El Paso del Norte



- Cross section through Paso del Norte along Rio Grande
- Basin flow from Mesilla basin forced up
- Recharge when entering the Hueco Bolson

El Paso Narrows well results

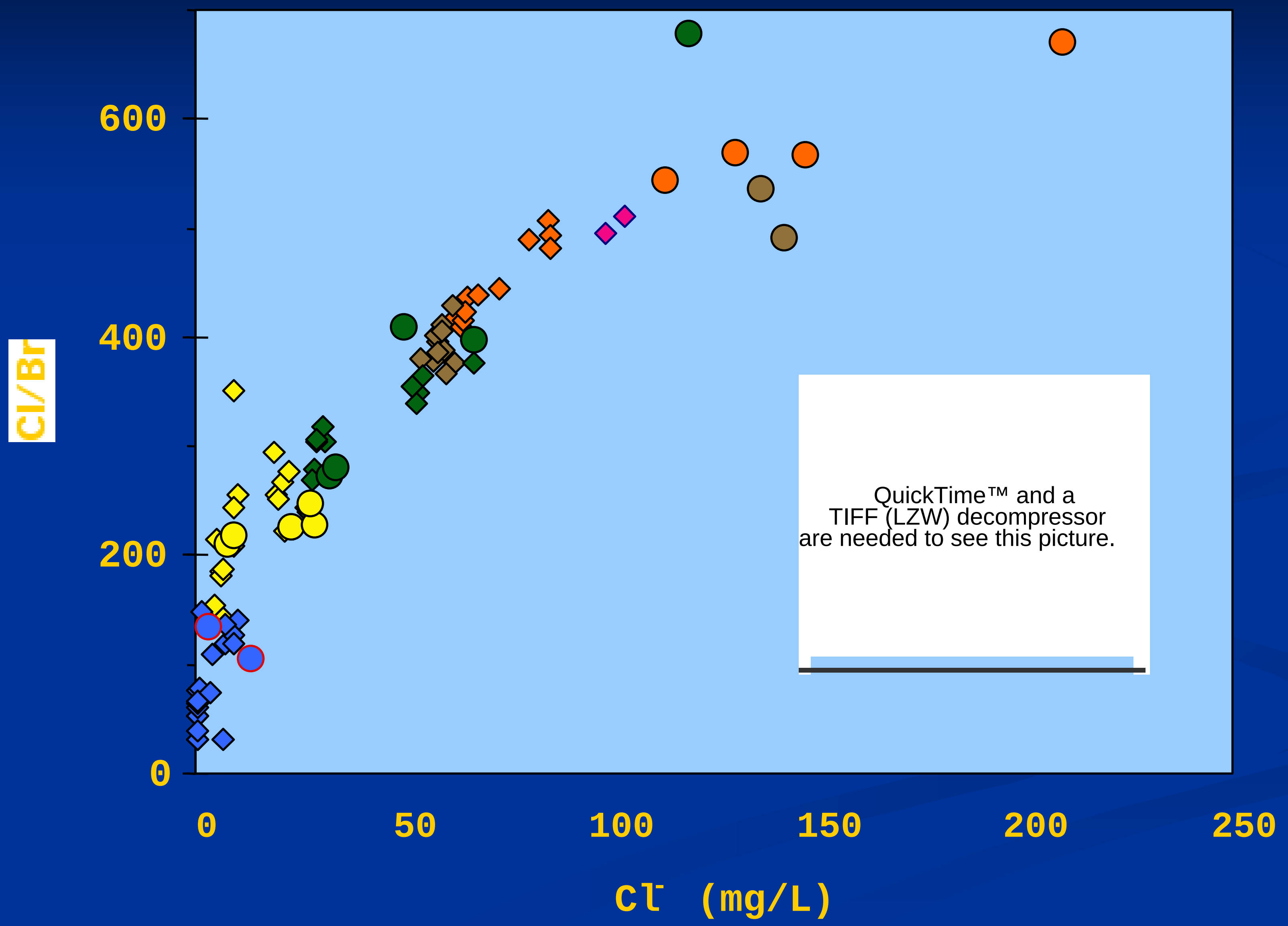


Findings from subsurface investigations

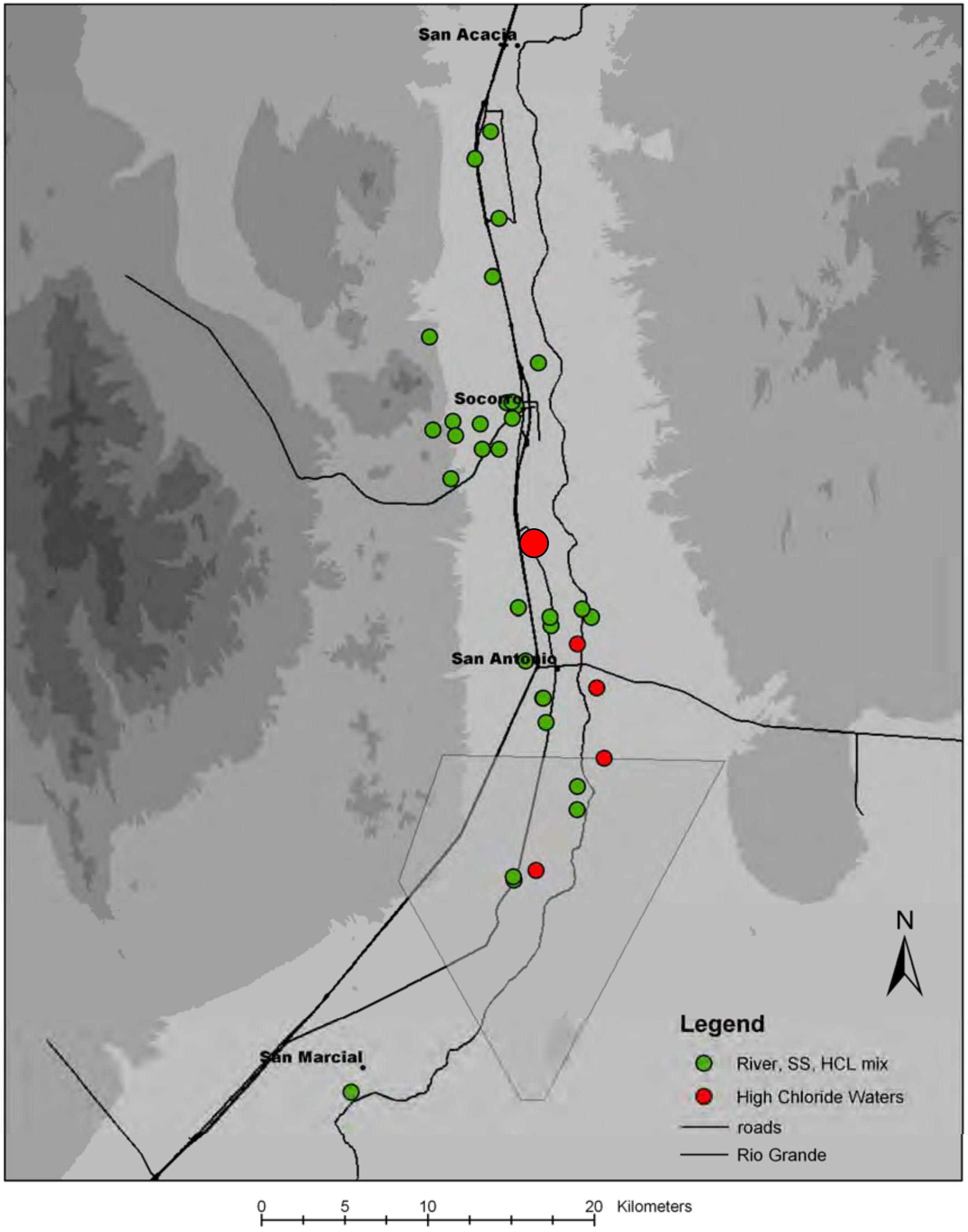
Sites of brine leakage along structurally-controlled pathways can be clearly identified in the field

Role of agriculture?

Influence of Drains

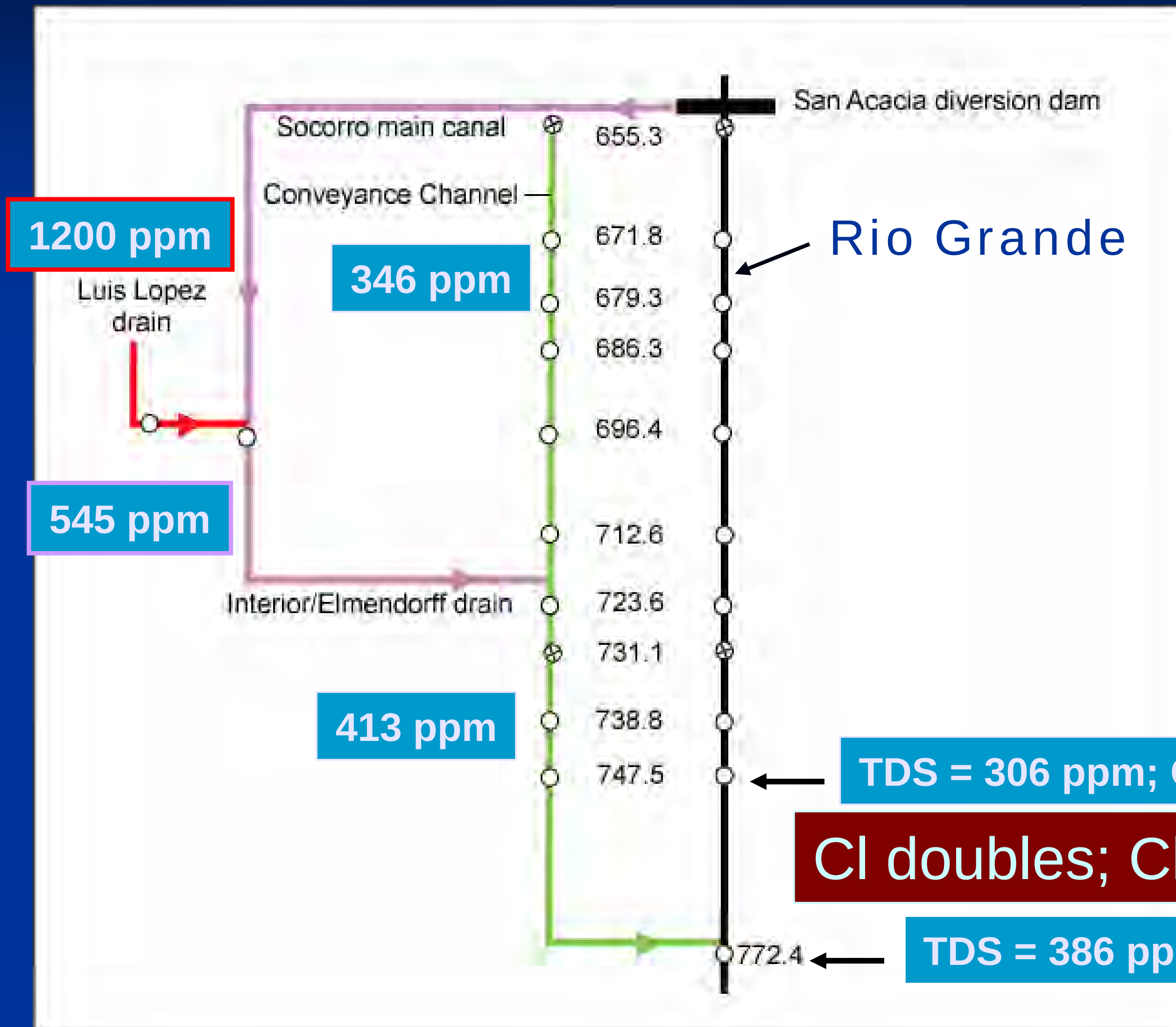


Location of high chloride waters



Talon Newton, M.S. Thesis, 2004

Drains pick up deep-basin salts



TDS = 306 ppm; Cl = 30 ppm; Cl/Br = 306

Cl doubles; Cl/Br increases 30%

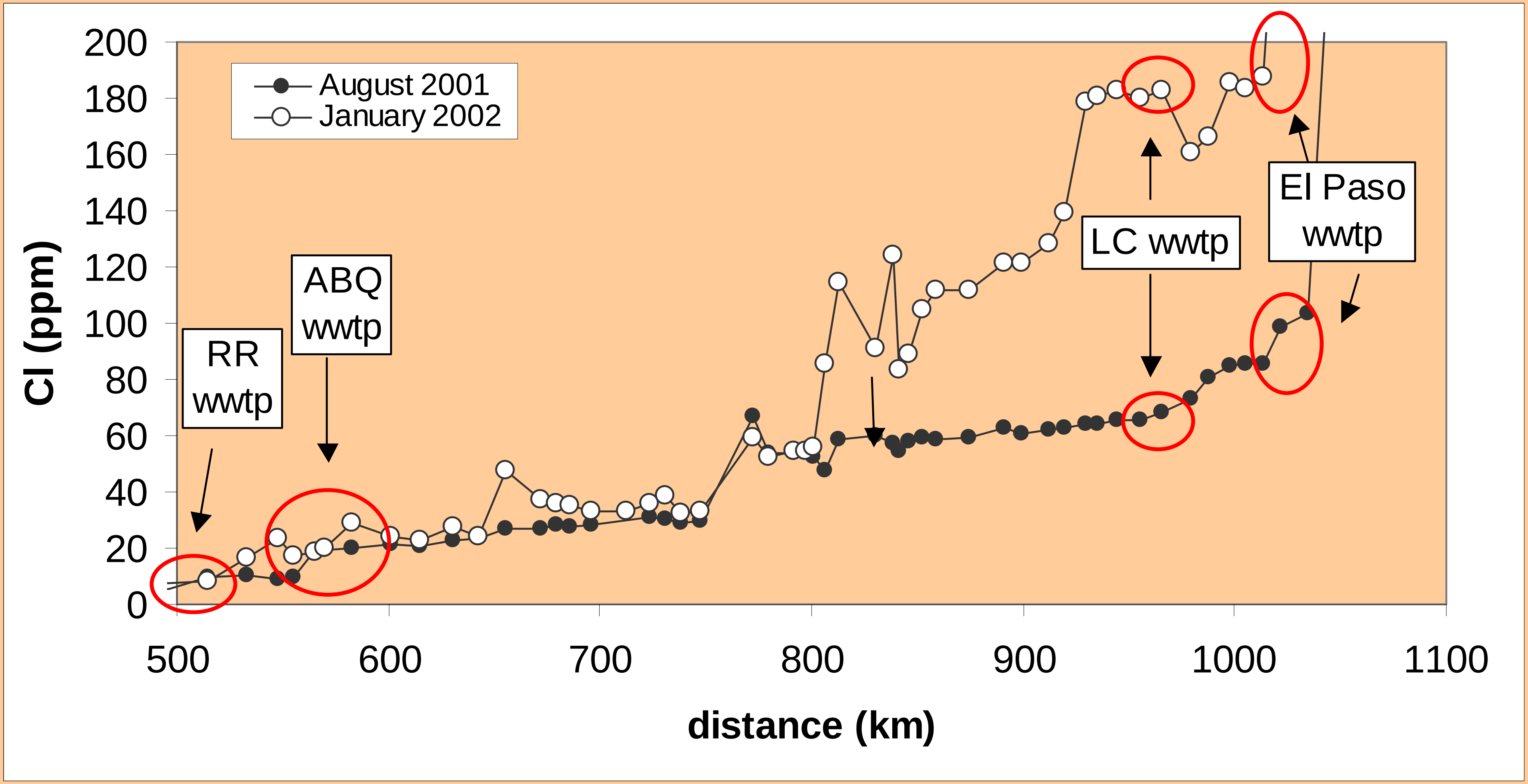
TDS = 386 ppm; Cl = 66 ppm; Cl/Br = 376

Summary of Findings

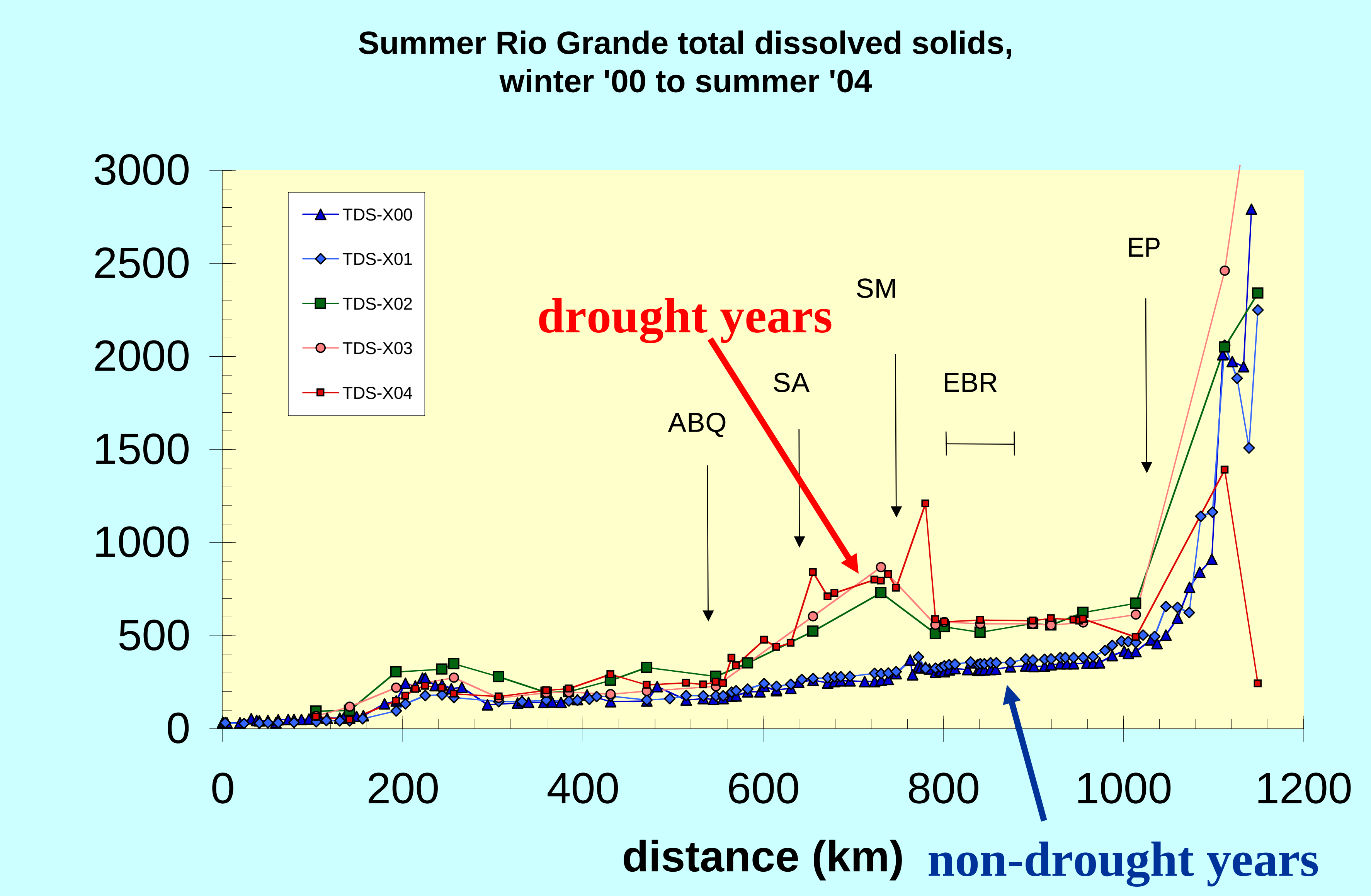
- Salt addition to the Rio Grande occurs in a stepwise pattern
- Salt is added at San Acacia, Elephant Butte, Selden Canyon, and the El Paso narrows (and T or C)
- Salt is either connate or from long-term rock/water interaction

Influence of wastewater

The Rio Rancho, Albuquerque, Las Cruces, and El Paso (Northwest WWTP) wastewater effluents all increase Cl^- and Cl/Br in the river.



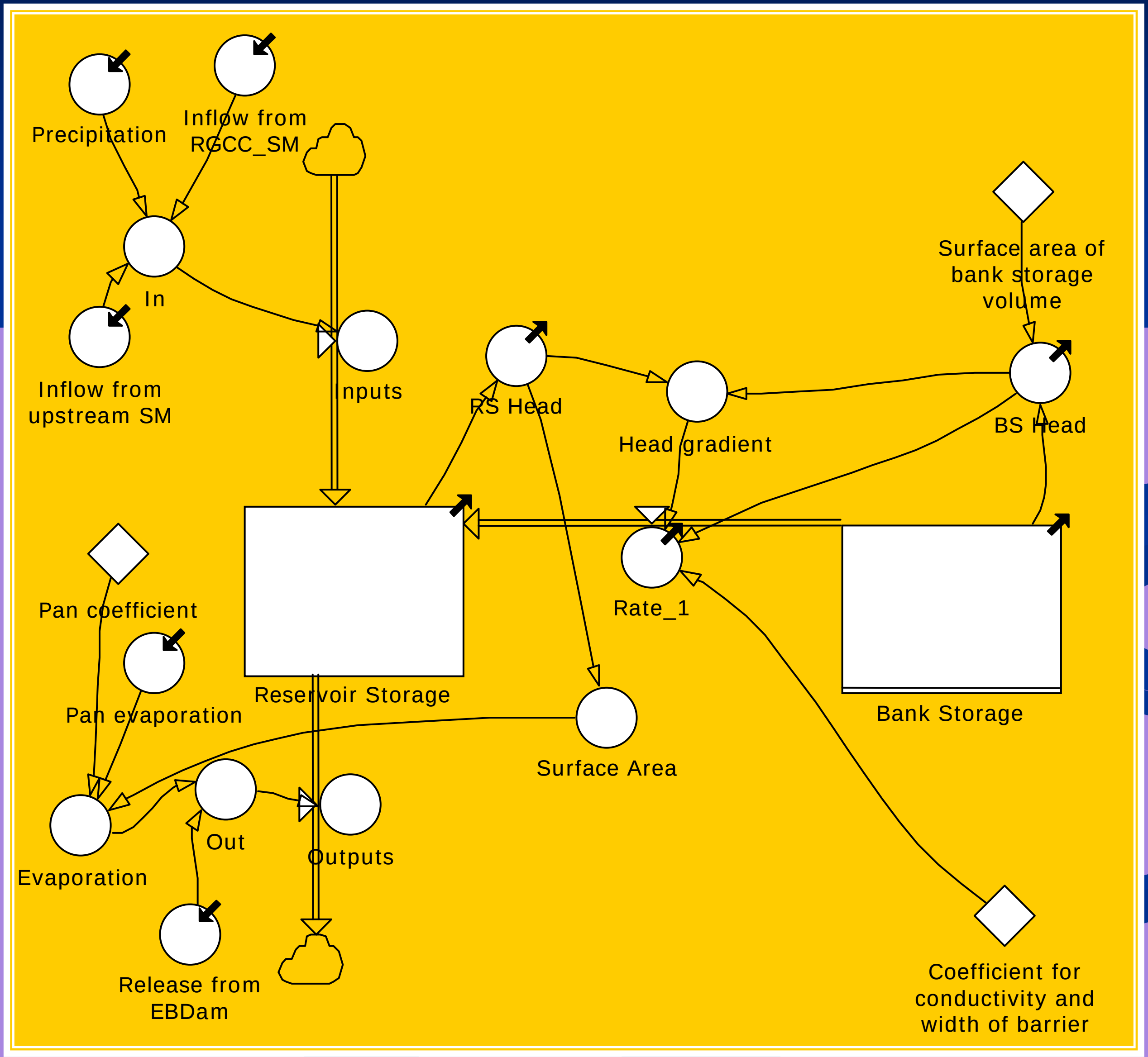
Response to drought



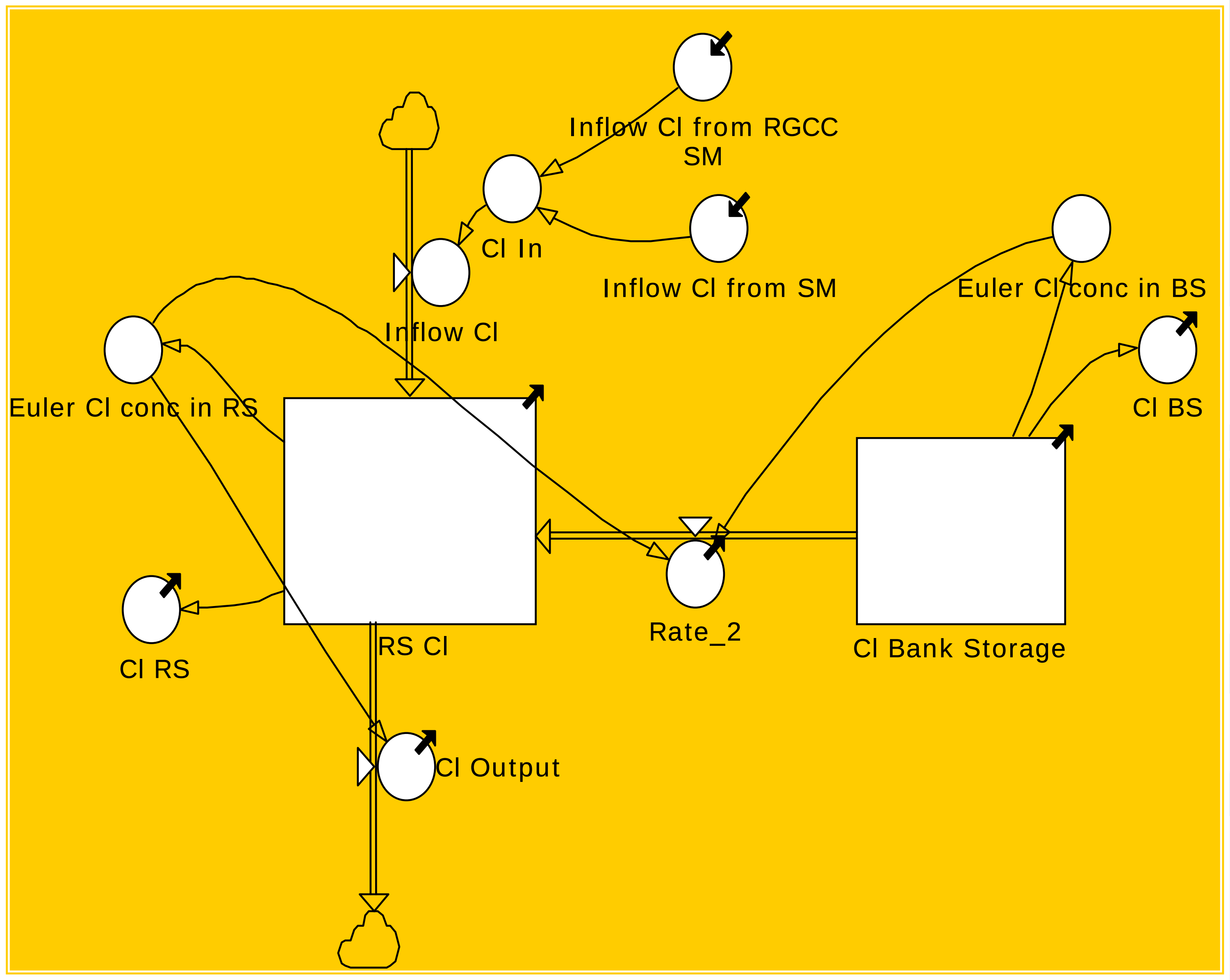
Chloride concentrations and loads are highly variable in time and location

We need a dynamic modeling tool to adequately understand budgets and variability of solutes in the Rio Grande

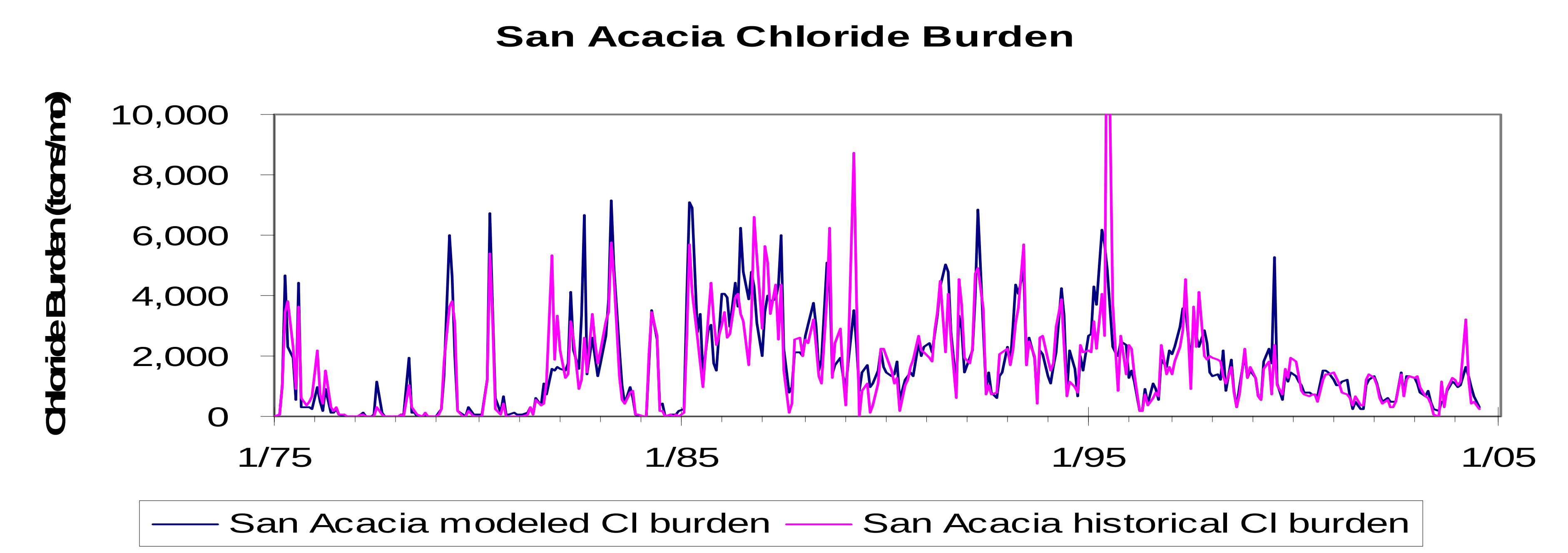
Powersim modeling - water model

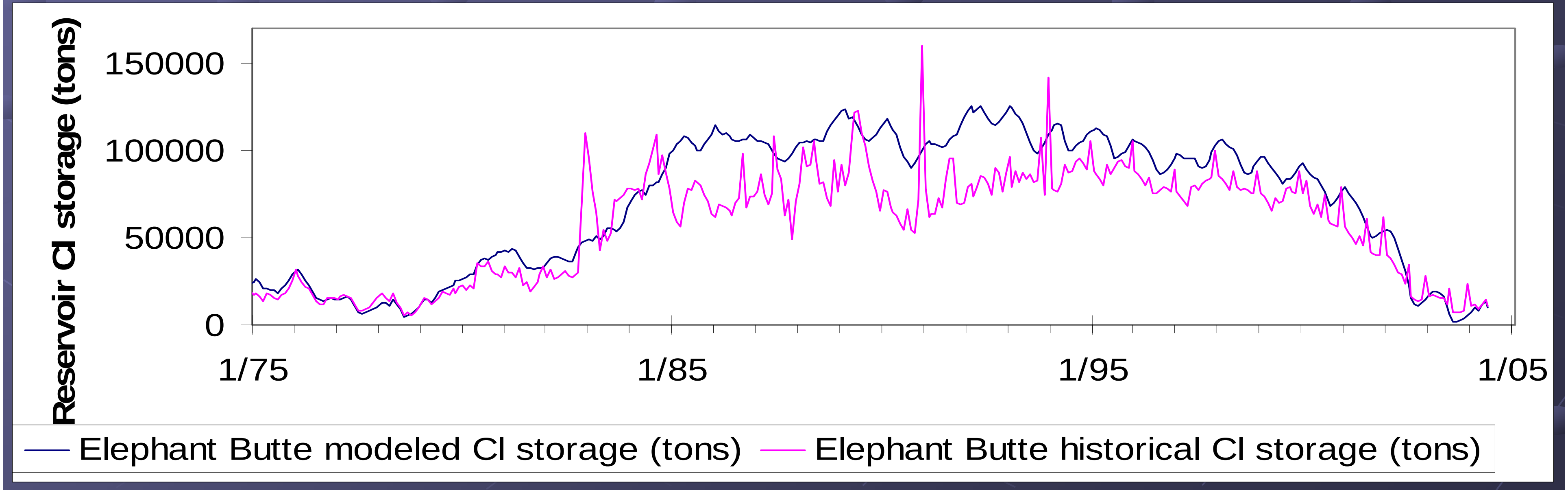


Powersim modeling - chloride model

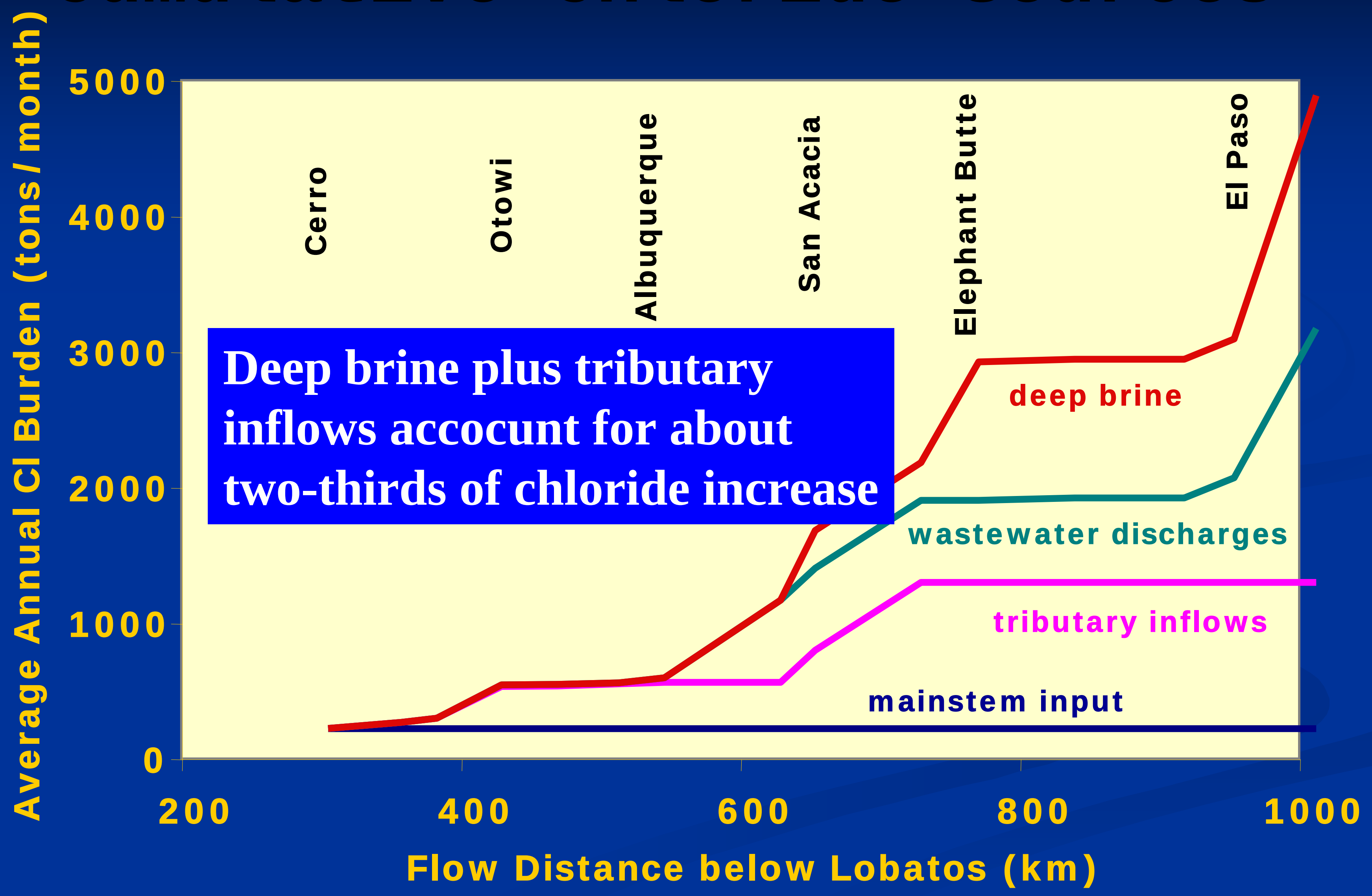


Model Results w/brine inflows: Cl burden





Cumulative Chloride Sources



Historical Perspective

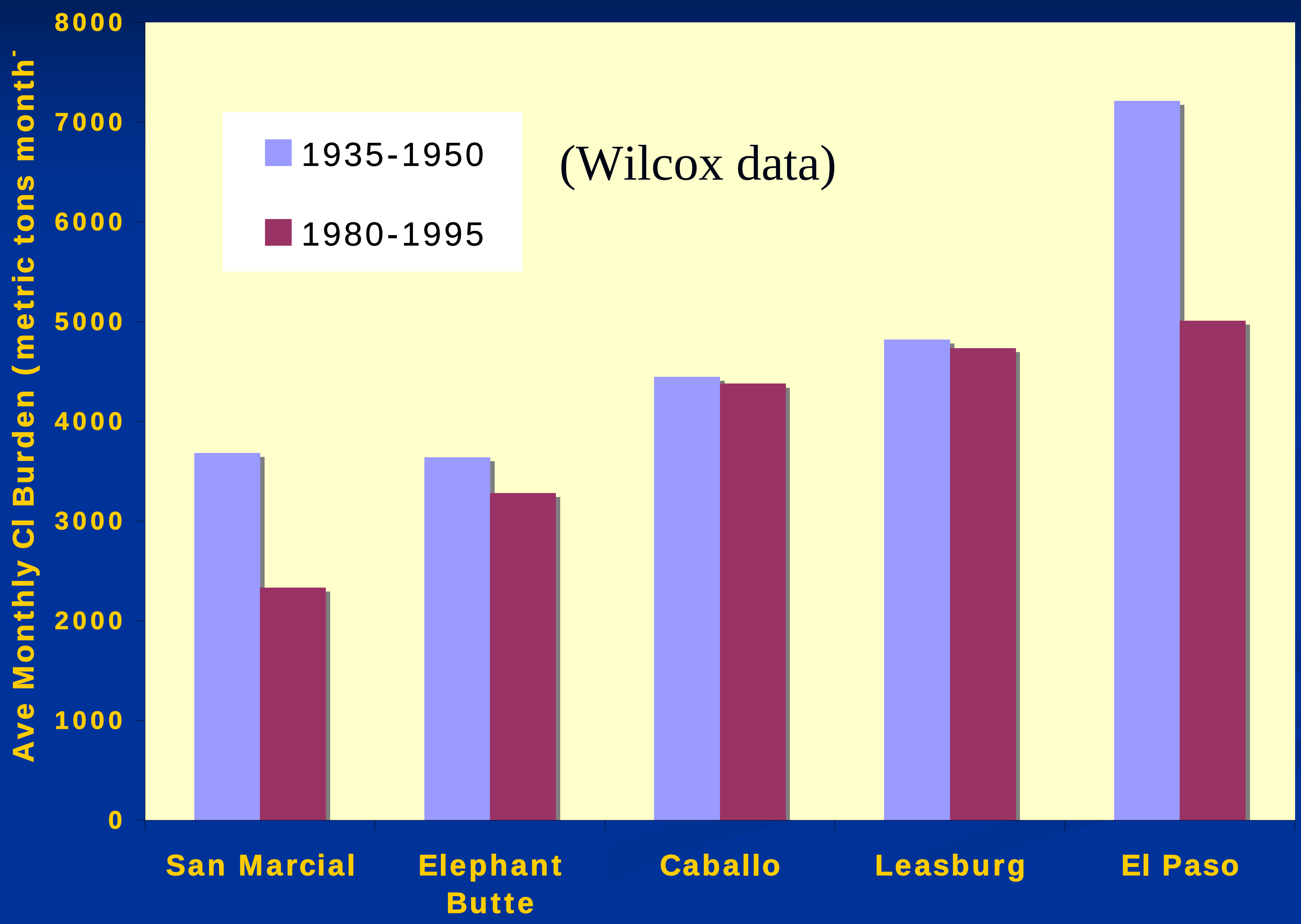
Are modern practices responsible for worsening water quality? (perhaps by increasing brine inflows?)

Two important past studies:

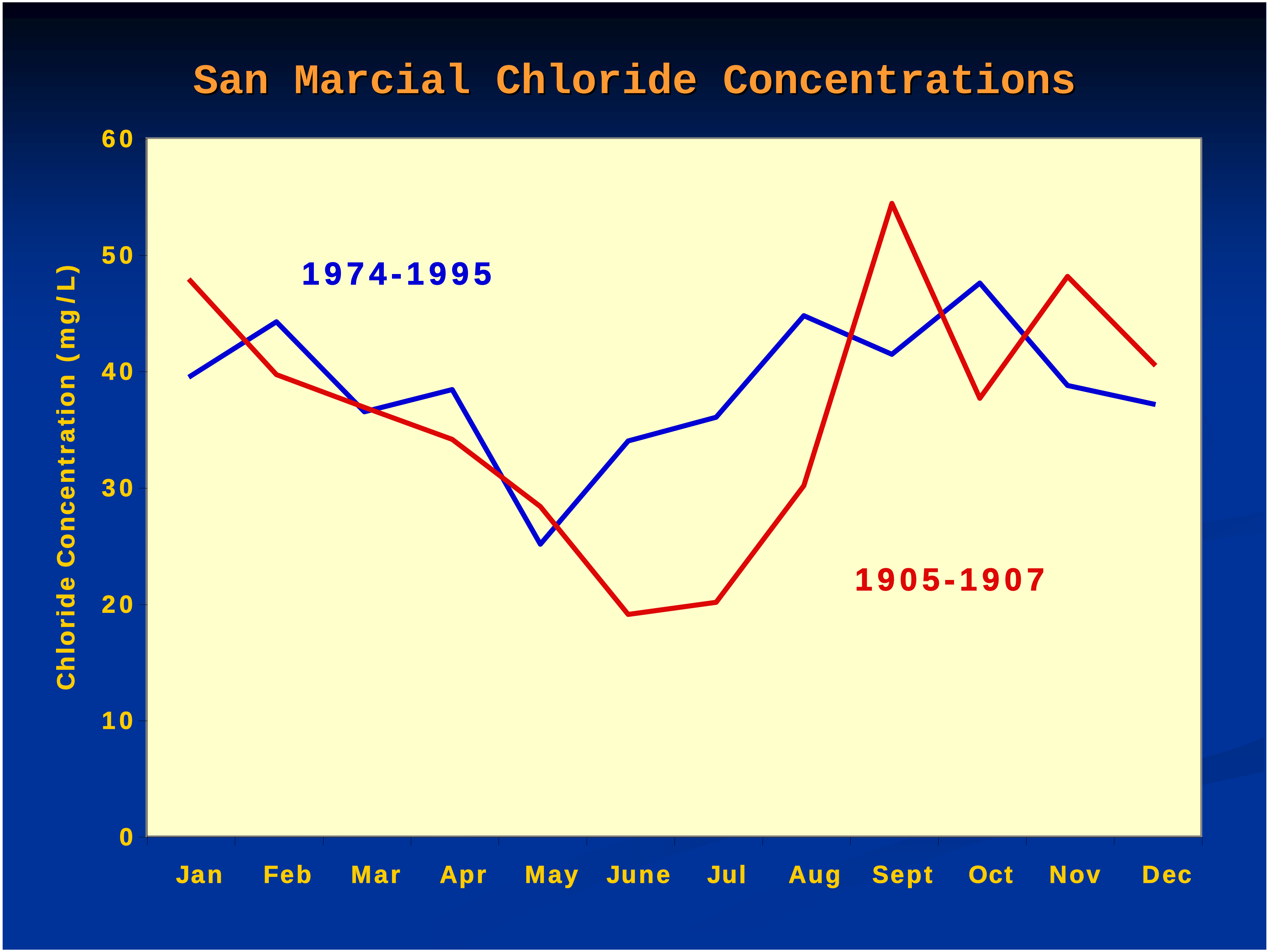
- **Wilcox 1934-1950 at many gauging stations**
- **Stabler 1905-1907 at San Marcial and El Paso**

Comparison with Wilcox (1934-1950) data set

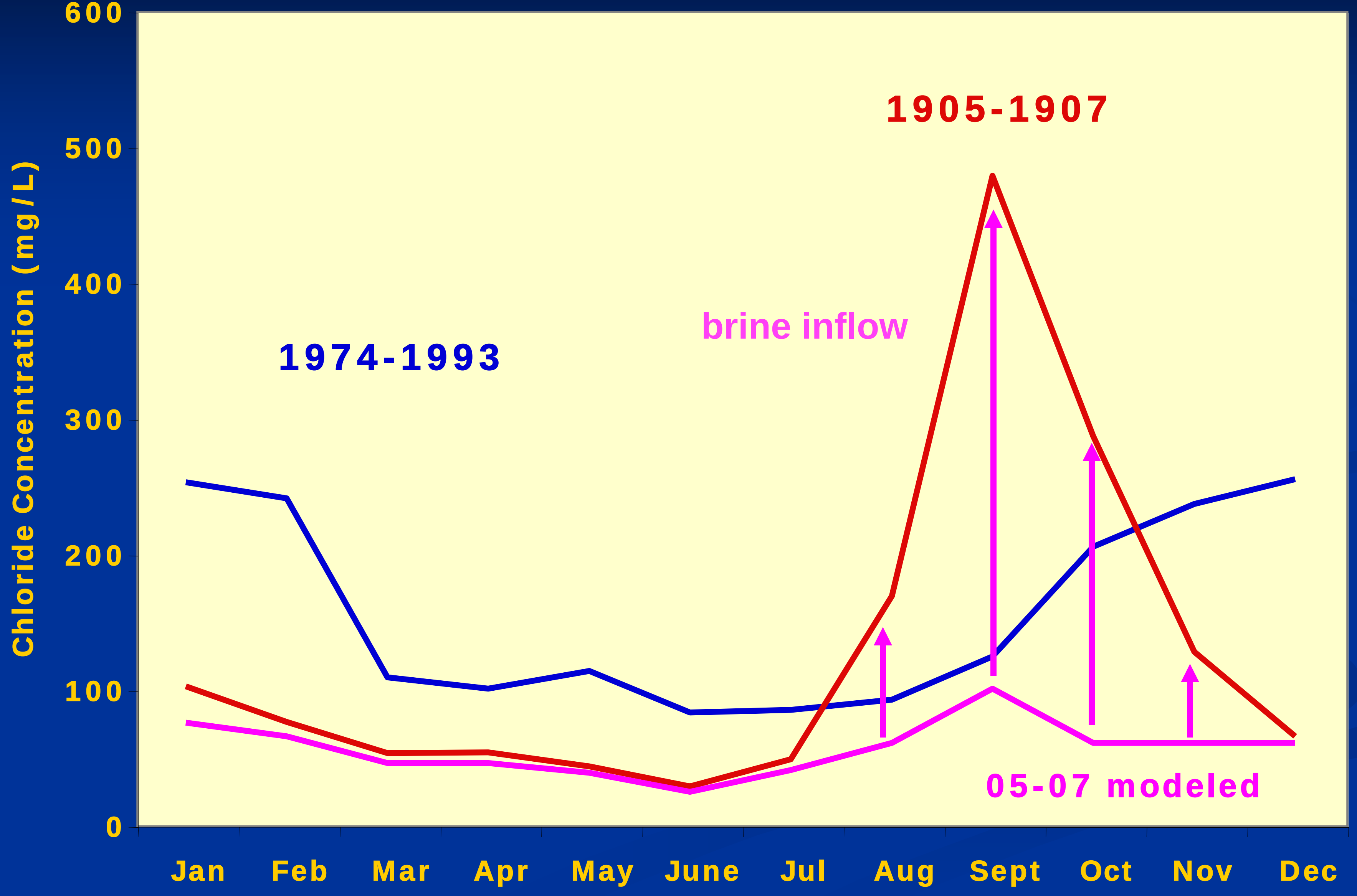
Monthly Chloride Burden



Comparison with Stabler (1905-1907) data set (before Elephant Butte Dam!)


San Marcial Chloride Concentrations
Chloride Concentration (mg/L)
60
50
40
30
20
10
0
1974-1995
1905-1907
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sept
Oct
Nov
Dec

El Paso chloride



Conclusions

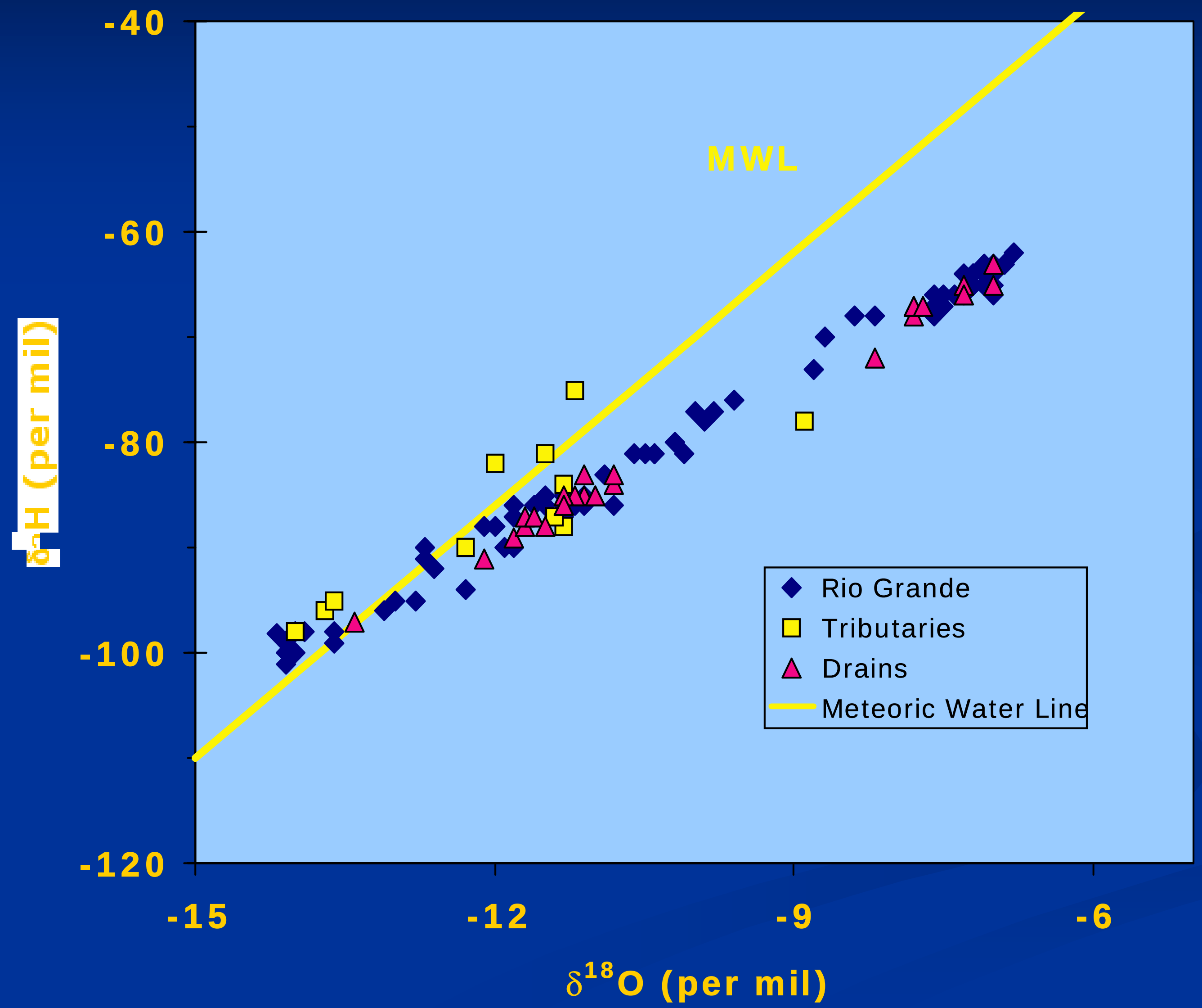
- About 2/3 of the chloride increase of the Rio Grande is from "geological salt", either from brine leakage or tributaries
- The brine leakage is along structural features (mostly faults) and might be intercepted and pumped

Conclusions

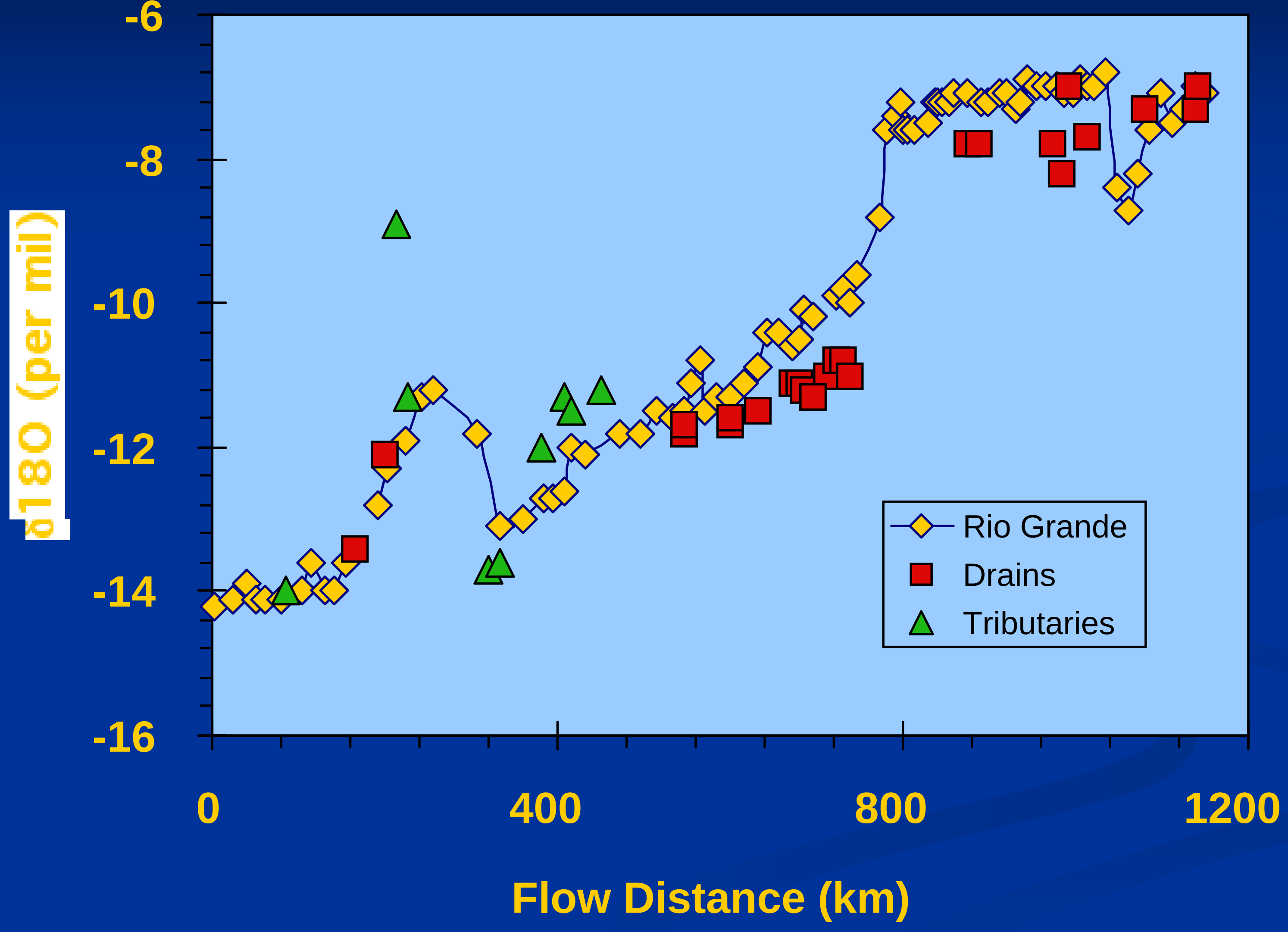
- The brine leakage predates development of the river and may have actually decreased over the 20th Century
- Agriculture contributes to the salinization of the Rio Grande but probably plays only a secondary role

Water and Salt Dynamics of the Rio Grande

$\delta^{18}O$ vs $\delta^{2}H$ (Summer '01)



$\delta^{18}O$ vs Flow Distance (Summer '01)

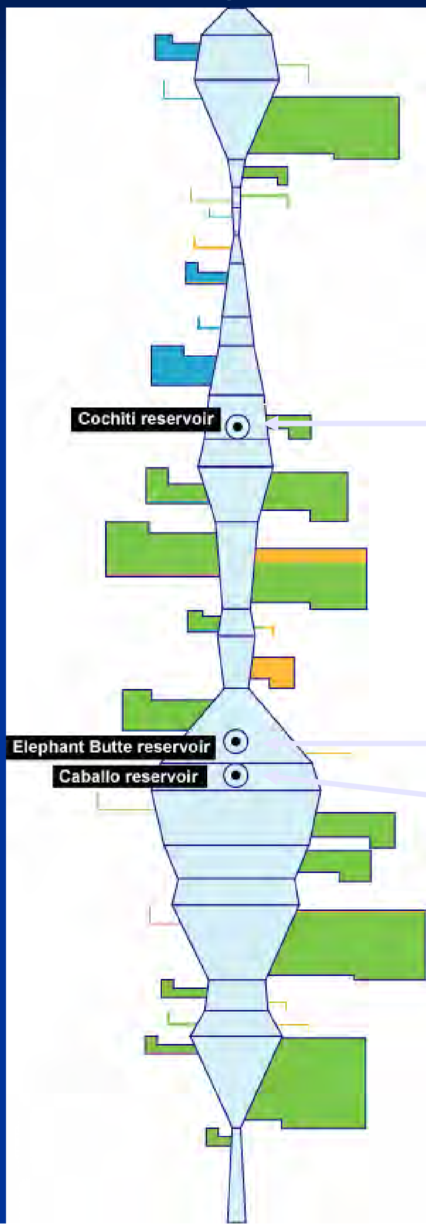


Significance of Stable Isotopes

- Water source is mnt. snowmelt
- Strong enrichment = much evaporation
- Simple Rayleigh distillation model indicates ~35% of inflow is evaporated
- ~1/3 of evaporation occurs from Elephant Butte Reservoir
- River gauging indicates ~75% lost to ET
- Loss is ~1/2 evap. and ~1/2 transp.

Where is water going?

Aug '01



Flow (cms)

Del Norte, CO

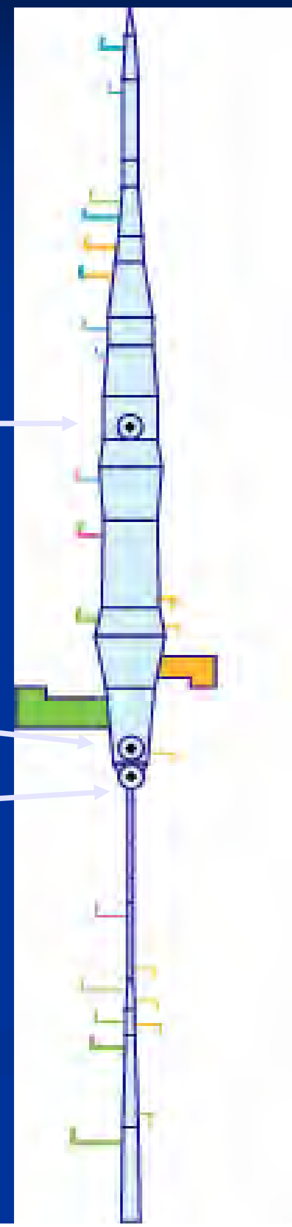
Cochiti

Elephant Butte

Caballo

Ft. Quitman

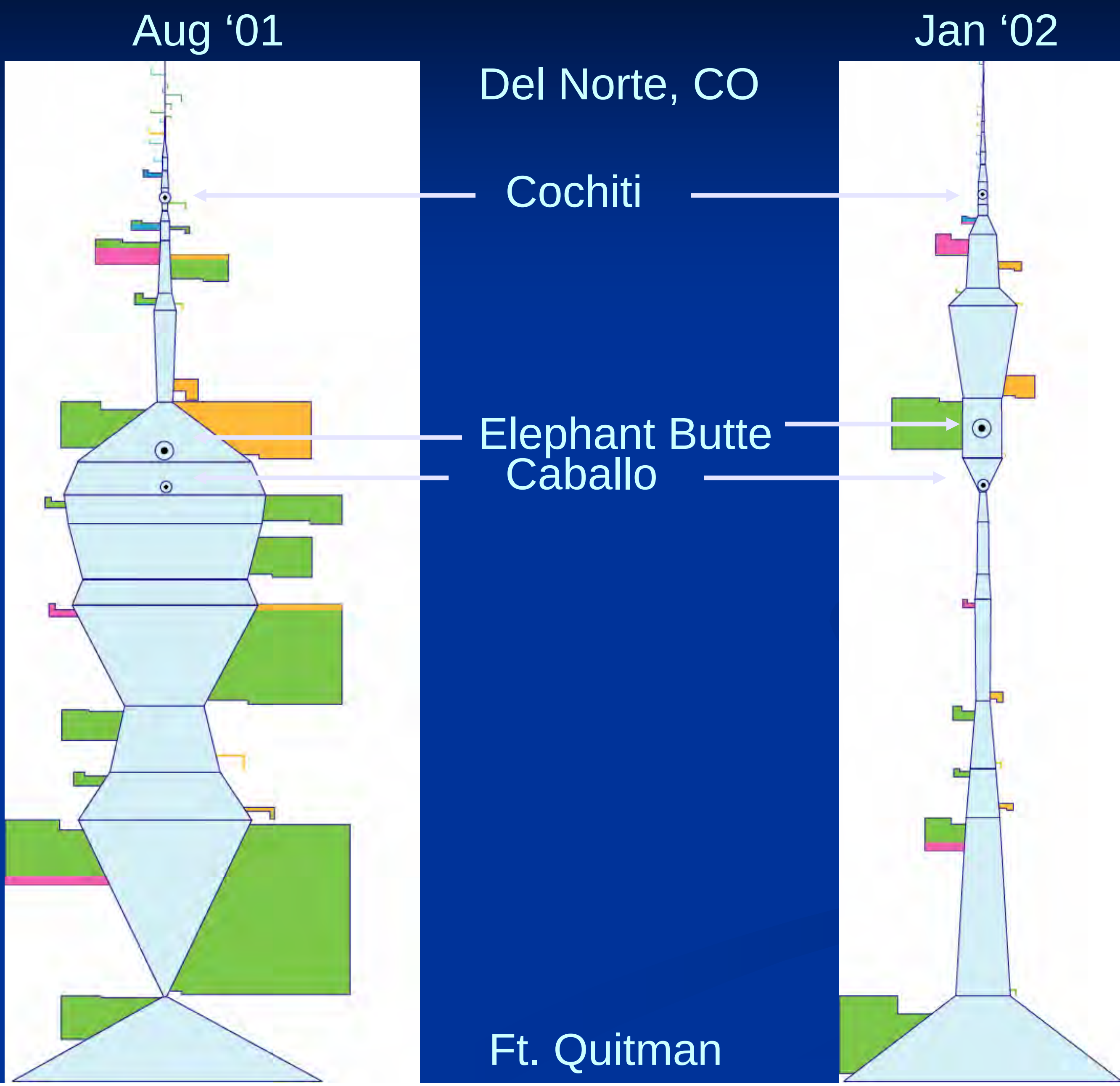
Jan '02



= ag
= seepage
= tribs
= wwtp

- Inputs on left
- Outputs on right
- Pipe width indicates flow magnitude

Where is salt going?



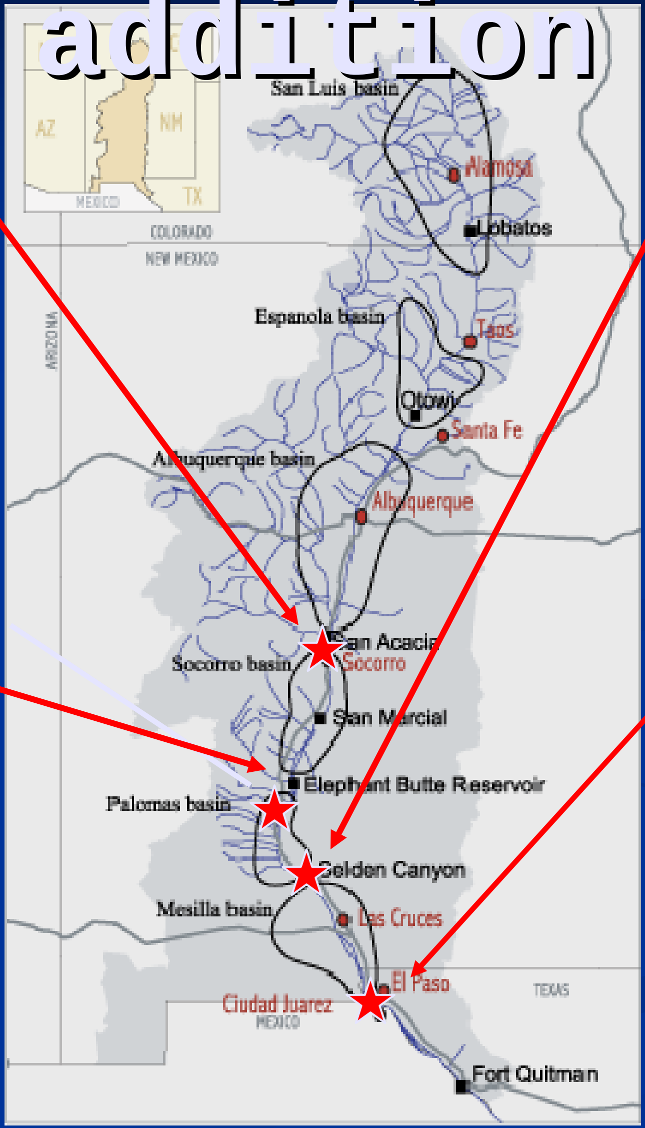
- = ag
- = seepage
- = tribs
- = wwtp

- Inputs on left
- Outputs on right
- Pipe width indicates burden magnitude

Deep groundwater addition

San Acacia: **1800 (summer) – 26,000 (winter) kg/dy**

Selden canyon: **300-6,000 kg/dy (winter only)**



T or C: **30,000 – 60,000 kg/dy**

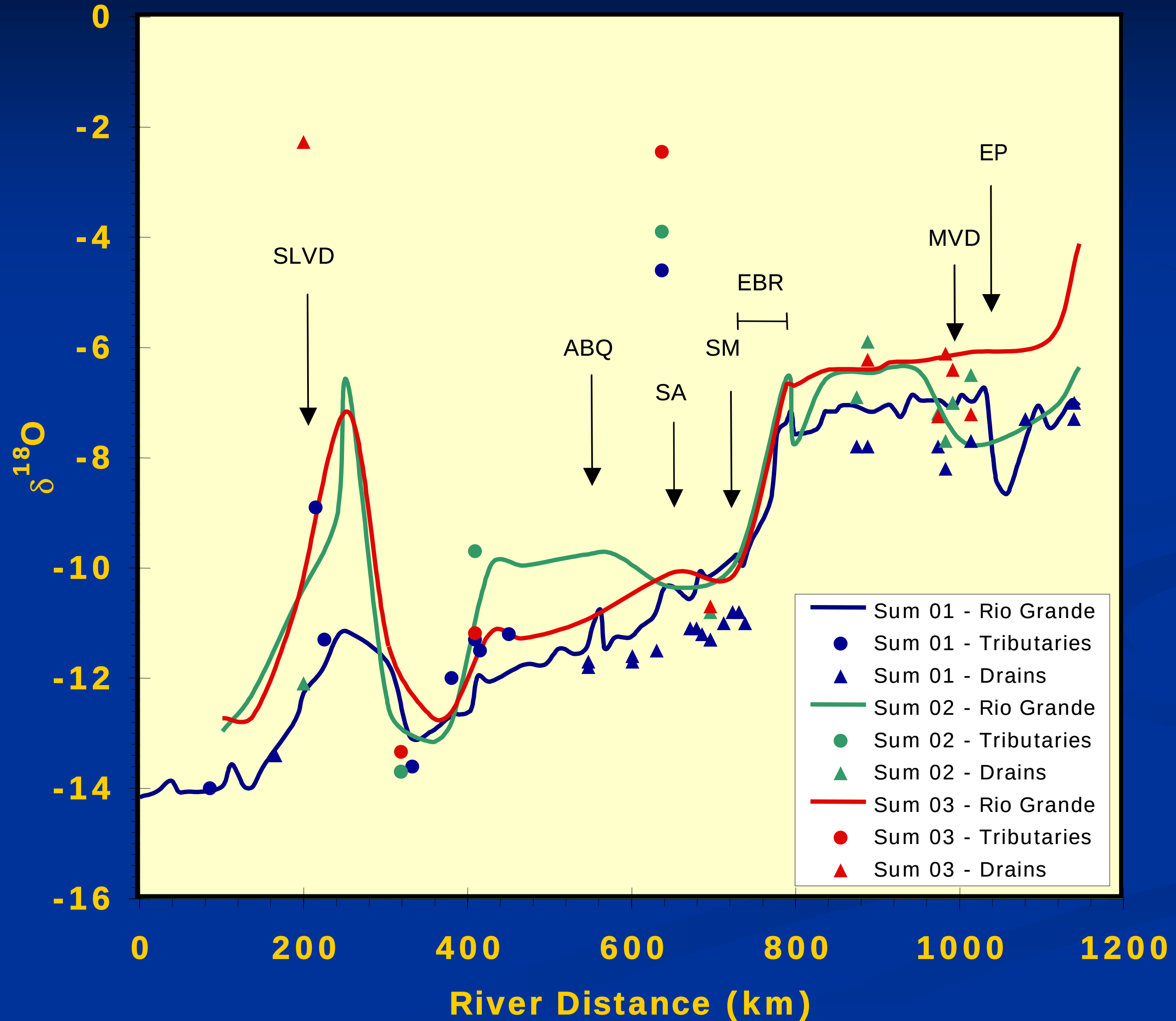
El Paso narrows: **18,000 – 30,000 kg/dy**

Rio Chama: **4,000 kg/dy**

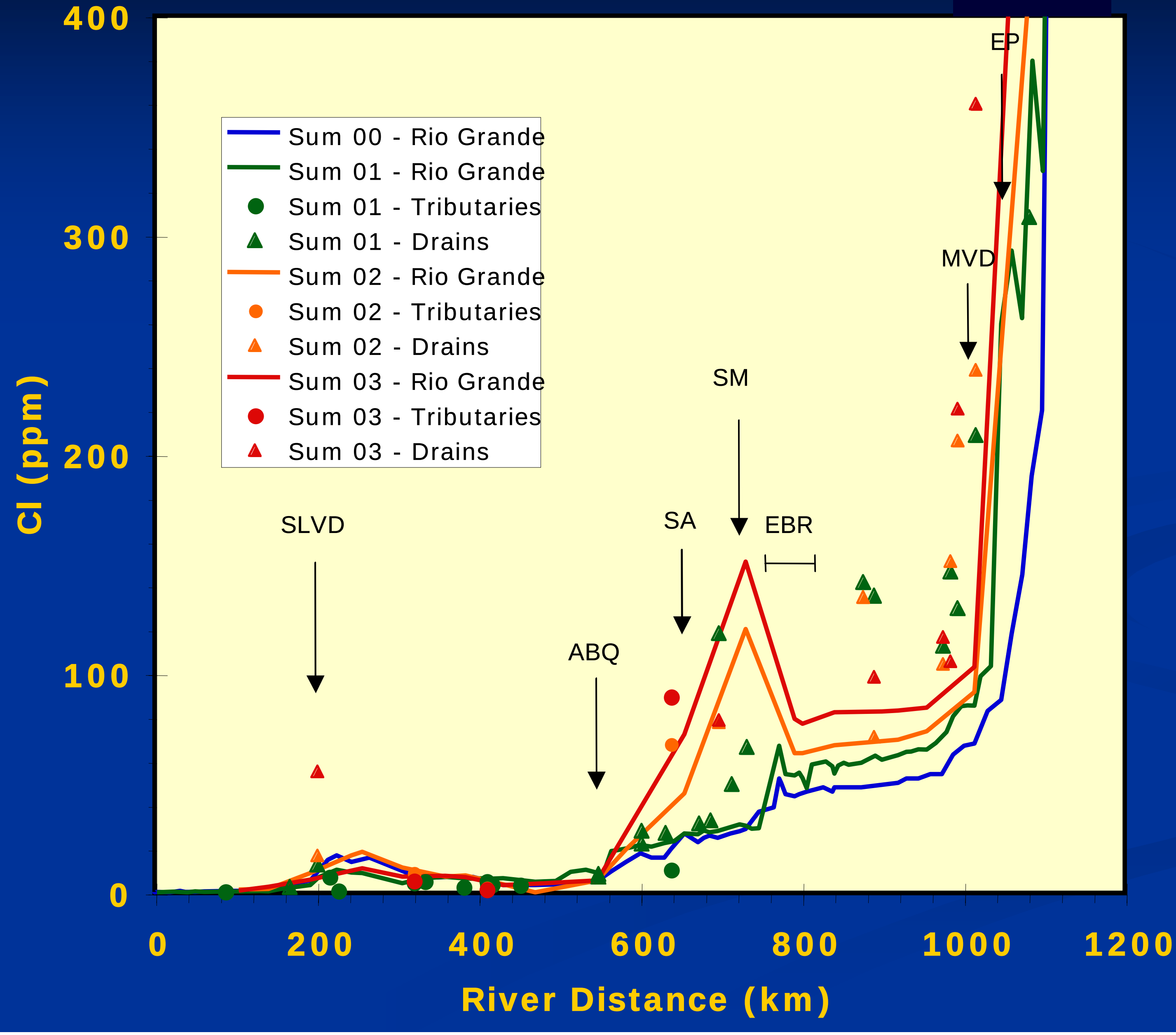
ABQ wwtp: **18,800 kg/dy**

Solute Dynamics Under Worsening Drought

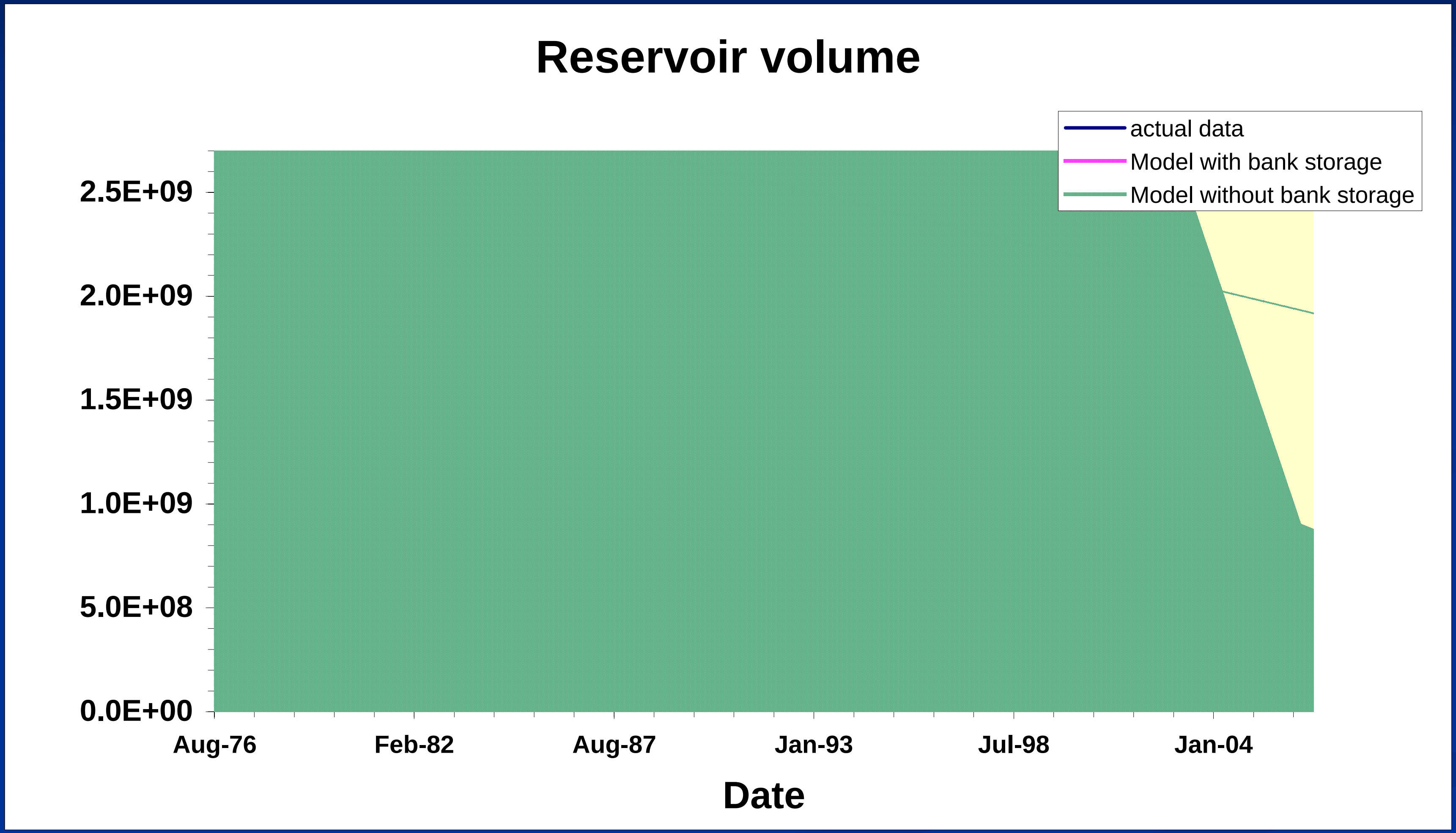
δ18O in Summer

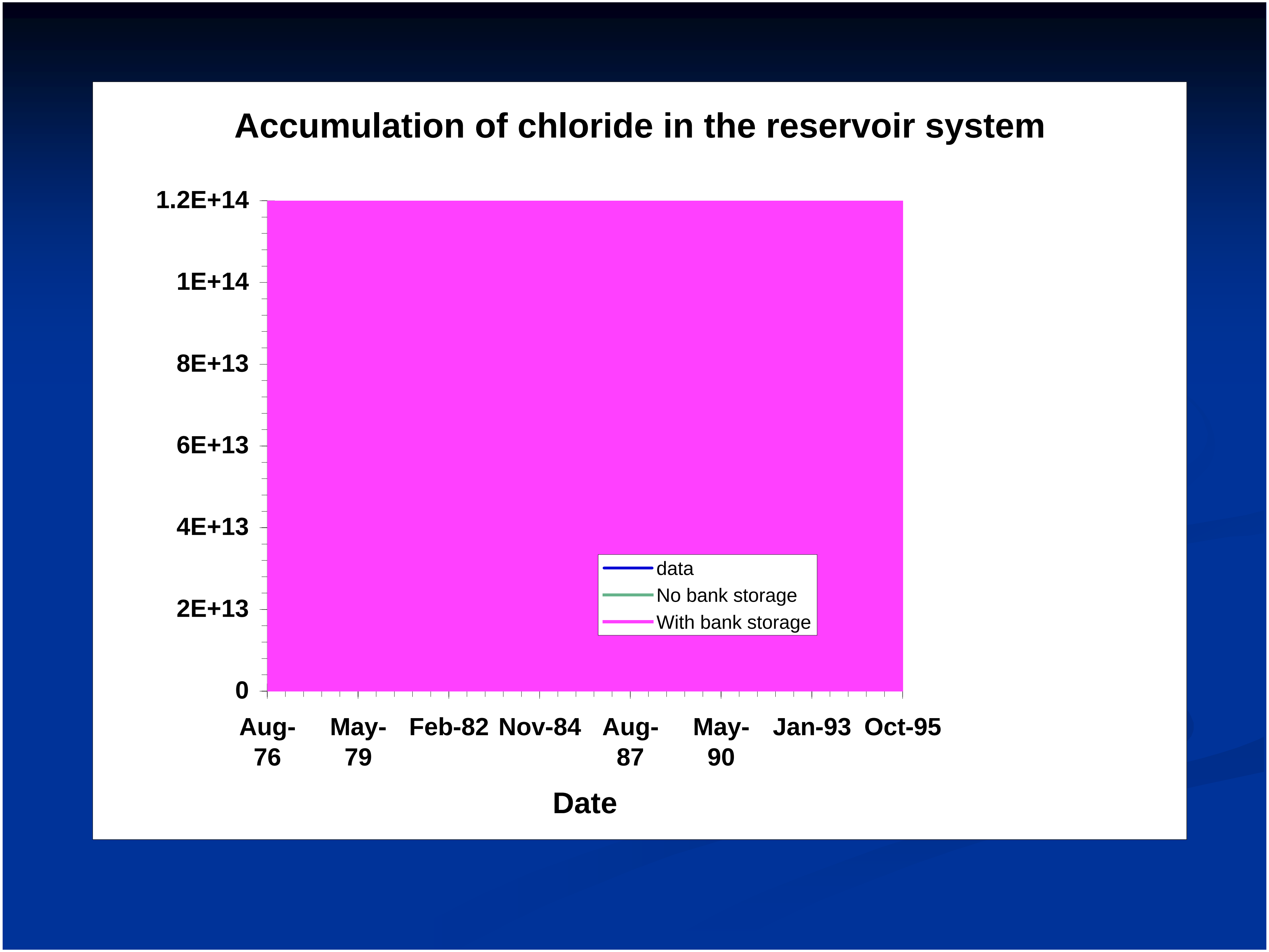


Cl in summer

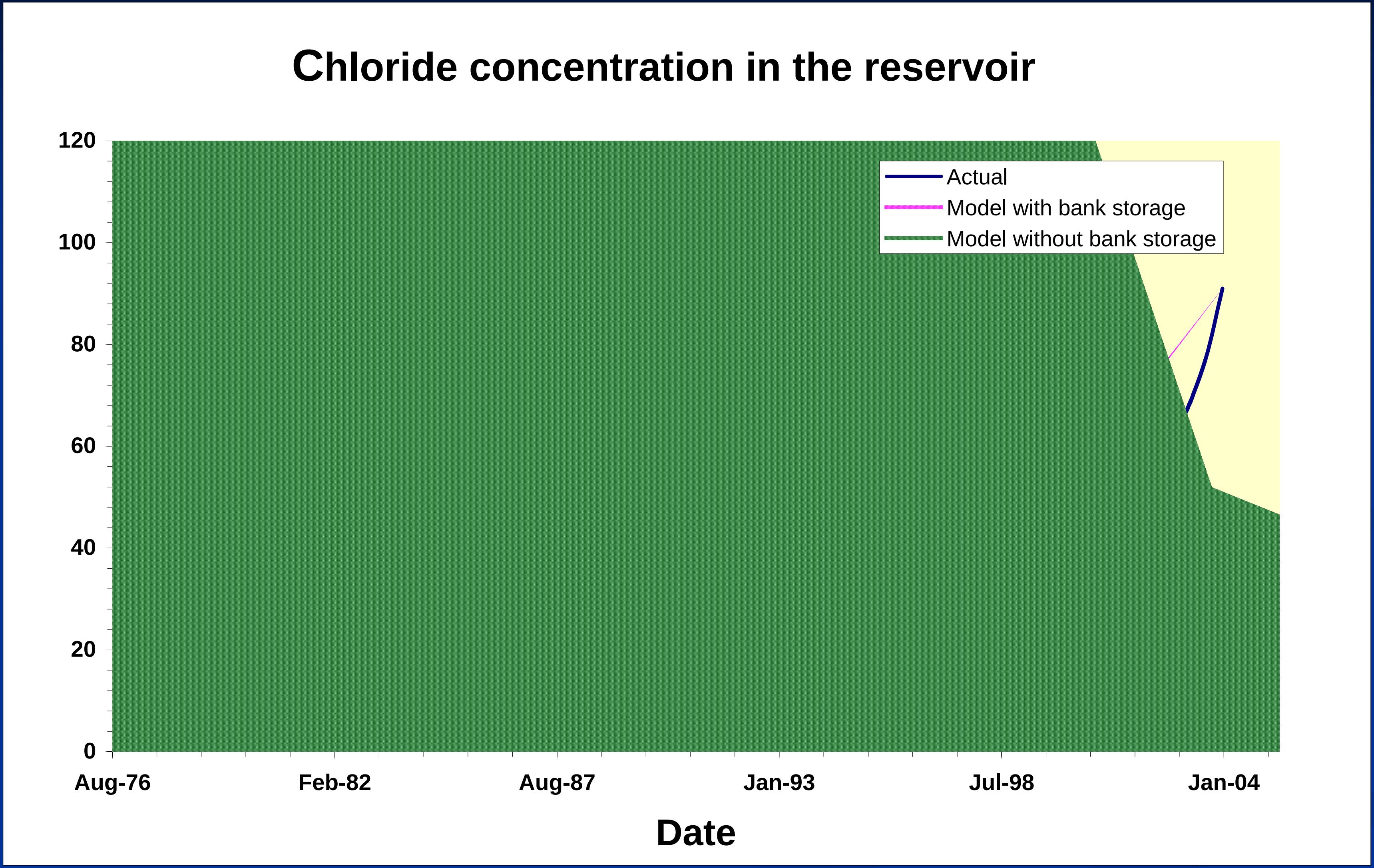


Sum 00 - Rio Grande
Sum 01 - Rio Grande
Sum 01 - Tributaries
Sum 01 - Drains
Sum 02 - Rio Grande
Sum 02 - Tributaries
Sum 02 - Drains
Sum 03 - Rio Grande
Sum 03 - Tributaries
Sum 03 - Drains
EP
MVD
SM
SA
EBR
SLVD
ABQ
Cl (ppm)
0
100
200
300
400
0
200
400
600
800
1000
1200
River Distance (km)

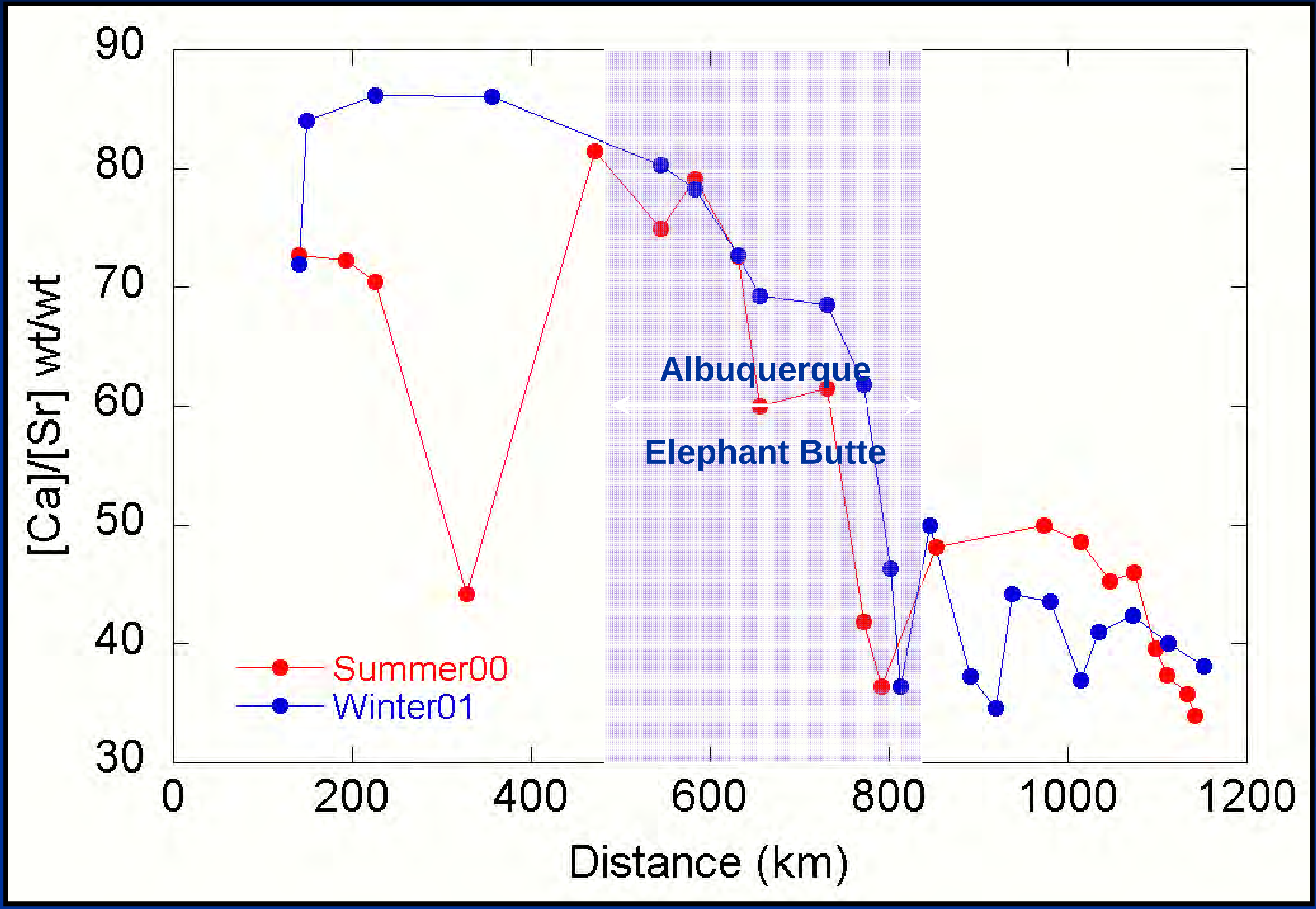

Reservoir volume
actual data
Model with bank storage
Model without bank storage
2.5E+09
2.0E+09
1.5E+09
1.0E+09
5.0E+08
0.0E+00
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Date



Accumulation of chloride in the reservoir system
1.2E+14
1E+14
8E+13
6E+13
4E+13
2E+13
0
Aug-76
May-79
Feb-82
Nov-84
Aug-87
May-90
Jan-93
Oct-95
Date
data
No bank storage
With bank storage


Chloride concentration in the reservoir
120
100
80
60
40
20
0
Actual
Model with bank storage
Model without bank storage
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Date

Tracing GW inputs …

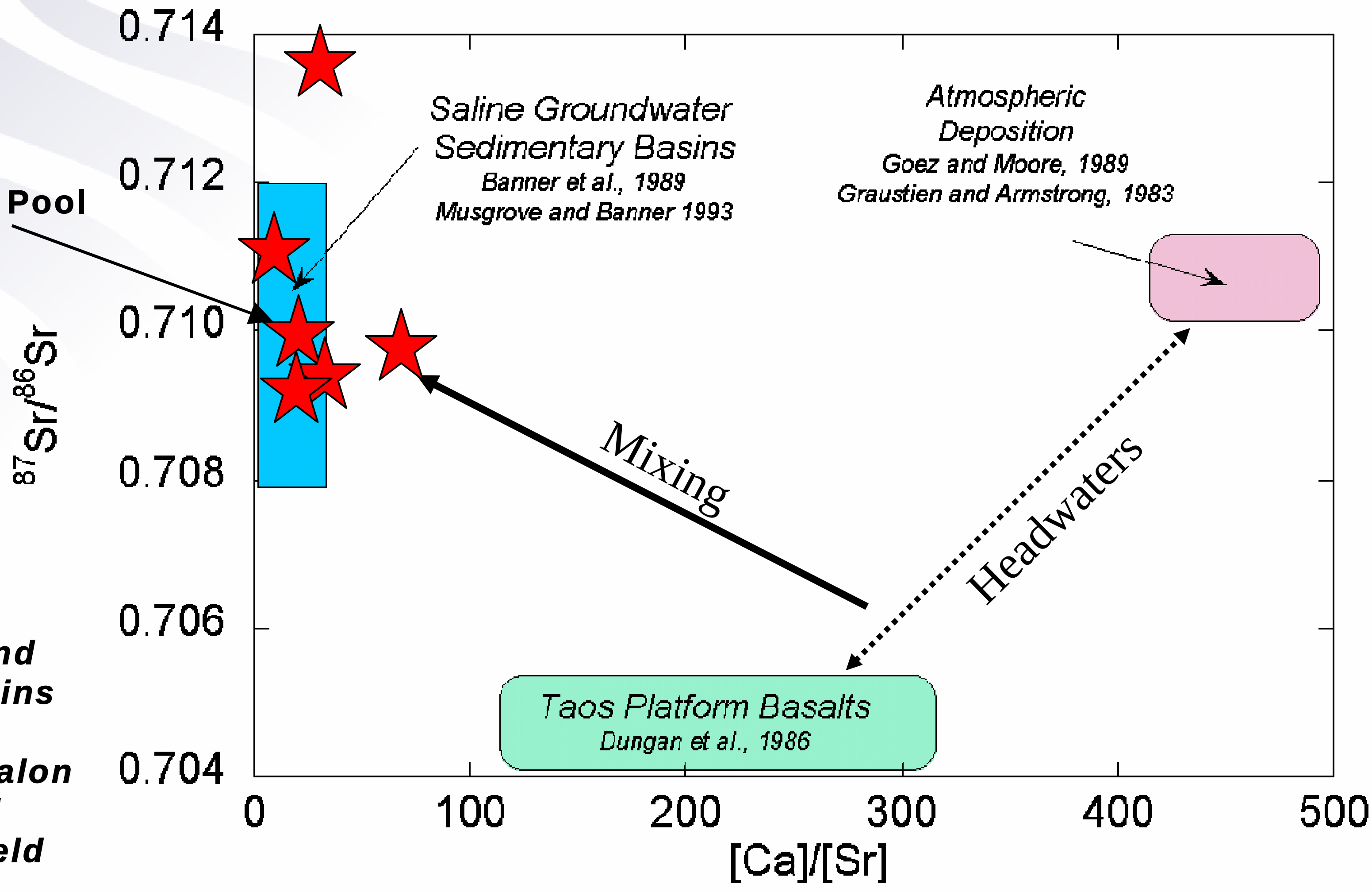


Sr End Members

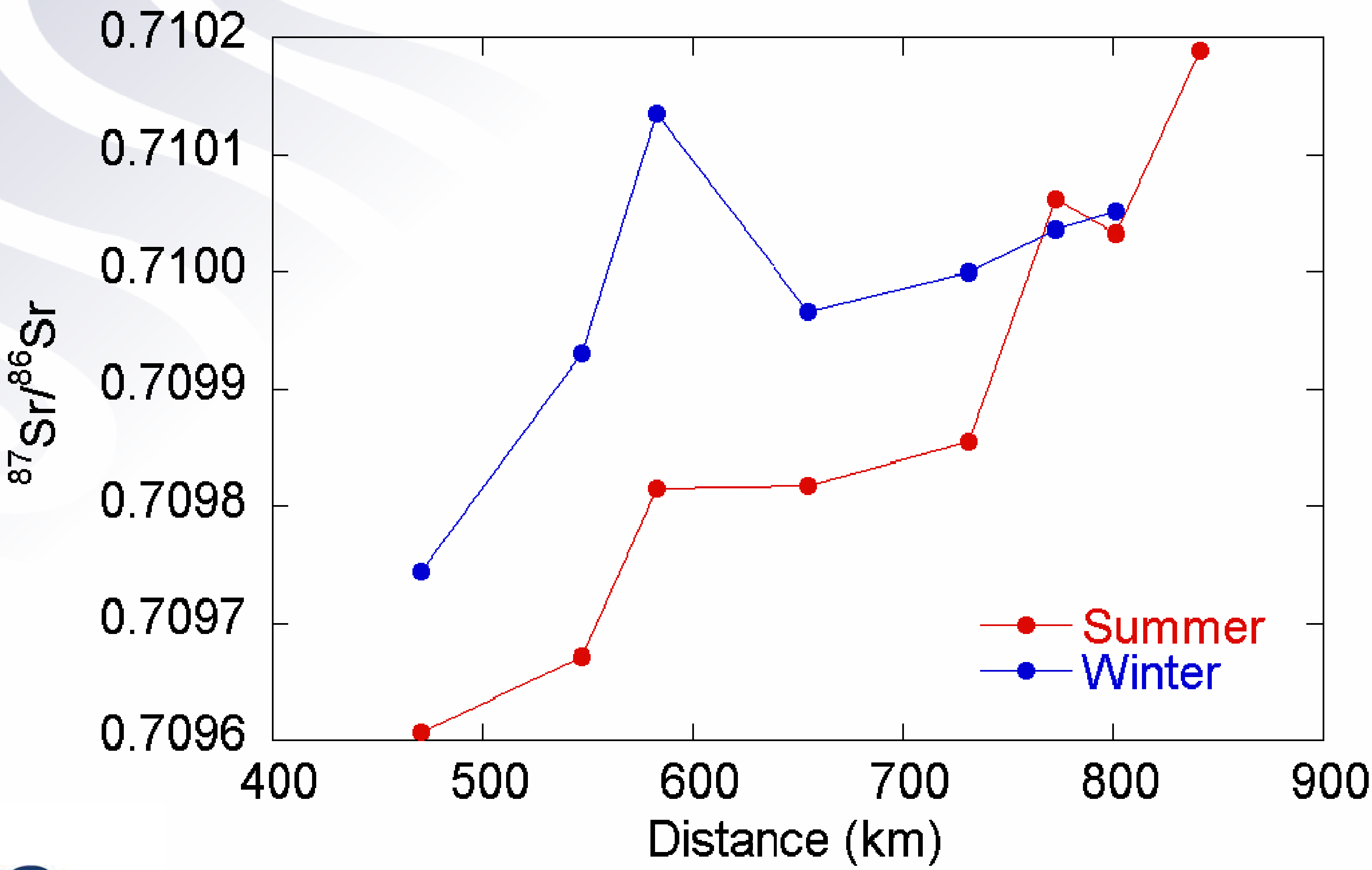
San Acacia Pool

"Shallow" Saline GW's from ABQ and Socorro Basins

Thanks to Talon Newton and Laura Bexfield

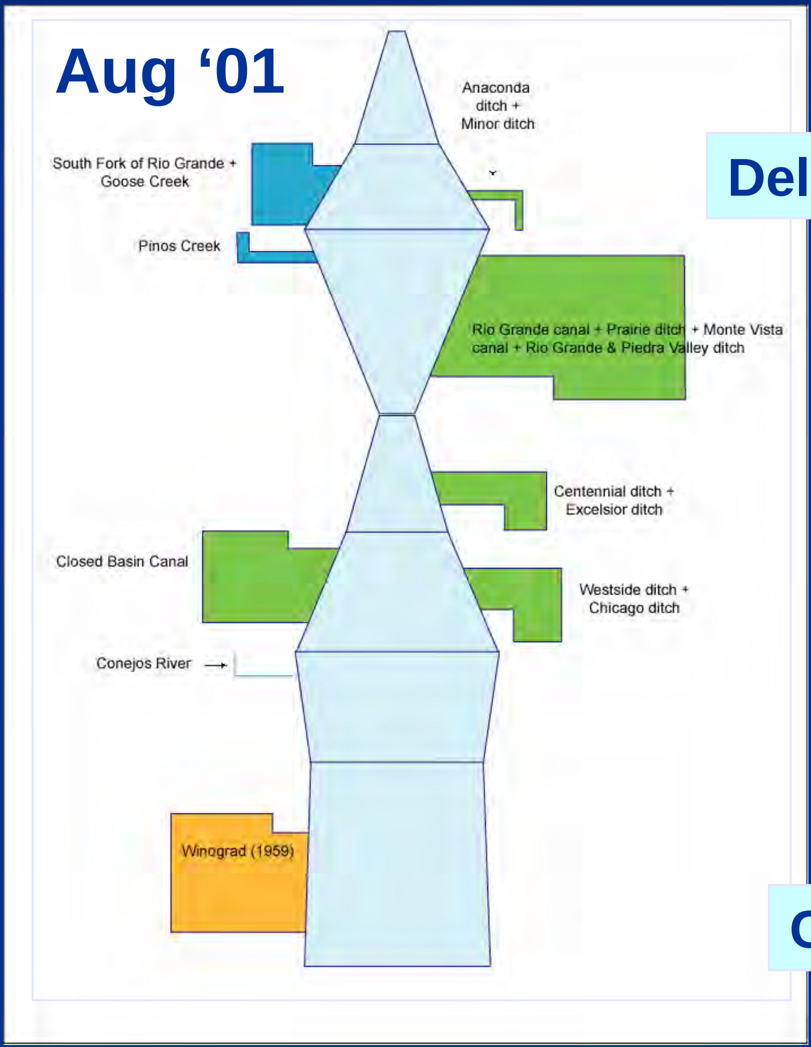


Strontium Isotopes



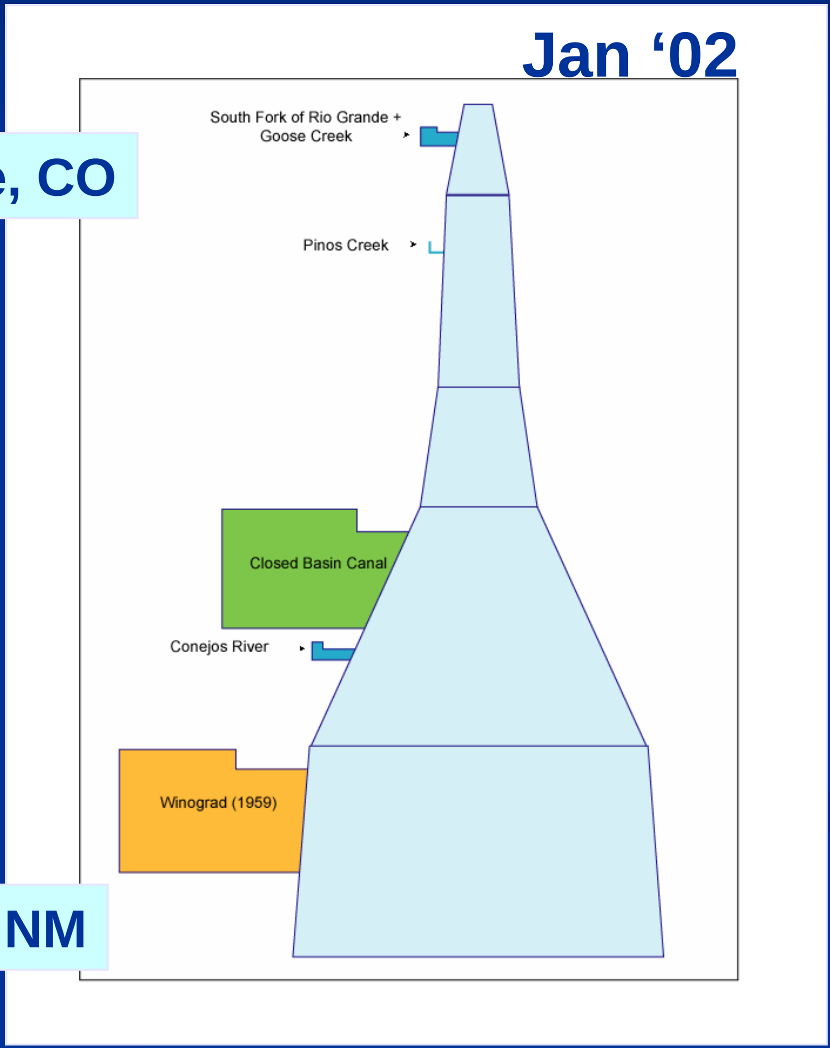
Influence of tributaries

Natural tributaries add most chloride in the headwaters (as well as the Closed Basin Canal).



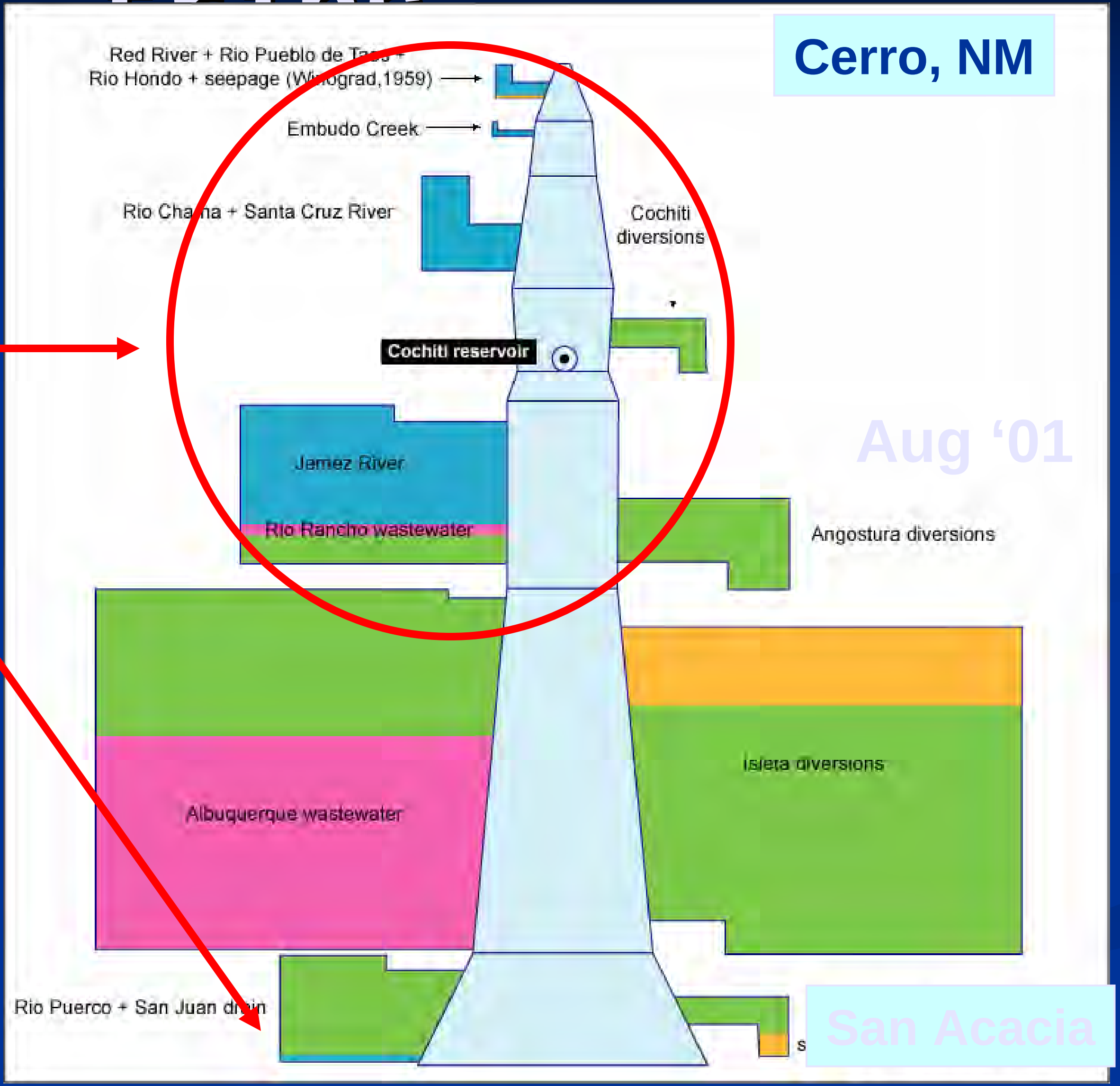
Del Norte, CO

Cerro, NM



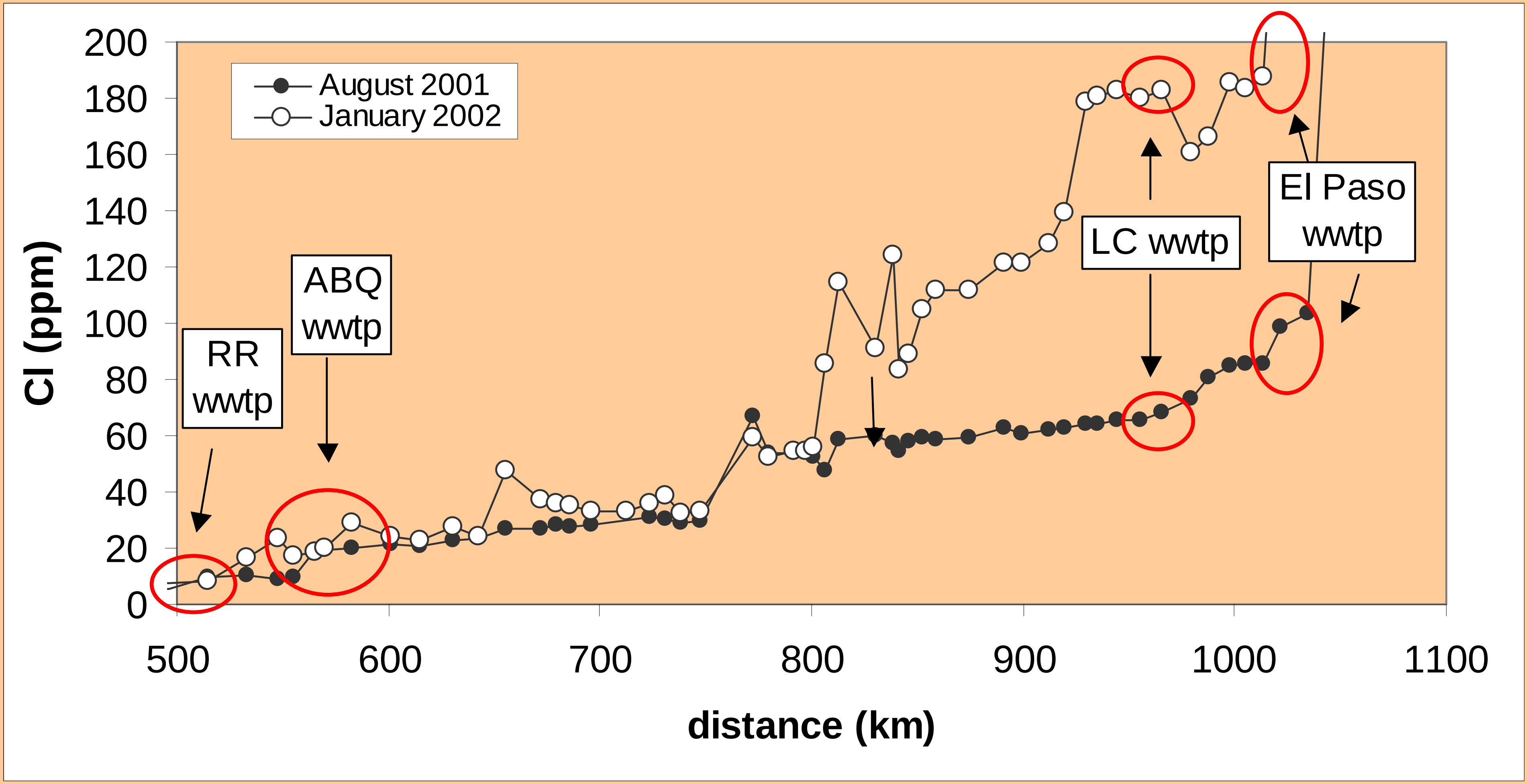
Further input of natural tribs

Chloride enters the river with natural tributaries.



Influence of wastewater

The Rio Rancho, Albuquerque, Las Cruces, and El Paso (Northwest WWTP) wastewater effluents all increase Cl^- and Cl/Br in the river.



An Overview: Upper Rio Grande Water Management and the Rio Grande Compact

09/19/06

Rolf Schmidt-Petersen
NMISC Rio Grande Basin Manager

Rio Grande Water Management Agencies/Entities

- U.S. Bureau Of Reclamation
- U.S. Army Corps of Engineers
- U.S. Bureau of Indian Affairs
- International Boundary & Water Commission
- New Mexico Office of the State Engineer
- New Mexico Interstate Stream Commission
- State of Colorado DWR
- Rio Grande Compact Commission
- Pueblo’s and Tribe’s
- Conservancy and Irrigation districts
- Acequias
- Cities, counties, mutual domestic water associations
- Flood control authorities

The Upper Rio Grande Basin

Platoro Dam

Rio Chama below Abiquiu Dam

Cochiti Dam

San Acacia Diversion Dam

San Marcial Railroad Bridge

Elephant Butte Dam and Reservoir

Generalized History

- Late 1800's – Drought and Increased Irrigation Diversion in Colorado
- 1896 – Federal Embargo on Water Development
- 1906 – Treaty of 1906
- 1916 – Elephant Butte Reservoir Operational
- 1925 – Federal Water Development Embargo Lifted
- Late 1920's – Middle Rio Grande Conservancy District
  - Construct the MRGCD diversion dams, canals, drains, and El Vado Reservoir
- 1929 – Interim Rio Grande Compact
  - Sets limits on depletions of water

Generalized History (Continued)

- 1935 – El Vado Reservoir Completed
  - Supreme Court Lawsuit by Texas
- 1938 – Rio Grande Compact Signed,
  - Supreme Court Lawsuit dismissed

The Rio Grande Compact

- Signed in 1938 in Santa Fe following those four decades of controversy to:
  - Effect an equitable apportionment of the waters of the Rio Grande above Ft. Quitman, Texas
  - Remove all causes of present and future controversy
  - Promote interstate comity

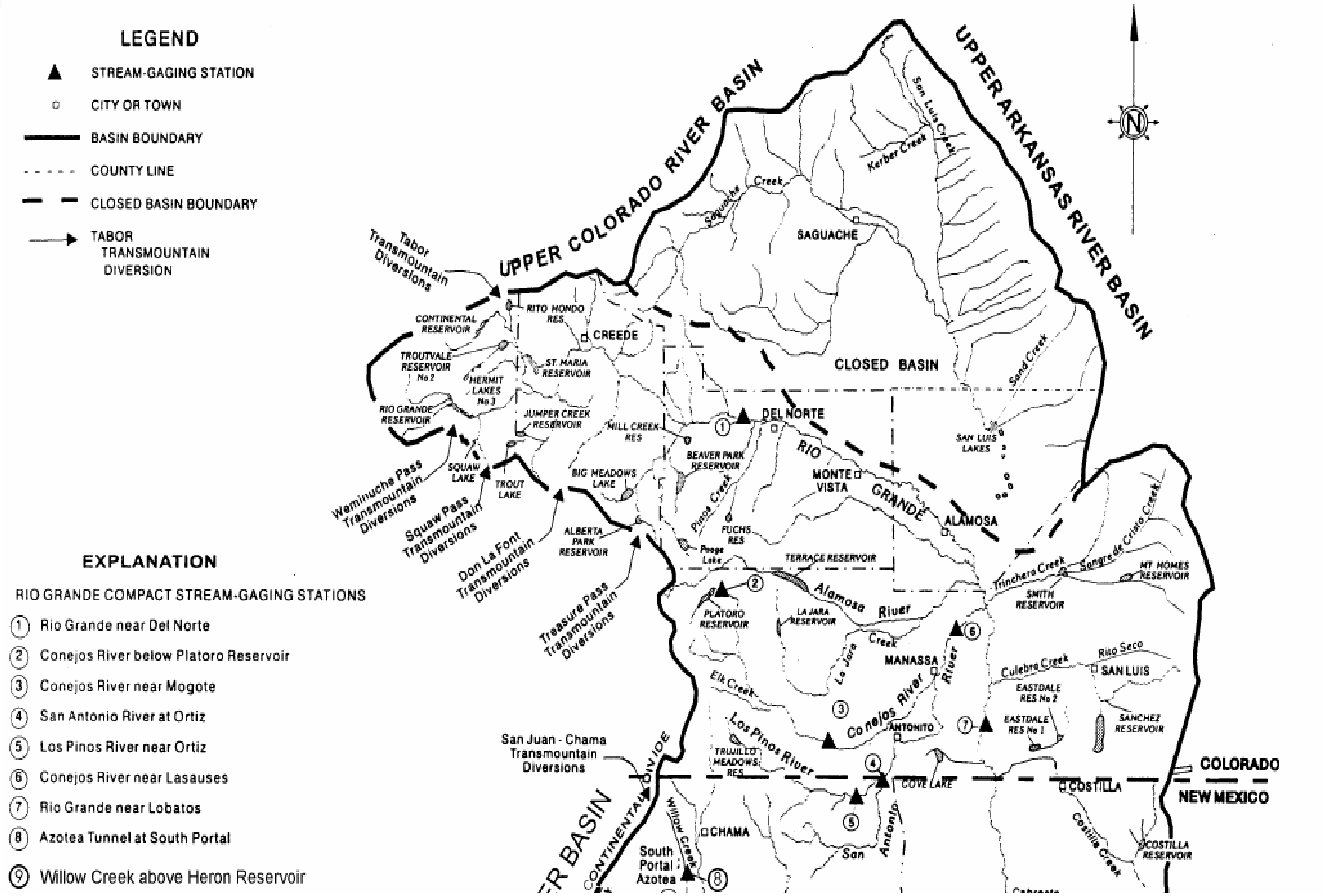
The Rio Grande Compact

- The Compact apportions the waters of the Upper Rio Grande Basin amongst the three States
- The Compact does not affect the obligations of the United States to Indian Tribes or impair their Rights
- San Juan-Chama Project Water is not subject to Compact apportionment

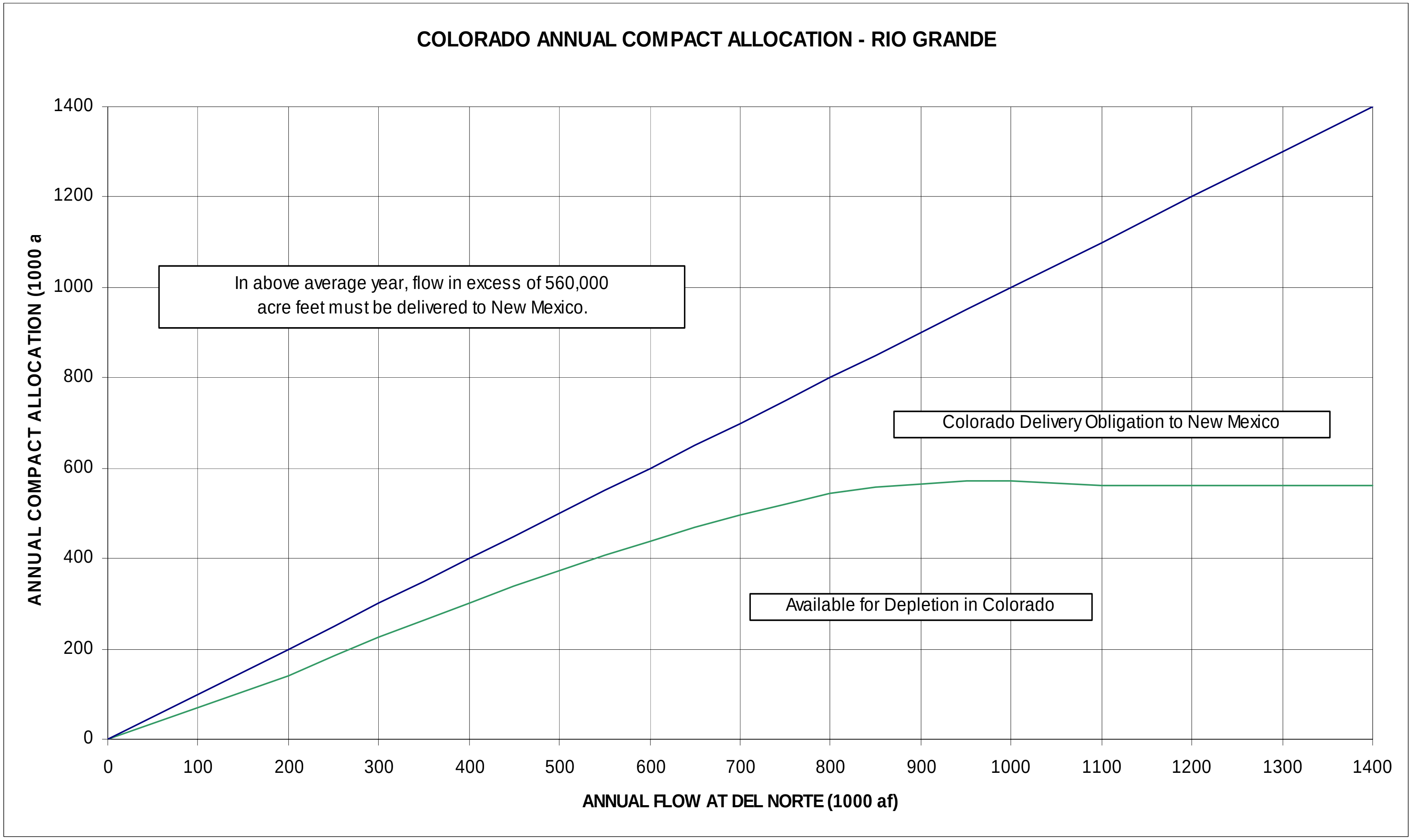
The Rio Grande Compact - Colorado

- Colorado is Required to Deliver Water to New Mexico at the Stateline

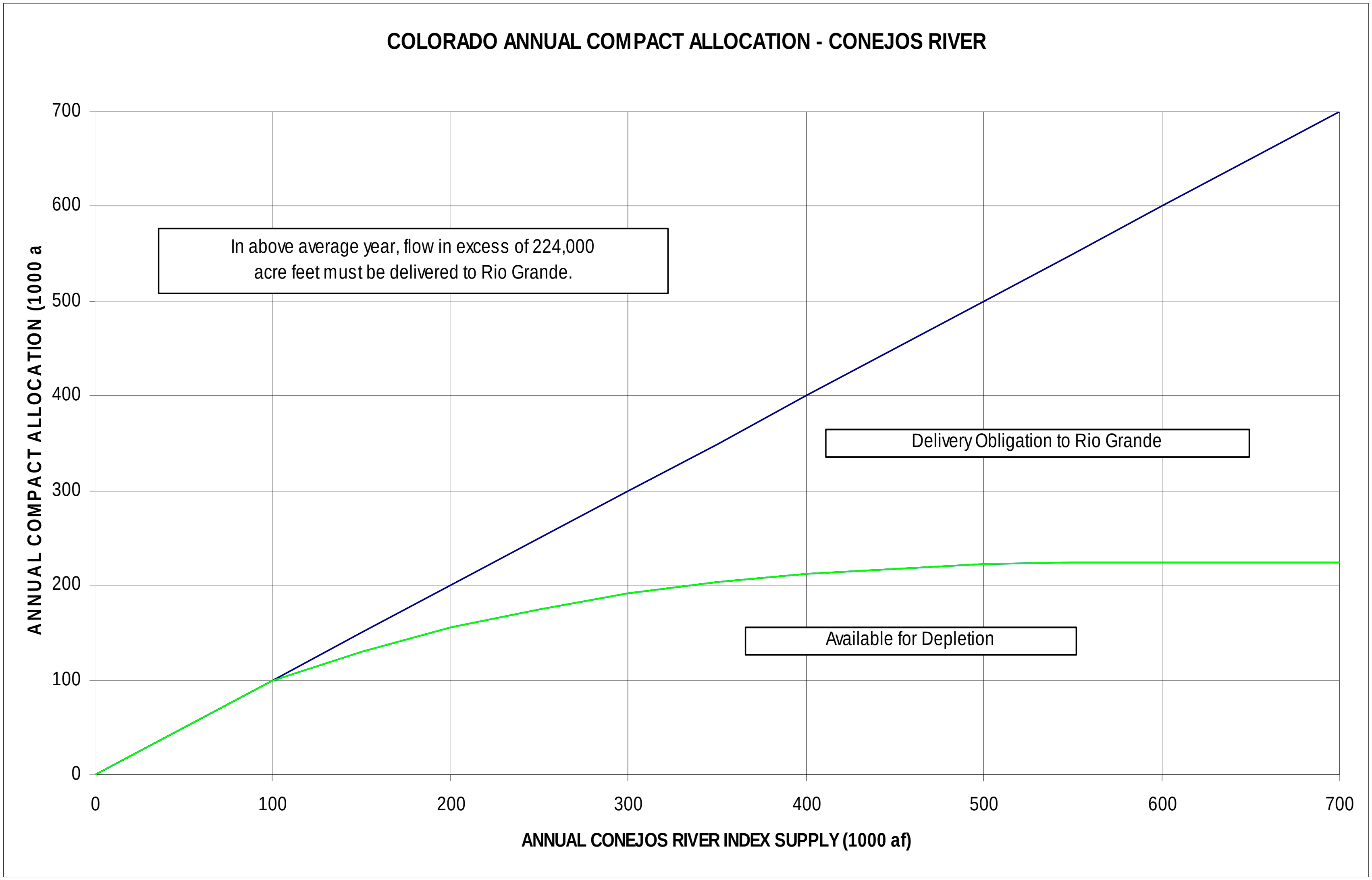
The Rio Grande Compact - Colorado



The Rio Grande Compact - Colorado



The Rio Grande Compact - Colorado



The Rio Grande Compact – New Mexico

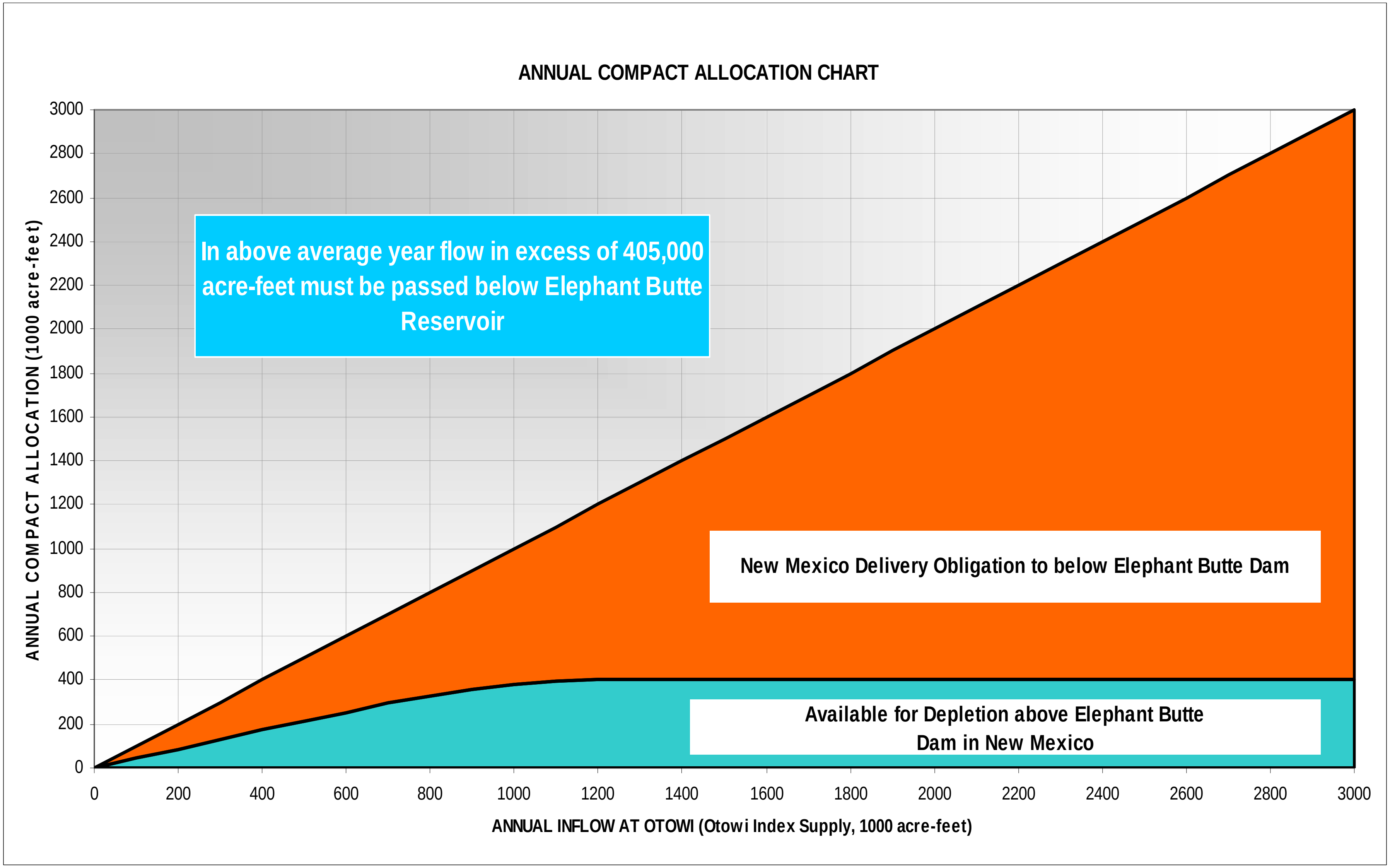
- New Mexico is Required to Deliver a Portion of the Flow at Otowi Bridge to Texas at Elephant Butte Reservoir
  - An explicit Middle Rio Grande allocation
- If depletions change between the Stateline with Colorado and Otowi Bridge, modify Middle Rio Grande allocation

The Upper Rio Grande Basin

Otowi Gage

Elephant Butte Dam

Middle Rio Grande Compact Allocation and Obligation



The Rio Grande Compact - Texas

- From Elephant Butte Reservoir to Fort Quitman, Texas
  - 57% of the Rio Grande Project Supply delivered to New Mexican's

The Rio Grande Project

Compact Storage Restrictions

- If We Accrue Debits to Texas:
  - Water Must be Retained in Storage in Post-1929 reservoirs to the extent of the debits and cannot be used
- If Usable Storage in Rio Grande Project Reservoirs is low:
  - cannot increase the amount of native water stored in post-1929 reservoirs
    - An accepted Relinquishment allows for some upstream storage

Credit, Debit, and Spills

- Colorado and New Mexico Credit Water is held in Elephant Butte Reservoir
- Colorado may accrue up to 100,000 acre-feet of debit
- New Mexico may accrue up to 200,000 acre-feet of debit
- Spills from Elephant Butte Reservoir eliminate credits and debits

Generalized History (Continued)

- 1941 – Severe Flooding north of Elephant Butte Reservoir
- 1948 & 1950 Flood Control Acts
  - Jemez Canyon, Abiquiu, Galisteo, and Cochiti dams
  - Rehabilitation of the MRGCD
- 1950's – Severe Drought
- Late 1950's – Additional Supreme Court Compact Litigation
- Late 1960's – San Juan-Chama Project
  - Diversions from San Juan Basin to Heron Reservoir

Rio Grande Floodway in 1952

Looking downstream from south boundary of Bosque del Apache (courtesy of Reclamation)

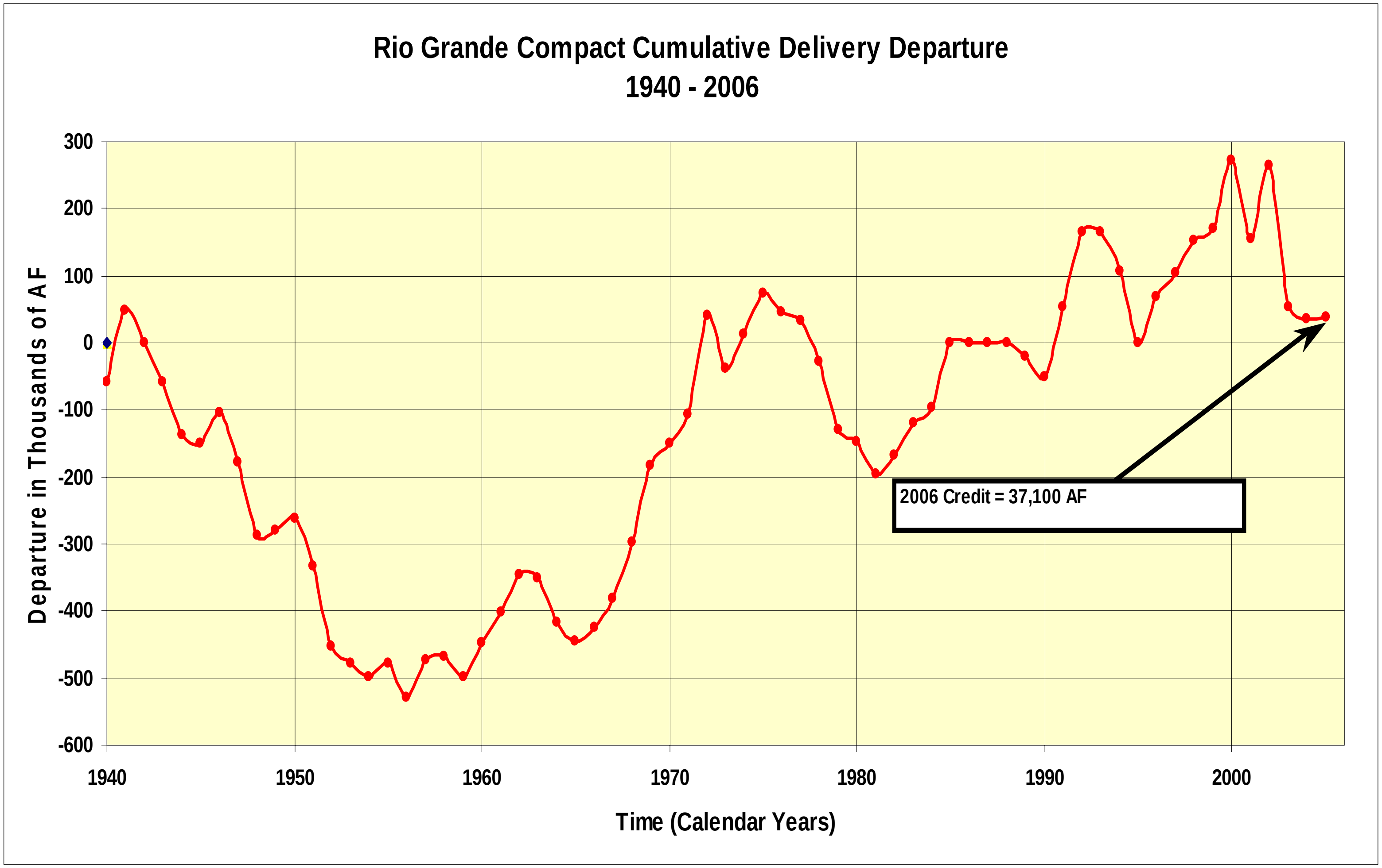
The Middle Rio Grande Project –Flood Control Reservoirs

The Middle Rio Grande Project – Rehabilitate the MRG

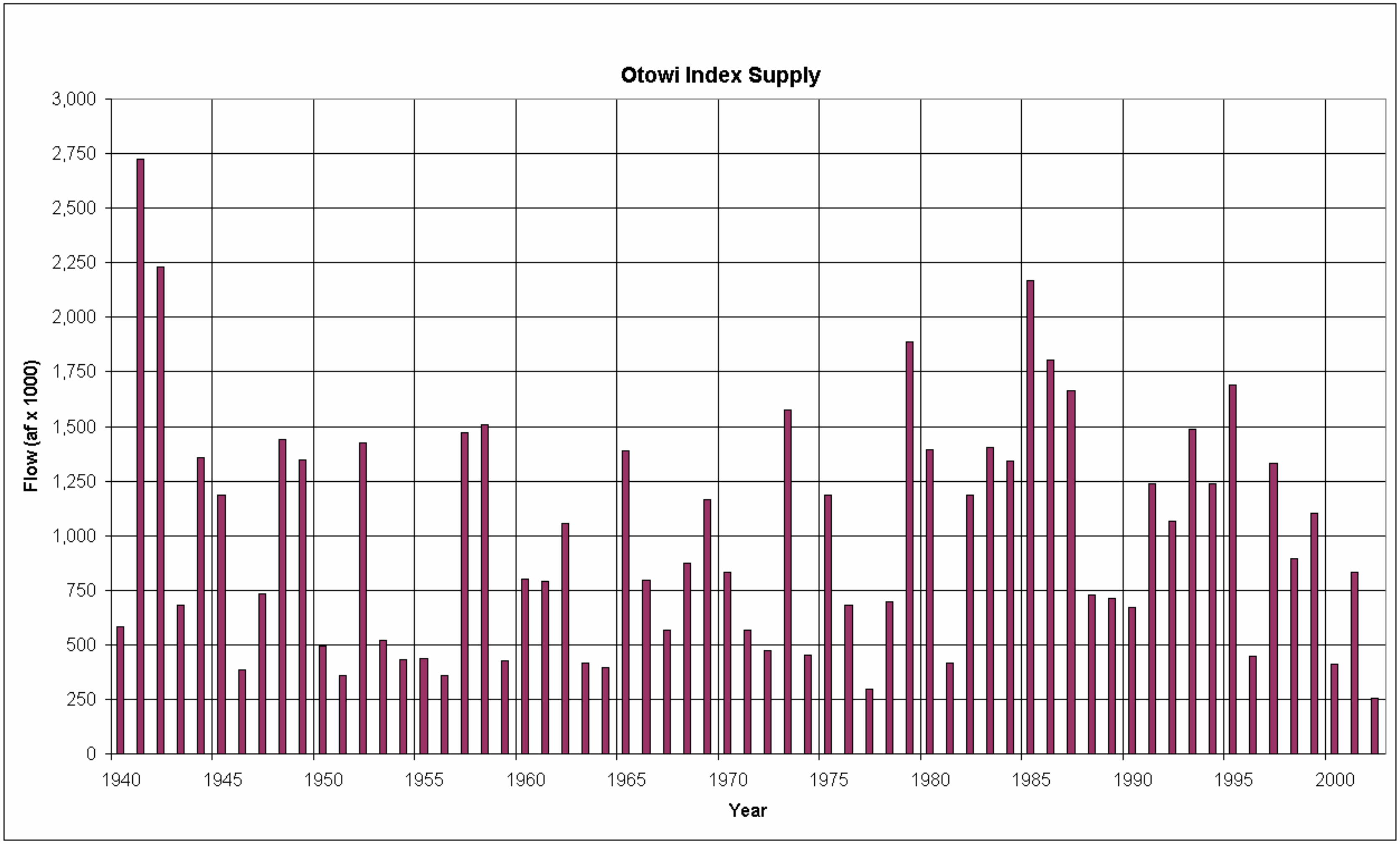
The San Juan-Chama Project – Import Water to Rio Grande

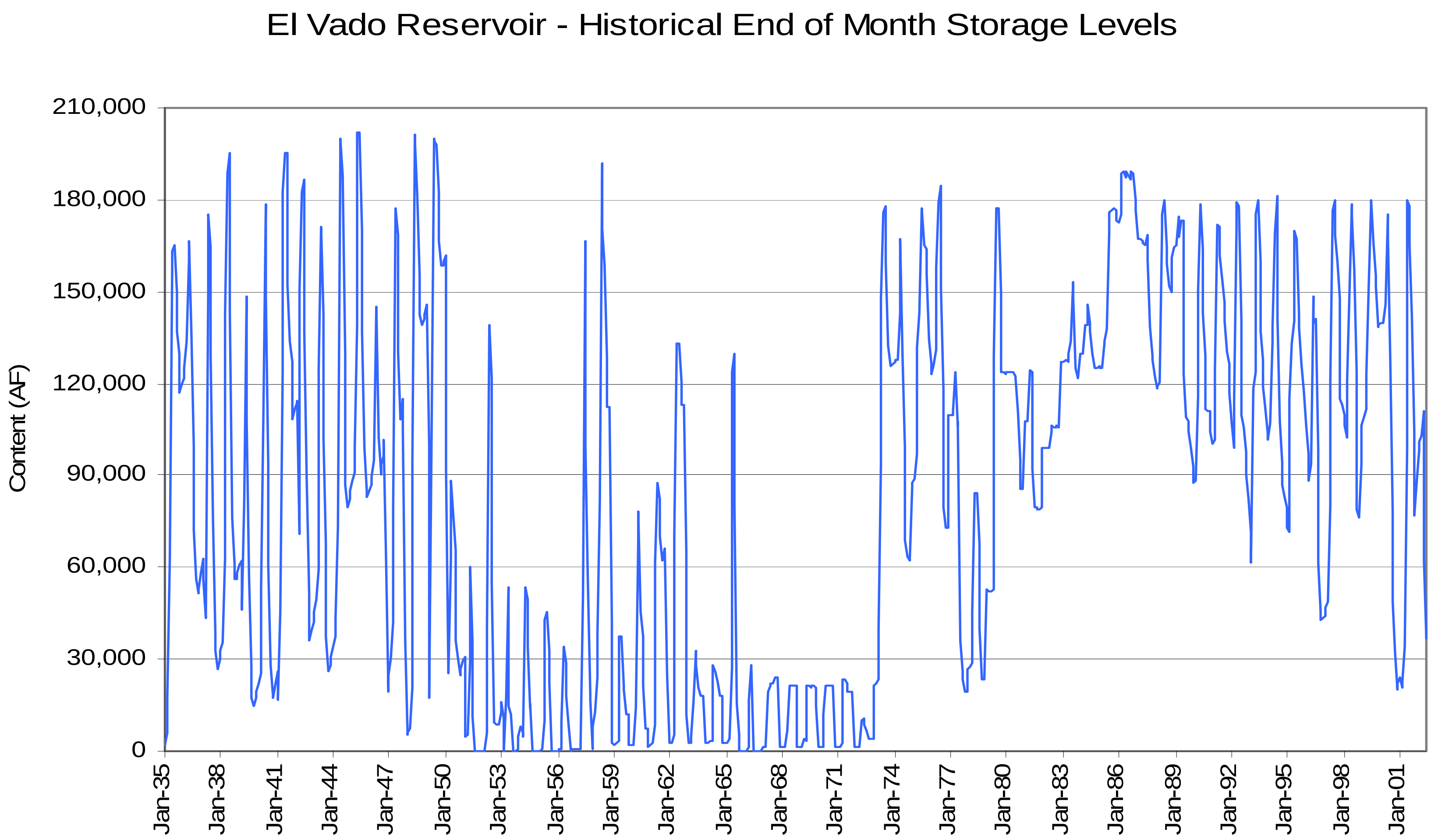
Source: SSPA, July 2000 Water Supply Study of the Middle Rio Grande

New Mexico's Compact Compliance

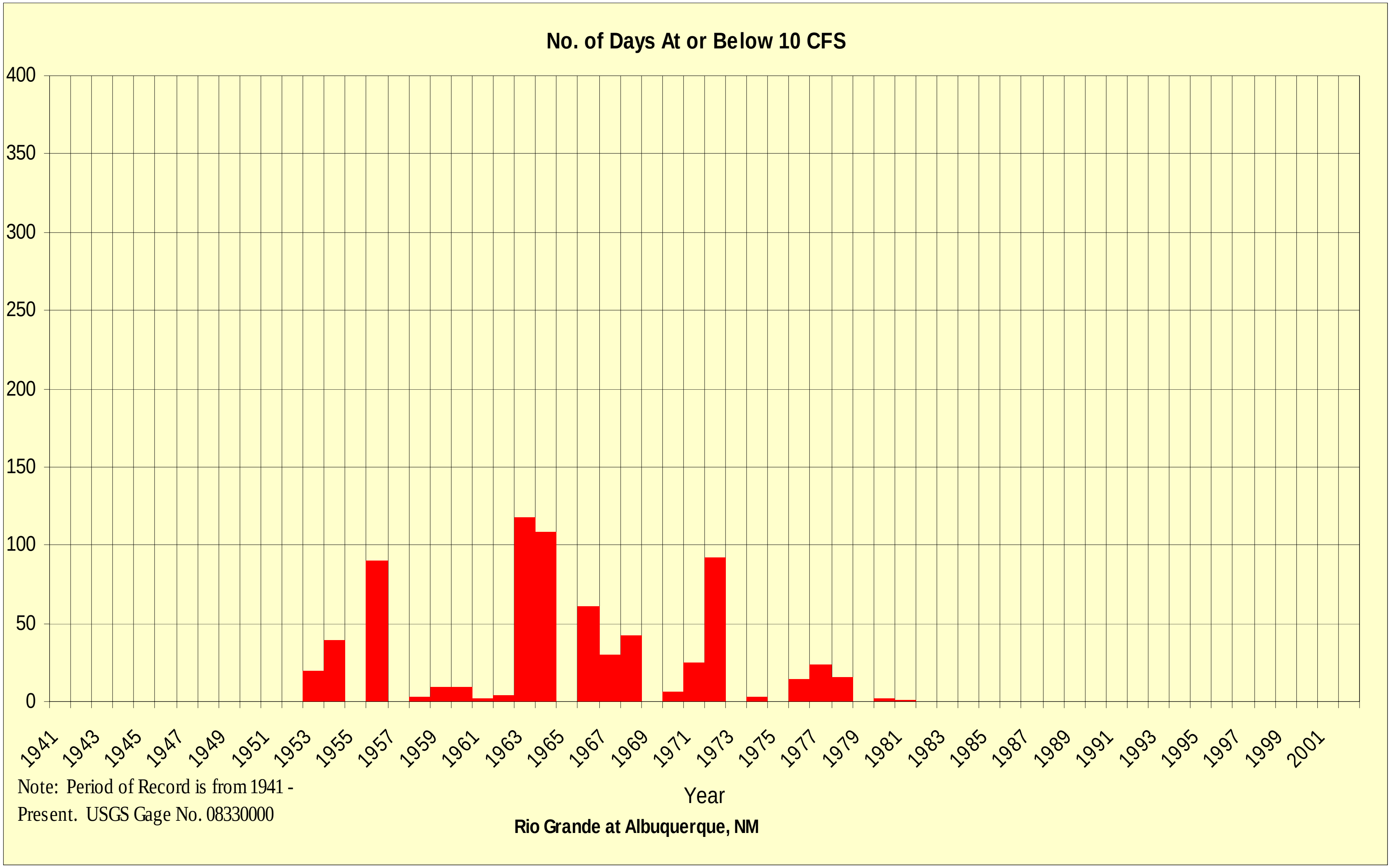


Variable and Limited Surface Water Supply

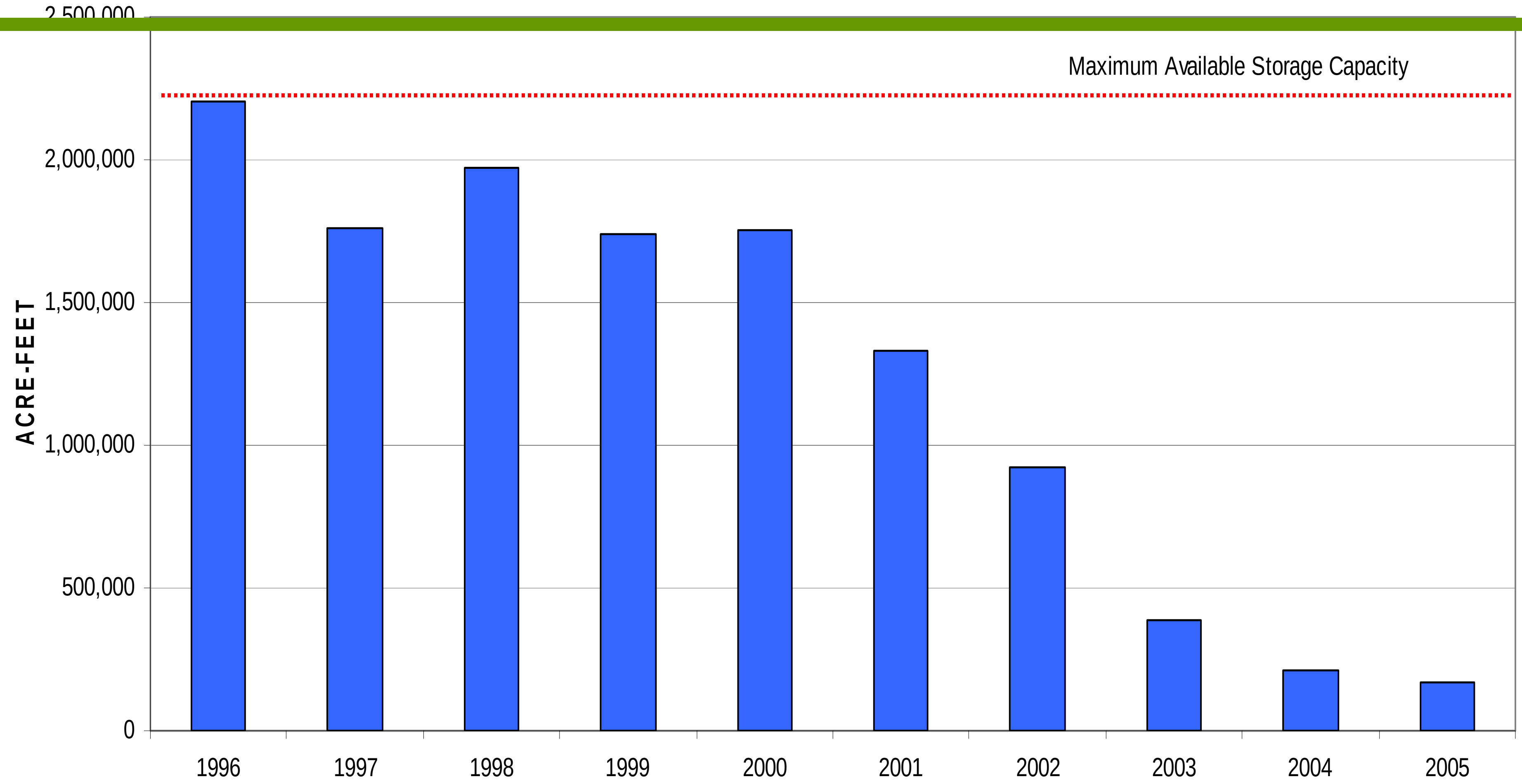



El Vado Reservoir - Historical End of Month Storage Levels
Content (AF)
210,000
180,000
150,000
120,000
90,000
60,000
30,000
0
Jan-35
Jan-38
Jan-41
Jan-44
Jan-47
Jan-50
Jan-53
Jan-56
Jan-59
Jan-62
Jan-65
Jan-68
Jan-71
Jan-74
Jan-77
Jan-80
Jan-83
Jan-86
Jan-89
Jan-92
Jan-95
Jan-98
Jan-01

Hydrologic Reality at Albuquerque



RIO GRANDE PROJECT STORAGE



Note: Storage values as of Jan 1 each year. Elephant Butte and Caballo Reservoirs included in analysis. Value for Jan 1, 2005 is estimated

Some NMISC Rio Grande Basin Bureau Work

- **Efforts to Balance/Increase Supply**
  - River Maintenance with Reclamation
  - Elephant Butte Pilot Channel
  - Daily River Management
  - Compact Oversight
  - Hydrologic Investigations and Research
- **Addressing Federal Natural Resource Issues**
  - NEPA
  - ESA Collaborative Program
  - Litigation
- **Addressing the Texas Litigation Threat**

Middle Rio Grande Endangered Species Act Collaborative Program

Facts on Rio Grande Endangered Species

Rio Grande silvery minnow *(Hybognathus amarus)*

Federally listed on July 20, 1994

Description: stout minnow with a maximum length of 3.5 inches. Historically 1 out of 7 most abundant minnows on the Rio Grande and is now the only spawning minnow left. Life span in the wild is ~2-years but few survive past 13 months.

Endangered due to:

- River regulation (dams, diversions), alteration of natural hydrograph
- Channelization
- Introduction of nonnative fishes
- Discharge of contaminants into the river

Southwestern willow flycatcher *(Empidonax traillii extimus)*

Federally listed on February 27, 1995

Description: Small gray-green bird measuring at most 5.75 inches. It is a neotropical migrant breeding in the southwest and migrates to Mexico down to South America.

Endangered due to:

- Loss, fragmentation or modification to habitat
- Urban, recreational and agricultural development, cattle grazing
- Water diversions, pumping and channelization
- Parasitization of the brown-headed cowbird

Why Save Endangered Species?

Since life began on Earth, countless creatures have come and gone, rendered extinct by naturally changing physical and biological conditions.

Since extinction is part of the natural order, and if many other species remain, some people ask: "Why save endangered species? Why should we spend money and effort to conserve them? How do we benefit?"

The Endangered Species Act of 1973 expressed the intent of Congress that recognized the esthetic, ecological, educational, historical and scientific value to the Nation. Although extinctions occur naturally, scientific evidence strongly indicates that the rate of extinction is much higher than what naturally occurred due to exploitation of resources, introduction of exotics, environmental pollution and diseases.

CIA

Water in the Middle Rio Grande

Prolonged Drought

- Years of below average snowpack runoff and weak monsoonal seasons
- Article VII of Rio Grande Compact in effect, limiting upstream reservoir storage

Impacts to the Species

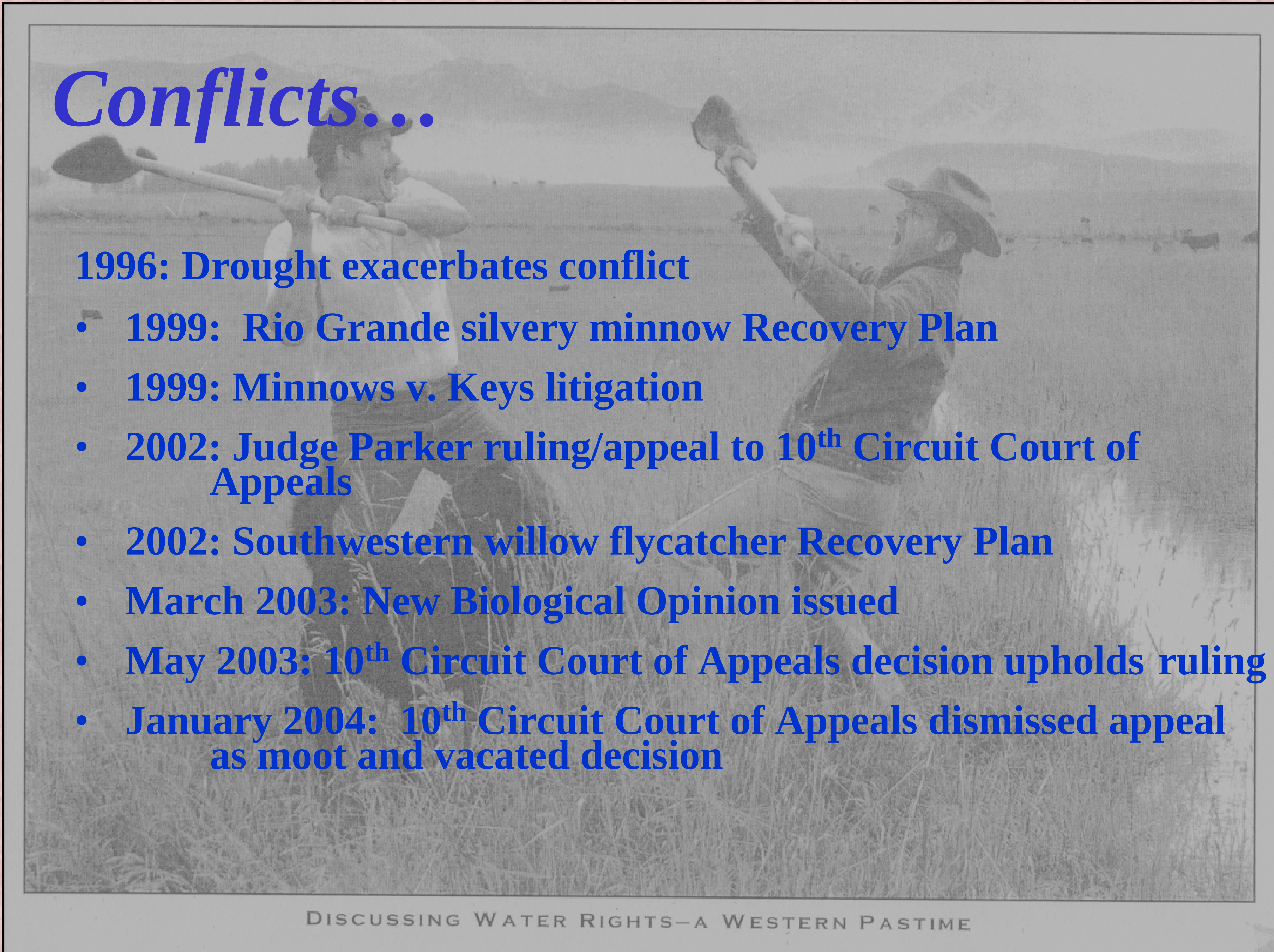
- Dams/Diversions
- Channelization
- Hydrograph

- Sediment
- Nonnative Plants and Animals

Conflicts…

1996: Drought exacerbates conflict

- **1999: Rio Grande silvery minnow Recovery Plan**
- **1999: Minnows v. Keys litigation**
- **2002: Judge Parker ruling/appeal to 10th Circuit Court of Appeals**
- **2002: Southwestern willow flycatcher Recovery Plan**
- **March 2003: New Biological Opinion issued**
- **May 2003: 10th Circuit Court of Appeals decision upholds ruling**
- **January 2004: 10th Circuit Court of Appeals dismissed appeal as moot and vacated decision**



Reaching Consensus

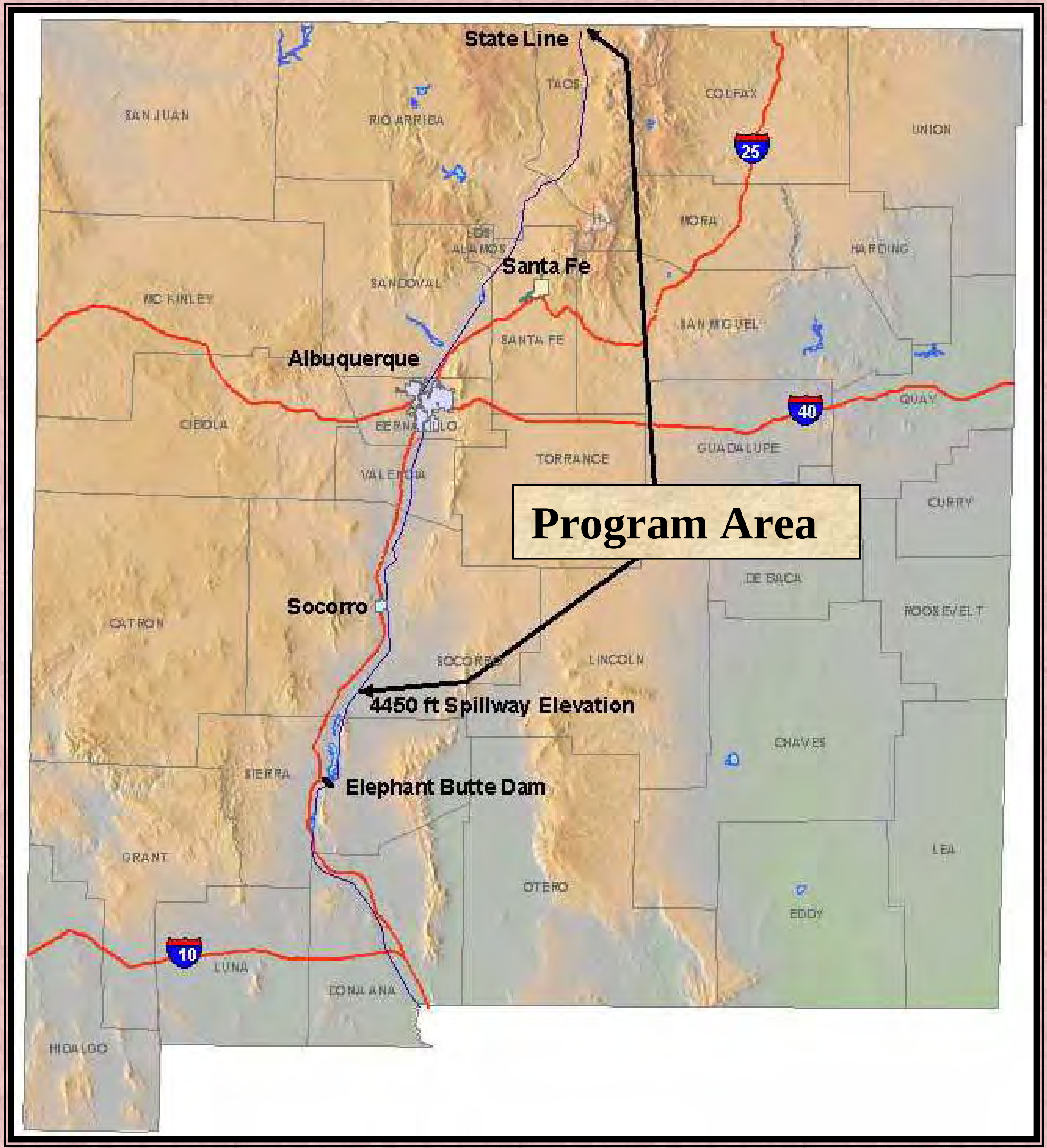
Collaborative Program History

- 1999 ESA Workgroup convened
- 2000 ESA Workgroup members sign first MOU
- 2002 Second MOU establishes Interim Steering Committee
- 2003 Executive Committee established; MOU extended and NEPA process commenced based on the 2003 Biological Opinion
- 2006 Administrative duties reside with the Bureau of Reclamation

Program Signatories

to the 2006 Memorandum of Understanding

- Assessment Payers Association of the MRGCD
- Attorney General, State of NM
- City of Albuquerque
- MRG Conservancy District
- National Association of Industrial and Office Properties
- New Mexico State University
- NM Department of Game and Fish
- NM Department of Agriculture
- NM Environment Department
- NM Interstate Stream Commission
- Pueblo of Santa Ana
- Pueblo of Santo Domingo
- Rio Grande Water Rights Association
- US Bureau of Indian Affairs
- US Bureau of Reclamation
- USDA, Forest Service, Rocky Mountain Research Station
- US Corps of Engineers
- US Fish and Wildlife Service
- University of New Mexico



State Line
TAOS
COLFAX
SAN JUAN
RIO ARRIBA
UNION
25
MORA
LOS ALAMOS
HARDING
Santa Fe
SANDOVAL
MC KINLEY
SAN MIGUEL
SANTA FE
Albuquerque
QUAY
40
CIBOLA
BERNALILLO
GUADALUPE
TORRANCE
VALENCIA
CURRY
Program Area
DE BACA
Socorro
ROOSEVELT
CATRON
SOCORRO
LINCOLN
4450 ft Spillway Elevation
CHAVES
SIERRA
Elephant Butte Dam
LEA
GRANT
OTERO
EDDY
10
LUNA
DONA ANA
HIDALGO

Program Goals

- Protect and improve the status of listed species in the Middle Rio Grande with emphasis on:
  - **Rio Grande silvery minnow**
  - **Southwestern willow flycatcher**
- Contribute to recovery of listed species
- Simultaneously protect existing and future water uses
- Achieve these objectives while complying with state and federal law, including compact delivery obligations


Habitat Restoration
Subcommittee

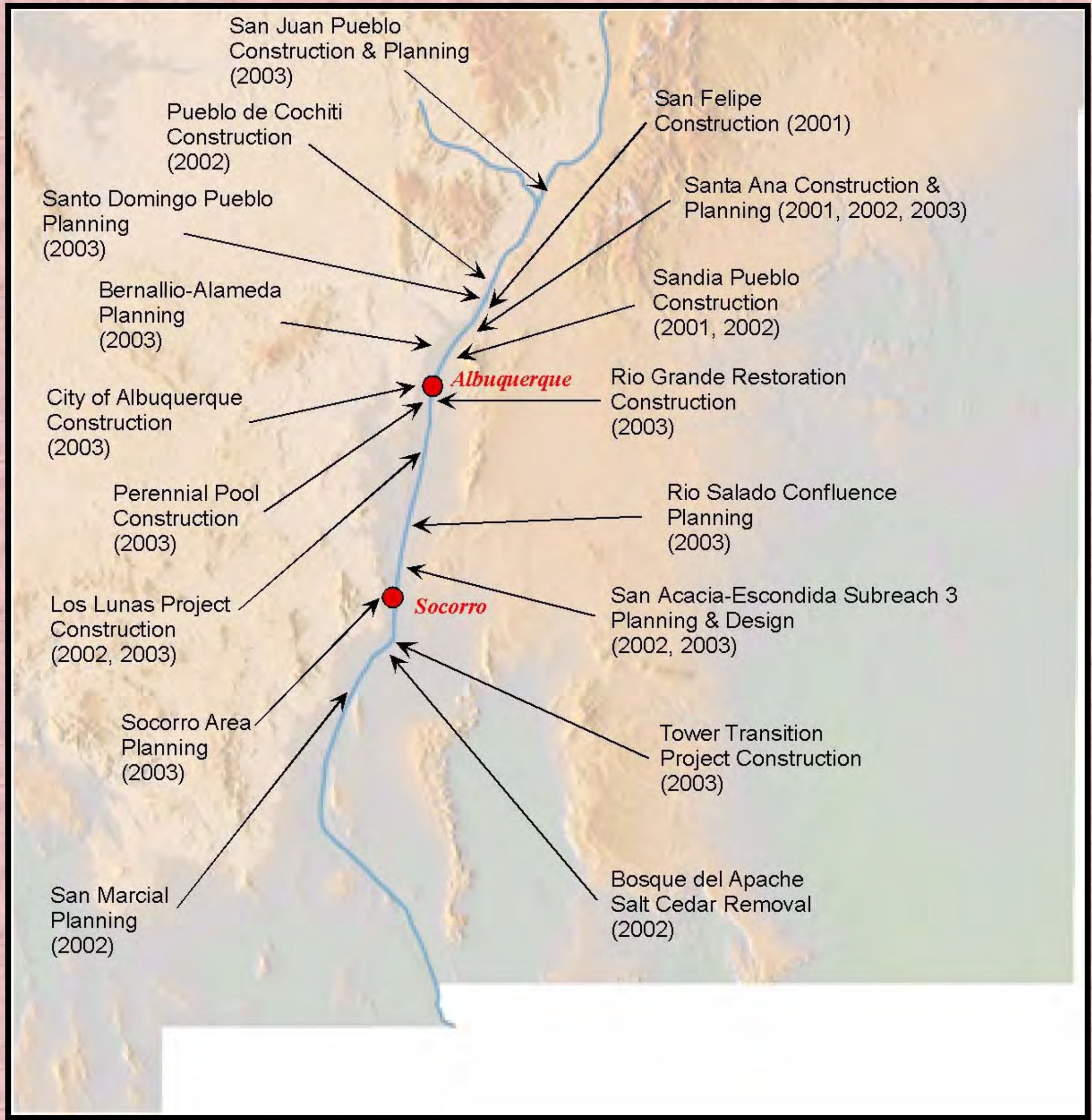
Habitat Restoration Goals

- Provide more suitable habitat for all life stages of the silvery minnow
  - Low velocity areas, especially at high flows
  - Conditions that reduce transport of eggs and larvae downstream
- Provide additional nesting habitat for flycatcher
  - Dense stands of young willows near water
  - Near other occupied territories and nests
- Reduce riparian water use
- Reduce fire danger

Habitat Restoration Priorities

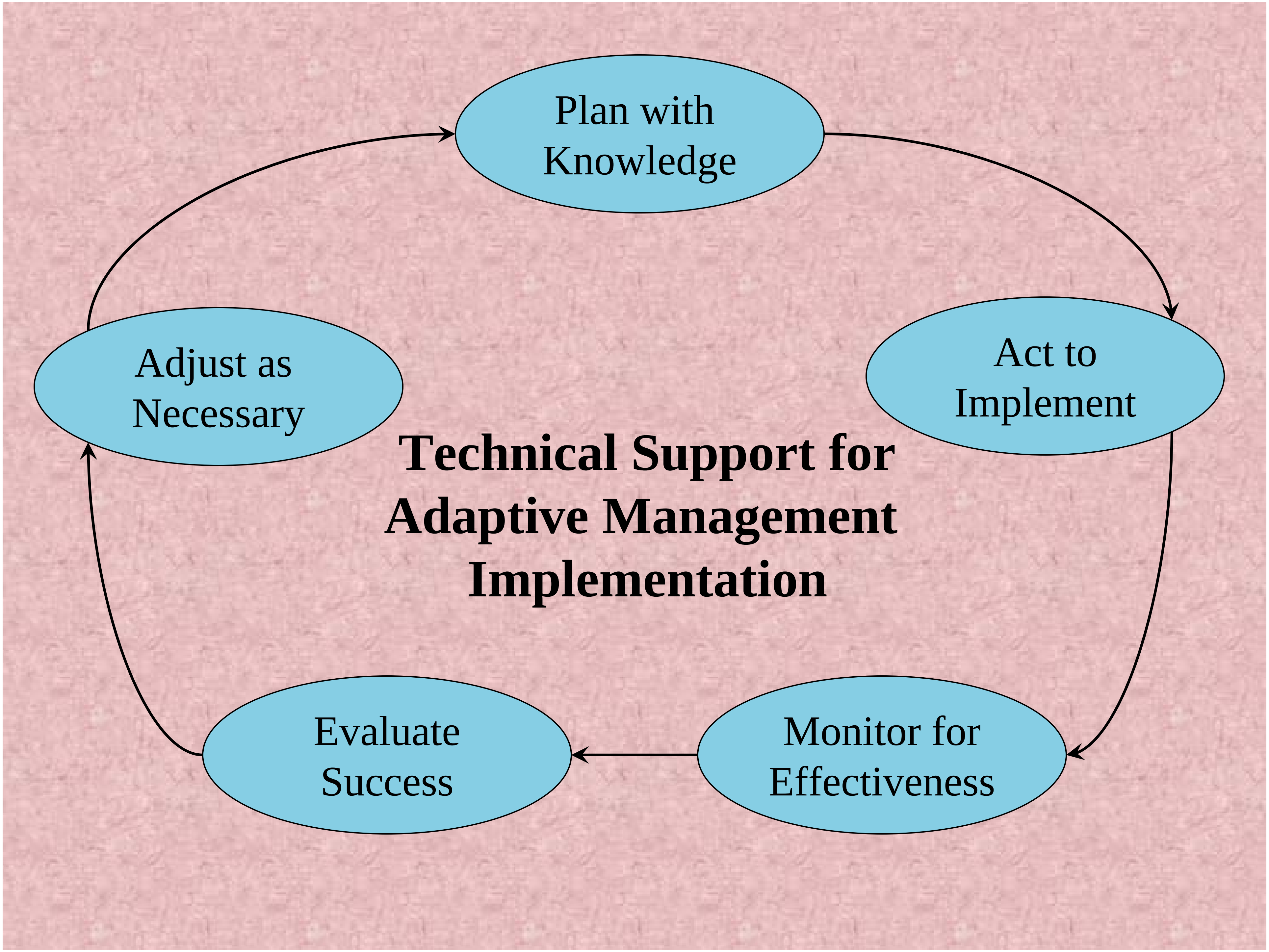
- Rio Grande silvery minnow habitat restoration between Cochiti Dam and Isleta Diversion Dam
- Fish passage planning and design
- Restoration projects that can be completed in the next 12 – 24 months

Habitat Restoration and Improvement Projects



Examples of Habitat Restoration

Science Subcommittee


Plan with Knowledge
Act to Implement
Monitor for Effectiveness
Evaluate Success
Adjust as Necessary
Technical Support for Adaptive Management Implementation

Science Goals

- Research to support knowledge-based decisions for improving and creating habitat for the species
- Research to understand the needs for species survival and recovery
- Monitoring to establish baseline and gauge success of Program activities

Science Priorities

- Research the population dynamics
- Augment and propagate the Rio Grande silvery minnow
- Research the hydrologic and geomorphic impacts on the species (e.g. changes to river, evapotranspiration, water quality)
- Monitor the southwestern willow flycatcher

Propagation and Augmentation

Naturalized Refugium at BioPark **Minnows Released in Rio Grande**

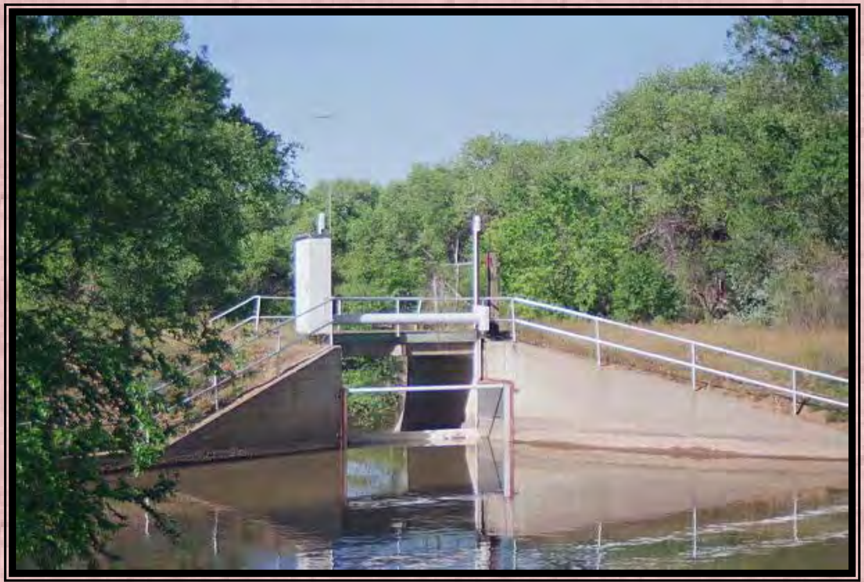
Monitoring

- **Collect data from projects**
- **Assess individual habitat projects**
- **Determine benefits of Program activities**

Water Acquisition and Management Subcommittee

Water Acquisition and Management Goals

- Evaluate and develop mechanisms for making water available for ESA purposes while protecting existing uses
- Assist in the negotiation and development of these mechanisms with Bureau of Reclamation



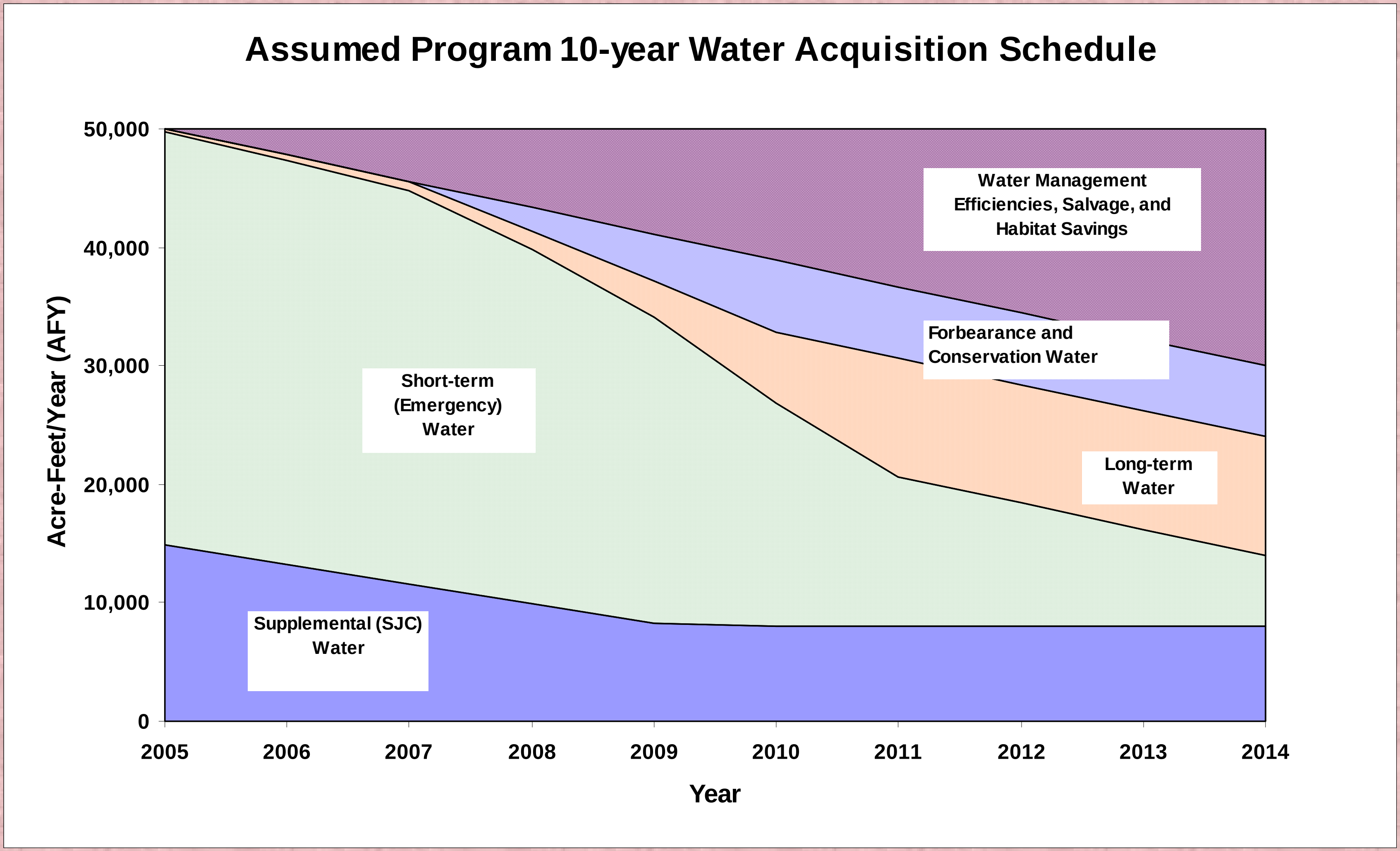
Water Acquisition and Management Priorities

- Meet the flow requirements established in the Biological Opinion
- Support measures for short-term water acquisition and pumping as necessary
- Develop long-term strategies for sustainable river and water management to promote recovery of the species

Meeting Future Water Demand

- Annual average projected water demand to meet needs of species estimated at 50,000 acre-feet
- Available San Juan-Chama lease water, (averaging 13,000 acre feet annually in 2003) decreases as entities start utilizing their contract water.

Potential Scenario for Long-Term Water Supply



Long-Term Strategies to Improve River and Water Management

Permanent acquisition, plus storage and management of Program water

Upstream storage for decrease in reservoir evaporation

City of Albuquerque curtailment of river diversions during periods of critical low flow

Improvements to irrigation metering, infrastructure and operational efficiency

Balancing of river flows through shallow groundwater pumping and recharge

Water salvage through riparian vegetation management

Voluntary irrigation forbearance and municipal conservation

Public Outreach

Purpose of Public Outreach

Communication to the Public, Media, and Government Officials

- Community presentations
- Information dissemination
- Program website

- News releases
- Interviews
- Site tours
- Educational programs


OVERVIEW

Adaptive Management within the Program

Development of a project review and evaluation process as well as a comprehensive **Monitoring Plan** to determine the Program success on the Middle Rio Grande endangered species

Routine feedback and direction from Executive Committee

Where we are going…

LET IT RAIN!

Achieve on-the-ground habitat restoration projects

Implement Long-term Plan

Finalize Programmatic Environmental Impact Statement

Seek Authorizing Legislation in next Congressional session

Develop strategic water planning for Middle Rio Grande ESA

Construct additional refugium for augmentation of RGSM

Middle Rio Grande Endangered Species Act Collaborative Program

http://www.fws.gov/mrgesacp/

Modeling Framework for the Middle Rio Grande Basin

Nabil Shafike

Interstate Stream Commission

10-3-2006

Model Types

Predictive:

Used to predict the consequences of certain actions.

Interpretive:

Used as a framework for studying system dynamics.

Generic:

Used to analyze hypothetical system.

MRG Models

- Surface Water Models:
  - *Upper Rio Grande Water Operation Model (URGWOM).*
  - *Flo-2D Model.*
- Groundwater Models:
  - *Albuquerque Basin Model.*
  - *Socorro Basin Model.*
  - *High Resolution GW models (riparian models).*
- Irrigation Management Models:
  - *MRG Decision Support System.*

URGWOM

Upper Rio Grande Water Operation Model (URGWOM)

URGWOM

- Rio Grande modeled in RiverWare™ Software
- Four Daily Time-Step Models: Accounting, Forecasting, Water Operations, & Planning
- Seven USBR & CORPS-operated reservoirs
- Physical modeling, reservoirs, reaches, diversions, etc.
- 16 Accounts of trans-basin "San Juan-Chama" water
- NRCS/NWS "coordinated" spring-runoff forecasts
- Rio Grande Compact "Lite" helps see Article VII status
- Operational "Rules" on how to run reservoirs (releases)

URGWOM models

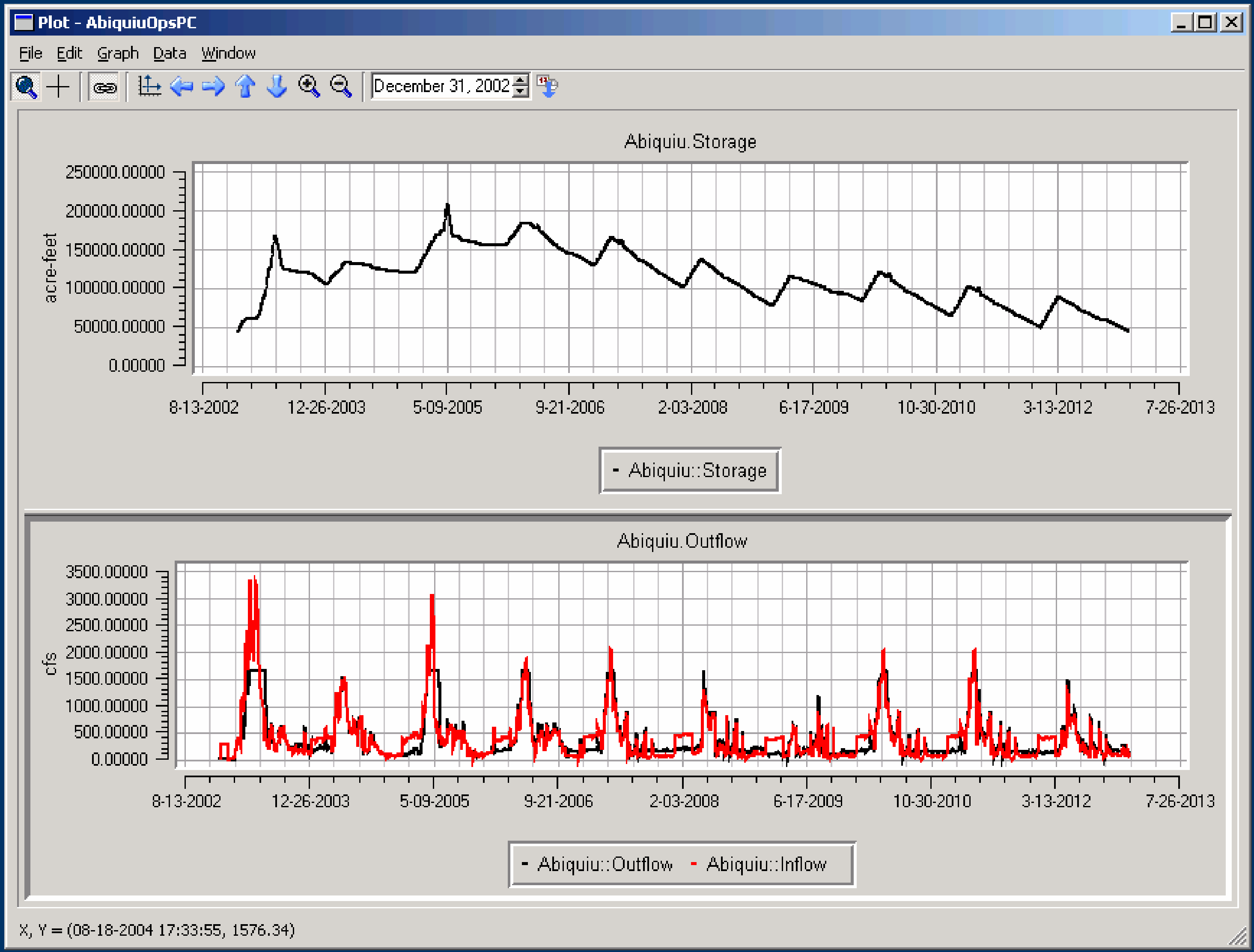
- Accounting (Reclamation, NMISC)
  - Input ♦ Up-to-current data; contractor and total outflows, storage (elevation), weather data , streamgages, and forecasted (from Forecast model)diversions, wastewater, etc.
  - Output ♦ Contractor losses and storages, total losses and computed inflow, local inflows, and reservoir reports

- Forecasting (Corps, Reclamation, NMISC)
  - Input ♦ Up-to-current volumes (from Account model), historic year hydrograph shapes, user-selected # of hydrograph shapes to average, and NRCS March-July (Volume) Forecasts to apply to shapes
  - Output ♦ Daily hydrographs, other parameters

URGWOM models

- Water Operations (Corps, Reclamation, NMISC)
  - Input ♦ Past days inflows, initial storages (total and contractor, from Account model) , and forecasted daily inflows, other parameters (from Forecast model)
  - Output ♦ Forecasted reservoir outflows and resulting streamflows, total and contractor storages (generally, releases from reservoirs are set by rules which consider all factors)
- Planning (Corps, NMISC, Reclamation)
  - Input ♦ Long-term forecasts and up-to-current conditions (total and contractor)
  - Output ♦ Long-term daily hydrographs, storages, system conditions (again, releases from reservoirs are set by rules)

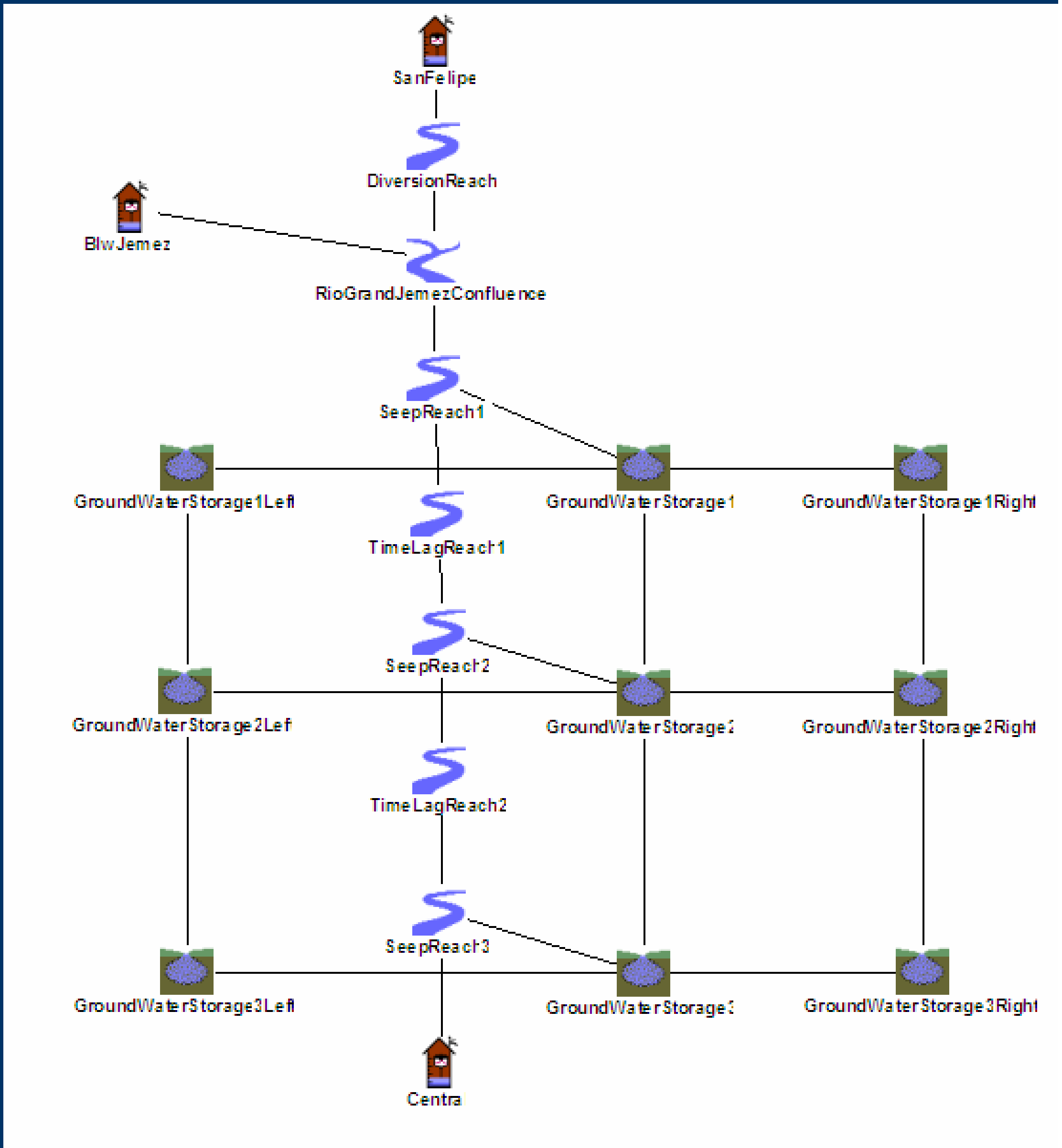
URGWOM


Plot - AbiquiuOpsPC
File Edit Graph Data Window
December 31, 2002
Abiquiu.Storage
acre-feet
250000.00000
200000.00000
150000.00000
100000.00000
50000.00000
0.00000
8-13-2002
12-26-2003
5-09-2005
9-21-2006
2-03-2008
6-17-2009
10-30-2010
3-13-2012
7-26-2013
Abiquiu::Storage
Abiquiu.Outflow
cfs
3500.00000
3000.00000
2500.00000
2000.00000
1500.00000
1000.00000
500.00000
0.00000
8-13-2002
12-26-2003
5-09-2005
9-21-2006
2-03-2008
6-17-2009
10-30-2010
3-13-2012
7-26-2013
Abiquiu::Outflow
Abiquiu::Inflow
X, Y = (08-18-2004 17:33:55, 1576.34)

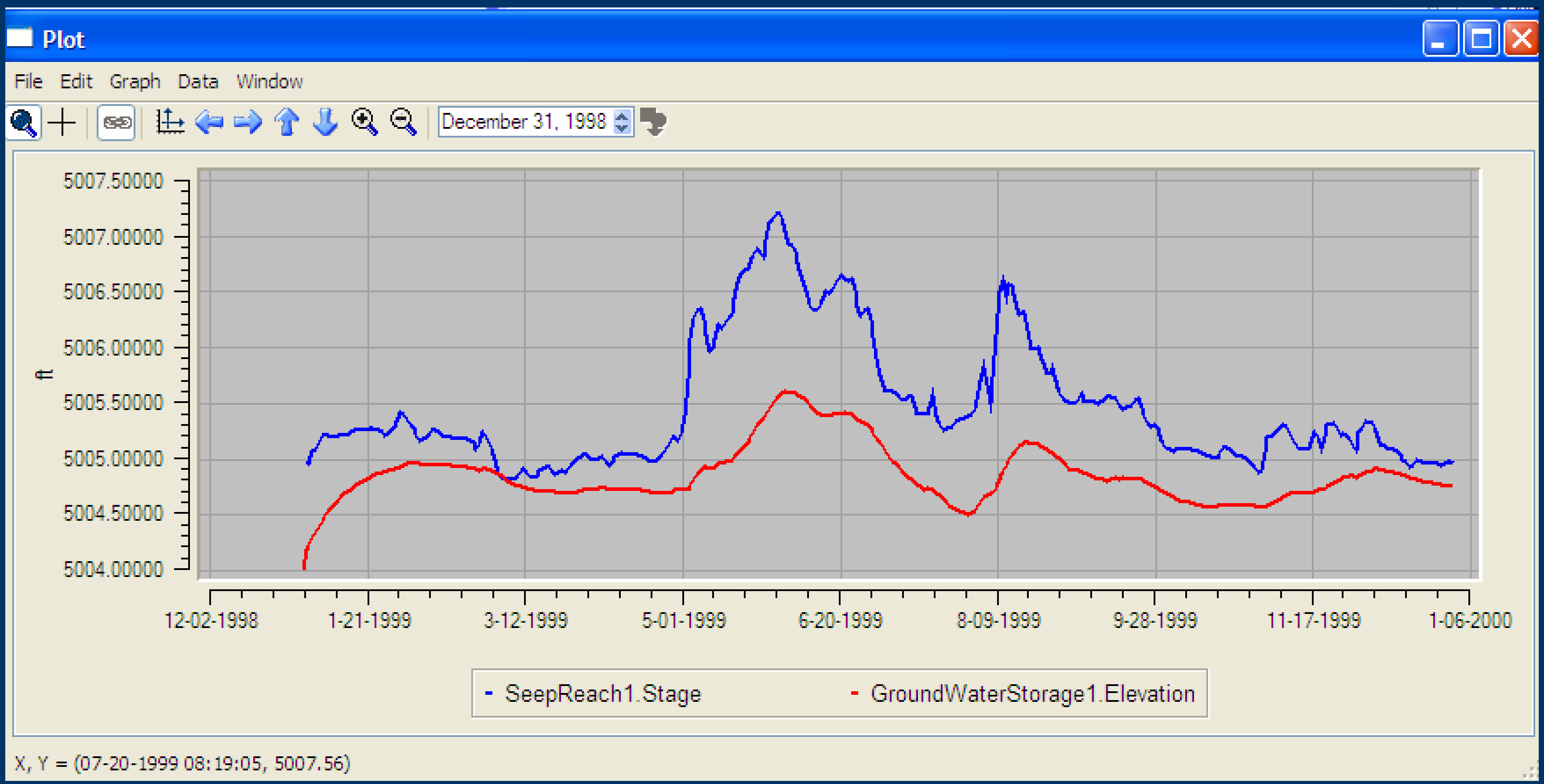
URGWOM

Improvements

1. *New Conceptual Design for the middle valley*
2. *SW/GW interaction*
3. *Monthly model (powersim)*



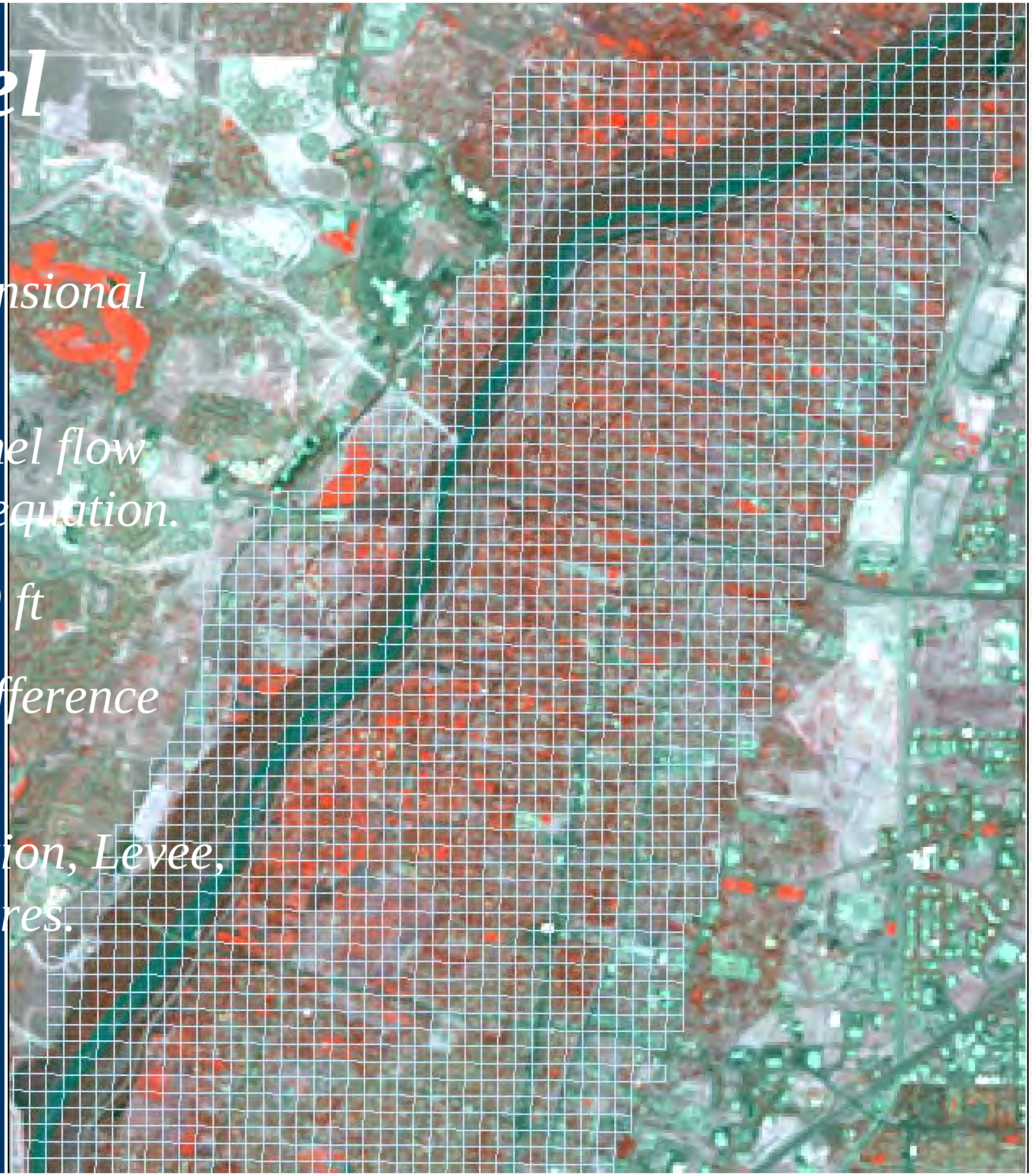
URGWOM



Plot
File Edit Graph Data Window
December 31, 1998
5007.50000
5007.00000
5006.50000
5006.00000
5005.50000
5005.00000
5004.50000
5004.00000
ft
12-02-1998
1-21-1999
3-12-1999
5-01-1999
6-20-1999
8-09-1999
9-28-1999
11-17-1999
1-06-2000
SeepReach1.Stage
GroundWaterStorage1.Elevation
X, Y = (07-20-1999 08:19:05, 5007.56)

Flo-2D Model

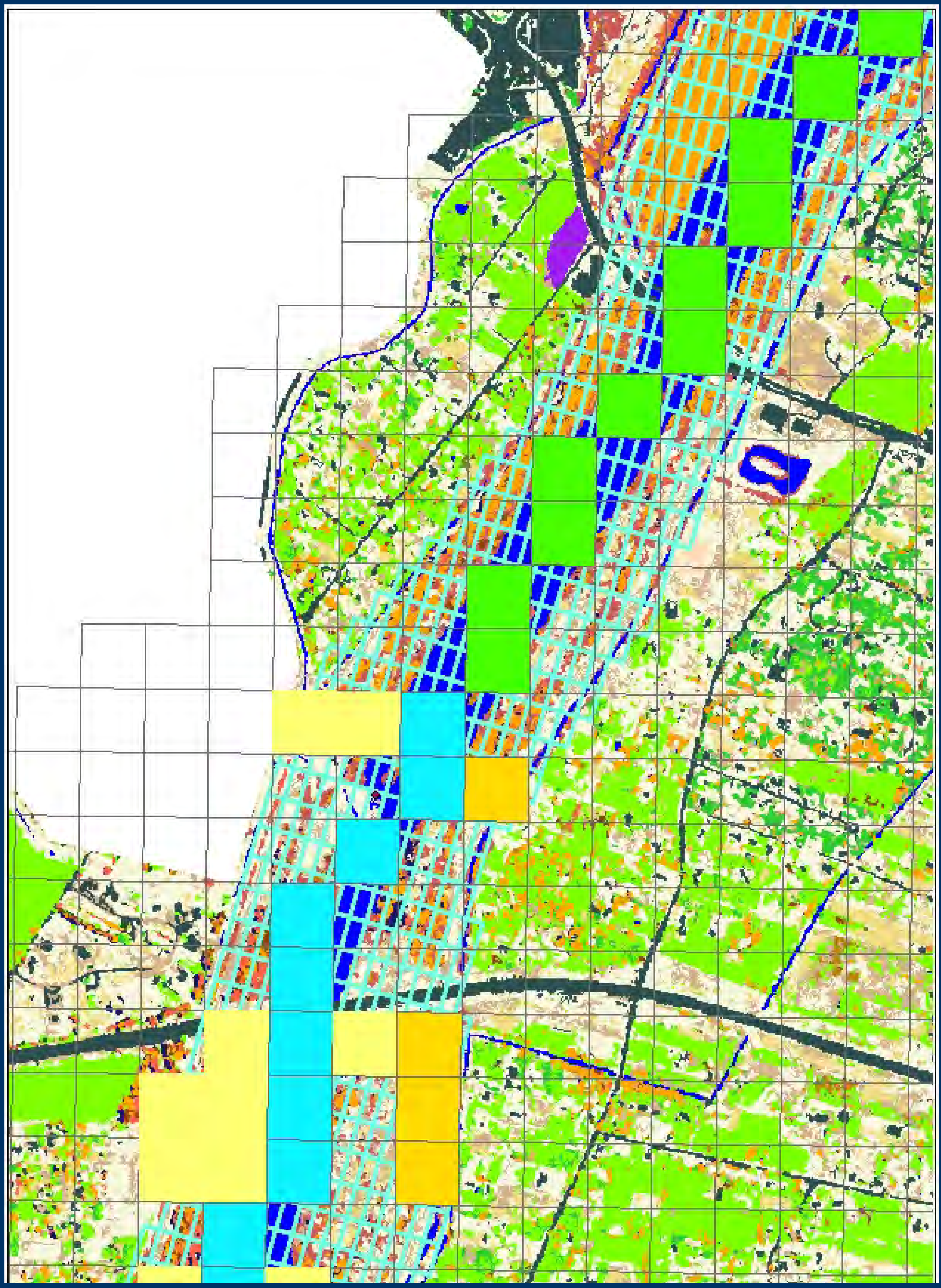
- Flo-2D is a two dimensional flood routing model.
- One dimension channel flow using dynamic wave equation.
- Grid size 500 ft x 500 ft
- Uses explicit finite difference approach.
- Infiltration, Evaporation, Levee, and hydraulic structures.



Flo-2D Model

Predicts:

- *Downstream Hydrograph*
- *Overland flooding.*



Albuquerque Basin Model

McAda and Barroll 2002 model grid is 1000x1000 meter uniform resolution and 9000 ft deep represented by 9 model layers. Seasonal stress period starts from 1990 to end of simulation.

Represented Physical Process:

- Specified Flow

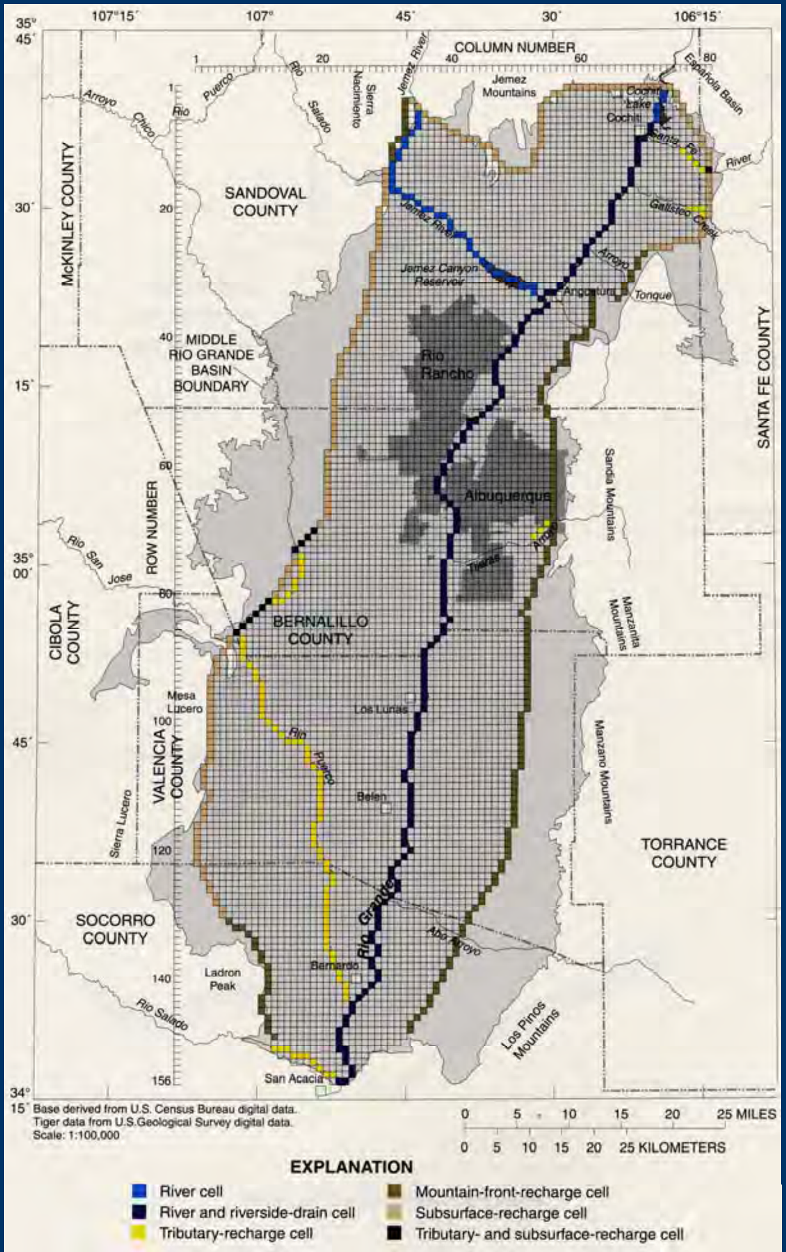
- Canal Seepage

- Crop Deep Percolation

- GW withdrawal

- Septic-Field Seepage

- Rio Puerco and Rio Jemez



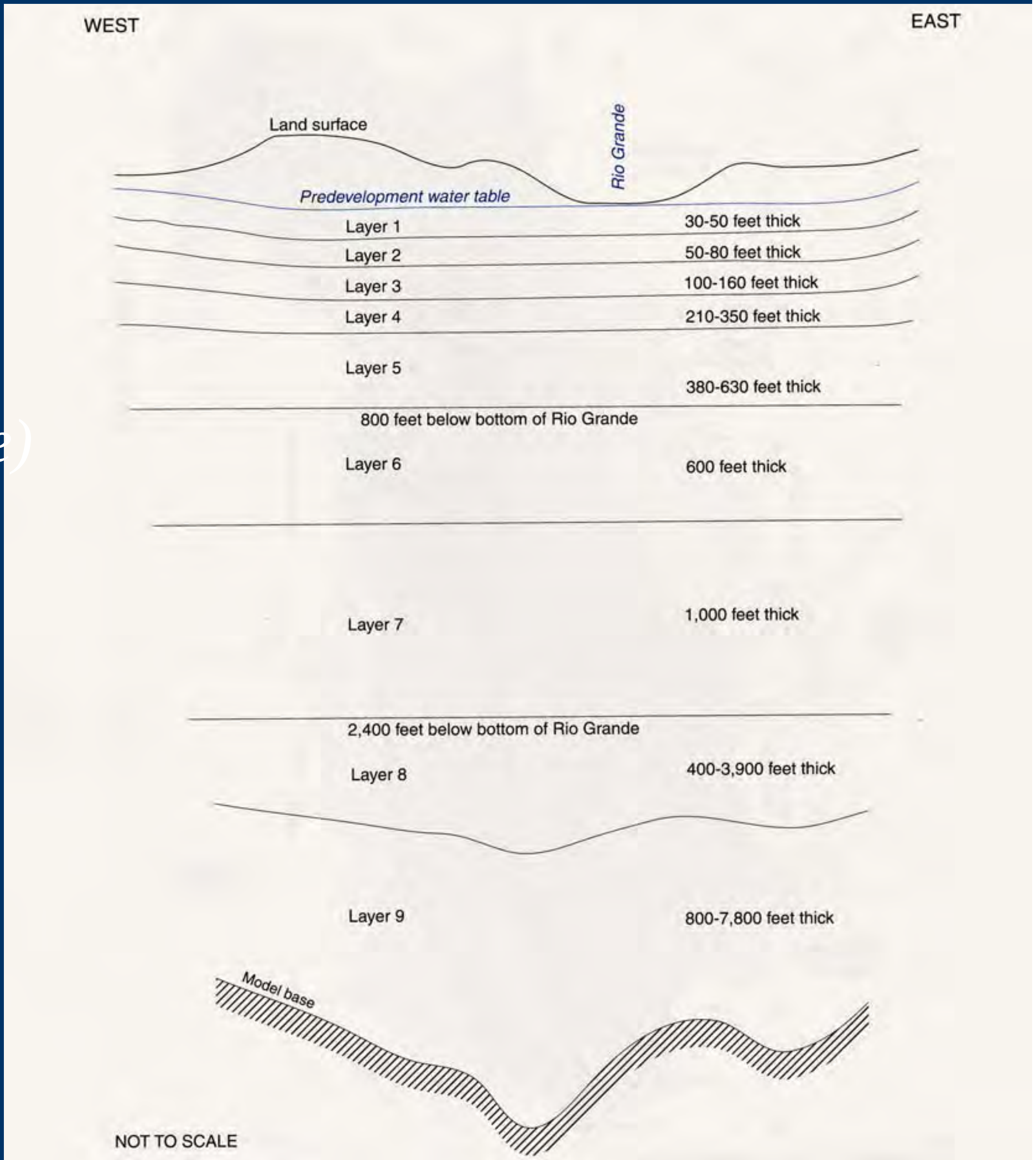
Albuquerque Basin Model

Head Dependent Flow

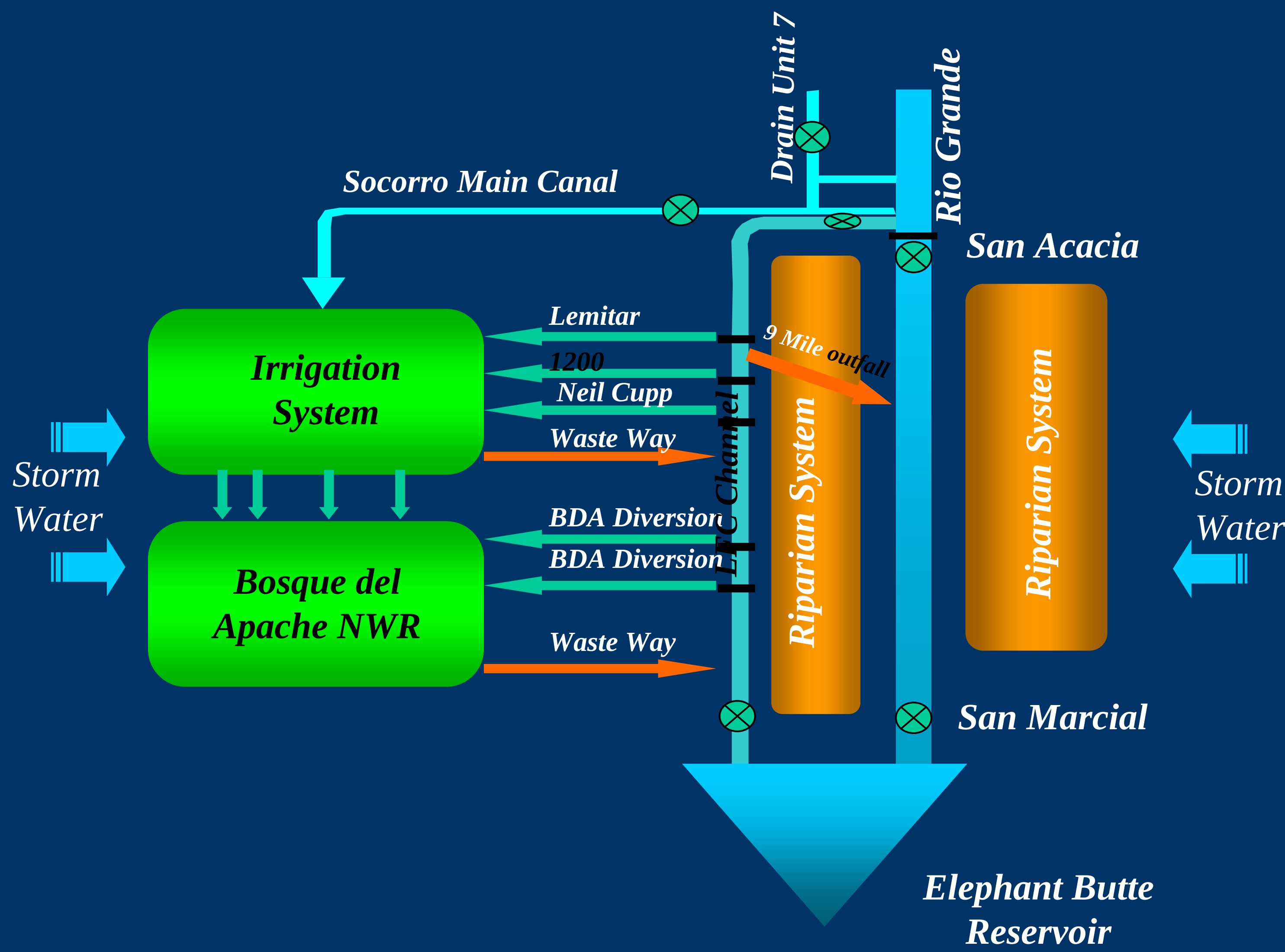
- *Rio Grande (Riv1)*
- *Riverside Drains (Riv1)*
- *Jemez River (Riv1)*
- *Riparian ET (ET-package)*

Predicts:

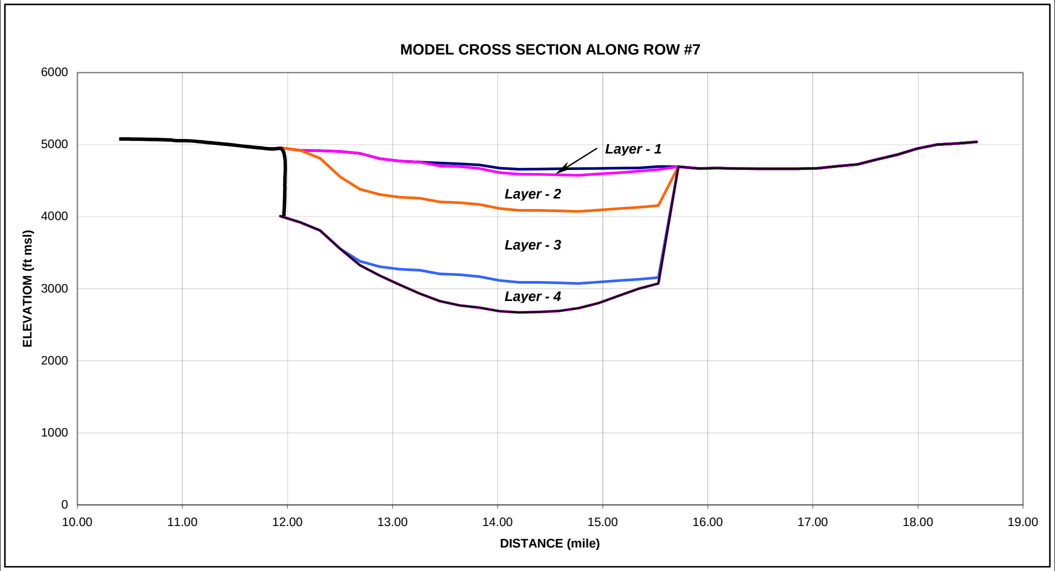
- *SW/GW Interaction.*
- *Aquifer Head and Drawdown.*

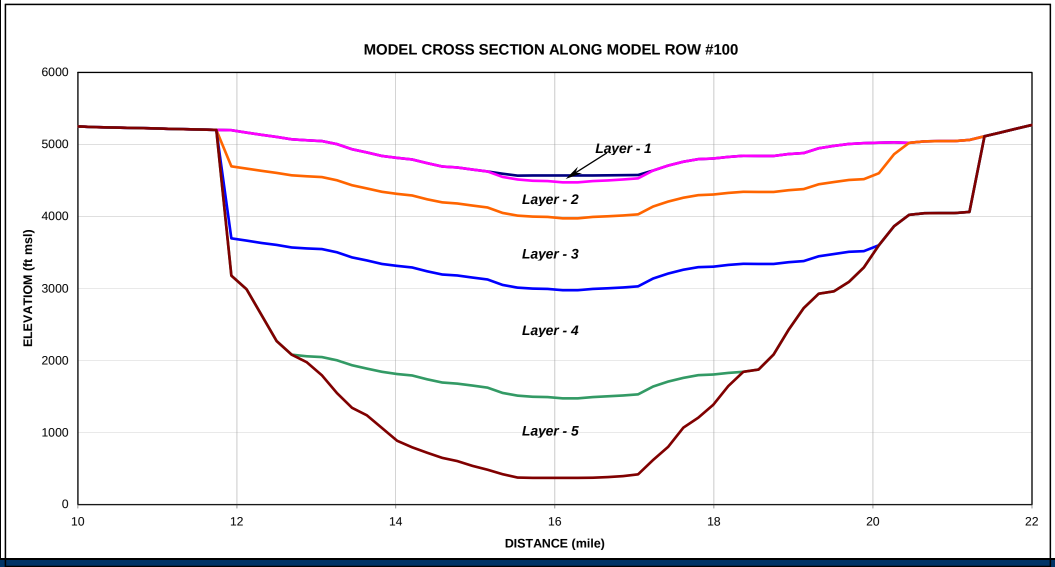


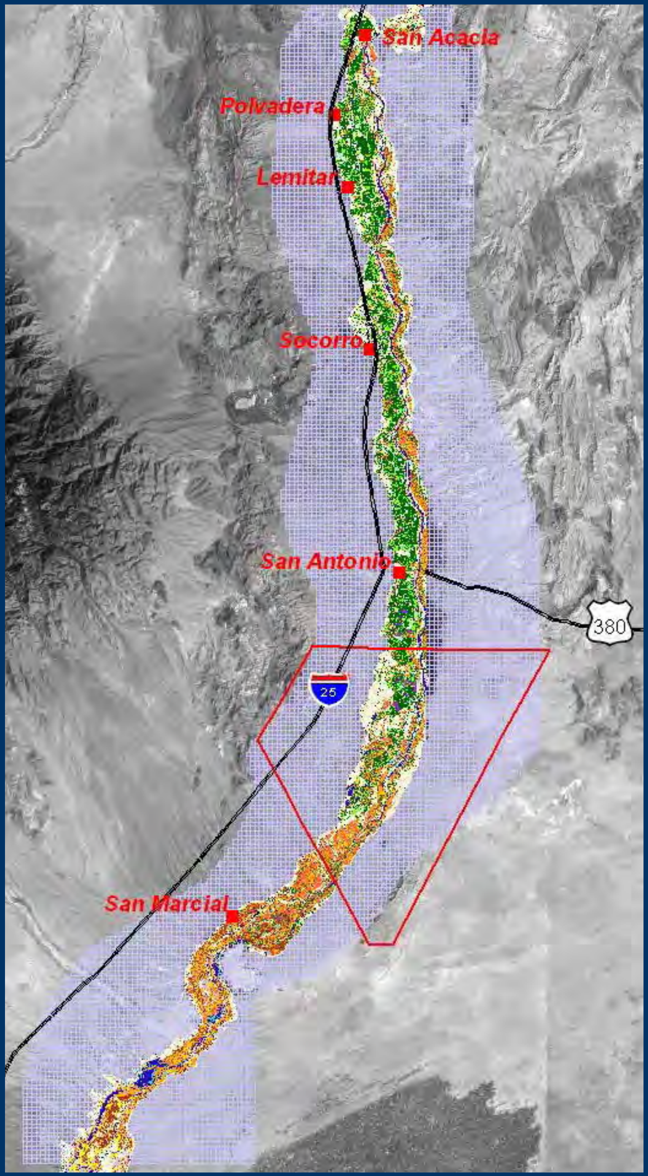
Socorro Basin Model



Socorro Basin Model



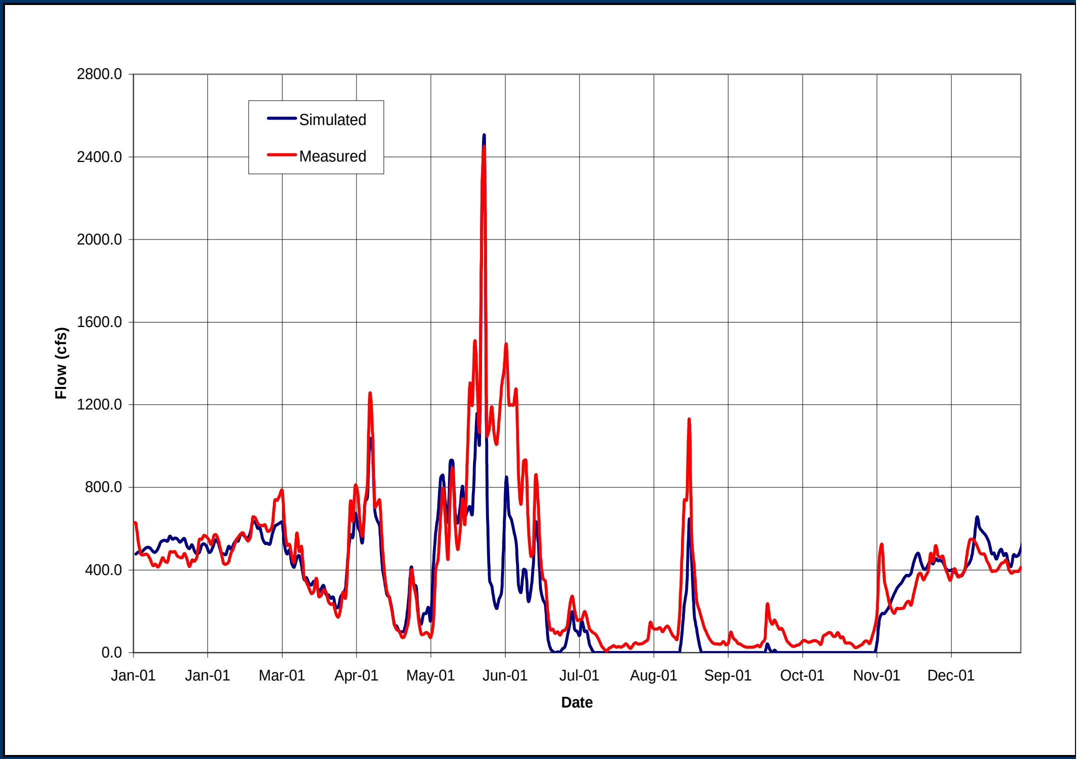




Socorro Basin Model

Represented Physical Process:

- *Rio Grande (Branch & Str.)*
- *LFCC (Branch & Str.)*
- *Crop Deep Percolation (Rch.)*
- *Canal Seepage (Str.)*
- *Drains (str-package)*
- *Riparian ET (ET-pckg)*
- *Mountain Front Recharge*



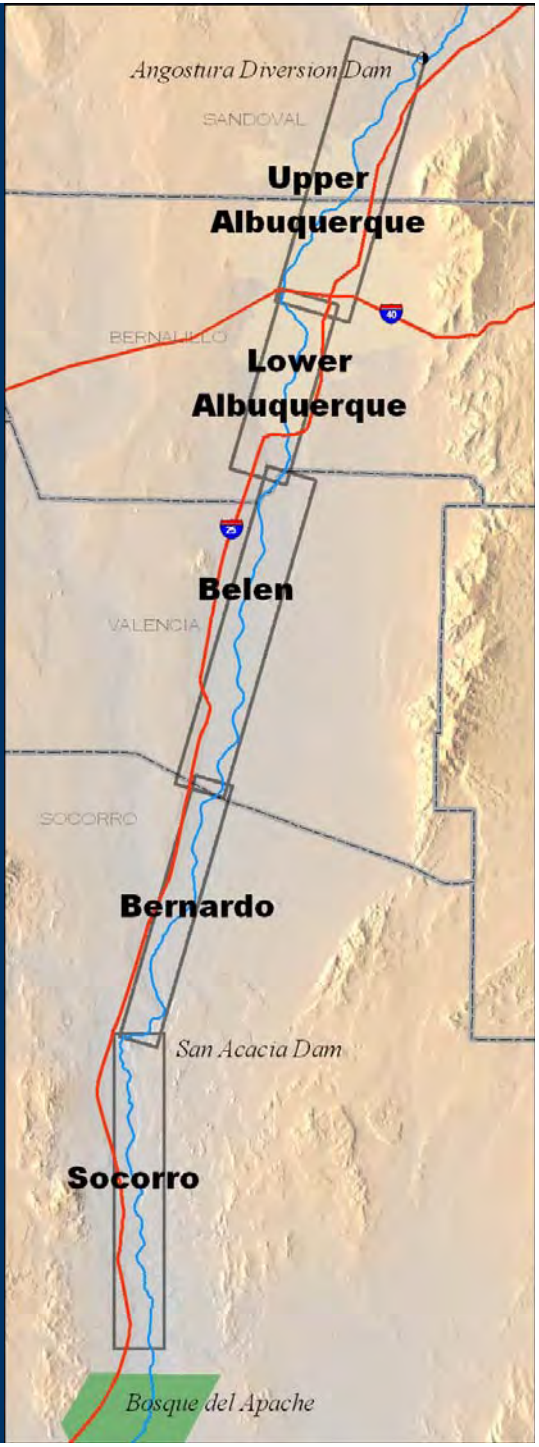
Predicts:

- *SW/GW Interaction*
- *SW downstream flow*
- *Aquifer Head and Drawdown*

Riparian Models

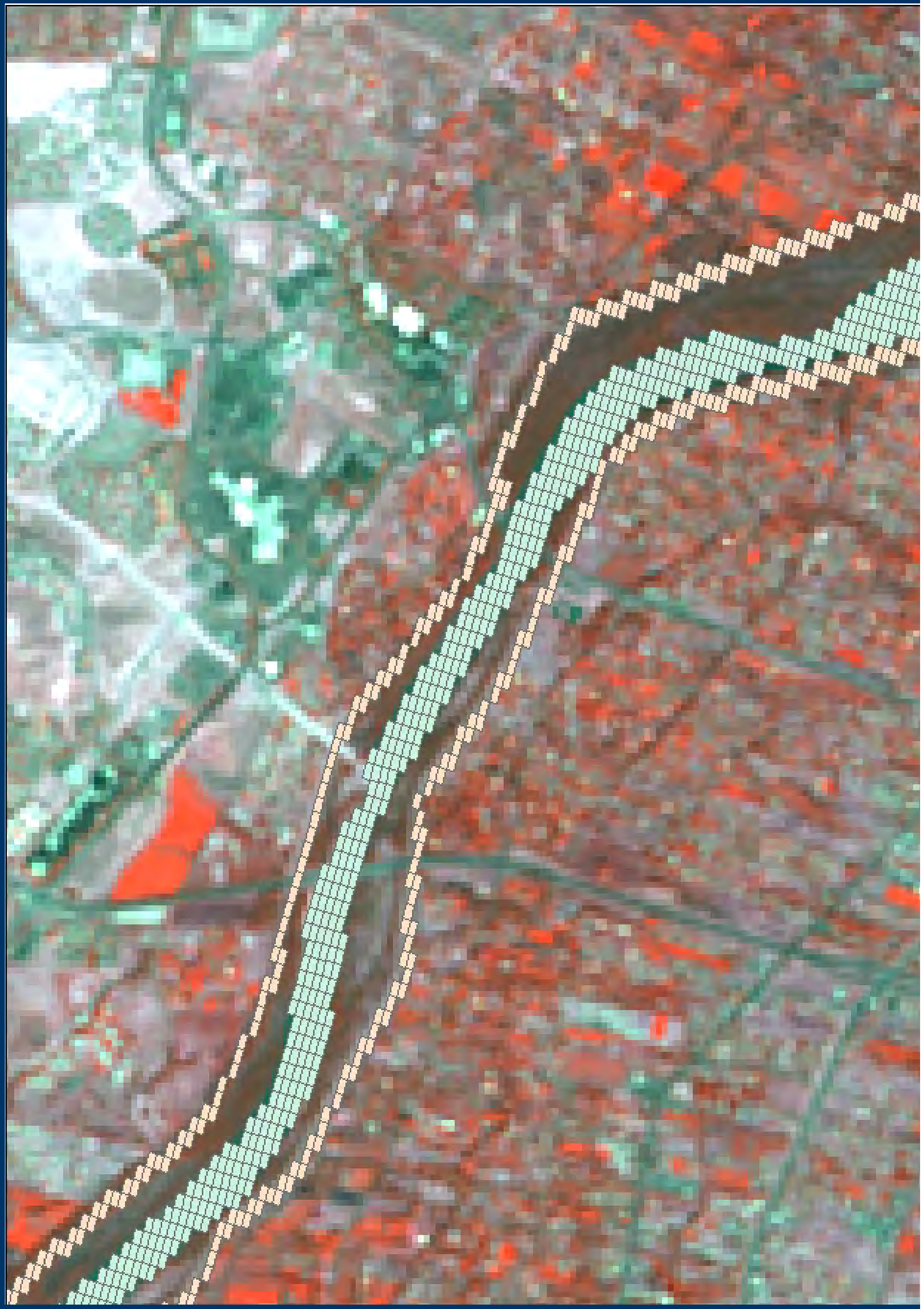
Series of 5 models, covering the Rio Grande from Angostura Diversion Dam to North Boundary of Bosque del Apache:

- ***Upper Albuquerque* -** Angostura Diversion Dam to I-40
- ***Lower Albuquerque* -** I-40 to Bernalillo-Valencia county line
- ***Belen* –** Bernalillo-Valencia county line to Valencia-Socorro county line
- ***Bernardo* -** Valencia-Socorro county line to San Acacia Dam
- ***Socorro* -** San Acacia Dam to North Boundary of the Bosque del Apache National Wildlife Refuge



Riparian Models

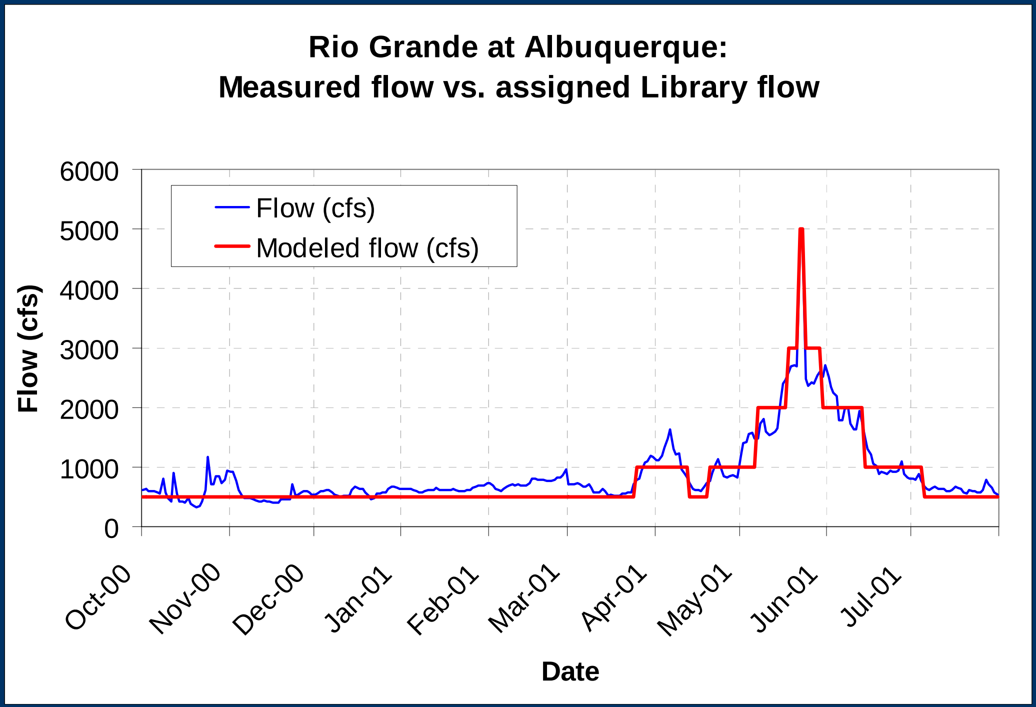
- Constructed in MODFLOW 2000
- Covers area between levees, including river, riverside drains, and riparian corridor contained within the levees
- Cells are 125’ by 250’ feet
- Four model layers:
  - Three layers within the Rio Grande Alluvium: 20’, 30’, 30’ in thickness
  - One layer within the Santa Fe Formation: 100’ in thickness



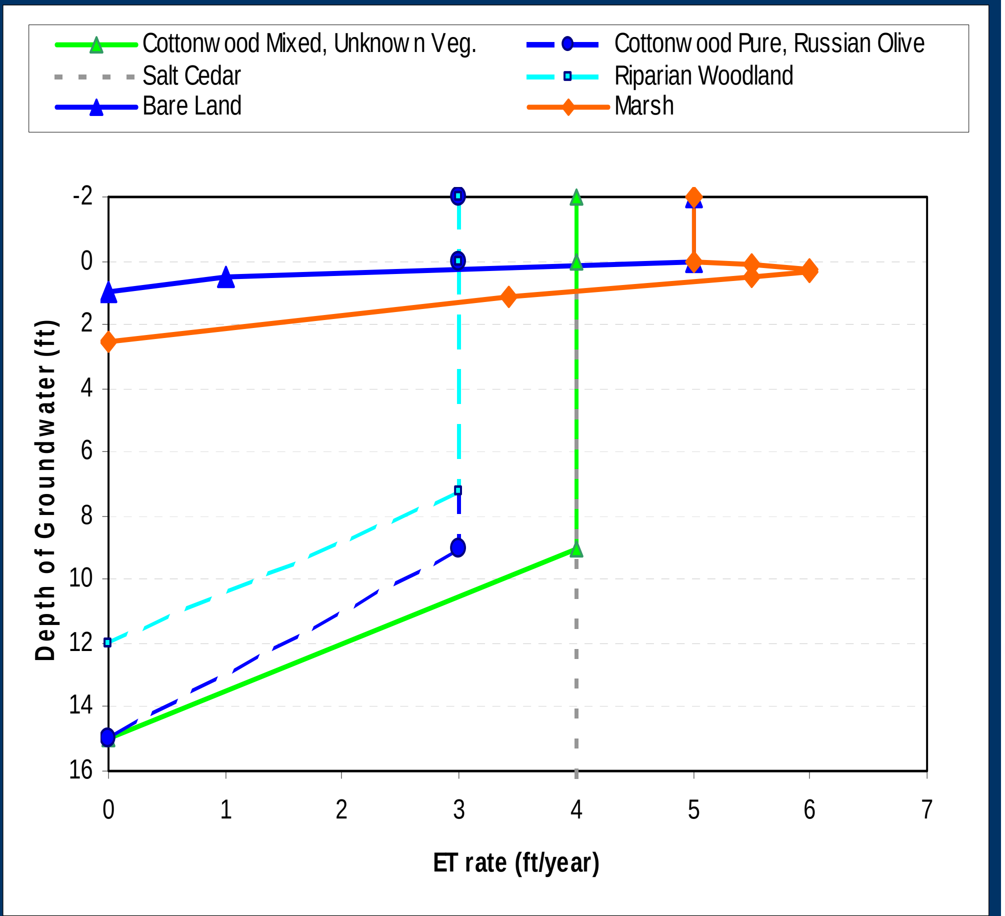
Structure

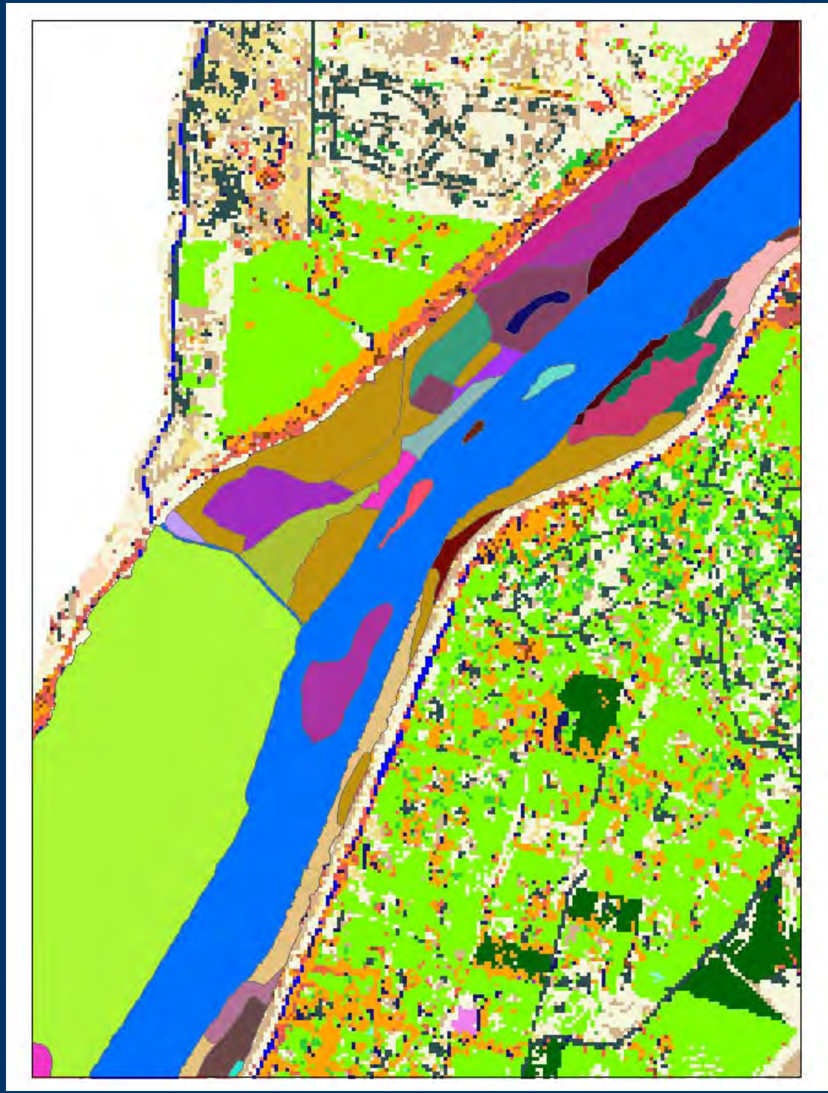
- Lateral boundaries include riverside drains (layer 1) and GHB cells (layers 2, 3, 4)
- Regional boundary conditions for GHB cells were obtained from regional groundwater model
- Variable riparian ET rates, dependent on mapped vegetation classifications.

Riparian Model Flow Library		
Low flow	Moderate Flow	High Flow
100 cfs	1,000 cfs	5,000 cfs
500 cfs	2,000 cfs	7,000 cfs
	3,000 cfs	10,000 cfs

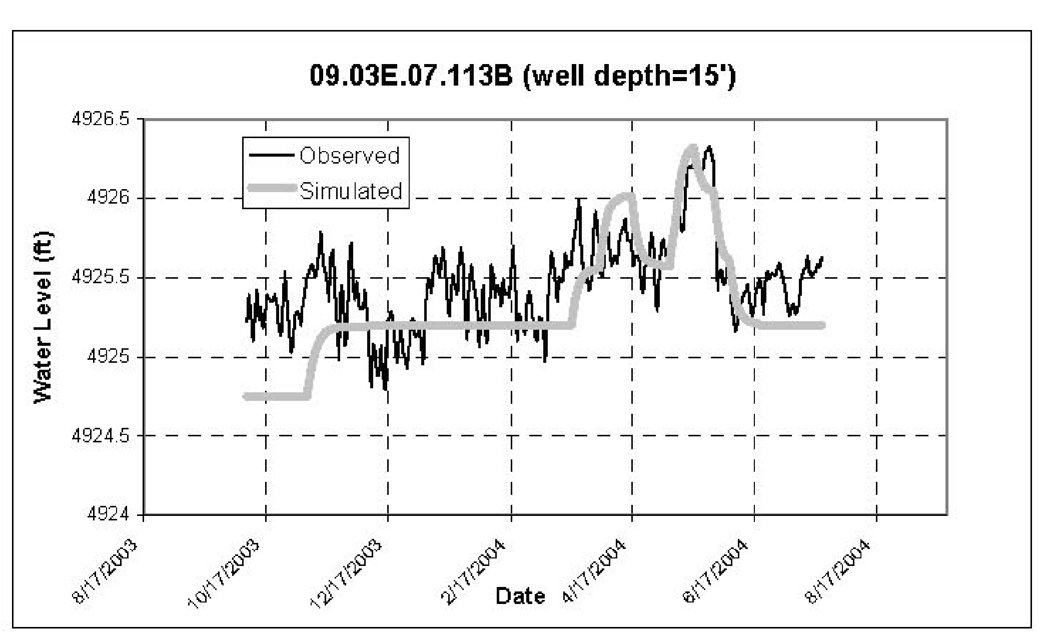


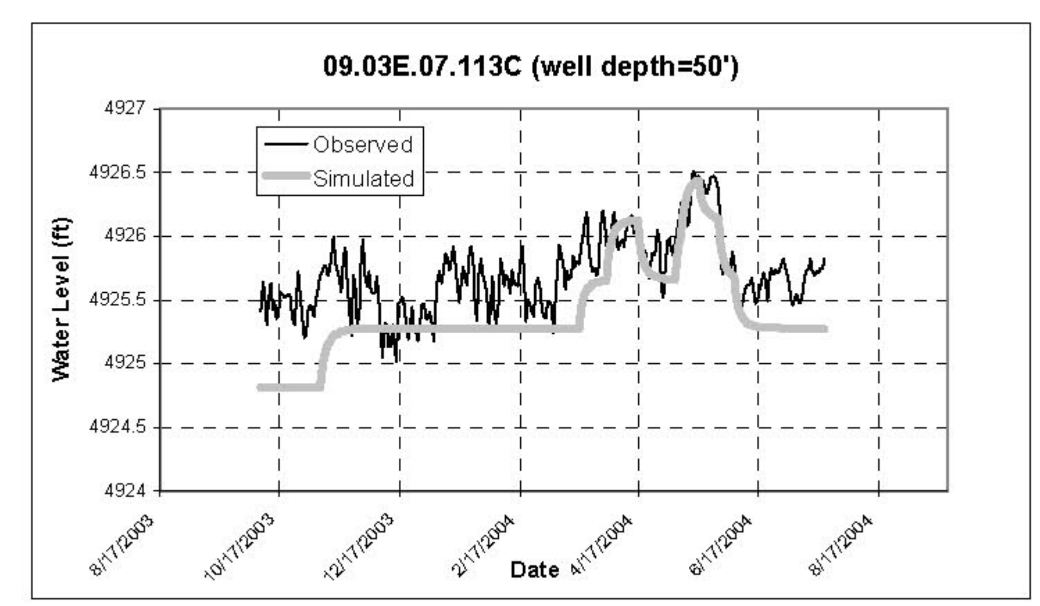
Riparian ET


Cottonwood Mixed, Unknown Veg.
Cottonwood Pure, Russian Olive
Salt Cedar
Riparian Woodland
Bare Land
Marsh
Depth of Groundwater (ft)
-2
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
ET rate (ft/year)

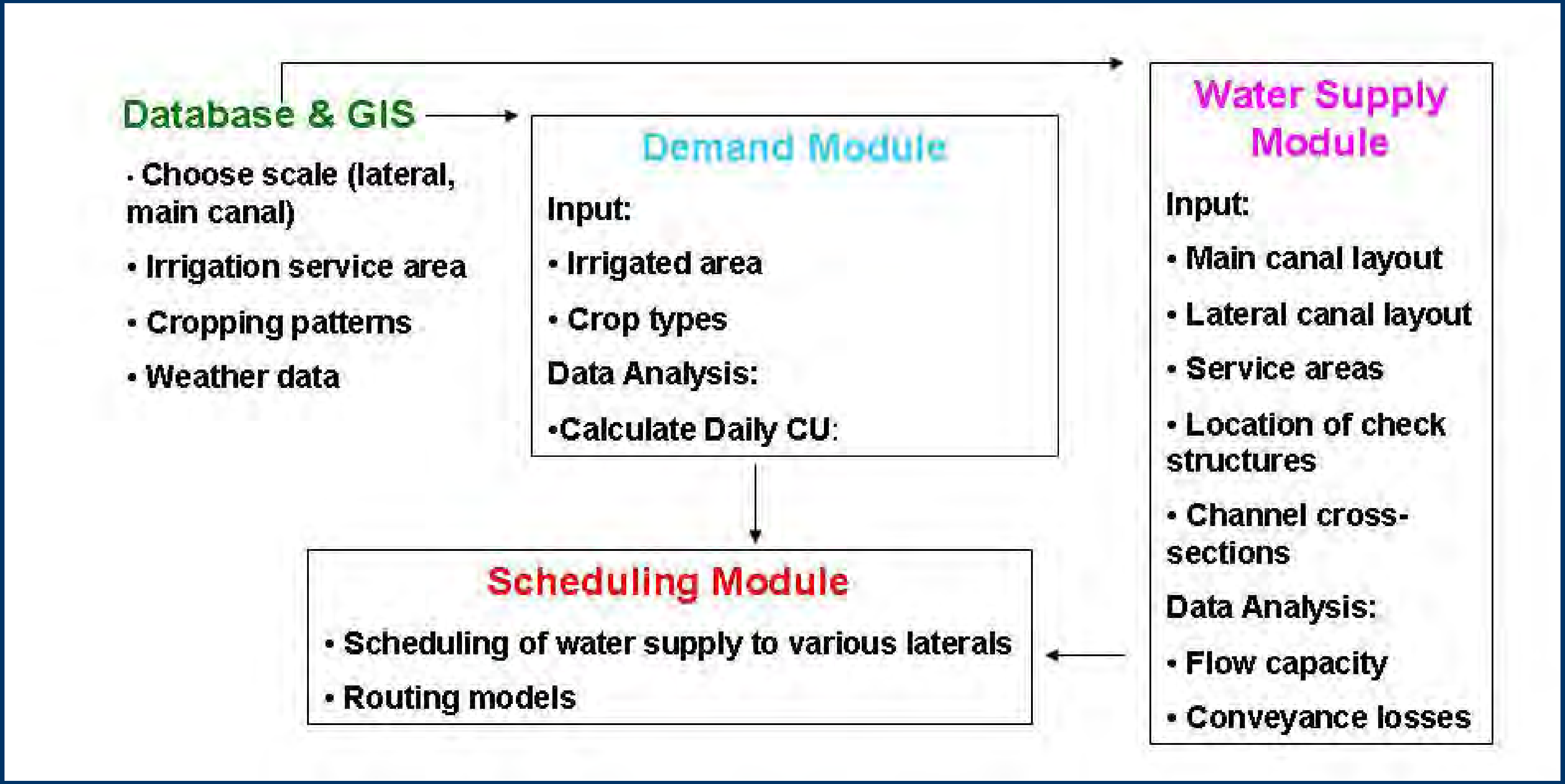


Riparian Model



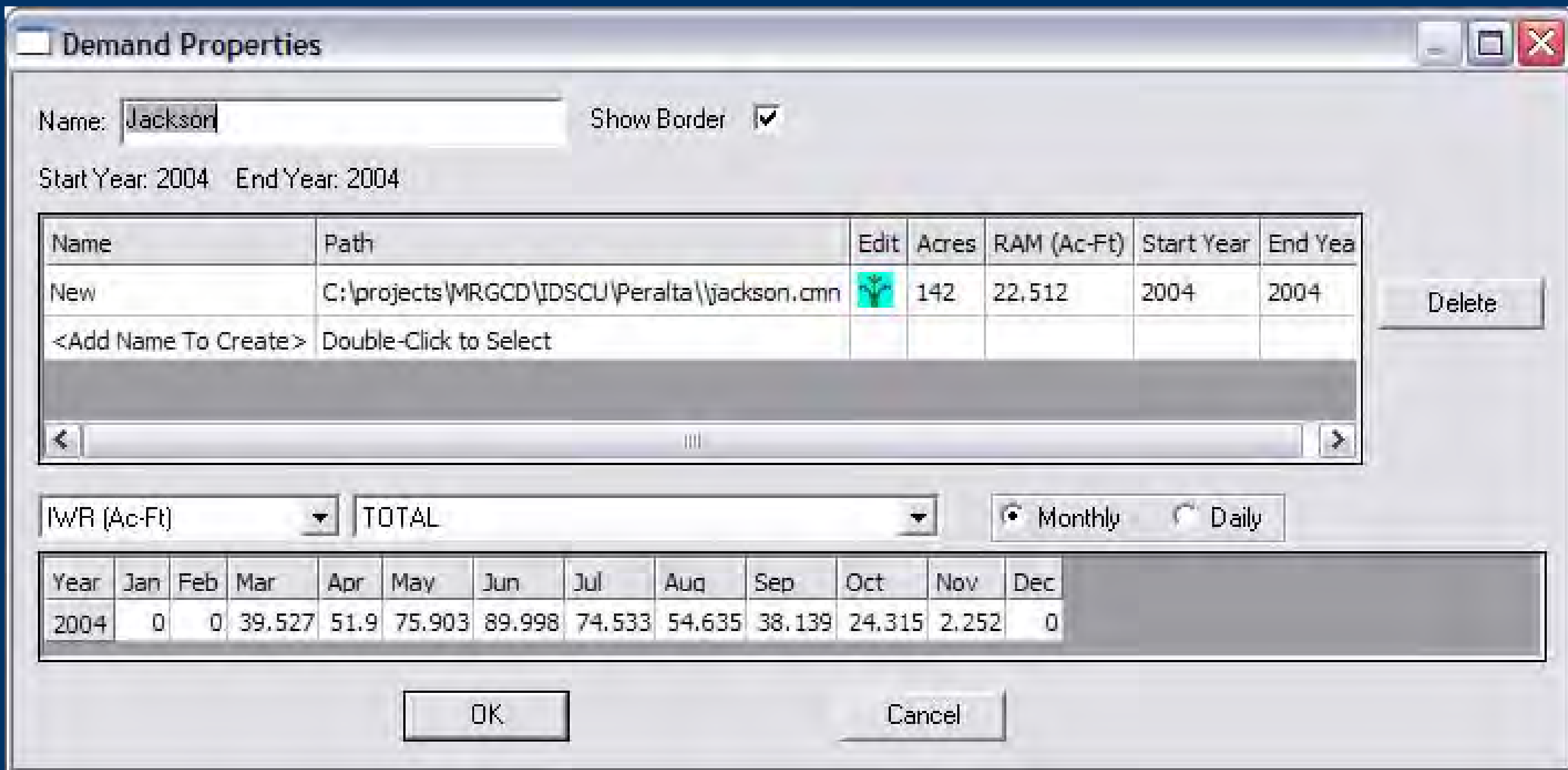


MRG Irrigation Scheduling Model



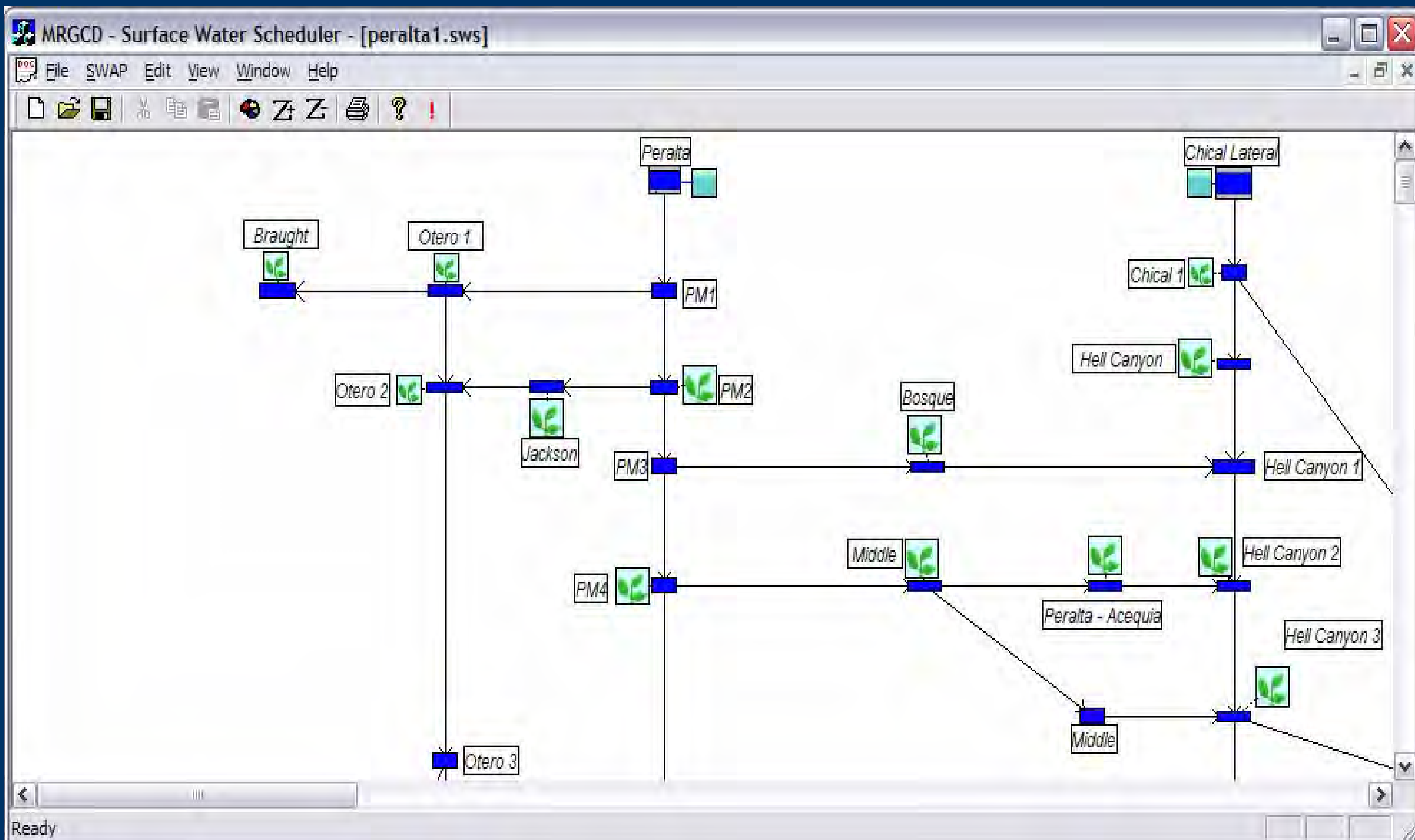
MRGCD DSS

Demand



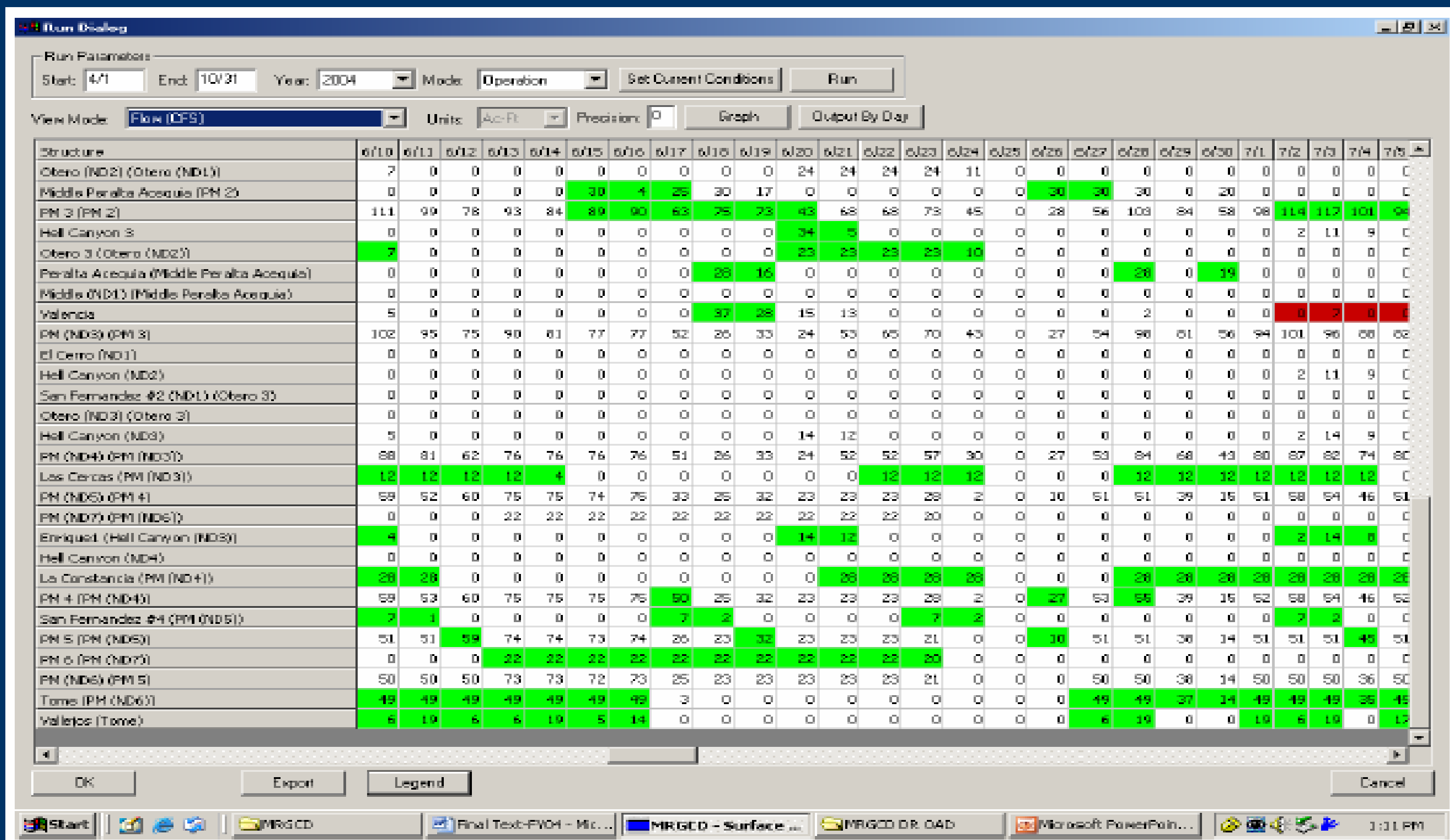
MRGCD DSS

Supply



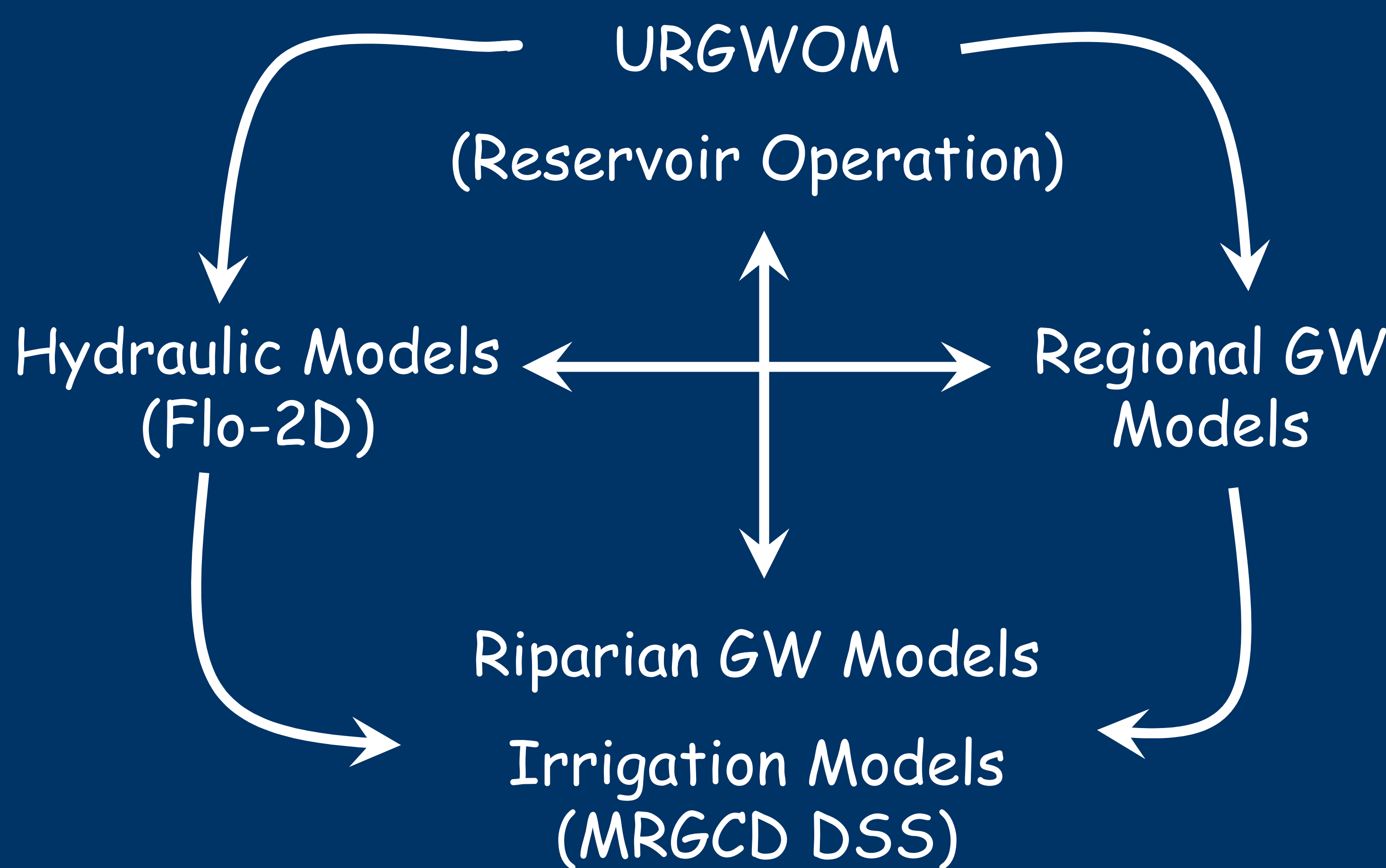
MRGCD DSS

Scheduling



Structure	6/10	6/11	6/12	6/13	6/14	6/15	6/16	6/17	6/18	6/19	6/20	6/21	6/22	6/23	6/24	6/25	6/26	6/27	6/28	6/29	6/30	7/1	7/2	7/3	7/4	7/5
Otero (ND2) (Otero (ND1))	7	0	0	0	0	0	0	0	0	0	24	24	24	24	11	0	0	0	0	0	0	0	0	0	0	0
Middle Peralta Acequia (PM 2)	0	0	0	0	0	30	4	25	30	17	0	0	0	0	0	0	30	30	30	0	20	0	0	0	0	0
PM 3 (PM 2)	111	99	78	93	84	89	90	63	75	73	43	68	68	73	45	0	28	56	103	84	58	98	114	117	101	[illegible]
Hell Canyon 3	0	0	0	0	0	0	0	0	0	0	34	5	0	0	0	0	0	0	0	0	0	0	2	11	9	0
Otero 3 (Otero (ND2))	7	0	0	0	0	0	0	0	0	0	23	23	23	23	10	0	0	0	0	0	0	0	0	0	0	0
Peralta Acequia (Middle Peralta Acequia)	0	0	0	0	0	0	0	0	28	16	0	0	0	0	0	0	0	0	28	0	19	0	0	0	0	0
Middle (ND1) (Middle Peralta Acequia)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valencia	5	0	0	0	0	0	0	0	37	28	15	13	0	0	0	0	0	0	2	0	0	0	0	7	0	[illegible]
PM (ND3) (PM 3)	102	95	75	90	81	77	77	52	26	33	24	53	65	70	43	0	27	54	98	81	56	94	101	96	88	82
El Cerro (ND1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hell Canyon (ND2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	9	0
San Fernandez #2 (ND1) (Otero 3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Otero (ND3) (Otero 3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hell Canyon (ND3)	5	0	0	0	0	0	0	0	0	0	14	12	0	0	0	0	0	0	0	0	0	0	2	14	9	0
PM (ND4) (PM (ND3))	88	81	62	76	76	76	76	51	26	33	24	52	52	57	30	0	27	53	84	68	43	80	87	82	74	80
Las Cercas (PM (ND3))	12	12	12	12	4	0	0	0	0	0	0	0	12	12	12	0	0	0	12	12	12	12	12	12	12	0
PM (ND5) (PM 4)	59	52	60	75	75	74	75	33	25	32	23	23	23	28	2	0	10	51	51	39	15	51	58	54	46	51
PM (ND7) (PM (ND6))	0	0	0	22	22	22	22	22	22	22	22	22	22	20	0	0	0	0	0	0	0	0	0	0	0	0
Enriquez (Hell Canyon (ND3))	4	0	0	0	0	0	0	0	0	0	14	12	0	0	0	0	0	0	0	0	0	0	2	14	8	0
Hell Canyon (ND4)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La Constancia (PM (ND4))	28	28	0	0	0	0	0	0	0	0	0	28	28	28	28	0	0	0	28	28	28	28	28	28	28	28
PM 4 (PM (ND4))	59	53	60	75	75	75	75	50	25	32	23	23	23	28	2	0	27	53	55	39	15	52	58	54	46	52
San Fernandez #4 (PM (ND5))	7	1	0	0	0	0	0	7	2	0	0	0	0	7	2	0	0	0	0	0	0	0	7	2	0	0
PM 5 (PM (ND6))	51	51	59	74	74	73	74	26	23	32	23	23	23	21	0	0	10	51	51	38	14	51	51	51	45	51
PM 6 (PM (ND7))	0	0	0	22	22	22	22	22	22	22	22	22	22	20	0	0	0	0	0	0	0	0	0	0	0	0
PM (ND6) (PM 5)	50	50	50	73	73	72	73	25	23	23	23	23	23	21	0	0	0	50	50	38	14	50	50	50	36	50
Tome (PM (ND6))	49	49	49	49	49	49	49	3	0	0	0	0	0	0	0	0	0	49	49	37	14	49	49	49	36	[illegible]
Vallejos (Tome)	6	19	6	6	19	5	14	0	0	0	0	0	0	0	0	0	0	6	19	0	0	19	6	19	0	[illegible]

Framework


URGWOM
(Reservoir Operation)
Hydraulic Models
(Flo-2D)
Regional GW
Models
Riparian GW Models
Irrigation Models
(MRGCD DSS)

The Middle Rio Grande's Habitat: Historical Trends and Future Hope

Paul Tashjian, USFWS, Water Resources

http://bhg.fws.gov

UTTON TRANSBOUNDARY RESOURCES CENTER

University of New Mexico School of Law

Susan Kelly, Esq.

- The Utton Center is a Water Policy Center.

- We address transboundary water resource issues by providing expertise from a neutral standpoint.

The University of New Mexico

The Utton Center
TRANSBOUNDARY RESOURCES

Overview of Rio Grande Legal and Transboundary Issues

October 17, 2006

Rio Grande Seminar

Pueblos

- First water users of Rio Grande.
- Tewa people supported their dryland farming with irrigation ditches even before 1200 A.D.
- Irrigation ditches used by Native American people were observed by Europeans as early as the 1500s.

Pueblos

- 18 Pueblos use water from Rio Grande.

- Estimates of irrigated areas:
  - 20,000 acres in 1896
  - 25,000 acres in 1924
  - over 8,000 acres today in MRG

Six Middle Rio Grande Pueblos

- Cochiti
- Santo Domingo
- San Felipe
- Santa Ana
- Sandia
- Isleta


ACEQUIAS

Acequias:

- Community-based systems of irrigation and water distribution.
- Formed the basis for settlement of Hispanic communities between two and four hundred years ago.
- 80% of water use in Northern New Mexico.

Key dates in New Mexico water law

- Treaty of Guadalupe Hidalgo - 1848
  - Transferred sovereignty from Mexico to the United States.
  - Guaranteed property rights in existence at that time.

1907 Water Code

- Protected surface waters of the State.
- Office of State Engineer authority.
- Water rights in existence were vested.

New Mexico Constitution

- Prior appropriation doctrine.
- Origin – early California mining law.
- First in time, first in right.
- Right continues as against subsequent appropriators as long as water is put to beneficial use.

Beneficial use

- Application of water to a lawful purpose that is useful to the appropriator.
- Includes most uses – but “waste” is not a beneficial use.
- The **Basis**, the **Measure**, and the **Limit** of water rights in the West.

Key word is **use**:

- Right can be lost if not put to beneficial use.

- Basis: water right is based on **when** first put to use and the type of use.

- Measure: The **amount of** a water right is determined by the amount put to beneficial use.

- Limit: Cannot use more than the amount of the permitted right.

Water rights can be lost:

- Forfeiture (requires State Engineer action).
- Abandonment (requires evidence of non-use).

Groundwater

- 1931 Water Code. Recognized groundwater connected to stream system.

- Permit required for withdrawals in declared basins.

Middle Rio Grande Basin

- 1956 Declaration of the MRG Basin.
- *City of Albuquerque v. Reynolds* resulted in City’s vested groundwater rights.

Water rights required for groundwater pumping:

- Based on ground water flow models.
- Water rights requirements are based upon effects on Rio Grande.
- Effects of pumping on River are delayed.

Rio Grande fully appropriated:

- All water in Rio Grande is appropriated.
- Therefore, any new or expanded use is required to be offset by the retirement of another use.
- This results in a “water market” and transfer process.

Transfer of water rights

- Conveyance is by deed, because water rights are a property right.
- Appurtenant to real estate – but can be severed.
- Only the consumptive use amount is transferred.

Transfer process

- Declaration (of vested rights).
- Application to Change Point of Diversion and Place and/or Purpose of Use from Surface to Groundwater.
- Advertisement.
- Opportunity for Protest.

State Engineer Criteria

- No impairment of other rights.
- Not contrary to public welfare.
- Not contrary to water conservation.

Priority study required in Middle Rio Grande:

- 1917 maps.
- 1926 appraisal sheets.
- Continuous use (aerial photos – 1935, 1947, 1955, 1965).
- Other proof of pre-1907.

Brief Overview of the Rio Grande water supply

UPPER RIO GRANDE MAP

Courtesy of Upper Rio Grande Water Operations Model

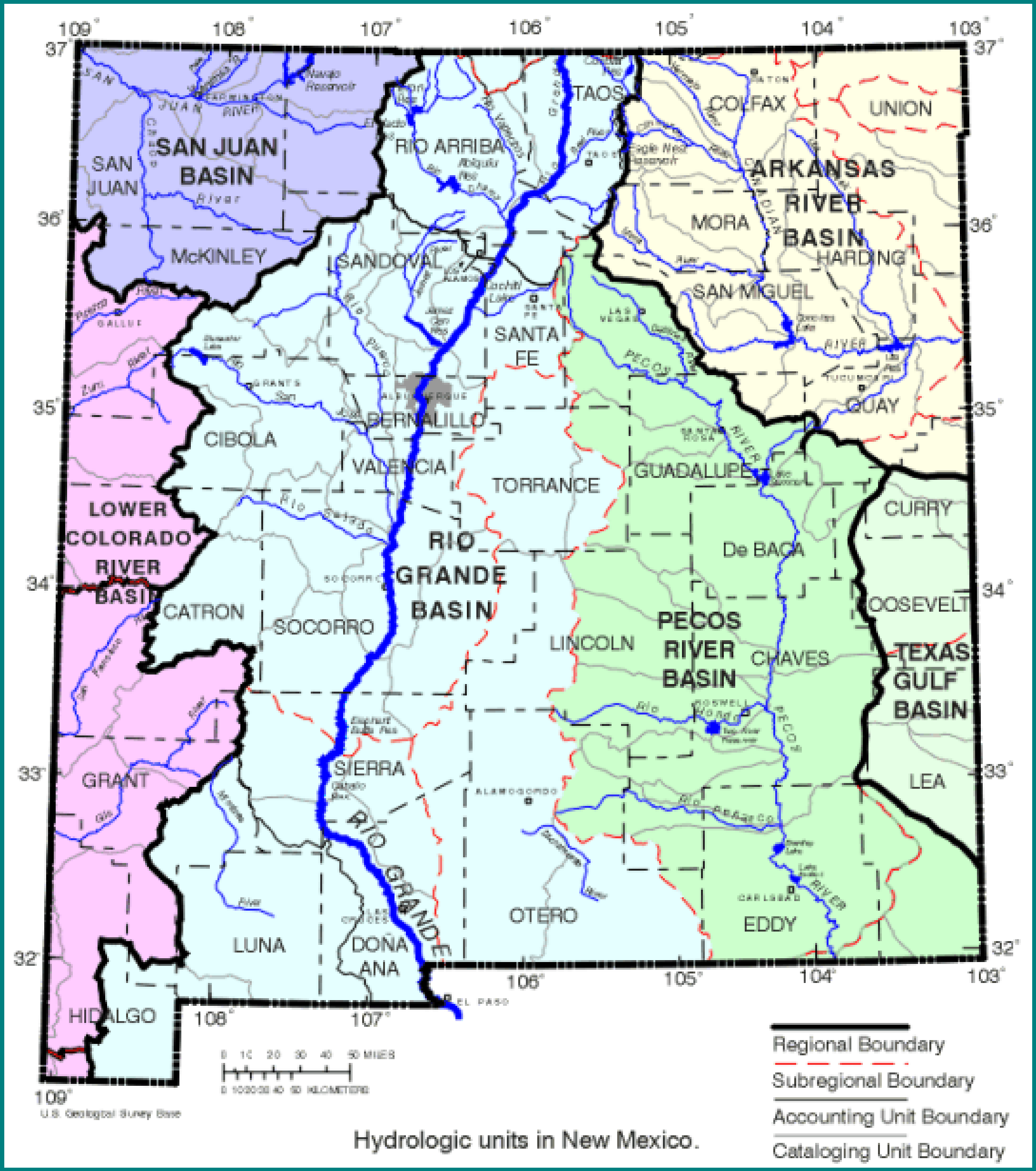
US Army Corps of Engineers

NM Interstate Stream Comm.

US Bureau of Reclamation

Interstate Compacts

- Like a treaty between states.
- Regulate the right to use water coming into and leaving the state.
- New Mexico is a party to 9 interstate compacts.
- The Rio Grande Compact, The Pecos River Compact and the Colorado River Compacts are the most significant.



Hydrologic units in New Mexico.

Rio Grande Compact

- Colorado, New Mexico, Texas.
- NM delivery requirement determined at Otowi gage.
- New Mexico delivers at Elephant Butte.

Heron Reservoir – Chama River

San Juan – Chama Project

- 1971 – tunnels through Continental Divide take water to Heron.
- Bureau of Reclamation project.
- Benefits City of Albuquerque, MRGCD, and other contractors.
- Subject of silvery minnow litigation


COLORADO
NEW MEXICO
Rio Blanco
Navajo R.
San Juan R.
DIVERSIONS
26 MILES OF TUNNELS
CHAMA
HERON RESERVOIR
EL VADO RESERVOIR
Rio Chama
ABIQUIU RESERVOIR
Rio Grande
ESPAÑOLA
CONTINENTAL DIVIDE
COCHITI RESERVOIR
Rio Grande
ALBUQUERQUE
KEY
BOLD TYPE Component of the San Juan-Chama Project
Rivers
Diversion
Tunnel

Little Navajo Diversion

El Vado Reservoir – on Chama River

El Vado Reservoir

- Built to store water for Middle Rio Grande Conservancy District.
- Stores prior and paramount Pueblo rights.
- Article VII restriction on post-1929 reservoir storage of native RG water.

Abiquiu Reservoir – on Chama River

Abiquiu Reservoir

- Built by Army Corps of Engineers for flood and sediment control.
- Stores San Juan-Chama water.
- Native Rio Grande storage authorized by federal law.

Cochiti Reservoir – on mainstem of Rio Grande

Cochiti Reservoir

- Built by Corps of Engineers - flood control for Albuquerque.
- Permanent storage - small recreational pool.
- Cochiti Pueblo concerns.

Uses in the MRG Valley

• Municipal	5%
• Riparian	37%
• Irrigation	37%
• Evaporation	21%

Municipalities using Rio Grande in New Mexico

Municipal

- Taos
- Espanola
- Santa Fe/Santa Fe County
- Bernalillo
- Rio Rancho
- Albuquerque
- Los Lunas, Belen, Socorro
- Truth or Consequences
- Las Cruces
- El Paso

Irrigation

Agriculture

- Peaked in Middle Valley between 1850 and 1880:
  – 125,000 acres irrigated.

- Today:
  – 50 – 70,000 acres irrigated through Middle Rio Grande Conservancy District works.

Middle Rio Grande Conservancy District

- Established in 1923.
- A system of diversions and dams for flood control and irrigation.
- The MRGCD operates ditches, reservoirs and dams.
- Raises revenues from its members to pay for construction and maintenance of projects.

Elephant Butte Irrigation District:

- Below Elephant Butte
- 90,000 acres

Lower Rio Grande Adjudication

- Elephant Butte to State Line
- 16,000 claimants.

Elephant Butte

Elephant Butte

- Storage for Rio Grande Project.
- Constructed by Bureau of Reclamation in 1916.
- 57% of water delivered to Texas pursuant to Rio Grande Compact is used in New Mexico.

Elephant Butte

- Evaporative loss 10-30% of basin depletions.
- 140,000 acre-feet or 2.5 times usage of City of Albuquerque.
- 1999 storage: 2 MAF.
- 2006 storage: 400,000 a-f.

Riparian

Evapotranspiration – The sum of evaporation and plant transpiration

Steps to reduce:

- Non-native species removal
- Water salvage potential
- Who gets savings?

Treaty with Mexico - 1906

- 60,000 acre feet delivered to Mexico at Ft. Quitman.
- Deliveries reduced proportionate to reductions in Rio Grande Project storage.

1944 Treaty

- Rio Grande below Ft. Quitman essentially a different river.
- Runoff from Mexican mountains.
- Roughly: 2/3 goes to Mexico and 1/3 to Texas.

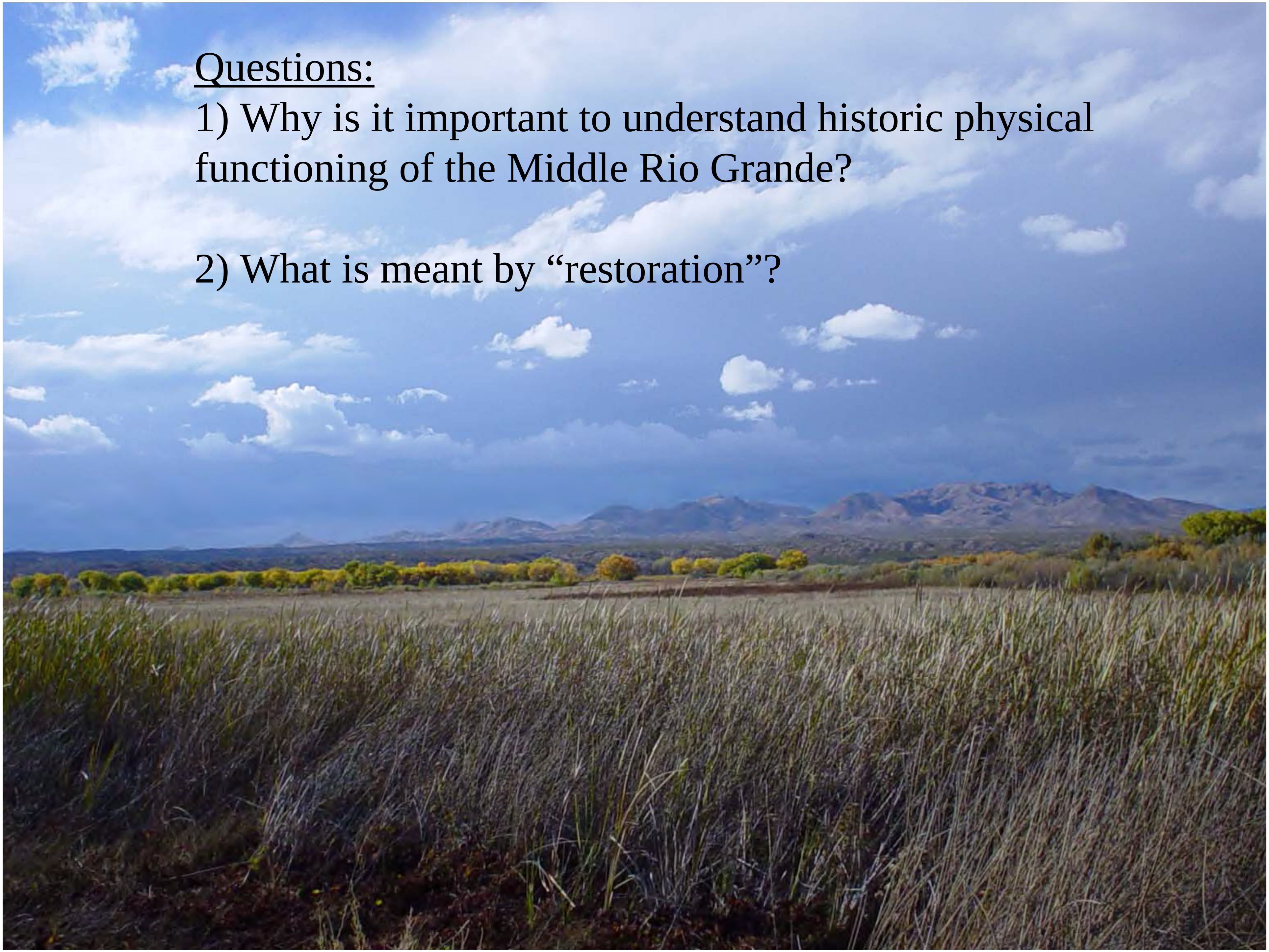
Transboundary Issues with Mexico:

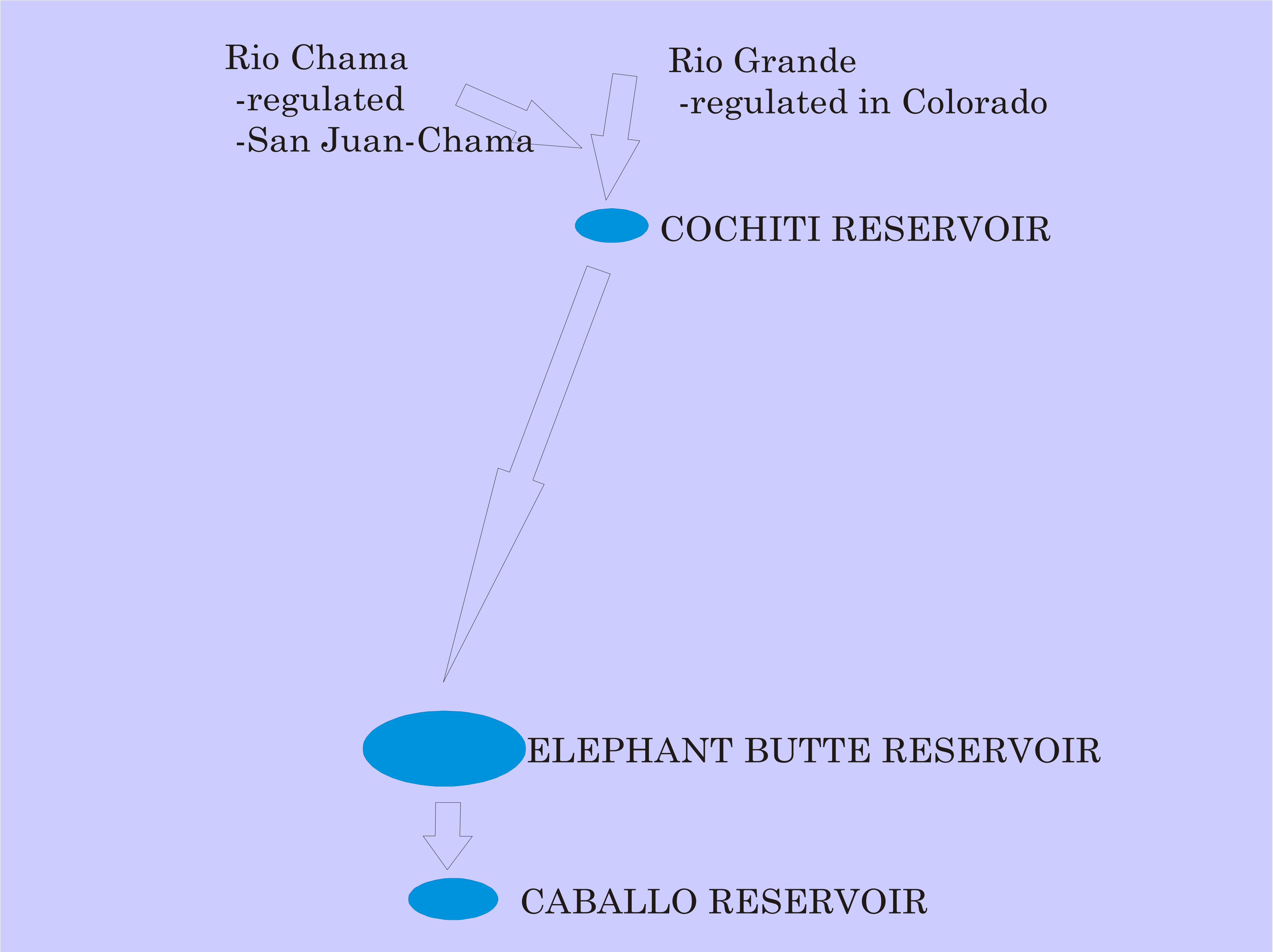
- Groundwater pumping
- Data exchange
- Water quality
- Extraordinary drought

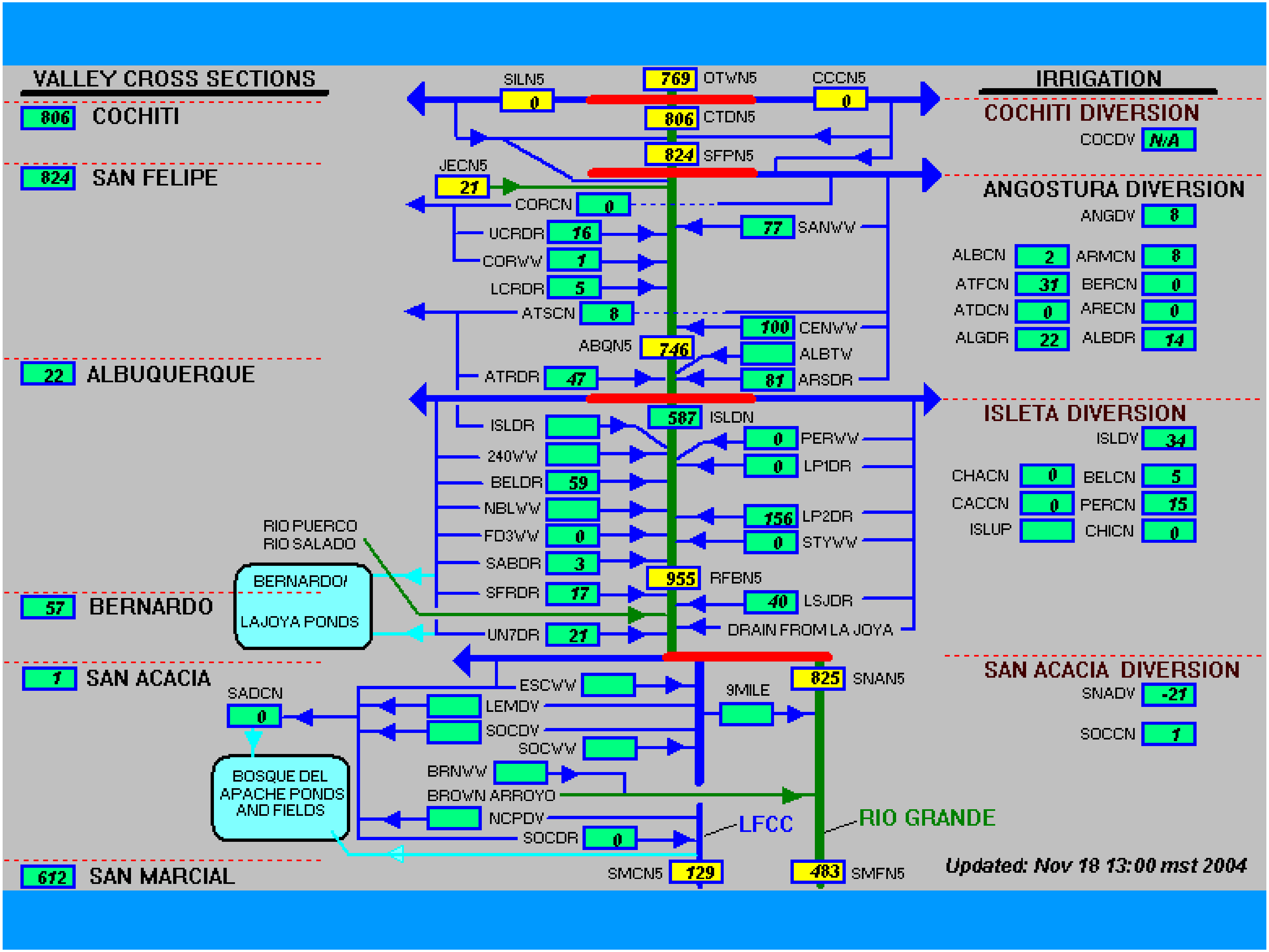
Questions:

1) Why is it important to understand historic physical functioning of the Middle Rio Grande?

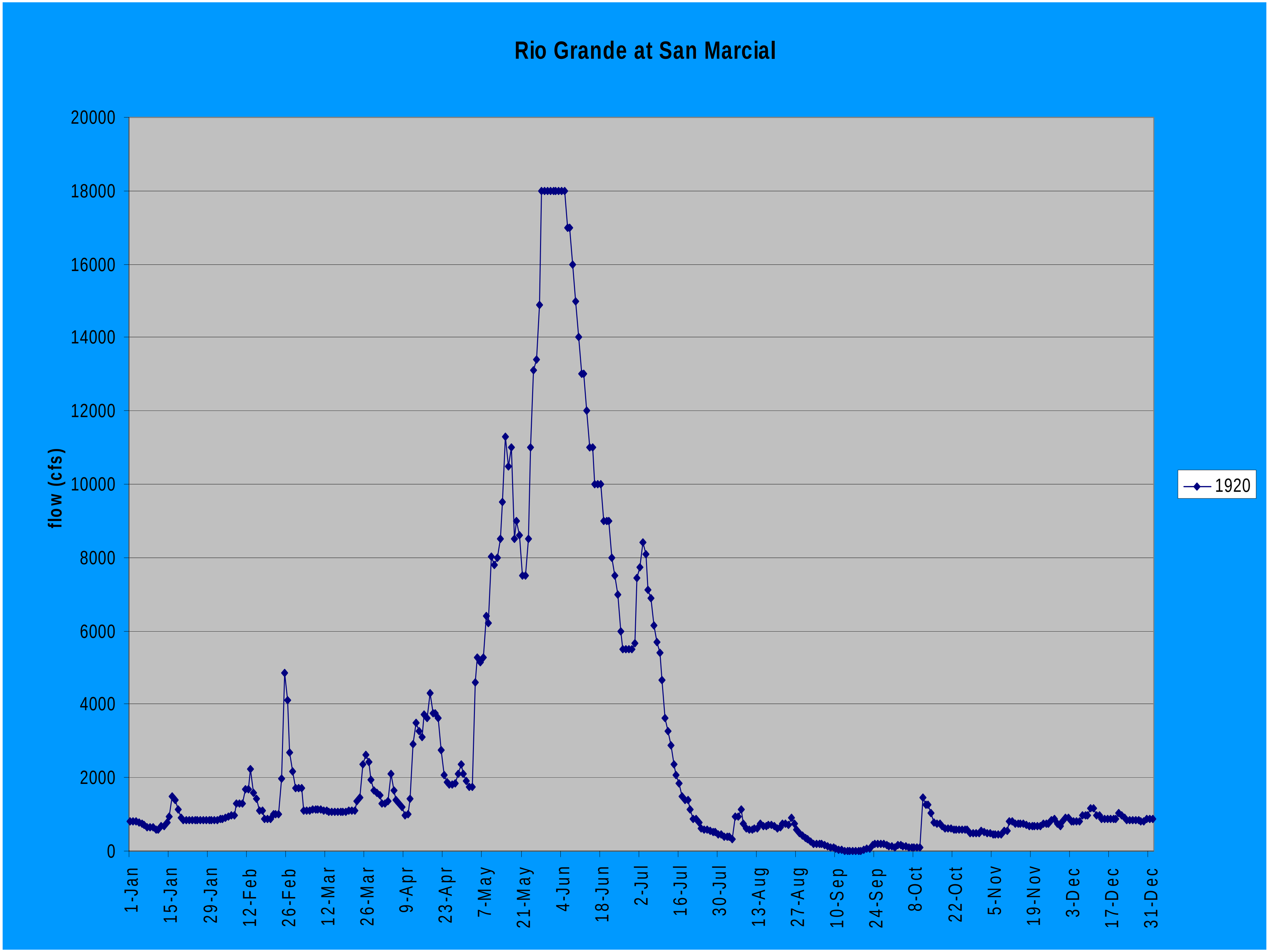
2) What is meant by “restoration”?



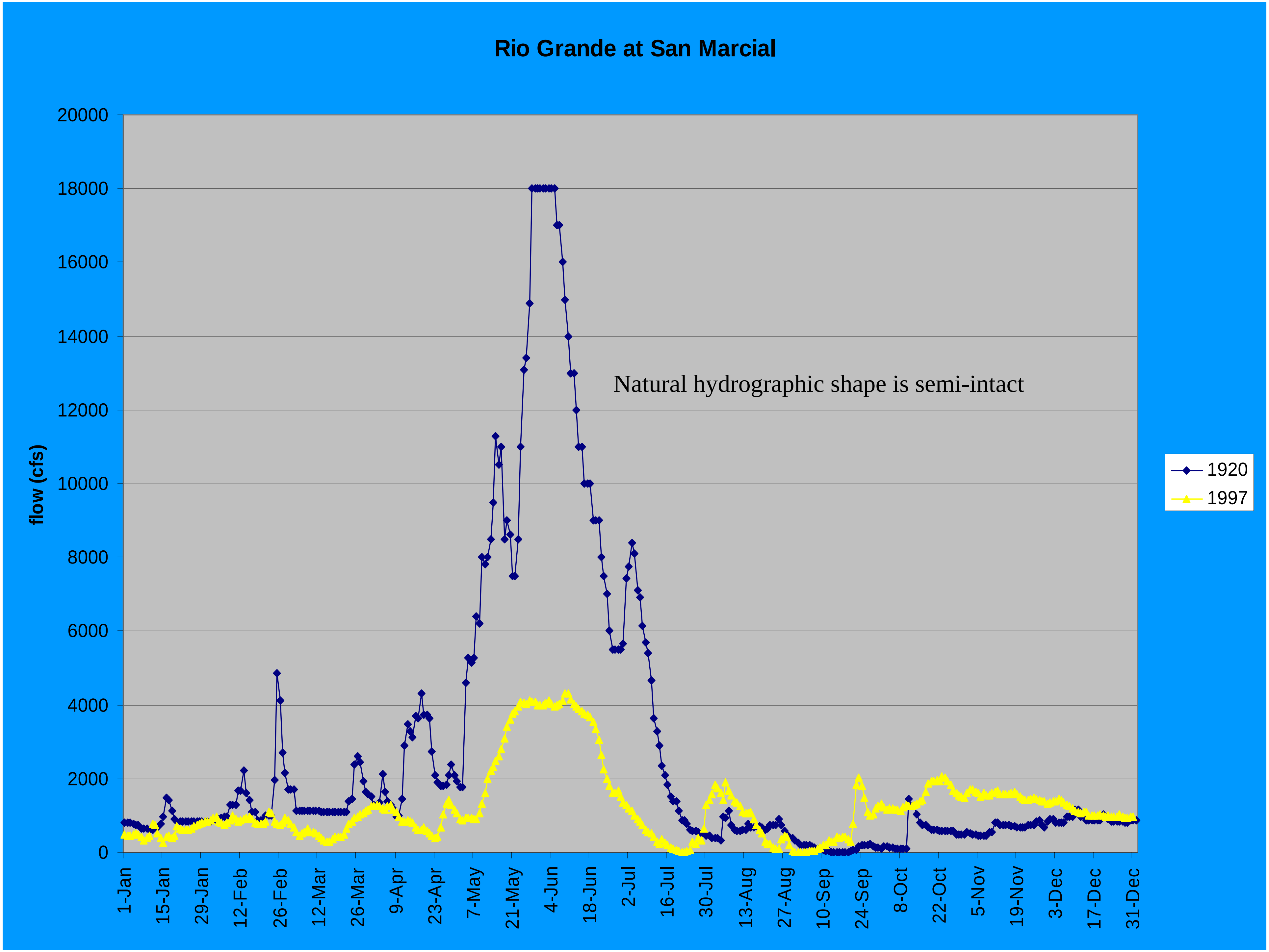

Rio Chama
-regulated
-San Juan-Chama
Rio Grande
-regulated in Colorado
COCHITI RESERVOIR
ELEPHANT BUTTE RESERVOIR
CABALLO RESERVOIR

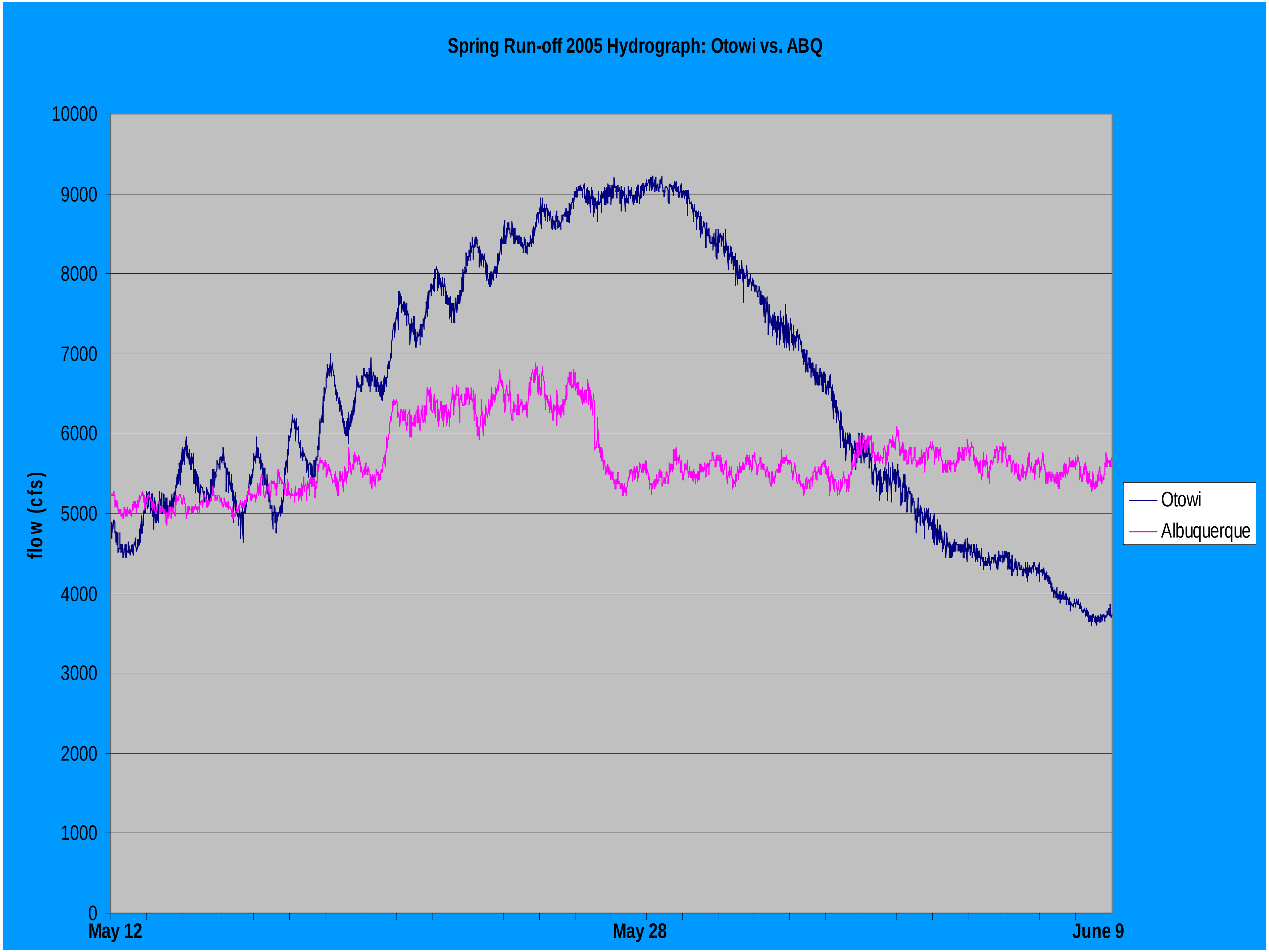


VALLEY CROSS SECTIONS
806 COCHITI
824 SAN FELIPE
22 ALBUQUERQUE
57 BERNARDO
1 SAN ACACIA
612 SAN MARCIAL
SILN5 0
769 OTWN5
CCCN5 0
806 CTDN5
824 SFPN5
JECN5 21
CORCN 0
UCRDR 16
CORWW 1
LCRDR 5
ATSCN 8
77 SANWW
100 CENWW
ABQN5 746
ALBTW
ATRDR 47
81 ARSDR
587 ISLDN
ISLDR
240WW
BELDR 59
NBLWW
FD3WW 0
SABDR 3
SFRDR 17
UN7DR 21
0 PERWW
0 LP1DR
156 LP2DR
0 STYWW
955 RFBN5
40 LSJDR
DRAIN FROM LA JOYA
RIO PUERCO
RIO SALADO
BERNARDO/
LAJOYA PONDS
ESCWW
LEMDV
SOCDV
SOCWW
BRNWW
BROWN ARROYO
NCPDY
SOCDR 0
SADCN 0
BOSQUE DEL APACHE PONDS AND FIELDS
9MILE
825 SNAN5
LFCC
RIO GRANDE
SMCN5 129
483 SMFN5
IRRIGATION
COCHITI DIVERSION
COCDV N/A
ANGOSTURA DIVERSION
ANGDV 8
ALBCN 2
ARMCN 8
ATFCN 31
BERCN 0
ATDCN 0
ARECN 0
ALGDR 22
ALBDR 14
ISLETA DIVERSION
ISLDV 34
CHACN 0
BELCN 5
CACCN 0
PERCN 15
ISLUP
CHICN 0
SAN ACACIA DIVERSION
SNADV -21
SOCCN 1
Updated: Nov 18 13:00 mst 2004



Rio Grande at San Marcial
flow (cfs)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1-Jan
15-Jan
29-Jan
12-Feb
26-Feb
12-Mar
26-Mar
9-Apr
23-Apr
7-May
21-May
4-Jun
18-Jun
2-Jul
16-Jul
30-Jul
13-Aug
27-Aug
10-Sep
24-Sep
8-Oct
22-Oct
5-Nov
19-Nov
3-Dec
17-Dec
31-Dec
1920

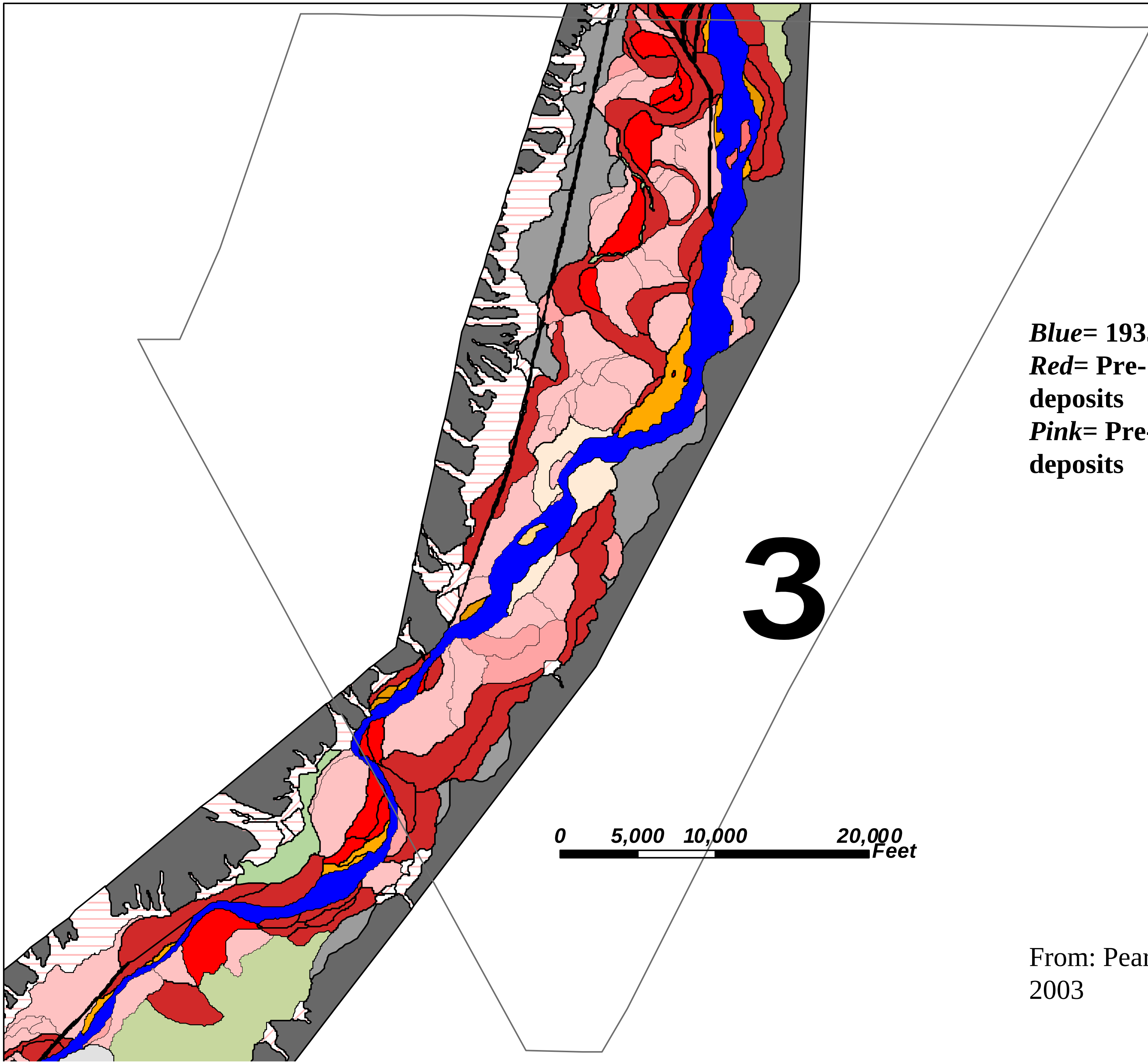

Rio Grande at San Marcial
flow (cfs)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1-Jan
15-Jan
29-Jan
12-Feb
26-Feb
12-Mar
26-Mar
9-Apr
23-Apr
7-May
21-May
4-Jun
18-Jun
2-Jul
16-Jul
30-Jul
13-Aug
27-Aug
10-Sep
24-Sep
8-Oct
22-Oct
5-Nov
19-Nov
3-Dec
17-Dec
31-Dec
Natural hydrographic shape is semi-intact
1920
1997



Spring Run-off 2005 Hydrograph: Otowi vs. ABQ
flow (cfs)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
May 12
May 28
June 9
Otowi
Albuquerque

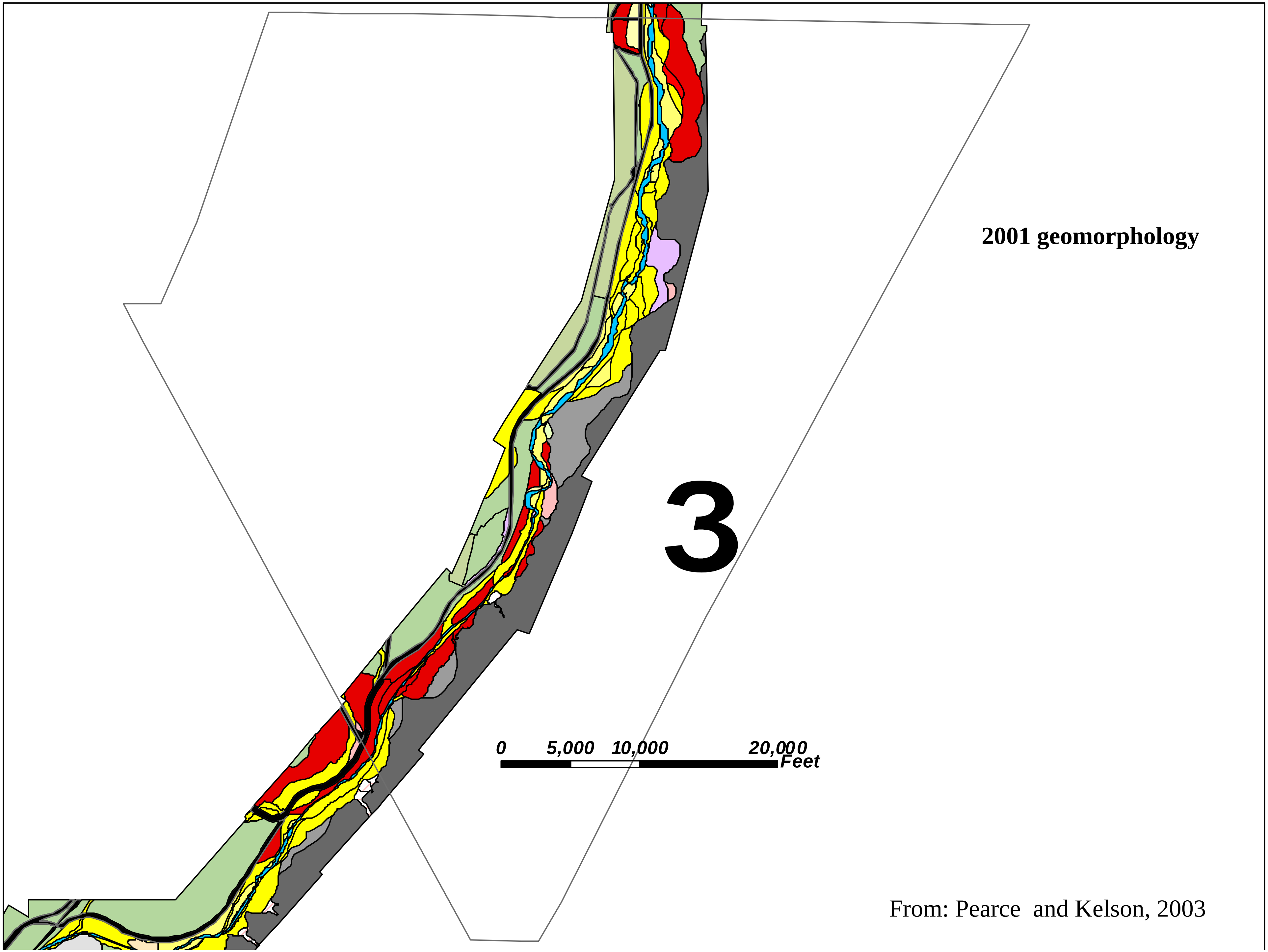
What was the historic physical functioning for the Middle Rio Grande?

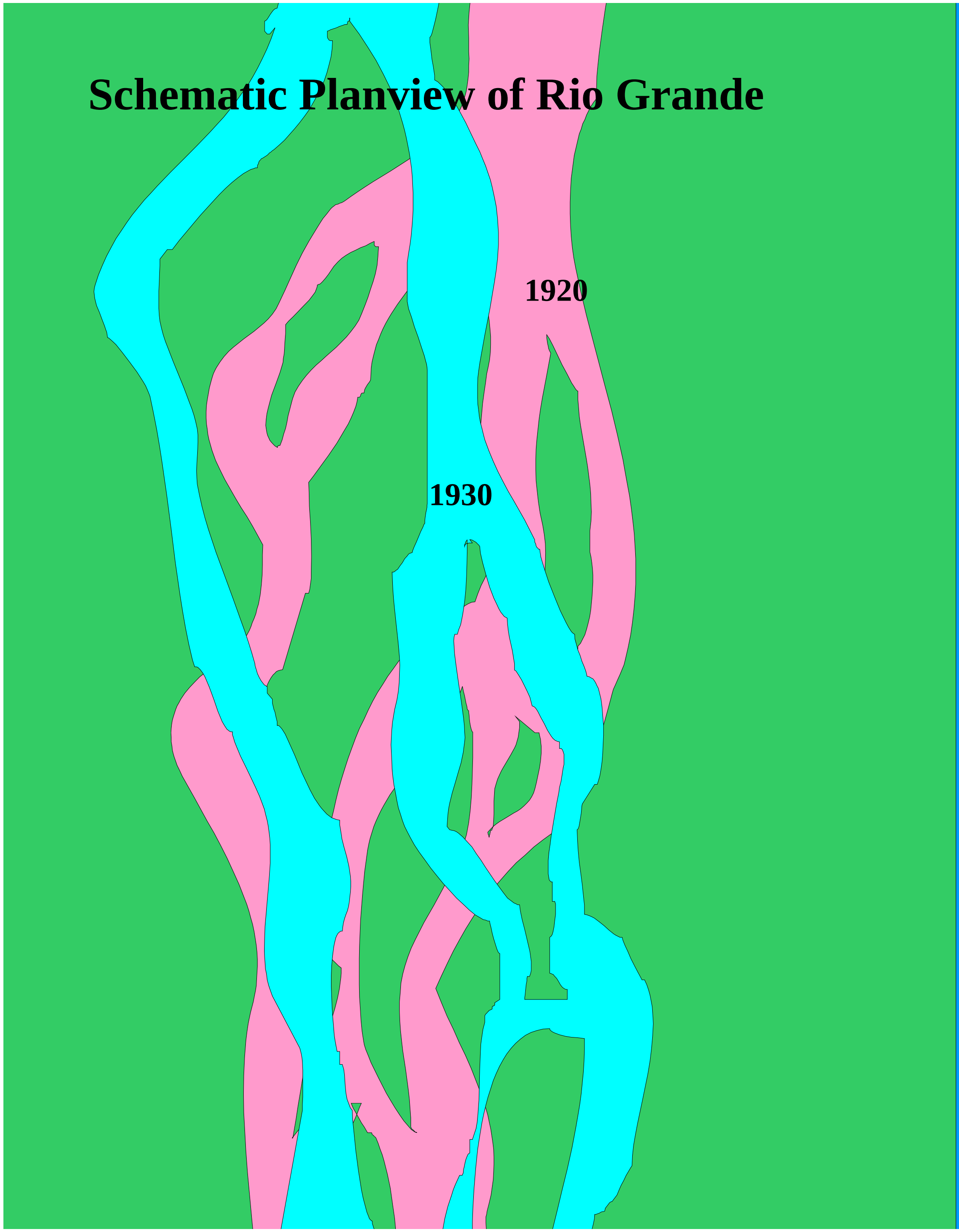
- Channel mobility
- Connected floodplain
- Sediment balance
- Naturally shaped hydrograph
- Wide active channel
- “Charged” floodplain



***Blue*= 1935 river**
***Red*= Pre-1935 channel deposits**
***Pink*= Pre-1935 flood plain deposits**

From: Pearce and Kelson, 2003


2001 geomorphology
3
0 5,000 10,000 20,000
Feet
From: Pearce and Kelson, 2003



Channel Avulsion

Example from Santa Domingo area

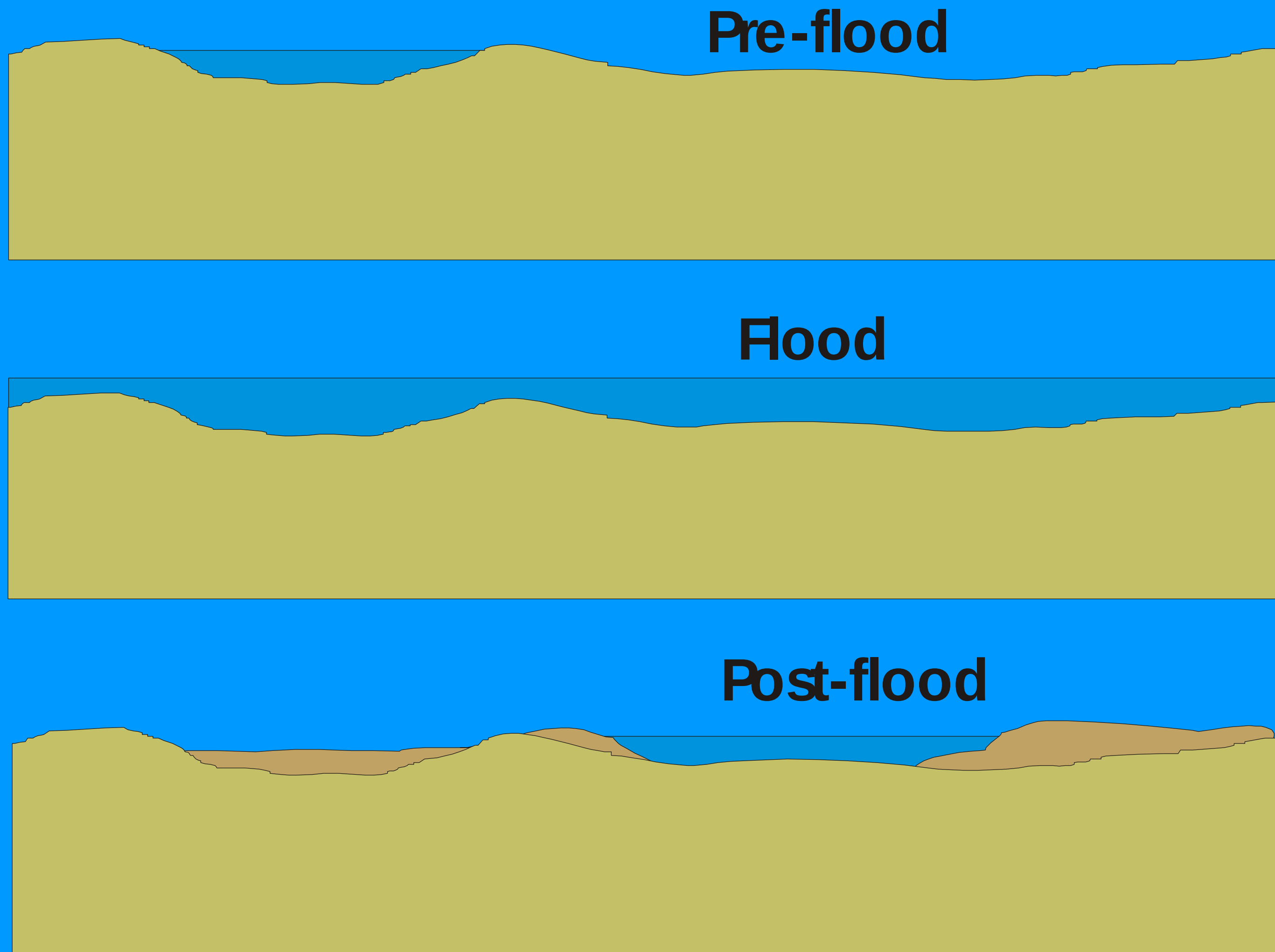
Large floods would abruptly shift channel position within the active floodplain

High sediment load

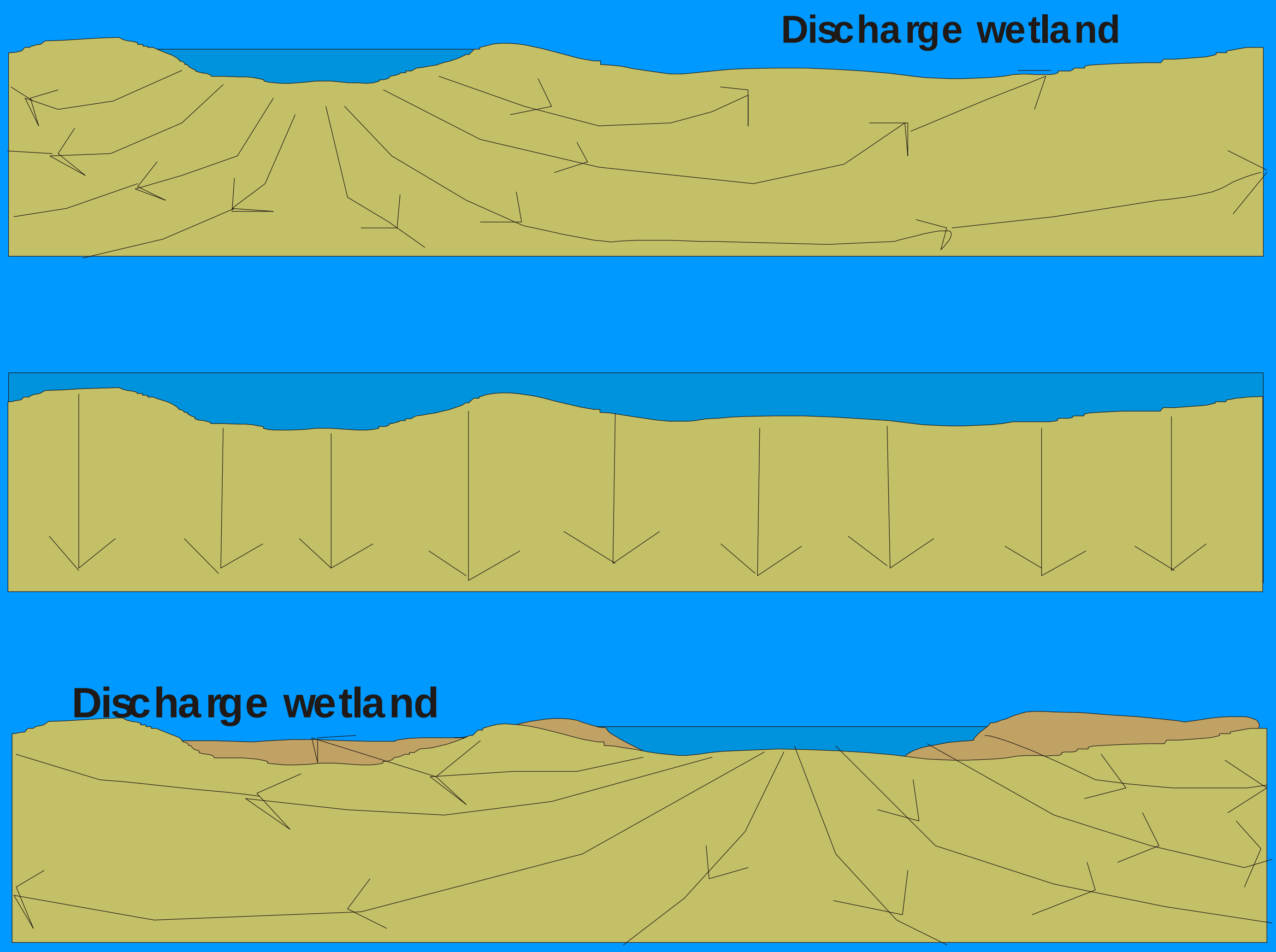
Active creation of new floodplains and erosion of older floodplains

Abandoned channels become wetlands and lakes

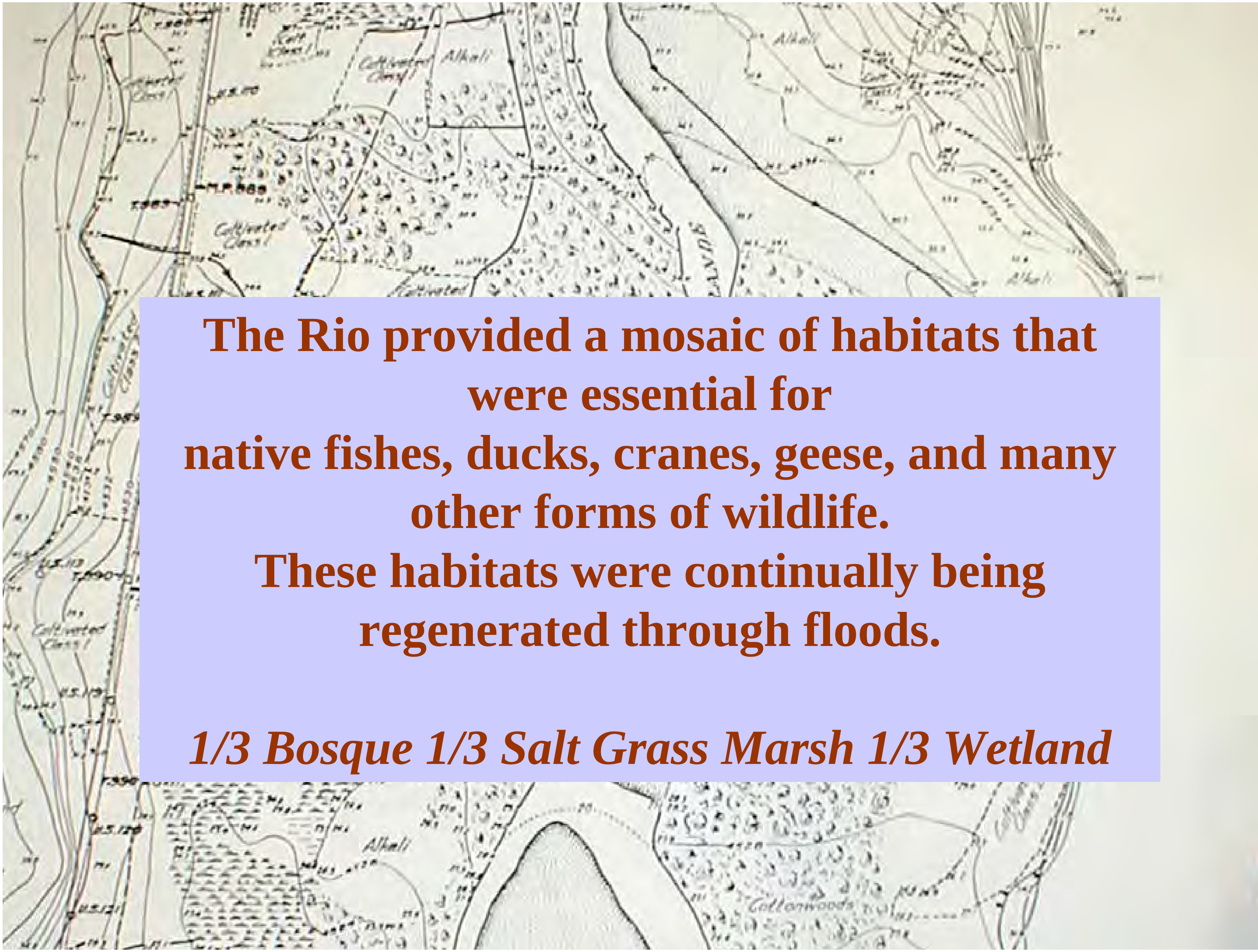
Rio Grande Avulsion



Groundwater flow



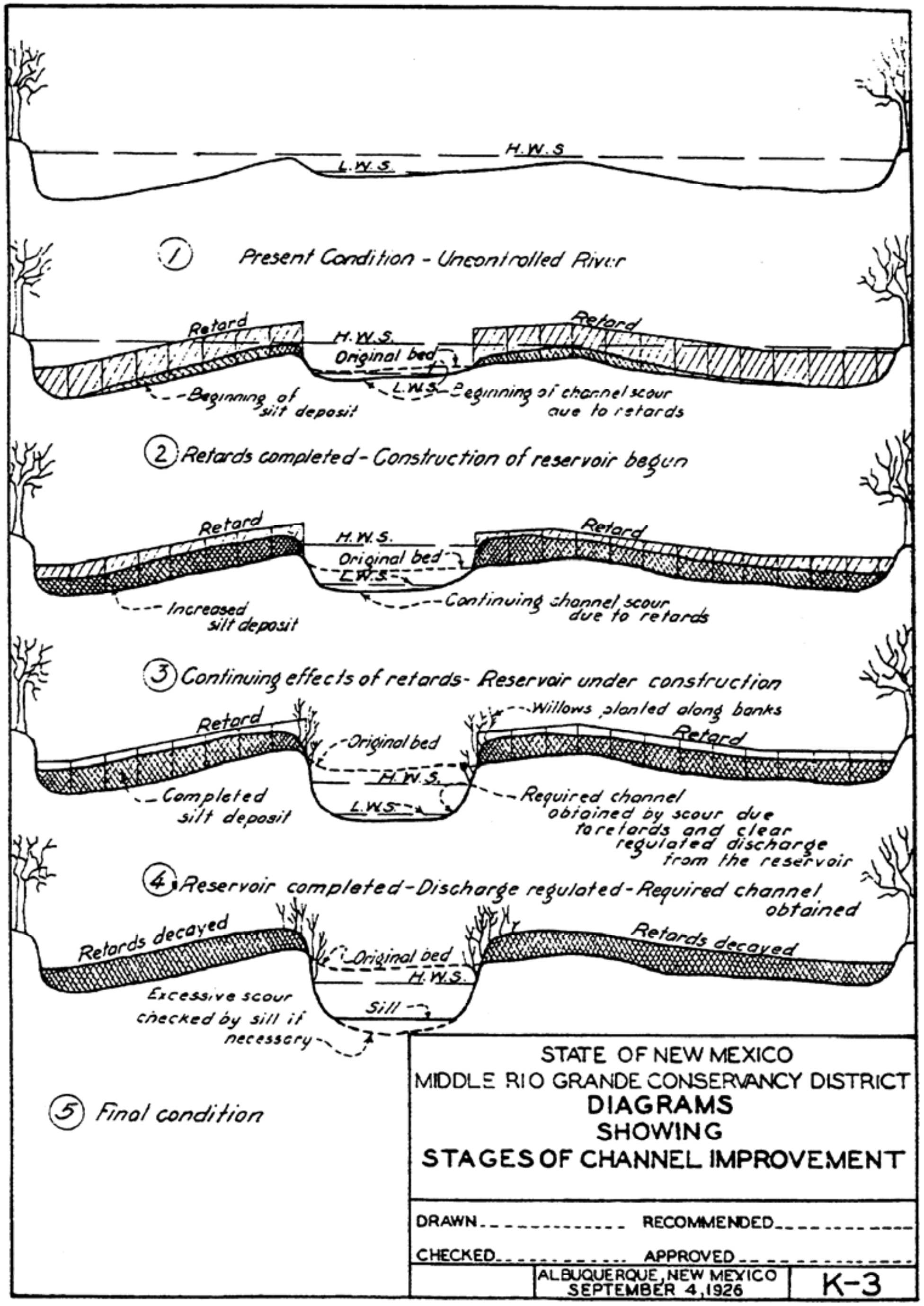
Groundwater flow (direction and speed) is dynamic!



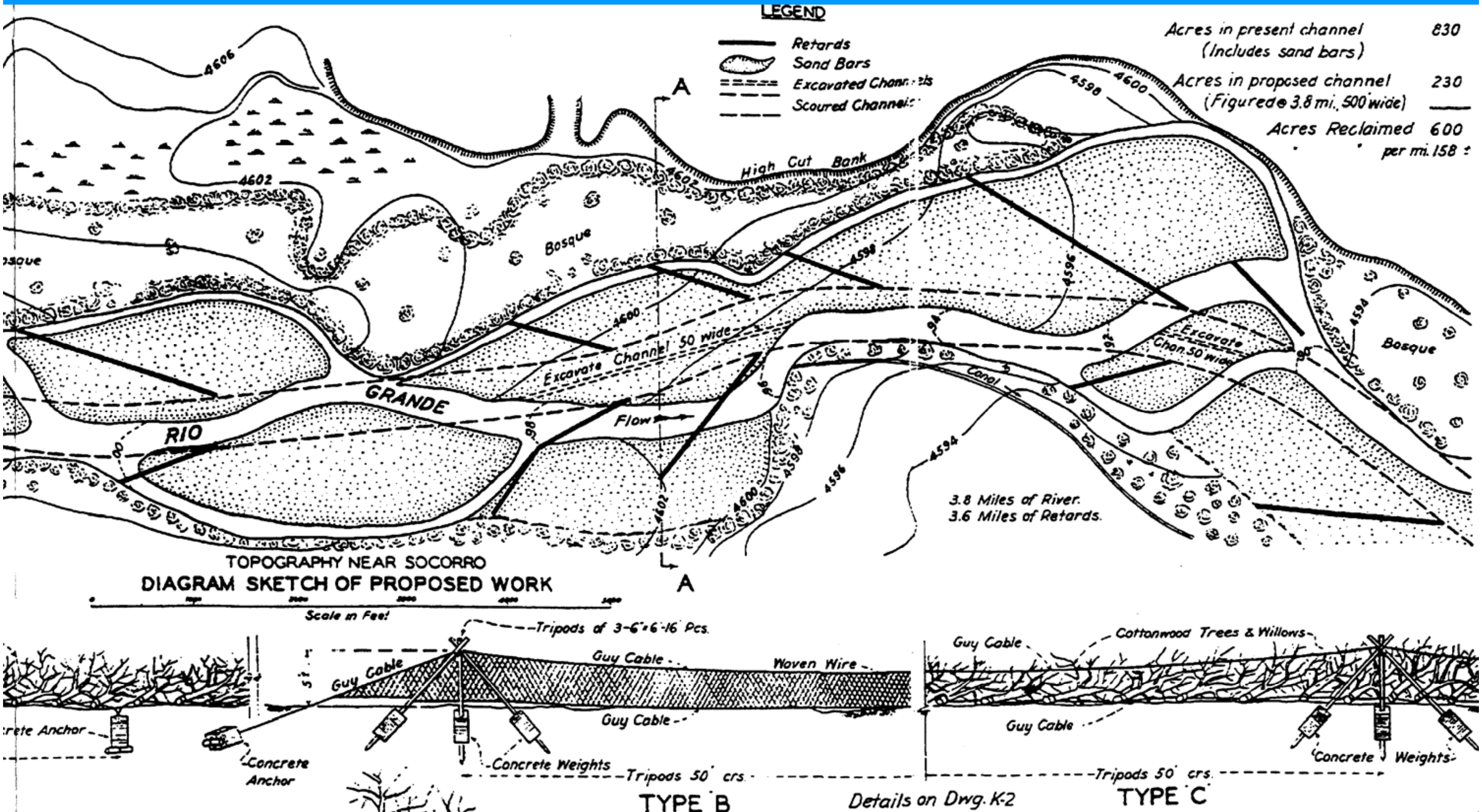
The Rio provided a mosaic of habitats that were essential for native fishes, ducks, cranes, geese, and many other forms of wildlife.

These habitats were continually being regenerated through floods.

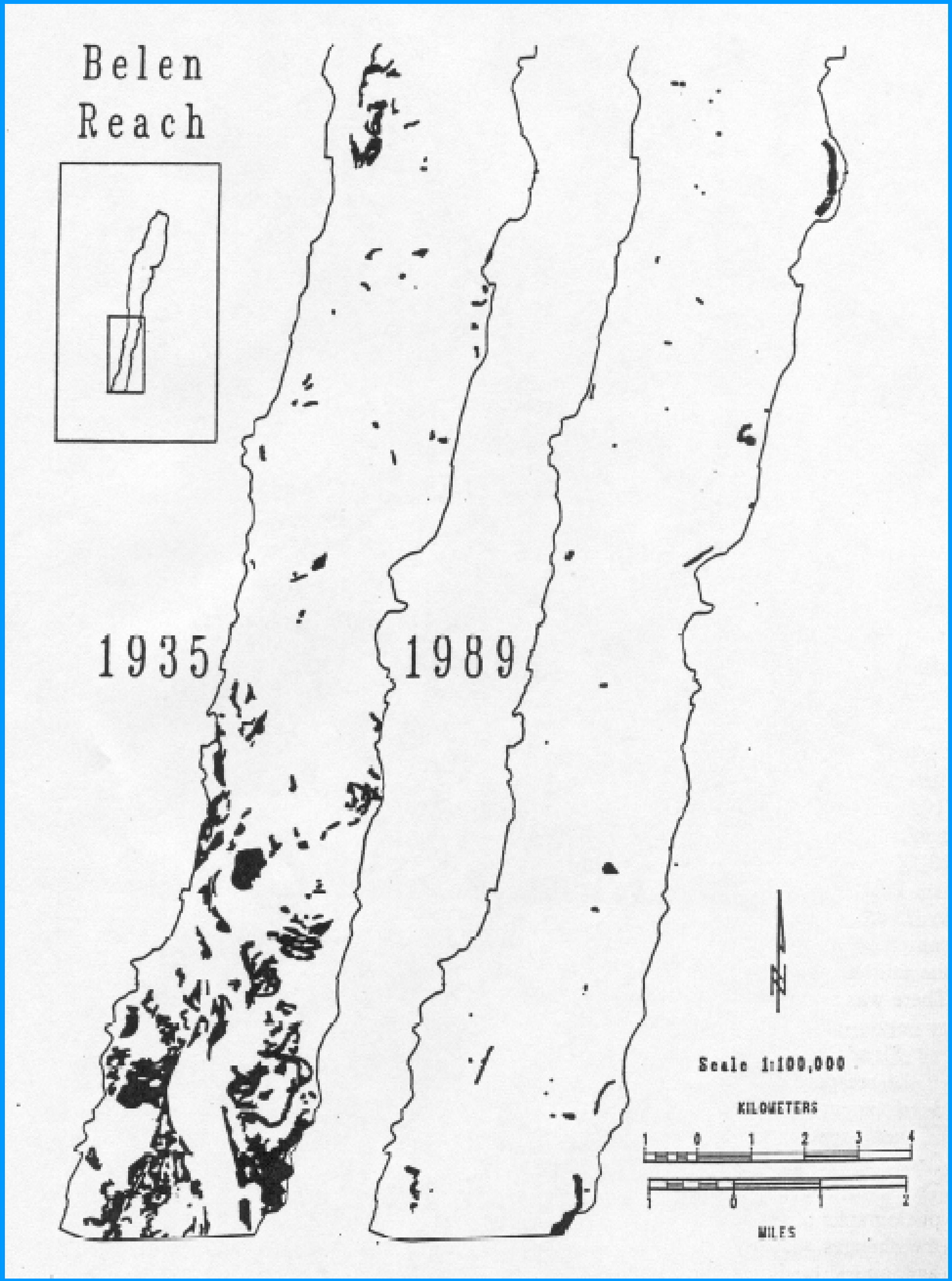
1/3 Bosque 1/3 Salt Grass Marsh 1/3 Wetland


H.W.S.
L.W.S.
(1) Present Condition - Uncontrolled River
Retard
H.W.S.
Original bed
Retard
L.W.S.
Beginning of silt deposit
Beginning of channel scour due to retards
(2) Retards completed - Construction of reservoir begun
Retard
H.W.S.
Original bed
L.W.S.
Retard
Increased silt deposit
Continuing channel scour due to retards
(3) Continuing effects of retards - Reservoir under construction
Willows planted along banks
Retard
Original bed
Retard
H.W.S.
L.W.S.
Completed silt deposit
Required channel obtained by scour due to retards and clear regulated discharge from the reservoir
(4) Reservoir completed - Discharge regulated - Required channel obtained
Retards decayed
Original bed
H.W.S.
Retards decayed
Sill
Excessive scour checked by sill if necessary
(5) Final condition
STATE OF NEW MEXICO
MIDDLE RIO GRANDE CONSERVANCY DISTRICT
DIAGRAMS
SHOWING
STAGES OF CHANNEL IMPROVEMENT
DRAWN
RECOMMENDED
CHECKED
APPROVED
ALBUQUERQUE, NEW MEXICO
SEPTEMBER 4, 1926
K-3


4/10/2

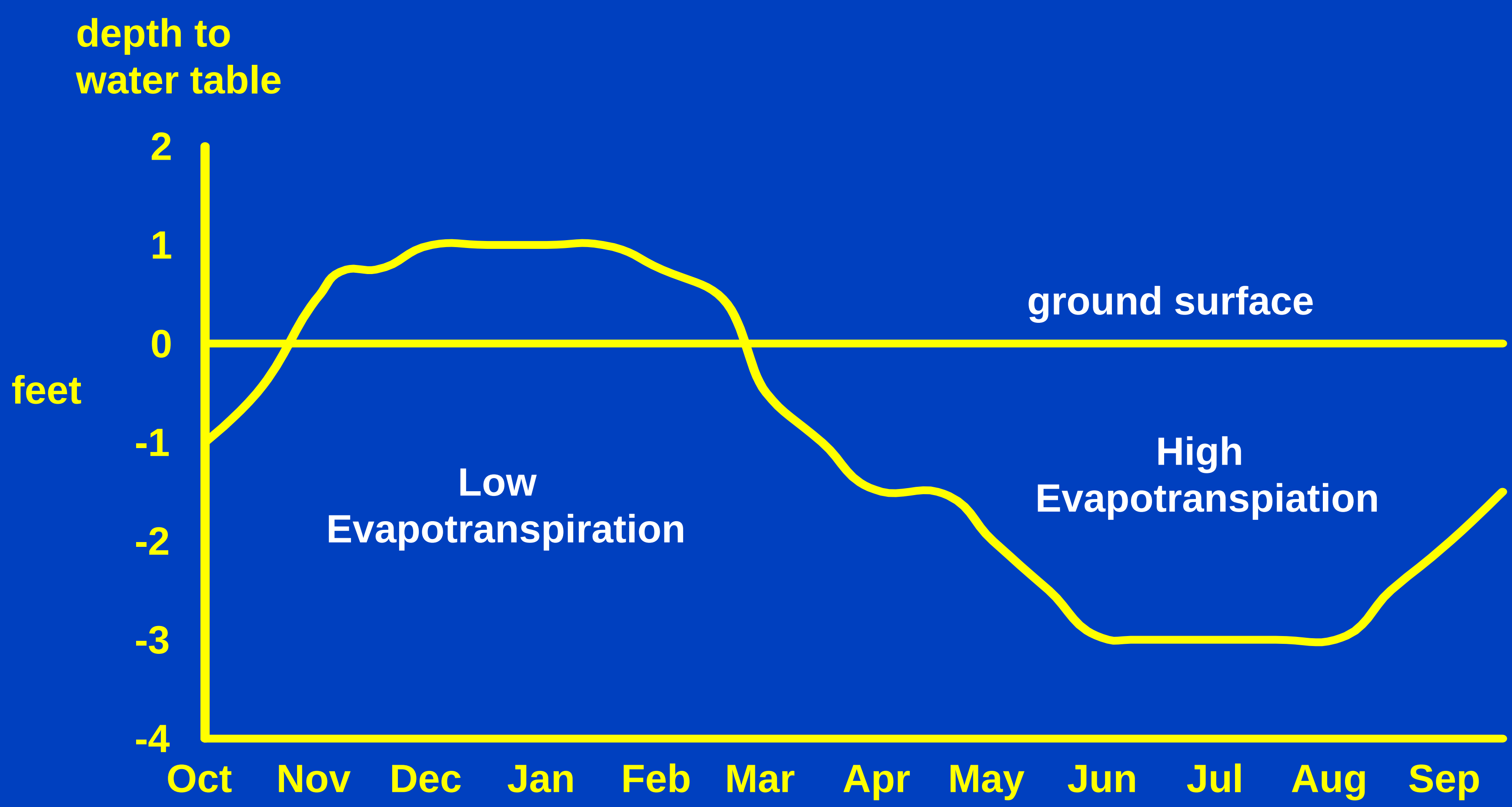

LEGEND
Retards
Sand Bars
Excavated Channels
Scoured Channels
Acres in present channel 830
(Includes sand bars)
Acres in proposed channel 230
(Figured @ 3.8 mi., 500' wide)
Acres Reclaimed 600
per mi. 158 ±
4606
4602
4600
4598
4596
4594
High Cut Bank
Bosque
RIO
GRANDE
Flow
Excavate Channel 50 wide
Excavate Chan. 50 wide
Canal
3.8 Miles of River.
3.6 Miles of Retards.
A
TOPOGRAPHY NEAR SOCORRO
DIAGRAM SKETCH OF PROPOSED WORK
Scale in Feet
Tripods of 3-6"x6-16' Pcs.
Guy Cable
Woven Wire
Concrete Anchor
Concrete Weights
Tripods 50' crs.
TYPE B
Details on Dwg. K-2
Cottonwood Trees & Willows
TYPE C

NM 47
A.T. & S.F. R.R. BRIDGE
RIVER MILE 171.1
BARR-CHICAL DIVERSION
RIVER MILE 172
R. 3 E.
R. 2 E.
ISLETA LAKES
RIVERSIDE
DRAIN
ALBUQUERQUE
ISLETA
RIVERSIDE
RIVERSIDE
DRAIN
ATRISCO
I-25 BRIDGE
RIVER MILE 172.6
ISLETA
INDIAN
ISLETA
INDIAN
DRAIN
RIVER
MILE 170
ACEQUIA
BLVD
LATERAL
LOS PADILLAS
DRAIN
ISLETA
I-25
CANAL

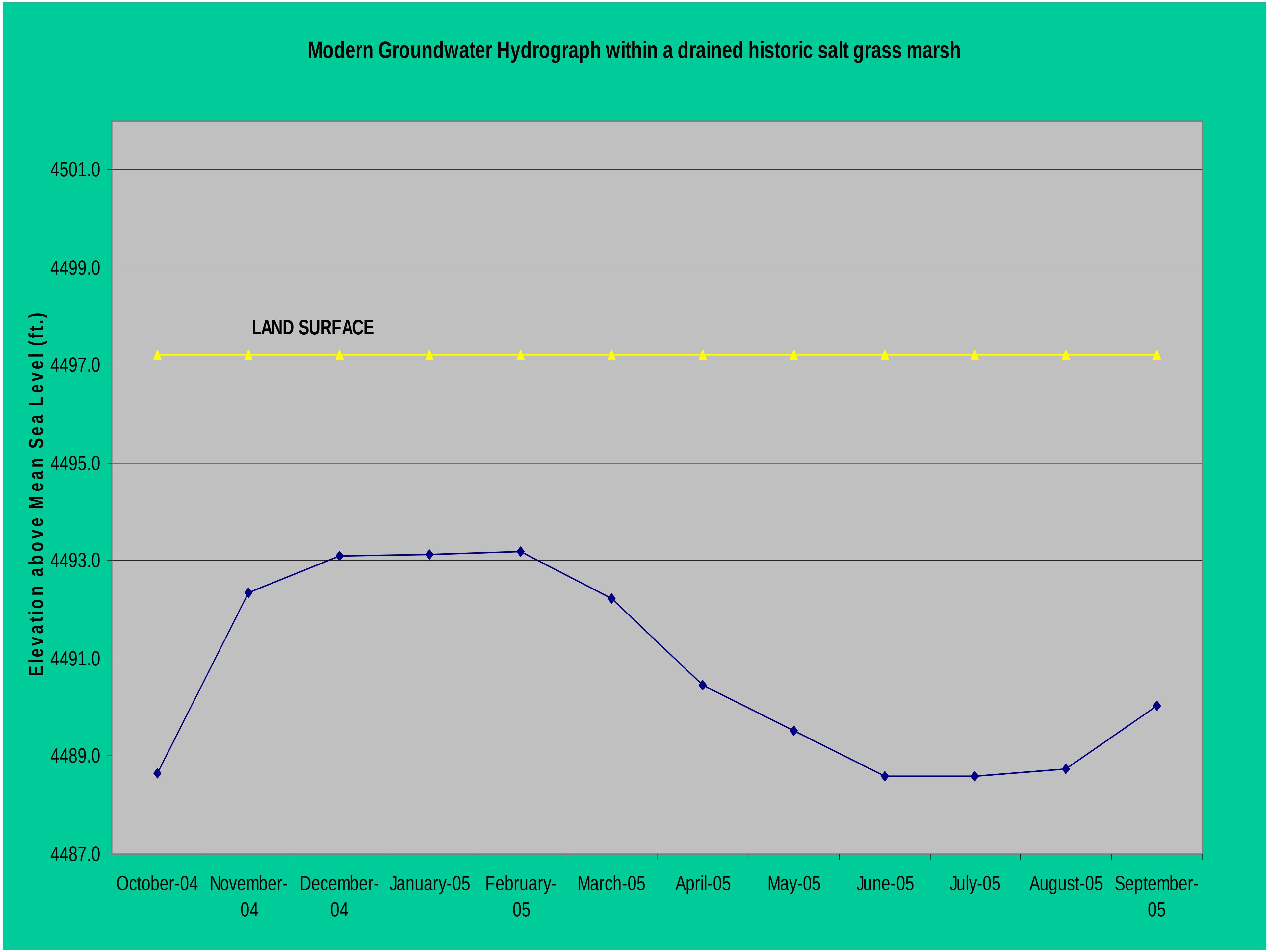


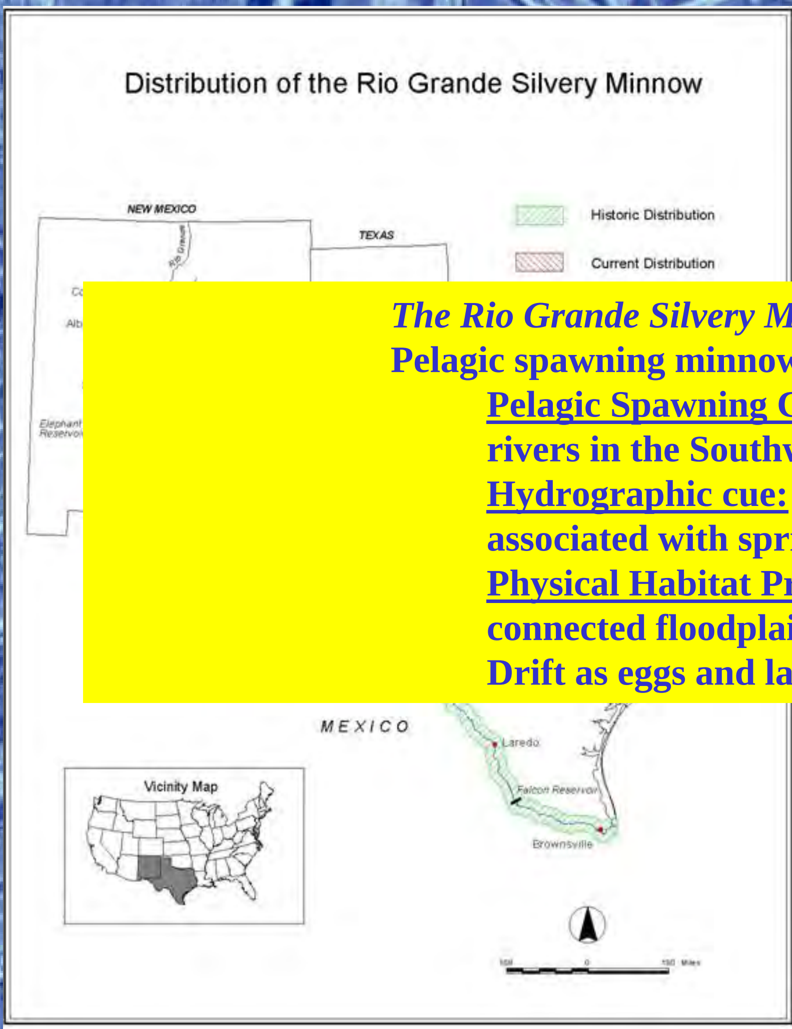
Belen
Reach
1935
1989
Scale 1:100,000
KILOMETERS
1 0 1 2 3 4
1 0 1 2
MILES

Saltgrass Community Groundwater



C/O John Taylor


Modern Groundwater Hydrograph within a drained historic salt grass marsh
Elevation above Mean Sea Level (ft.)
4501.0
4499.0
4497.0
4495.0
4493.0
4491.0
4489.0
4487.0
LAND SURFACE
October-04
November-04
December-04
January-05
February-05
March-05
April-05
May-05
June-05
July-05
August-05
September-05



The Rio Grande Silvery Minnow

Pelagic spawning minnow: 1 of 5 remaining in MRG

<u>Pelagic Spawning Cyprinids:</u> Associated with sand bed rivers in the Southwestern and Great Plains United States.

<u>Hydrographic cue:</u> Spawn on increase in discharge associated with spring run-off.

<u>Physical Habitat Preference:</u> Braided sand bed and connected floodplain. Produce semi-buoyant eggs. Drift as eggs and larvae for 3-5 days.

Only remaining pelagic spawner in the MRG – 2 others have gone extinct and 2 were extirpated

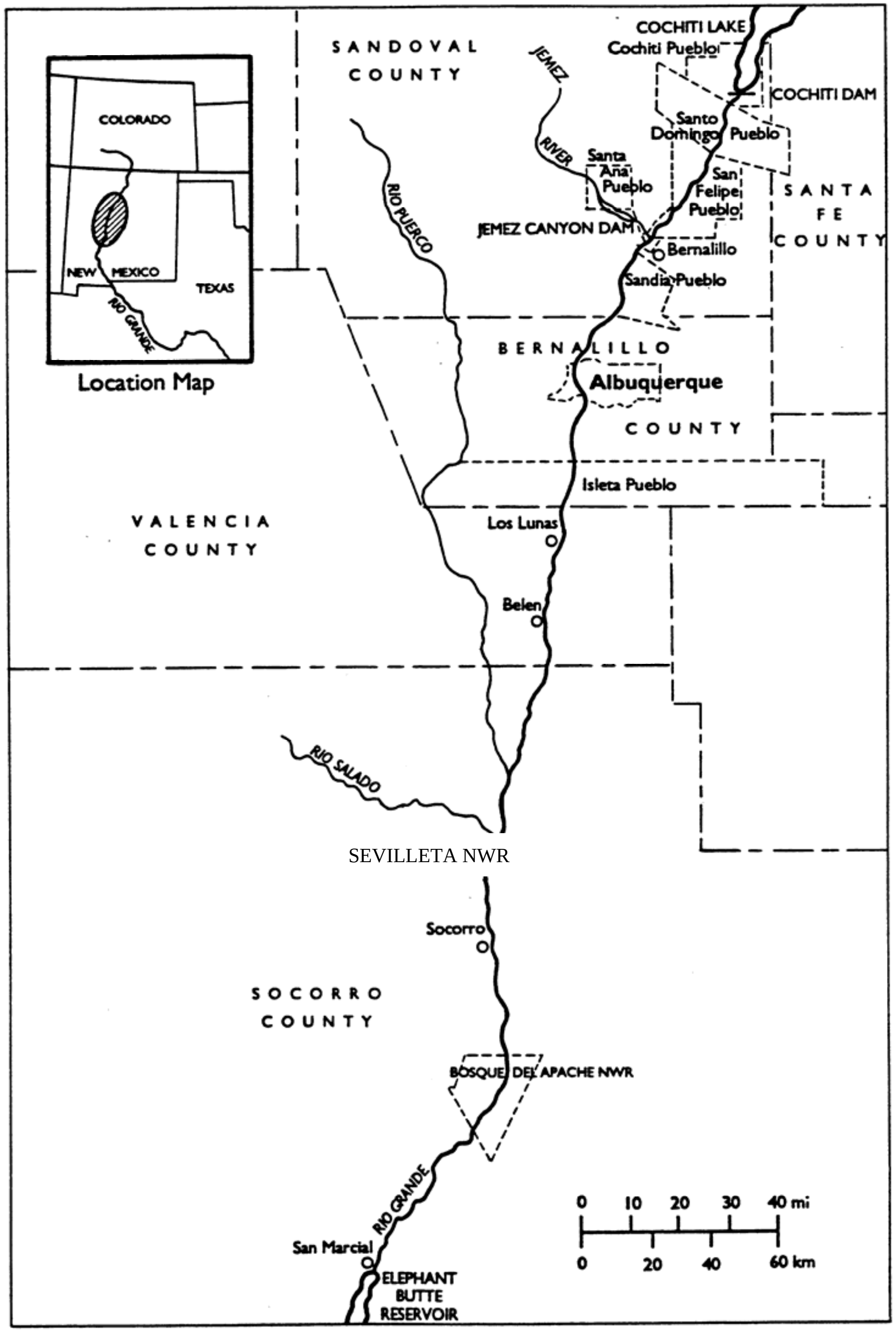
...nstream of ...s of Elephant

...) of its known

...nde from ...co

Historically one of the most widespread and abundant fishes in the Rio Grande Basin

Now one of the rarest fishes in the Rio Grande



COCHITI RESERVOIR, 0 Mile

Cochiti Pueblo

Santa Domingo Pueblo

San Felipe Pueblo

ANGOSTORA DIVERSION DAM , 22.9 Mile

Santa Ana Pueblo

Sandia Pueblo

Albuquerque

ISLETA DEVERSION DAM, 63.3 Mile

Isleta Pueblo

Belen

Sevilleta NWR

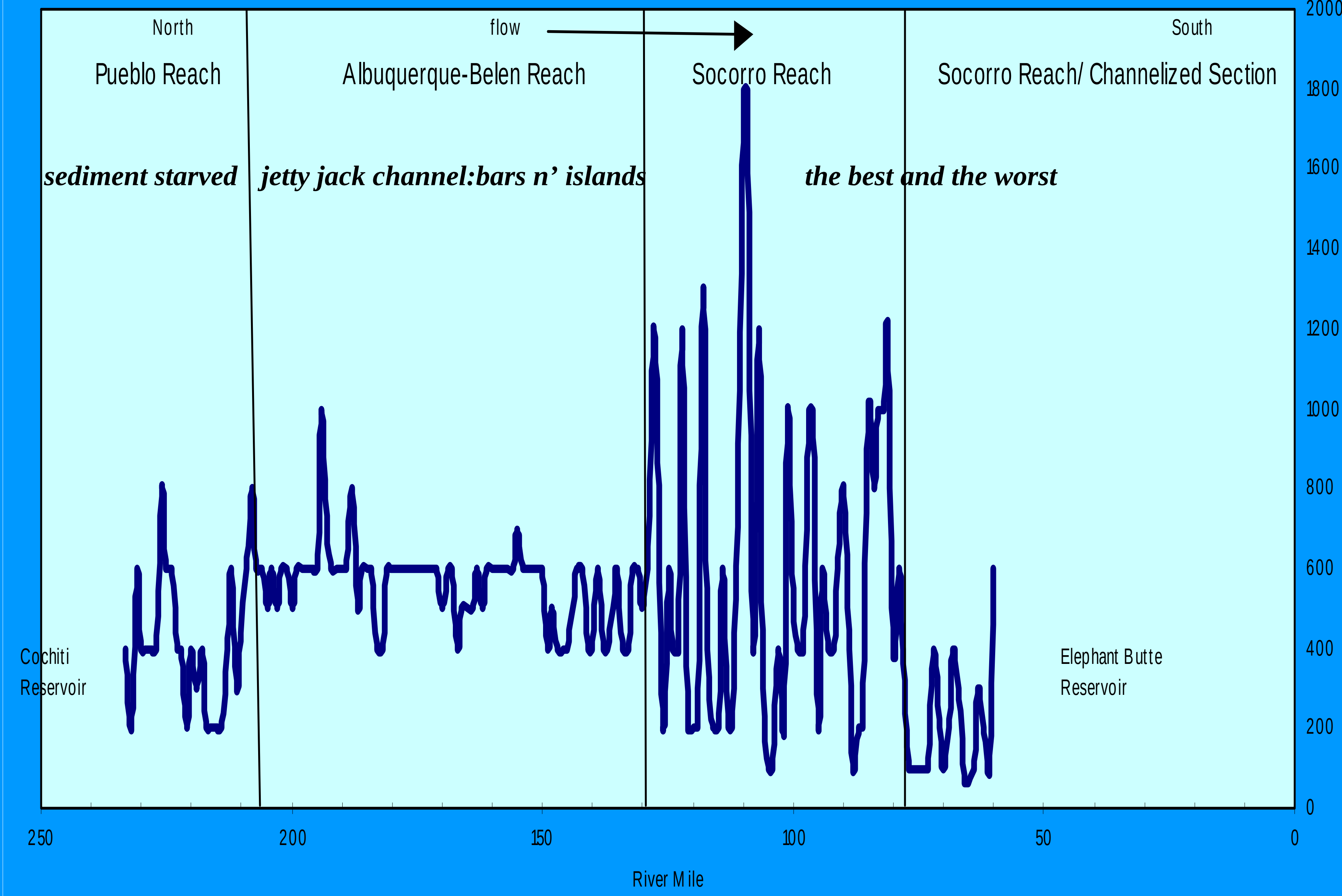
SAN ACACIA DIVERSION DAM, 116.4 Mile

Socorro

Bosque Del Apache NWR

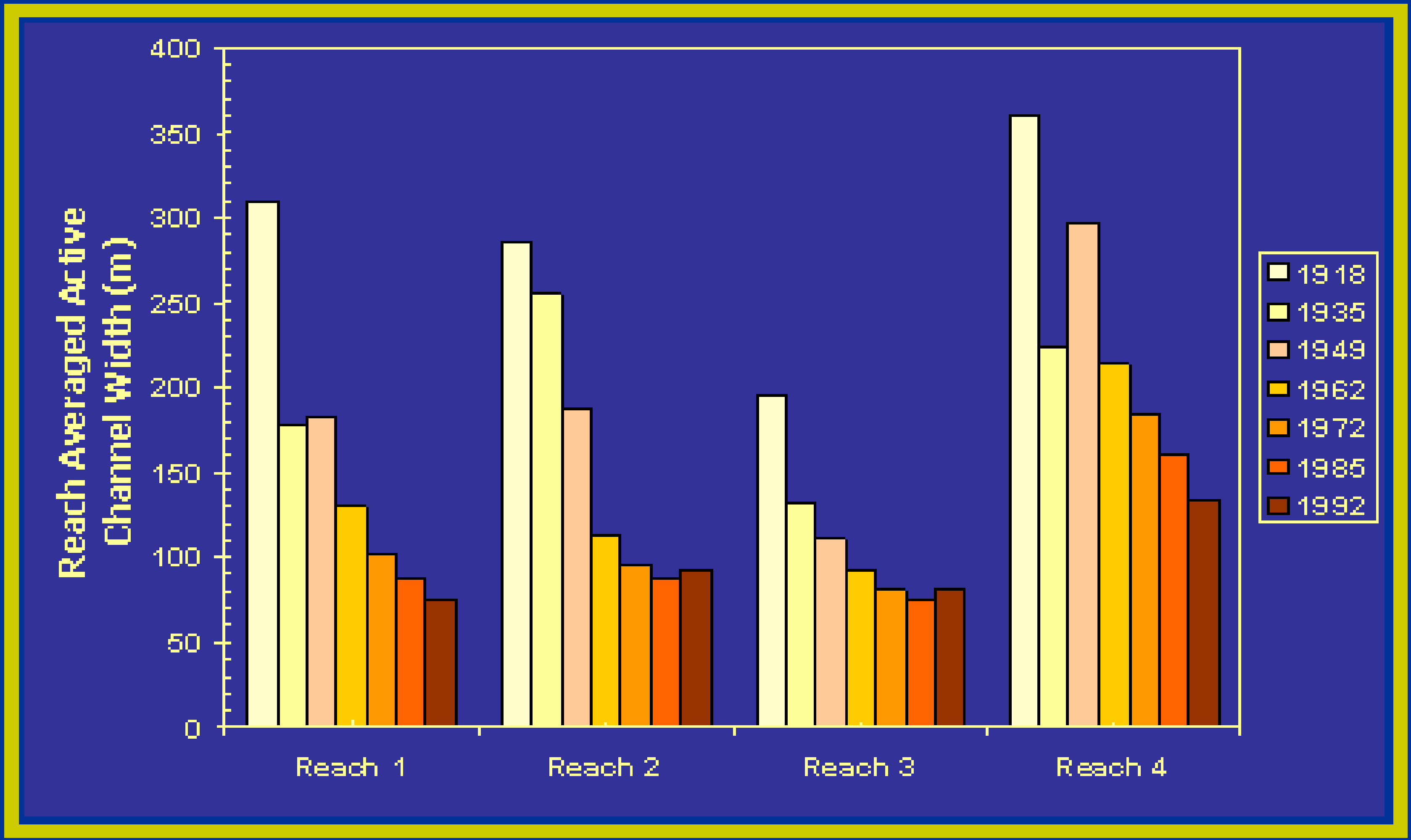
ELEPHANT BUTTE RESERVOIR, 176.6 Mile

Middle Rio Grande in 1992: River Mile vs. Channel Width



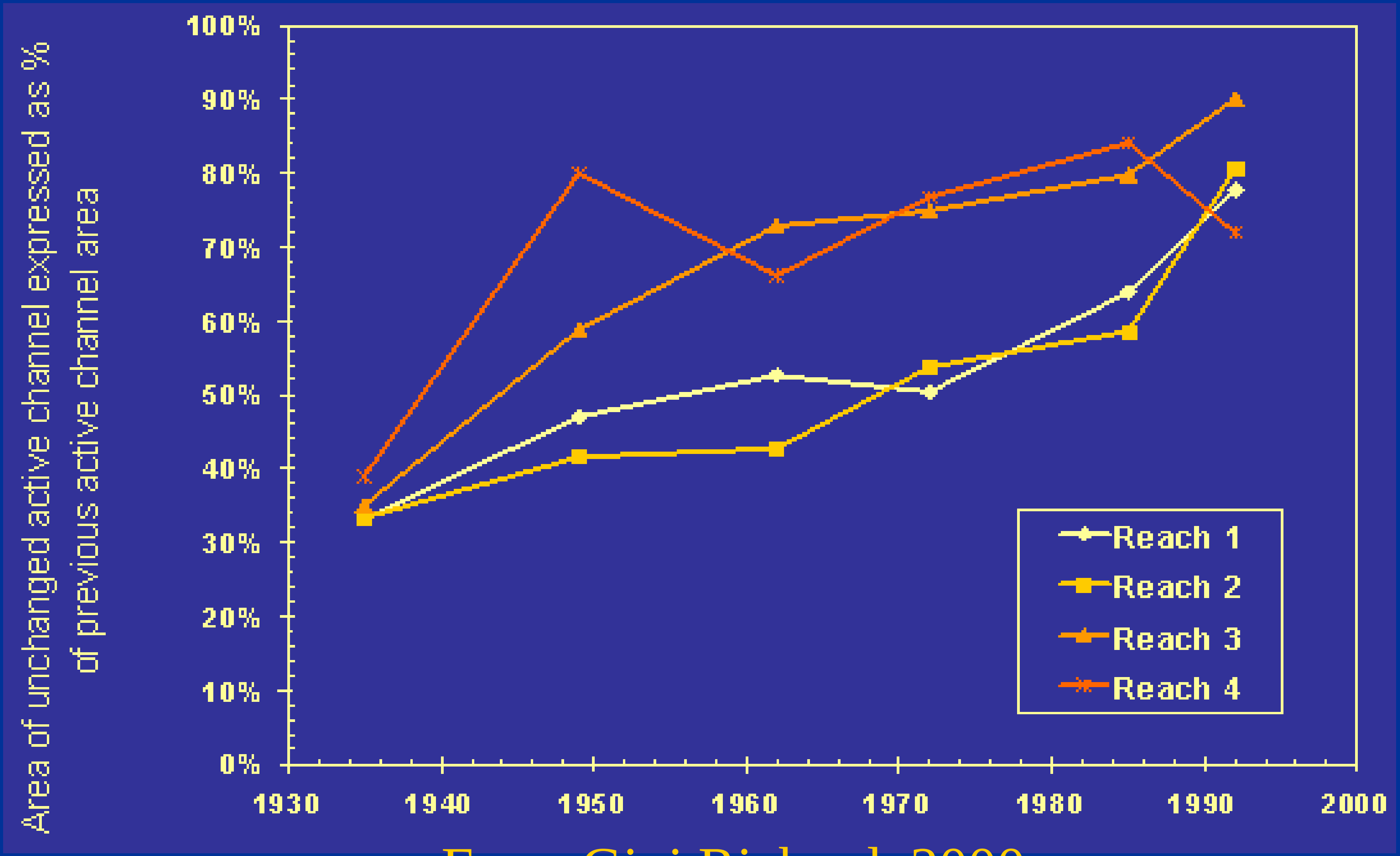

COCHITI DIVISION
RIVER MILE
PENA BLA
NM 22
RIVER
SANTA FE
COCHITI EAST SIDE MAIN CANAL
RIVER MILE 232
RIVER MILE 230
COCHITI PUEBLO
SIDE
NM 22
MAIN CANAL
RIVER MILE 228
PERALTA CANYON
R.6 E.
R.5 E.

Active Channel Width

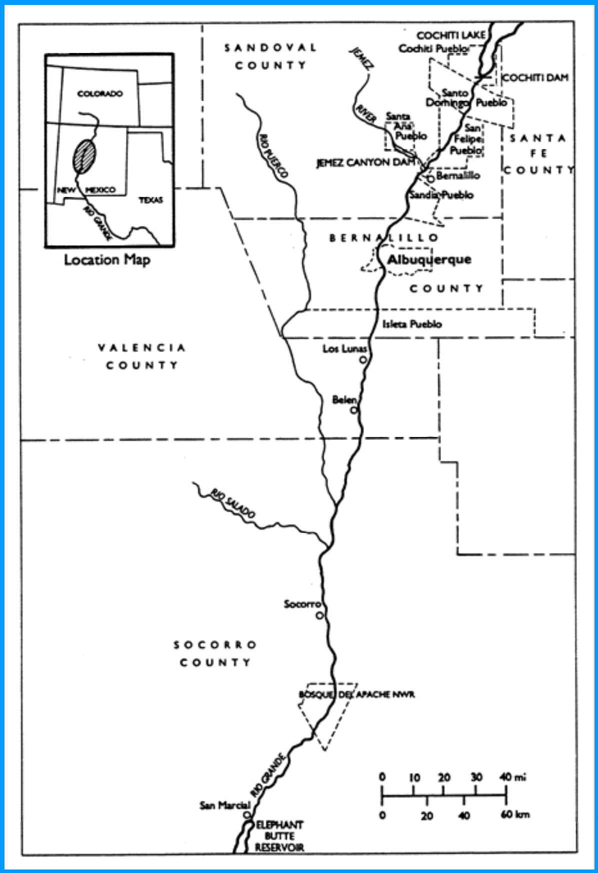


From Gigi Richard, 2000

Stability of channel planform



From Gigi Richard, 2000



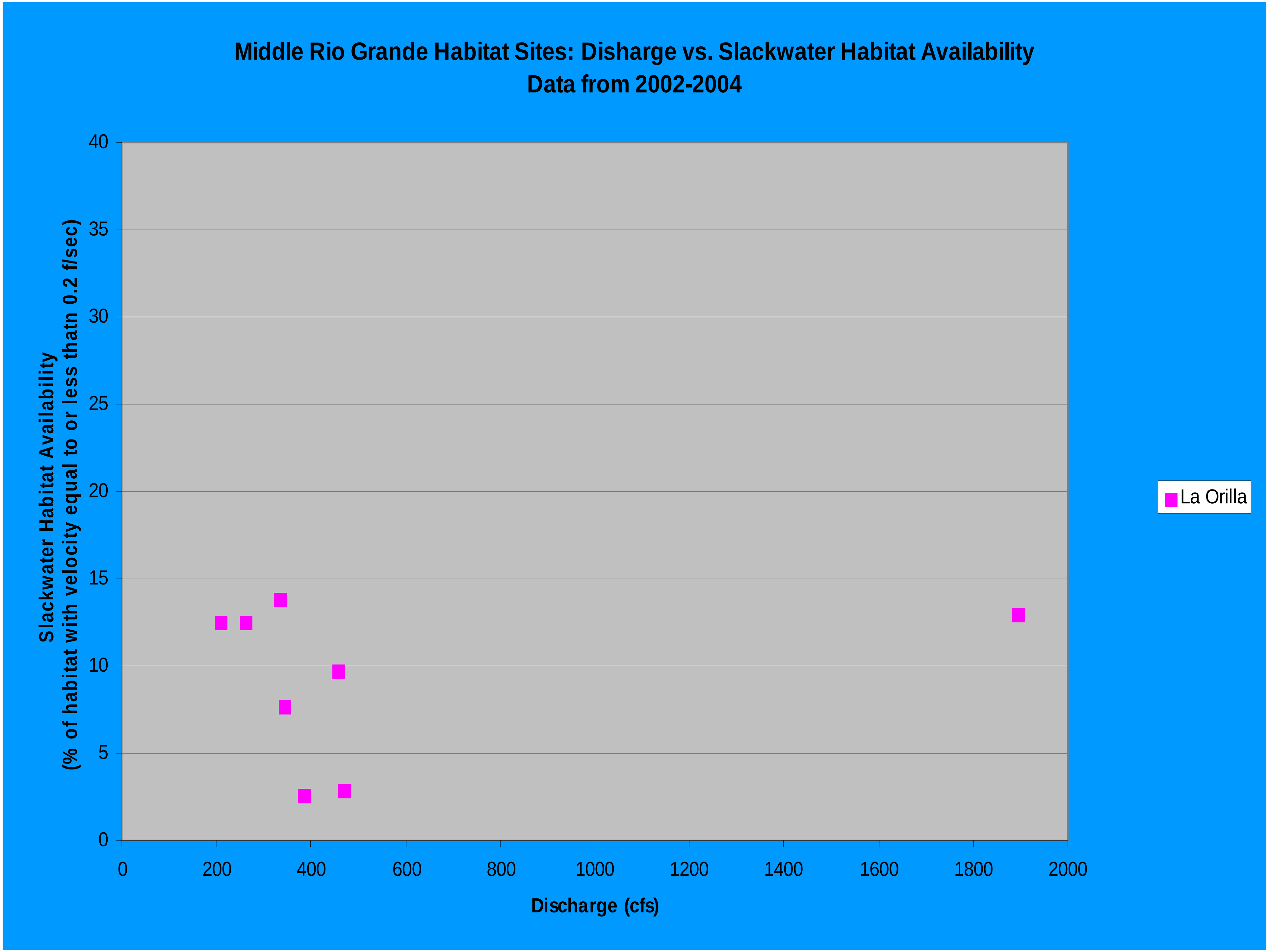
Shorelines at differing discharge (cfs)

- FLO2D_9000
- GPS_1894
- GPS_469
- GPS_261
- GPS_208

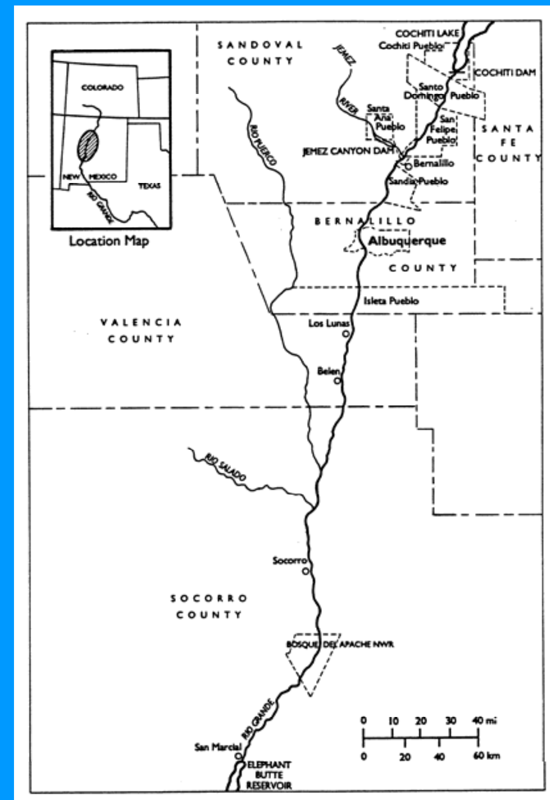
3

La Orilla

300 150 0 300 Meters


Middle Rio Grande Habitat Sites: Disharge vs. Slackwater Habitat Availability
Data from 2002-2004
Slackwater Habitat Availability
(% of habitat with velocity equal to or less thatn 0.2 f/sec)
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Discharge (cfs)
La Orilla


CAT
325B
CAT
4/10/



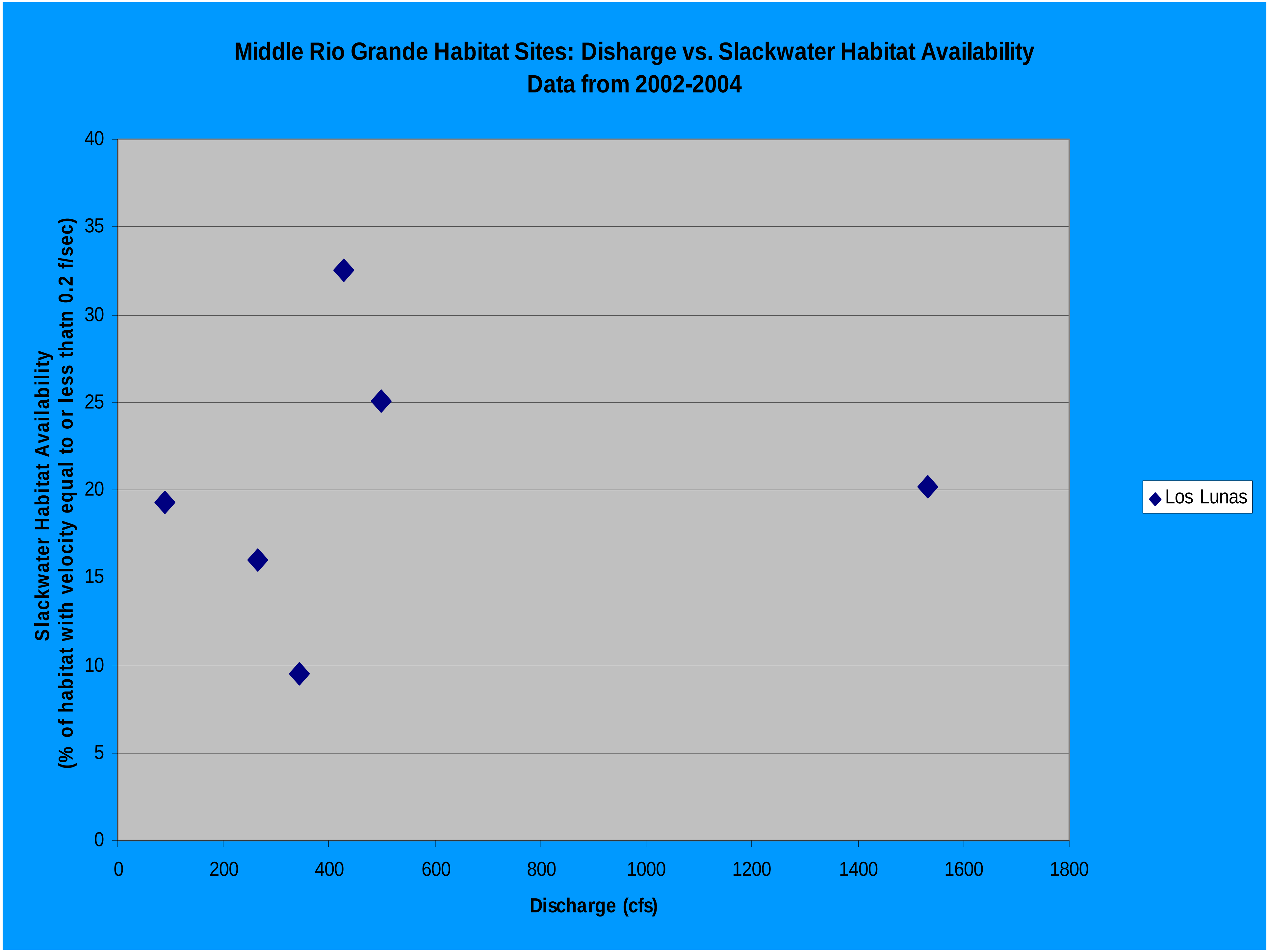
3

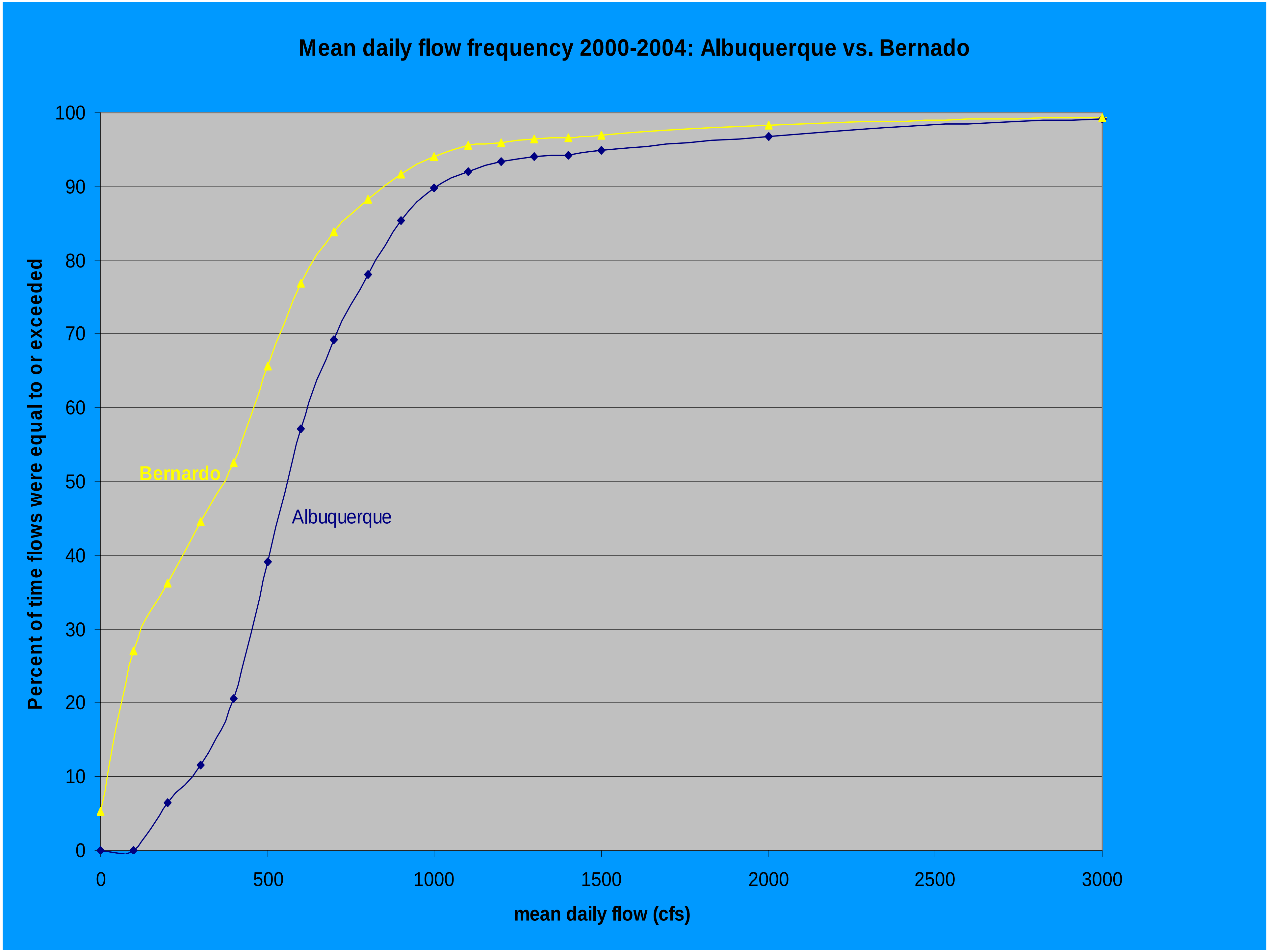
Shorelines at differing discharge (cfs)

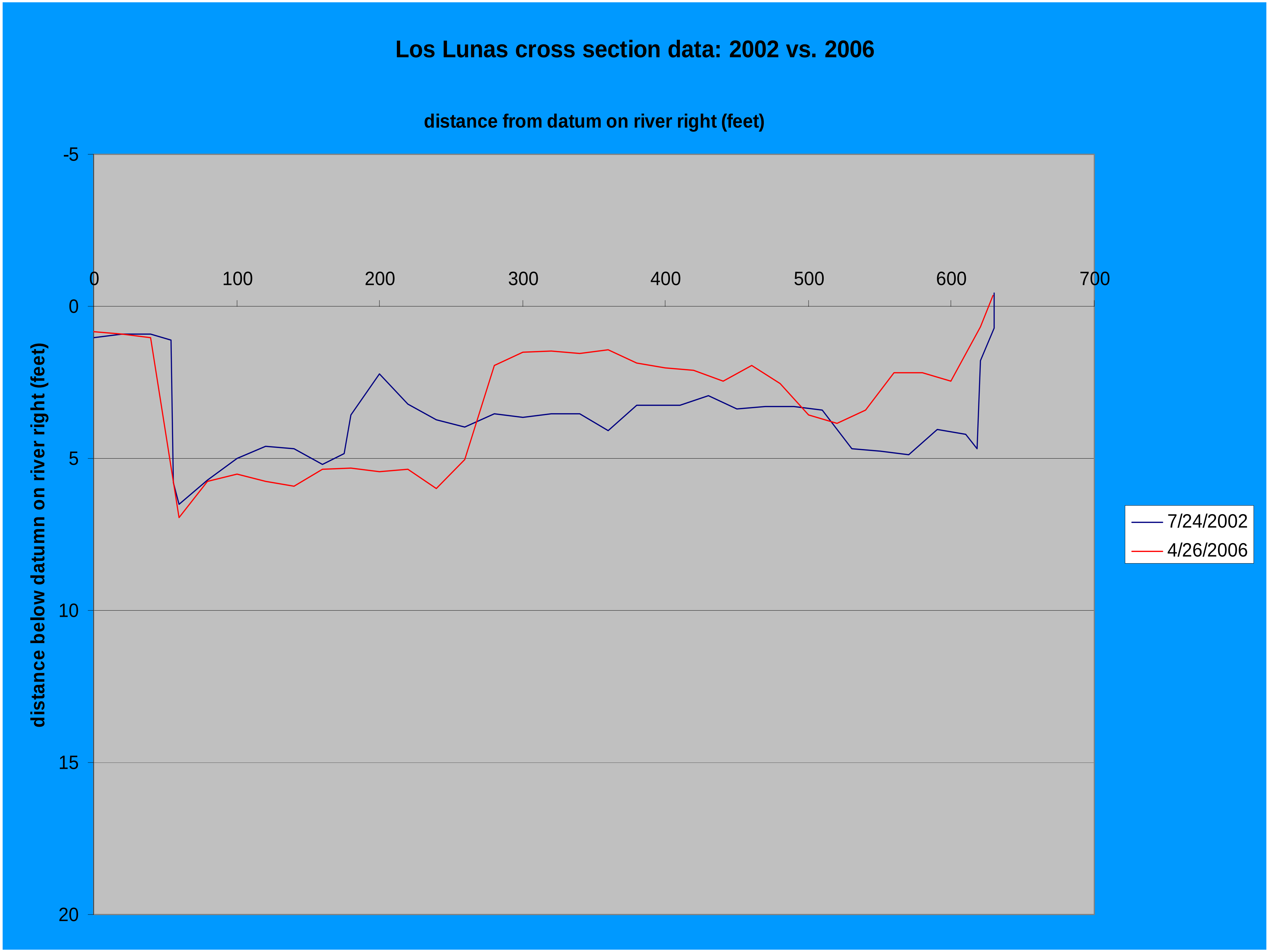
- FLO2D_8000
- GPS_1532
- GPS_498
- GPS_428
- GPS_266

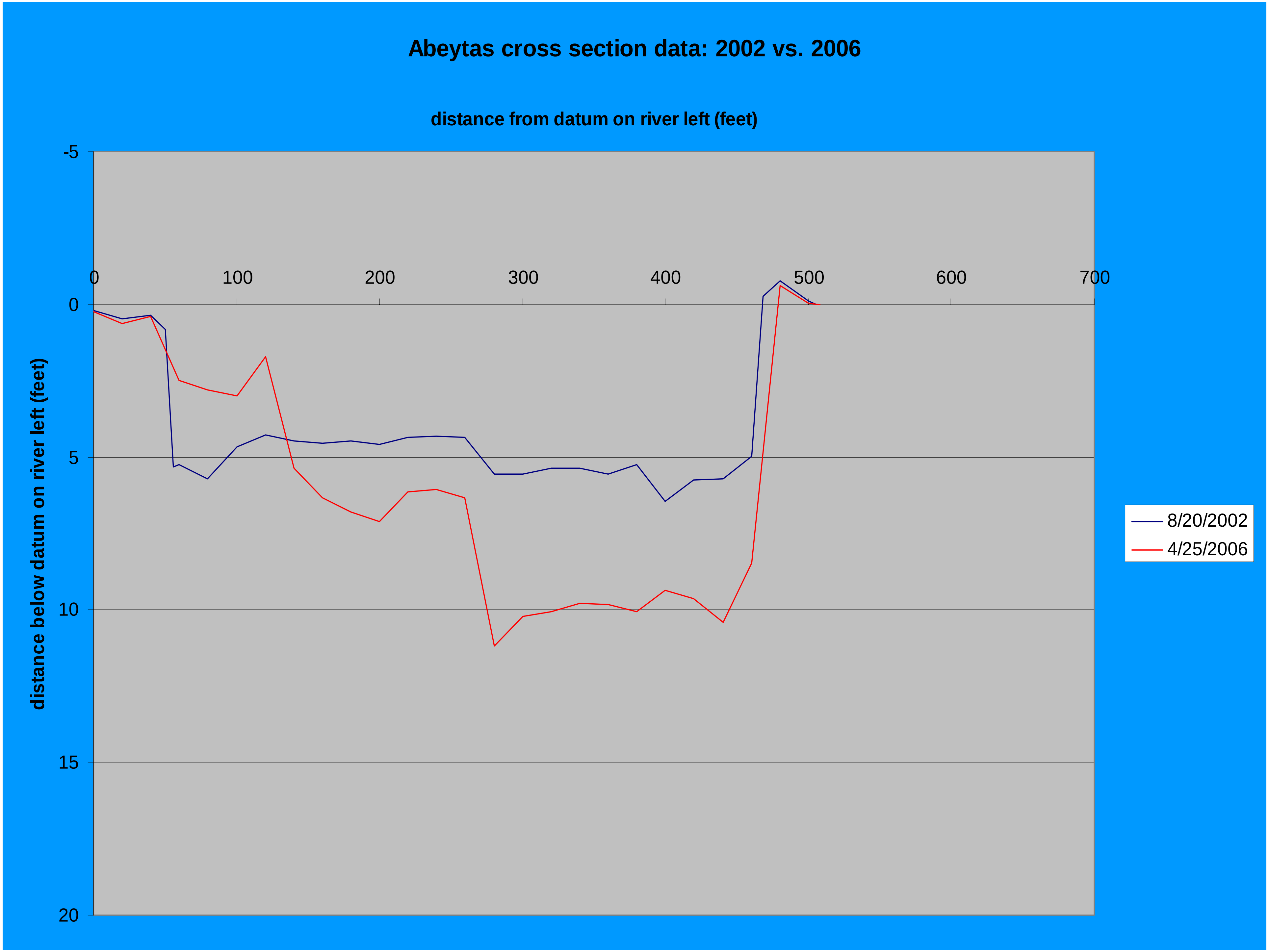
Los Lunas

300 150 0 300 Meters


Middle Rio Grande Habitat Sites: Disharge vs. Slackwater Habitat Availability
Data from 2002-2004
Slackwater Habitat Availability
(% of habitat with velocity equal to or less thatn 0.2 f/sec)
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
1400
1600
1800
Discharge (cfs)
Los Lunas


Mean daily flow frequency 2000-2004: Albuquerque vs. Bernado
Percent of time flows were equal to or exceeded
100
90
80
70
60
50
40
30
20
10
0
Bernardo
Albuquerque
0
500
1000
1500
2000
2500
3000
mean daily flow (cfs)


Los Lunas cross section data: 2002 vs. 2006
distance from datum on river right (feet)
distance below datumn on river right (feet)
0
100
200
300
400
500
600
700
-5
0
5
10
15
20
7/24/2002
4/26/2006

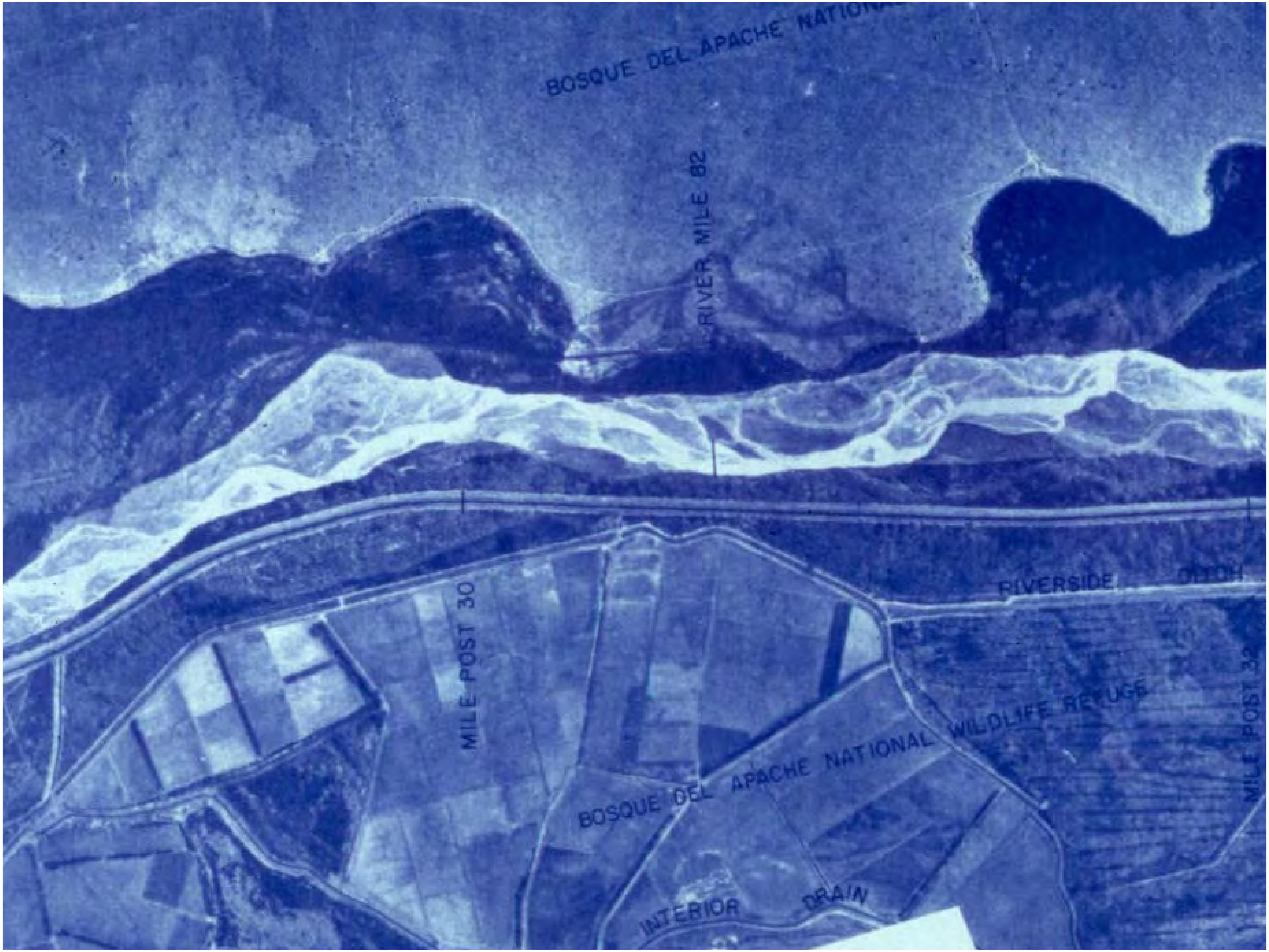


Abeytas cross section data: 2002 vs. 2006
distance from datum on river left (feet)
distance below datum on river left (feet)
-5
0
5
10
15
20
0
100
200
300
400
500
600
700
8/20/2002
4/25/2006

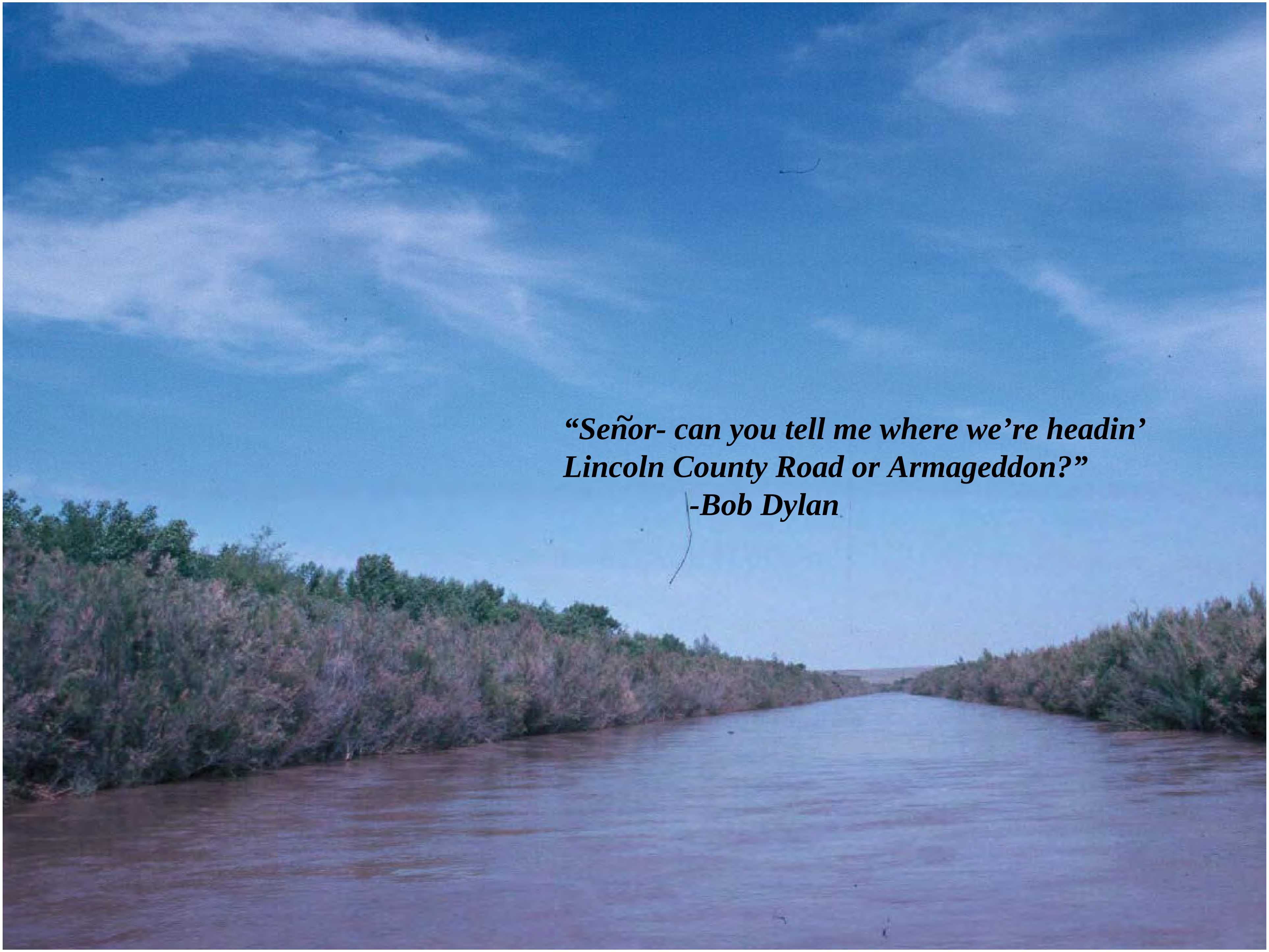

Rio Salado
Rio Grande
South


San Acacia Diversion
Low Flow Canal
Socorro Main
6/


North
Rio Grande
Low Flow Canal
South
6/8/1999

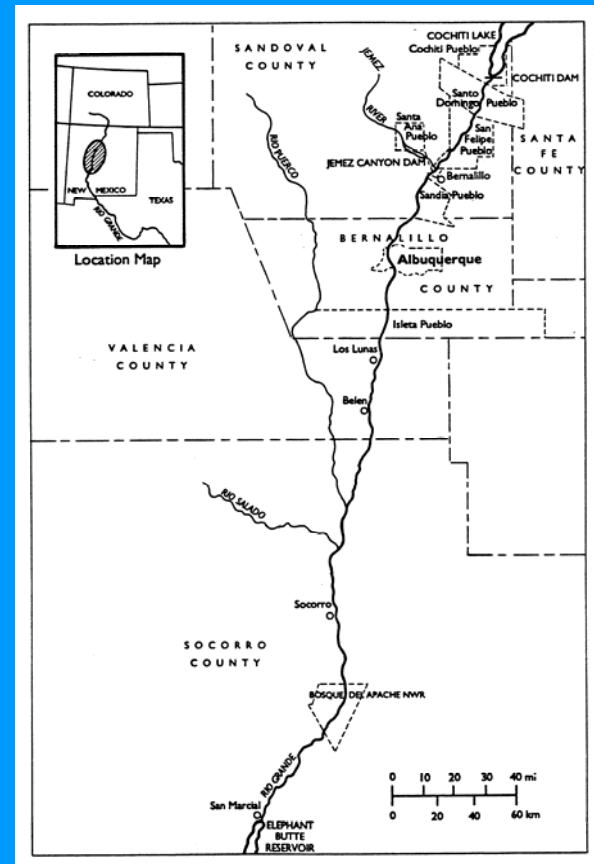

BOSQUE DEL APACHE NATIONAL
RIVER MILE 82
RIVERSIDE DITCH
MILE POST 30
MILE POST 32
BOSQUE DEL APACHE NATIONAL WILDLIFE REFUGE
INTERIOR DRAIN


RIVER MILE 88
US 380
SAN PEDRO
RIVER MILE 86
LOW FLOW
RIVERSIDE
DRAIN
MAIN
CANAL
SOUTH
US 380 BRIDGE
MILE POST 26
SAN ANTONIO
LATERAL
SAN ANTONIO
CREEK
A T & S F R R
NM 1
ELMENDORF DITCH
SAN


“Señor- can you tell me where we’re headin’
Lincoln County Road or Armageddon?”
-Bob Dylan

Arroyo Del Tajo

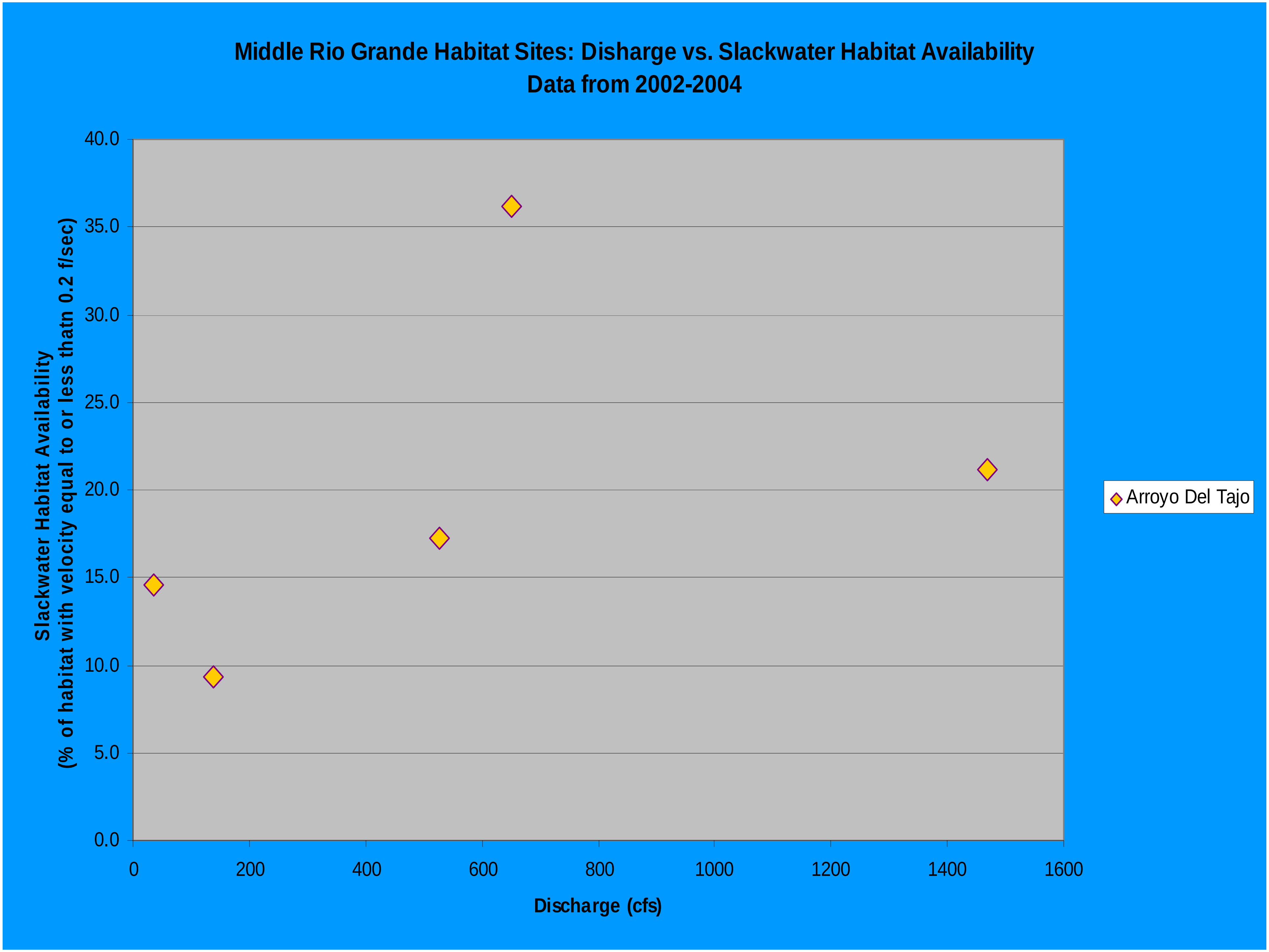
300 150 0 300 Meters



Shorelines at differing discharge (cfs)

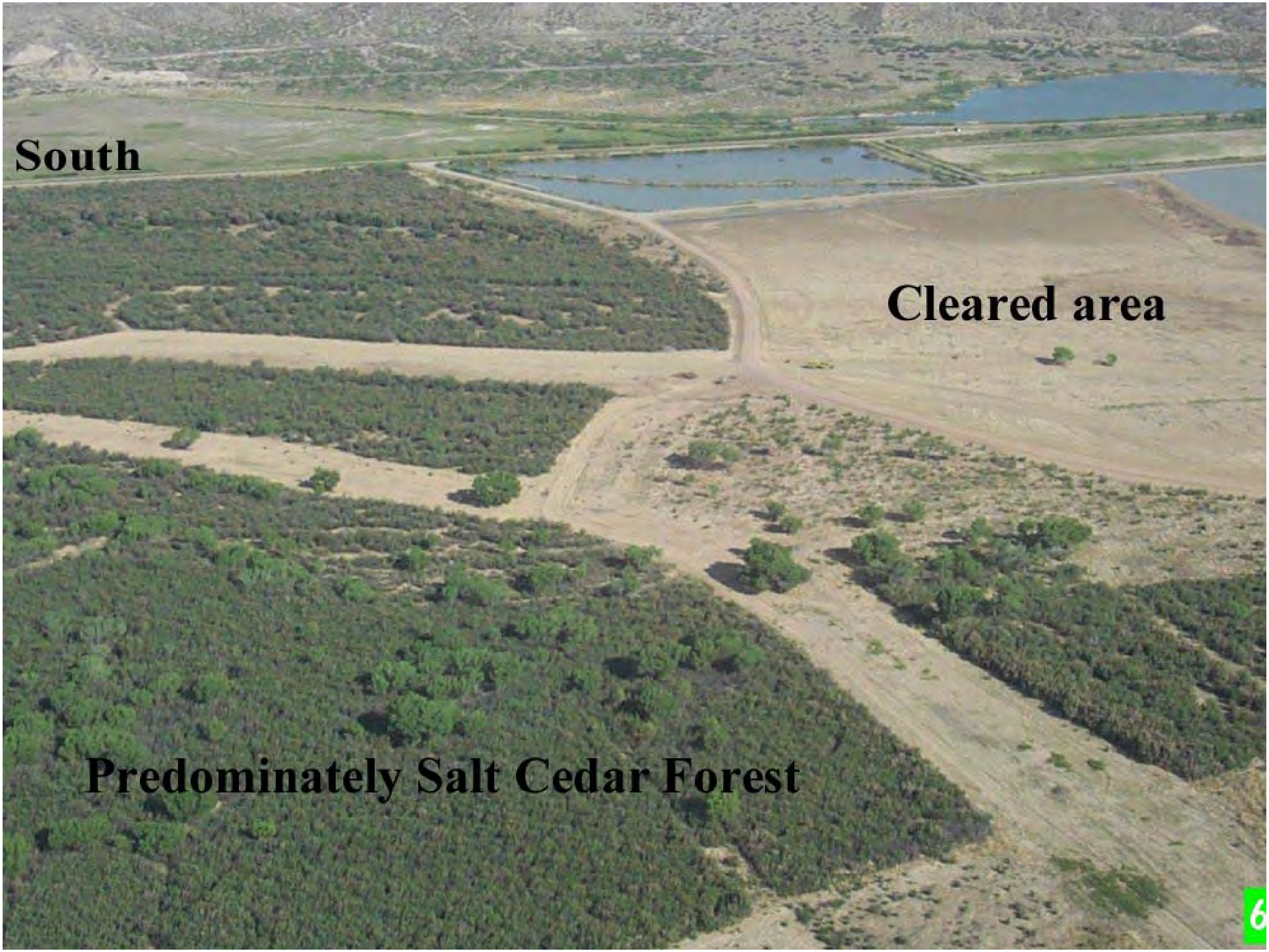
- FLO2D_7000
- GPS_1470
- GPS_555
- GPS_190
- GPS_139
- GPS_36

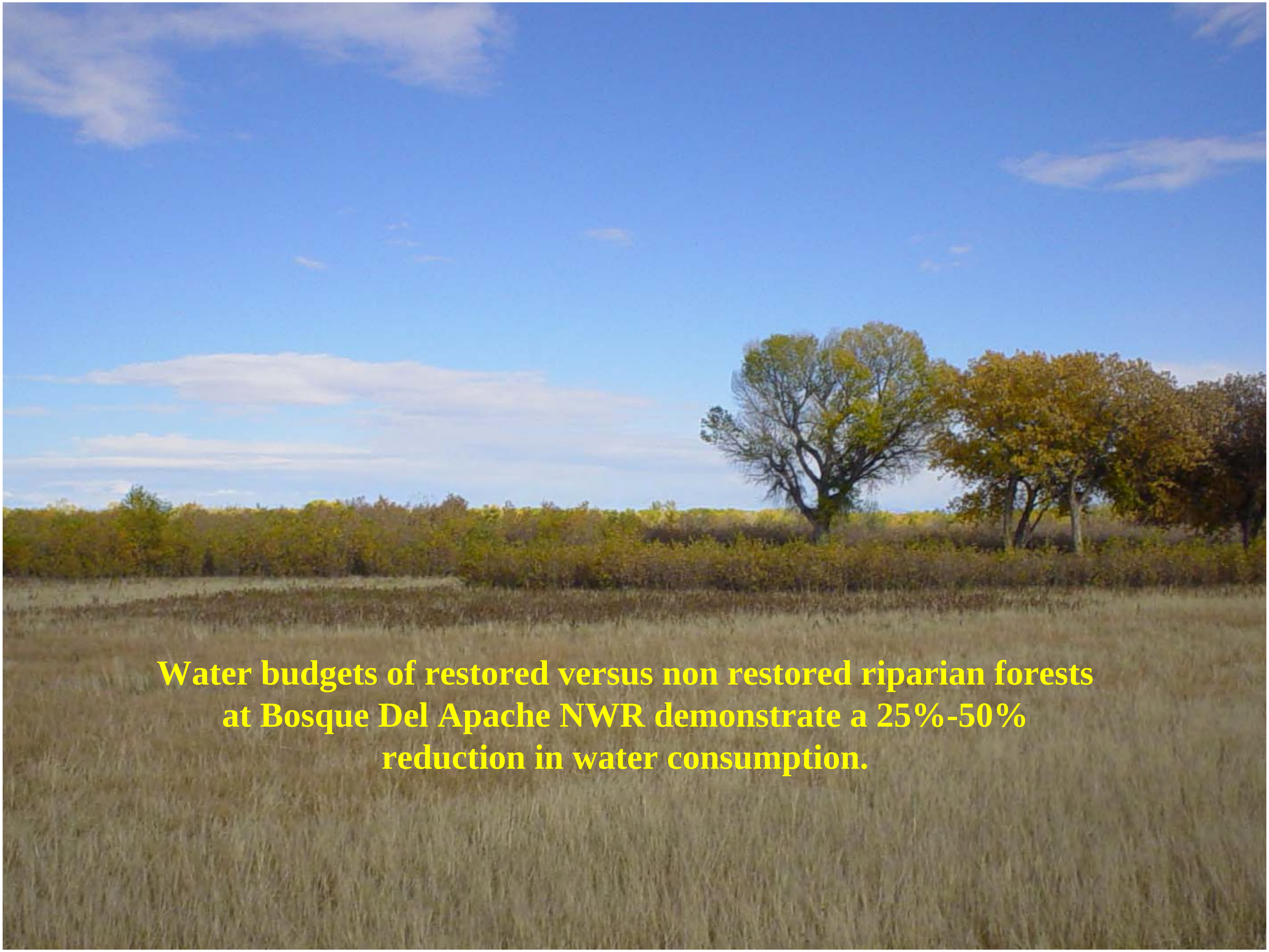
3


Middle Rio Grande Habitat Sites: Disharge vs. Slackwater Habitat Availability
Data from 2002-2004
Slackwater Habitat Availability
(% of habitat with velocity equal to or less thatn 0.2 f/sec)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
200
400
600
800
1000
1200
1400
1600
Discharge (cfs)
Arroyo Del Tajo


uth
Nor
Salt Cedar Forest
Predominately Open Native Bosque
6/8/1999


Photo John Taylor


South
Cleared area
Predominately Salt Cedar Forest
6


Water budgets of restored versus non restored riparian forests
at Bosque Del Apache NWR demonstrate a 25%-50%
reduction in water consumption.

ECONOMIC BENEFITS OF RESTORATION

Fire Threat Reduction:

-Impact of fires on neighboring communities, health, safety and community structures.

-Feedback between fires and non-native phreatophytes.

Water Salvage:

-Estimates of water budgets for non-native phreatophyte dominated vs. restored native-dominated mosaic forests indicate promise for salvage.

Flood Peak Attenuation:

-The potential benefits of an active floodplain comprised of an open structured native dominated forest for flood control.


Restore historic processes by:
-remove jetty jacks: assist channel mobility, protect levees
-assist with a connected floodplain and floodplain
-forest t
-manage
g flows
ease low
and mid flow variability in ABQ
-sediment balance: add sediment up north
-wetland restoration in floodplain and farmland
Economic analysis of 2004 Bosque Del Apache NWR generated ~$20 million of economic activity in Socorro, Bernalillo and Sierra Counties


QUESTIONS?

UTTON TRANSBOUNDARY RESOURCES CENTER

The University of New Mexico

The Utton Center

TRANSBOUNDARY RESOURCES

University of New Mexico School of Law

Susan Kelly, Esq.

- The Utton Center is a Water Policy Center.

- We address transboundary water resource issues by providing expertise from a neutral standpoint.

Overview of Rio Grande Legal and Transboundary Issues

October 17, 2006

Rio Grande Seminar

Pueblos

- First water users of Rio Grande.
- Tewa people supported their dryland farming with irrigation ditches even before 1200 A.D.
- Irrigation ditches used by Native American people were observed by Europeans as early as the 1500s.

Pueblos

- 18 Pueblos use water from Rio Grande.

- Estimates of irrigated areas:
  - 20,000 acres in 1896
  - 25,000 acres in 1924
  - over 8,000 acres today in MRG

Six Middle Rio Grande Pueblos

- Cochiti
- Santo Domingo
- San Felipe
- Santa Ana
- Sandia
- Isleta

ACEQUIAS

Acequias:

- Community-based systems of irrigation and water distribution.
- Formed the basis for settlement of Hispanic communities between two and four hundred years ago.
- 80% of water use in Northern New Mexico.

Key dates in New Mexico water law

- Treaty of Guadalupe Hidalgo - 1848
  - Transferred sovereignty from Mexico to the United States.
  - Guaranteed property rights in existence at that time.

1907 Water Code

- Protected surface waters of the State.
- Office of State Engineer authority.
- Water rights in existence were vested.

New Mexico Constitution

- Prior appropriation doctrine.
- Origin – early California mining law.
- First in time, first in right.
- Right continues as against subsequent appropriators as long as water is put to beneficial use.

Beneficial use

- Application of water to a lawful purpose that is useful to the appropriator.
- Includes most uses – but “waste” is not a beneficial use.
- The **Basis**, the **Measure**, and the **Limit** of water rights in the West.

Key word is **use**:

- Right can be lost if not put to beneficial use.
- Basis: water right is based on **when** first put to use and the type of use.
- Measure: The **amount of** a water right is determined by the amount put to beneficial use.
- Limit: Cannot use more than the amount of the permitted right.

Water rights can be lost:

- Forfeiture (requires State Engineer action).

- Abandonment (requires evidence of non-use).

Groundwater

- 1931 Water Code. Recognized groundwater connected to stream system.
- Permit required for withdrawals in declared basins.

Middle Rio Grande Basin

- 1956 Declaration of the MRG Basin.
- *City of Albuquerque v. Reynolds* resulted in City's vested groundwater rights.

Water rights required for groundwater pumping:

- Based on ground water flow models.
- Water rights requirements are based upon effects on Rio Grande.
- Effects of pumping on River are delayed.

Rio Grande fully appropriated:

- All water in Rio Grande is appropriated.
- Therefore, any new or expanded use is required to be offset by the retirement of another use.
- This results in a “water market” and transfer process.

Transfer of water rights

- Conveyance is by deed, because water rights are a property right.
- Appurtenant to real estate – but can be severed.
- Only the consumptive use amount is transferred.

Transfer process

- Declaration (of vested rights).
- Application to Change Point of Diversion and Place and/or Purpose of Use from Surface to Groundwater.
- Advertisement.
- Opportunity for Protest.

State Engineer Criteria

- No impairment of other rights.
- Not contrary to public welfare.
- Not contrary to water conservation.

Priority study required in Middle Rio Grande:

- 1917 maps.
- 1926 appraisal sheets.
- Continuous use (aerial photos – 1935, 1947, 1955, 1965).
- Other proof of pre-1907.

Brief Overview of the Rio Grande water supply

UPPER RIO GRANDE MAP

Courtesy of Upper Rio Grande Water Operations Model

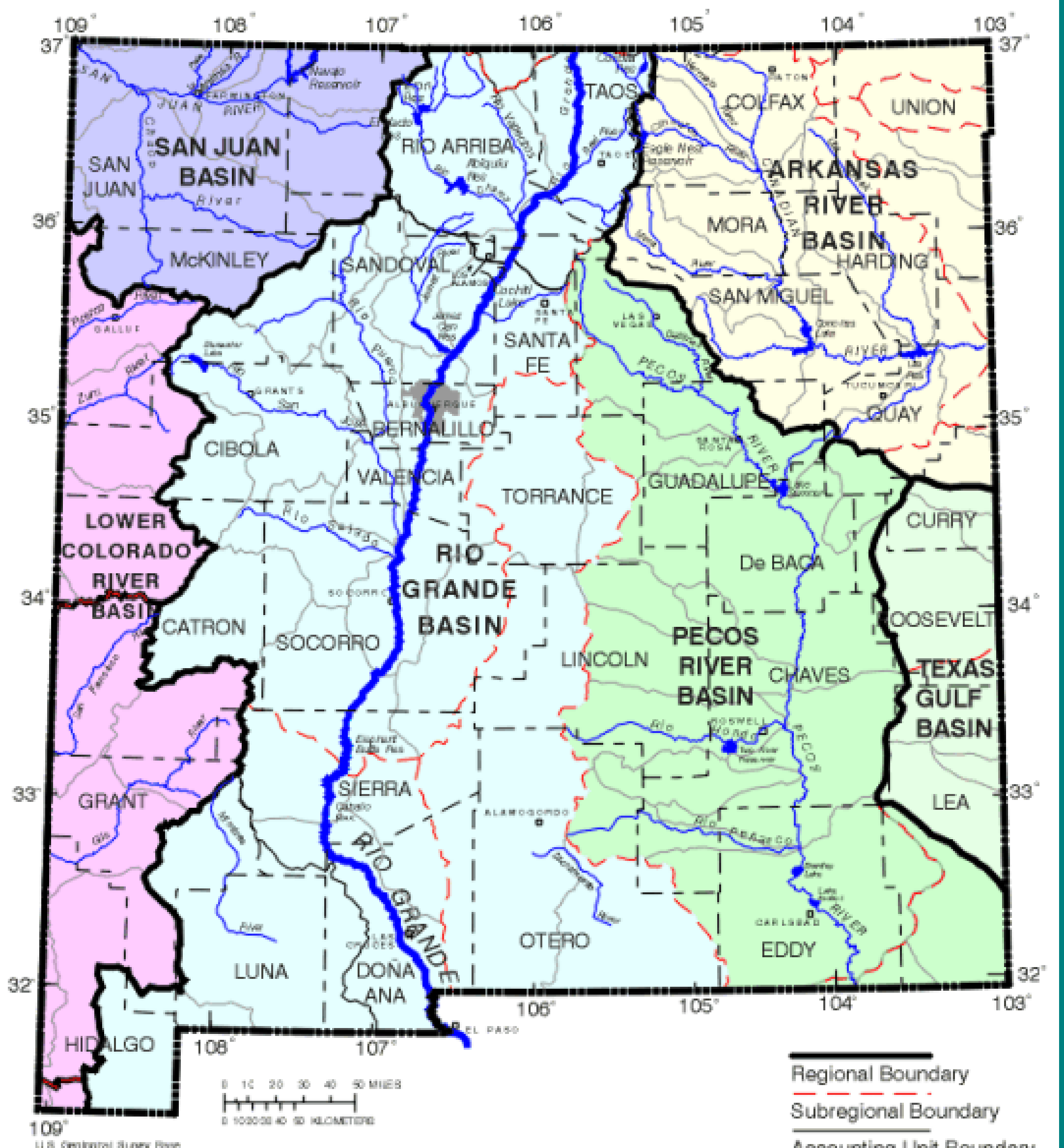
US Army Corps of Engineers

NM Interstate Stream Comm.

US Bureau of Reclamation

Interstate Compacts

- Like a treaty between states.
- Regulate the right to use water coming into and leaving the state.
- New Mexico is a party to 9 interstate compacts.
- The Rio Grande Compact, The Pecos River Compact and the Colorado River Compacts are the most significant.



Hydrologic units in New Mexico.

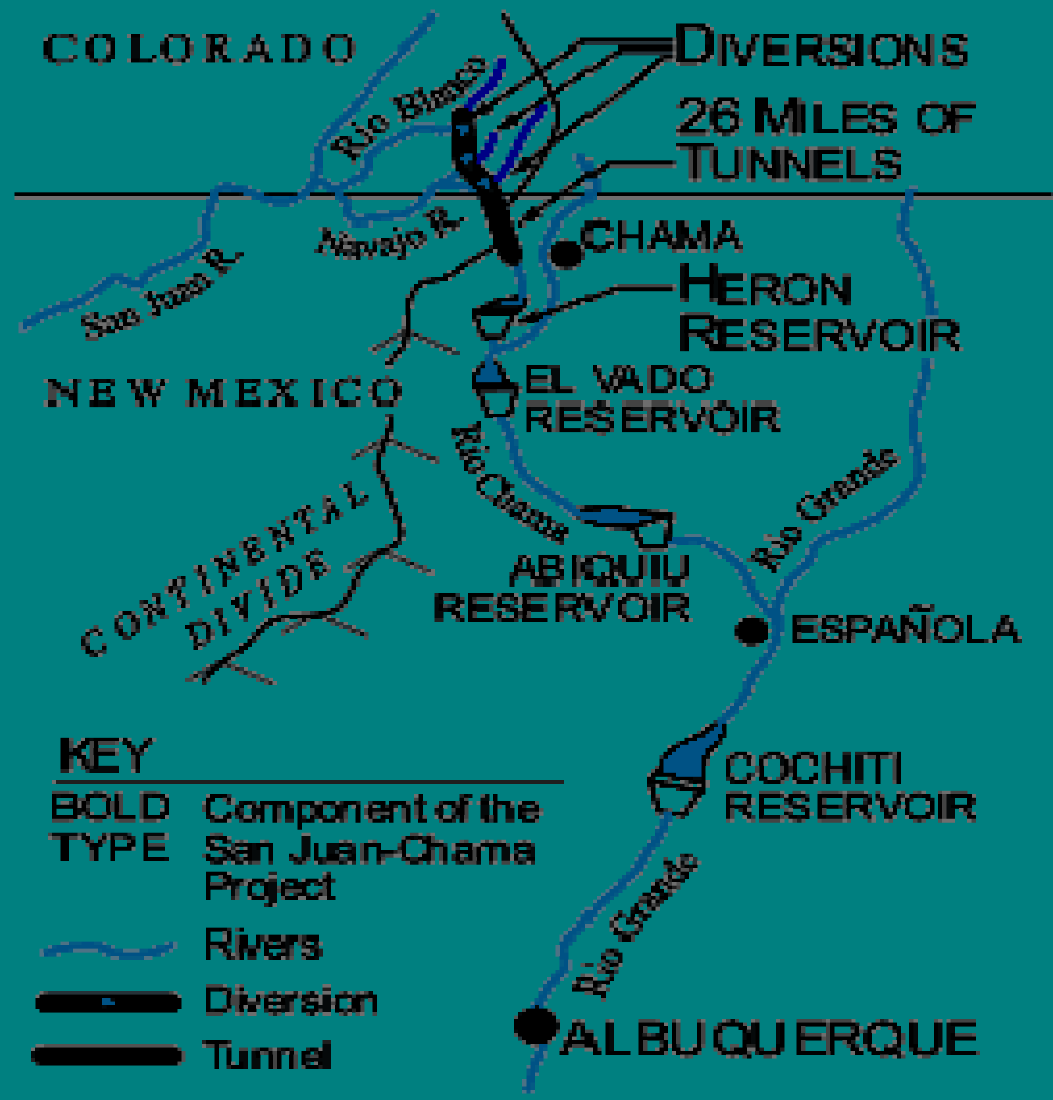
Rio Grande Compact

- Colorado, New Mexico, Texas.
- NM delivery requirement determined at Otowi gage.
- New Mexico delivers at Elephant Butte.

Heron Reservoir – Chama River

San Juan – Chama Project

- 1971 – tunnels through Continental Divide take water to Heron.
- Bureau of Reclamation project.
- Benefits City of Albuquerque, MRGCD, and other contractors.
- Subject of silvery minnow litigation


COLORADO
NEW MEXICO
Rio Blanco
Navajo R.
San Juan R.
DIVERSIONS
26 MILES OF TUNNELS
CHAMA
HERON RESERVOIR
EL VADO RESERVOIR
Rio Chama
ABIQUIU RESERVOIR
Rio Grande
ESPAÑOLA
CONTINENTAL DIVIDE
COCHITI RESERVOIR
Rio Grande
ALBUQUERQUE
KEY
BOLD TYPE
Component of the San Juan-Chama Project
Rivers
Diversion
Tunnel

Little Navajo Diversion

El Vado Reservoir – on Chama River

El Vado Reservoir

- Built to store water for Middle Rio Grande Conservancy District.
- Stores prior and paramount Pueblo rights.
- Article VII restriction on post-1929 reservoir storage of native RG water.

Abiquiu Reservoir – on Chama River

Abiquiu Reservoir

- Built by Army Corps of Engineers for flood and sediment control.
- Stores San Juan-Chama water.
- Native Rio Grande storage authorized by federal law.

Cochiti Reservoir – on mainstem of Rio Grande

Cochiti Reservoir

- Built by Corps of Engineers - flood control for Albuquerque.
- Permanent storage - small recreational pool.
- Cochiti Pueblo concerns.

Uses in the MRG Valley

• Municipal	5%
• Riparian	37%
• Irrigation	37%
• Evaporation	21%

Municipalities using Rio Grande in New Mexico

Municipal

- Taos
- Espanola
- Santa Fe/Santa Fe County
- Bernalillo
- Rio Rancho
- Albuquerque
- Los Lunas, Belen, Socorro
- Truth or Consequences
- Las Cruces
- El Paso

Irrigation

Agriculture

- Peaked in Middle Valley between 1850 and 1880:
  - 125,000 acres irrigated.

- Today:
  - 50 – 70,000 acres irrigated through Middle Rio Grande Conservancy District works.

Middle Rio Grande Conservancy District

- Established in 1923.
- A system of diversions and dams for flood control and irrigation.
- The MRGCD operates ditches, reservoirs and dams.
- Raises revenues from its members to pay for construction and maintenance of projects.

Elephant Butte Irrigation District:

- Below Elephant Butte
- 90,000 acres

Lower Rio Grande Adjudication

- Elephant Butte to State Line
- 16,000 claimants.

Elephant Butte

Elephant Butte

- Storage for Rio Grande Project.
- Constructed by Bureau of Reclamation in 1916.
- 57% of water delivered to Texas pursuant to Rio Grande Compact is used in New Mexico.

Elephant Butte

- Evaporative loss 10-30% of basin depletions.
- 140,000 acre-feet or 2.5 times usage of City of Albuquerque.
- 1999 storage: 2 MAF.
- 2006 storage: 400,000 a-f.

Riparian

Evapotranspiration – The sum of evaporation and plant transpiration

Steps to reduce:

- Non-native species removal
- Water salvage potential
- Who gets savings?

Treaty with Mexico - 1906

- 60,000 acre feet delivered to Mexico at Ft. Quitman.
- Deliveries reduced proportionate to reductions in Rio Grande Project storage.

1944 Treaty

- Rio Grande below Ft. Quitman essentially a different river.
- Runoff from Mexican mountains.
- Roughly: 2/3 goes to Mexico and 1/3 to Texas.

Transboundary Issues with Mexico:

- Groundwater pumping
- Data exchange
- Water quality
- Extraordinary drought