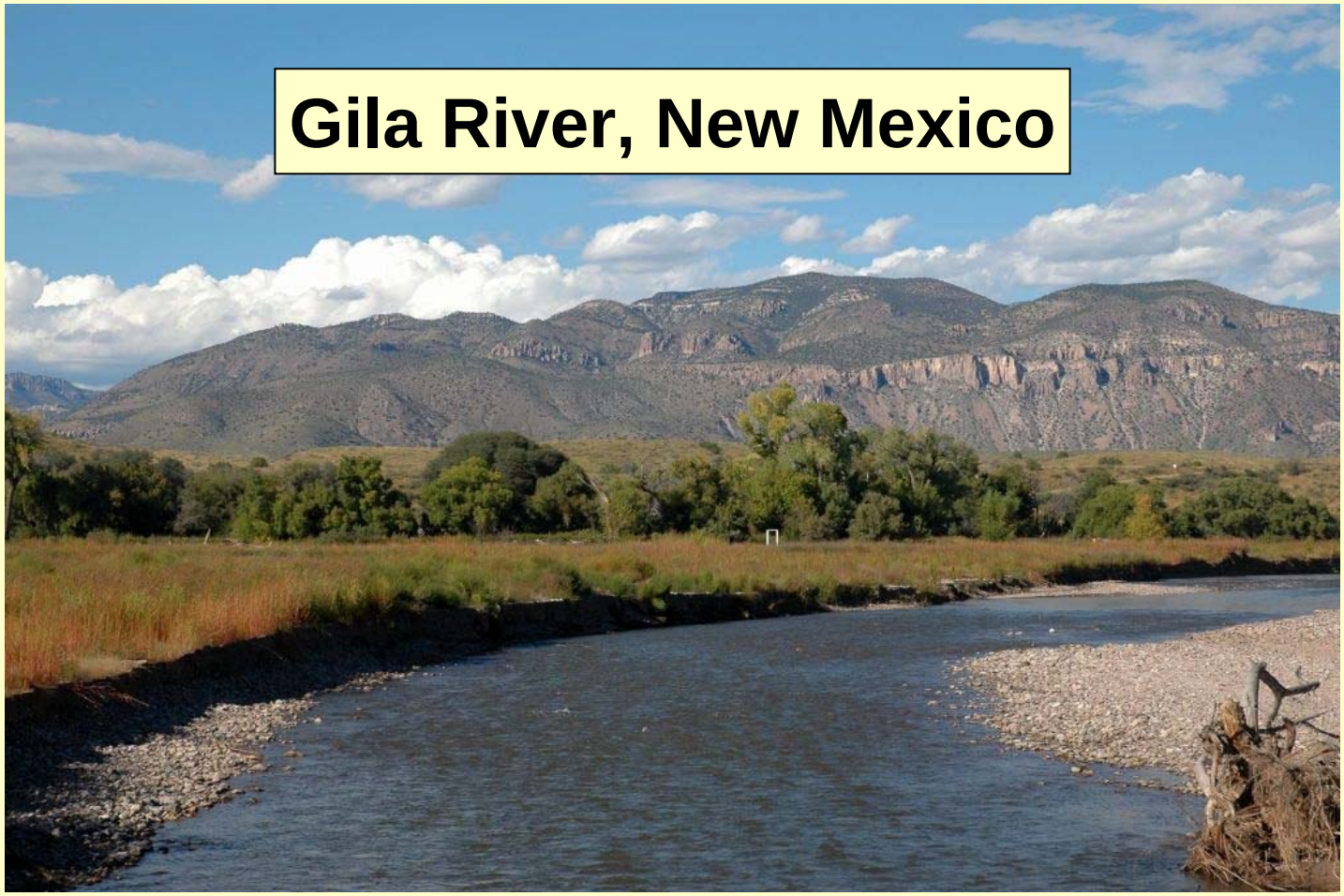
Rivers and Floodplains: Linking Science and Society in New Mexico, Florida, and Australia – Cliff Dahm



The University of New Mexico

Griffith UNIVERSITY

UNM BIOLOGY

Outline of Talk

1. New Mexico – Ecohydrology, Evapotranspiration (ET), Water Budgets, and Climate Change
2. Florida – River and Floodplain Restoration and Setting Environmental Flows
3. Australia – Arid Land Rivers, Healthy Waterways Initiative, and Tropical Rivers and Coastal Knowledge (TRACK)

"The Next Season" – Barbara Coleman

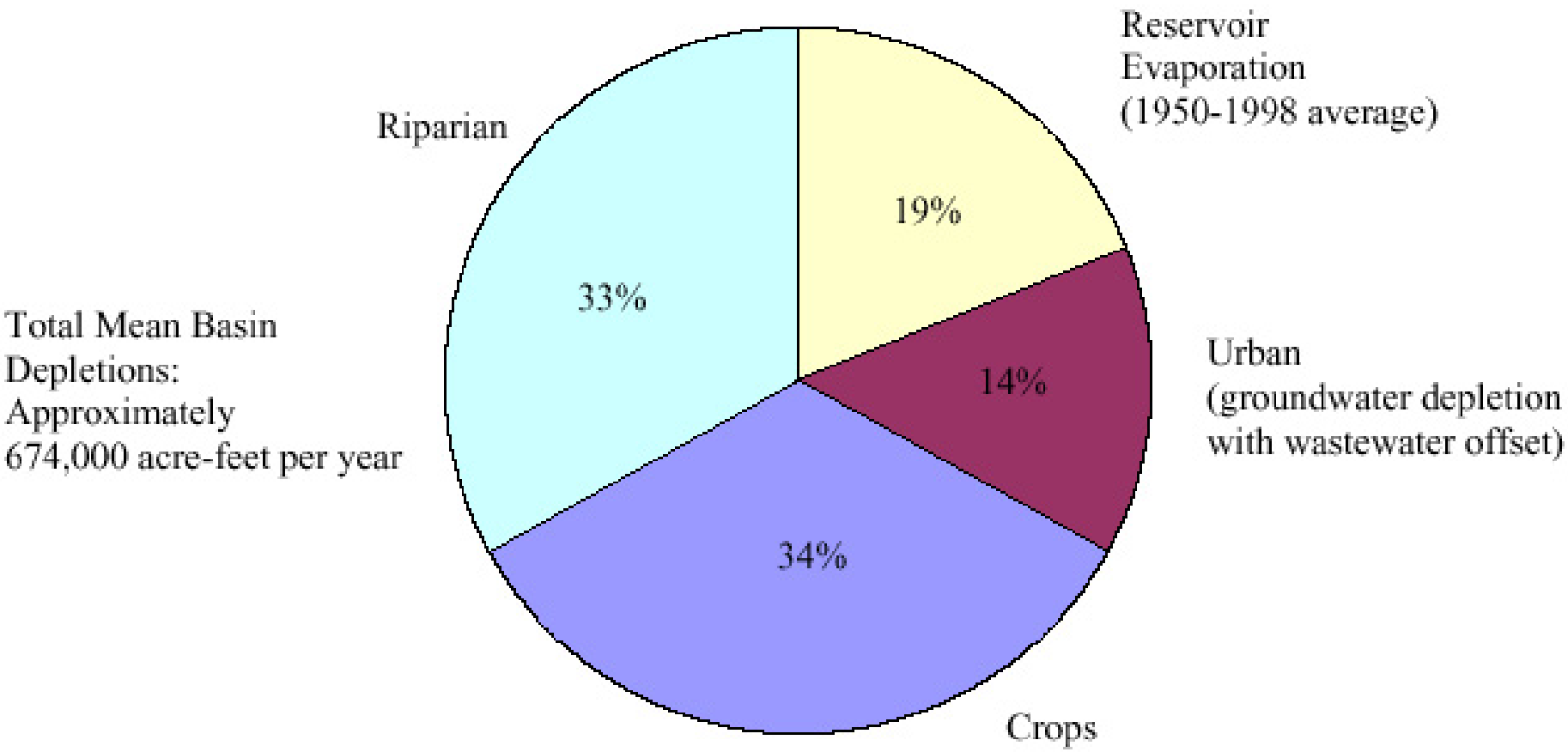
What is Ecohydrology?

- **Ecohydrology seeks to elucidate (1) how hydrological processes influence the distribution, structure, function, and dynamics of biological communities and (2) how feedbacks from biological communities affect the water cycle.**
- **From Newman et al. (2006) Ecohydrology of water-limited environments: A scientific vision. Water Resources Research 42, W06302, doi:10.1029/2005WR004141**

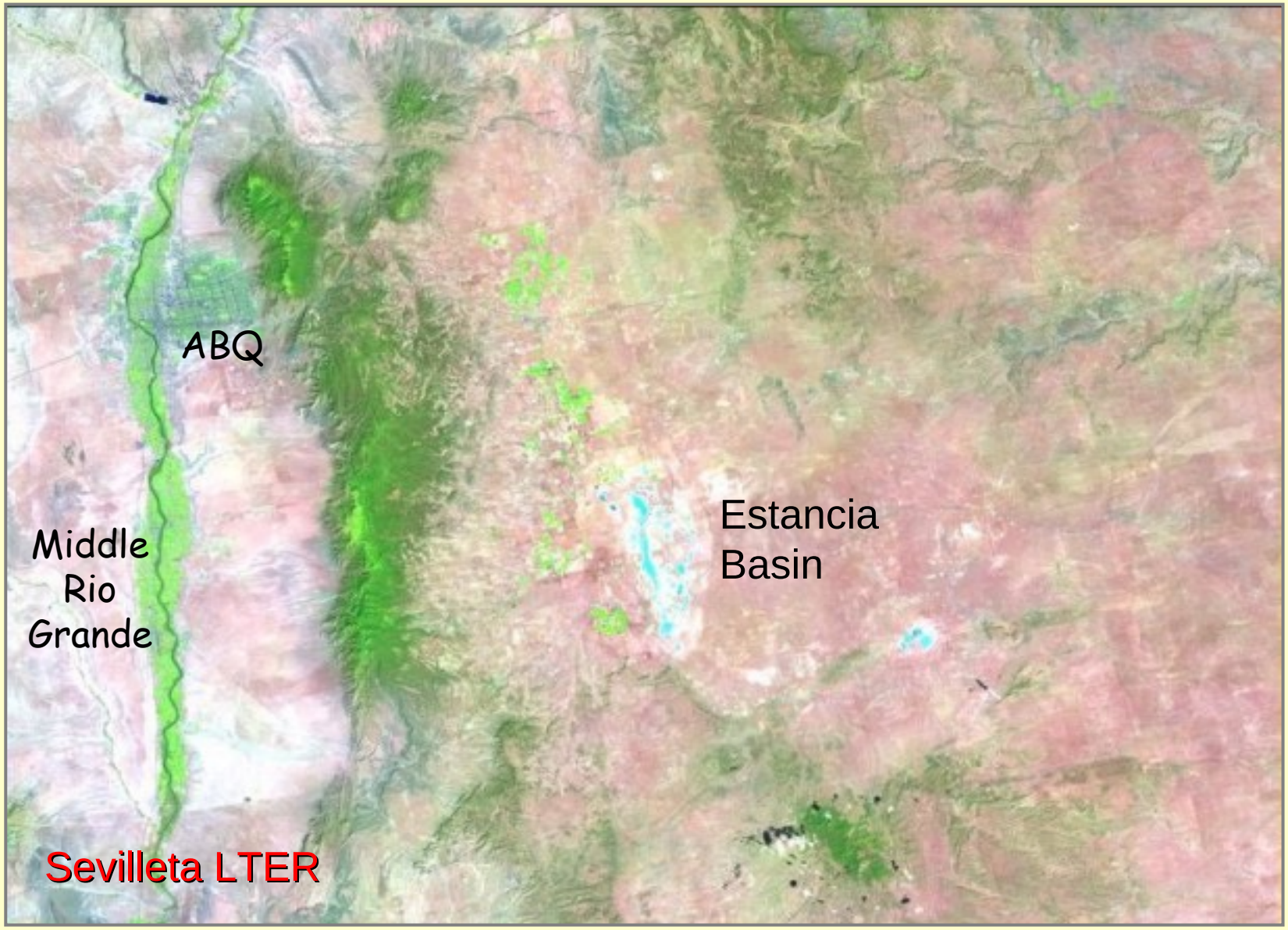
Why Do We Need Ecohydrology?

An example from the Rio Grande of central New Mexico

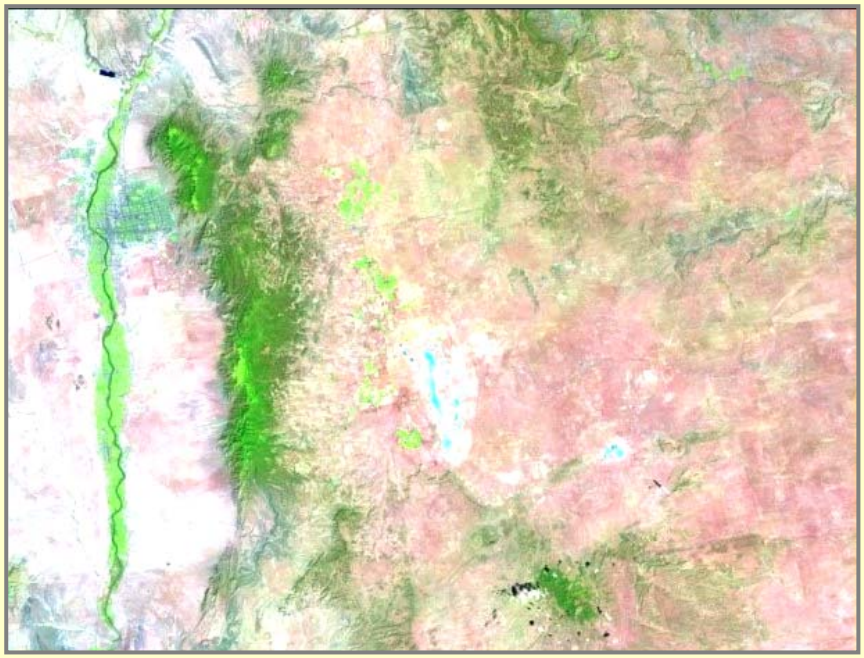
b) Mean total Middle Rio Grande depletions (including depletion from groundwater storage),under present land use and groundwater development conditions

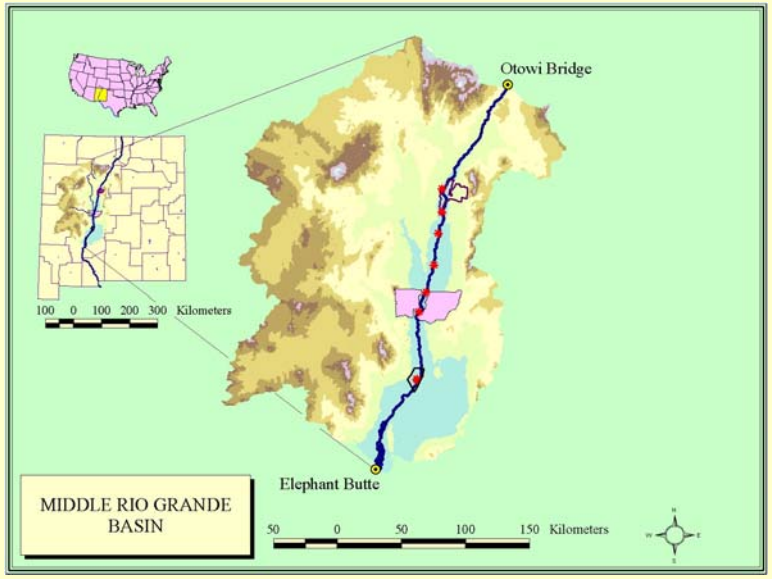


Rio Grande, New Mexico, USA



Middle Río Grande - Evapotranspiration

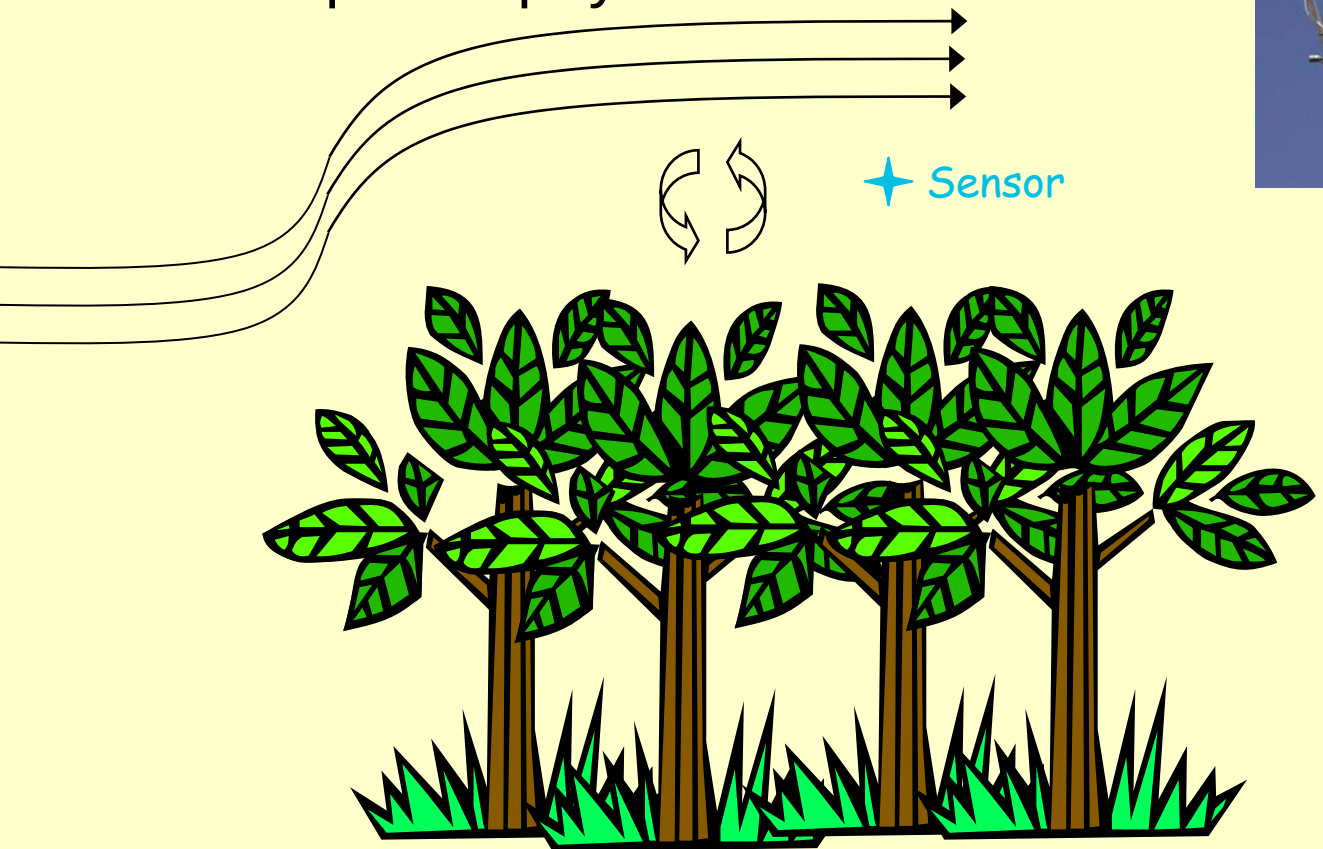




- **What are the annual rates of water use (evapotranspiration or ET) by riparian forests (bosque)?**
- **How much water does native and non-native bosque use?**
- **What is the water use in bosque that floods regularly versus areas isolated from the river?**

Riparian Zone ET
3-D Eddy Covariance

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



Saltcedar flooding site
Bosque del Apache NWR

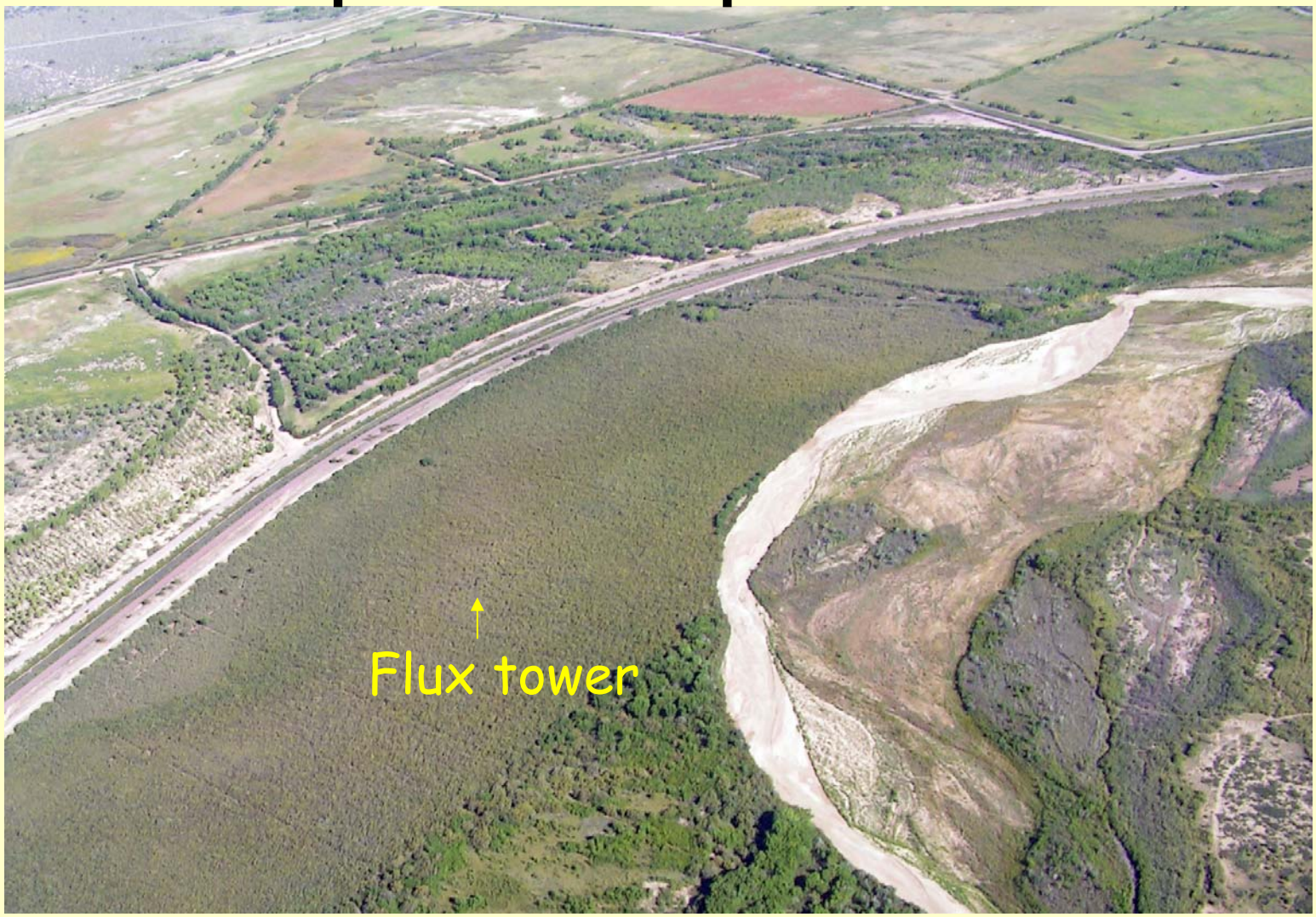
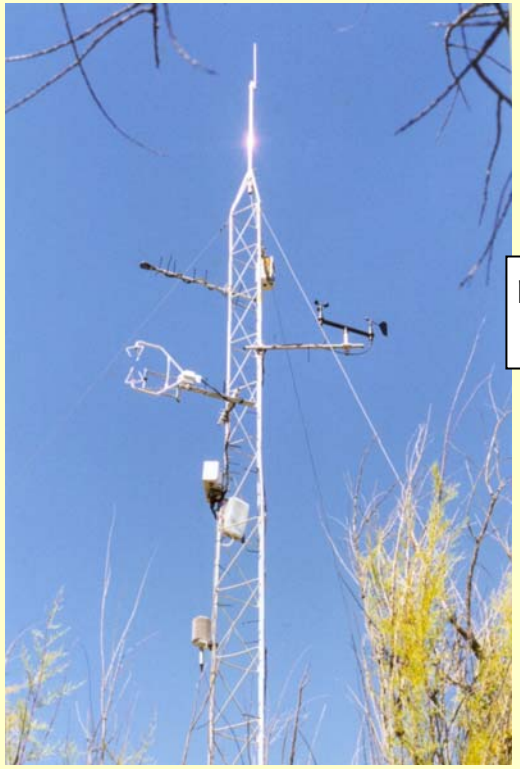
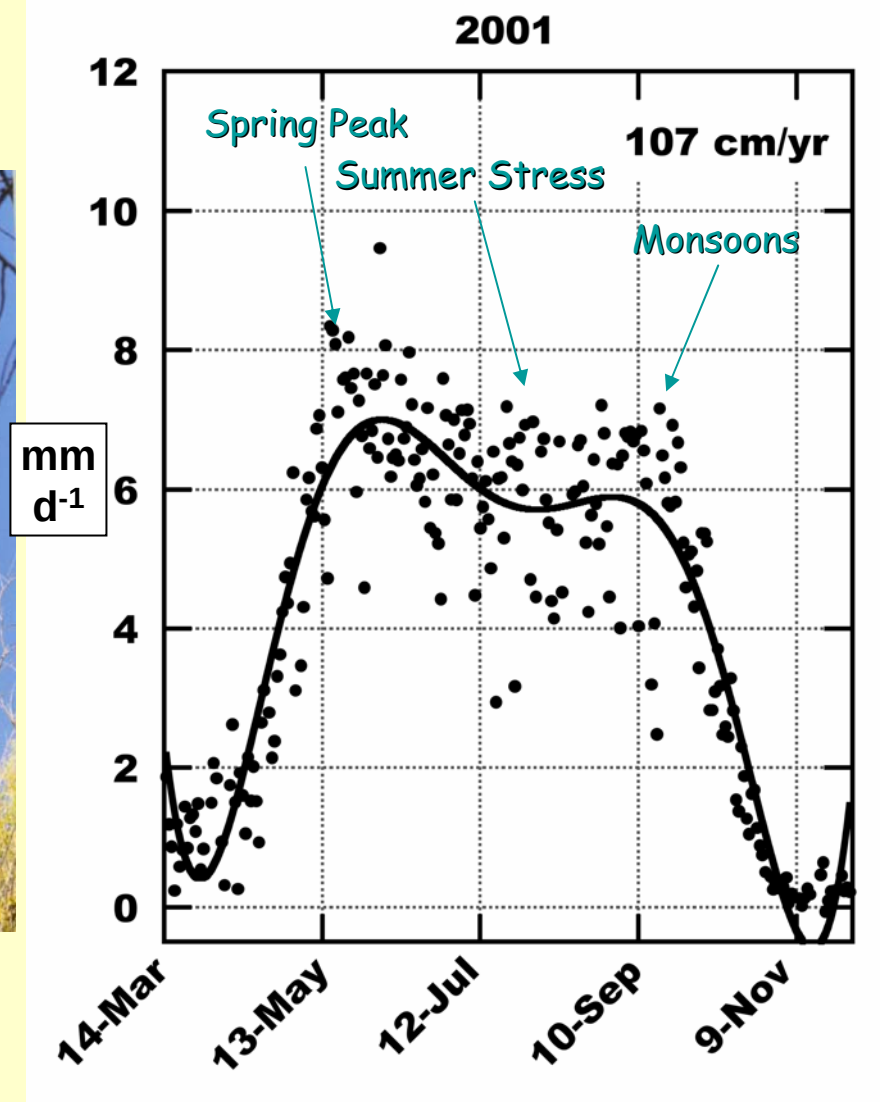


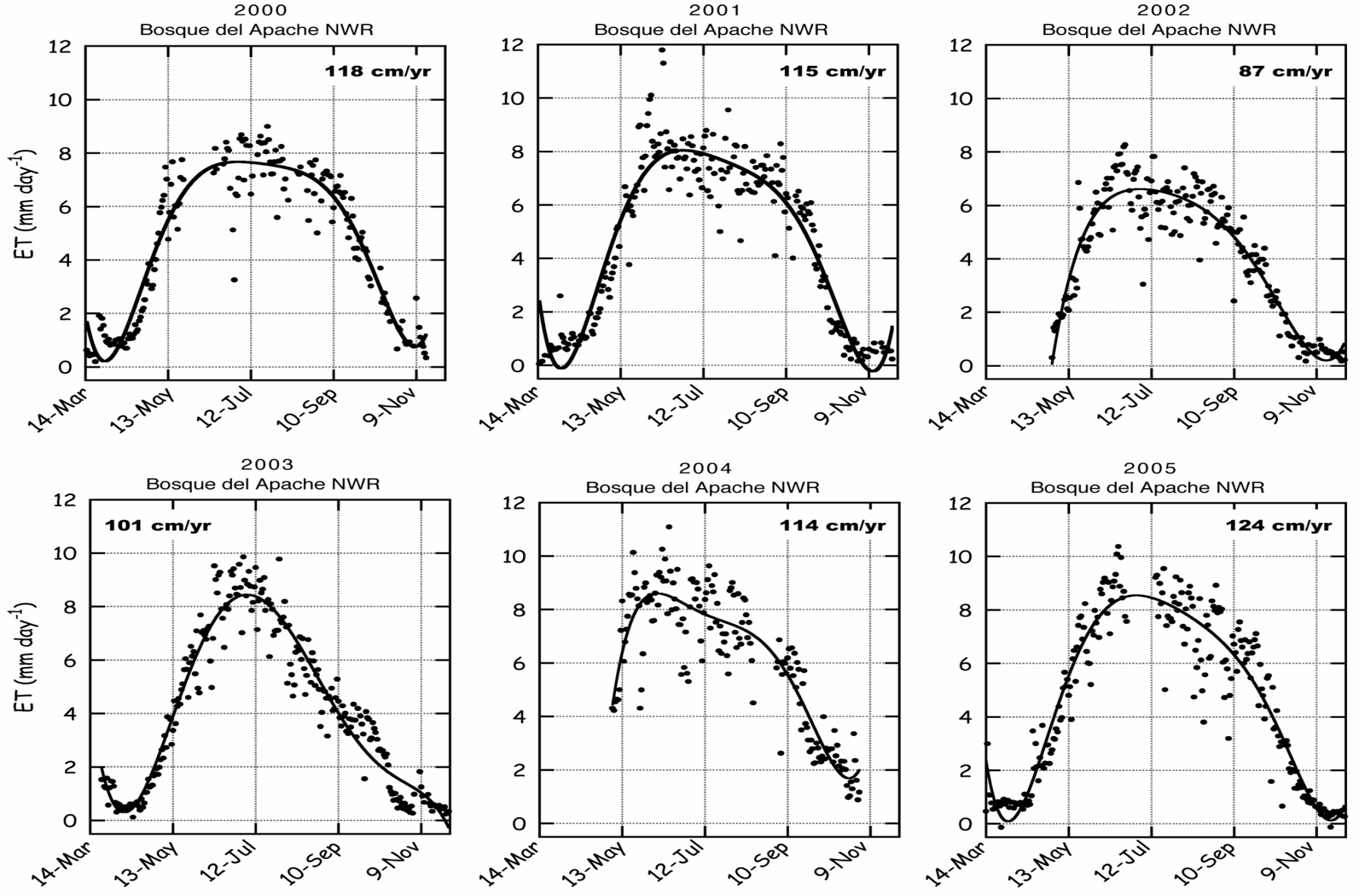
Photo: Bosque del Apache

Seasonal ET

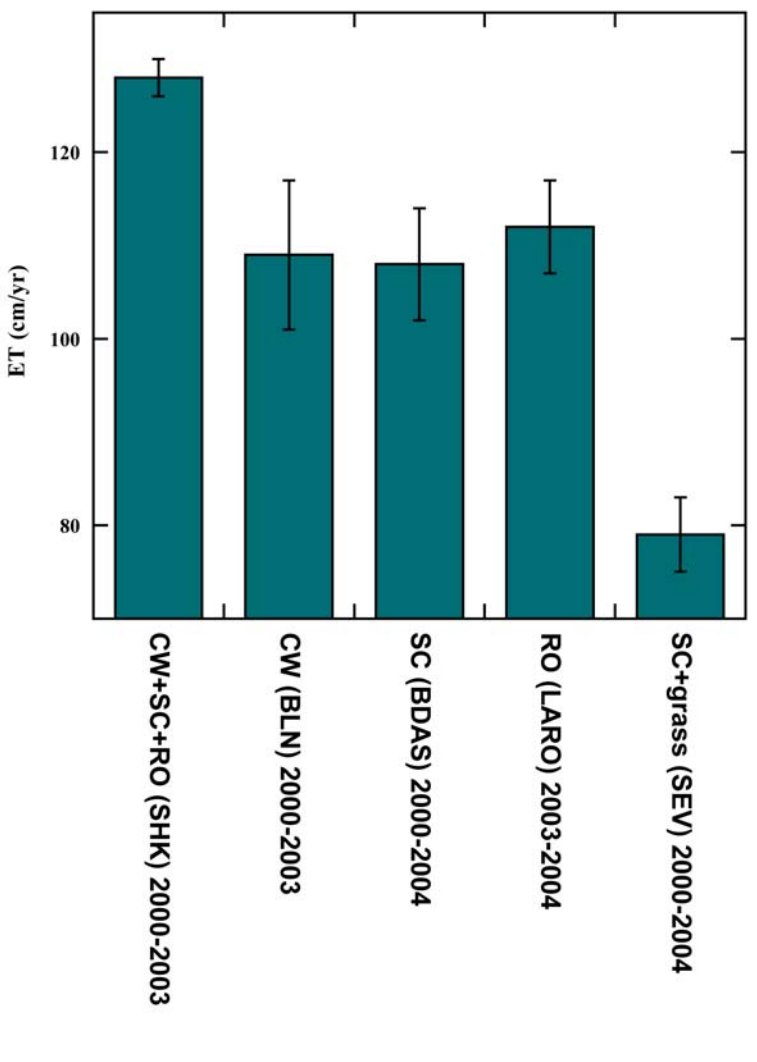


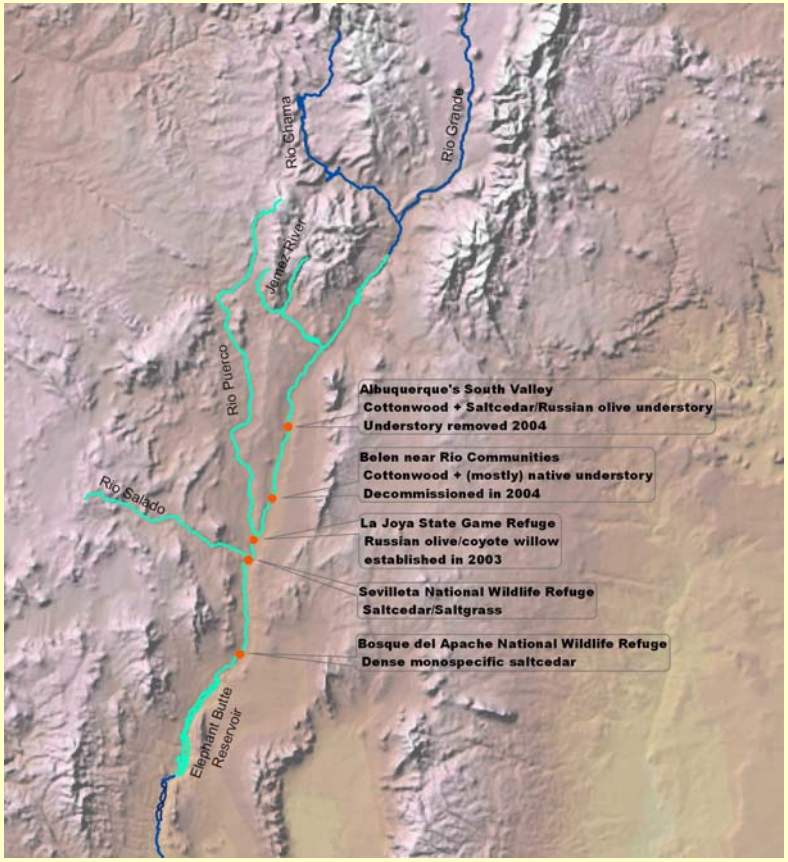

2001
Spring Peak
Summer Stress
Monsoons
107 cm/yr
mm d-1
12
10
8
6
4
2
0
14-Mar
13-May
12-Jul
10-Sep
9-Nov

Bosque del Apache ET – 2000-2005 Interannual Variability

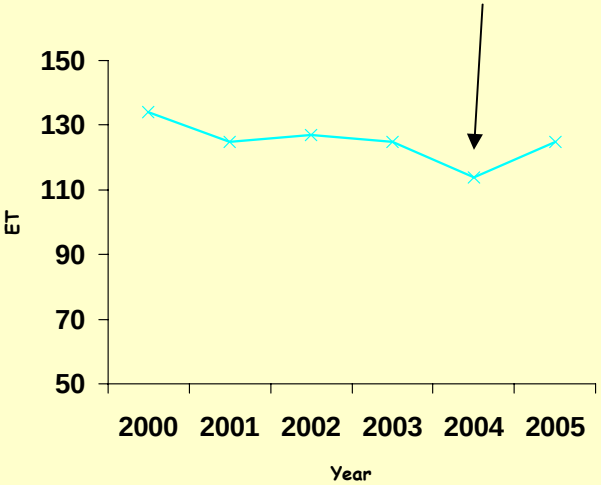


Saltcedar or Cottonwood?





Understory Restoration



Restoration (2005) – Understory Regrowth

Populus deltoides

heterogeneous understories

Total Area ~ 3750 ha

Elaeagnus angustifolia

homogenous large patches

Total Area ~ 600 ha

Tamarix chinensis

homogenous (mostly south)

Total Area ~ 5200 ha

Salix exigua & other scrub

highly variable

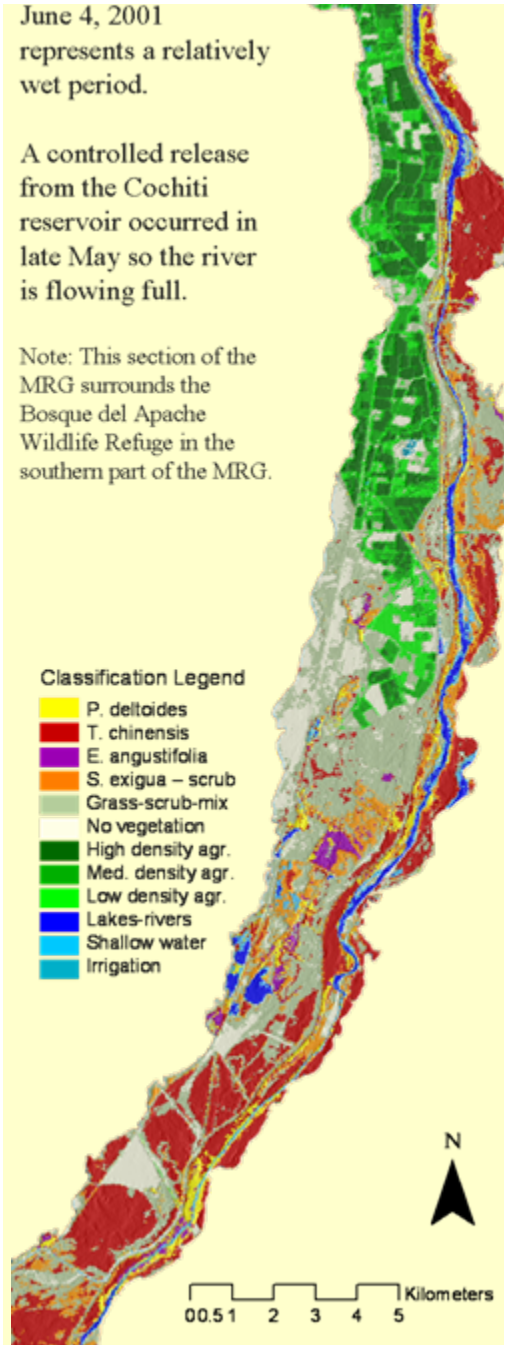
Total Area ~ 3150 ha

Scrub-grass-mix

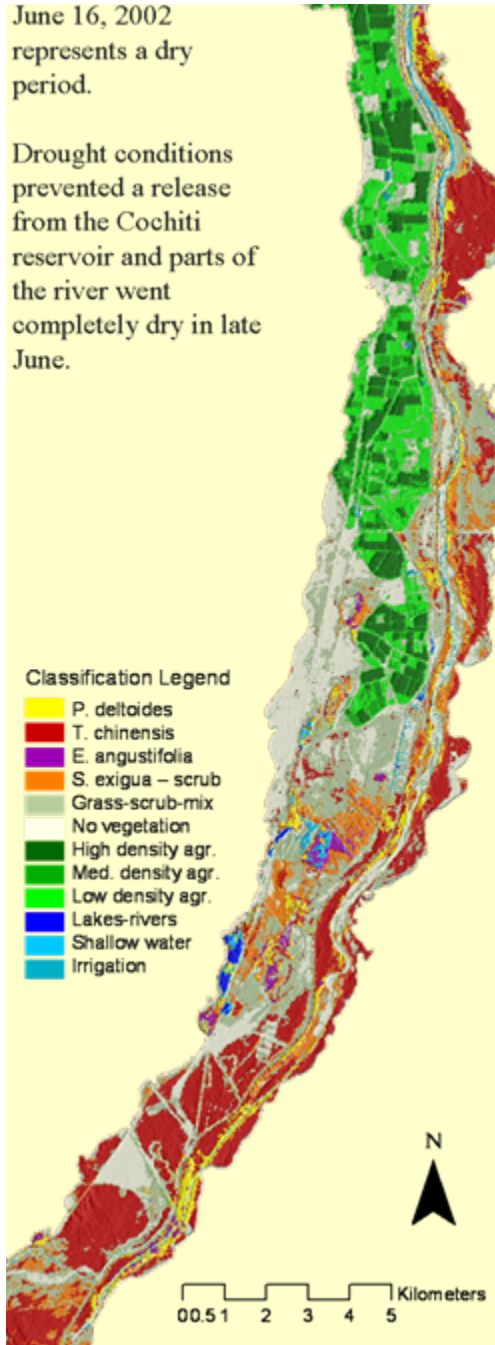
low density - highly variable

Total Area ~ 6400 ha

Class June 4, 2001

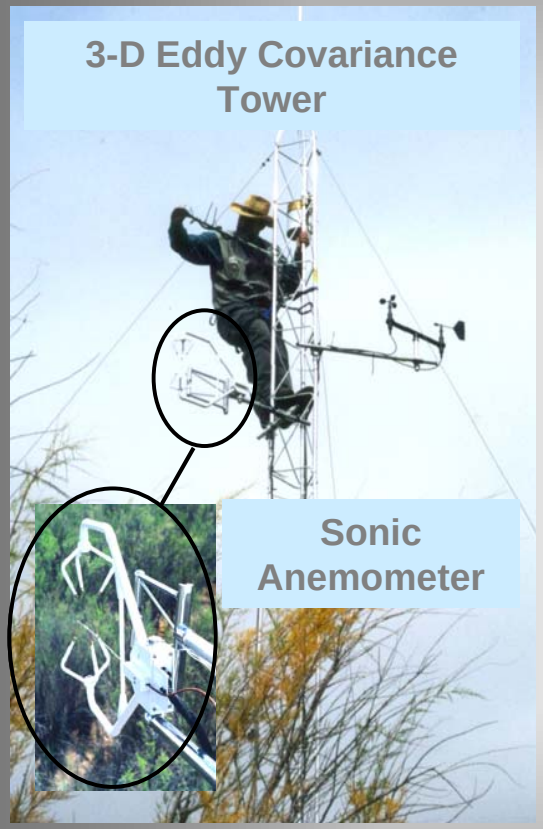


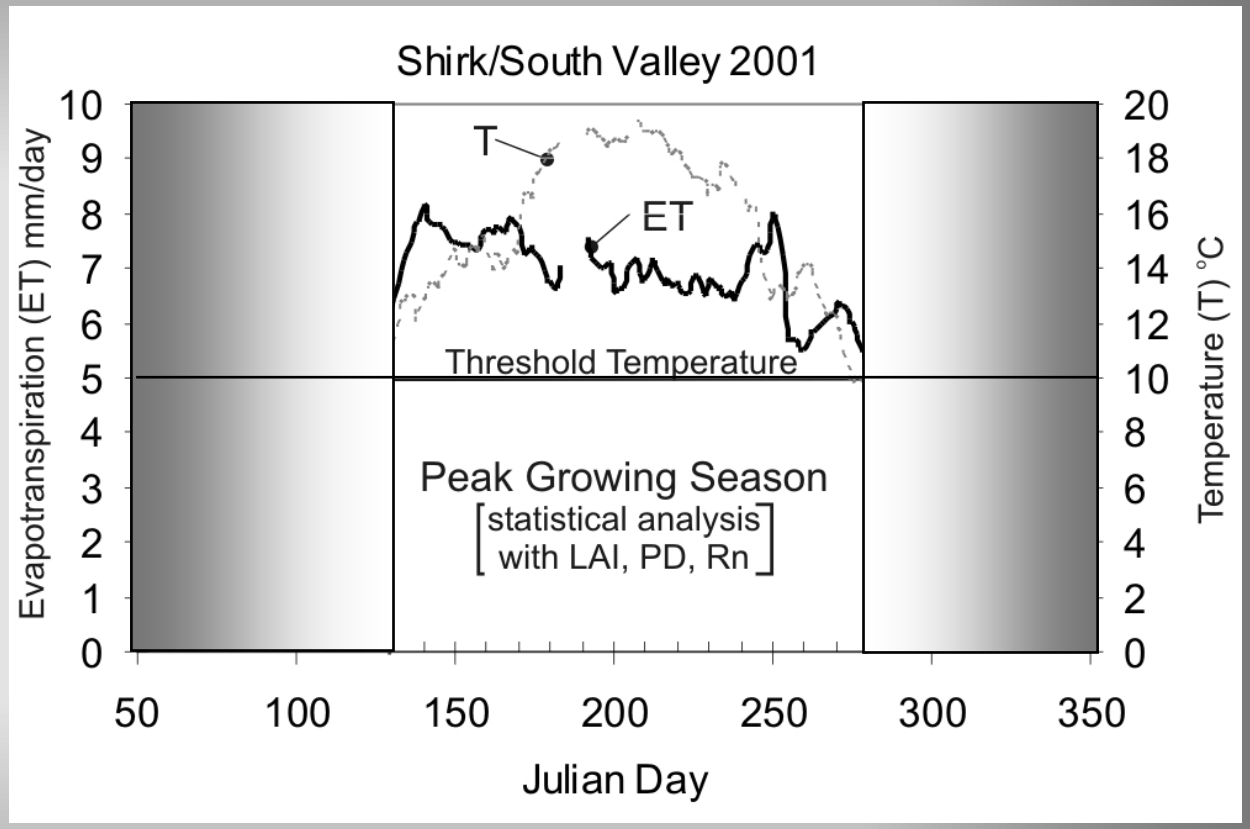
Class June 16, 2002



Scaling Evapotranspiration (ET)

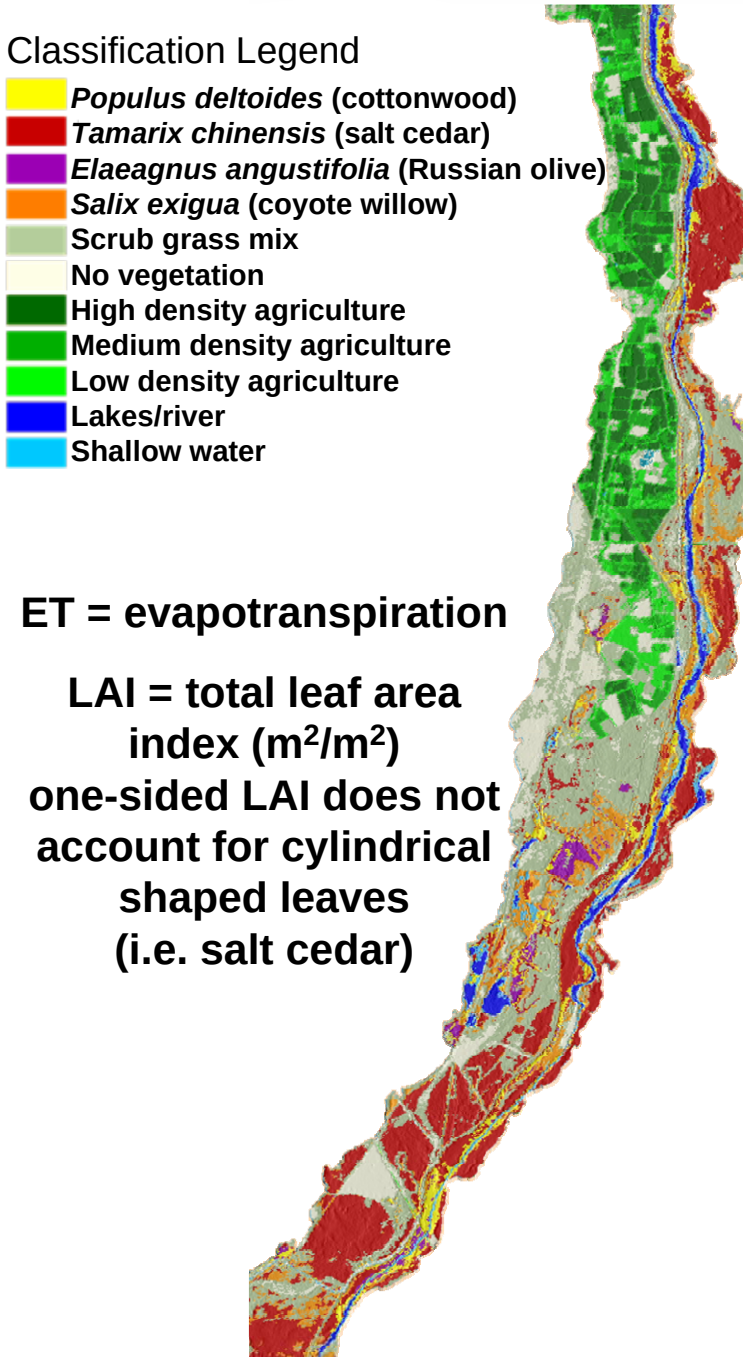
Methodology – Peak Growing Season





Statistical analysis to establish the equation that calculates ET for each Landsat image during the peak of the growing season

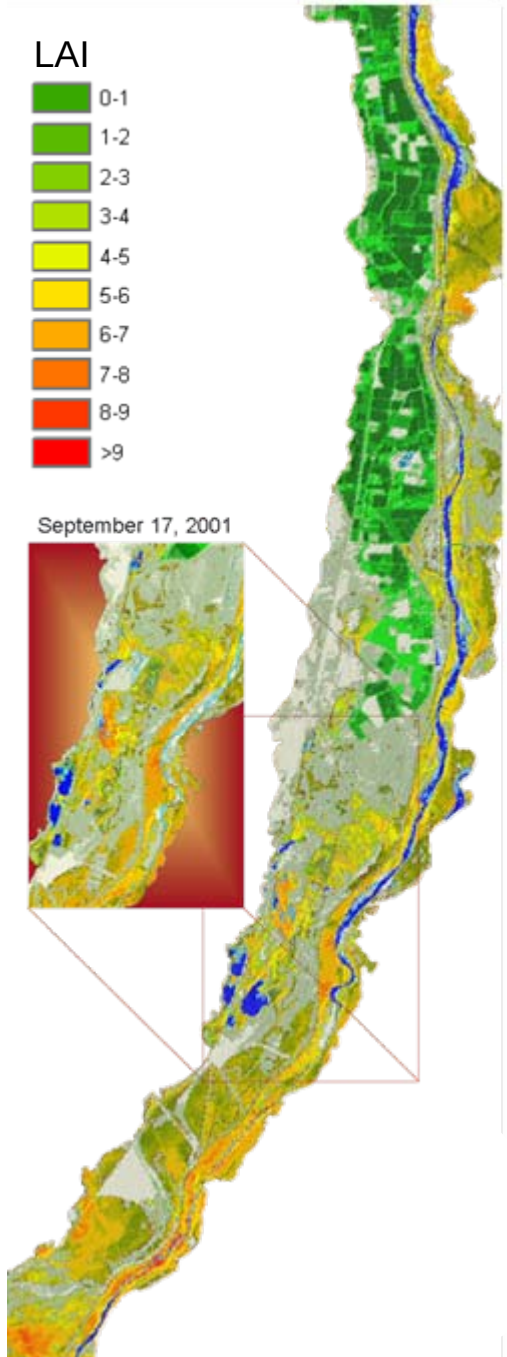
Classification June 4, 2001



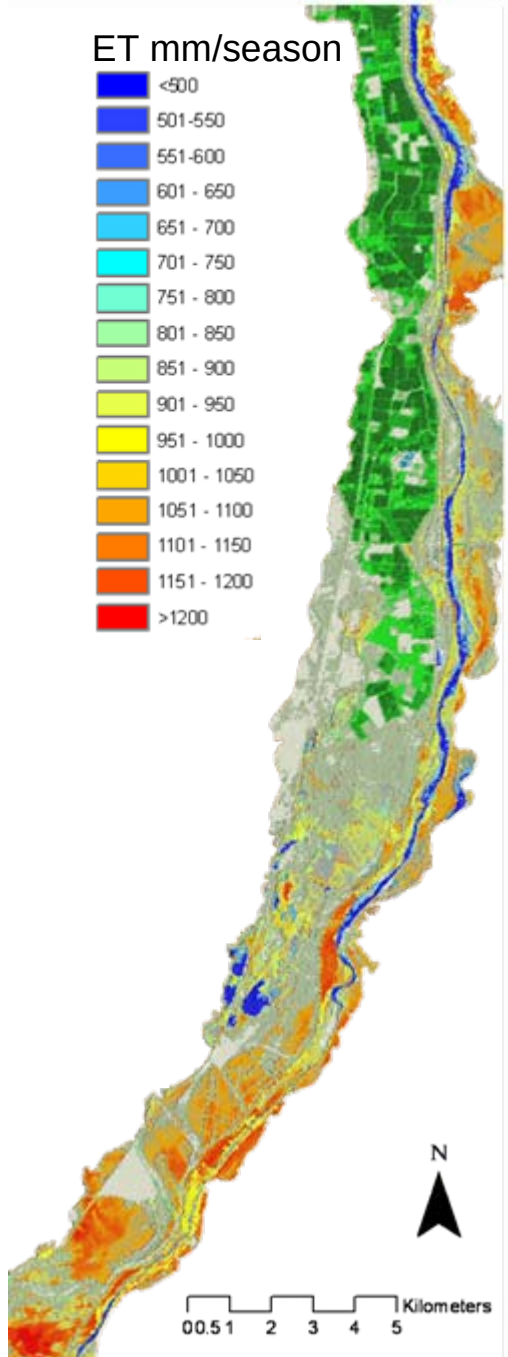
ET = evapotranspiration

LAI = total leaf area index (m^2/m^2)
one-sided LAI does not account for cylindrical shaped leaves (i.e. salt cedar)

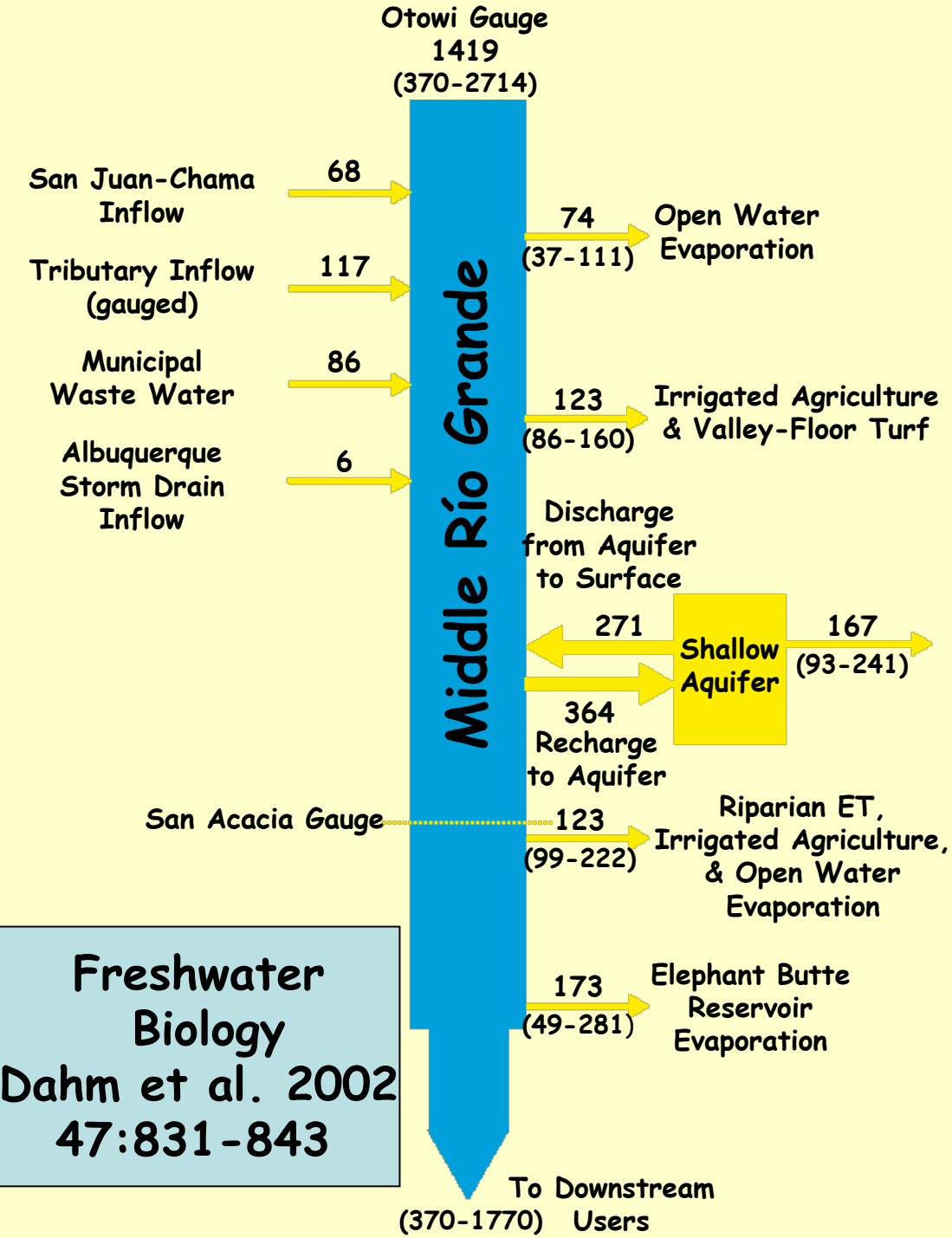
LAI June 4, 2001



Seasonal ET 2001



Río Grande Water Budget (1972-1997) (10^6 m^3 yr^{-1})



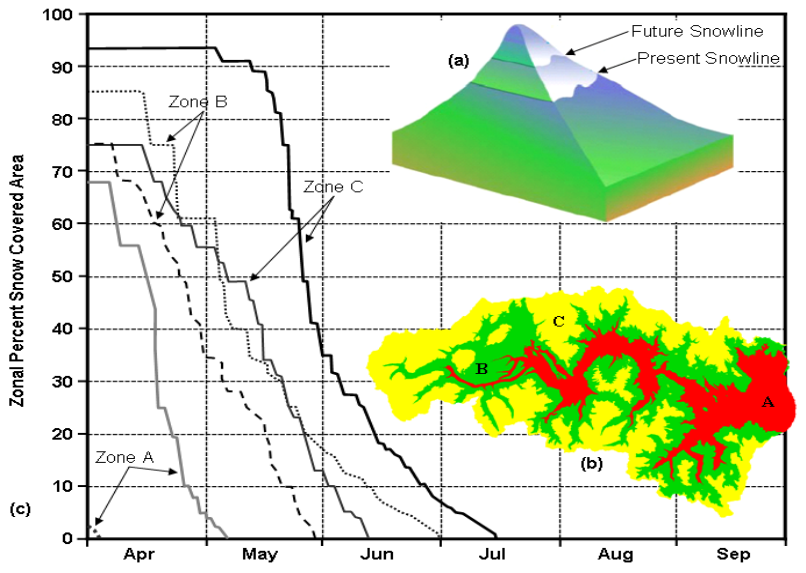
Riparian Zone ET ~ 127-165 (2001-2006)

Freshwater Biology
Dahm et al. 2002
47:831-843

Major Depletions

1. Evaporation
2. Riparian ET
3. GW Recharge
4. Agriculture

Global Change & Snowmelt Rivers



(Al Rango – NMSU/ARS)

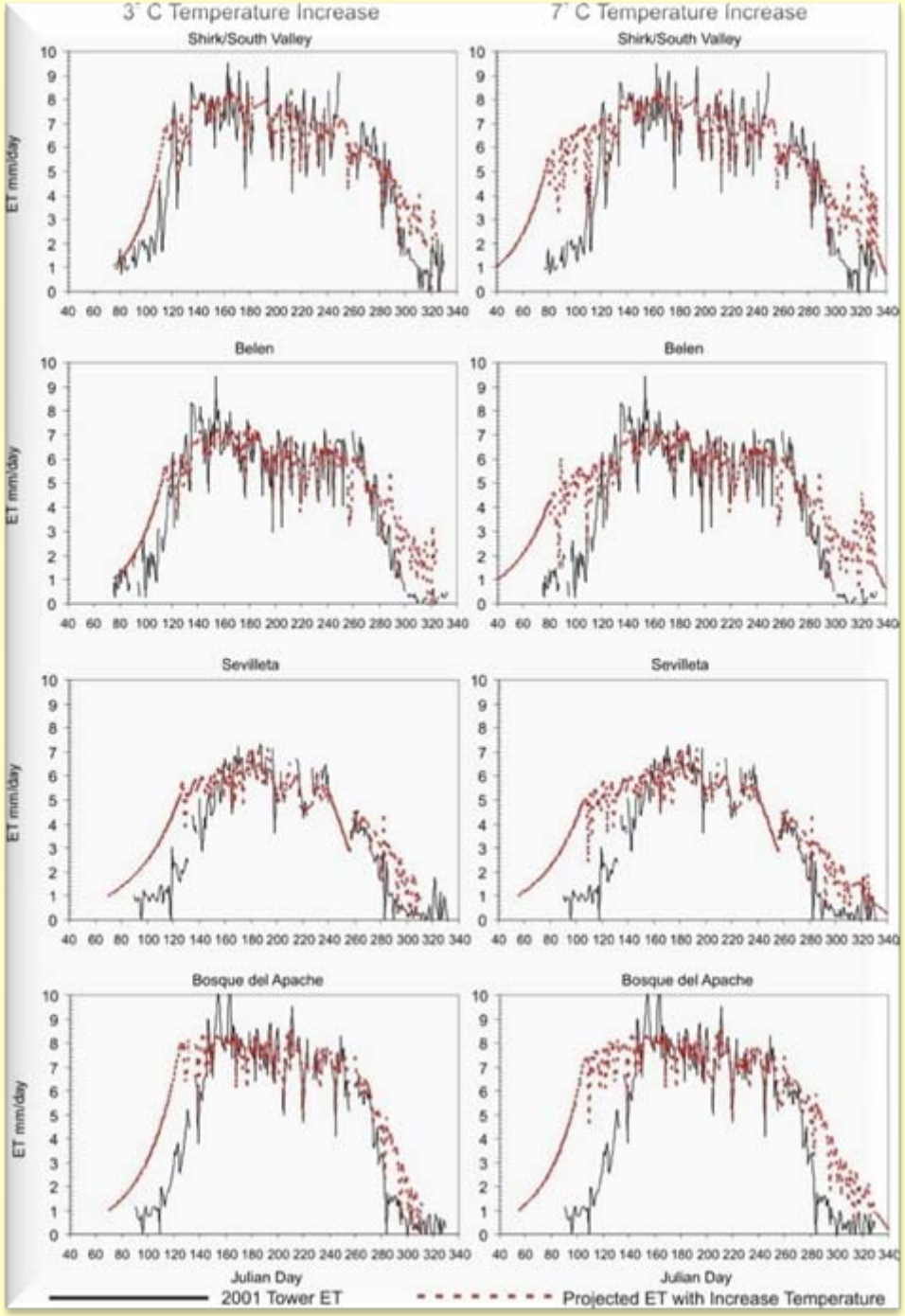
Rio Grande Headwaters

Snowmelt Rivers

- Particularly vulnerable to global warming (timing and quantity)
- Relied upon by one-sixth of Earth's human population
- Smaller snowpack throughout the Rocky Mountains
- Western US will warm on average by 5°C by 2100

Warming and Riparian ET

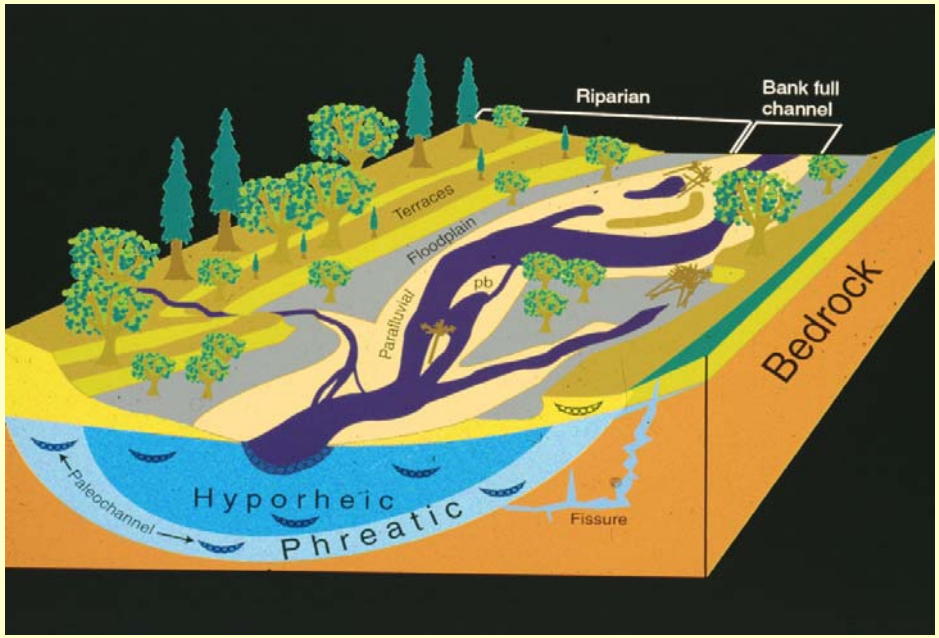
- Ramp-up period most impacted
  - Days are longer
  - Leaf area plus longer days = increased ET
- For a typical water year (e.g., snow melt and monsoon), ET would increase ~20 % with +2 ºC warming
- Actual impacts depend upon meteorological conditions



Urban Water Use

- City of Albuquerque Rio Grande Water Diversion
- Divert 116 x 10^6 m^3 y^{-1} beginning in 2008
- Return flow credit for half of the diverted water
- Alternative to non-sustainable use of ground water
- First major effort to use surface water for drinking water supply

Groundwater Recharge



Streambed Infiltration Rates in Arid-land Rivers

Ronan et al. 1998 Water Resources Research 34:2137-2153

"The increased infiltration rates are attributed to viscosity effects on hydraulic conductivity from increased temperatures."

Water viscosity changes ~2% per degree C from 15-30 ^{o}C

Field studies of infiltration rates often produce variation with T larger than predicted by viscosity (Lin et al. 2003 SSSAJ).

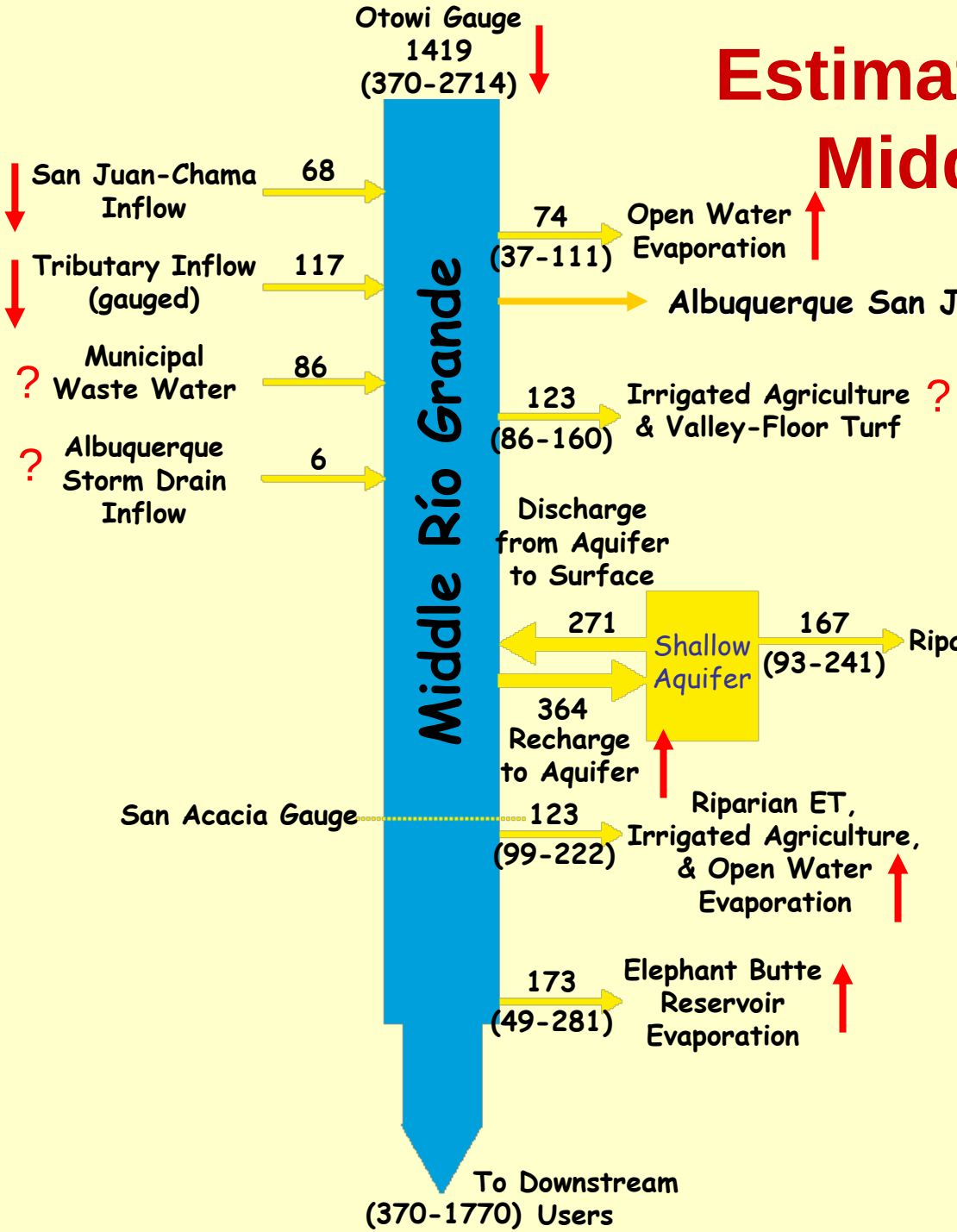
Agricultural Water Use

ET and CO_2 Flux - Alfalfa

Dominant Crop is Alfalfa
Irrigated Land ~ 20,000 ha
Water use approximately 1.2 m annually
Warmer conditions already allowing 5-6 cuttings per year of alfalfa

Estimated Water Budget Middle Río Grande

(10^6 m^3/yr)

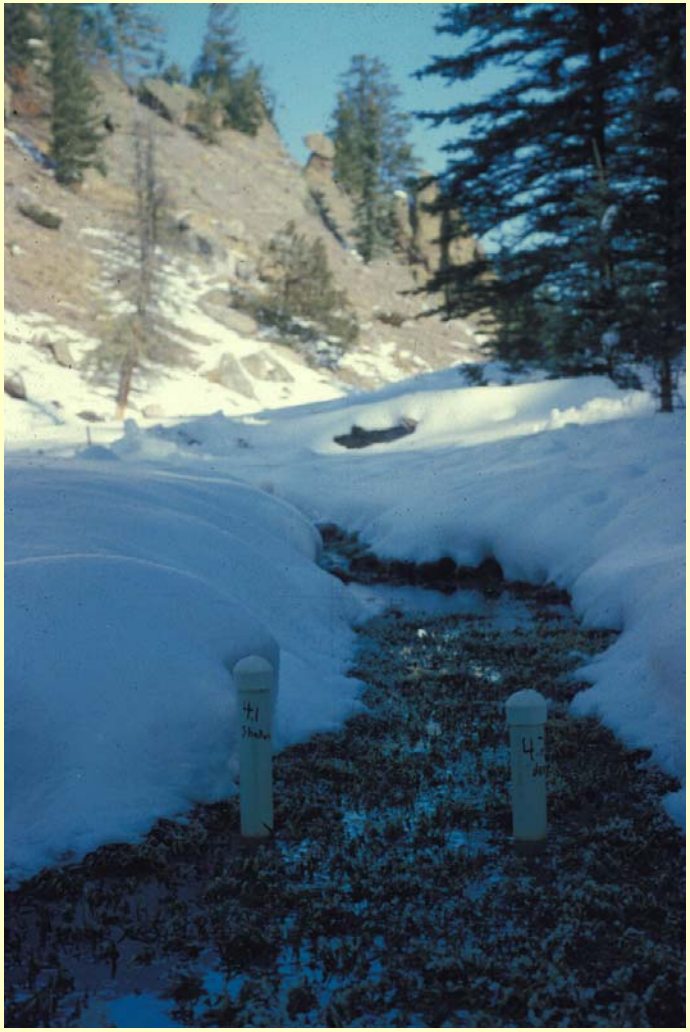


Arrows indicate the direction of change for source waters and depletions with a warmer climate.

Major Depletions

- Evaporation
- Riparian Zone ET
- Agriculture
- Urban Use
- Groundwater Recharge

Drought and Temperature - 1

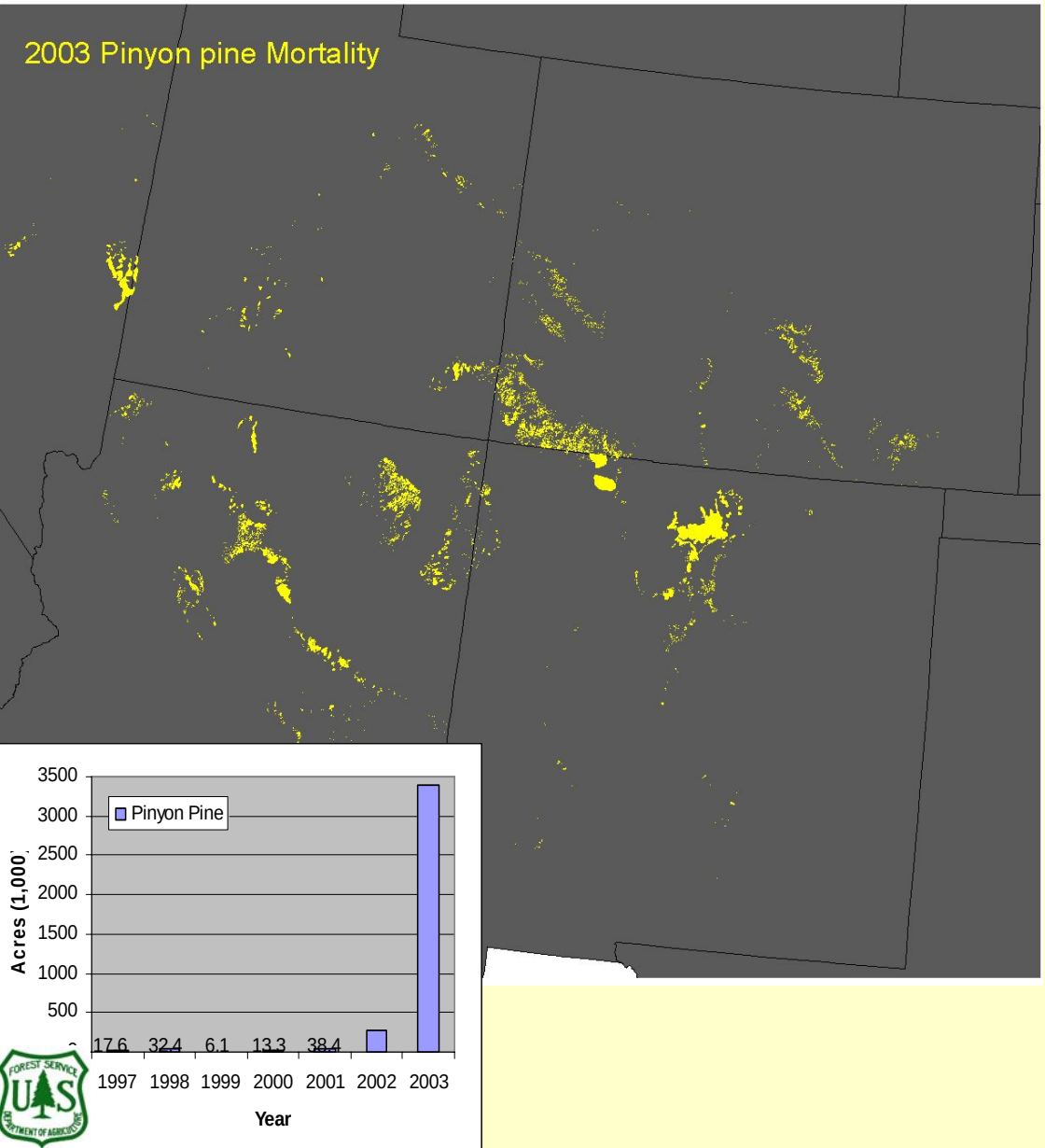


“The most severe future droughts will still occur during persistent La Niña events, but they will be worse than any since the Medieval period because the La Niña conditions will be perturbing a base state that is drier than any experienced recently.”

Seager et al. (2007) Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science – April 5, 2007

316:1181-1184.

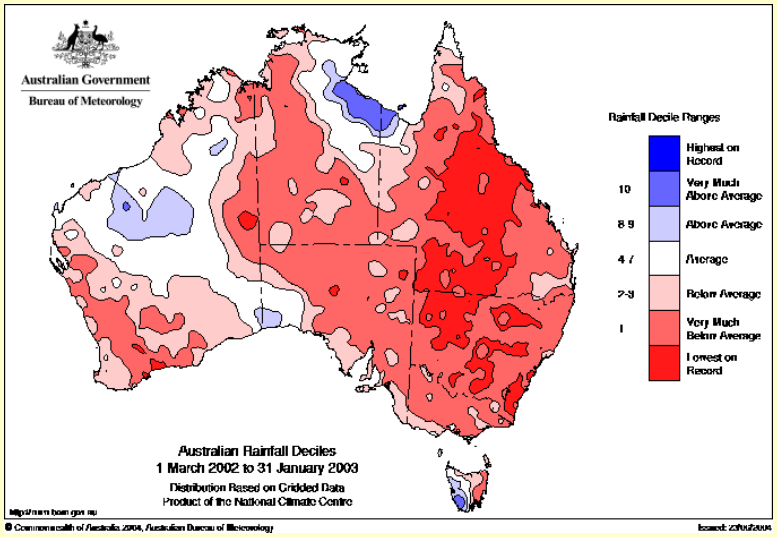
Drought and Temperature - 2



D.D. Breshears et al. 2005 PNAS 102:15144-15148

"This recent drought episode in southwestern North America may be a harbinger of future global-change-type drought throughout much of North American and elsewhere, in which increased temperature in concert with multidecadal drought patterns associated with oceanic sea surface oscillations can drive extensive and rapid changes in vegetation and associated land surface properties."

Drought and Temperature - 3

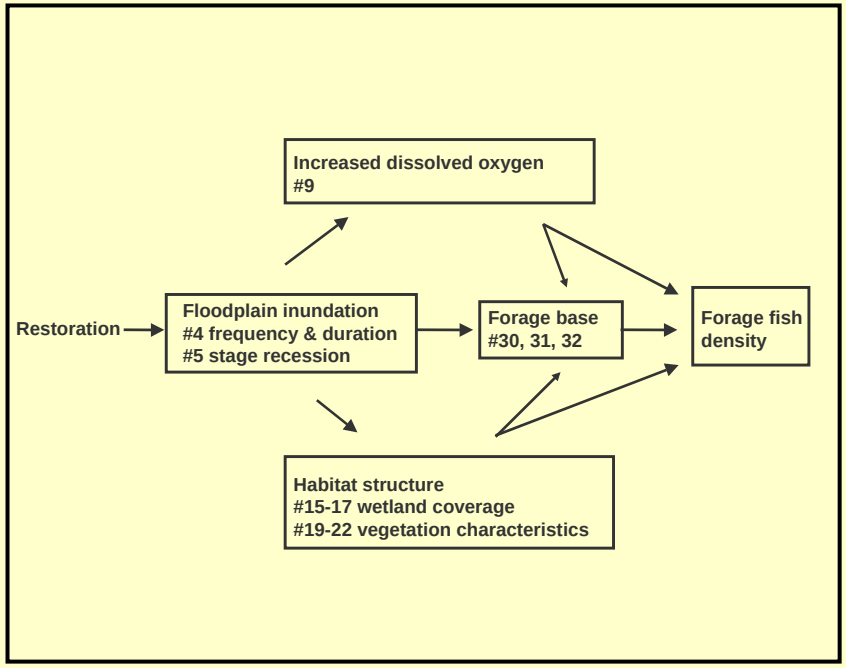


"The possibility that the enhanced greenhouse effect is increasing the severity of Australian droughts, by raising temperature and hence increasing evaporation, even if rainfall does not decrease, needs to be considered." N. Nicholls 2004. Climatic Change 63:323-336.

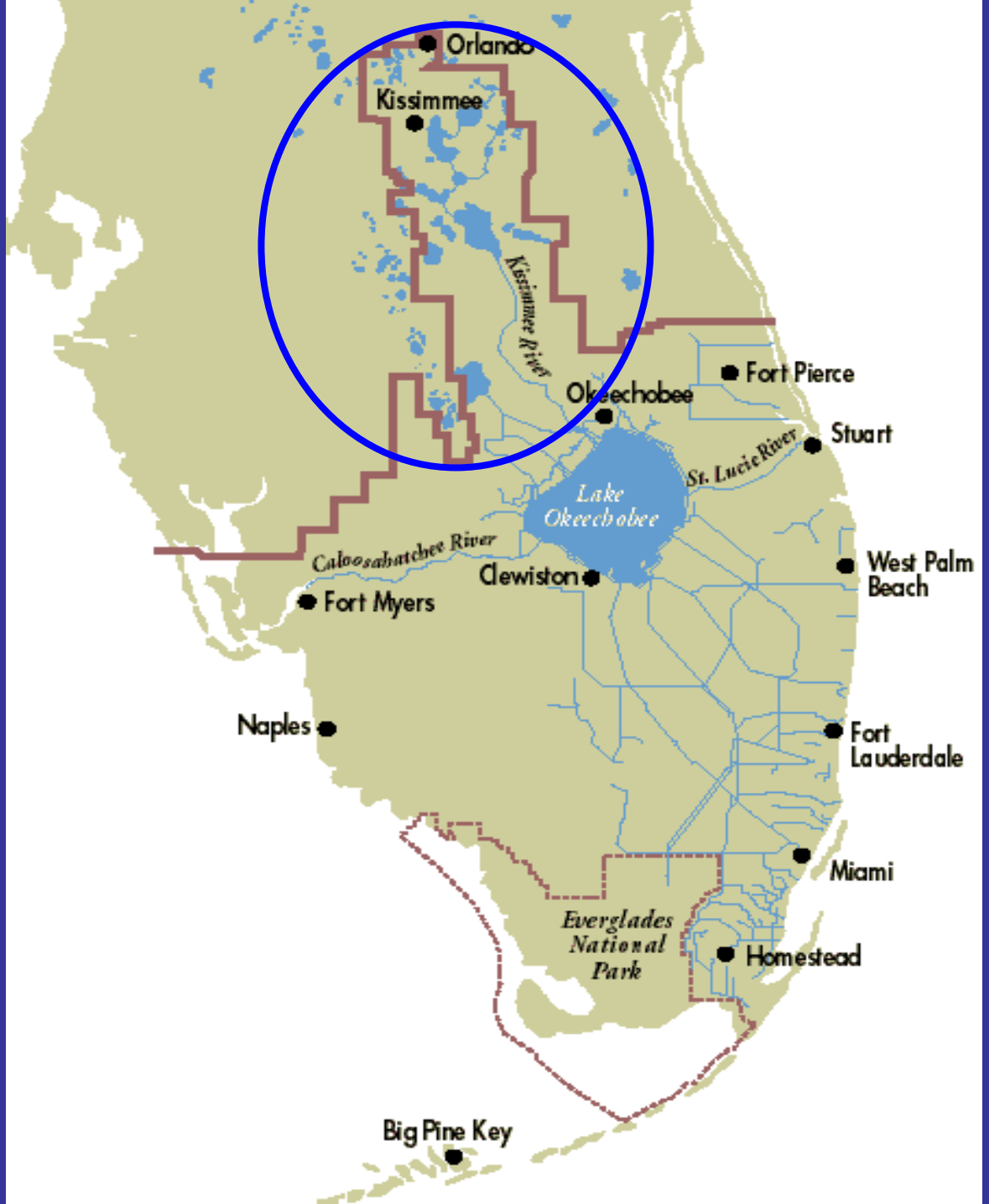
Restoring Ecological Integrity in the Kissimmee River, Florida: Applying Restoration Expectations

Restoration of the Kissimmee River.

?



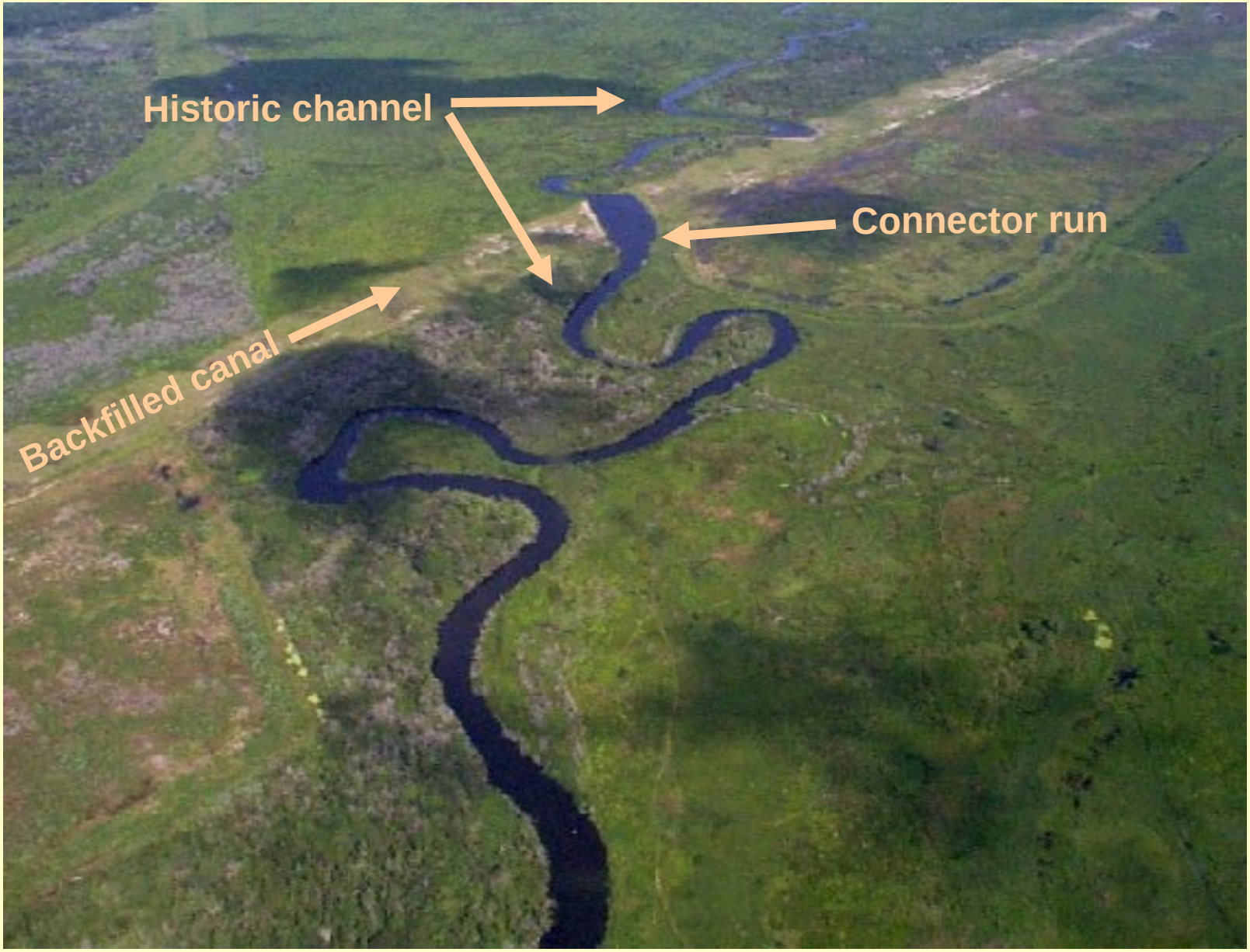
Applying restoration expectations.


Orlando
Kissimmee
Kissimmee River
Okeechobee
Fort Pierce
Stuart
St. Lucie River
Lake Okeechobee
Caloosahatchee River
Clewiston
West Palm Beach
Fort Myers
Naples
Fort Lauderdale
Miami
Everglades National Park
Homestead
Big Pine Key

C-38 Canal and remnant Kissimmee River, post channelization circa 1980

Anatomy of the Phase I Backfilling

February 9, 2001

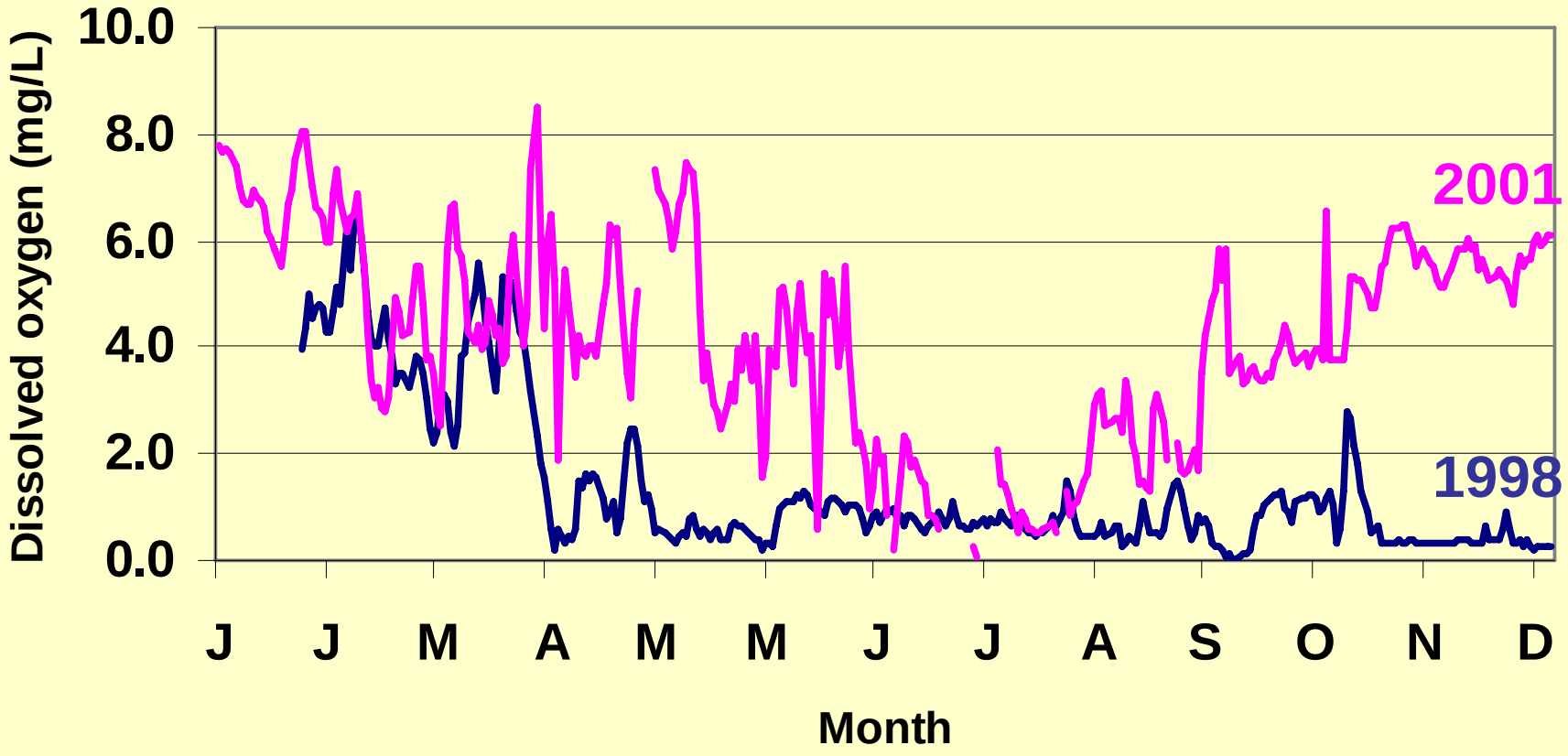

Historic channel
Connector run
Backfilled canal

60 Restoration Expectations

- Hydrology - 6
- Geomorphology - 2
- Water Quality - 4
- Vegetation - 10
- Invertebrates - 11
- Algae - 2
- Herps - 2
- Fish - 7
- Birds - 11
- Listed species - 5

Emphasis was placed on defining testable expectations with current measurement techniques
Three percent of the restoration costs were budgeted towards a robust evaluation program

A Testable Restoration Expectation



Southwest Florida Water Management District (SWFWMD) Mandate

"The minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area."

Section 373.042
Florida Statutes

Setting Flow Requirements

"There is no universally accepted method or combination of methods that is appropriate for establishing instream flow regimes on all rivers or streams. Rather, the combination or adaptation of methods should be determined on a case-by-case basis; . . . In a sense, there are few bad methods – only improper applications of methods. In fact, most . . . assessment tools . . . can afford adequate instream flow protection for all of a river's needs when they are used in conjunction with other techniques in ways that provide reasonable answers to specific questions asked for individual rivers and river segments. Therefore, whether a particular method 'works' is not based on its acceptance by all parties but whether it is based on sound science, basic ecological principles, and documented logic that address a specific need."

Instream Flow Council 2002

Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity

– Bunn and Arthington. 2002. Environmental Management 30 (4): 492-507

- *Principle 1:* **Flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biotic composition.**
- *Principle 2:* **Aquatic species have evolved life history strategies primarily in direct response to the natural flow regime.**
- *Principle 3:* **Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.**
- *Principle 4:* **The invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regimes.**

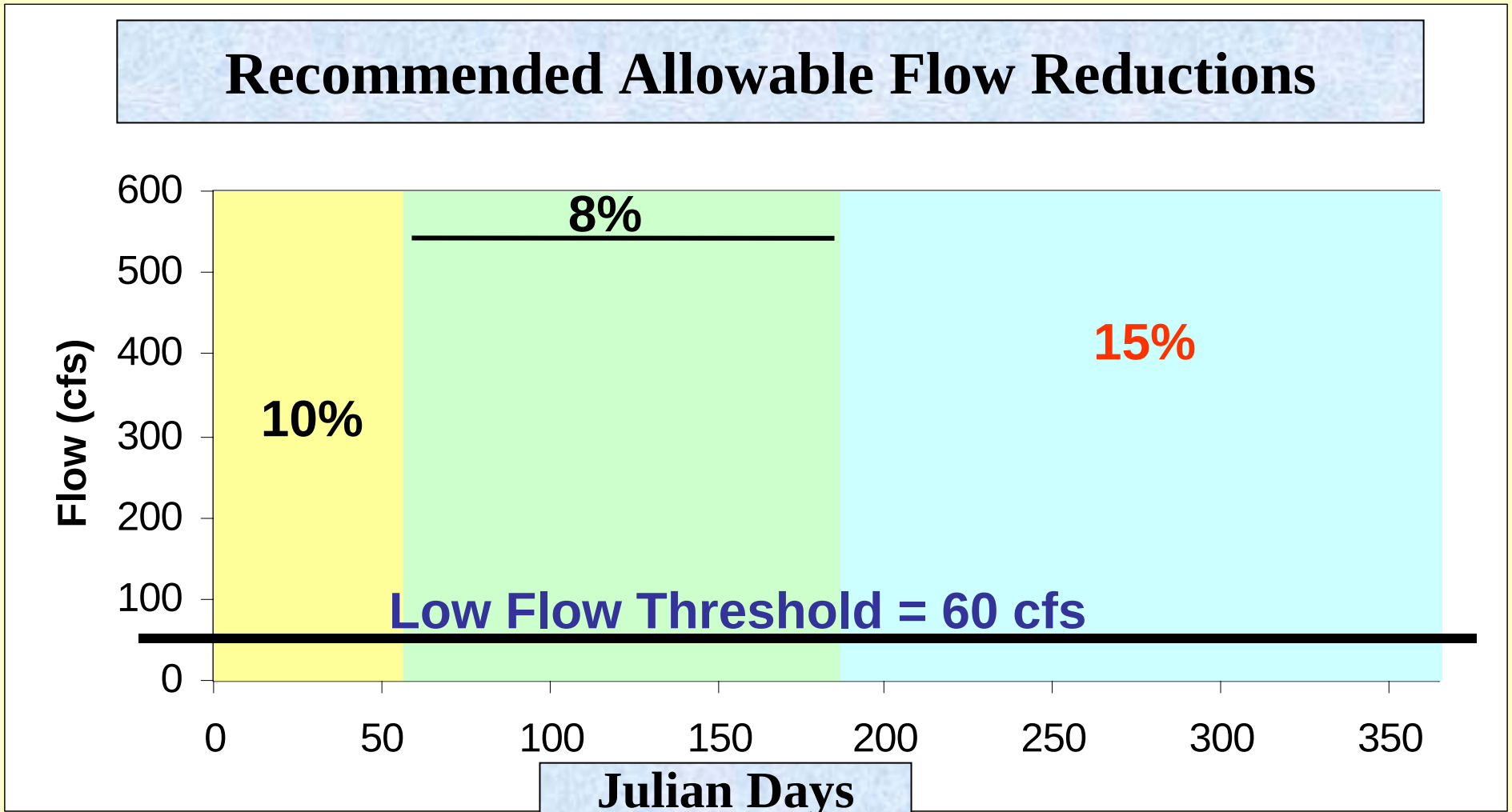
Setting Minimum Flows and Levels (MFLs)

- ***Flow Regime – Building Block Approach***
- ***Multiple MFLs - address seasonality***
- ***Percent of Flow Reduction Technique***
- ***Physical Habitat Simulation (PHABSIM)***
- ***Significant Harm - 15% reduction in available habitat is assumed***
- ***River-floodplain-groundwater connection is examined carefully***

Modeling Tools

- **Hydrograph Characterization** (***Richter et al. 1996 – Magnitude, Timing, Flow Duration, Frequency***)
- **HEC-RAS Model** ***(U.S. Army Corps of Engineers Hydrologic Engineering Center – River Analysis System)***
- **Inundation Analysis (FLOW2D)**
- **Recent and Long-Term Positional Hydrograph (RALPH) Analyses**
- **Physical Habitat Simulation (PHABSIM) Analysis**
- **HEC-RAS/Sandia SDM Analyses**
- **HEC-RAS/Ecosystem Functions Model (EMF)**
- **Prescribed Flow Hydrographs**

An Example from Florida
The Hillsborough River



An Australian Perspective
The Australian Rivers Institute

Three Major Programs
1. **Dryland Rivers**
2. **Healthy Waterways**
3. **TRACK**

HEALTHY WATERWAYS

TRaCK
Tropical Rivers and Coastal Knowledge

Australia's freshwater resources

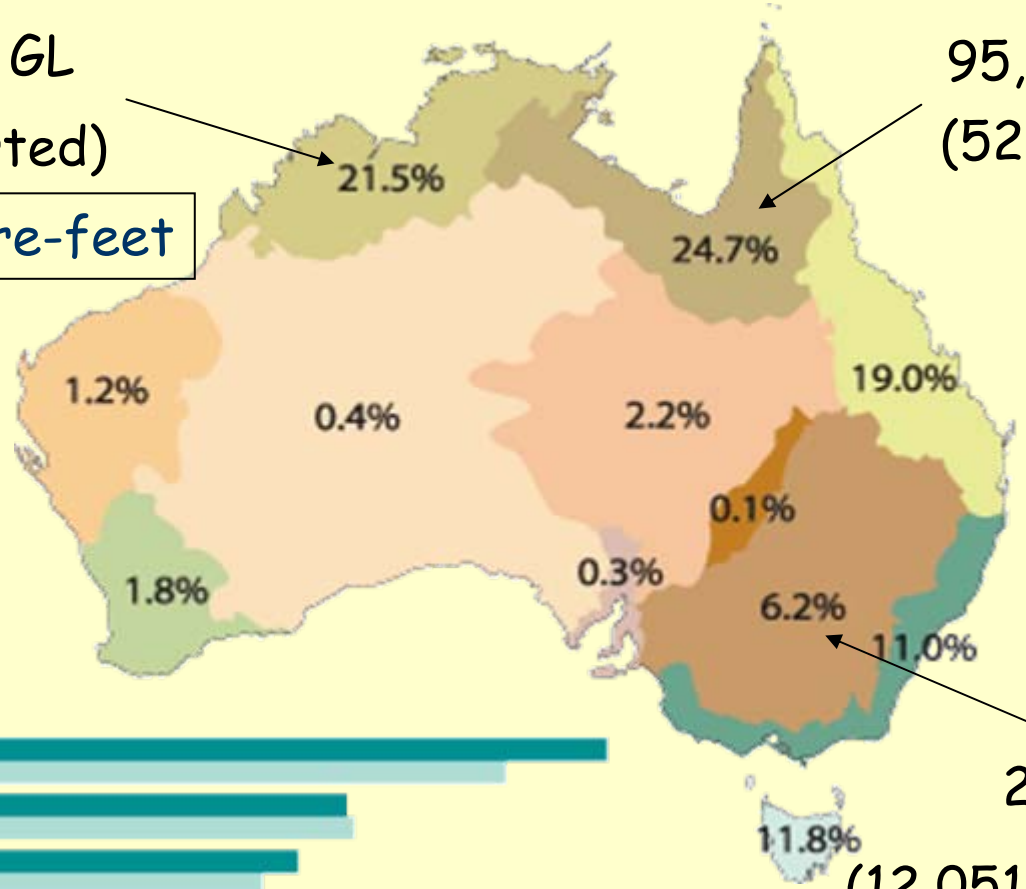
83,320 GL

(48 GL diverted)

1 GL = 811 acre-feet

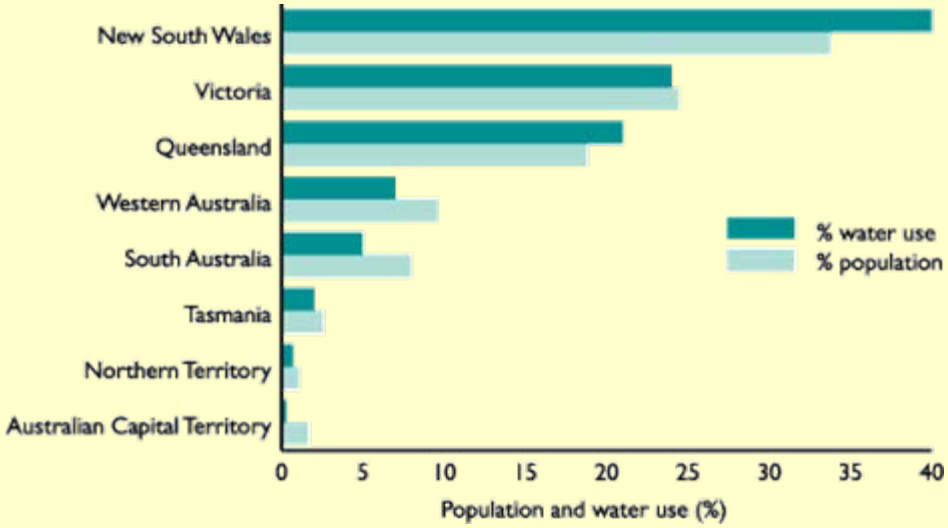
95,615 GL

(52 GL diverted)



23,850 GL

(12,051 GL diverted)

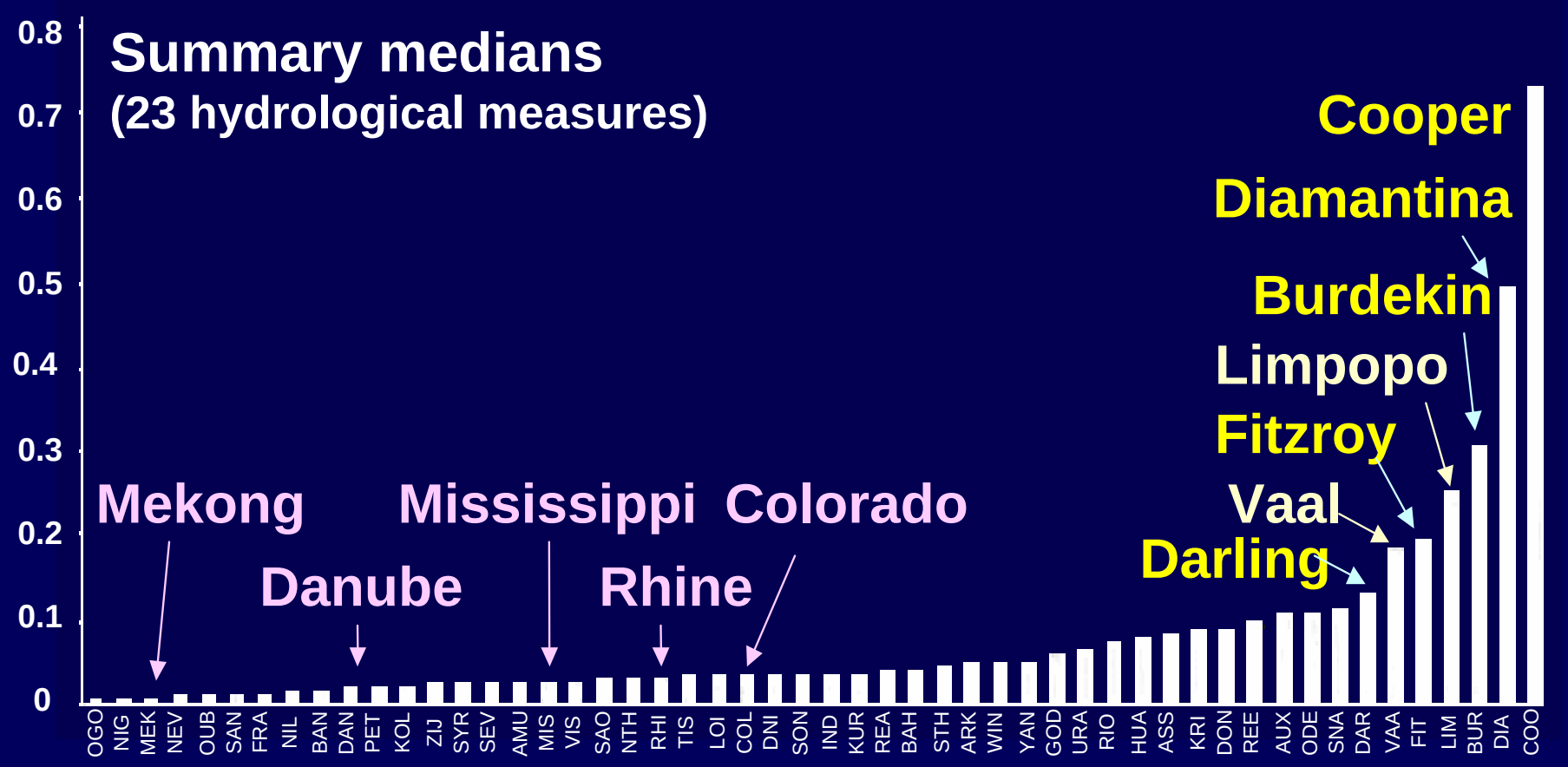


Big users:

- dairy – 2,834 GL
- cotton – 2,908 GL
- rice – 1,951 GL

Extreme variability – arid zone

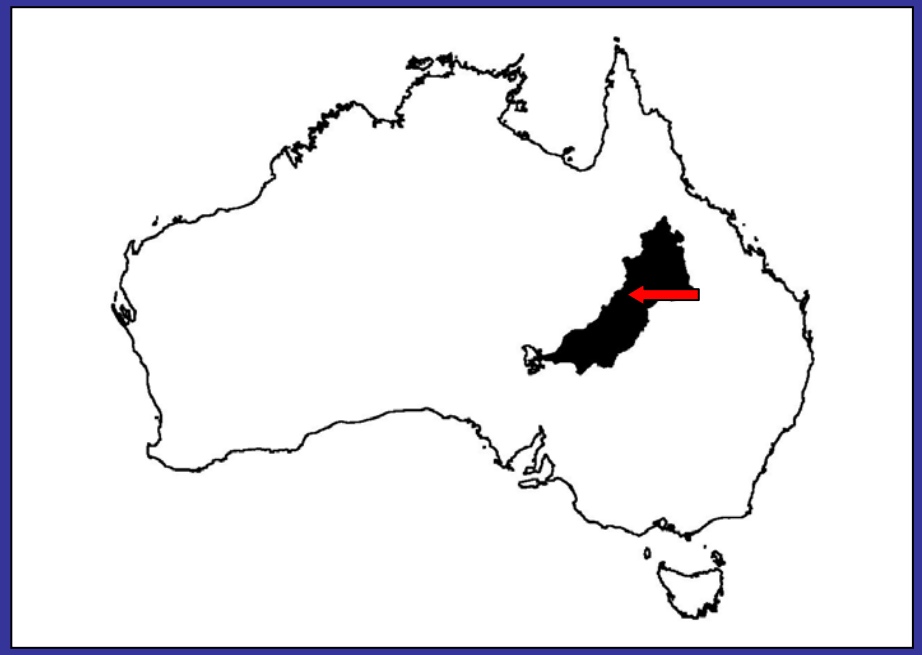
High flow variability

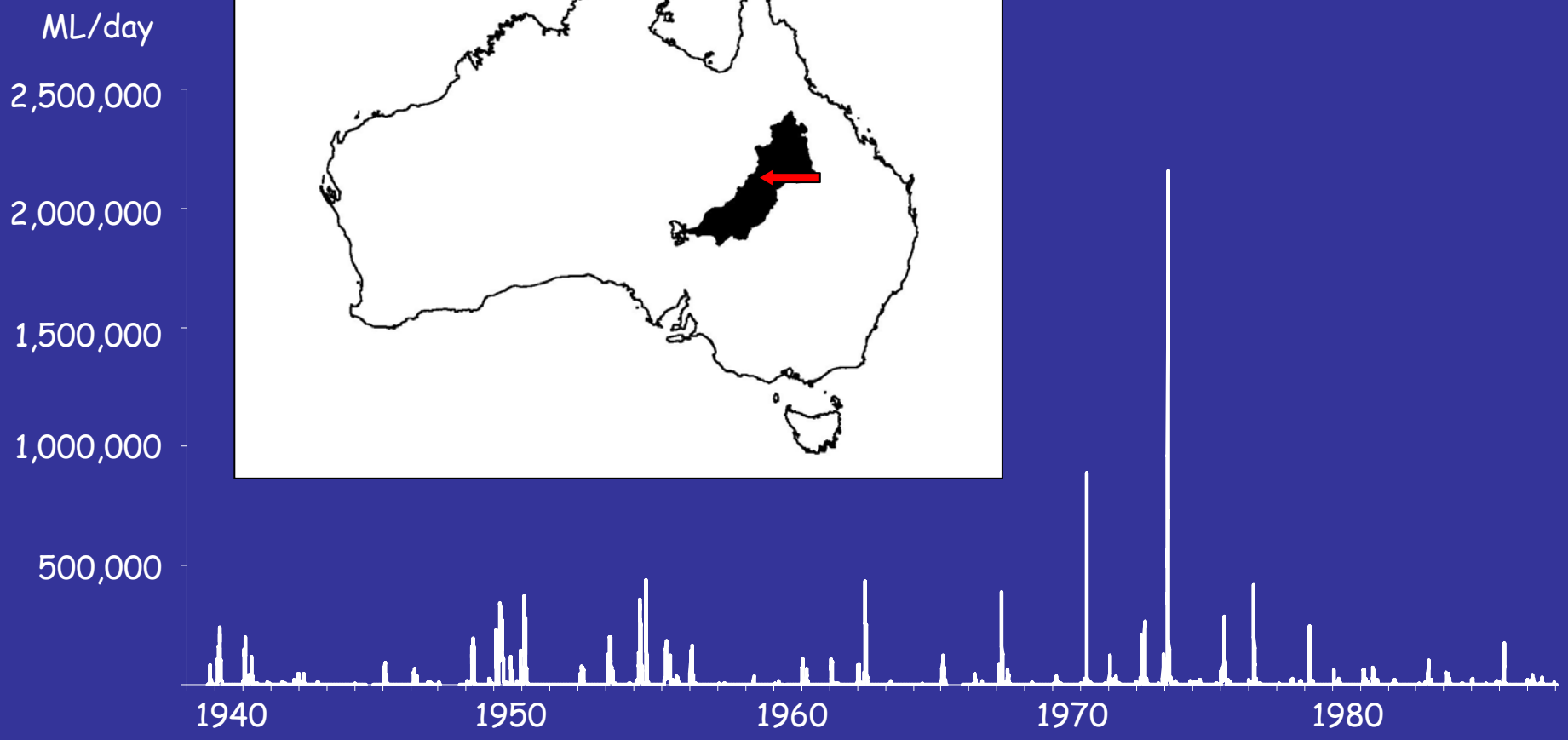


from Puckridge *et al.* (1998). *Mar. Freshw. Res.* 49, 55-72

Cooper Creek

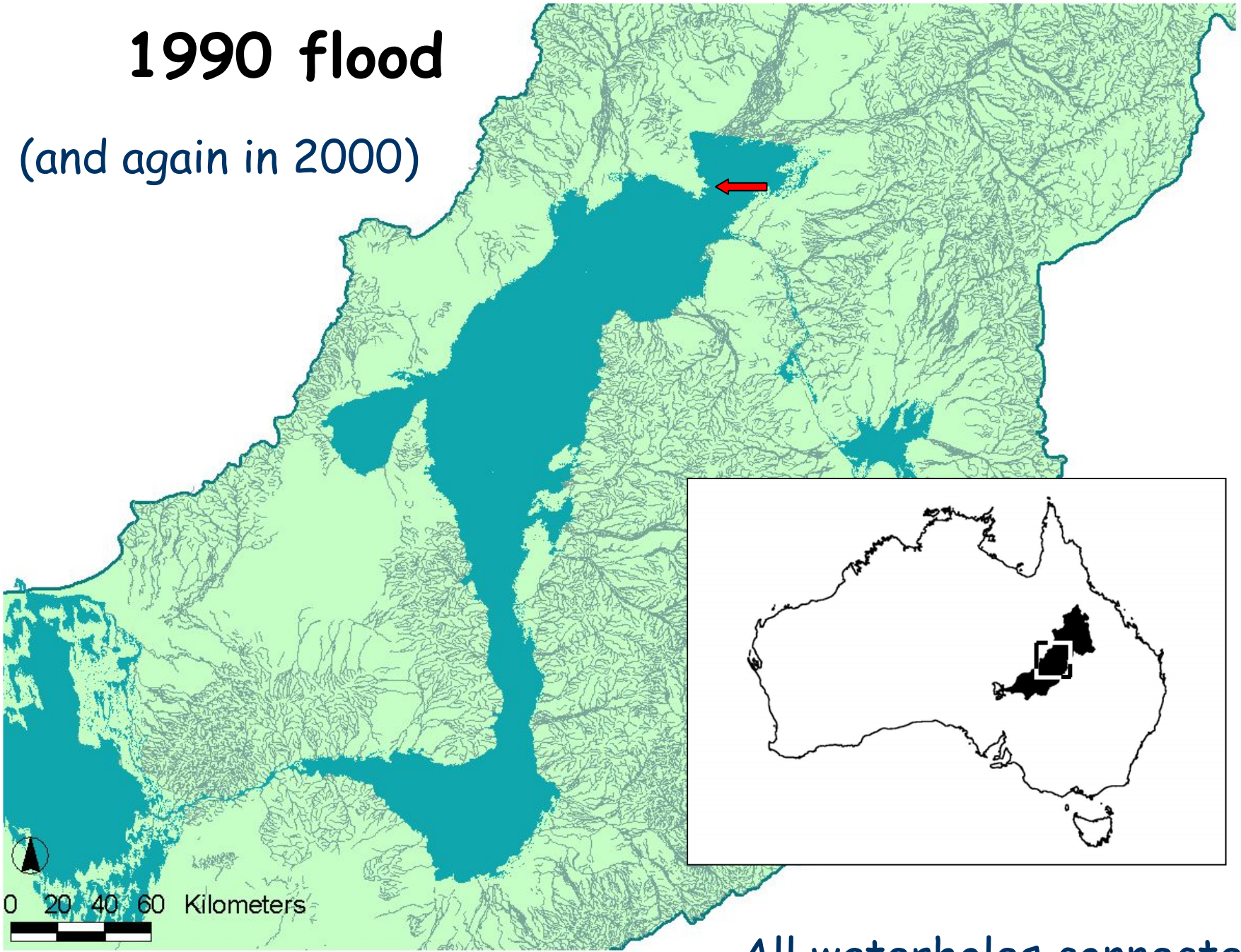
- 296,000 km^2
- ~35% floodplain





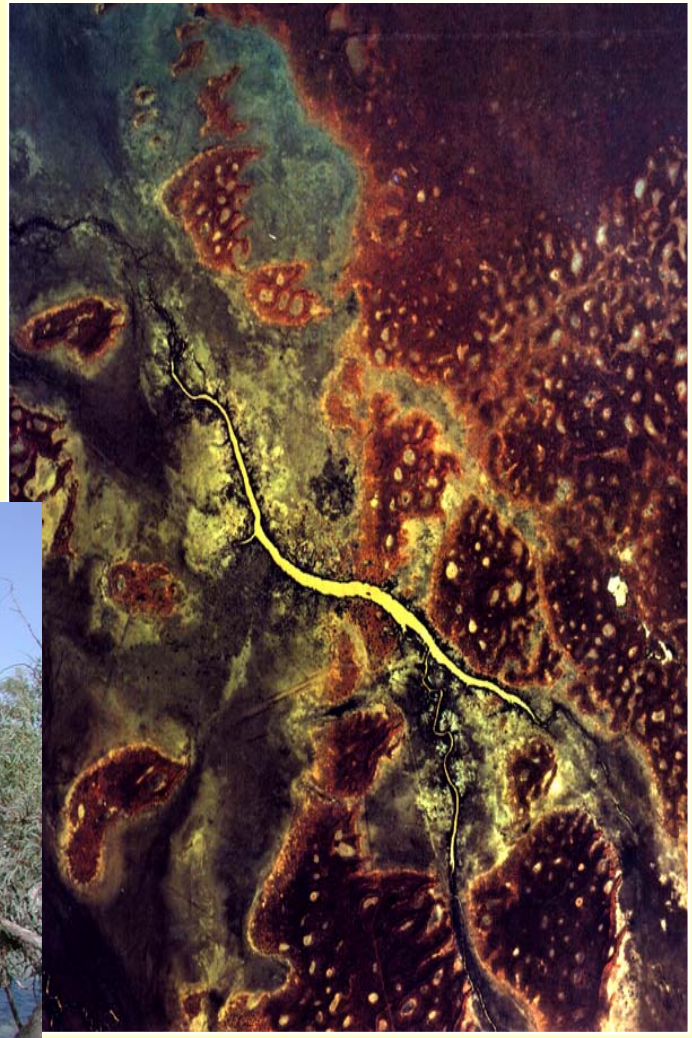
1990 flood

(and again in 2000)

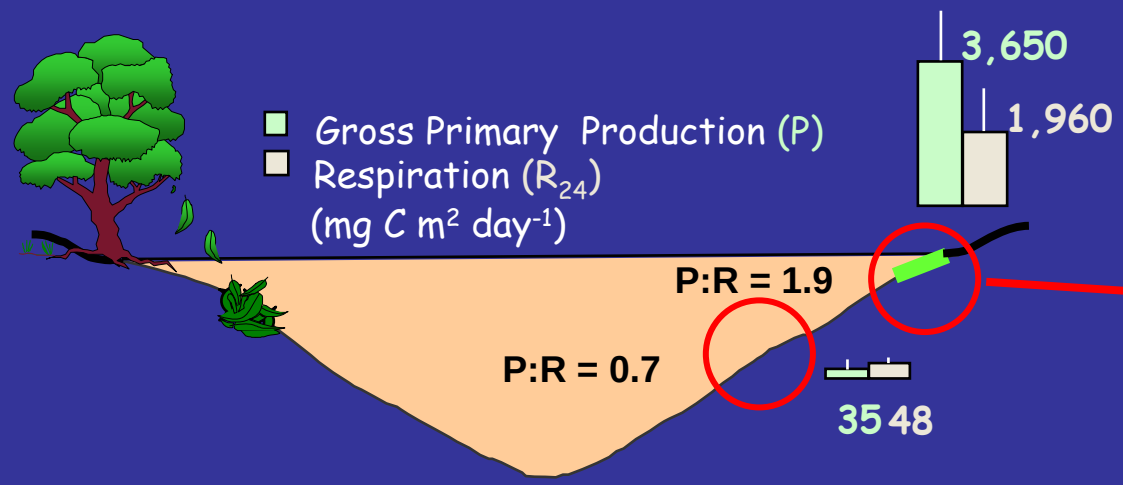


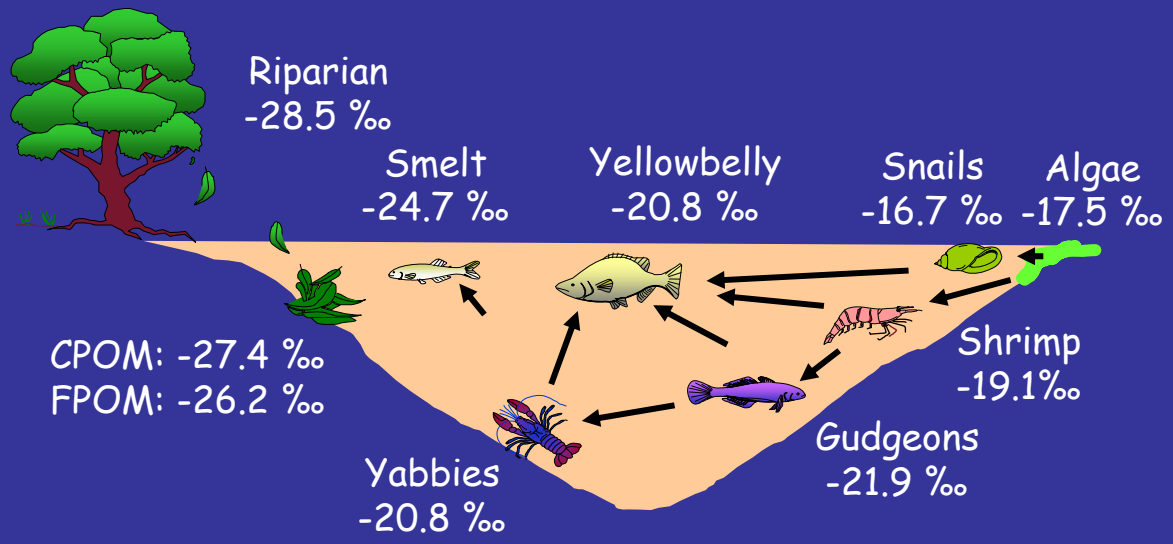
All waterholes connected

Water holes - refugia



Food webs in waterholes





Stable isotope signatures

Bunn *et al.* (2003)

Benthic algae = 70-80% consumer biomass

Healthy Waterways Program - SE Queensland

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

Formation of the Partnership

3 levels of government

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

Strong research support

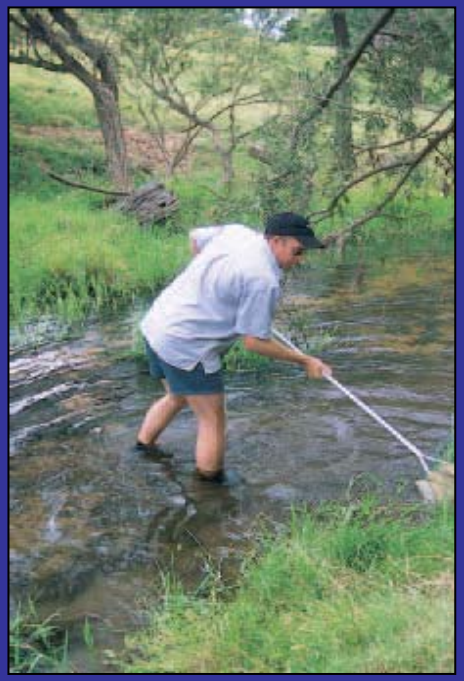
- 3 Universities
- CSIRO
- 3 Cooperative Research Centres

Community & industry advisory groups (>40)

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

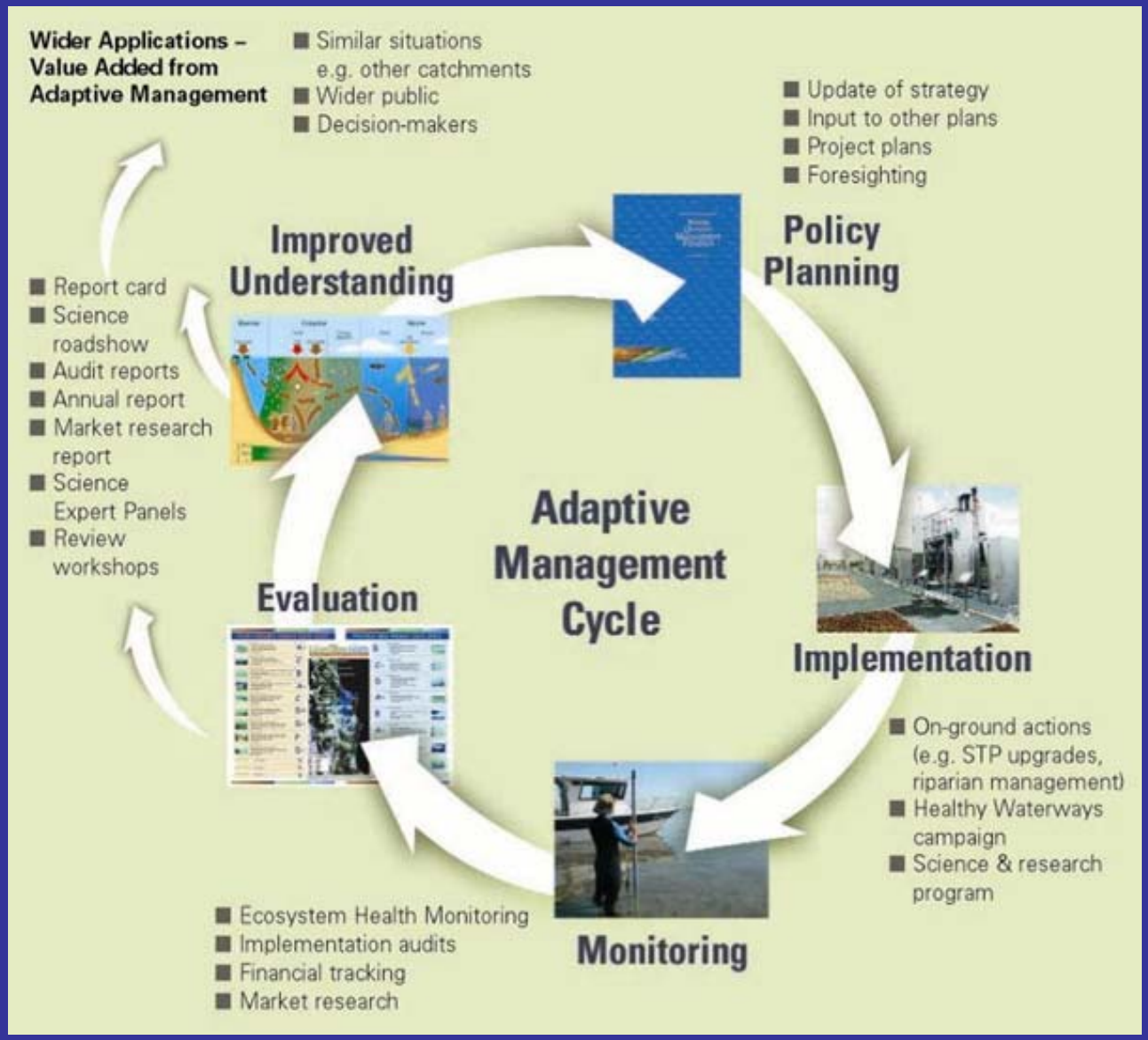
Ecosystem Health Monitoring Program

Freshwater EHMP
- Designed stage 3 ; Implemented 2002



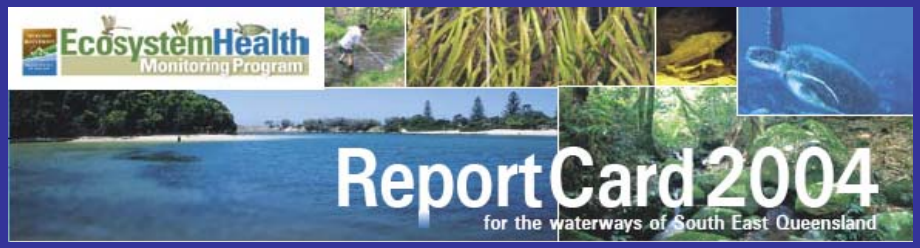
120 freshwater sites
(sampled 2x/yr)

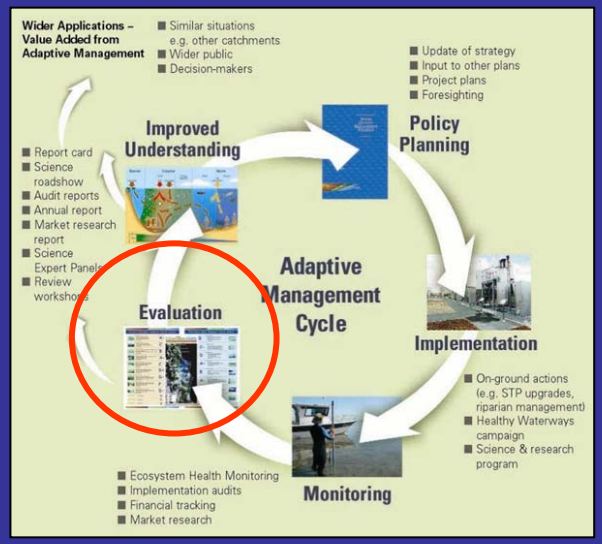
Adaptive management framework

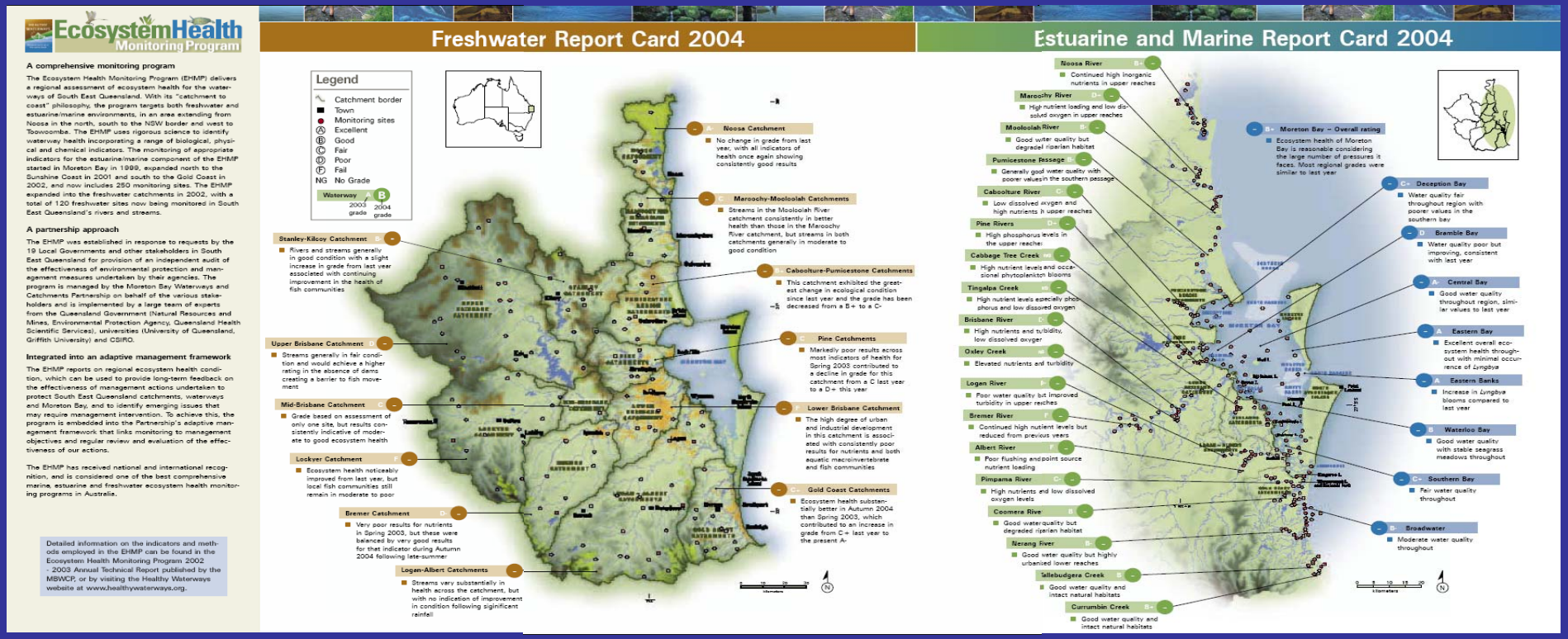


- ongoing knowledge acquisition
- critical role of monitoring
- continuous improvement in the identification and implementation of management.
- effective communication of knowledge for policy/planning

Report cards on progress







EcosystemHealth Monitoring Program

A comprehensive monitoring program

The Ecosystem Health Monitoring Program (EHMP) delivers a regional assessment of ecosystem health for the waterways of South East Queensland. With its "catchment to coast" philosophy, the program targets both freshwater and estuarine/marine environments, in an area extending from Noosa in the north, south to the NSW border and west to Toowoomba. The EHMP uses rigorous science to identify waterway health incorporating a range of biological, physical and chemical indicators. The monitoring of appropriate indicators for the estuarine/marine component of the EHMP started in Moreton Bay in 1999, expanded north to the Sunshine Coast in 2001 and south to the Gold Coast in 2002, and now includes 250 monitoring sites. The EHMP expanded into the freshwater catchments in 2002, with a total of 120 freshwater sites now being monitored in South East Queensland's rivers and streams.

A partnership approach

The EHMP was established in response to requests by the 19 Local Governments and other stakeholders in South East Queensland for provision of an independent audit of the effectiveness of environmental protection and management measures undertaken by their agencies. The program is managed by the Moreton Bay Waterways and Catchments Partnership on behalf of the various stakeholders and is implemented by a large team of experts from the Queensland Government (Natural Resources and Mines, Environmental Protection Agency, Queensland Health Scientific Services), universities (University of Queensland, Griffith University) and CSIRO.

Integrated into an adaptive management framework

The EHMP reports on regional ecosystem health condition, which can be used to provide long-term feedback on the effectiveness of management actions undertaken to protect South East Queensland catchments, waterways and Moreton Bay, and to identify emerging issues that may require management intervention. To achieve this, the program is embedded into the Partnership's adaptive management framework that links monitoring to management objectives and regular review and evaluation of the effectiveness of our actions.

The EHMP has received national and international recognition, and is considered one of the best comprehensive marine, estuarine and freshwater ecosystem health monitoring programs in Australia.

Detailed information on the indicators and methods employed in the EHMP can be found in the Ecosystem Health Monitoring Program 2002 - 2003 Annual Technical Report published by the MBWCP, or by visiting the Healthy Waterways website at www.healthywaterways.org.

Freshwater Report Card 2004

Legend
- Catchment border
- Town
- Monitoring sites
- Ⓐ Excellent
- Ⓑ Good
- Ⓒ Fair
- Ⓓ Poor
- Ⓕ Fail
- NG No Grade

Waterway A (2003 grade) B (2004 grade)

A- Noosa Catchment
No change in grade from last year, with all indicators of health once again showing consistently good results

C Maroochy-Mooloolah Catchments
Streams in the Mooloolah River catchment consistently in better health than those in the Maroochy River catchment, but streams in both catchments generally in moderate to good condition

B- Caboolture-Pumicestone Catchments
This catchment exhibited the greatest change in ecological condition since last year and the grade has been decreased from a B+ to a C-

Stanley-Kilcoy Catchment B-
Rivers and streams generally in good condition with a slight increase in grade from last year associated with continuing improvement in the health of fish communities

Upper Brisbane Catchment D
Streams generally in fair condition and would achieve a higher rating in the absence of dams creating a barrier to fish movement

Mid-Brisbane Catchment C
Grade based on assessment of only one site, but results consistently indicative of moderate to good ecosystem health

Lockyer Catchment F
Ecosystem health noticeably improved from last year, but local fish communities still remain in moderate to poor

Bremer Catchment D-
Very poor results for nutrients in Spring 2003, but these were balanced by very good results for that indicator during Autumn 2004 following late-summer

Logan-Albert Catchments
Streams vary substantially in health across the catchment, but with no indication of improvement in condition following significant rainfall

C Pine Catchments
Markedly poor results across most indicators of health for Spring 2003 contributed to a decline in grade for this catchment from a C last year to a D+ this year

Lower Brisbane Catchment
The high degree of urban and industrial development in this catchment is associated with consistently poor results for nutrients and both aquatic macroinvertebrate and fish communities

C- Gold Coast Catchments
Ecosystem health substantially better in Autumn 2004 than Spring 2003, which contributed to an increase in grade from C+ last year to the present A-

Estuarine and Marine Report Card 2004

Noosa River B+
Continued high inorganic nutrients in upper reaches

Maroochy River D-
High nutrient loading and low dissolved oxygen in upper reaches

Mooloolah River B-
Good water quality but degraded riparian habitat

Pumicestone Passage B-
Generally good water quality with poorer values in the southern passage

Caboolture River C-
Low dissolved oxygen and high nutrients in upper reaches

Pine Rivers D-
High phosphorus levels in the upper reaches

Cabbage Tree Creek
High nutrient levels and occasional phytoplankton blooms

Tingalpa Creek
High nutrient levels especially phosphorus and low dissolved oxygen

Brisbane River C-
High nutrients and turbidity, low dissolved oxygen

Oxley Creek
Elevated nutrients and turbidity

Logan River F
Poor water quality but improved turbidity in upper reaches

Bremer River F
Continued high nutient levels but reduced from previous years

Albert River
Poor flushing and point source nutrient loading

Pimpama River C-
High nutrients and low dissolved oxygen levels

Coomera River B
Good water quality but degraded riparian habitat

Nerang River B-
Good water quality but highly urbanised lower reaches

Tallebudgera Creek B
Good water quality and intact natural habitats

Currumbin Creek B+
Good water quality and intact natural habitats

B- Moreton Bay – Overall rating
Ecosystem health of Moreton Bay is reasonable considering the large number of pressures it faces. Most regional grades were similar to last year

C+ Deception Bay
Water quality fair throughout region with poorer values in the southern bay

D Bramble Bay
Water quality poor but improving, consistent with last year

A- Central Bay
Good water quality throughout region, similar values to last year

A Eastern Bay
Excellent overall ecosystem health throughout with minimal occurrence of *Lyngbya*

A Eastern Banks
Increase in *Lyngbya* blooms compared to last year

B Waterloo Bay
Good water quality with stable seagrass meadows throughout

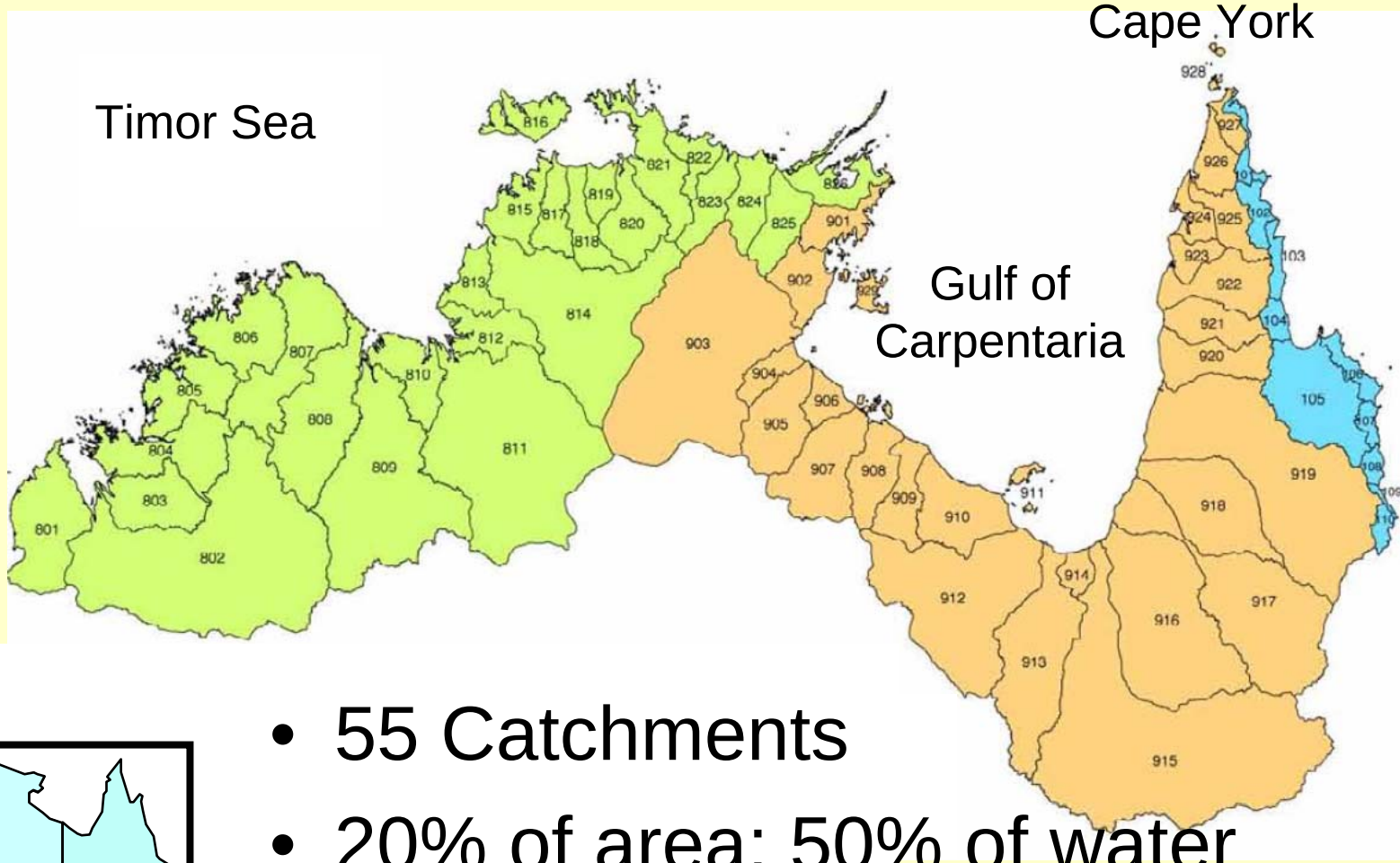
C+ Southern Bay
Fair water quality throughout

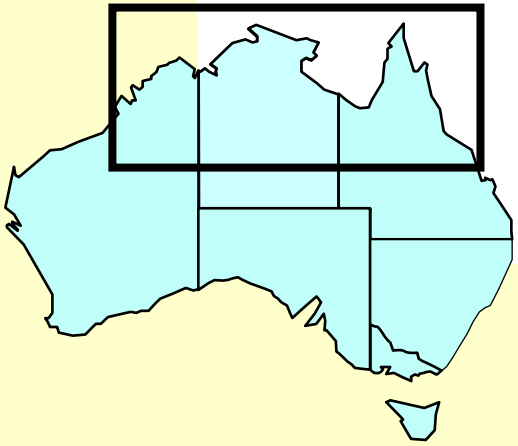
B- Broadwater
Moderate water quality throughout

TRaCK

Tropical Rivers and
Coastal Knowledge

Australia's wet-dry tropical rivers



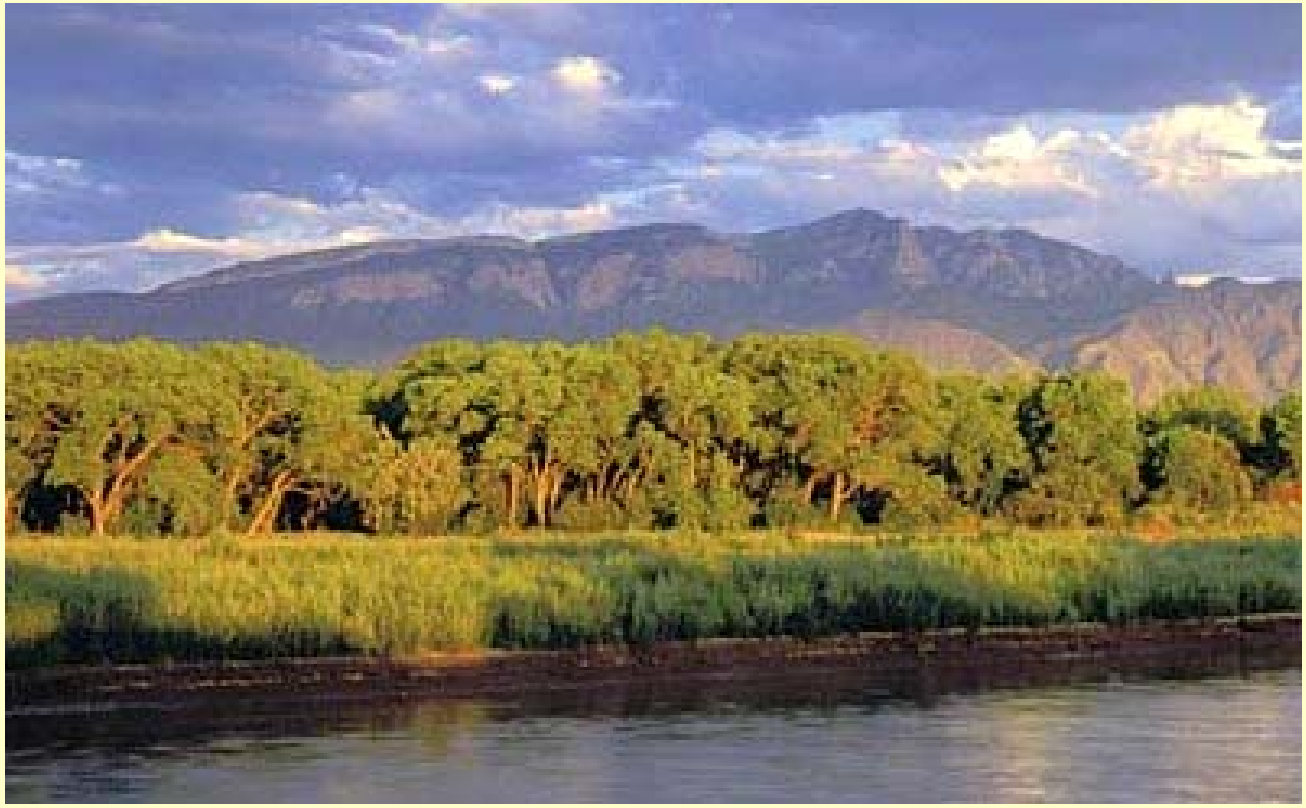


- 55 Catchments
- 20% of area; 50% of water
- 0.8% of Australian population
- 25% Aboriginal

TRaCK's Aim

To provide the science and knowledge that governments, communities and industries need for the sustainable management of Australia's tropical rivers and estuaries

Acknowledgements



NM - James Cleverly, Julie Coonrod, Dianne McDonnell, Jim Thibault, David Gutzler, Scott Collins, Vicenc Acuña FL - Lou Toth, Marty Kelly, Adam Munson AUS – Stuart Bunn, Angela Arthington, Christy Fellows, Mike Douglas