Ecosystem Services of Binational Effluent in the Upper Santa Cruz River Watershed;

An application of the Santa Cruz Watershed Ecosystem Portfolio Model (SCWEPM)

Laura M. Norman, PhD
U.S. Geological Survey, Western Geographic Science Center
520 N. Park Avenue, Suite #102K, Tucson, AZ 85719-5035
Phone: (520) 670-5510; Fax: (520) 670-5113; lnorman@usgs.gov

Presentation to the Arizona-Mexico Commission (AMC) Summer Plenary—Environment Committee; June 8, 2012; JW Marriott Starr Pass, Tucson, AZ
"Arizona & Sonora: Taking Charge of Change."

"The USGS is a science organization that provides impartial information on:

- the health of our ecosystems and environment,
- the natural hazards that threaten us,
- the natural resources we rely on,
- the impacts of climate and land-use change, and
- the core science systems that help us provide timely, relevant, and useable information."

http://www.usgs.gov/aboutusgs/

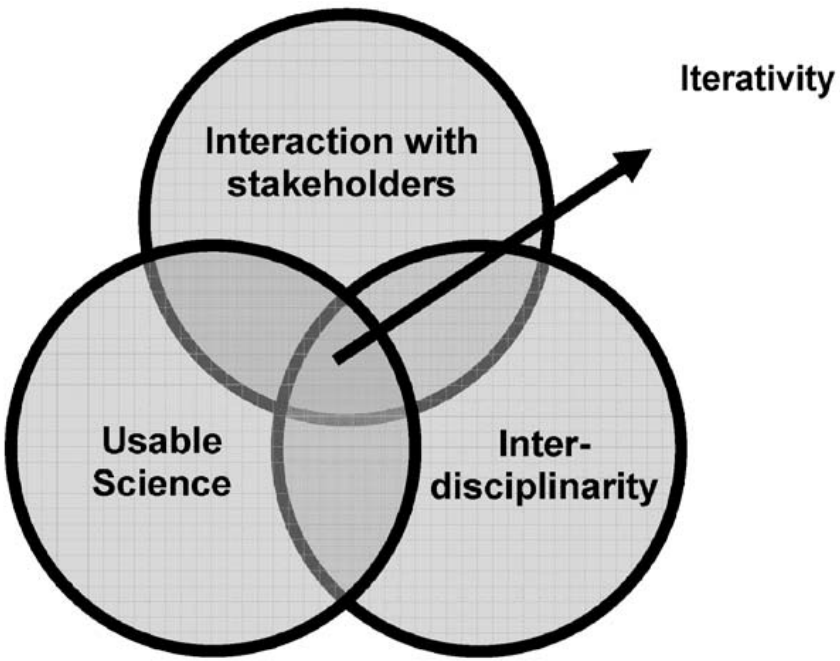
Binational Water Policy & Decision-making

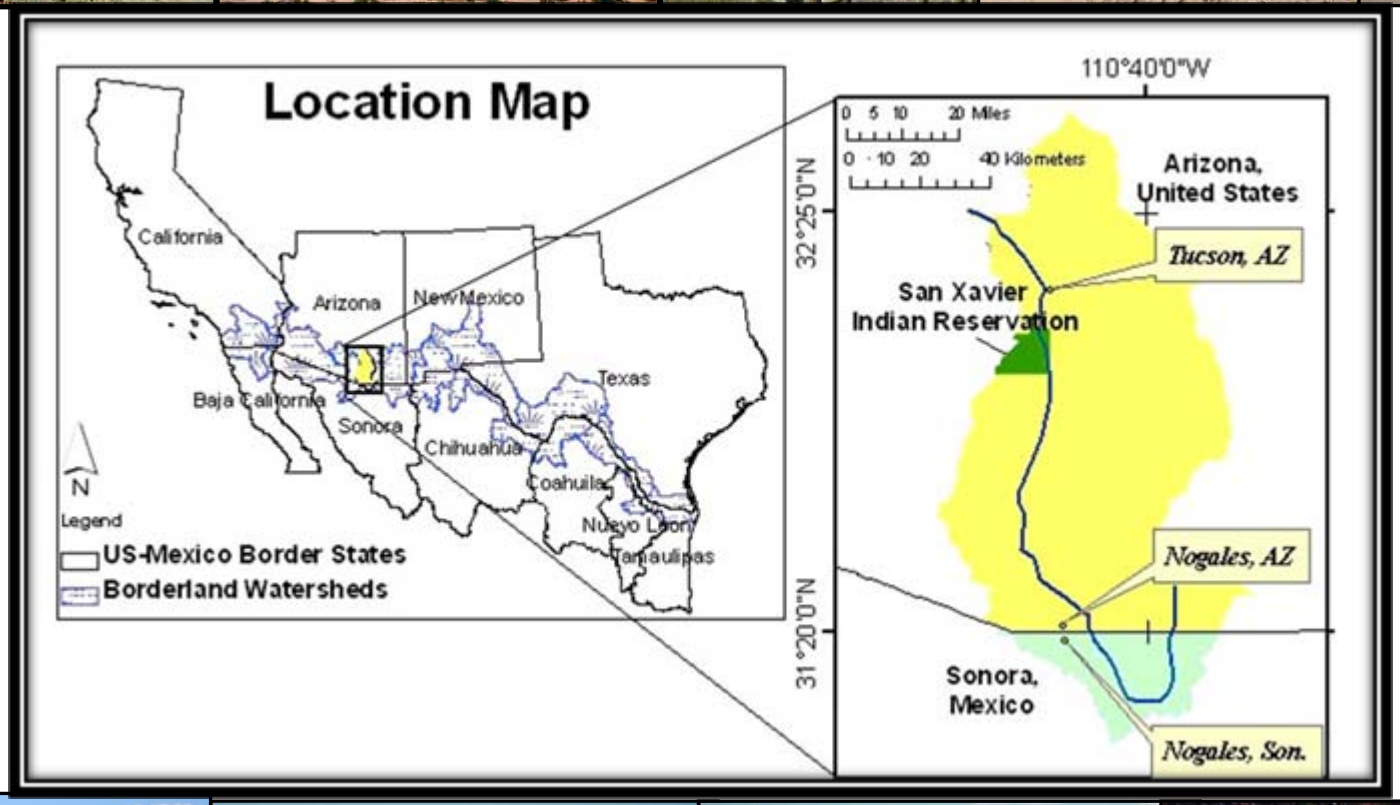
GOAL: Bring SCWEPM tool to AMC "Action Item"

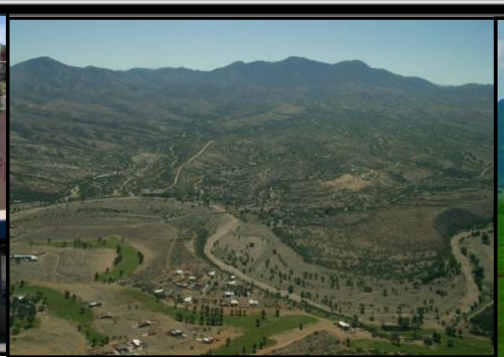
Action item:

The Environment Committee will identify datasets at its disposal to improve the functionality of the Santa Cruz Watershed Ecosystem Portfolio Model.

By incorporating environmental monitoring data, the model can evaluate the ecosystem services generated by the river, and the economic value of the wastewater that supports it.




Location Map
California
Arizona
New Mexico
Texas
Baja California
Sonora
Chihuahua
Coahuila
Nuevo Leon
Tamaulipas
N
Legend
US-Mexico Border States
Borderland Watersheds
110°40'0"W
0 5 10 20 Miles
0 10 20 40 Kilometers
32°25'0"N
31°20'0"N
Arizona, United States
Tucson, AZ
San Xavier Indian Reservation
Nogales, AZ
Sonora, Mexico
Nogales, Son.

Victoria


Ecosystem Services

Ecosystem Services **identify the benefits provided by the nature to people.**

Ecosystem services assessments:

- ✓ Provide a conceptual foundation for stakeholder issues and concerns.
- ✓ Identify benefits of the environment to people to facilitate conservation.
- ✓ Quantify the costs and benefits of different management scenarios.
- ✓ Provide an objective context for discussing opposing interests and values.

Ecosystem service assessments help decision makers evaluate resource management alternatives.

Ecosystem Services

Ecosystem Portfolio Model **is a web-based decision support tool for ecosystem service assessments.**

- Integrate land use-change models for tracking ecological, economic, and quality of life endpoints.
- Values model outcomes by considering the utility of different decision criteria, as well as changes in land valuation.
- Are Spatially-explicit and multi-scale.

Ecosystem Services

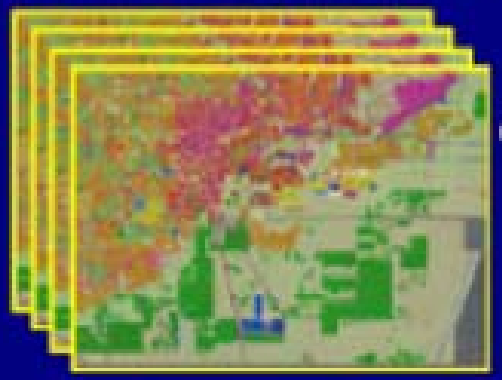
<u>Ecosystem Portfolio Model</u> **is a web-based decision support tool for ecosystem service assessments.**

- Integrate land use-change models for tracking ecological, economic, and quality of life endpoints.
- Values model outcomes by considering the utility of different decision criteria, as well as changes in land valuation.
- Are Spatially-explicit and multi-scale.

Ecosystem Portfolio Models provide decision makers with user friendly tools for evaluate resource management alternatives.

How the EPM works …

1. Multiple land use plans considered



Model-based characterization of outcomes

2. Evaluated against multiple criteria

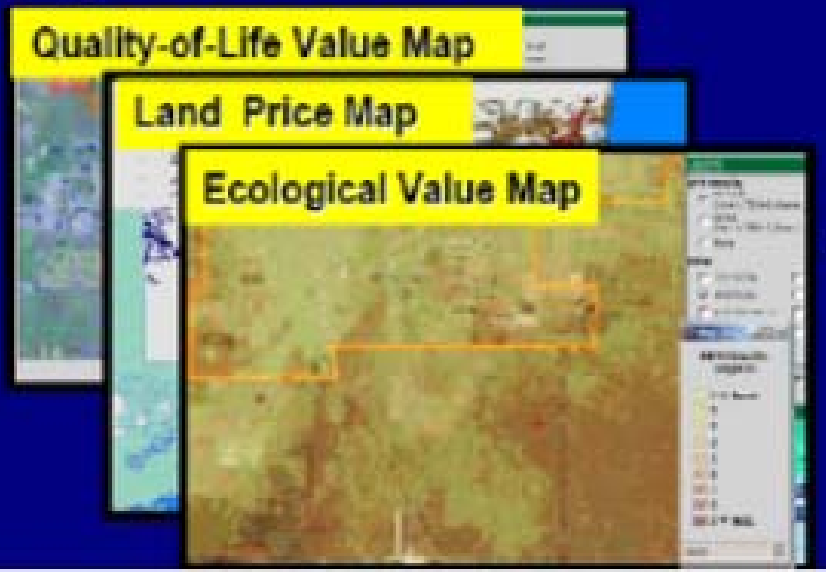
Ecological Value Model

Land Price Model

Quality-of-Life Indicators

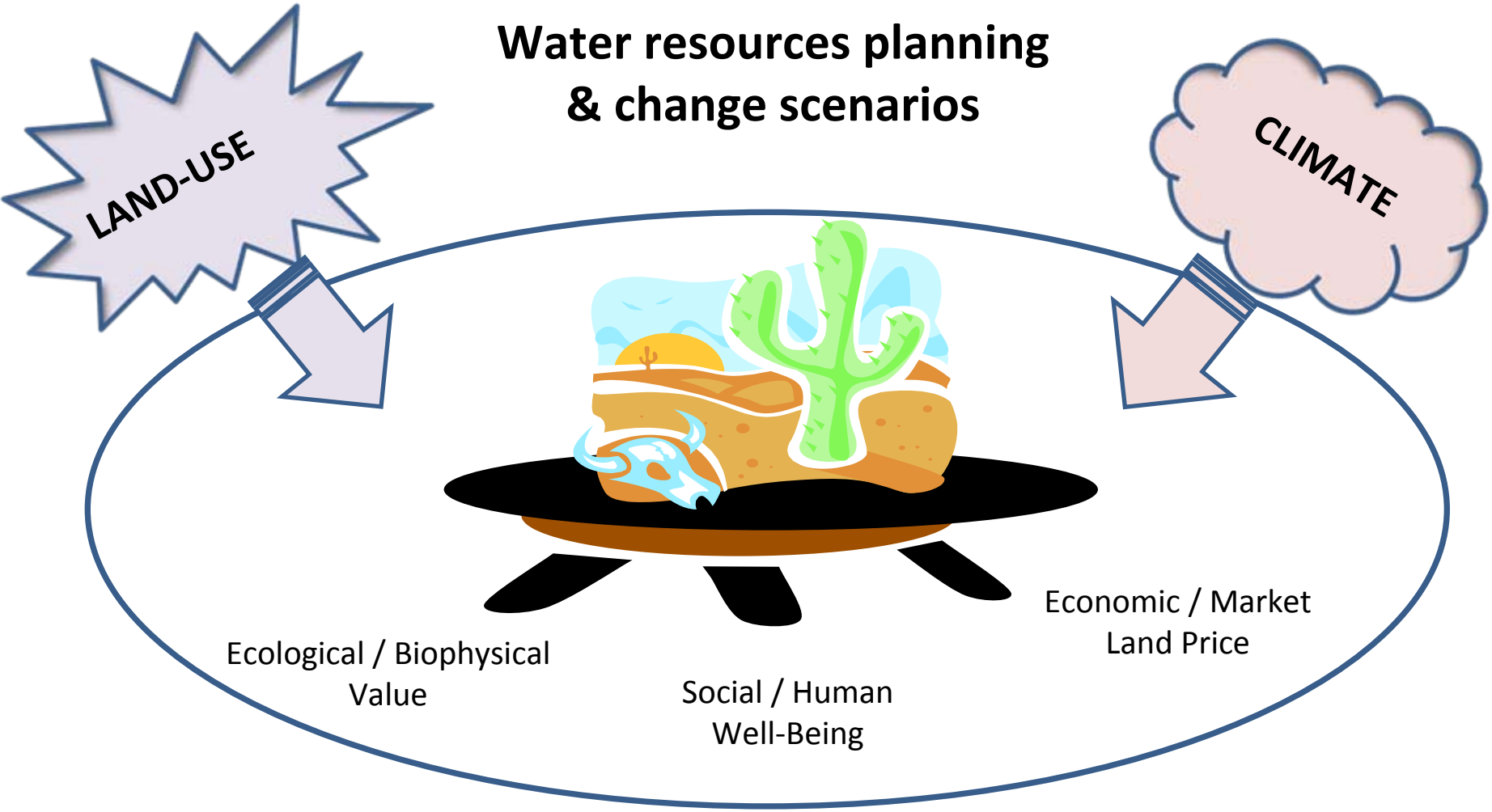
Multi-attribute utility valuation

3. Value maps combine user-elicited value judgments and criteria scores



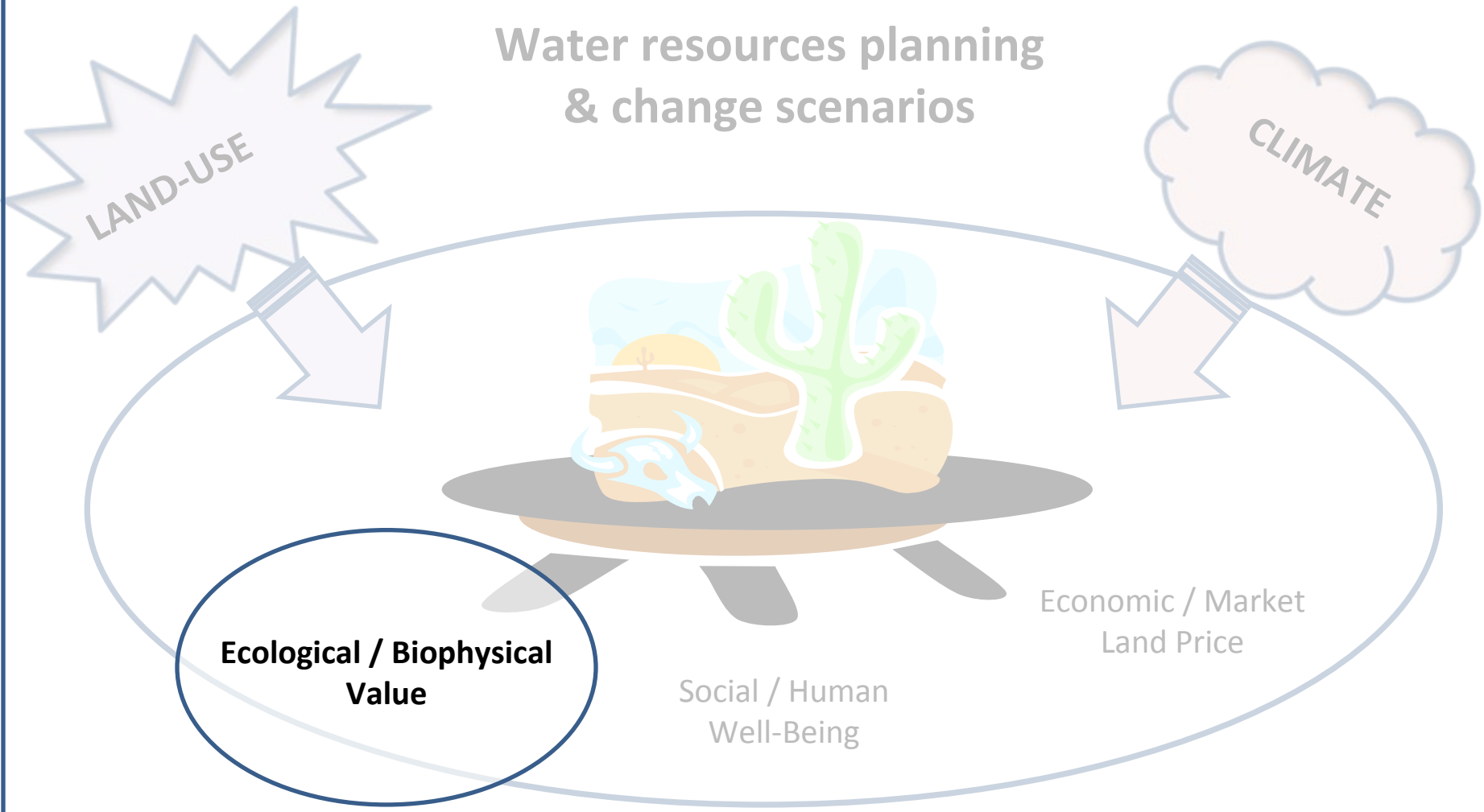
Santa Cruz Watershed Ecosystem Portfolio Model "SCWEPM"

Water resources planning & change scenarios



Santa Cruz Watershed Ecosystem Portfolio Model "SCWEPM"

Water resources planning & change scenarios



Modelling the Santa Cruz River

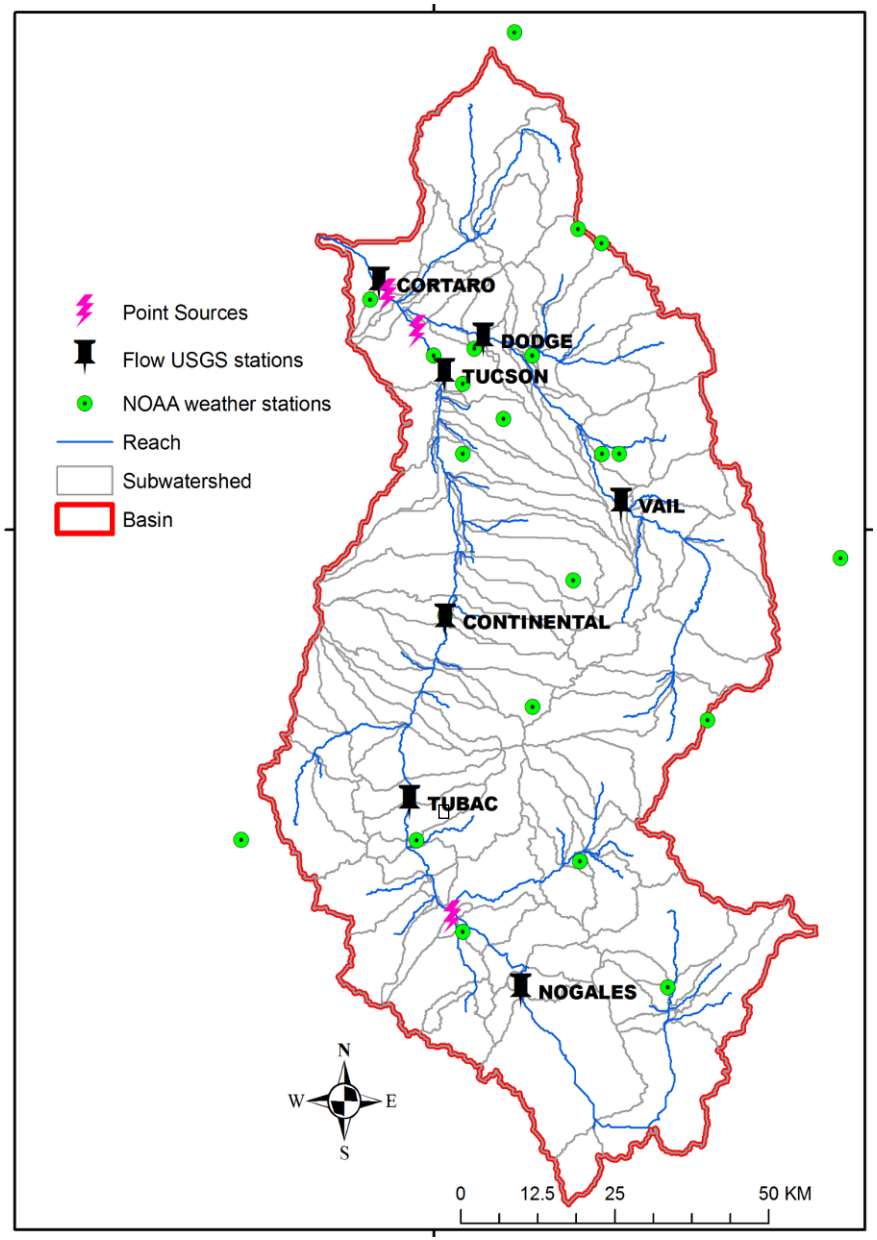
Soil and Water Assessment Tool
SWAT Model

Model Inputs:

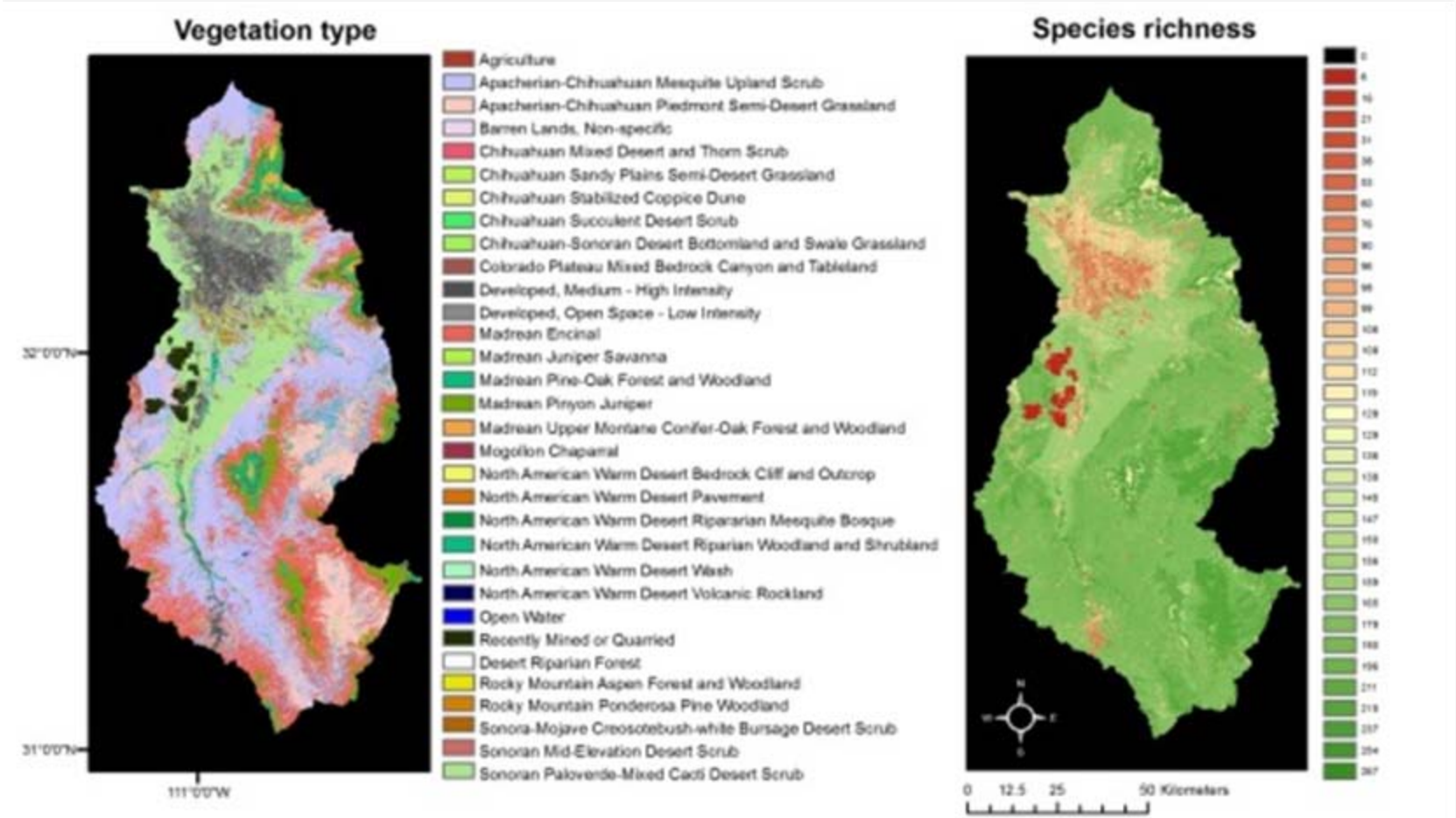
131 Sub-watersheds
2583 Hydrological Response Units Effluent:
3 Wastewater Treatment Plants
@ Ina Road, Roger Road and Rio Rico
22 climate stations

Outputs:

- Flow
- Evapotranspiration
- Sediment
- Nutrient
- Pesticide
- Bacteria
- Transmission Loss



Terrestrial Vertebrate Species Richness Maps



Biodiversity hotspots occur in the riparian corridors and the grasslands.

"Sonoran riparian cottonwood-willow forests are among the most threatened forest types in the U.S."

- Endangered Species Act (ESA)– requires the identification and designation of "**Critical Habitat**"—that can be protected to prevent extinction.
- Species such as the **Yellow-billed Cuckoo**, and **Lucy's Warbler** do not adapt to non-riparian habitats & prefer cottonwood-willow habitat

Upper Santa Cruz River Important Bird Area (IBA)

<u>Species of Global Conservation Concern</u>:

- Bell's Vireo

<u>Species of Conservation Concern:</u>

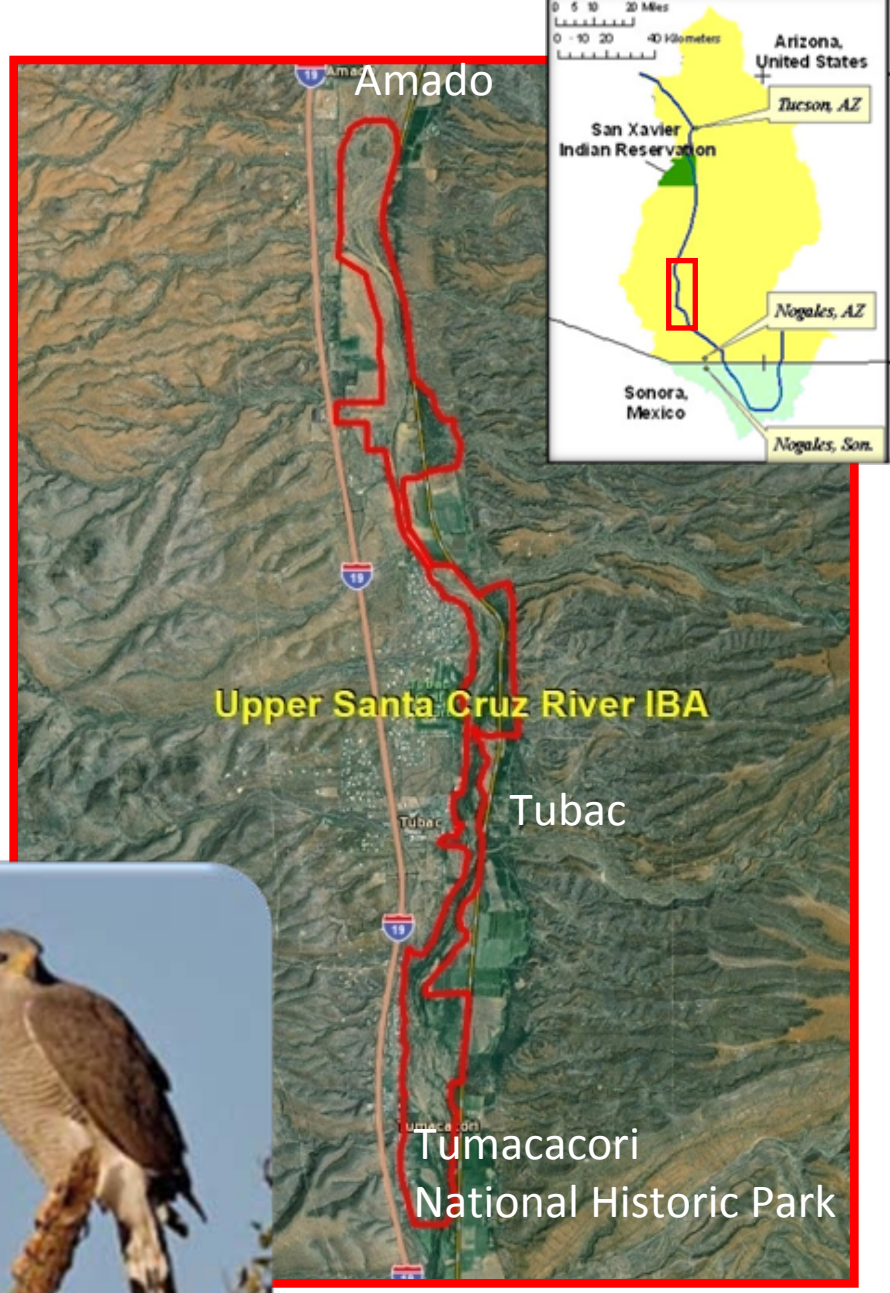
- Gray Hawk
- Yellow-billed Cuckoo
- Bell's Vireo
- Northern Beardless-Tyrannulet
- Lucy's Warbler
- Abert's Towhee
- Rufous-winged Sparrow
- Varied Bunting

<u>State raptors breeding</u>:

- Gray Hawk

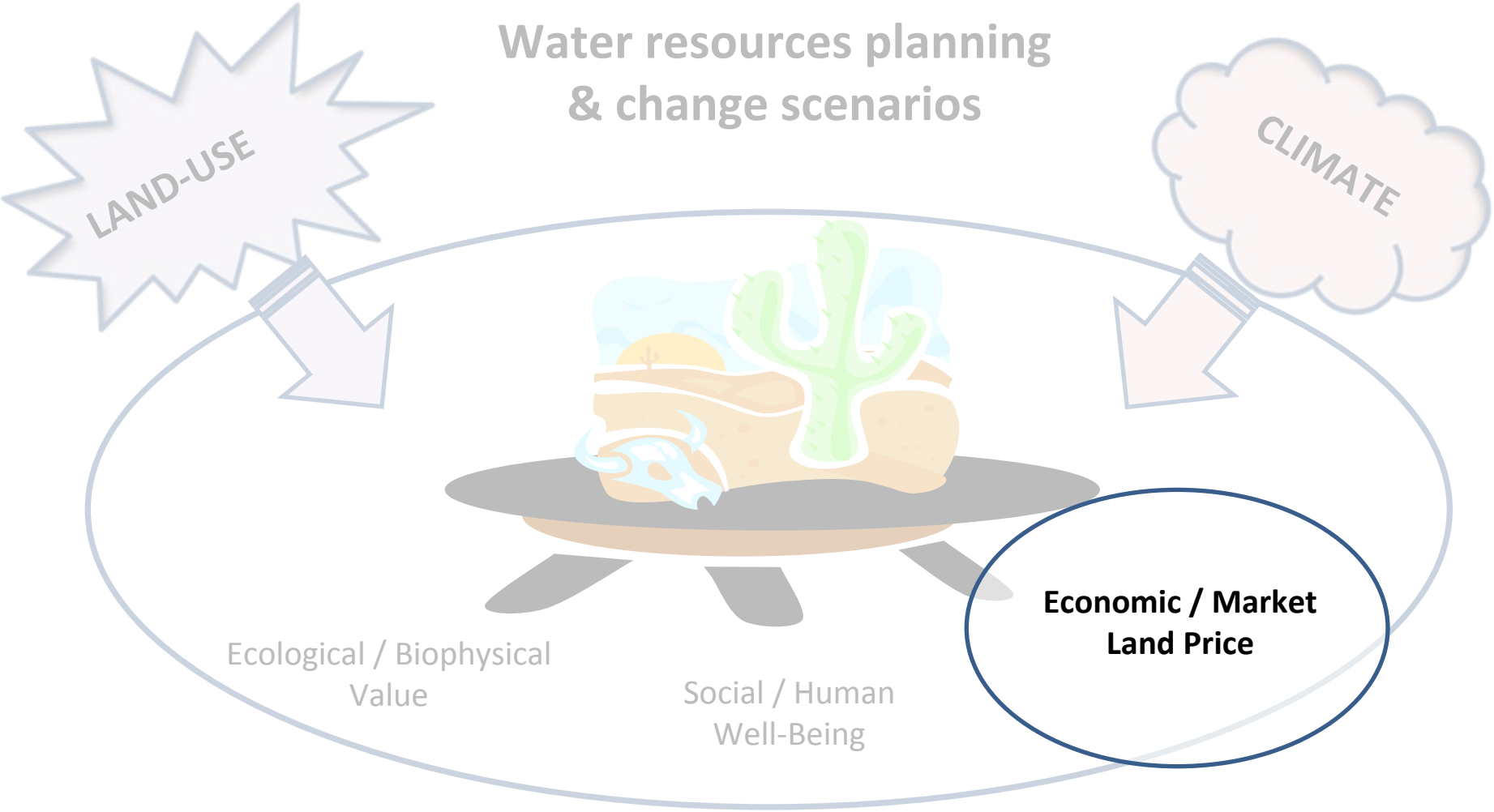
<u>Species in rare/unique habitat:</u>

- Riparian



Santa Cruz Watershed Ecosystem Portfolio Model "SCWEPM"

Water resources planning & change scenarios



Measuring the Impacts of Natural Amenities on Housing Value

Property Value Function V=f(H,E,S,B)

Where V = MEDIAN HOME PRICE

H = Home structure

E = Environmental amenities

S = Societal factors

B = Proximity to Border

Neighborhood	Structural	LULC	Land Ownership	More Environmental	Other
% homes vacant (vs. occupied)	Median # of rooms	%_Open Water	%_State Trust	% area under 100-yr Floodplain (FEMA)	ON THE U.S.–MEXICO BORDER
% mobile homes	% of homes without a phone	%_Evergreen Forest	%_US Forest Service	% Vegetation_Type	NEAR TUCSON INTL. AIRPORT and DAVIS MONTHAN AIR BASE
% housing units built in last two years.	% of homes without complete plumbing	%_Deciduous Forest	%_NPS	# Species supported	SCHOOL DISTRICTS – Catalina Foothills and Tanque Verde
% housing units built before 1939.	Persons / Home	%_Wetlands	%_BLM		COUNTIES: PIMA-PINAL vs. SANTA CRUZ – COCHISE
% Minorities		%_Shrubs/ Scrubs	%_Local Parks		ADJACENT TO RIVER
% earning population		%_Grasslands			
% housing units occupied by an owner (vs. rented)		%_Pasture			
		%_Cultivated Land			
		%_Barren Land			

Spatially-Weighted Hedonic Modeling

US Census block groups with

- **more vegetation identified as "species-rich"**,
- **proximity to public lands**, or
- **more undeveloped** and
- **private land**

had *higher median home values*. $$$$$

In contrast, home values in US census block groups

- **closer to the US-Mexico border or**
- **airports/air bases**

had *lower median home values*. $

~ Hearing from the Public ~

10 Focus Groups; 37 Individual Interviews; Over 100 Participants Total; ~800 pages of transcription

Tumacacori, AZ

North of Amado, AZ

Near W. St. Mary's Rd., Tucson, AZ

Near W. El Camino del Cerro, Tucson, AZ

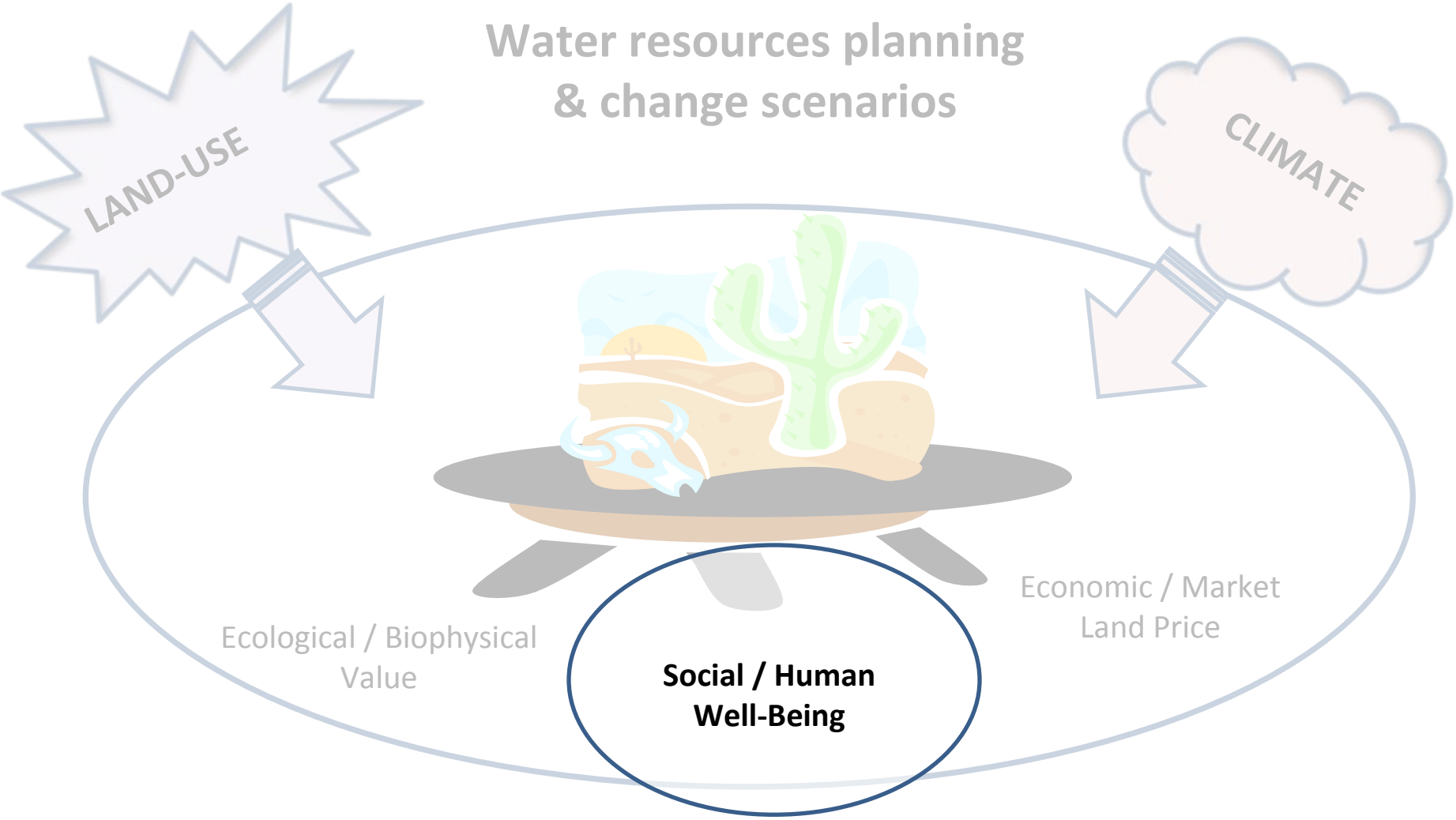
~ Local Values and Preferences ~

What Do People Talk About?

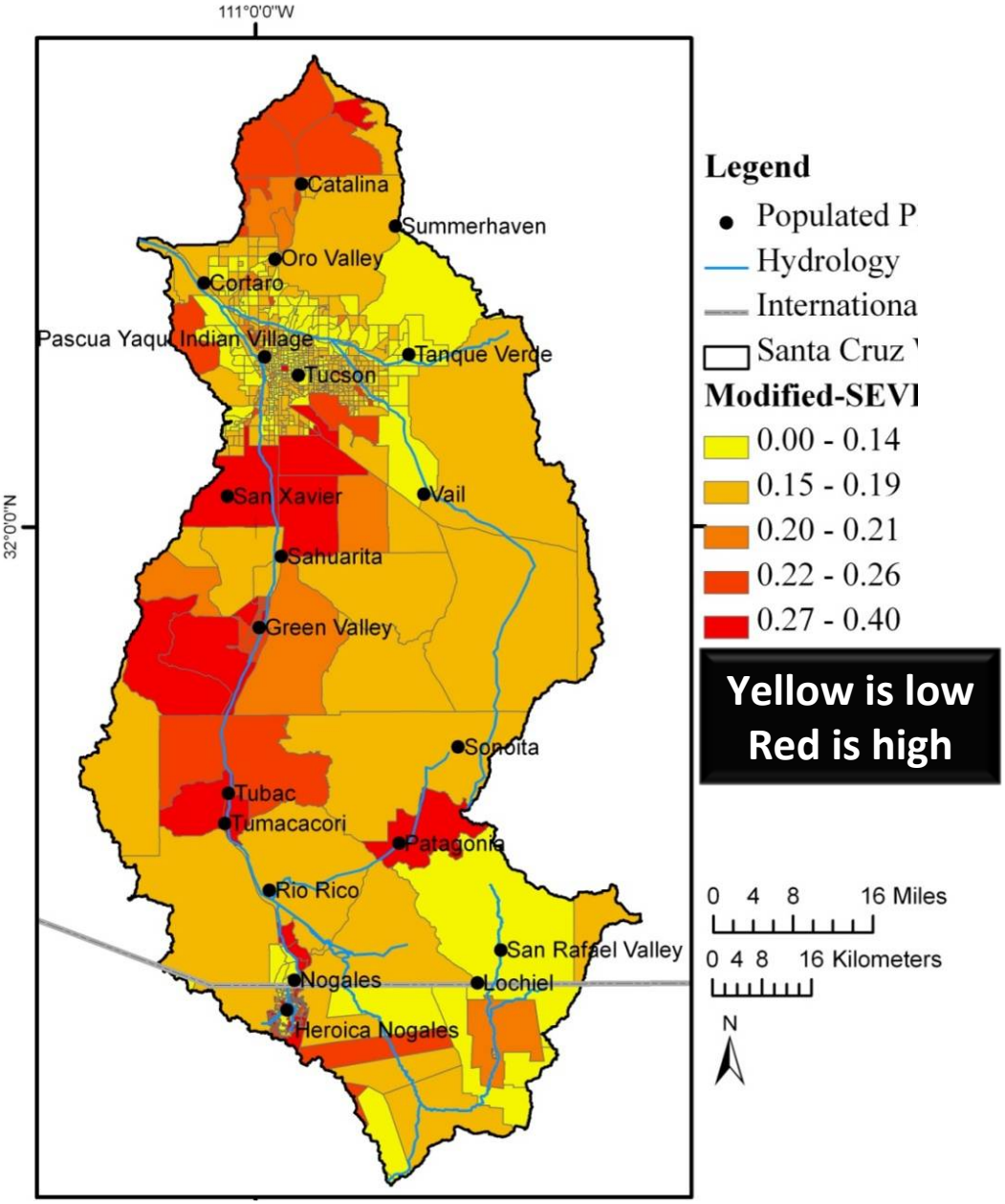
- Visible Water: *Rosalia (Tucson) - "After we got the water back in there…every kid would be like drawn to the Santa Cruz as kind of like our heart spot, where Tucson lives."*
- Vegetation: *Charles (Tubac) - "If you look around this section of the river you become a tree lover. They're huge, they're beautiful, I love photographing them."*
- Wildlife: *Gary (Tucson) - "I would love to see more of this, what's at Tumacacori… I'd like to see more of the wetlands there, where we can attract back more of the wildlife and birds."*

Santa Cruz Watershed Ecosystem Portfolio Model "SCWEPM"

Water resources planning & change scenarios



Modified Socio-Environmental Vulnerability Index (M-SEVI)



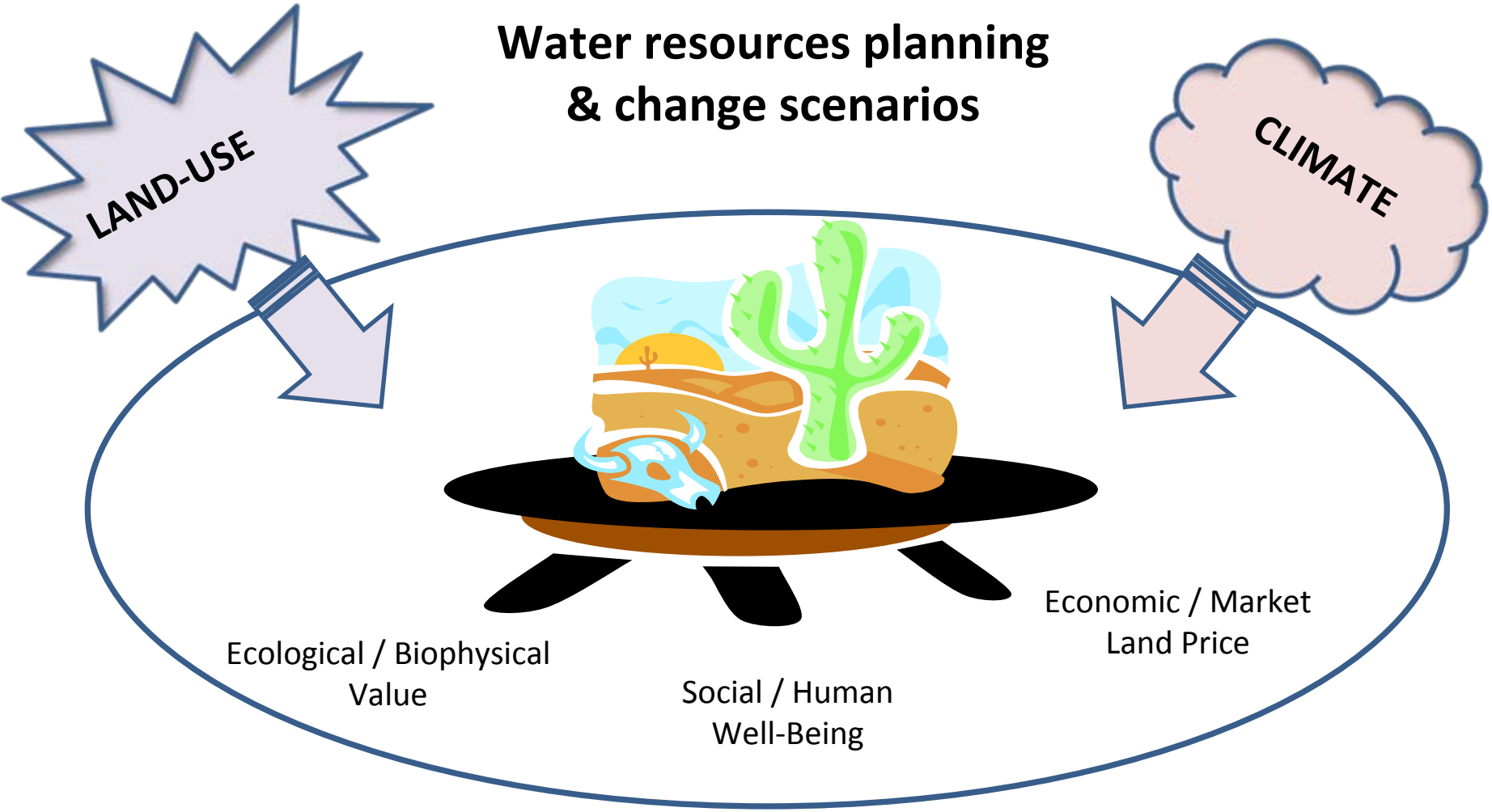
Yellow is low
Red is high

Mexican & U.S. Census Block Groups:

- ❑ *population,*
- ❑ *education,*
- ❑ *access to urban services &*
- ❑ *household assets.*

Santa Cruz Watershed Ecosystem Portfolio Model "SCWEPM"

Water resources planning & change scenarios



SCWEPM→ Impacts of Change

- What are the associated costs and benefits of different management regimes?
- Which ecosystem service is taking the hardest hits?
- Are vulnerable populations becoming more vulnerable?

Diverting effluent to Los Alisos will alter the Santa Cruz River

The Weekly Bulletin

Covering Northeastern Santa Cruz County

HOME | NEWS ▸ | OPINION ▸ | CLASSIFIEDS

Home ▸ The Bulletin ▸ News

Sonora sewage plant has ramifications for SC River

Story | Comments

Share | Print | Font Size

Tweet 0 | Like

Posted: Tuesday, January 18, 2011 11:00 pm

By Dick Kamp
For the Bulletin | 0 comments

Nogales, Sonora is expected to have its own sewage plant by the end of 2012, significantly reducing the flow of treated effluent into the Santa Cruz River north of Rio Rico.

Currently, about 10 million gallons of wastewater flows downhill each day from Nogales, Sonora, and across the border to the Nogales International Wastewater Treatment Plant (NIWTP) in Rio Rico.

But after February 2012, some of that sewage will be pumped about 4 1/2 miles uphill from a compression station before it is sent flowing more than 10 miles downhill to the new Los Alisos plant, said Francisco Gastelum Ceballos, director general of the Nogales,

Sonora sewage plant has ramifications for SC River

A group of dignitaries gets a tour of the Los Alisos sewage treatment plant, currently under construction south of Nogales, Sonora. CONTRIBUTED PHOTO

tp://www.nogalesinternational.com/t...jpg?r=http://www.fordgreenvalley.com

Cronkite News

HOME | ABOUT | STORIES | NEWSWATCH | NEWS21 | CRONKITE | CONTACT

Mexican wastewater treatment plant threatens oasis along Santa Cruz River

Tweet 4 | +1 0 | @

Thursday, March 31, 2011
By CHANNING TURNER
Cronkite News

TUMACACORI – Lined with lush trees and a refuge for wildlife, the Santa Cruz River cuts a 16-mile oasis through the parched landscape near Nogales.

"When you put water and desert together, boy there's something about it that makes it pretty wonderful," said Grant Hilden, a volunteer at the Tumacacori National Historic Park.

Water is a blessing that Hilden knows not to take for granted. Deep wells driven by the area's thirst have historically strained the Santa Cruz's flow, drying it up completely during the 1970s.

A decade later, the river returned in this area, thanks in part to an agreement with Mexico that allows the International Wastewater Treatment Plant in Nogales, Ariz., to pump 15 million gallons per day of treated effluent into the river and sustain it year-round.

Comparing the plants:

International Wastewater Treatment Plant (Nogales, Ariz.):

- Total Capacity: 17.2 million gallons daily (MGD)
- Current Usage: 15 MGD
- Run-over from Mexico: 80 percent or 9.9 MGD (reported at closer to 12.5 MGD at times)

Los Alisos Wastewater Treatment Plant (Nogales, Sonora):

- Initial Capacity: 5 MGD
- Planned Future Capacity: 10 MGD
- Planned Completion: February 2012

Much of that water comes from sewage flowing north across the border, but that will change in February 2012 with the completion of a new wastewater treatment plant in Mexico that will send its effluent into a south-flowing river.

The international agreement allows up to 9.9 million gallons daily from Nogales, Sonora, across the border and, when treated, into the Santa Cruz. In fact, rapid growth has caused the Mexican side to regularly exceed its allotment, reaching an annual average of 12.5 million gallons daily, according to plant certification documents.

But the new Los Alisos plant, under construction about 20 miles south of Nogales, Sonora, will give Mexico the ability to control its own wastewater, including where it's reintroduced into the water table.

Tumacacori, known for its rugged landscape and three Spanish mission ruins, the oldest of which dates back to 1691, depends on the river for its picturesque appeal, Hilden said, adding that less water could hurt the area's aesthetics.

://cronkitenews.asu.edu/assets/images/11/03/31-wastewater_map-full.jpg enjoy it while we can and hope

Search

Wastewater in the Nogales border area

Use this illustrated map to see how current and proposed paths for treated water differ.
Photo by Ashley Slaney

While the many wells in the area made the Santa Cruz River dry up in the 1970s, effluent released by an international wastewater treatment plant in Nogales, Ariz., created a 16-mile-long oasis through Tumacacori.
Photo by Channing Turner

Grant Hilden, a volunteer at the Tumacacori National

What happens when there is no water ?...

BEFORE

AFTER(?)

What *is* the value of the effluent in the Santa Cruz Watershed?

Ecosystem Services

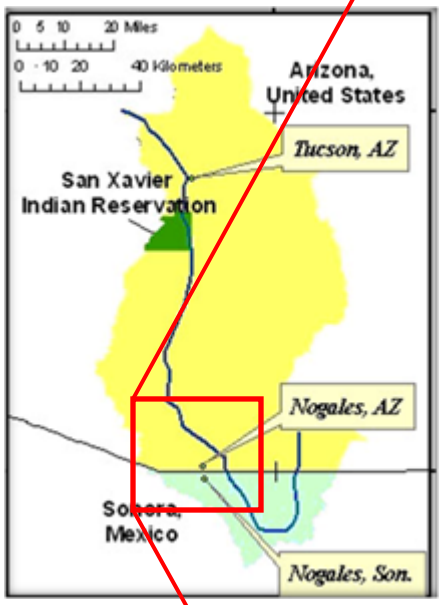
- recharge groundwater
- sustain riparian forests
- carbon sequestration
- habitat for animals
- ecotourism (bird watching)
- scenic areas for recreation
- flood regulation
- erosion control
- channel maintenance
- real-estate value

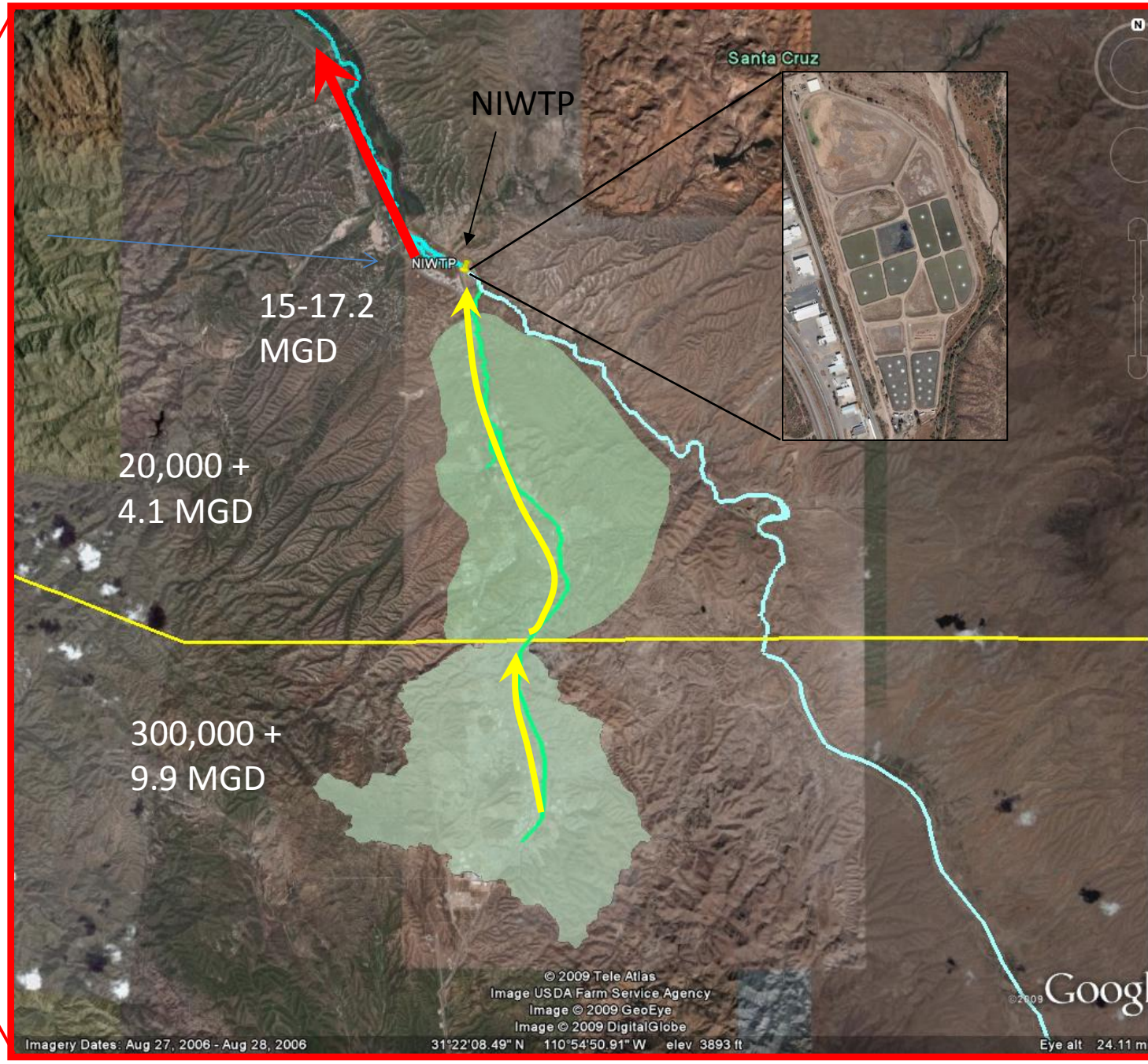
Binational Effluent

Arizona must comply w/ the Groundwater Management Act (GMA) of 1980, which defined **safe yield** to keep the aquifer in balance.

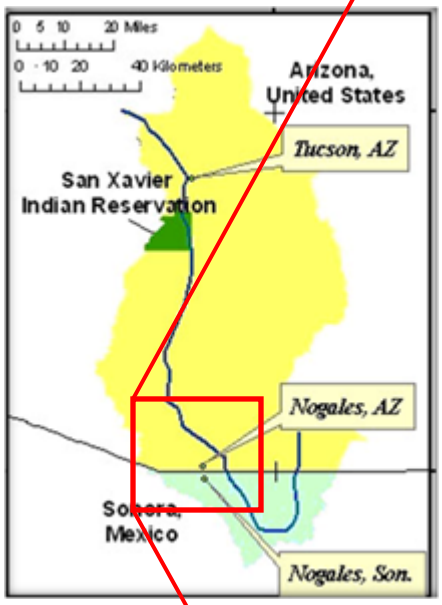
Sonora pays about $350,000 annually for operating costs of treatment at the Rio Rico plant.

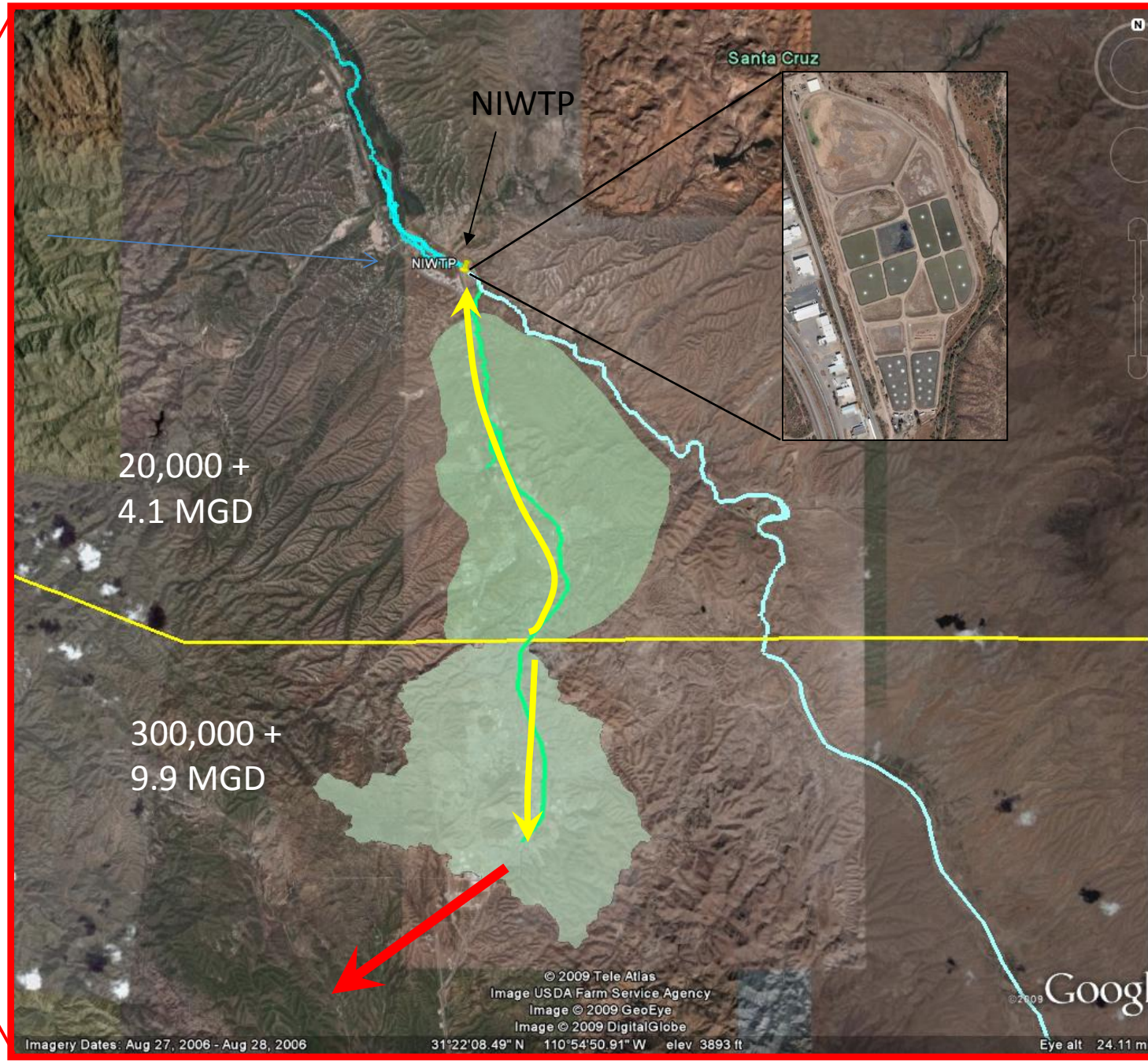
Binational Effluent





Binational Effluent

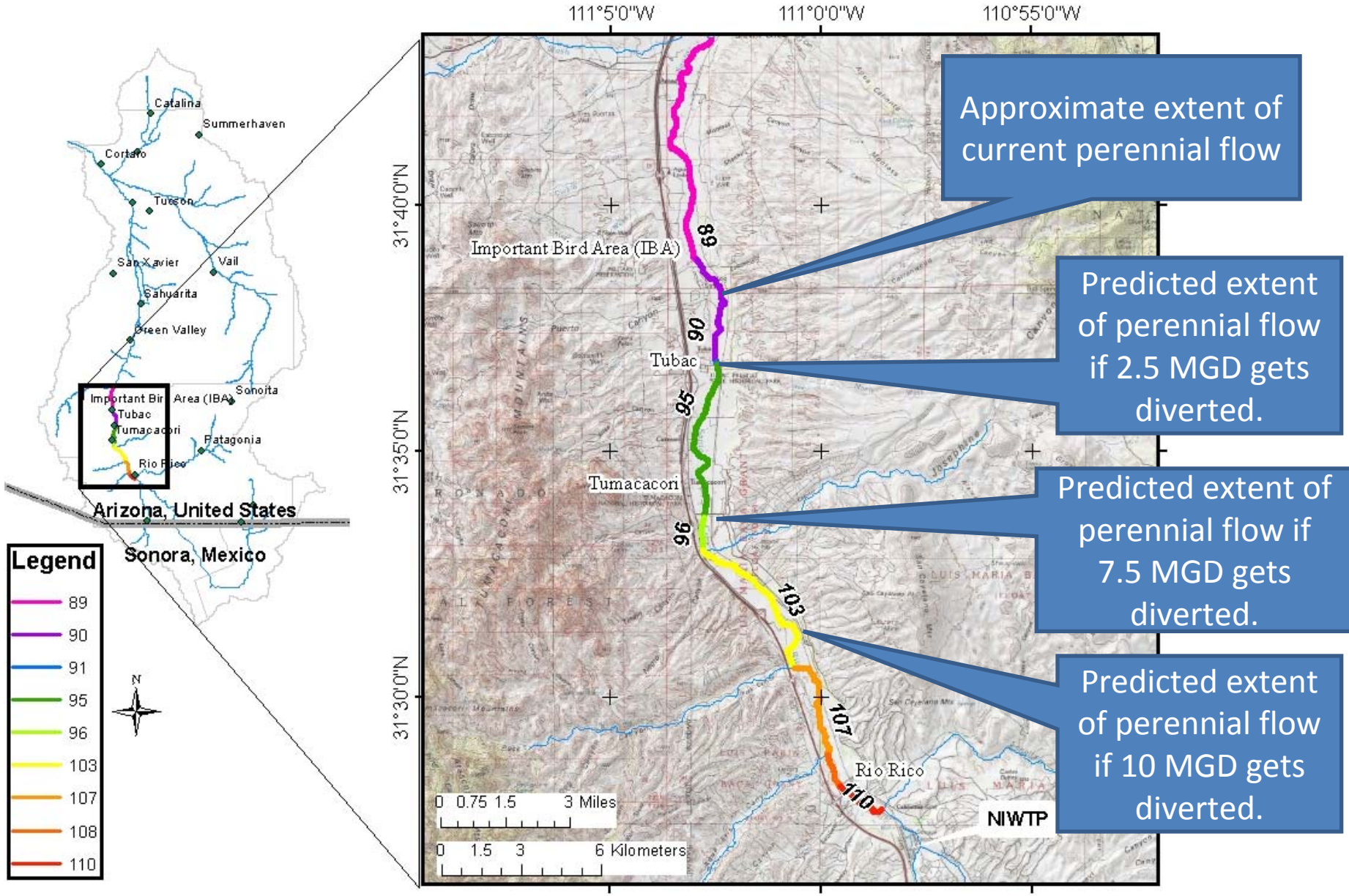


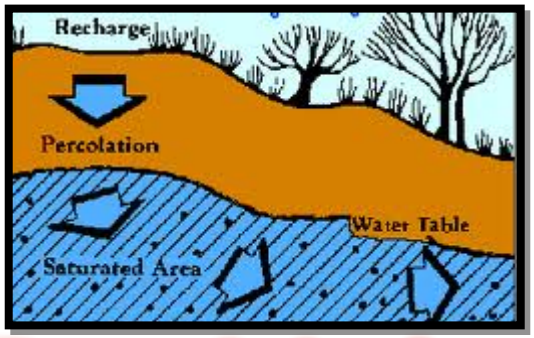


Scenarios of Effluent to be released at NIWTP

- **S.1.) Current = 15 MGD**
- **S.2.) 12.5 MGD** (*2.5 MGD diverted*)
- **S.3.) 10 MGD** (*5 MGD diverted*)
- **S.4.) 7.5 MGD** (*7.5 MGD diverted*)
- **S.5.) 5 MGD** (*10 MGD diverted*)

SWAT Model Prediction of *Perennial Flow*

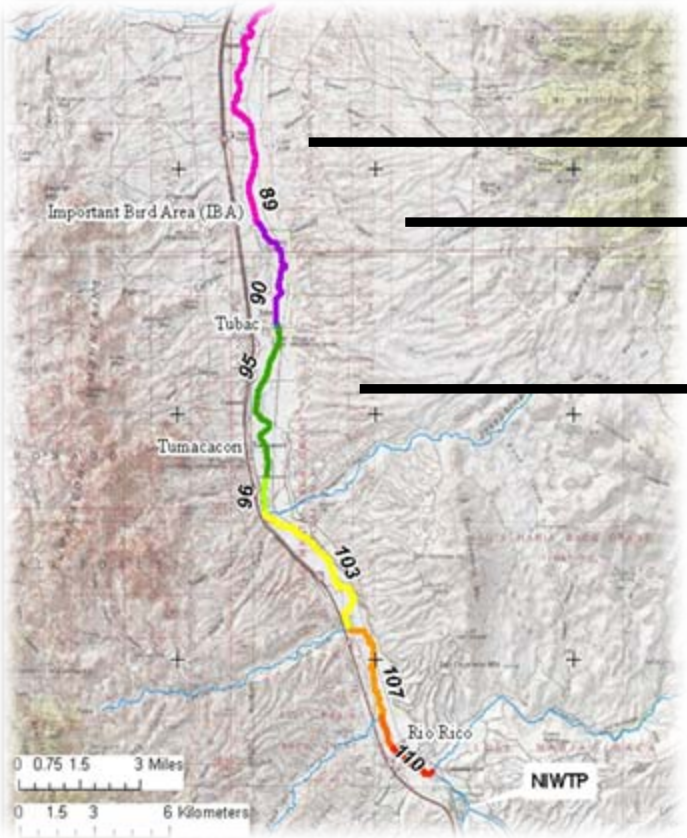


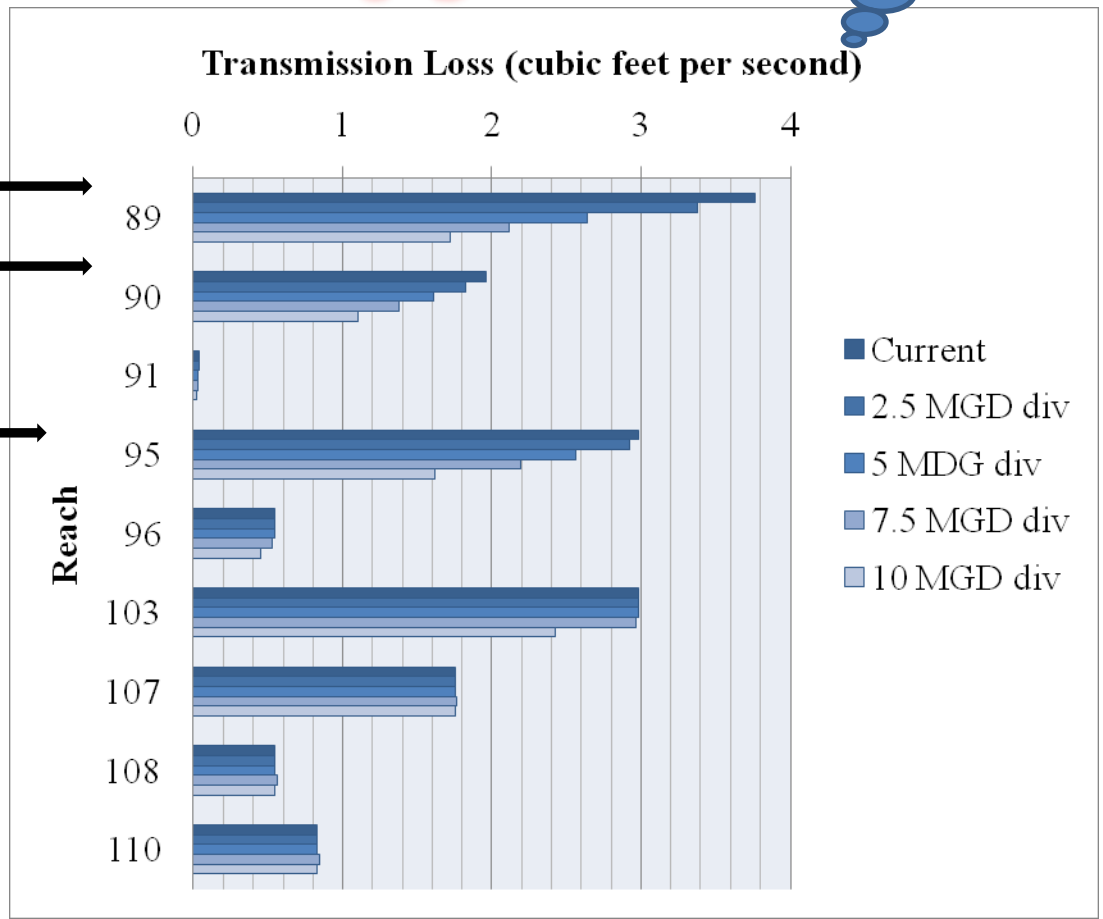


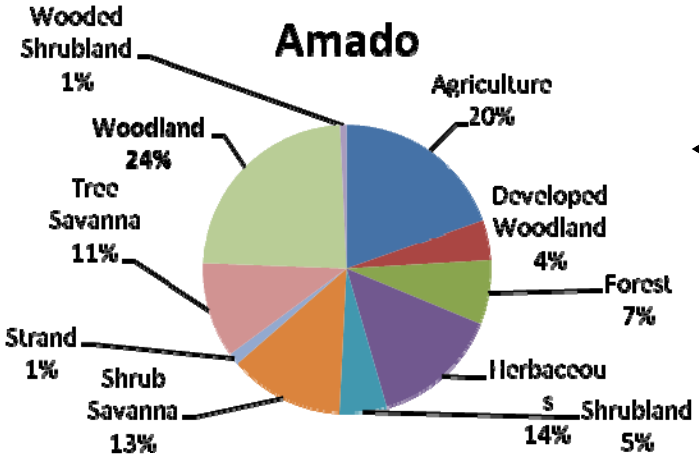
SWAT Model Prediction of *Transmission Loss in the channel*

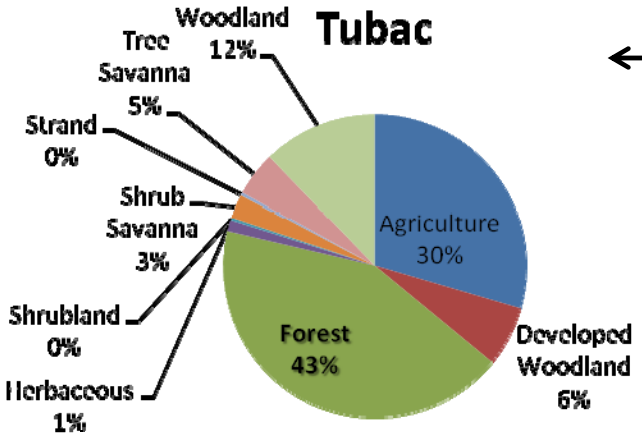
Transmission losses percolate the soil layers & recharge the shallow aquifer

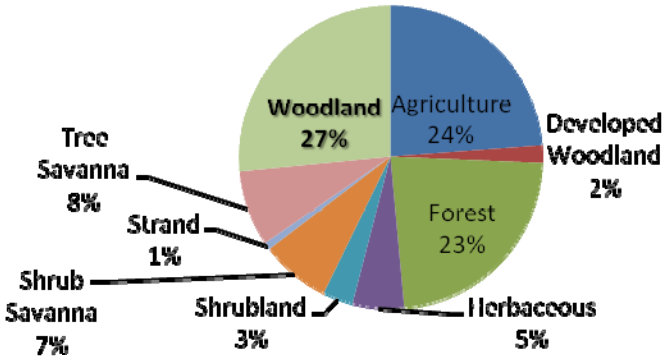
1 cfs = 0.645 MGD = 28.32 lps

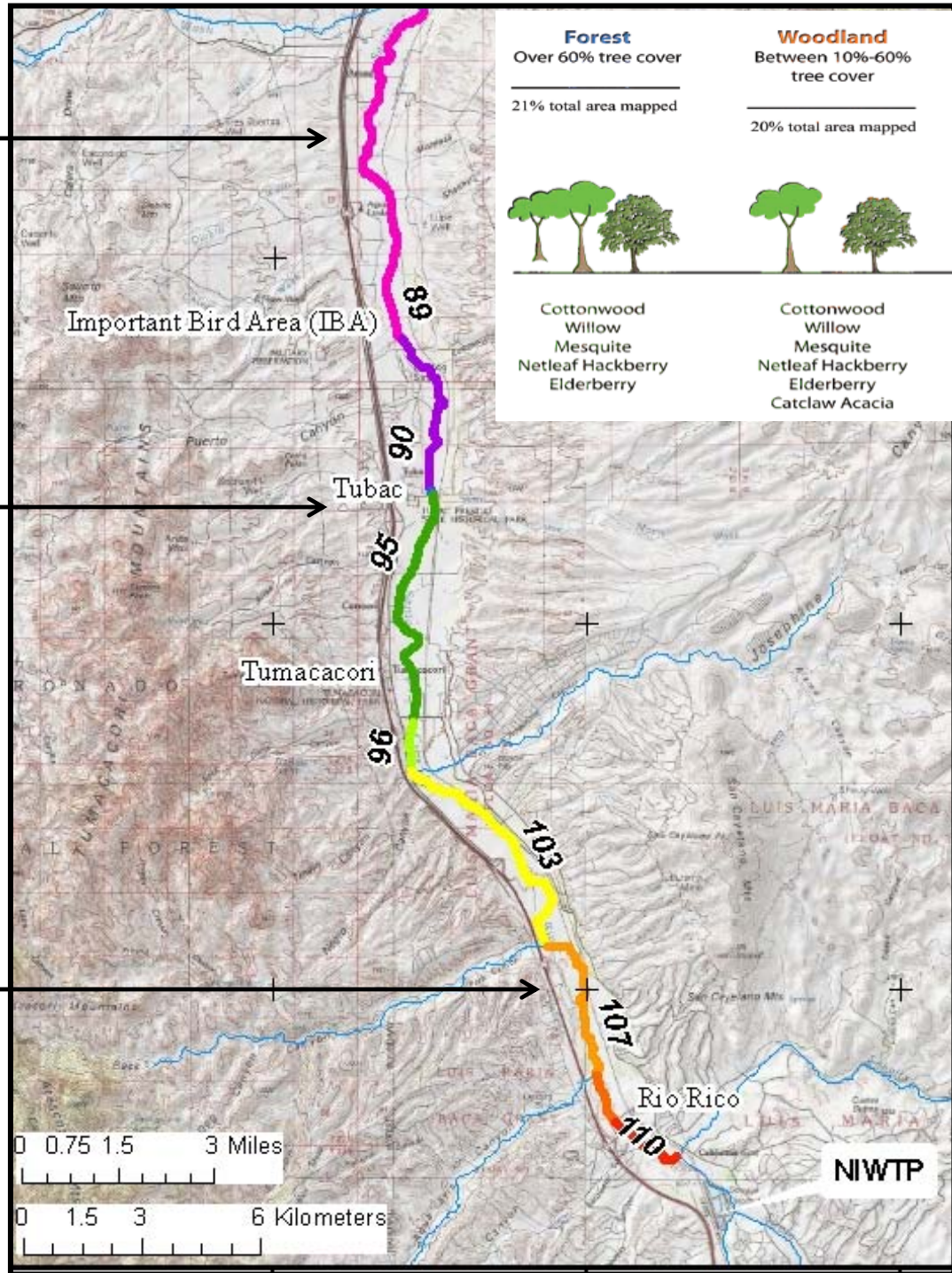





Amado
Wooded Shrubland 1%
Agriculture 20%
Woodland 24%
Developed Woodland 4%
Tree Savanna 11%
Forest 7%
Strand 1%
Herbaceous 14%
Shrub Savanna 13%
Shrubland 5%


Tubac
Woodland 12%
Tree Savanna 5%
Strand 0%
Shrub Savanna 3%
Agriculture 30%
Shrubland 0%
Forest 43%
Developed Woodland 6%
Herbaceous 1%


Rio Rico
Woodland 27%
Agriculture 24%
Tree Savanna 8%
Developed Woodland 2%
Strand 1%
Forest 23%
Shrub Savanna 7%
Shrubland 3%
Herbaceous 5%


Forest
Over 60% tree cover
21% total area mapped
Woodland
Between 10%-60% tree cover
20% total area mapped
Cottonwood
Willow
Mesquite
Netleaf Hackberry
Elderberry
Cottonwood
Willow
Mesquite
Netleaf Hackberry
Elderberry
Catclaw Acacia
Important Bird Area (IBA)
Tubac
Tumacacori
Rio Rico
NIWTP
89
90
95
96
103
107
110
0 0.75 1.5 3 Miles
0 1.5 3 6 Kilometers

Vegetation (Alliance) Sustainability

- ✓ Sites with no effluent are dominated by a *riparian shrub and non-native herbaceous alliances*
- ✓ Sites with effluent since 1972 have a *rapid increase in area of riparian forest and woodland …*

Cottonwoods and Willows need surface flow 76% of the time…

Fremont **cottonwood** (*Populus fremontii*)

* can tolerate fluctuating water tables

Goodding **willow** (*Salix gooddingii*)

* requires permanently available shallow ground water

Habitat Sustainability

Birds

- Loss of water will decrease cottonwood-willow habitat
  - **IBA** designation
  - Neotropical birds
  - Sensitive species (Yellow-billed cuckoo)
  - Nesting birds (Gray hawk)

Fish

- Rely in Perennial and Intermittent flows
  - Mosquitofish (*Gambusia affinis*)
  - Species of Concern: Longfin Dace (*Agosia chrysogaster*)

Humans

- Groundwater supply ~ recharge rates decline
- Real-estate prices ~ decline with riparian forests/biodiversity
- Vulnerable communities ~ less resilient to change

Scenario Analysis

SCENARIO	PERRENIAL SURFACE FLOW	VEGETATION HABITAT	REAL-ESTATE VALUE	VULNERABLE COMMUNITIES	GROUNDWATER RECHARGE
S.1.) 15 MGD to Santa Cruz	18-25 mi.	Riparian corridor forest or woodlands			Recharge estimates from the channel ~11,160 acre feet per year
S.2.) 12.5 MGD to Santa Cruz	16 mi.	IBA riparian zone on Tucson Audubon held conservation easement impacted	Home values ~ 2-9 mi. of riparian area decreased	Highly vulnerable communities at Tubac impacted	Recharge estimates from the channel decrease by **~4% (~428 acre feet per year)**
S.3.) 10 MGD to Santa Cruz	11.5 mi.	IBA riparian zone on Tucson Audubon held conservation easement **AND North of TUMA impacted**	Home values ~ 6-14 mi. of riparian area decreased	Highly vulnerable communities at Tubac **AND Tumacacori impacted**	Recharge estimates from the channel decrease by **~12% (~1,377 acre feet/year)**
S.4.) 7.5MGD to Santa Cruz	10.7 mi.	IBA riparian zone on Tucson Audubon held conservation easement and North of TUMA **AND TUMA impacted**	Home values ~ 8-15 mi. of riparian area decreased	***Same*** highly vulnerable communities at Tubac and Tumacacori impacted	Recharge estimates from the channel decrease **by ~20% (~2,186 acre feet per year)**
S.5.) 5 MGD to Santa Cruz	6.3 mi.	***Same*** IBA riparian zone on Tucson Audubon held conservation easement and North of TUMA and TUMA impacted	Home values ~ 12-19 mi. of riparian area decreased	***Same*** highly vulnerable communities at Tubac and Tumacacori impacted	Recharge estimates from the channel decrease by **~32% (~3,564 acre feet per year)**

*As a rule of thumb in U.S. water management, one acre-foot is taken to be the planned water usage of a suburban family household, annually

Sustainable Water Use

"The mission of the Santa Cruz Active Management Area (SCAMA) is to manage all water resources in the AMA conjunctively, to assure a reliable water supply for current and future uses, and to protect aquatic and riparian habitat while sustaining a healthy economy."

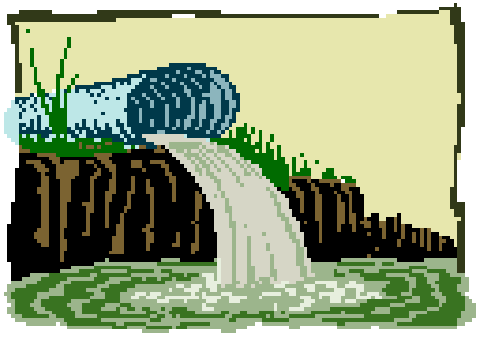
What is the Price of Water?

→*If the goal is to achieve safe-yield* in the Santa Cruz Active Management Area (SCAMA), this could be done via conservation requirements, water-harvesting, inter-basin transfers, selling agricultural rights, etc.

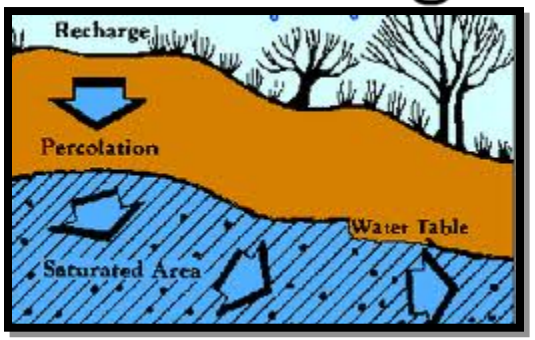
**Evaluating substitutes requires understanding the replacement value:

a. In Lake Havasu City last year, the City Council raised the effluent water rate from **$52 per-acre-foot** charge to roughly **$144 per-acre-foot [in 2011]** and it is expected to increase to about **$330 per-acre-foot in 2014**.
b. According to the Lower Colorado River Authority (2012), the current annual rate for domestic water is **$151 per acre-foot of water**, based on the current firm raw water rate typically charged to municipal and industrial customers.
c. Tucson Water currently pays **$122 per-acre-foot** for CAP-water based upon the Municipal and Industrial Rate charged by CAP for FY 2012. The FY 2013 rate will be **$129 per-acre-foot**. Tucson Water also pays a Capital Rate charged for Municipal and Industrial contracts at **$15 per-acre-foot**. So in FY13, Tucson Water will pay **$144 per acre-foot** of CAP water.

Total water accounting v. Aquifer accounting



Pipe v. Ground

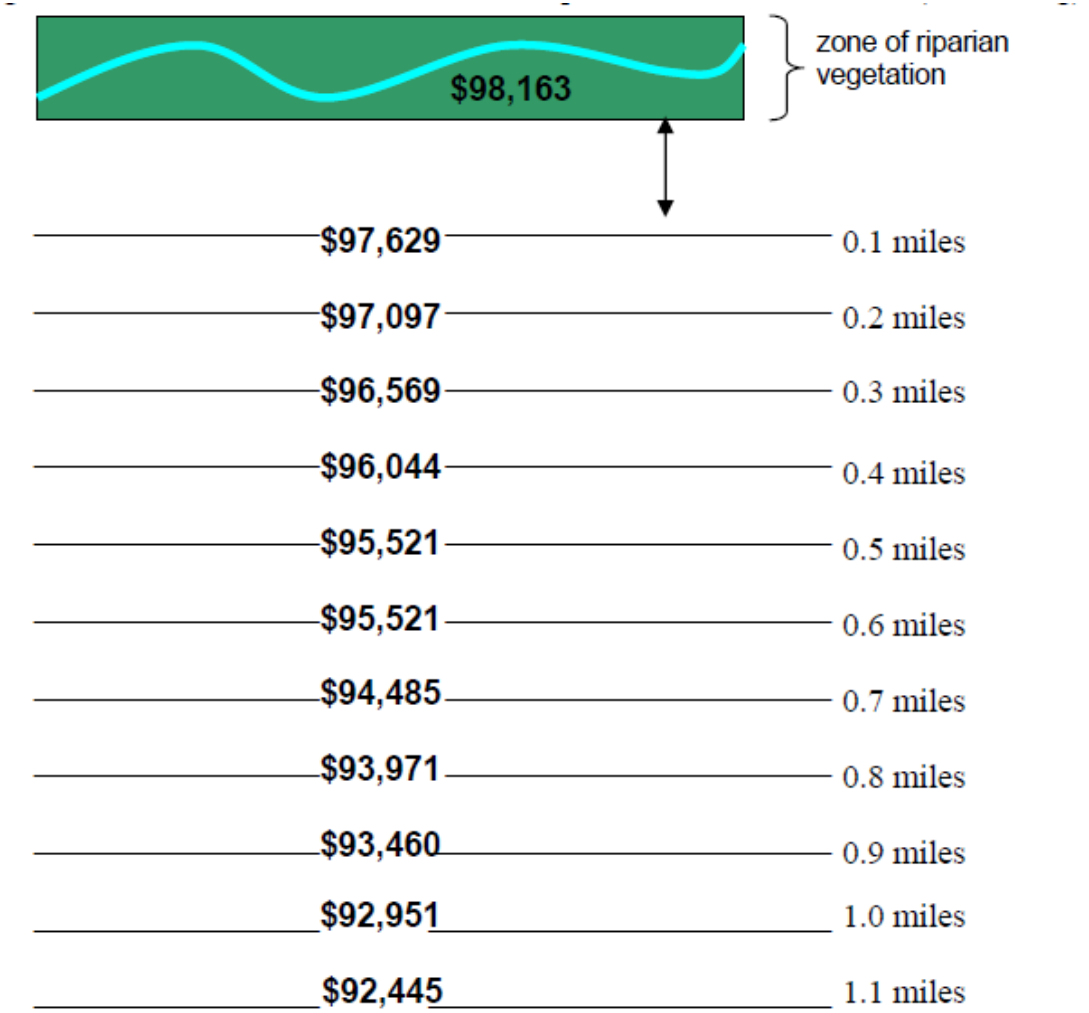


Scenarios	Water Discharged at the NIWTP Outfall	Dollar value of treated effluent at outfall/year*	Dollar value difference from current scenario of treated effluent at outfall/year*	Water Percolating to the SCAMA Aquifers derived by SWAT SCWEPM	Dollar value of water recharging the SCAMA Aquifers/year*	Dollar value difference from current scenario to recharge SCAMA Aquifers/year*
S.1	15 MGD	$2.42 MIL		11,160 acre-ft/yr	$1.6 MIL	
S.2	12.5 MGD	$2.02 MIL	($403 K)	10,732 acre-ft/yr	$1.55 MIL	($62 K)
S.3	10 MGD	$1.61 MIL	($807 K)	9,783 acre-ft/yr	$1.4 MIL	($198 K)
S.4	7.5 MGD	$1.21 MIL	($1.21 MIL)	8,974 acre-ft/yr	$1.29 MIL	($315 K)
S.5	5 MGD	$807 K	($1.61 MIL)	7,596 acre-ft/yr	$1.1 MIL	($513 K)

***Where $144 per acre-foot of water (325,851 gallons)**

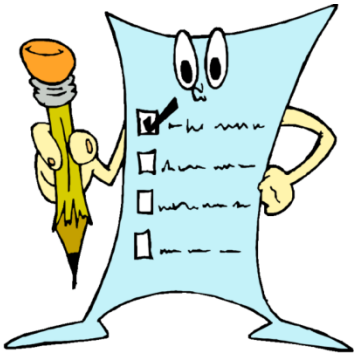
Effect of distance to Santa Cruz River Riparian Corridor on Value of representative Rio Rico Home

Homes within 1.1 miles of riparian vegetation, received an average price premium of 3.1% with premiums ranging as high as 5.8%.



*One story house, 6 years old, parcel size 36,363 square feet, 6 bathroom fixtures, 163 square feet of living area, 2 car garage, distance to nearest golf course is greater than 0 miles (0.5 used in calculation),

Willingness to Pay (WTP) for Binational Effluent



→A contingent valuation (CV) survey of visitors to Tumacacori National Historic Park & Tubac Presidio State Park was used to obtain estimates of WTP to maintain the Upper Santa Cruz riparian corridor, per respondent:

» Mean = $71.

» Median (*50th percentile*) = $30

» Mode (*most common*) = $50.

→The WTP measure for the Santa Cruz is about 20% less than for the other rivers.

AMC Action Item

Capture/model the "net benefit" of effluent per acre-foot.

Description of Action Item:

•Identify datasets at committee's disposal to improve the functionality of the model for the Santa Cruz River (i.e. water quality monitoring results can generate a more accurate economic value of the river for the region).

Target Completion Date: June 2013

Tactic A: Identify missing environmental quality datasets to include in the model.

Tactic B: Incorporate missing datasets and update the model.

- Real estate impact of shifting riparian zone (based on assessed premiums)
- Potable water provisioning (quality)
- Ecotourism (bird watching)
- Scenic areas for recreation /qualitative
- Non-use /existence value (WTP)

Future: Scenarios & Tradeoffs

- Mine developments
- Urbanization
- Climate Change

ARIZONA-MEXICO COMMISSION

ACKNOWLEDGEMENTS

This project is funded by:

USGS Geographic Analysis and Monitoring (GAM) Program;
USGS U.S.-Mexico Border Environmental Health Initiative (BEHI); &
US EPA's Ecosystem Services Research Program (ESRP)

Agencies and partners:

USGS (Bill Labiosa, Miguel Villarreal, James Callegary, David Strong, Mark Feller, Cynthia Wallace, Floyd Gray, Nicholas Paretti, Charles van Riper, Rachel Sleeter, Silvia Wilson, Diana Papoulias, and Jean Parcher);
US EPA (Matt Weber, Yongping Yuan, Wenming Nie, and John Lin);
US NPS, Tumacacori National Historical Park (Jeremy Moss & Jason Welborn);
Tohono O'Odham Nation, San Xavier District (Austin Nunez, & Scott Rogers);
Arizona State University (Francisco Lara-Valencia);
University of Arizona (George Frisvold, Tom Meixner, Rewati Niraula, Gaurov Arora, Felipe Caldeira, Gladys Amaya, Katie Hirschboeck, Sandy Dall'erba, Laura López-Hoffman, Phil Guertin, Francina Dominguez, Amy McCoy, and Chris Scott);
New Mexico State University (Ken Boykin)
Arizona Department of Environmental Quality (Hans Huth and Jose Rodriguez);
Instituto Municipal de Investigación y Planeacíon (Claudia Gil Anaya, Edgar Castellanos, Edgar Tepezano);
Sonoran Institute (Emily Brott and Claire Zugmeyer);
Friends of the SCR (Sherry Sass and Ben Lomeli).

Thank you

- George Frisvold
- Hans Huth
- Rewati Niraula
- Miguel Villarreal
- Matt Weber
- Tom Meixner
- Gaurav Arora
- Bill Labiosa

Laura M. Norman, PhD
U.S. Geological Survey, Western Geographic Science Center
520 N. Park Avenue, Suite #102K, Tucson, AZ 85719-5035
Phone: (520) 670-5510; Fax: (520) 670-5113; lnorman@usgs.gov

http://geography.wr.usgs.gov/science/ecoSevicesSCWatershed.html

en Espanol: http://geography.wr.usgs.gov/science/ecoSevicesSCWatershedSp.html