REGIONAL WATER QUALITY NEWSLETTER

DATE: Report for June 2007
Samples Collected on June4-5, 2007
From the Phoenix, Tempe, Peoria, CAP, SRP – ASU Regional Water Quality Partnership

http://enpub.fulton.asu.edu/pwest/tasteandodor.htm

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SUMMARY: EVALUATION AND RECOMMENDATIONS

1. MIB concentrations are only above 10 ng/L in the Verde River system. It is possible that the Verde WTP could be having MIB concentrations approaching 10 ng/L (a common odor threshold level for consumers) if PAC is not being applied.
2. Geosmin concentrations have been reduced significantly in Saguaro lake from > 200 ng/L in May to 10 ng/L in June this year.
3. Tempe South WTP and Peoria WTP contain total dissolved nitrogen levels higher than other WTPs because of groundwater pumping by SRP into canals. This groundwater contains nitrate.
4. Slides for a presentation by an ASU faculty (Prof. Neuer) on using satellites to monitor algae in Arizona reservoirs is presented.
5. A draft report on modeling water and salt fluxes through the City of Scottsdale water infrastructure is reported.

Table 1 Summary of WTP Operations

	Union Hills	24th Street WTP	N.Tempe J.G. Martinez	Deer Valley	Greenway WTP	Val Vista	South Tempe	Chandler WTP
Location	**CAP**	**Arizona Canal System**				**South Canal System**		
PAC Type and Dose		Norit 20B 10 ppm		Norit 20B 17 ppm	None	Norit 20 B 10 ppm	None	No
Copper Sulfate		None		None	None	0.25 ppm	None	
PreOxidation		none		none	1.7 mg/L ozone	0.2-0.5 ppm on top of filters	None	
Alum Dose Alkalinity pH		45 142/114 6.75		43 148/108 8.1 / 6.9	30 146 7.35	65 110 7.0	14 170 7.73	
Finished water DOC DOC removal[2]	2.4 mg/L 17%	2.84 mg/L 35%	3.5 15%	3.03 mg/L 39%	2.35 mg/L 35%	2.6 mg/L 36%	1.7 mg/L 17%	
WTP plant comments		Some dead algae built-up on raw water barscreen						

[1] **Ferric chloride instead of alum**
[2] Calculated based upon influent and filtered water DOC (note that DOC – not TOC – is used in this calculation)
[3] Also adding 4.4 mg/L floc aid

Table 2 - Water Treatment Plants – June 4, 2007

Sample Description	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
Verde WTP Inlet (assumed same as Verde River at Beeline Bridge)	**10**	**5.2**	**<2**
24th Street WTP Inlet	**<2.0**	**<2.0**	**<2.0**
24th Street WTP Treated	**<2.0**	**<2.0**	**<2.0**
Deer Valley Inlet	**3.9**	**2.7**	**<2.0**
Deer Valley WTP Treated	**<2.0**	**2.4**	**<2.0**
Val Vista Inlet	**<2.0**	**<2.0**	**<2.0**
Val Vista WTP Treated –East	**<2.0**	**<2.0**	**<2.0**
Val Vista WTP Treated -West	**<2.0**	**<2.0**	**<2.0**
Union Hills Inlet	**<2.0**	**2.0**	**<2.0**
Union Hills Treated	**<2.0**	**2.1**	**<2.0**
Tempe North Inlet	**3.0**	**2.5**	**3.8**
Tempe North Plant Treated	**3.5**	**2.9**	**<2.0**
Tempe South WTP	**<2.0**	**2.1**	**<2.0**
Tempe South Plant Treated	**2.7**	**5.1**	**<2.0**
Tempe South Plant Treated (Lab)			
Greenway WTP Inlet	**<2.0**	**<2.0**	**<2.0**
Greenway WTP Treated	**<2.0**	**<2.0**	**<2.0**

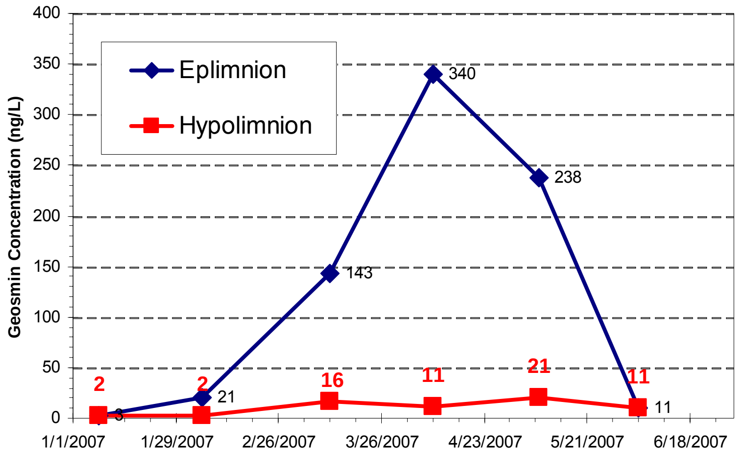
Table 3 - Canal Sampling – June 4, 2007

System	Sample Description	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
CAP	Waddell Canal	**<2.0**	**<2.0**	**<2.0**
	Union Hills Inlet	**<2.0**	**2.0**	**<2.0**
	CAP Canal at Cross-connect	**<2.0**	**<2.0**	**<2.0**
AZ Canal	Salt River @ Blue Pt Bridge	**<2.0**	**<2.0**	**<2.0**
	Verde River @ Beeline	**10.0**	**5.2**	**<2.0**
	AZ Canal above CAP Cross-connect	**3.8**	**2.8**	**4.1**
	AZ Canal below CAP Cross-connect	**<2.0**	**<2.0**	**2.7**
	AZ Canal at Highway 87	**3.5**	**3.2**	**<2.0**
	AZ Canal at Pima Rd.	**<2.0**	**<2.0**	**3.9**
	AZ Canal at 56th St.	**3.5**	**4.1**	**<2.0**
	AZ Canal - Inlet to 24th Street WTP	**<2.0**	**<2.0**	**<2.0**
	AZ Canal - Central Avenue	**4.0**	**3.0**	**<2.0**
	AZ Canal - Inlet to Deer Valley WTP	**3.9**	**2.7**	**<2.0**
	AZ Canal - Inlet to Greenway WTP	**<2.0**	**<2.0**	**<2.0**
South and Tempe Canals	South Canal below CAP Cross-connect	**4.7**	**3.3**	**<2.0**
	South Canal at Val Vista WTP	**<2.0**	**<2.0**	**<2.0**
	Head of the Tempe Canal	**<2.0**	**2.1**	**<2.0**
	Tempe Canal - Inlet to Tempe's South Plant	**<2.0**	**2.1**	**<2.0**
	Chandler WTP – Inlet			

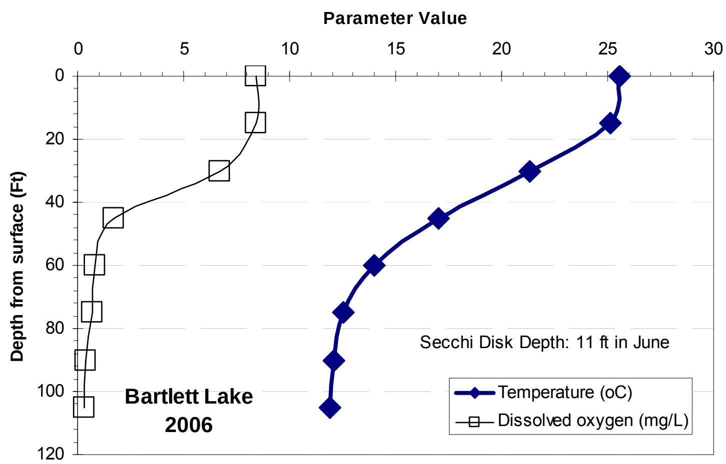
Table 4 - Reservoir Samples – June 4, 2007

Sample Description	Location	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
Lake Pleasant (June 5, 2007)	Eplimnion	<2.0	<2.0	<2.0
Lake Pleasant	Hypolimnio	<2.0	<2.0	<2.0
Verde River @ Beeline		10.0	5.2	<2.0
Bartlett Reservoir	Epilimnion	13.3	<2.0	<2.0
Bartlett Reservoir	Epi-near dock	15.7	<2.0	<2.0
Bartlett Reservoir	Hypolimnio	<2.0	<2.0	<2.0
Salt River @ BluePt Bridge		<2.0	<2.0	<2.0
Saguaro Lake	Epilimnion	<2.0	10.5	<2.0
Saguaro Lake	Epi - Duplicate	<2.0	10.8	<2.0
Saguaro Lake	Epi-near doc	<2.0	9.6	<2.0
Saguaro Lake	Hypolimnio	<2.0	2.6	<2.0
Verde River at Tangle (May 30, 2007)		<2.0	3.3	6.7
Havasu (June 5, 2007)		<2.0	<2.0	<2.0

The figure below illustrates the trend for Geosmin concentrations in Saguaro Lake this year. The eplimnion (operationally defined here as the top 10 m of the water surface depth when the reservoir is not thermally stratified) had geosmin levels over 300 ng/L. However, this tended not to affect geosmin concentrations, to the same degree, in water leaving the reservoir through hypolimnetic release (water exits Saguaro Lake via an outlet near the downstream – bottom of the lake). Thus what happens in the surface of the lake does not always affect water delivered downstream to water treatment plants. This is especially important to keep in mind, because sometimes local newspapers report fish-kills in Saguaro Lake – mostly resulting from algal toxins in the epilmnion of the lake.



As an example of lake stratification, below are plots of water temperature with depth. As usual we observe development of a strong thermal profile in Bartlett Lake, which is typical of reservoirs. Along with a thermal gradient is a dissolved oxygen profile which indicates that biological activity in the reservoir depths is consuming oxygen. However, in Saguaro Lake a weaker stratification exists because of how upstream Salt River reservoirs operate. While Saguaro Lake has a weak thermal gradient the dissolved oxygen does show a strong gradient, with supersaturation of oxygen near the surface probably due to production of oxygen by the photosynthetic algae. The low dissolved oxygen with depth implies that cellular debris from the top of the lake settles into the deeper parts of the lake to fuel biological degradation of the material, and at the same time could be degrading compounds like geosmin (see previous page)



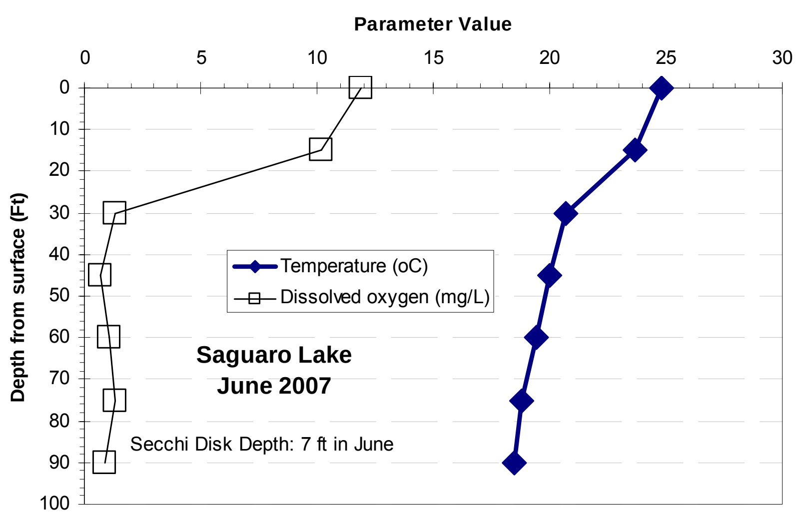


Table 5 - SRP/CAP OPERATIONS
Values in cfs, for June 4, 2007

System	SRP Diversions	CAP
Arizona Canal	765	195
South Canal	475	43
Pumping	249	0
Total	1489	238

SRP is releasing water from both Verde and Salt River Systems. Salt River release from Saguaro Lake: 1013 cfs; Verde River release from Bartlett Lake: 139 cfs.

Table 6 - Water Treatment Plants – June 4, 2007

Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA	TDN
24th Street WTP Inlet	4.39	0.087	2.0	0.4906
24th Street WTP Treated	2.84	0.041	1.4	0.362
Deer Valley Inlet	4.29	0.086	2.0	0.453
Deer Valley WTP Treated	3.03	0.046	1.5	0.3796
Val Vista Inlet	4.22	0.0914	2.17	0.4269
Val Vista WTP Treated –East	2.54	0.0352	1.39	0.3377
Val Vista WTP Treated -West	2.79	0.0392	1.41	0.3999
Union Hills Inlet	2.88	0.042	1.44	0.544
Union Hills Treated	2.40	0.020	0.84	0.5326
Tempe North Inlet	4.13	0.086	2.08	0.4271
Tempe North Plant Treated	3.51	0.060	1.71	0.4345
Tempe South WTP	1.39	0.0246	1.76	2.014
Tempe South Plant Treated	1.29	0.0202	1.57	2.258
Greenway WTP Inlet	3.54	0.074	2.1	0.9352
Greenway WTP Treated	2.35	0.023	1.0	1.452

DOC = Dissolved organic carbon
UV254 = ultraviolet absorbance at 254 nm (an indicator of aromatic carbon content)
SUVA = UV254/DOC
TDN = Total dissolved nitrogen (mgN/L)

Table 7 - Canal Sampling – June 4, 2007

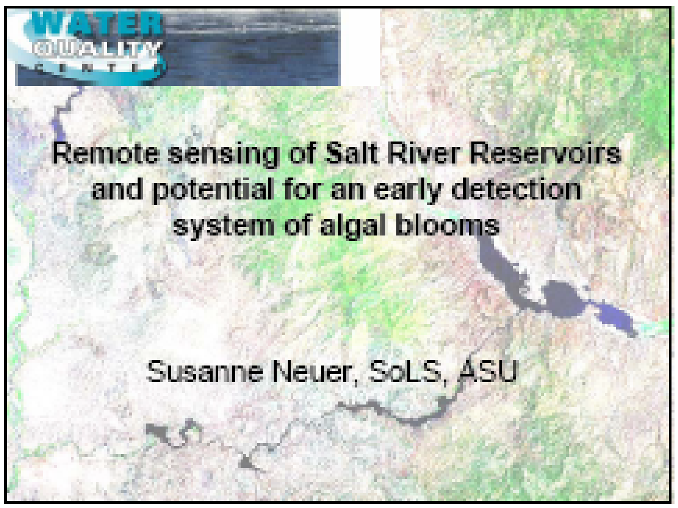
System	Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA	TDN
CAP	Waddell Canal	2.98	0.0450	1.51	0.4788
	Union Hills Inlet	2.88	0.0416	1.44	0.544
	CAP Canal at Cross-connect	2.94	0.0431	1.47	0.5865
AZ Canal	Salt River @ Blue Pt Bridge	4.83	0.0980	2.03	0.4294
	Verde River @ Beeline	2.04	0.0601	2.95	0.4137
	AZ Canal above CAP Cross-connect	4.52	0.0939	2.08	0.3451
	AZ Canal below CAP Cross-connect	3.99	0.0751	1.88	0.4406
	AZ Canal at Highway 87	4.14	0.0811	1.96	0.473
	AZ Canal at Pima Rd.	4.24	0.0837	1.97	0.441
	AZ Canal at 56th St.	4.27	0.0881	2.06	0.412
	AZ Canal - Inlet to 24th Street WTP	4.39	0.0867	1.97	0.491
	AZ Canal - Central Avenue	4.26	0.0845	1.98	0.412
	AZ Canal - Inlet to Deer Valley WTP	4.29	0.0865	2.01	0.453
	AZ Canal - Inlet to Greenway WTP	3.54	0.0737	2.08	0.935
South and Tempe Canals	South Canal below CAP Cross-connect	4.40	0.0924	2.10	0.382
	South Canal at Val Vista WTP	4.22	0.0914	2.17	0.427
	Head of the Tempe Canal	3.64	0.0736	2.02	0.965
	Tempe Canal - Inlet to Tempe's South Plant	1.39	0.0246	1.76	2.014
	Chandler WTP – Inlet				

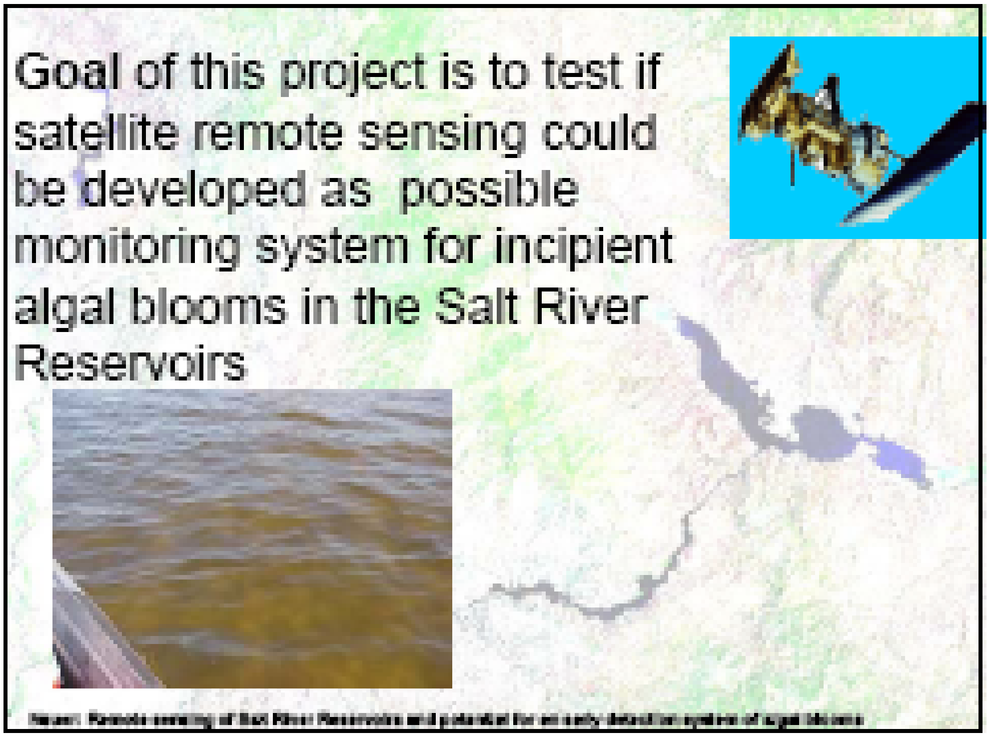
Table 8 - Reservoir Samples – June 4, 2007

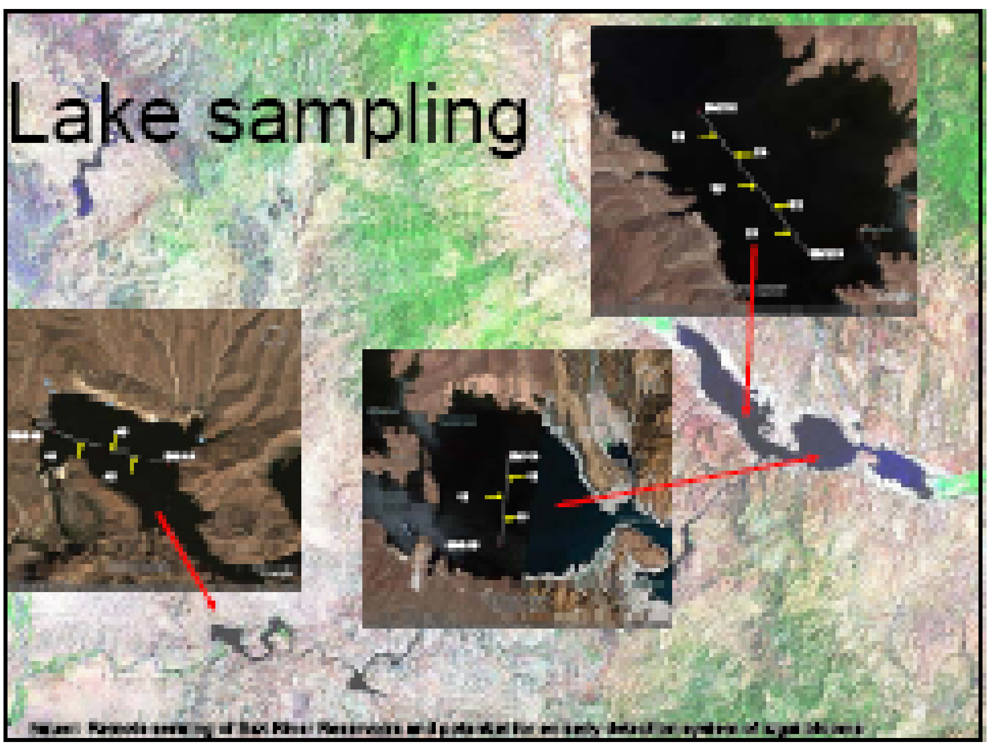
Sample Description	Location	DOC (mg/L)	UV254 (1/cm)	SUVA	TDN
Lake Pleasant	Eplimnion	3.62	0.0452	1.25	0.305
Lake Pleasant	Hypolimnio	3.67	0.0447	1.22	0.270
Verde River @ Beeline		2.04	0.0601	2.95	0.414
Bartlett Reservoir	Epilimnion	2.14	0.0357	1.67	0.251
Bartlett Reservoir	Epi-near dock				
Bartlett Reservoir	Hypolimnio	1.82	0.0418	2.30	0.225
Salt River @ BluePt Bridge		4.83	0.0980	2.03	0.429
Saguaro Lake	Epilimnion	5.15	0.0952	1.85	0.411
Saguaro Lake	Epi - Duplicate	5.20	0.0937	1.80	0.362
Saguaro Lake	Epi-near doc				
Saguaro Lake	Hypolimnio	5.27	0.0984	1.87	0.584
Verde River at Tangle		0.99	0.0464	4.68	0.138
Havasu		2.73	0.0428	1.57	0.668

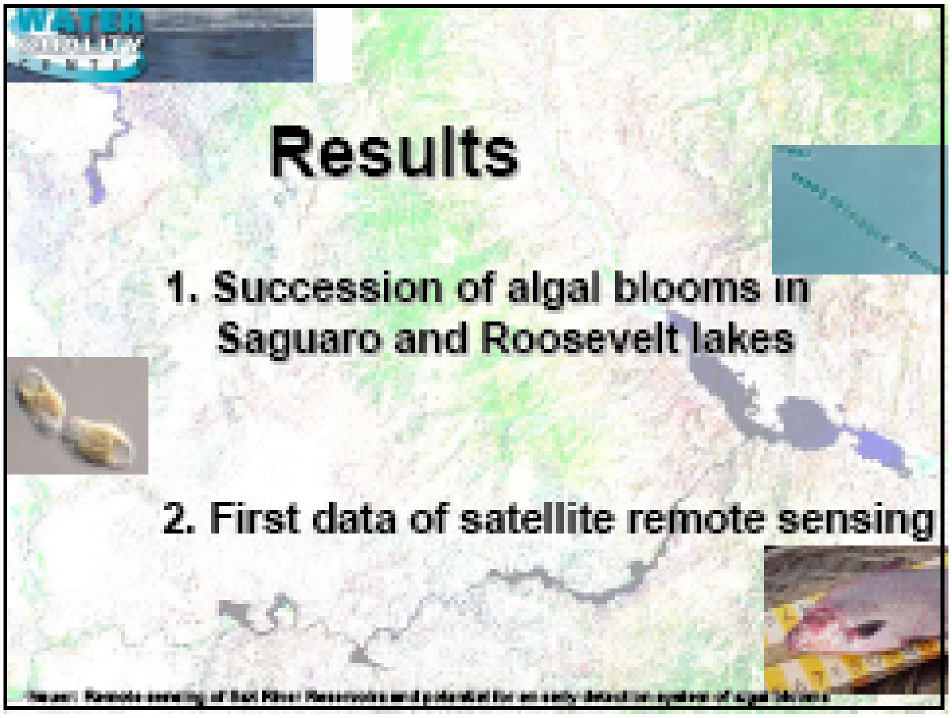
Special Quest Contribution

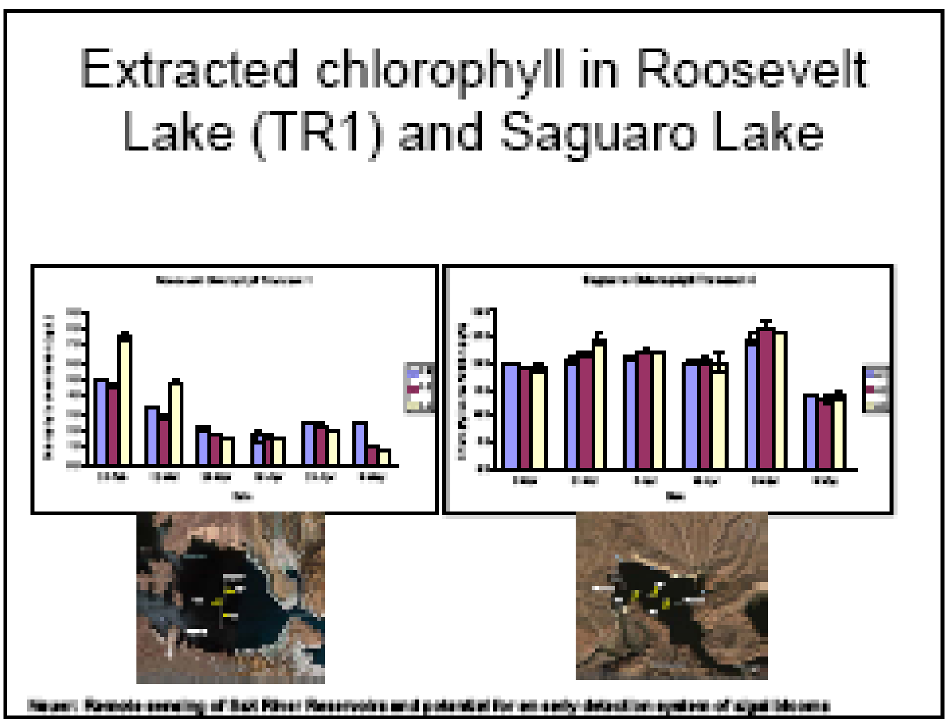
Prof. Susanne Neuer has a small ongoing project funded through the ASU Water Quality Center, a National Science Foundation Industrial-University Collaborative Research Center (http://wqc.asu.edu/) to investigate the use of remote satellite sensing to monitor algae growth in Arizona Reservoirs. The project is only 9-months in duration, but has already yielded great results. The following slides were presented at the May 2007 Water Quality Center meeting. Satellite monitoring of water quality in the reservoirs is very promising, and her team is seeking continued financial support for this project. Please contact Prof. Neuer (Susanne.Neuer@asu.edu) with comments, questions or interest in being part of this project. We are considering using field data collected by the Regional T&O project to validate satellite images back to 2002. Feel free to contact Profs. Westerhoff (p.westerhoff@asu.edu) or Abbaszadegan (Morteza.Abbaszadegan@asu.edu) for more details about the Water Quality Center and our next meeting at ASU in November 2007.

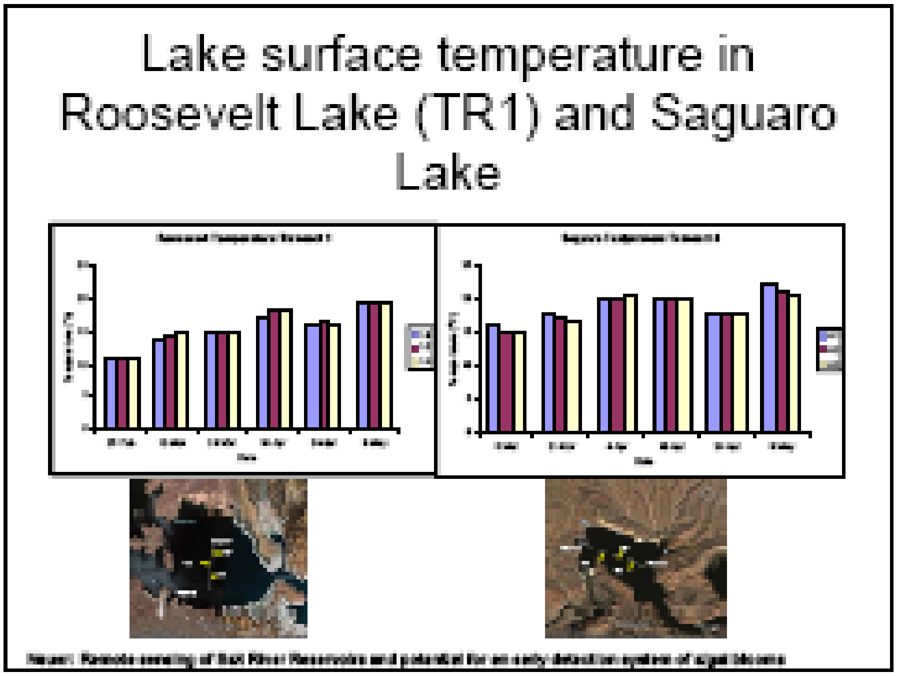


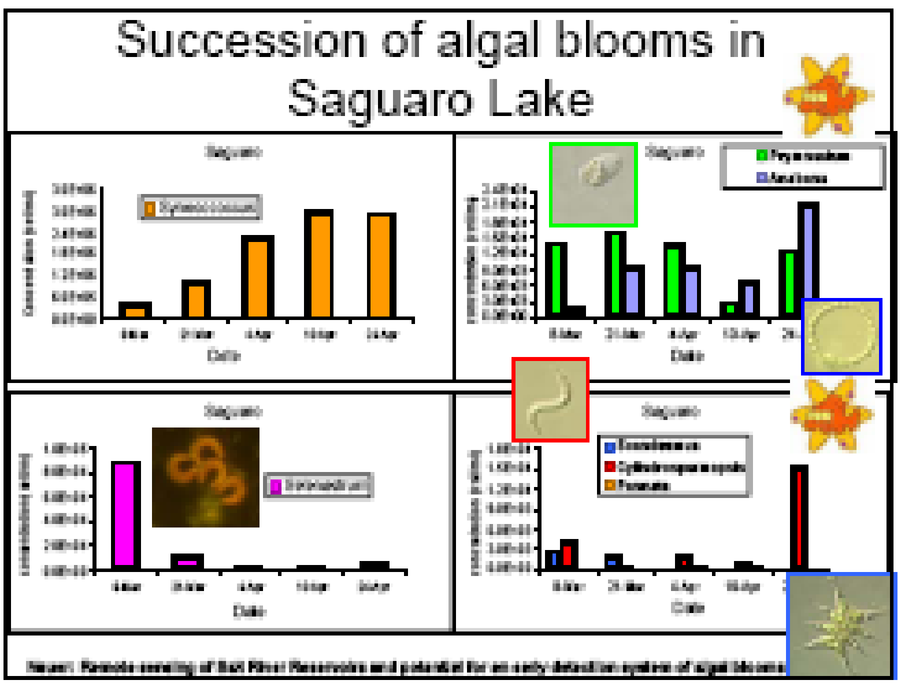

Goal of this project is to test if satellite remote sensing could be developed as possible monitoring system for incipient algal blooms in the Salt River Reservoirs

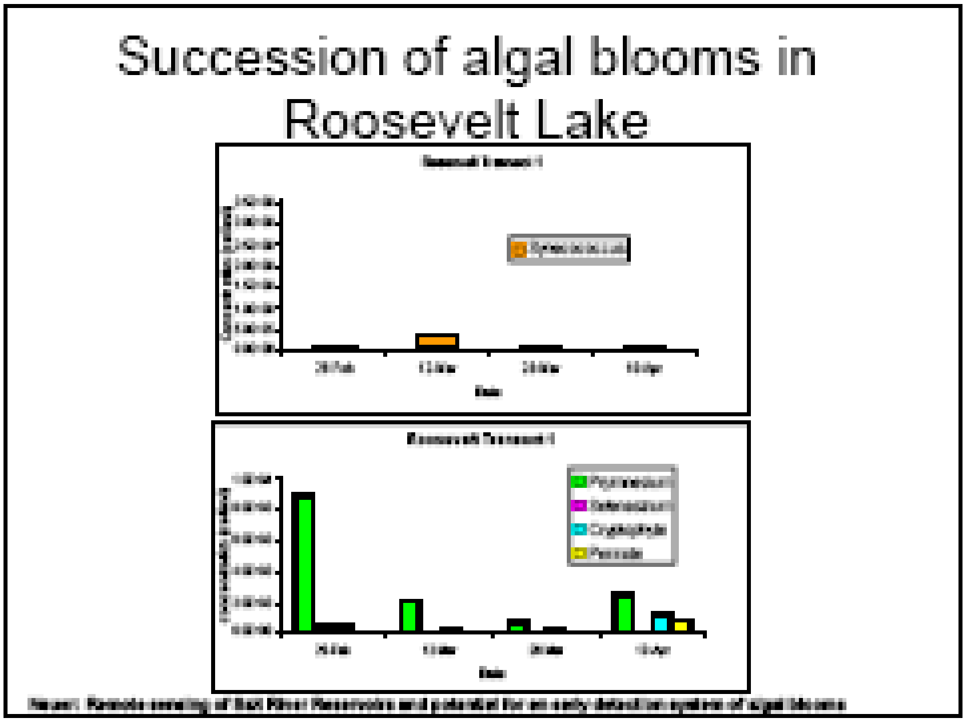

Lake sampling

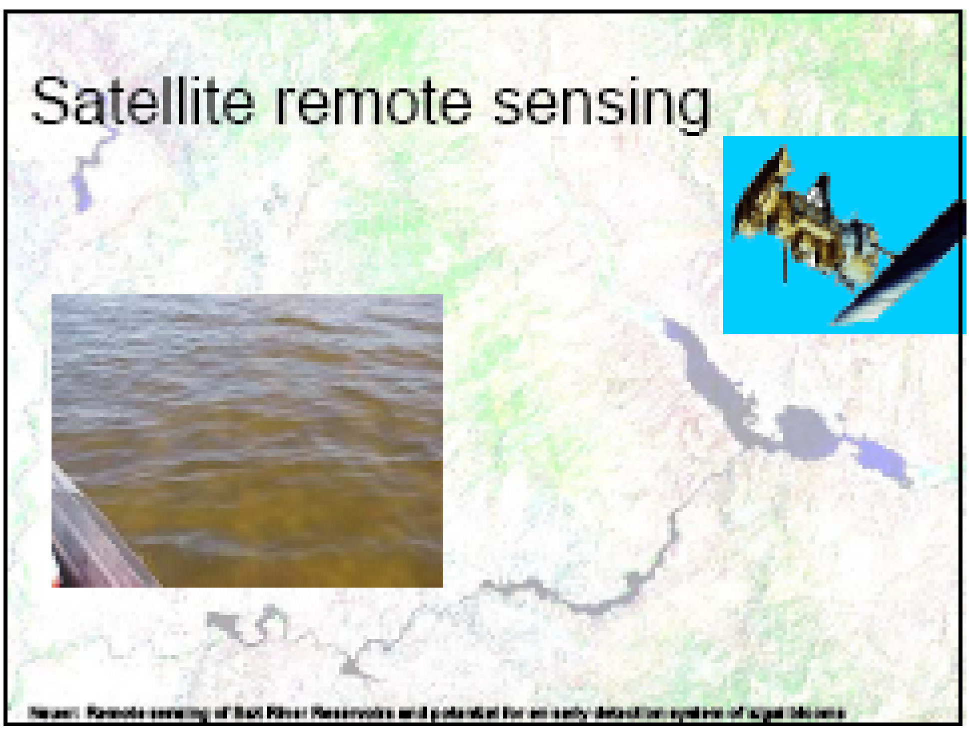

Results
1. Succession of algal blooms in Saguaro and Roosevelt lakes
2. First data of satellite remote sensing

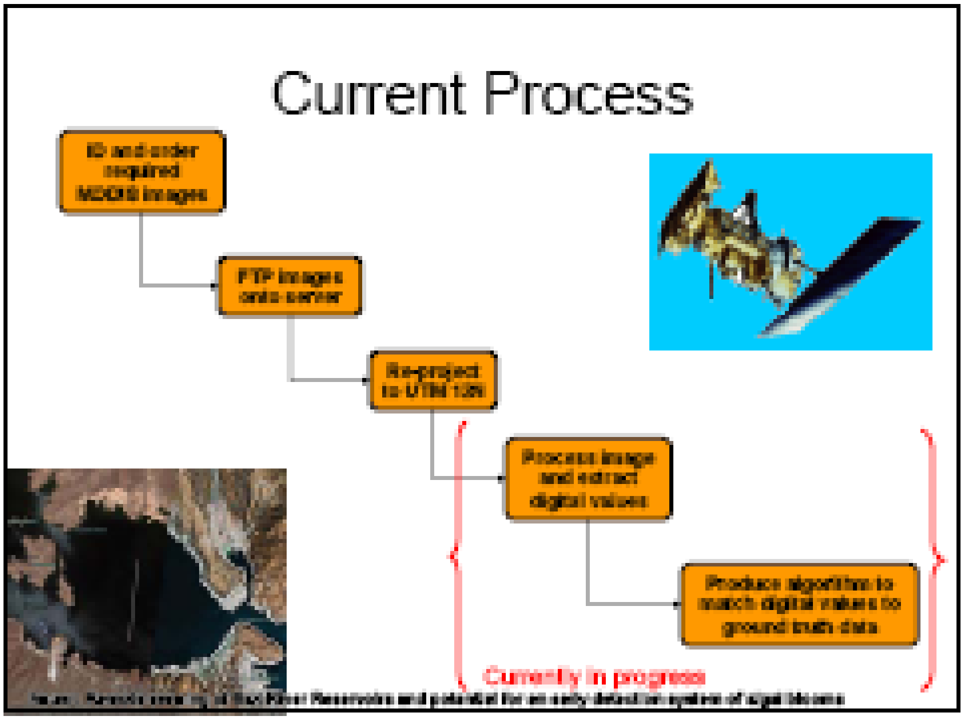

Extracted chlorophyll in Roosevelt Lake (TR1) and Saguaro Lake


Lake surface temperature in Roosevelt Lake (TR1) and Saguaro Lake

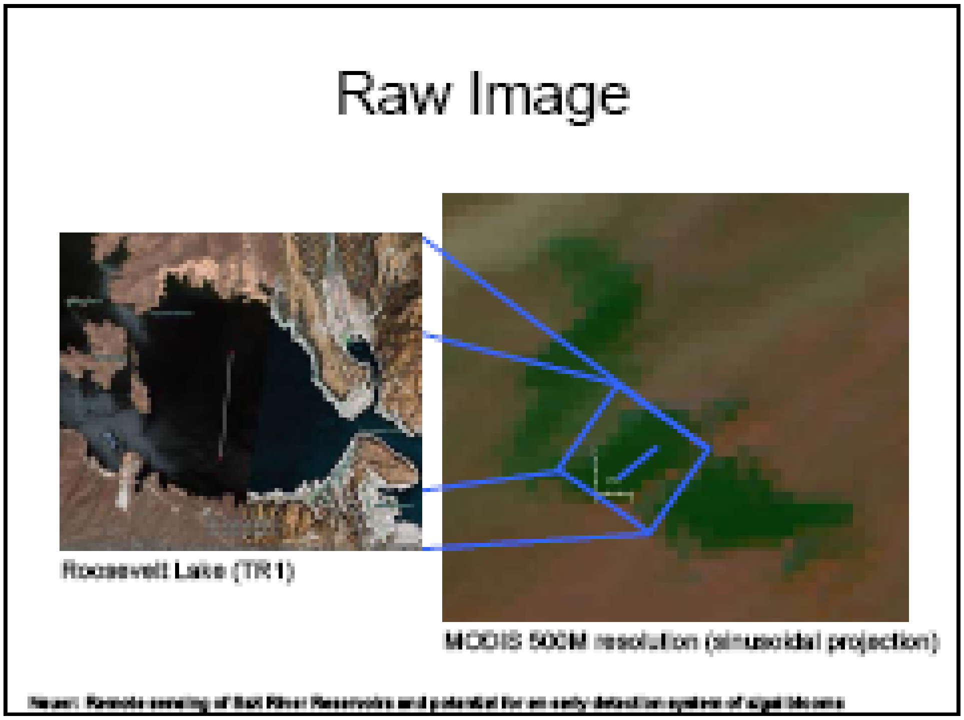

Succession of algal blooms in Saguaro Lake
Saguaro
Date


Succession of algal blooms in Roosevelt Lake

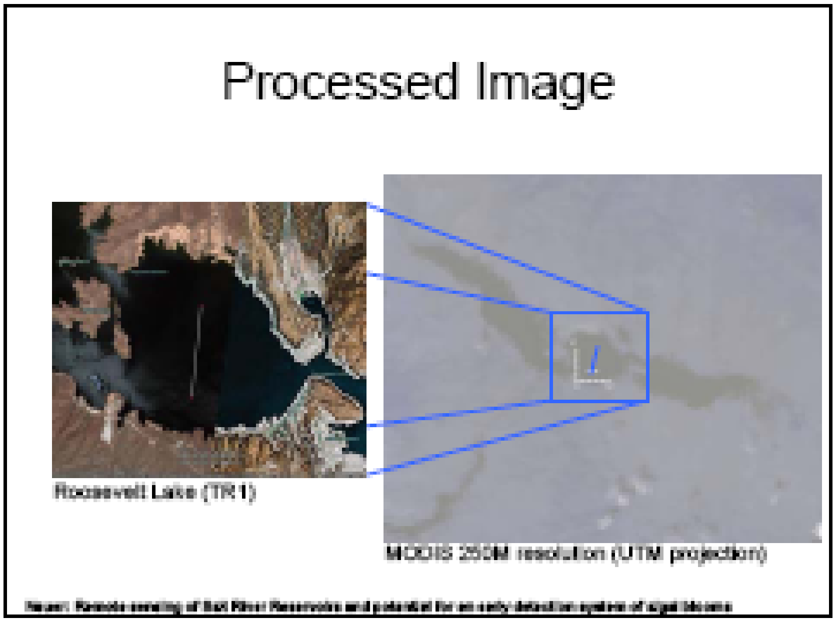

Satellite remote sensing

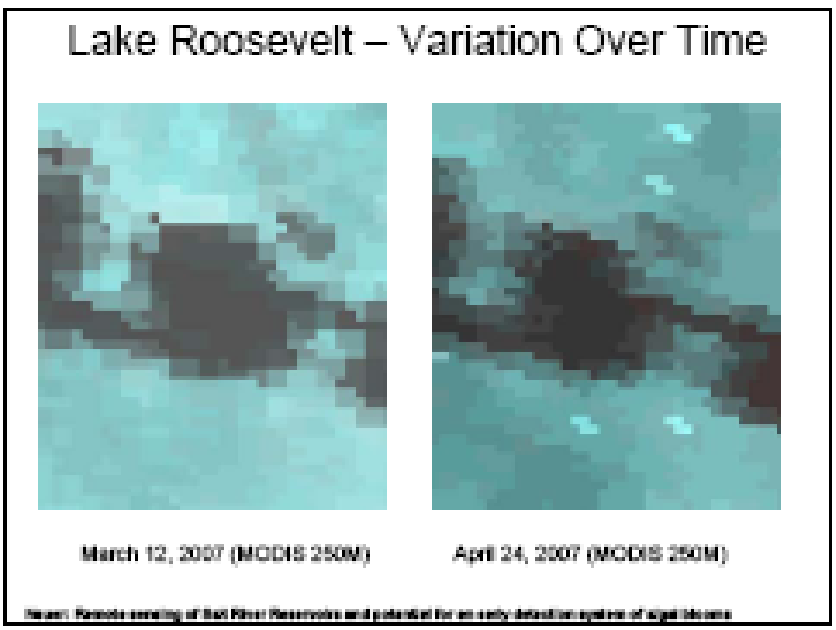


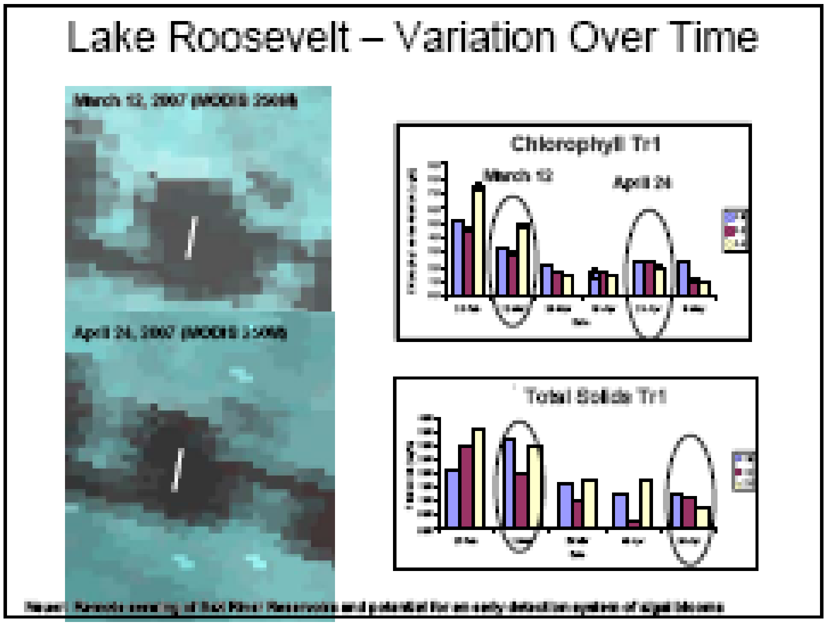
Current Process
ID and order required MODIS images
FTP images onto server
Re-project to UTM 12N
Process image and extract digital values
Produce algorithm to match digital values to ground truth data
Currently in progress
Remote sensing of Salt River Reservoirs and potential for an early detection system of algal blooms

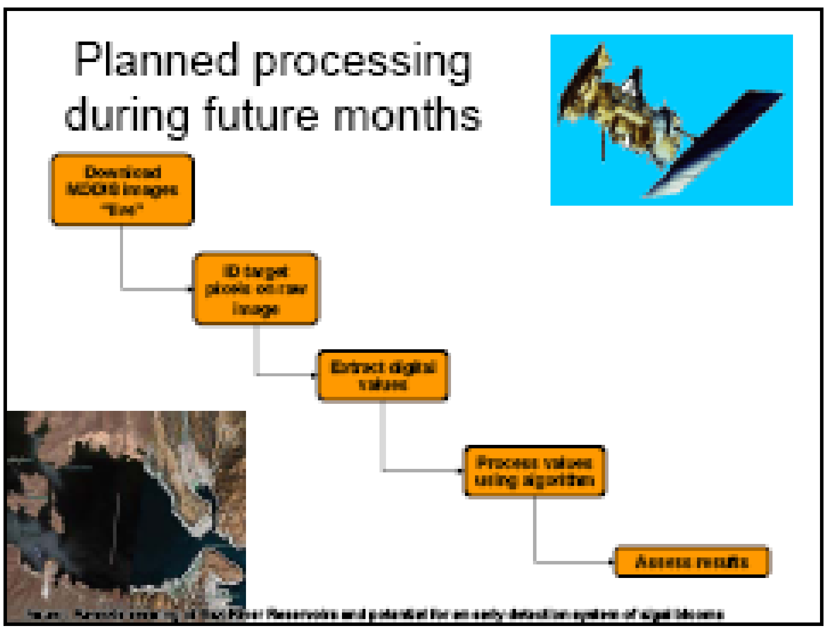


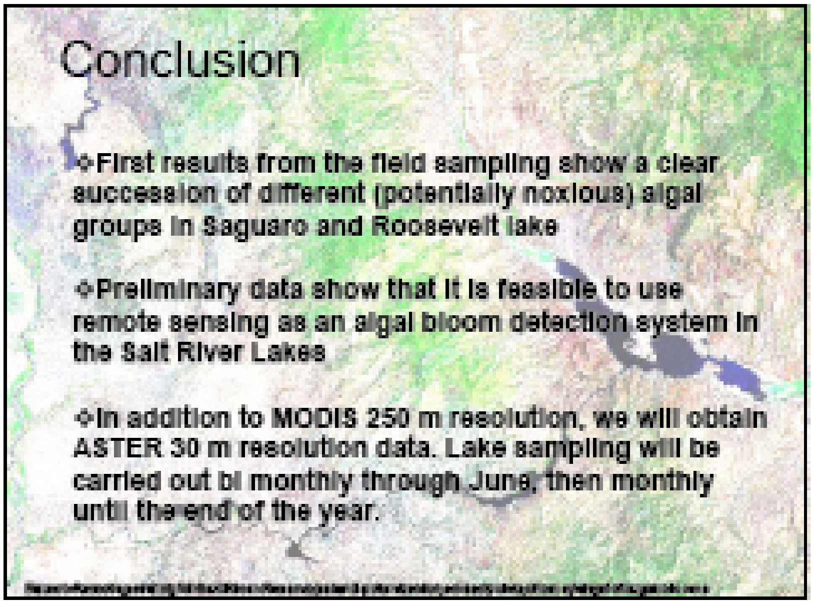
Raw Image
Roosevelt Lake (TR1)
MODIS 500M resolution (sinusoidal projection)
Remote sensing of Salt River Reservoirs and potential for an early detection system of algal blooms


Processed Image
Roosevelt Lake (TR1)
MODIS 250M resolution (UTM projection)


Lake Roosevelt – Variation Over Time
March 12, 2007 (MODIS 250M)
April 24, 2007 (MODIS 250M)


Lake Roosevelt – Variation Over Time
March 12, 2007 (MODIS 250M)
April 24, 2007 (MODIS 250M)
Chlorophyll Tr1
March 12
April 24
Total Solids Tr1


Planned processing during future months
ID target pixels on raw image
Extract digital values
Process values using algorithm
Assess results



New Feature Section: For Salt Sakes

This section will periodically give updates on salinity related issues in the valley. If you have something to add, please send it along. Below is a rough draft of a Chapter by Peng Zhang, a MS graduate student working with Profs. Crittenden and Westerhoff at ASU. He is developing a model of water and salt fluxes for Scottsdale, AZ in an attempt to link together the urban hydrologic system with salt flows. While this modeling approach mirrors that of CASS, it is being undertaken using a more dynamic modeling platform (POWERSIM) instead of Excel spreadsheets.

WATER AND SALT FLUX MODELING THROUGH URBAN HYDRAULIC INFRASTRUCTURE

1. Introduction

Water is a precious resource for semi-arid central Arizona area. Water infrastructures such as canals, wells, reservoirs, and dams have been built one after one to adapt to the urban development. The earliest water infrastructure construction in this area is the gravity-flow canal system built by Hohokam community three thousand years ago to irrigate their agriculture with water from Gila River and Salt River, the remains of which could still be seen in the Salt River valley (Artiola et al. 2006). In last century, hydraulic infrastructures such as the Central Arizona Project, which import water from Colorado River to the central Arizona area, have been built to sustain agriculture development, urban expansion and population growth.

Of the water conveyed through the urban infrastructure, 68% is used for irrigation (Water Resource Research Center, 2002). While irrigation salinity is a common problem for semi-arid regions (Proust, 2003; Khan et al., 2006), salt accumulation in soil due to increasing irrigation salinity is also a concern for the central Arizona. Water and wastewater agencies in central Arizona have launched the Central Arizona Salinity Study to address salinity issue, and the Phase One of the study has reported that 1.5 million tons of salts are imported into the region annually, 0.4 million tons leave, and more than 1 million tons of salts are added to this region (Smith, 2005).

To understand water and salt flux through urban hydraulic infrastructures, we selected Scottsdale, Arizona for a case study. In this study, information on water usage and salinity were collected, water and salt flux within the city boundary were modeled, and future water and salt flux were projected under several scenarios. The urban water flux within Scottsdale includes potable water supply, wastewater and reclaimed water, and precipitation and runoff. Real flow rate data are collected, as well as total dissolved solids (TDS) data. PowerSim, a simulation software, is used to integrate water usage and salinity information for flux modeling.

2. Site Description

Potable water supplies for Scottsdale include Salt River and Verde River water delivered through Salt River Project (SRP), Colorado River water delivered through Central Arizona Project (CAP), and ground water wells. Wastewater is treated and reclaimed for golf course irrigation as well as groundwater recharge. Most runoff is taken by Indian Bend Wash (IBW) south to the Salt River. Figure 1.1 shows the spatial location of these infrastructures. Water for shaded area is supplied by Salt River Project (SRP) and Central Groundwater Treatment Facility (CGTF), while water for blank area is supplied by Central Arizona Project (CAP) and supplemental groundwater. Wastewater generated north to the dash line shown in the figure is treated in Water Campus and Gainey Ranch Water Reclamation Plant (GR WRP), while wastewater generated south to the dash line is sent to 91st Ave WWTP in Phoenix. 7-mile long Indian Bend Wash (IBW) is the main collector that carries runoff from the city down to the Salt River, which is recorded by the McKellips gauge station. Table 1.1 lists these infrastructures and specifies sources for these infrastructures.

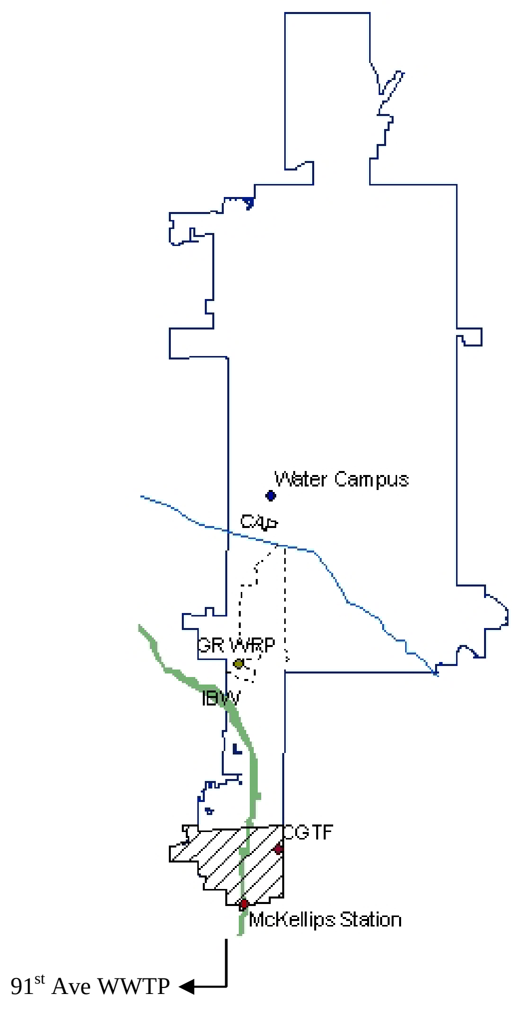


Figure 1.1 Location of water infrastructures of Scottsdale.
Table 1.1
Water Infrastructures in Scottsdale

Infrastructure	Source
Potable water	
CAP Water Treatment Plant	CAP
Verde Water Treatment Plant (in Phoenix)	SRP
Groundwater wells (including CGTF)	Groundwater
Wastewater	
Water Campus Wastewater Reclamation Plant	Wastewater north to Doubletree Ranch Rd
Gainey Ranch Wastewater Reclamation Plant	Sewer pipeline passing by
91st Ave Wastewater Treatment Plant	Wastewater south to Doubletree Ranch Rd
Reclaimed Water Irrigation	
Reclaimed Water Distribution System	Reclaimed water from Water Campus and CAP water
Irrigation Water Distribution System	Reclaimed water from Water Campus and CAP water
Gainey Ranch Golf Course Irrigation	Reclaimed water from Gainey Ranch WRP
Recharge	
Water Campus Recharge	Reclaimed water from Water Campus and CAP water
West World Golf Course Recharge	CAP water
Desert Mountain Golf Course Recharge	CAP water

3. Model Framework and Data Acquisition

3.1 Model framework

The framework of the flux model is developed by PowerSim, a simulation software. The simulations in PowerSim are based on system dynamics, a computer-based simulation methodology developed at Massachusetts Institute of Technology in the 1950s. The framework shown in Figure 1.2 conveys the basic information of water resources of Scottsdale: (a) CAP, SRP, and rainfall are the external sources; (b) groundwater and reclaimed water are internal sources; (c) atmosphere, Salt River, and 91st Avenue WWTP are sinks; (d) usage of water consists of potable use and other irrigation (golf course irrigation); (e) groundwater is replenished by CAP water and reclaimed water recharges and infiltration from vadose zone, while vadose zone is replenished by percolation from the landscape and golf courses and percolation during storm events.

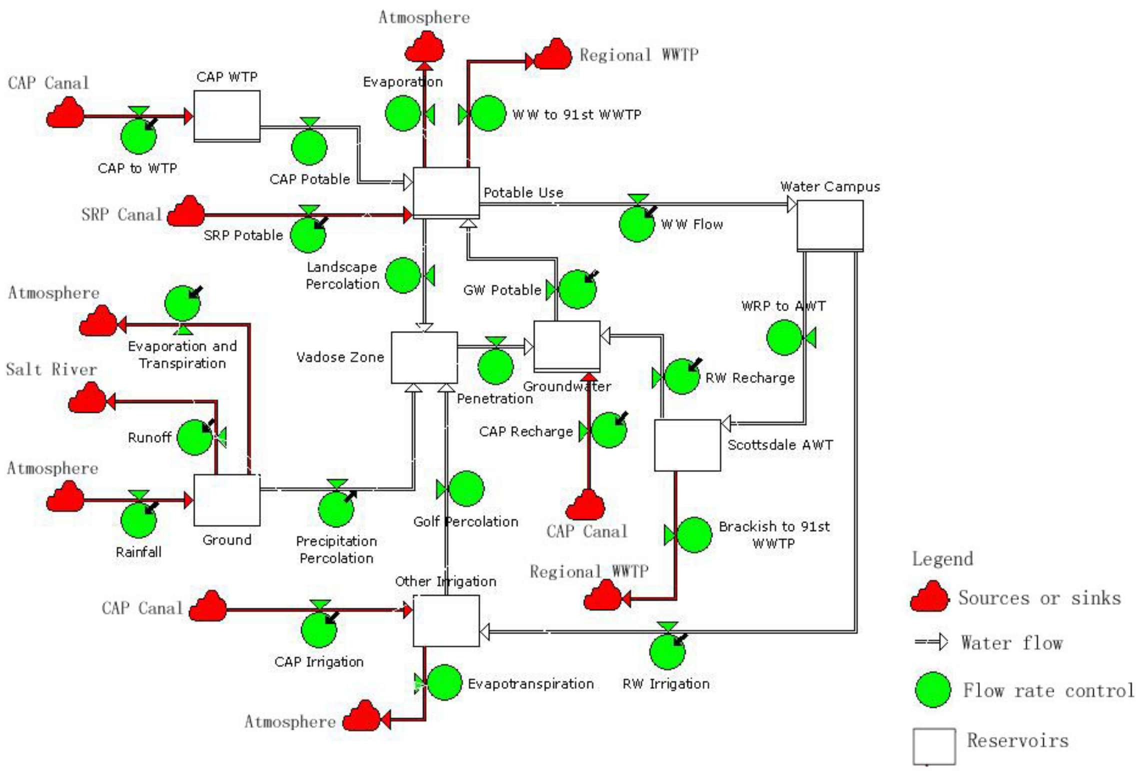


Figure 1.2. Framework of water flux model.

3.2 Potable water supply and wastewater data

Most of data inputs for the model are acquired from the Supervisory Control And Data Acquisition (SCADA) system in Water Campus. SCADA provided us with hourly or daily data on: (a) water pumped from CAP for potable use; (b) production of groundwater wells; (c) wastewater flowing into Water Campus WWTP and Gainey Ranch WWTP; (d) reclaimed water delivered to irrigate golf courses through IWDS and RWDS; (e) reclaimed water sent for recharge from the AWT plant; (f) CAP water for recharge; and (g) CAP water for golf course irrigation.

In 2005, Scottsdale had an entitlement of 17.8 million m^3 SRP surface water and received treated SRP water from Phoenix Verde Water Treatment Plant. This SRP supply was patterned after CAP and groundwater supply. The average daily wastewater left Scottsdale for 91st Ave WWTP was monitored to be around 65 thousand m^3 in 1999 and 2000 (Scottsdale, 2001a), and it was assumed in 2005 the same amount, i.e. 65 thousand m^3 daily, of wastewater flowing from Scottsdale to 91st Ave WWTP.

3.3 Rainfall-runoff data

The rain falling within the city boundary is quantified by multiplying the average precipitation of 6 stations along IBW by the area of Scottsdale, 475 square kilometers. The runoff leaving from IBW to the Salt River is provided by the gauge station at McKellips.

Rainfall in excess of infiltration forms overland runoff. Guo and Urbonas (2002) used 30-year continuous rainfall data to develop a runoff capture curve for Phoenix metropolitan area. The curve could be described by following equations.

$$R = 0 \qquad\qquad P \le 2.5mm$$

$$R = 0.90(P - 2.5) \qquad P > 2.5mm$$

R – runoff capture volume, in mm;

P – precipitation, in mm.

For semi-arid area such as the central Arizona, it is most likely that the rainwater captured in soil voids during rainfall will evaporate later after the storm events. Therefore, the rain evaporation could be derived from runoff capture curve assuming rain evaporation equal to the difference between rainfall and runoff. It is found that 93 mm rainfall is captured in soil and evaporated by using 2005 precipitation data,

$$E_R = P \qquad\qquad P \le 2.5mm$$

$$E_R = 0.1 \times P + 2.25 \qquad P > 2.5mm$$

E_R – rainfall evaporation

The difference between the runoff captured, which is calculated using capture curve equations, and the runoff leaving the city, which is provided by the McKellips gauge station, is the runoff percolation into the groundwater.

3.4 Evaporation and percolation of potable water

Heaney et al (1999) studied residential water use of 12 cities in US including Scottsdale. The study shows that 66.5% of residential water use for single-family homes in Scottsdale is for outdoor irrigation. Western Resource Advocates (2003) reported that 51% and 14% of potable water is consumed by single- and multi-family home respectively, and 35% potable water is consumed by commercial and institutional customers. In the following analysis, the assumption is adopted that multi-family homes allocate the same portion, i.e. 66.5%, of potable water for landscape irrigation as single-family homes do, and commercial and institutional customers do not irrigate landscape with potable water.

Evapotranspiration (ET), a measure of total loss of water through both soil evaporation and plant transpiration, is calculated by multiplying the reference evapotranspiration (ET_0), which could be computed using Penman-Monteith Equation and is available at the Arizona Meteorological Network (AZMET, http://ag.arizona.edu/azmet/), by adjustment factors which is known as crop coefficients (K_C) (Brown et al, 2000). It is found that annual ET for turf landscape in Scottsdale is around1380 mm. As discussed above, 93 mm rainfall is captured, which could offset part of the evapotranspiration demands. Therefore, only 1287 mm potable water is in need for evapotranspiration. While according to ADWR (2003)'s investigation of 33 residential landscape irrigation cases, average 1520 mm is irrigated on residential turf landscape annually. Consequently, 233 mm out of 1520 mm water is percolated into groundwater annually, and 1287 mm out of 1520 mm water is evaporated.

Based on above numbers and assumptions, following equations are developed to relate potable water evaporation and percolation to total potable water supplies.

$$E_P = \alpha_{evap} \beta_{irri} \gamma_{res} \left(CAP_P + SRP + GW \right)$$

$$P_P = \alpha_{perc} \beta_{irri} \gamma_{res} \left(CAP_P + SRP + GW \right)$$

E_P – evaporation of landscape irrigation water;
P_P – percolation of landscape irrigation water;
α_{evap} – ratio of evaporation to landscape irrigation, 1287 mm/1520 mm;
α_{perc} – ratio of percolation to landscape irrigation, 233 mm/1520 mm;
β_{irri} – percentage of irrigation usage in residential usage, 66.5%;
γ_{res} – percentage of residential usage in potable supplies, 65% (51%+14%);
CAP_P – potable water supply from CAP;
SRP – potable water supply from SRP;
GW – potable water supply from groundwater.

3.5 Evapotranspiration and percolation of golf irrigation water

Brown (2006) investigated the percolation of a turf facility to evaluate the ADWR water duty regulation which caps groundwater use at 1380 and 1470 mm per year for turf grass within Tucson and Phoenix AMAs, respectively. Assuming all of rainfall is captured for evapotranspiration, Brown (2006) found average 15% percent of total water input (irrigation + precipitation) passed through root zone for deep percolation.

To estimate the evapotranspiration and percolation of golf course irrigation in Scottsdale, golf irrigation water use is assumed 1470 mm per year, as regulated by ADWR for groundwater turf facilities. And the same assumption as made by Brown (2006) is taken that all rainfall is captured by turf for evapotranspiration. As shown above, in Scottsdale, annual evapotranspiration for turf is1380 mm, and annual precipitation is235 mm. Therefore, 1145 mm irrigation water is evaporated, and 325 mm irrigation water is percolated into groundwater. The evapotranspiration and percolation are related to the golf irrigation water as following.

$$E_I = \varepsilon_{evap} \left(CAP_I + RW \right)$$

$$P_I = \varepsilon_{perc} \left(CAP_I + RW \right)$$

E_I – evapotranspiration of golf irrigation water;

P_I – percolation of golf irrigation water;
ε_{evap} – ratio of evaporation to golf course irrigation, 1145 mm/1470 mm;
ε_{perc} – ratio of percolation to golf course irrigation, 325 mm/1470 mm;
CAP_I – golf irrigation water supply from CAP;
RW – reclaimed water from Water Campus WRP and Gainey Ranch WWTP.

3.6 Salinity and salt flux

To address salt flux issue, Total Dissolved Solids (TDS) is employed as an indicator of water salinity. TDS of several types of water are listed in Table 1.2.

Table 1.2
Salinity of Water within Scottsdale

	TDS (mg/L)
CAP	650
SRP	620
Groundwater	620
Wastewater	1130
Reclaimed water for irrigation	1130
Reclaimed water for recharge	27
Brackish from AWT	7380
Runoff to the Salt River	350

With these TDS information, most salt flux can be figured out with the flux model. But to quantify the salt input from domestic to wastewater and the salt flux from landscape and golf course irrigation percolation, mass balance analysis is needed.

$$S_S = (TDS_{WW} - TDS_{DR})Q_{WW}$$

S_S – salt input from domestic to wastewater;
TDS_{WW} – TDS of wastewater, 1130 mg/l;
TDS_{DR} –TDS of potable water, assumed to be the same as CAP water, 650 mg/l
Q_{WW} – flow rate of wastewater to 91st Avenue WWTP, Water Campus WRP, and Gainey Ranch WWTP

The percolation water brings all the salt in irrigation water into vadose zone.

$$S_{PL} = \beta_{irri}\gamma_{res}\left(TDS_{CAP}CAP_P + TDS_{SRP}SRP + TDS_{GW}GW\right)$$

$$S_{PG} = TDS_{CAP}CAP_I + TDS_{RW}RW$$

S_{PL} – salt flux along with landscape irrigation percolation
S_{PG} – salt flux along with golf course irrigation percolation
TDS_i – TDS of water supply i, and i could be CAP, SRP, GW (groundwater), and RW (reclaimed wastewater).

4. Results and Discussion

4.1 Water flux

Water resources for Scottsdale include CAP supply, SRP supply, groundwater, reclaimed water, and precipitation. The 2005 accumulative supplies from these resources are shown in Figure 1.3. Surprisingly, storms especially winter and summer monsoons brought most water, about 112 million m^3, to the city. And CAP, groundwater, SRP and reclamation contributed 52, 37, 18 and 15 million m^3 water to the city respectively.

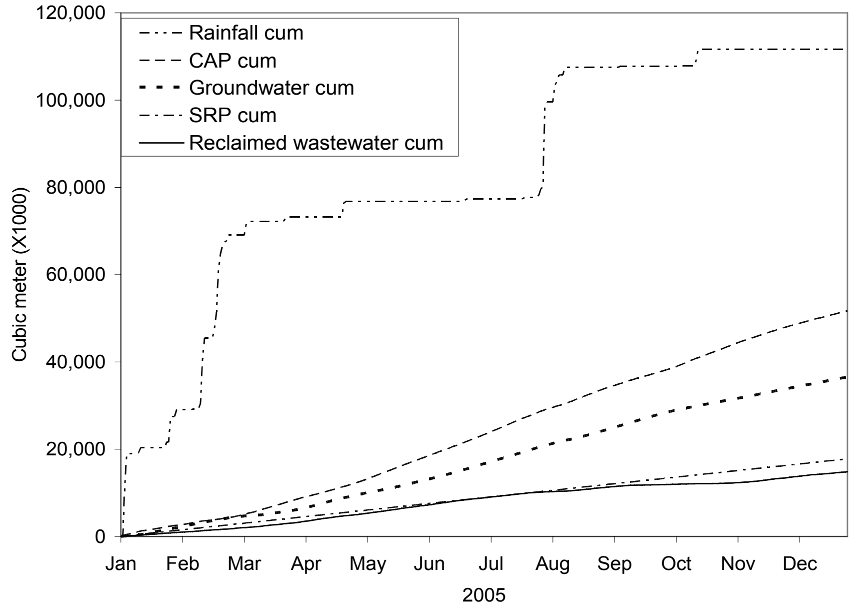


Figure 1.3. Water resources for Scottsdale.

Water leaves Scottsdale by evaporation, percolation, flowing to 91st Avenue WWTP, running into the Salt River, and recharging into aquifers (Figure 1.4). Annual evaporation of 2005 for Scottsdale is 95 million m^3. The accumulative percolation into vadose zone is 65 million m^3 in 2005. 24 million m^3 wastewater left Scottsdale for 91st Avenue WWTP, and 13 million m^3 runoff flowed out of Scottsdale in 2005. Annual recharge of CAP and reclaimed water was 7 million m^3.

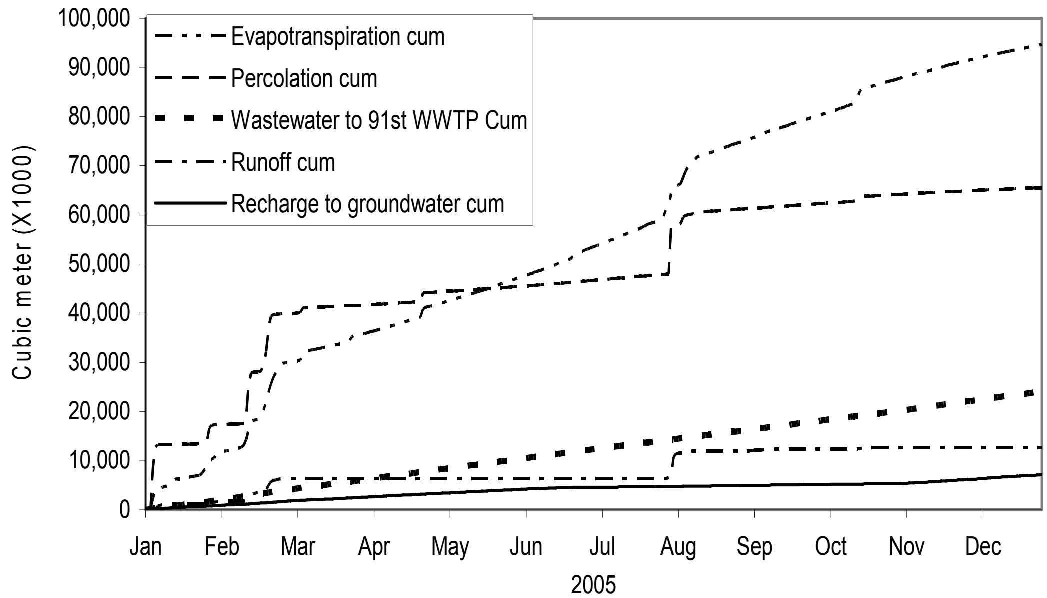


Figure 1.4. Water sinks for Scottsdale.

For precipitation that brought most water to Scottsdale, 40% evaporated, 49% infiltrated into vadose zone when runoff going through washes, and 11% left the boundary of the city.

4.2 Salt flux

The sources of salt include CAP supply, SRP supply, groundwater, human activities and residential softener use (Figure 1.5). In 2005, CAP water, surface runoff, groundwater, and SRP water brought 38, 24, 22, and 11 thousand ton salt with them respectively, and domestic released 19 thousand ton salt to wastewater. Totally 114,049 ton salt was brought into Scottsdale water infrastructure in 2005.

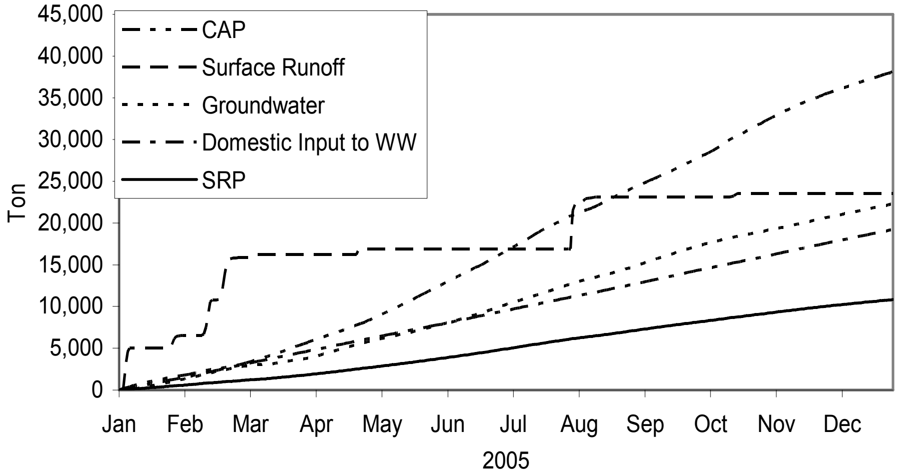


Figure 1.5. Salt sources for Scottsdale.

In 2005, 63 thousand tons of salt in the irrigation water from CAP and reclaimed wastewater plants entered into vadose zone, wastewater and brackish brought 33 thousand ton salt to 91st Avenue WWTP from Scottsdale, and storm runoff picked up 4 thousand ton salt from the city and brought into the Salt River (Figure 1.6).

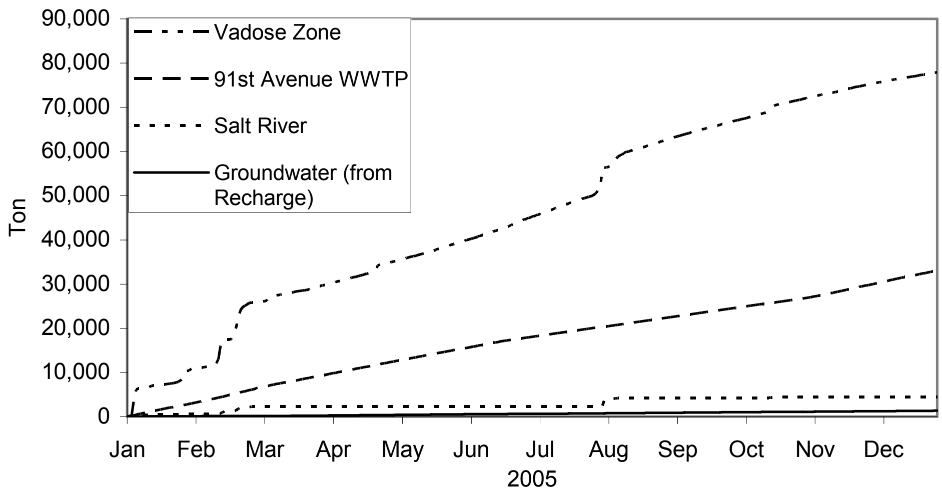


Figure 1.6. Salt sinks of Scottsdale.

Among 63 thousand tons of salt entered into vadose zone in 2005, most came from percolation, and small portion came from recharge (Figure 1.7).

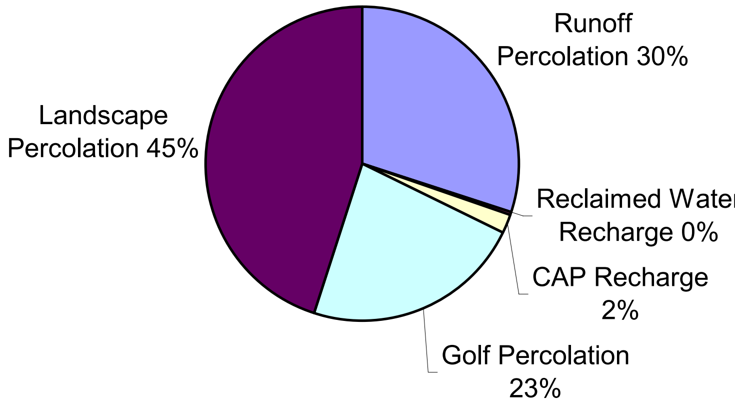


Figure 1.7. Salt left in soil and aquifers.