Mystic Lake Impacts on TMDL Stakeholders

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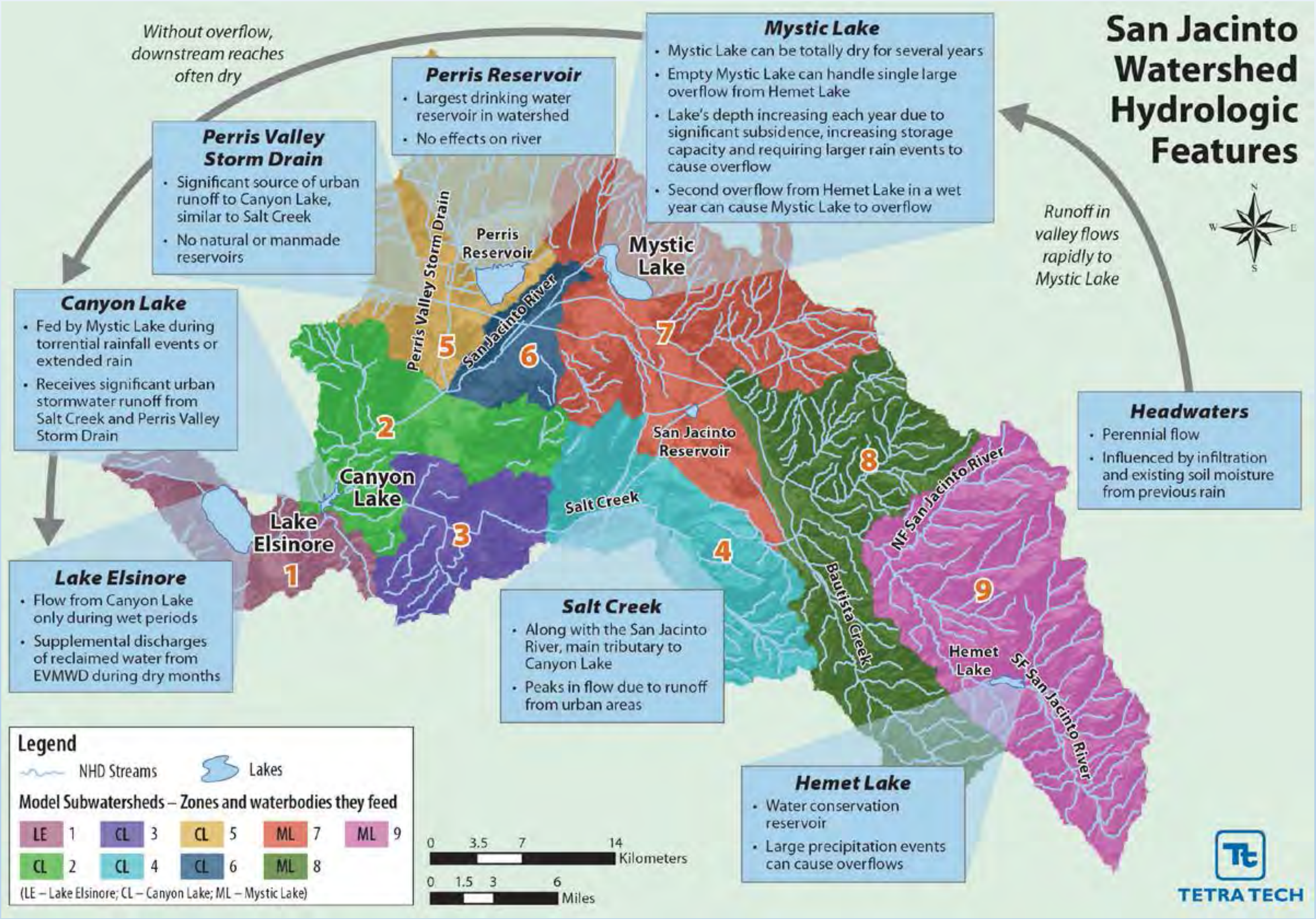
Western Riverside County Agriculture Coalition

August, 2015

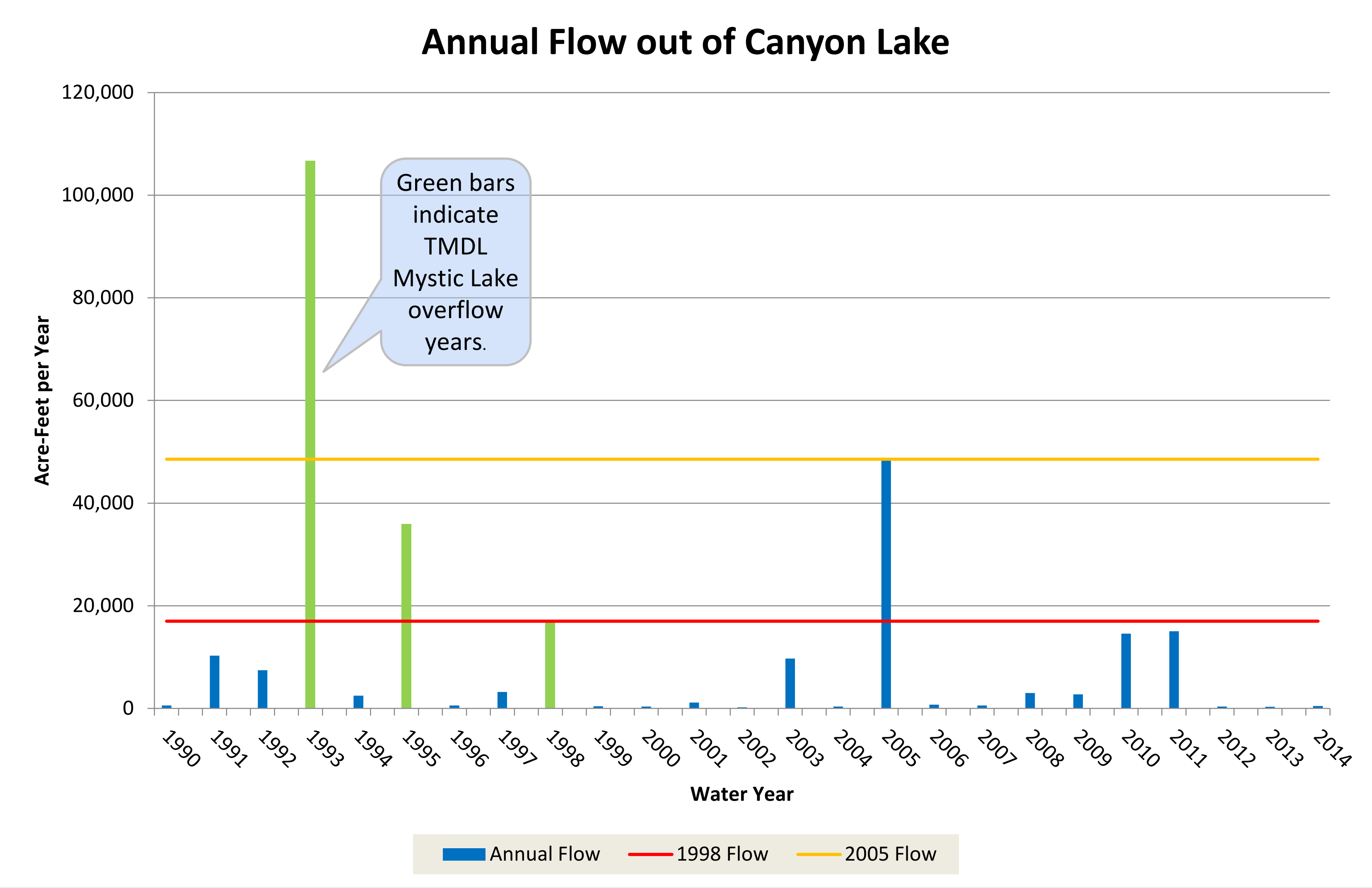
Hydrology Review



Historical Review

- TMDL 2004
  - Dry, moderate, wet hydrologic scenarios
  - Wet hydrologic scenario (Mystic Lake overflow) defined as occurring in 1998.
  - Threshold flow 17,000 af/y.
  - Threshold flow exceeded 14 out of 86 years on record at the time (16%).
- Monitoring post-2000
  - Moderate hydrologic scenario occurred 2005.
  - 2005 Mystic Lake was very full, but did not overflow.
  - 2005 flow from Canyon Lake was over 48,000 af/y.

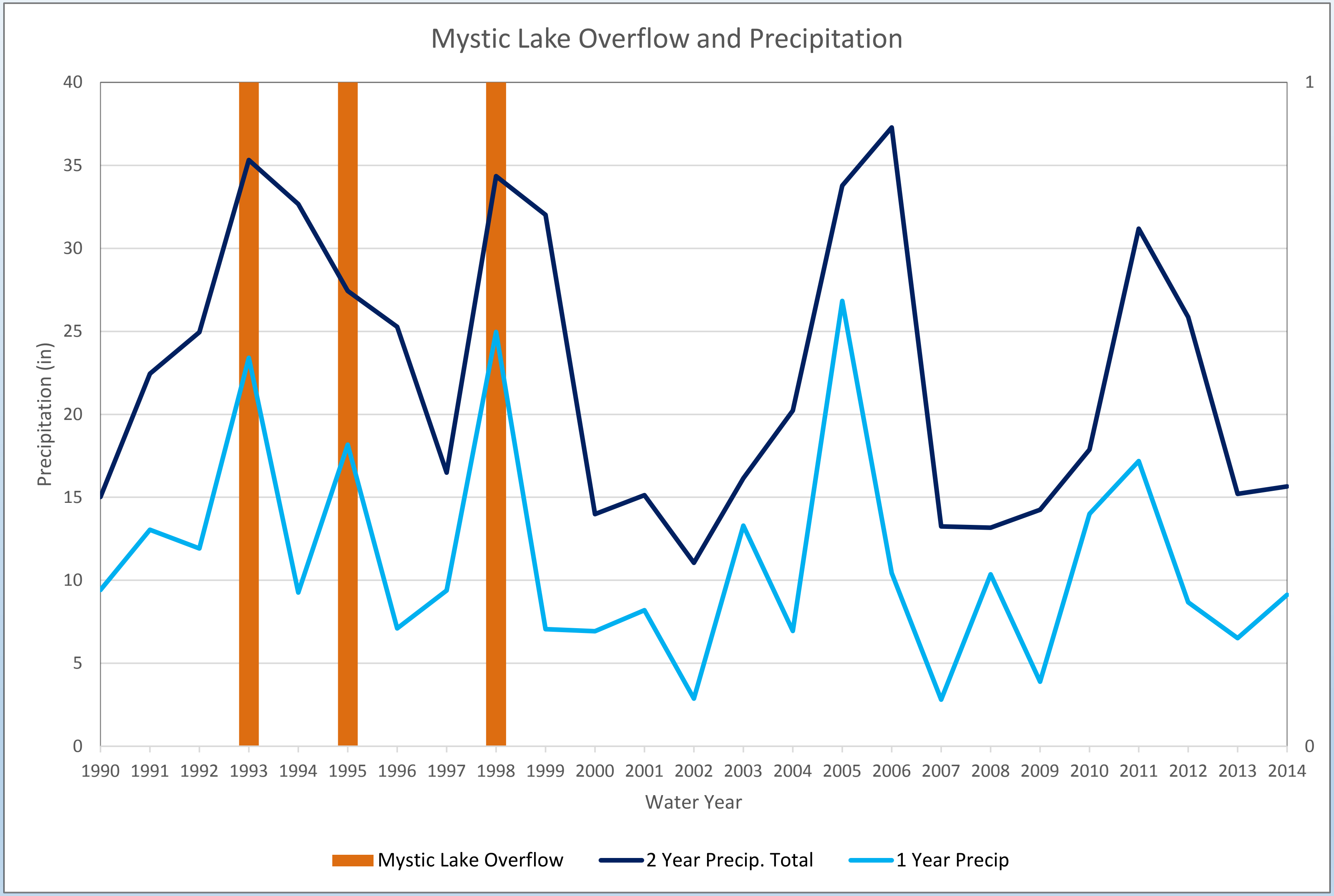
Wet Hydrologic Scenarios



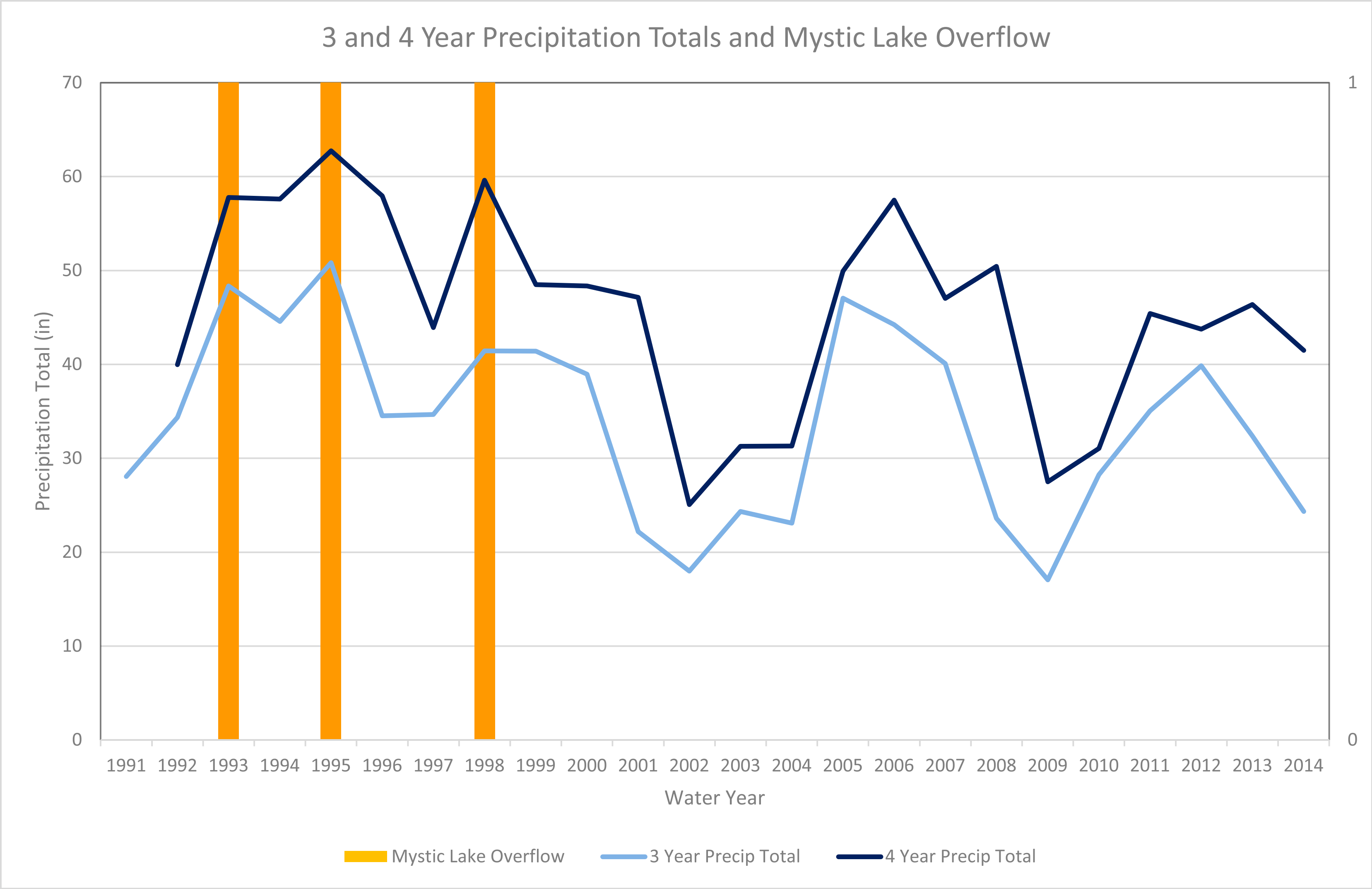
Hydrologic Changes

- 1922 and 1927 qualified as wet hydrologic scenario years. Railroad Canyon Dam construction finished in 1929.
- 29,000 af transfer from Canyon Lake to Lake Elsinore in 1964. Annual flow volume was 27,250 af in 1964, flow profile looks like a transfer as opposed to storm events.
  - Mystic Lake overflow 9 of 98 years, 9% frequency of nutrient discharge.
- Land use changes.

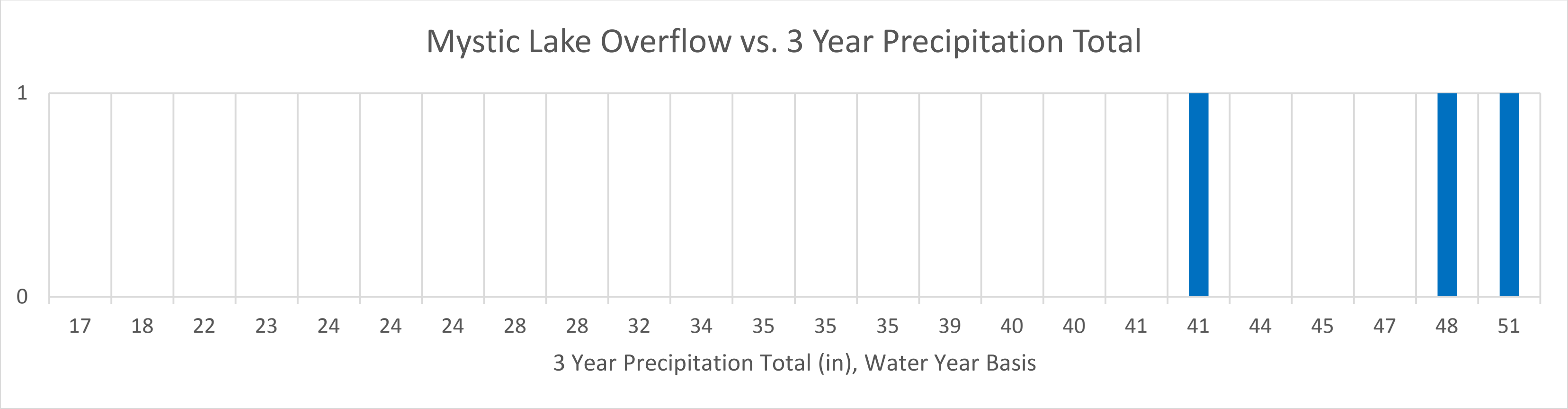
Multiple Precipitation Years (1)

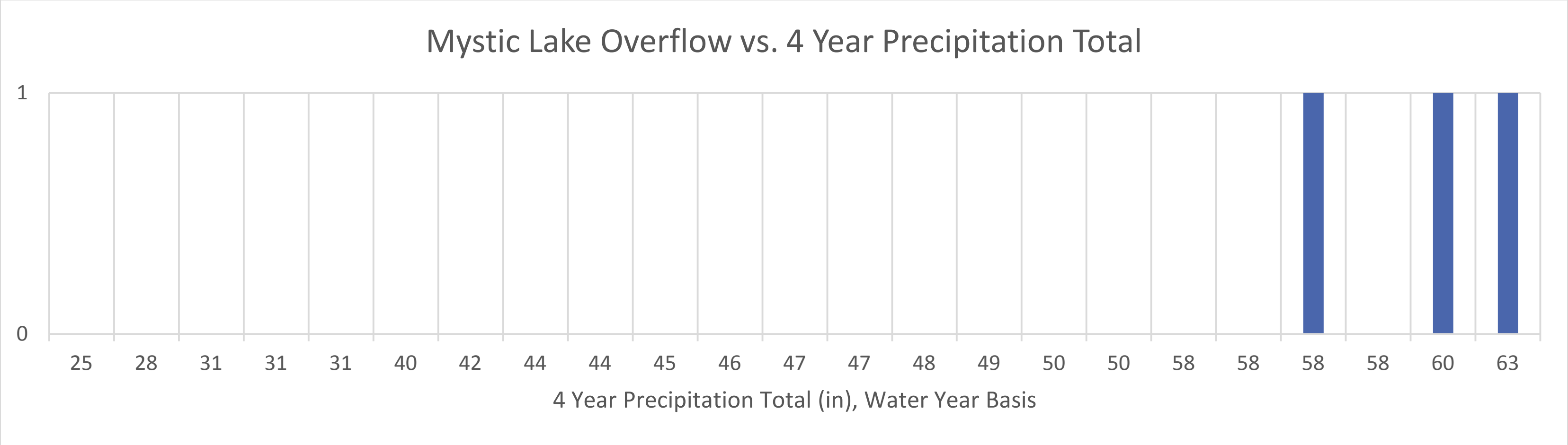


Multiple Precipitation Years (2)



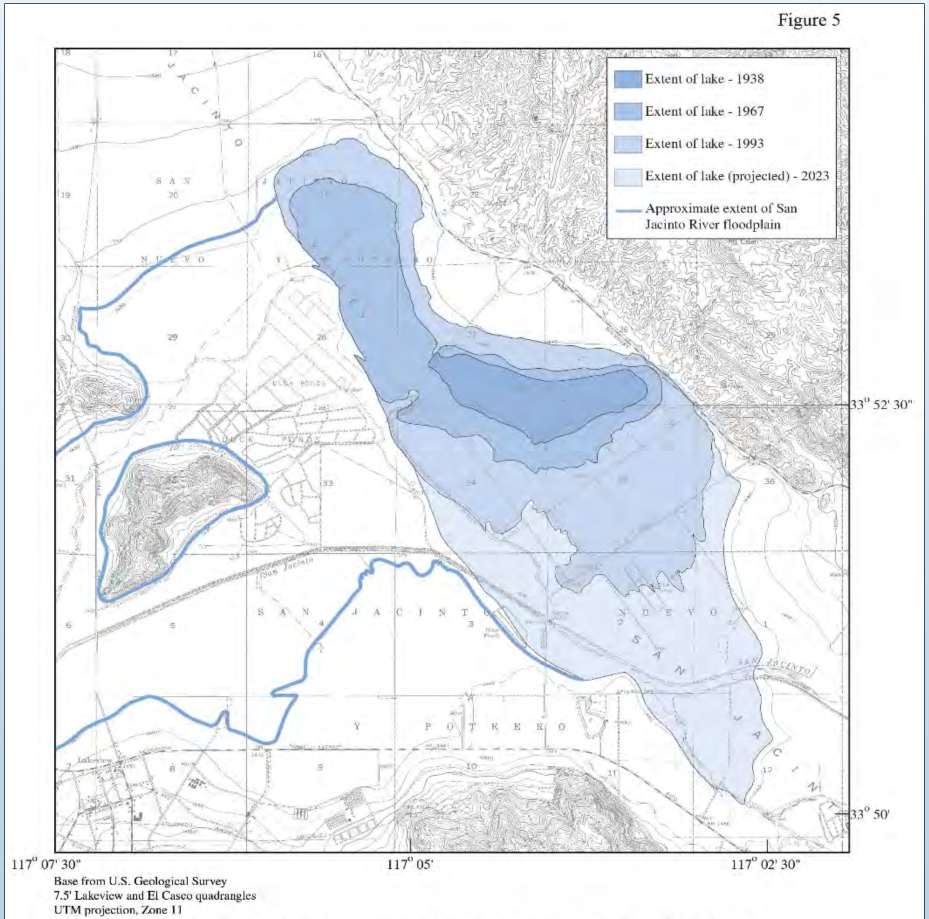
Multiple Precipitation Years (3)





Precipitation correlation leads to false accounting and prediction, variable over time and space.

Subsidence (1)

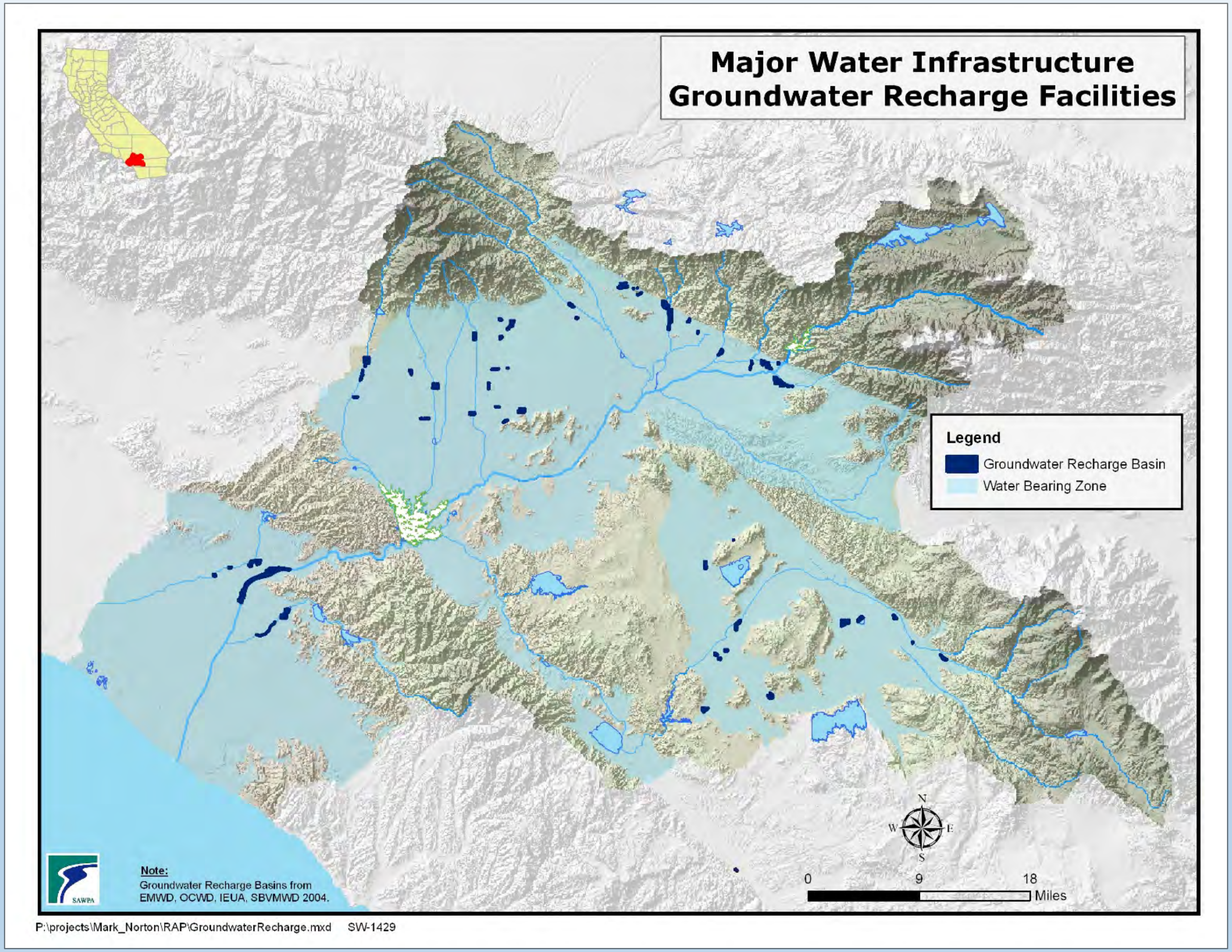


Historic Lake Levels of Mystic Lake, Riverside County, California

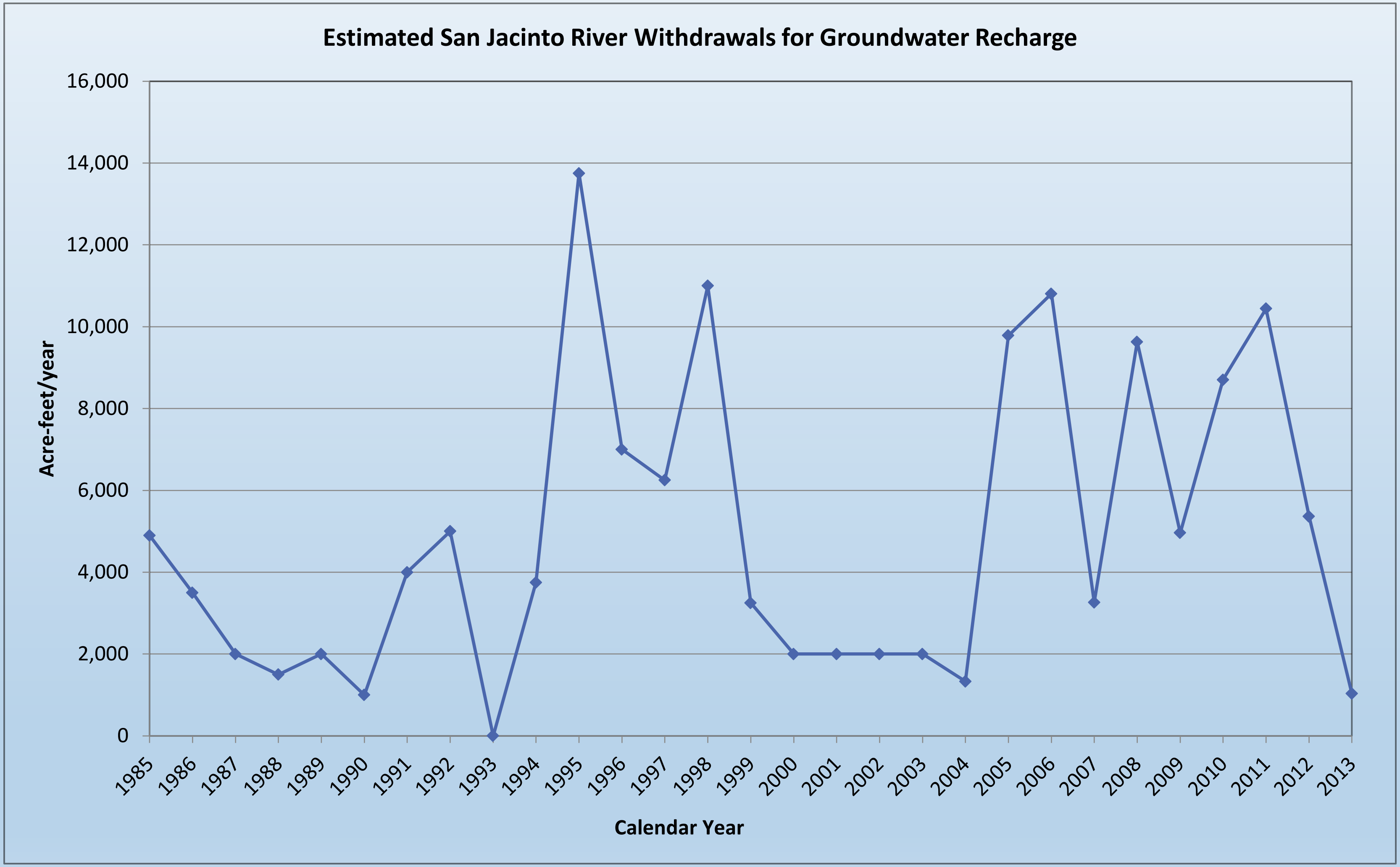
Subsidence (2)

- Effect on Mystic Lake capacity.
- Subsidence rates in literature vary, 2.5-5 cm/year :
  - Conservatively assume 2.5 cm/year over the surface area from the 2004 RCFC stage-storage curve, 210 af/year.
  - Mystic Lake storage capacity increasing well over 2000 af every 10 years.

Diversions (1)



Diversions (2)



Diversions (3)

- Over 12,000 af diverted in 1995.
- Over 20,000 af diverted 2005 and 2006.
- Diversions likely to be maximized.

Summary

- TMDL responsibility needs to be updated for a wet hydrologic scenario that has not occurred in the last 17 years.
- The flow volume from Canyon Lake to Lake Elsinore is a poor predictor of a wet hydrologic scenario; with 2005 flow volume exceeding the 1998 threshold by more than 2 fold.
- Hydrologic changes due to subsidence, diversions, and land use lessen the frequency and relative magnitude of contribution.
- Natural and anthropogenic hydrologic changes are expected to continue, making overflow prediction difficult to impossible.

Next Steps

- All stakeholders in subwatershed zones 7, 8, and 9 that contribute to Mystic Lake are fiscally responsible for contribution at a frequency that has not occurred, and gets less likely to occur with time.
- How do we treat stakeholders in subwatershed zones 7, 8 and 9 in a fair manner?

Stable Isotope Composition, Bulk Elemental, and Mobile-P Concentrations in Lake Elsinore Sediments

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Objective

- To better understand the processes that affect the cycling of organic matter and nutrients in Lake Elsinore as well as infer past changes in nutrient dynamics

Background: Phosphorus

- Phosphorus exists in different forms in the sediment which vary in bioavailability and reactivity
  - Loosely adsorbed and pore-water P
  - Redox-sensitive P
    - Iron and manganese oxides
  - Aluminum-oxide bound P (not redox-sensitive)
  - Organic P
  - Ca-bound P
- Identify mobile vs refractory forms to understand P mobility

Background: Stable Isotopic Composition of Sediment

- Stable C and N isotopic composition of sediments has been a useful tool in inferring:
  - Sources of organic matter and
  - Processes occurring during its cycling
- Delta notation ($\delta^{13}C$, $\delta^{15}N$)
  - Ratio of heavy to light isotope
  - Negative delta value = more light than heavy
- Fractionation
  - Lighter isotope selectively utilized over heavy isotope during biological & chemical processes

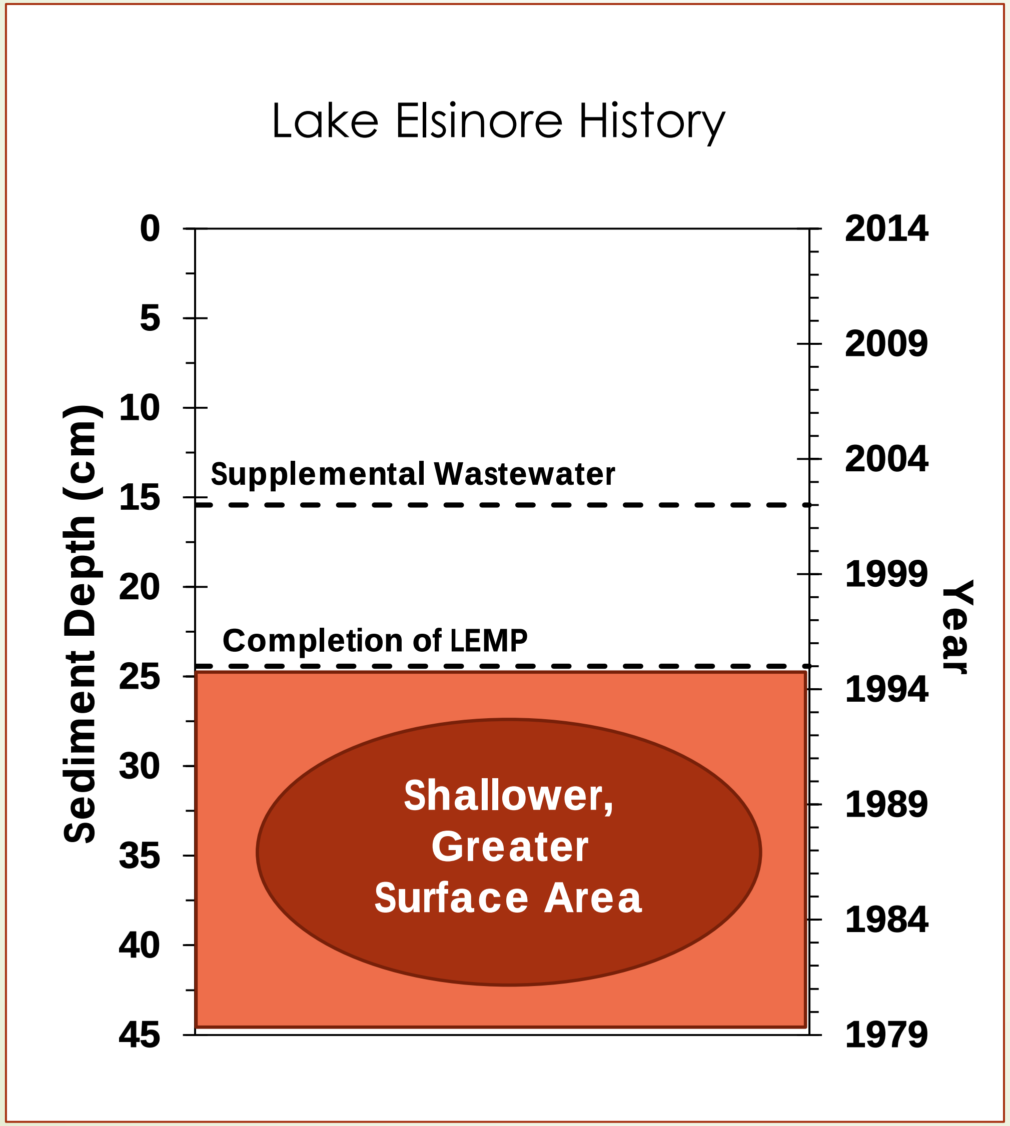
Methods

- Sample Collection
  - 42 cm profundal sediment cores, July 2014
    - Sectioned into 1-2 cm intervals
    - Homogenized
    - Stored at 4°C until analysis
  - Suspended organic matter in epilimnetic water, July 2014
- Phosphorus Fractionation (Psenner et al. 1988)
  - 1M NH_4Cl: Pore water and loosely-sorbed P
  - 0.11M $Na_2S_2O_4$/0.11M $NaHCO_3$: P bound to redox-sensitive Fe compounds
  - 0.1M NaOH: P bound to Al (hydr)oxides

Methods

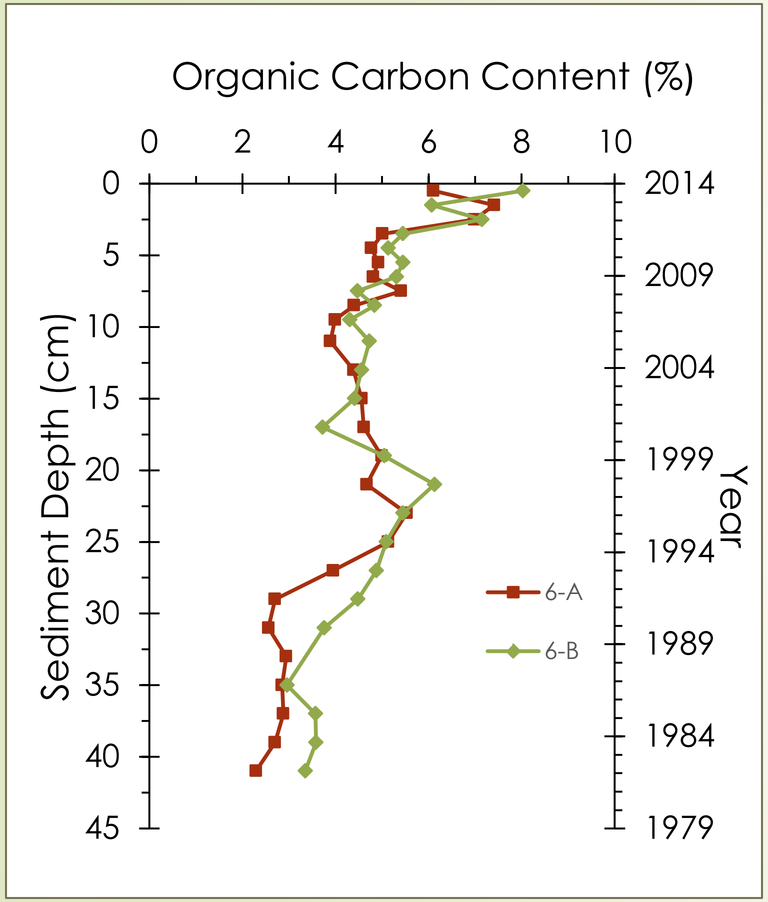
- Stable Isotopic Composition ($\delta^{13}C$ and $\delta^{15}N$)
  - Delta V Advantage Isotope Ratio Mass Spectrometer
  - Costech Elemental Analyzer
- Elemental Composition
  - X-ray Fluorescence Spectrometer

Methods

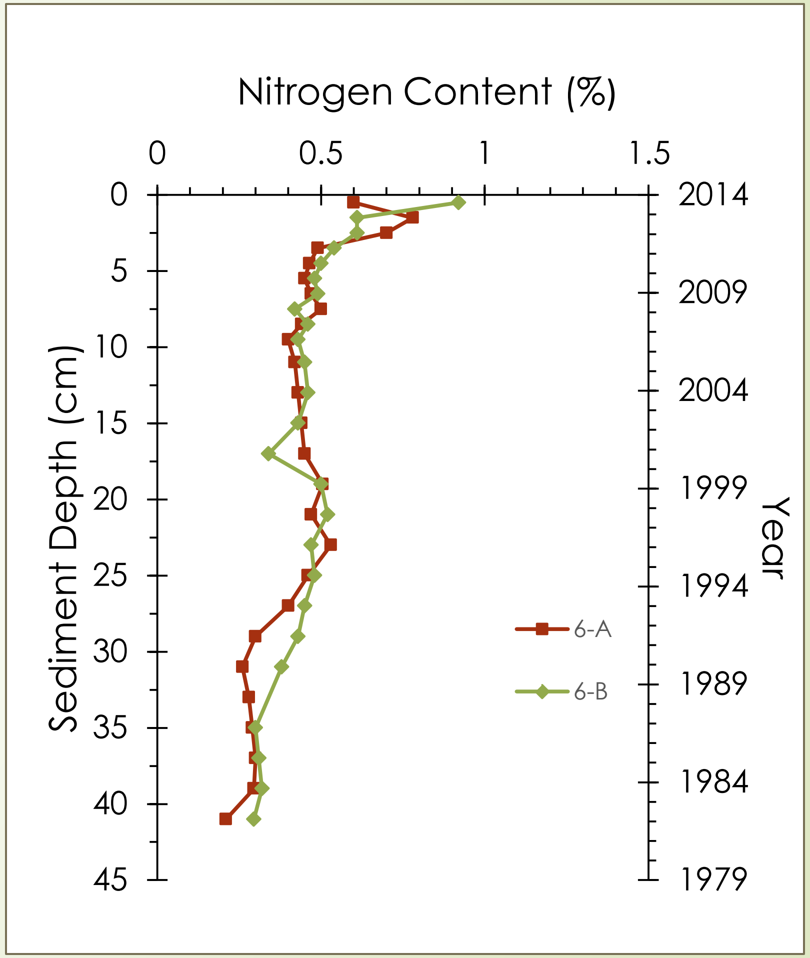


- Sedimentation rate: 1.27 cm/yr (Mat Kirby)

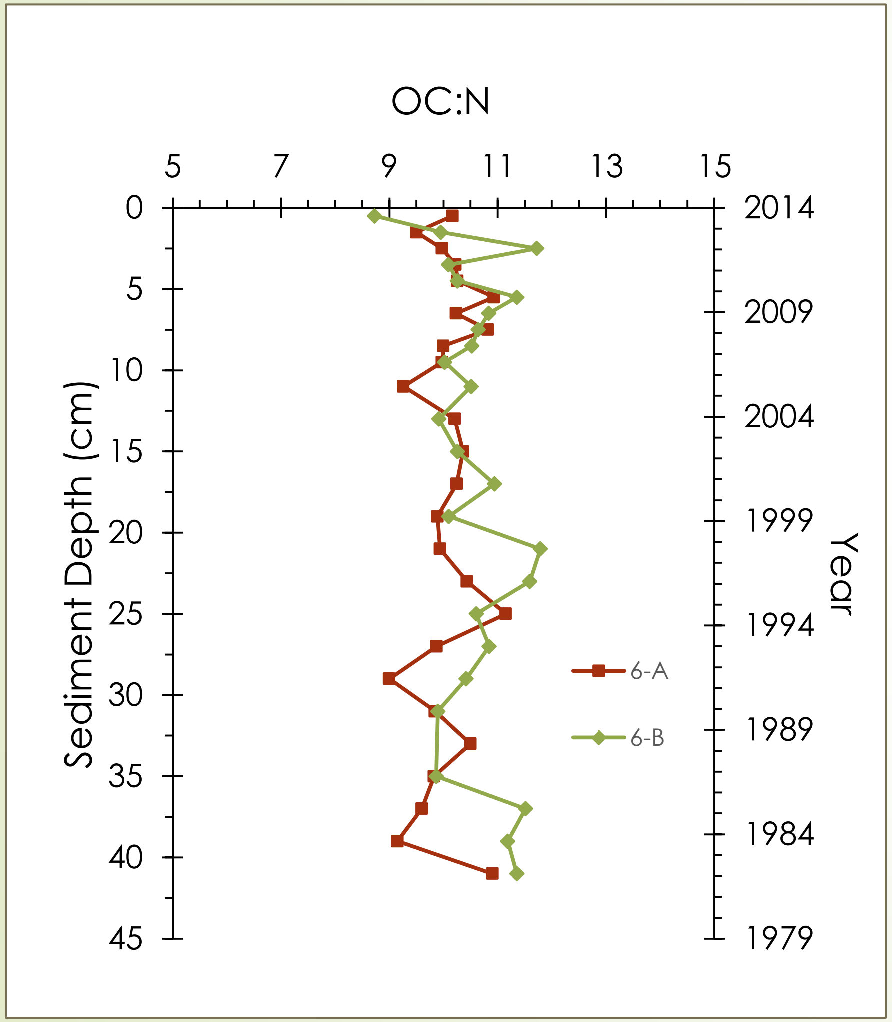
Results: Sediment Composition



- OC and N content significantly correlated ($r^2 = 0.98$, $r^2 = 0.94$)
- Increase in 1994
  - Greater mean lake depth
  - Enhanced OM preservation
  - Greater OM input per sediment surface area
- Exponential decrease in top 10 cm due to organic matter decomposition

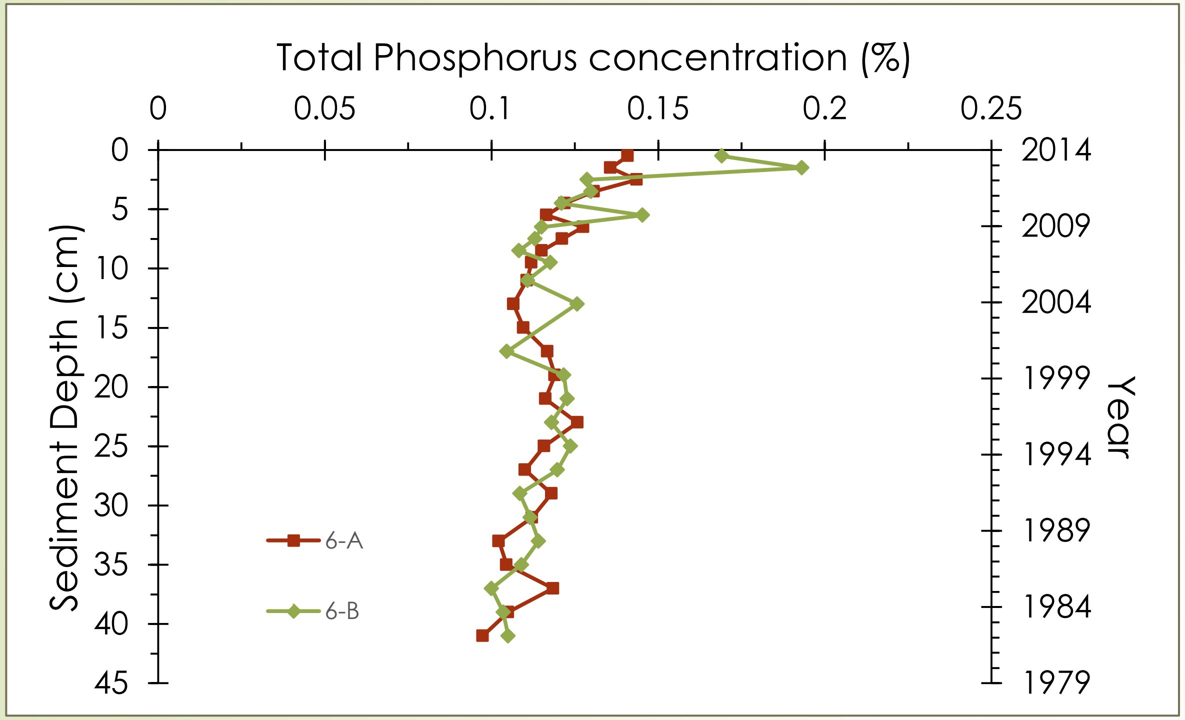


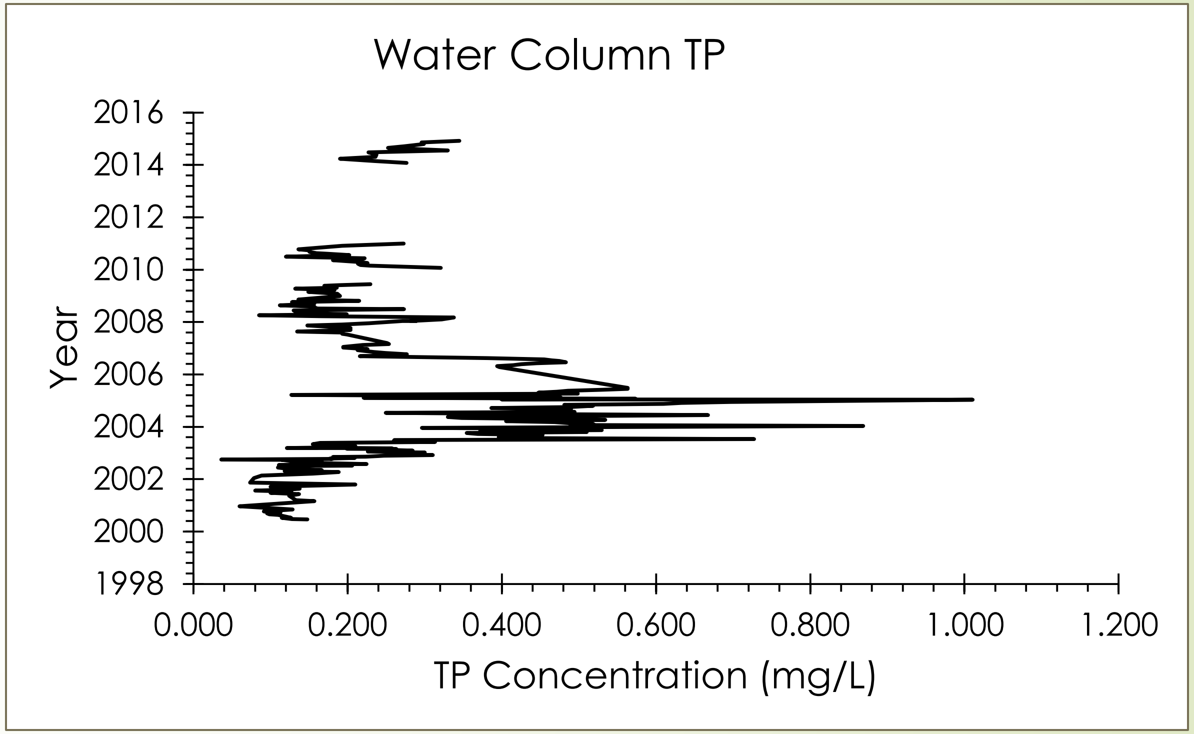
Results: Sediment Composition



- OM highly recycled in water column
  - Relatively constant with depth
  - OC:N of algae = 6.9
  - N selectively recycled from settling OM
- 2010 Study:
  - Sediment Trap
    - TN = 0.85%
    - OC = 6.48%
    - C:N = 7.7
  - Surface Sediment
    - TN = 0.5%
    - OC = 4.3%
    - C:N = 8.6

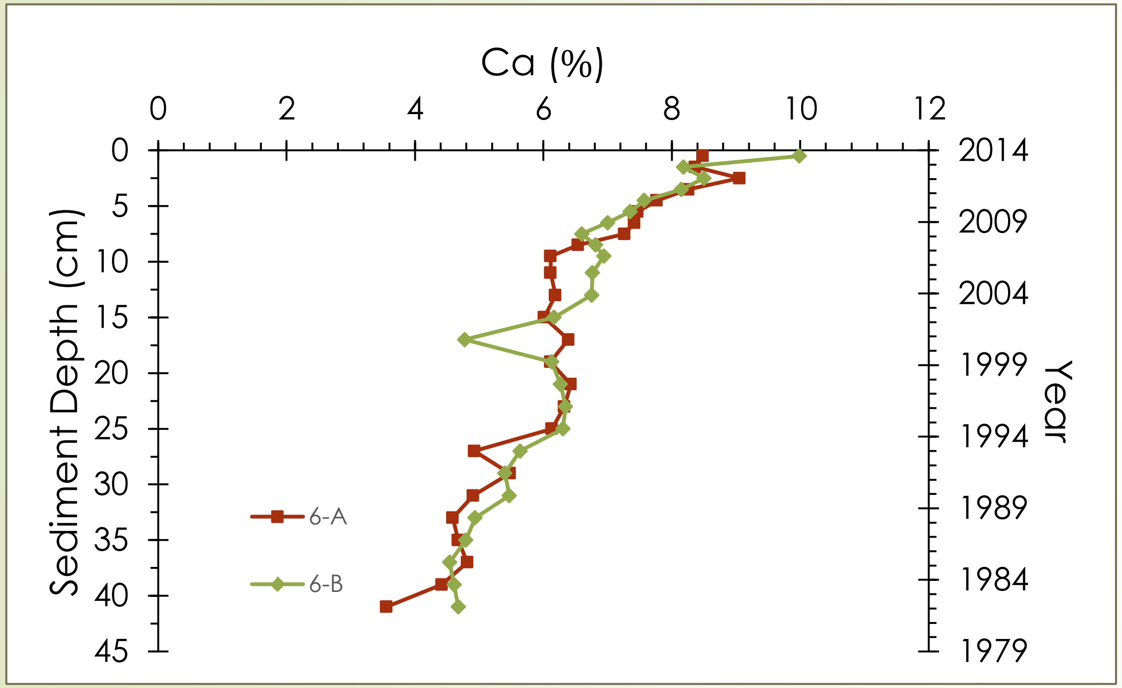
Results: Phosphorus





- Exponential decrease typical for eutrophic lakes
- Mineralization of OM in top 10 cm; not due to increased TP loading to lake

Results: Elemental Composition



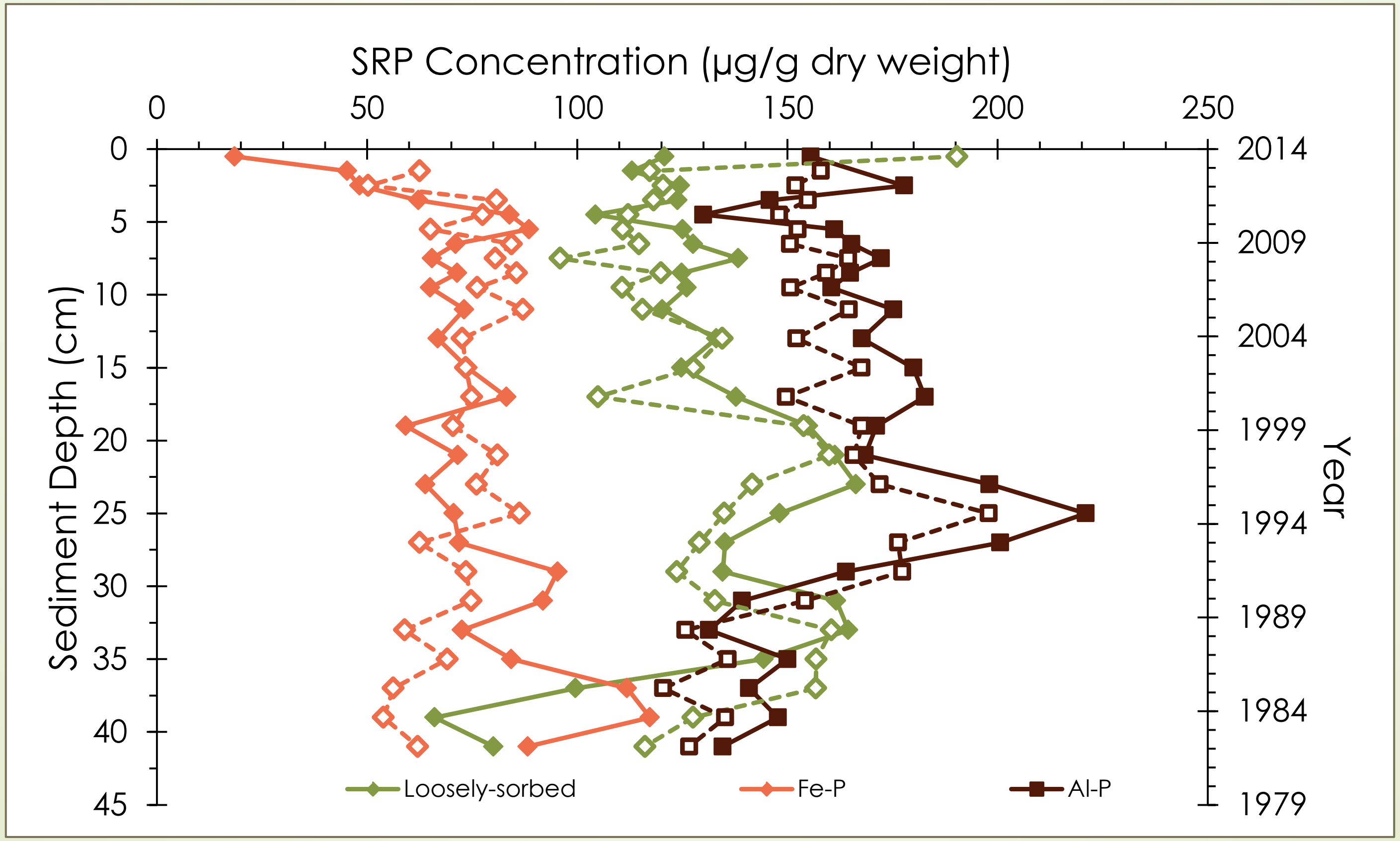
- Calcium and organic carbon correlated ($r^2 = 0.79$)
- $CaCO_3$ co-precipitation with organic matter
  - Primary productivity increases pH
  - OM: nuclei for precipitation
- Decrease in top 10 cm due to $CaCO_3$ dissolution coupled to OM decomposition
  - Respiration leads to increasing CO_2 in porewater
  - Lower pH= $CaCO_3$ dissolves

	k_r (yr^{-1})	$t_{1/2}$ (yr^{-1})
Organic C	**0.071 ± 0.004**	**9.7 ± 0.5**
Total N	**0.079 ± 0.008**	**8.7 ± 0.9**
Total P	**0.047 ± 0.022**	**14.7 ± 7.6**
Calcium	**0.055 ± 0.010**	**12.5 ± 2.3**

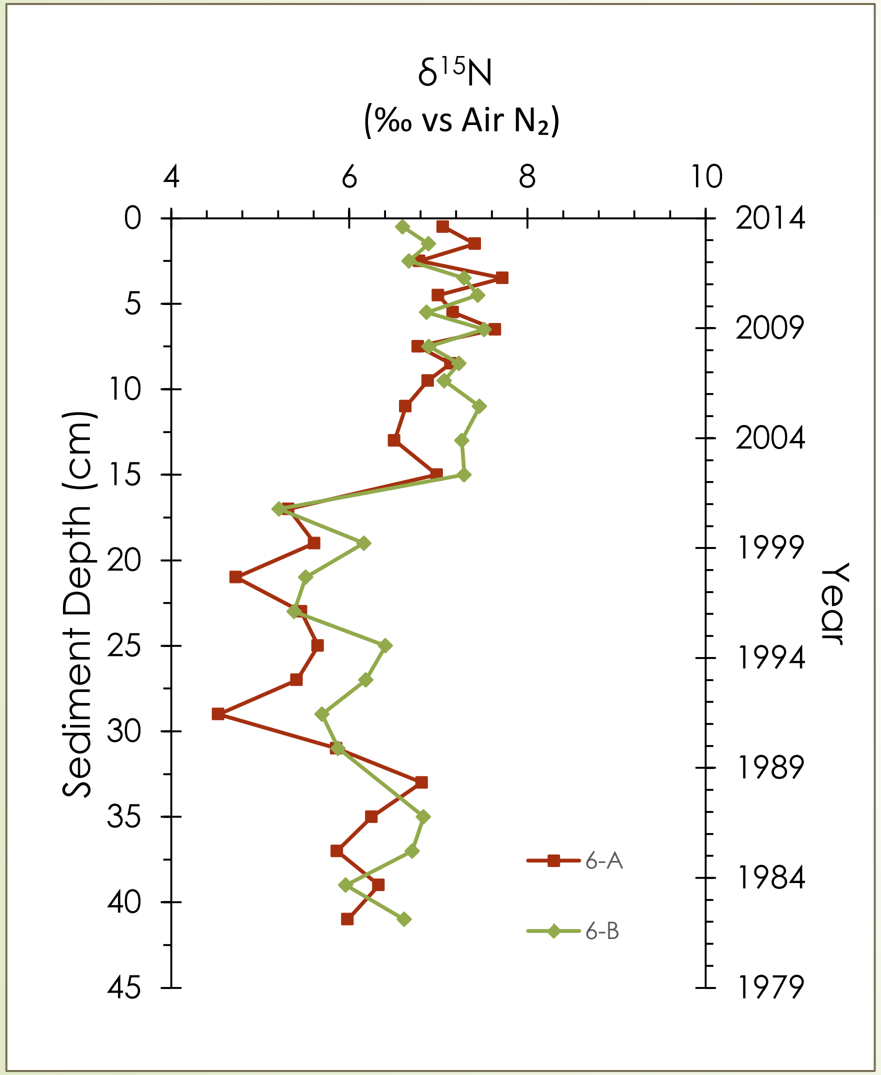
- Half-lives of OC and N
  - <10 years
- Half-lives of TP and Calcium
  - 10-15 years

Results: Phosphorus Fractions

- Fe-P least abundant P fraction
- Atypical trends for eutrophic lakes
- Shift to greater Al-P in 1994
- Little change in pore-water P and Fe-P with depth

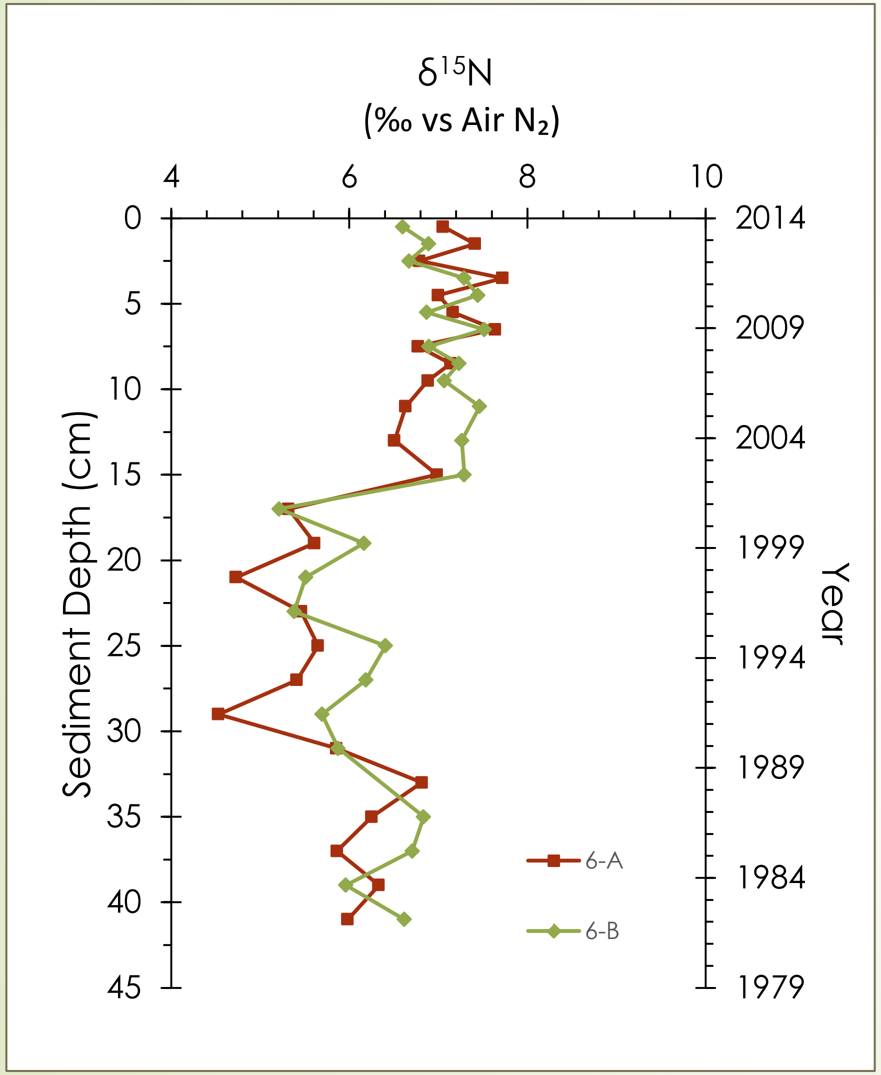


Results: Stable Isotopic Composition



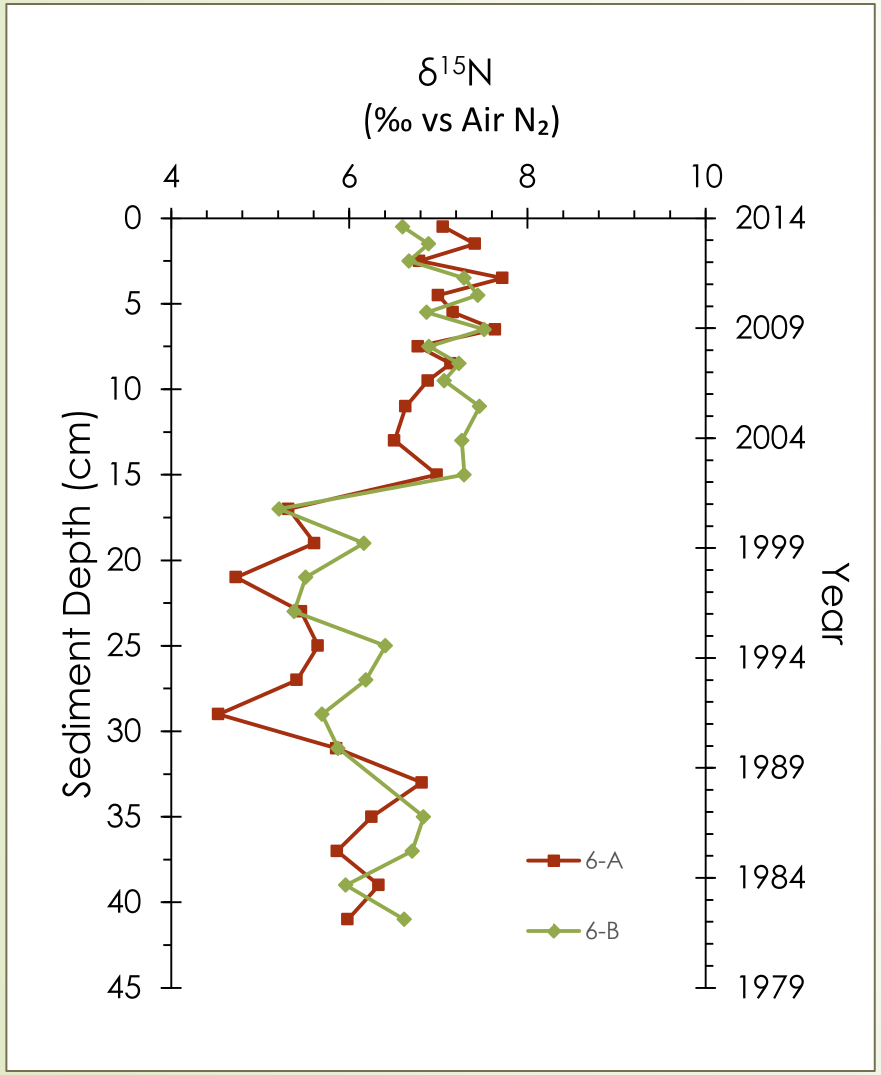
- 3 Different Periods
  - Shallow mean depth lake
    - $\delta^{15}N = 6.2 \pm 0.4$ ‰
  - Shift to deeper lake
    - $\delta^{15}N = 5.3 \pm 0.5$ ‰
  - Input from recycled water
    - $\delta^{15}N = 7.1 \pm 0.4$ ‰
- Mean $\delta^{15}N$ of each period significantly different

Results: Stable Isotopic Composition



- Decrease in $\delta^{15}N$ with LEMP completion
  - Greater mean lake depth = decreased circulation and increased stratification
  - 2.5-4‰ decrease in $\delta^{15}N$ during anoxic decay
    - Due to bacterial growth in sediment

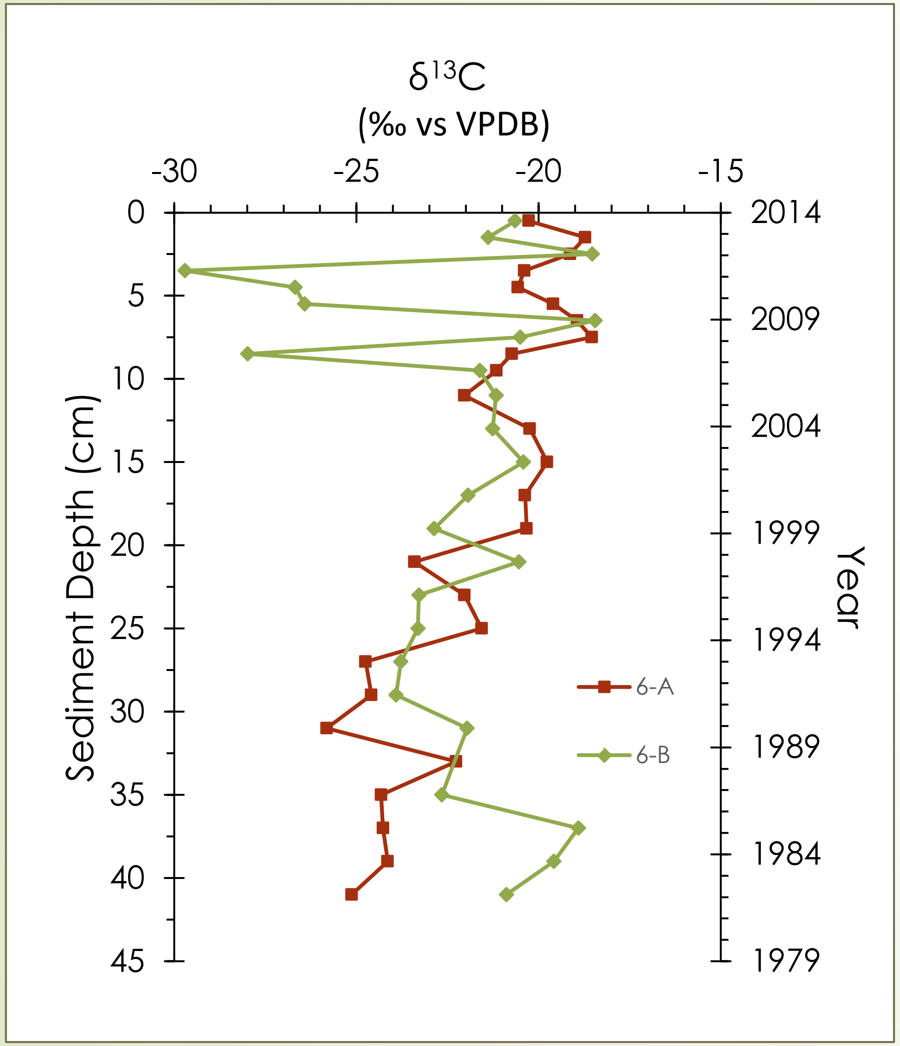
Results: Stable Isotopic Composition



- Shift to greater $\delta^{15}N$ in 2002
  - Input from supplemental wastewater (sewage)

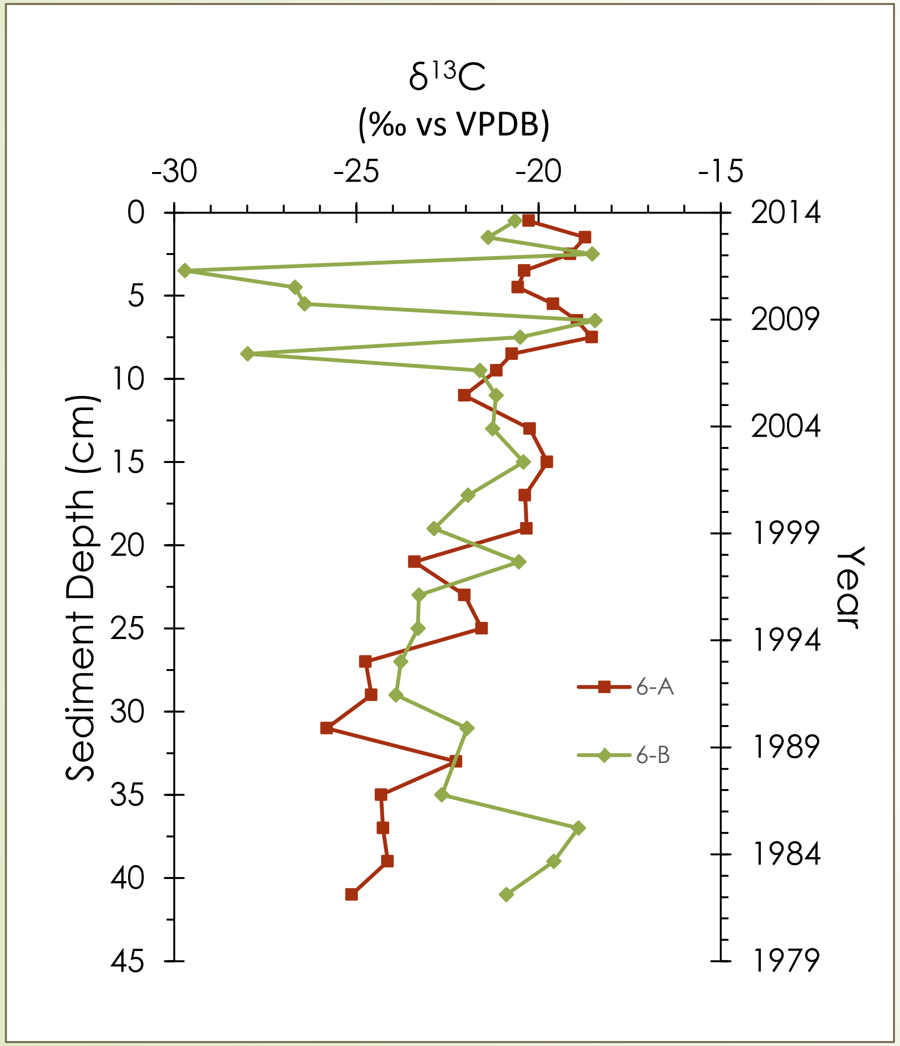
    $\delta^{15}N$ = 10-20 ‰
  - Denitrification
    - ^{14}N preferentially reduced to N_2
    - Residual NO_3 more enriched (greater $\delta^{15}N$)
- $\delta^{15}N$ of algae
  - 5.8
  - Indicates denitrification occurring in water column before sedimentation

Results: Stable Isotopic Composition



- Gradual increase in $\delta^{13}C$ from -25 to -20 ‰
- Significant change with depth ($r^2 = 0.72$ for 6-A)
- Cause of increase
  - Diagenesis?
  - Increasing eutrophication?

Results: Stable Isotopic Composition



- Diagenesis
  - Typically accounts for 1.6-1.8‰ decrease over time due to:
    - Selective degradation of carbs and proteins (greater $\delta^{13}C$)
    - Contribution of ^{13}C-depleted microbial biomass
- Increasing eutrophication
  - Depletion of CO_2 during blooms
  - Phytoplankton less selective against ^{13}C
  - Use increasingly more ^{13}C

Conclusions

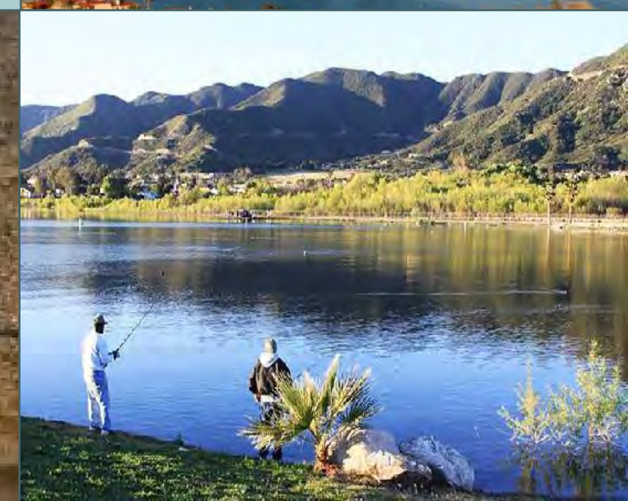
- Change in mean depth has resulted in changes in biogeochemistry within the sediments
- Diagenesis of OC, TN, TP, and Calcium occurring in top 10 cm of sediment
- Shift to higher $\delta^{15}N$ due wastewater input and denitrification (denitrification stimulated by wastewater input)
- Organic matter highly recycled in water column prior to sedimentation

Lake Elsinore and Canyon Lake Water Quality Monitoring – Update 2015

Presented at SAWPA for the Lake Elsinore/ Canyon Lake TMDL Task Force

Chris Stransky and John Rudolph

August 11, 2015



In-Lake Monitoring Approach

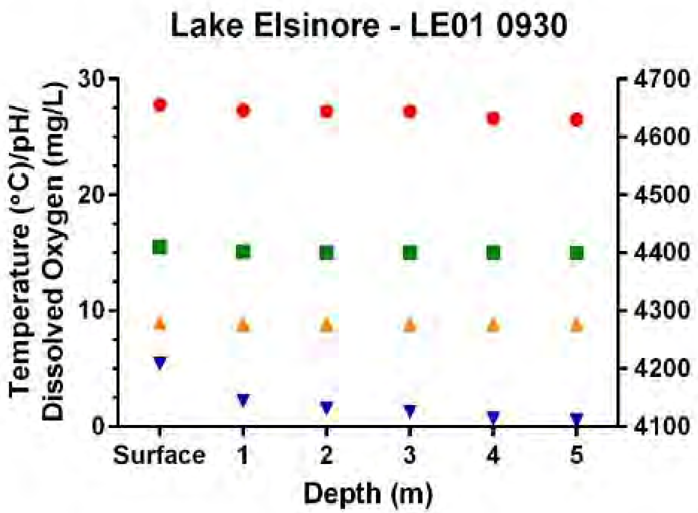
1. Bi-monthly sampling (every other month) ***Potential revised final freq. to enhance sampling in the summer pending additional historic analysis and discussion with the RWQCB.***
2. Water column vertical profiles (DO, pH, water clarity, temp, cond.) 1 m intervals (am/pm)
   - 3 sites in Lake Elsinore
   - 4 sites in Canyon Lake
3. Water column chemistry/nutrient sampling – depth integrated samples
   - 1 site in Lake Elsinore (LE02)
   - 3 sites in Canyon Lake (CL07, CL08, CL10)
4. Chlorophyll-a
   - Depth-integrated and 0-2m surface sample (all chem stations)
   - 0-2m surface sample only (CL09)
5. Lake-wide satellite imagery
   - Chlorophyll-a
   - Turbidity
6. Plankton sampling – preserved and archived

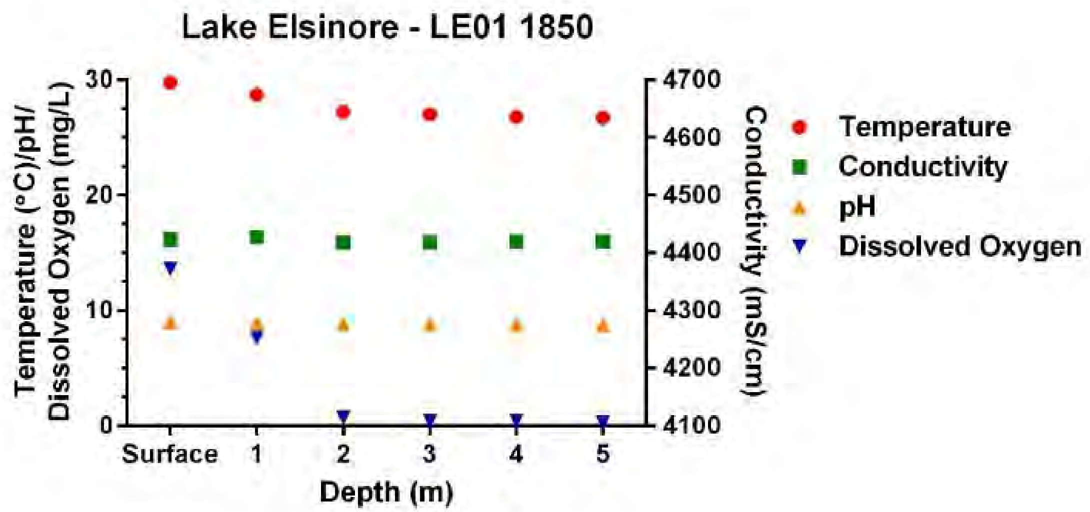
Station Locations – Lake Elsinore

Station Locations – Canyon Lake

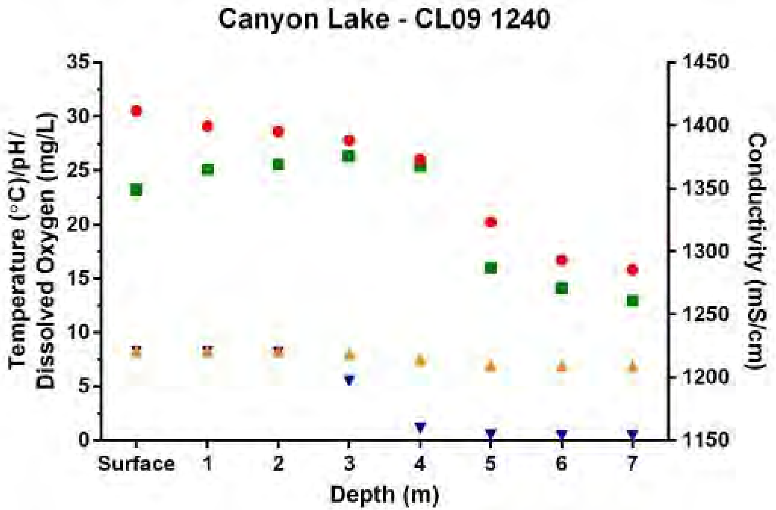
First Sampling Event – July 31st, 2015

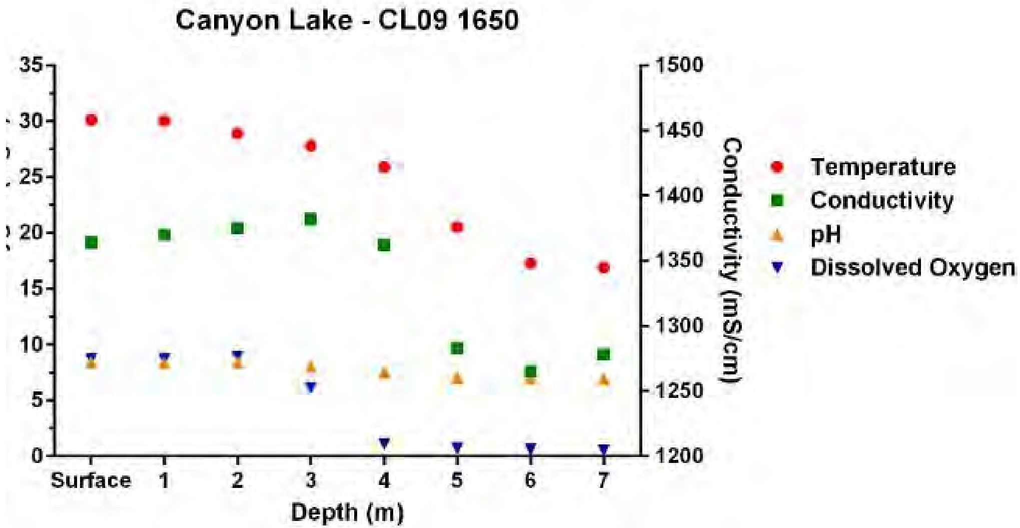
Example Water Profiles – July 31st, 2015
Lake Elsinore





Example Water Profiles – July 31st, 2015
Canyon Lake





Satellite Imagery and Analysis Vendor Comparison

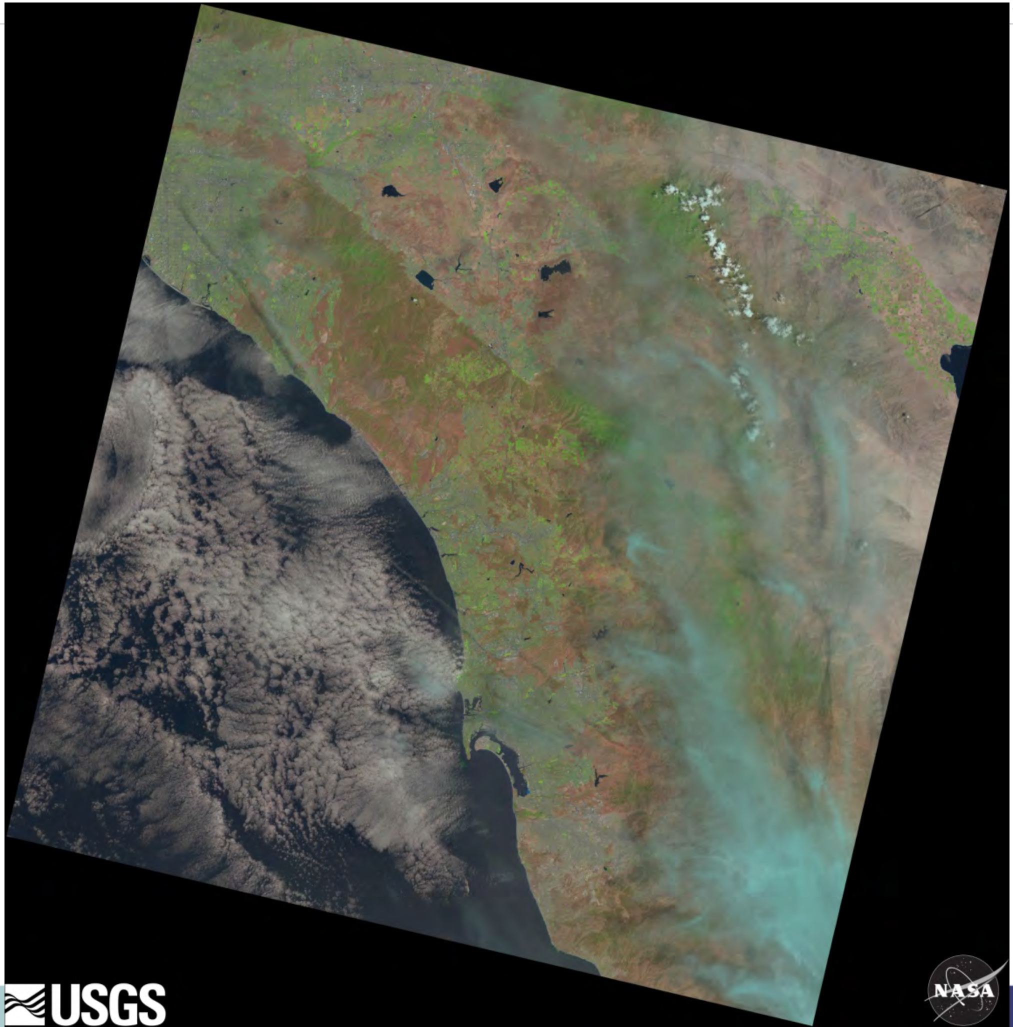
Satellite Imagery Utilized	Blue Water Satellite (Chl-a only)	EOMaps (Chl-a only)	EOMaps (Chl-a & Turbidity)
Landsat 7	$37,350	$6,770	$7,250
Landsat 8/Sentinel 2[a]	$67,050	$6,770	$7,250

Note: Annual costs for 6 image dates is shown. Landsat 7/8 satellite images free from USGS & offer 30m pixel resolution
[a] Sentinel 2 to be launched in October 2015 (15-20m resolution) with data available in early Spring 2016.

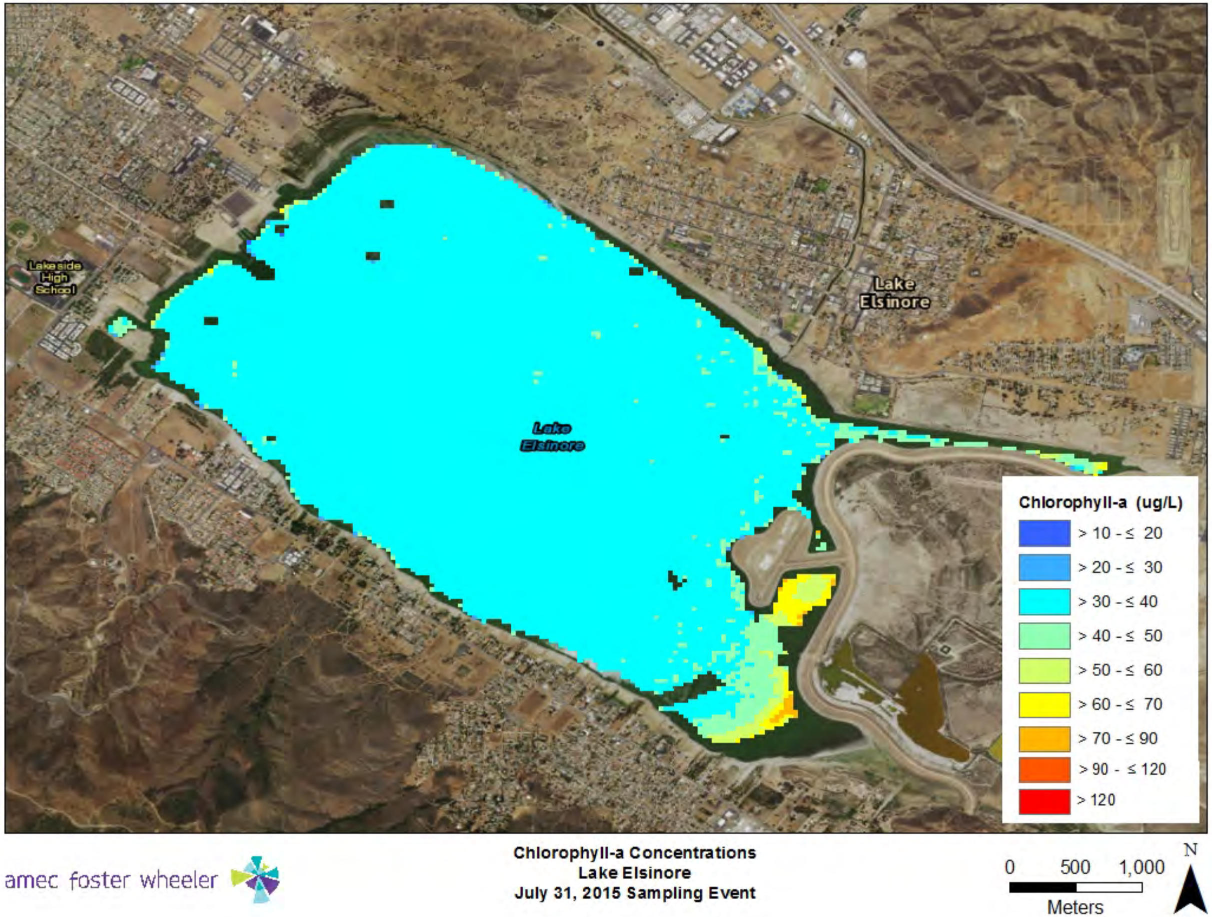
- **EOMaps Data Products**
  - **GIS files with approximately 11,300 LE and 2,000 CL data points**
  - **TIFF & KMZ (Google Earth) files**
  - **Put the Chl-a sample concentration into lake context**
  - **Able to run statistics**
    - **% of lake above/below target values**
    - **Lake-wide trends as sampling continues**
  - **QA data to determine value reliability**

http://www.eomap.com/services/water-quality/

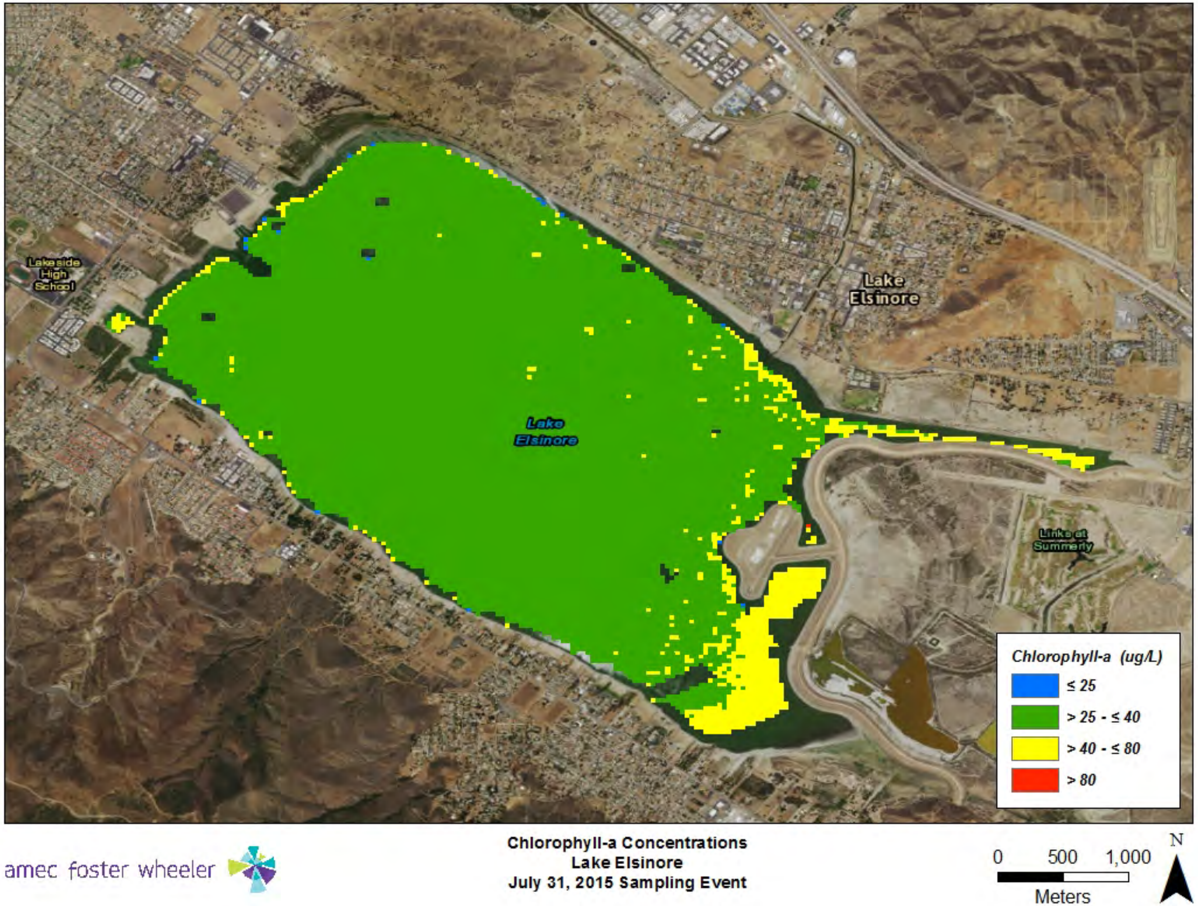
Satellite Imagery – Conditions on July 31



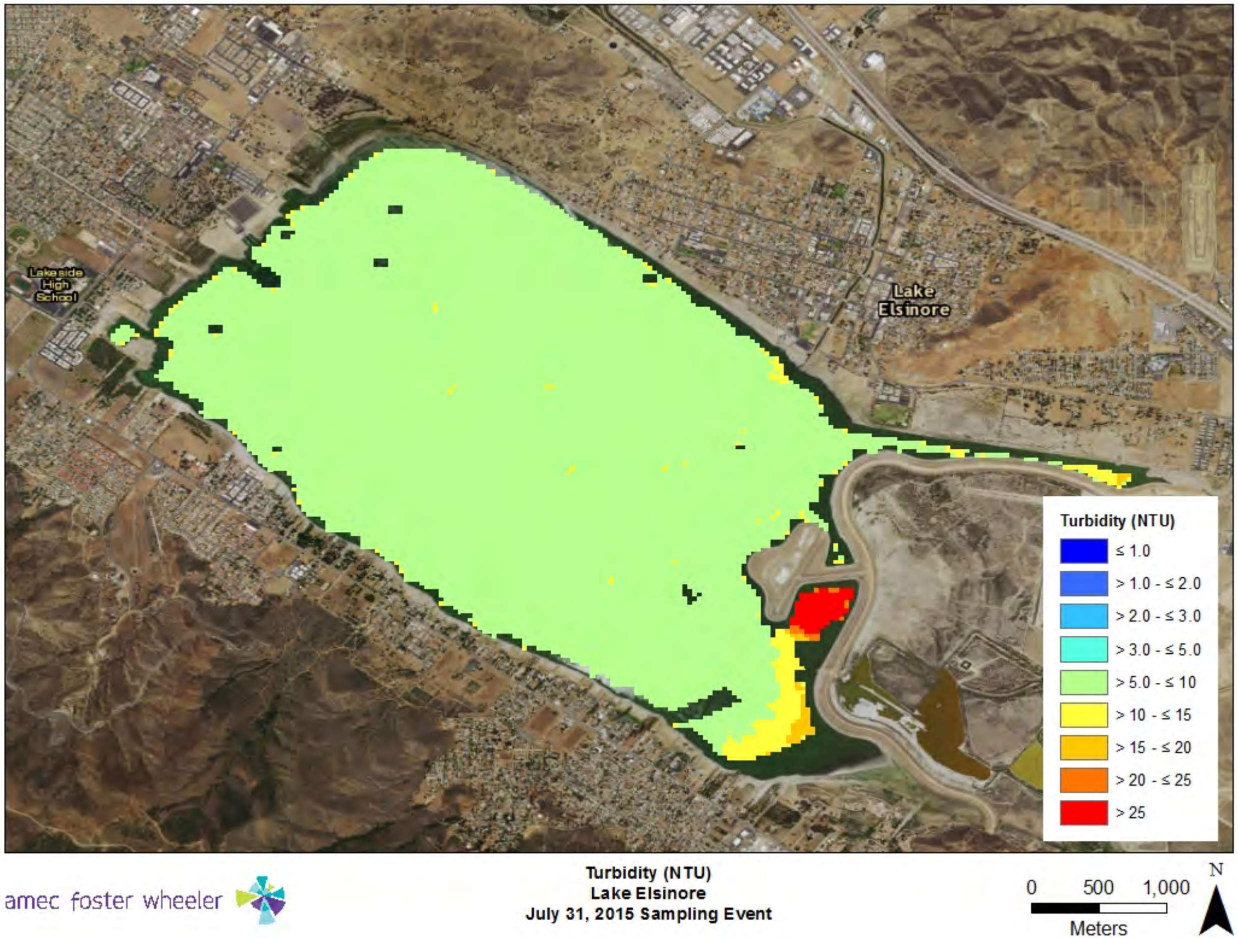
Satellite Imagery – Chlorophyll-a in LE (fine scale gradient)



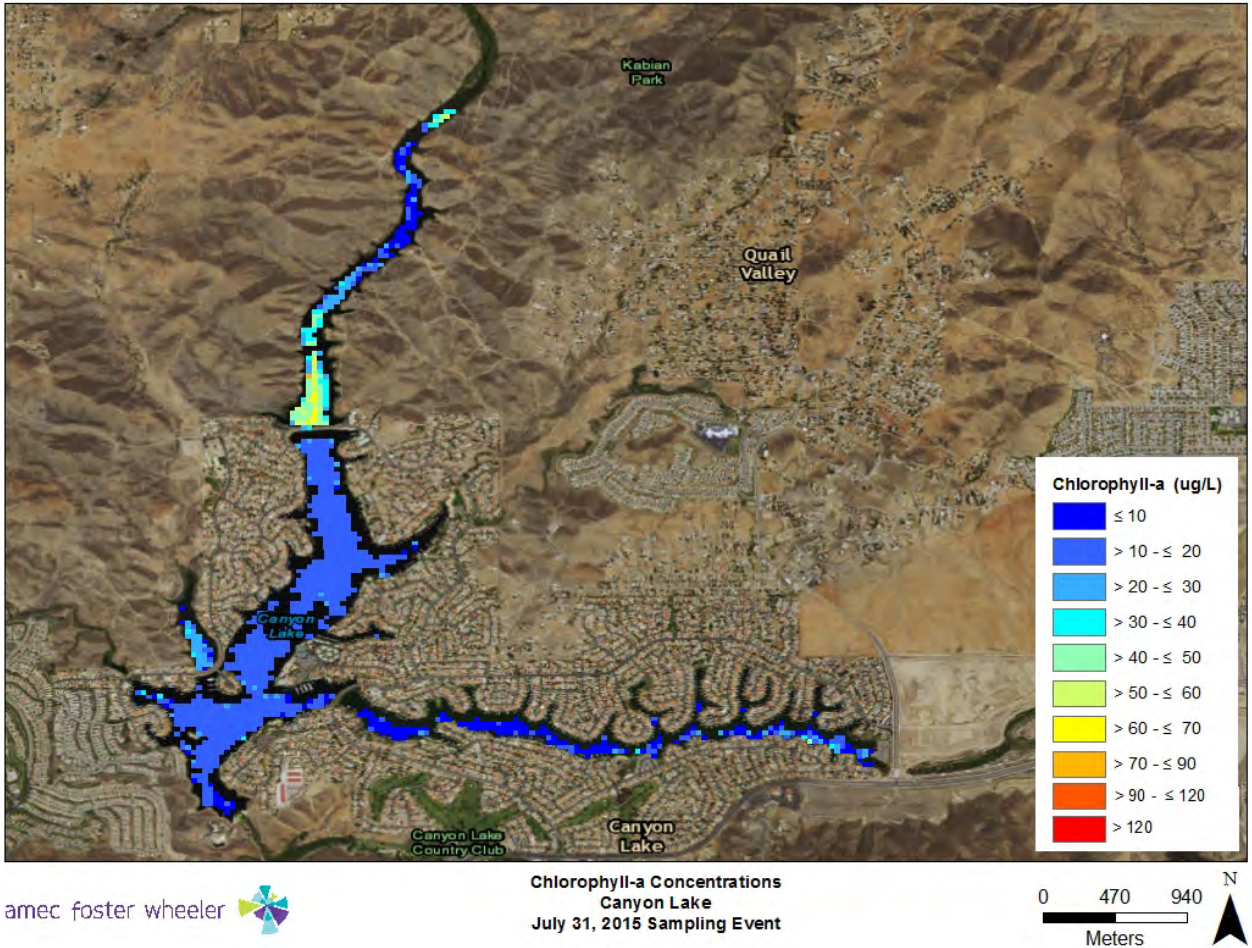
Satellite Imagery – Chlorophyll-a in LE (relative to TMDL targets)



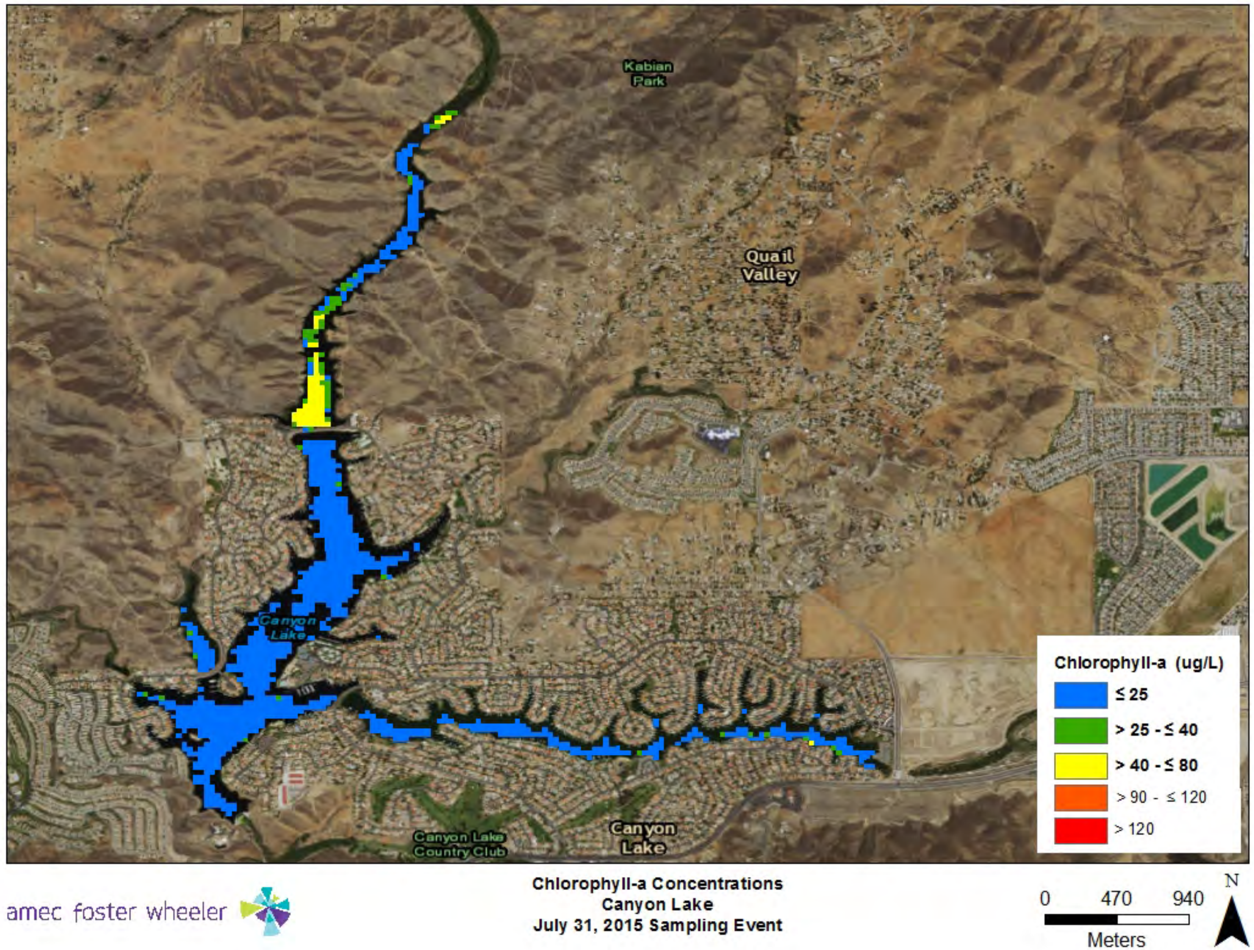
Satellite Imagery – Turbidity in LE



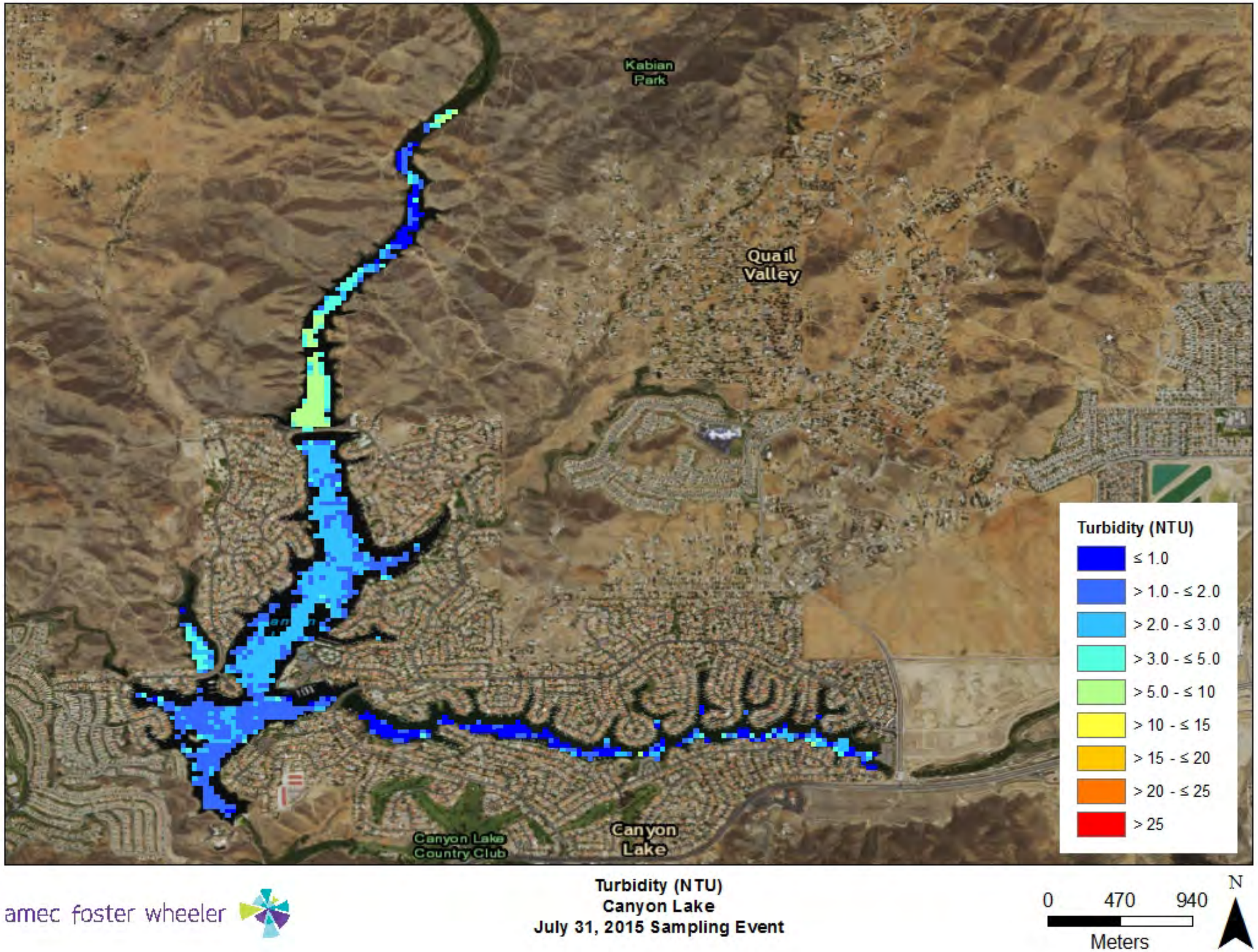
Satellite Imagery – Chlorophyll-a in CL (fine scale gradient)



Satellite Imagery – Chlorophyll-a in CL (relative to TMDL targets)



Satellite Imagery – Turbidity in CL



Turbidity (NTU)
Canyon Lake
July 31, 2015 Sampling Event

Next Steps

- Frequency distribution curves and statistics for satellite imagery
  - Mean, median, 95^{th} percentiles for chlorophyll-a and turbidity; compare to in situ measures and TMDL targets
- Download from Lake Elsinore aeration data sonde (30 day period)
  - Compare to in situ measures of pH, DO, conductivity, water clarity, and temp.
  - Calculate average values based on discreet and continuous data
  - TMDL compliance comparison for DO
- Analytical chemistry data expected soon
  - Summarize, stats, and comparison to TMDL targets
- Integrate data with historical measurements
- Next sampling date October 19 (LandSat8 overpass)
- Watershed monitoring prep