Watershed GIS and Remote Sensing to Assess Regional Water Quality

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Background

Since the 1980's, an extensive field sampling campaign has been conducted by the Central Utah Water Conservancy District (CUWCD) in response to high levels of nutrients and algal blooms in Deer Creek Reservoir. Remote sensing studies were used to provide additional information and insight into the evaluation of historical and current water quality through the detection of chlorophyll. The use of focused GIS software such as ENVI and Aquaveo's Watershed Modeling System (WMS) allowed for convenient analysis of the entire region including 5 reservoirs, and provided additional insight into the water quality on a regional scale.

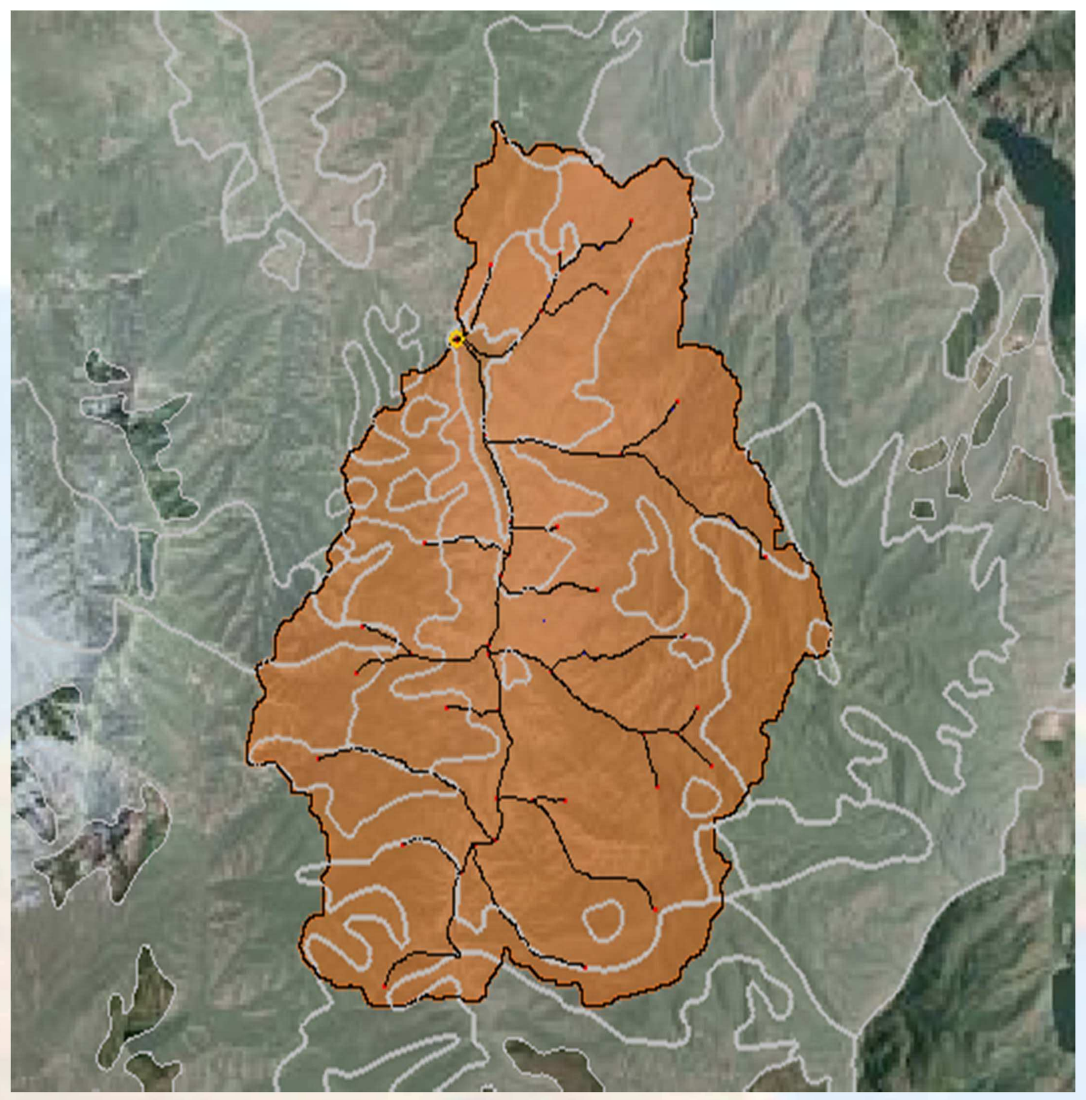


Figure 1. Watershed Delineation and Land Use Coverage Overlay

Analysis of contributing watersheds of each of the reservoirs provided valuable information about the types of activities and land use that affect the reservoirs. WMS was used to delineate watersheds and compute land use coverage overlays. An example of the land use coverage and intersecting watershed is shown for East Canyon Reservoir in Figure 1.

Percent of Watershed Land Use Coverages

Reservoir	% Urban	%Agricultural	%Forested	%Rangeland
Deer Creek	1	13.5	10	52.5
East Canyon	0	1	27.5	70
Echo	1	6	48	43.5
Jordanelle	0	4	67	27.5
Rockport	1	12.5	46	39.5

The five reservoirs included in the study were located between 5420 and 6040 feet in elevation and ranged in size from 684 acres (East Canyon) to 3300 acres (Jordanelle).

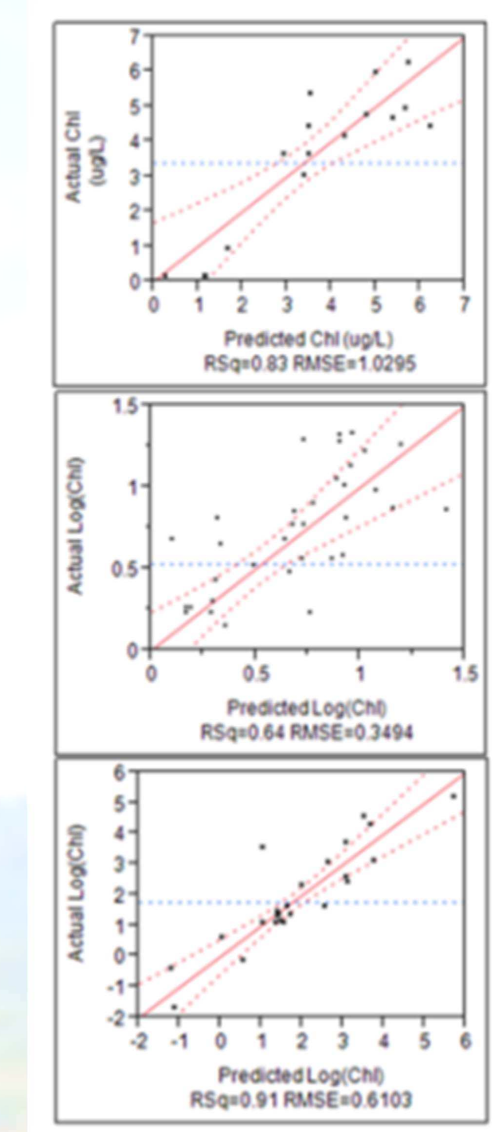


Figure 2. Regression of Estimation Expression and Field Measured Values

Remote Sensing Model Development

Robust seasonal chlorophyll detection models were developed using historical field data collected in the Wasatch Mountain area and Landsat images from the Landsat-5 and -7 missions. A seasonal approach was used to provide more accurate estimates than models developed using the entire growing season or a limited portion of the growing season. This seasonal approach takes into account the different characteristics of the populations of algae that dominate the reservoirs at different times in the growing season.

To develop the models for each sub-season, 9-pixel grids were created at each of the field sampling locations. The reflectance values within the grids went through a noise-filtering and averaging process. The average reflectance values were then used in three stepwise regressions (one for each season). Tests of leverage aided in identifying outliers, and the final estimation expressions were created for application to the Landsat images. The correlation between field measured chlorophyll values and values based on the estimation expression are shown in Figure 2.

The expressions were applied using the reflectance values of each pixel in the satellite image as inputs, and ENVI band math, resulting in a spatial distribution map of estimated chlorophyll values. This process is illustrated in Figure 3.

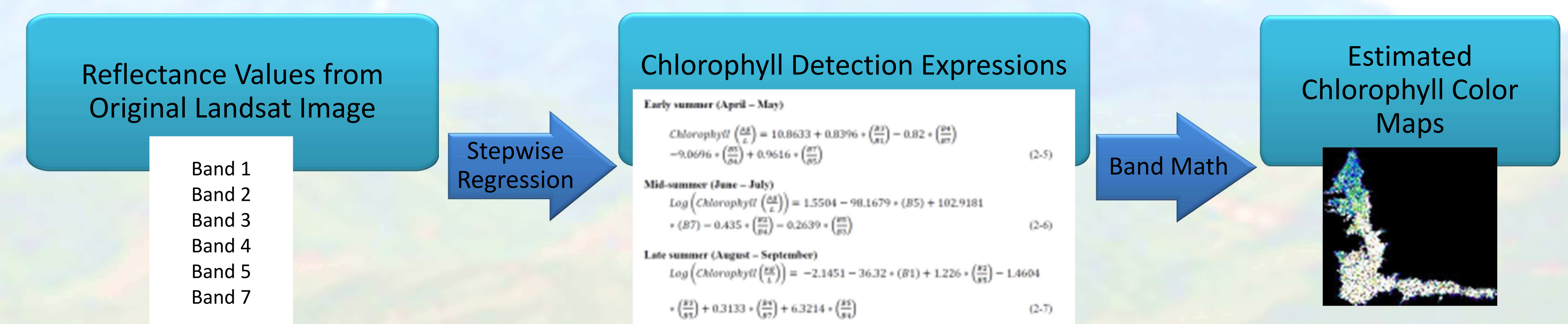
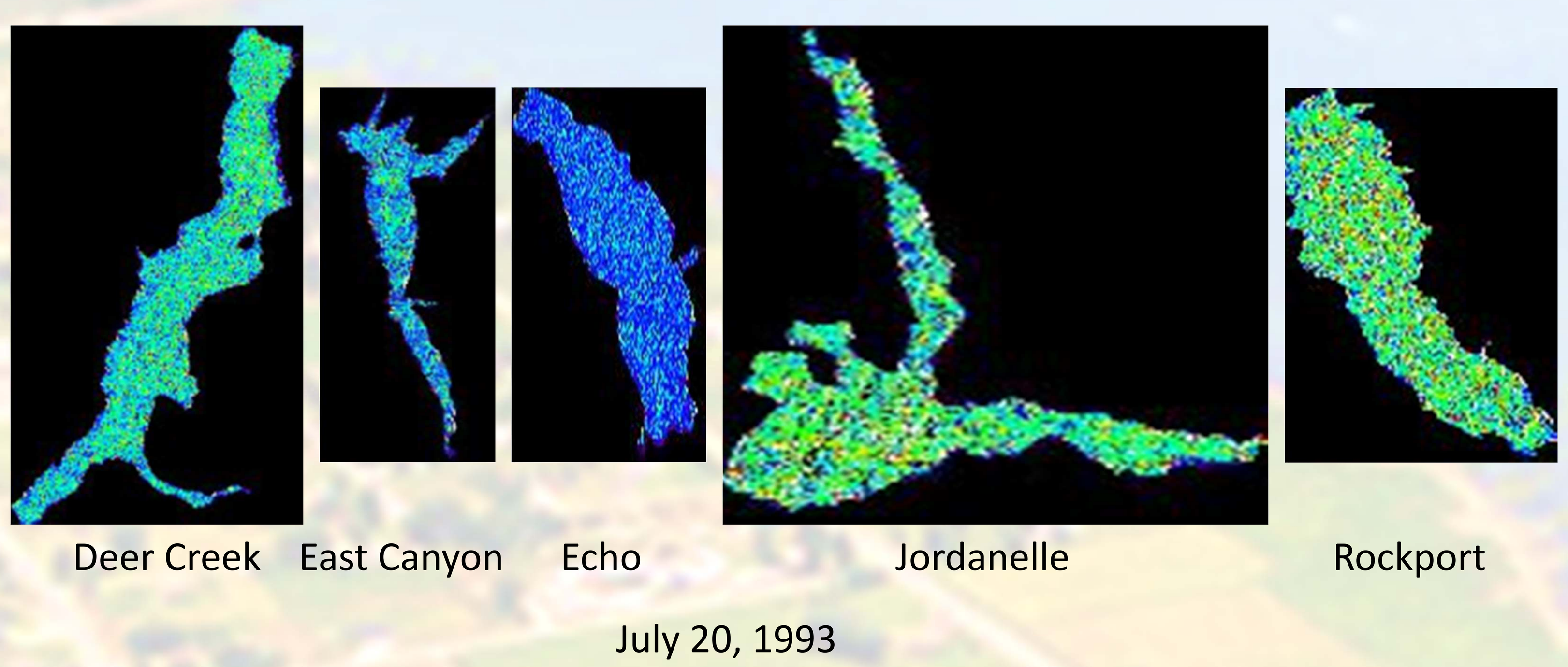
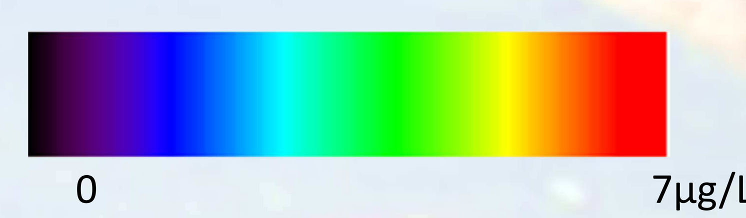


Figure 3. Process of Creating Spatial Distribution Map

Remote Sensing Model Application





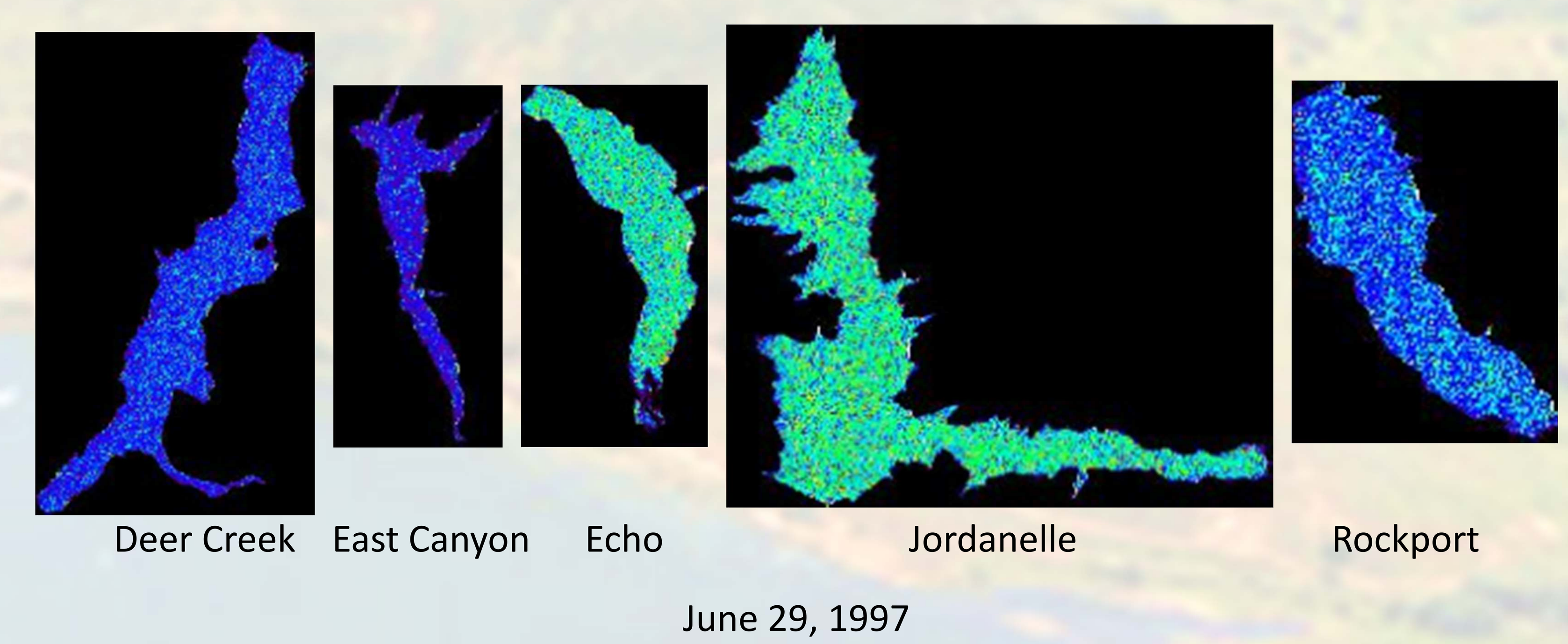


Figure 4. Examples of Color Maps for all 5 Reservoirs

Historical Trends

Reservoir and Season	Mode (µg/L/year)	Max (µg/L/year)	Standard Deviation (µg/L/year)
Deer Creek – Early	-0.05	-0.10	-0.04
Deer Creek – Mid	-0.06	-0.12	-0.03
Deer Creek – Late	-2.14	-3.48	-1.33
Jordanelle – Early	0.06	0.09	0.02
Jordanelle – Mid	-0.07	-0.19	-0.05
Jordanelle – Late	-0.79	-2.50	-0.81
East Canyon - Early	0	-0.12	-0.05
East Canyon – Mid	-0.04	-0.25	-0.10
East Canyon – Late	0.17	-2.08	-0.65
Echo – Early	0.06	0.04	0
Echo – Mid	-0.04	-0.17	-0.07
Echo – Late	0.30	0.18	-0.01
Rockport – Early	-0.04	0.02	0.02
Rockport – Mid	-0.05	-0.10	-0.03
Rockport - Late	0.18	-2.19	-0.86

Figure 5. Change in Estimated Total Reservoir Chl-a levels for Each Season from 1984 to 2012

Conclusions

Each of the reservoirs included in the regional study demonstrated unique behavior over the past 30 years. By analyzing the degree of change in µg/L/year for each of the sub-seasons and the contributing land use, common trends and behaviors between the reservoirs were identified.

The reservoirs with high percentages of forested land cover (Jordanelle, Rockport, and Echo) demonstrate increasing amounts in maximum and average values, despite varying widely in area, depth, and other characteristics (highlighted in red). High percentages of forested land may indicate less regulation and fewer nutrient-reduction efforts. The reservoirs with the highest average chlorophyll values were Deer Creek and East Canyon Reservoirs, the reservoirs with the highest percentage of rangeland, which may be a significant source of nutrients which lead to algal blooms.

The greatest decreases in both average and maximum levels for 4/5 reservoirs occurred in the late summer months (highlighted in blue), reflecting a concentrated focus and efforts on this portion of the growing season.

The standard deviation provides a description of how varied chlorophyll levels are throughout the lake, which aids in describing the magnitude of blooms. Observations from 1984-2012 indicate that the each of the variation within each of the lakes is near constant, or decreasing. This provides evidence that blooms are decreasing in their magnitude.

Average Chlorophyll Values between 1984-2012 (µg/L)				
East Canyon	Jordanelle	Deer Creek	Echo	Rockport
10.23	8.56	11.03	5.65	4.85

Figure 6. Average (Mode) of Total Reservoir Chl-a Levels

Historical data - both field sampled and remotely sensed - coupled with land use information can provide insights and improve evaluations of the ongoing activities and mitigation efforts that impact our lakes and reservoirs. GIS programs make processing and analysis of this large amount of data convenient and feasible.

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