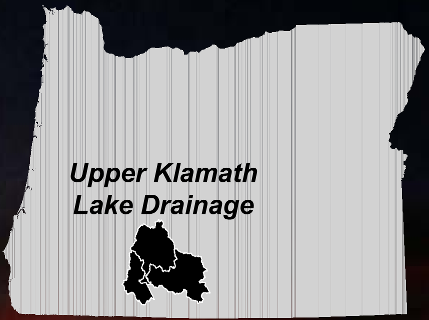
Overview of the Upper Klamath Lake and Agency Lake TMDL



Upper Klamath Lake - Hanks Marsh

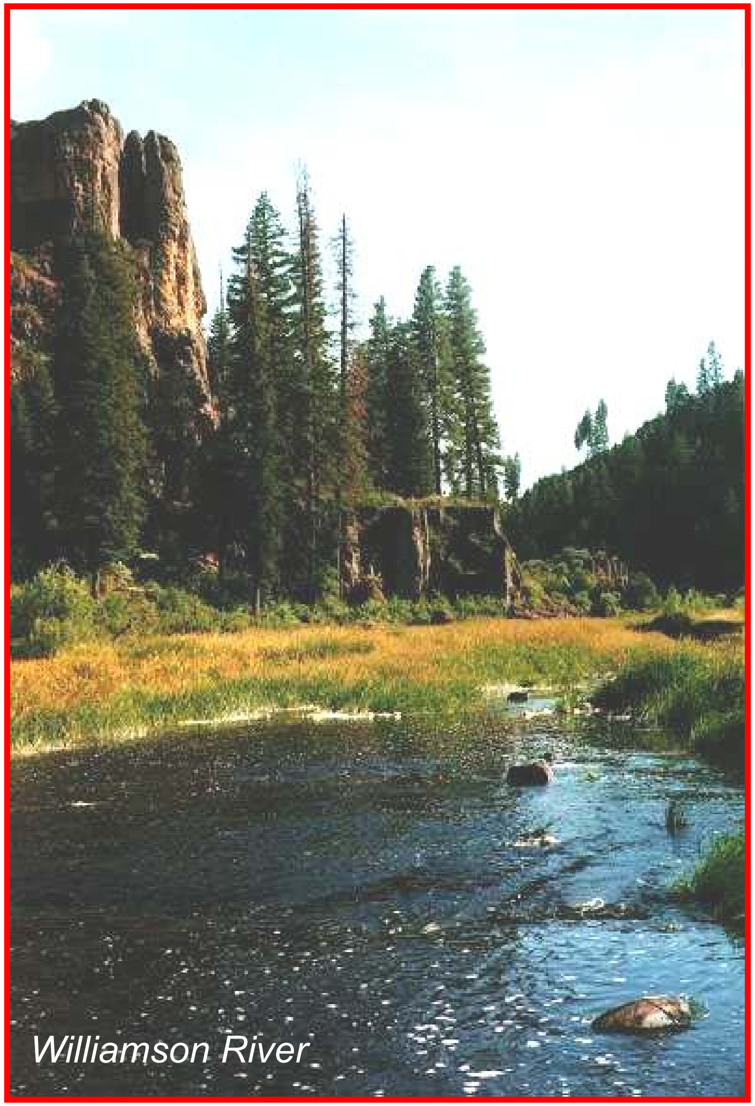
State of Oregon Department of Environmental Quality

Why is DEQ doing a Total Maximum Daily Load (TMDL)?

1. The federal Clean Water Act requires that water quality standards are developed to protect sensitive beneficial uses.

2. Water bodies that do not meet water quality standards are designated as water quality limited and placed on the 303(d) list.

3. All 303(d) listed water bodies are required to have TMDLs that develop pollutant loading that meet water quality standards.

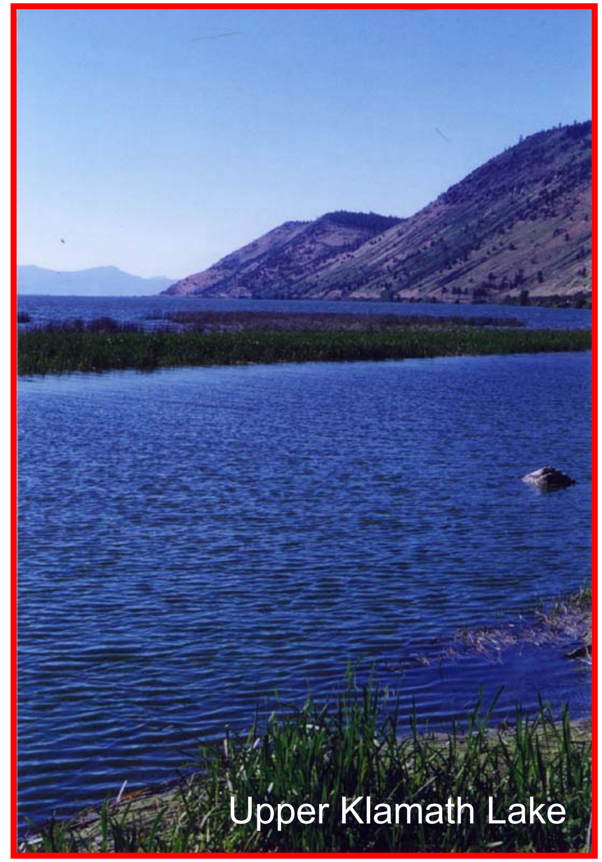


What is a Total Maximum Daily Load?

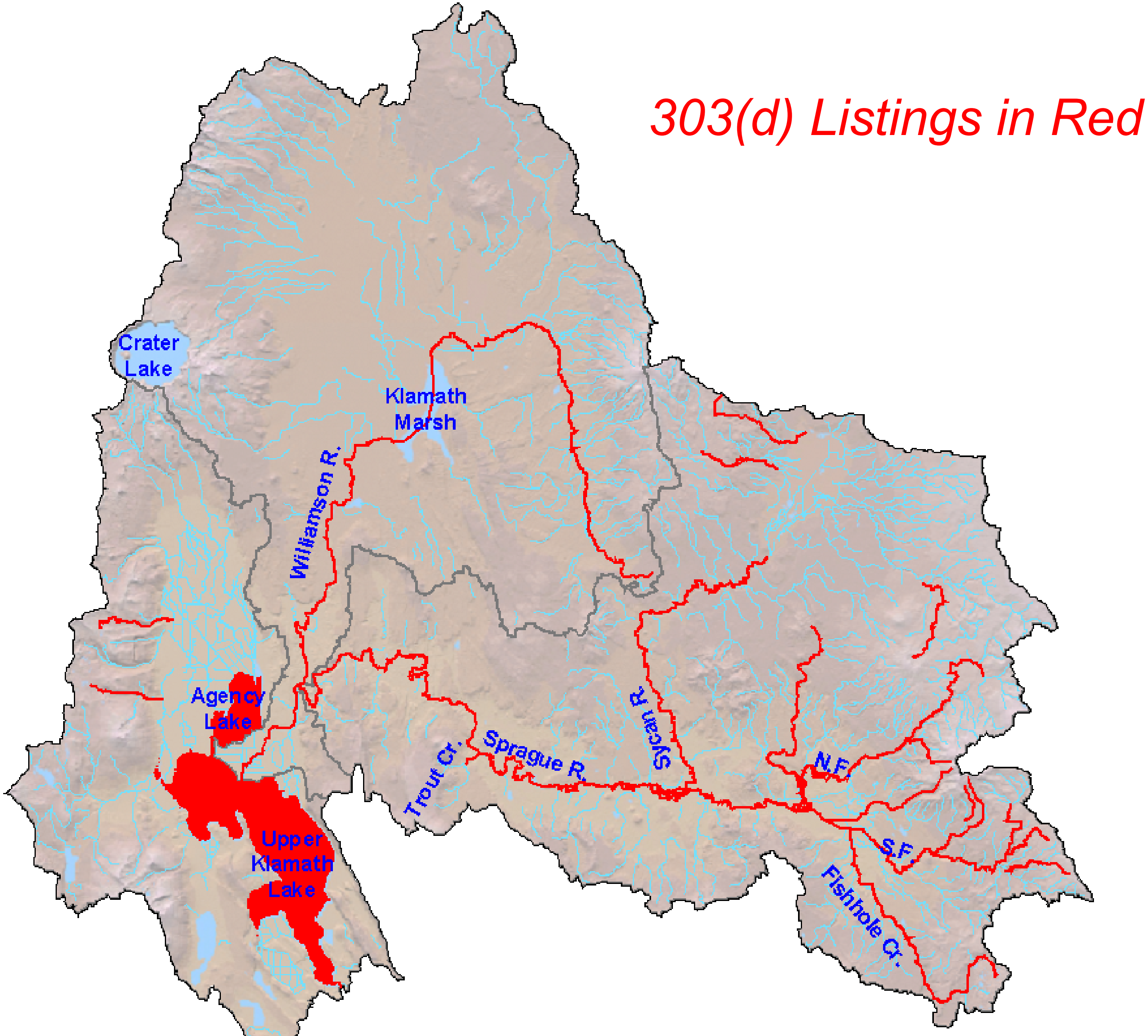
A TMDL Distributes the Allowable Pollutant Loading Between Sources

$$TMDL = WLA + LA_{(NPS+Background)} + MOS + RC$$

- **Waste Load Allocations (WLA)** - Allowable pollutant loading from point sources
- **Load Allocations ($LA_{(NPS+Background)}$)** - Allowable pollutant loading from nonpoint sources and natural background sources
- **Margin of Safety (MOS)** - Portion of the pollutant load held back to account for uncertainty in the analysis.
- **Reserve Capacity (RC)** - Portion of the pollutant load held back in reserve for future growth



Water Quality Limited Water Bodies



Why is Phosphorus Targeted in the TMDL?

Total phosphorus load reduction is the primary and most practical mechanism to reduce algal biomass and attain water quality standards for pH and dissolved oxygen.

- Seasonal maximum algal growth rates are controlled primarily by phosphorus, and secondarily by light and temperature.

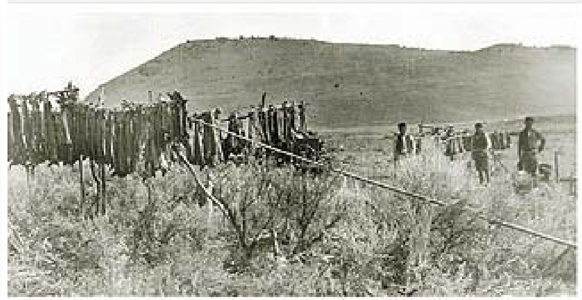
- High phosphorus loading promotes production of algae, which, then modifies physical and chemical water quality characteristics that diminish the survival and production of fish populations.

Algal Bloom in Upper Klamath Lake

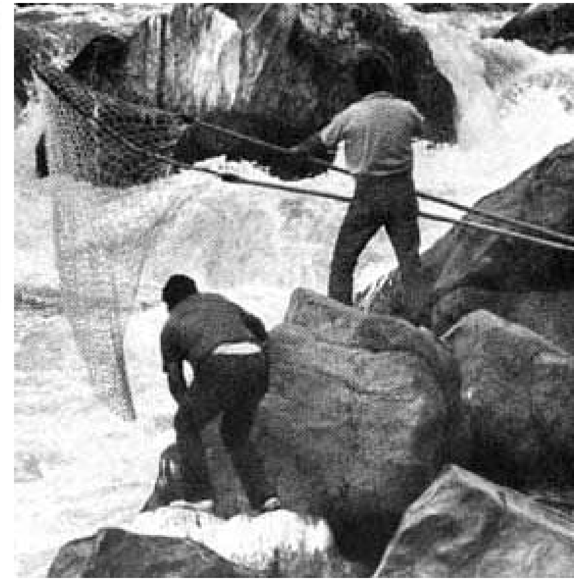
Impacts of Poor Water Quality on Beneficial Uses

Fisheries and aquatic health have suffered from poor water quality

"We thought nothing of catching a five- or six-pound trout," recalls Basin resident Ivan Bold, remembering days of better fishing. Fishing guides are also noting declining catches as the Basin's waterways struggle to support the demands placed on them. (OWRD, 2001)

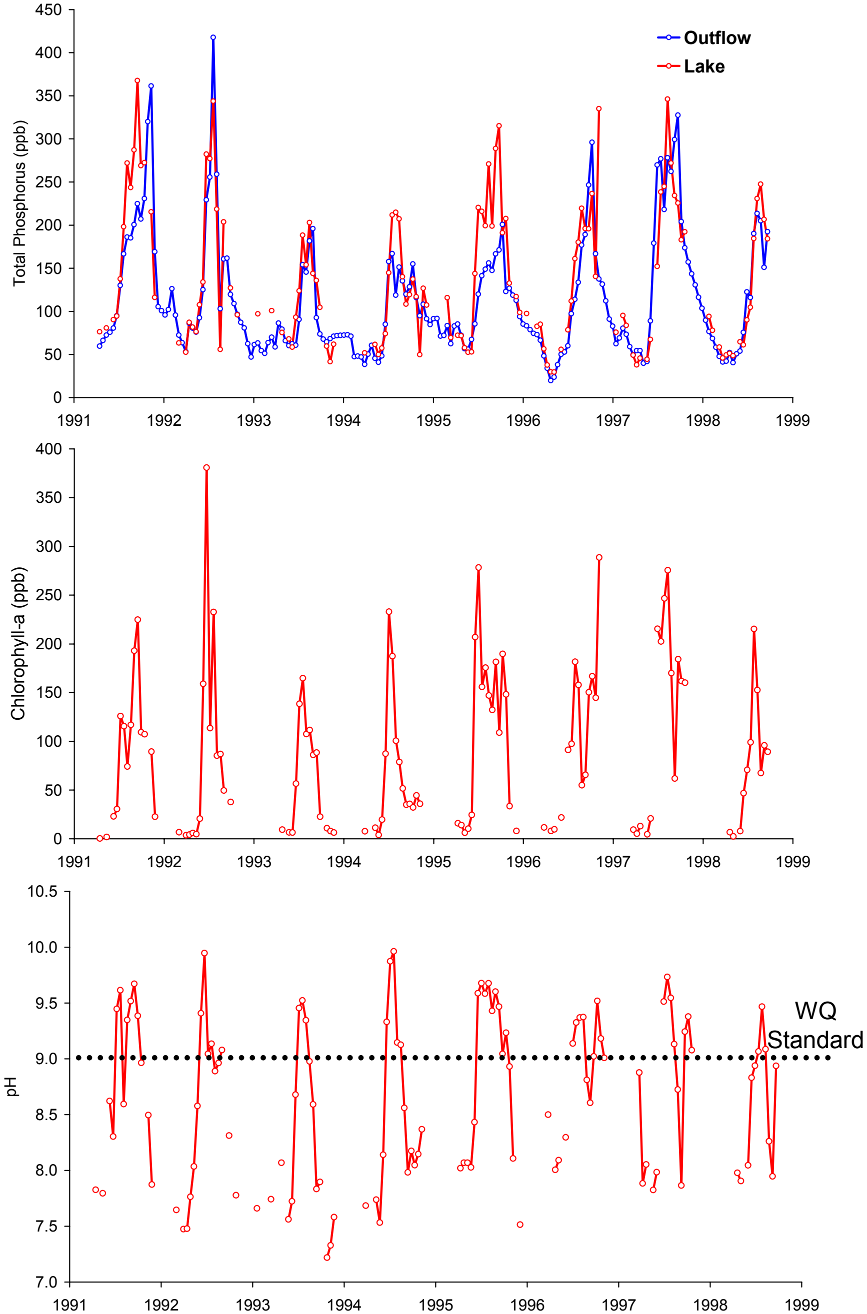


Drying sucker fish at the Lost River. Tribal fishing for suckers was stopped in the mid-1980's.

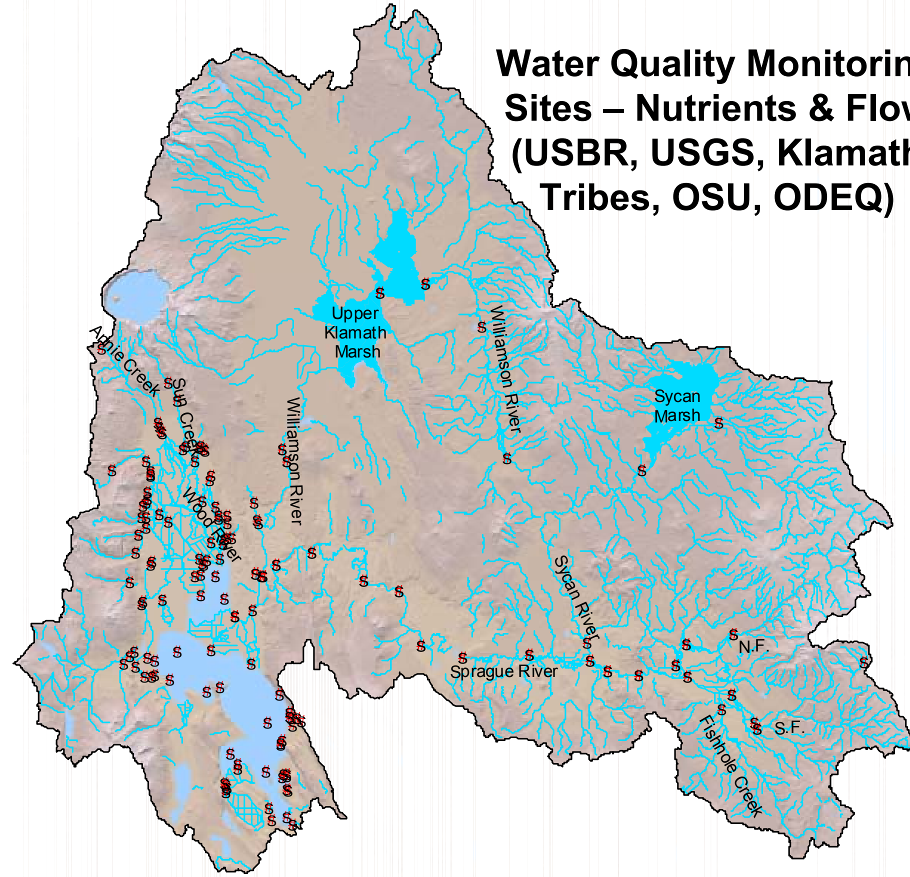


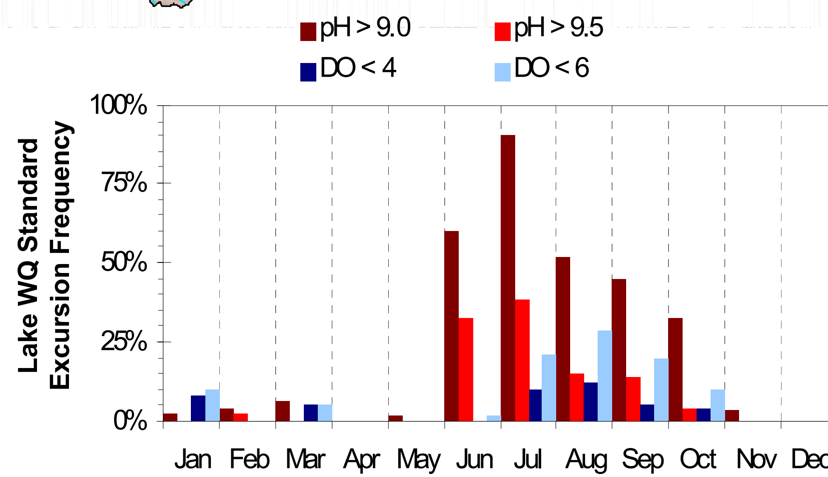
Historically, the Karuk people of the Klamath River harvested fish. Contemporary Karuk fishermen continue to dip net at Ishi Pishi Falls on the Klamath River. There, they may still harvest salmon and winter steelhead for subsistence purposes (NCIDC Photo Gallery).

Mean Lake Data (Kann and Walker, 2001)



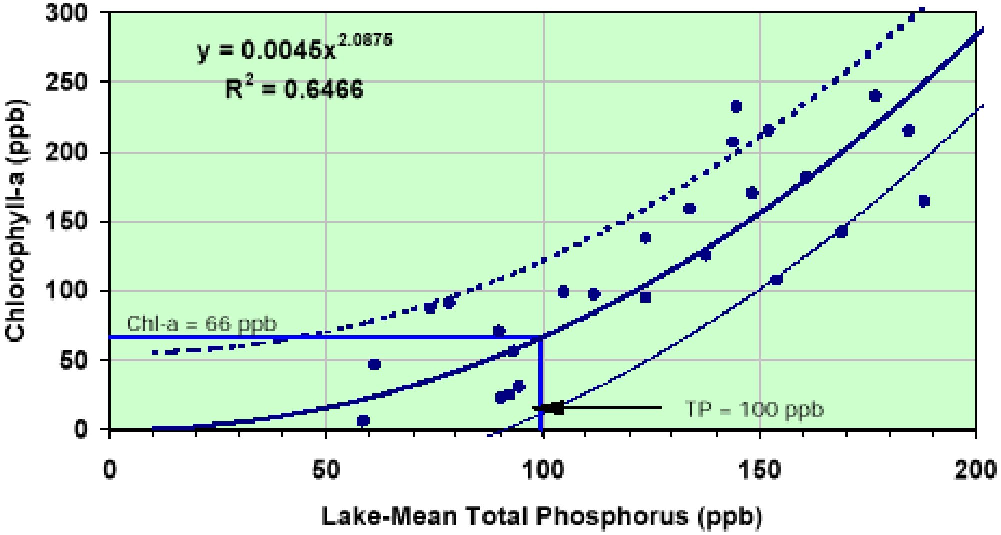
Water Quality Monitoring Sites – Nutrients & Flow (USBR, USGS, Klamath Tribes, OSU, ODEQ)





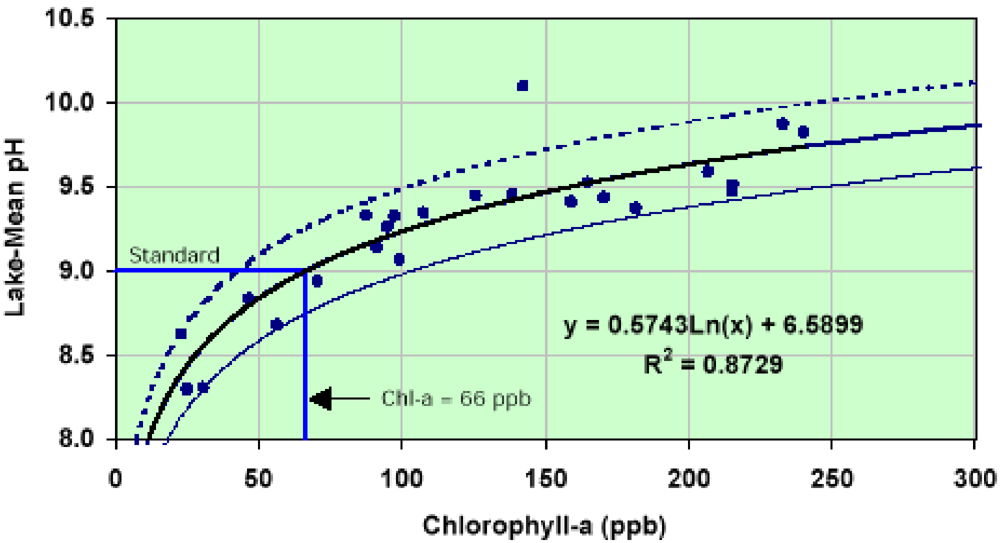
Empirical Relationship Relating Total Phosphorus, Chlorophyll-a and pH *(Walker 2001)*

Violations of water quality standards for pH and dissolved oxygen are directly related to algal productivity which in turn, is a function of phosphorous loading. Statistical Relationships support total phosphorus load reduction as the management goal for Upper Klamath and Agency Lakes



Chlorophyll-a v. Phosphorus

Yearly lake mean total phosphorus is associated with chlorophyll-a to derive a TMDL target for total phosphorus.



Lake Mean pH v. Chlorophyll-a

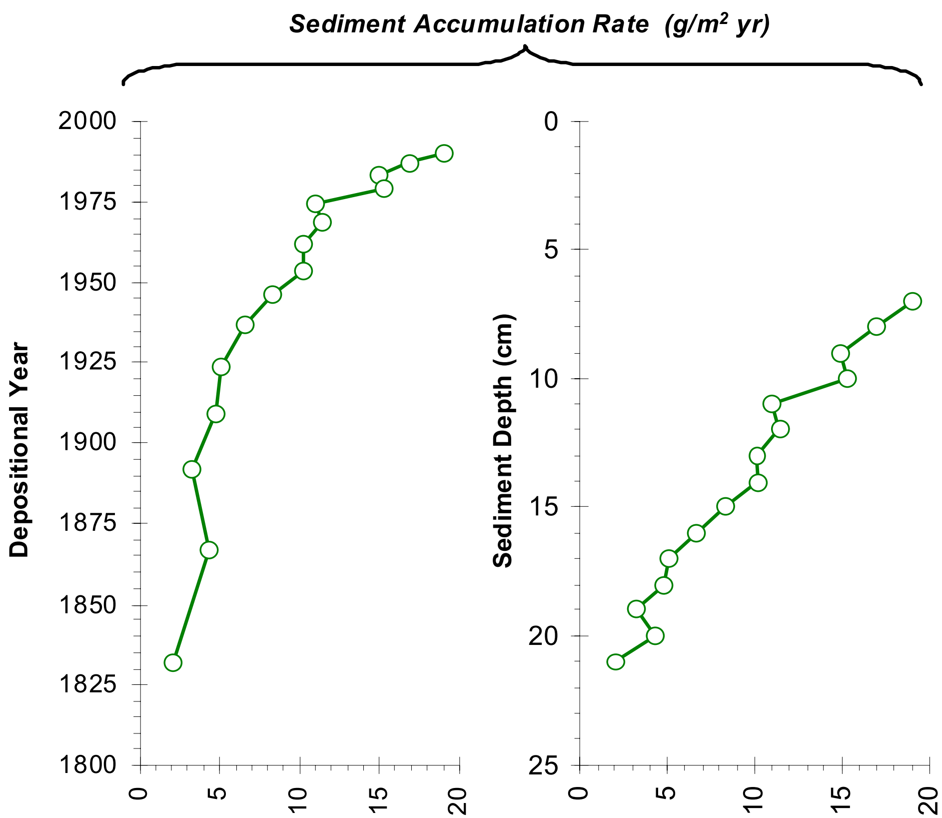
Chlorophyll-a correlates to lake mean pH. To achieve the pH standard of 9.0, a target concentration of chlorophyll-a is necessary.

Indications of Lake Water Quality Changes

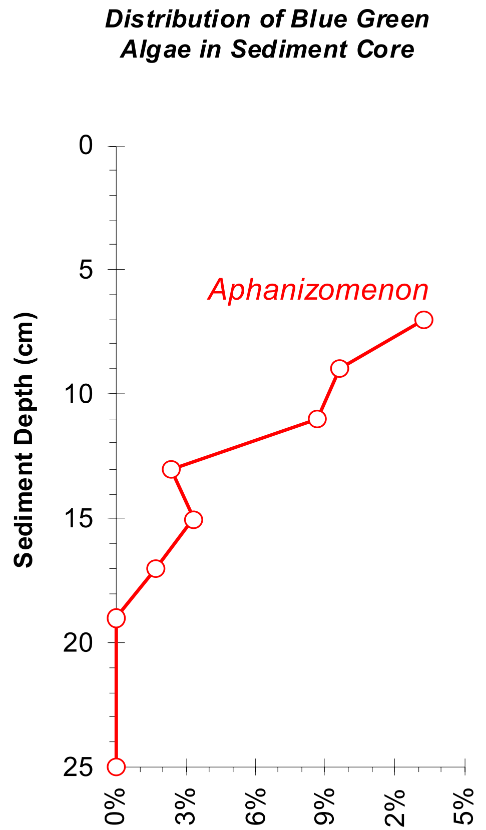
"The view of the lake as a naturally hypereutrophic system is consistent with its shallow morphology, deep organic-rich sediments, and a large watershed with phosphorus-enriched soils. However, watershed development, beginning in the late-1800's and accelerated through the 1900's, is strongly implicated as the cause of its current hypereutrophic character."

-Bortleson and Fretwell 1993

Sediment Core Data (Eilers 2001)

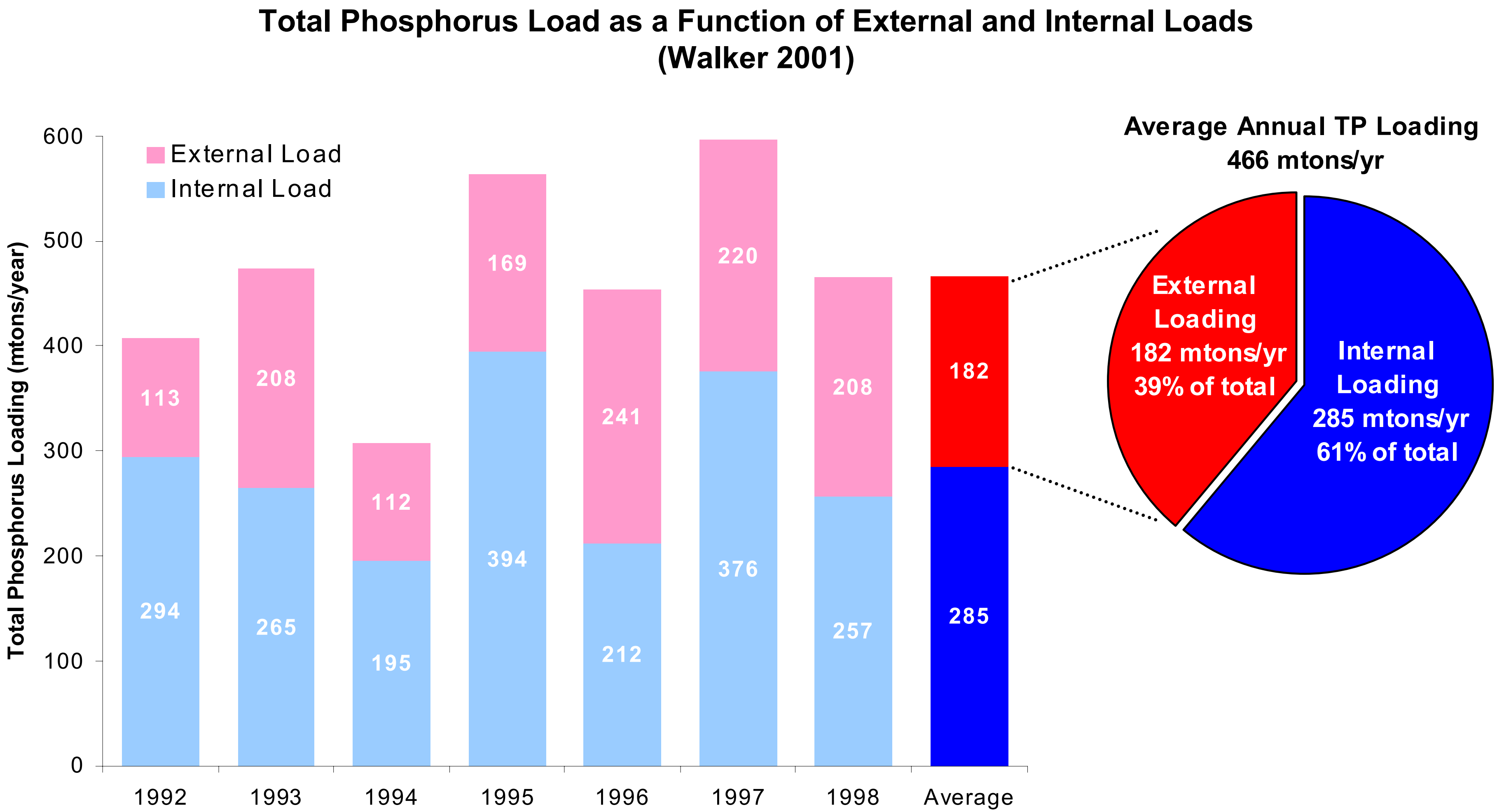


Sediment core analysis demonstrates that sediment accumulation rates have increased over that past 120 years



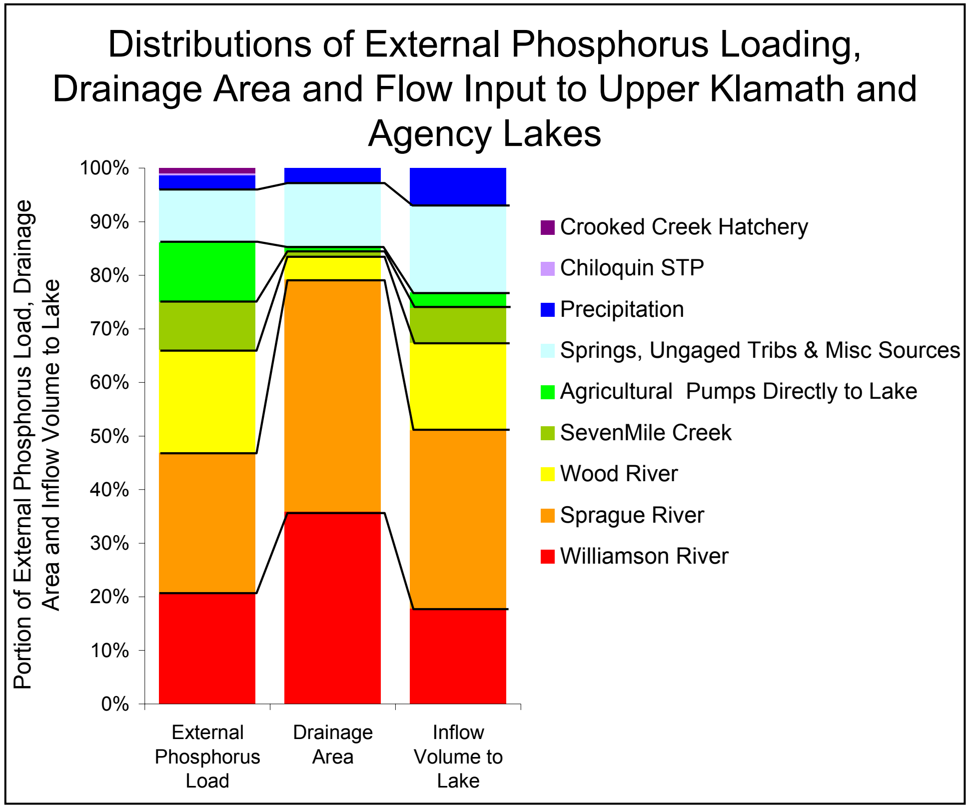
Nitrogen fixing blue-green algae are now more abundant indicating an increase in phosphorus availability

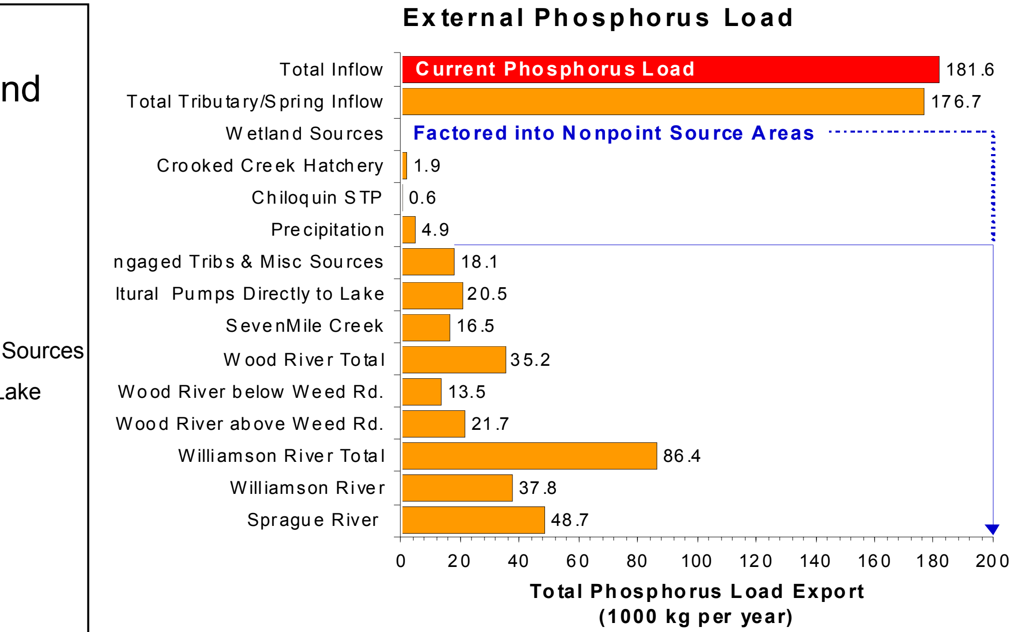
Total Phosphorus Loading to the Lake

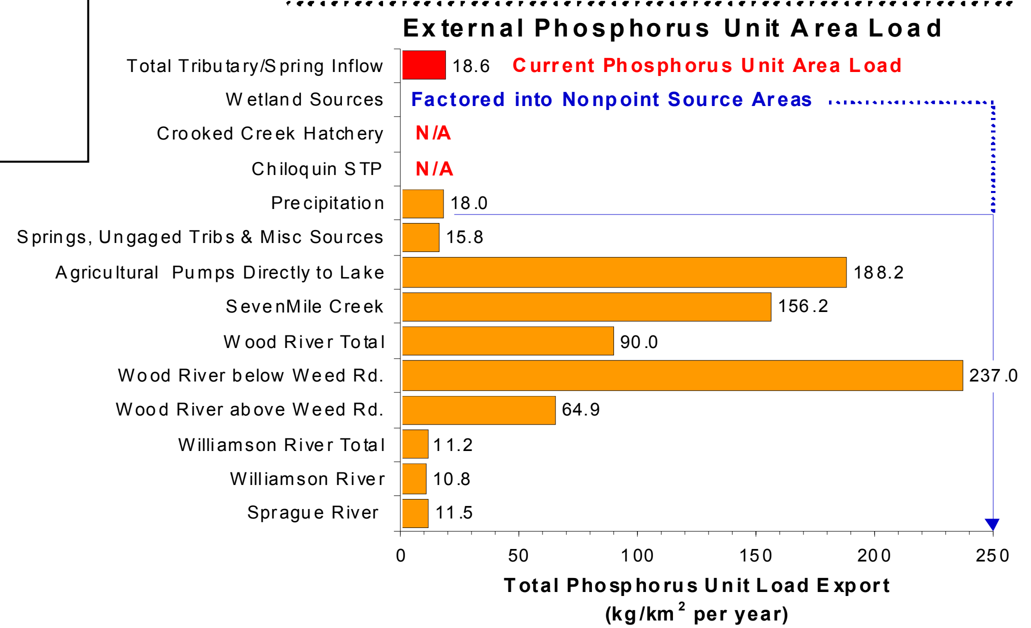


External Total Phosphorus Loads are Targeted as the Primary Control for AFA blooms and Corresponding pH Increases

Annual External Total Phosphorus Loads (Kann and Walker, 2001)







- External sources of phosphorus are distributed throughout the Upper Klamath Lake drainage.
- For simplicity, these sources are broken into source areas and that contribute directly to the lake phosphorus levels.
- Unit area loads can be used to identify pollutant “hot spots” or source areas.

Anthropogenic External Sources of Total Phosphorus

Anthropogenic sources of external loading (loading from sources other than natural background and sediments in the lake) have increased total loading to the lake via:

1) **Reclaiming/draining near lake wetlands for agricultural uses**. Wetland reclamation and use may account for 29% of the external total phosphorous loading to the lake (ODEQ 2001), and
2) **Increased water yields and runoff rates in the Williamson and Sprague River Drainages** have been documented in the 1951-1996 period that are independent of climatic conditions (Riseley and Laenen 1998). The increase in water yield is likely caused by channelization, wetland/riparian area conversions and reductions evapotranspiration in the watershed. Increased water yields are associated with increased erosion and particulate total phosphorus transport. These increased water yields are likely the result human land use and may account for 18% of the external phosphorus loading to the lake (ODEQ 2001).

Agriculture Pumps on Reclaimed Wetlands

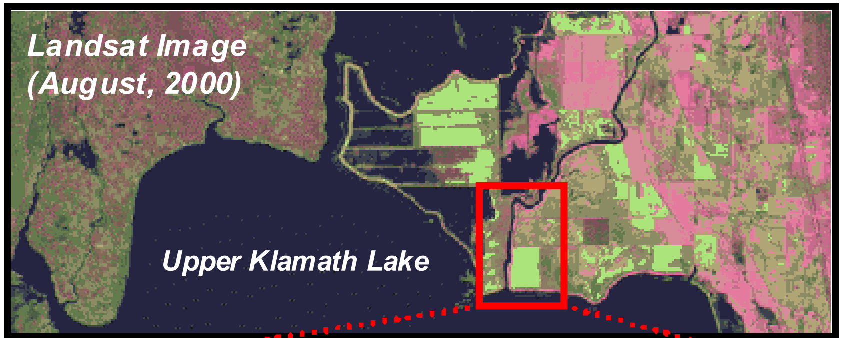
Wood River Reclaimed Wetland at Modoc Point Road

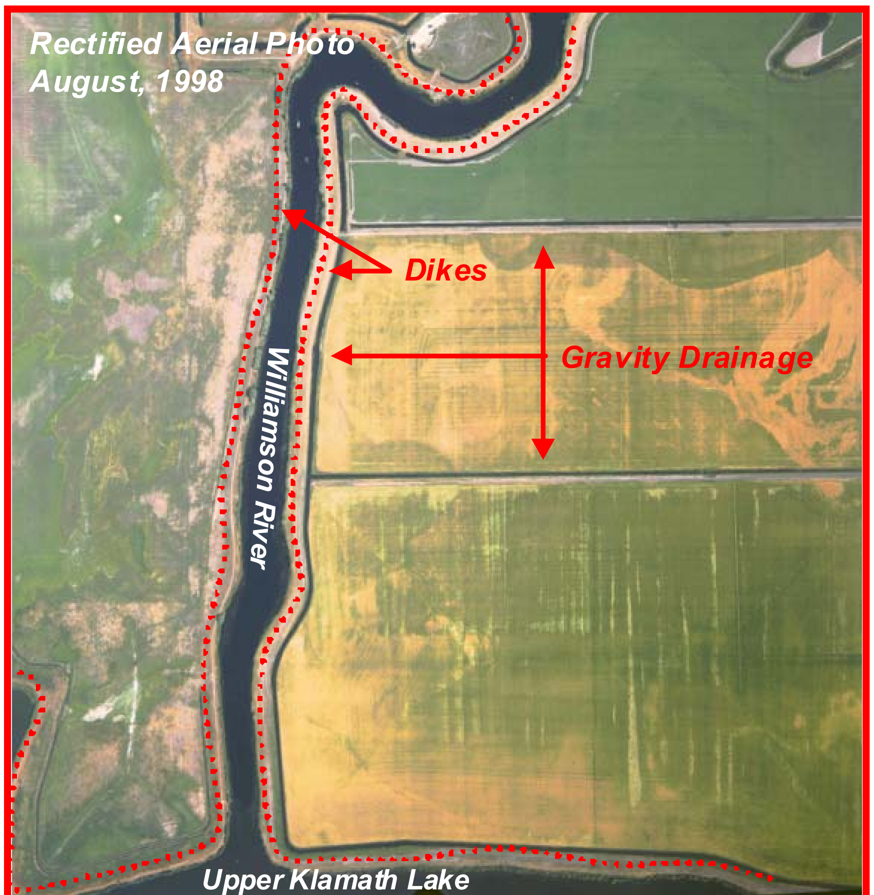
Turn of the century canal construction & wetland draining

Erosion and Particulate Total Phosphorus Transport

Agricultural Returns and Nutrient Leaching from the Lower Williamson River Delta

Aerial Views of a Reclaimed Wetland – Williamson River Delta

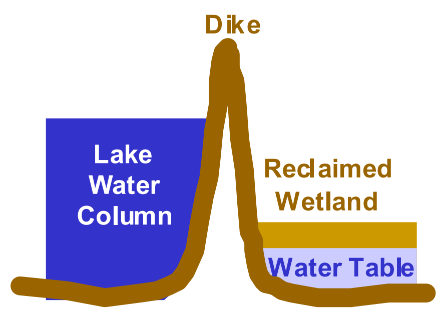




Example of an Upper Klamath Lake Reclaimed Wetland

Williamson River Delta

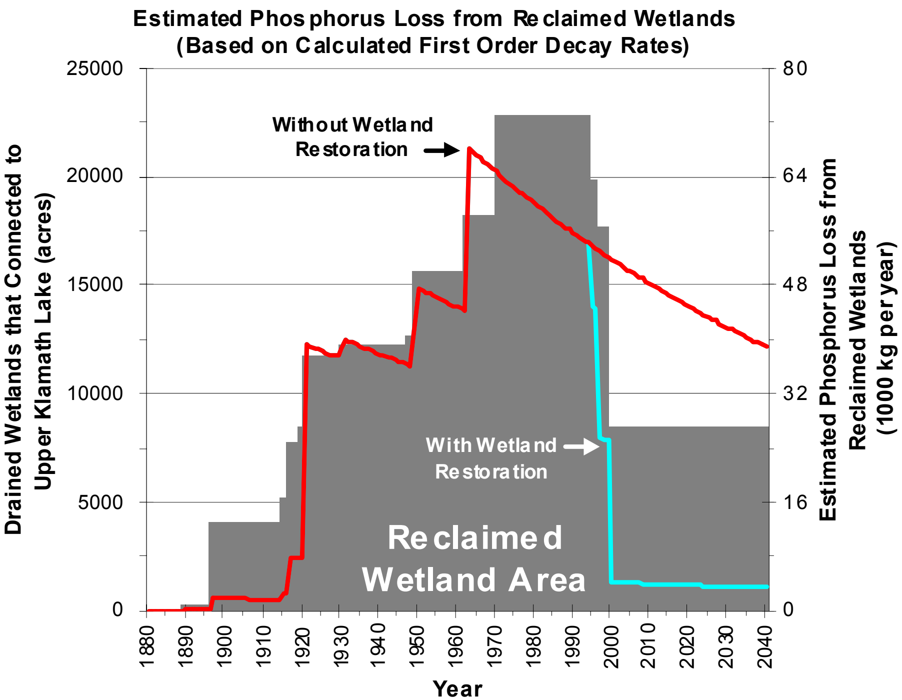
Dikes are constructed to disassociate the wetland from the river and lake waters. Gravity drainage and agricultural pumps maintain lower water surface elevations below the dikes. The difference between lake water surface elevation and the reclaimed wetland can reach 7-8 feet. Subsidence is commonly experienced in these areas due to soil loss, decomposition and loss of buoyancy (Snyder, personal communication). Maximum subsidence in this area is reported as 9-10 feet (TNC, personal communication).

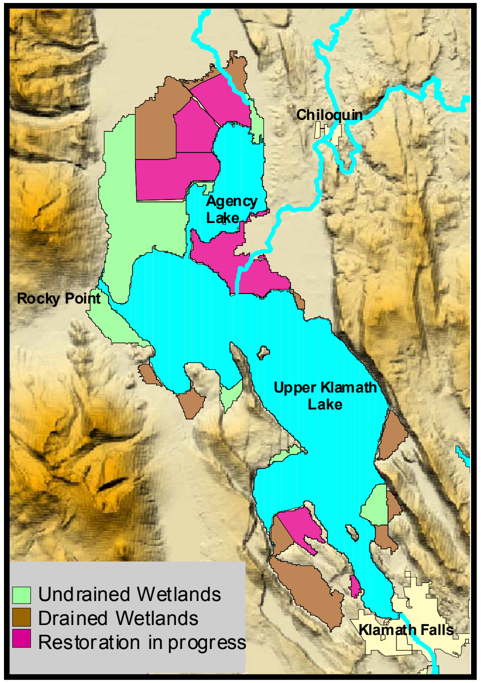


Wetland Reclamation - Physical Changes to the Lake System

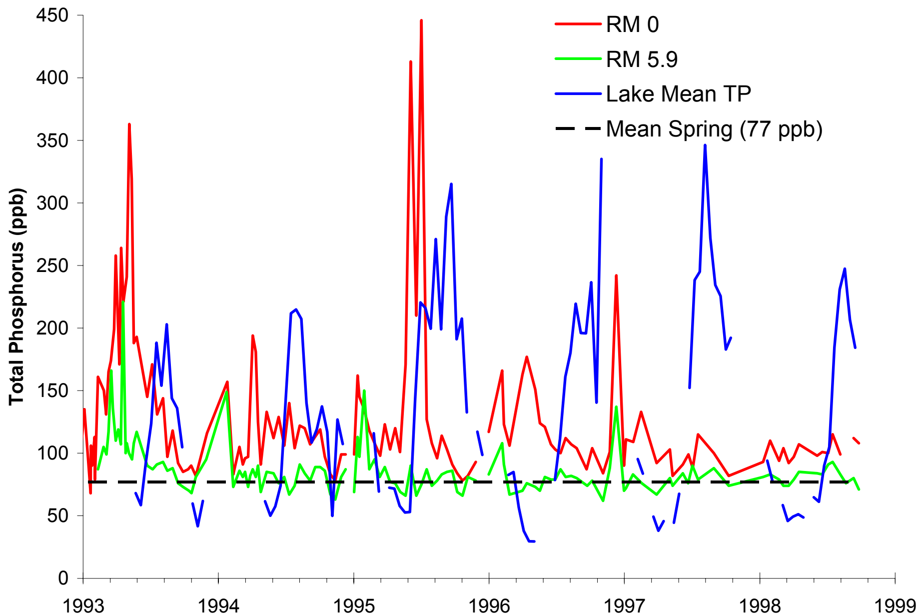
Extensive wetland draining has occurred around Upper Klamath Lake and Agency Lake, starting in 1889 and continuing through 1971. Drained wetlands are a large source of nutrients to Upper Klamath Lake (data and image from Snyder, 2001).

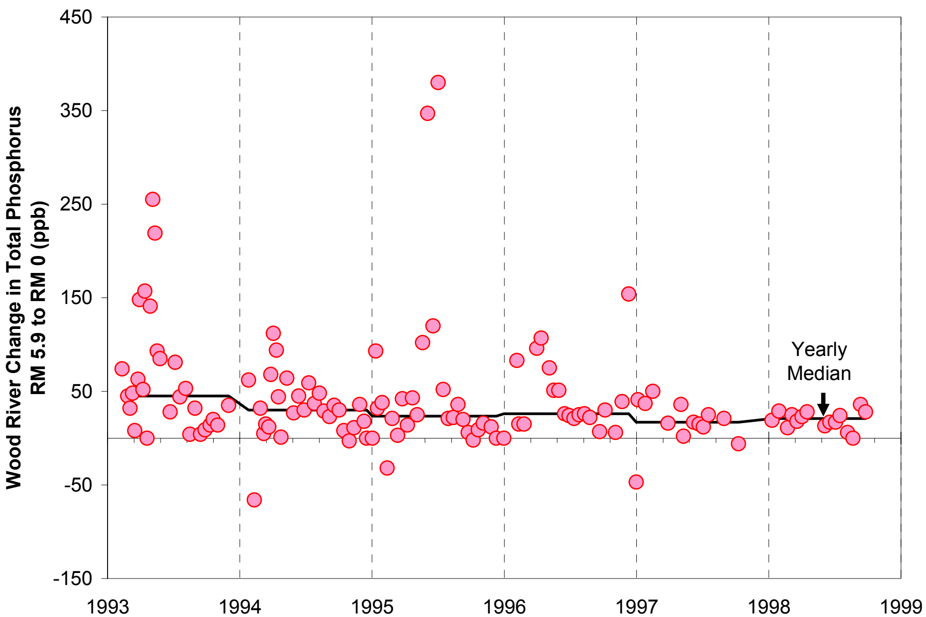
Phosphorus losses from reclaimed wetlands peaked in 1963 at 68,200 kg per year. Estimated year 2001 estimates are greatly reduced to ≈11,000 kg per year due to wetland restoration that is in progress. This represents a best-case scenario where restored wetlands not longer contribute to peat soil decomposition. Calculations that estimate a condition in which no restoration is occurring substantially increase the losses in phosphorus to ≈52,000 kg per year. It is important to note that the average total external phosphorus load to Upper Klamath Lake is 181,600 kg per year. Therefore, total phosphorus derived from reclaimed wetlands potentially account for 29% of the external load.



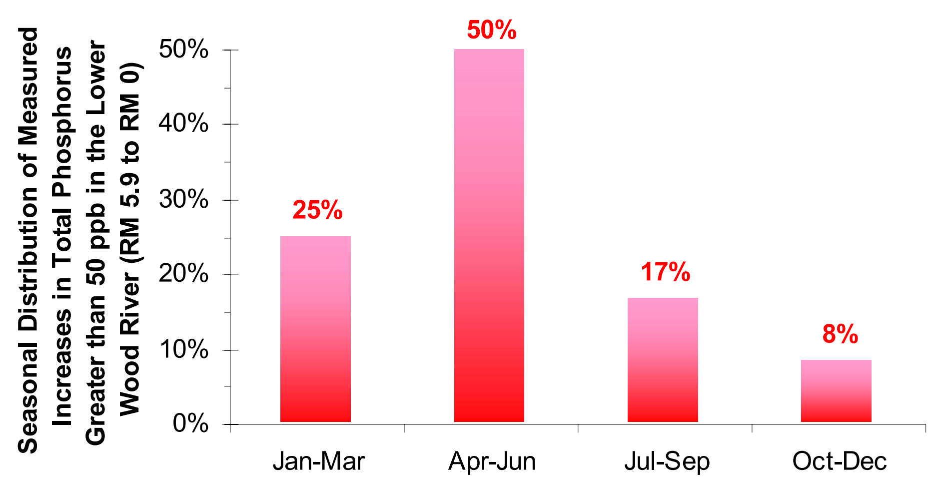


Wood River Longitudinal Increases in Total Phosphorus Concentration (river mile 0.0 and river mile 5.9)



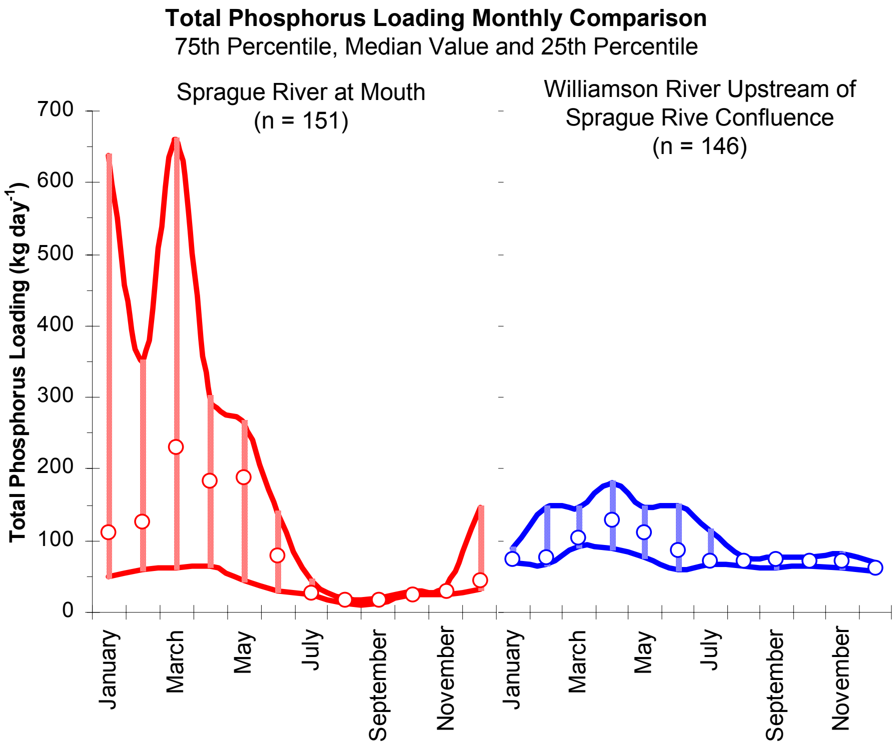


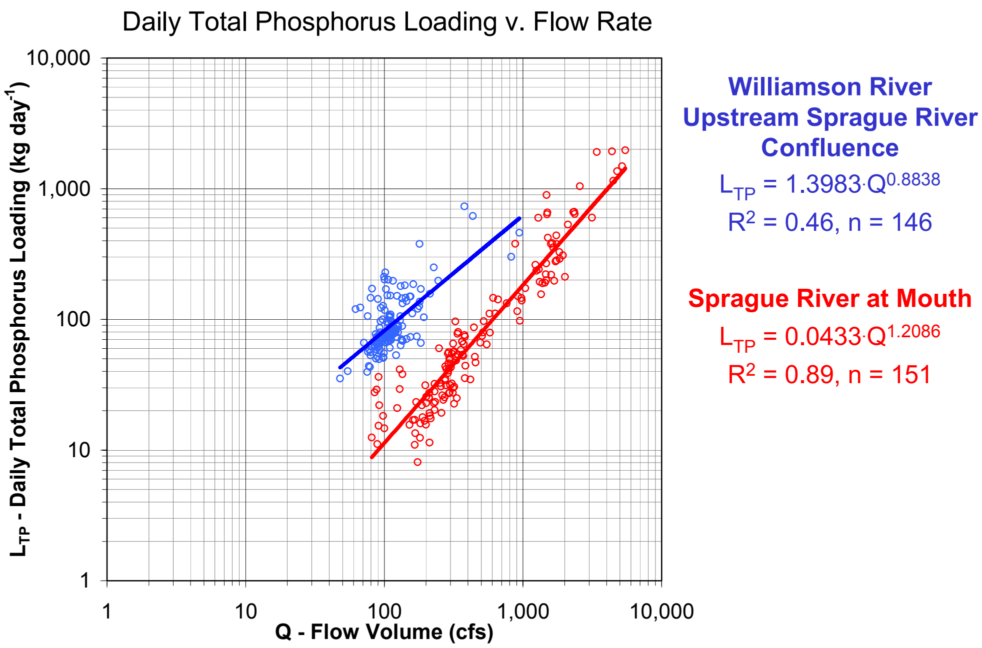
- Total phosphorus concentrations measured in tributaries and rivers are elevated above headwater spring (background) conditions.
- Paired water quality data collected longitudinally along Wood River over a five-year period showed that nutrient concentrations increased consistently as the river traveled through heavily impacted areas in the lower watershed (i.e. downstream from Weed Road Bridge) (Kann and Walker, 2001).
- Median total phosphorus concentrations increases summarized by year (1993 to 1999) range from 45 to 17 μg/l.
- Seasonal increase greater than 50 μg/l are associated with winter and spring flows.



Upland Total Phosphorus Loading as a Function of Flow Rate

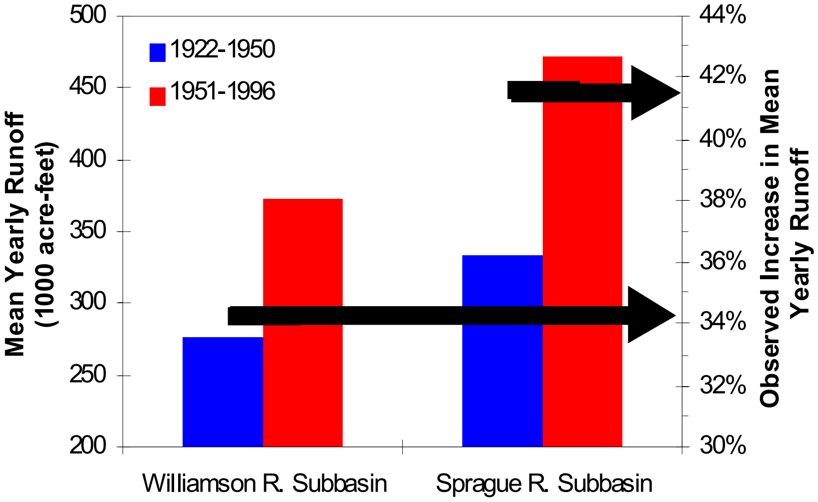
- A strong signal of watershed disturbance is provided in sediment core values for titanium (Ti) and aluminum (Al), both of which suggest major increases in erosion inputs to Upper Klamath Lake in the last century (Eilers et al. 2001).
- Gearheart et al. (1995) report that the total phosphorus concentrations in many of the UKL tributaries can be correlated to both runoff events and suspended solids concentrations.
- Spring systems such as Spring Creek, a major tributary to the Williamson River that comprises the majority of base flow downstream of Upper Klamath Marsh, cause a poor correlation between water yield and total phosphorus loading rates.
- A strong correlation between water yield and loading rates indicates that the Sprague River is a primary source of erosional and runoff phosphorus loading. When summarized by monthly values, the Sprague River phosphorus loading is a function of season and high flow timing.





Upland Total Phosphorus Loading as a Function of Flow Rate and Increased Water Yield

Two Sample Tests for Differences in Williamson and Sprague River Annual Runoff for Two Periods (1922-1950 and 1951-1996)
(Risley and Laenen, 1998)

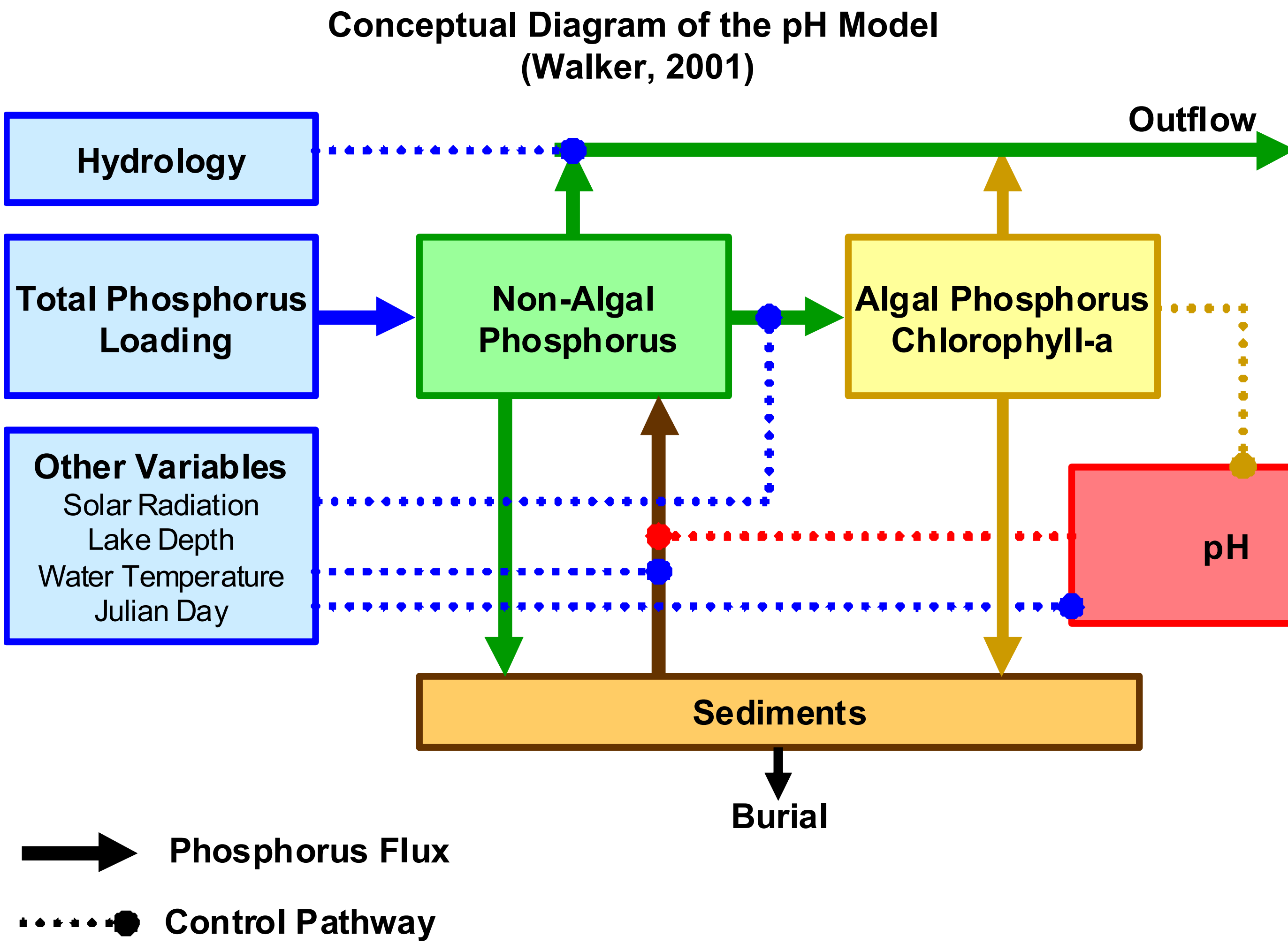


- Historical flow data from the Williamson River and Sprague River drainages suggest that runoff patterns have changed as a result of human land use patterns (Riseley and Laenen 1998).
- Long-term climate data (precipitation and air temperature) were included in the analysis to account for the influence of climate on historical runoff data.
- Annual runoff in the Williamson River has been measured below the confluence and at the mouth of the Sprague River near Chiloquin.
- The average yearly water yields have increased by 34% in the Williamson River subbasin and 42% in the Sprague River subbasin (Riseley and Laenen 1998).

Williamson River and Sprague River Drainage Water Yields and Associated Total Phosphorus Loading Rates

	Increase in Water Yield from 1922-1950 Period to 1951-1996 Period	**Current External Total Phosphorus Load (1000 kg/year)**	**External Phosphorus Load Associated with Increased Water Yield (1000 kg/year)**	**Potential Total Phosphorus Load Reduction as a Percent of the Total External Load (181,600 kg/year)**
Williamson River Subbasin	34.2%	37.8	12.9	7.1%
Sprague River Subbasin	41.6%	48.7	20.2	11.1%
Total	37.8%	86.5	32.7	18.0%

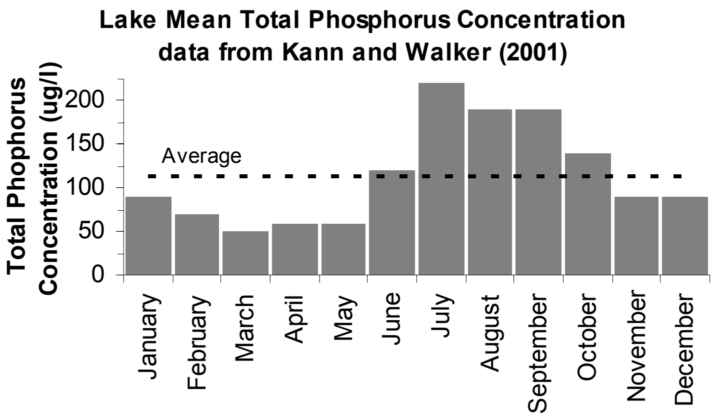
pH Model

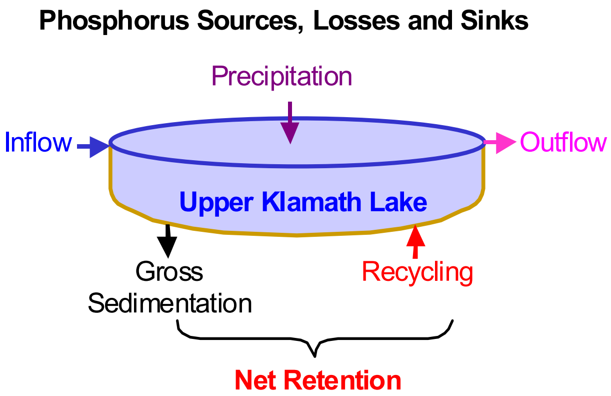


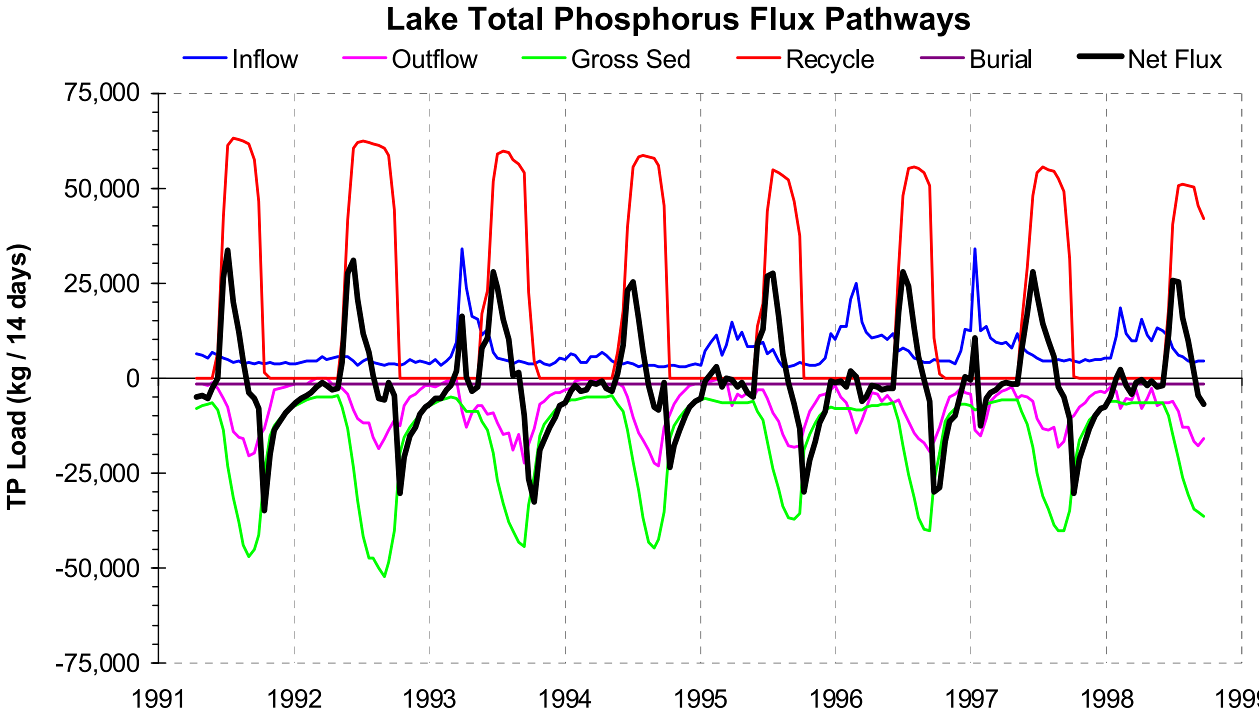
The response of pH levels at various phosphorus loading levels for Upper Klamath and Agency Lakes was developed using a dynamic mass-balance model that simulates phosphorus, chlorophyll-a and pH variation as function of external phosphorus loads and other controlling factors (see Conceptual Diagram). The model is calibrated with extensive monitoring data collected for the Lake and its tributaries between 1992 and 1998.

Lake Time Series Total Phosphorus Mass Balance Dynamics (Walker, 2001)

Phosphorus sources to the lake water column result from inflow (including precipitation) and recycling from lake sediments. Phosphorus losses from the lake result from outflow and gross sedimentation. Biweekly phosphorus flux pathways (i.e. inflows, outflows, gross sedimentation, recycling and burial) combine to control the total available phosphorus concentration in the lake at any given time (see black line). Seasonally, external loading dominates in the spring and internal loading is dominant in the summer, while the fall is period when gross sedimentation creates a negative flux from the lake water column.







pH Response at Various Total Phosphorus Load Reduction

Lake-Mean pH Frequency as a Function of Phosphorus Load Reduction
(Walker, 2001)

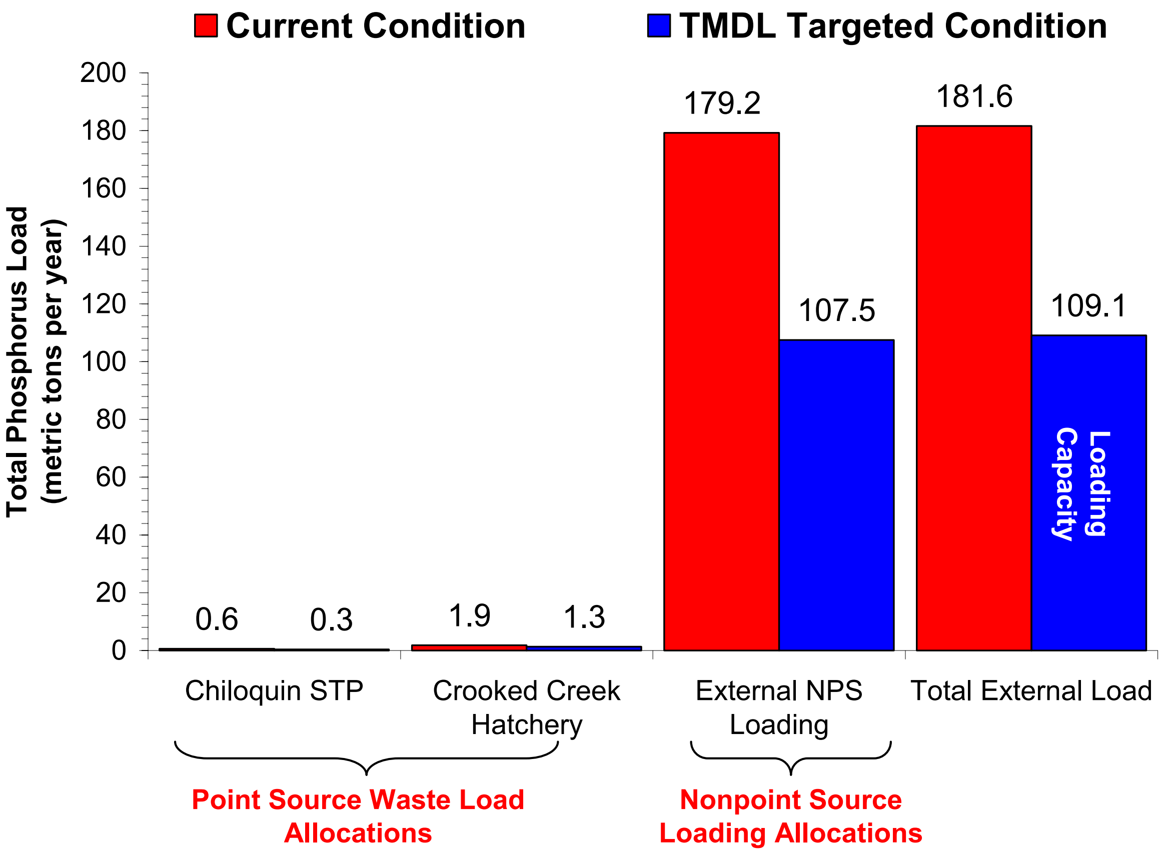
TP Load Reduction

	Frequency of pH Values > 9.0	
Reduction in External Loading	Year Round Mean	Summertime Mean June-July
0%	29%	75%
25%	16%	28%
30%	15%	19%
35%	5%	11%
40%	4%	6%
45%	0%	3%
50%	0%	0%
55%	0%	0%

Improvement in pH

Simulation results are expressed as relationships between percent reductions in external total phosphorus loads and pH excursion frequencies, computed using various spatial and temporal averaging methods. Total phosphorus reduction simulation results for external phosphorus loading reductions ranging from 0% to 55%. Analytical outputs suggest that excursion frequencies for the pH standard can theoretically be reduced to ~0%, if the load for total phosphorous is reduced by 50% (Walker 2001). However, there is evidence that such a load reduction is not possible/feasible.

Phosphorus Loading - Current Condition and Allocated Condition



Loading Capacity is: "the greatest amount of loading that a water can receive without violating water quality standards." (40 CFR § 130.2(f)). The load capacity is estimated for purposes of this TMDL as the external total phosphorus loading into Upper Klamath and Agency Lakes that corresponds to a reduction of approximately 40% from current conditions.

A **Load Allocation (LA)** is the amount of pollutant that non-point sources can contribute to the stream without exceeding state water quality standards.

The **Waste Load Allocation (WLA)** is the amount of pollutant that point sources can contribute to the water body without violating water quality standards.

In light monitoring and analytical limitations and the complexity of the lake and drainages, the selection of a TMDL targeted loading condition and compliance frequency ultimately becomes a professional judgment. As is the case in any such professional judgment, there are varying perspectives on an appropriate targeted condition. Regardless, **a 40% reduction in external total phosphorus loading to Upper Klamath Lake represents the targeted condition for this TMDL.** This target acknowledges external load reductions that range from 33% to 47% as well as, other potential external loading reductions that demonstrates a potential 29% reduction in external total phosphorus loading from near-lake wetland restoration and an additional 18% reduction in external total phosphorus loading resulting from upland hydrology and land cover restoration.

Upper Klamath Lake Analysis

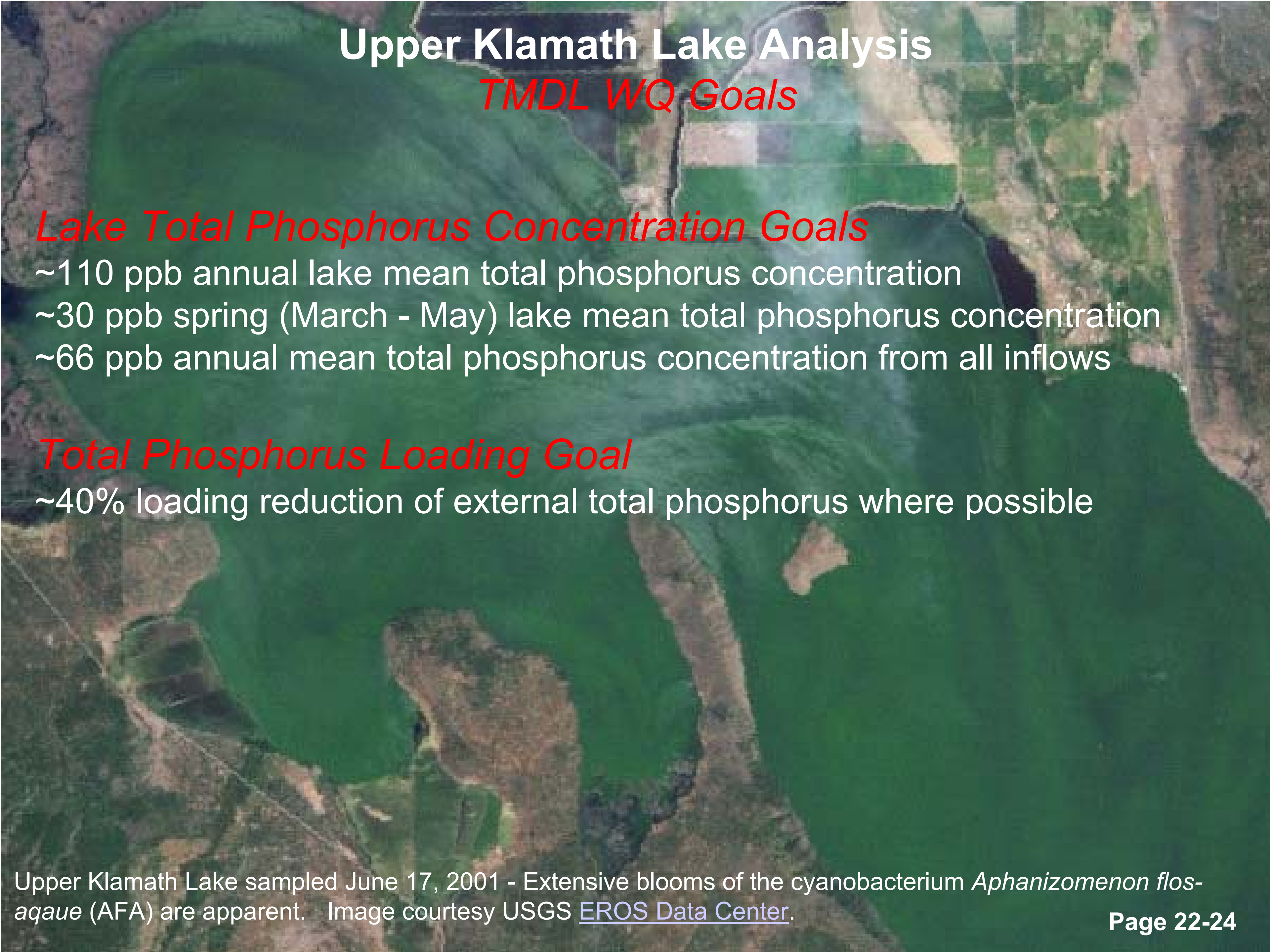
TMDL WQ Goals

Lake Total Phosphorus Concentration Goals

~110 ppb annual lake mean total phosphorus concentration
~30 ppb spring (March - May) lake mean total phosphorus concentration
~66 ppb annual mean total phosphorus concentration from all inflows

Total Phosphorus Loading Goal

~40% loading reduction of external total phosphorus where possible



Upper Klamath Lake sampled June 17, 2001 - Extensive blooms of the cyanobacterium *Aphanizomenon flos-aqaue* (AFA) are apparent.   Image courtesy USGS EROS Data Center.

Participants - Designated Management Agencies

Temperature

- U.S. Forest Service
- Oregon Department of Agriculture
- City of Chiloquin
- Oregon Department of Transportation
- U.S. Fish and Wildlife Service
- Oregon Department of Forestry

pH, DO and Chlorophyll-a

- U.S. Bureau of Reclamation
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- Bureau of Land Management
- Oregon Department of Agriculture
- Oregon Department of Transportation
- Crater Lake National Park
- Klamath County


Spring Creek

TMDL Implementation

The Water Quality Management Plan is focused on:

1. Continuing restoration efforts

- Reductions in nutrient loading
- Riparian & wetland restoration/protection
- Channel morphology improvements
- Instream flow conservation

2. Adaptive Management

- Monitor management effects
- Evaluate management with site specific information
- Alter management accordingly
- Create a technical review team to assess the TMDL targets and implementation strategy and refine where appropriate.