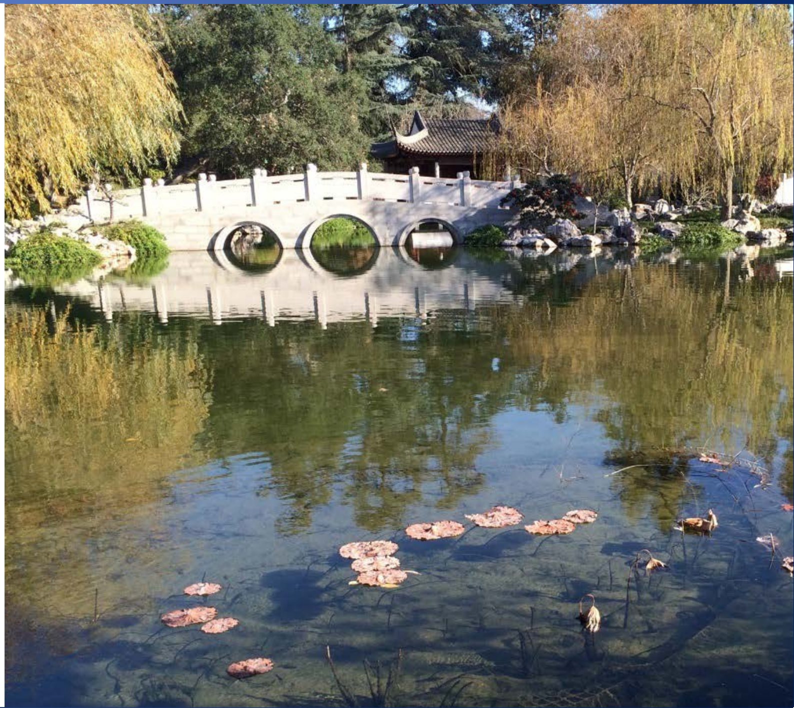
Choosing a Remediation Approach: A Case Study Based in First Principles and Mass Balance

David A. Caron
Department of Biological Sciences
University of Southern California
Los Angeles, CA 90089-0371
(dcaron@usc.edu)



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Great diversity of aquatic ecosystems

(size, hydrography, chemistry, etc.)

Great diversity of uses

(drinking water, recreation, fisheries, etc.)

These varying features dictate different approaches. Therefore, each approach should be tailored to the *system*, the *existing problem*, and the *desired outcome(s).*

Disclaimer: This presentation is NOT an exhaustive overview of specific remediation/management practices, but there are a lot of them...

- Floating islands
- Riparian vegetation
- Barley straw
- Aeration
- Mechanical circulation
- Hypolimnetic oxygenation
- Chemical Controls:
  - Alum
  - Ozone
  - Ferric salts
  - Clays
  - Phoslock
  - and others…
- Drawdown & dessication
- Surface skimming
- Ultrasound

- Algaecides:
  - Cu
  - K-permanganate
  - Chlorine
  - Lime
  - Hydrogen peroxide
  - Various organic Chemicals
  - and others…
- Coagulation/floculation
- Biological controls & biomanipulations:
  - Viruses
  - Algicidal bacteria
  - Parasites
  - Filter-feeding bivalves
  - and others...

What are your best weapons in choosing an approach(es)?

Guiding Principles:

- Know your endgame (what is the intended use(s) of your resource?).
  - Are there competing interests? (that may change your approach)
- Understand the *upsides* and the *downsides* of possible approaches.
  - BOTH exist: Cost, effectiveness, longevity, aesthetics, etc.
- Try to let sound science dictate action, not politics.
  - Ultimately, only a sound scientific approach will be sustainable.

A few more guiding Principles:

- Acquire basic information on the nature, magnitude and composition of your problem.
  - ESTABLISHING THE PRIMARY DRIVER(S) OF THE PROBLEM IN ***YOUR*** ECOSYSTEM IS FUNDAMENTAL.
  - Species, toxins, water chemistries, hydrographies, seasonalities all vary from location to location (sometimes even with an ecosystem).

- Common sense goes a long way.
  - Accumulate data on your system. Evaluate if your approach is working. If not, it may be time to reevaluate your approach.

- Be in it for the long haul.
  - Attempt to design & enact a good long-term strategy for management.
    - Try not to be soley 'reactive'.
  - Don't expect an immediate, easy, or cheap solution.
    - There is often no 'silver bullet'.

Try to address the causes of algal blooms

(get to the 'root' of the problem)

Primary Drivers (generally speaking):

Loading of major nutrients is ultimately the problem:

N, **P*** are key, Nutrient *ratios*

'Higher level' physical/environmental effects

Residence time***

Climate (including drought) and Weather

affects physical structure of water body

affects nutrient availability

Light (day length)

NOT strong drivers, per se (but certainly play a role)

Temperature (affects water structure & timing of blooms)

'Pollution' (unless severe or comes with nutrients)

Management: The desirability of 'quick fix' solutions

Alum (potassium aluminum sulfate)
(aggregation & sedimentation)

Chelated or unchelated toxic metals
(why chelated?)

Lanthanum-rich bentonite clay
(aggregation & sedimentation)

'Quick fix' solutions: The good and the bad of it
(from a scientist's perspective)

<u>Advantages</u>:

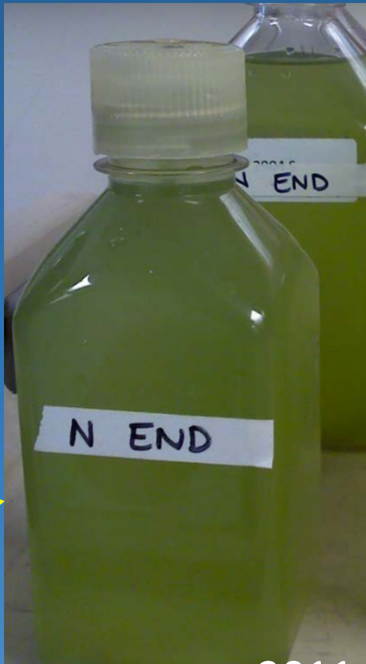
Immediate improvement in water clarity*,**
Reduced abundances of 'problem' algal/cyanobacterial species*,**
Removal of nutrients from surface waters*

<u>Potential disadvantages</u>:

Killing of ALL algal/cyanobacterial species (& the food web) *,**
(& sometimes desirable micro- & macrofauna)
Problematic nutrients are not really removed**
Potential release of intracellular toxins into the water**
Delivery of toxins in high concentrations to the benthos*,**
Delivery of high biomass to the benthos (increased O_2 demand) *,**
Survival and proliferation of more-resistant species*,**
(Community may shift to less-desirable species)
Continued remedial activity generally will be required**

*aggregation & sedimentation
**toxic chemical treatments

A case study (addressing the core issue): Huntington Garden's Chinese Garden Lake



2011

250-310 µg Chlorophyll per liter!

2011

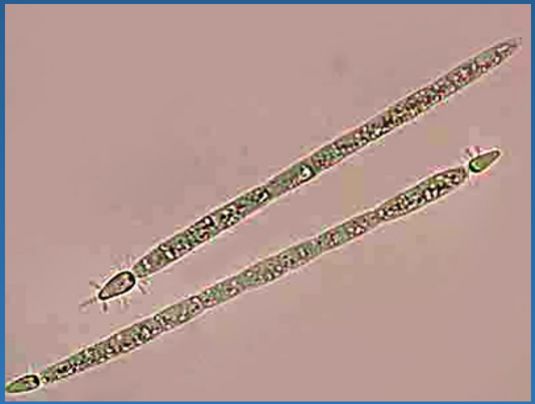
TABLE 3. A classification of lakes according to the extent of their eutrophication

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Average total phosphorus	8.0	26.7	84.4	> 200
Average total nitrogen	661	753	1875	high
Average Chlorophyll *a*	1.7	4.7	14.3	>100, range 100-200>
Chlorophyll *a*, peak concentration	4.2	16.1	42.6	> 500

Organization for Economic Cooperation and Development (OECD) in the 1970s and 1980s

Issues with Chinese Garden Lake

Phytoplankton community composition



Dominant species: *Cylindrospermopsis*
Filamentous cyanobacteria
Nitrogen-fixer (can 'make' nitrogen)
Can store phosphorus
Known to be a bloom former and
a toxin producer: (saxitoxins, cylindrospermopsin)

Nutrient sources causing hypereutrophication in CGL

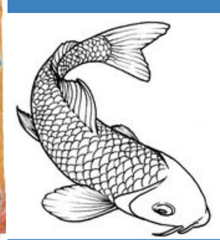
Significant fish population (large koi)
Fish food additions
Drainage from fertilized lawn and landscape
Significant water fowl population (ducks, gulls, etc)
No turnover of the water in the lake water
(no removal, replacement of evaporative losses)

Redesigning the Chinese Garden Lake

Mass Balance approach!

Land Plant Fertilizers

Fowl waste

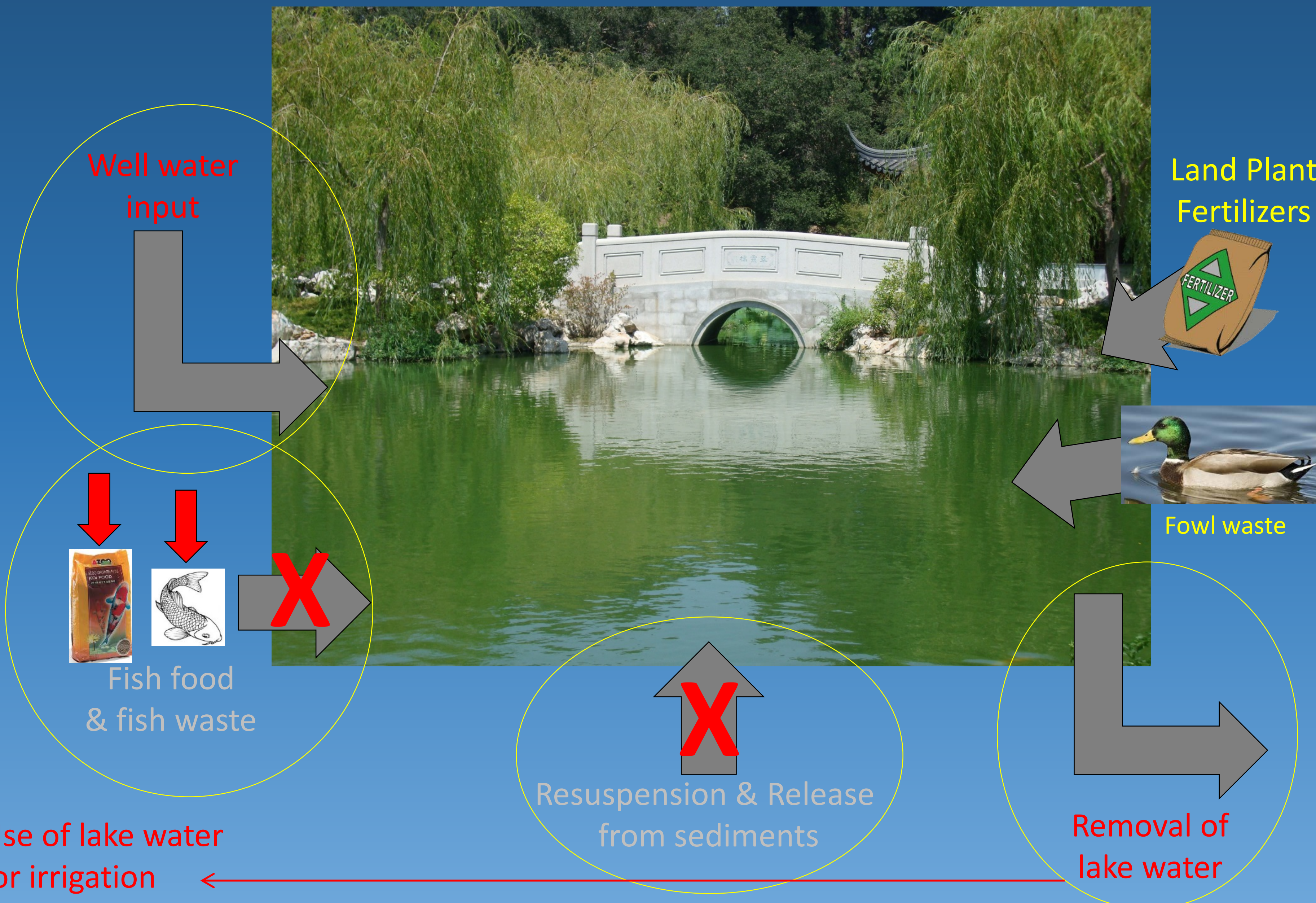


Fish food
& fish waste

Resuspension & Release from sediments

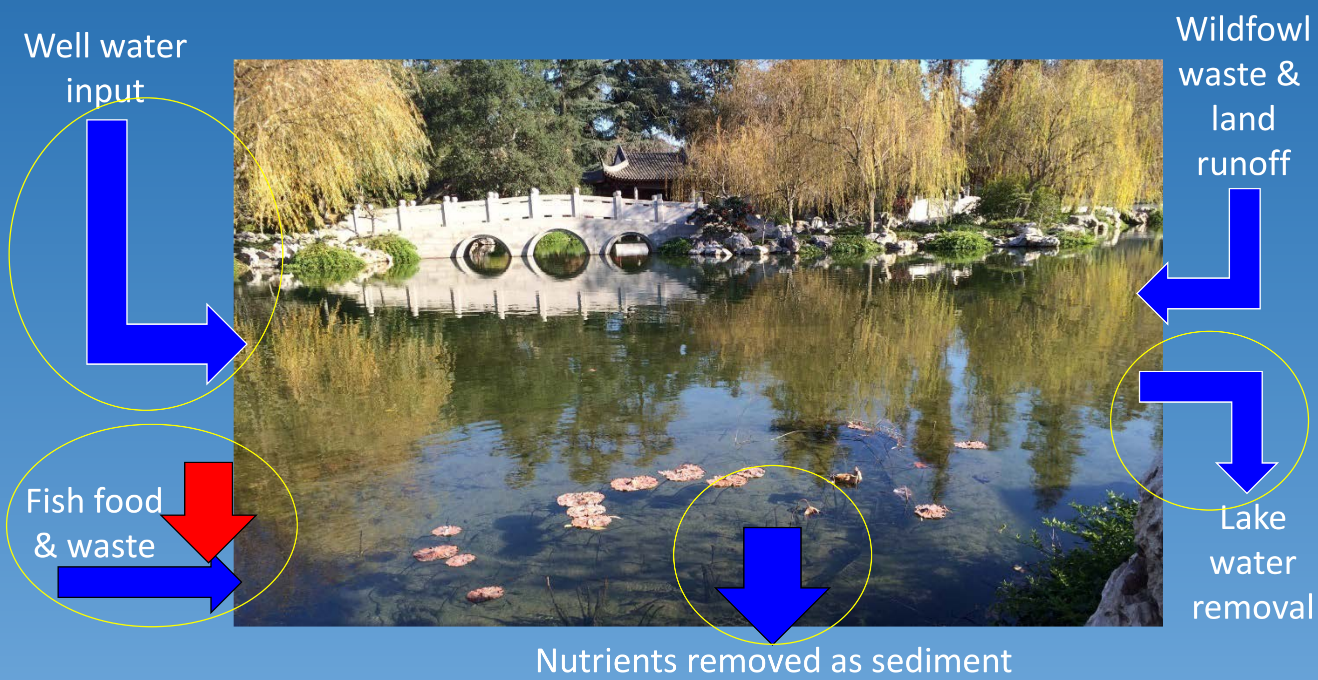
Removal of lake water

Redesigning the Chinese Garden Lake



BEFORE

AFTER



Caron et al. (2016) Lakeline. 36:17-21

Obviously, such a dramatic approach will not work for all (or most) systems, but the basic principles are the same.

Before you choose an approach, you should…

- **Start with the intended use(s) of your system.**
  - Drinking water supply? (maybe you don't want to break those cells open).
  - Recreational use? (scums are highly undesirable).
  - Fisheries? (do you have fish-killing species present?)
  - *Use(s) should guide 'acceptable' remedial & management approaches.*

- **Assess the root cause(s) of your problem.**
  - Too much algae or cyanobacteria? Are toxic species present?
  - *Don't simply pick a method off the shelf, and apply it.*

- **Try to choose the *most appropriate* approach.**
  - Based on scientific principles informed by ecosystem assessment (magnitude, hydrography, biology, etc.) & public acceptability.
  - *Avoid the 'quick fix' (unless it's right!). Look for long-term sustainability.*