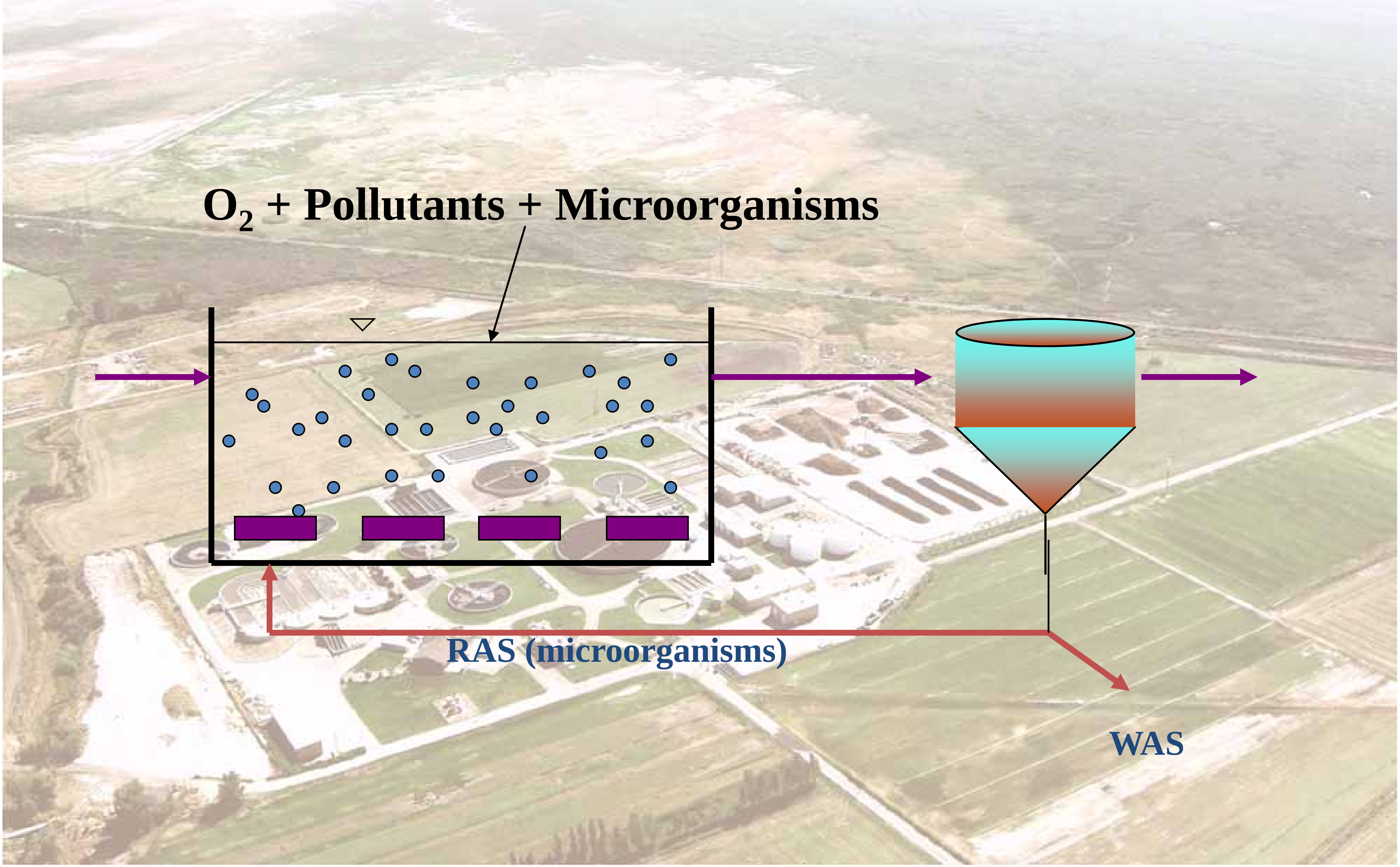
History of Nutrient Control in U.S.

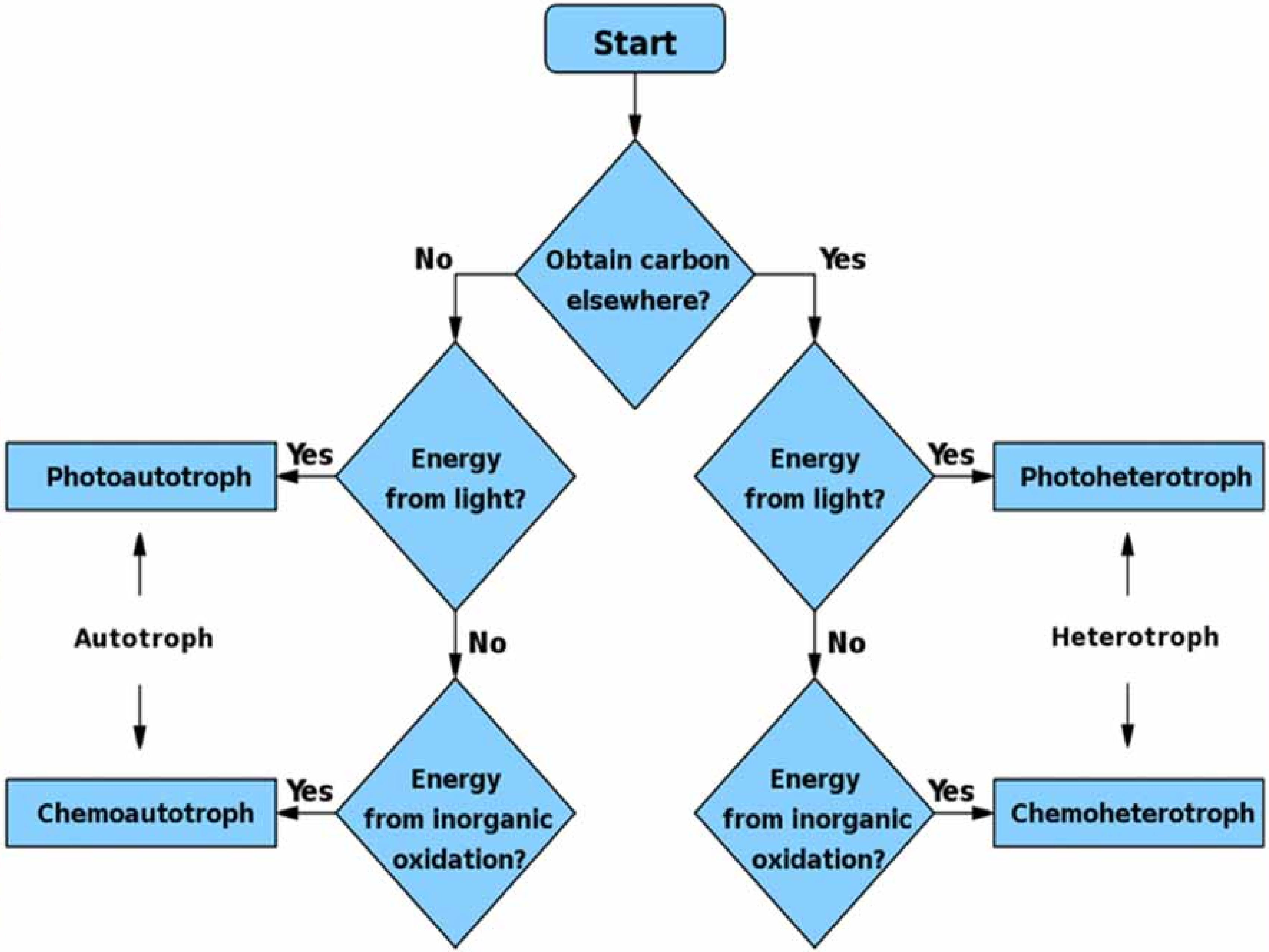
- Great Lakes Water Quality Agreement (1978):
  - Phosphorus Load Supplement 1983
  - All POTWs of 1 mgd or more discharging to Great Lakes and tribs to 1.0 mg/L TP
  - Widespread phosphate detergent bans
- Chesapeake Bay Agreement (1983):
  - 1987 Goal: 40% reduction in TP and TN
  - Current Goal: Typically 3.0 mg/L TN and 0.3 mg/L TP for larger POTWs
- Other more localized programs in 1980s (Neuse R, NC; Tualatin R, OR; Lake Champlain; etc.)
- Wisconsin adopts technology-based TP control state-wide in 1990s (1.0 mg/L for POTWs)

EPA Nutrient Criteria Strategy (1998) and Action Plan (2001)

- Affirmed in May 2007 Memo from EPA HQ
- EPA Wanted:
  - 4 Parameters (TP, TN, chlorophyll, clarity)
  - 4 Water Body Types (lakes and reservoirs, streams and rivers, estuaries, wetlands)
- Eco-Region (Reference Condition) Approach:
  - TP Generally 0.01 to 0.05 mg/L
  - TN Generally 1 to 2 mg/L
- Effects-Based Approach:
  - Shifts in Biological Metrics
  - Aquatic Ecosystem Modeling (e.g., AQUATOX)
- Weight of Evidence Approach
  - EPA R3 Examples in PA TMDLs

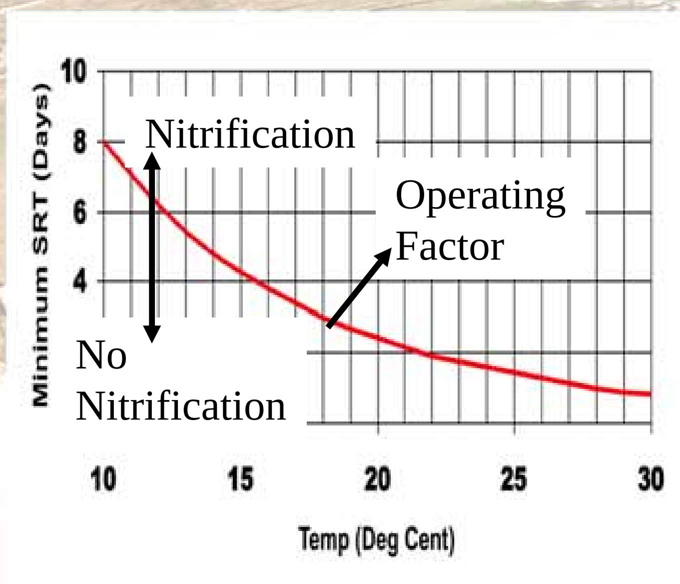
Aerated Bioreactor

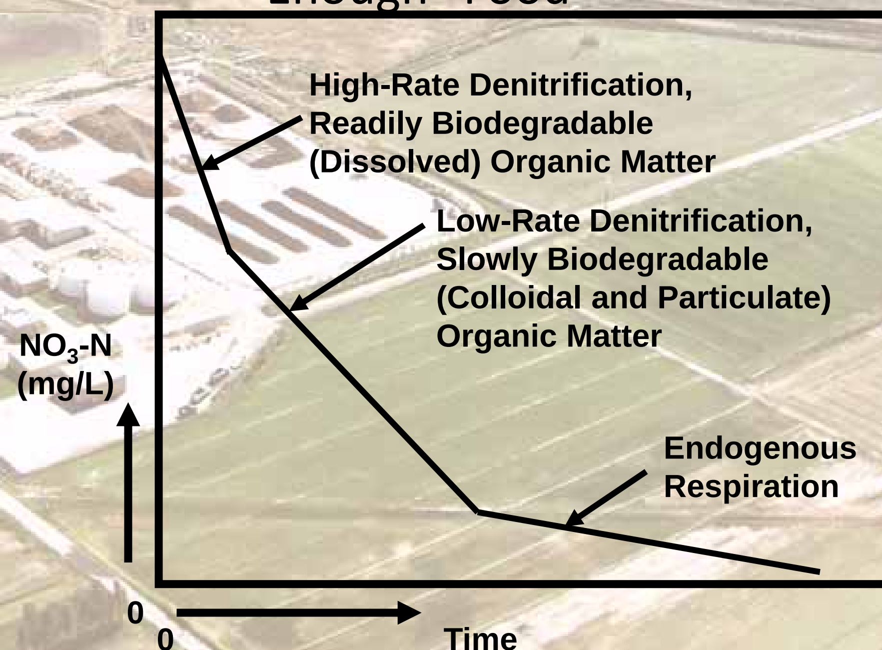



Start
Obtain carbon elsewhere?
No
Yes
Energy from light?
Yes
Photoautotroph
No
Energy from inorganic oxidation?
Yes
Chemoautotroph
Autotroph
Energy from light?
Yes
Photoheterotroph
No
Energy from inorganic oxidation?
Yes
Chemoheterotroph
Heterotroph

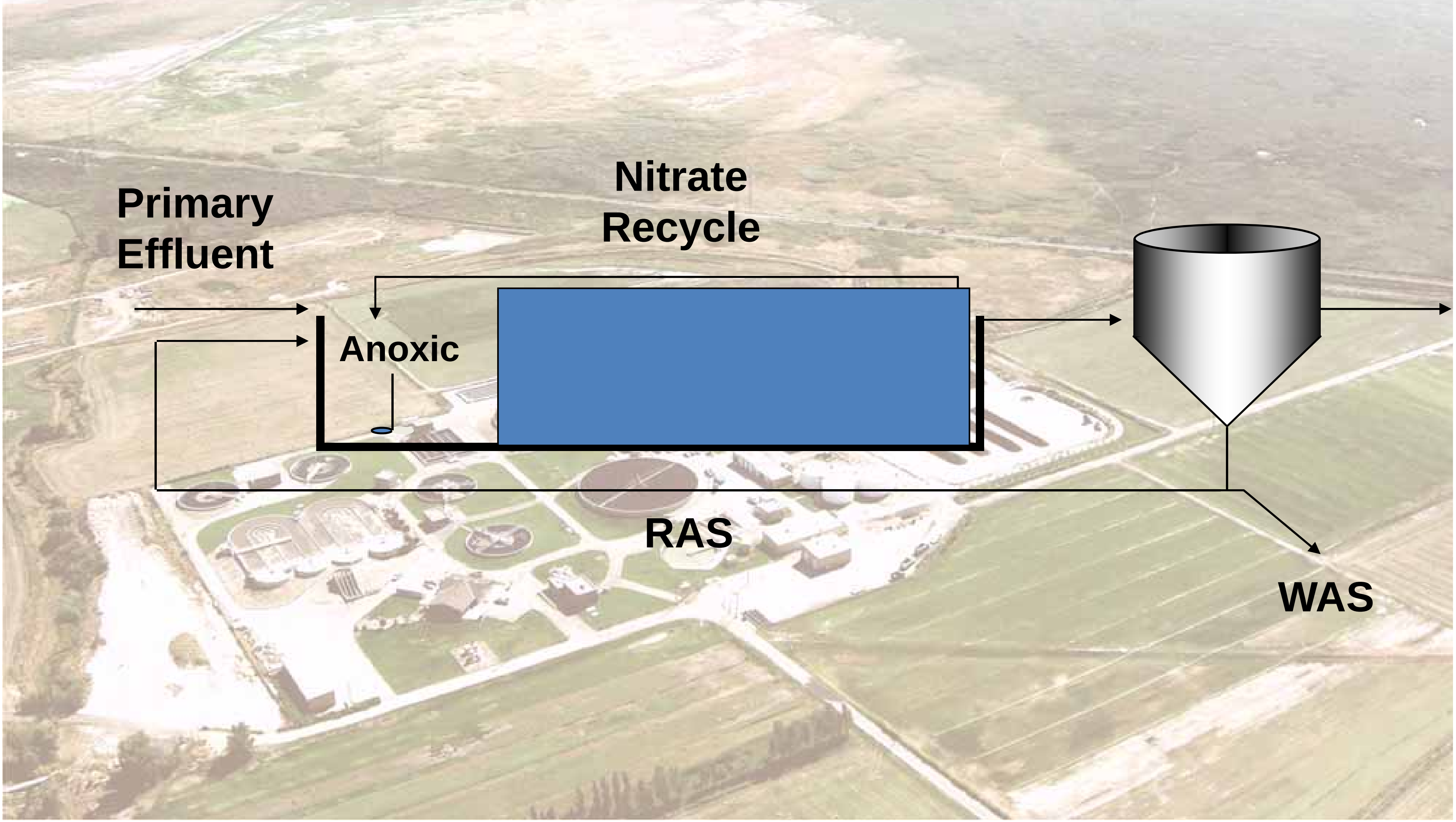
Here's What's Needed to Do This:

- Nitrification:
  - Adequate Aerobic SRT
  - Adequate Oxygen Supply
  - Adequate Buffering (Alkalinity)
- Denitrification:
  - Adequate Anoxic SRT
  - Recycle of Nitrate to Anoxic Zone
  - Exclude DO
  - Enough "Food"

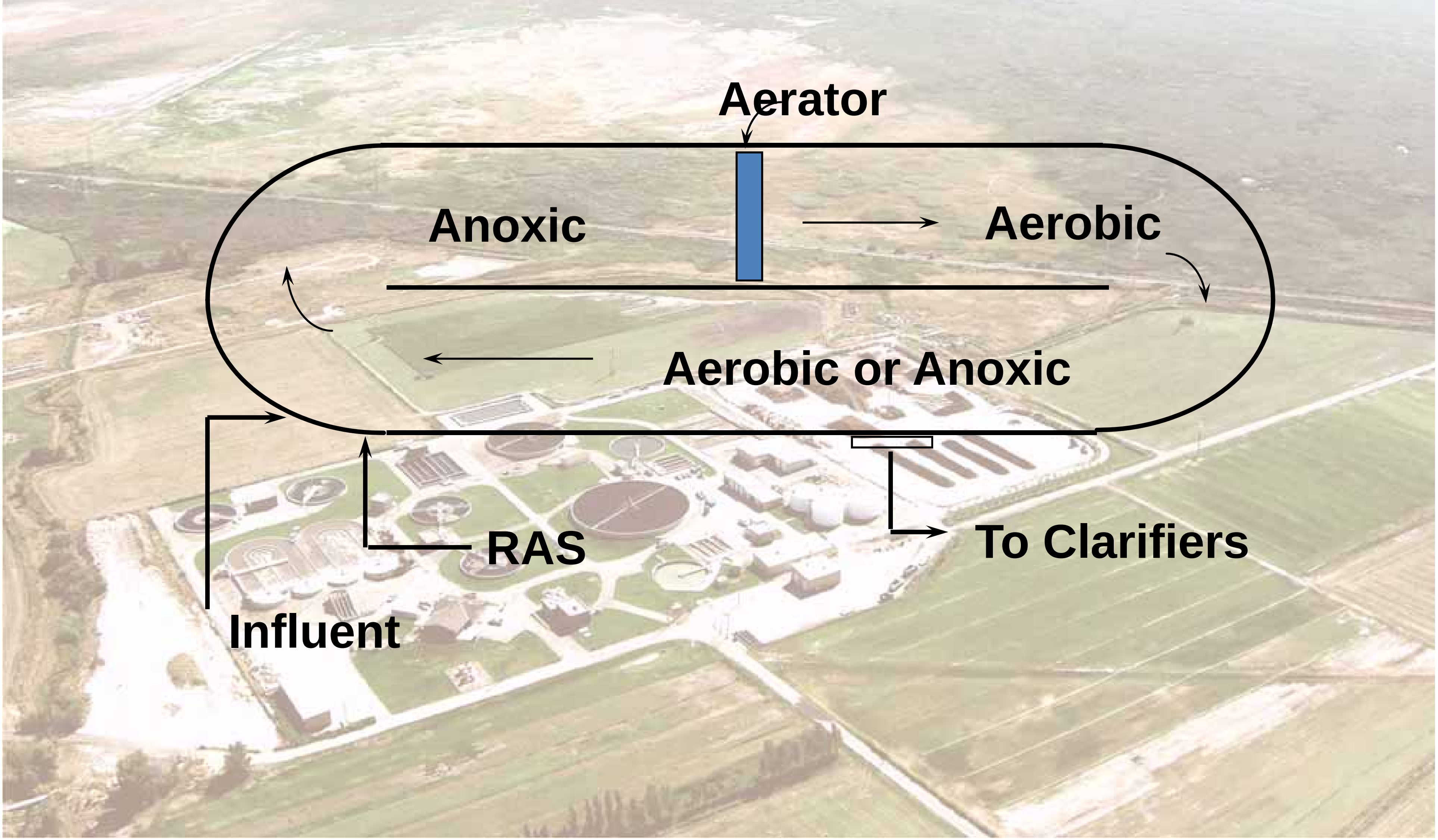




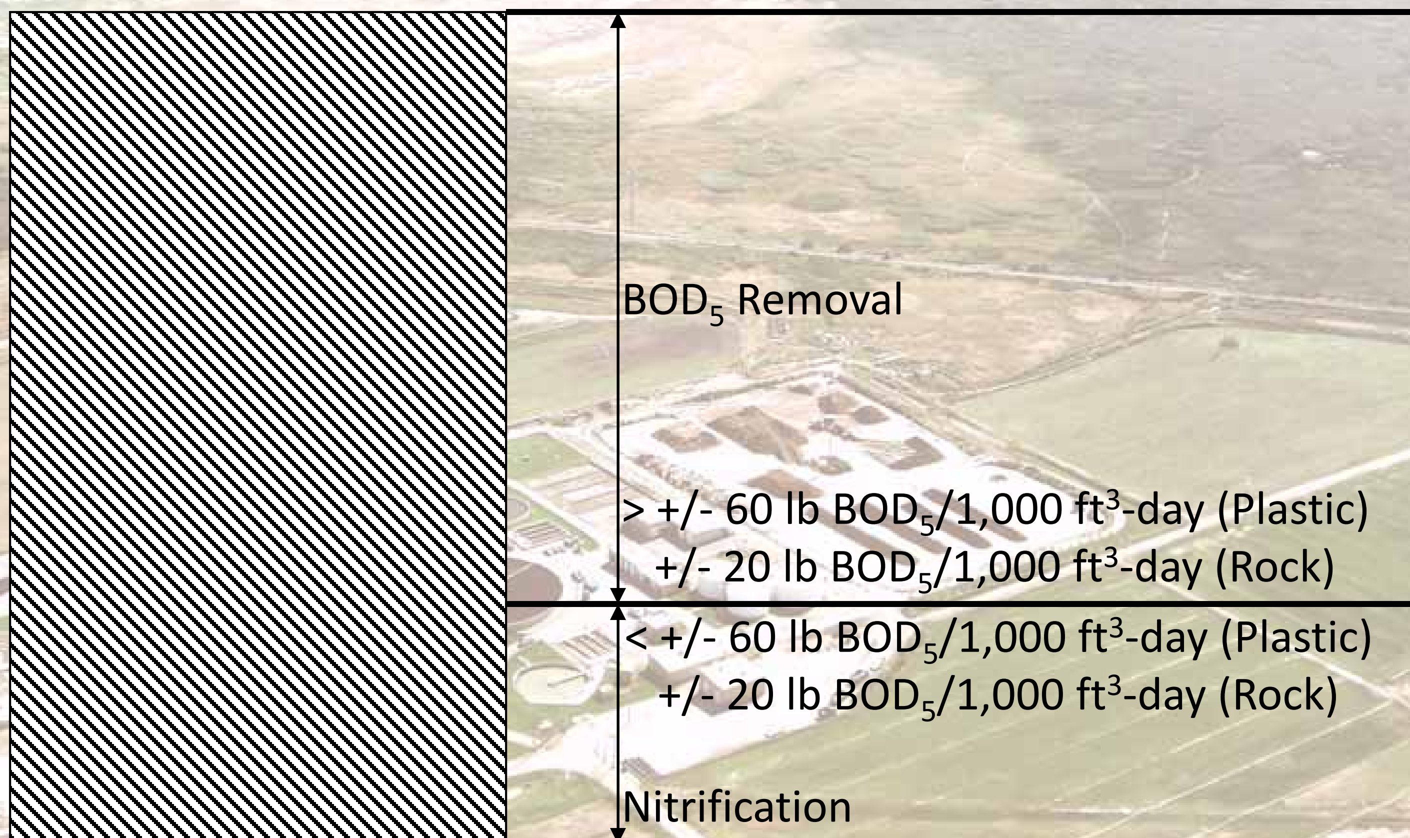
Un-aerated Bioreactor (Anoxic Zone)



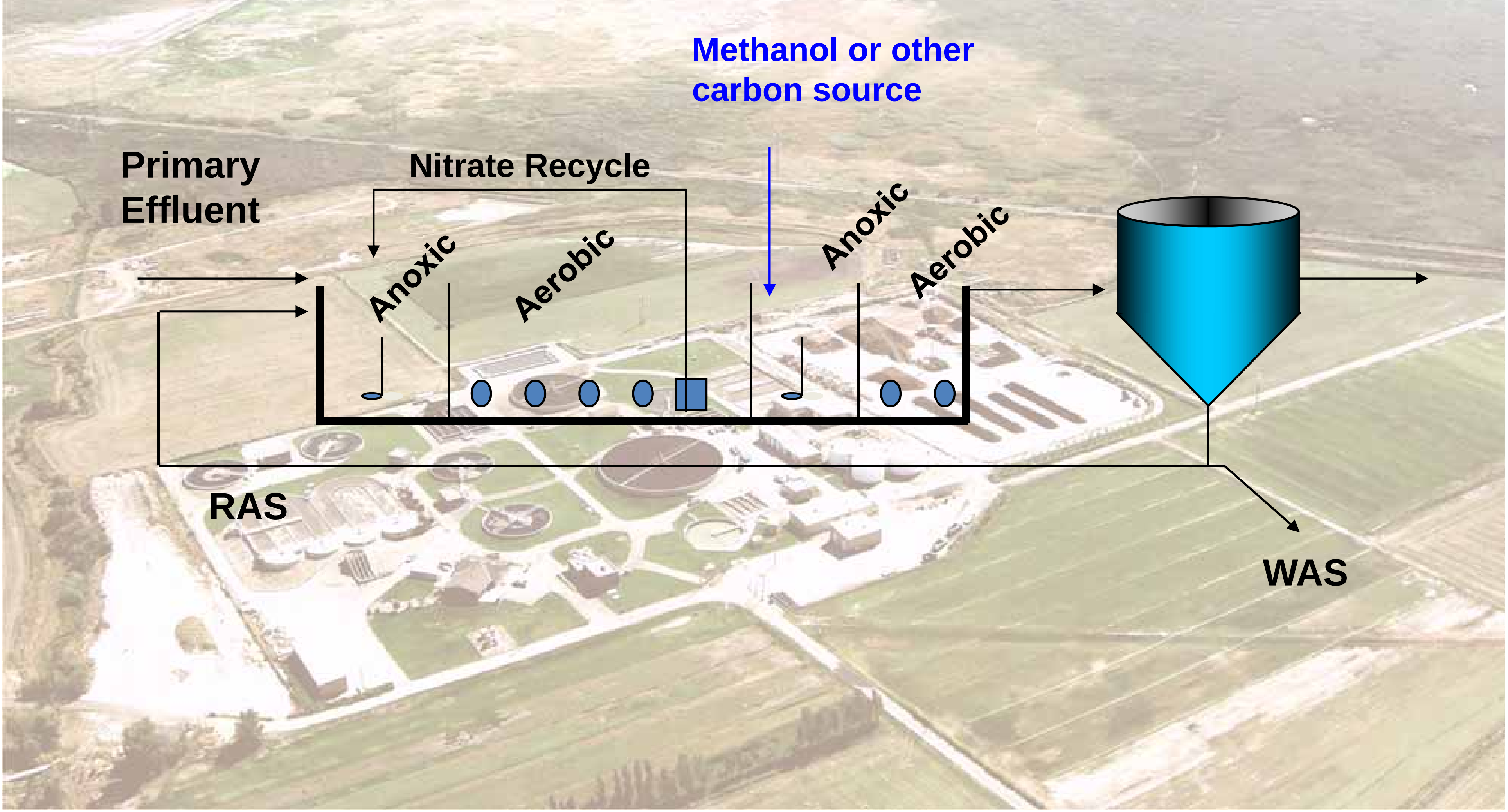
Denitrification Can Also Occur Due to Bioreactor Mixing Pattern



Organic Loading Determines Whether Nitrification Will Occur in T/F



Denitrification with Supplemental Carbon



Maintain Adequate Dissolved Oxygen

- Oxygen Stoichiometry
  - 4.6 mg of oxygen demand per mg of NO3-N produced
- Nitrification is inhibited by low dissolved oxygen
  - Ensure 2 mg/l DO throughout aerobic zone

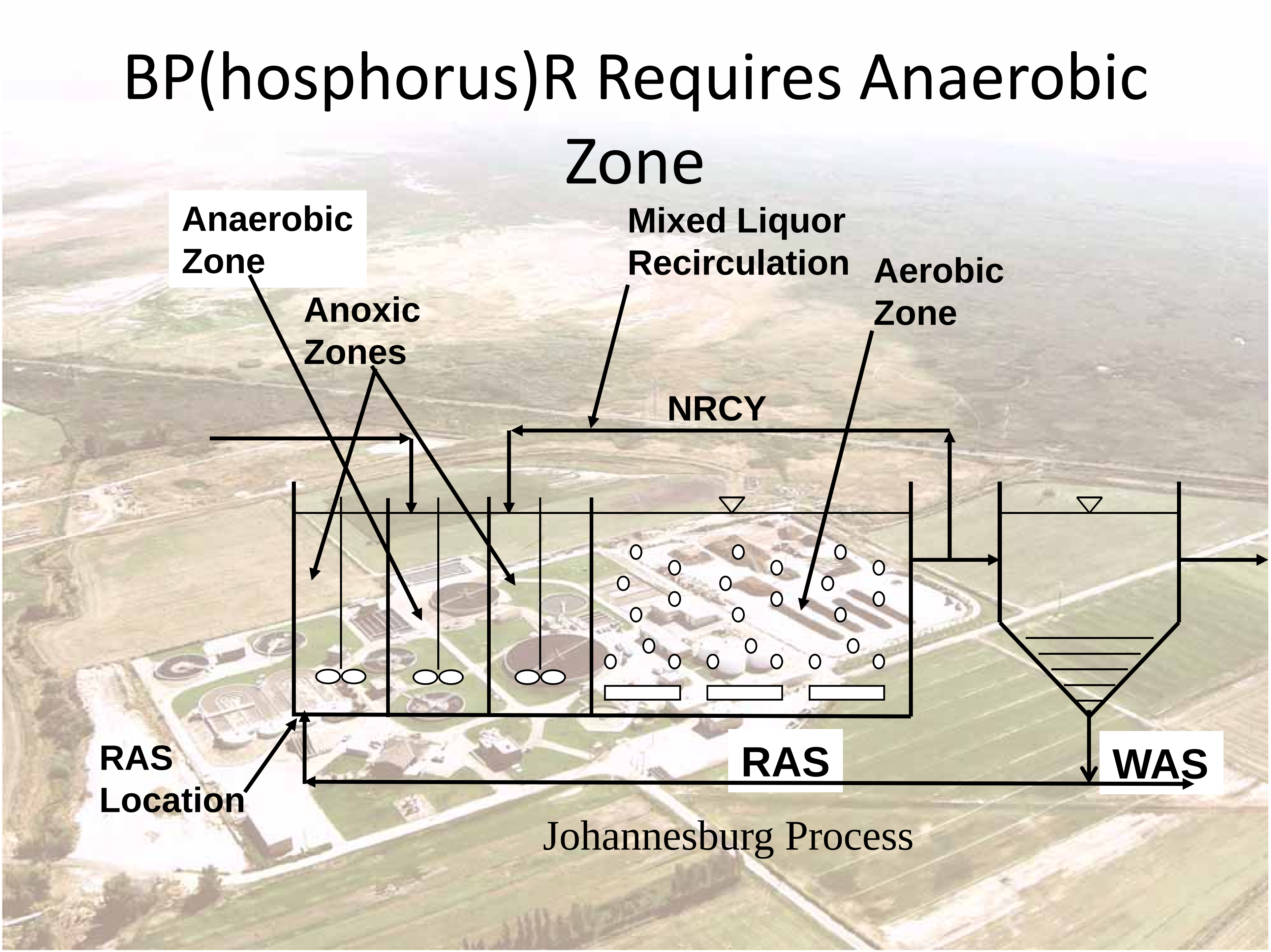
Maintain pH 7.0 or Greater

- **Alkalinity Stoichiometry:**
  - **Nitrification consumes 7.2 lbs alkalinity as $CaCO_3$ per lb ammonia-N oxidized**
  - **Denitrification produces 3.6 lbs alkalinity as $CaCO_3$ per lb nitrate-N denitrified**

Stoichiometry Controls Phosphorus Removal

- Efficiency Depends on Organic Matter:
  - Expressed as BOD_5/TPO_4 Ratio; Typically Requires 15 to 25 mg BOD_5/mg TPO_4, Depending on Process.
- Specifically Requires VFAs:
  - Acetic and Propionic Acid; 7 to 10 mg VFA/mg P Removed by Bio-P
- Sufficient VFAs
  - Influent Wastewater (Produced in Collection System)
  - Produce in Anaerobic Zone
  - Produce From Influent Organics
  - Purchase and Add

BP(hosphorus)R Requires Anaerobic Zone



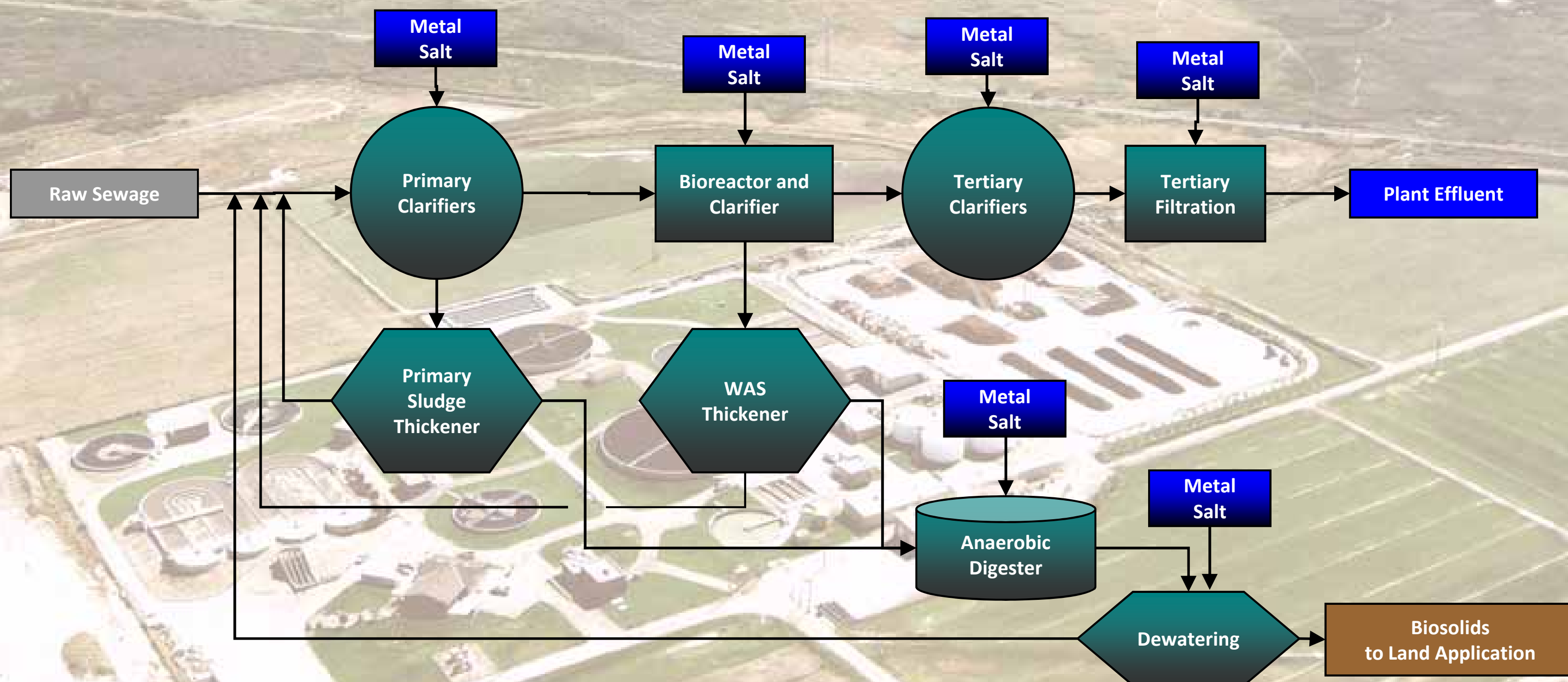
Johannesburg Process

What is Chemical Phosphorus Removal?

- There are two steps to chemical phosphorus removal:
  - The adsorption of soluble (PO_4^{-3}) phosphate into metal hydroxide floc.
  - The subsequent separation of the metal hydroxide/phosphate floc from the liquid phase
    - by settling/clarification
    - by filtration
- It is NOT precipitation!
  - $FePO_4$ and $AlPO_4$ only exists at very low pH, less than 5.

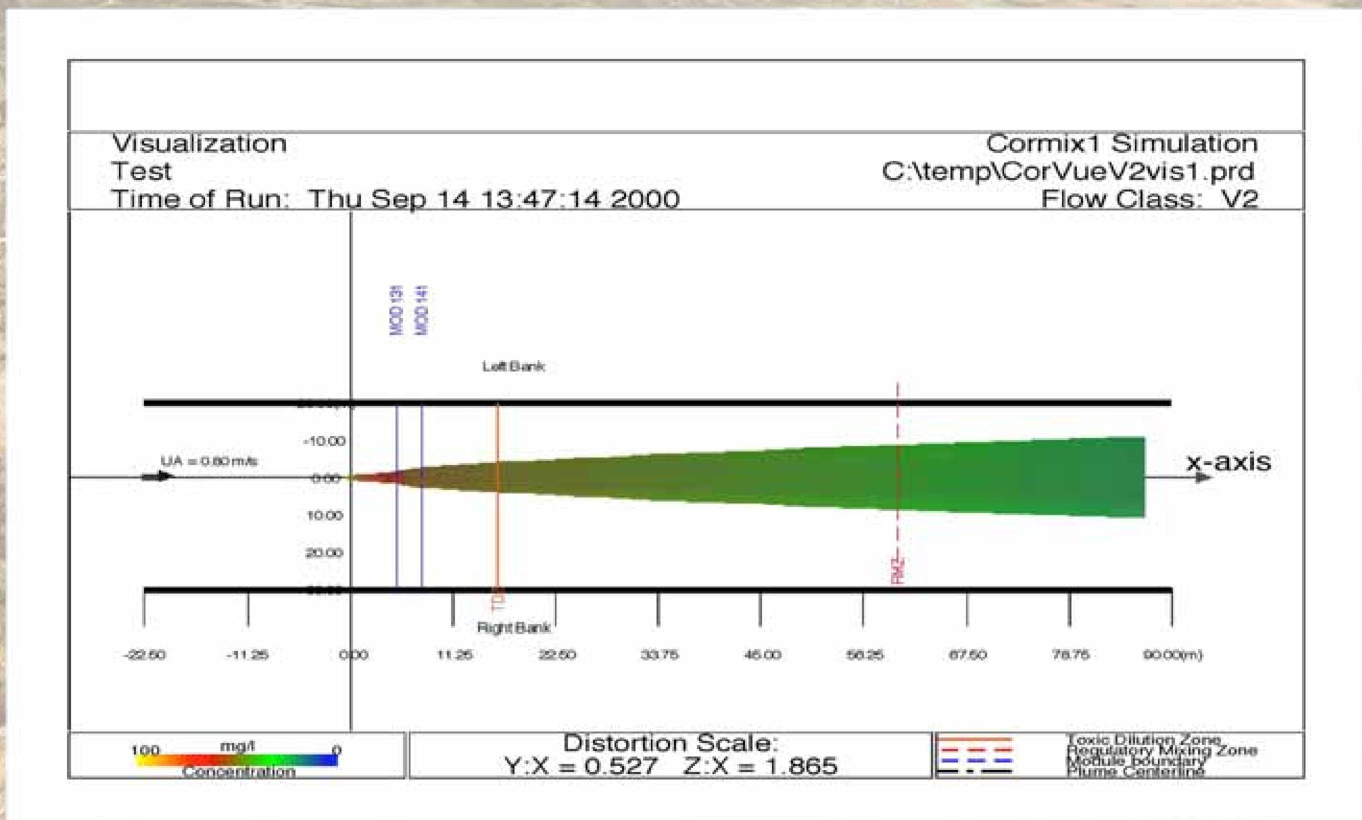
Metal Salt Addition

- There are many places metal salts can be added



Wasteload Mass Balance

- Effluent Dominated Streams - Florida
- Lakes – Mixing Zones

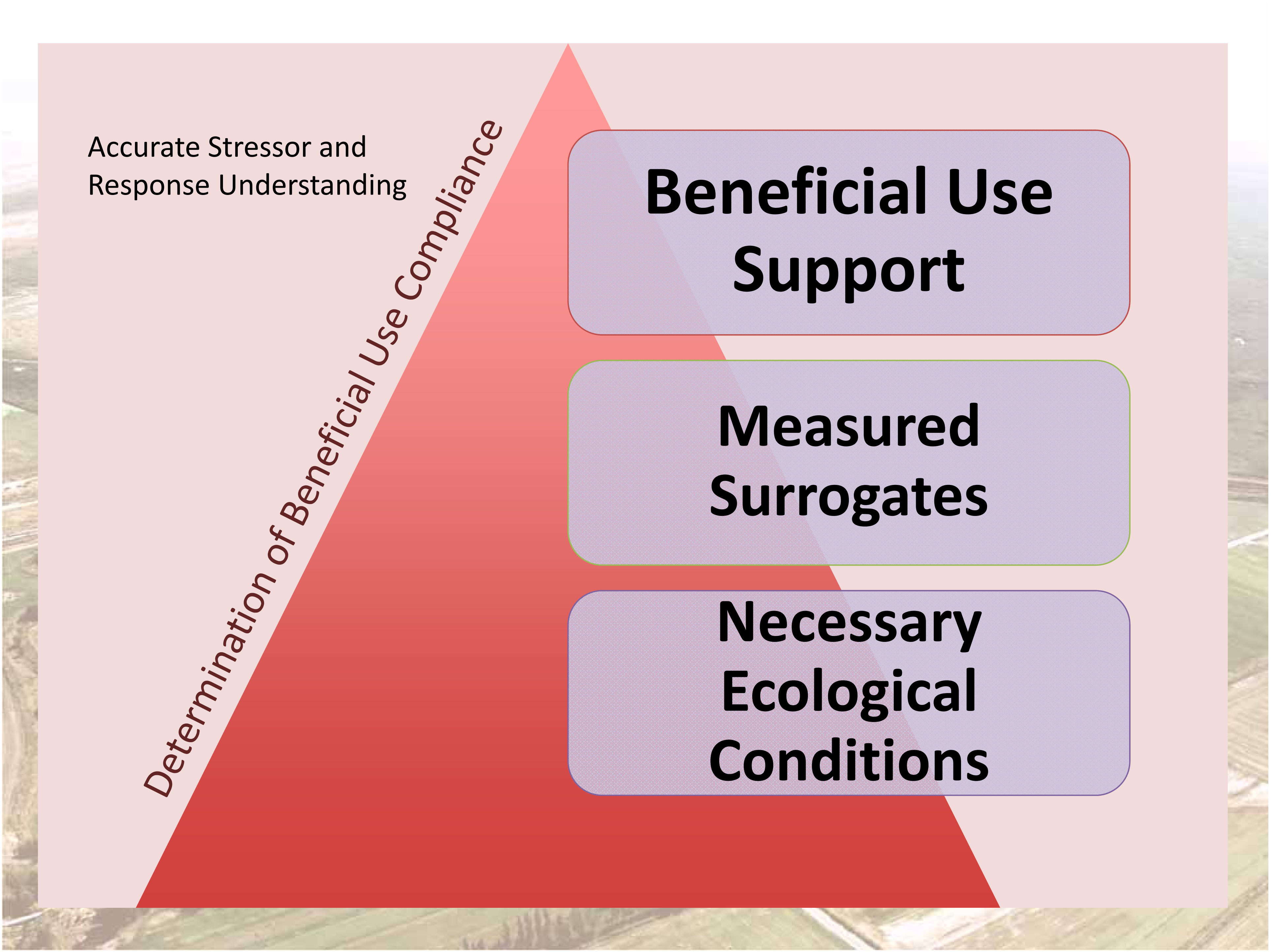


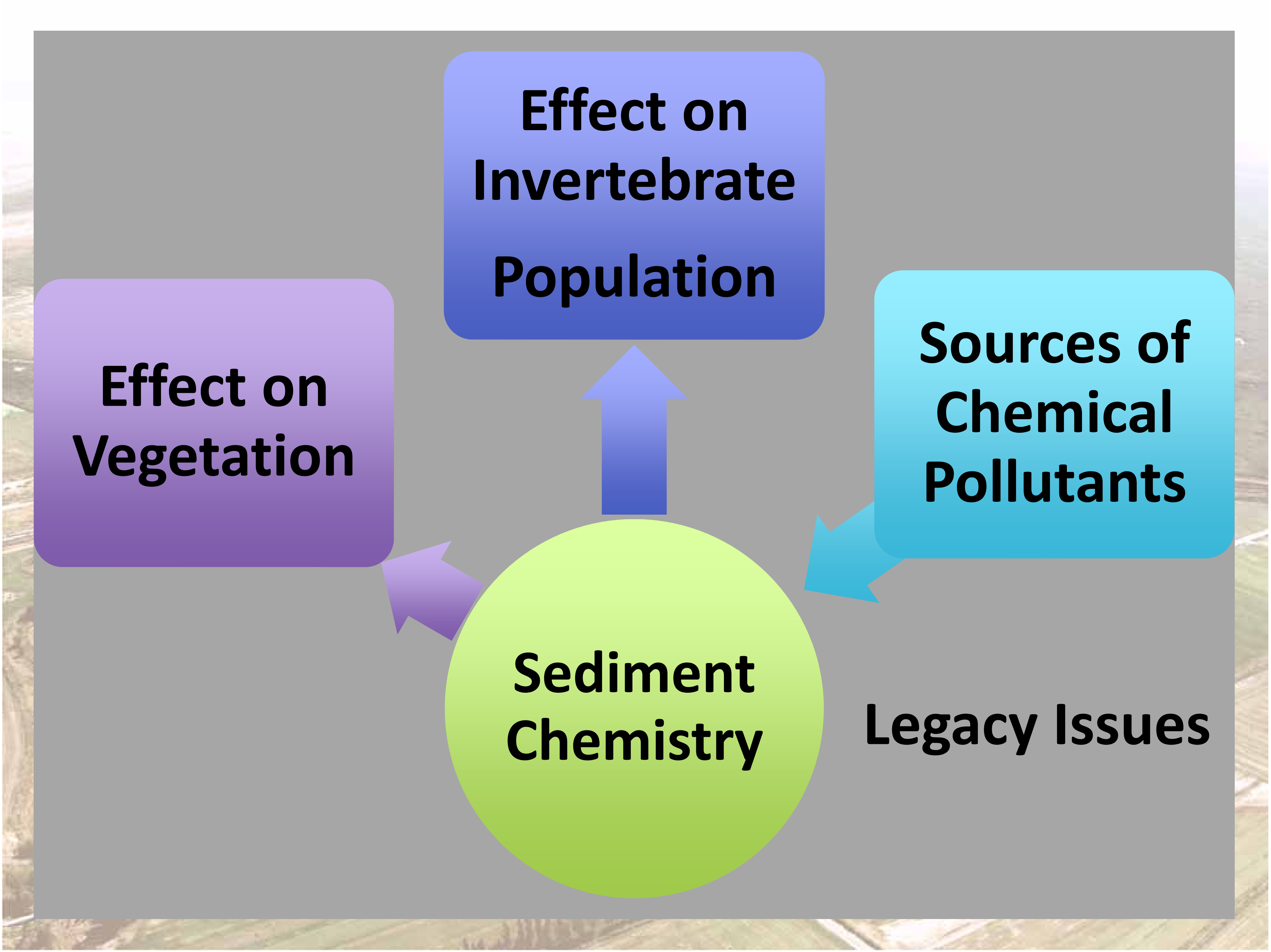
0.09 T-phos.
1.2 T-nitrogen

Limits of [Economic] Technology

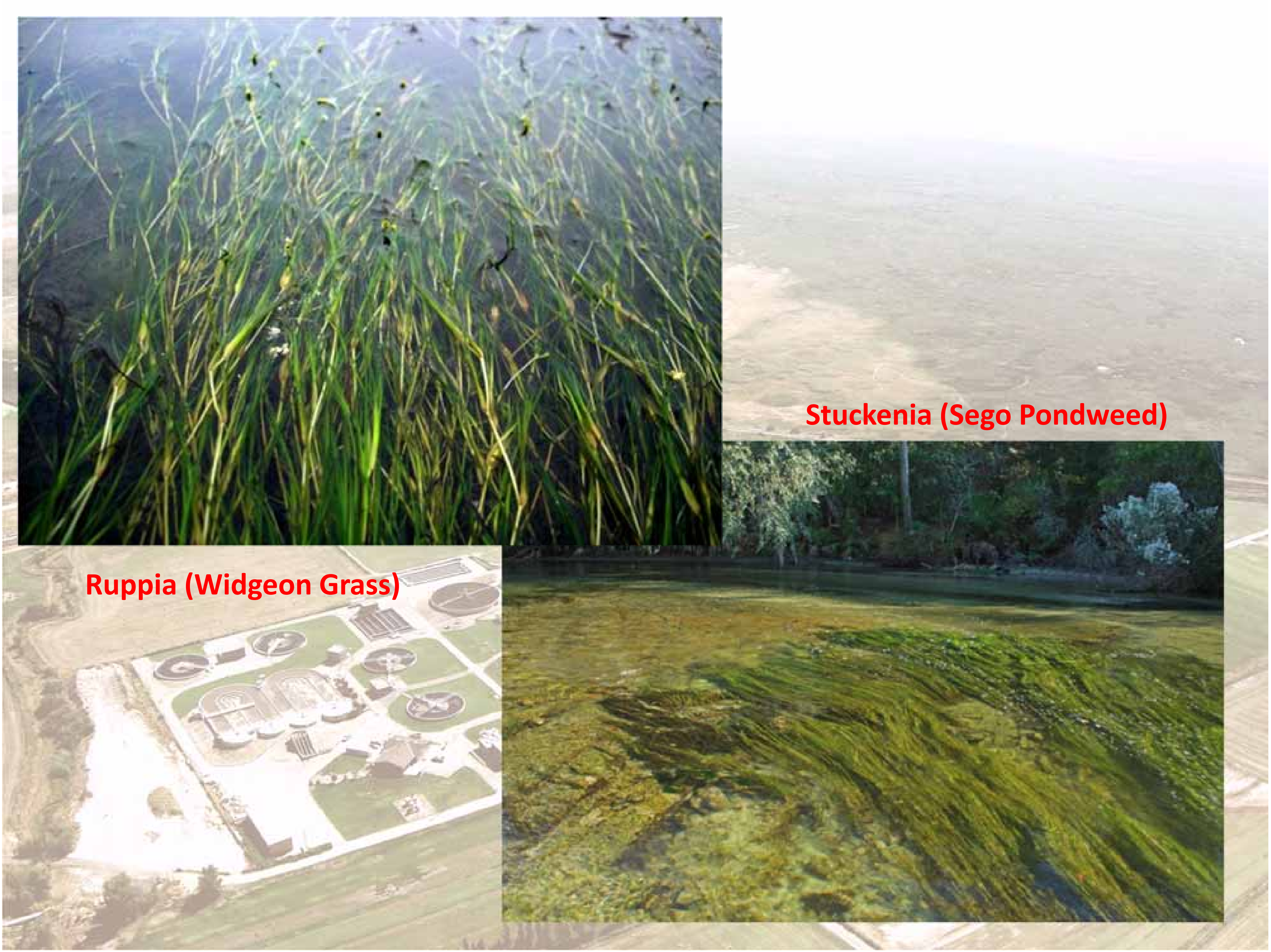
Science Based Nutrient Criteria

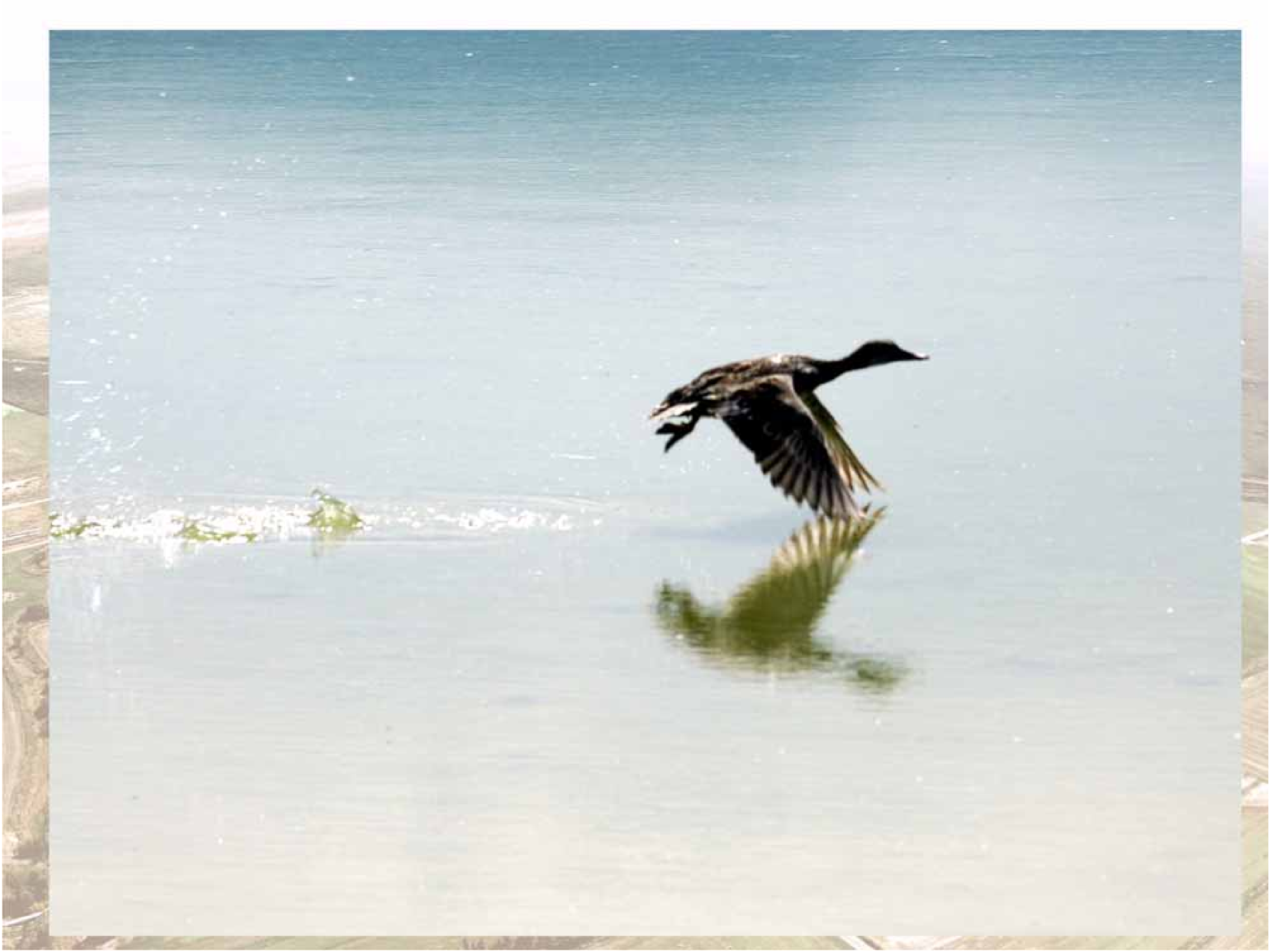
Based on Attainable Uses and Condition


Accurate Stressor and
Response Understanding
Determination of Beneficial Use Compliance
Beneficial Use Support
Measured Surrogates
Necessary Ecological Conditions

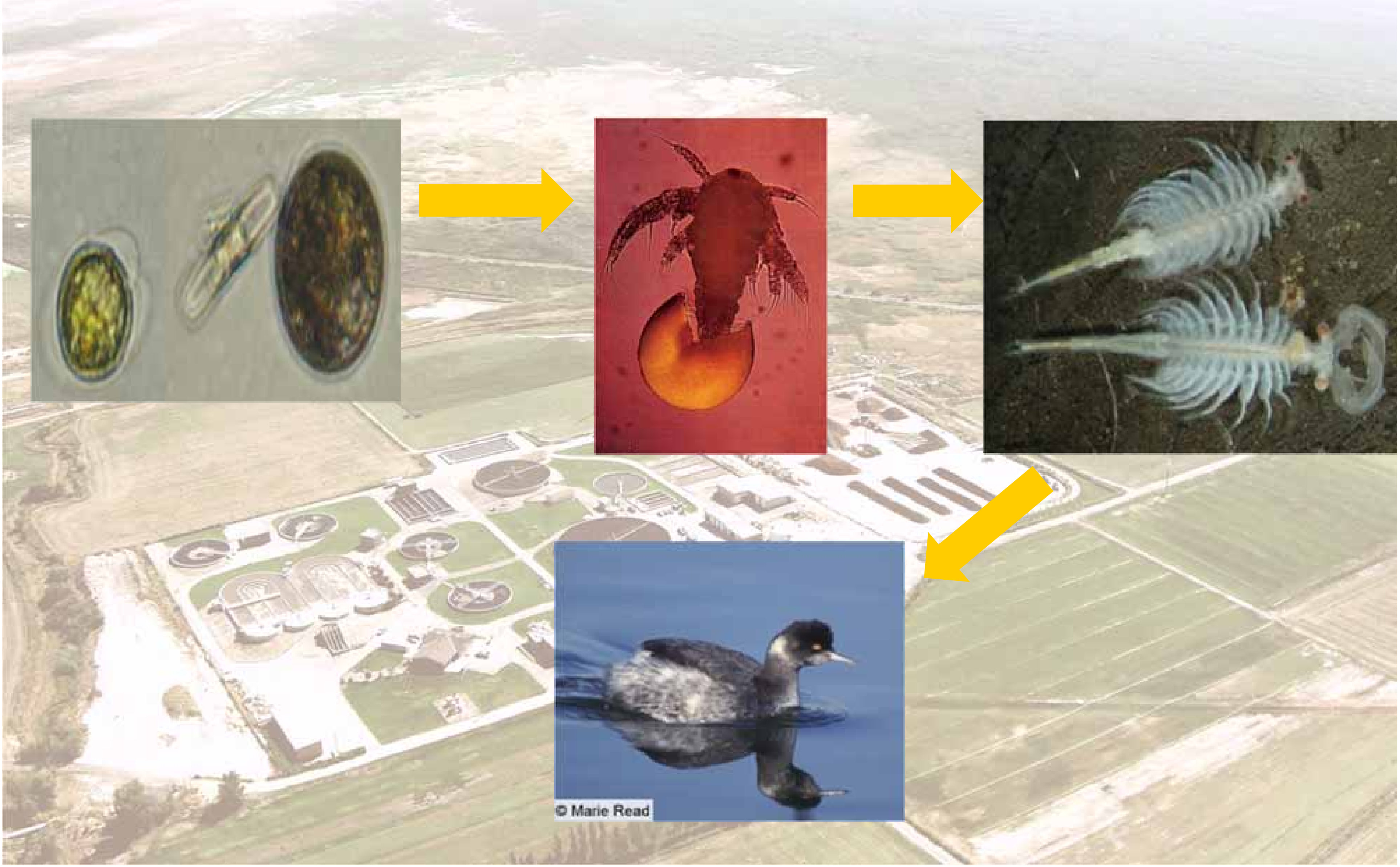

Effect on Invertebrate Population
Effect on Vegetation
Sources of Chemical Pollutants
Sediment Chemistry
Legacy Issues


Great Salt Lake


Stuckenia (Sego Pondweed)
Ruppia (Widgeon Grass)



Nutrients and Brine Shrimp



Natural Conditions

Wastewater

Sediment & Water Chemistry

Storm Water

Industrial/Legacy

The Apparent Truth is That Point and Non-Point Source Control Will Ultimately be Required to Meet Water Quality Objectives.

The Issue is How Much of Each and Who Pays.

Alternate Criteria Development

Category 1 Waters

Use literature based values to protect drinking watersheds and pristine areas

Alternate Criteria Development

Follow UAA/TMDL process based on priorities – Develop funding mechanism for NPS mitigation

Alternate Criteria Development

Urbanized Watershed Systems

Generate funds to develop adequate science to determine appropriate action

If you need political cover for the delay in implementing criteria while science is being developed, implement modest technology based standards for POTW's