Issues in Developing the San Joaquin River, CA DO TMDL:
Balancing Point and Non-Point Oxygen Demand/Nutrient Control

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Presented at WEF TMDL Science Conference St Louis, MO March 2001

- Characteristics of Low-DO Problem in San Joaquin River(SJR) Deep Water Ship Channel (DWSC)
- Responsible Parties
- Approaches Being Followed to Control Low DO Problem

Biographical Information

BA Degree San Jose State University -- 1955

MSPH University of North Carolina -- 1967

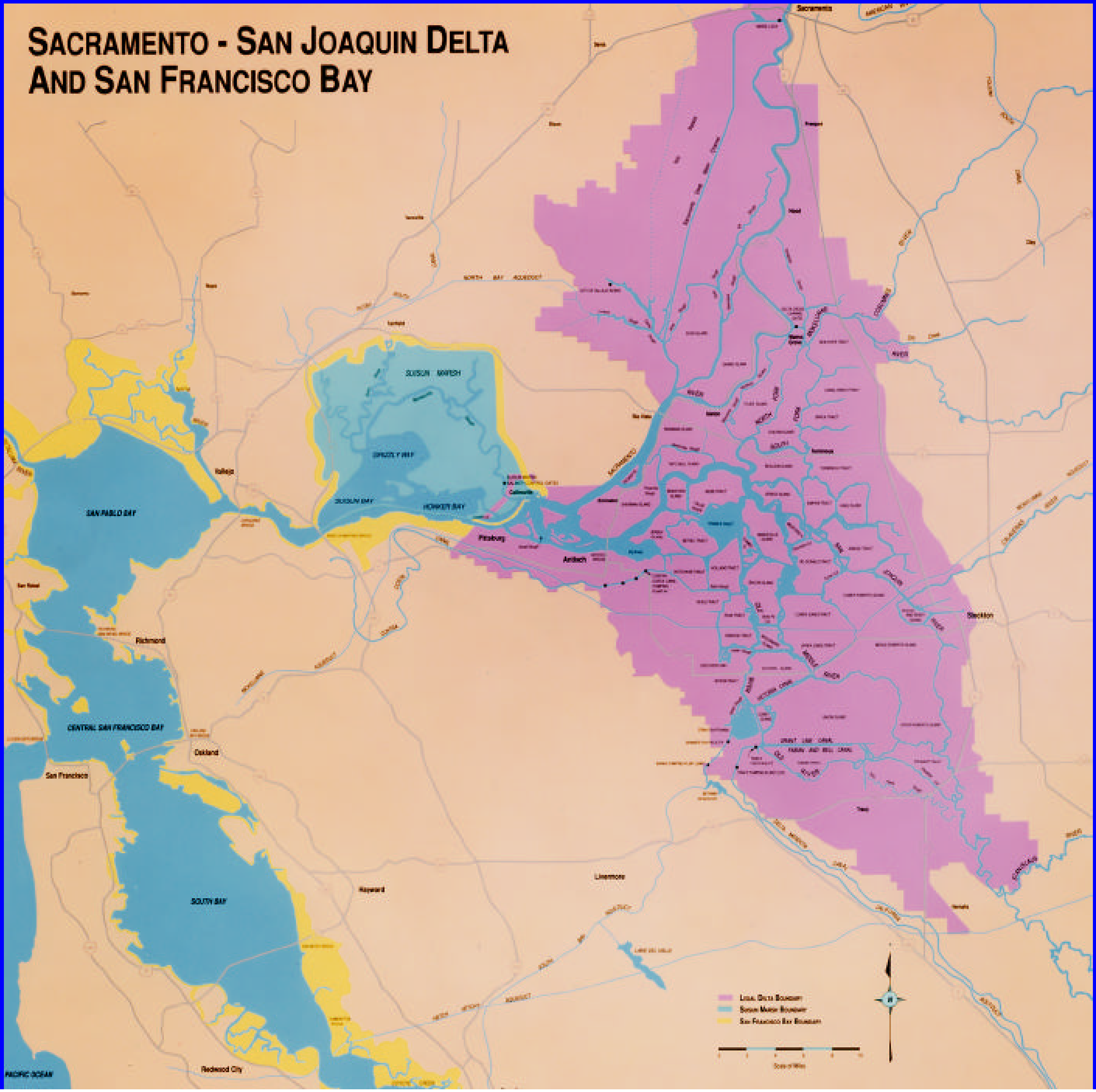
PhD Harvard University -- 1960
    Environmental Engineering/Science

30 years Graduate-Level Teaching and Research in Environmental Engineering/Science
    $6 Million in Research/850 papers and Reports

Full Time Consultant 12 years in:

* Water Supply Water Quality,
* Water and Wastewater Treatment,
* Water Pollution Control,
* Solid and Hazardous Waste Management

Delta Is the Water Supply Source for 20 Million People



SJR DWSC Watershed:

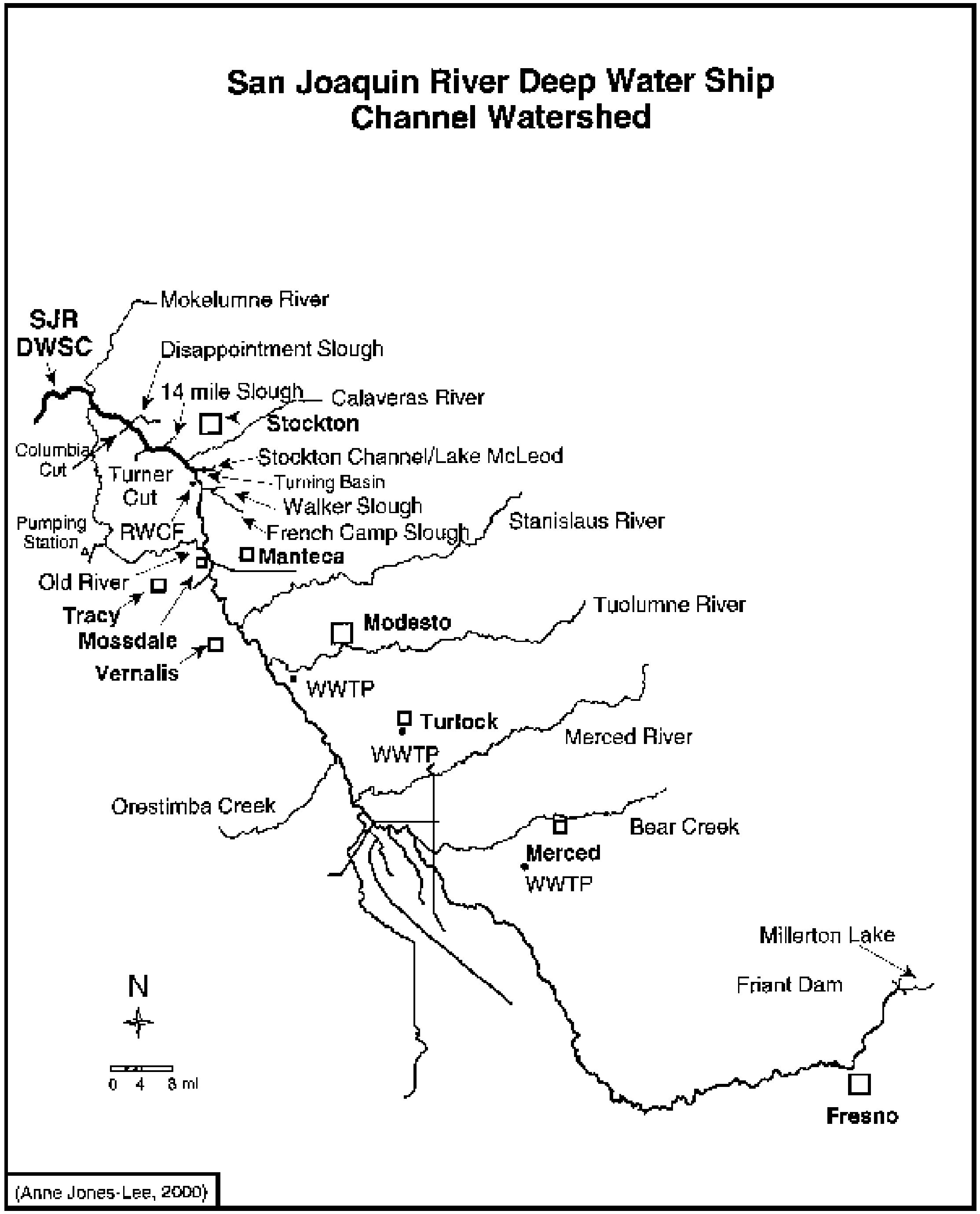
Area: 7,300 mi^2

Intense Agriculture:
- Fruits/Nuts
- Row Crops

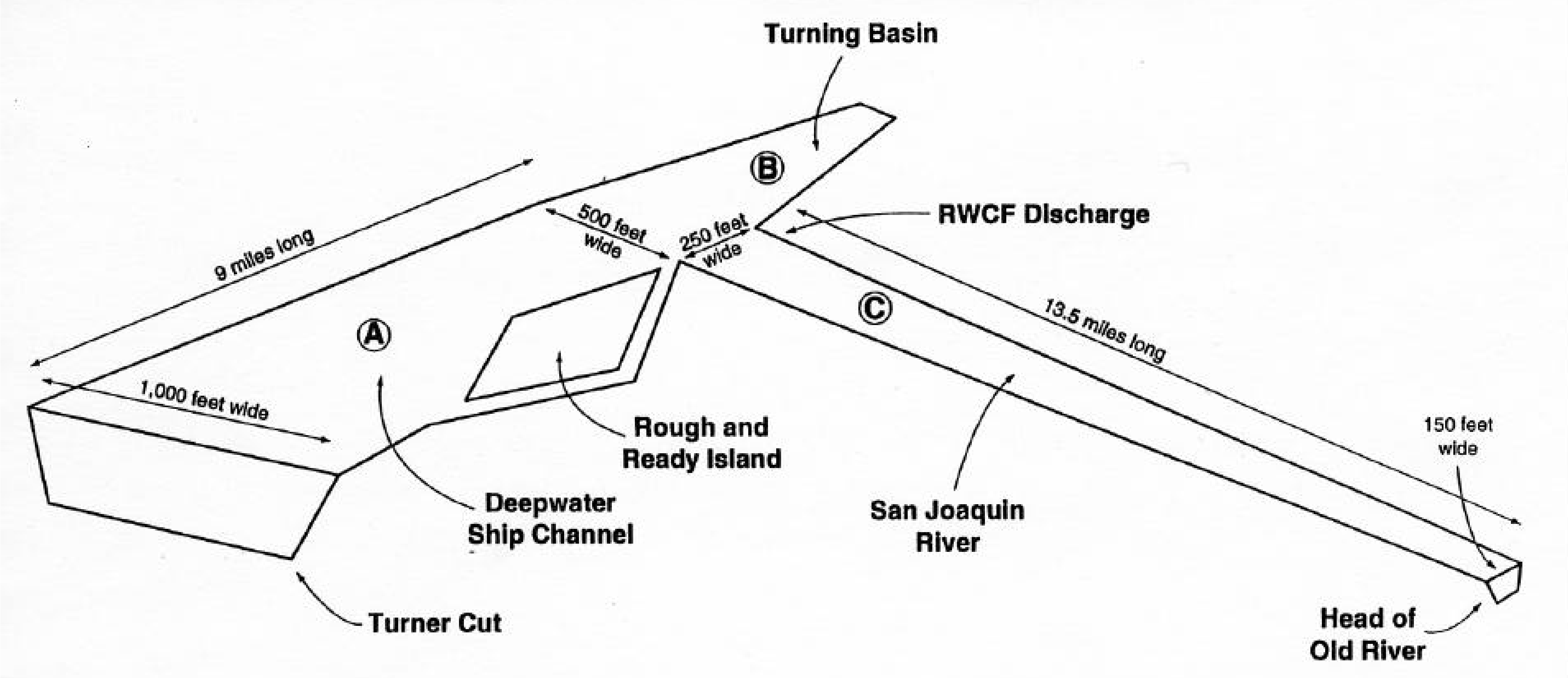
Diaries, Feedlots, Ducks

2 Million People
- Increasing 2%/yr

SJR Flow Highly Regulated



Characteristics of the Deep Water Ship Channel (DWSC)



from Jones & Stokes (1998)

SJR DWSC Reach of Concern Is the First 15 mi below Port of Stockton

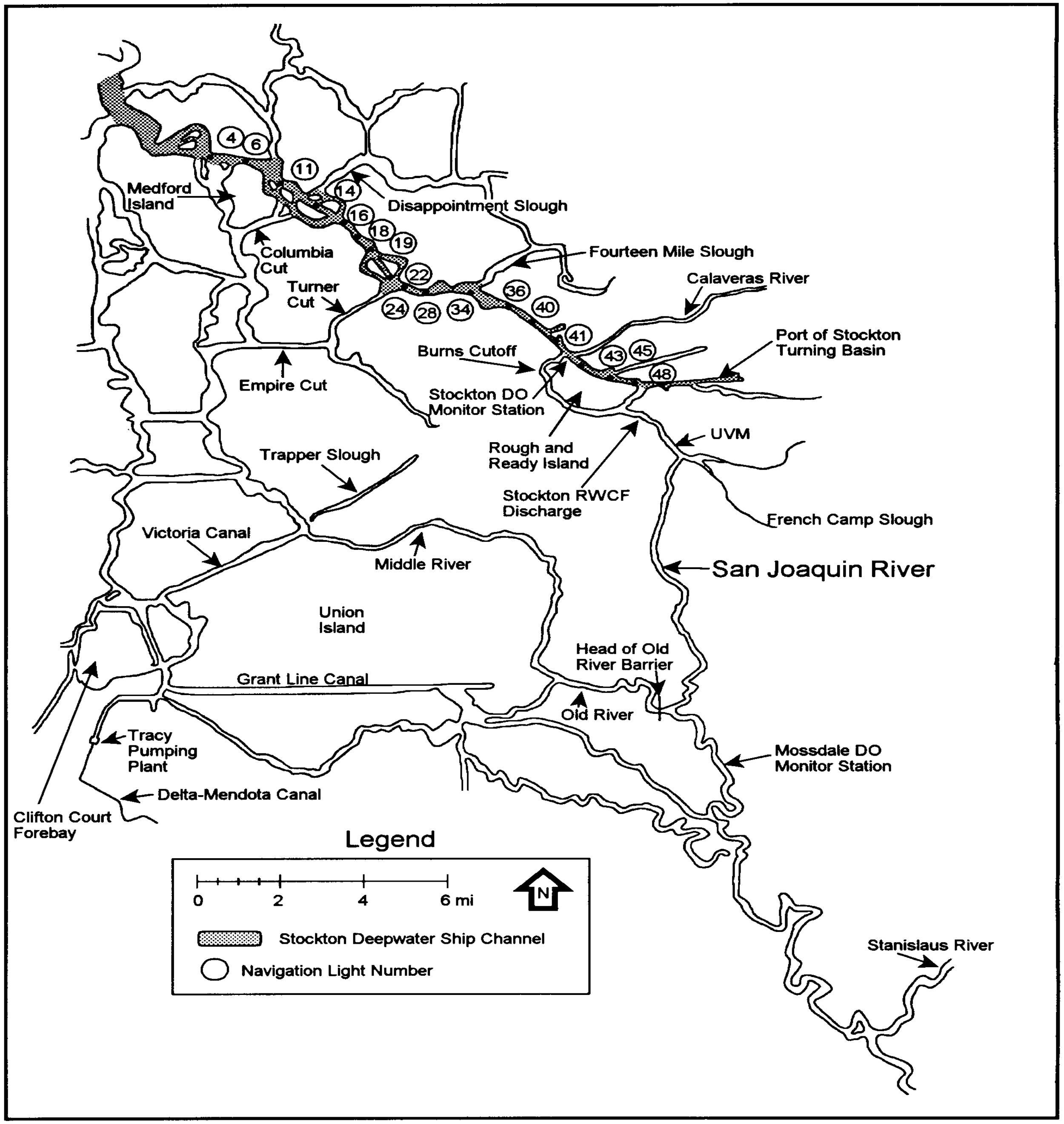


Figure 5
Location of Navigation Lights on the San Joaquin River in the Vicinity of Stockton

Figure 3 - DWSC DO Data Summer/Fall 1999

Adapted from DWR - Lehman (2000)

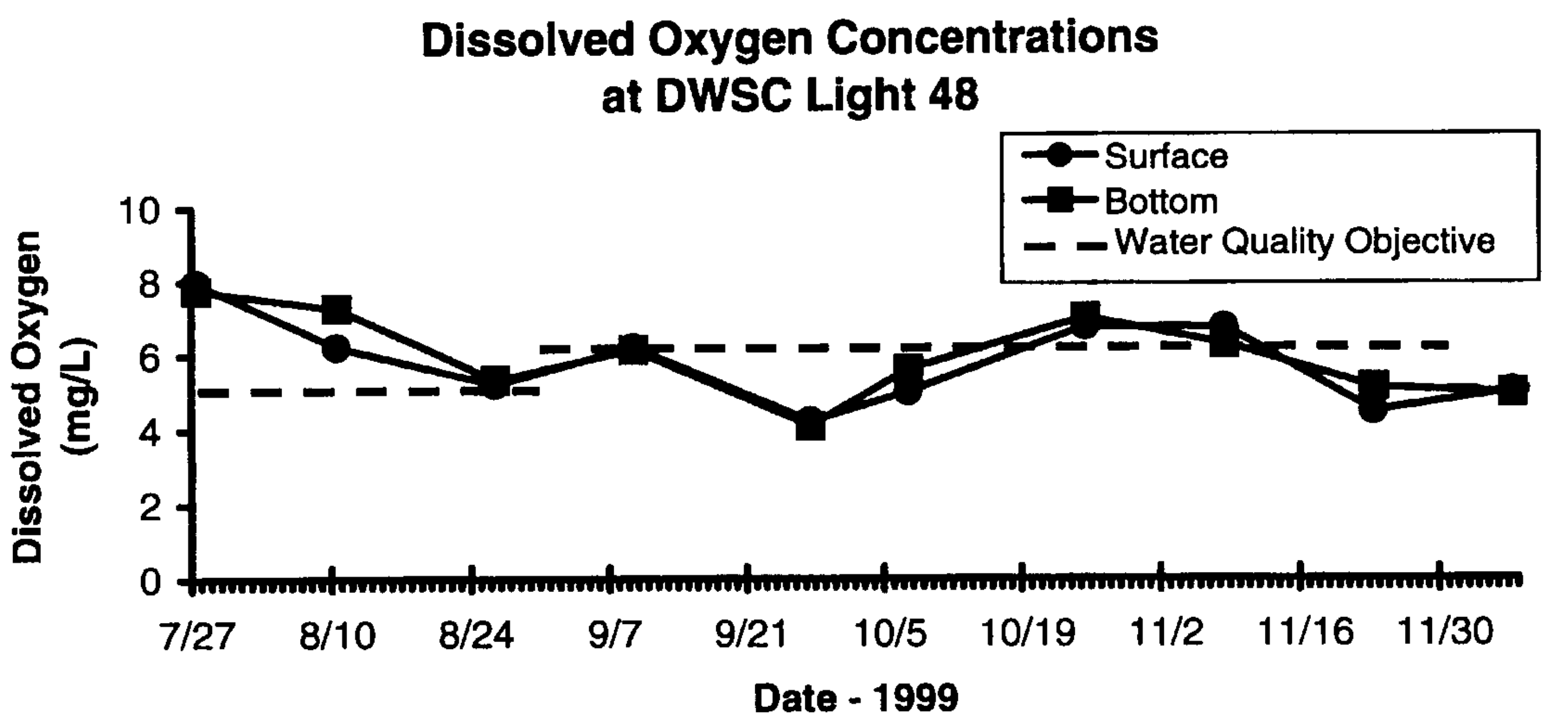
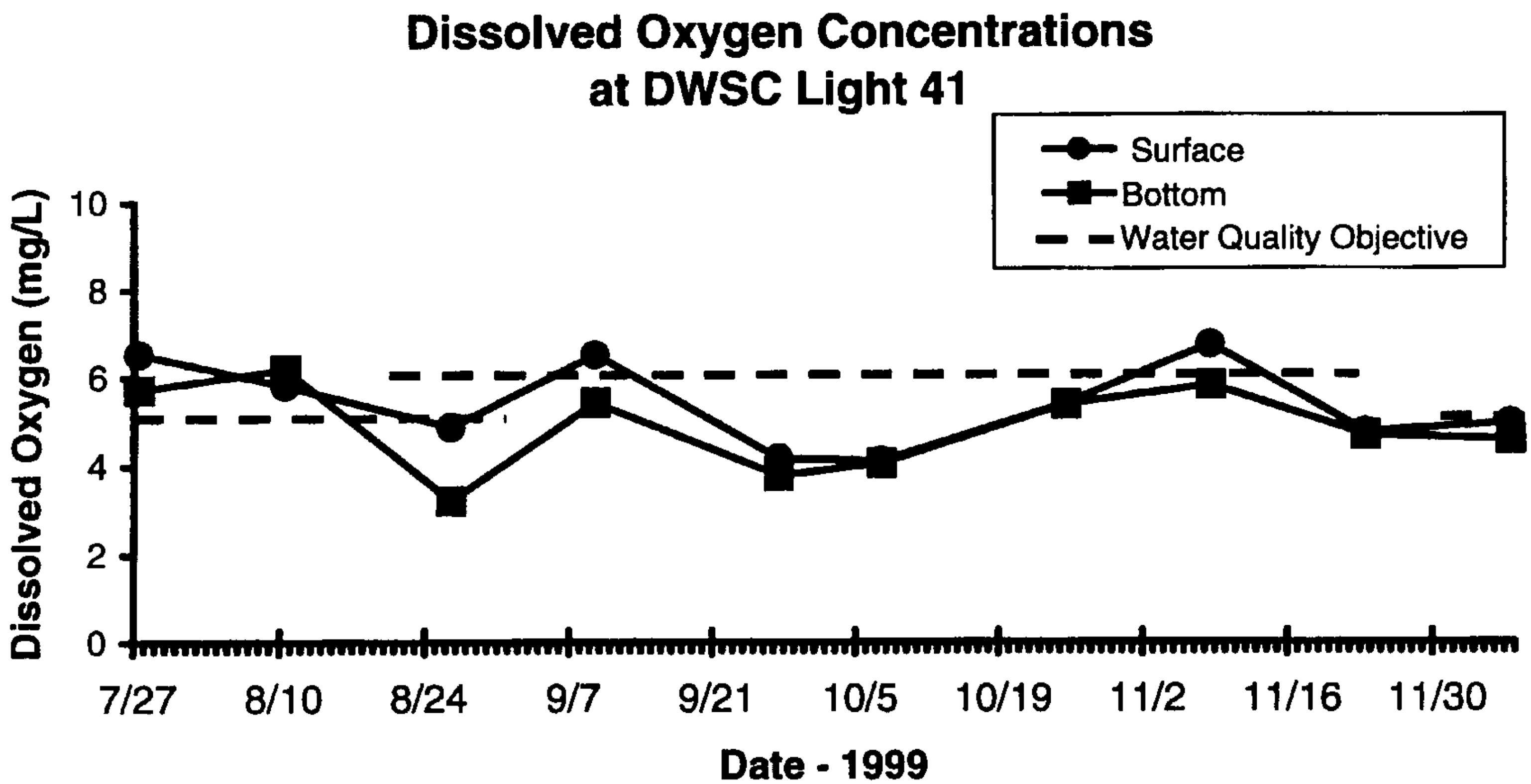
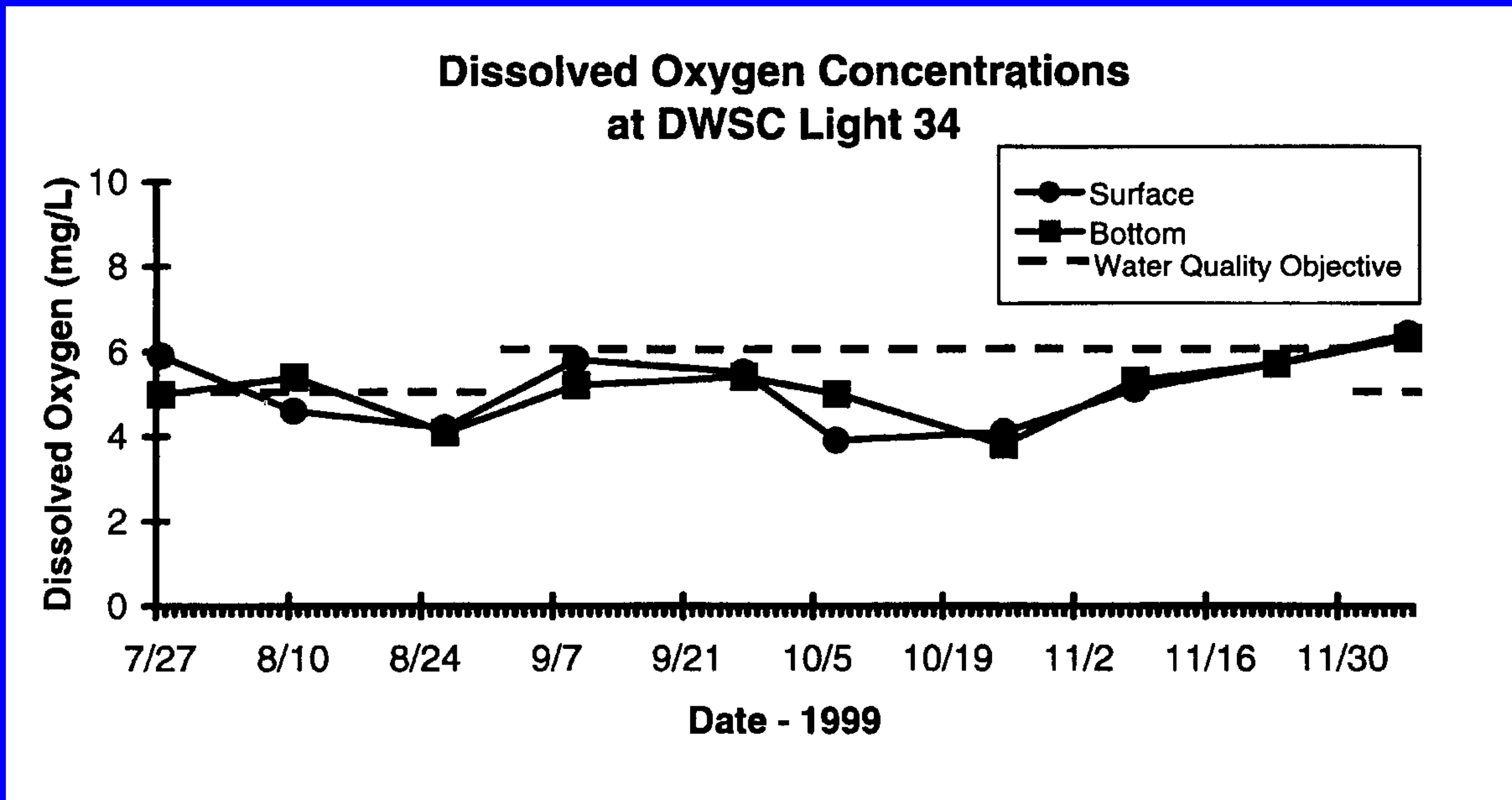
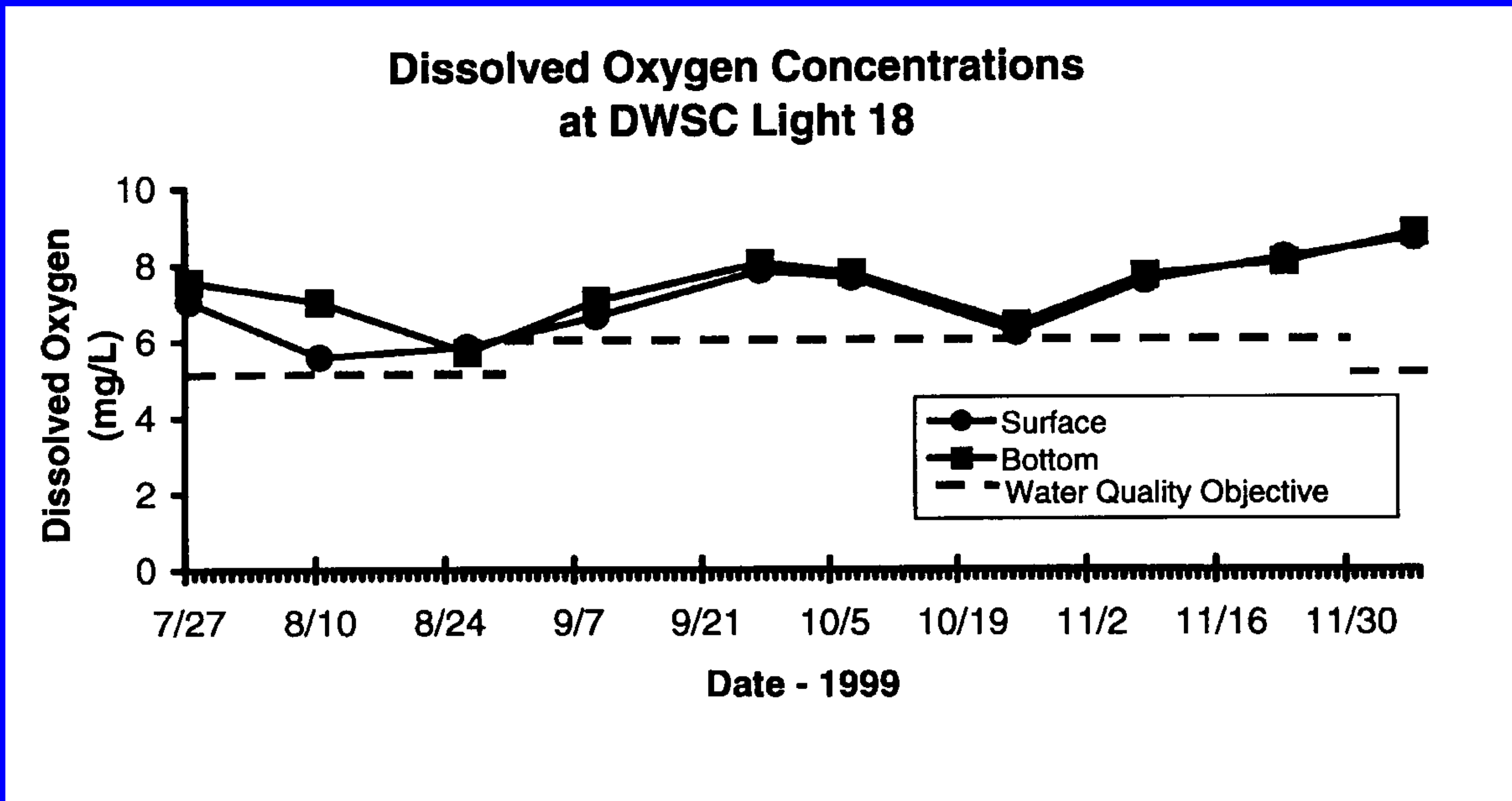


Figure 3 (continued)





Dissolved Oxygen Concentrations
at DWSC Light 34
Surface
Bottom
Water Quality Objective
Dissolved Oxygen (mg/L)
10
8
6
4
2
0
7/27
8/10
8/24
9/7
9/21
10/5
10/19
11/2
11/16
11/30
Date - 1999


Dissolved Oxygen Concentrations
at DWSC Light 18
Dissolved Oxygen
(mg/L)
10
8
6
4
2
0
7/27
8/10
8/24
9/7
9/21
10/5
10/19
11/2
11/16
11/30
Date - 1999
Surface
Bottom
Water Quality Objective

Problem

At Times, DO in the San Joaquin River Deep Water Ship Channel Violates Water Quality Objective/Standard

- SJR DWSC Placed on 303(d) List of "Impaired" Waterbodies

  - Requires TMDL to Control Oxygen Depletion below Water Quality Objective by June 2003

Approach

CVRWQCB Organized Stakeholder Process to Develop TMDL for Oxygen Demand Substances and Allocation of Loads among Municipal Wastewater/Stormwater Dischargers, Agriculture Runoff/Tail Water, Dairies, Feedlots, Riparian Wetlands Runoff/Releases

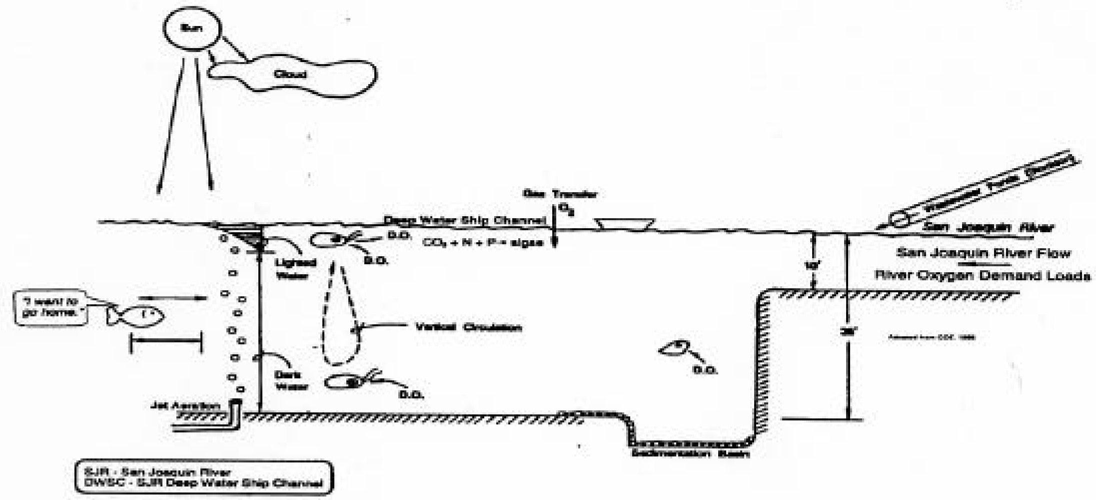
If the Stakeholders Do Not Develop Consensus Allocation of Responsibility by December 2002, CVRWQCB Will Assign Allocation of Load Reduction

CALFED Provided $866,000 for Studies in 2000

Applied for $2.5 million/yr for 2 yrs to Conduct the Studies Needed to Develop TMDL and Allocate Responsibility for Control of Low DO in DWSC

Total 3-yr Study Effort in Excess of $6 Million

Issues Report Discusses the Issues That Will Need to Be Addressed to Control the Low DO Problem



Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL

Report to

San Joaquin River Dissolved Oxygen Total Maximum Daily Load Steering Committee and the

Central Valley Regional Water Quality Control Board
Sacramento, CA

Submitted by

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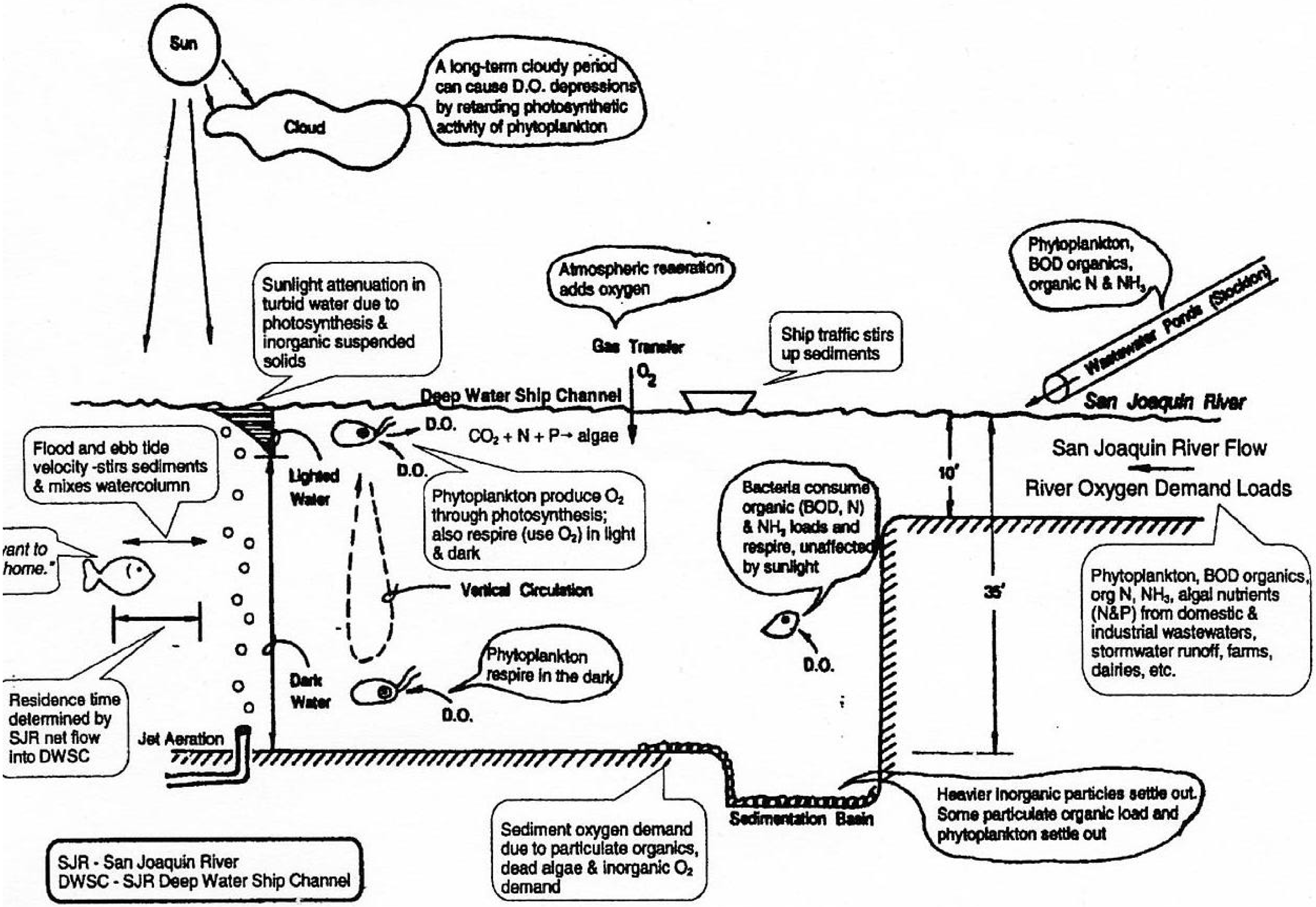
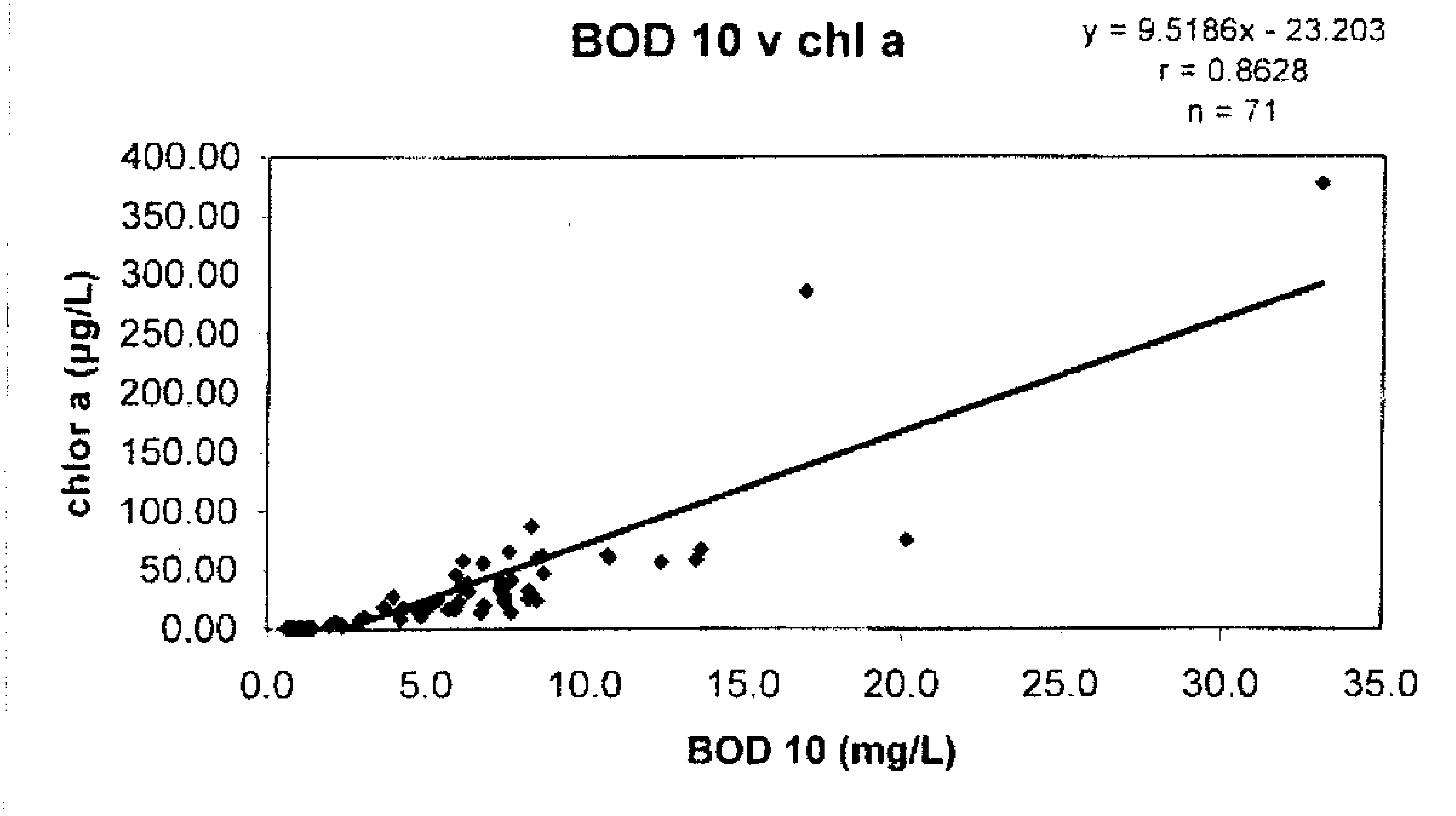
August 17, 2000

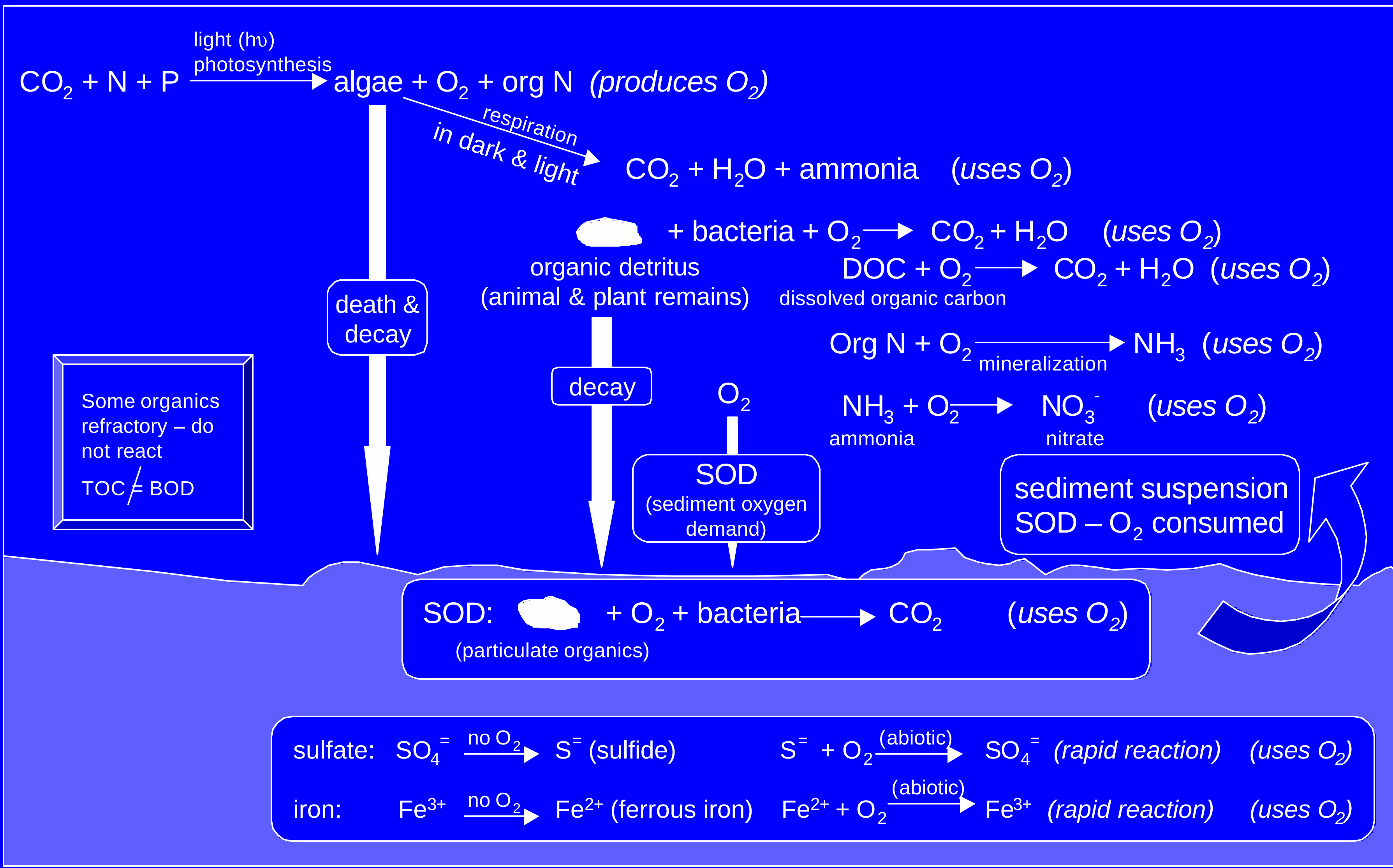


Factors Affecting Dissolved Oxygen in the Ship Channel

Algae as a Source of BOD



Algae & Organic Detritus as Sources of Oxygen Demand



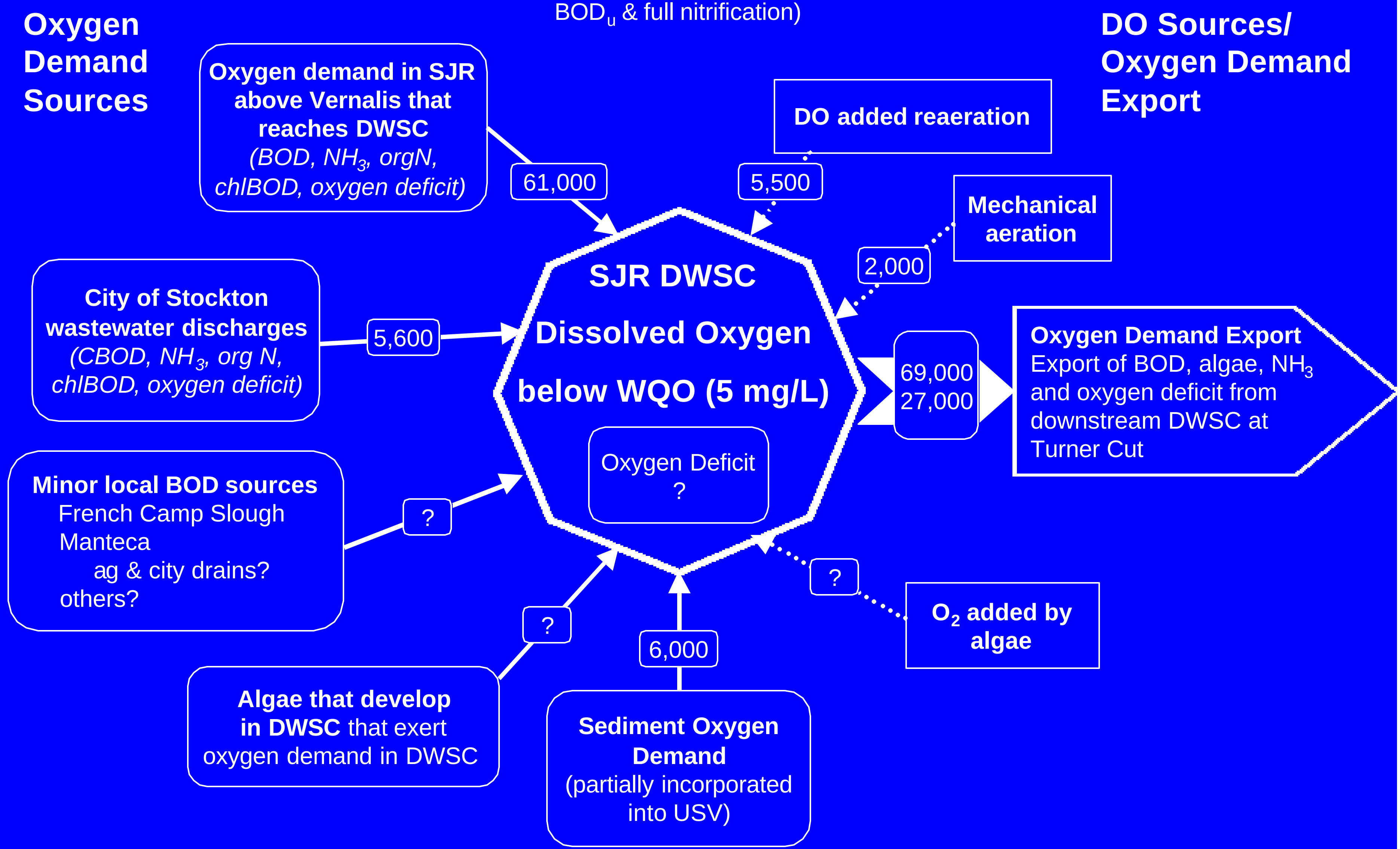
Upstream SJR Diversions for Southern CA Water Supplies and Central Valley Agriculture Adversely Impact Oxygen Demand Assimilative Capacity

Sacramento–San Joaquin Delta Atlas

Department of Water Resources

Box Model of Estimated DO Sources/Sinks in SJR DWSC August 1999

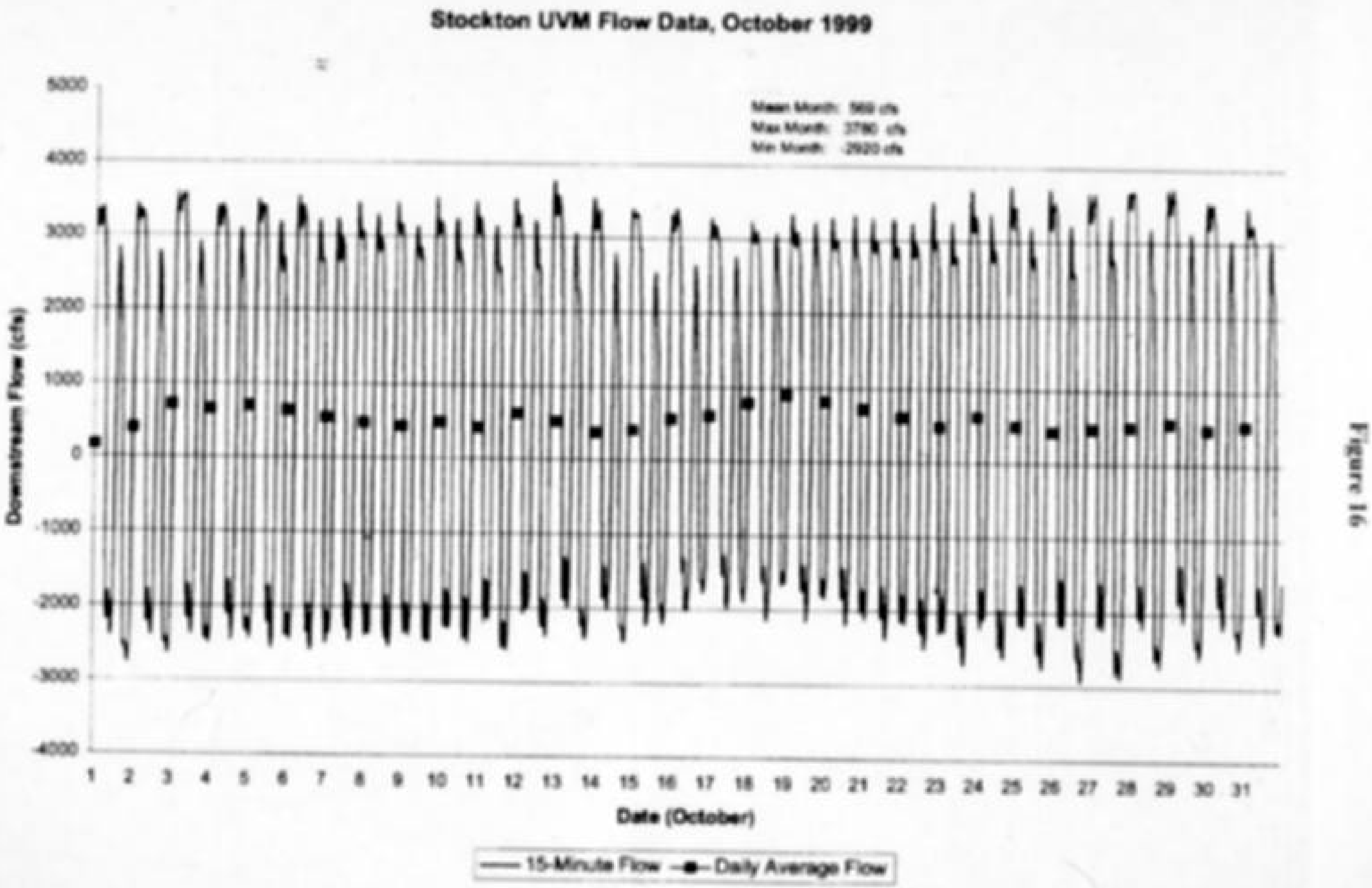
(values in lbs/day of oxygen demand BOD_u & full nitrification)



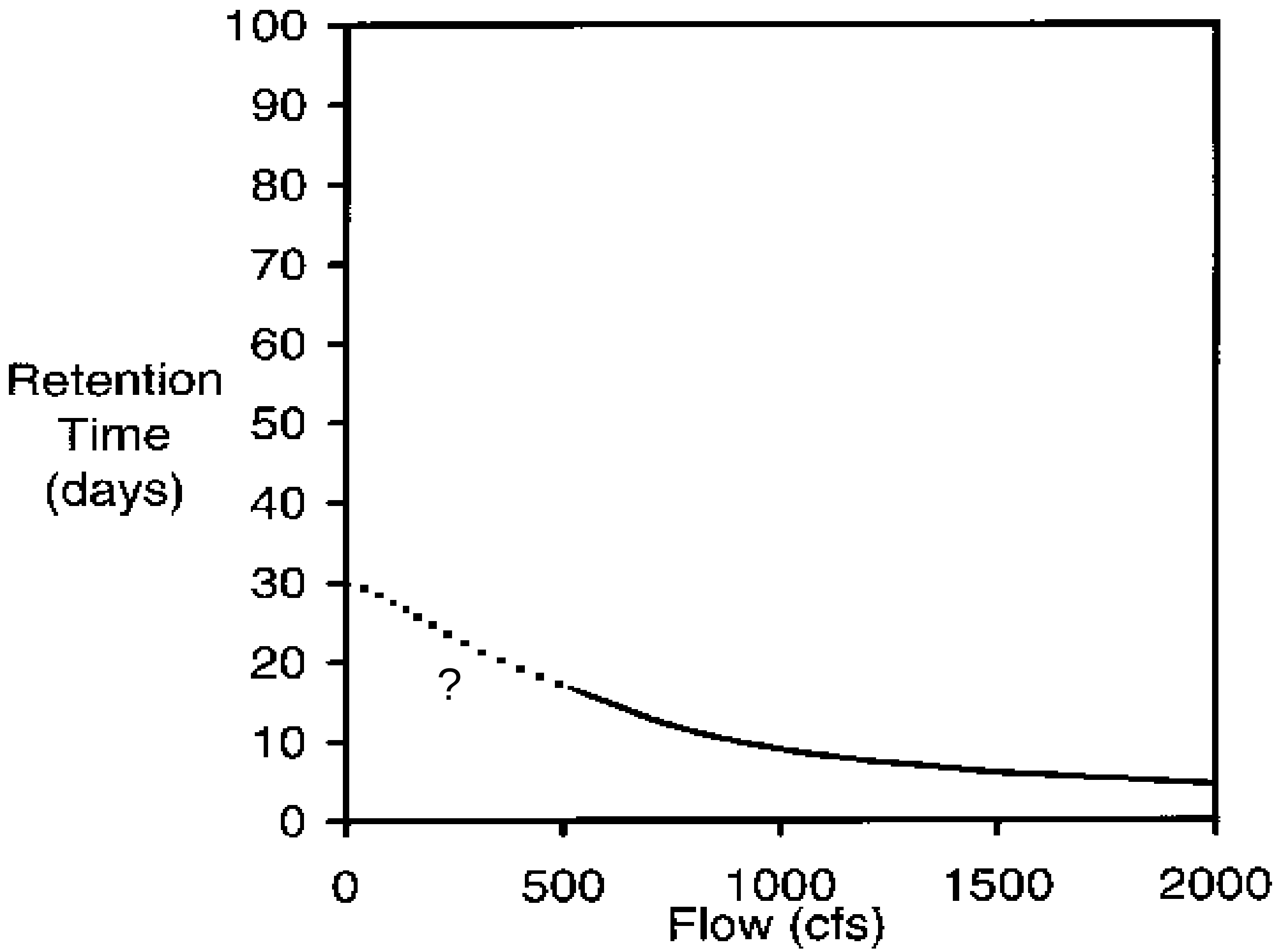
Box Model Calculations of Oxygen Demand Sources & Sinks for San Joaquin River Summer/Fall 1999

Source	BODu (lbs/day)				
	August	September	October		
SJR DWSC Net Flow (cfs):	**~ 900**	**~ 900**	**150**	**400**	**1,000**
Upstream of Vernalis	61,000	70,000	6,300	14,130	35,325
City of Stockton	5,600	9,300	12,200	12,000	12,000
Local DWSC	?	?	1,750	1,750	1,750
SOD	6,000	6,000	6,000	6,000	6,000
Aeration(Natural)	5,500	5,500	?	?	?
Aeration(Mech.)	2,000	2,000	?	?	?
DWSC Algae	?	?	?	?	?
Export from DWSC	27,000	27,000	?	?	?

SJR DWSC Tidal vs Net Flow



Retention Time in SJR Deep Water Ship Channel (to Turner Cut, including Turning Basin) as a Function of Flow



Summer Oxygen Demand Loads Control
DO Depletion

Short Hydraulic Residence Time of the DWSC 5 to 30 days for SJR Flows of 2,000 cfs to 100 cfs

Only Summer Oxygen Demand Loads Important to Summer/Fall DO Depletion

High Winter-Spring Flows/Loads Flush Through the DWSC

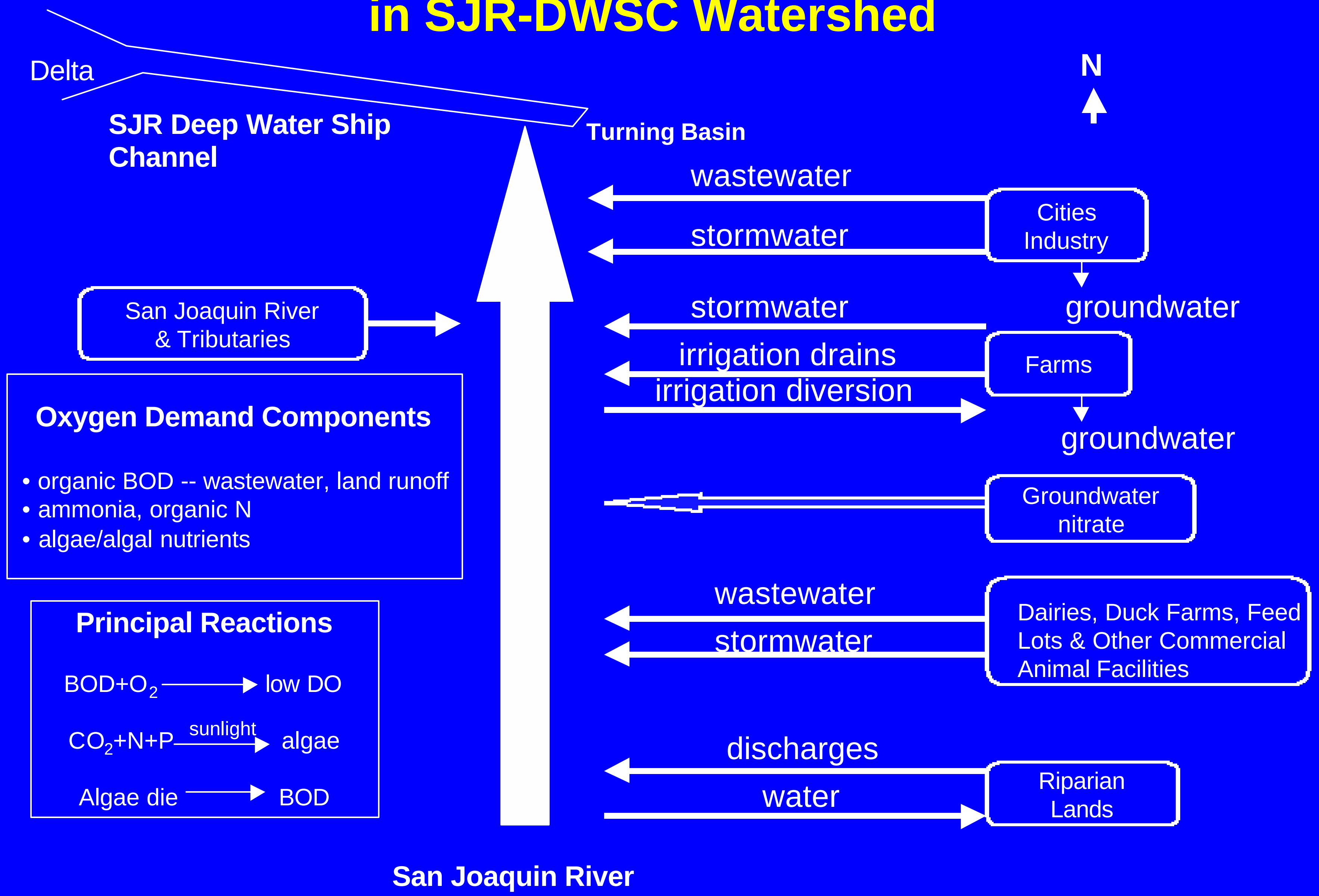
Stormwater Runoff Not Important Source of BOD

Conclusion -- Impact of SJR DWSC Flow on Low DO

Diversion of SJR Flow Upstream of DWSC Increases the Hydraulic Residence Time and Reduces the Oxygen Demand Assimilative Capacity of the DWSC

- Flow Diverters Are Responsible Parties in the Low DO Problem

Sources/Sinks of Oxygen Demand in SJR-DWSC Watershed

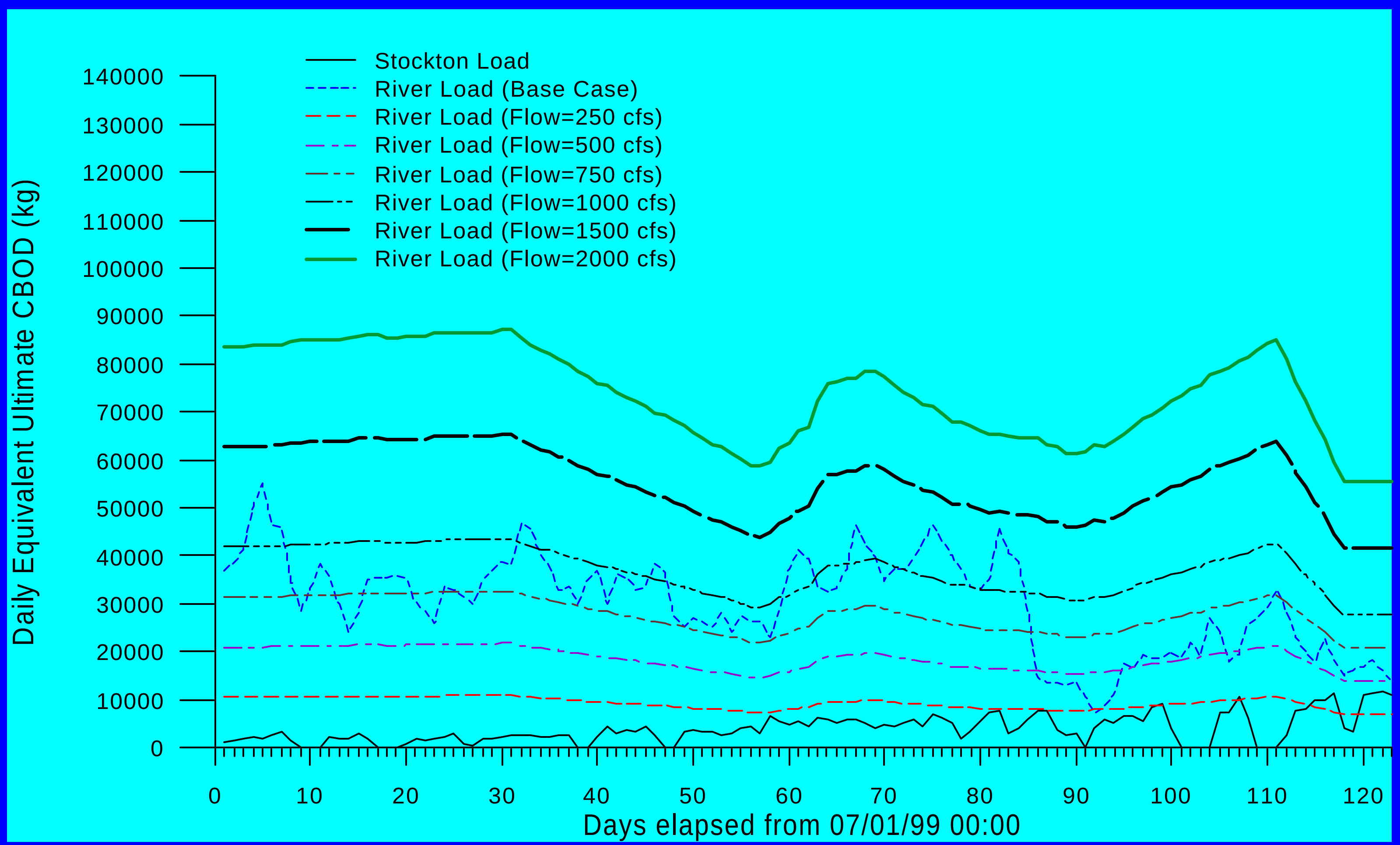


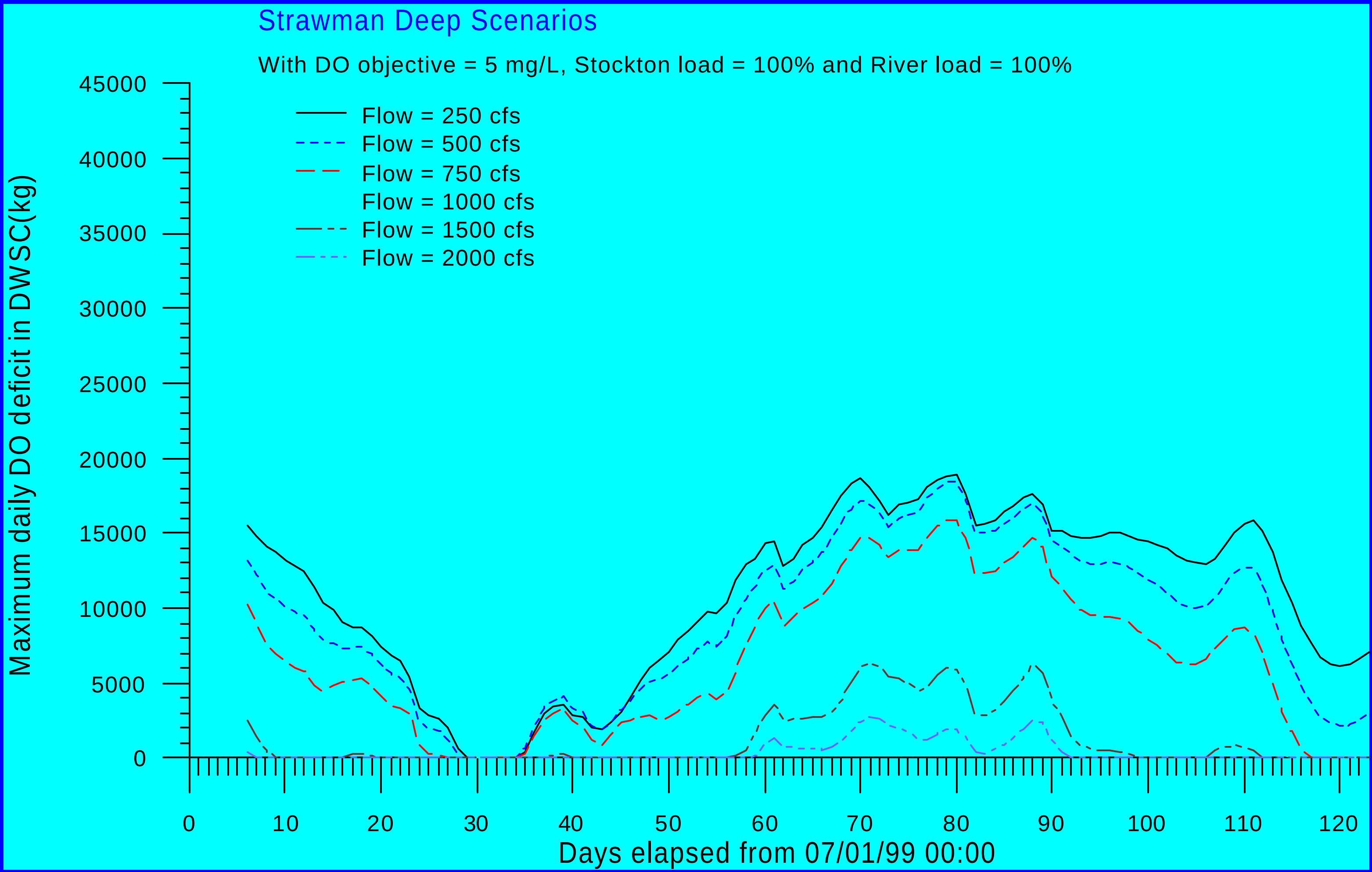
Application of DO Model to Strawman Analysis

Carl W. Chen and Wanteng Tsai

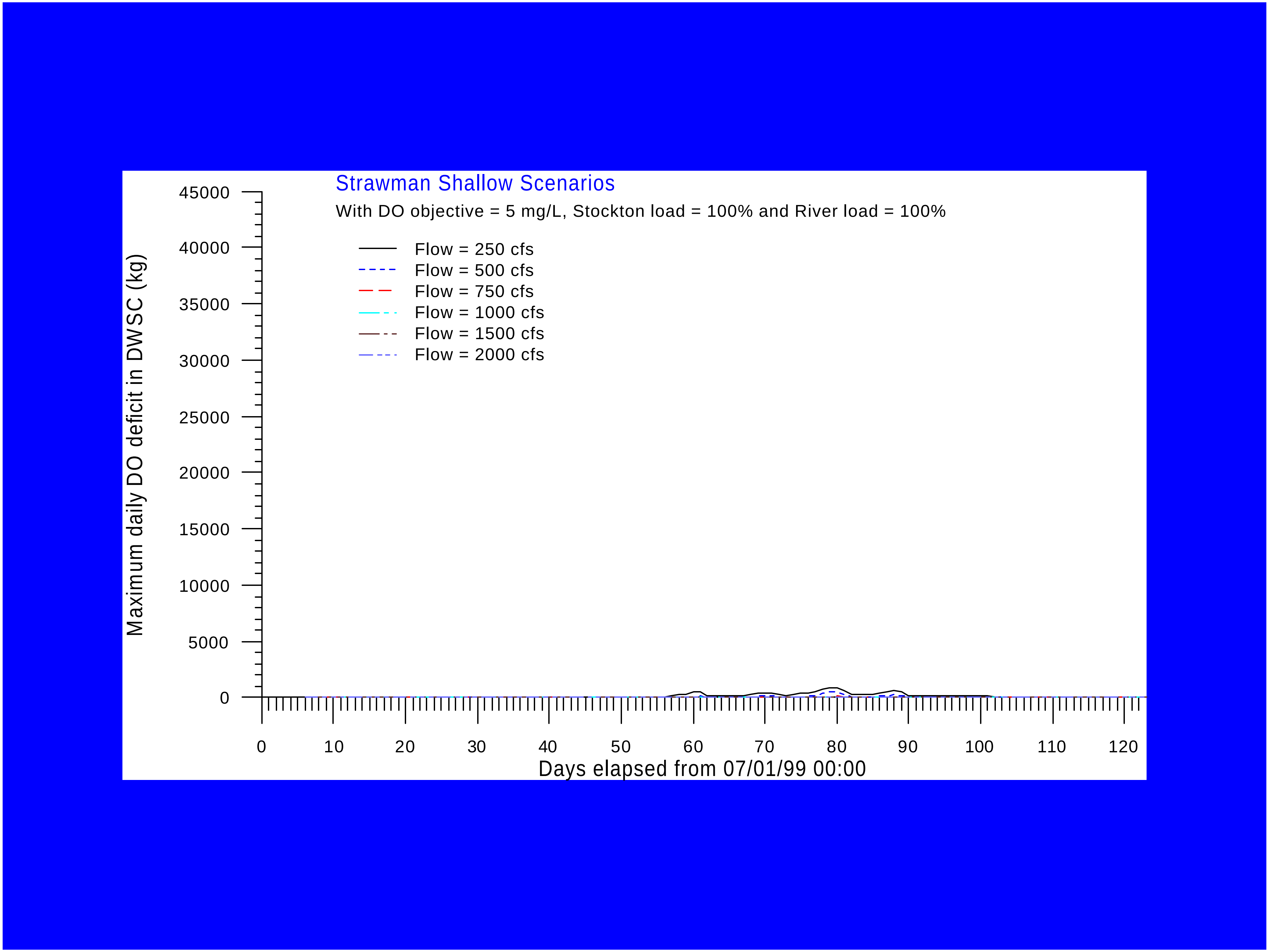
Systech Engineering, Inc.

February 21, 2001


Stockton Load
River Load (Base Case)
River Load (Flow=250 cfs)
River Load (Flow=500 cfs)
River Load (Flow=750 cfs)
River Load (Flow=1000 cfs)
River Load (Flow=1500 cfs)
River Load (Flow=2000 cfs)
Daily Equivalent Ultimate CBOD (kg)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
110000
120000
130000
140000
0
10
20
30
40
50
60
70
80
90
100
110
120
Days elapsed from 07/01/99 00:00



Strawman Deep Scenarios
With DO objective = 5 mg/L, Stockton load = 100% and River load = 100%
Flow = 250 cfs
Flow = 500 cfs
Flow = 750 cfs
Flow = 1000 cfs
Flow = 1500 cfs
Flow = 2000 cfs
Maximum daily DO deficit in DWSC(kg)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
0
10
20
30
40
50
60
70
80
90
100
110
120
Days elapsed from 07/01/99 00:00



Strawman Shallow Scenarios
With DO objective = 5 mg/L, Stockton load = 100% and River load = 100%
Flow = 250 cfs
Flow = 500 cfs
Flow = 750 cfs
Flow = 1000 cfs
Flow = 1500 cfs
Flow = 2000 cfs
Maximum daily DO deficit in DWSC (kg)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Days elapsed from 07/01/99 00:00

Conclusion on the Impact of DWSC Depth

Without the Deep Water Ship Channel, the Low DO Problem Would Not Occur

The Port of Stockton & Those Who Benefit by the Port/Channel Should Be Responsible Parties in Controlling the Low DO Problem

Responsibility for SJR DWSC DO Depletion below Water Quality Objective

Sources of Oxygen Demand

- NPDES Permittees
  - Municipal and Industrial Wastewater Discharges and Stormwater Runoff – City of Stockton & Other Municipalities
  - Dairies and Other Animal Husbandry Operations, Including Feedlots, Hogs, Horses, Chickens

Responsibility for SJR DWSC DO Depletion below Water Quality Objective

Sources of Oxygen Demand

- Non-Point Runoff/Discharge of Oxygen Demand
  - Agricultural Lands, Irrigation Drainage, Stormwater Runoff
  - Non-NPDES Permitted Urban Stormwater Runoff
  - Riparian Lands
- Pollution of Groundwater That Leads to Nitrate Discharge to Surface Waters
  - Agriculture
  - Dairies & Other Animal Husbandry Activities
  - Land Disposal of Municipal Wastewaters
  - Urban Areas

Responsibility for SJR DWSC DO Depletion below Water Quality Objective

DWSC Geometry

- Port of Stockton & Those Who Benefit from Commercial Shipping to Port
  - Channel Depth Impacts Oxygen Demand Assimilative Capacity
- Ship Traffic That Stirs Sediments into Water Column That Increases SOD

Responsibility for SJR DWSC DO Depletion below Water Quality Objective

SJR DWSC Flow

- All Entities That Divert Water from the SJR above the DWSC, as Well as Those That Alter the SJR Flow Pattern through the Delta
  - Municipal and Agricultural Diversions

Responsibility for SJR DWSC DO Depletion below Water Quality Objective

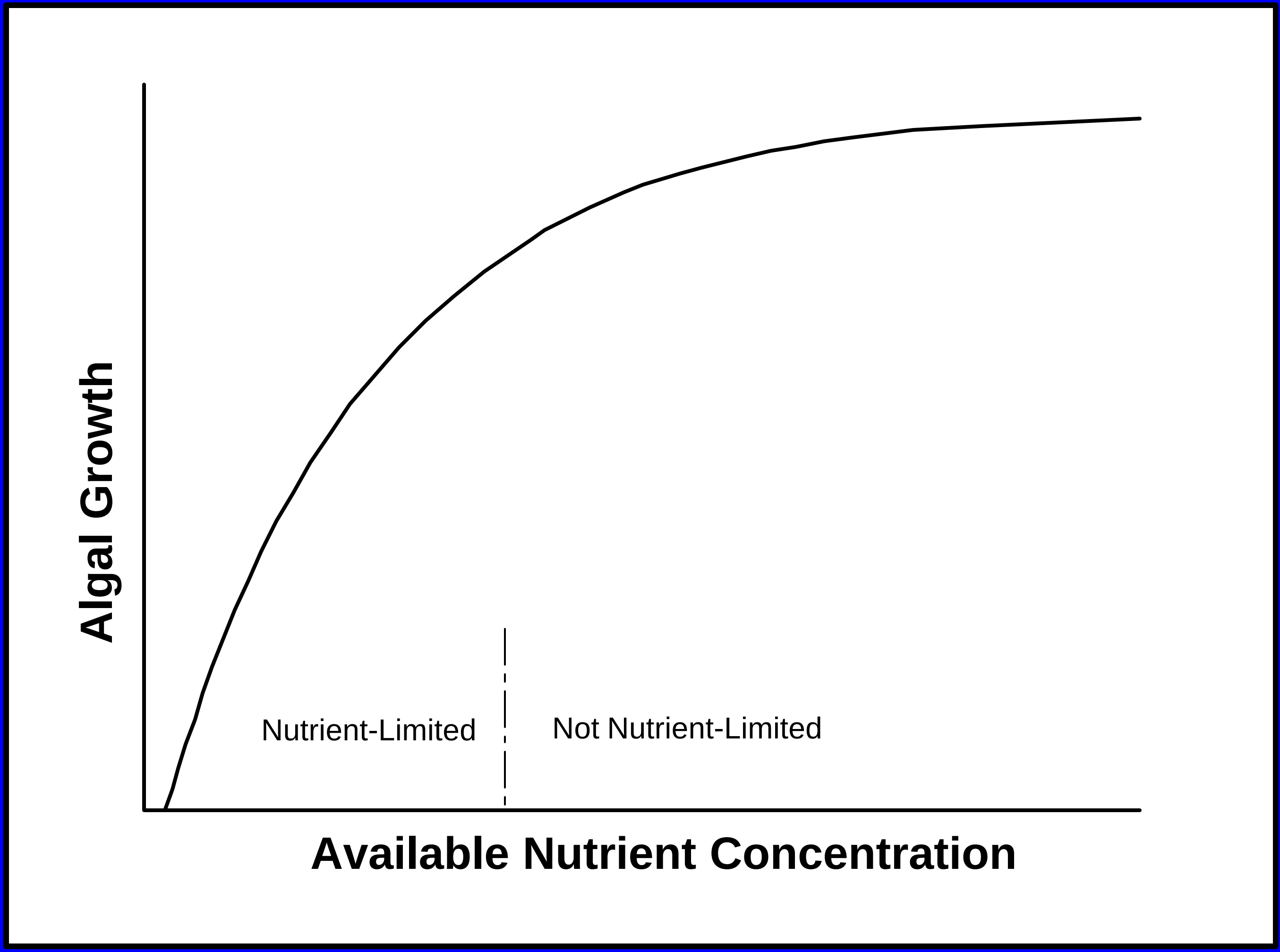
Future Urban Development in Watershed

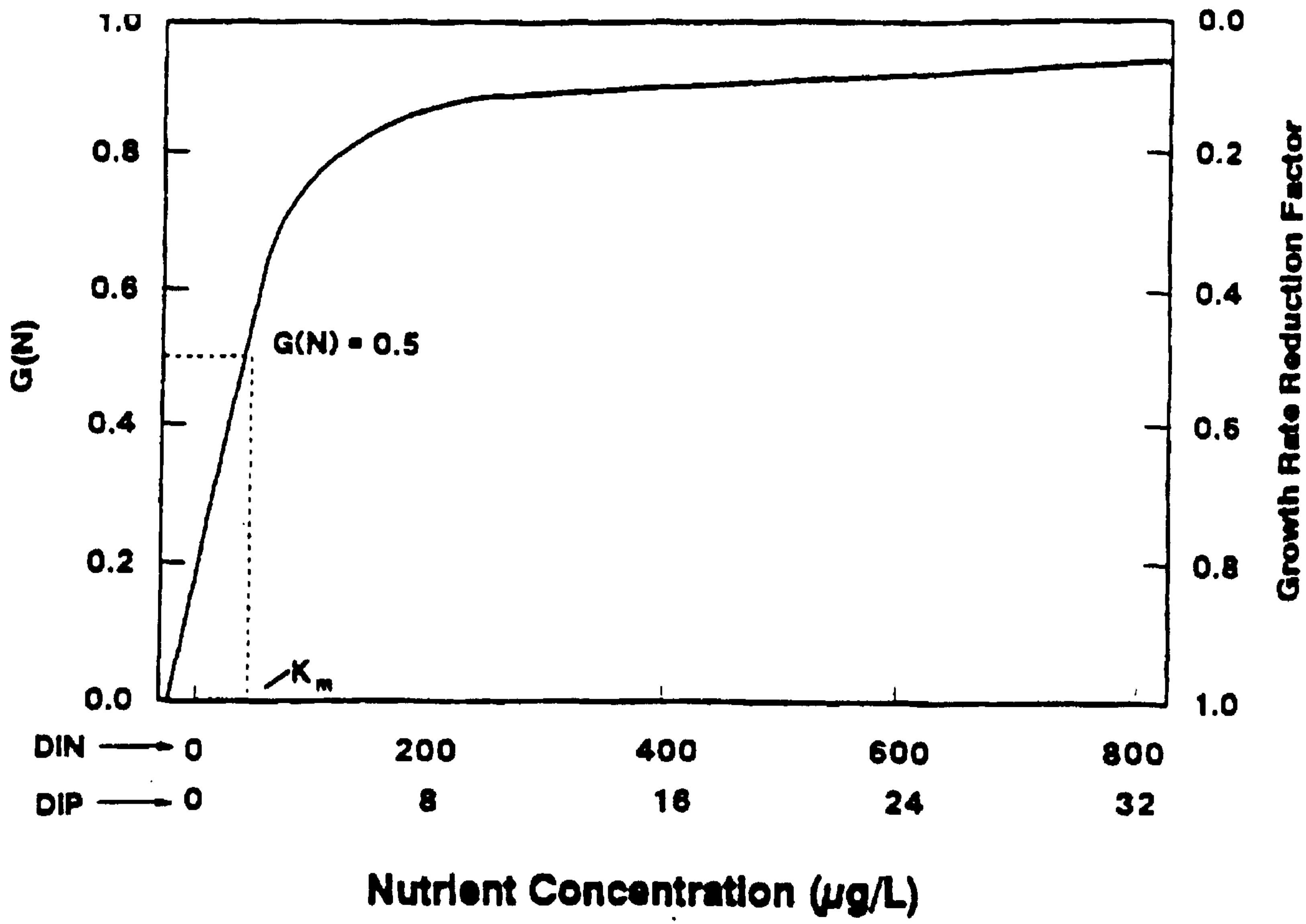
- How Will Future Development in the SJR DWSC Be Controlled so That the Increased Oxygen Demand and Nutrients Associated with Urban Development Will Not Cause Future Low DO Problems in the DWSC?

Issues in Controlling Algal Biomass as a Means of Reducing Algae-Caused BOD

- Surplus N and P Compared to Algal Needs
- Algal Biomass Controlled by Light Limitation
  - Large Amounts of N or P Control Needed to Limit Algae-Caused BOD
    - 30 to 100 Times Excess N and P

Relationship between Nutrient Concentration and Algal Biomass





EFFECT OF NUTRIENTS ON ALGAL GROWTH
(After Ambrose et al., 1993a)

Channel Aeration

- Likely Need Selective Aeration of DWSC to Eliminate All Low-DO Problems
  - Sidestream with Air or 100% O_2
  - Funding – Who Will Pay for It?
    - All Responsible Parties?

Issues That Will Need to Be Addressed

- Export/Loss of BODu, CBOD, NBOD, Algae, N and P between Source (Land Runoff/Discharges) and DWSC
- Assess Additional Oxygen Demand and Nutrient Loads to SJR between Vernalis and Channel Point in DWSC
- Impact of SJR Flow at Vernalis and in DWSC on DWSC DO Depletion
- Understanding the Factors Controlling the Impacts of SJR Flow through DWSC on DO Depletion below WQO's

Issues That Will Need to Be Addressed

- Understanding Significance of DWSC DO Excursions below 5 mg/L for a Few Hours to a Few Days on the Growth Rates of Fish in DWSC
- Assessing the Significance of DO Depletion below 6 mg/L in Inhibiting Upstream Chinook Salmon Migration
- Cost of Controlling N, P, NBOD, and CBOD from Wastewater, Stormwater Runoff, and Irrigation Return (Tail) Water
- Can a Reliable Oxygen-Demand-Load/DO-Depletion-below-WQO Model for Given SJR DWSC Flow Be Developed That Can Be Used to Establish a Reliable Oxygen Demand TMDL?
- How to Best Manage the Increasing Urbanization (approx. 2%/yr) of the SJR DWSC Watershed with Its Potentially Increased Oxygen Demand Load

Conclusions

- San Joaquin River Deep Water Ship Channel Low DO Problem Is Primarily Due to the Discharge/Release of Aquatic Plant Nutrients That Develop into Algae That Die and Consume Oxygen in the Deep Water Ship Channel

- Oxygen Demand Assimilative Capacity of the San Joaquin River Has Been Greatly Reduced by Construction of the Deep Water Ship Channel

- Upstream Diversions of SJR Flow Exacerbate the DO Depletion Problem

Conclusions

- Nutrient Control from Agricultural, Wetland, and Other Rural Sources Will Not Likely Eliminate the Algal-Related Oxygen Demand So That Violations of the DO Water Quality Objectives Do Not Occur

- A Combination of Instream Aeration, and Nutrient and Oxygen Demand Control Will Be Needed to Control Low DO Problems

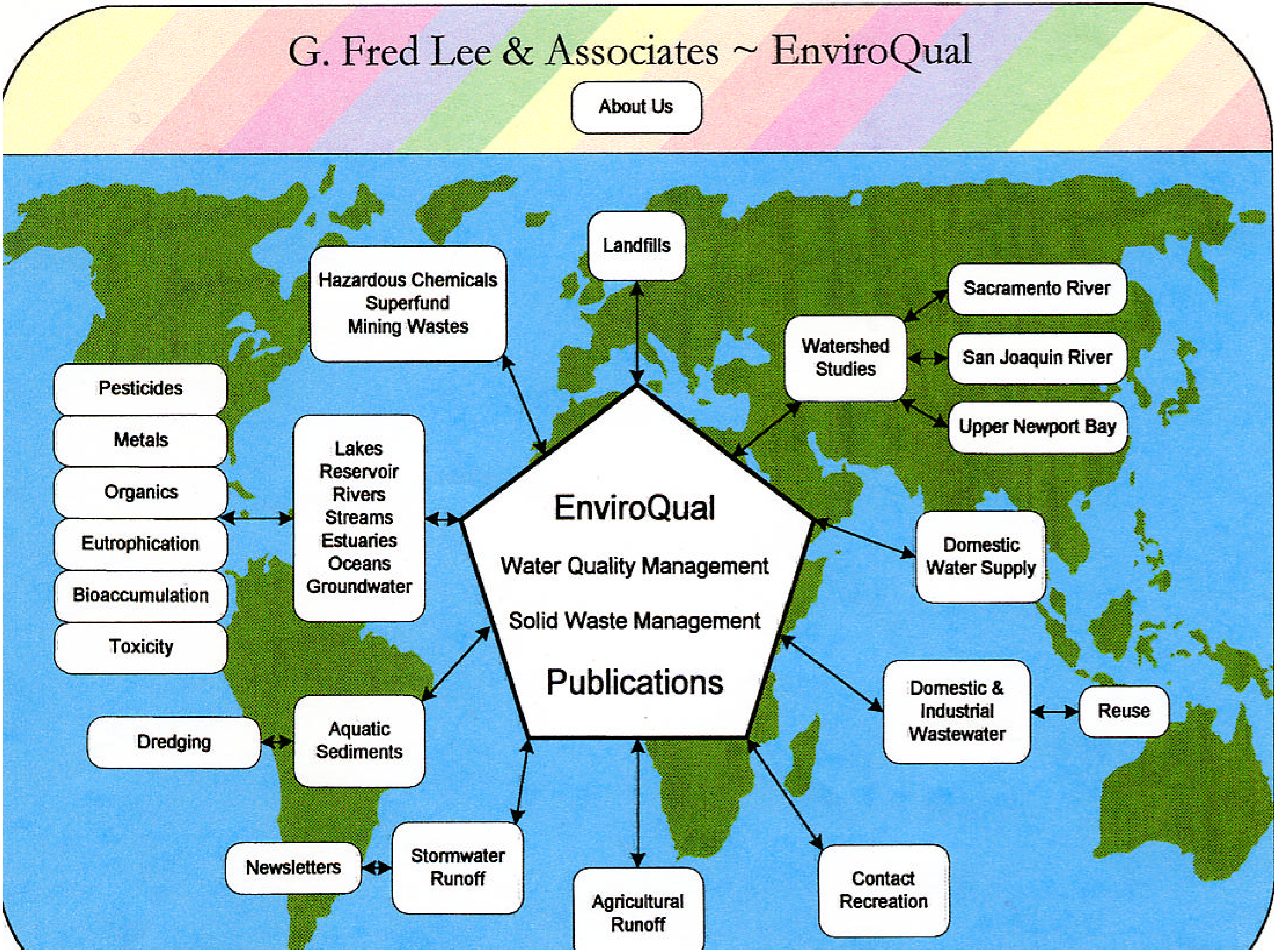
- Will It Be Possible to Obtain Financial Support by Water Diverters and Those Who Benefit from the Existence of the Channel to Help Pay for Nutrient Control and Aeration?

Further Information

Consult Website of

Drs. G. Fred Lee and Anne Jones-Lee

http://www.gfredlee.com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