Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
March 7-8, 2006

Agenda Item

Warm Water Nonnative Species Research and Control Plan

Action Requested

√ Feedback requested from AMWG members.
The presentation will include a proposed research and control plan, most of which will be included in the FY 2007-08 budget and workplan.

Presenter

Matthew E. Andersen, Biological Resources Program Manager, Grand Canyon Monitoring and Research Center

Previous Action Taken

√ By AMWG:

At the **October 2004** AMWG meeting, the following consensus item was approved:
"Authorize funds for workshops, and direct GCMRC to further develop warm water species plan with TWG. The workshops include GCMRC workshop as described in the prospectus for warm water species research, and participation in the Upper Basin Recovery Implementation Plan workshop on non-native fish control."

At the **March 2005** AMWG meeting, the following motion was approved:
"To approve the TWG's recommendation to reprogram funds for a GCMRC symposium on warm water fish suppression from line #150, AMWG-TWG requests."

At the last AMWG meeting in **August 2005**, the following motion was approved
"Part A: To add a warm water fish monitoring and suppression workshop, as approved in October 2004; move $27,600 from FY06 Project B.9 to fund the workshop; and ask TWG and GCMRC to bring forward the results of that workshop, with a workplan and budget recommendation, to AMWG at its next meeting; and

"Part B: To add a fish sampling project below Diamond Creek to the FY06 Work plan and budget as described in the FY05 Work plan; to move $67,500 from the Experiment Flow line (F.7) item to fund this project: and to direct GCMRC to move forward with the project by incorporating results and recommendations from the warm water suppression workshop, as feasible."

√ By TWG:

At its January 2005 meeting, TWG endorsed the spending of $42,000 for a warm water species biologist in FY06 from the dollars realized due to the change in the CPI.

Relevant Science

√ The following describes the relevant research or monitoring on this subject:

Warmer water, and associated low dissolved oxygen, have been released from Glen Canyon Dam over the past three years, with the warmest water released in 2005. (See attached PowerPoint presentation for more water quality information.) Expansion of warm water in other habitats, including the nearby San Juan, Green, and Colorado rivers, has allowed nonnative fish species to expand, which has had a negative impact on native fishes. We're concerned that this will happen in Grand Canyon as well. Regional fisheries scientists generally agree that early action to control nonnatives is very important to controlling these species; some would argue that without rapid response the situation is hopeless. The efforts to control rainbow trout in the Grand Canyon

have yielded encouraging results. However, nonnative fish, parasites, and crayfish represent distinct challenges that will likely be more difficult to address.

As noted above, AMWG directed GCMRC to convene a warm water workshop to determine whether warmer water released from Glen Canyon Dam presented additional risk to native species. The workshop was conducted in December 2005.

The workshop participants agreed that this environmental change did increase risk to native species. The research plan is intended to address these additional risks. The AMP would be wise to begin efforts to control nonnatives as soon as possible.

Background Information

√ I have attached the background information to be included in the AMWG packet that is distributed 30 days before the meeting, and posted on the website.

Attached is the draft research plan for warm water nonnative species control. Also attached is a PowerPoint presentation on this agenda item.

Warm Water Nonnative Aquatic Species in the Grand Canyon
DRAFT Research and Treatment Plan Outline
Prepared by:
USGS SBSC Grand Canyon Monitoring and Research Center
L.G. Coggins and M.E. Andersen
13 January 2006

I. Introduction

On August 11, 2004 the AMWG passed the following motion*: "…GCMRC and TWG make a recommendation to AMWG in October 2004 on warm water species studies including a plan starting in January 2005"*. Subsequently on September 27, 2004 the TWG passed an additional motion: *"GCMRC will develop a process, a schedule, and a recommended budget for suppression and control of non-native fish (warm water species) to be presented to AMWG at their October meeting"*. GCMRC staff presented a prospectus for research and monitoring in response to the various motions listed above at the October, 2004 meeting. As part of this prospectus, GCMRC recommended convening a workshop to obtain input into the planning process. GCMRC subsequently received AMWG approval to host the workshop.

In December 2005, a workshop to address existing and potential issues associated with warm water nonnative species was held in Flagstaff, Arizona. The meeting was attended by fisheries professionals working on similar issues throughout the Colorado River basin, TWG members representing several stakeholder groups, and fisheries professionals from outside the basin with expertise deemed helpful in guiding the planning process. During the first and second days, the group heard presentations from attendees regarding: planning for non-native control (risk analysis, management issues, strategies), case studies of mechanical removal programs in other areas, overview of current work in Grand Canyon, species specific capture and detection techniques used in other systems, and recent research and potential applications of bio-control techniques. Distributed among the presentations was limited discussion of management issues associated with nonnative species, potential control options, and research and monitoring issues. An additional half day was utilized to develop a list of recommendations and issues that the fisheries professionals felt important for managers to consider (see below). The group also developed some outlines of potential research programs to address critical information needs associated with warm water nonnative issues in Grand Canyon. The remainder of this document outlines a proposal for non-native research and monitoring to be conducted by the GCDAMP. Because this is a multi-faceted issue that represents a new initiative for the AMP, the addition of a full-time GCMRC staff biologist is recommended to lead the effort.

Because the trout removal project has had some success and because total funding is limited, it is anticipated that a warm water species control initiative will be funded, at least in part, by funds currently being applied to trout removal. The trout removal project would have to be reduced to accommodate this funding approach.

Nonnative Warm Water Aquatic Biota Management Actions developed by attendees at the December 2005 workshop:

1. Develop nonnative and native fish management policies.

2. Pre-invasion risk assessment; identify spatial extent of potential impacted populations and nonnative source systems; prioritize areas by likelihood of severe impacts; identify agency authorities and responsibilities.

3. Prevent invasions

4. Post-invasion assessment of impacts of nonnative fish on native fish populations, including prioritization of problem species (impacts to specific native fish species and life history stages, reproductive potential, migratory habits, geographic extent, etc) and probable impact mechanisms.

5. Development of coordinated nonnative fish control strategies; identify conflicts (sport fishing, agency jurisdiction/policy, etc).

6. Develop list of acceptable control methods (chemical, biological, etc.)

7. Identification and use of cost-effective nonnative fish control methods.

8. Development of programs to monitor results of nonnative fish control measures.

9. Assure I & E and Outreach programs are in place to communicate intentions and findings to the public.

10. Managers consult fish experts on critical fish related issues and prior to fish related decisions.

11. Establish list, including flows, of emergency actions based on specific trigger points (including juvenile native fish concerns).

12. Integrate with science planning group, particularly related to long-term experimental planning.

13. AMWG should work with Upper Basin, Missouri River stakeholders, and others to pursue issues regarding use of genetically modified species, especially crayfish.

14. The presence of yet another threat to native fishes, i.e., warm water nonnative species, suggests that it is important to pursue development of strategies for holding and rearing humpback chub in captivity.

15. Seek funding from other AMP participating agencies.

II. Risk

a. Problem Statement. The nonnative warm water species that pose the greatest risk to native fishes in the Grand Canyon are not known with certainty.

b. Questions.
   i. Which species currently prey on/compete with native fishes?
   ii. Which species may be expected to prey on/compete with native fishes?
   iii. Which nonnative species are currently in the Colorado River and Little Colorado River in Grand Canyon?
   iv. Which nonnative species have access to Grand Canyon, either from upstream or downstream?
   v. Can we prevent invasion/expansion by existing and/or new populations?

c. Research
   i. BOR contracted research on warm water nonnative species has begun and continues. Expect this will assemble life histories and potential vulnerabilities of these species.
   ii. Need: risk assessment of nonnative aquatic species to determine what one or more species pose the greatest risk to native fishes. Should address:
      1. Which species are now present in the Grand Canyon ecosystem?
      2. Which species are/will prey on native fishes?
      3. Which species are/will alter native aquatic habitats?
   iii. Sources. This information will also impact analysis of control measures. Expect that the sources of greatest concern are the Colorado River and Little Colorado River.
      1. Additional sources, in order of importance
         a. Lakes Powell and Mead
         b. Tributaries
         c. Upstream sources
      2. Need: risk analysis of fishes currently in Grand Canyon and comparative analysis of potential sources

d. Projects
   i. BOR research on warm water nonnative fishes includes risk of invasion based on life histories. Continue (no cost to AMP)
   ii. Risk analysis. Initiate in 2006. AMP funded. Incorporate BOR study as appropriate. Deliver draft report early 2007.
   iii. Monitor nonnative species sources and initiate policies and control as necessary. Initiate in 2006. May be cost shared with partner agencies.
   iv. Policy review of nonnative control. AGFD conducts with GCMRC input as requested, reports back to AMP.
   v. Conduct *ex situ* and *in situ* experiments to distinguish and determine roles of competition and predation between warm water nonnative and native fishes.
   vi. Develop a rapid response plan

III. Water Quality Monitoring

a. Problem statement: Fall 2005 releases from Glen Canyon Dam were warmer than historic temperatures. Lower dissolved oxygen accompanied these releases. Monitoring has allowed development of temperature profiles in the mainstem in the Grand Canyon. Water temperature modeling has been initiated by GCMRC. A better understanding of how native and nonnative fishes will respond to warmer than historic (since 1964) river temperatures is needed. Use of a Selective Withdrawal Structure could alter Glen Canyon Dam releases, seasonally and cumulatively, depending on operational criteria.

b. Questions
    i. What is the temperature profile of the Colorado River in Grand Canyon historically and currently?
    ii. Does dissolved oxygen remain at safe levels for aquatic life throughout the Grand Canyon?
    iii. Will operation of a SWS for warming increase the chances of intercepting the late summer/fall low dissolved oxygen below the surface?
    iv. How are native and nonnative fishes responding to the current temperatures and dissolved oxygen, and how can they be anticipated to react to future temperatures and oxygen levels?
    v. Where are the habitats with the warmest temperatures and other favorable habitat features for native fishes, e.g., substrates, cover, depth?
    vi. Will other water quality factors altered by operation of a SWS affect the downstream fishery, ecosystem, and food web?

c. Research
    i. Need: refined temperature and chemical profiles in Colorado River in Grand Canyon
    ii. Identify the downstream location where re-aeration reaches acceptable safe levels over various seasonal, climatic, and operational scenarios.

d. Projects
    i. Temperature and water quality monitoring of Colorado River in Grand Canyon and Lake Powell
    ii. Temperature and water quality modeling of Colorado River in Grand Canyon and Lake Powell

IV. Fish Monitoring

a. Problem statement: Current monitoring and research does not characterize, with satisfactory accuracy and precision, the distribution and abundance of native and nonnative fishes and crayfish in Grand Canyon. Methods need to minimize impacts to native fishes.

b. Questions
    i. Where are native fishes found in the Grand Canyon?
    ii. What are the population dynamics of native fishes in the Grand Canyon?
    iii. Where are nonnative fishes found in the Grand Canyon?
    iv. What are the population dynamics of nonnative fishes in the Grand Canyon?

c. Research

i. Need: Effective, and ideally less invasive, methods for detecting fishes in the GC.

d. Projects
    i. Continue investigation into the use of acoustic technologies to help monitor and assess native and nonnative fishes. Begin in 2006.
        1. Acoustic camera can be utilized to locate fish assemblages
        2. Acoustic tagging can be utilized to document fish movement
    ii. Begin movement studies of nonnative fishes in the Little Colorado River, inner gorge tributaries, and nearby mainstem locations. Begin LCR work in 2006. Begin inner gorge work in 2007 in coordination with National Park Service
    iii. Increase monitoring in mainstem beginning in 2006 in order to increase documentation of fish species, fish distributions, and gear effectiveness.
    iv. Use remote PIT tag monitoring stations to document movement of tagged (especially native) fishes.
    v. Investigate the safety of using trammel nets to capture and monitor humpback chub.

V. Control

a. Problem statement: How do we control nonnative warm water species in Grand Canyon?
b. Questions
    i. Are current aquatic habitat management policies sufficient to control additional influx of nonnative warm water species (fishes and crayfish)? If not, how should they be changed?
    ii. In what locations in the Colorado River and tributaries is control of nonnative species most important to benefit native species?
    iii. What locations in the Colorado River and tributaries are the most important to control nonnative fishes and crayfish in order to limit their abundance and distribution?
    iv. To what degree does the LCR contribute nonnative species to the Grand Canyon?
    v. Do warm water nonnative species use the LCR as a spawning and rearing area?
    vi. How important are inner gorge tributaries (e.g., Bright Angel Cr., Clear Cr.) in contributing nonnative fishes to the system, e.g., brown trout?
    vii. How do brown trout use inner gorge tributaries as spawning and rearing areas?
    viii. What is the relative importance of crayfish in the system?
    ix. Will incidence of Asian tapeworm infection increase in the presence of warmer water? Are there acceptable methods for the treatment of individual fish?
c. Research
    i. Need: methods and gear analysis
        1. After identifying one or more most threatening species, what will be the most effective way(s) to capture and control these species?

2. What results can and cannot be expected? It should be recognized from the start that we are unlikely to ever remove all nonnative species from the system

ii. Sources. This information will also impact risk analysis. Expect that the sources of greatest concern are the Colorado and Little Colorado rivers.
    1. Additional sources, in presumed order of importance
        a. Lakes Mead and Powell
        b. Tributaries
        c. Upstream sources
    2. Need: source analysis of fishes and crayfish currently in Grand Canyon and comparative analysis of potential sources
    3. Need: Better understanding of the use of LCR and inner gorge tributaries as sources of nonnative fishes and crayfish

d. Projects
    i. Continue mechanical removal projects as appropriate.
    ii. Methods and gear analysis. Initiate in FY 2007. AMP funded.
    iii. Monitor nonnative species sources and initiate policies and controls as necessary. Initiate in 2006 and 2007. May be cost shared with partner agencies.
        1. Work in LCR and LCR Inflow to understand movement dynamics and life history of channel catfish and common carp in critical humpback chub habitat. Initiate in 2006 and piggyback on LCR monitoring and Mechanical Removal Work.
        2. Work in inner gorge tributaries to understand movement dynamics and life history of Brown Trout. Initiate in 2007 in coordination with NPS.
    iv. Using sonic-tagged nonnative fishes, especially channel catfish, smallmouth bass, and common carp, investigate the proportion of fish vulnerable to capture with different gear types
    v. Determine distribution and relative abundance of crayfish in the Grand Canyon
    vi. In cooperation with other programs and agencies, support research into genetic control of crayfish
    vii. Investigate safety, effectiveness, and necessary authorities for treating individual humpback chub with praziquantel

Draft
Warm Water Nonnative Species Research and Control Program

8 March 2006

Matthew E. Andersen

USGS - SBSC - GCMRC

Guidance to GCMRC

- Glen Canyon Dam releases are warming; potential risks from nonnatives increase
- AMWG and TWG direct development of a research program to address immediate threats from warm water nonnative species
- AMWG and TWG direct conduct of a workshop
- GCMRC translates workshop results into draft research program

Presentation Objectives

- Present
  - Research Areas
  - Research Projects Overview

December ’05 Workshop Results

- Recommendations
  - Summarized in handout
- Research Areas
  - Risk
  - Water Quality Monitoring
  - Fish Monitoring
  - Control

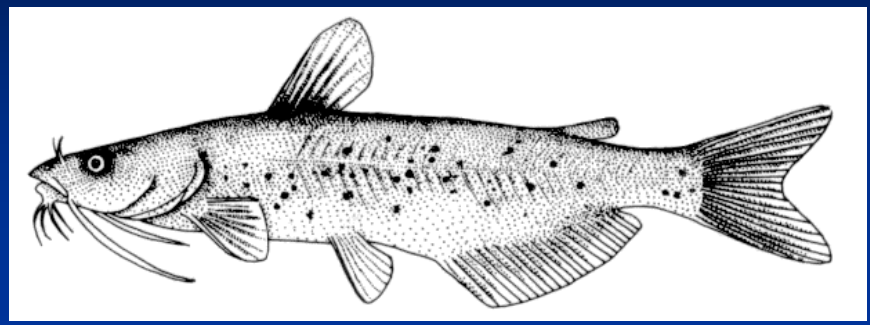
Research Areas Format

- Problem Statement
- Research Questions
- Research
- Projects
  - Most projects intended for 2007 and beyond
  - All proposed projects included

Risk Problem Statement

- The nonnative warm water species that pose the greatest risk to native fishes in the Grand Canyon are not known with certainty

(Illustrations: AFS)



Risk Projects

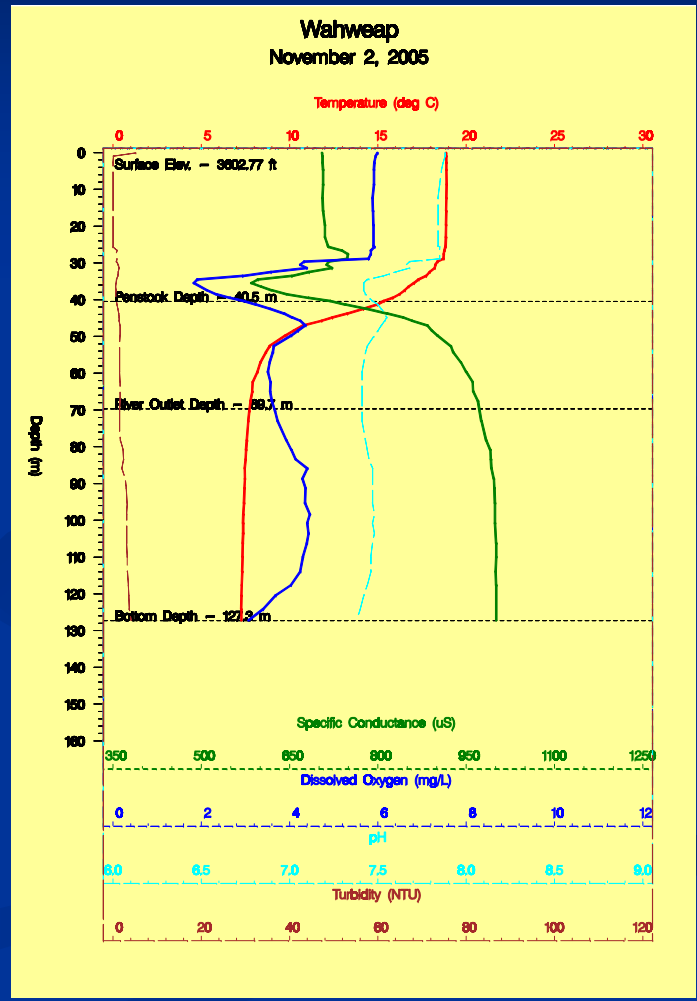
- 2006: Risk of invasion based on life histories (BOR)
- Monitor nonnative species sources; initiate policies and control as necessary; LCR, LCR confluence, and lower GC
- Risk analysis – incorporate life history info, environmental data, species interactions
- Nonnative species control policies review (AZGF & GCMRC)

Risk Projects (cont'd)

- Conduct *ex situ* and *in situ* experiments distinguishing and determining competition and predation
- Develop rapid response plan

Water Quality Monitoring
Problem Statement

- Fall 2005 Glen Canyon Dam releases were warmer than historic; dissolved oxygen was low. A better understanding of how native and nonnative fishes will respond to warmer temperatures is needed.



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Water Quality Monitoring Projects

- In Lake Powell and Colorado River in Grand Canyon, conduct
  - Monitoring
  - Modeling

Fish Monitoring Problem Statement

- Need to improve characterization of distribution and abundance of native and nonnative fishes and crayfish in GC. Methods need to minimize impacts to native fishes.

Fish Monitoring Projects

- Investigate acoustic technologies
  - Acoustic tags (fish movements)
  - DIDSON camera (fish assemblages)
- Nonnative fishes movement studies
  - LCR
  - Diamond Creek and below
  - Inner gorge and tributaries

Fish Monitoring Projects (cont'd)

- Study effects of trammel nets, especially on native fishes
- Increased, more effective, mainstem monitoring
- Use remote PIT tag monitoring to document movement of tagged fishes, especially natives

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Control Problem Statement

- How do we control nonnative warm water species in Grand Canyon?

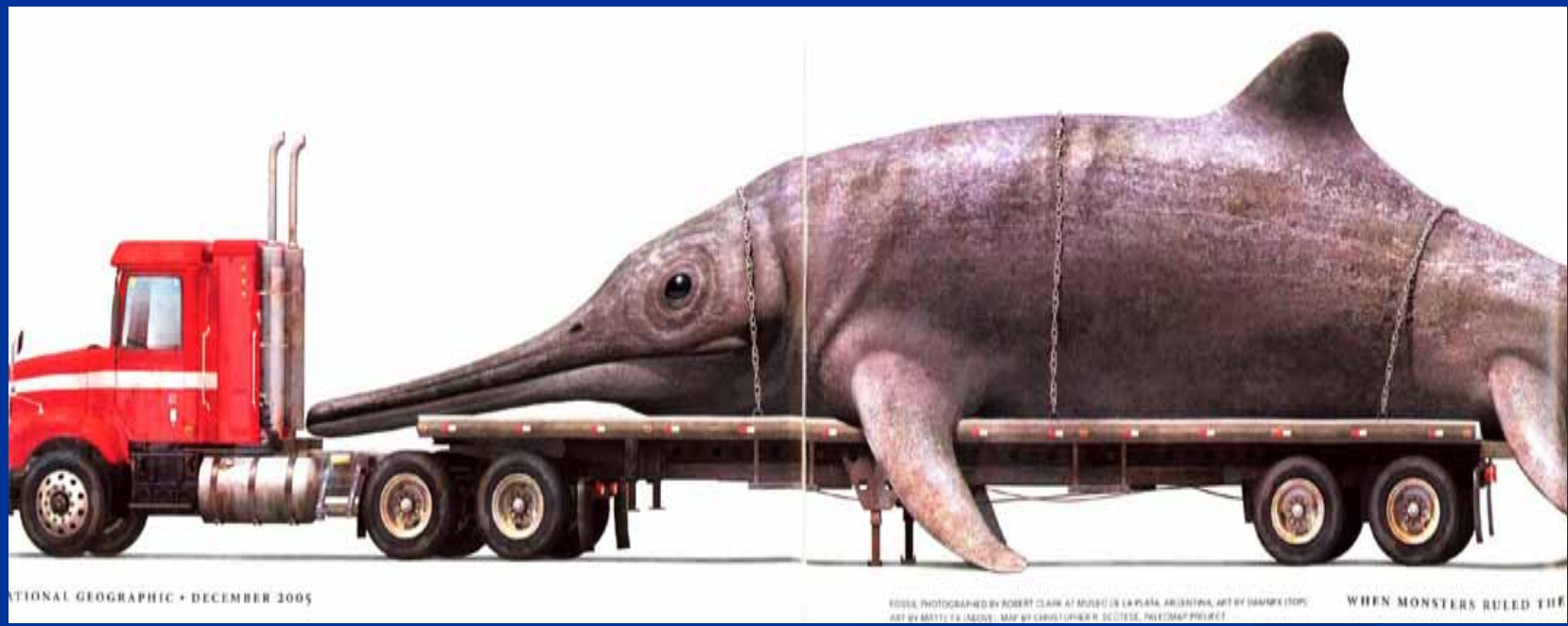

Illustration: NGS

Control Projects

- Investigate control methods and gear effectiveness – continue mechanical removal, at least for near term; consider geographic expansion
- Monitor nonnative species sources and modify applicable policies and controls as necessary
  - Channel catfifsh, smallmouth bass, and common carp in LCR and mainstem
  - Brown trout in inner gorge tributaries
  - Small-bodied fishes

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Control Projects

- Investigate proportion of nonnatives vulnerable to gear; use sonic technologies
- Determine distribution and relative abundance of crayfish in GC
- Support research into genetic/molecular control of crayfish
- Investigate safety, effectiveness, and authorities for using praziquantel to treat individuals for Asian tapeworm

Projects Highlights

- 2006: Risk of invasion based on life histories (BOR)
- 2006: Add warm water species biologist at GCMRC ($42K in 2006 from CPI) to develop research and control plan

Projects Highlights

- High priority for 2007 and beyond:
  - Continue mechanical removal, but decrease effort on rainbow trout, increase effort to locate and remove warm water species
  - Study effects of trammel nets
  - Acoustic tags (fish movements)
  - DIDSON camera (fish assemblages)
  - Monitor nonnative species sources; initiate policies and control as necessary; LCR, LCR confluence, and lower GC

Water Quality Below Glen Canyon Dam and Reaeration of Releases

Bill Vernieu
Southwest Biological Science Center
Grand Canyon Monitoring and Research Center

Adaptive Management Work Group Meeting

March 7-8, 2006

U.S. Department of the Interior
U.S. Geological Survey

2005 Glen Canyon Dam Releases

Two Unusual Events

- **Highest Release Temperature Since 1971**
  - 16°C (61°F) on October 8, 2005
- **Lowest Dissolved Oxygen on Record**
  - 3.3 mg/L on October 8, 2005 from draft tubes
    - **(Data since 1990 – no evidence of prior hypoxia)**

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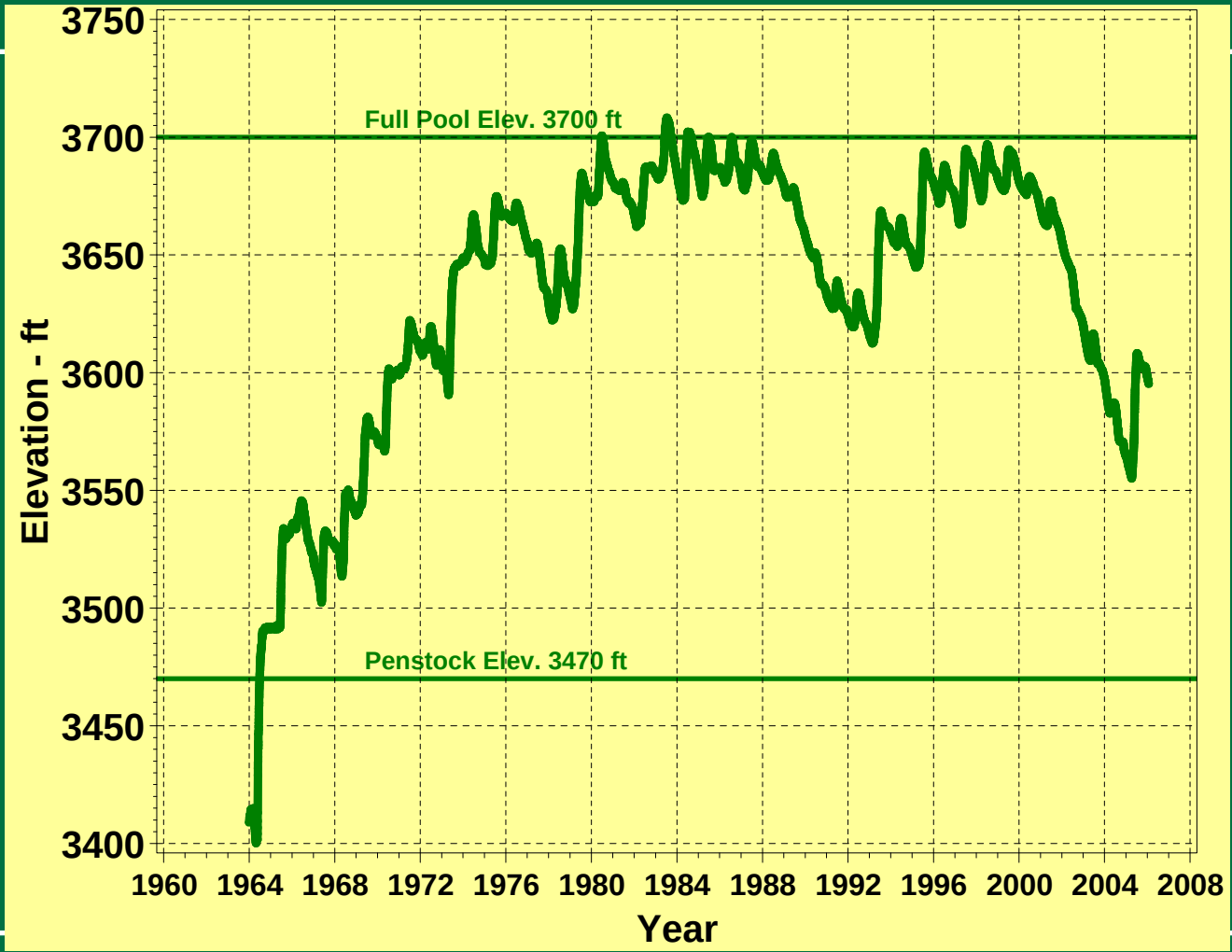
Lake Powell Hydrology - 2005

- **Pre-Runoff Conditions**
  - Surface elevation - 3555 ft on April 8, 2005
  - Lowest elevation since May 1969
  - 38 % of total capacity
- **2005 Runoff**
  - Apr-Jul 2005 unreg. inflow - 111% of normal
  - Surface elevation - 3608 ft on July 13, 2005
  - Runoff increased elevation by 53 ft in 2005
  - 55% total capacity

USGS

Lake Powell Surface Elevation



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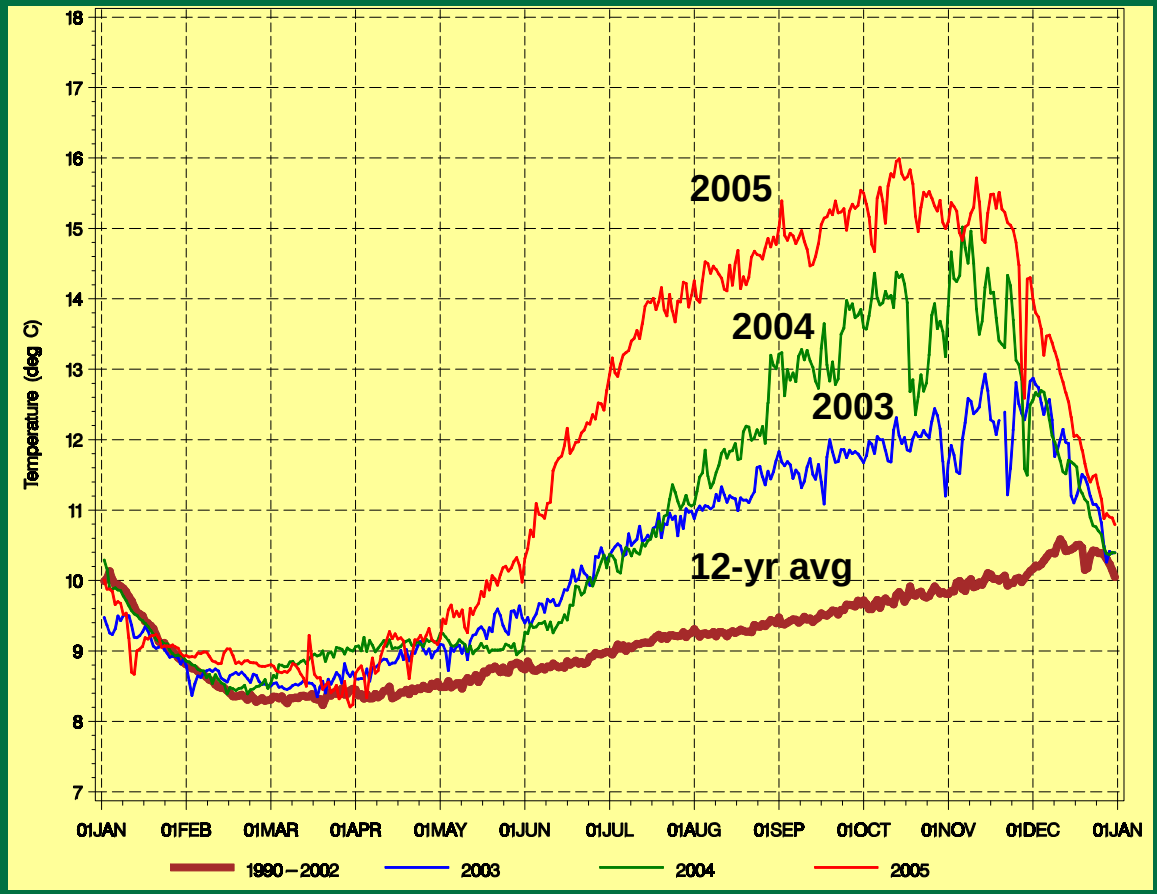
Glen Canyon Dam Release Temperature

- Warmest releases since 1971
  - 16°C (61°F) on October 8, 2005
  - 6°C above 12-yr average (1990-2002)
  - Low reservoir brings warmer surface water closer to penstocks



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2005 Inflow to Lake Powell

- Above average inflows caused head cutting of deltaic sediments
- Resuspension of large amount of sediment from inflow areas
- Resulted in low dissolved oxygen levels in inflow plume as it traveled through reservoir

USGS

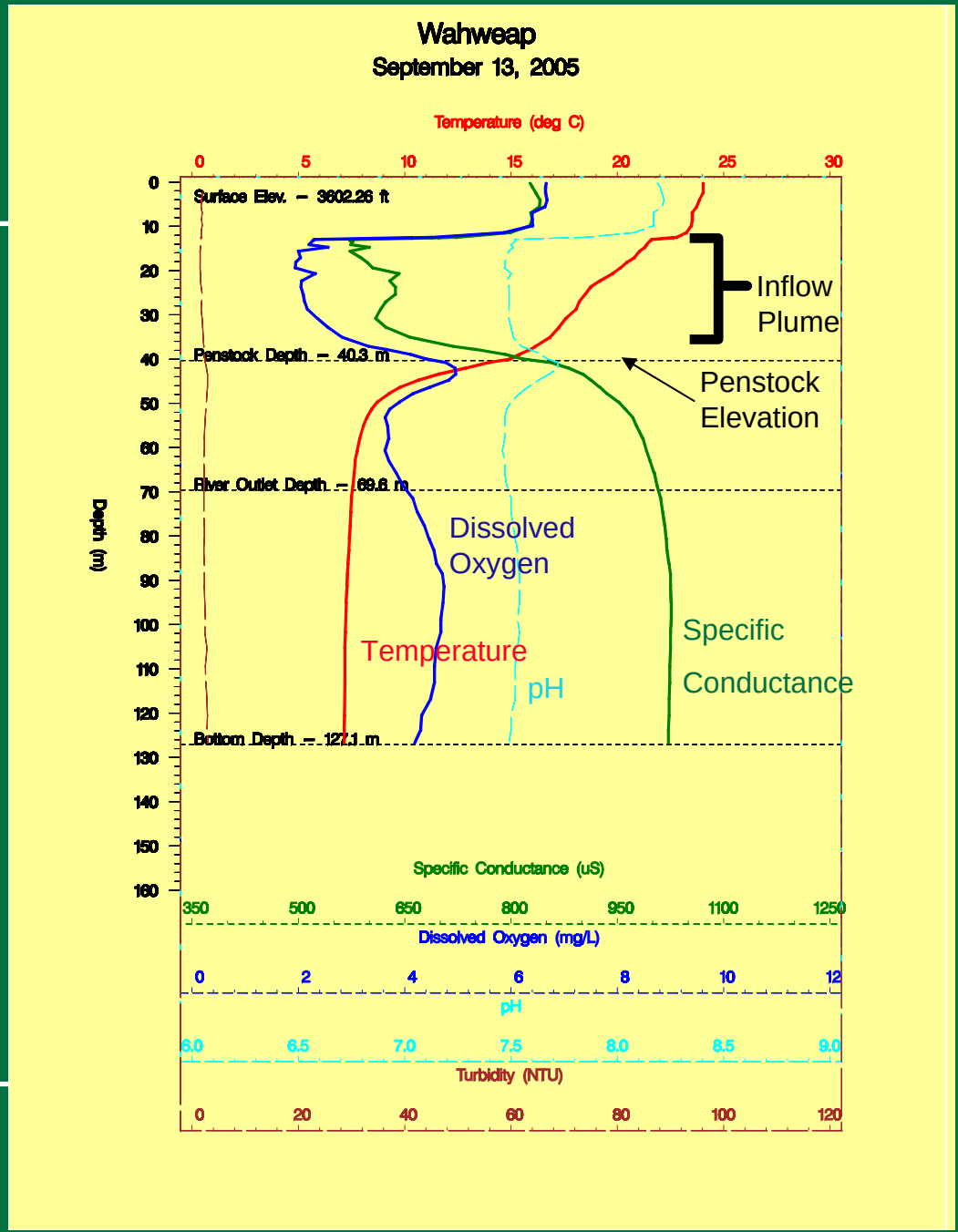
Forebay Water Quality

September 13, 2005

Inflow plume has arrived at forebay

Beginning to affect Glen Canyon Dam releases

- Inflow plume
  - 13m-38m
  - Minimum D.O. 1.9 mg/L
- Glen Canyon Dam Release
  - T - 14.5 °C (58 °F)
  - D.O. - 4.5 mg/L (51 %)



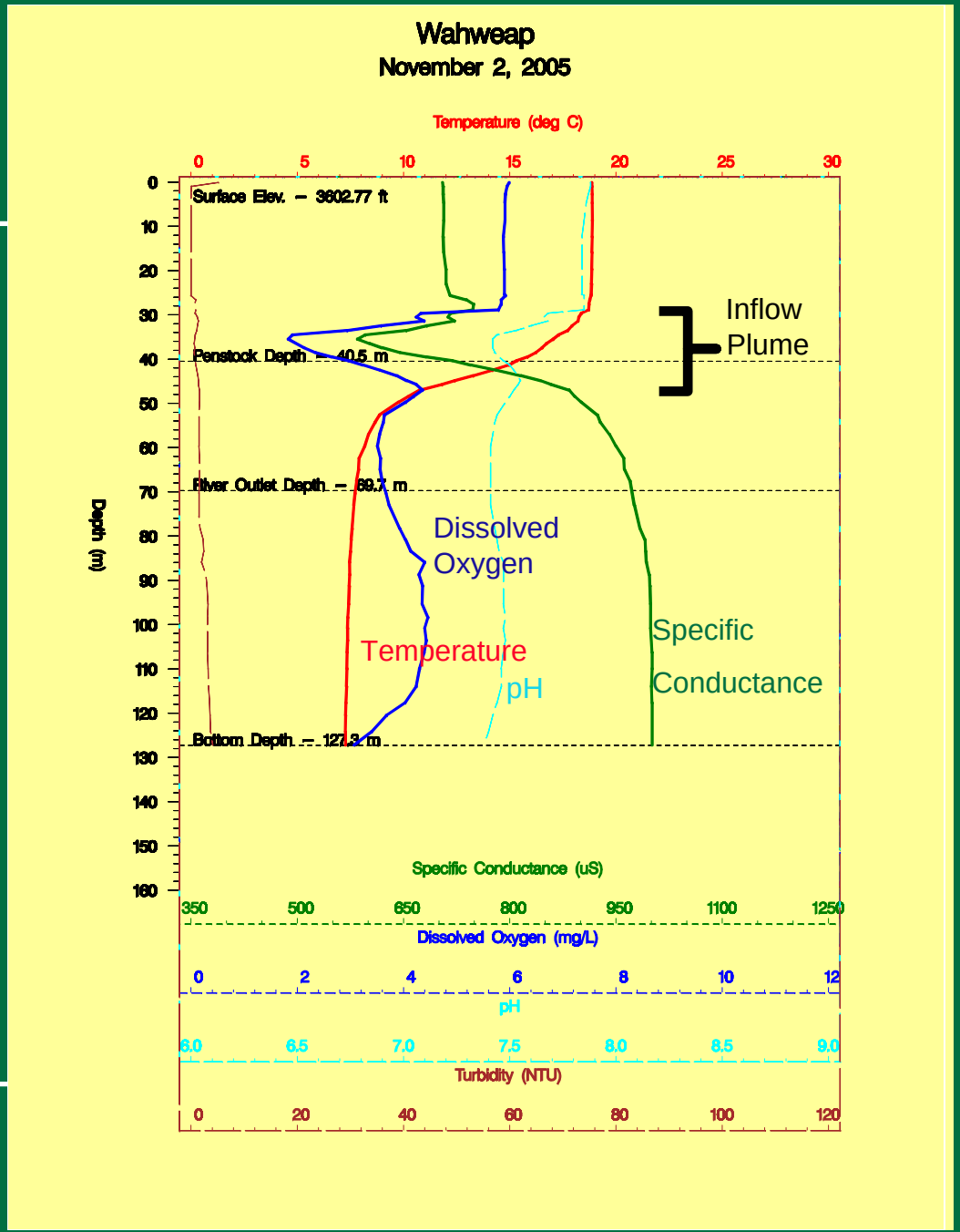
Forebay Water Quality

November 2, 2005

Surface of reservoir beginning to mix and deepen

Release WQ further affected by inflow plume

- Inflow plume
  - 28m-48m
  - Minimum D.O. 1.7 mg/L
- Glen Canyon Dam Release
  - T - 15.8 °C (58 °F)
  - D.O. - 3.6 mg/L (41 %)



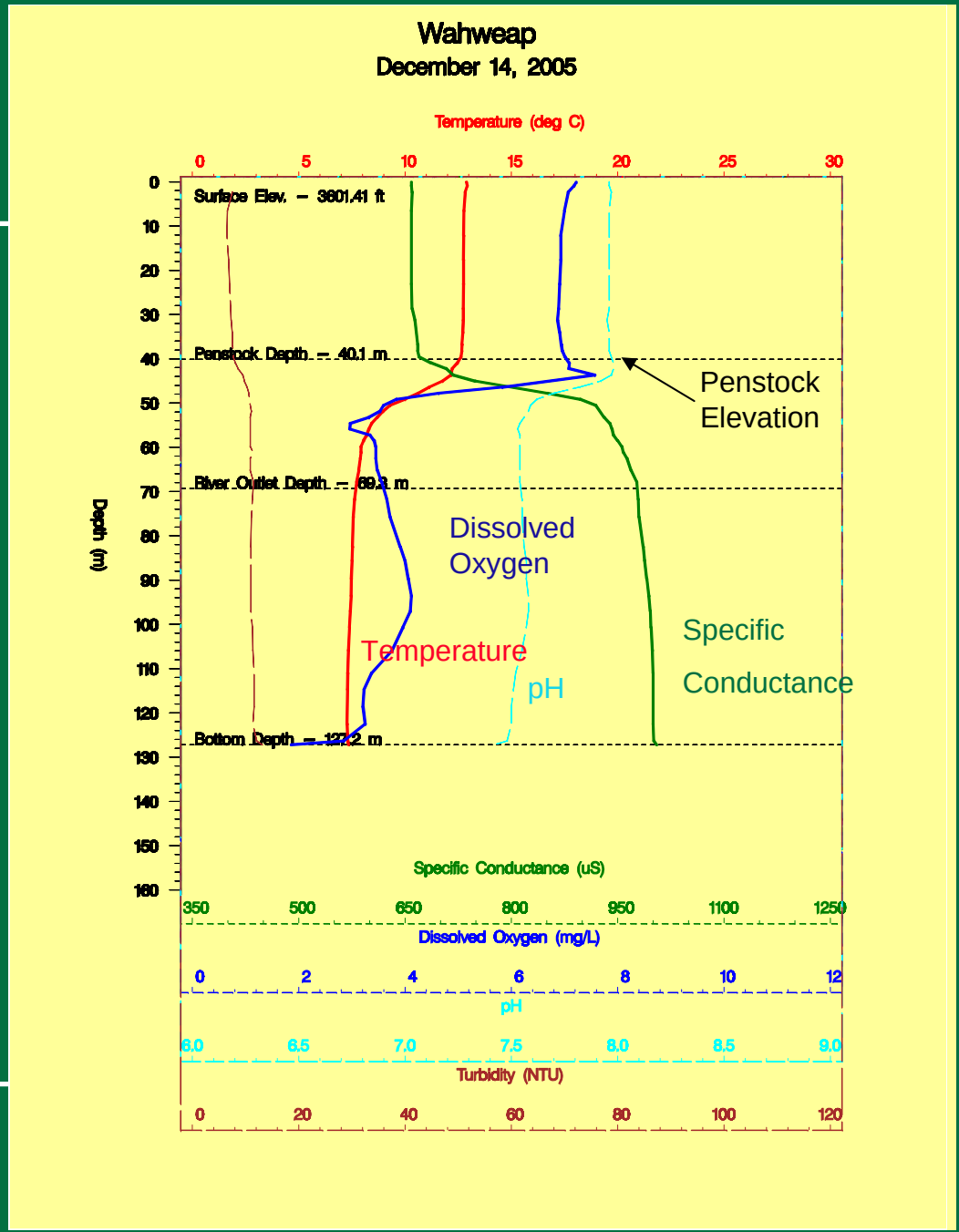
Forebay Water Quality

December 14, 2005

Surface mixing has progressed to penstock level

Inflow plume has dissipated and has been incorporated into mixed surface layer

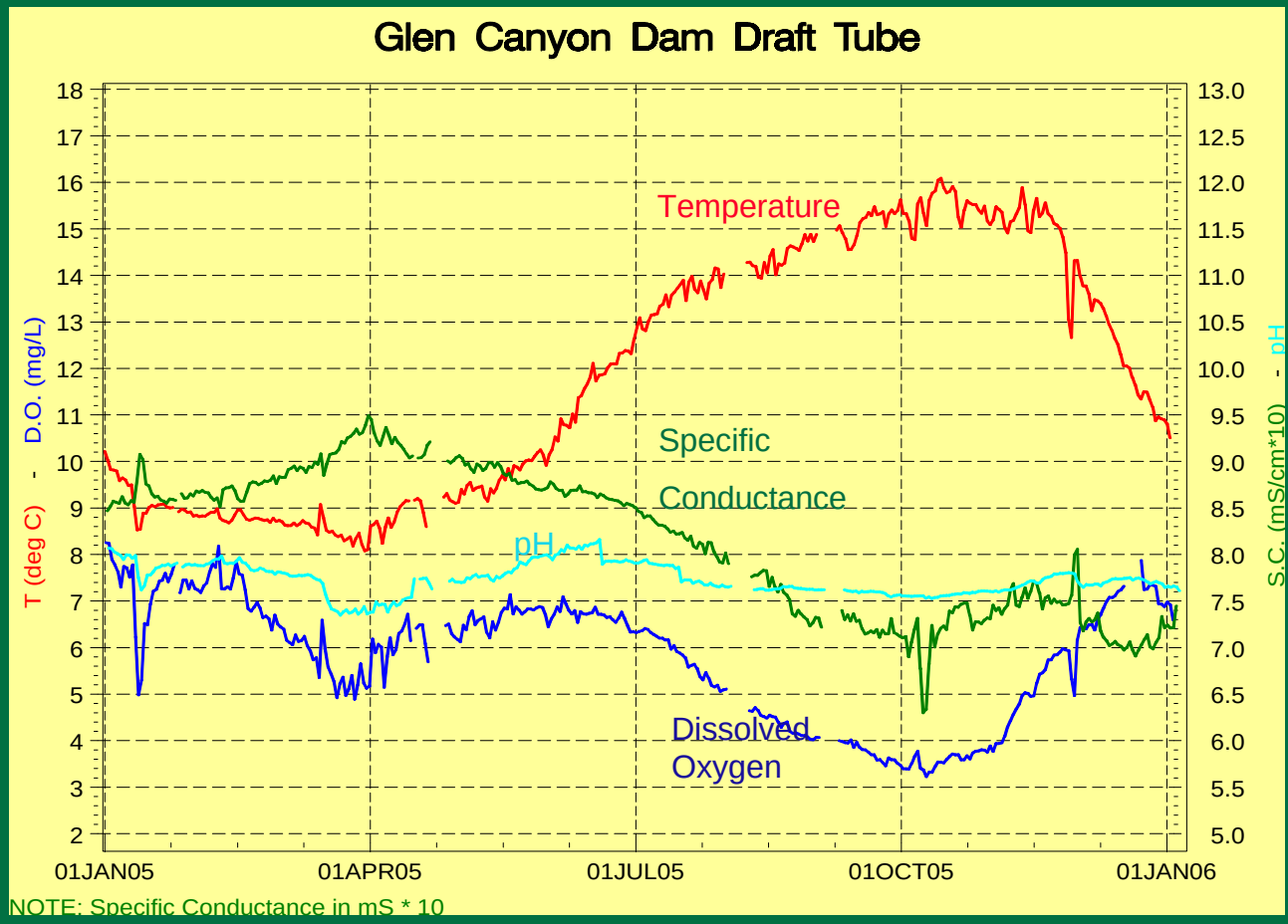
- Glen Canyon Dam Release
  - T - 12.5 °C (56 °F)
  - D.O. – 7.7 mg/L (80 %)



Glen Canyon Dam Releases 2005

Mean daily values

- Lowest dissolved oxygen on record (since 1990)
- 3.3 mg/L on October 8, 2005 from draft tubes
- Hypoxia dissipated by reservoir surface mixing
- Data since 1992 – no evidence of prior hypoxia

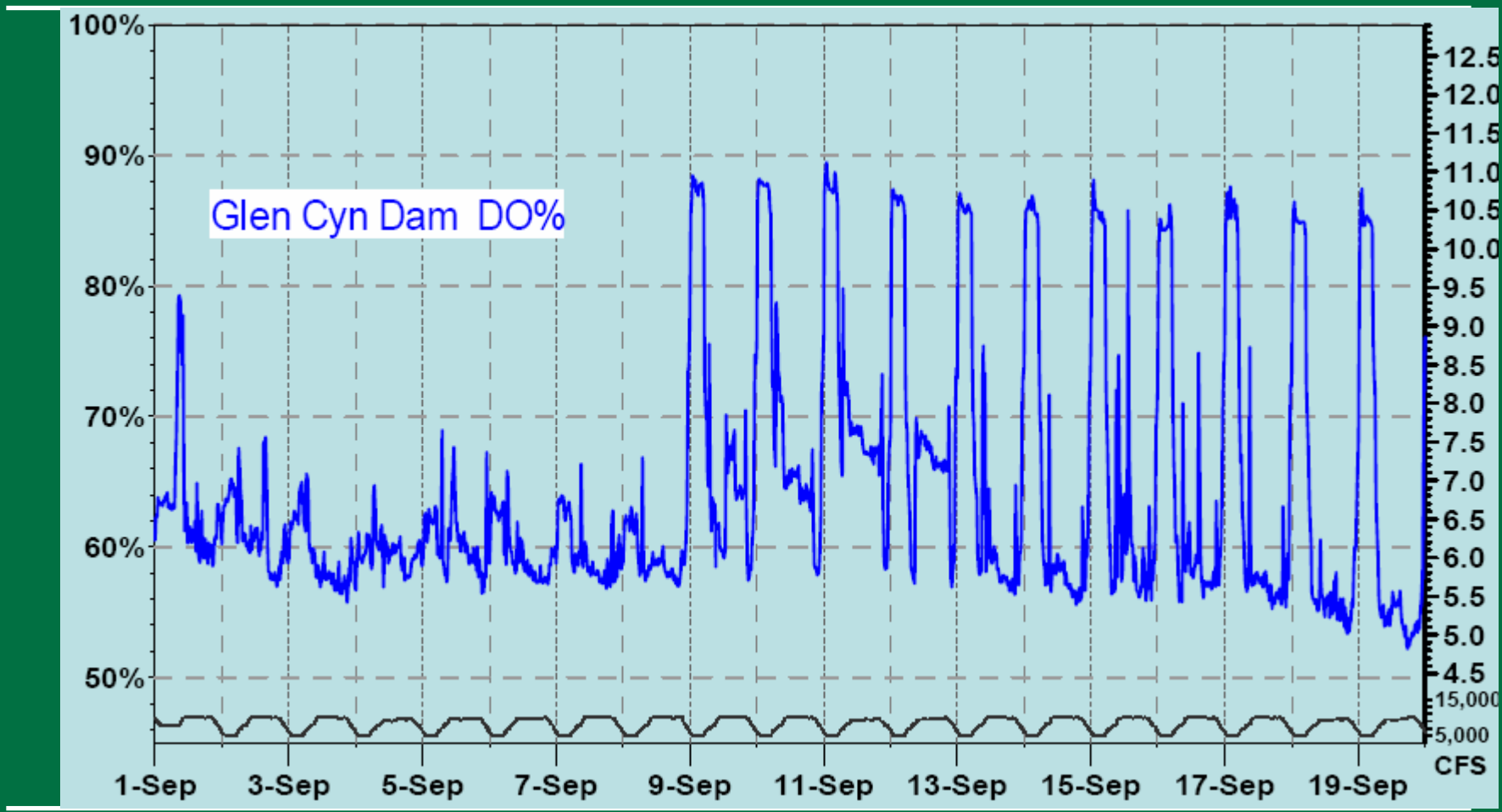


Reaeration of Dam Releases

- Past monitoring data has shown elevated dissolved oxygen levels in GCD tailwater during nighttime hours (~11 pm to ~7 am)
- These spikes appear to be associated with low discharge levels from individual turbines
- Turbine discharges resulting in maximum reaeration of releases may cause inefficient power generation and damage to turbines
- Reclamation experimented with various operational regimes during recent experimental flow period (9/3/06 to 10/31/06) to achieve optimal balance

USGS

Nighttime Reaeration Spikes - 2005



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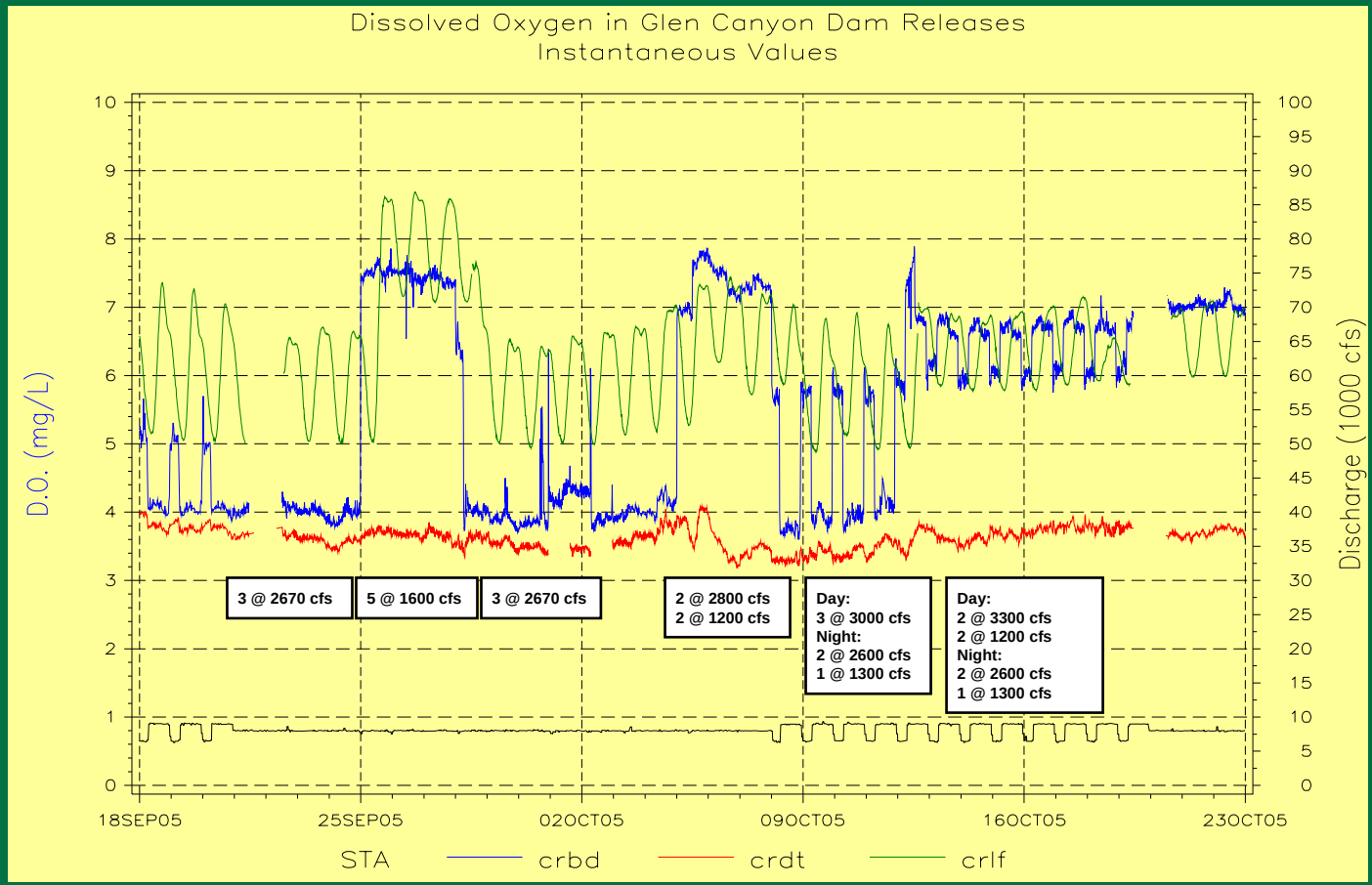
Reaeration Experiment

Long-term monitoring at three locations:

- CRDT (red) GCD Draft Tube
- CRBD (blue) GCD tailwater
- CRLF (green) Lees Ferry



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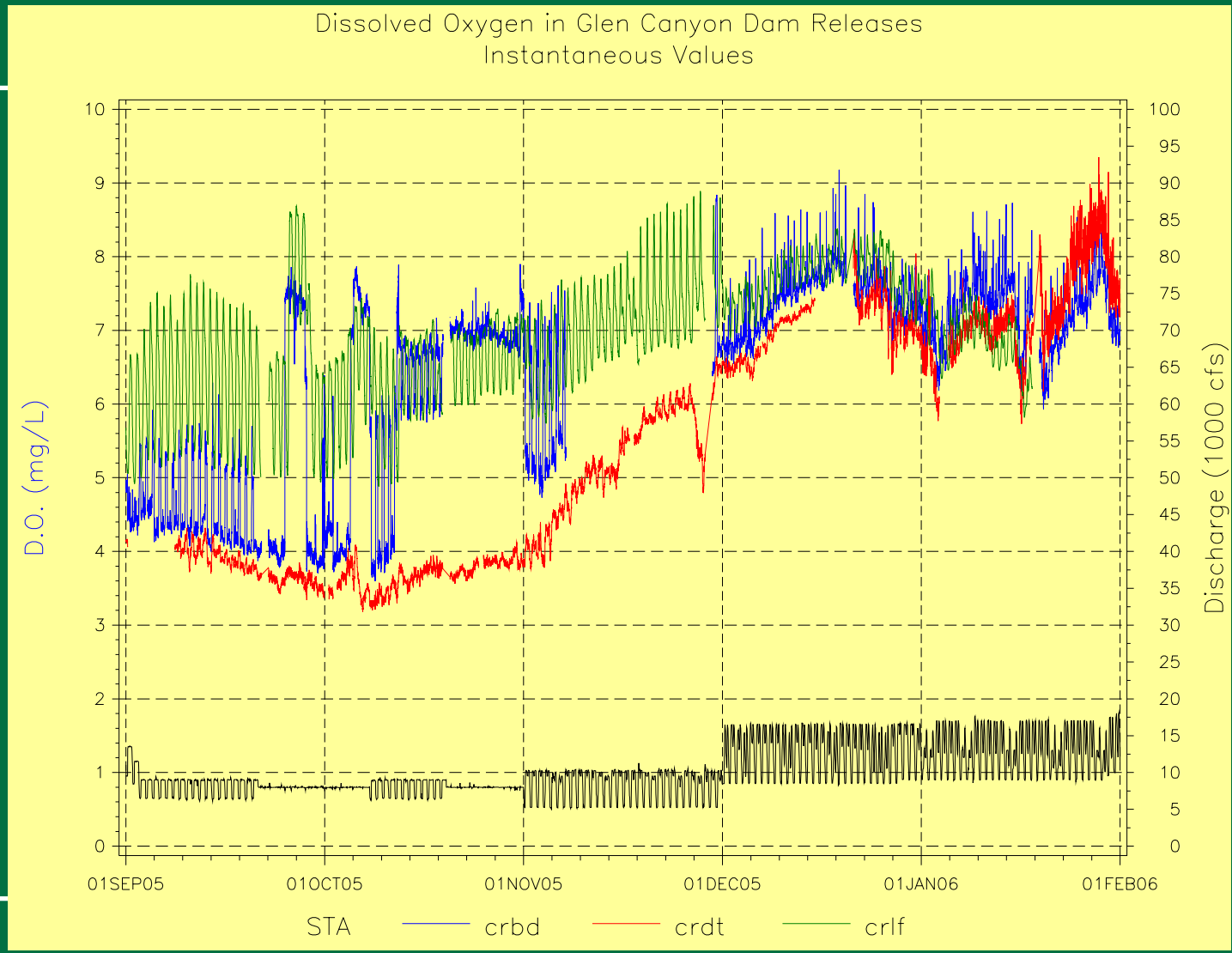
Recent Dissolved Oxygen Patterns

- CRBD reaeration (blue line) reduced with cessation of experimental flows (10/31/06)
- Displaying nighttime D.O. spikes
- Increase in draft tube D.O. (red line) indicating reservoir mixing
- No CRBD data available Nov 8-28



Conclusions from Reaeration Experiment

- D.O. in tailwater affected by GCD release concentrations, turbine operations, atmospheric equilibration and photosynthetic productivity
- Certain aspects of dam operations can cause significant aeration in the GCD tailwater
- Concerns remain about low operating efficiency and damage to powerplant machinery
- Reaeration observed in CRBD station persists throughout tailwater
- Cooperative effort between Bureau of Reclamation, Arizona Game & Fish, GCMRC, environmental groups

USGS

What's in store for 2006?

- **Temperature**
  - Expect above-average release temperatures but similar to 2003
  - Based on projected pre-runoff reservoir elevations
  - Maximum release temperature of ~13°C expected Oct-Nov
- **Dissolved Oxygen**
  - Hypoxic inflow plume not expected because of increased reservoir surface elevation and less deltaic resuspension