Glen Canyon Dam Temperature Control Device

AMWG UPDATE

July 18, 2002

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Bureau of Reclamation

Brief History of Selective Withdrawal

- First constructed: Tibi Dam near Alicante, Spain in 1594; highest in world for 3 centuries
- First in USA: Arrowrock Dam, Boise River, 1915 by USBR; 25 outlets in 3 tiers
- Response to Public Laws: FWCA (1958 amendment) FWPCA (amended 19 61) ESA 1973
- Primary purposes: Meet water quality standards/management for municipal/industrial uses, recreation, and endangered species

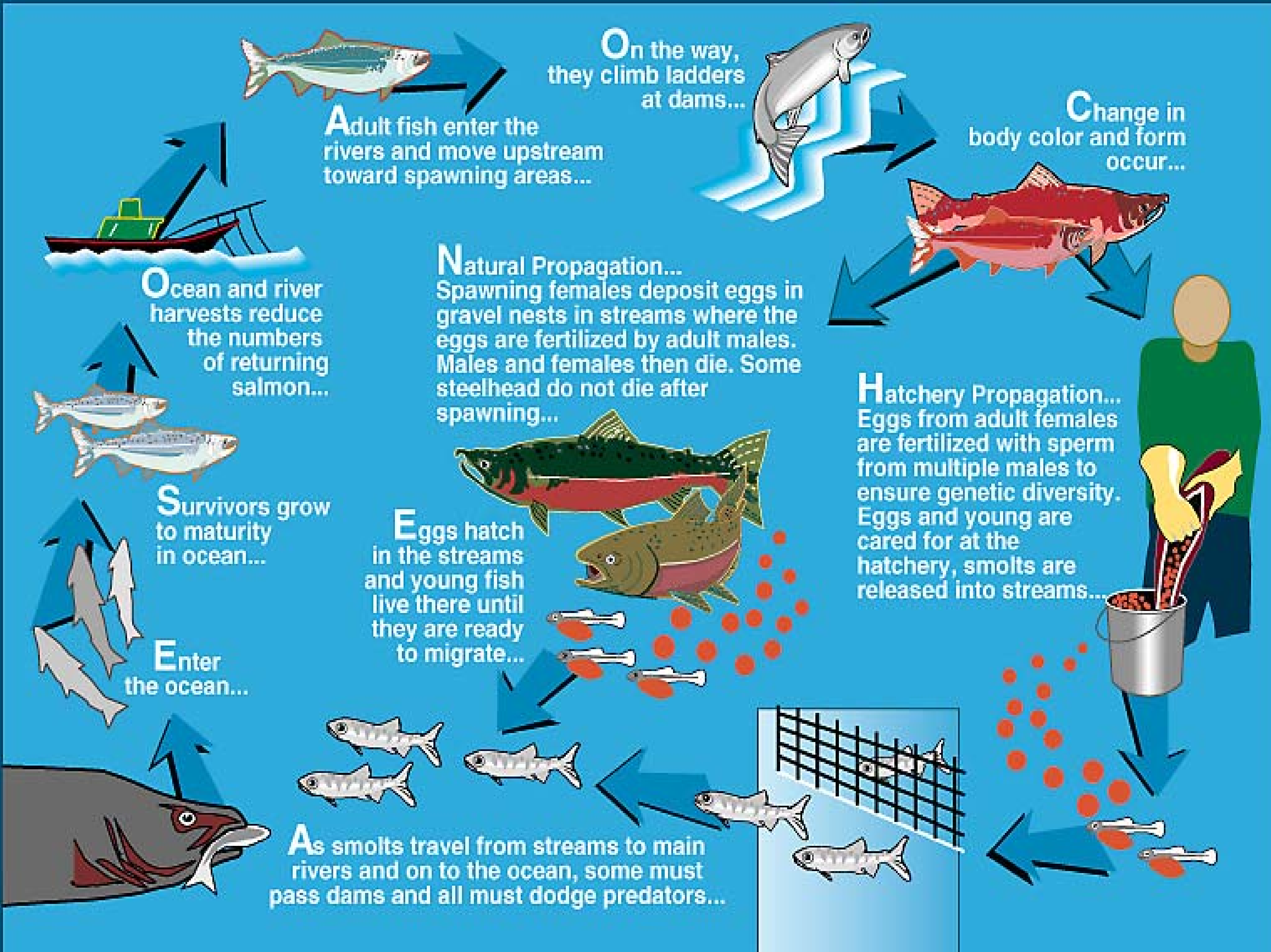
Survey Results

- Conducted survey of Reclamation and non-Reclamation facilities with selective withdrawal capabilities
- Questions related to TCD design & purpose, TCD operations, pre- and post-construction environmental/water quality studies, TCD maintenance and modifications
- 36 facilities contacted to submit surveys; 20 facilities responded thus far
- Of the 20 responses, 11 have TCDs that are applicable to Glen Canyon; the other facilities use selective withdrawal for purposes other than temperature control or do not currently use selective withdrawal

Applicable Projects

• Libby Dam, MT	COE
• Hungry Horse Dam, MT	USBR
• Lost Creek, OR	COE
• Dworshak Dam,ID	COE
• Flaming Gorge, UT	USBR
• Jordanelle Dam,UT	USBR
• Folsom Dam, CA	USBR
• Whiskeytown Dam, CA	USBR
• Shasta Dam, CA	USBR
• Spring Creek, CA	USBR
• Oroville, CA	California DWR


Columbia River Basin
Corps of Engineers Dams
Dams owned by Others
Bureau of Reclamation Dams
Mica
Revelstoke
Arrow Lakes
Duncan
Kootenay Lake
Keenleyside
Canada
U.S.
Libby
Hungry Horse
Grand Coulee
Chief Joseph
Albeni Falls
Noxon
Wells
Rocky Reach
Pend Oreille Lake
Flathead Lake
Kerr
Rock Island
Seattle
Little Goose
Lower Monumental
Wanapum
Lower Granite
MT
Priest Rapids
WA
Dworshak
Ice Harbor
The Dalles
McNary
Portland
Bonneville
John Day
Hells Canyon
Oxbow
Brownlee
ID
OR
Willamette R.
Boise Projects
Jackson Lake
Snake R.
CA
NV
N


Adult fish enter the rivers and move upstream toward spawning areas...
On the way, they climb ladders at dams...
Change in body color and form occur...
Natural Propagation...
Spawning females deposit eggs in gravel nests in streams where the eggs are fertilized by adult males. Males and females then die. Some steelhead do not die after spawning...
Hatchery Propagation...
Eggs from adult females are fertilized with sperm from multiple males to ensure genetic diversity. Eggs and young are cared for at the hatchery, smolts are released into streams...
Eggs hatch in the streams and young fish live there until they are ready to migrate...
As smolts travel from streams to main rivers and on to the ocean, some must pass dams and all must dodge predators...
Enter the ocean...
Survivors grow to maturity in ocean...
Ocean and river harvests reduce the numbers of returning salmon...

TCD Purpose and Design

- Purpose of S/W: All structures control release water temperature; many are used to protect endangered species by providing specific thermal environment and/or habitat
- Selective withdrawal method: either face of dam or vertical tower with multiple withdrawal elevations
- These TCDs have high discharge capabilities (up to 28,000 cfs)

Success of TCD Systems

- Frequency of compliance generally >90%
- Environmental improvement (i.e. water temperature, fish habitat) typically demonstrated by before and after studies, but not biological responses not consistently measured
- TCD systems have proven flexible to changing operational needs - like endangered species or other changes in temperature/water quality requirements

Environmental Studies

Name of Dam/Reservoir	Water Quality/ Limnological	Physical	Numerical	Environmental
Libby	YES	YES	NO	NO
Flaming Gorge	YES	NO	YES	YES
Folsom	YES	NO	YES	UNKNOWN
Whiskeytown	YES	UNKNOWN	UNKNOWN	YES
Spring Creek	YES	UNKNOWN	UNKNOWN	YES
Shasta	YES	YES	YES	YES
Dworshak	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN
Jordanelle	YES	NO	YES	YES
Hungry Horse	YES	YES	YES	YES

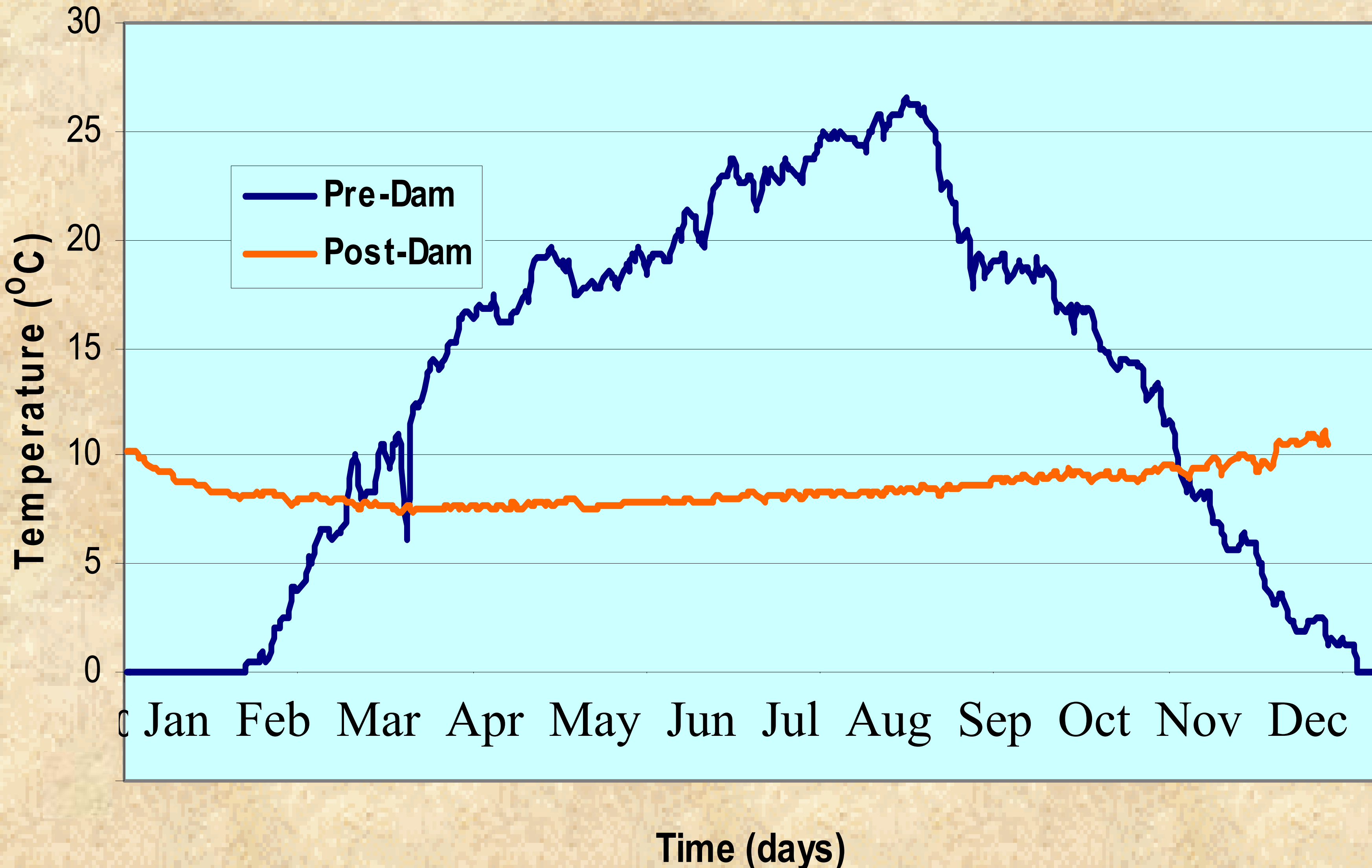
What do we Desire?

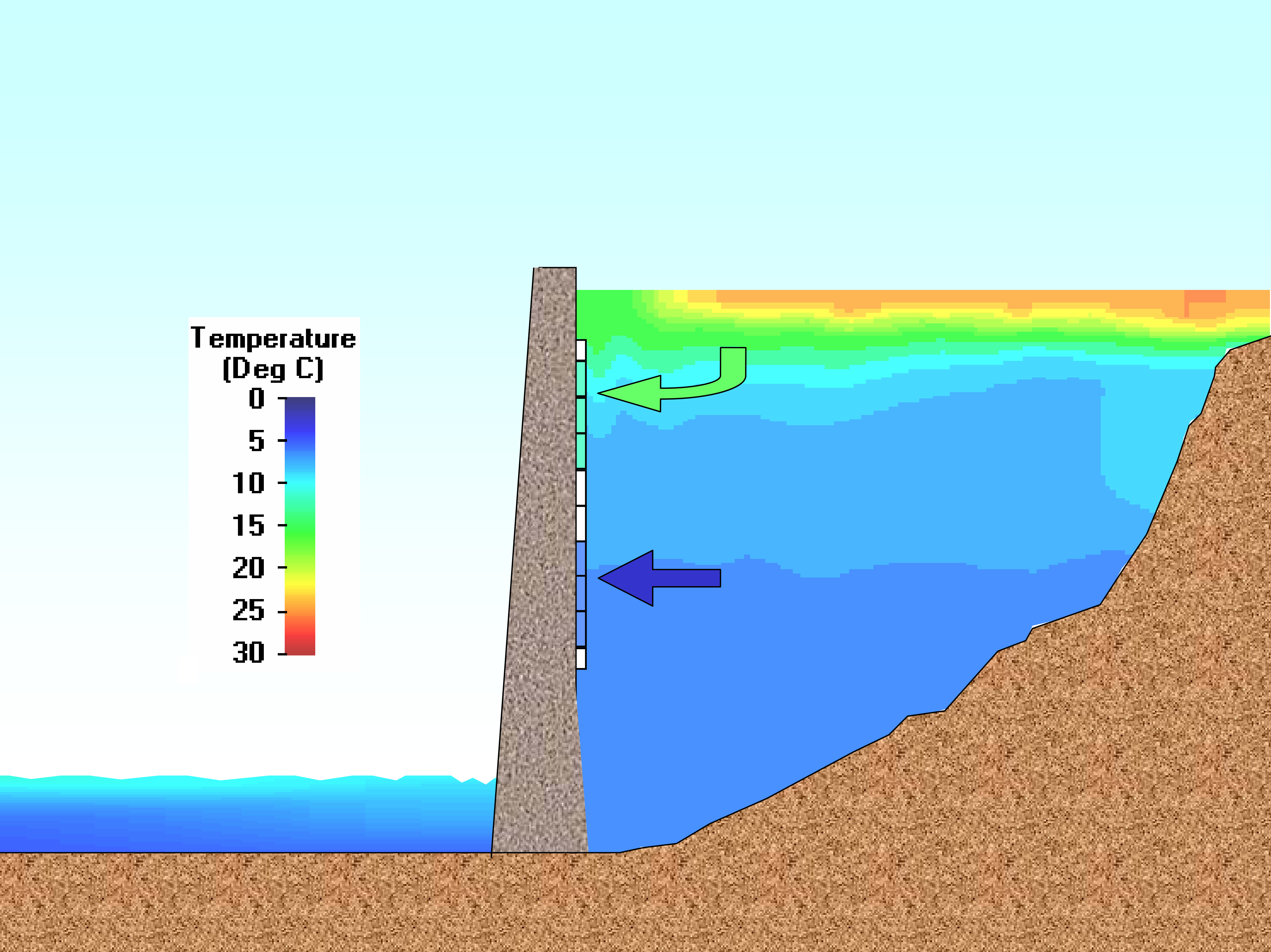
- To provide environmental conditions suitable for successful reproduction and recruitment of humpback chub and other native fish in the Colorado River
- To do no harm to other important resources in the system

What Do We Know?

- Cold water temperatures restrict successful reproduction of humpback chub
- Cold water temperatures cause mortality of young humpback chub by thermal shock
- In the post-dam period, some non-native fish have been reduced, others have increased
- Primary productivity has increased

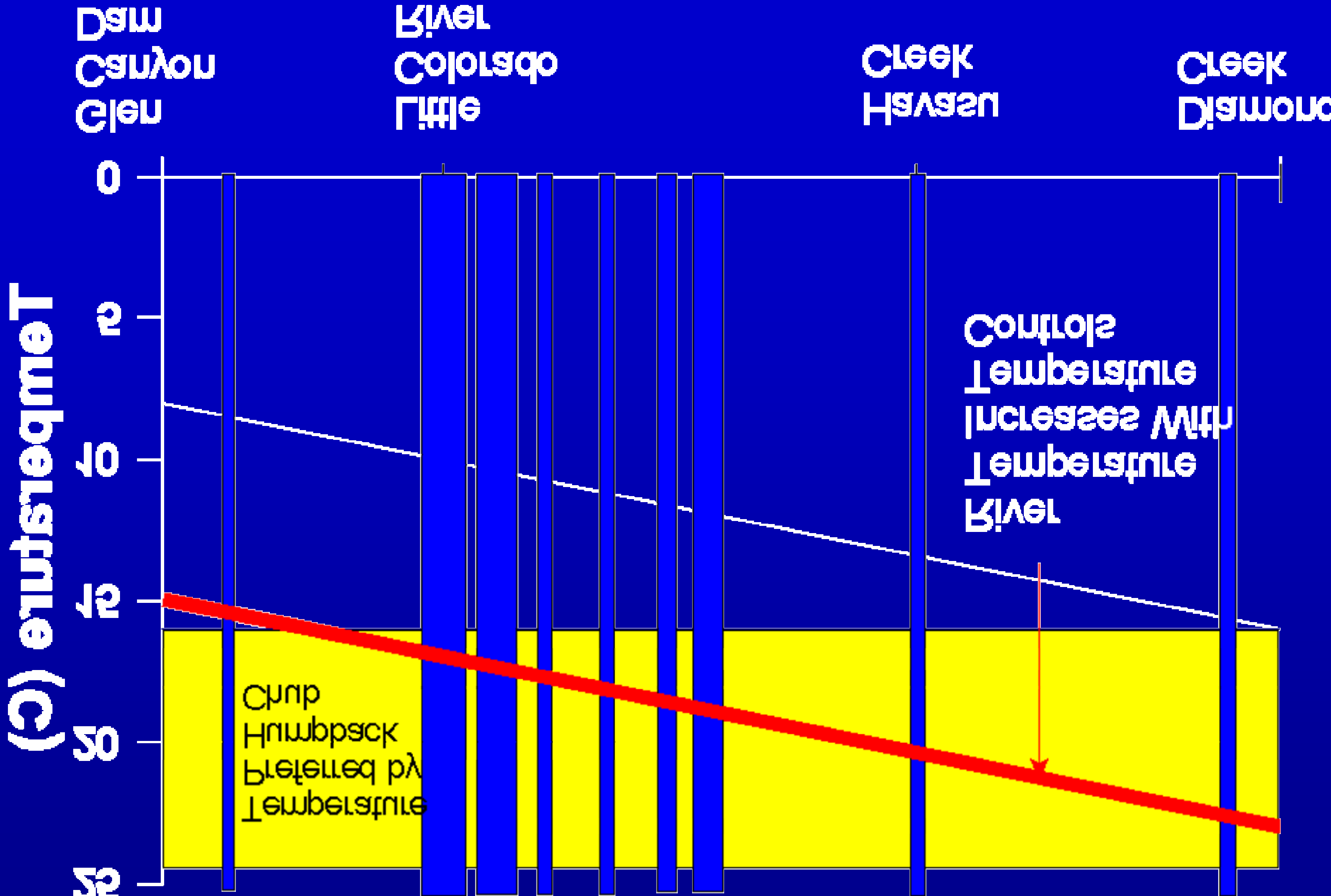
Pre- and Post-Dam Water Temperature





Temperature
(Deg C)
0
5
10
15
20
25
30

Conditions below Glen Canyon Dam with Controls



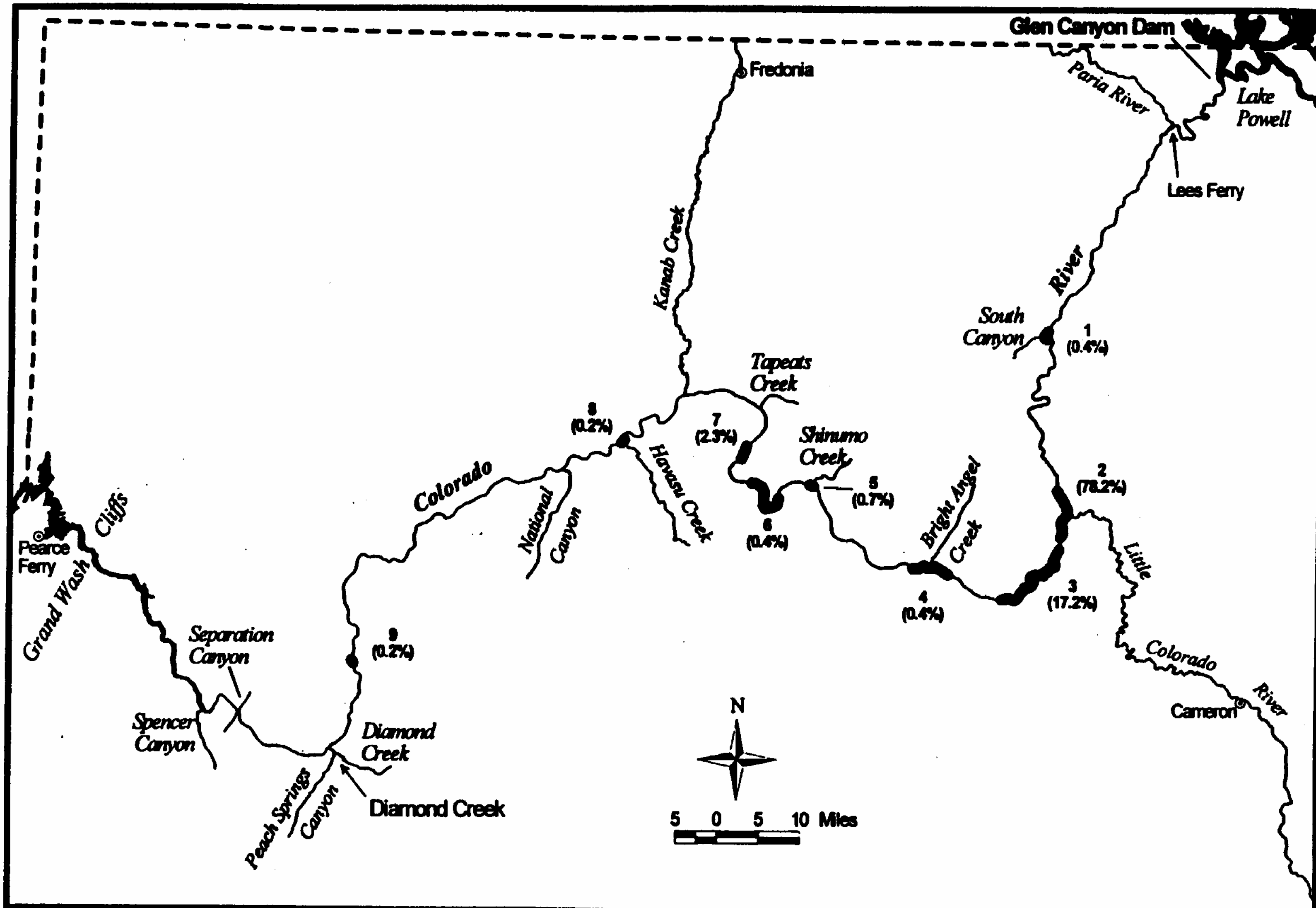
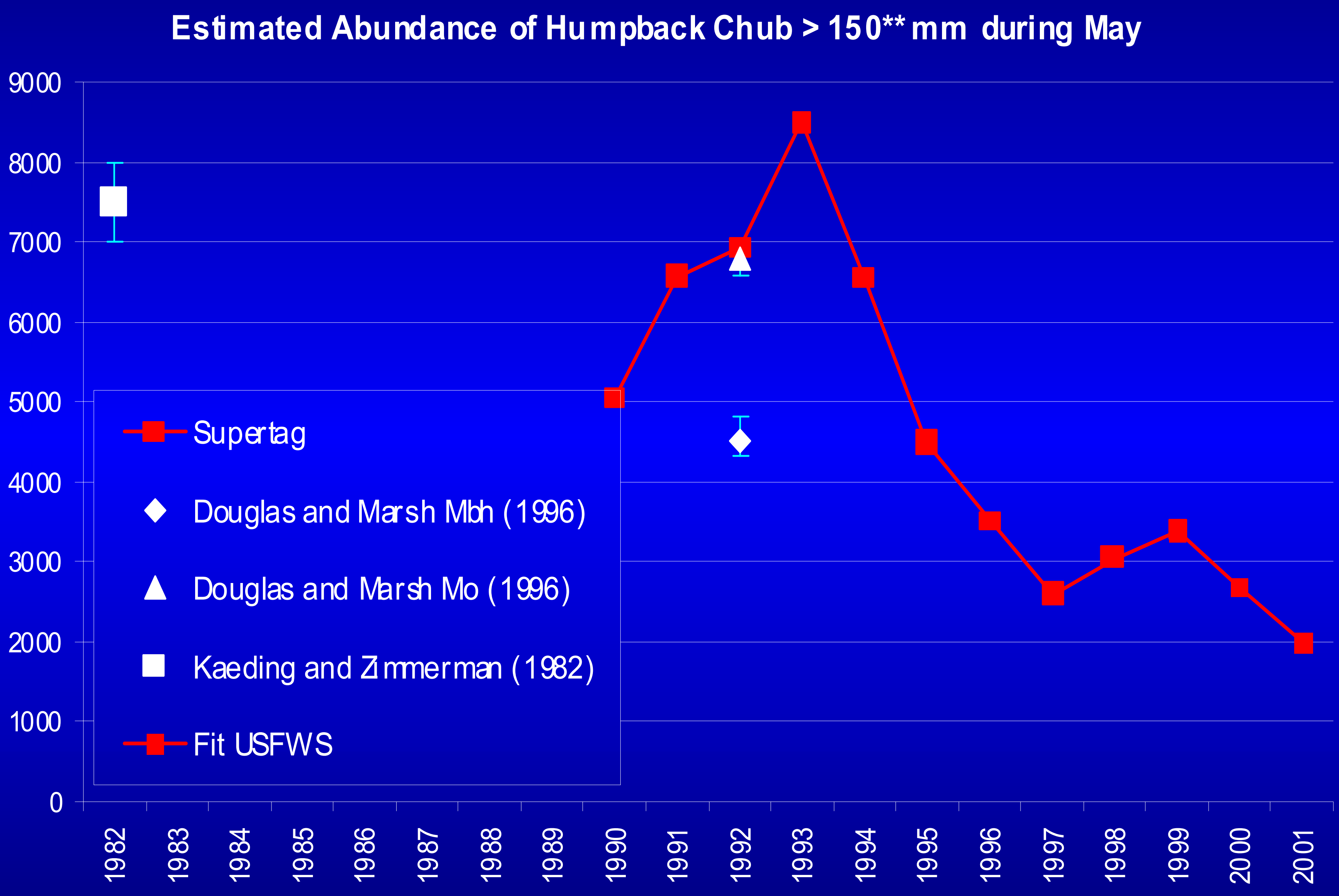


Figure 18. Locations of nine aggregations of humpback chub in the Colorado River through Glen and Grand Canyons. Percentage of total captures are indicated for 1990-1993. (Valdez and Ryel 1995)

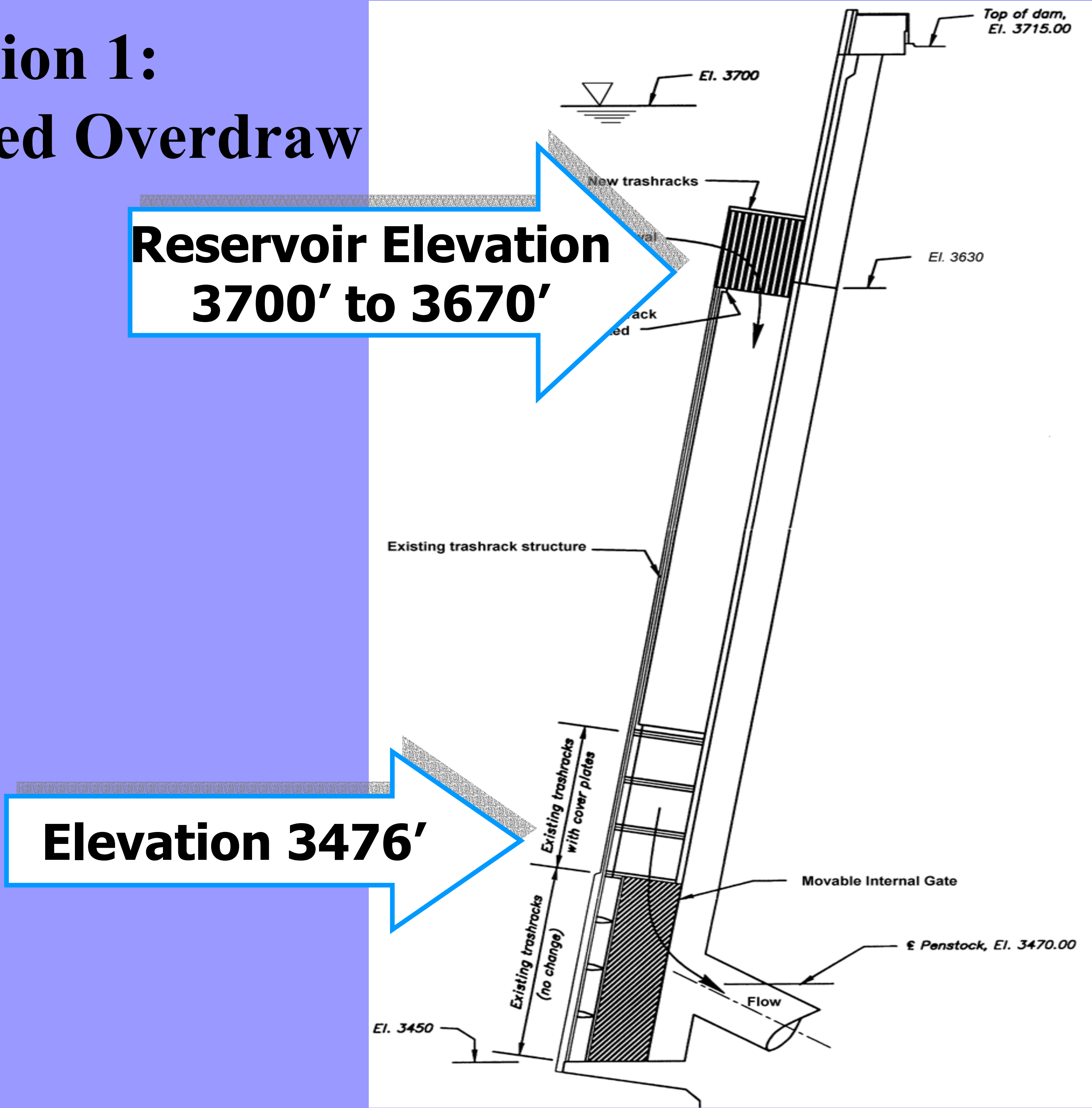
Results – Abundance Trend



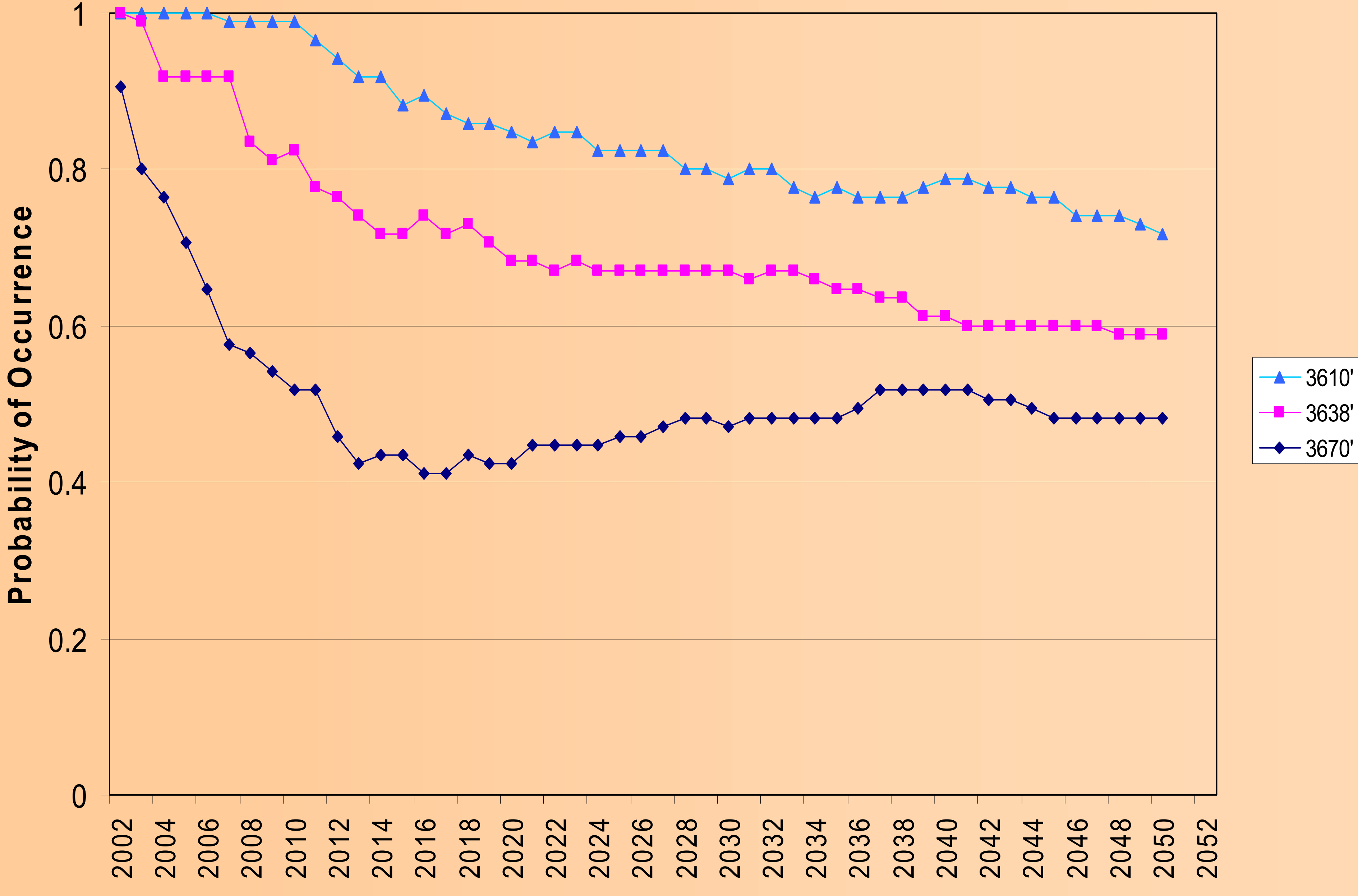
What Are Our Options?

To TCD or not to TCD, that is the question

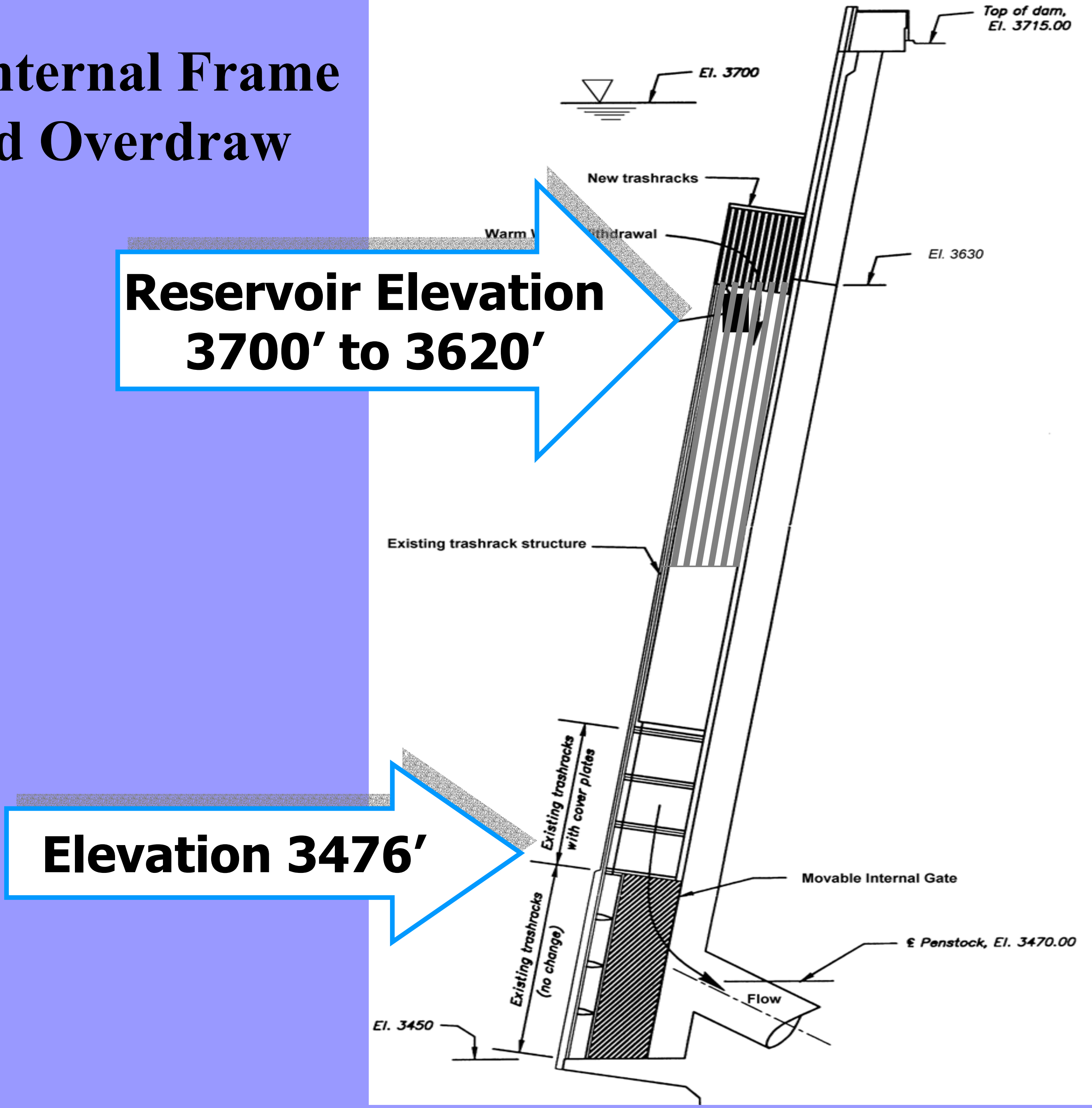
Option 1: Uncontrolled Overdraw



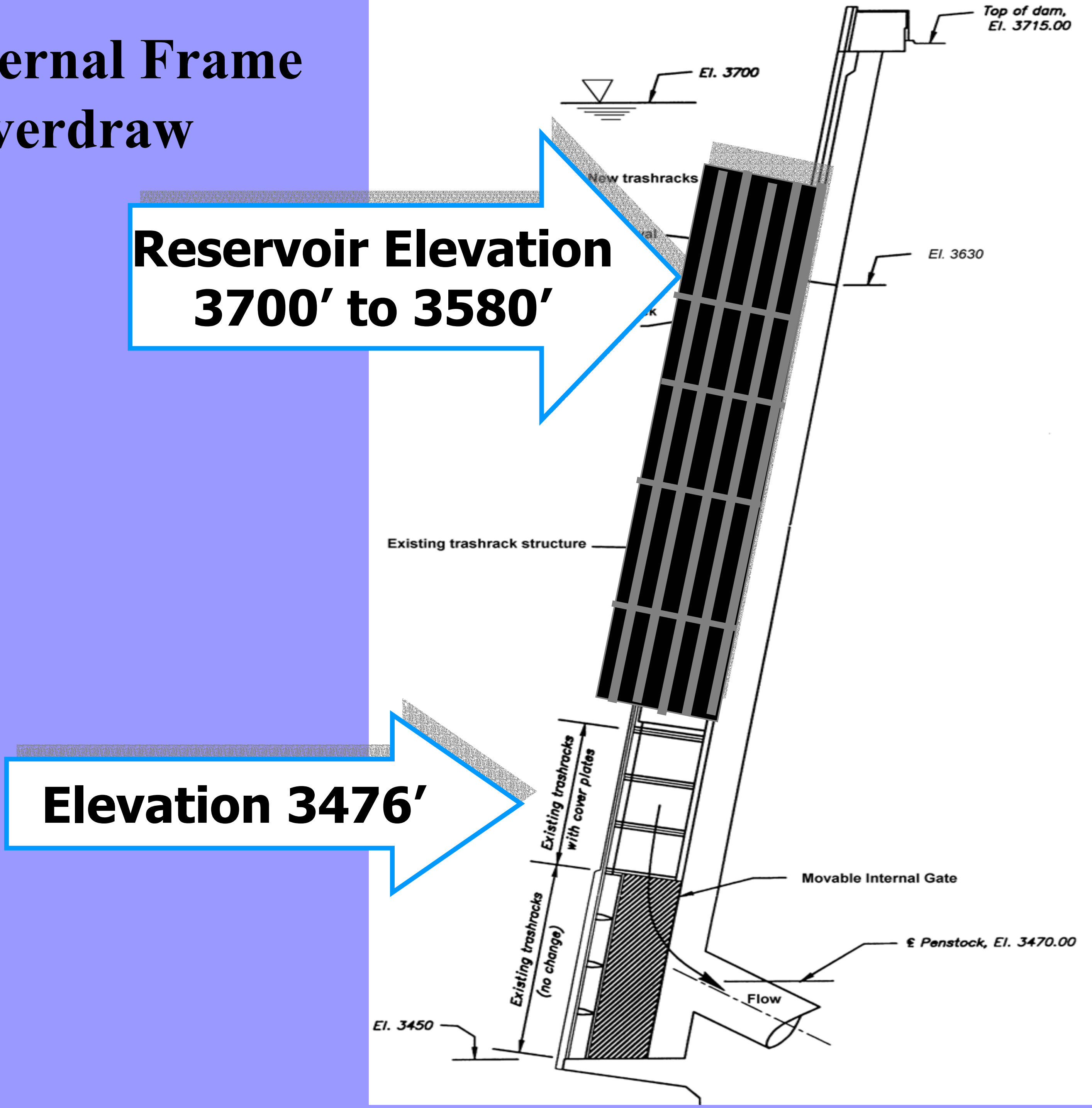
Probability of Future Lake Powell Elevation Exceedances in July



Option 2: Internal Frame Controlled Overdraw



Option 3: External Frame Controlled Overdraw



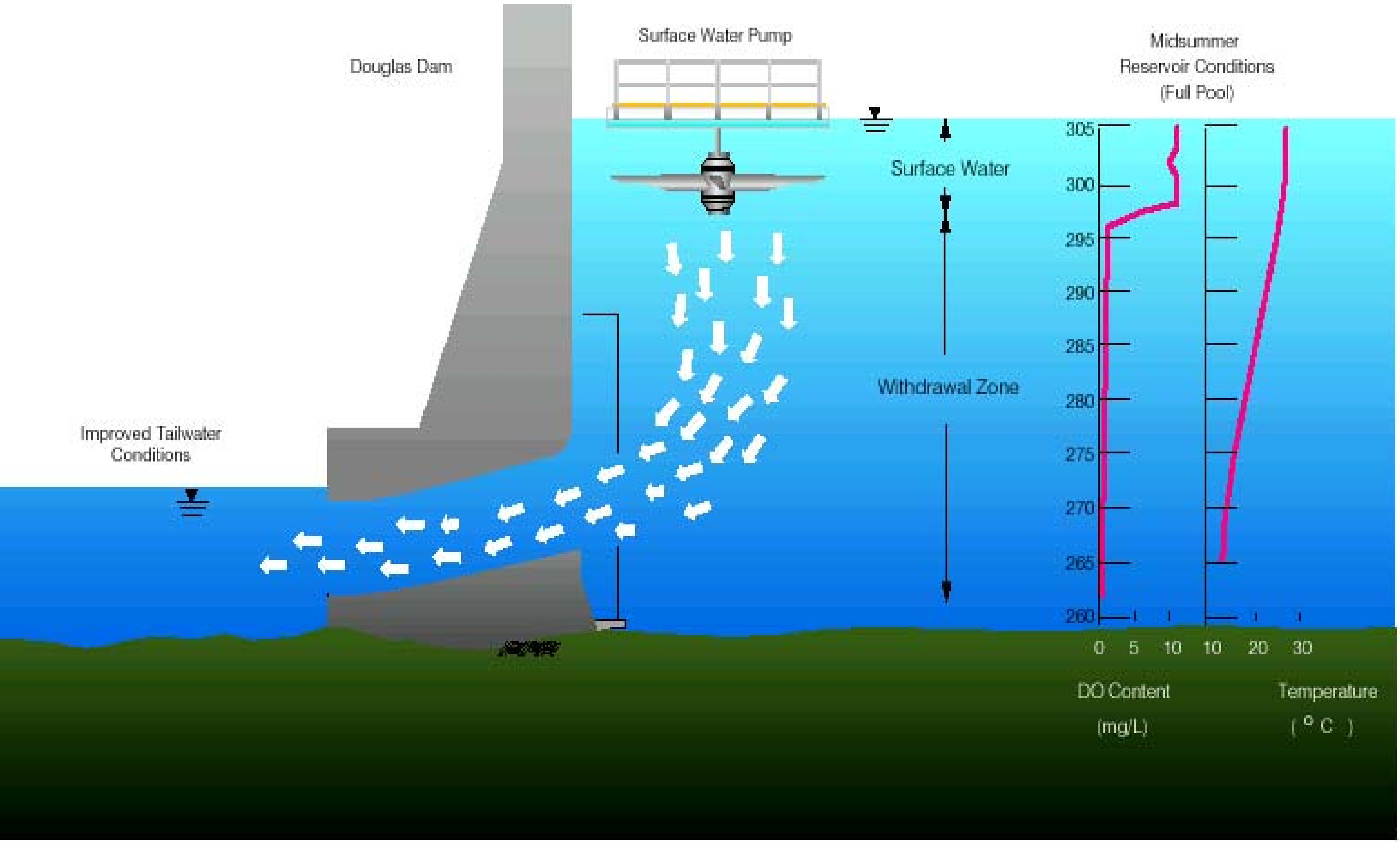
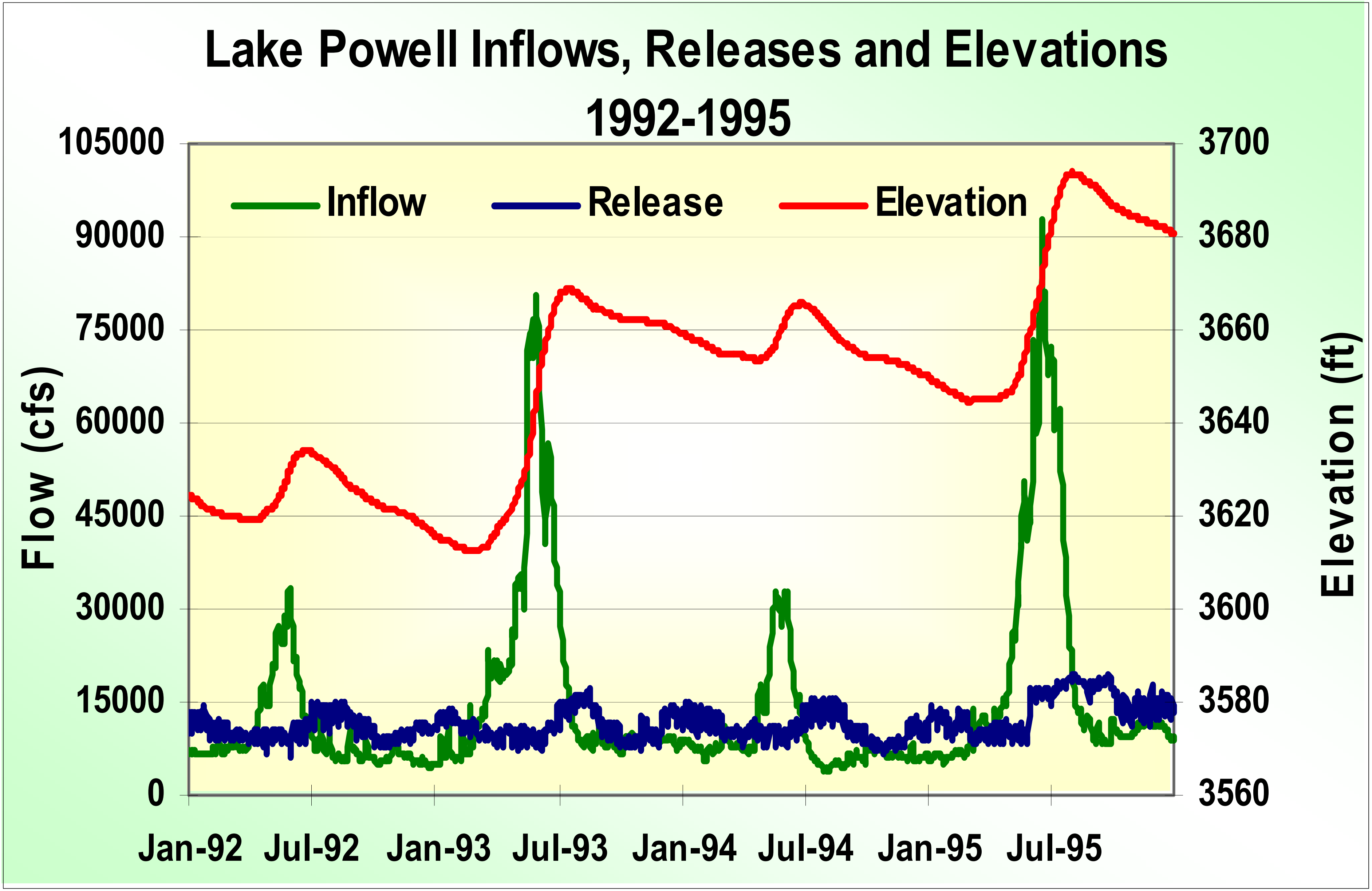
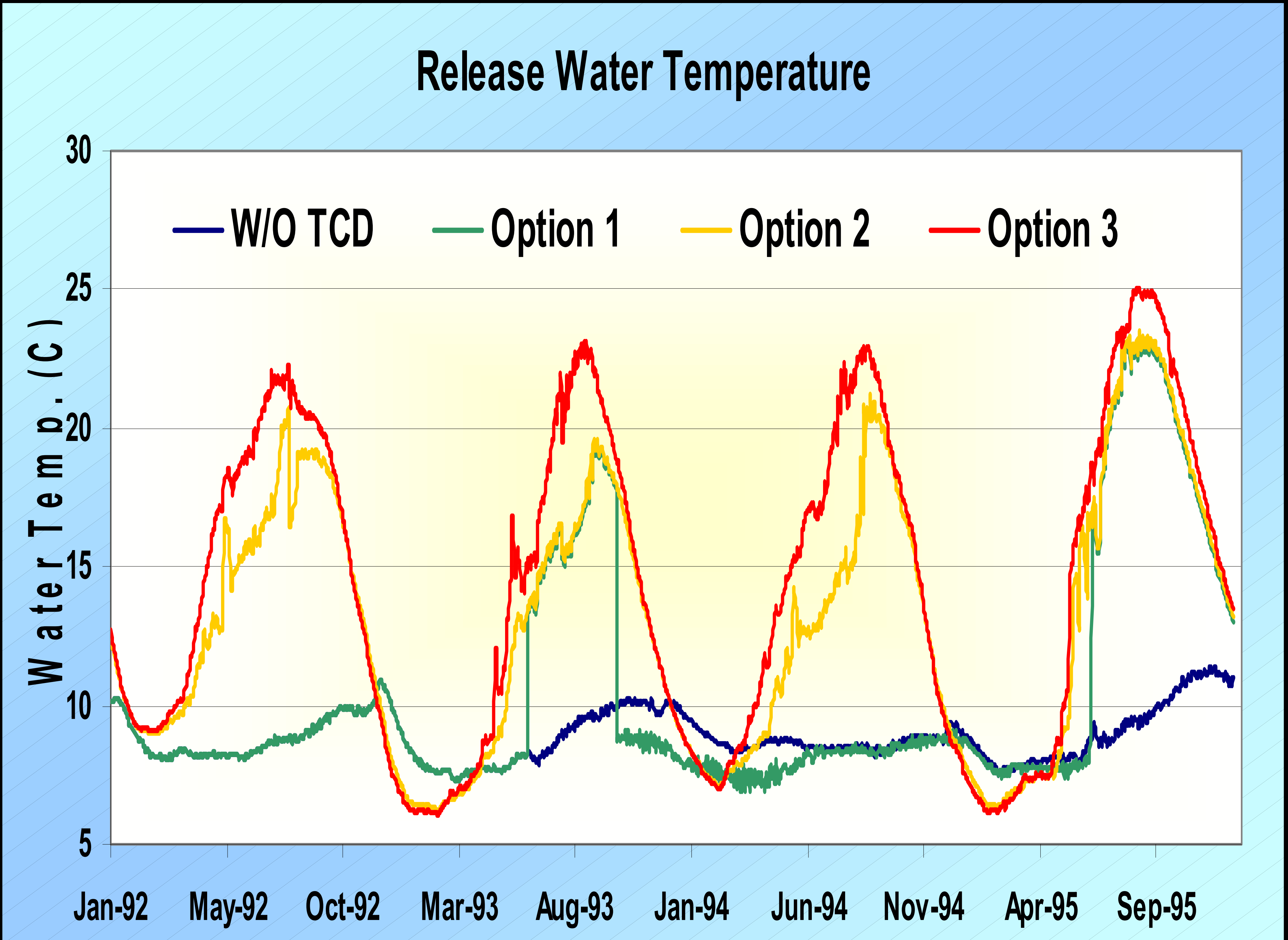


Figure 1. Schematic of Surface Water Pump Concept


Lake Powell Inflows, Releases and Elevations
1992-1995
Inflow
Release
Elevation
Flow (cfs)
Elevation (ft)
105000
90000
75000
60000
45000
30000
15000
0
3700
3680
3660
3640
3620
3600
3580
3560
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95

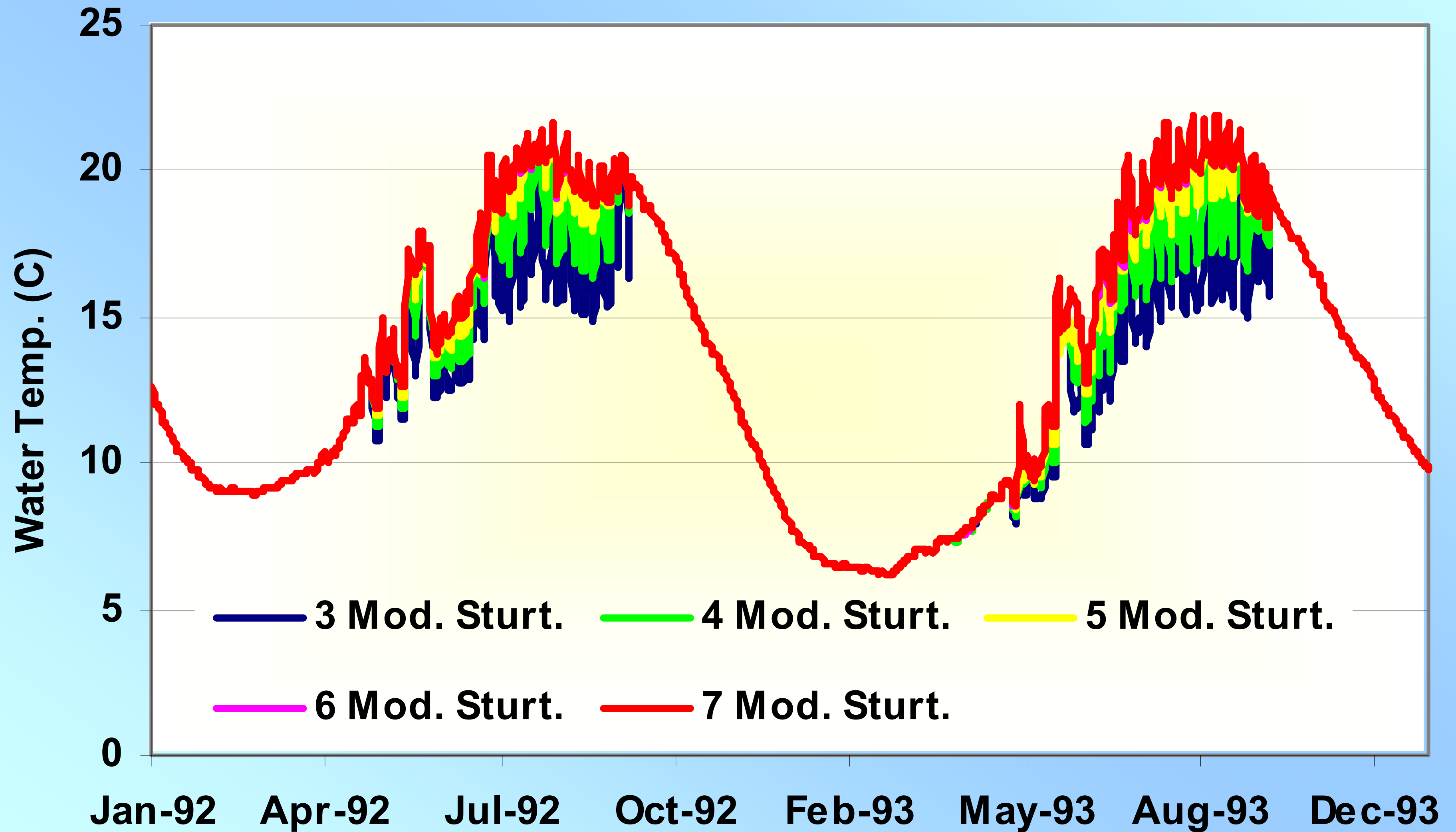


Release Water Temperature
W/O TCD
Option 1
Option 2
Option 3
Water Temp. (C)
30
25
20
15
10
5
Jan-92
May-92
Oct-92
Mar-93
Aug-93
Jan-94
Jun-94
Nov-94
Apr-95
Sep-95

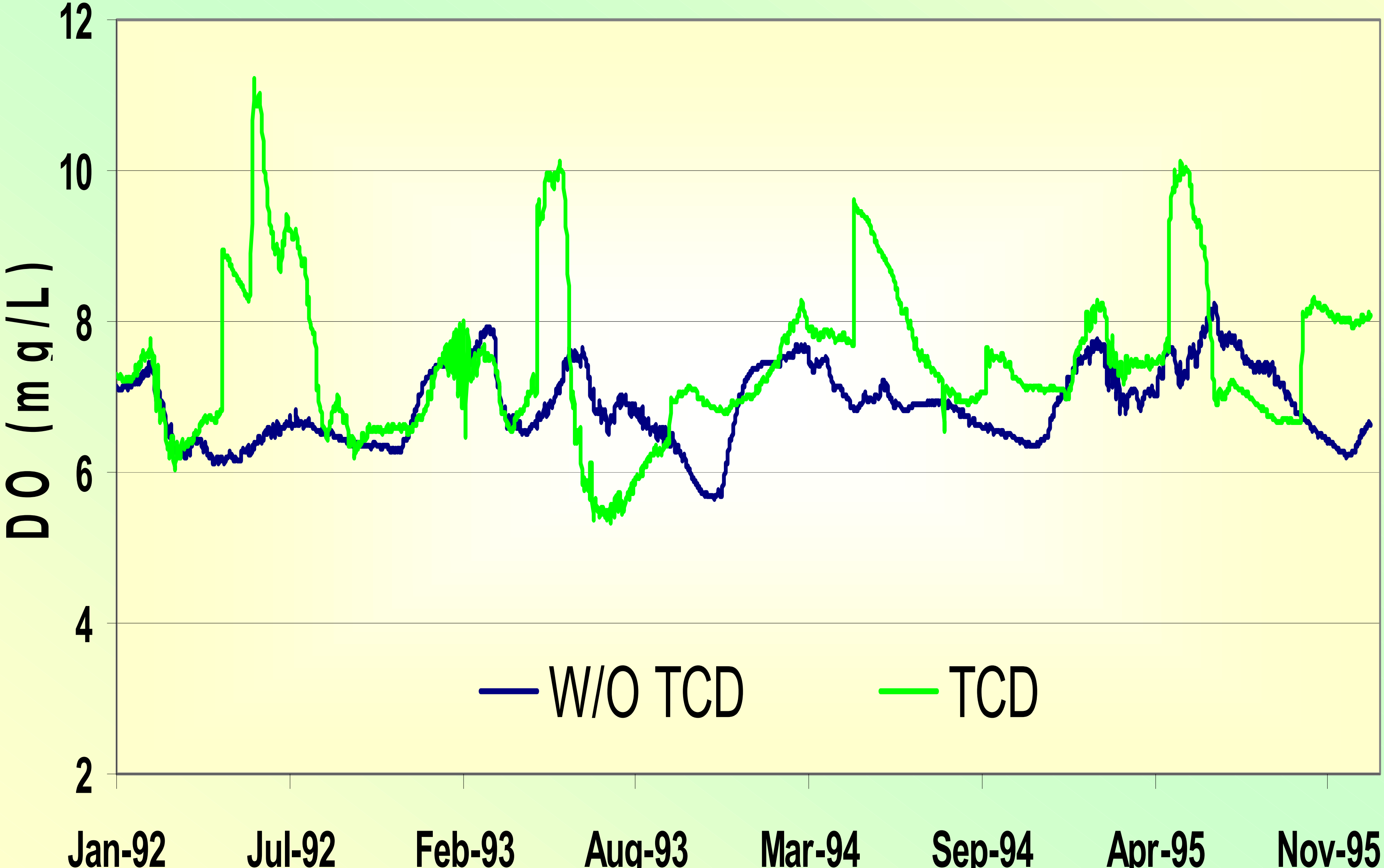
Time of Year When Temperature is Reached

11^{o} C	Earliest	Latest
Uncontrolled	19-Jun	22-Jun
Internal	20-Apr	31-May
External	10-Apr	21-May
15^{o} C		
Uncontrolled	6-Jul	11-Jul
Internal	26-May	1-Aug
External	4-May	2-Jun

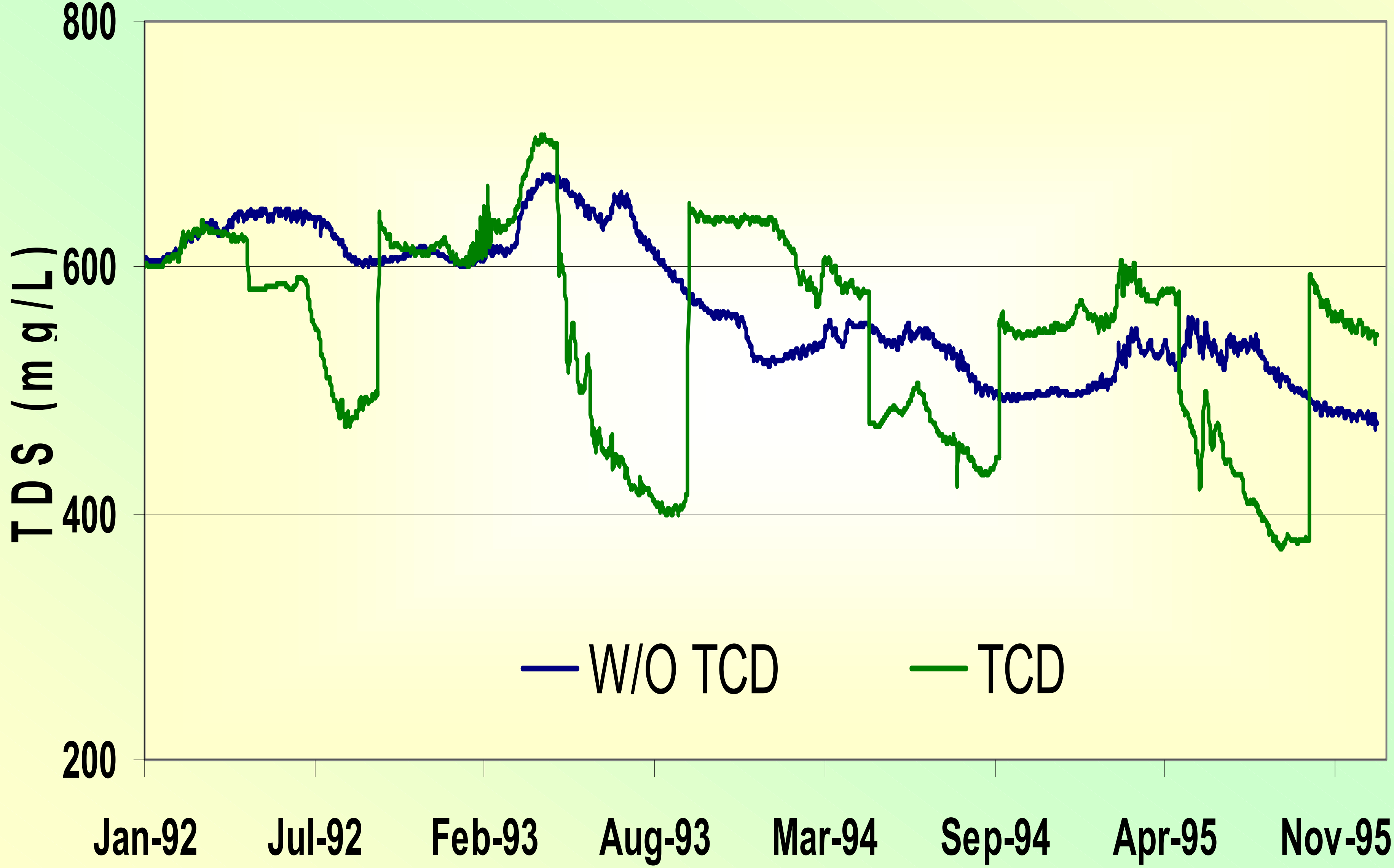
Release Water Temperature Hourly Operation Across a Range of 8,000cfs to 25,000cfs



Dissolved Oxygen



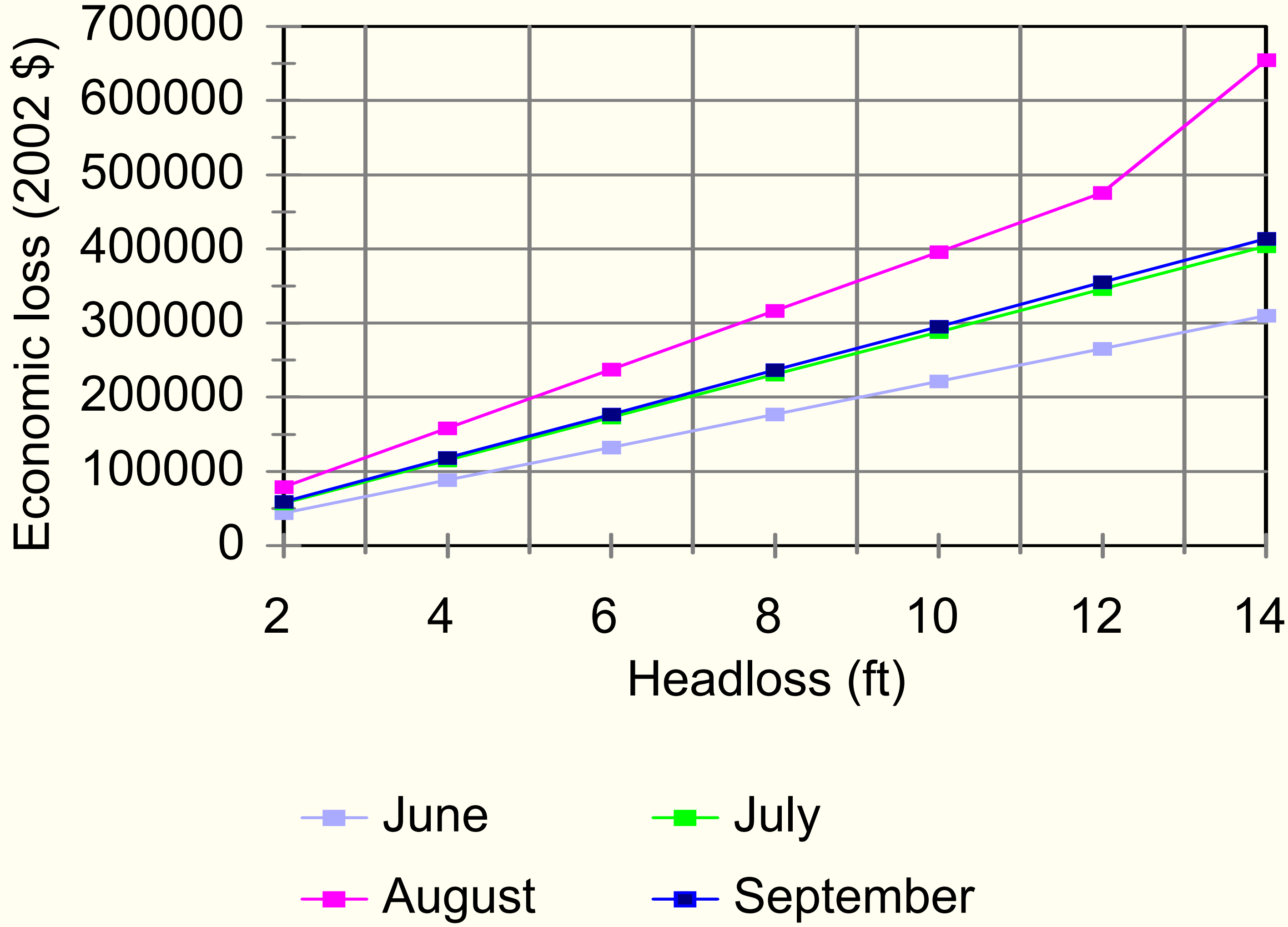
Total Dissolved Solids



In the Next 50 Years

- Uncontrolled Overdraw: 50%
- Internal Controlled: 85%
- External Frame Controlled: 90%

Economic Loss vs Headloss



Costs over life of TCD (50 yrs)

Table 2. Projected Economic Effects of Operating Two Types of TCD's over a 50 Year Design Life

TCD Design	Lifetime Cost ($) at d=0.03	Lifetime Cost ($) at d=0.06125[1]
Internal Control	11,405,258.99	6,866,671.97
External Frame	7,392,760.19	4,450,899.29

for details, refer to filename=TCD_analysis_results.xls

Temperature Control Device Alternatives and Estimated Costs

Design option	**Operating range (Min. op. W.S.***)**	**Construction cost**	**Add'l design time***	**Construction time**
Option 1 - Fixed inlet design (baseline)	30 feet (El.3670)	$13.5 M	2 months	24 months
Option 2- Internal controlled overdraw	80 feet (El. 3600)	$43.0 M (6/8 = $32 M)	15 months	33-35 months
Option 3 – External frame controlled overdraw	120 feet (El. 3580)	$65.0 M (6/8 = $49 M)	18 months	24 months
Option 4 - Surface water pumps	150 feet	$9.9 M	10 months	12 Months

What (else) Could Go Wrong?

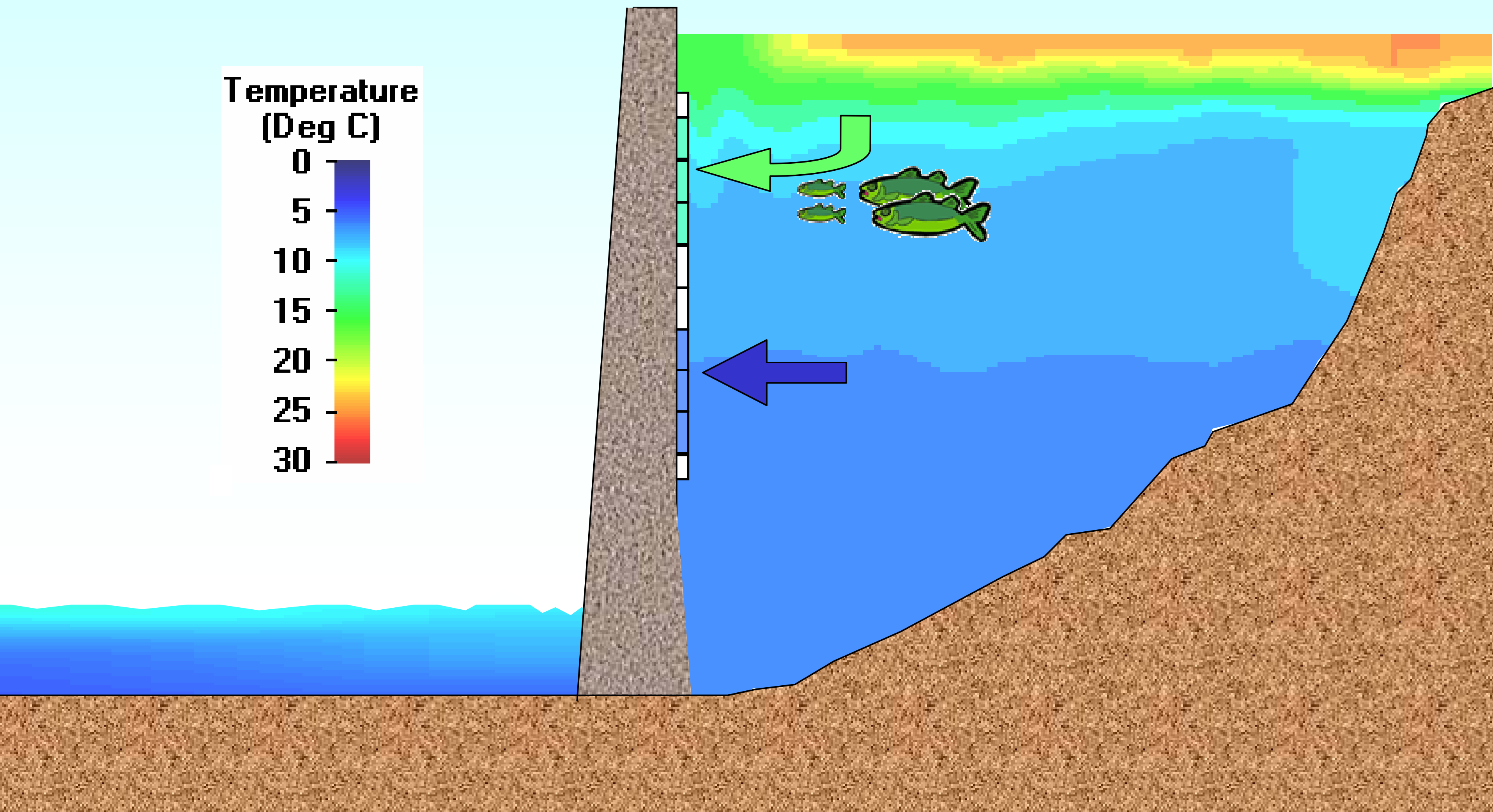
- We may entrain undesirable fish from higher levels in the reservoir and deliver them to the tailwater. Some will survive.
- Benthic algae and invertebrates that form the fish food base are adapted to constant, cold water temperatures. They may not be able to withstand cycling between warm and cold temperatures.
- Cold water temperatures suppress important diseases, parasites, competitors, and predators of native fish and some diseases of rainbow trout. Therefore, warming the water could result in negative impacts to these fish, including the endangered humpback chub.

Fish of Lake Powell

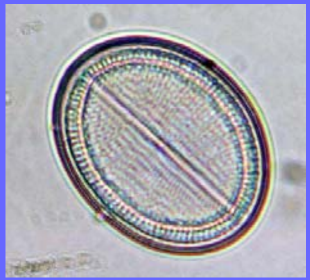
Striped bass   Threadfin shad

Largemouth bass   Walleye

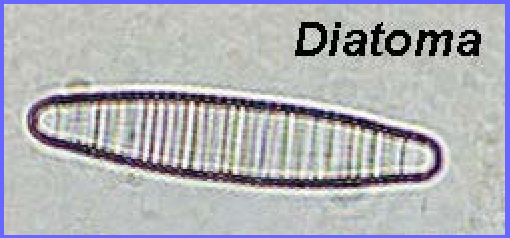
Carp   Red shiner   Crappie



Aquatic Vegetation Colorado River



Cocconeis



Potamogeton

Oscillatoria

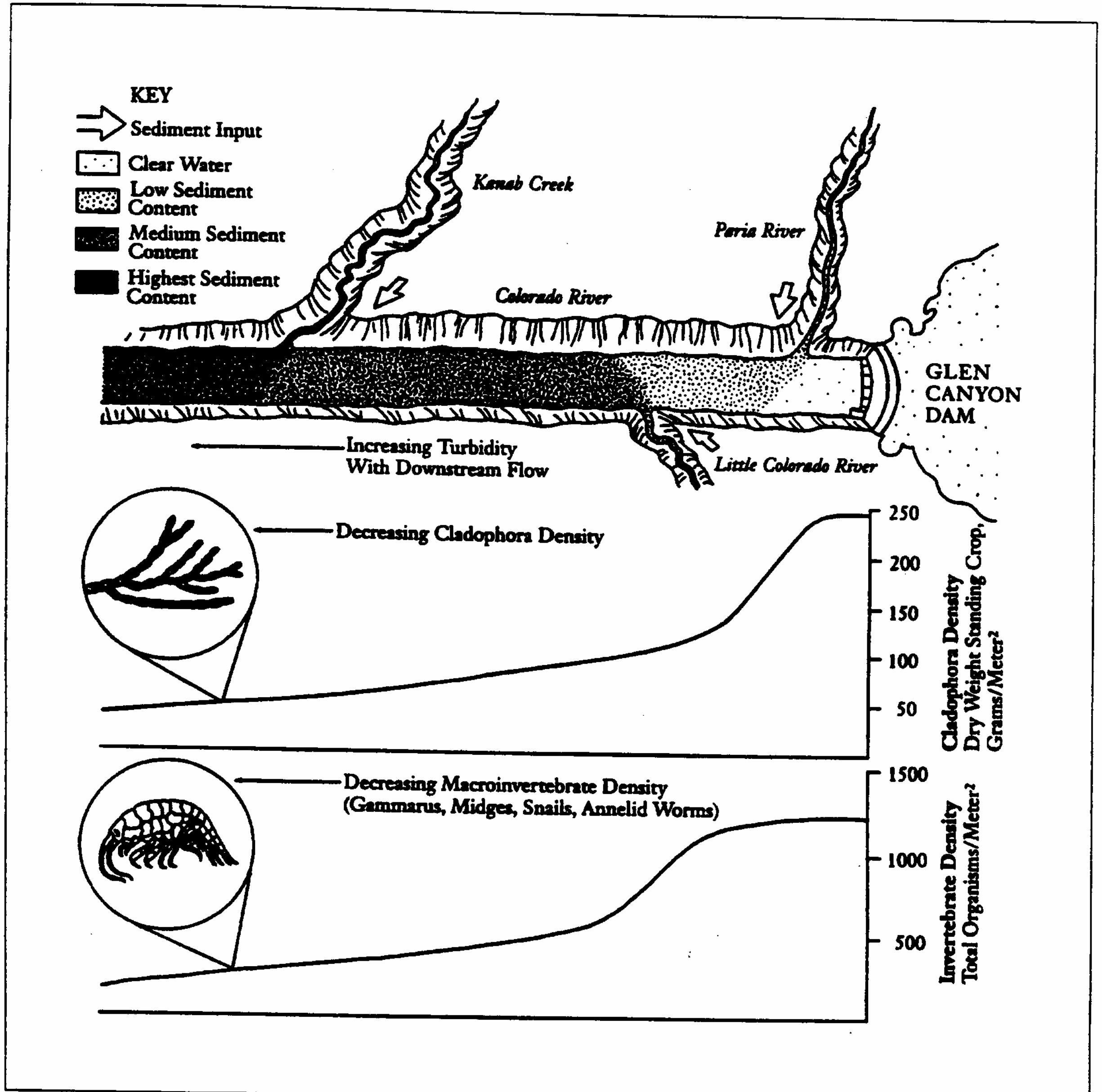
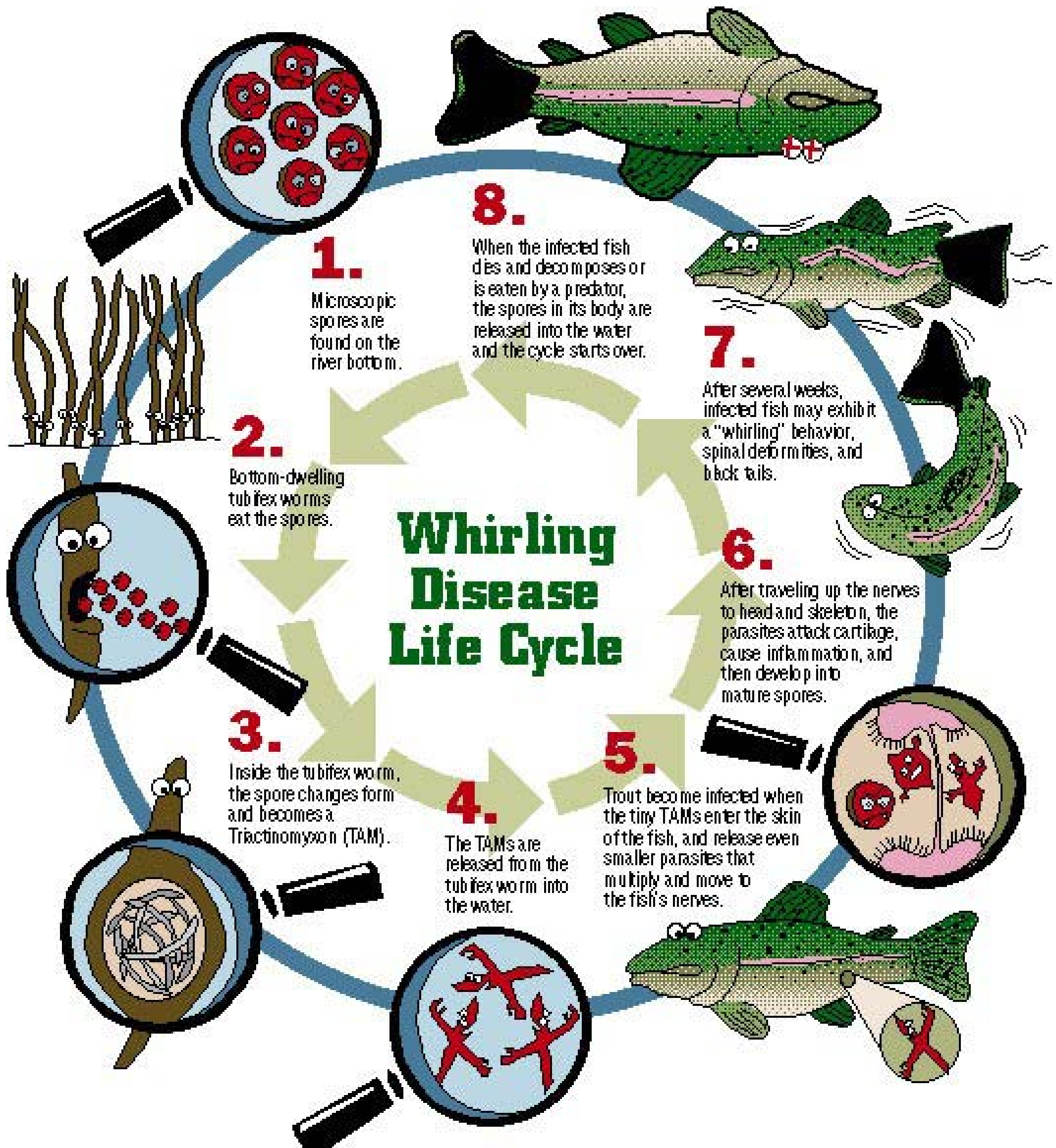


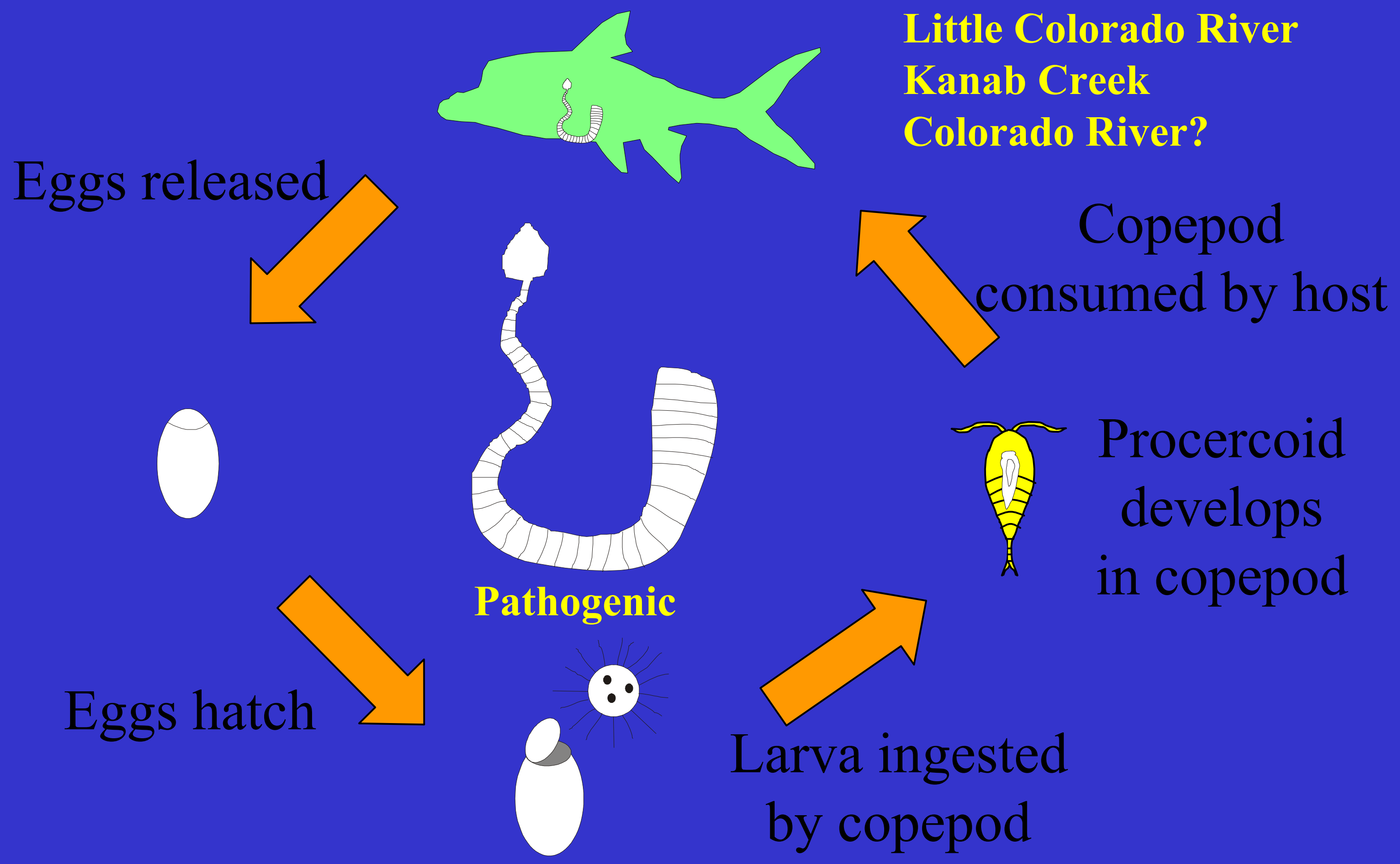
Figure 14. Longitudinal sediment concentration and biomass of *Cladophora* and macroinvertebrates in the Colorado River from Glen Canyon Dam to Diamond Creek (Source: Carothers and Brown 1991).

Life Cycle of Whirling Disease

Whirling Disease poses a serious threat to New Mexico's trout population. To prevent the spread of this disease it is helpful to understand its life cycle.



Life Cycle of *Bothriocephalus acheilognathi*



Source: AGFD 1999

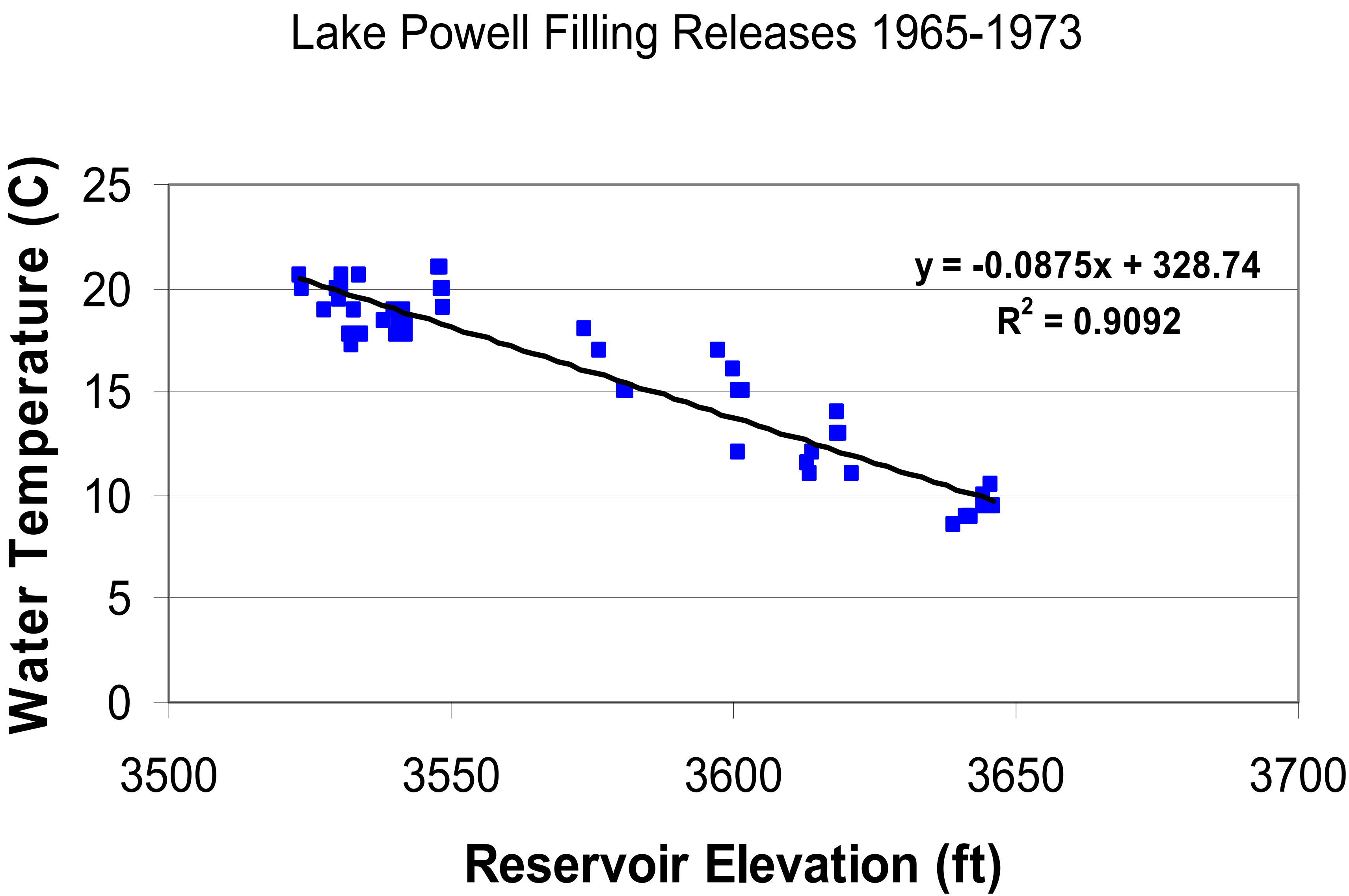
Suspected and Known Interactions between Native and Non-native Fishes of the Colorado River in Glen Canyon and Grand Canyons

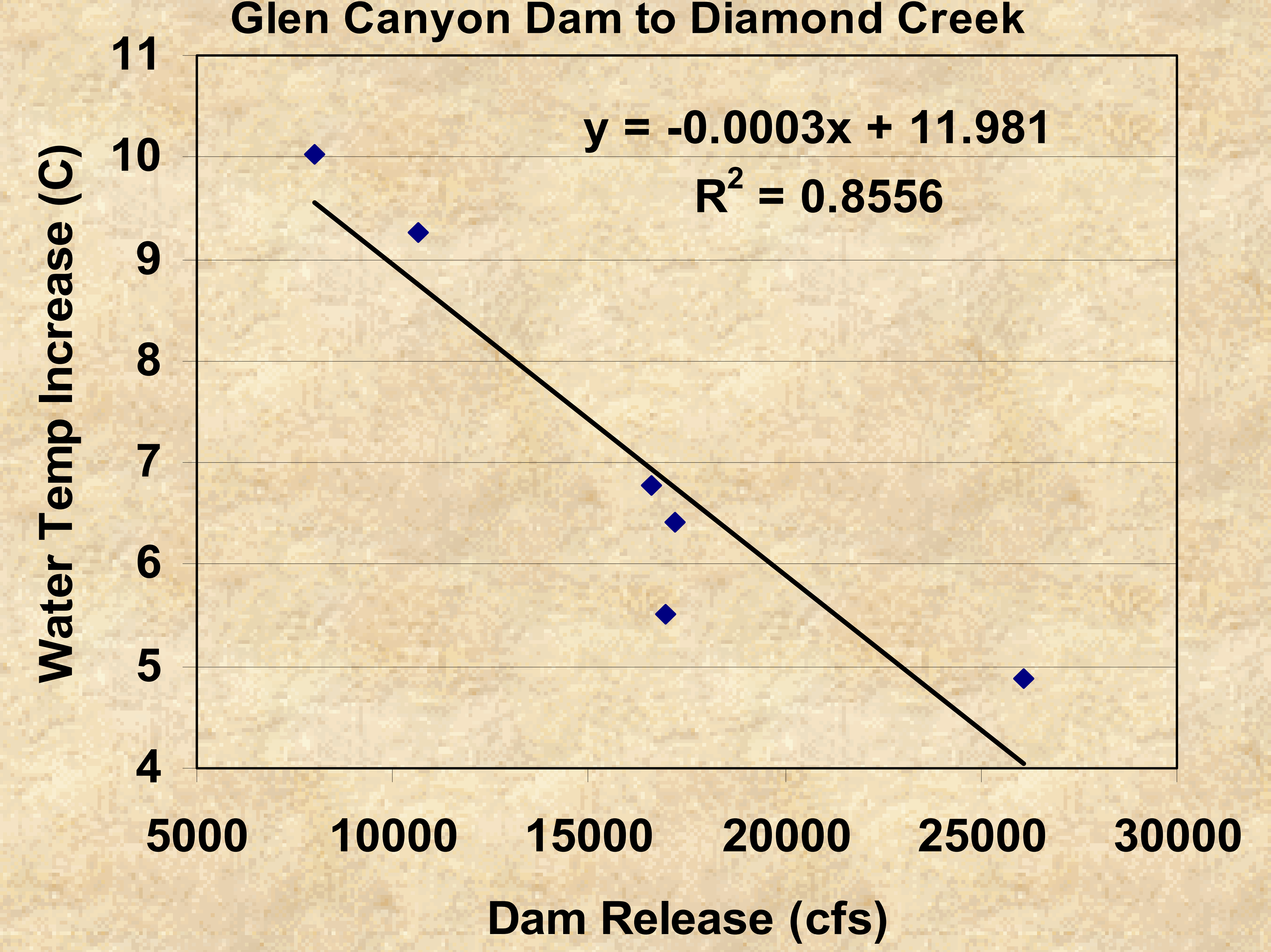
Non-native species	Humpback chub	Razorback sucker	Flannelmouth sucker	Bluehead sucker	Speckled dace
Brown trout	P	P?	P	P	P
Rainbow trout	P		P?	P?	P
Channel catfish	D, P	P	D, P	D, P	D, P
Black bullhead	P		P	P	P
Largemouth bass	P?	P?	P	P?	P?
Striped bass	P?	P?	P?	P?	P
Walleye	P?	P?	P?	P?	P?
Black crappie	P?	P?	P?	P?	P?
Green sunfish	P?	P?	P?	P?	P?
Bluegill	P?	P?	P?	P?	P?
Red shiner	D, P?	P?	D, P?	D, P?	D, P?
Fathead minnow	P?,C?	P?	P?,C?	P?,C?	P?, D,C?
Common carp	P?,D	P?,D	P?,D	P?,D	P,D,H
Plains killifish	D, C?	C?	C?	C?	D, C?
Mosquitofish	C?	C?	C?	C?	C?

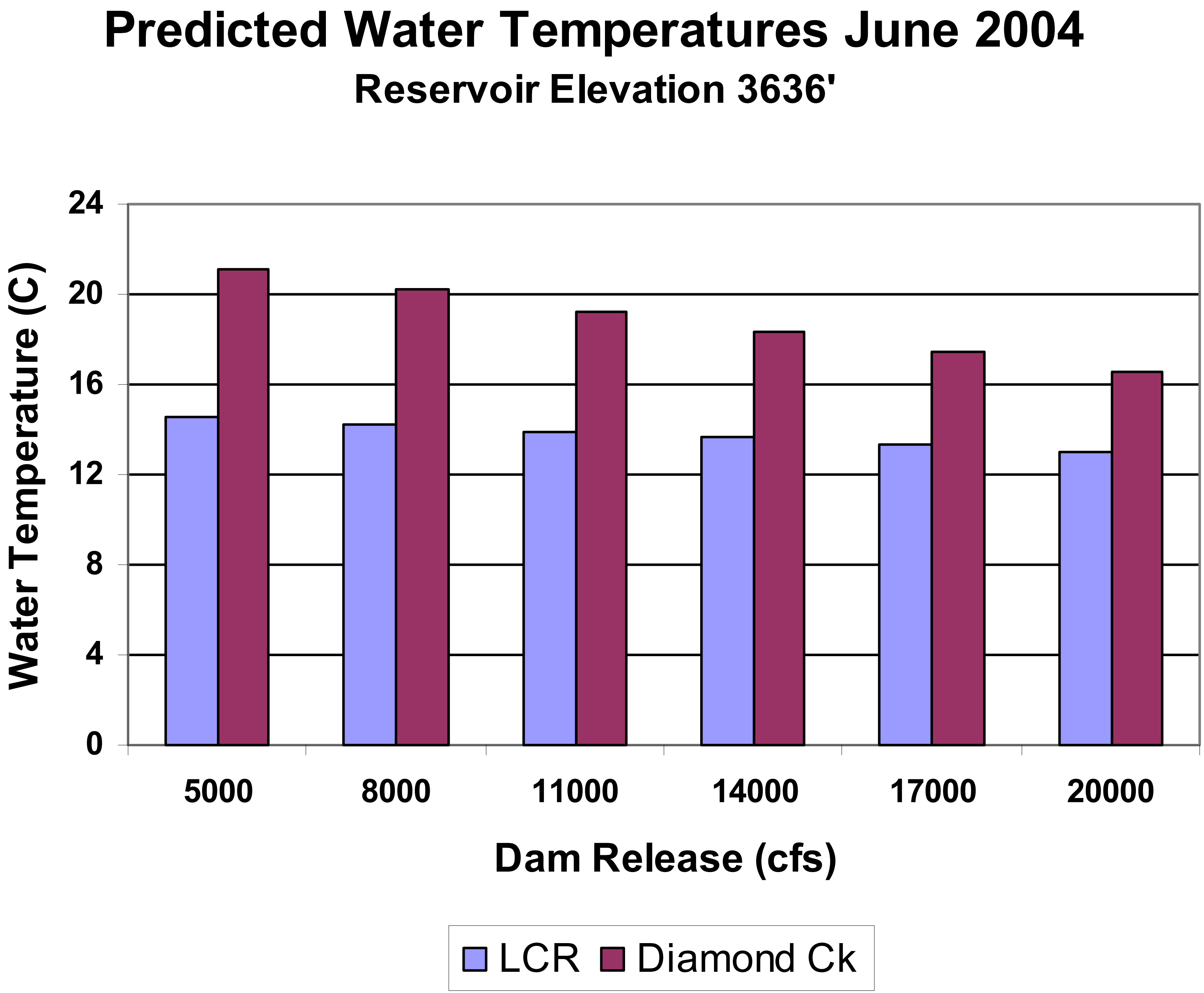
P = Predation; D = Disease and Parasites; C = Competition; H = Habitat Alteration

What May Happen Regardless?

The drought may continue and the reservoir elevation may decline further

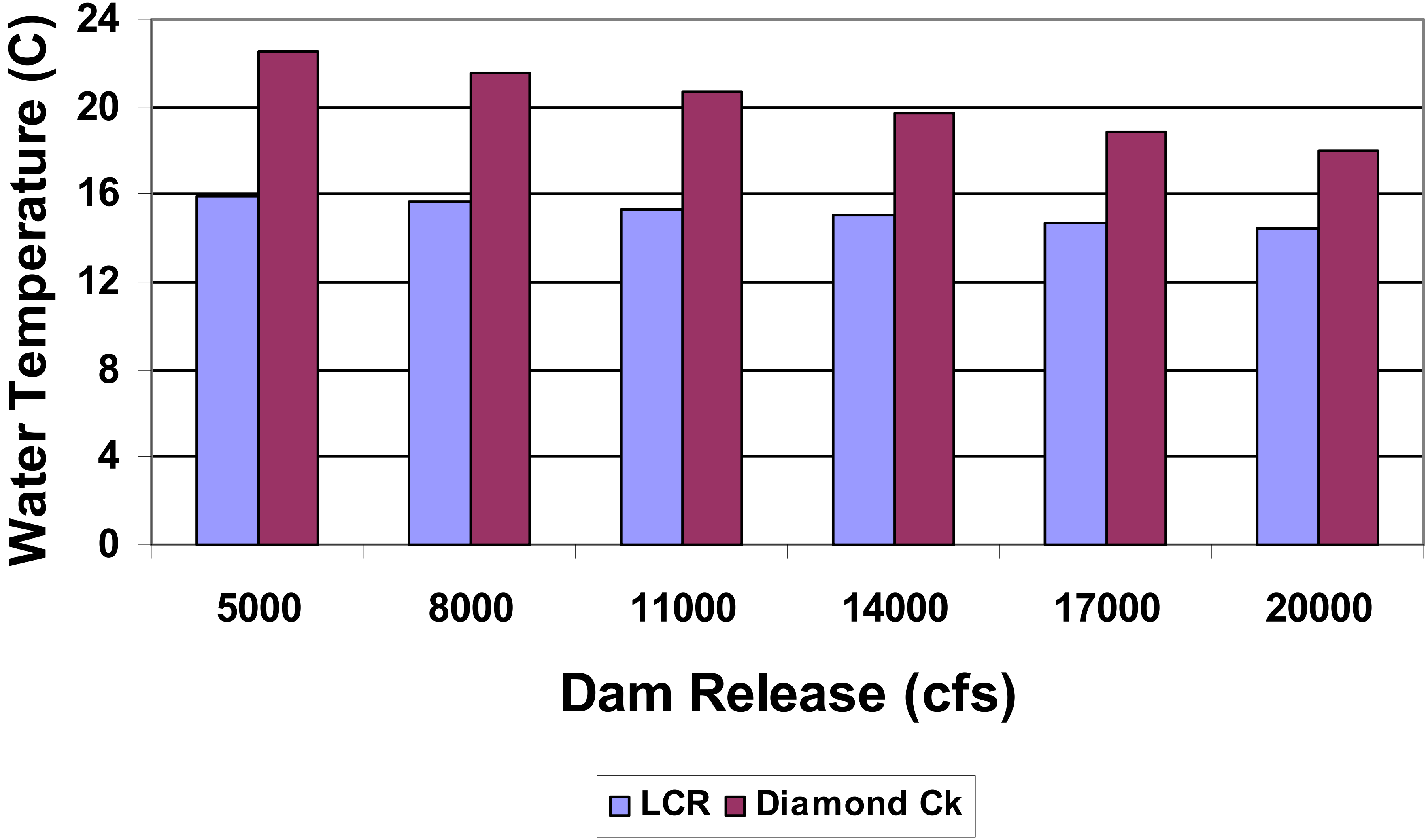

Lake Powell Filling Releases 1965-1973
Water Temperature (C)
25
20
15
10
5
0
3500
3550
3600
3650
3700
Reservoir Elevation (ft)
y = -0.0875x + 328.74
R2 = 0.9092


Glen Canyon Dam to Diamond Creek
y = -0.0003x + 11.981
R2 = 0.8556
Water Temp Increase (C)
11
10
9
8
7
6
5
4
5000
10000
15000
20000
25000
30000
Dam Release (cfs)


Predicted Water Temperatures June 2004
Reservoir Elevation 3636'
Water Temperature (C)
24
20
16
12
8
4
0
5000
8000
11000
14000
17000
20000
Dam Release (cfs)
LCR
Diamond Ck

Predicted June Water Temperatures

Reservoir Elevation 3620



Selective Withdrawal Guideline

- Review historic information and employ existing modeling with possible updates using alternative reservoir and operating conditions to prepare a set of possible scenarios of temperature changes in the mainstem.
- Assess the temperature induced interactions between native and non-native fish competitors and predators.
- Assess the effects of temperature, including seasonality and degree, on *Cladophora* and associated diatoms, *Gammarus*, aquatic insects, and fish parasites and disease.

Selective Withdrawal Guideline

- Determine from the literature, experimentation, and consultation with cooperating agencies, tribes and other native fish species experts the anticipated effects on native fish populations which may result from implementation of temperature changes from a selective withdrawal structure. Determine the range of temperatures for successful larval fish development and recruitment and the relationship between larval/juvenile growth and temperature.

Selective Withdrawal Guideline

- Evaluate effects of withdrawing water on the heat budget of Lake Powell, effects of potentially warmer inflow into Lake Mead, and the concomitant effects on the biota within both reservoirs. Evaluate the temperature profiles along with heat budget for both reservoirs.
- Evaluate effects of reservoir withdrawal level on fine particulate organic matter and important plant nutrients to understand the relationship between withdrawal level and reservoir and downstream resources.

Questions for AMWG

- Should any guidelines or criteria for feasibility be added to those in the biological opinion?
- Which guidelines or criteria should be evaluated in the NEPA document and which will have to be evaluated by operation of the device?
- Should operational scenarios be identified in the NEPA document as alternatives or as experiments in the science plan?