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Managing Water in the West

Threat of Mussel to Reclamation Water Facilities

U.S. Department of the Interior
Bureau of Reclamation

What Water Storage and Delivery Facilities are Vulnerable to a *Dreissena* Mussel Infestation?

Comparison of Zebra Mussel Colonization Potential with Environmental Tolerances

Variable	Colonization Potential (Infestation Probability)			
	High	Moderate	Low	Very Low
Salinity, ppm	0-1,000	1,000-4,000	4,000-10,000	10,000-35,000
Calcium, ppm	25,000-125,000	20,000-25,000	12,000-20,000	<12,000
pH	7.4-8.5	7.0-7.4 8.5-9.0	6.5-7.0	<6.5 >9.0
Water temperature °C (°F)	17-25 (63-77)	25-27 (77-81)	15-17 (59-63)	<12 (<50)
Turbidity, cm (Secchi disk)	40-200	20-30	10-20 200-250	<10 >250
Dissolved Oxygen, ppm	8-10	6-8	4-6	<4
Water velocity, (ft./sec.)	1.6-2.3	2.3-3.3	3.3-6.6	>6.6

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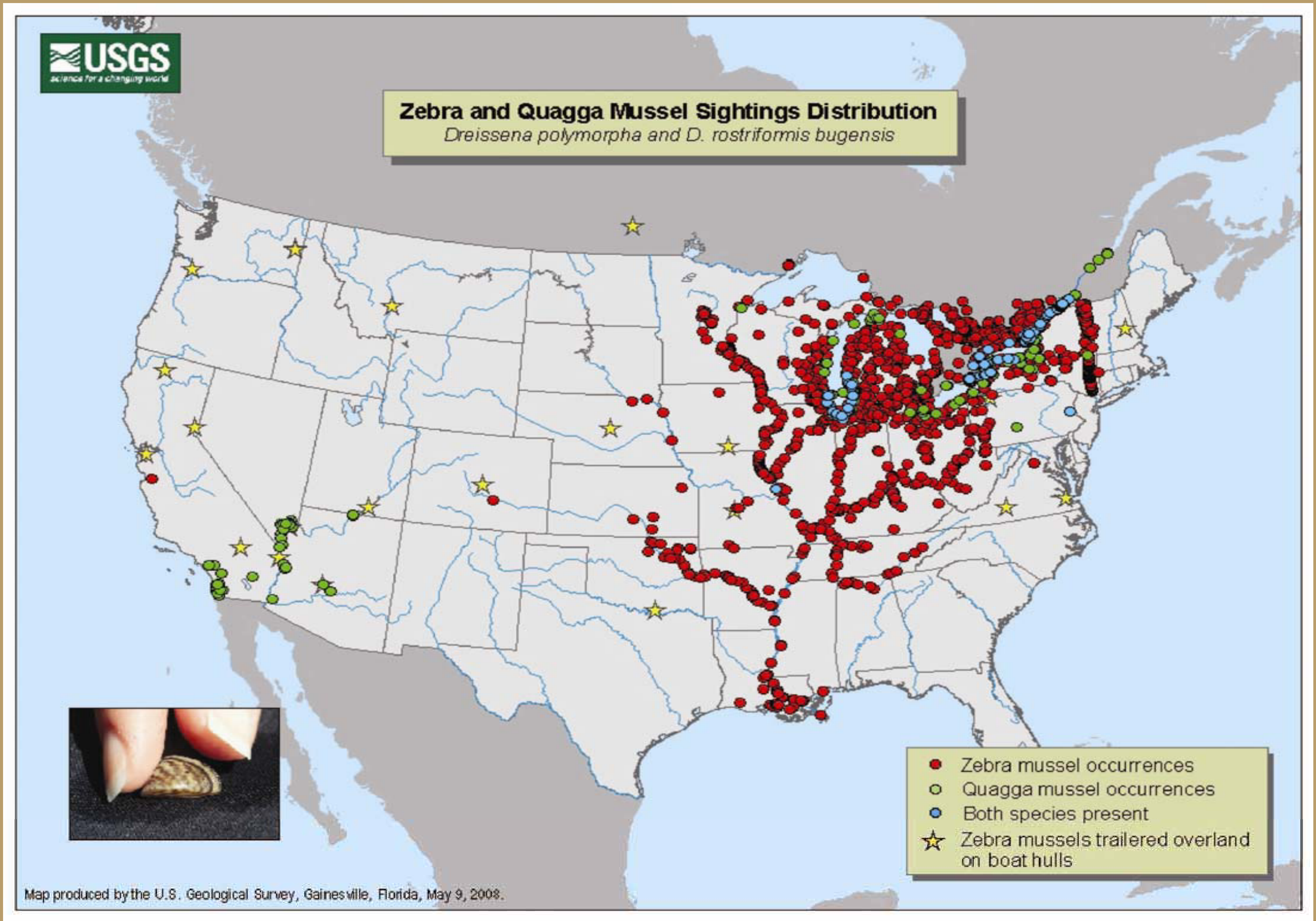
Current Distribution - 2008



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Water Transfers

- Western water systems differ from eastern:
  - Long, continuously managed reaches of flowing water
  - Systems designed for water dispersal
- Structures often lack designs and management plans to contend with quaggas and zebras
- New problems are apparent requiring new management techniques

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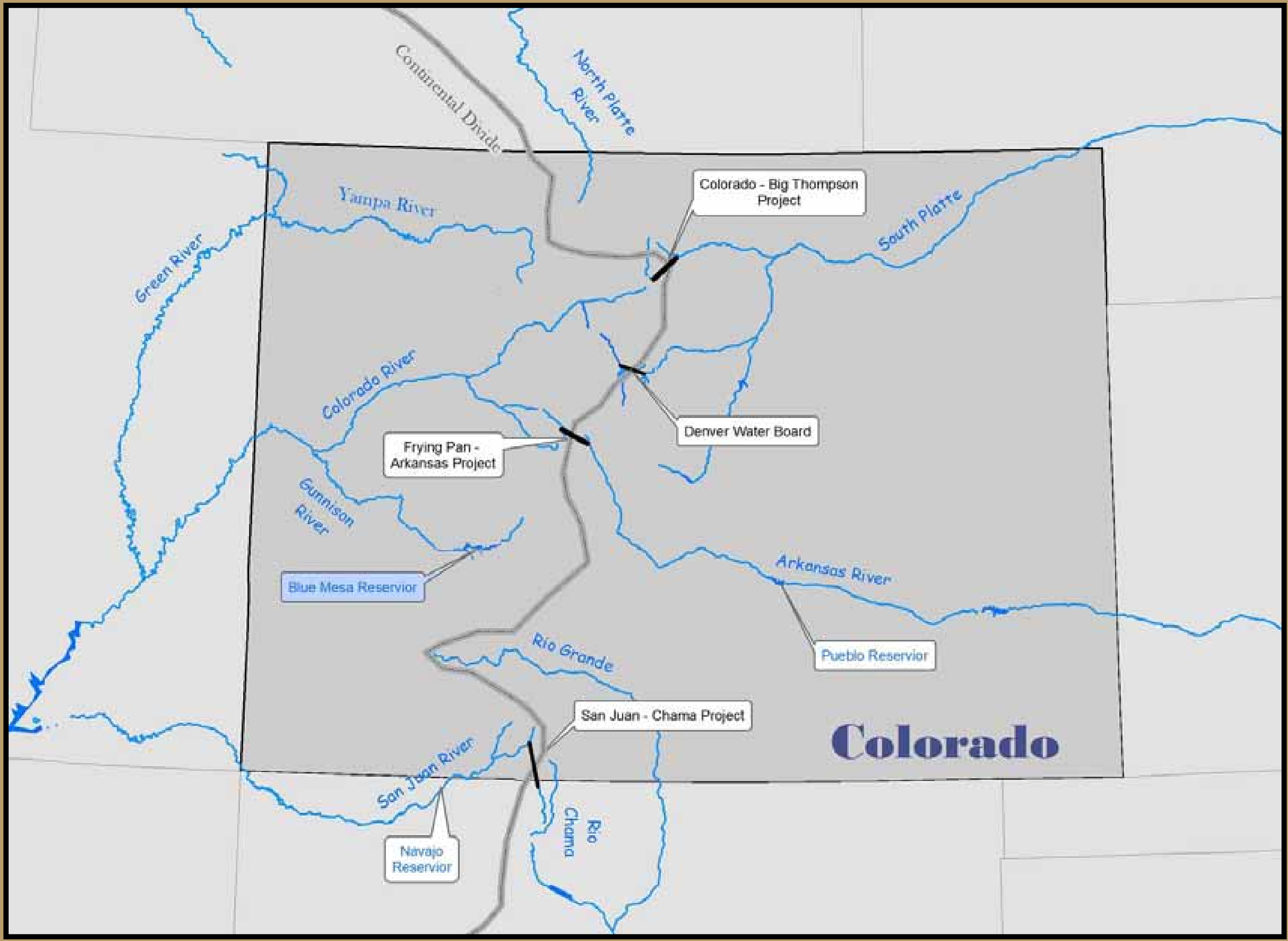
Water Transfer - Colorado



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Assets We Manage

- 348 storage reservoirs
- 254 diversion dams
- 16,075 miles of canals
- 1,460 miles of pipelines
- 280 miles of tunnels
- 37,495 miles of laterals
- 17,040 miles of project drains
- 268 pumping plants over 1,000 horsepower
- 58 hydroelectric power plants

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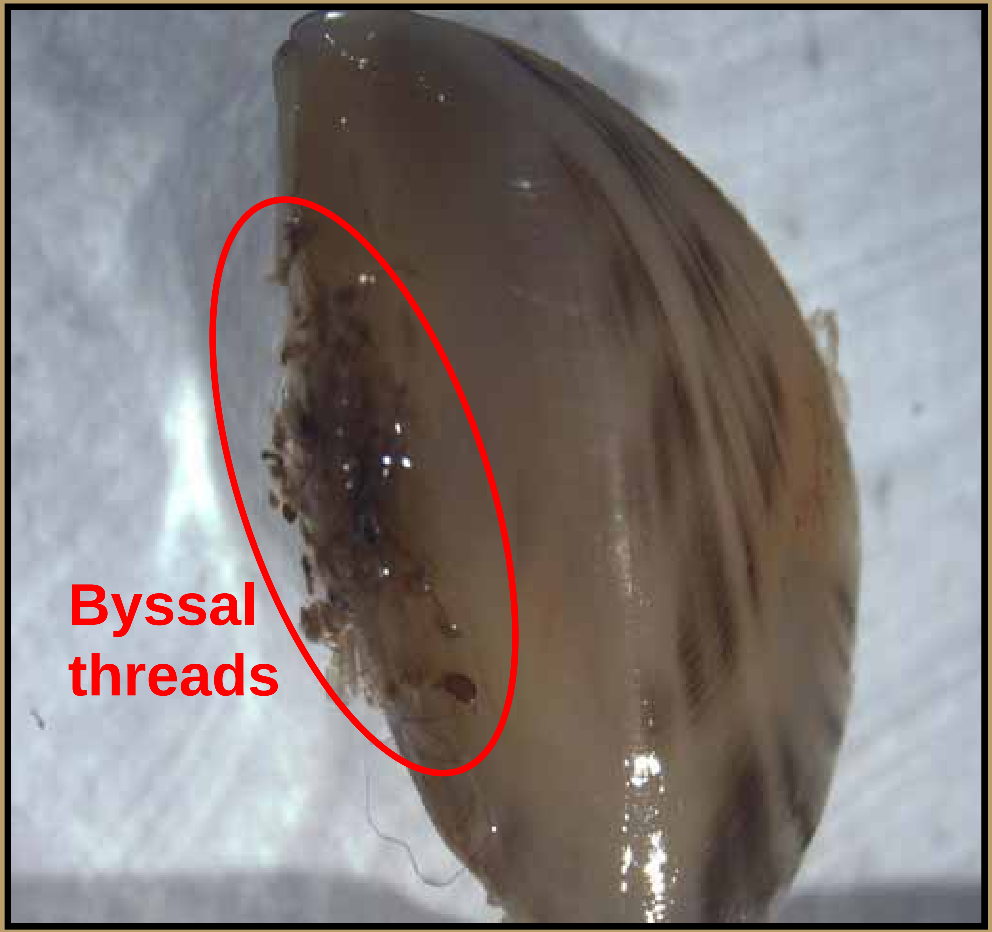
Forms of Problems

- Flow restriction
  - Roughening (Friction loss)
  - Blockage
- Chemical degradation
- Biological/Environmental
  - Food chain
  - Habitat
  - Water quality
  - Water resource industry
  - Toxic accumulations



Quagga mussel, Lake Havasu – Jan. 2007

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Flow Restriction, cont'd

Fouled Trash Rack, Corps of Engineers

Intake screen blocked by shells

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Biological/Environmental

Recreational loss - Zebra mussels on Lake Michigan Beach

Habitat loss - Catfish near zebra mussel covered substrate

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What BOR has learned from the Great Lake Region

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Site Visit Experience Ontario Hydro Power Facilities (reactive approach)

Sir Adam Beck #2

Sir Adam Beck #1

DeCew #2

Pump Generating Station

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Nanticoke Coal Fired Facility Ontario (proactive approach)

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Over time if left untreated

- **Transformer cooling water piping plugged at Ontario Hydro Power**

Water Cooled Transformer Piping

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Ontario Hydro Plant Unit Coolers

Dead Mussels Found in Unit Coolers

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Quagga Mussel Infestation at LCD Dams (Parker & Davis)

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Sampling Plates at Parker Dam
November 11/07 – 6 Weeks of Settlement

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Stainless Steel Pipe 11/07

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Underwater Photo – Trash Rack
Parker Dam - January 15, 2008

RECLAMATION

Underwater Photo – Domestic Water Intake Parker Dam - January 15, 2008

RECLAMATION

Underwater Photo – Domestic Water Intake Parker Dam - January 15, 2008

RECLAMATION

Underwater Photo – Domestic Water Intake Parker Dam

RECLAMATION

Underwater Photo – Domestic Water Intake
Parker Dam - February 21, 2008

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SPILLWAY GATES – PARKER DAM

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Davis Dam Penstock Gate Oct.07

RECLAMATION

Davis Dam Domestic Water Intake April 2008

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Quagga Mussel Findings and Recommendations for Hoover Dam

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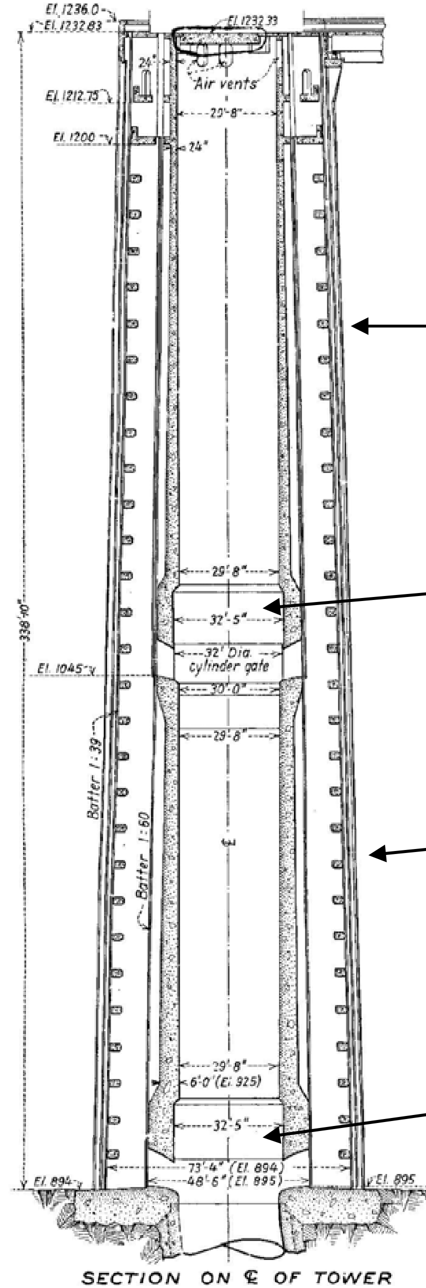

Elev 1111
Dec 2007 Lake
Mead Level

Elev 1045
66’

Elev 970
141’

Elev 894
217’

Elevation 1045, (66’ below water)

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Observations from inspection of external surfaces

- Mussels present in the intake towers at upper gate opening
- Decreasing settlement as depth increases
- Virtually no settlement at lower gate opening
- Inspection of the intake tower provided population vs. depth of settlement profile

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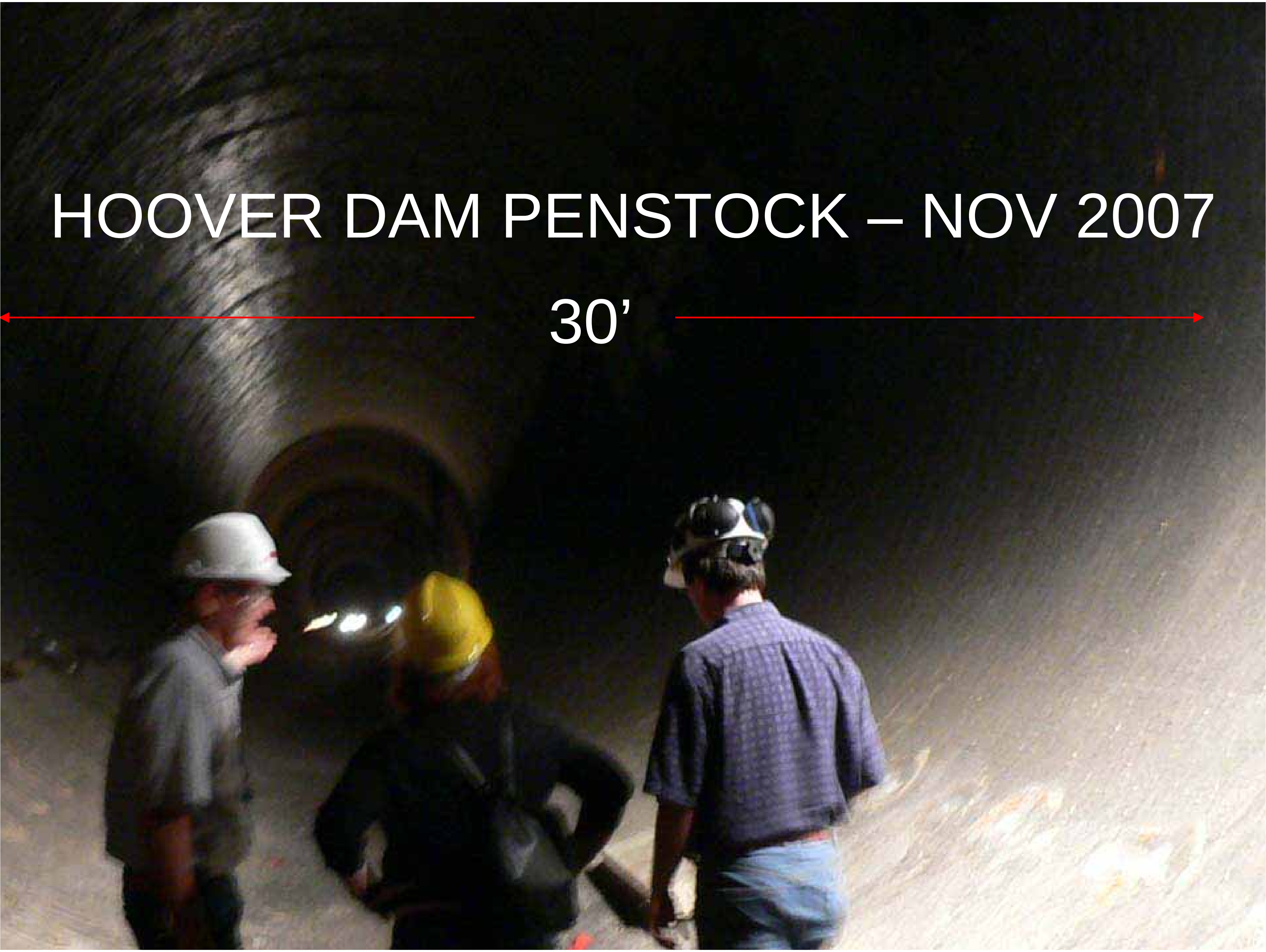
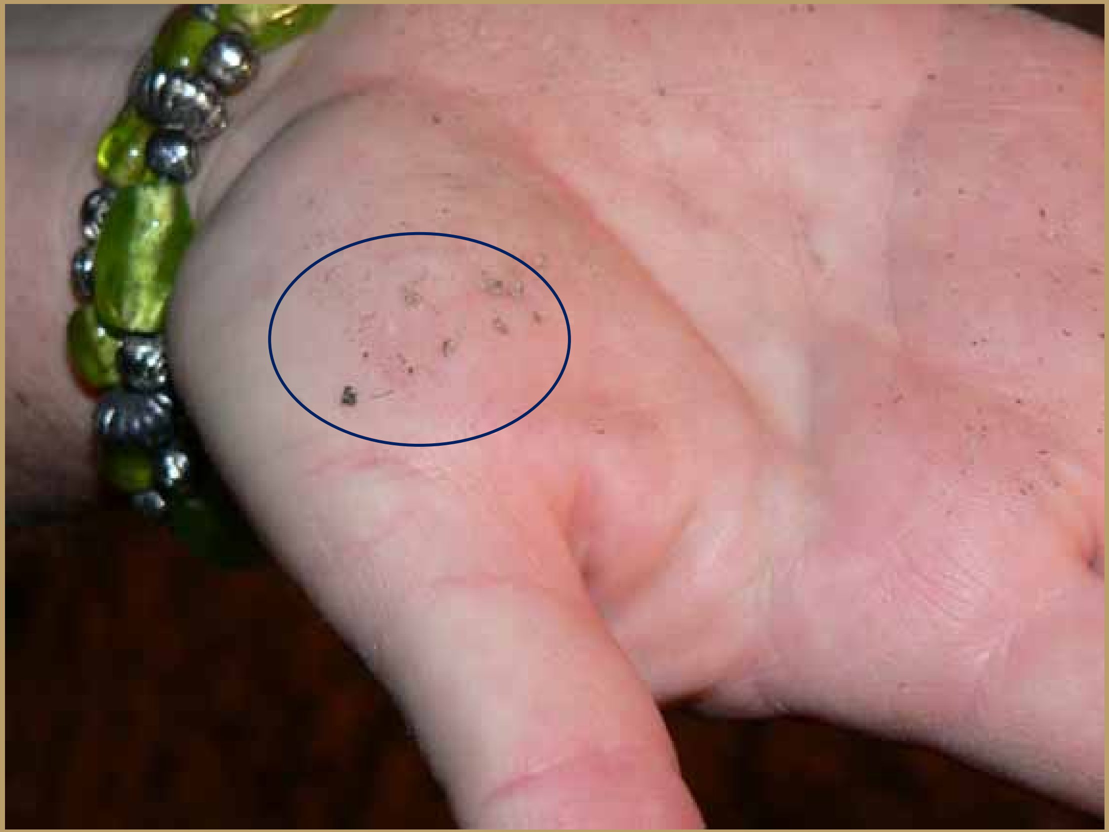

HOOVER DAM PENSTOCK – NOV 2007
30’

Observations from inspection of external surfaces

- Mussels were found in the lower penstock at depth of 217’



Observations from inspection of external surfaces

Uncertainty about the ultimate size of the mussel population, if in doubt, expect the worse scenario

Penstock drains may be plugged by shell debris and live shells in the future

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Observations from inspection of external surfaces

- Several size classes of mussels observed in the sample collected from the penstock, indicative of multiple spawning events
- Apparent new settlement present at the penstock, breeding is still on-going

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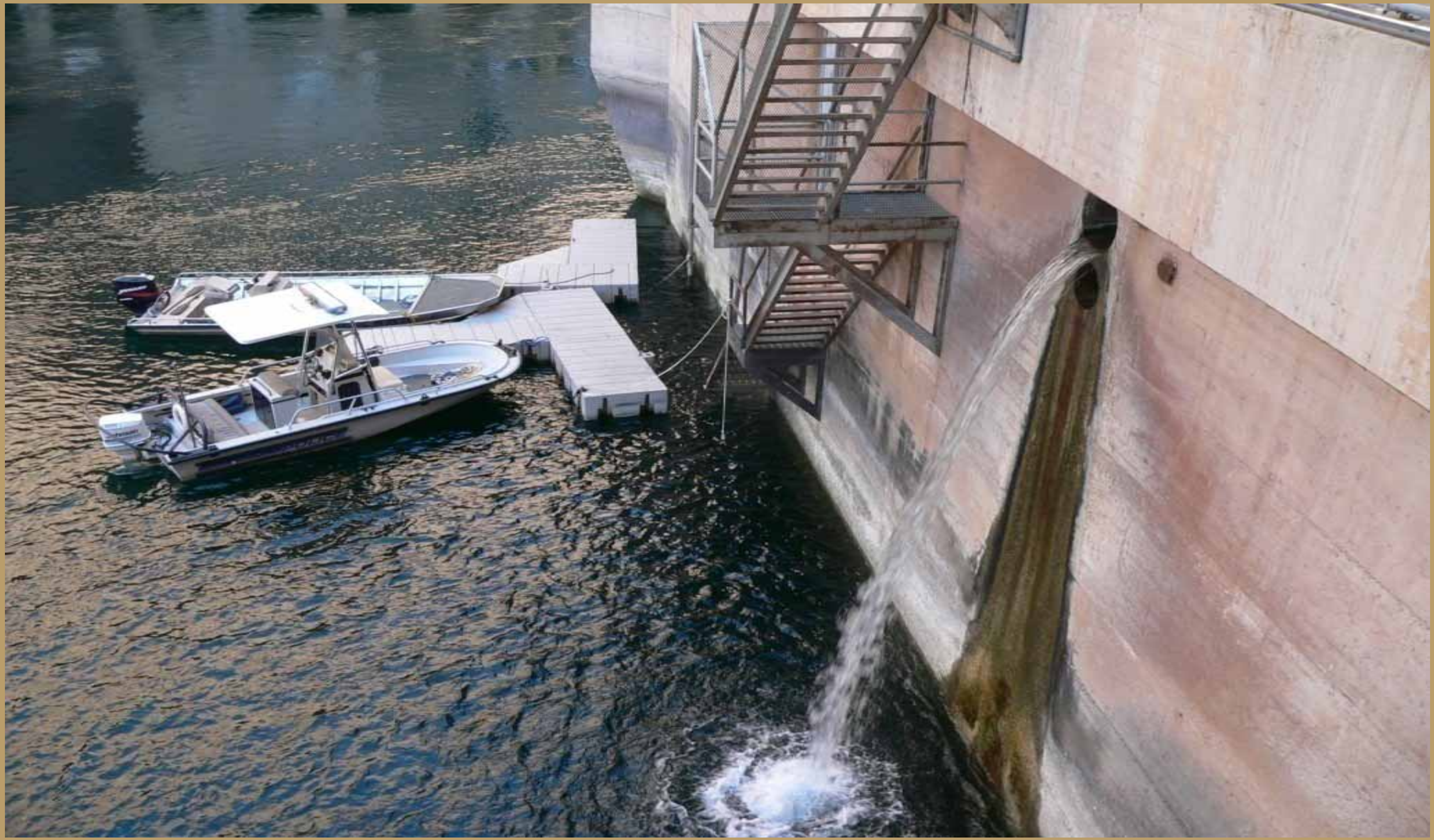
Observations from inspection of external surfaces

- Mussels are present in the tailrace area, apparently in much lower numbers



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Tail bay cooling water overflow

Mussel Confirmed Present

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Inside the Power House

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What have we observed in the power house

- **Some evidence of mussel presence inside plant raw water systems**
- **Potential for fouling by primary settling and from incoming shells**

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Cooling Water Take-Off

- All cooling water enters the plant through;

penstock take-offs (four take offs /penstock)

- There is no barrier to ingress of shells from penstock take offs

High Pressure Supply

And through tail bay suction via eductors

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HOOVER DAM COOLING WATER SUPPLY – APRIL 11, 2008

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Generator Air Cooler

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Inlet of generator air cooler

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What have we observed in the plant

- **The smallest diameter of cooling water piping 2”**
- **Equipment most likely to get plugged by live mussels; oil coolers (5/16 inch diameter tubes) and supply leading to local air conditioners**
- **Equipment most susceptible to plugging by dead shells from upstream, generator coolers. Unlikely live mussels will settle in generator coolers as they are made of copper**

Other Impacted Systems

(Source ACOE – ZMIS)

Piping	Circulating water systems	Service water systems
Traveling screens	Once through	Pumps
Water towers	Pumps	Piping
Trash racks	Piping	Raw water makeup
Trash bars	Condenser water boxes	Heat exchangers
Forebays	Condenser tubes	Emergency systems
Holding ponds	Fire protection systems	Area coolers
Storage tanks	Main pumps	Seal water systems
Wet wells	Jockey pumps	Strainers
Pump wells	Submerged pumps	Drag valves
Pump suction chambers	Intake structures	Makeup demineralizers
Lift pumps	Intake screens	Circulation systems
Pump bell housings	Intake tunnels	Emergency water systems
Screen wash systems		

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Components of Facilities

- Storage Reservoirs (Hydroelectric Power)
- Diversion Structures (Gravity or Pump)
- Conveyance Channels (Canals, Laterals)
- Fields
- Drains - Return to Waterway
- Sites Needing Special

Bouse Hills Pumping Plant, CAP

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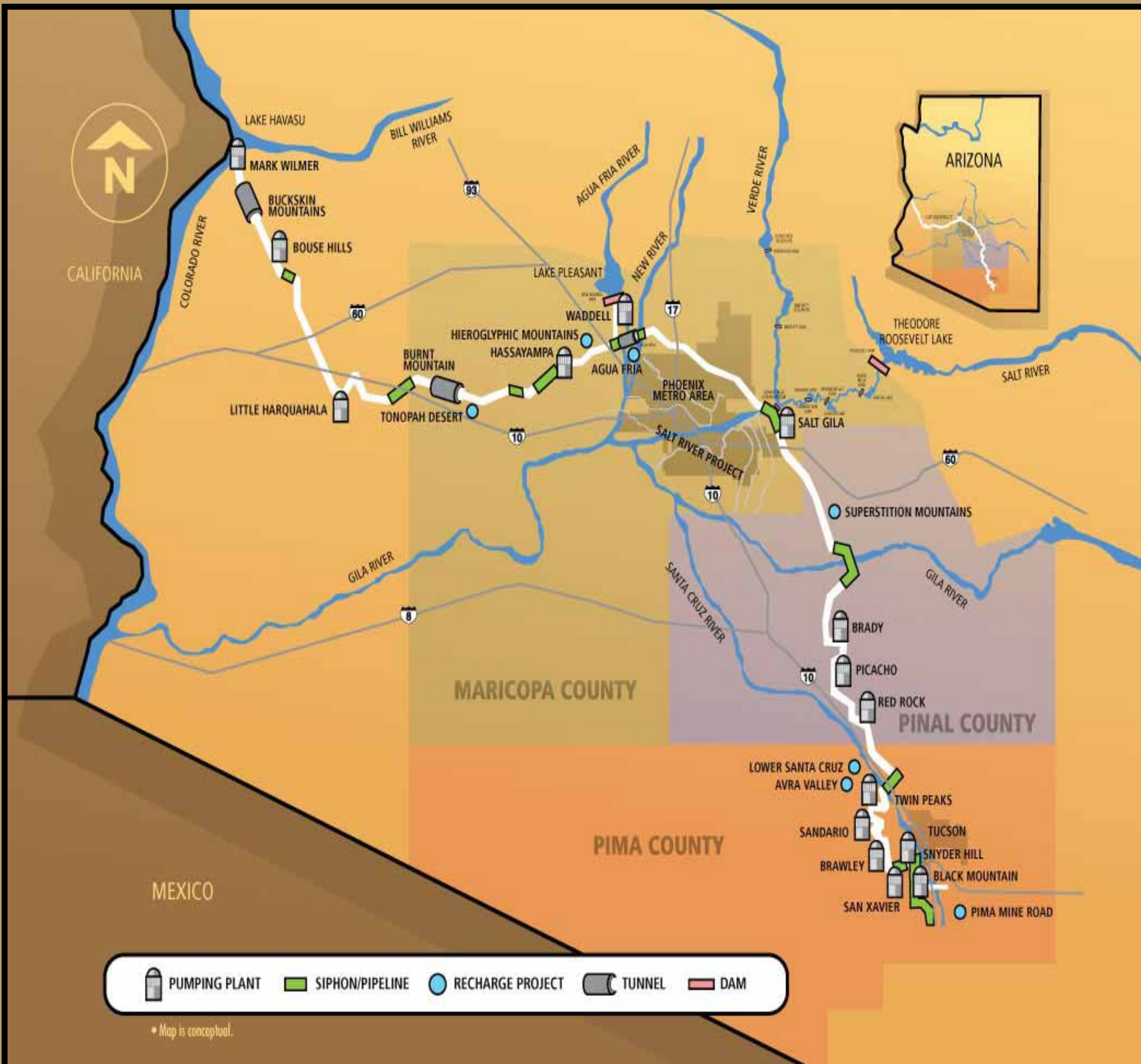
Central Arizona Project



Feature

- **Pumping Plants 15**
- **Tunnels 3**
- **Siphons 19**
- **Pipelines 3**
- **Aqueduct 340 miles**

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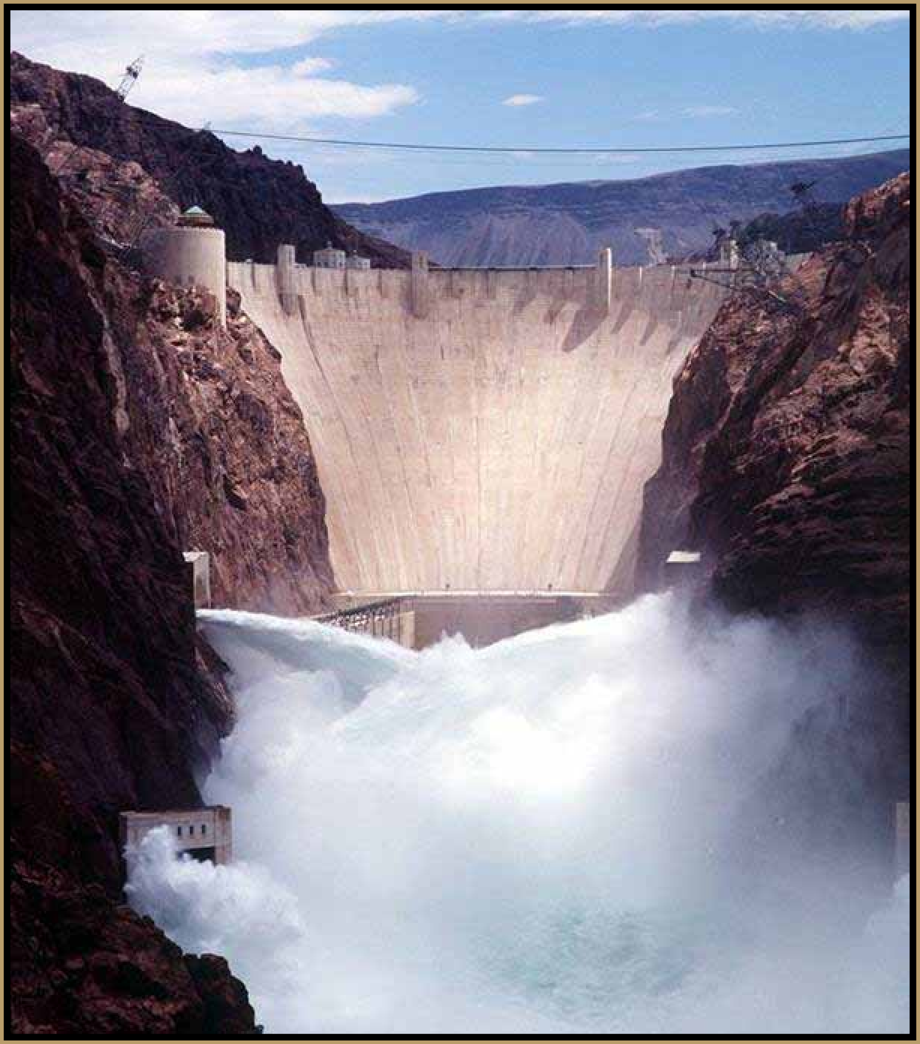
Storage Reservoirs (Hydroelectric Power)



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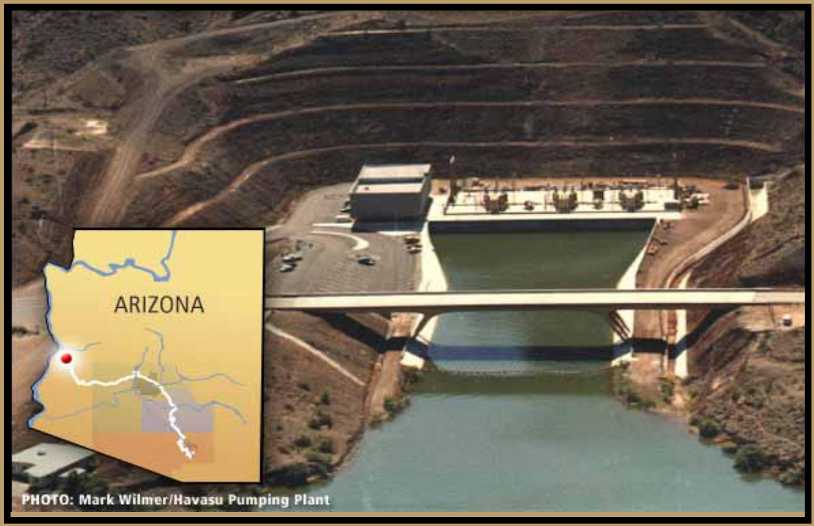
Diversion Structures (Gravity and Pumped)



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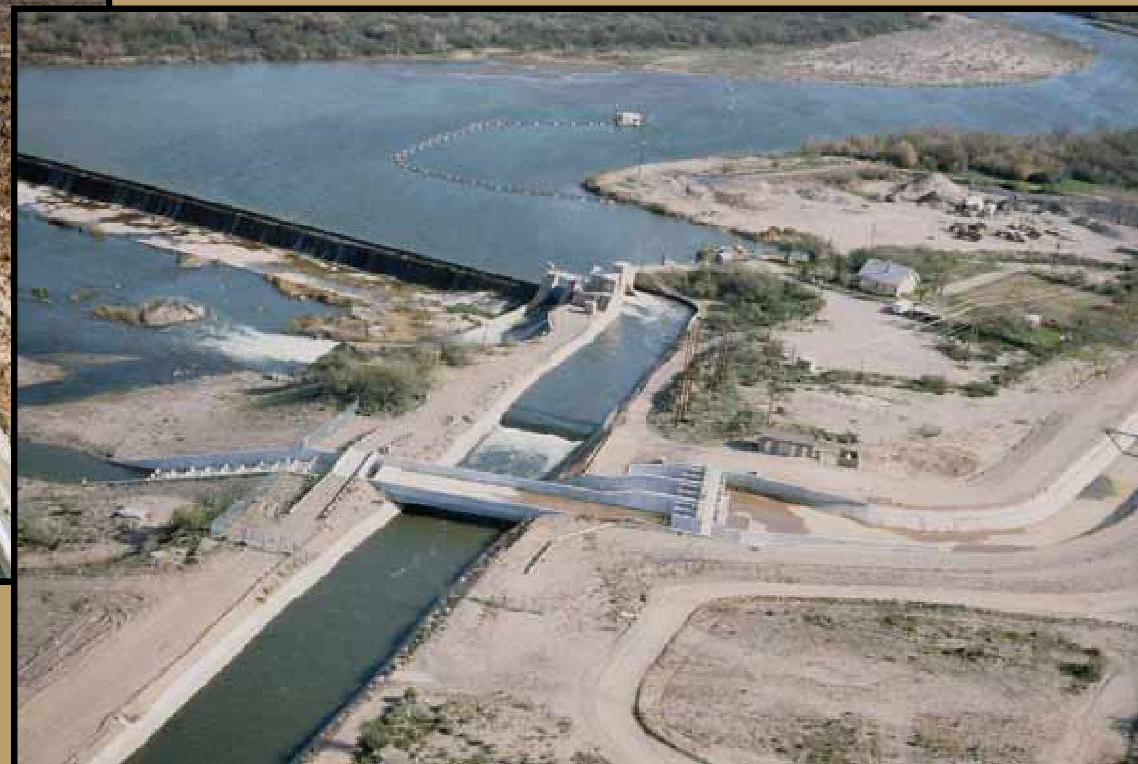
Conveyance Channels (Canals, Laterals)

Central Arizona Project – Hayden-Rhodes Aqueduct



Confluence of CAP and SRP Eastern Canal at Granite Reef Diversion Dam

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Conveyance Channels (Canals, Laterals), cont'd

Turnouts and Trash racks

Radial Gates

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Fields

Ditch with furrow siphons

Pipelines

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Drains - Return to Waterway

Main Drain, Palo Verde Irrigation District

Drain, Yuma Valley Irrigation District

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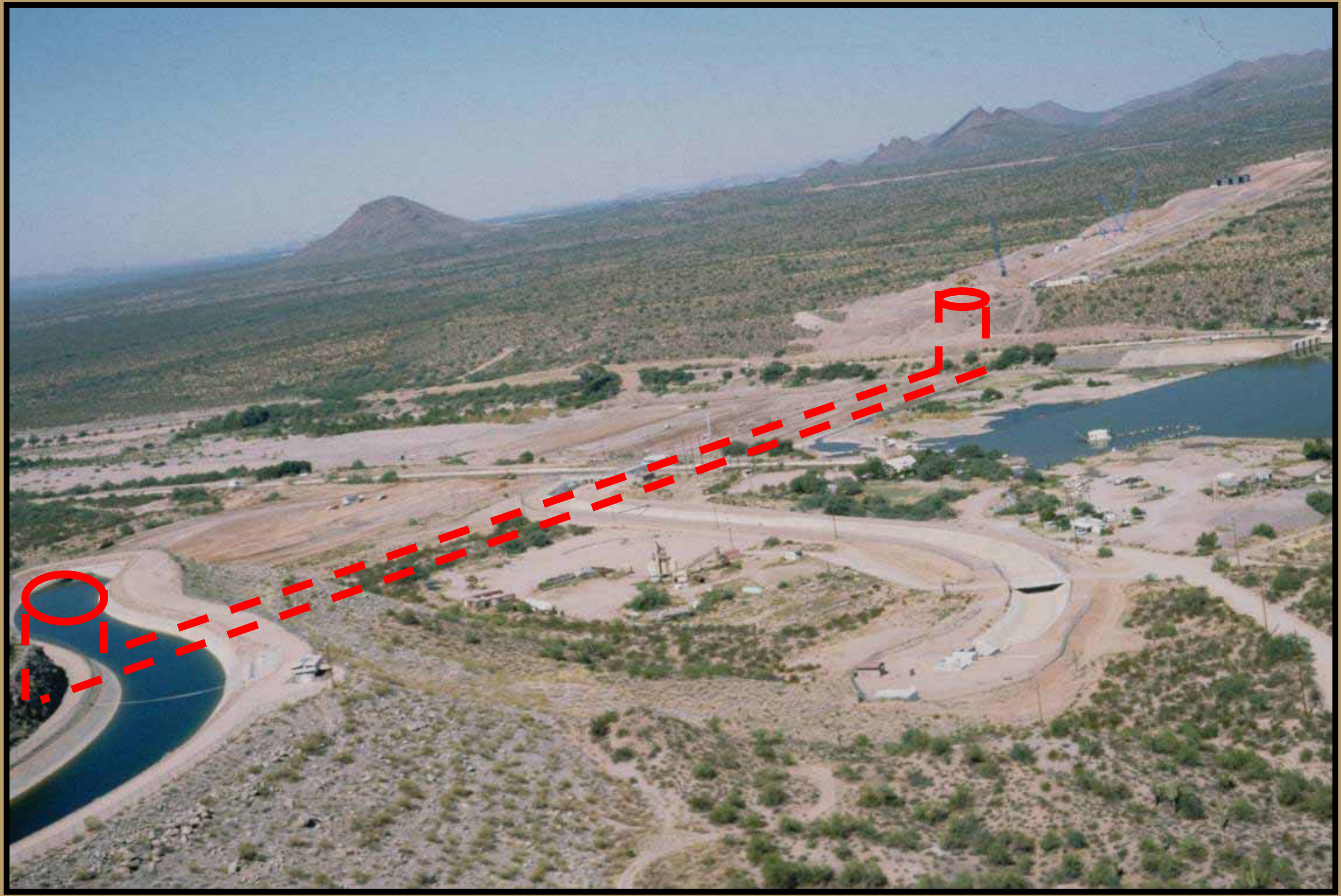
Sites Needing Special Consideration



Inverted Siphons – Salt River Siphon (CAP)

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Special Consideration, cont'd

Instrumentation

Fish Protection Facilities, PNR

What is recommended

Know thy enemy – monitor

Regular inspect and clean external structures as required

Set up monitoring plan

Implement control of incoming veligers and
of mussel shell debris in critical areas

Develop rapid response plan should mussel
infestation start to impact critical areas

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Monitoring, why and how

- Second year for Quagga mussels in the Colorado River system
- Great Lake experience useful but not necessarily accurate
- May see huge seasonal variations in population density, larval production, settling patterns in the West vs. East
- Bureau of Reclamation can’t make good decisions without better local data

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Monitoring – why

- Outside of the facilities

  - To determine when the breeding cycle starts, when settlement begins and ends

  - How many mussels will settle and grow in one year/cycle

  - How deep can mussels settle and grow

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Monitoring – why

- **Within the facility**

  To determine the level of infestation and if required, effectiveness of treatment

  - side stream samplers (Bio-Boxes)

  - temperature sensors on critical coolers in power plants

  - ROV inspections

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- **Monitoring – How?**

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Plankton Tows

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Plankton tows

- Quick and easy way to establish presence or absence of veligers at the beginning and end of the breeding season. Take large samples, process by “density separation” using sugar solution method

- Can be used to do actual veliger counts in the incoming water, tedious and offers limited information for the plant

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CONTINUE MONITORING USING SETTLING PLATES

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Recommendation

- Use the same settlement substrate material at all facilities
- Same dimensions
- At the same depth (10ft, 20….down to maximum depth)
- Examine the plates at the same time interval and in the same manner
- Multiple strings of sampling plates upstream and down

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Recommendation

- Install at least one side stream sampler, two if possible
- One at the front of the system, one near the end would be ideal
- Recommended flow-through 5 gpm (20L/min)
- Settlement plates within the sampler should be the same material as outside settling plates

Davis Dam Bio-Box

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Bio-Box Spiked with Live Mussels

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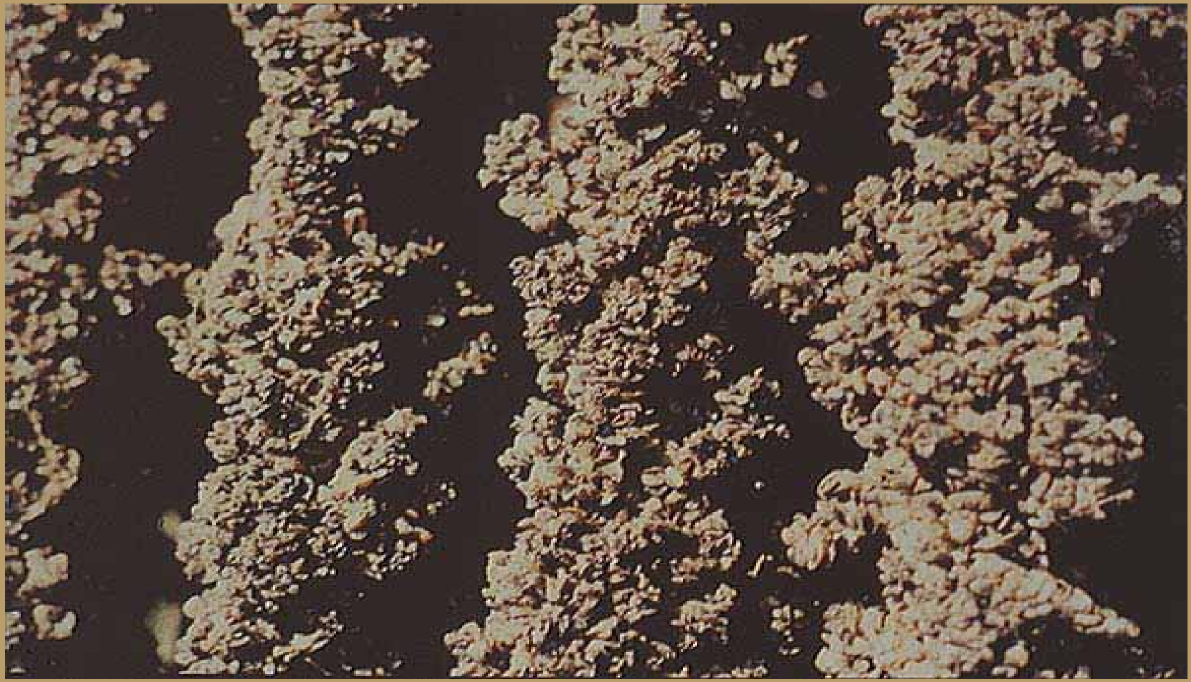
Mussel Control

- Develop rapid response plan to immediate threat
- Decide on long term strategy
- Implement



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Control Options Myth

- All facilities can use the same control options in the same way
- Engineering staff has all the knowledge required to design a perfect control system
- Technology vendors and Service providers do not have their own agenda

So……Buyer beware

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Fact – Every Facility is unique Evaluate before you decide on a strategy

- Strategy may be:
  - Do nothing, react only when disaster is imminent
  - Implement planned treatments at regular intervals
  - Prevent as many mussels as possible from entering the plant, alive or dead

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Facility Evaluations

- As a team decide what level of infestation is tolerable in the various parts of your system
- If there is a danger of blockage by primary settlement or shell debris, what are the consequences of such a blockage (safety and economic)
- What will your customer/regulator/insurer/ fire marshall say about mussel presence in various systems and the risks they may pose?
- What will your regulator say about your treatment of choice? Can permits be obtained in time?
- What is your operational preference?

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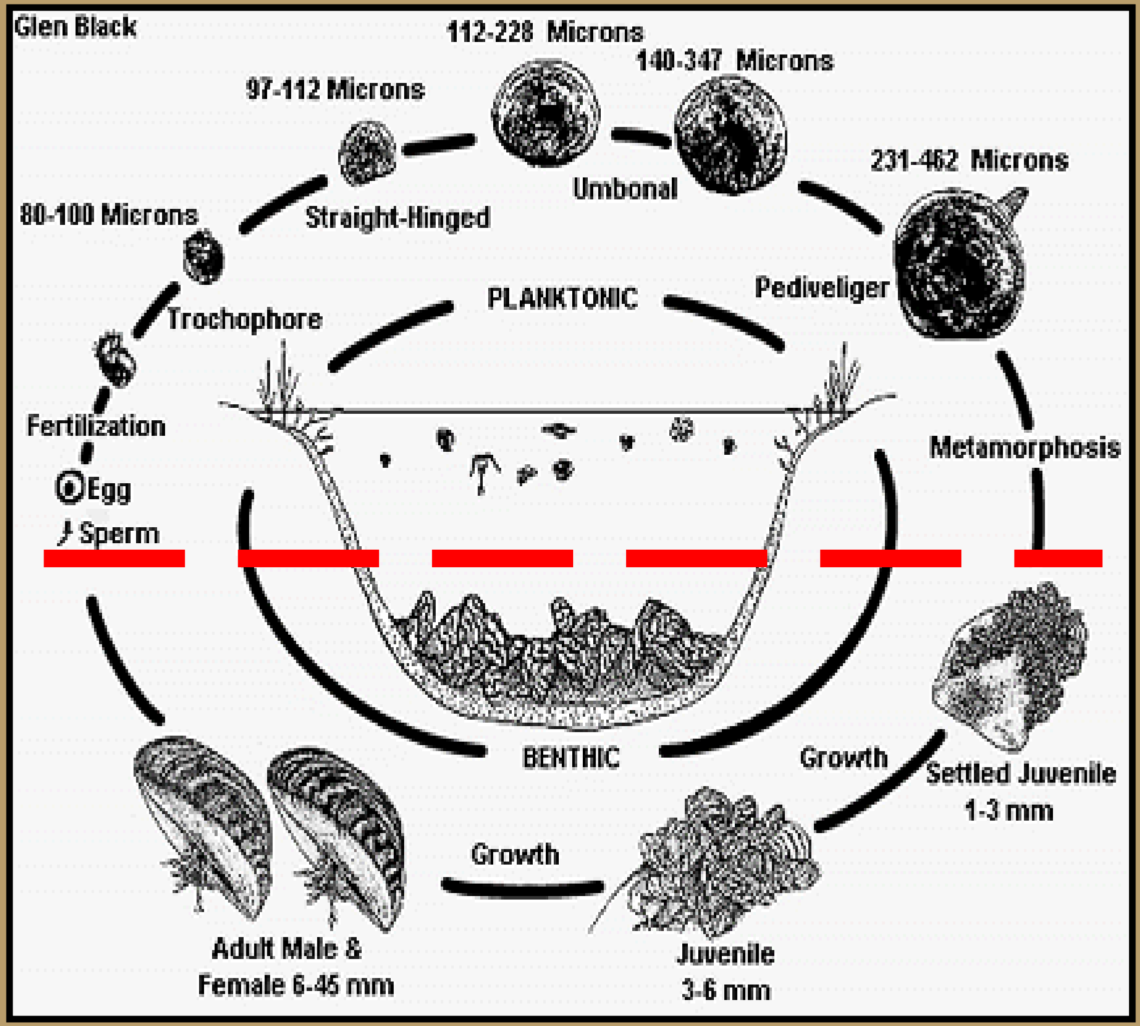
Control Strategies

- Proactive
  - Preventive measures
  - Does <u>not</u> allow growth of mussels in the system or on the surface protected
- Reactive
  - “Clean” after establishing
  - Can be labor intensive
  - <u>Does</u> allow mussels to grow in the system or on the surface. Established populations have to be eliminated periodically

----

- Redesign
  - Retrofit



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Options for External Structures*

***Structures That Are in Direct Contact With the External Environment; No Isolation Is Possible**

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Reactive Options for External Structures

Mechanical Cleaning

- de-water and use powerwash (104 F preferred)
- underwater, scrape and vacuum or powerwash

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Proactive Options for External Structures

Antifouling Coating - for both steel and concrete

- **Toxic, copper based coatings**

Foul Release Coating

- **Non-toxic, silicone based**

Life-span 5-7 years before topcoat needs to be refreshed

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Substrate Preference
(Decreasing from Top to Bottom)

- Copper
- Galvanized Iron
- Aluminum
- Acrylic
- PVC
- Teflon
- Vinyl
- Pressure Treated Wood
- Black Steel
- Polypropylene
- Asbestos
- Stainless Steel

Kerr Lock and Dam (COE), Tulsa OK

Source - Kilgour and Mackie, 1993

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Options for Internal Piping Systems

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Reactive Options for Internal Piping Systems

- **Thermal Wash - 32ºC for 48 hours (90º F)**
  40ºC for 1 hour (104º F)

- **Mechanical Cleaning such as**
  - scrape large diameter pipes
  - use expanding air bubbles ?? or remote vehicle tools on difficult areas

- **Flushing with weak acids**

- **Oxygen Deprivation**

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Reactive Options for Internal Piping Systems (Cont)

- **Periodic (once or twice/year) application of**

  - Non-oxidizing chemicals

  - Oxidizing chemical

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Oxidizing Chemical Treatment

- Chlorine
- Bromine
- Chlorine dioxide
- Chloramines
- Ozone
- Potassium permanganate

Chlorine tankers used at Metropolitan Water District of Southern California at Copper Basin for Mussel Control – Lake Havasu

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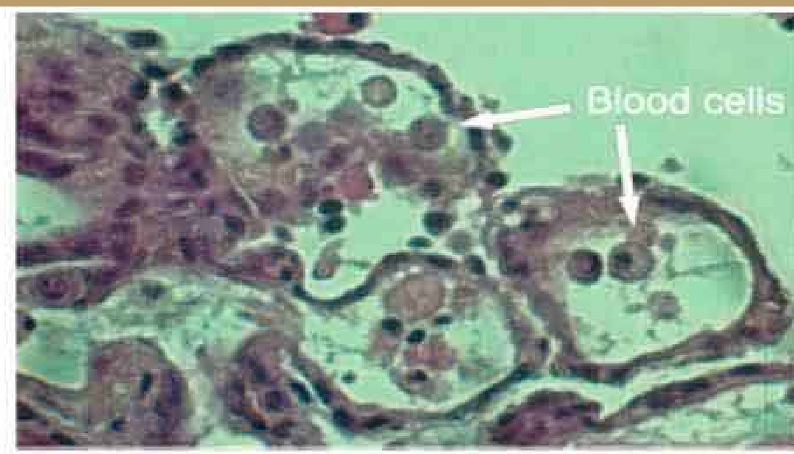
Emerging Options

- **Bacterial product (Marrone Organic Innovations), zebra mussel specific chemical….being tested on Quagga now**

How does it work?

The bacteria produce natural compounds that kill the mussels when ingested. It destroys the mussels' digestive system.

In healthy mussels, epithelial cells (arrows) appear as a thick layer lining the tubules of the digestive gland.



Following bacterial treatment, epithelial cells are destroyed. Blood cells are abundant as the digestive gland hemorrhages.

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Proactive Options for Internal Piping Systems

- Sand/media filtration - has to remove all particles greater than 40 micron

- Mechanical filtration - has to remove all particles greater than 40 micron

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Example of Self Cleaning Filters

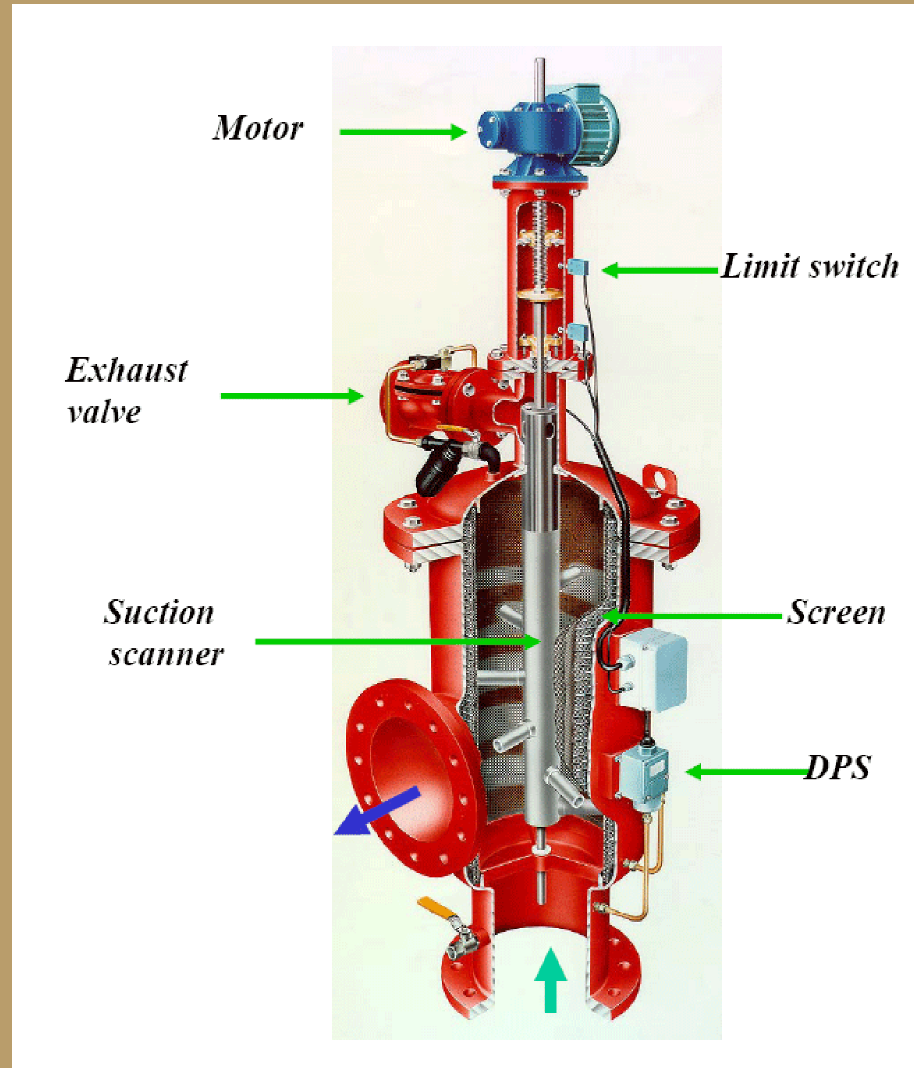

Figure 7: Automatic Self-cleaning Filter

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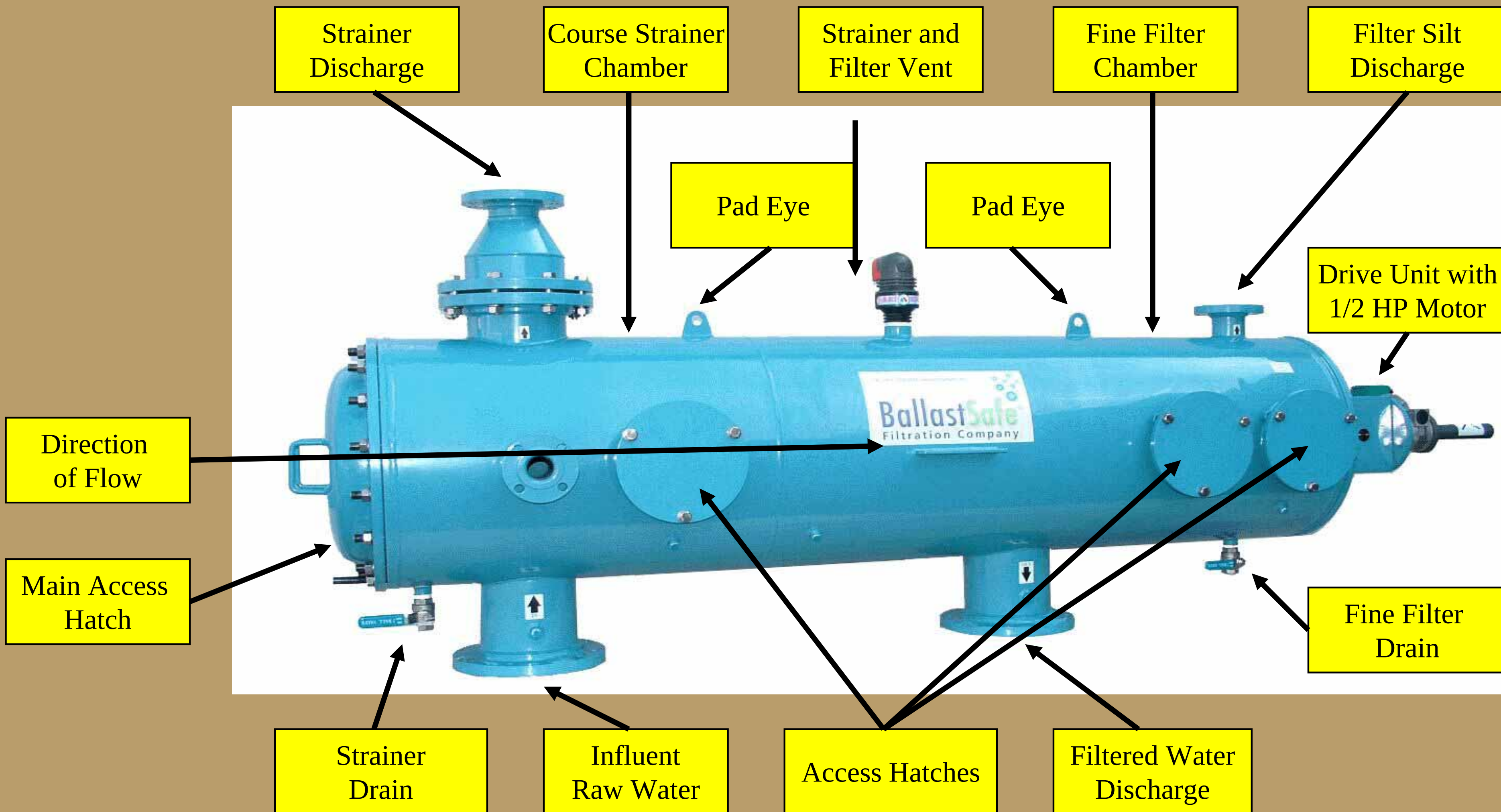
25 to 50 MICRON SELF CLEANING FILTER



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Mesh Requirements

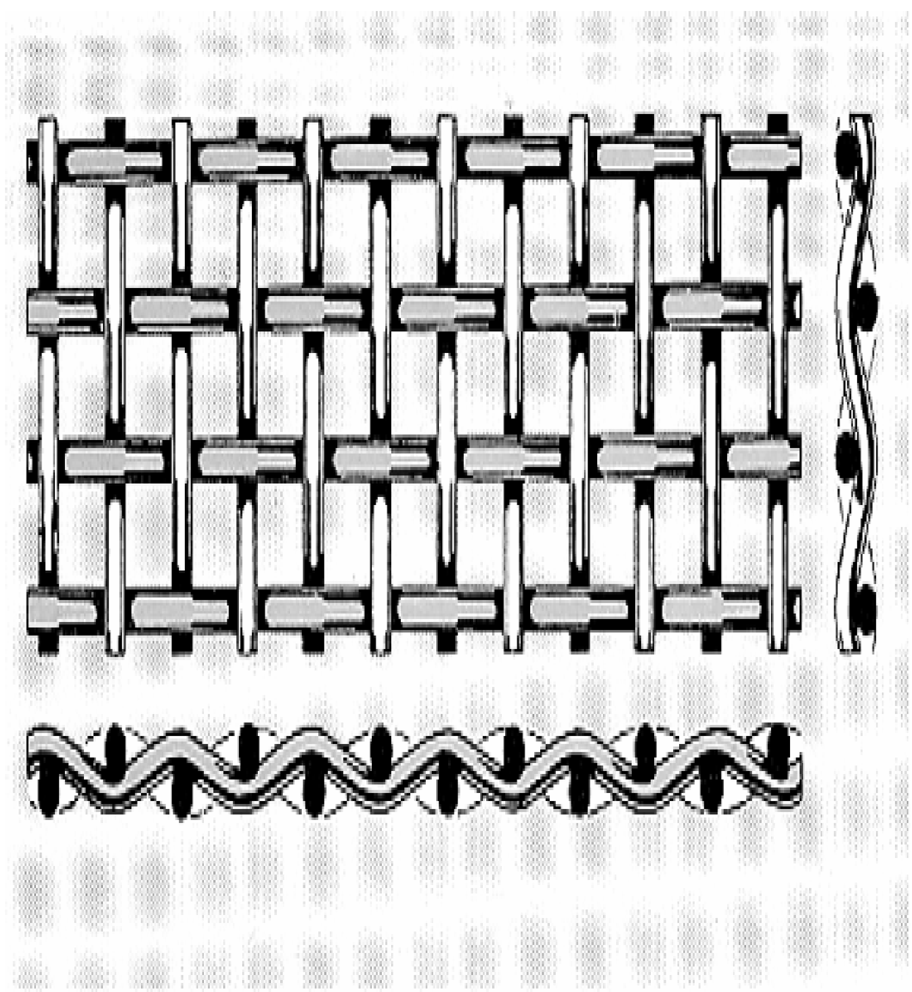

Figure 2: Square Weave

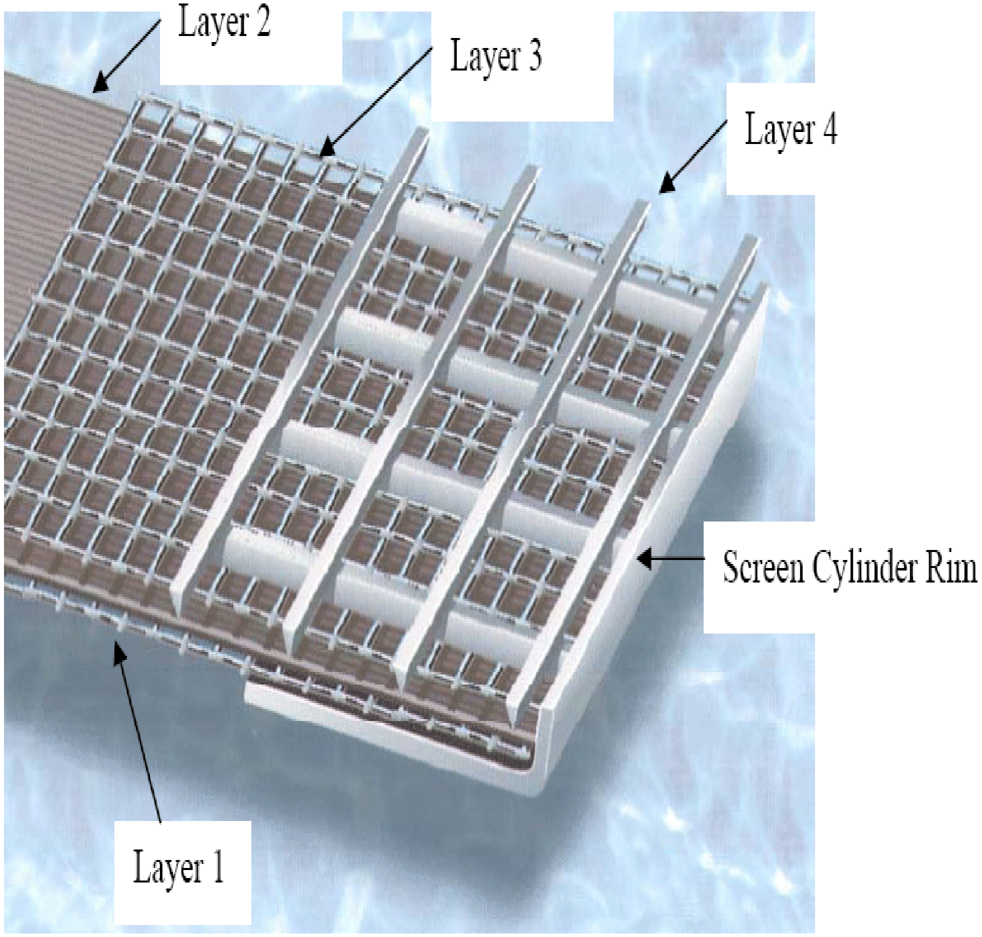

Figure 4: Patented Four-layer Screen

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Additional Proactive Options for Internal Piping Systems

- **Strainers with 1/8” screens followed by UV systems**
- **Closed Loop Cooling**
- **Oxidizing chemicals**
- **Non-Oxidizing chemicals**

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Duplex Strainer

Closed-pipe UV system

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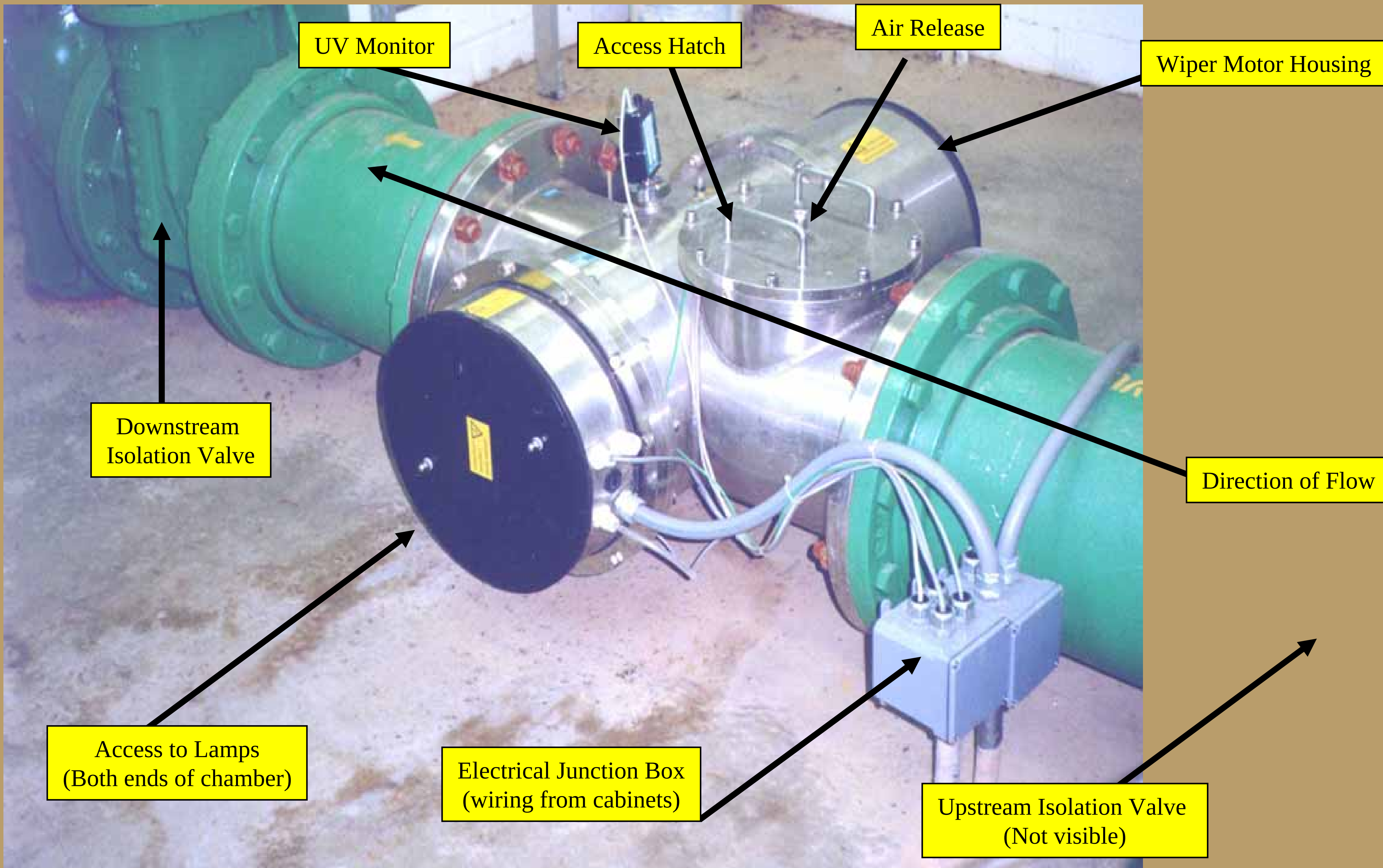
In Line Pipeline UV Installation



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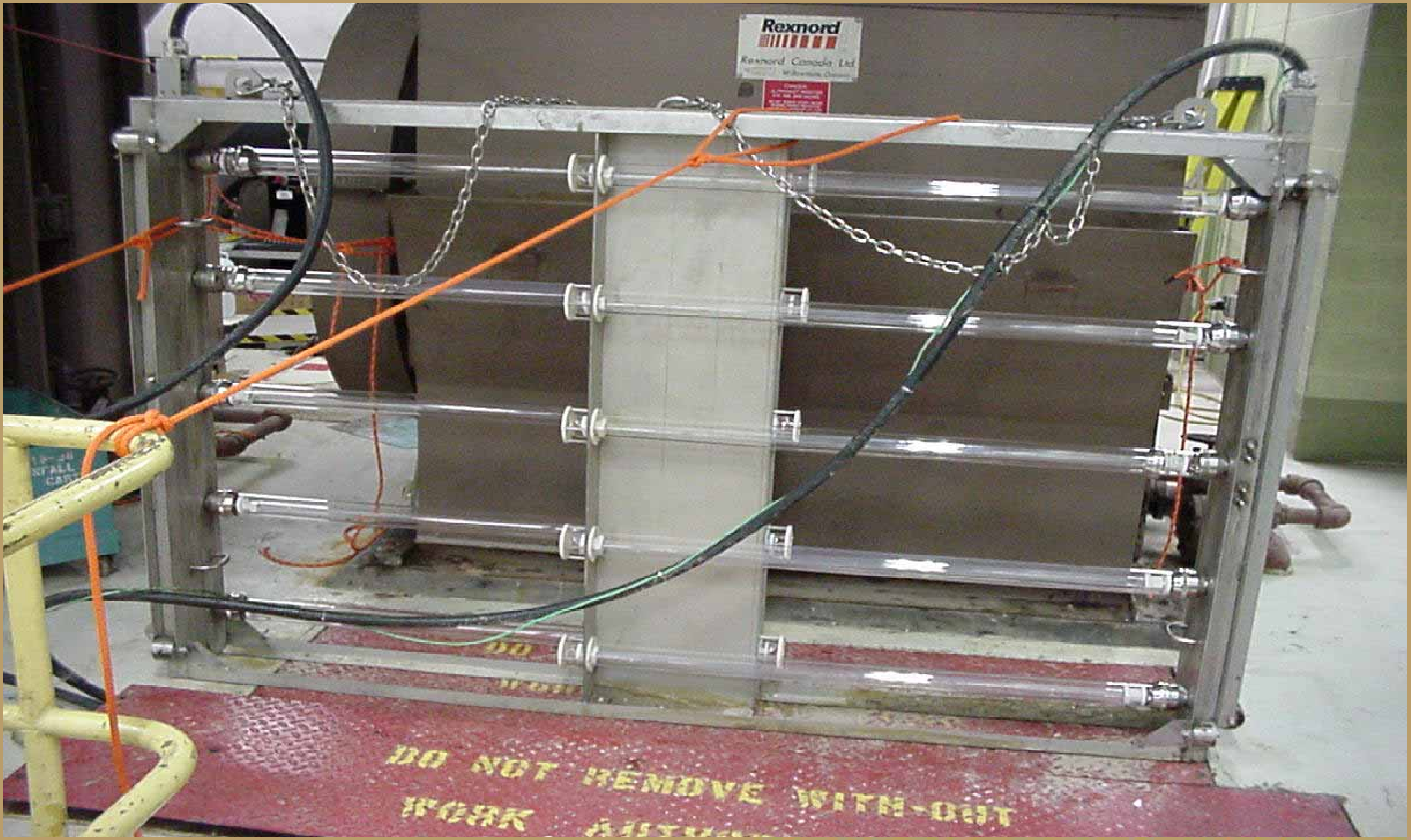
UV Light Bank for Open Channel



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Proactive Use of Oxidizing Chemicals for Protection of Internal Piping Systems

Low levels of the chemical are added continuously or semi-continuously throughout the mussel breeding season to prevent settling by creating a hostile environment.

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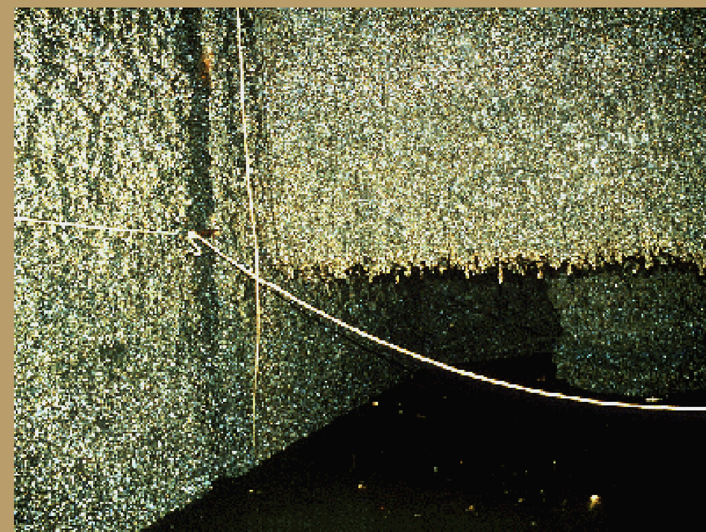
Other Options for Effective Control

- Oxygen Deprivation
- Temperature Treatments
- Exposure and Dry up
- Manual Scraping
- High-pressure Jetting
- Passive and Barrier Filtration
- Removable Substrates
- Chemicals or Molluscicides
- Electric Currents
- Sonic Vibration
- Natural Predators or Biological Controls



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Initial Suggestions for Control

- **Rapid Response Option (if settlement and shell transport increases dramatically and suddenly):**

  – **Install portable chlorine**
  skids to protect critical areas

Use thermal treatment where possible

– **Use weak acids to dissolve shells and corrosion products**

– **Mechanical cleaning as system performance deteriorates**

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Control and Mitigation Ideas

Use 50 micron self cleaning filters instead of strainers.

– **Protects all downstream equipment**

– **Coarse pre-straining may still be required**

– **Does not require NPDES Permitting**

– **Environmental Friendly**

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Control and Mitigation Ideas

Chemical Injection

- Periodic or Continuous approach
- Requires approval of Regulator
- Multiple injection points required
- May require detoxification before discharge

- Risk – Shell material can still enter, strainers may still be required

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Path Forward

- Implement monitoring immediately ie; settling plates, bio-boxes, and develop contingency plan
- Team made up of stakeholders does a detailed engineering evaluation of systems at risk vs. mitigation options
- Team agrees on the acceptable risks and selects mitigation options best suited to achieve control within the risk criteria

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Summary

- Current Situation –
  - Still learning characteristics of the mussel in this environment
- Monitor and measure to: detect presence, understand the mussel breeding and growth cycle, determine risk areas in plant and develop response
- Engineering evaluation of possible control options to establish feasibility vs. operational preference vs. risk
- The actual choice of treatment will be based on a combination of regulatory, economic and operational considerations

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CONCLUSION

- There is no silver bullet !
- The mussels are adaptive and continue to surprise…..No one has a crystal ball!
- Site specific integration of control strategies and continuous vigilance is required.

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Cost for Mussel Control

- **Ontario Hydro Experience**

  Average cost per MW = $1020/MW (Capital Costs)

  Average Annual Operating Cost = $50/MW

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Quagga Mussel Point of Contact and Consultant

- **Bureau of Reclamation – Hoover Dam Engineering**
  Mr. Leonard Willett, Water Treatment Manager
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- **Contracted with RNT Consulting Inc.**
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Managing Water in the West

QUESTIONS

U.S. Department of the Interior
Bureau of Reclamation