Pend Oreille River Temperature TMDL Boundary Reach

Discussion of Key Technical Issues
Seattle City Light

- Lag Time / Frequency Analysis
- Use of Volume/Flow Weighted Averages
- Use of Heat Wasteloads for Dams

Monday, May 12, 2008
Spokane, WA

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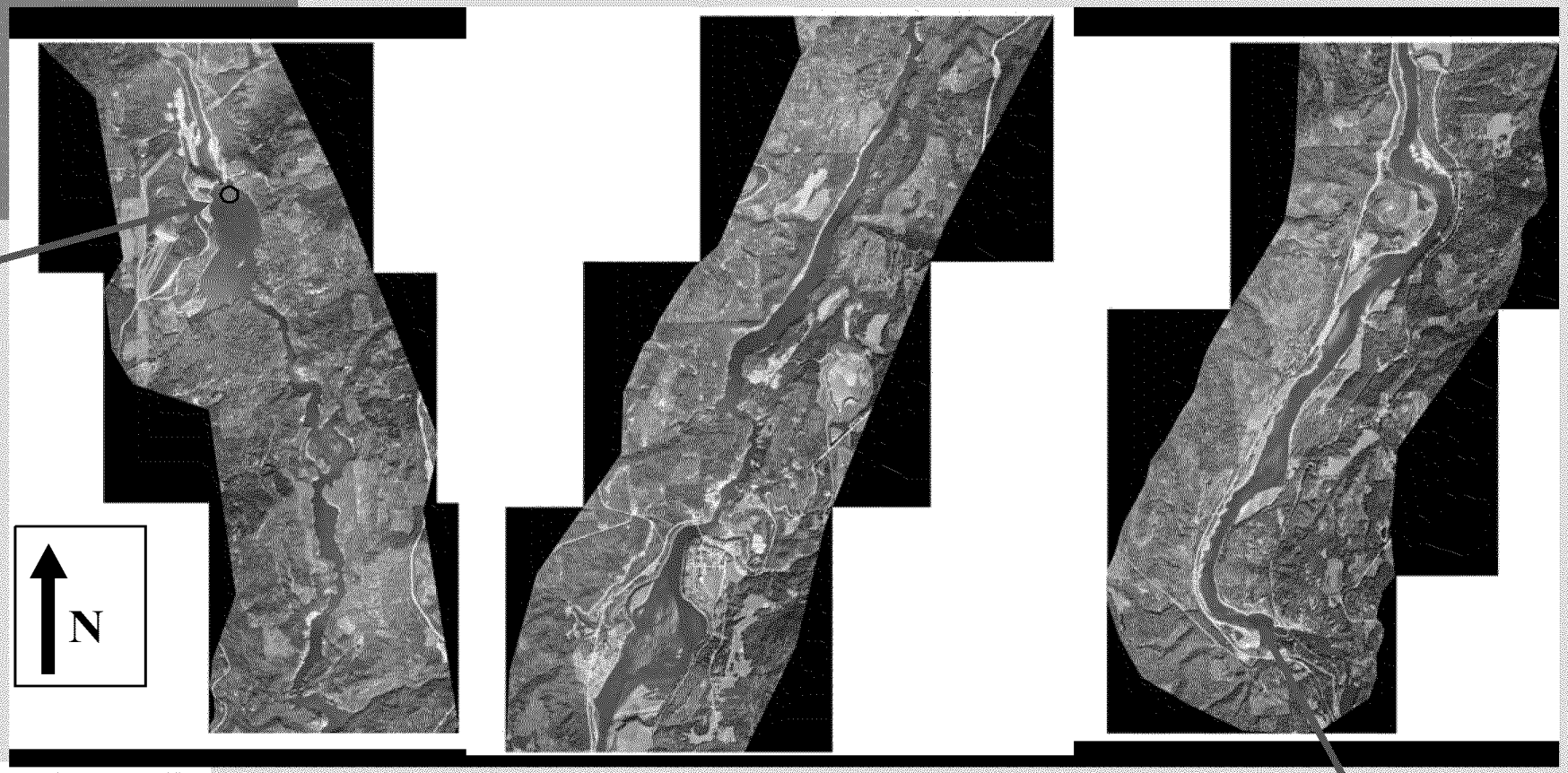
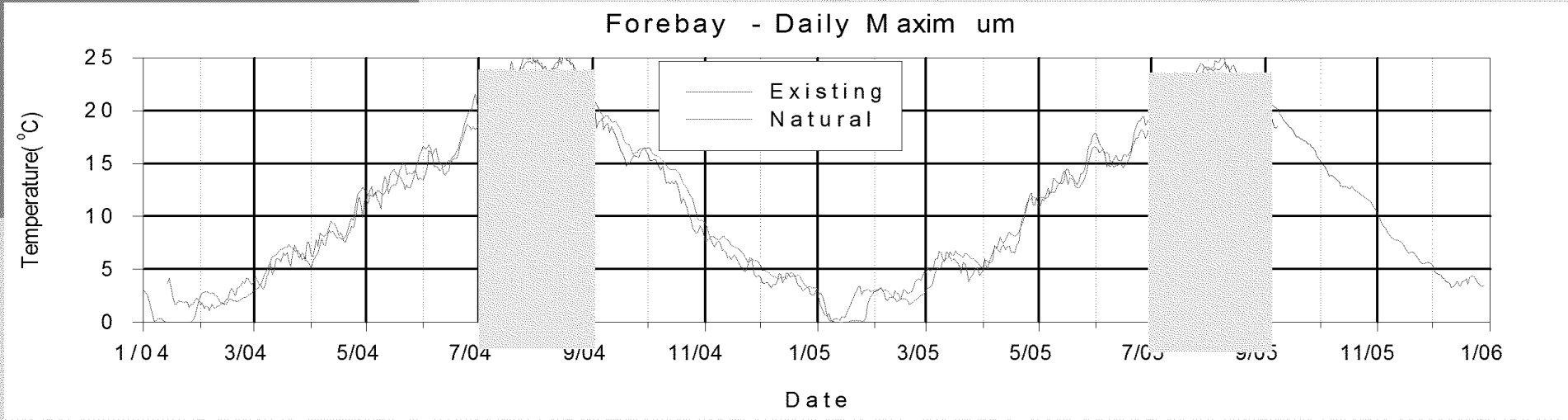
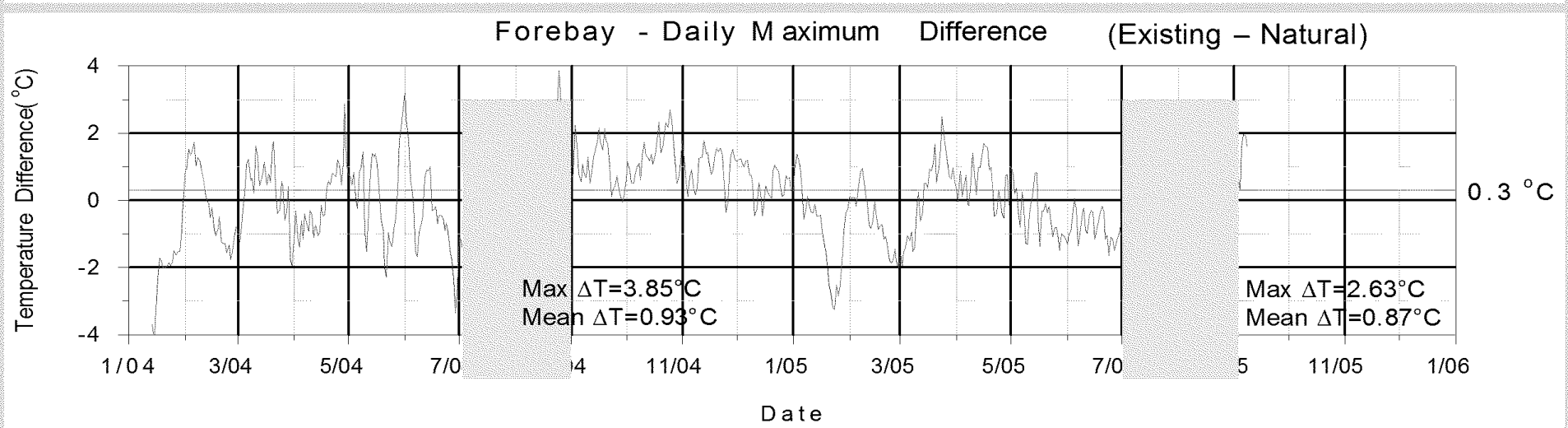
Boundary Reservoir Study Area



Daily Maximum Temperatures Forebay of Boundary Dam

Existing and Natural (No Dams) – Surface Temperatures





- Existing and Natural conditions are very similar even at peaks
- Differences occur as the temperature rise or drop
- Differences are both higher and lower than natural

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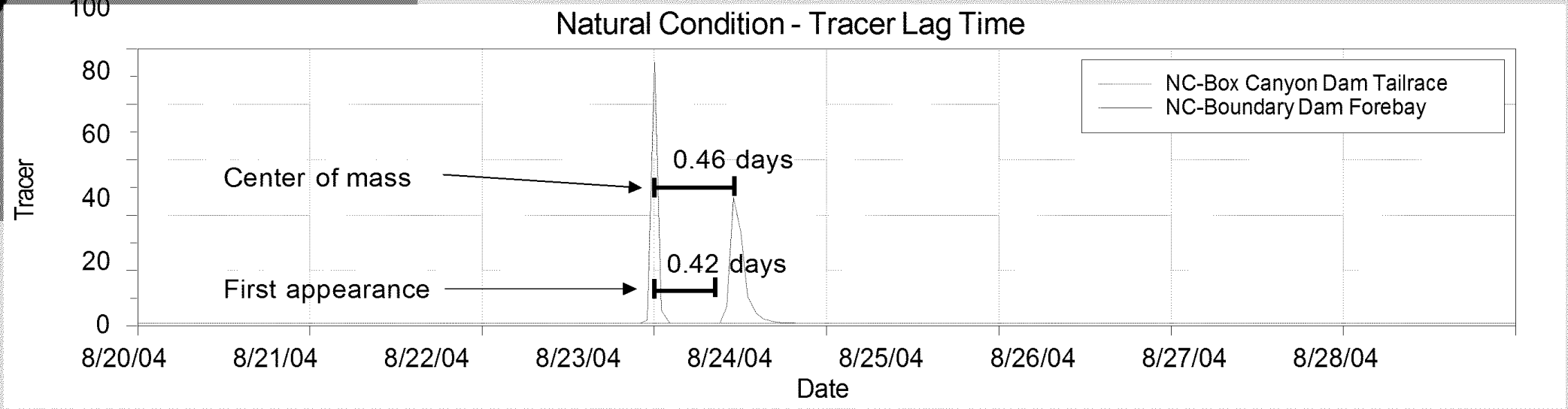
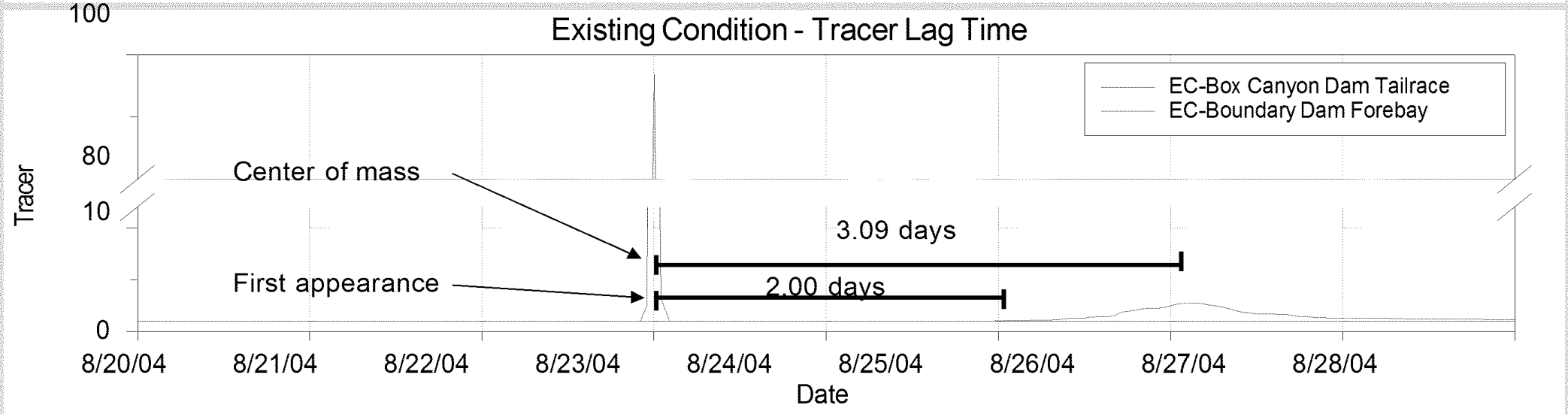
Travel Time - Lag through Boundary Reservoir Reach





™Time of travel is shorter for Natural Conditions (NC) ≈ 0.5 days
™Time of travel for Existing Condition (EC) ≈ 3 days

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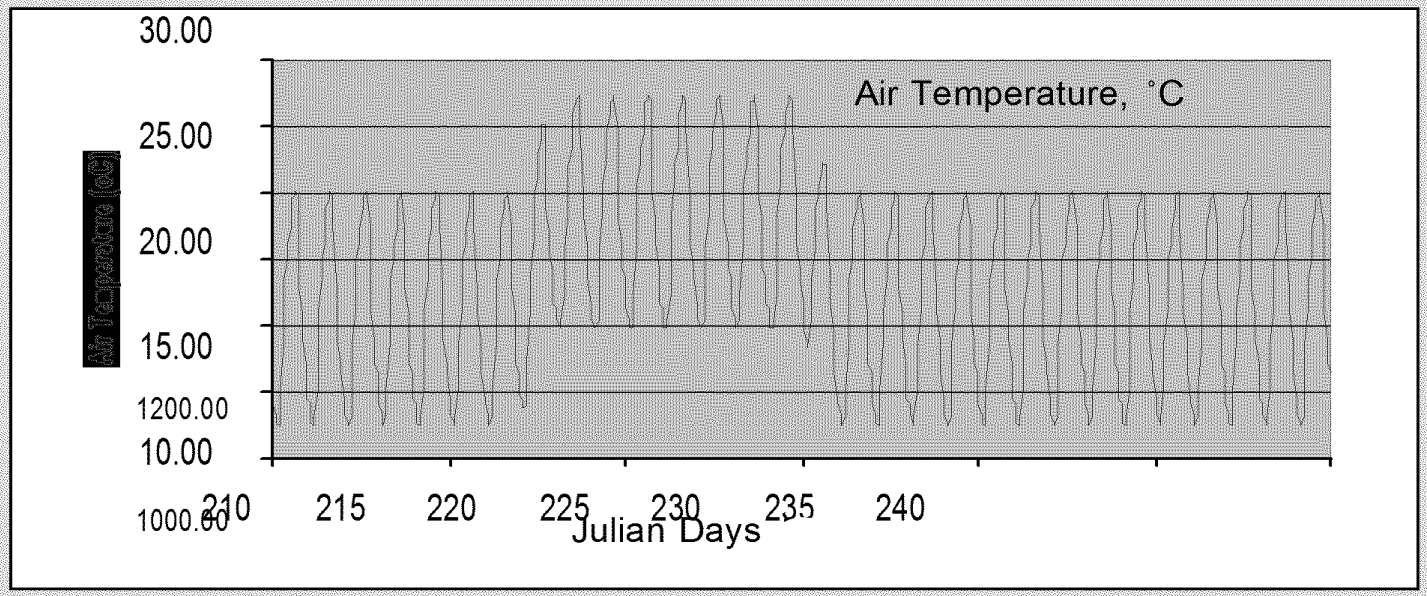
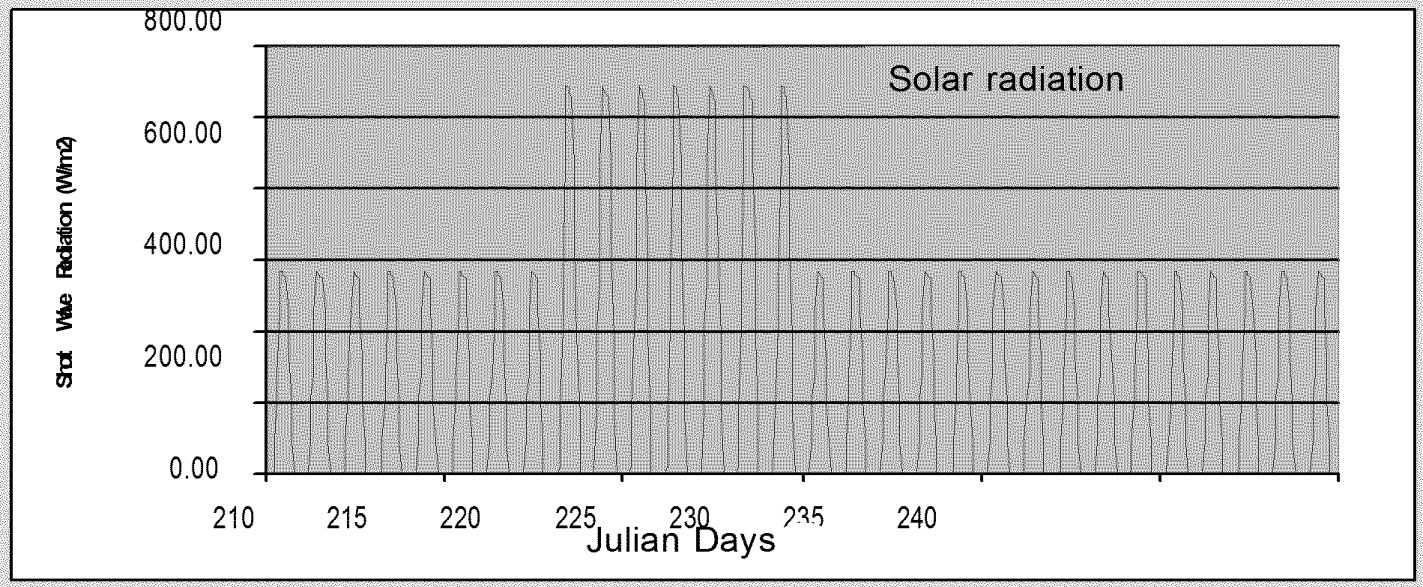
Thermal Inertia Induced Lag Boundary Reservoir Heat Wave or Cold Front Effect

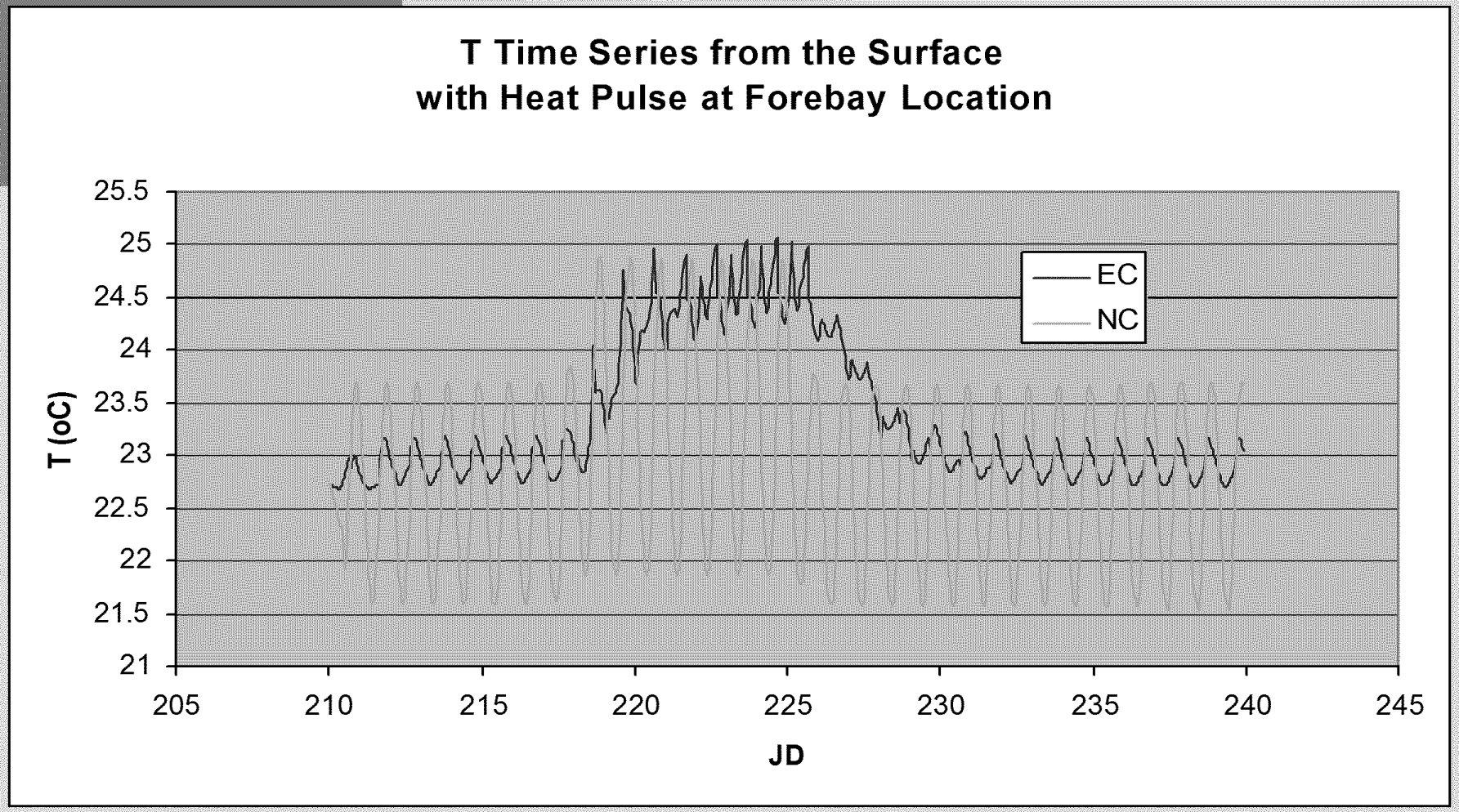
Model setup

- 30-day simulation period
- Increased atmospheric heat exchange for 7 days
  - Day 1-7: normal
  - Day 9-15: heat wave
  - Day 17-30: normal
- Box Canyon temperatures
  - EC – average of NC
  - NC – no dams upstream
- Tributaries set to zero flow





Boundary Reservoir Heat Pulse Thermal Lag Demonstration ≈ 4-5 days



™EC = Existing Condition (temperature response with dams ≈ 5 days)
™NC = Natural Condition (temperature response < 1day)
Existing temperatures with dams are slower to respond and results in a lag (Thermal Inertia)

Overall Lag Time Effect on Temperature Assessment

Travel Time lag (around 8/24/2004)

- ≈ 2.5 days

Thermal Inertia lag

- ≈ 4-5 days

This affects Assessment of Impairment

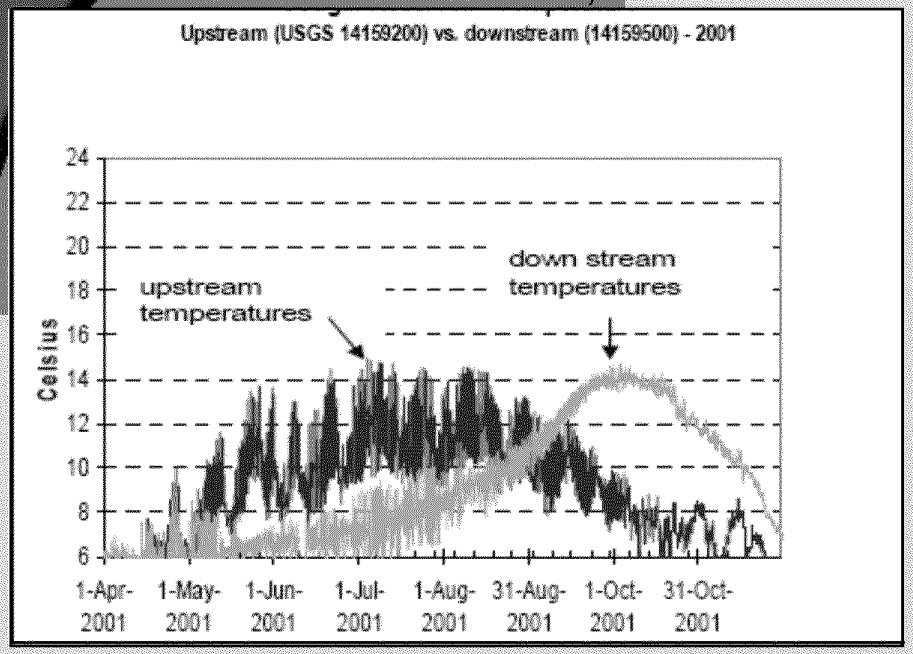
- *Is this real Impairment?*
  - Sustained river temperatures (higher than fish tolerance)
  - Added external heat (point sources, and tributaries)
    - not redistribution of existing heat

    or
- *Is this Apparent Impairment?*
  - One-day comparisons with Natural Conditions
    - Parcels of water at forebay are not the same (lagrangian fish)
  - "Impairment" attributed due to lag (travel time and thermal inertia) with respect to simulated natural temperature

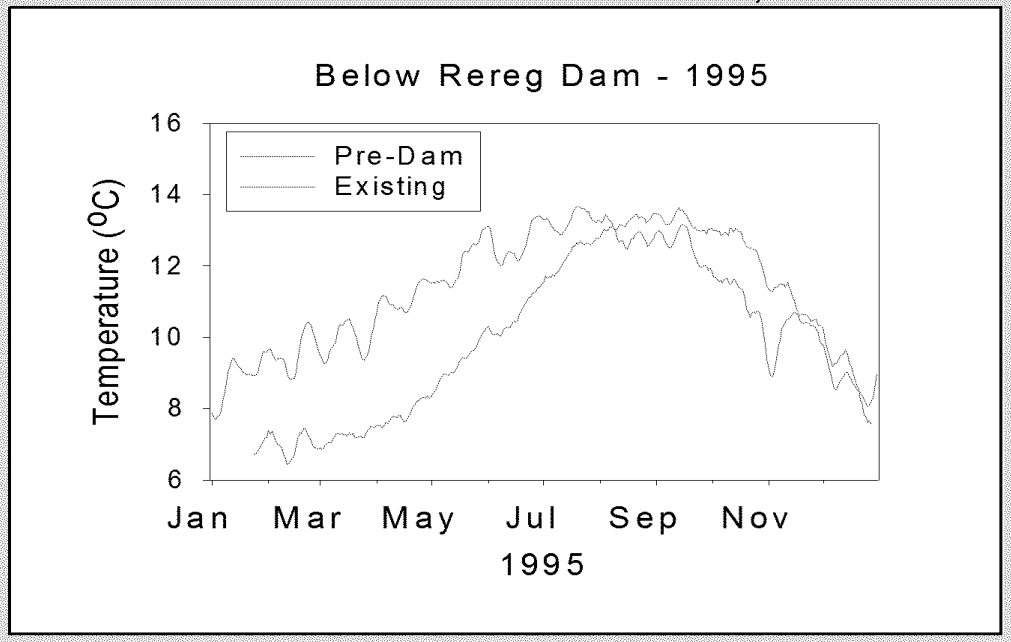
Seasonal vs Daily Temperature Lag

Strong effects on temperature are possible based on site specific conditions but not at Boundary Reservoir

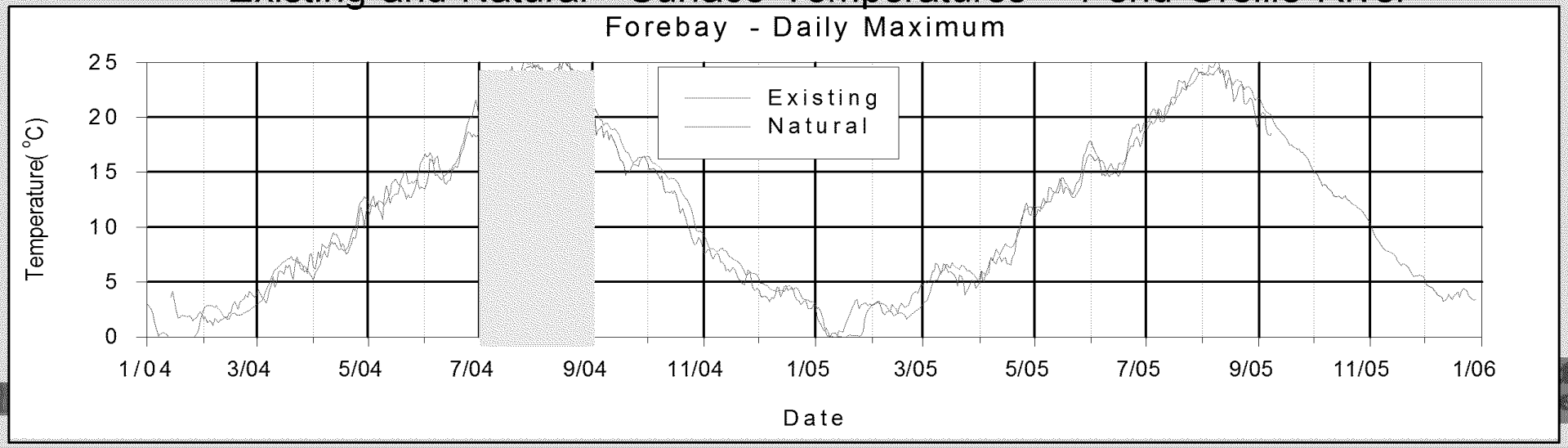
McKenzie River, OR



Lower Deschutes River, OR



Existing and Natural - Surface Temperatures – Pend Oreille River



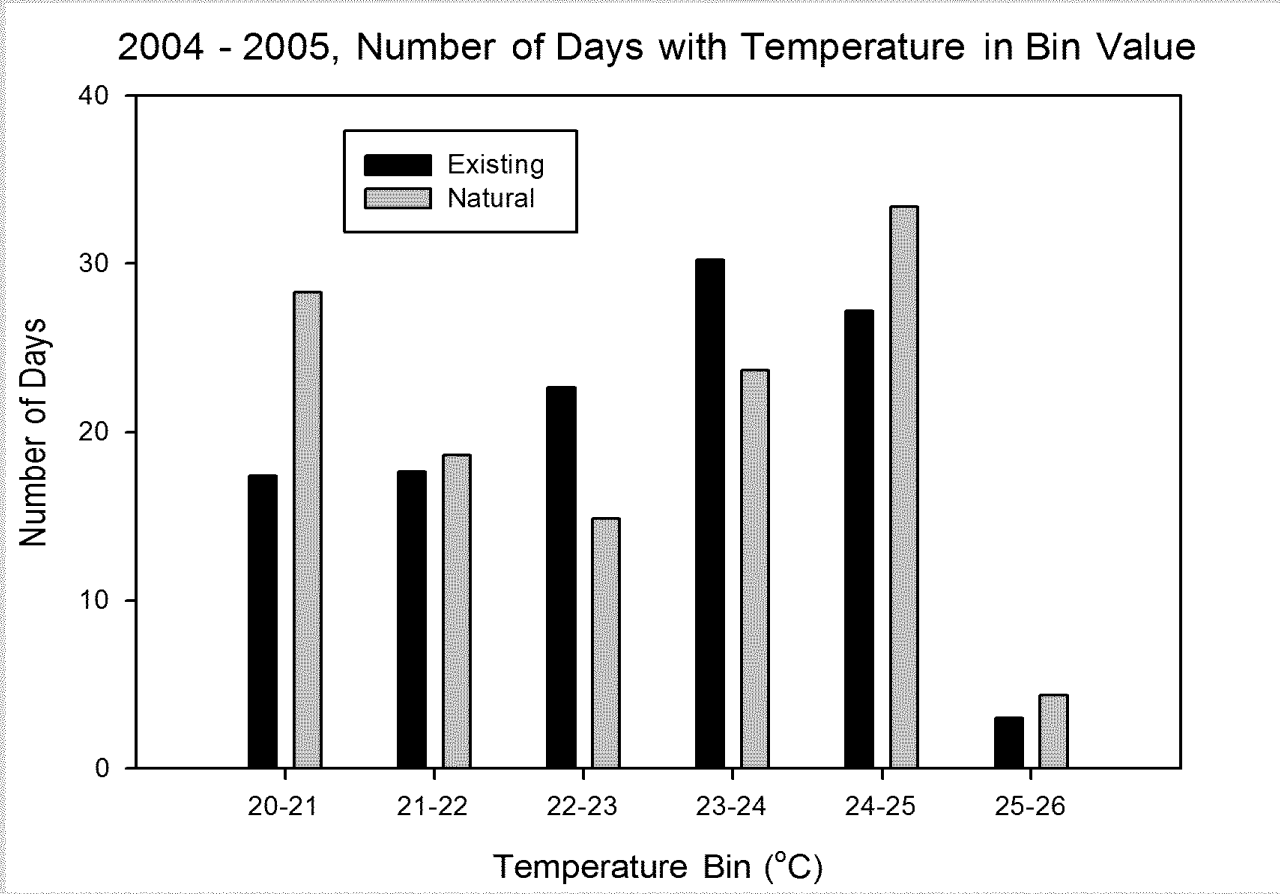
Another Look at Impairment Boundary Dam Forebay

Are the temperatures in existing condition higher than natural?

Is 20˚C criterion exceeded more often than natural condition?

Number of Days >20ºC forebay surface temperatures

- July-August, 2004 - 2005
- Existing condition
  - 118 days
  - T_{max} = 25.25 ºC
- Natural condition
  - 123 days
  - T_{max} = 25.29 ºC



™Existing conditions in Boundary reservoir do not cause more days to exceed 20˚C, relative to Natural Conditions

™Differences in number of days > 20˚C and peak temperature magnitudes not significant

Number of Days Exceeding 20ºC Forebay Location at Surface, 2004 & 2005

2004

- Existing 58 days
- T_{max} = 25.25 ºC

- Natural 63 days
- T_{max} = 25.29 ºC

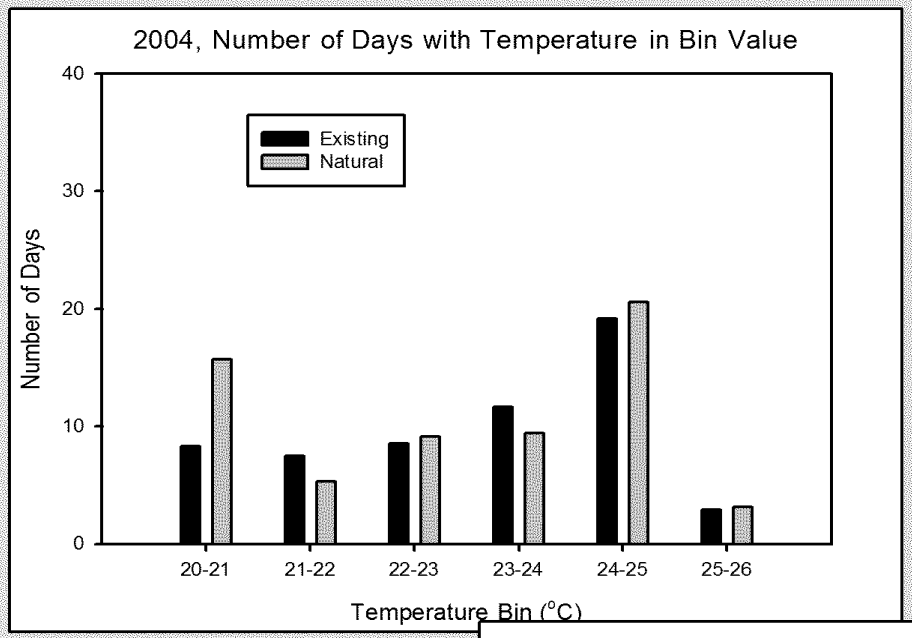
2005

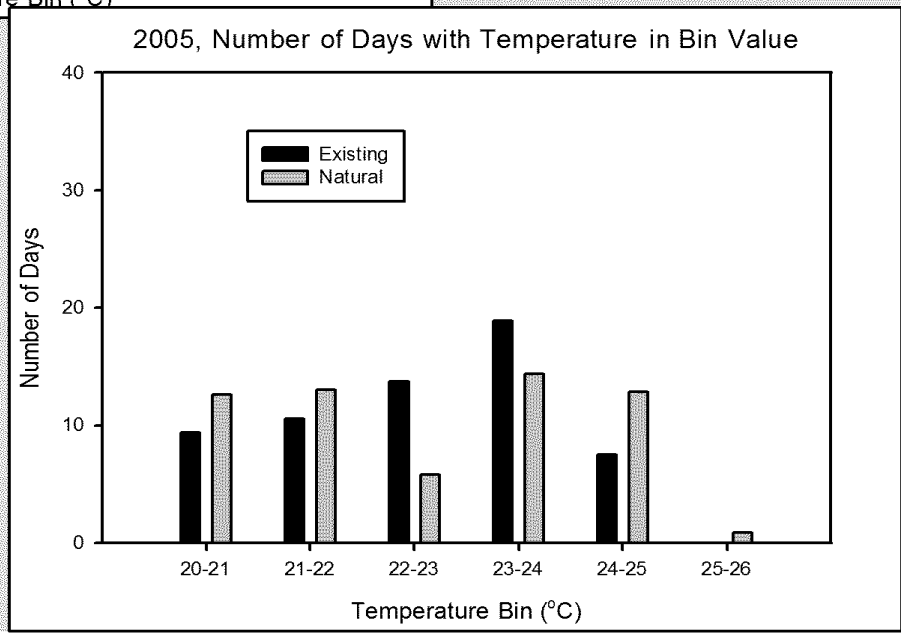
- Existing 60 days
- T_{max} = 24.55 ºC

- Natural 60 days
- T_{max} = 25.15 ºC

™ Even after separating out 2004 and 2005 data, existing conditions in Boundary reservoir do not cause more days to exceed 20˚C, relative to Natural Conditions

™ Conclusions remain the same

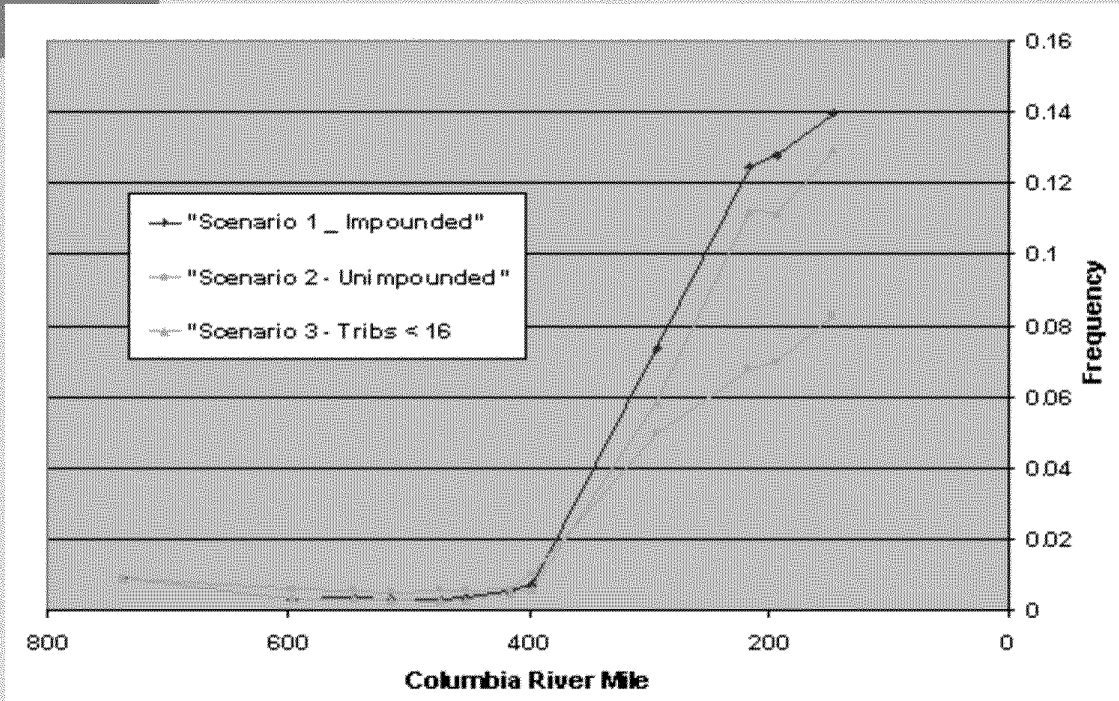




Columbia River TMDL – Example

Problem Assessment for the Columbia/Snake River Temperature TMDL
Preliminary Draft
(U.S. EPA October 18, 2001)

Frequency of Predicted Temperature Excursions Over 20˚C in The Columbia River



Frequency analysis technique used successfully by U.S. EPA to show

- Temperatures at Bonneville Dam exceed the 20˚C criteria more frequently (impounded) than in Natural Conditions (unimpounded)
- Frequency analysis detects where real impoundment is present

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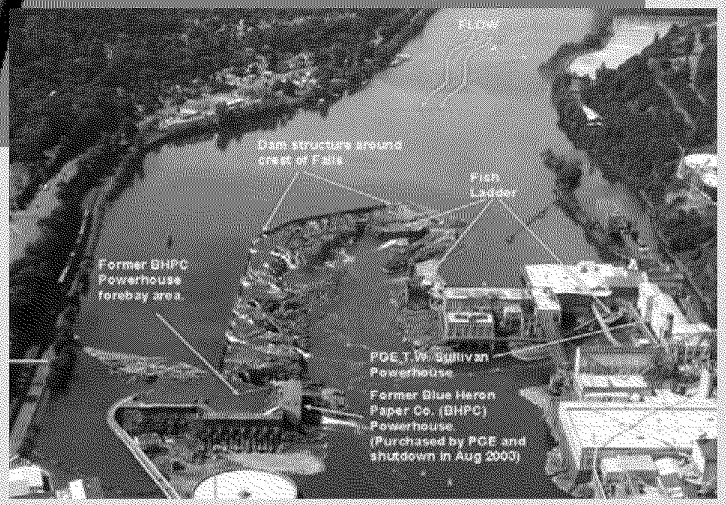
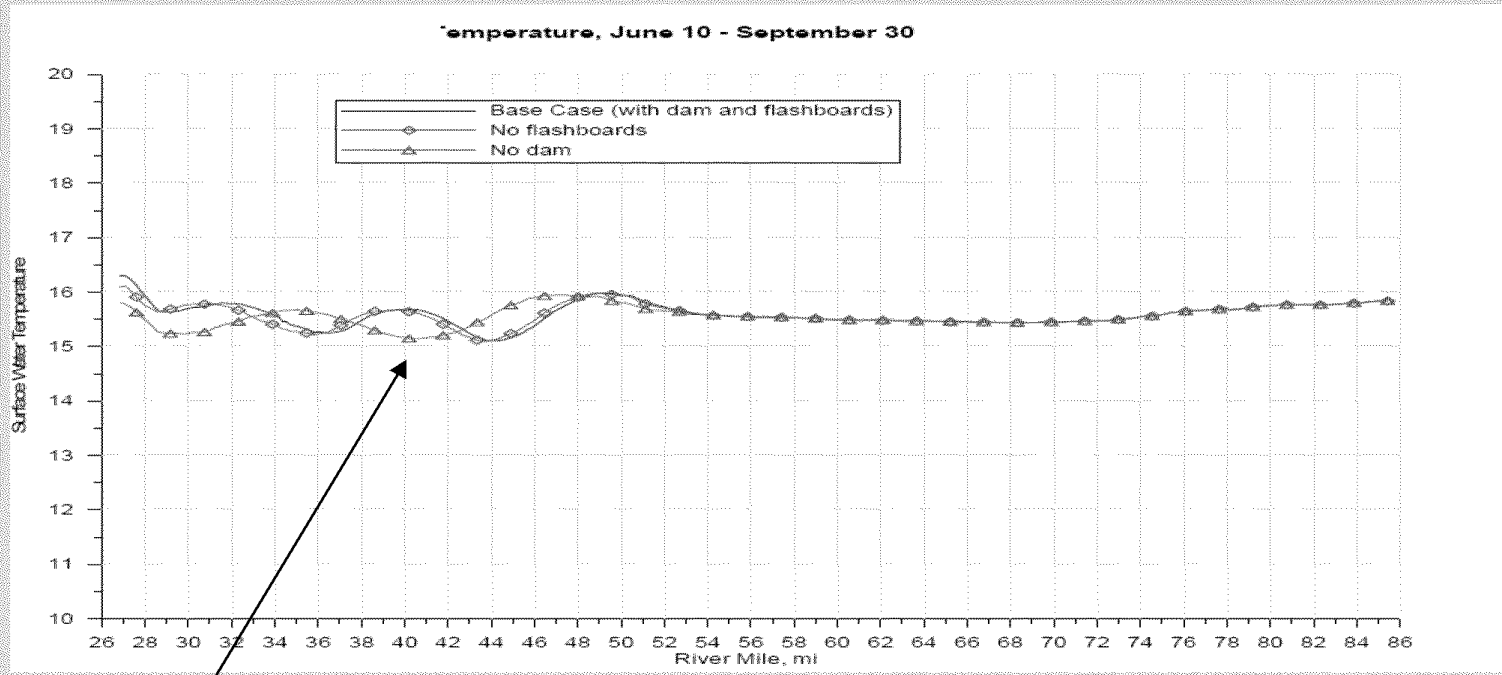
Willamette River TMDL – Approach

Willamette Basin TMDL CHAPTER 4: TEMPERATURE -MAINSTEM TMDL AND SUBBASIN SUMMARY (ODEQ September 2006)





Phase effects on temperature induced by the Willamette Falls Dam – No increase in peak temperature but a lag of 4 days

™Maximum temperature difference ≈ 1°C

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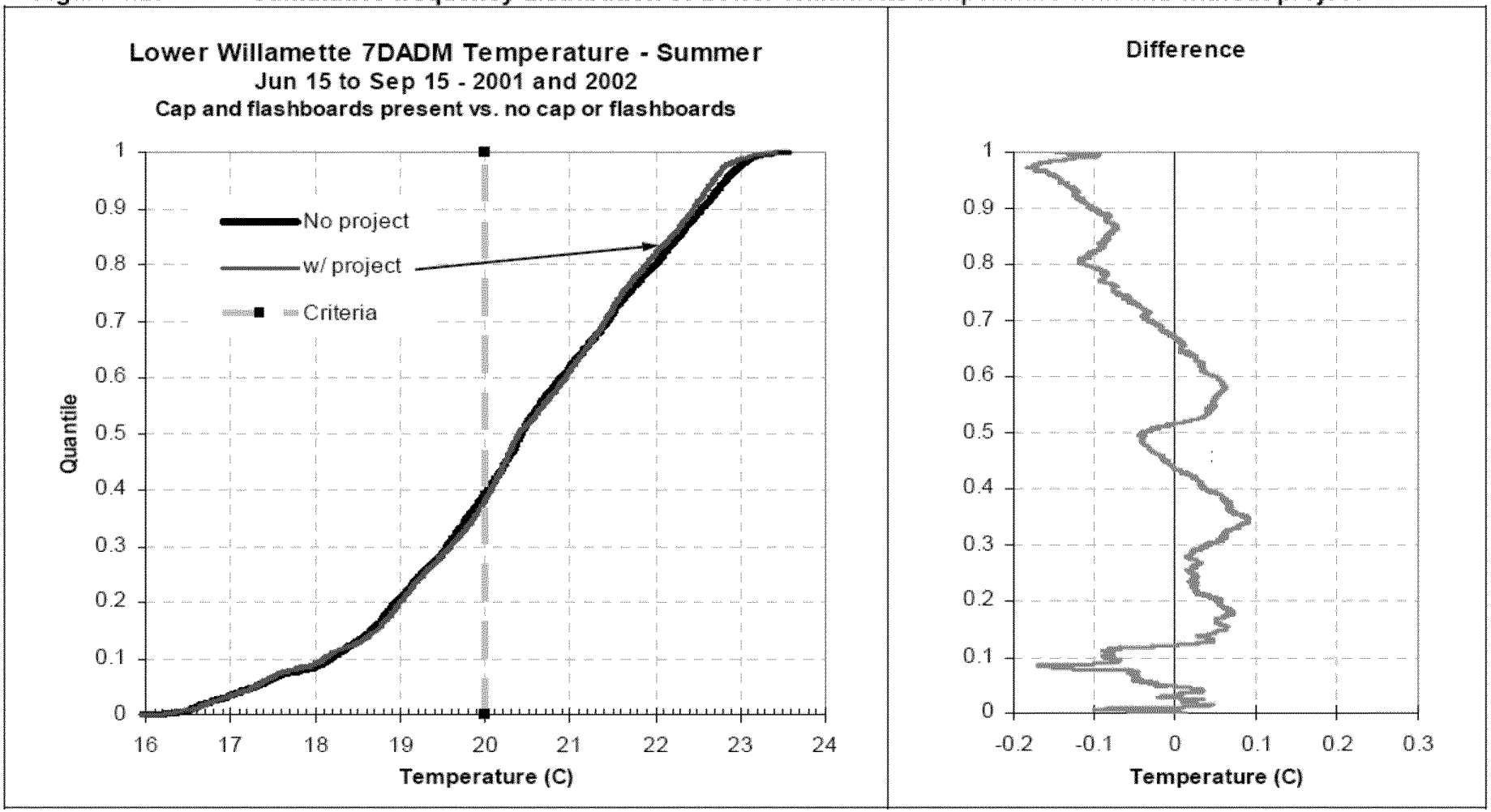
Willamette River TMDL – Frequency Analysis

Figure 4.27 Cumulative frequency distribution of Lower Willamette temperature with and without project

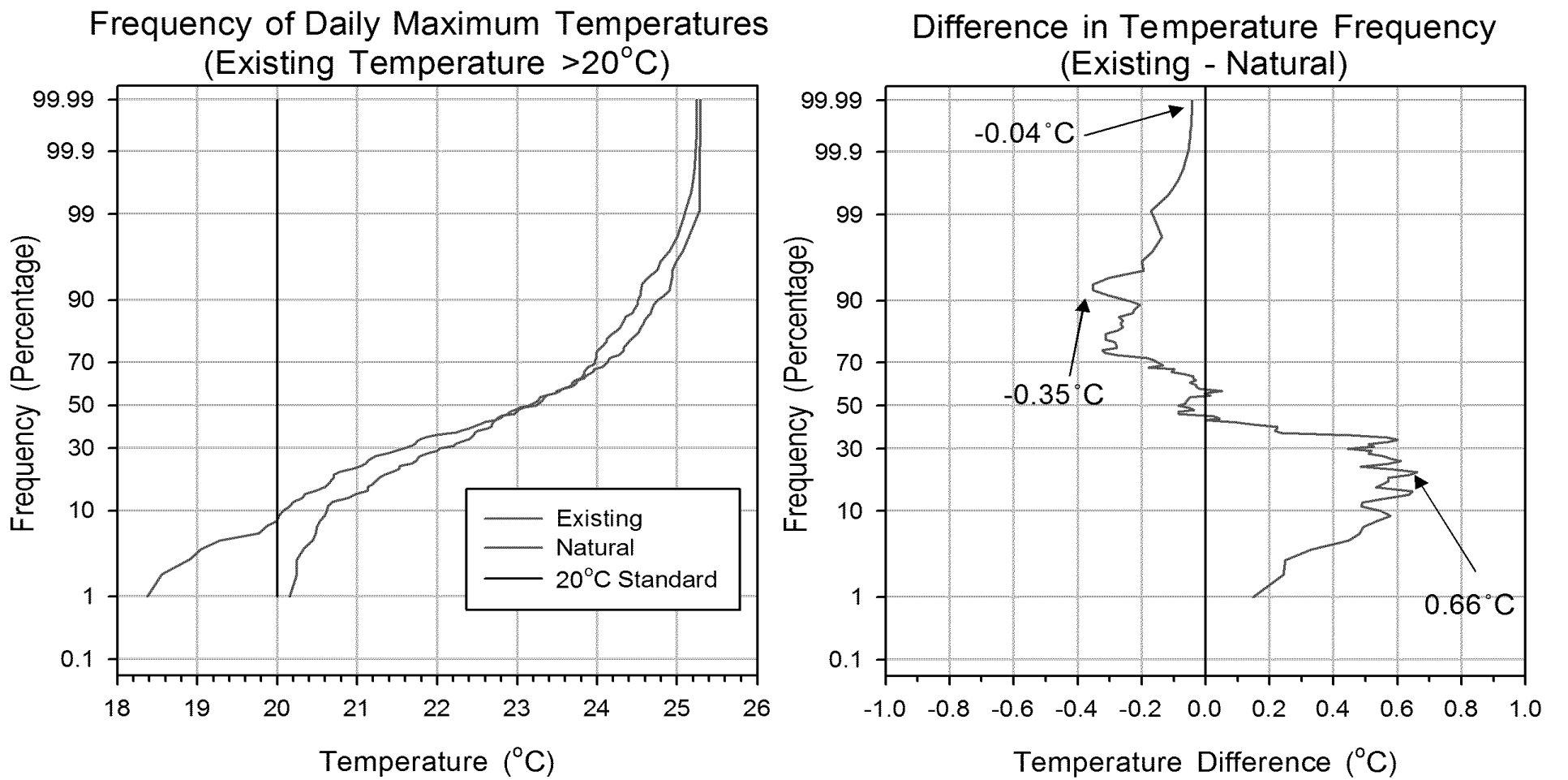


™Real difference in high temperatures at Willamette Falls ≈ 0.1˚C (EC-NC) is only 1/10th of what is apparent

™In several temperature ranges, including peak temperatures, reduction in temperatures is seen

Frequency Distribution (Surface Data) Daily Maximum Temperatures >20ºC

Existing and Natural Temperatures – **Boundary Forebay**



Frequency analysis similar to the Willamette TMDL method shows, greatest difference in high temperatures at Boundary Forebay ≈ 0.66˚C (Existing Conditions – Natural Conditions) compared to >3˚C apparent ΔT

50/50 chance that Existing > or < Natural

Period Covered –Summer 2004 to Summer 2005
Dates:7/9/2004 to 9/4/2004 & 7/8/2005 to 9/8/2005

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Review of Moving 7-day Frequency Analysis Presented by Ecology on 2/25/08

- Start with maximum daily temperature data
  - Existing Condition (EC)
  - Natural Condition (NC)
- Pool the data
  - All model segments (whole domain)
  - 7-day period
- Compute frequency analysis on the pooled data
  - Frequency intervals from 1% to 99%
  - Both EC and NC
- Compute differences in frequency intervals (EC-NC)
  - only when EC >20ºC and EC-NC>0.3ºC
  - otherwise the difference is zero
- Advance the calculations by **1 day** (running from June 16 – Sept 26)
  - Data pooling, frequency analysis, differences

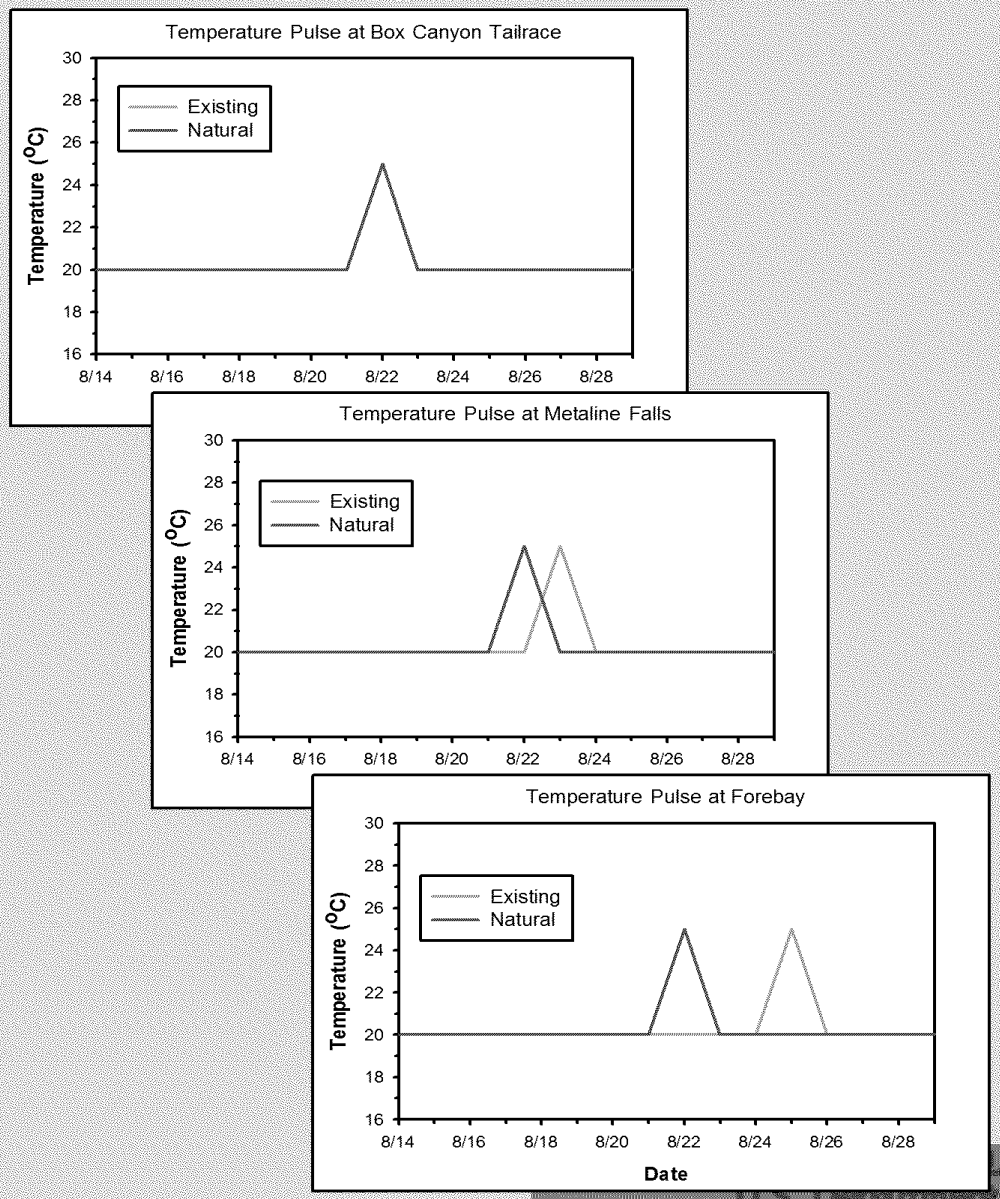
Use of 7-day moving analysis masks travel time and thermal inertia lag effect

Temperature Pulse Test – 7-day Method Existing and Natural Conditions

1-day maximum temperature pulse starts at Box Canyon

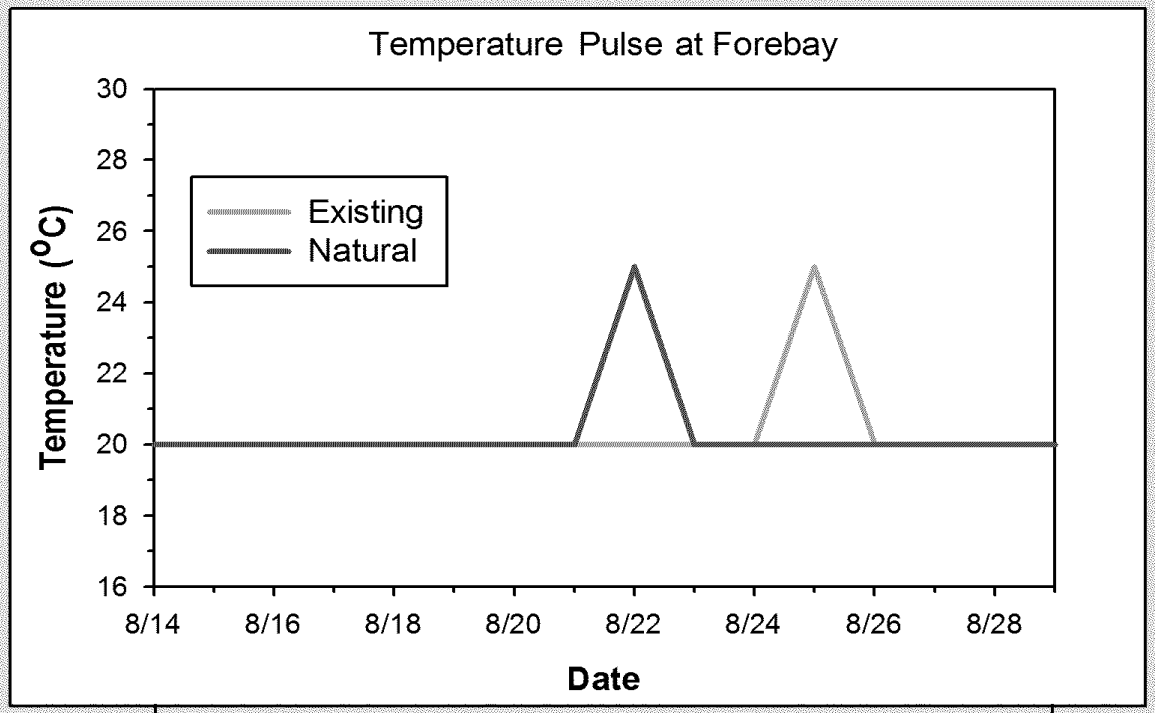
Pulse travels through Boundary Reservoir

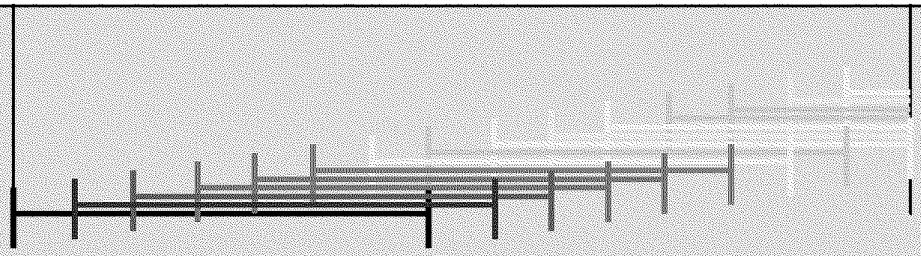
Pulse ends in Forebay



Moving 7-day Analysis of Temperature Pulse Forebay Location

Moving 7-day analysis gives 15 sets of results





Moving 7-day periods

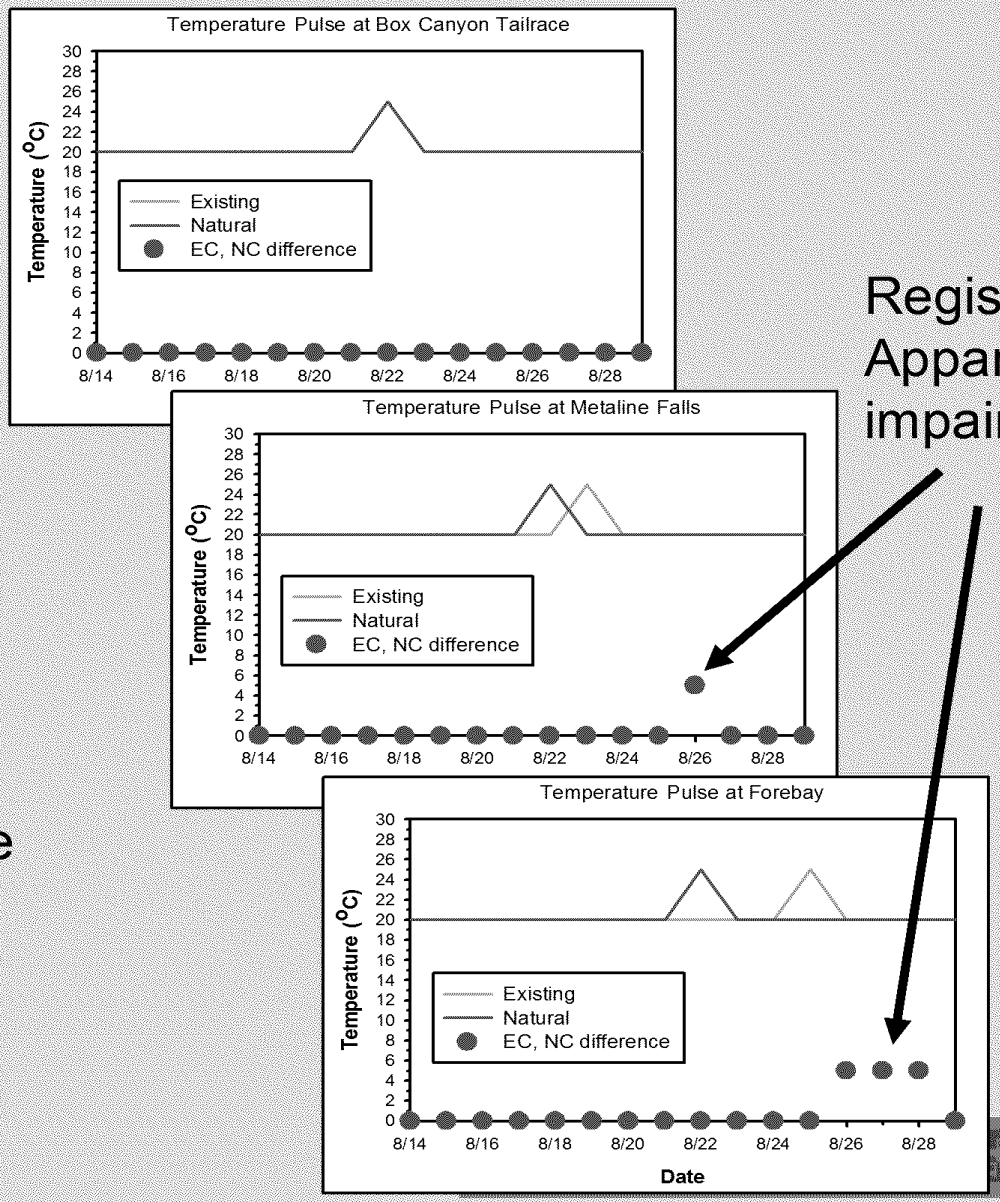
Due to 7-day short window

™Natural Condition pulse is registered first, then both, and then Existing

™Correct assessment is possible only when both pulses are in the same (7-day) window

Moving 7-day Analysis of Temperature Pulse

- Existing
  - 2.7 day travel time
  - Maximum temperature = 25 ºC
- Natural
  - 0.5 day travel time
  - Maximum temperature = 25 ºC
- Maximum apparent impairment
  - 5.0 ºC
- Number of days of apparent impairment
  - 3
- The problem with running daily analysis
  - Involves multiple sampling of the same data
  - So days of apparent impairment are counted more than once



Registers as Apparent impairment

Summary of Lag Time Issue

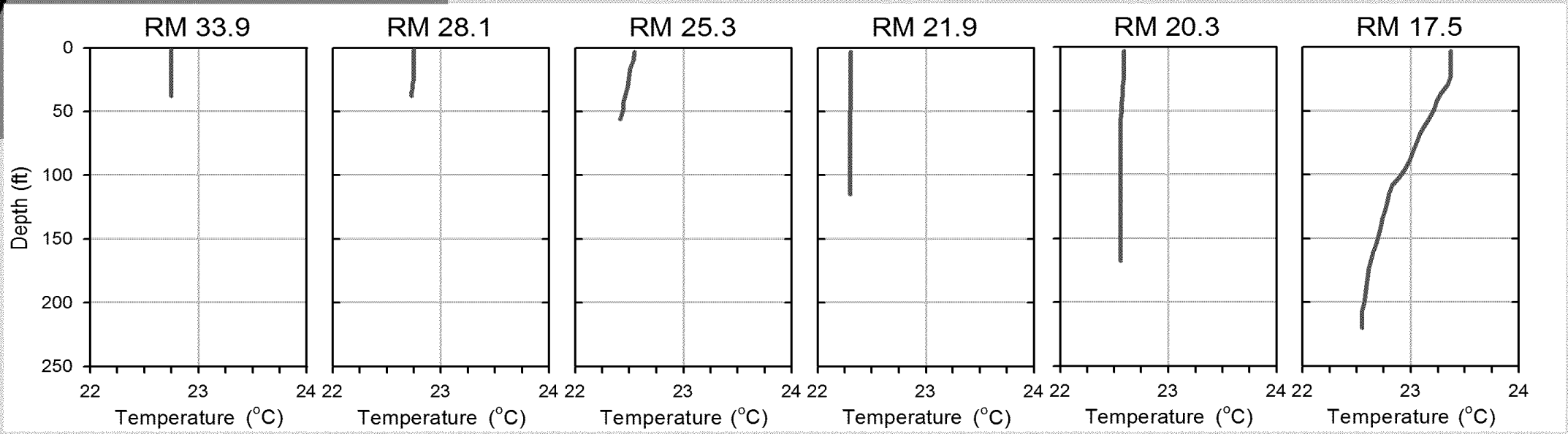
- Frequency analysis over the summertime critical period is the effective approach for Boundary – Pend Oreille River
  - Addresses both travel time and thermal inertia lag
  - Recommended approach – EPA approved Willamette TMDL method
- The moving 7-day approach
  - Ineffective in isolating real impairment
  - Results in double counting

Volume or Flow Weighted Average Temperature

- Approved by ODEQ and U.S. EPA (Willamette TMDL – ODEQ 2006)
- Approved by Ecology (Rocky Reach 401 Cert.)
- Within the capability of PSU – CE-QUAL-W2 model

Stratification in Boundary Reservoir

August 24, 2004



Stratification in Boundary Reservoir is a short duration event controlled by release of cooler water from upstream

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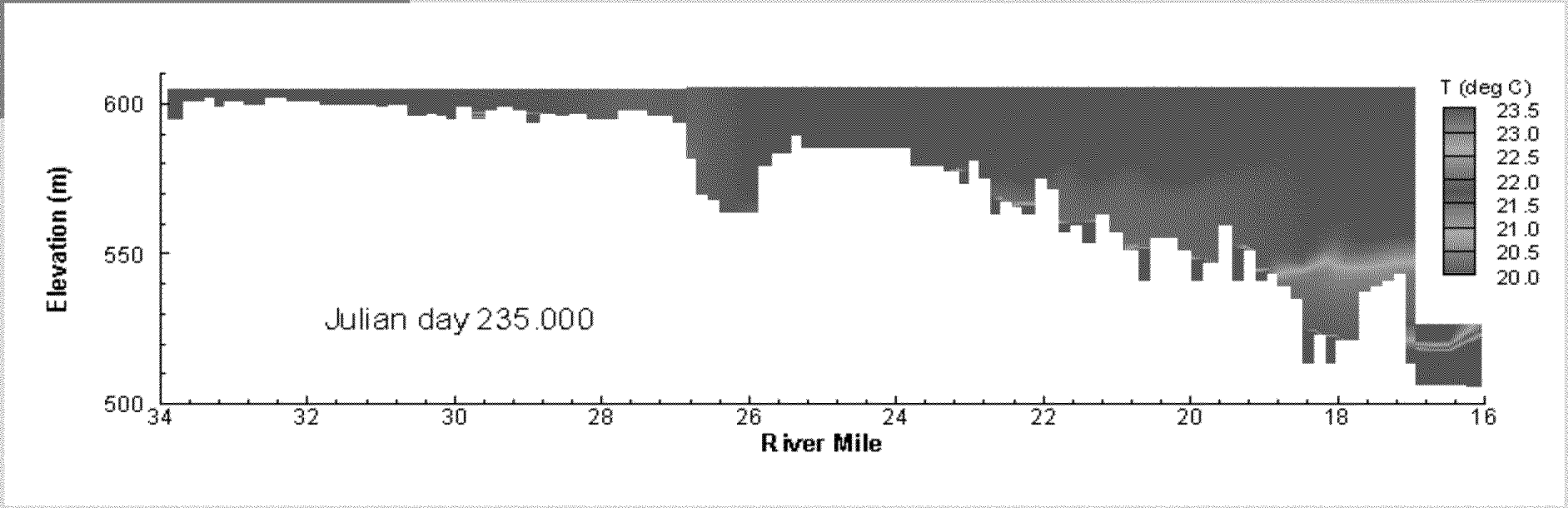
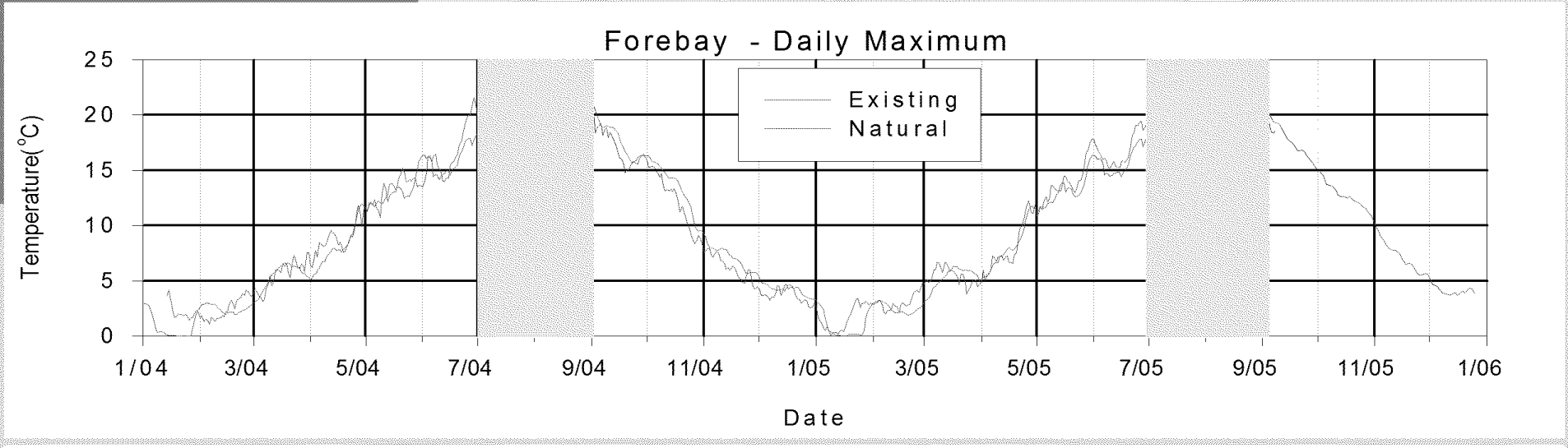
Temperature Contours Animation

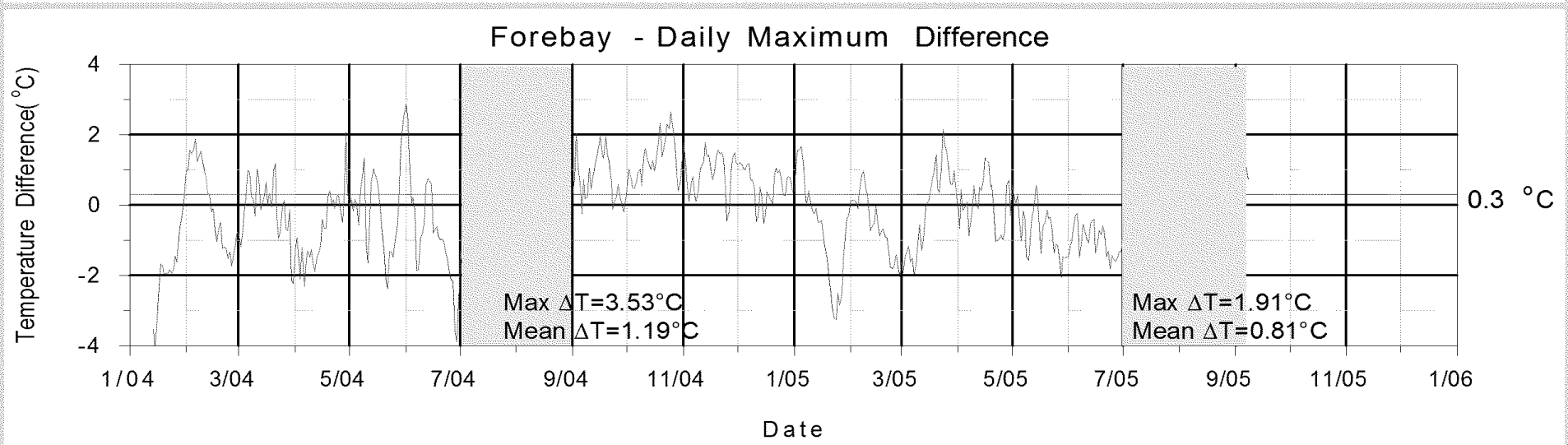


Julian Day 235 = August 23, 2004

Daily Maximum Temperatures Forebay of Boundary Dam

Existing and Natural - Volume Weighted Temperatures





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Use of Heat Wasteloads for Dams

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Heat Equation Calculation

$$HL = Q \times \frac{28.3169L}{ft3} \times \frac{1kg}{1L} \times \frac{86{,}400\,\text{sec}}{day} \times \frac{1kcal}{kg/1^{\circ}C} \times T = \frac{kcal}{day} \qquad (1)$$

Where

HL = Heat Load (kcal/d)

Q = Discharge (cfs)

T = Temperature (°C)

* A kilocalorie (kcal) is the energy needed to increase the temperature of 1 kg (or 1 L) of water by 1°C.

This approach which leads to inconsistency between heat and temperature balance assumes that:

- The whole water column is at the same temperature
- Highest temperature persists for the 24-hour duration
- Flow is constant over the entire 24-hour duration

Potential remedy

- Volume or flow weighted averaging
- 24-hour integrated heat flux calculation