# Preliminary evaluation of the effects of wastewater discharge on Cook Inlet beluga whales

Cook Inlet Beluga Whale Science Conference

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# What happens to our wastewater?

- What treatment does wastewater get before discharge into Cook Inlet?
- Once the discharge is released into Cook Inlet, what is the potential for exposure to whales and their prey?
- Are there constituents in the discharge of a type and amount that could be harmful to whales?

# AWWU treats ~30 million gallons of wastewater daily

Eagle River

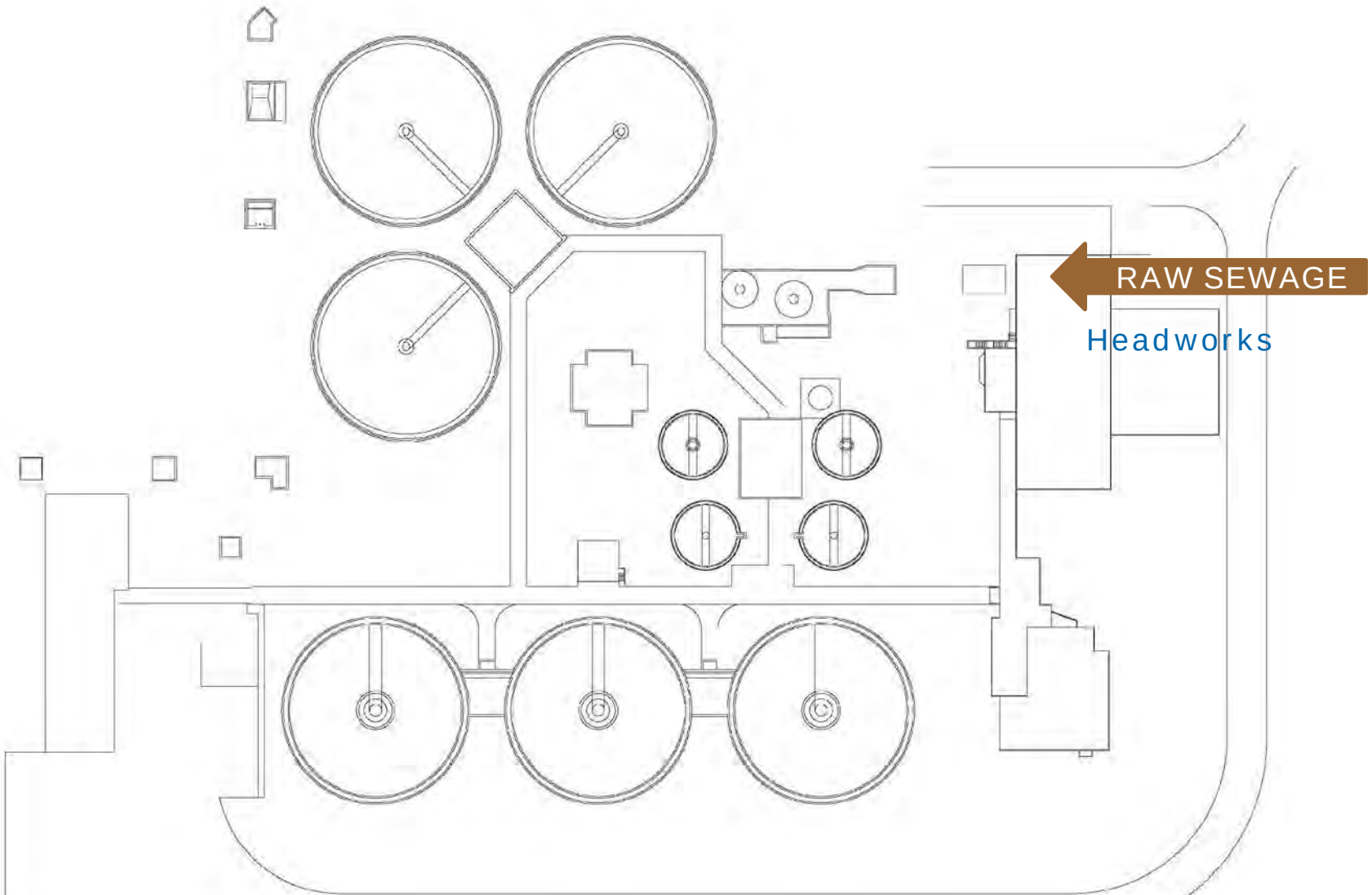
Girdwood

John Asplund
(Pt. Woronzof)

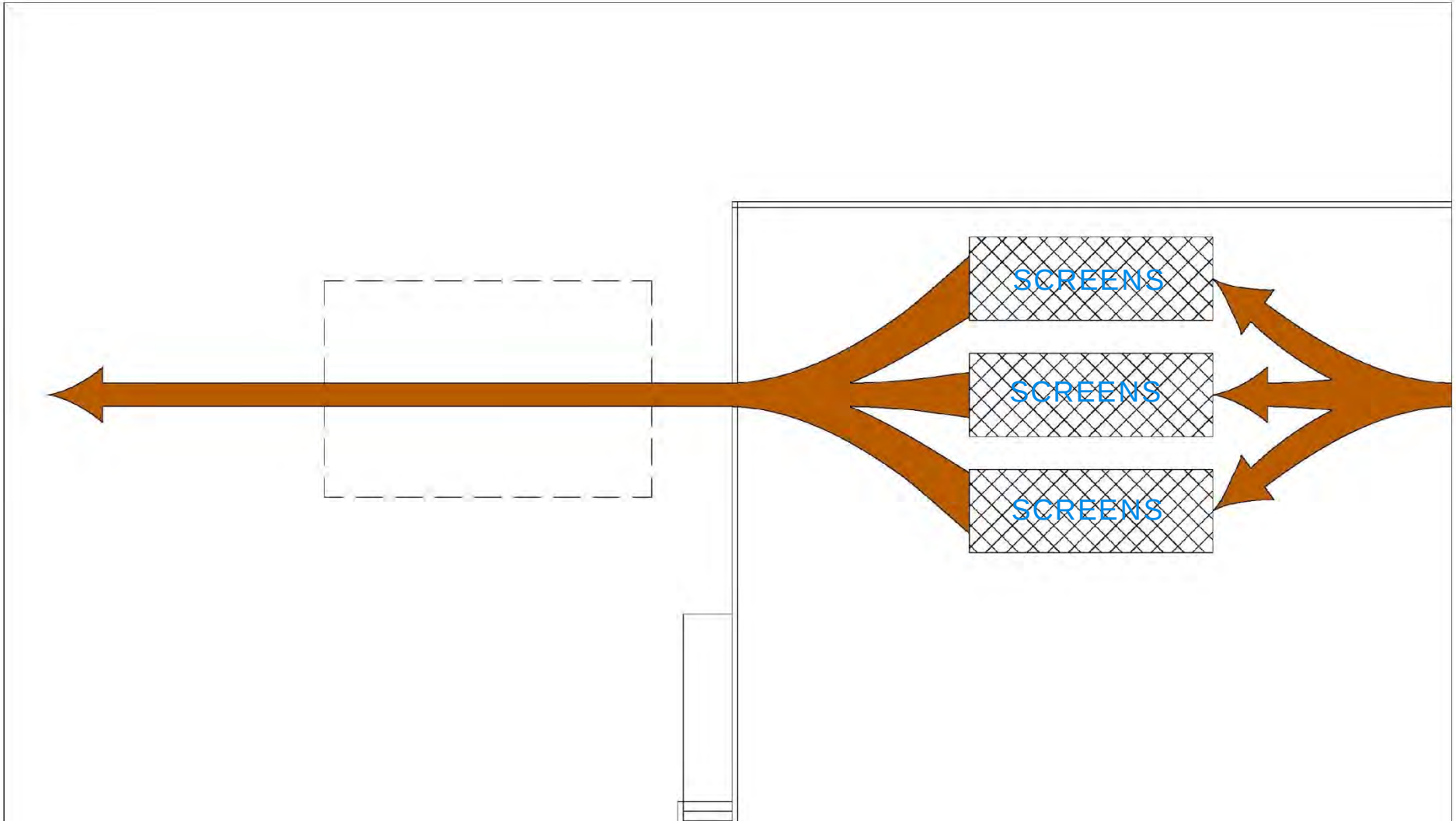
# We have invested $40 million over the past 10 years to keep technology current

# Aerial View of the Asplund Facility

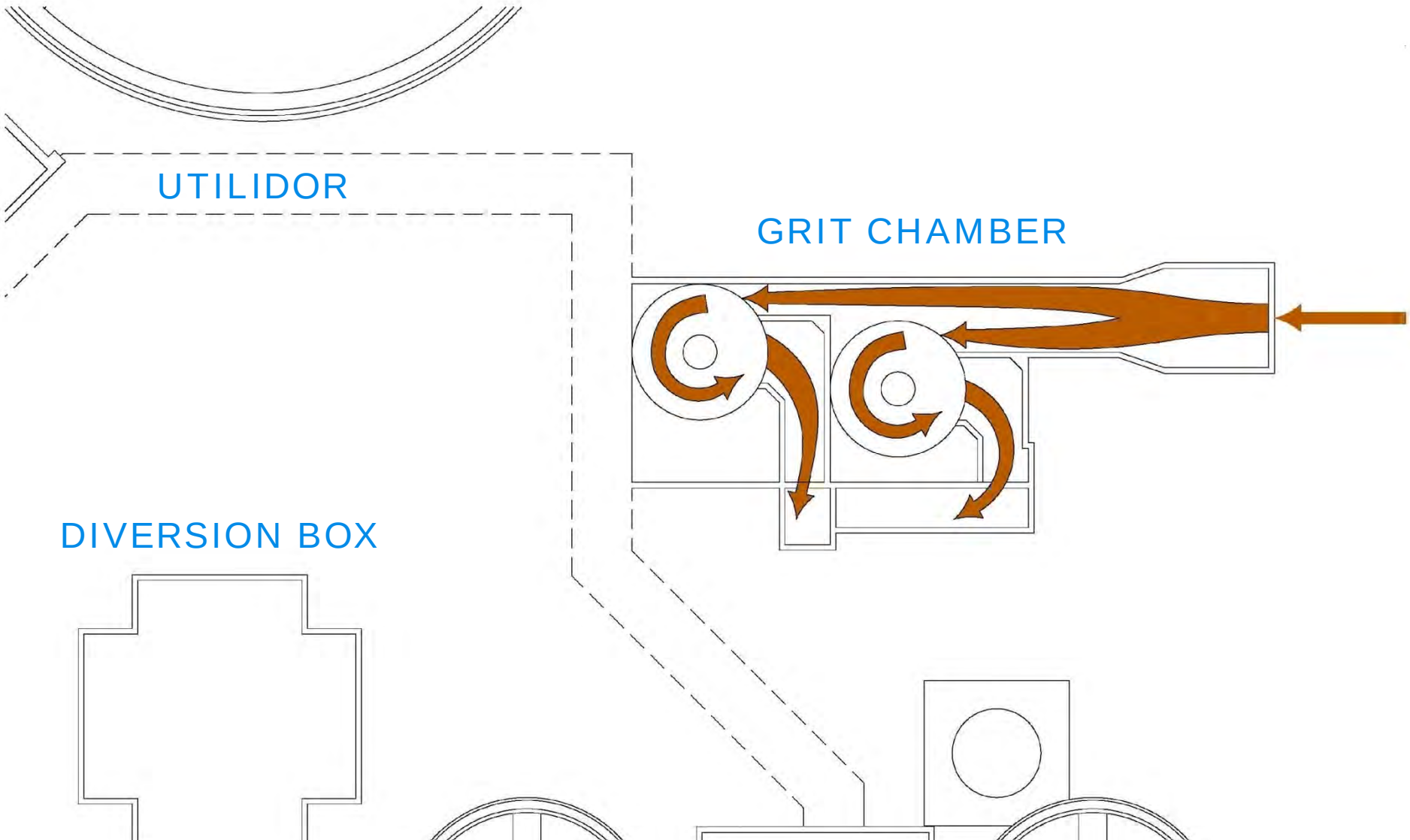
# Sewage enters via 8’ tunnel under the airport runway.



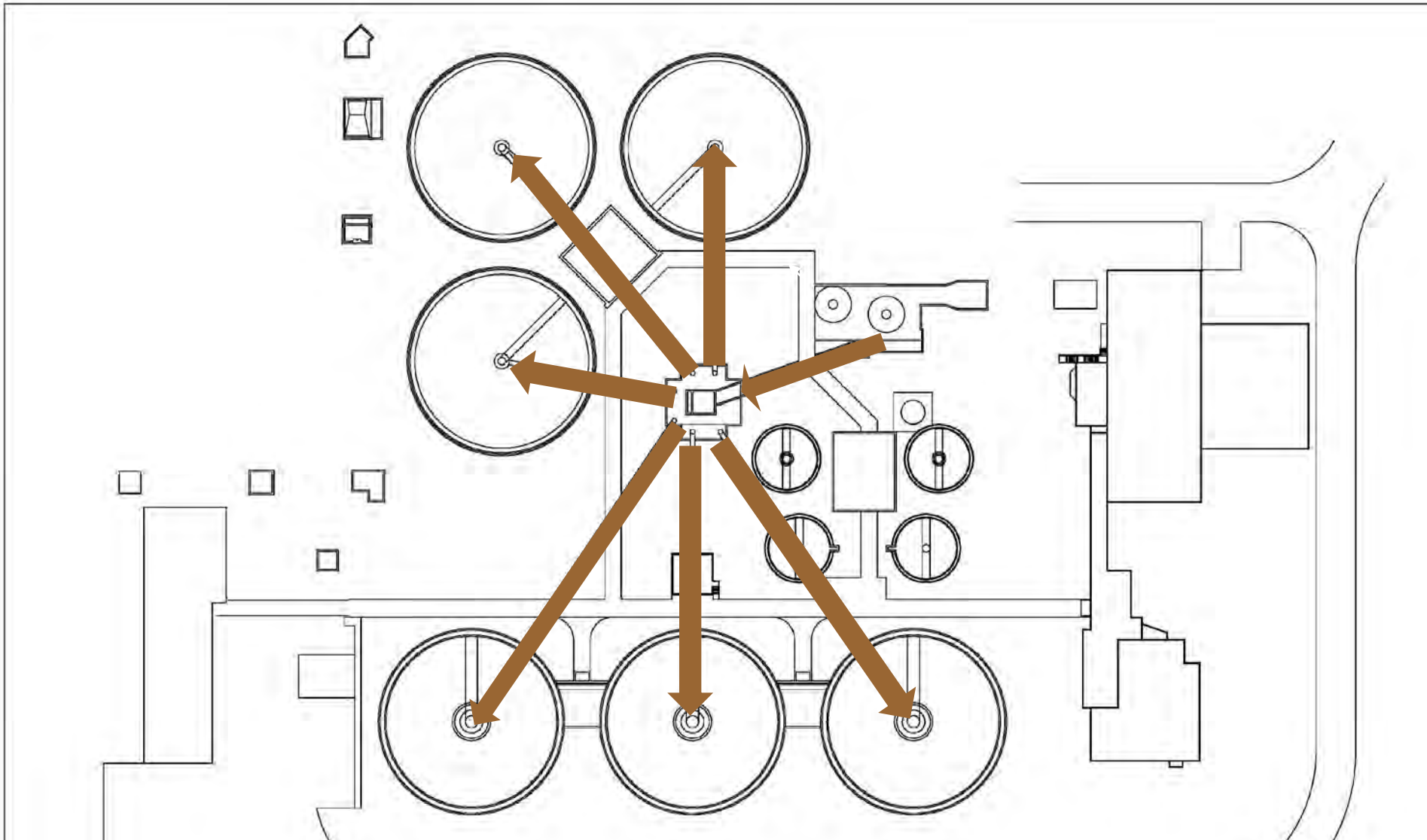
# Three screens capture debris and large particles.



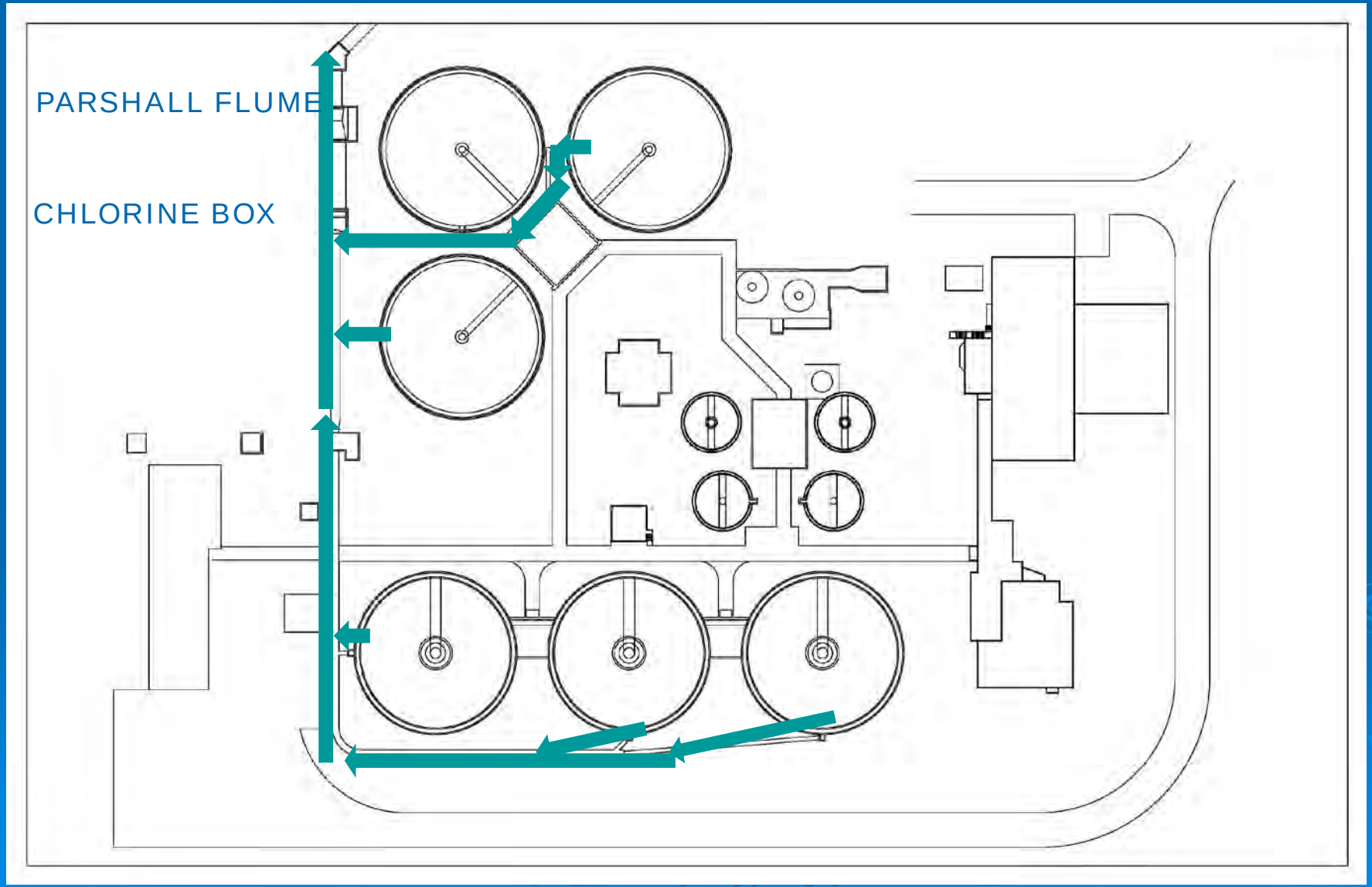
# Degritters remove sandy particles abrasive to equipment.



# Six large clarifiers provide for quiescent settling.



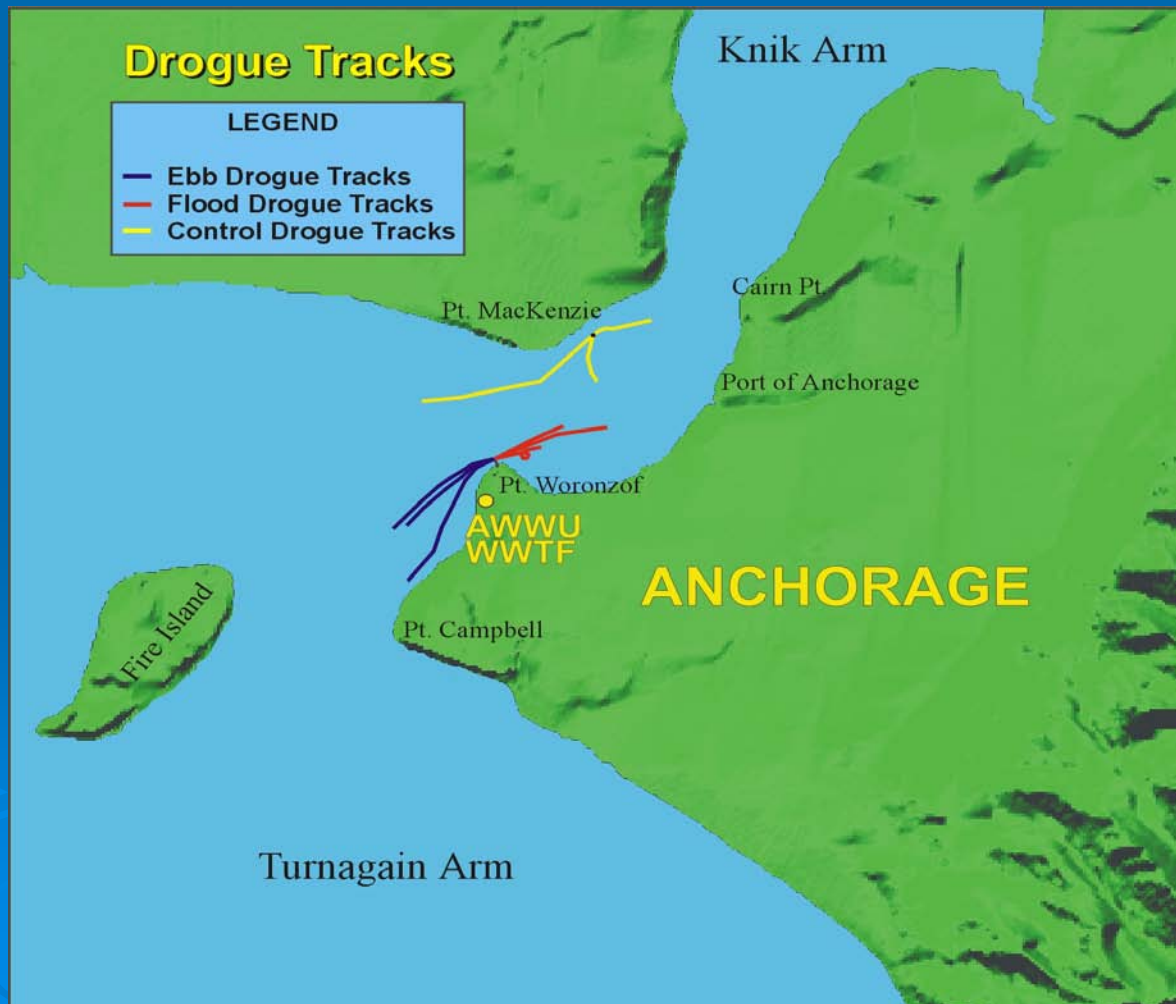
# Chlorination follows removal of ~70% of waste stream solids



# Final effluent is discharged 800' offshore through a diffuser

# Outfall diffuser creates rapid mixing and dispersion of discharge.

- Tidal velocities can exceed 8 feet/sec.
- Tides travel upstream as much as 20 miles, then
- Flow outward for 23 miles
- Knik Arm waters refreshed in days

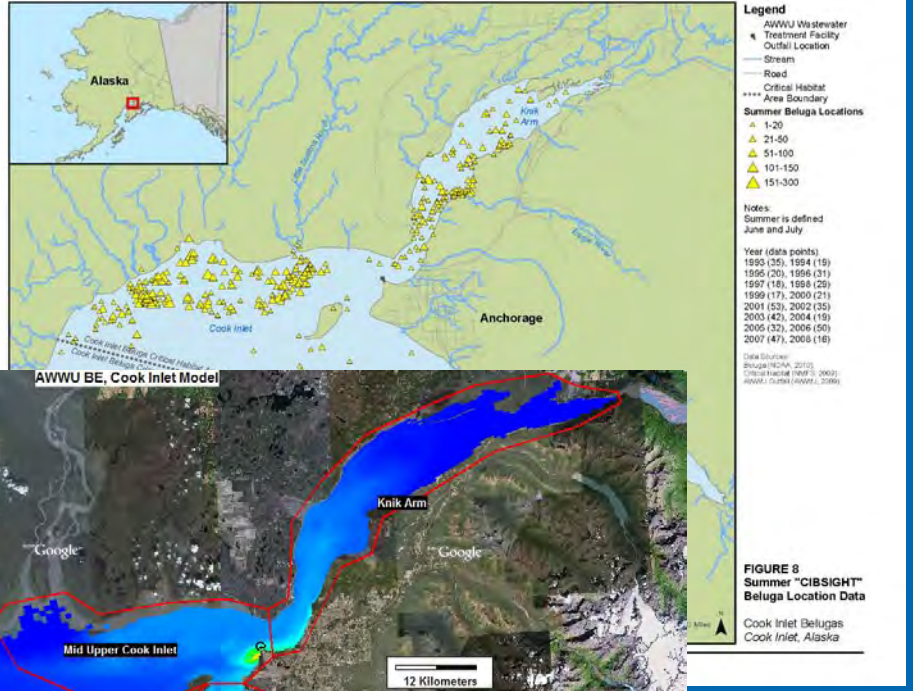


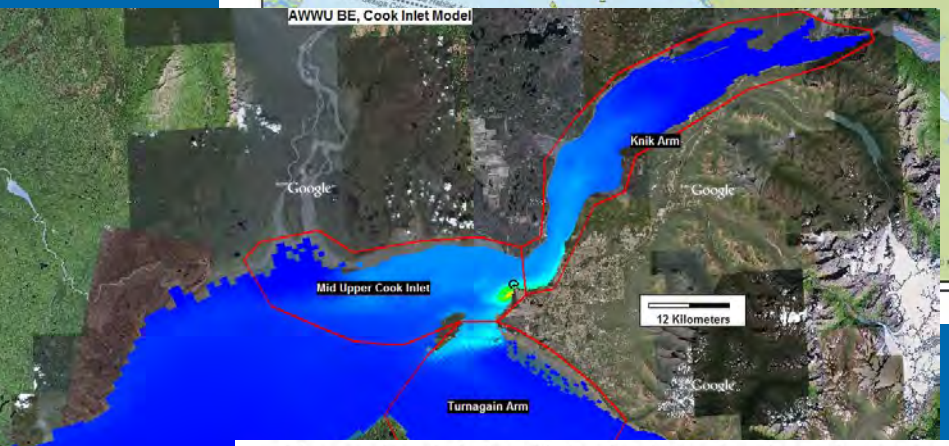
# >20 years of monitoring finds:

- Plant meets all permit conditions.
- Effluent yields very low levels of trace contaminants.
- Cook Inlet has naturally high levels of trace metals from discharge from glacial streams.
- No measurable Water Quality effects.
- No toxicity in effluent bioassays.
- No bioaccumulation of toxic materials.
- No sediment effects at outfall.
- No sediment contamination from outfall.
- Asplund primary effluent =
  secondary effluent elsewhere.

# AWWU's recent work in support of EPA permit renewal has added to our knowledge base

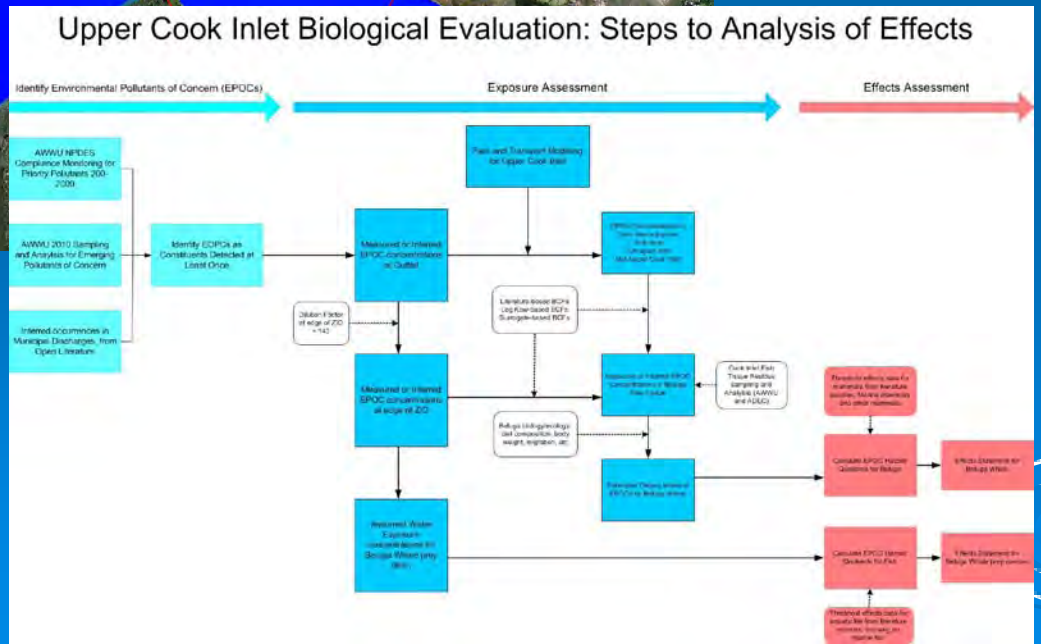
Mapping



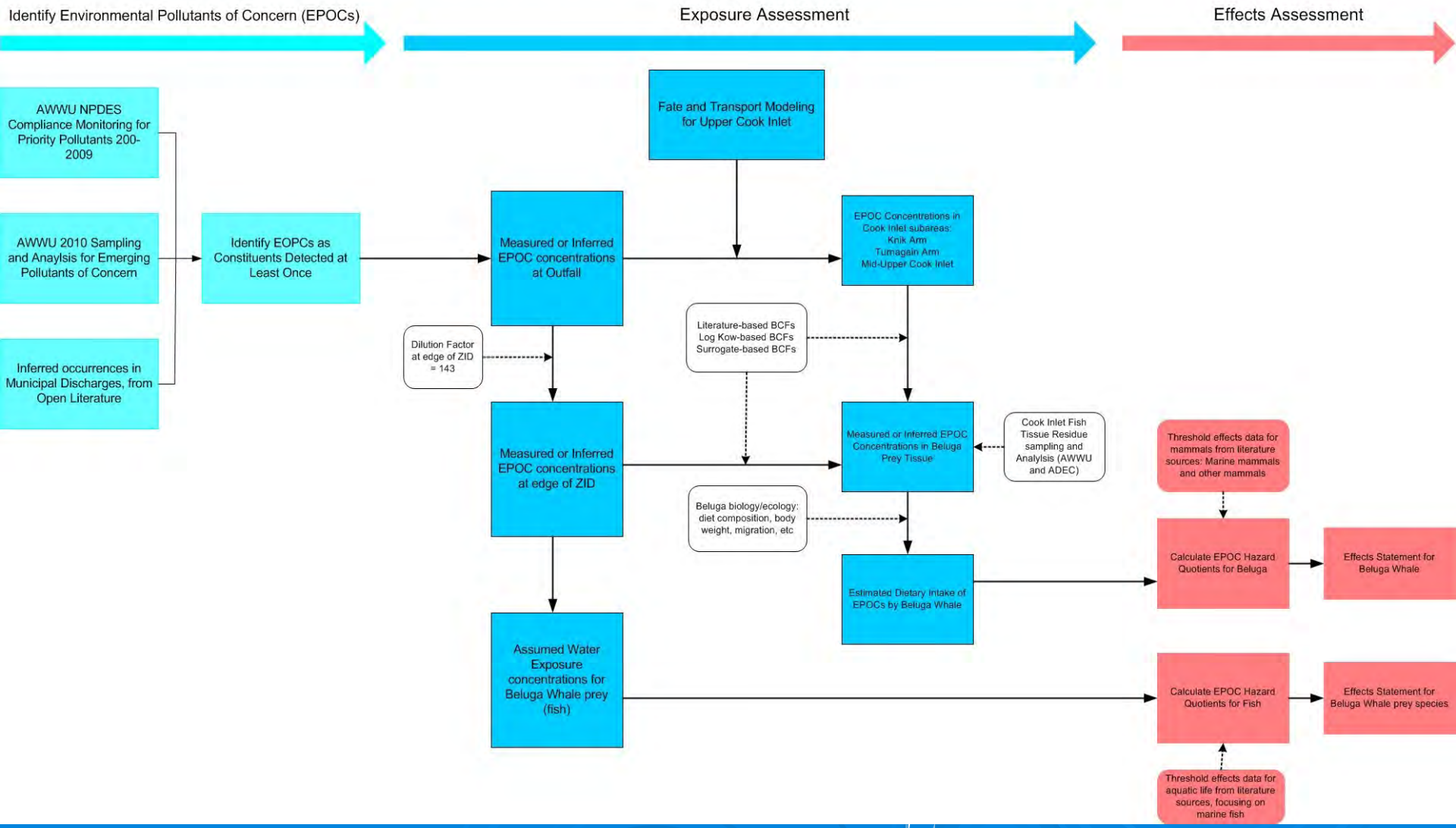




Modeling

Analysis



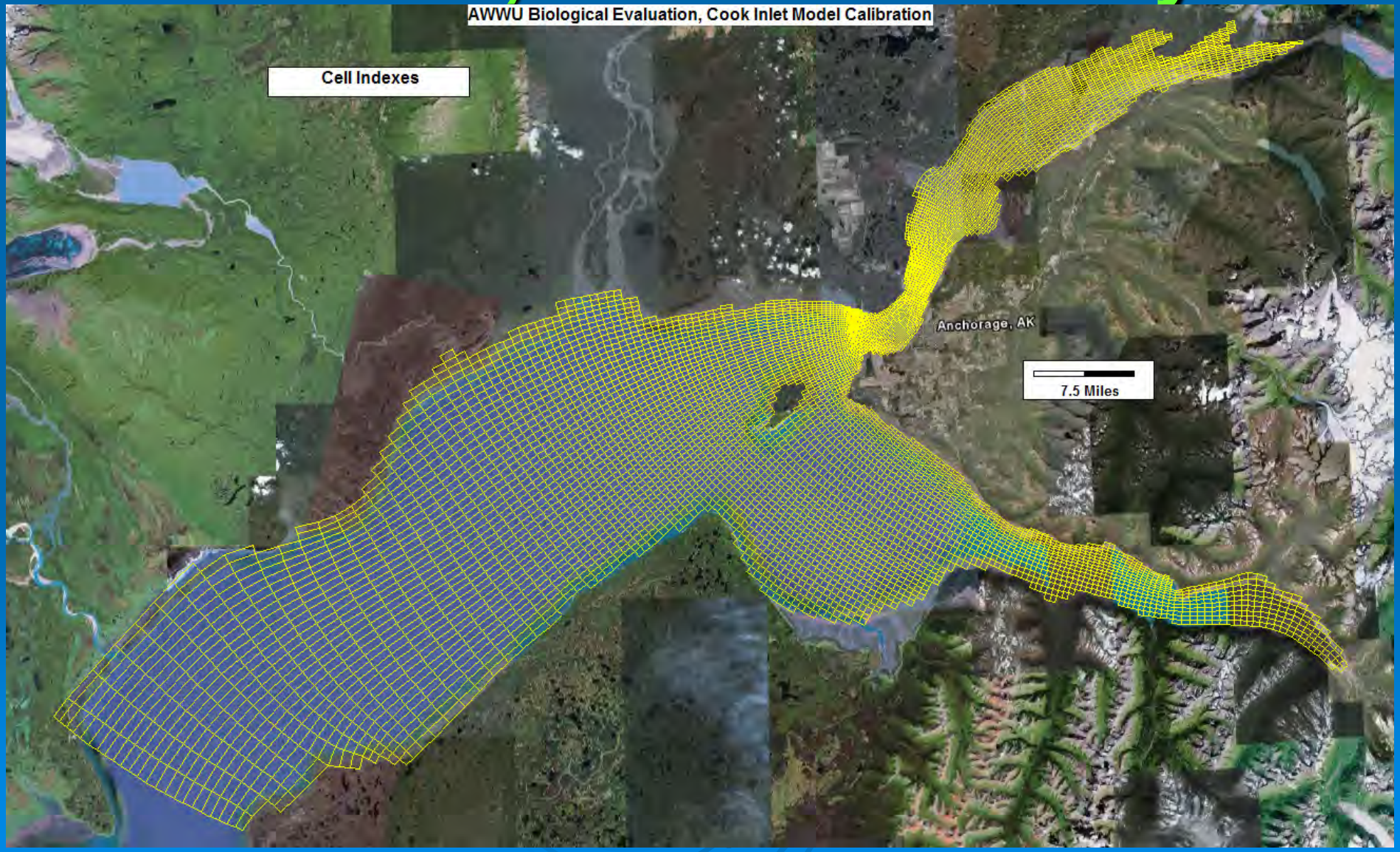
# Upper Cook Inlet Biological Evaluation: Steps to Analysis of Effects



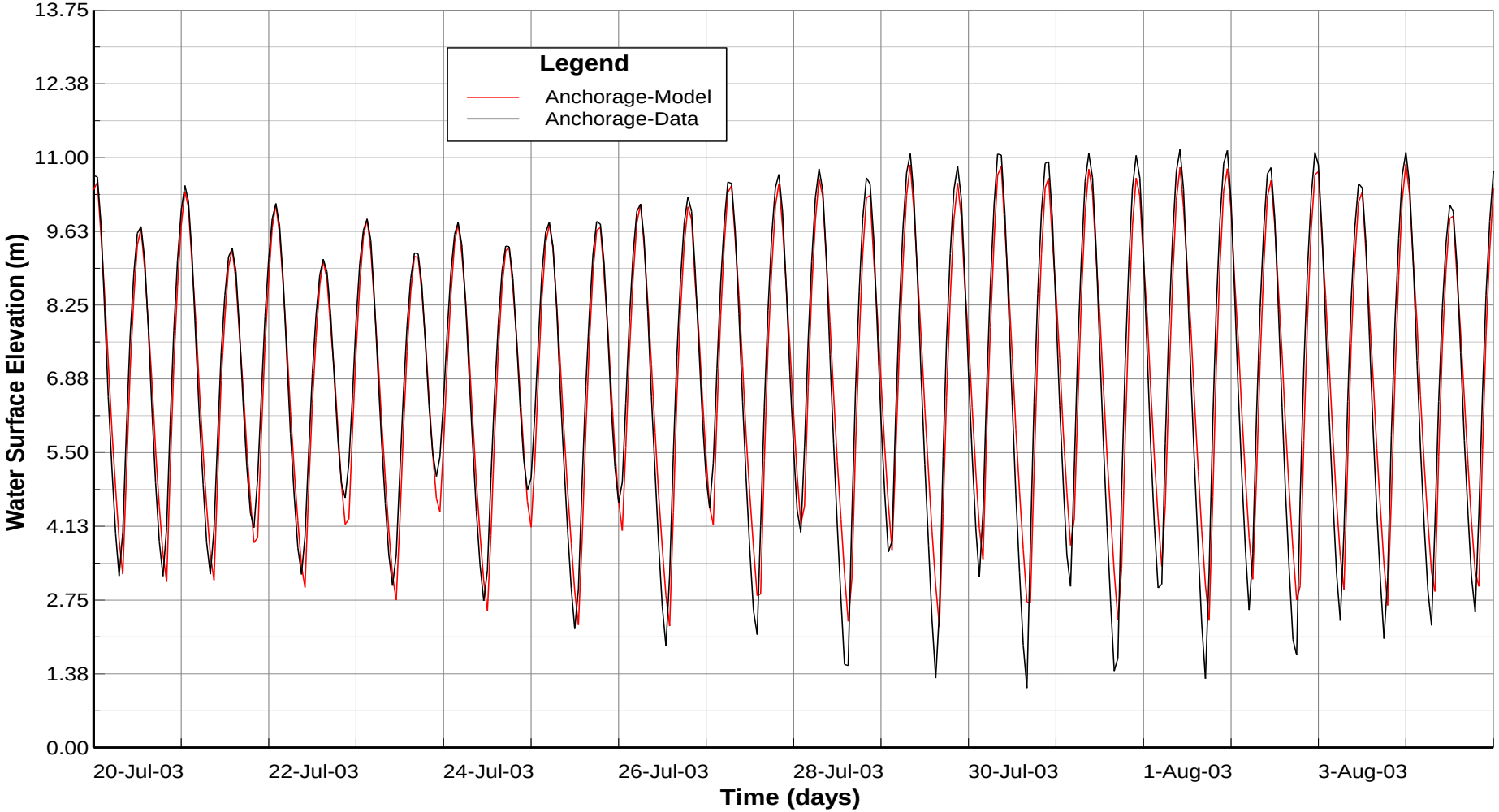
# Fate and transport of effluent in Cook Inlet modeled with EFDC

- Computes mixing and circulation driven by tides, wind, and density gradients
- Allows estimates of exposure of aquatic life to contaminants associated with wastewater
- Provides a visual representation of changes in water quality over time.

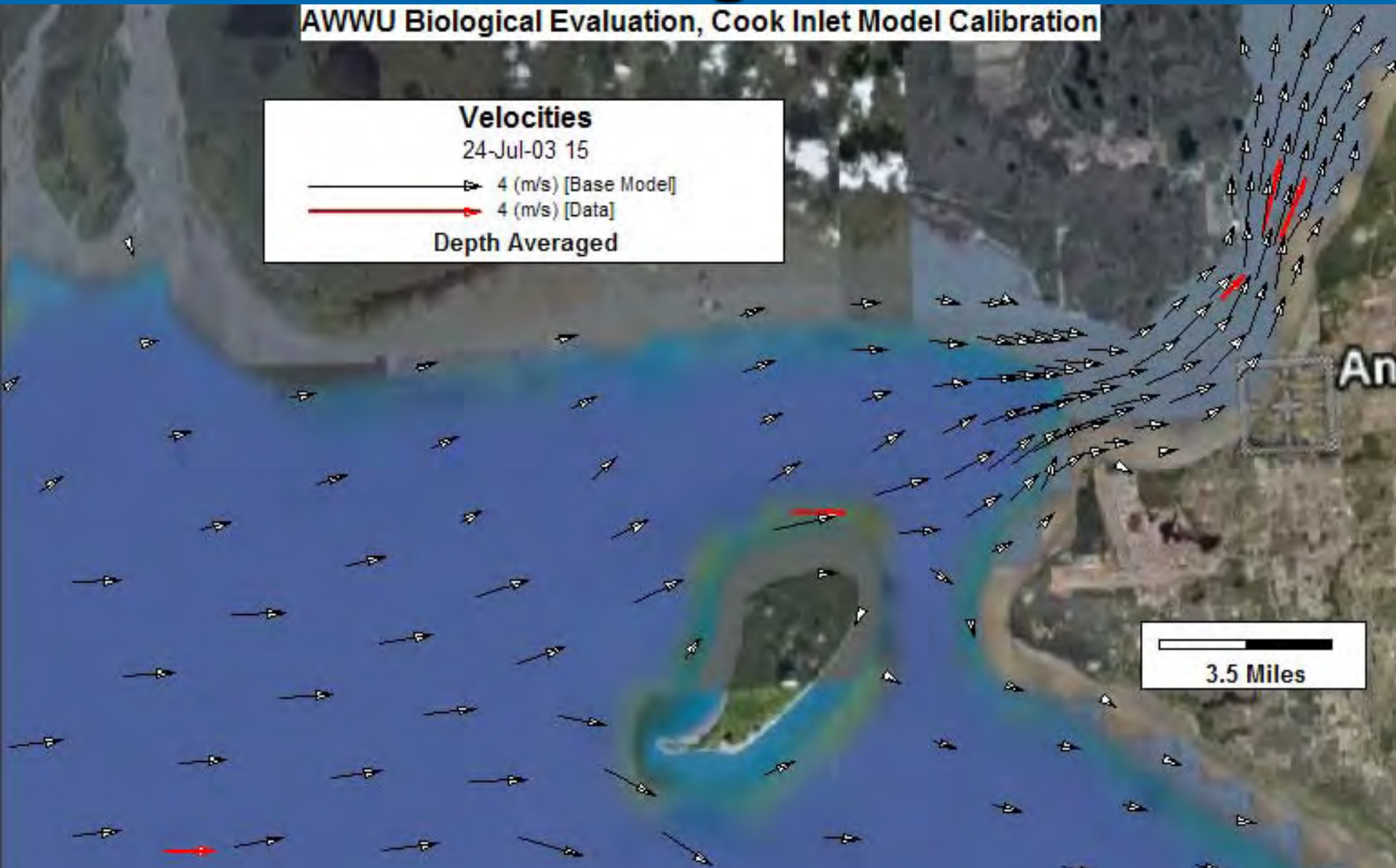
# EFDC Model uses fixed grid of >9000 cells, with 4 vertical layers



# Good match with tidal heights

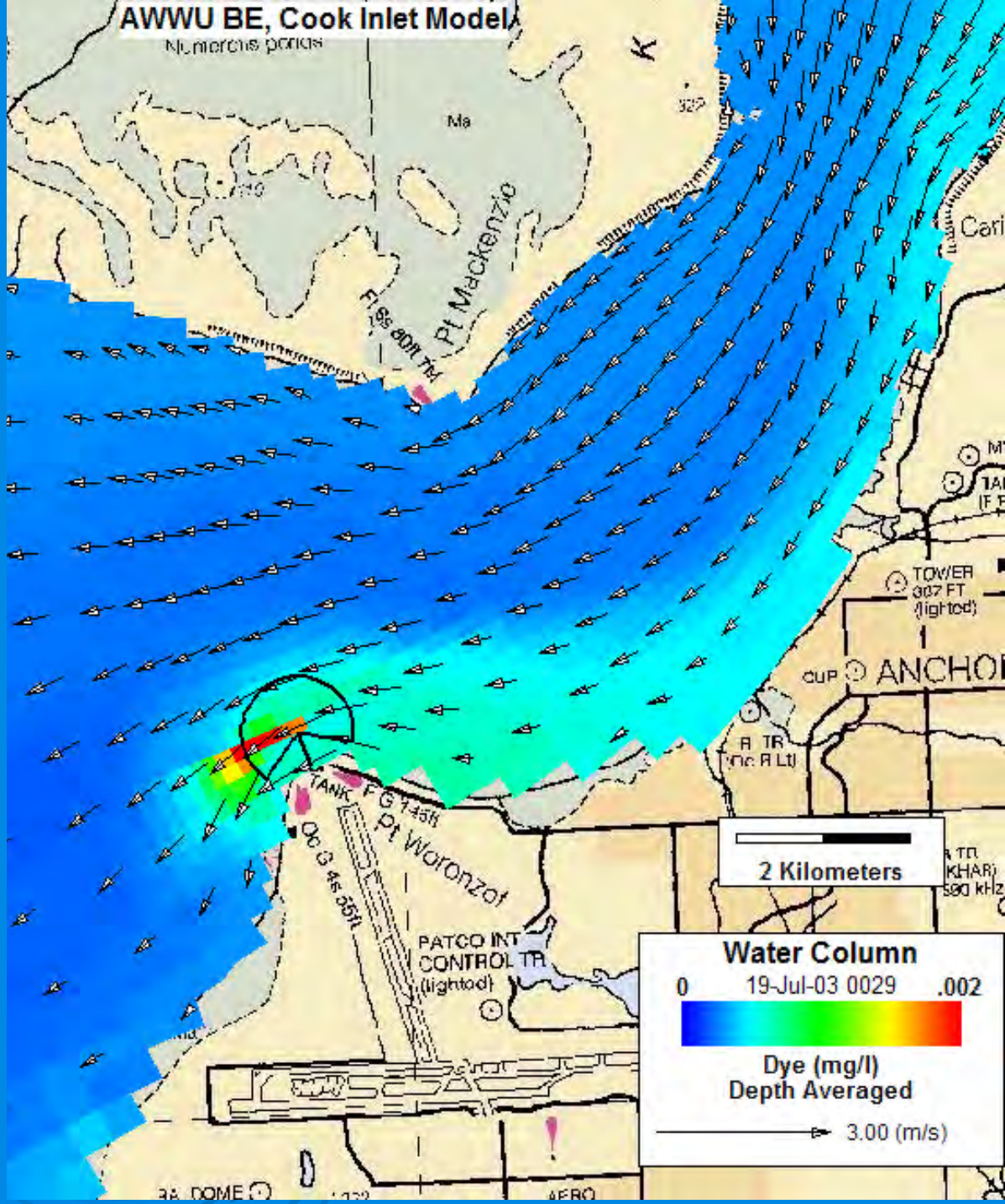


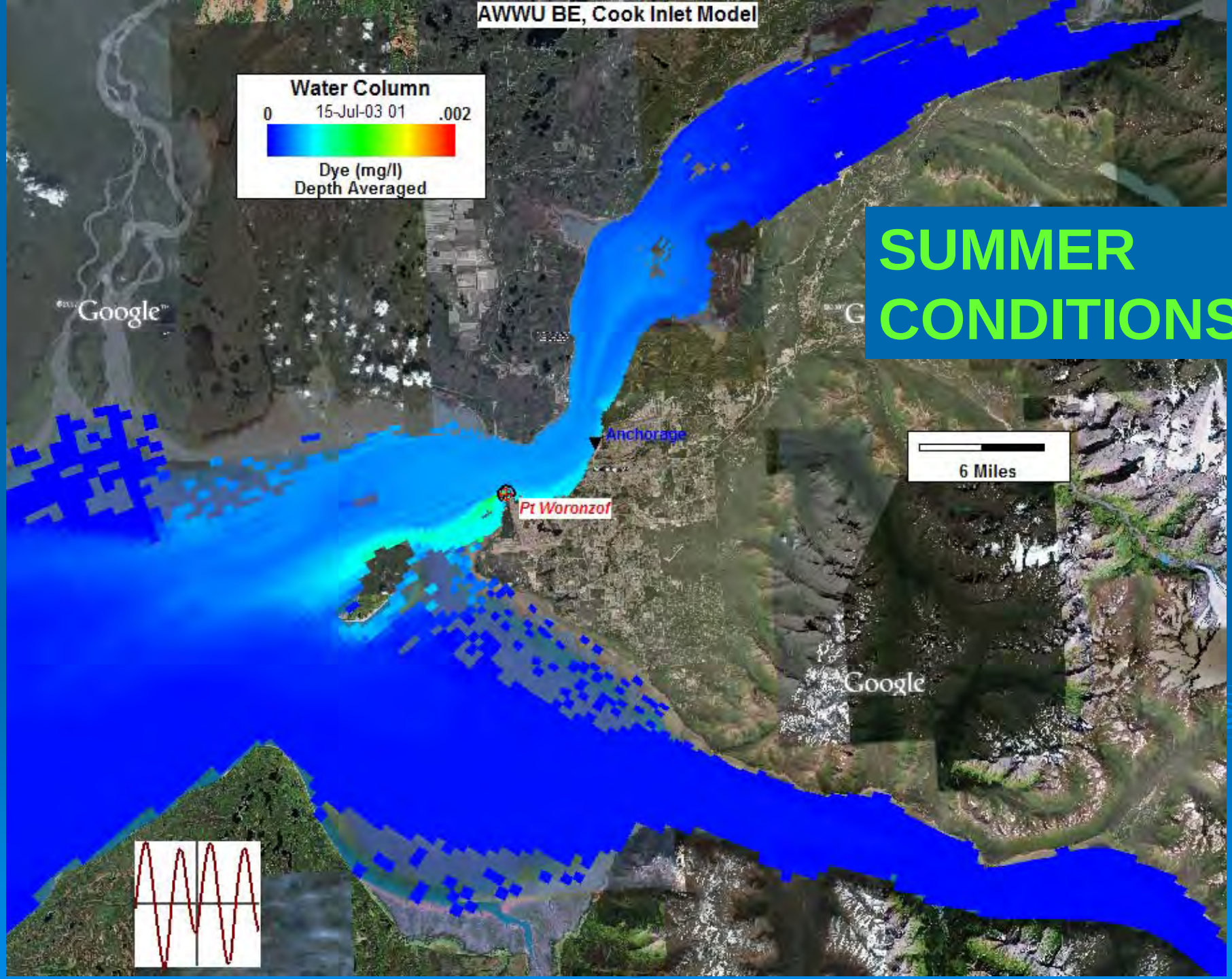
# Good match with velocities on flowing tide

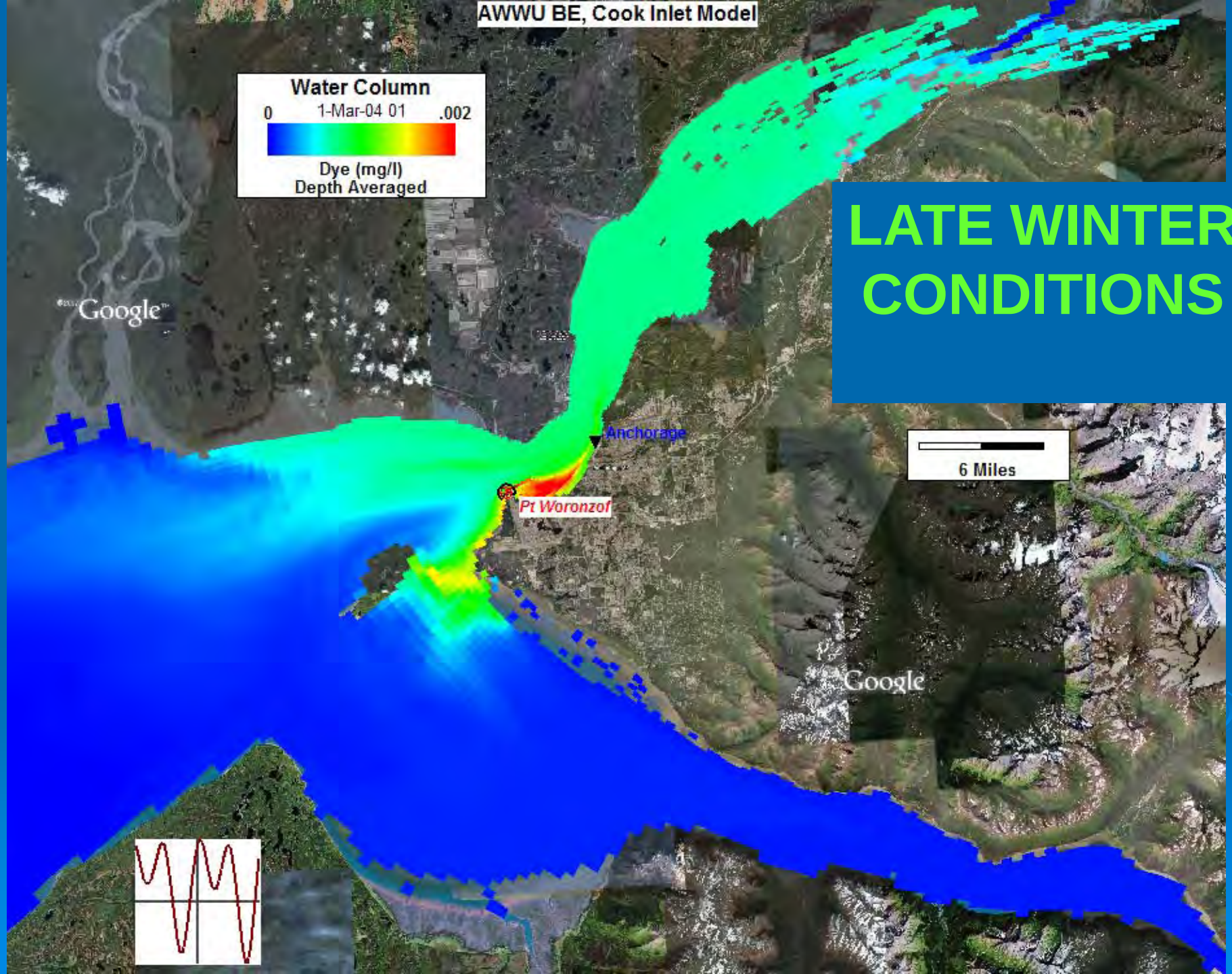


# And on the ebb

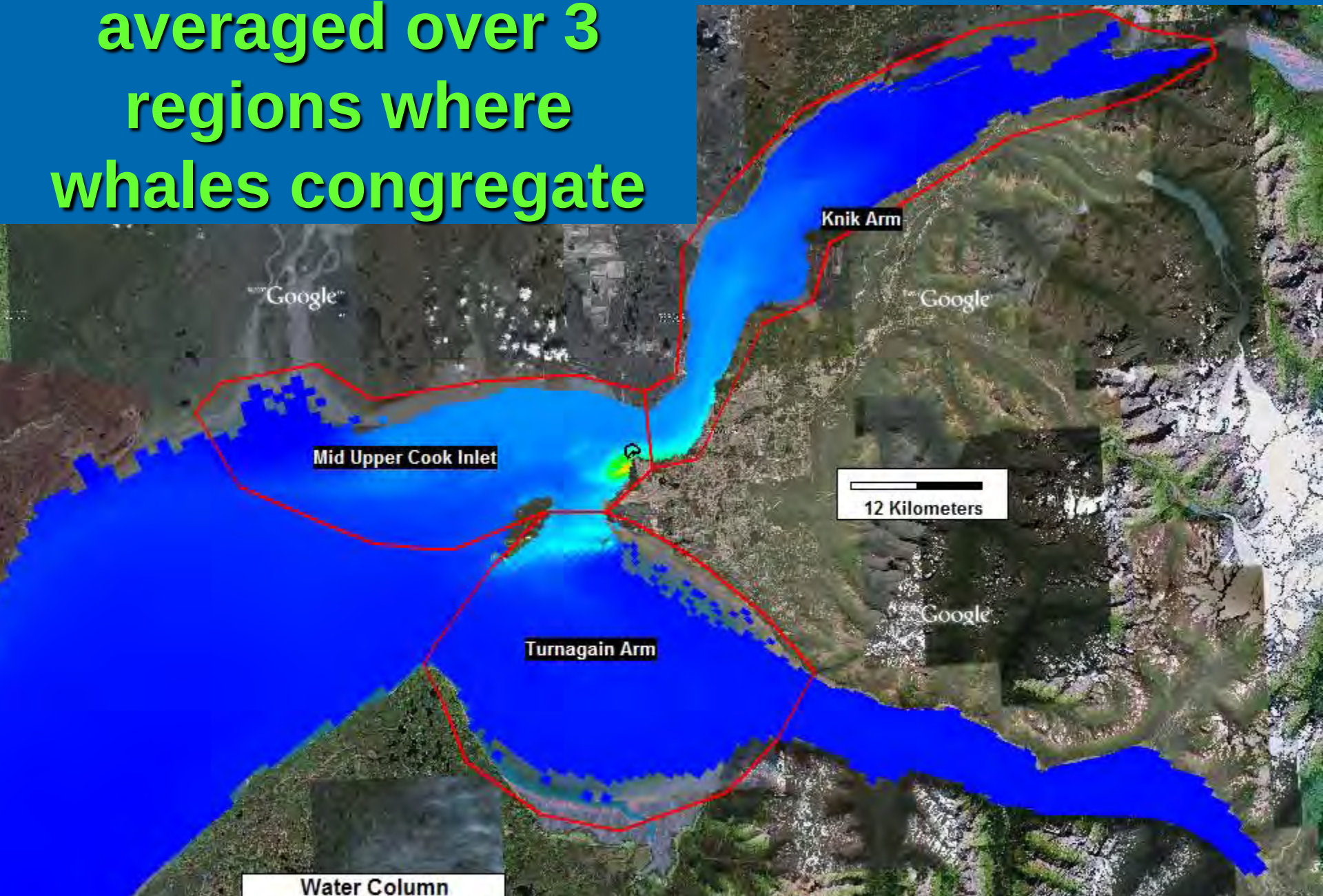
# Effluent concentration represented as a virtual "dye" distributed throughout the water column



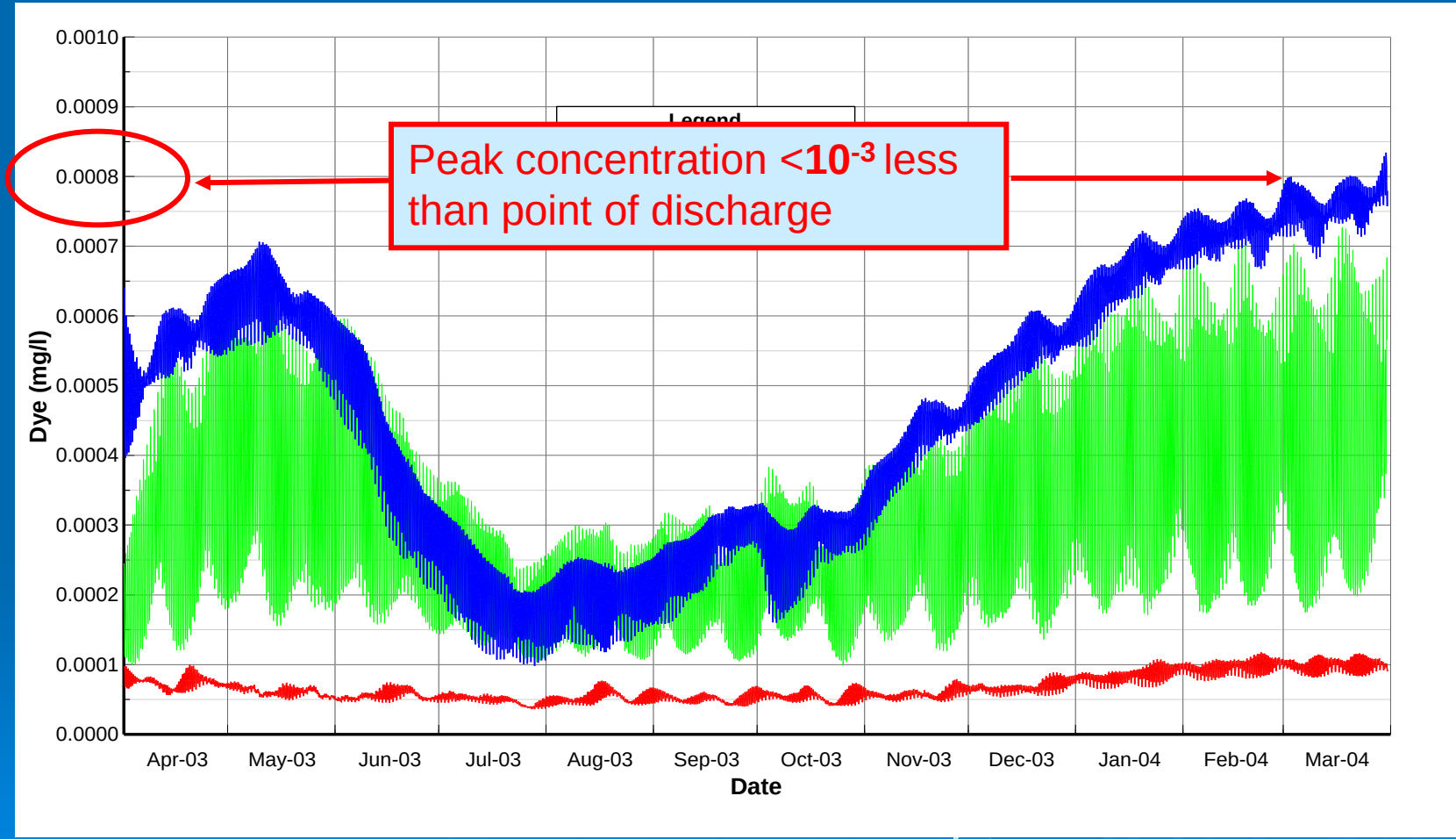

AWWU BE, Cook Inlet Model
Water Column
0
15-Jul-03 01
.002
Dye (mg/l)
Depth Averaged
SUMMER CONDITIONS
Google
Anchorage
Pt Woronzof
6 Miles
Google


AWWU BE, Cook Inlet Model
Water Column
0
1-Mar-04 01
.002
Dye (mg/l)
Depth Averaged
LATE WINTER CONDITIONS
Google
Anchorage
Pt Woronzof
6 Miles
Google

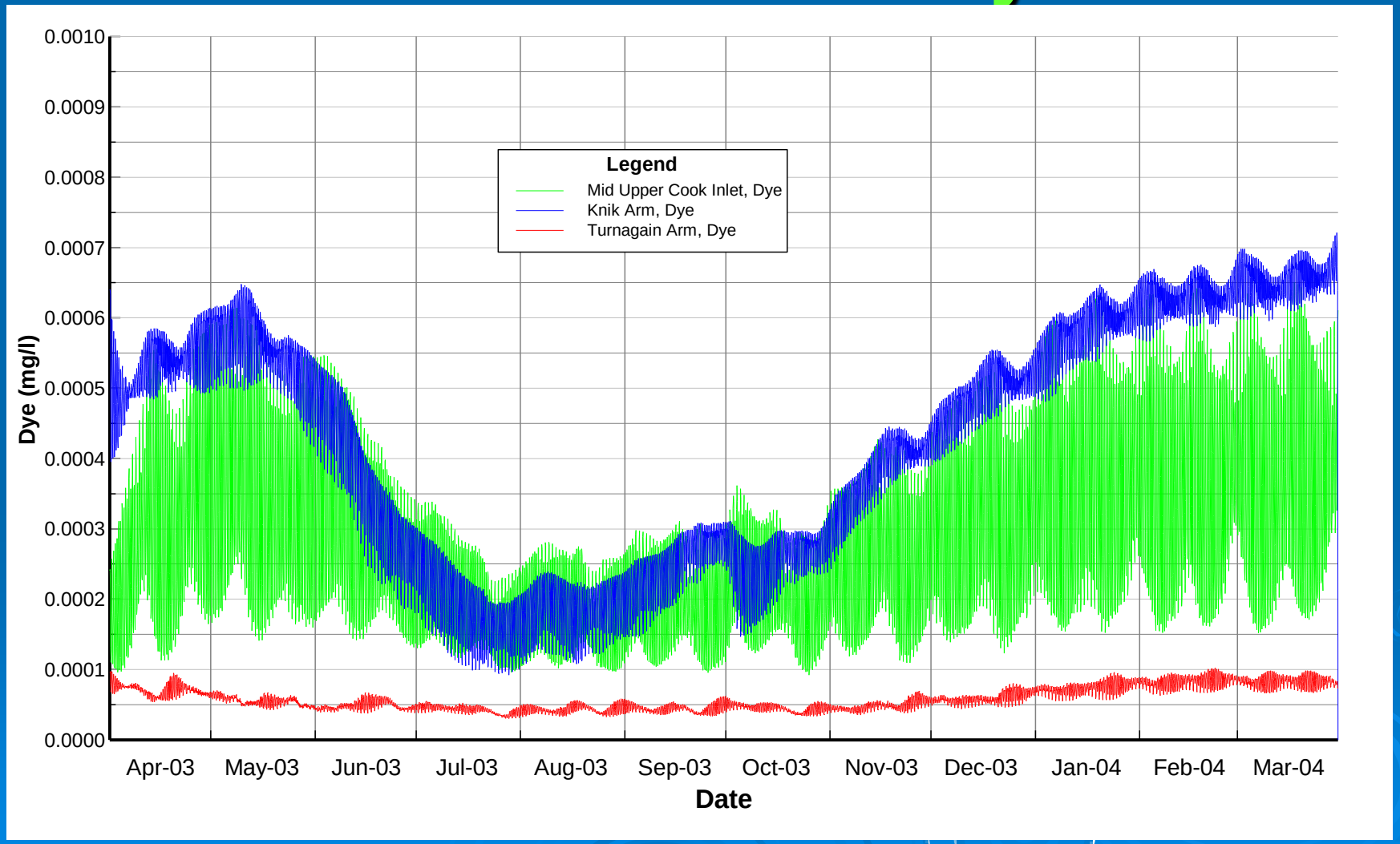
# Exposure estimates averaged over 3 regions where whales congregate



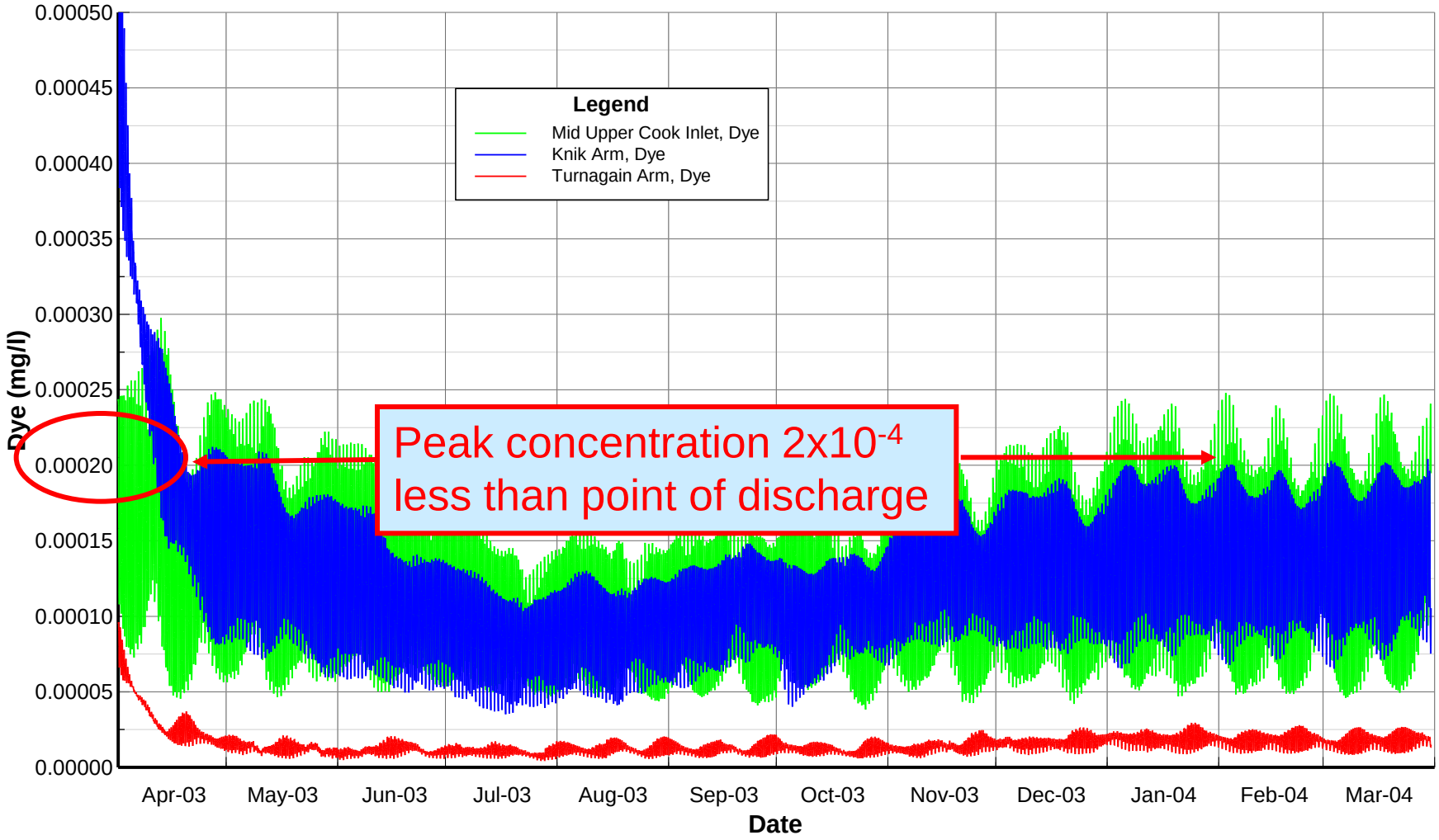
# Water Column Summary: No Degradation



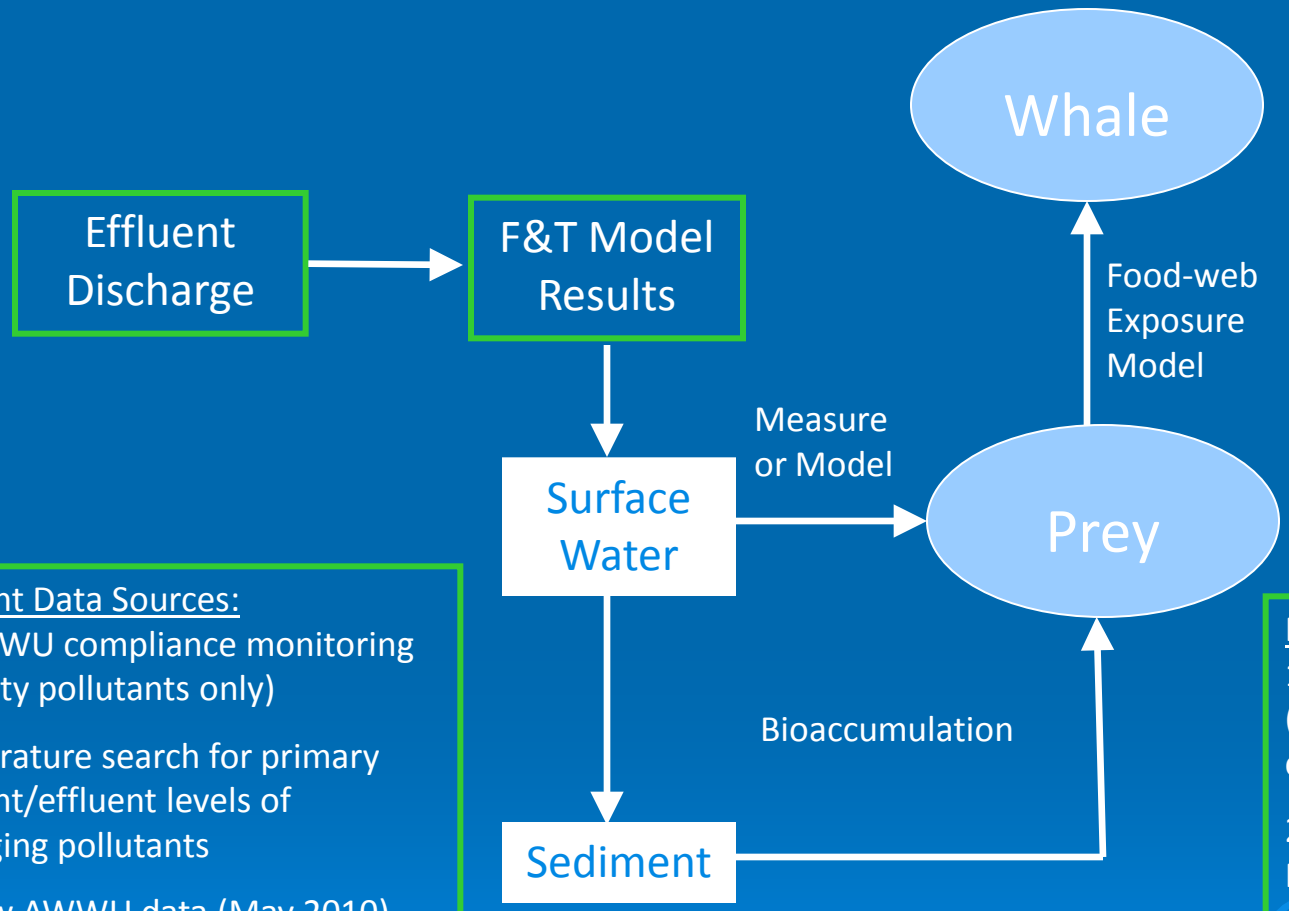
# Water Column Summary: Half Life: 150 days



# Water Column Summary: Half Life: 7 days



# Conceptual Exposure Model




Effluent Data Sources:

1) AWWU compliance monitoring (priority pollutants only)

2) Literature search for primary influent/effluent levels of emerging pollutants

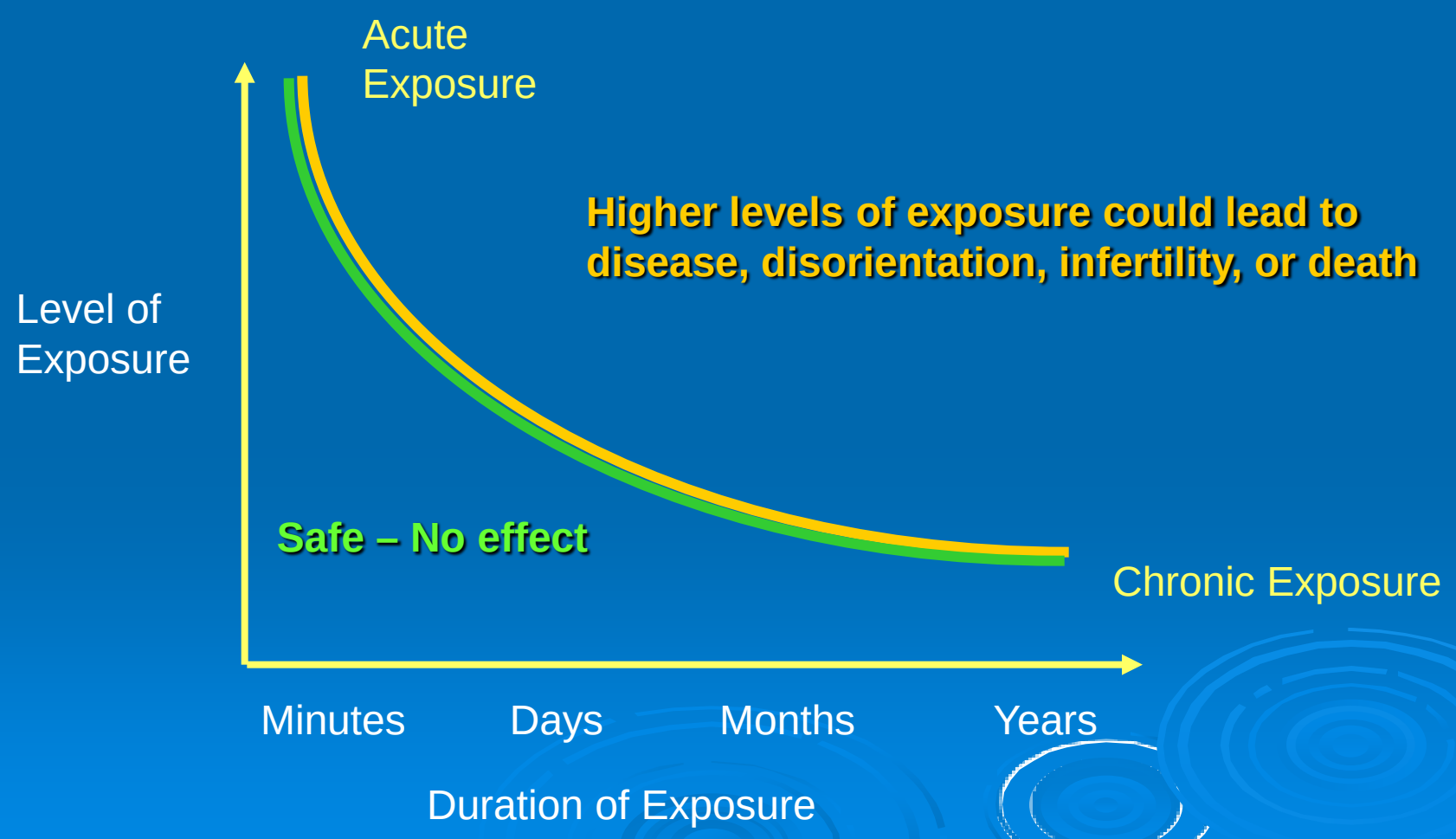
3) New AWWU data (May 2010)

Prey Tissue Data Sources:

1) AWWU 2004 Annual Report (priority pollutants in Pacific cod).

2) ADEC Fish Monitoring Program data for Cook inlet (salmon) – metals, pesticides, PCBs, dioxins, and PBDEs)

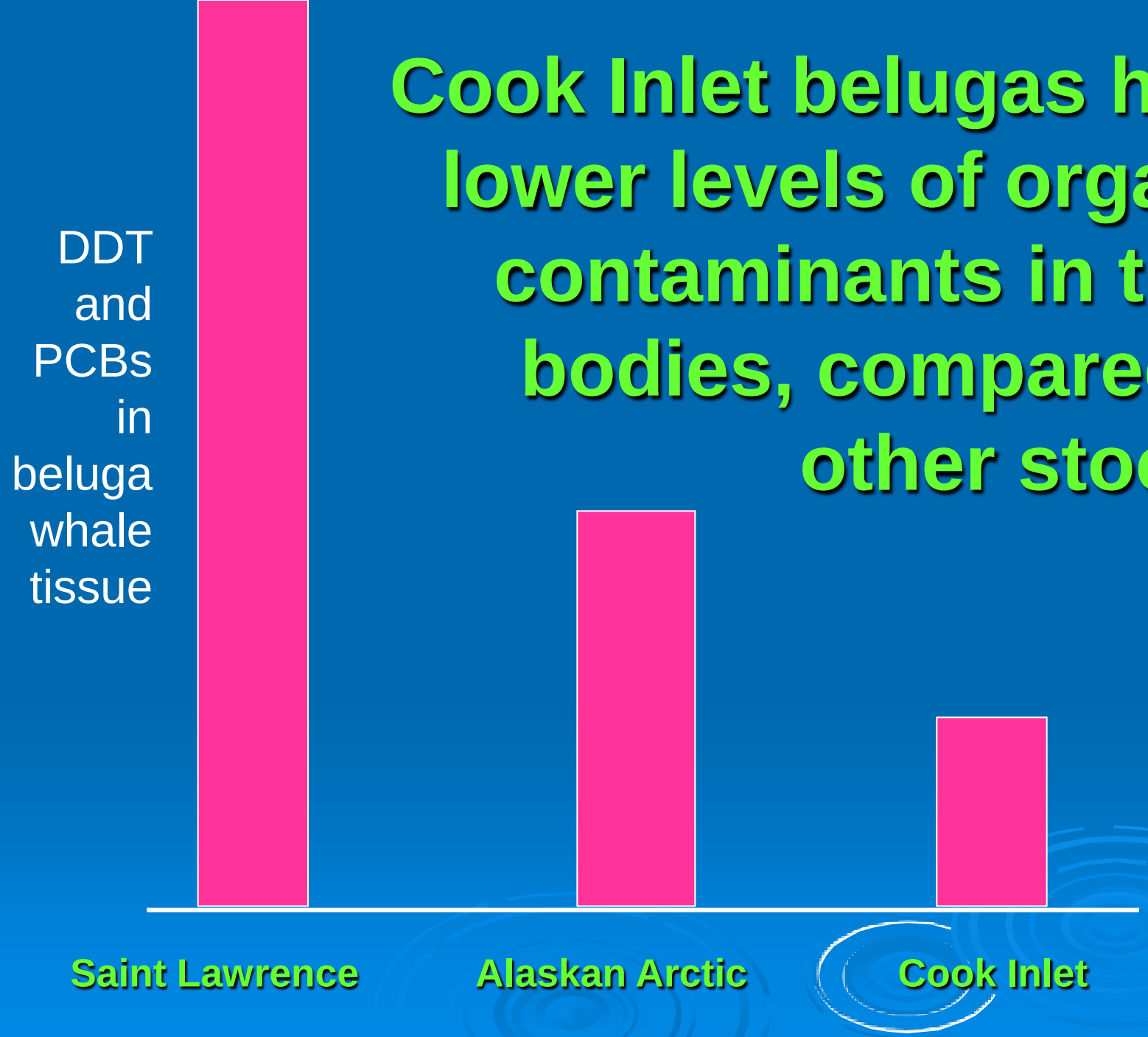
# Risk of exposure to contaminants depends on intensity and duration



# Lines of Evaluation for Discharge Effects on Beluga Whale

1. Direct exposure to prey species
2. Exposure of beluga whale by consumption of prey
3. Whole effluent testing results

# Cook Inlet belugas have lower levels of organic contaminants in their bodies, compared to other stocks.



# Ecological Hazard Quotient for Fish

$$HQ = C_w / TRV$$

where:

HQ = Ecological hazard quotient (unitless)

$C_w$ = Estimated concentration at edge of ZID (µg/L)

TRV = Toxicity reference value (µg/L) -
Highest level of exposure without adverse effects

HQ > 1: Potential for adverse ecological effects

HQ < 1: Considered protective of beluga whale prey.

# Ecological Hazard Quotient for Beluga Whale

$$HQ = E_{diet}/TRV$$

where:

HQ = Ecological hazard quotient (unitless)

$E_{diet}$ = Estimated daily dietary intake of POC (mg/kg body weight-day)

TRV = Toxicity reference value (mg/kg body weight-day) – highest level of exposure without anticipated adverse effects in mammals

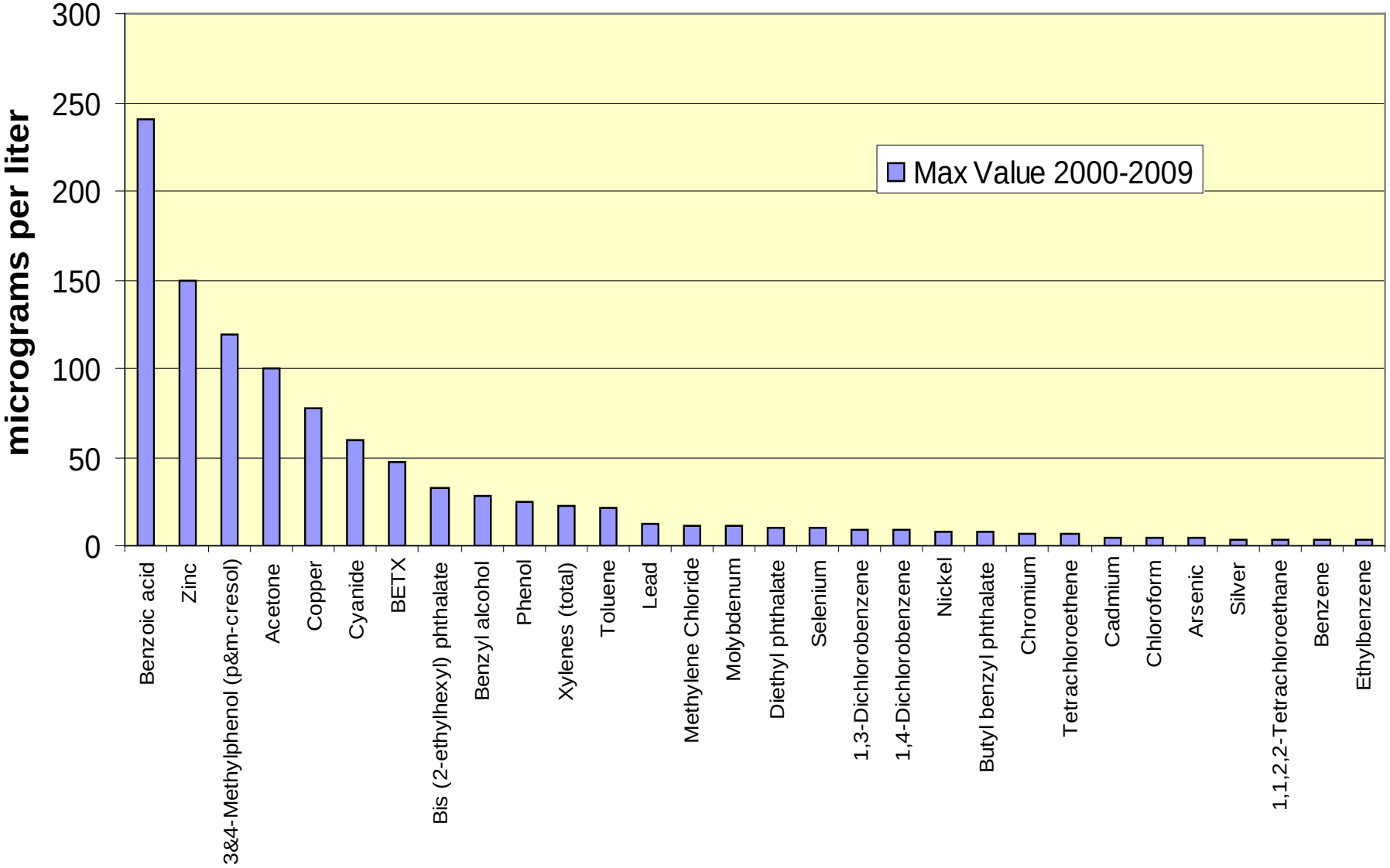
HQ > 1: Potential for adverse ecological effects

HQ < 1: Considered protective of beluga whales

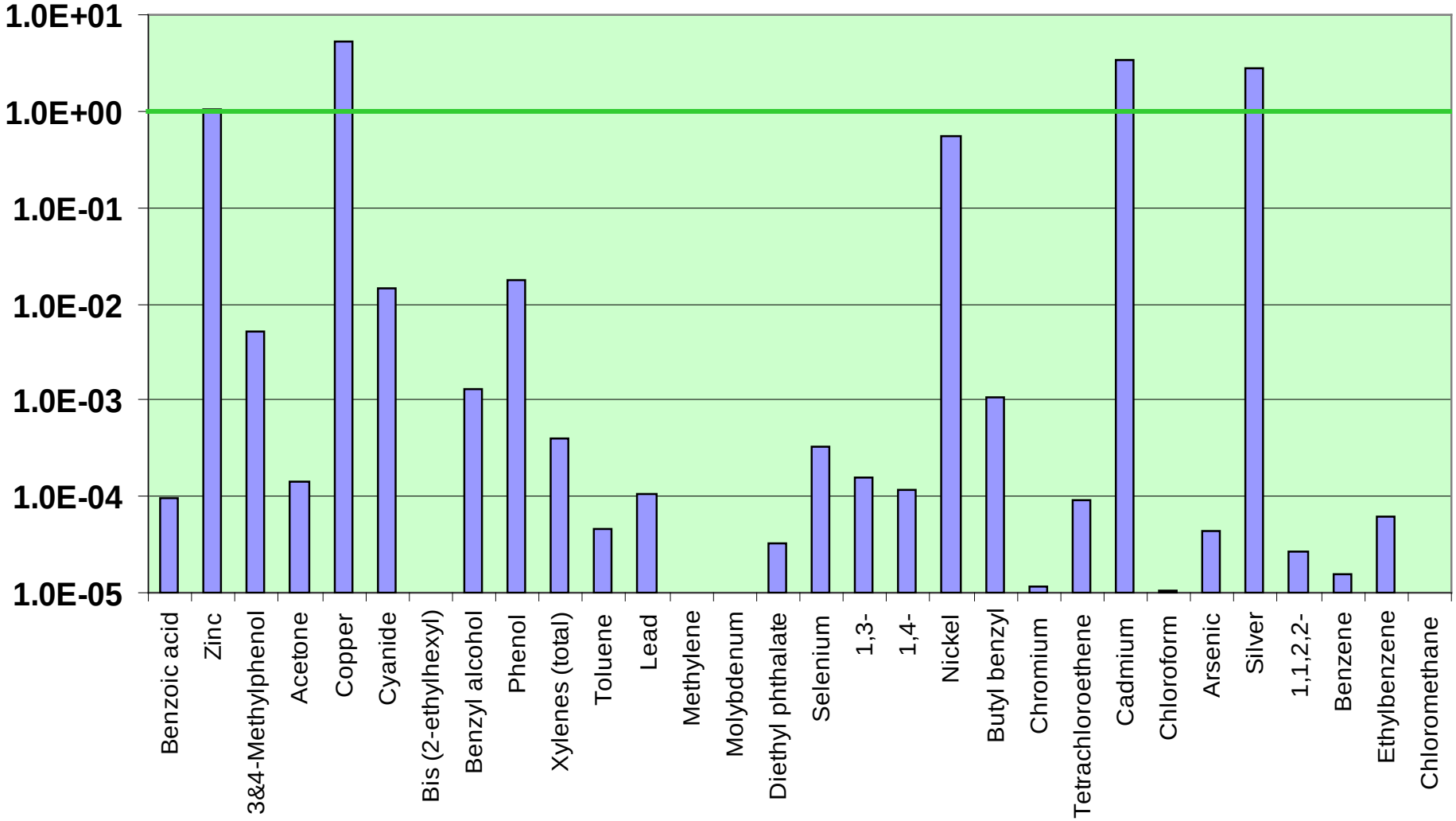
# Analysis accompanied by a host of conservative assumptions

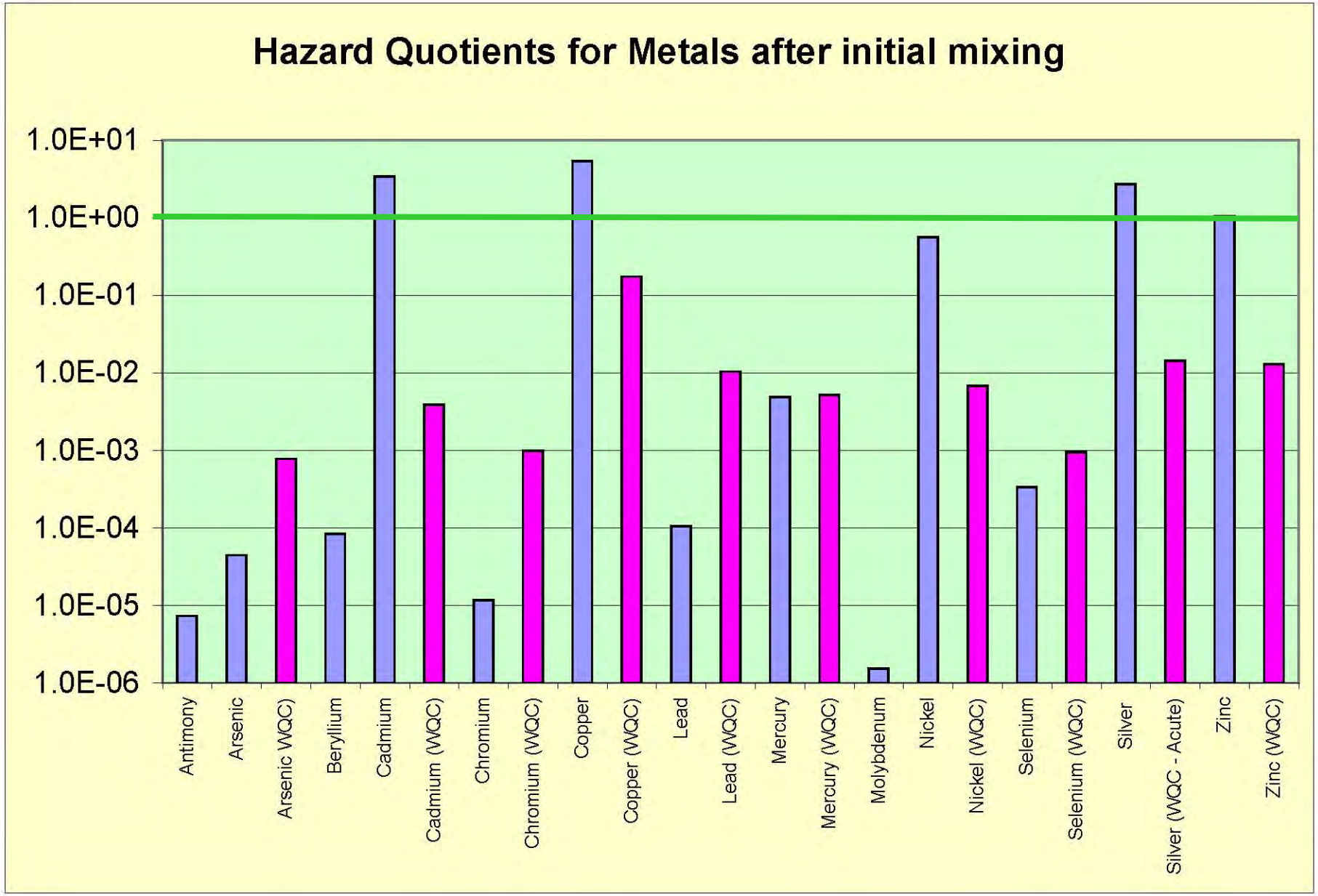
- Prey organisms continually exposed to effluent at the edge of the ZID
- Maximum levels used in analysis
  - Peak of record
  - Peak reported in literature
- TRVs based on most sensitive species studied – Not necessarily CI species

# Top 30 Detected Trace Constituents from LongTerm Monitoring @ Asplund



# HQ's after initial mixing for Top 30 Detected Trace Constituents from Long Term Monitoring (Logarithmic Scale)

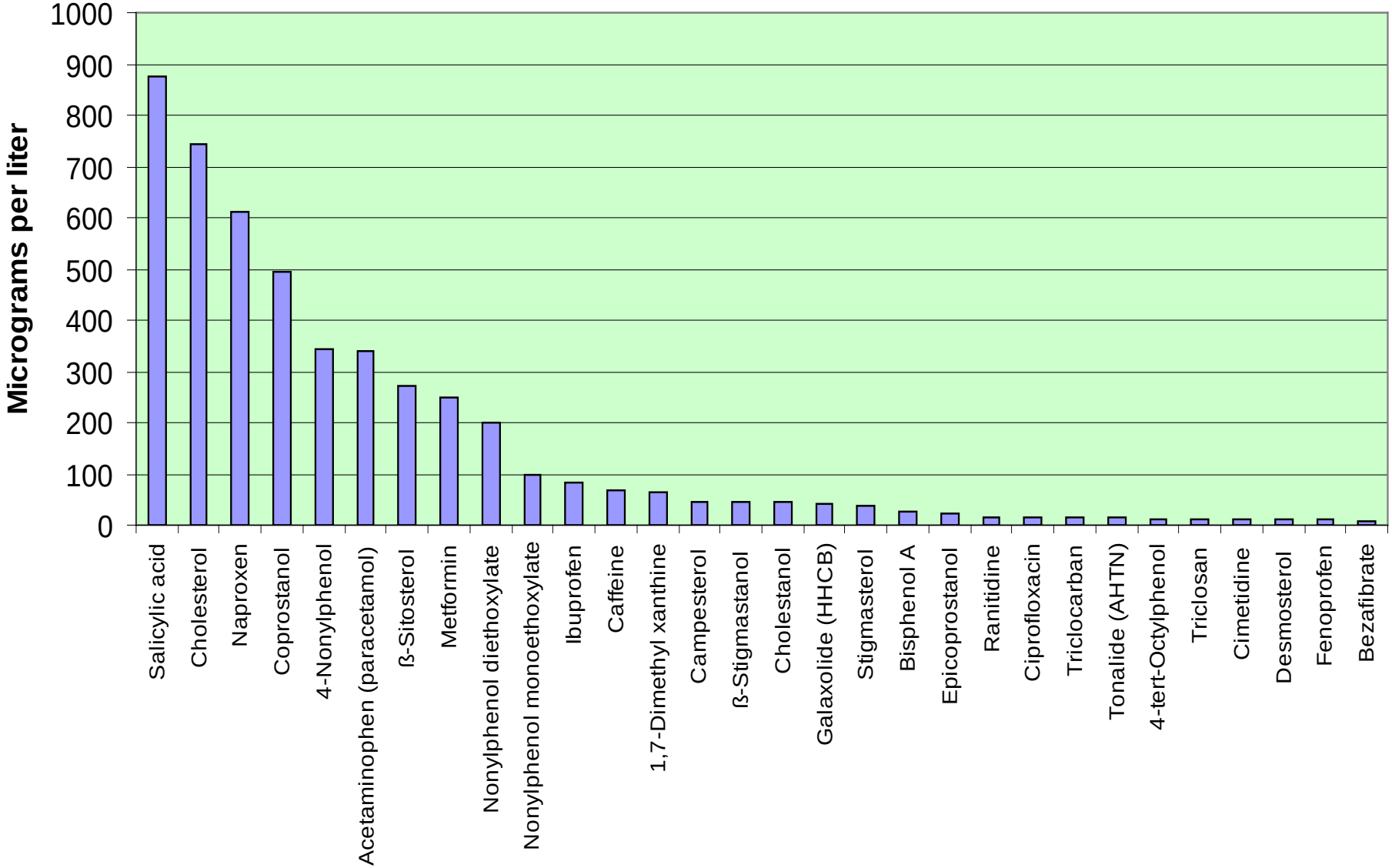


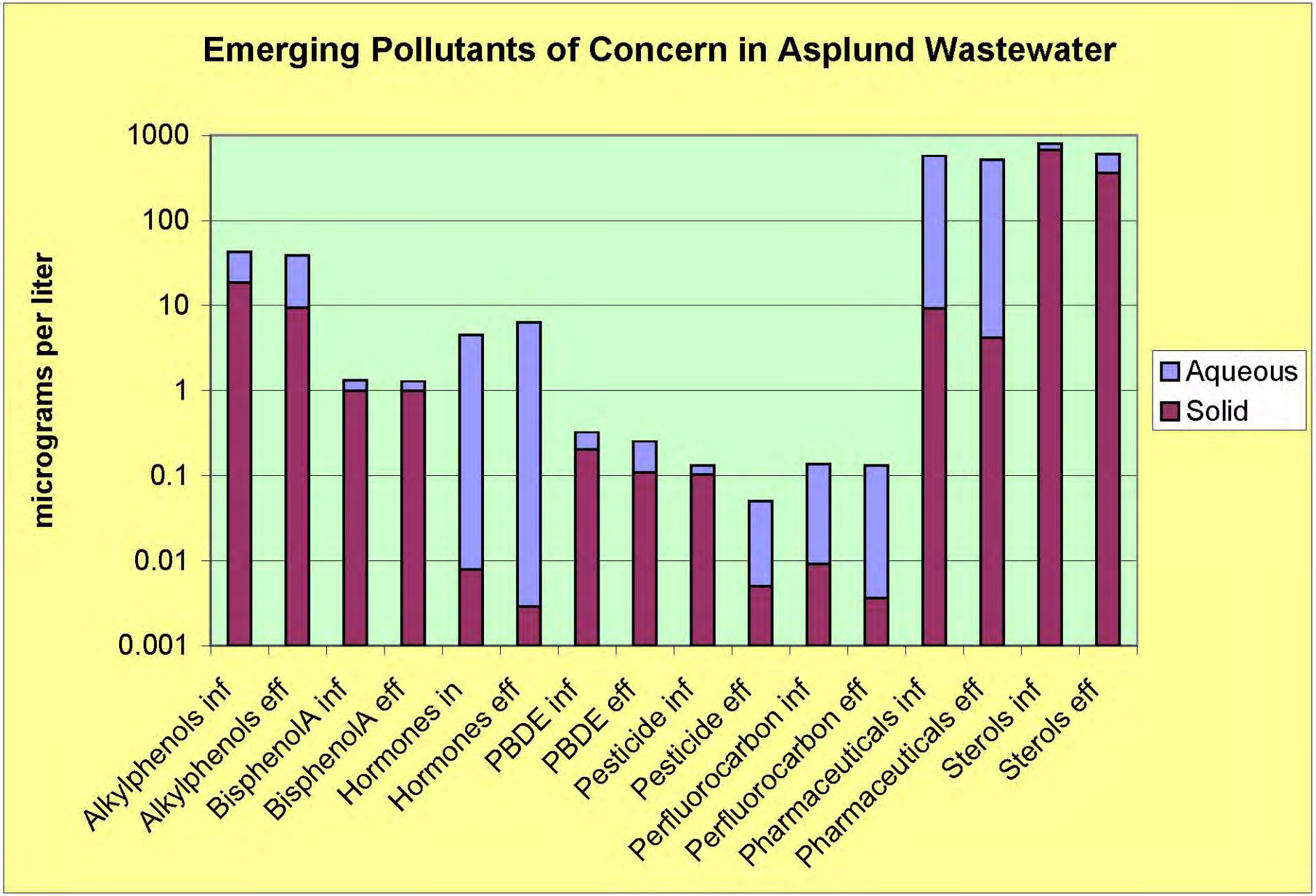

Hazard Quotients for Metals after initial mixing
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
Antimony
Arsenic
Arsenic WQC)
Beryllium
Cadmium
Cadmium (WQC)
Chromium
Chromium (WQC)
Copper
Copper (WQC)
Lead
Lead (WQC)
Mercury
Mercury (WQC)
Molybdenum
Nickel
Nickel (WQC)
Selenium
Selenium (WQC)
Silver
Silver (WQC - Acute)
Zinc
Zinc (WQC)

# Results of Effects Evaluation for Beluga Prey (fish): Regulated POCs

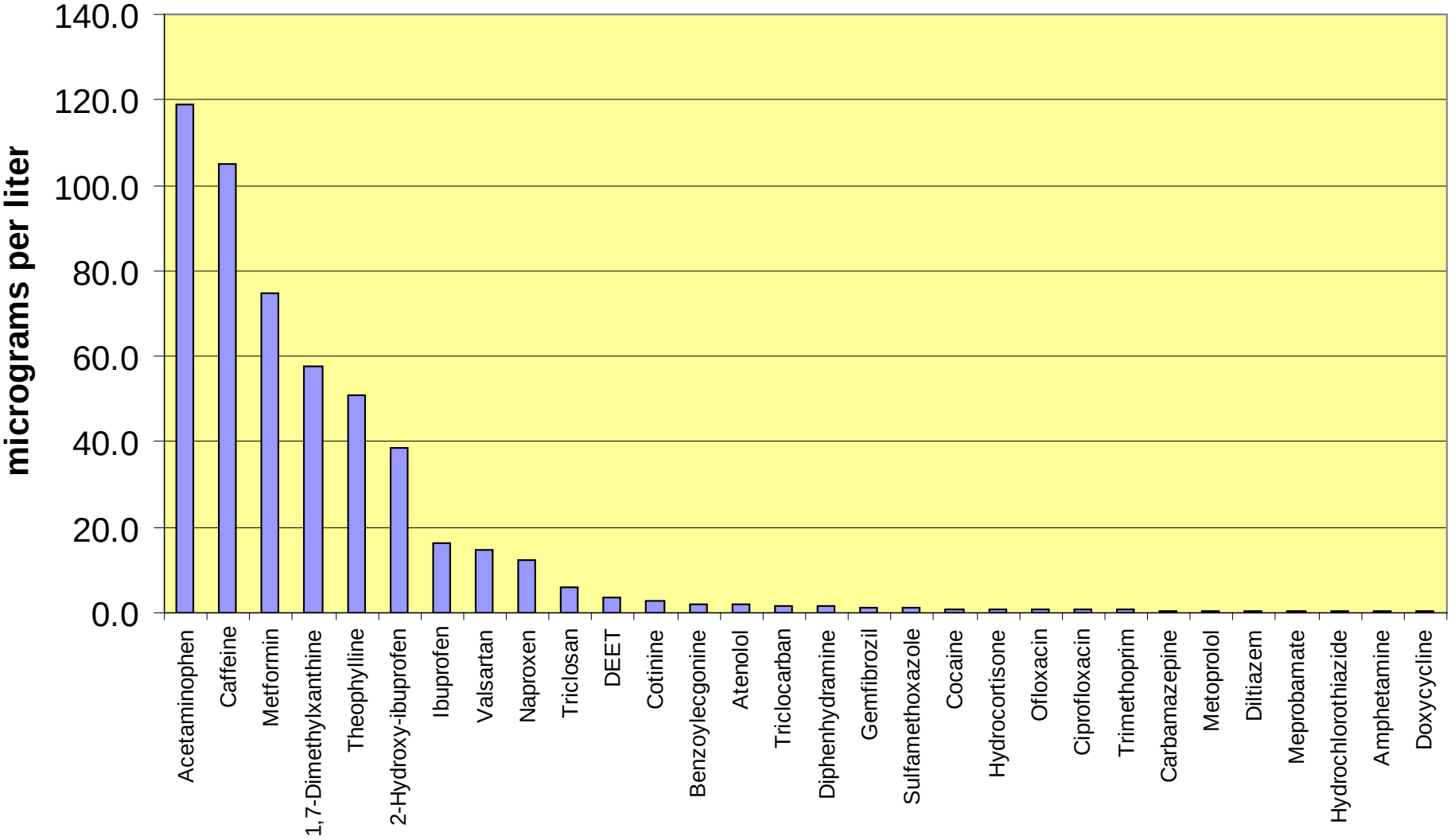
- 48 regulated constituents detected in effluent at least once between 2000 and 2009
- Only 4 metals exceed HQ > 1:
  - cadmium (HQ = 3.4)  max 4.9 ug/L; (effluent limit 1,322 ug/L)
  - copper (HQ = 5.4)  max 77 ug/L; (effluent limit 317 ug/L)
  - silver (HQ = 2.7)  max 3.9 ug/L; (effluent limit 257 ug/L)
  - zinc (HQ = 1.1)  max 150 ug/L; (effluent limit 11,249 ug/L)
- HQ based on State Water Quality Criteria <<1

# Top 30 Emerging Pollutants of Concern from Wastewater Literature

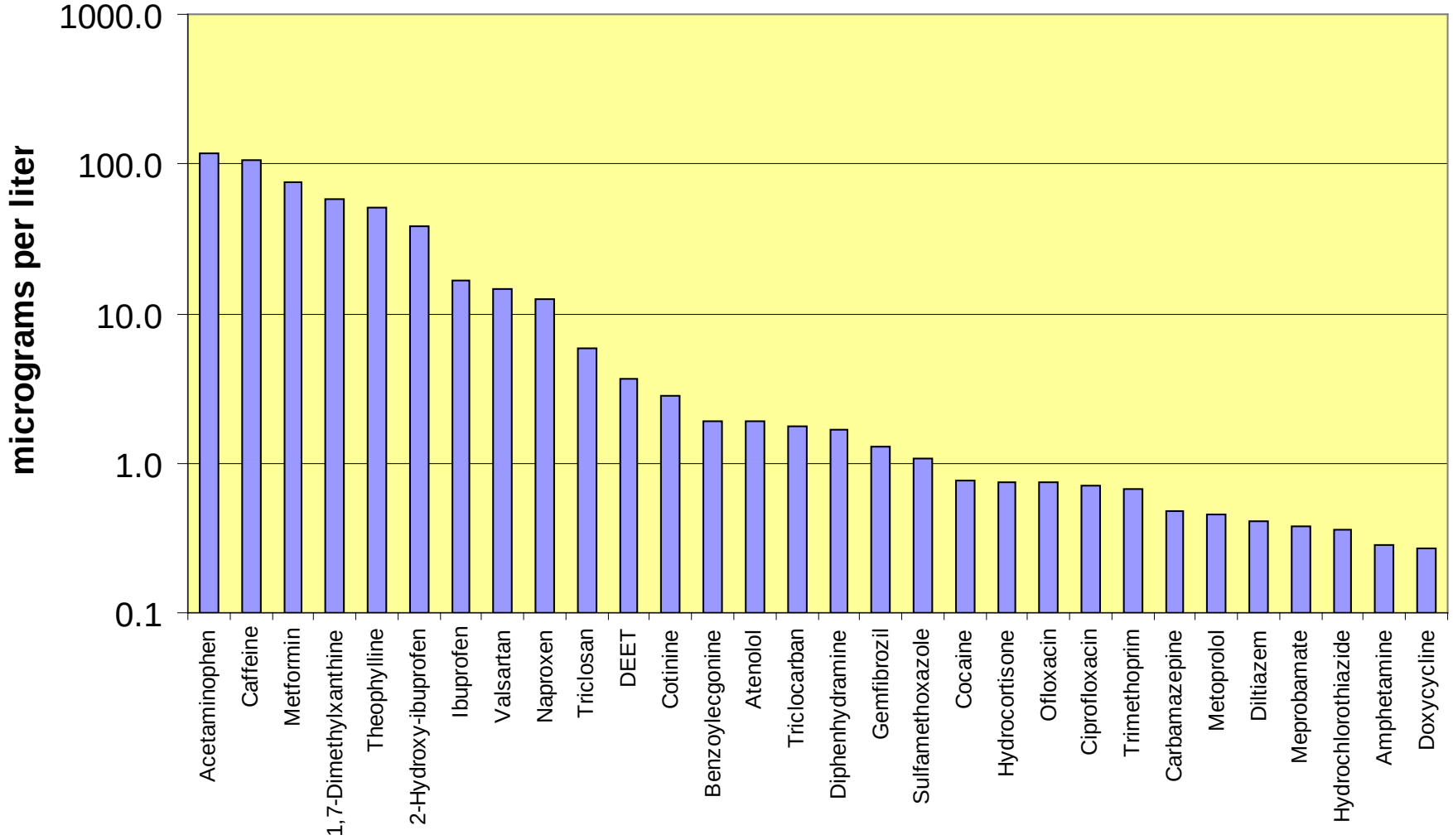



Emerging Pollutants of Concern in Asplund Wastewater
micrograms per liter
1000
100
10
1
0.1
0.01
0.001
Alkylphenols inf
Alkylphenols eff
BisphenolA inf
BisphenolA eff
Hormones in
Hormones eff
PBDE inf
PBDE eff
Pesticide inf
Pesticide eff
Perfluorocarbon inf
Perfluorocarbon eff
Pharmaceuticals inf
Pharmaceuticals eff
Sterols inf
Sterols eff
Aqueous
Solid

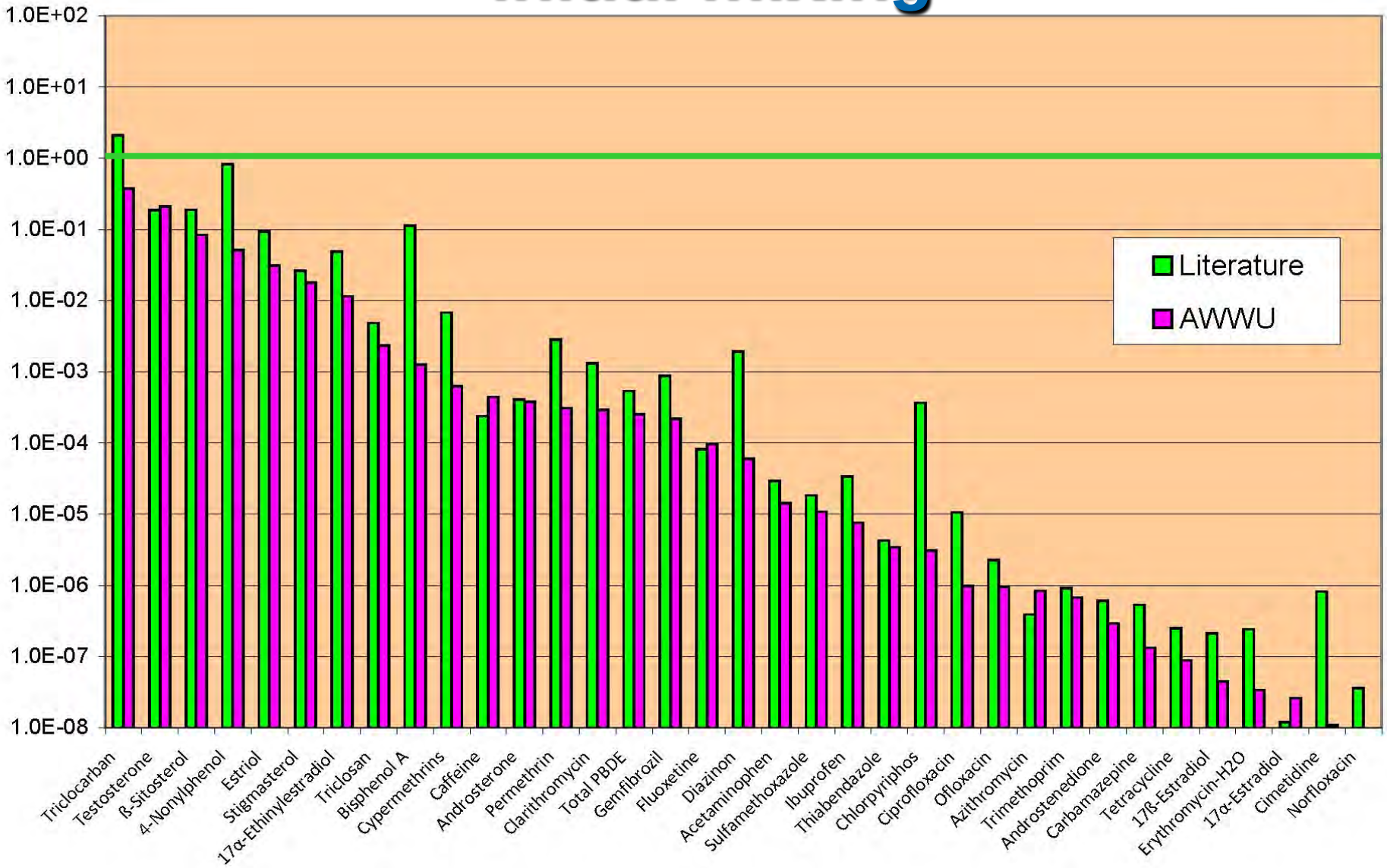
# Top 30 Pharmaceuticals Detected in Asplund Effluent



# Top 30 Pharmaceuticals Detected in Asplund Effluent (logarithmic scale)



# Hazard Quotients for PPCPs after initial mixing



# Results of Effects Evaluation for Beluga Prey (fish): Non-regulated EPOCs

- 116 constituents reported with detectable concentrations in the evaluated literature sources,
- Only one constituent HQ >1 (Triclocarban 2.1)
  - Very hydrophobic (log Kow of 4.9)
  - Strongly associated with suspended solids
  - Measured lower conc @ Asplund
  - HQ with on-site data: 0.37

# Results of Effects Evaluation for Beluga Whale: BCF Approach

- Of the 87 constituents evaluated, none has an HQ exceeding 1.0, even when conservatively using estimated concentrations at the edge of the ZID.
- When using more realistic environmental concentrations in the Knik Arm, Turnagain Arm, and the Upper CI subareas (based on the hydrodynamic model results), the HQs are below 1.0 by several orders of magnitude.

# Results of Effects Evaluation for Beluga Whale: Fish Tissue Approach

- Of the 33 constituents reported with detectable concentrations in fish tissue, none resulted in an HQ value exceeding unity

# Recap

- 20 years of monitoring shows no ill effects
- Body burdens of CIBW less than other stocks
- Effluent contains low levels of contaminants
- Effluent is rapidly mixed and dispersed
- Refreshment of Knik Arm is reduced in winter but…
  Water column never more than 0.1% effluent
- Maximum duration of exposure near outfall: minutes
- HQ's in vicinity of outfall <1
- HQ's in areas of chronic exposure <<<1.

*Conclusion: No adverse effects on beluga whales associated with Asplund discharge*

# Visitors are always welcome.

# Bring the kids!

www.awwu.biz/einfo

# Summary of model results

| | | Average Concentrations (mg/l) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No Degradation | | | Half Life: 150 Days | | | Half Life: 7 Days | | |
| Date | N | Mid Upper Cook Inlet | Knik Arm | Turnagain Arm | Mid Upper Cook Inlet | Knik Arm | Turnagain Arm | Mid Upper Cook Inlet | Knik Arm | Turnagain Arm |
| Apr-03 | 720 | 3.11E-04 | 5.57E-04 | 7.47E-05 | 2.97E-04 | 5.30E-04 | 7.13E-05 | 1.54E-04 | 2.33E-04 | 3.23E-05 |
| May-03 | 744 | 3.82E-04 | 6.15E-04 | 6.15E-05 | 3.53E-04 | 5.55E-04 | 5.51E-05 | 1.38E-04 | 1.40E-04 | 1.30E-05 |
| Jun-03 | 720 | 3.26E-04 | 4.13E-04 | 5.61E-05 | 2.98E-04 | 3.69E-04 | 4.89E-05 | 1.24E-04 | 1.12E-04 | 1.15E-05 |
| Jul-03 | 744 | 2.13E-04 | 2.06E-04 | 4.93E-05 | 1.99E-04 | 1.92E-04 | 4.28E-05 | 1.01E-04 | 8.75E-05 | 1.06E-05 |
| Aug-03 | 745 | 2.00E-04 | 2.01E-04 | 5.31E-05 | 1.85E-04 | 1.88E-04 | 4.34E-05 | 9.94E-05 | 9.22E-05 | 1.23E-05 |
| Sep-03 | 720 | 2.13E-04 | 2.68E-04 | 5.12E-05 | 1.99E-04 | 2.51E-04 | 4.44E-05 | 1.03E-04 | 1.08E-04 | 1.23E-05 |
| Oct-03 | 743 | 2.36E-04 | 2.82E-04 | 5.42E-05 | 2.17E-04 | 2.60E-04 | 4.52E-05 | 1.07E-04 | 1.06E-04 | 1.22E-05 |
| Nov-03 | 720 | 2.75E-04 | 4.15E-04 | 5.77E-05 | 2.56E-04 | 3.79E-04 | 4.85E-05 | 1.21E-04 | 1.31E-04 | 1.39E-05 |
| Dec-03 | 744 | 3.36E-04 | 5.43E-04 | 6.82E-05 | 3.10E-04 | 4.90E-04 | 5.97E-05 | 1.30E-04 | 1.37E-04 | 1.68E-05 |
| Jan-04 | 744 | 3.95E-04 | 6.59E-04 | 8.50E-05 | 3.60E-04 | 5.83E-04 | 7.43E-05 | 1.38E-04 | 1.43E-04 | 1.90E-05 |
| Feb-04 | 696 | 4.06E-04 | 7.23E-04 | 9.71E-05 | 3.65E-04 | 6.30E-04 | 8.34E-05 | 1.34E-04 | 1.42E-04 | 1.80E-05 |
| Mar-04 | 720 | 4.23E-04 | 7.61E-04 | 9.91E-05 | 3.75E-04 | 6.54E-04 | 8.30E-05 | 1.37E-04 | 1.46E-04 | 1.73E-05 |

# Steps to Analysis of Effects

Risk = Exposure X Toxicity

1. Quantify Exposure
   - Indirect modeling in exposure media
     - in surface water for fish (beluga prey)
     - Log Kow-based bioconcentration model into fish tissue
   - Directly measure in exposure media
     - in prey items for beluga
2. Determine Toxicity
   - Literature sources
   - Direct measure (whole effluent toxicity testing)
3. Calculate Hazard Quotient (exposure/toxicity)

# Assumptions Used for Estimating Effects on Beluga Prey (fish)

- Used maximum effluent levels of priority pollutants detected during AWWU NPDES compliance monitoring (2000-2009)
- Inferred maximum reported levels of non-regulated emerging constituents of concern from literature (EPA 9 POTW, WERF, etc.)
- Point of exposure assumed to be at the edge of ZID, whereas vast majority of beluga prey is outside the ZID
- Aquatic toxicity data sources include NOECs for most sensitive marine fish species (used FW fish or SW/FW invertebrate data where needed).
- The WET data are for notably highly sensitive tests and species, such as the sea urchin fertilization test (not a species found at Point Woronzof).

# Assumptions Used for Estimating Effects on the Beluga: Exposure Using Fish Tissue Concentrations

- Used maximum fish tissue levels reported by ADEC (salmon) and AWWU (Pacific cod) for metals, pesticides, PCBs, SVOCs, dioxins, and PBDEs
- Assumed tissue residues originated from Asplund WPCF, even though concentrations beyond the ZID are minute and primary dietary species migrate beyond CI and accumulate from other sources
- Computed HQs using concentrations at edge of ZID, and three CI subareas
- Interpolated toxicity from studies in terrestrial mammals (using allometric scaling to account for body size differences)
- Included both NOAELs and LOAELs for the most sensitive endpoints (NOEL was used in some cases)
- Assumed beluga body weight 313 kg (Tamura, 2000)
- Assumed dietary composition as 70% fish, 30% inverts from Pauly et al. 1998 (but same concentration applied for both)
- Selected food ingestion rate from most conservative of several allometric models

# Assumptions Used for Estimating Effects on the Beluga: Exposure Using Effluent Concentrations

- Used maximum effluent levels of regulated priority pollutants detected during AWWU NPDES compliance monitoring (2000-2009)
- Used maximum reported levels of non-regulated EPOCs from literature (EPA 9 POTW, WERF, etc.)
- Included constituents with Log Kow $\geq$ 3.5 (77 chemicals) and 10 metals
- Assumed no biodegradation, which is very conservative for some POCs ($t_{1/2}$ estradiol is about 10 days; PBDE about 150 days)
- Assumed all uptake is via bioconcentration from water column into beluga prey (ignoring likely sorption to suspended particulates, preventing gill uptake)
- Did not account for prey residence time for uptake exposure to levels at the edge of the ZID (appropriate for three CI subareas evaluated)
- Estimated many BCF values using Log Kow-based model that assumes steady-state uptake levels and does not account for *in-vivo* metabolism in fish

# Assumptions Used for Estimating Effects on the Beluga: Exposure Using Effluent Concentrations (cont.)

- Used default food-chain multipliers for trophic level transfer to fish (EPA 1995)
- Included constituents directly detected in fish tissue to provide an additional line of evidence
- Interpolated toxicity from studies in terrestrial mammals (using allometric scaling to account for body size differences)
- Included both NOAELs and LOAELs for the most sensitive endpoints (NOEL was used in some cases)
- Assumed beluga body weight 313 kg (Tamura, 2000)
- Assumed dietary composition as 70% fish, 30% inverts from Pauly et al. 1998 (but same concentration applied for both)
- Selected food ingestion rate from most conservative of several allometric models

# Conclusions

- Conventional discharge constituents:
  - Not likely to adversely affect prey species or beluga whale
- Emerging pollutants of concern
  - Not likely to adversely affect prey species or beluga whale
- Metals found in fish tissue are largely attributable to naturally-occurring levels.
  - HQs for available fish tissue data indicate that metals are **not likely to adversely affect** the CI beluga whale.
- Whole effluent toxicity
  - test species most relevant to this evaluation of beluga prey species is the top smelt test, where WET test results have indicated the absence of toxicity over the entire 10-year period evaluated.