

# Hydropower Projects: Climate Change Impacts and Adaptation

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**Water Power License Fee**

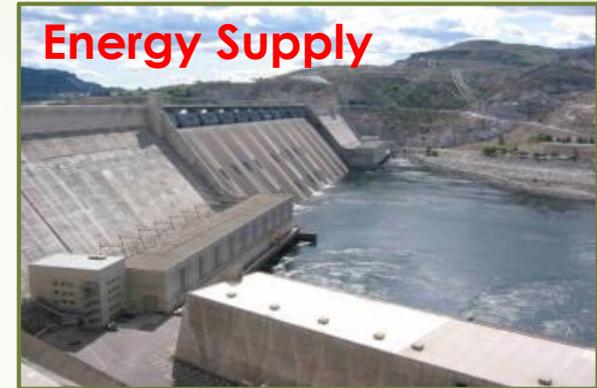
**stakeholder meeting**

**October 23, 2018**



# Hydropower Projects: Climate Change Impacts and Adaptation

Hydropower operations interact with a variety of potential climate change impacts



# Hydropower Projects: Climate Change Impacts and Adaptation

## FERC hydro licensing environmental issues

- Described in Ecology's *Water Quality Certifications for Existing Hydropower Dams: Guidance Manual*  
<https://fortress.wa.gov/ecy/publications/SummaryPages/0410022.html>

Total Dissolved Gas	Temperature	Turbidity
Nutrients/Trophic Status	Fecal Coliform	pH
Dissolved Oxygen (DO)	Oil and Grease	Toxics
Aquatic Plants & Animals	Fish Habitat – Flow	Wildlife Habitat
Recreation and Aesthetics		

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## Impacts of more intense storm events on watershed

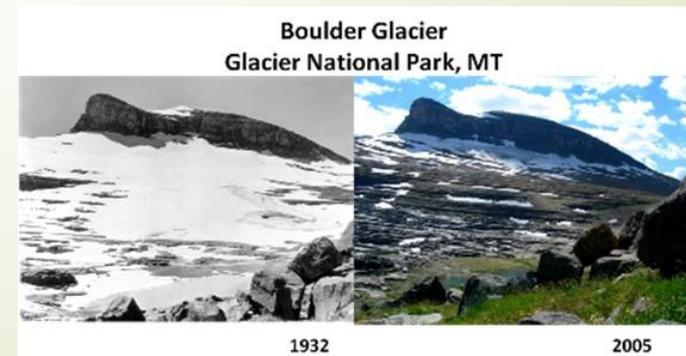
- Increased watershed erosion
- More high turbidity events
- Increased nutrient loading to reservoir
- Increased wash-off of bacteria, oil, toxics
- Impacts on fishery and recreation
- Debris management challenges
- More sediment deposition
  - Shorter reservoir life from filling with sediment
  - More sediment flushed downstream



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## Patterns of changes in inflow hydrology

- Wetter wet season, drier dry season
- Greater swings in extremes (peak flows, low flows)
- Loss of snowpack – shift in rain/snow mix
  - snow → rain/snow → rain
- Earlier, more rapid snowmelt runoff
  - TDG events earlier, longer, more intense
- Changes in storage and downstream flows
- Unprecedented spillway use tests structural integrity
  - e.g. Oroville Dam  
(record spill triggered spillway failure)



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## Patterns of changes in reservoir physical structure

- **Warmer inflows**
- **Warmer surface waters extend deeper**
- **Earlier hypolimnion setup & longer stratified period**
- **Loss of fish habitat from the “squeeze”**
  - **warm surface waters and low DO deep waters**
- **More challenging storage management**
  - **More risk of lower summer reservoir levels**
  - **Outlet structures may present opportunities or challenges**



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## Patterns of changes in reservoir ecosystem structure

- **More nutrients + longer growing season → Increased eutrophication**
  - Increased algal blooms
  - Lower hypolimnetic oxygen
  - Higher epilimnetic pH
- **Shifts in algal species**
  - More blue-green algae (cyanobacteria)
  - Other nuisance species



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## Patterns of changes in reservoir ecosystem structure

- Loss of cool-water and other sensitive species
- Appearance of warm-water adapted species
- Increased non-native and invasive species
- Increased levels of bioaccumulative toxics
  - e.g. methylated mercury



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## Effects of fires in the reservoir watershed

- Increase in runoff: e.g. 100-year → 1,000 year event
- Increased erosion → more sediment & nutrients
  - Debris flows and landslides
- Post-fire vegetation shifts



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## Patterns in changes in downstream water quality

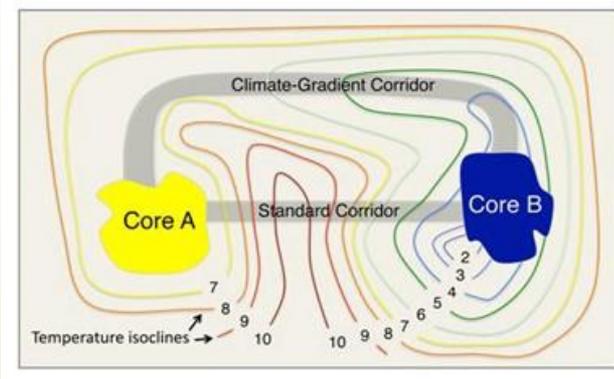
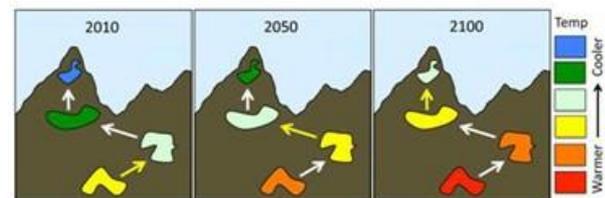
- **Could be warmer**
- **More nutrients and algae**
- **More turbidity**
- **Lower DO, higher pH**



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## Potential ecosystem shifts and climate migration

- Dams as barriers to climate migration corridors
  - As climate conditions shift, species need to move
- Vegetation shifts in the watershed due to changed temperature and moisture regimes (and fire)
- Changes in associated wetlands
- Changes in water-related disease vectors
  - Migration of tropical diseases (e.g. West Nile)
- Altered effectiveness of mitigation projects



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## Potential recreation impacts

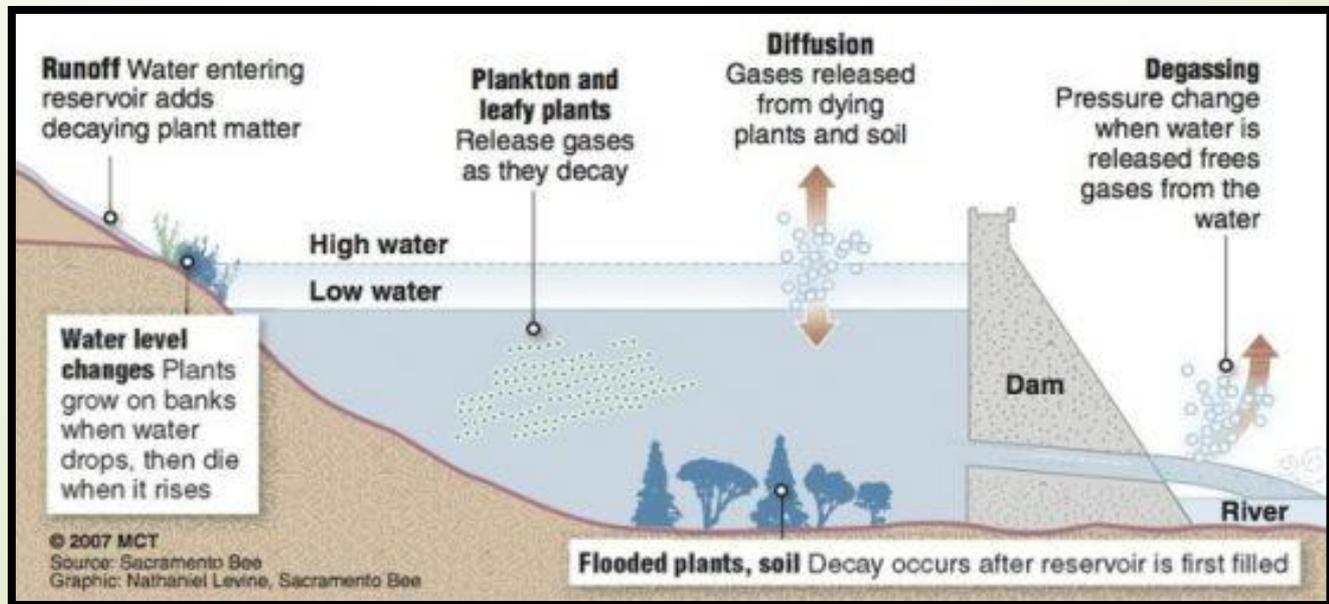
- Lower or more variable summer reservoir levels
- Increased algal blooms, including toxic blooms
- Warmer water temperatures
- Shifts in fish populations
- Longer recreation season
  - More conflicting uses
  - More WQ impacts



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## Carbon emission and sequestration

- Reservoir as a carbon sink
  - Detrital carbon settling
  - Associated wetlands
- Reservoir as a carbon source: methane releases



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## Hydropower projects as low-carbon energy

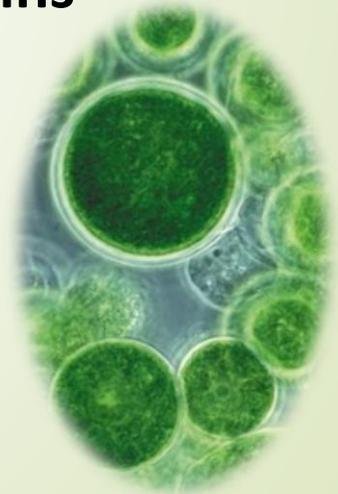
- **Shift in timing of energy production**
  - **More generation earlier in winter**
    - **Could be good – align winter needs w flow**
  - **But winters warmer, summers hotter**
    - **Energy demand shifts to summer**
- **Risk management planning needed**
  - **Heat waves and extreme storms**
  - **Multi-year drought**



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## Adaptation – monitoring

- **Monitor for critical climate-sensitive parameters**
  - Temperature profile time series
  - Hypolimnetic depth and DO levels
  - Chlorophyll-*a* & algal species assemblages
    - Cyanobacteria (blue-green) and toxins
- **Monitor for changes in watershed loading**
  - Suspended sediment and turbidity
  - Nutrient loading
  - Especially extreme weather events
- **Frequency & duration of spill events (TDG)**
  - 7Q10 may go up with increasing rainfall intensity



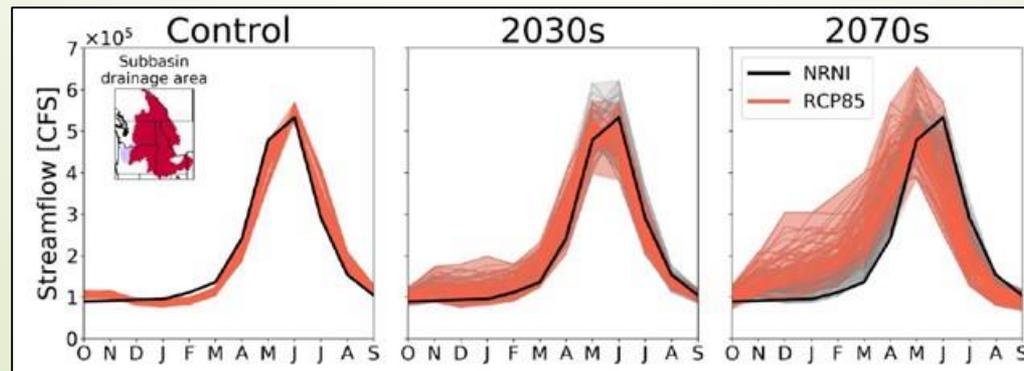
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## Adaptation – modeling a future with climate change

- Altered patterns of hydrology
- Changes in watershed runoff & project inflow quality
- Shifts in reservoir and downstream water quality
- Fish bioenergetics and volitional movement
- Impacts of project operation alternatives
- Mitigation – vulnerability or resilience

”Death of stationarity”:

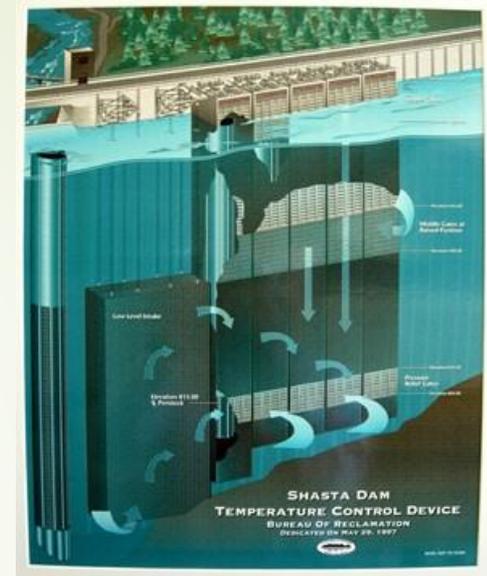
you can no longer predict the future from the past



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## Adaptation

- **Structural changes**
  - **Outlet configuration**
    - **Manage downstream DO & temperature**
    - **Alter reservoir hydraulics to optimize water quality**
- **Operational changes**
  - **Revised operation rules**
    - **Optimize for water quality and other uses**
  - **Long-term risk management planning**
    - **Plan for an uncertain future**



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## Adaptation

- **Watershed management**
  - **Mitigation to reduce erosion and runoff**
- **Watershed vegetation management to reduce fire risk**
  - **Response plans for fires: erosion control, replanting**
- **Cold water refuges**
- **Downstream impacts**
  - **Minimum flows and ramping rates**
  - **Outlet reaeration**
  - **Tributary mitigation**



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## Adaptation

- **Mitigation strategies**
  - **Plan for resilience under future conditions**
  - **Cold water refuges: tributaries, springs, upwelling**
  - **Biota shifts and migration corridors**
    - **Vegetation resilience and distribution shifts**
    - **Mobility for both fish and terrestrial wildlife**
    - **Build resilience for associated wetlands**
  - **Downstream impacts**
    - **Restore floodplain functions**
    - **Tributary restoration and enhancement**



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## Adaptation

- **How do we do it?**
  - **Adaptive management: “Plan-do-check-act” cycle**
    - **“Monitor–Evaluate–Adjust Plans–Implement”**
  - **Make adjustments as the situation evolves**
  - **Create a Project “WQ risk management plan”**
  - **Apply to reservoir and downstream impacts**
    - **Apply to mitigation projects**
  - **Managing projects in a changing world requires creativity, flexibility, and adaptability**



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## Tools for evaluating climate impacts and resilience

- NW climate tool box

<https://climatetoolbox.org/>

- UW CIG resources

<https://cig.uw.edu/>

- UW Columbia River Climate Change hydrology modeling

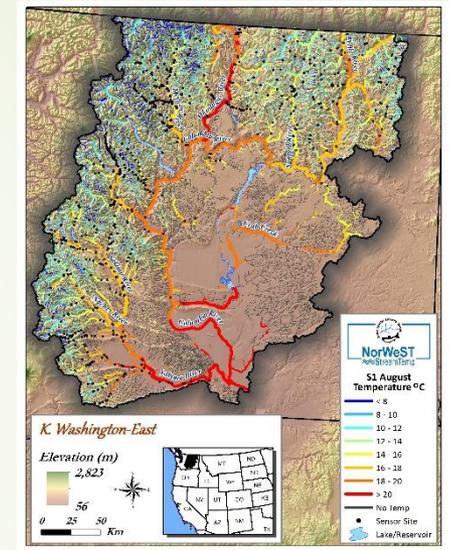
<http://www.hydro.washington.edu/CRCC/>

- National Climate Assessment PNW chapter

<https://nca2014.globalchange.gov/report/regions/northwest>

- NorWeST (for tributary conditions)

<https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST/ModeledStreamTemperatureScenarioMaps.shtml>



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## Questions?

