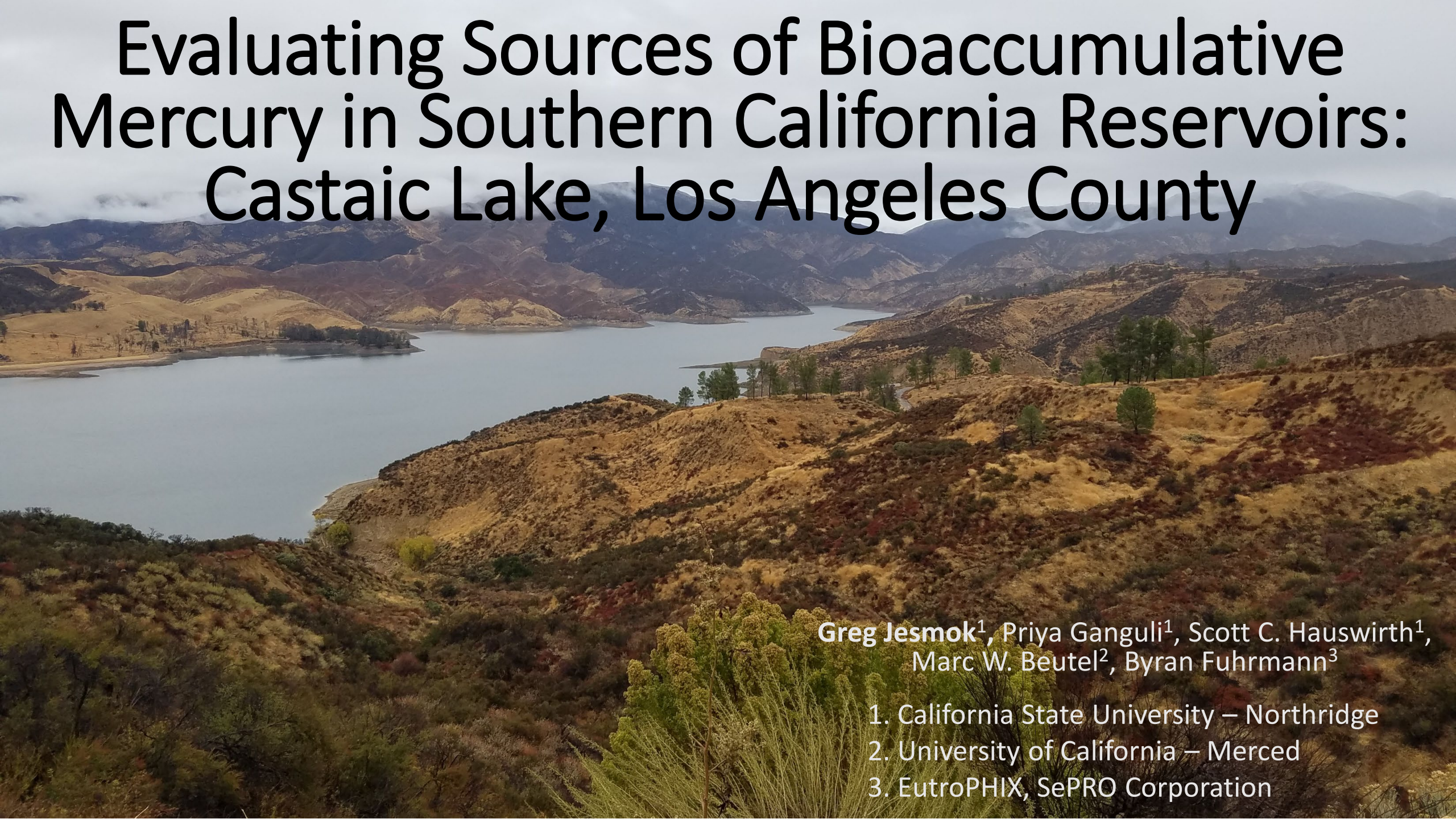
Evaluating Sources of Bioaccumulative Mercury in Southern California Reservoirs: Castaic Lake, Los Angeles County



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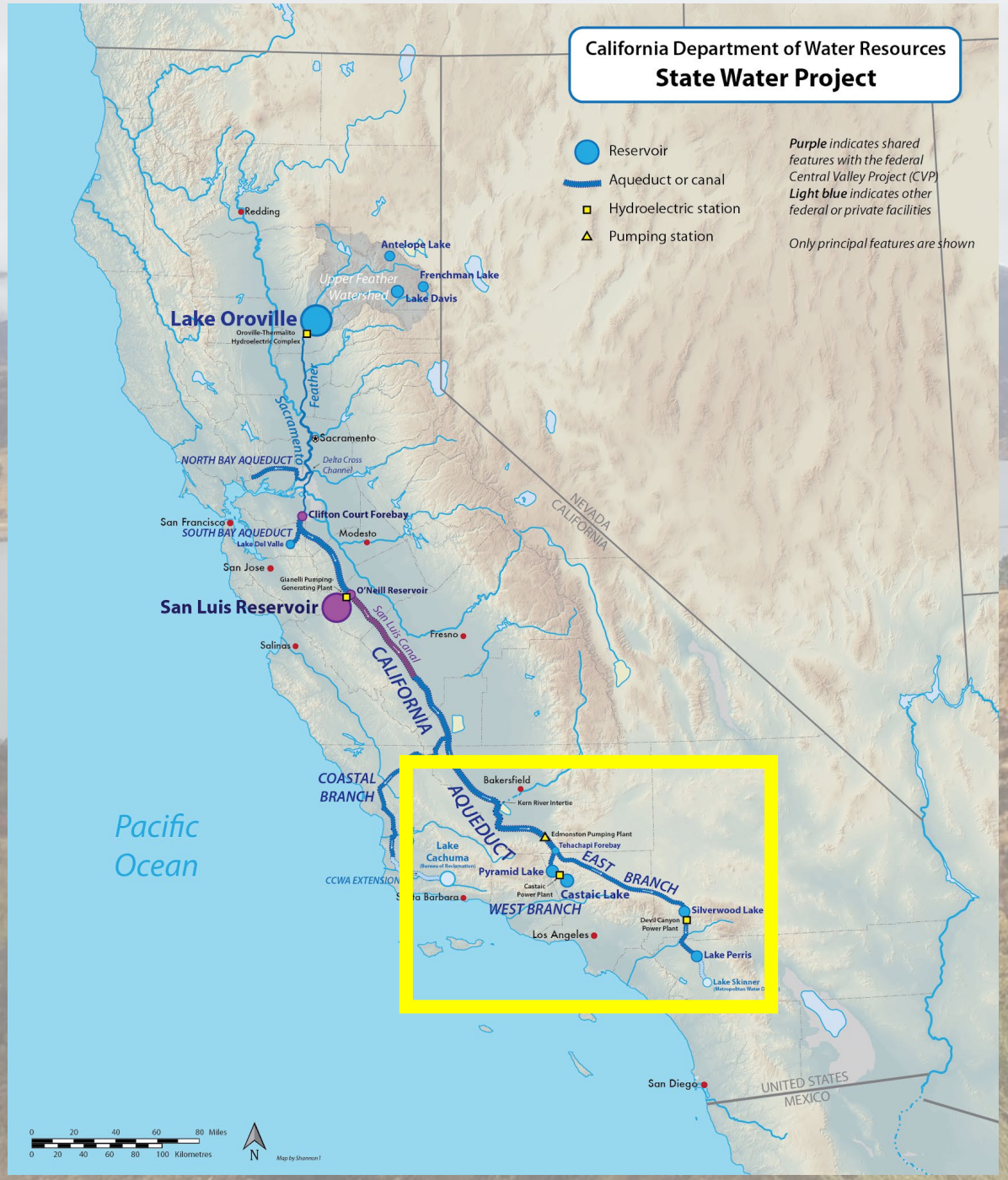
Castaic Lake is a vital resource for Southern California

- Located ~65 km northwest of downtown Los Angeles
- Former land of the Pi'ibitam, now part of the Fernandeño Tataviam Band of Mission Indians

Castaic Lake is a vital resource for Southern California

- Castaic dam was erected in 1973 as a southern addition to the California State Water Project [CSWP]



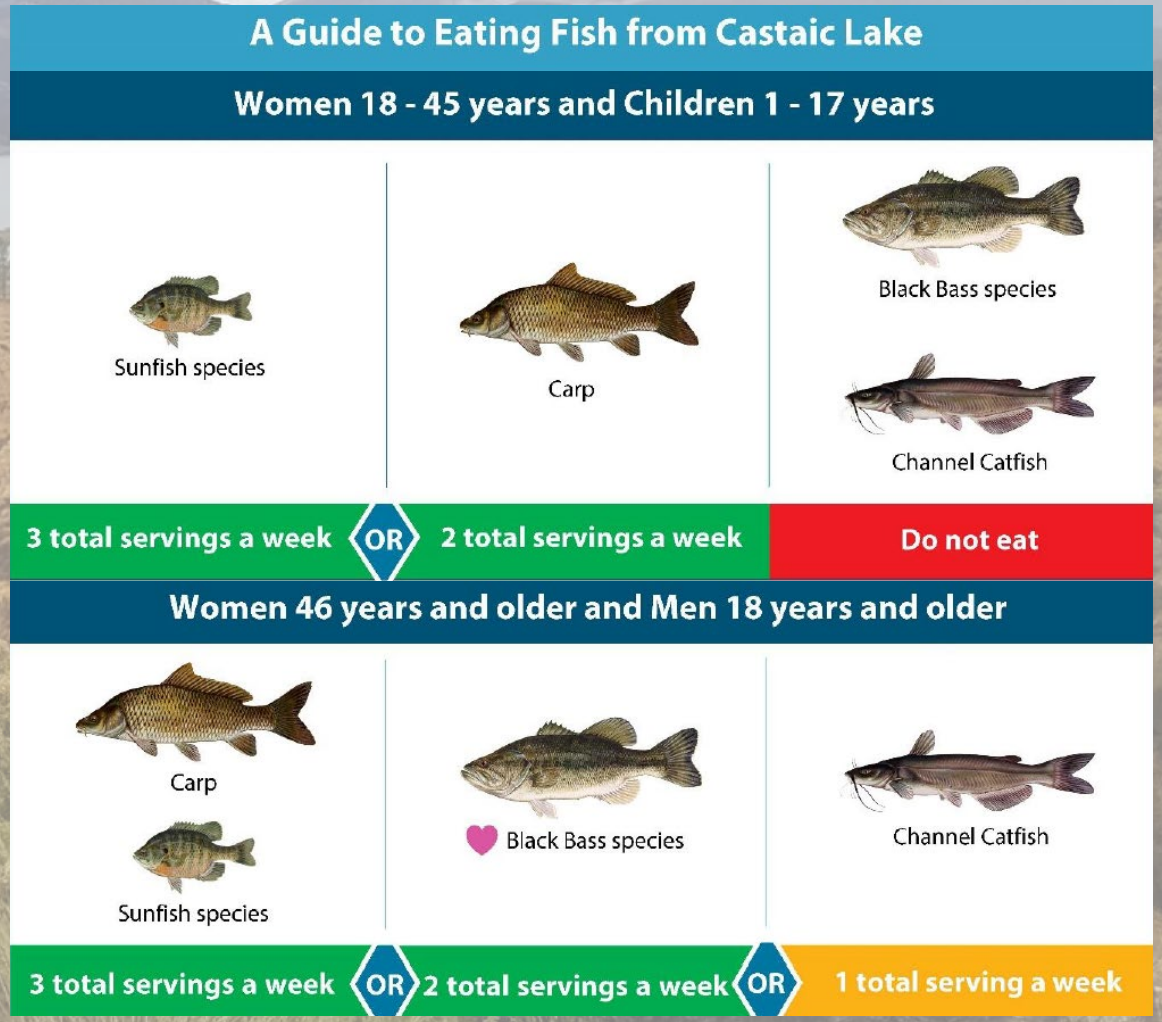
Castaic Lake is a vital resource for Southern California

- Terminus of the West Branch of the California Aqueduct
- ~0.4 km^3 volume for municipal water storage
  - Third largest storage facility associated with the CSWP
  - Largest reservoir in Los Angeles County
- Pumped-storage hydroelectric plant provides power daily

Castaic Lake is listed as impaired water body with respect to mercury and fish consumption advisories are posted

Regularly utilized for recreation and fishing

Castaic Lake is one of 140 CA lakes/reservoirs listed as impaired with respect to mercury (Hg) concentrations



Our study aims to contribute to existing data by evaluating water column depth profiles (>200 ft.) at Castaic Lake for HgT and MeHg

- Incomplete Hg data at Castaic
  - Resource agency data focuses primarily on surface water and fish tissue samples
  - Dearth of data within the water column
  - No measurements near bottom-water sediments

- Unknowns that promote MeHg production
  - Seasonal temperature changes may disconnect profundal waters from the atmosphere
  - Climate change may alter existing trends
- Necessity
  - Baseline measurements of HgT and MeHg concentrations in Castaic Lake

Mercury is a transition metal that exists as multiple species in the environment

Species	**Elemental**	**Inorganic**	**Organic**
	Metallic	Mercuric ***or*** Ionic	Monomethylmercury
Chemical formula	Hg^0	Hg^{2+}	CH_3Hg^+ ***or*** MeHg
Common state	Gas ***or*** Liquid (Volatile)	Particle-Bound	Particle-Bound ***or*** Dissolved
Sphere of Influence	Atmosphere	Lithosphere	Biosphere

Methylation is the process whereby a methyl group (CH_3) is bonded to a mercuric ion to form the compound methylmercury (MeHg)

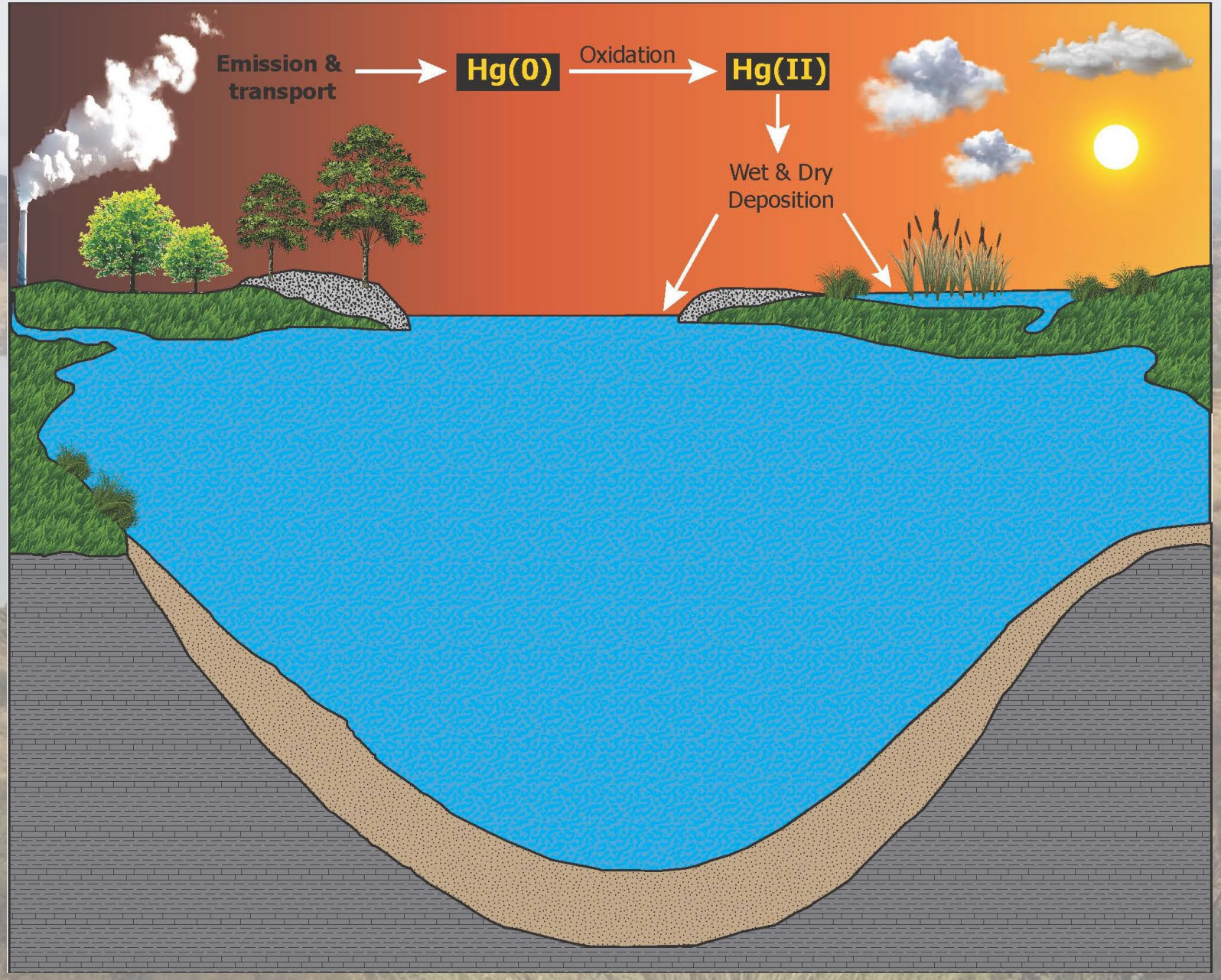
- Enacted by microbial communities possessing the Hgcab gene pair
  - Sulfate-reducing bacteria, iron-reducing bacteria, and archaea (syntrophs and methanogens)

MeHg is a bioaccumulative neurotoxin

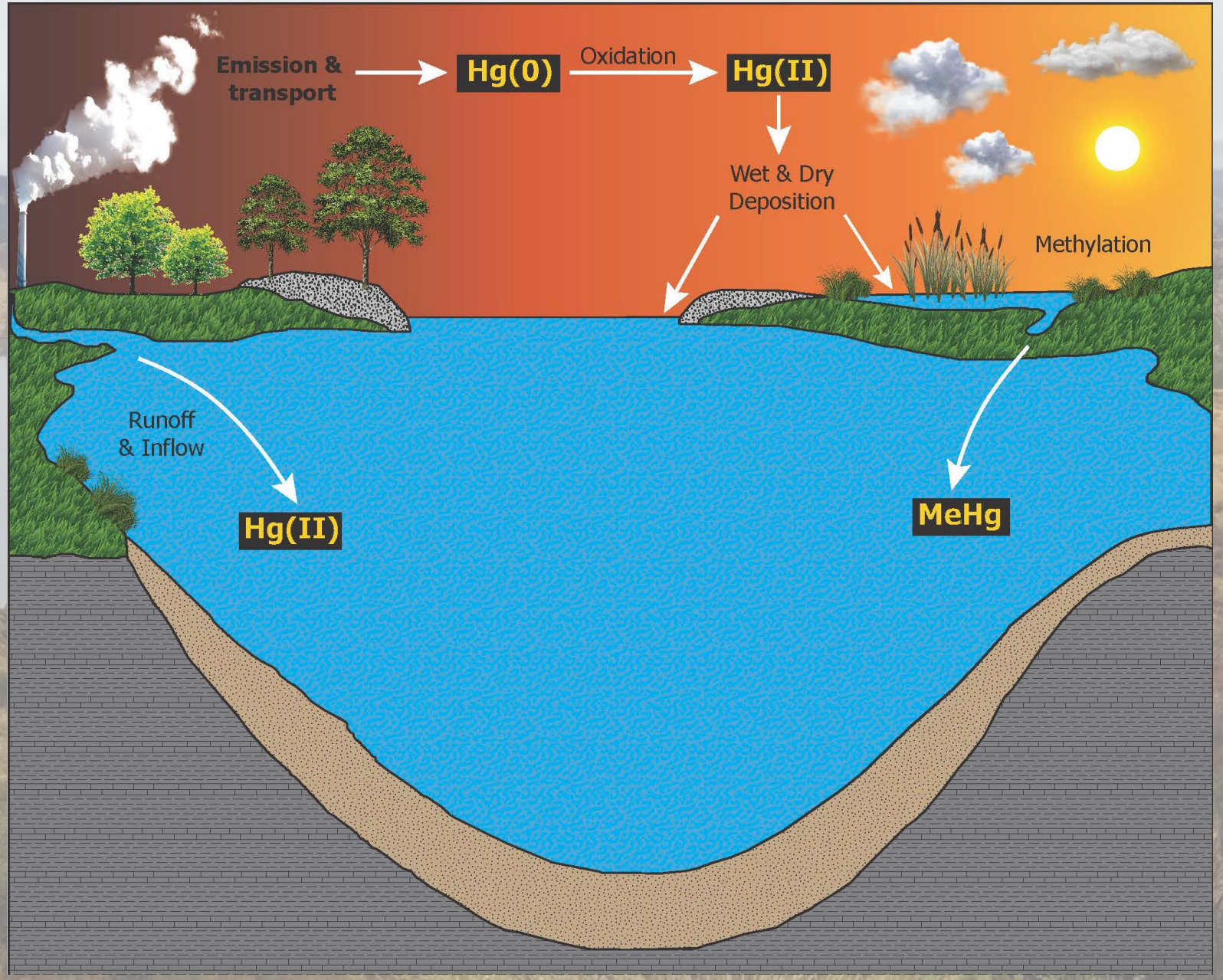
- Biomagnifies in concentration moving up the food chain
- Birth defects, Persistent motor deficits
- Adverse cardiovascular effects (e.g. heart attacks)
- Impairment of speech, hearing, and/or immune function

The effects of mercury toxicity are not isolated to humans and may result in collapse of part of the food web

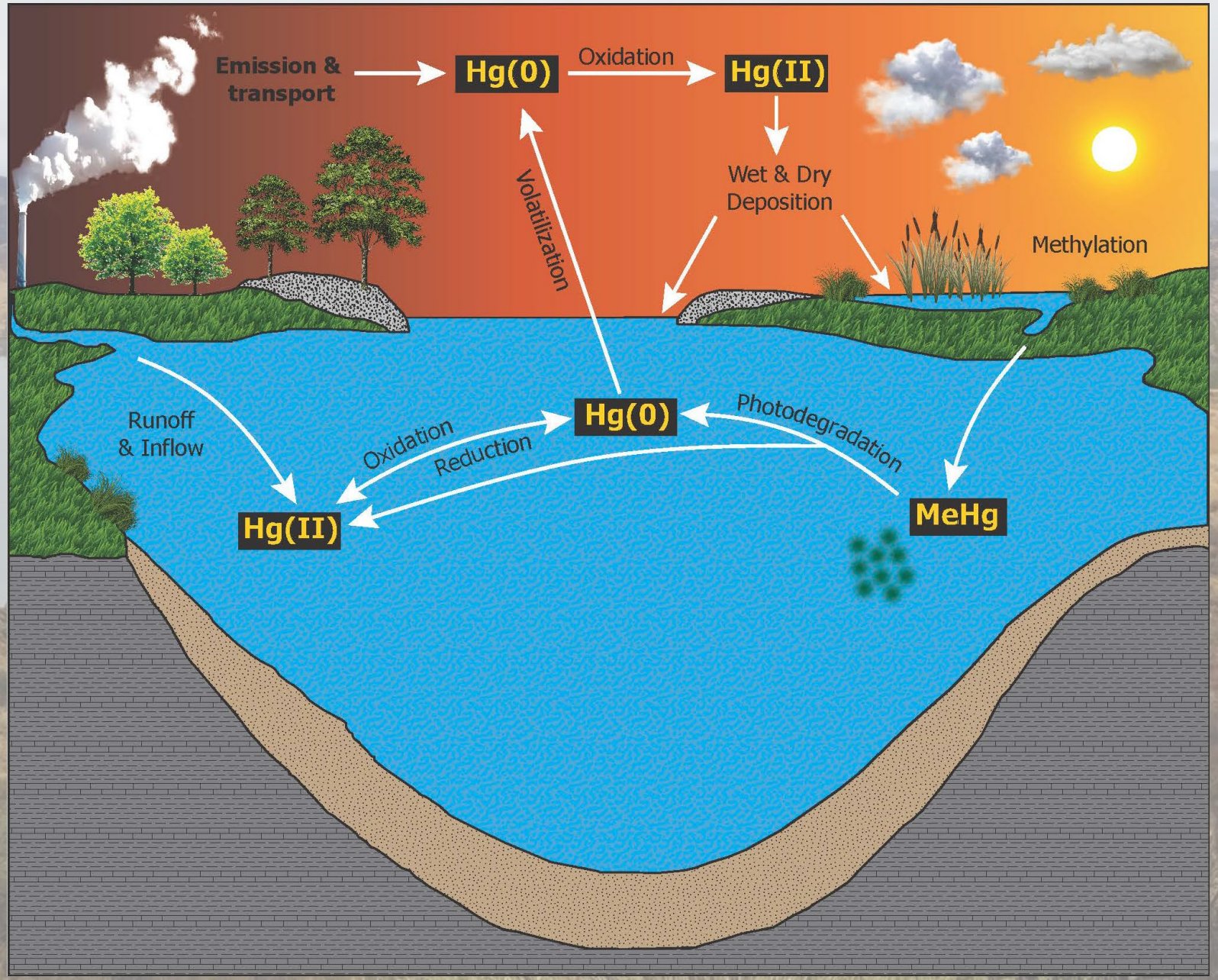
Hg is transported and deposited on local to global scales



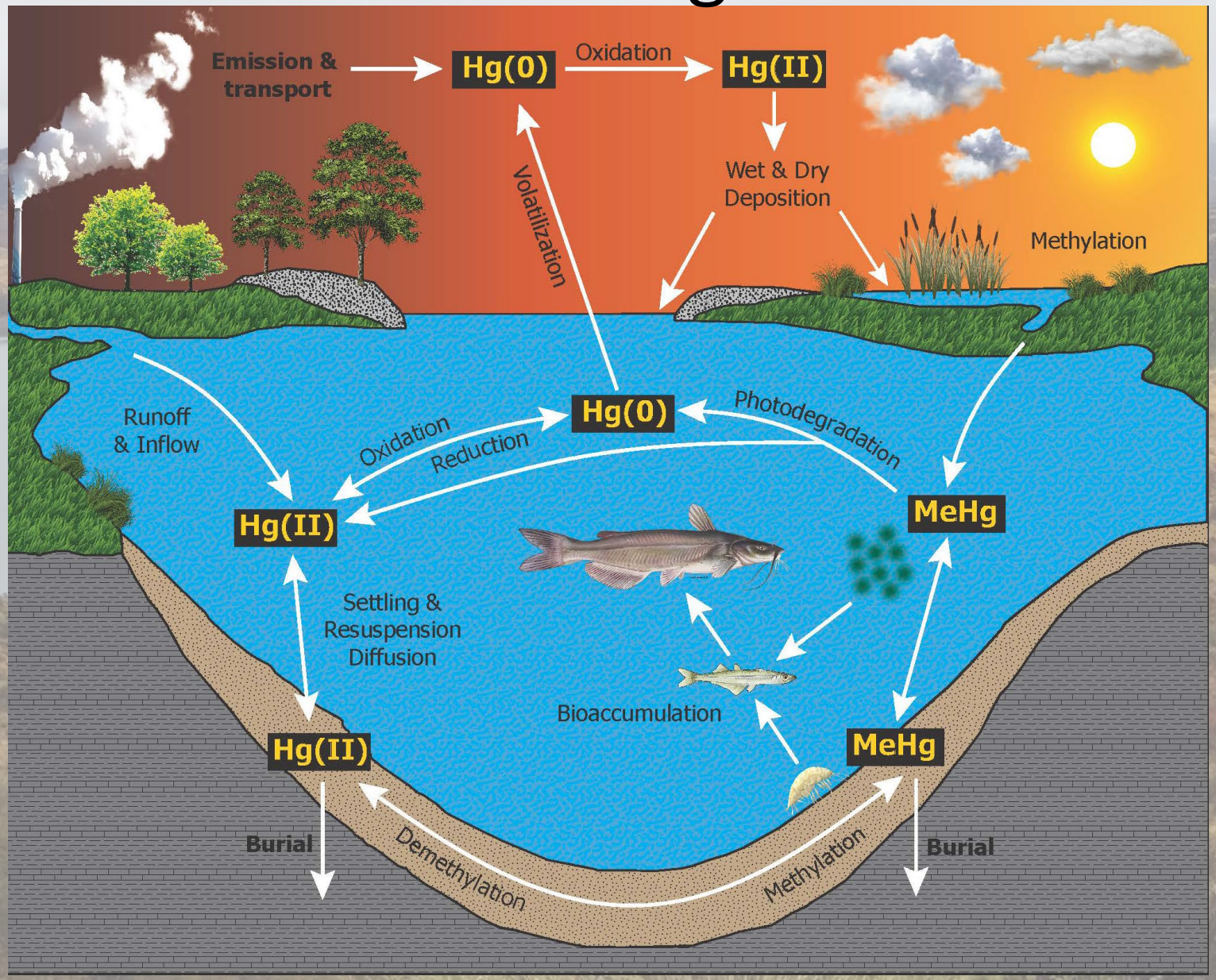
Hg flows into lakes via streams and wetlands



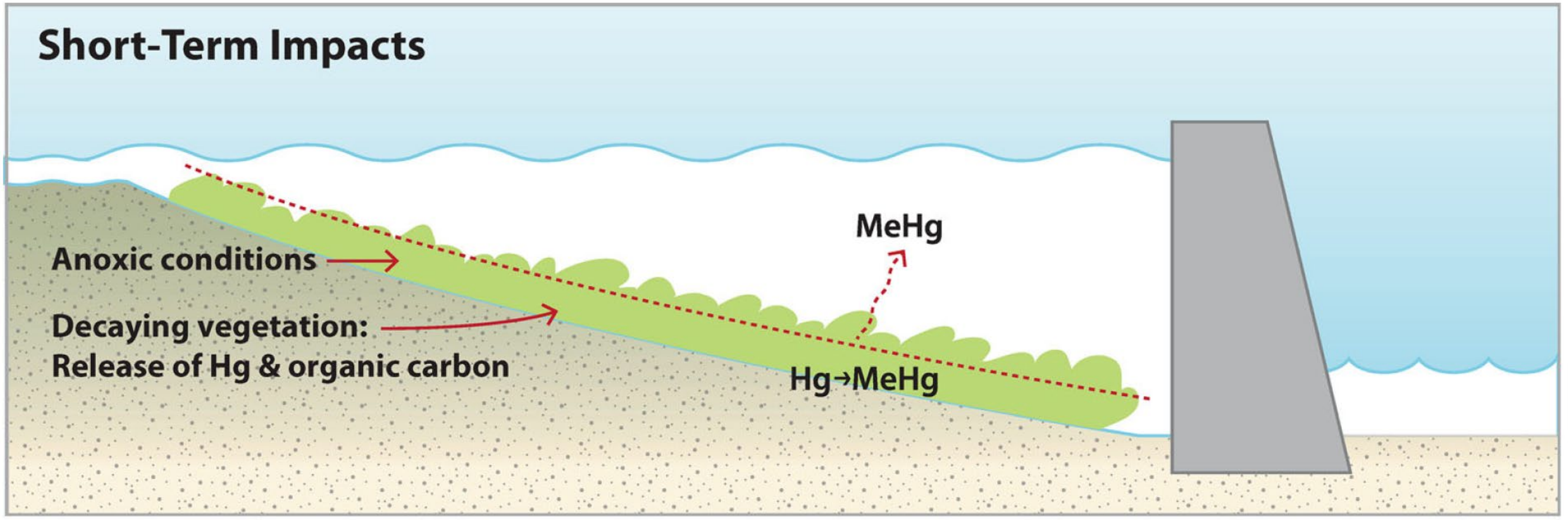
In the water column Hg undergoes regular transformations



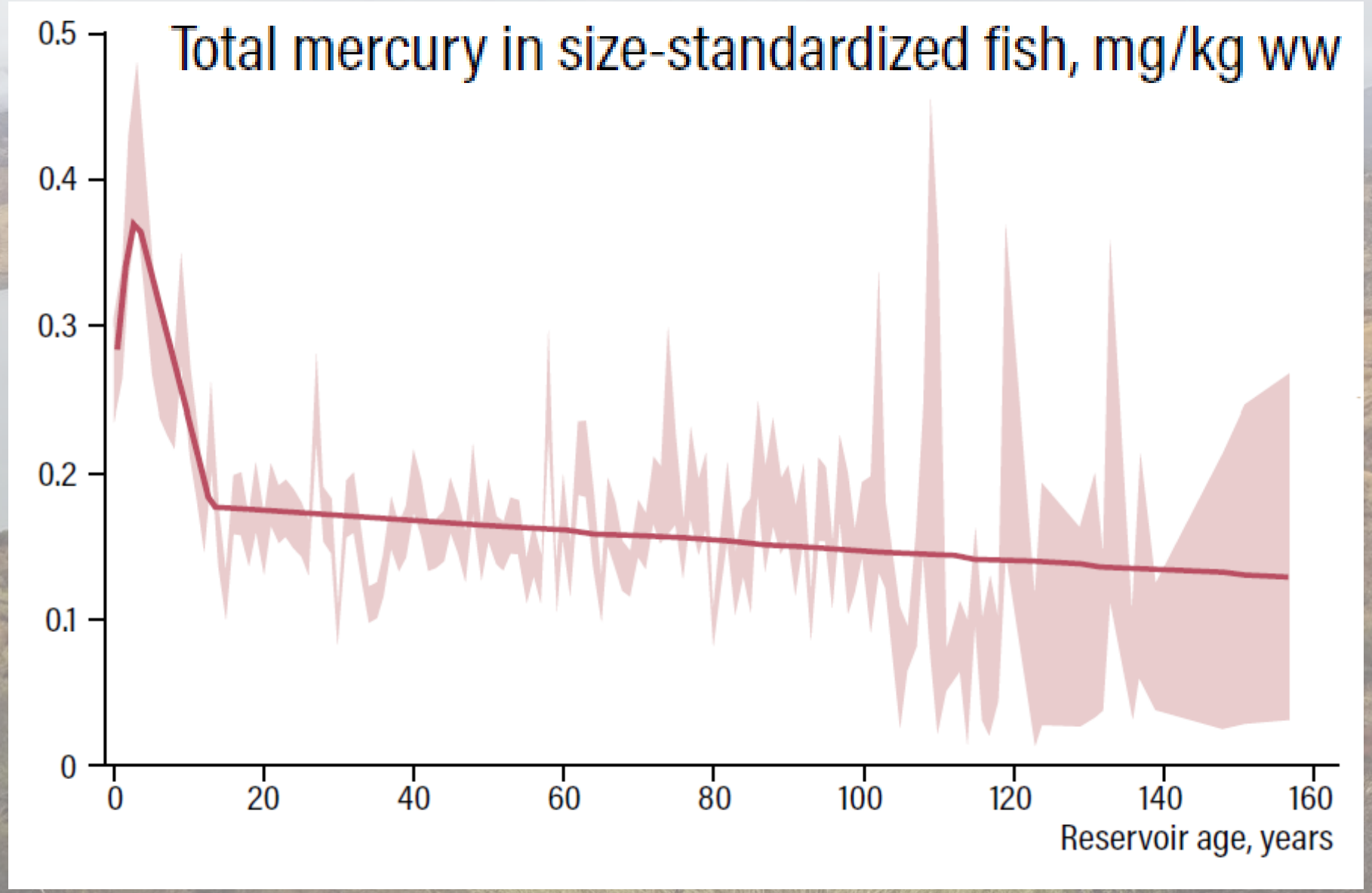
At depth, Hg continues to transform, bioaccumulates, or settles out of solution and gets buried



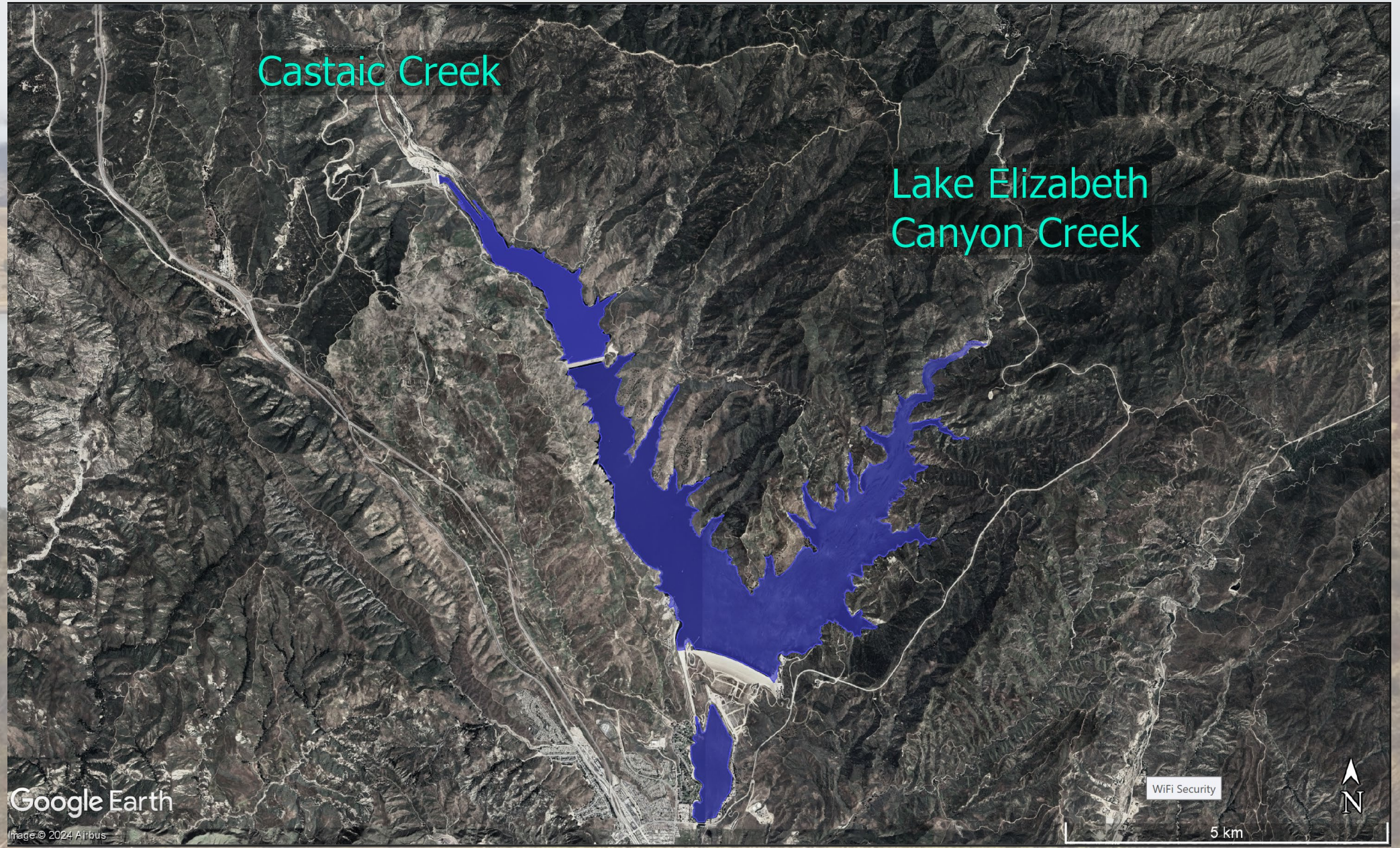
Dams cause short-term MeHg spikes in the water column



Newly constructed reservoirs have MeHg spikes in fish but concentrations decrease over time



Castaic Lake is a 3-tiered water storage system



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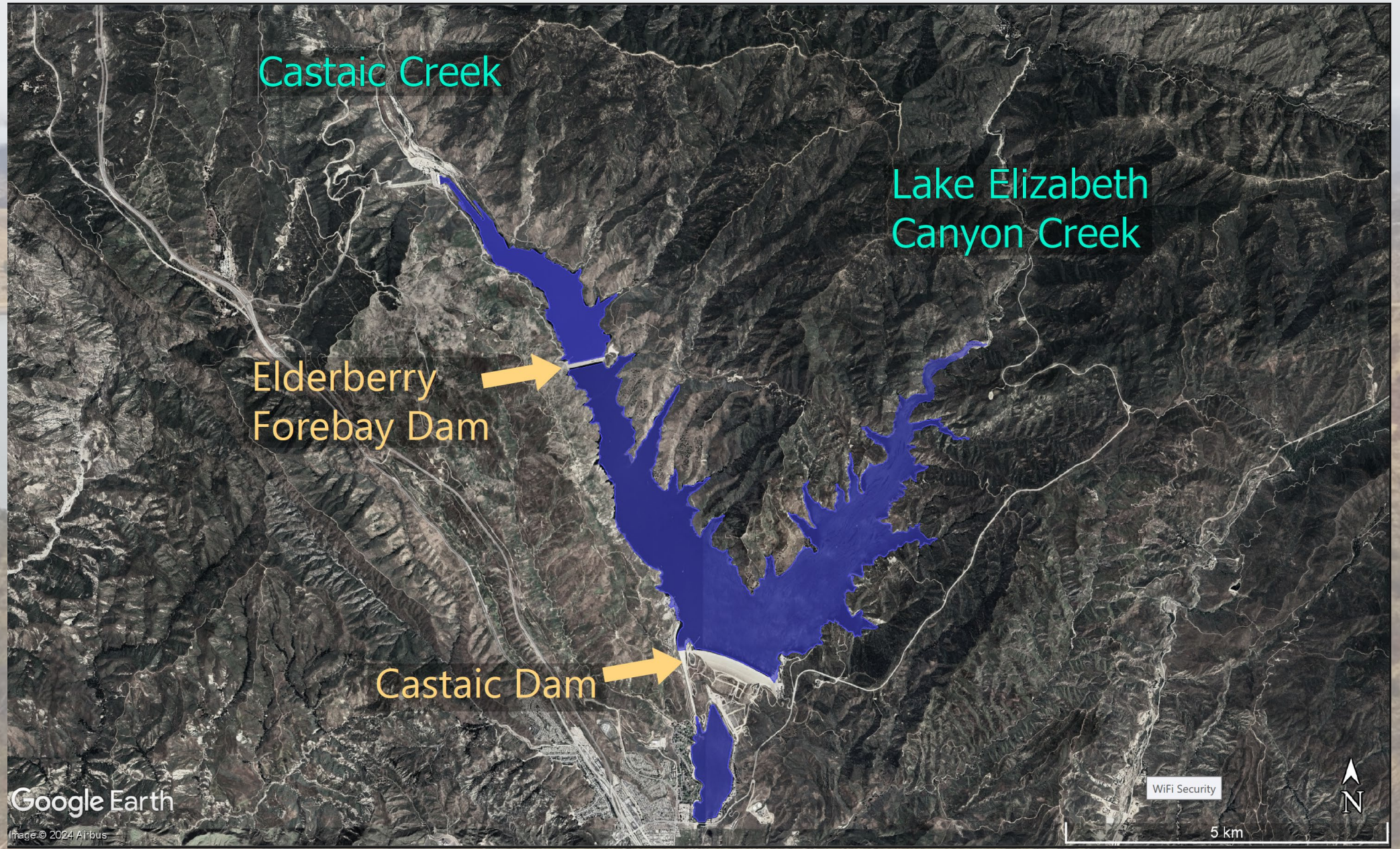

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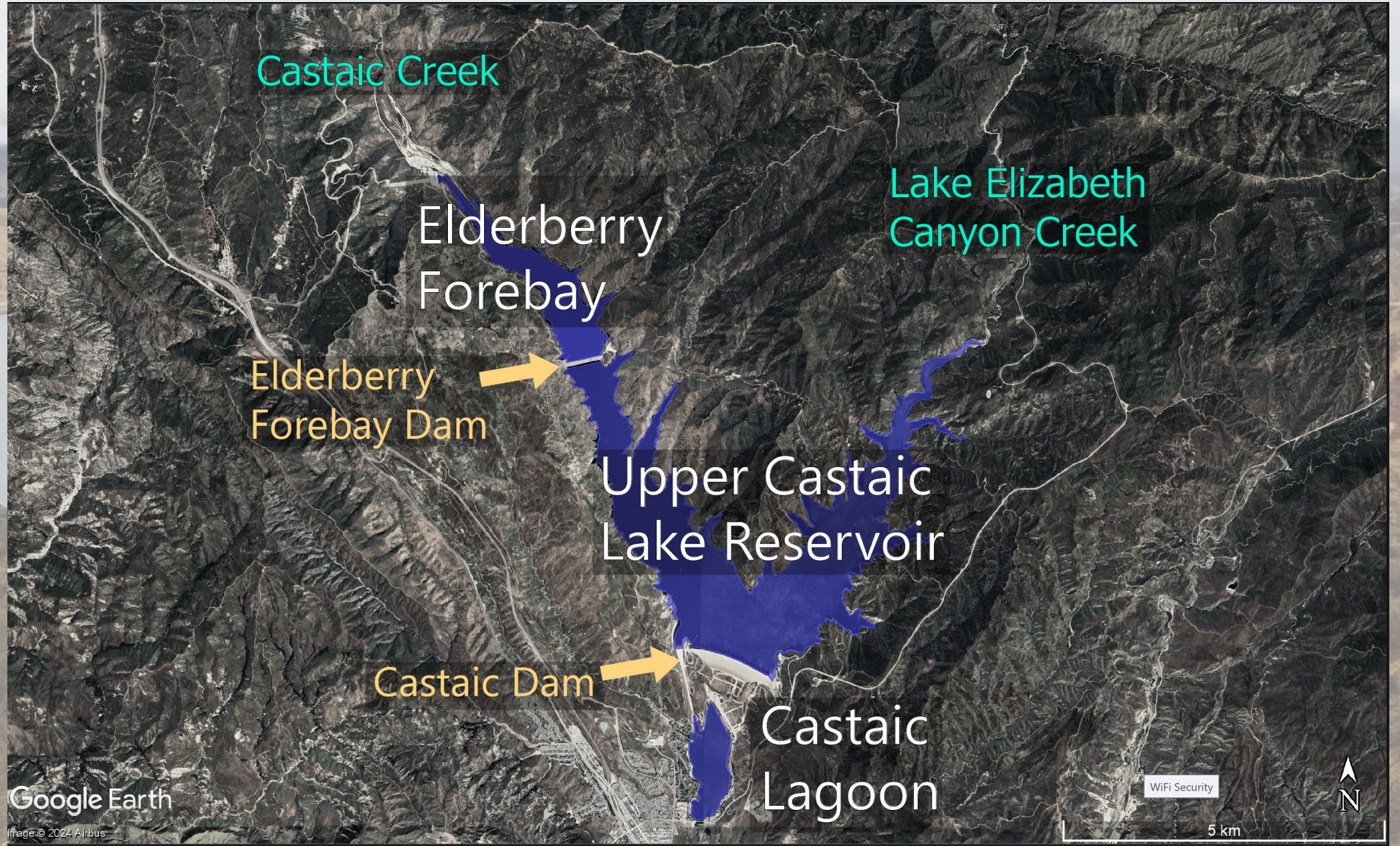
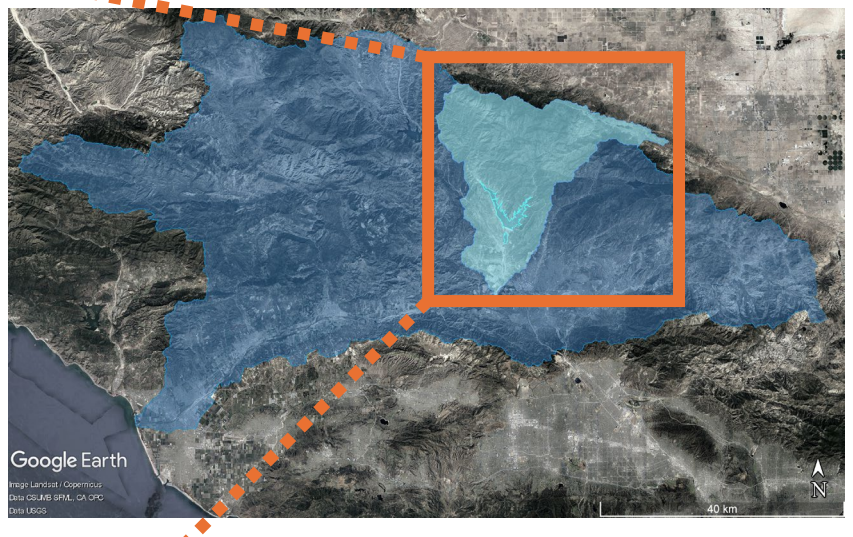


Castaic is hydrologically connected to areas extending from the San Andreas Fault to the Santa Clara River

EPA WATERS GeoViewer 2.0

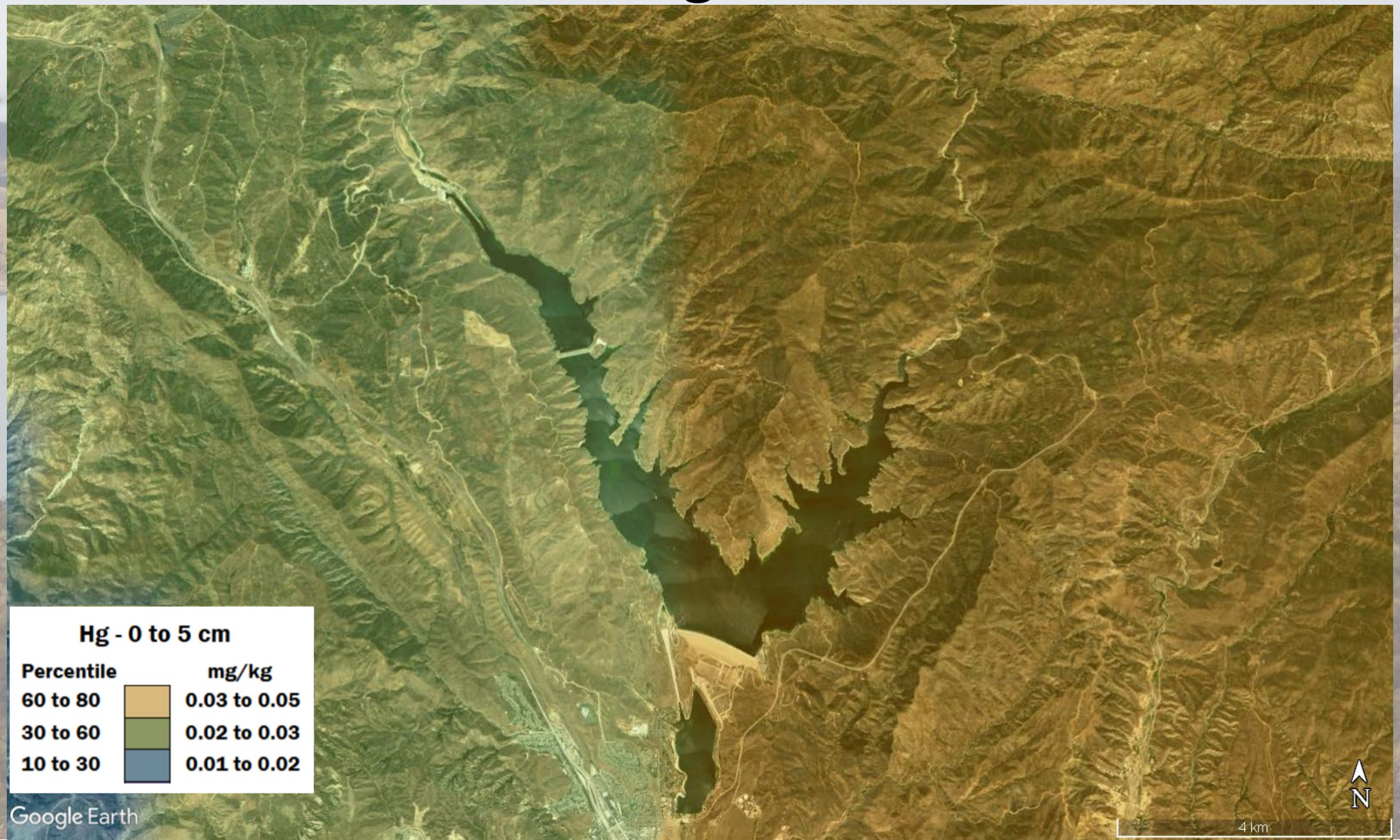


Subbasin (HUC-8)
Santa Clara River

Watershed (HUC-10)
Castaic Creek

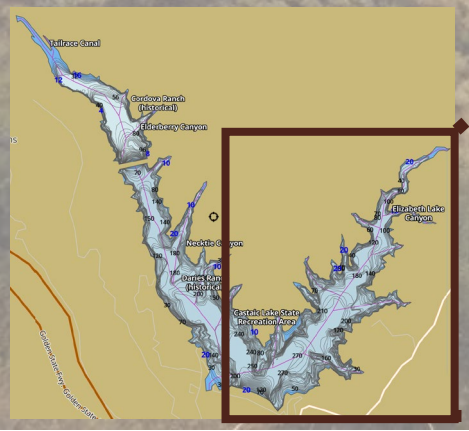
Castaic Lake Boundary

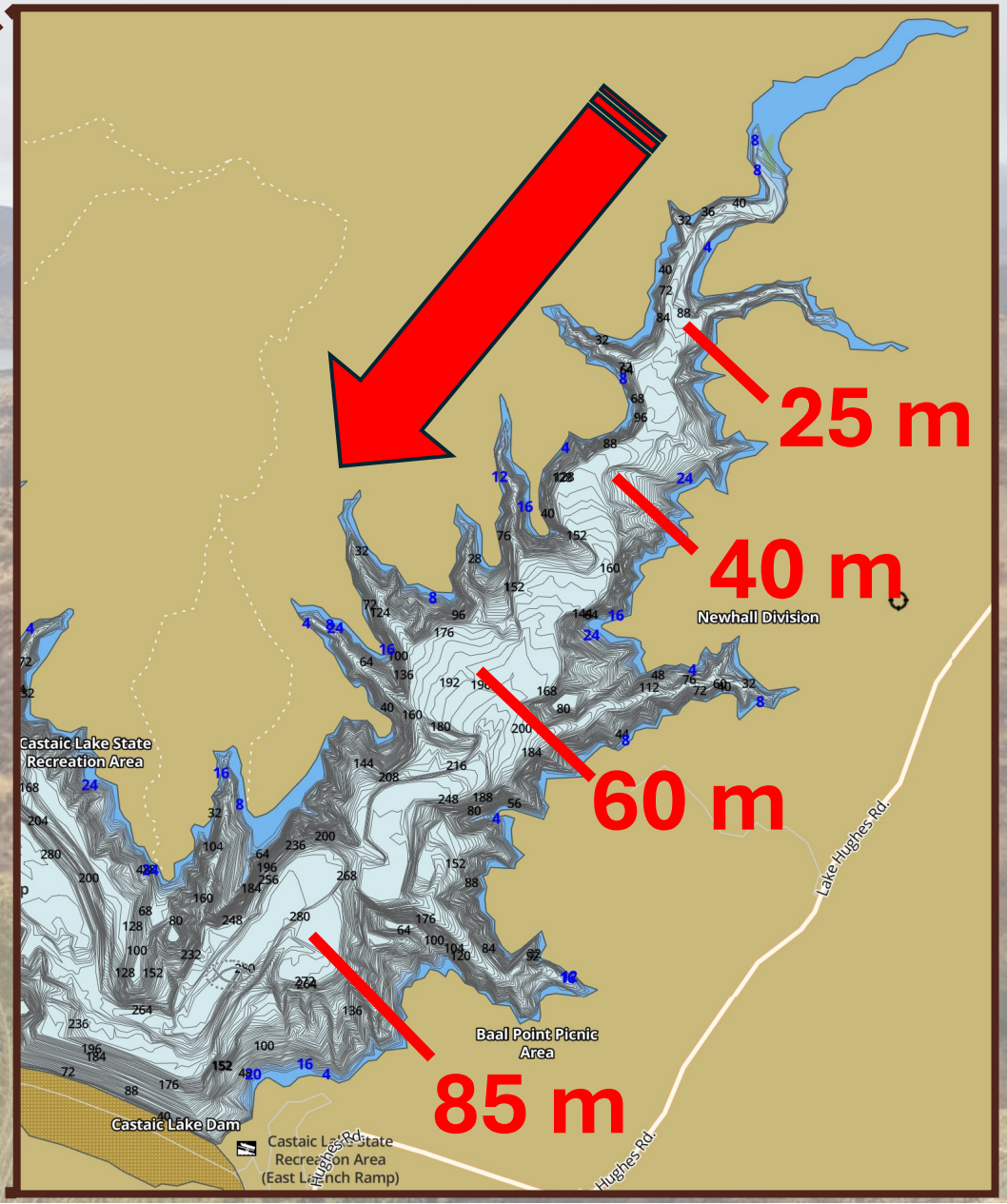
Atmospheric deposition maps indicate increasing HgT concentrations moving SW → NE across Castaic



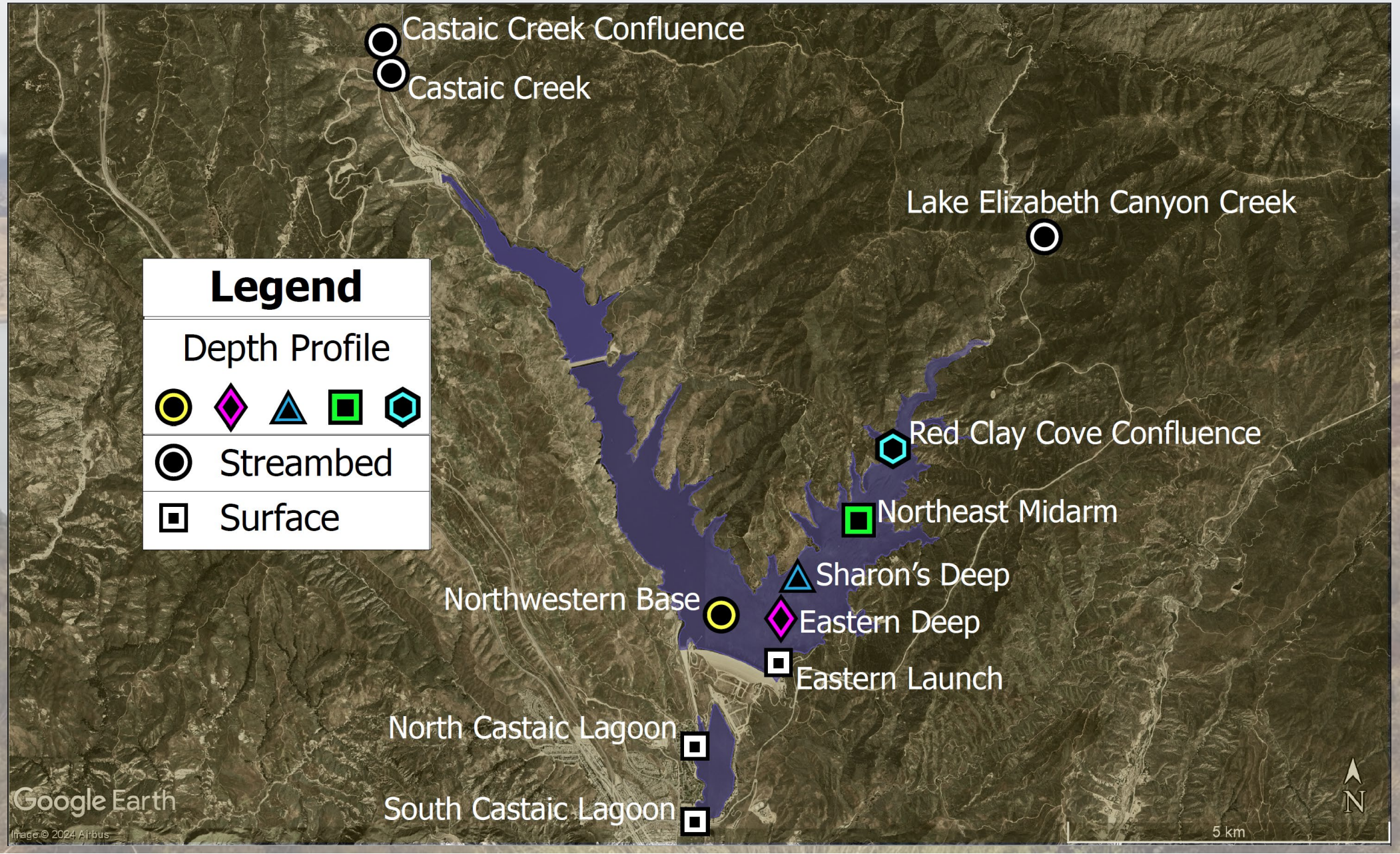
We aimed to sample where we may see stratification and zones of anoxia at depth

Along the northeastern arm,
depth of the reservoir increases moving southwest,
following the flow path of the former streambed





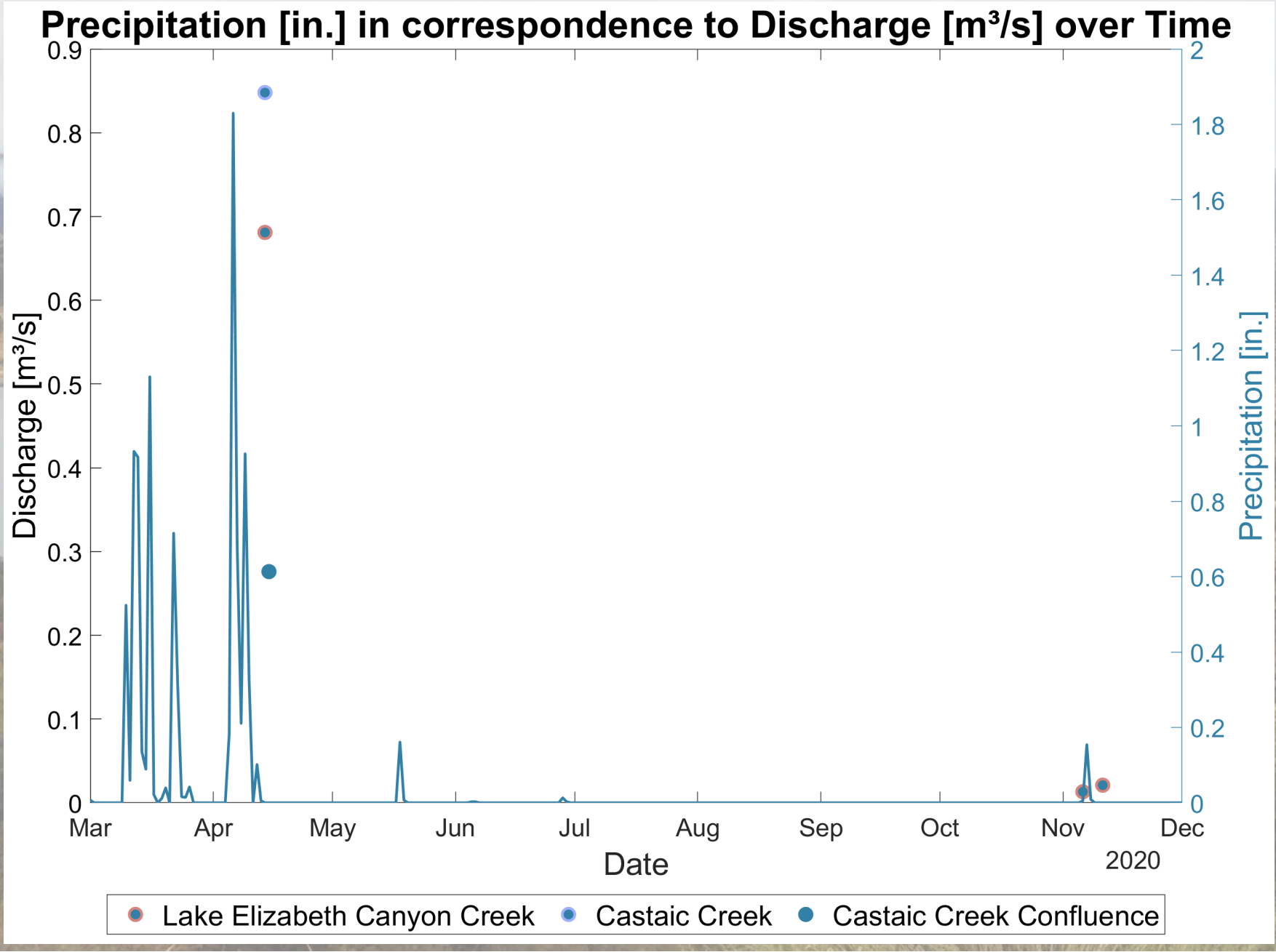
Castaic sampling sites cover the breadth of the NE arm

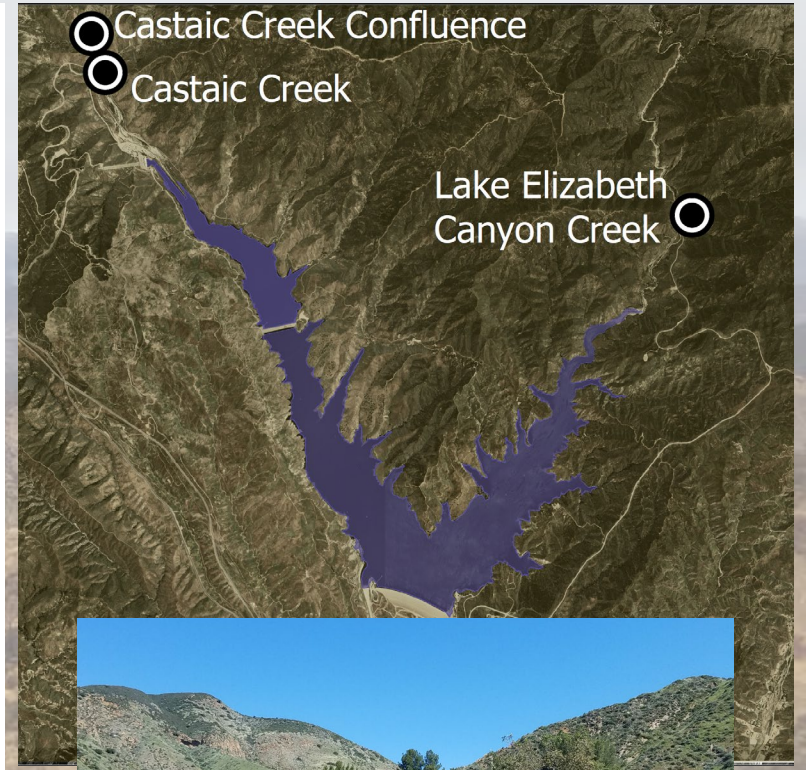


Samples were collected to evaluate multiple parameters

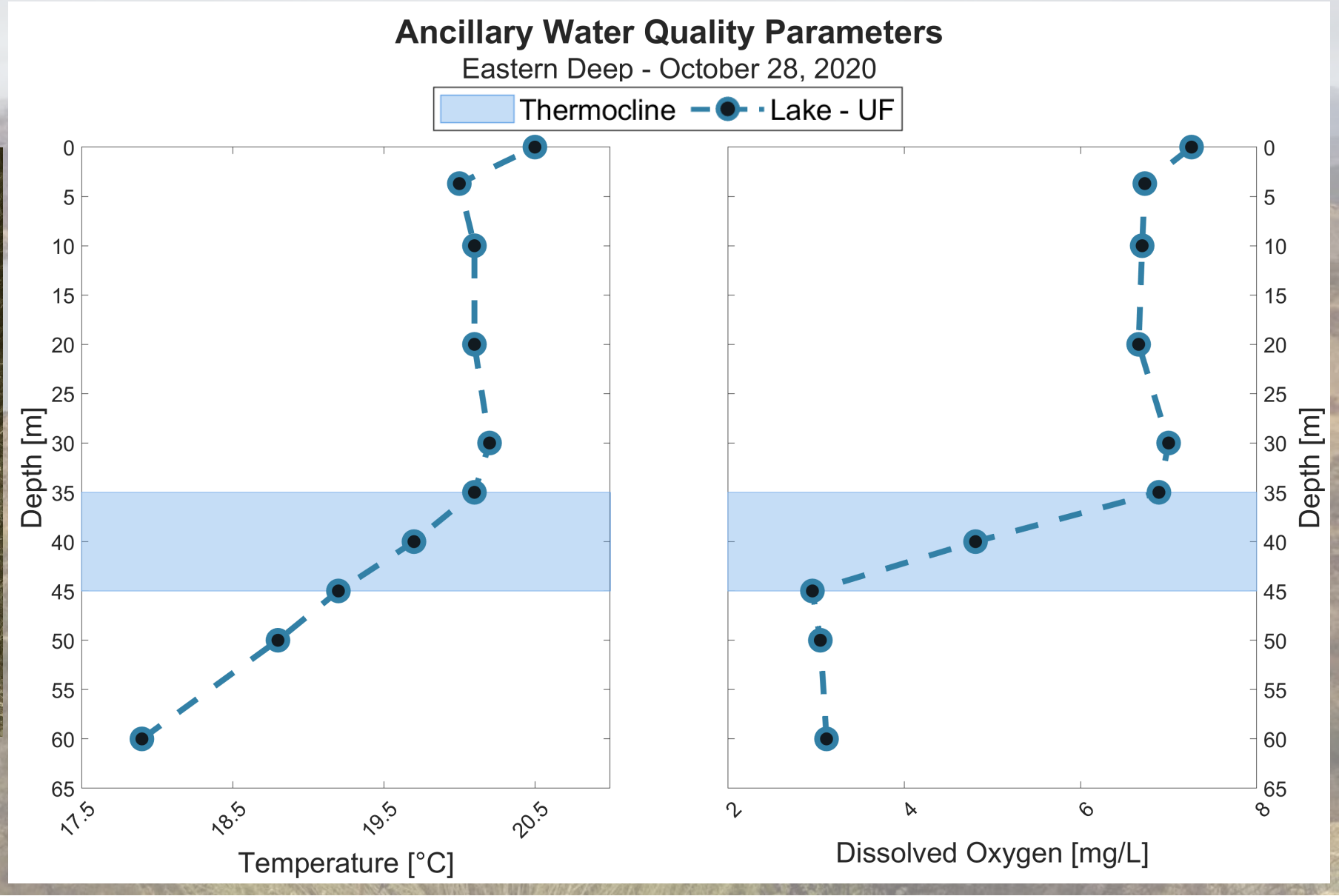
- Filtered (<0.22 µg/L) and unfiltered water
  - **Mercury species**
    - **(HgT and MeHg)**
  - other metals
    - (e.g., Fe, Pb, Zn)
- In-situ parameters
  - **Temperature**
  - **Dissolved oxygen (DO)**
  - pH
  - Conductivity
  - Turbidity
- **Nutrients/Anions**
  - **NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}**
- Suspended particulate matter (SPM)
- Organic carbon
- PAHs
- **Stream discharge [m^3/s]**
- Sediments

Discharge, predictably, rises with increased precipitation





Temperature and Dissolved Oxygen provide evidence for a weak thermocline/chemocline



Low NO_2^- concentrations imply a nitrogen-limited watershed

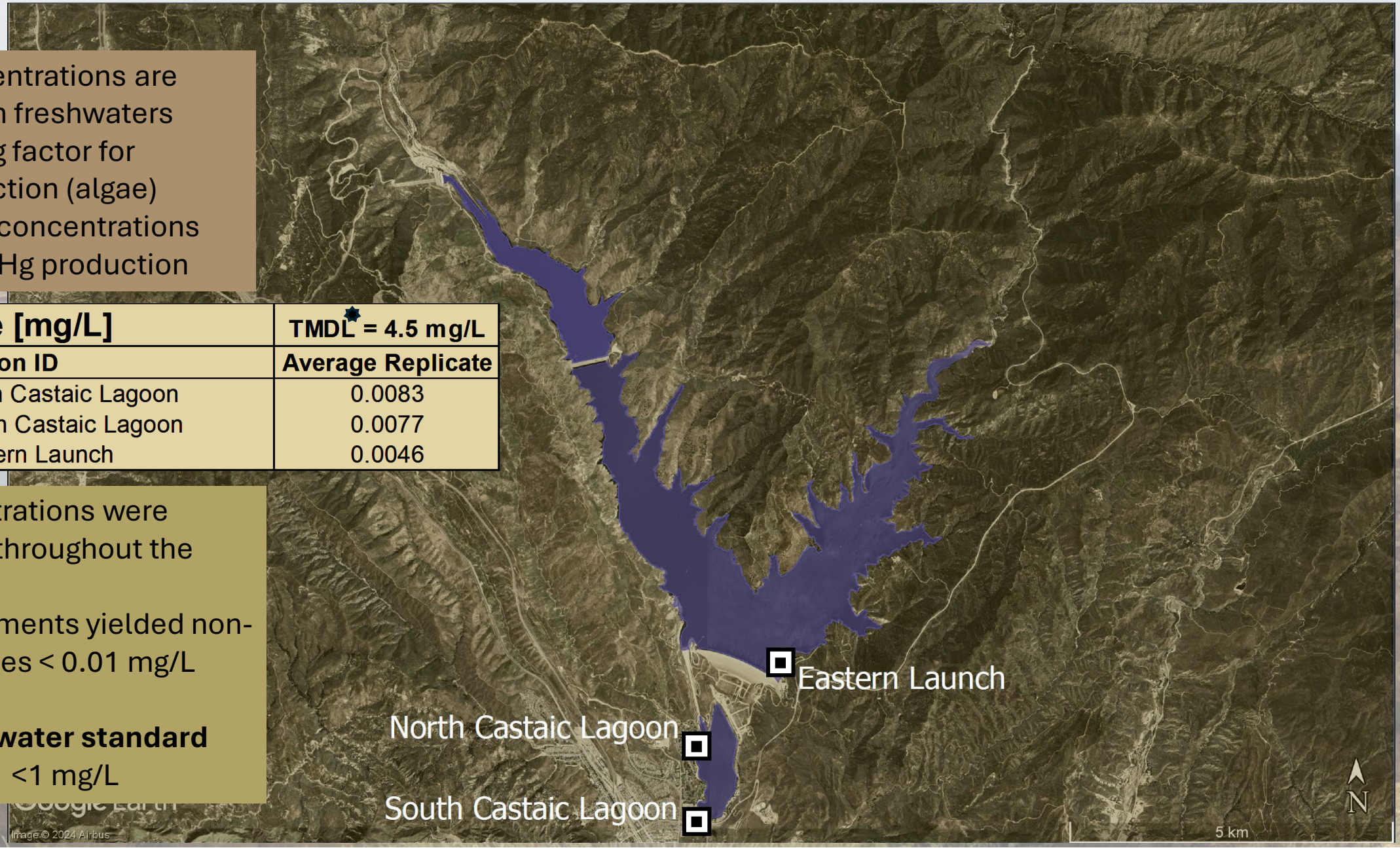
- Nitrogen concentrations are generally low in freshwaters
- Often a limiting factor for primary production (algae)
- Elevated NO_2^- concentrations may inhibit MeHg production

Nitrite [mg/L]		TMDL = 4.5 mg/L
Collection Date	**Station ID**	**Average Replicate**
4/14/2020	North Castaic Lagoon	0.0083
4/14/2020	South Castaic Lagoon	0.0077
4/14/2020	Eastern Launch	0.0046

- Nitrite concentrations were extremely low throughout the watershed
- Most measurements yielded non-detects or values < 0.01 mg/L

EPA Drinking water standard

NO_2^- -N <1 mg/L



Low NO_3^- concentrations imply a nitrogen-limited watershed

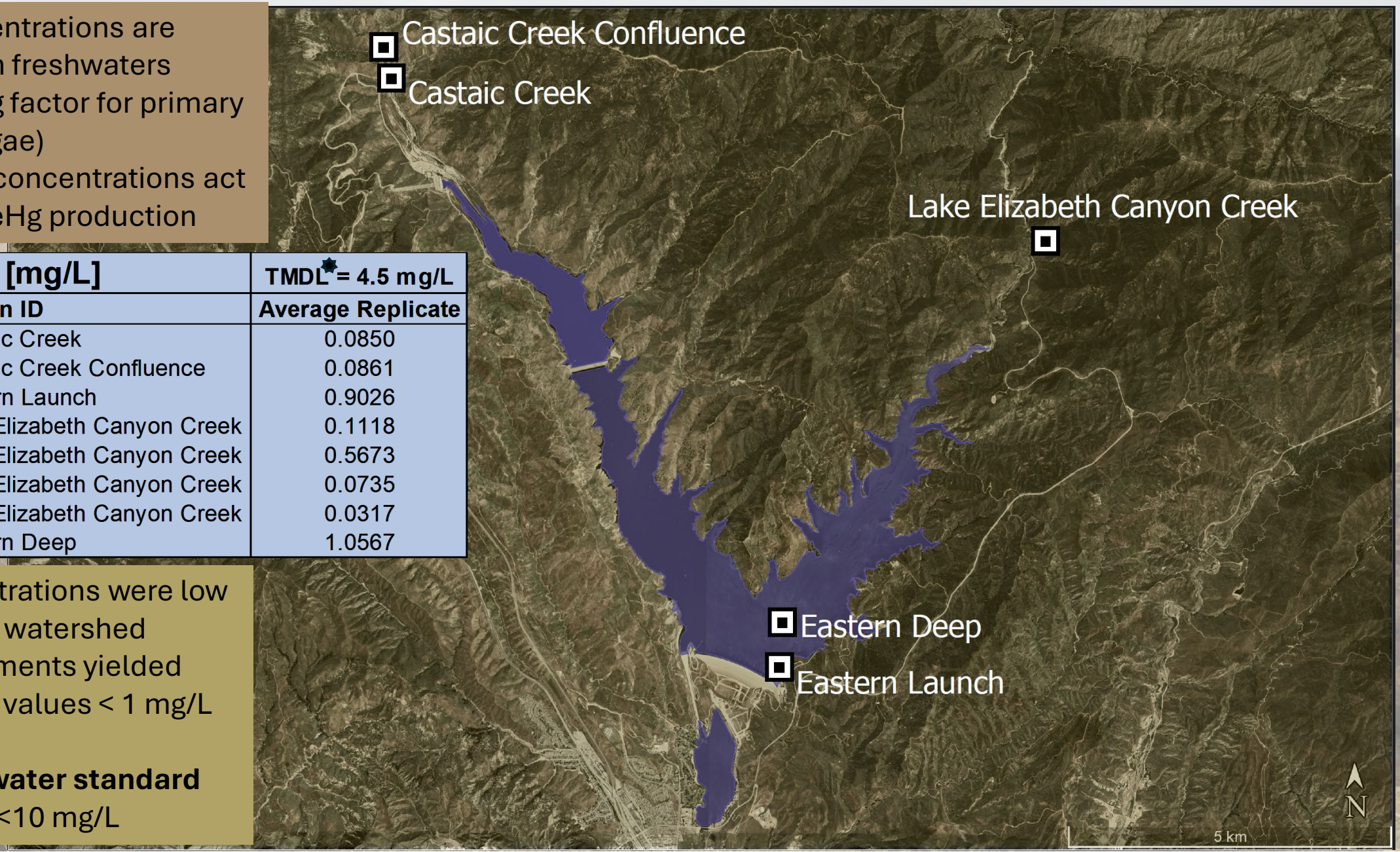
- Nitrogen concentrations are generally low in freshwaters
- Often a limiting factor for primary production (algae)
- Elevated NO_3^- concentrations act to suppress MeHg production

Nitrate [mg/L]		TMDL = 4.5 mg/L
Collection Date	**Station ID**	**Average Replicate**
4/14/2020	Castaic Creek	0.0850
4/14/2020	Castaic Creek Confluence	0.0861
4/14/2020	Eastern Launch	0.9026
07/20/2019	Lake Elizabeth Canyon Creek	0.1118
4/14/2020	Lake Elizabeth Canyon Creek	0.5673
11/6/2020	Lake Elizabeth Canyon Creek	0.0735
11/11/2020	Lake Elizabeth Canyon Creek	0.0317
10/28/2020	Eastern Deep	1.0567

- Nitrate concentrations were low throughout the watershed
- Most measurements yielded non-detects or values < 1 mg/L

EPA Drinking water standard

NO_3^- -N <10 mg/L



PO_4^{3-} concentrations approach the TMDL*

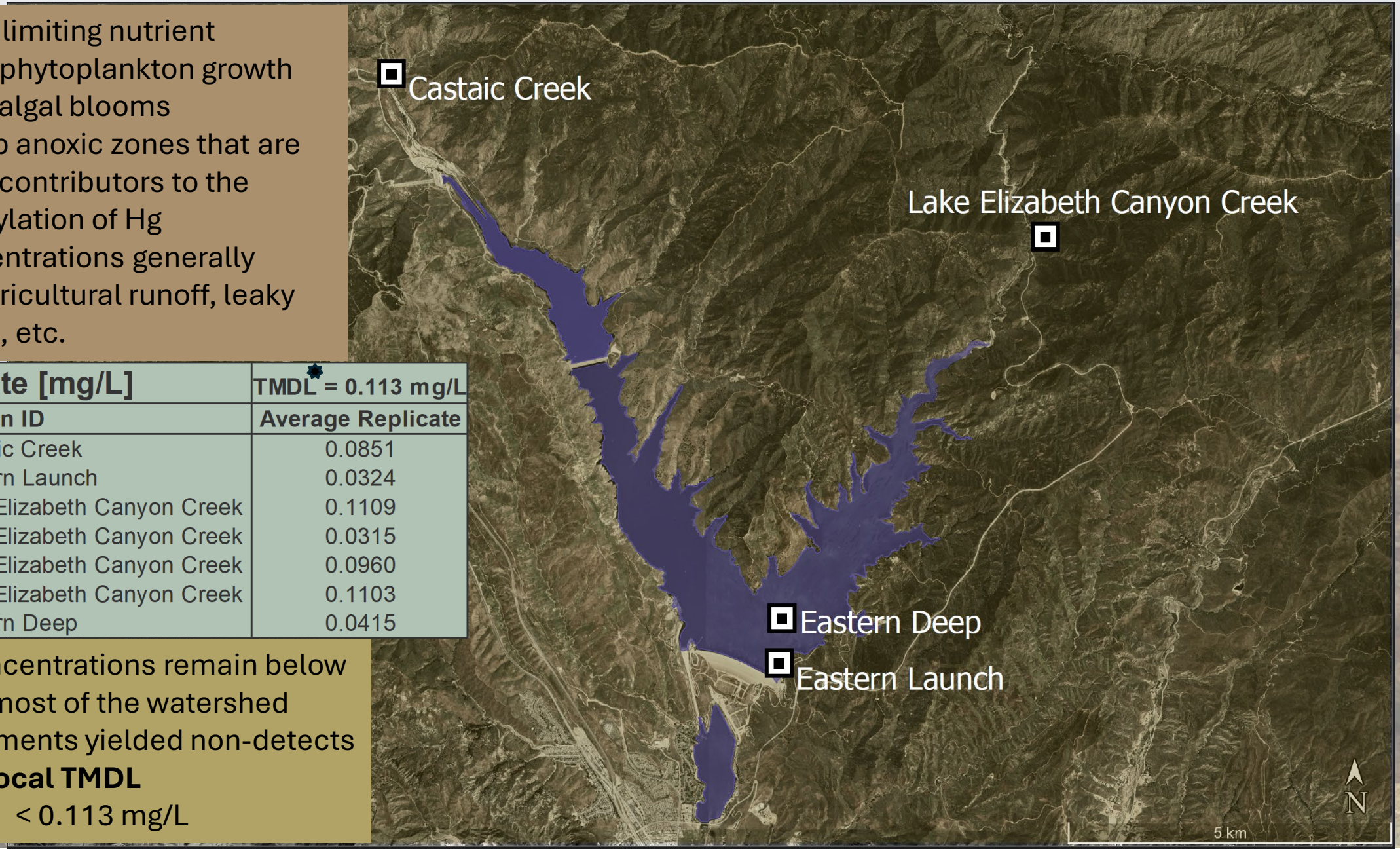
- Phosphate is a limiting nutrient
  - Crucial to phytoplankton growth
  - Stimulate algal blooms
    - Set up anoxic zones that are great contributors to the methylation of Hg
- Elevated concentrations generally indicative of agricultural runoff, leaky septic systems, etc.

Phosphate [mg/L]		TMDL = 0.113 mg/L
Collection Date	Station ID	Average Replicate
4/14/2020	Castaic Creek	0.0851
4/14/2020	Eastern Launch	0.0324
7/20/2019	Lake Elizabeth Canyon Creek	0.1109
4/14/2020	Lake Elizabeth Canyon Creek	0.0315
11/6/2020	Lake Elizabeth Canyon Creek	0.0960
11/11/2020	Lake Elizabeth Canyon Creek	0.1103
10/28/2020	Eastern Deep	0.0415

- Phosphate concentrations remain below 0.113 mg/L in most of the watershed
- Most measurements yielded non-detects

Local TMDL

PO_4^{2-} < 0.113 mg/L



SO_4^{2-} concentrations rise following storms, but remain low

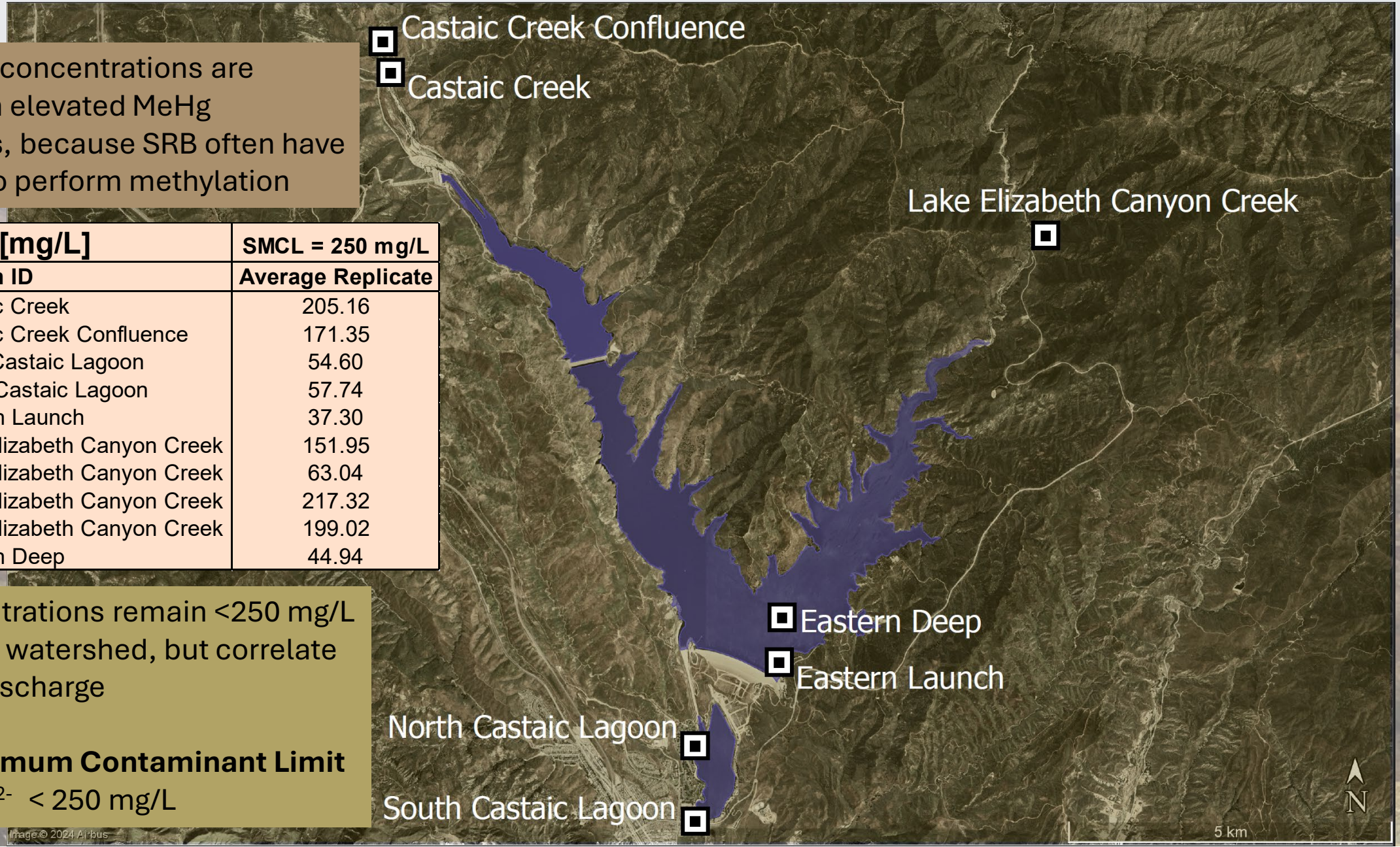
- Elevated SO_4^{2-} concentrations are correlated with elevated MeHg concentrations, because SRB often have the gene pair to perform methylation

Sulfate [mg/L]		SMCL = 250 mg/L
Collection Date	Station ID	Average Replicate
4/14/2020	Castaic Creek	205.16
4/14/2020	Castaic Creek Confluence	171.35
4/14/2020	North Castaic Lagoon	54.60
4/14/2020	South Castaic Lagoon	57.74
4/14/2020	Eastern Launch	37.30
07/20/2019	Lake Elizabeth Canyon Creek	151.95
4/14/2020	Lake Elizabeth Canyon Creek	63.04
11/6/2020	Lake Elizabeth Canyon Creek	217.32
11/11/2020	Lake Elizabeth Canyon Creek	199.02
10/28/2020	Eastern Deep	44.94

- Sulfate concentrations remain <250 mg/L throughout the watershed, but correlate to increased discharge

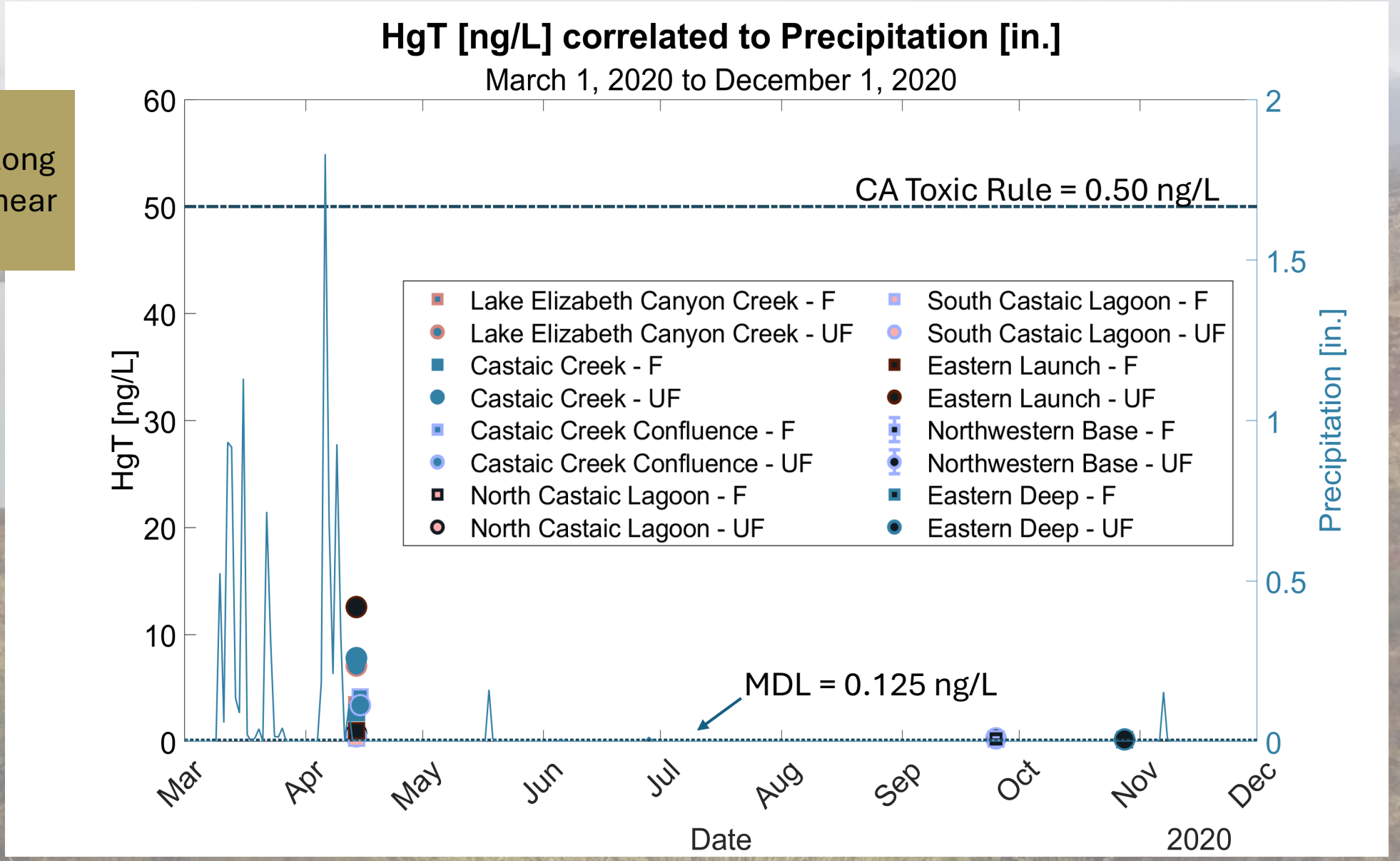
Secondary Maximum Contaminant Limit

SO_4^{2-} < 250 mg/L

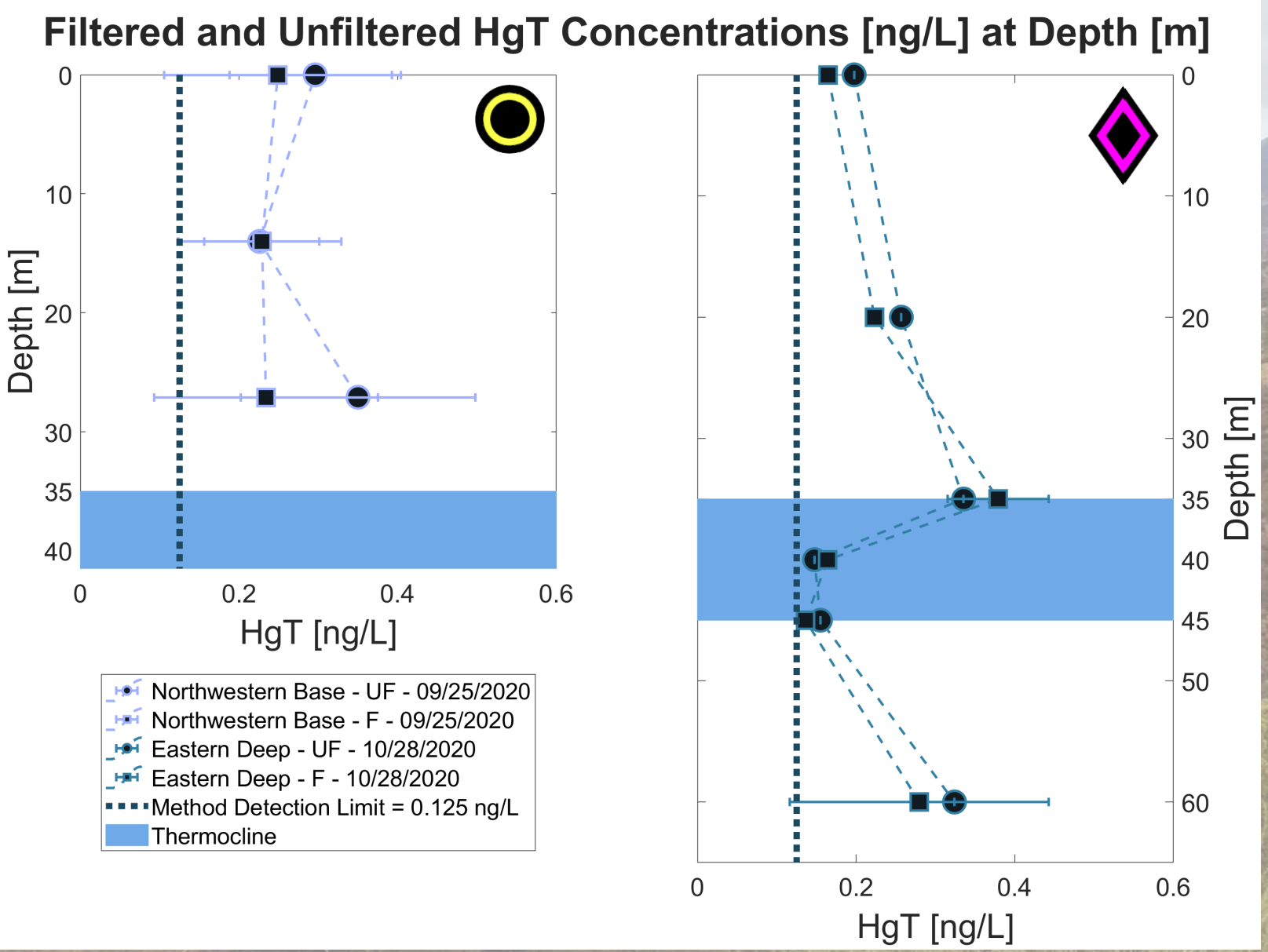


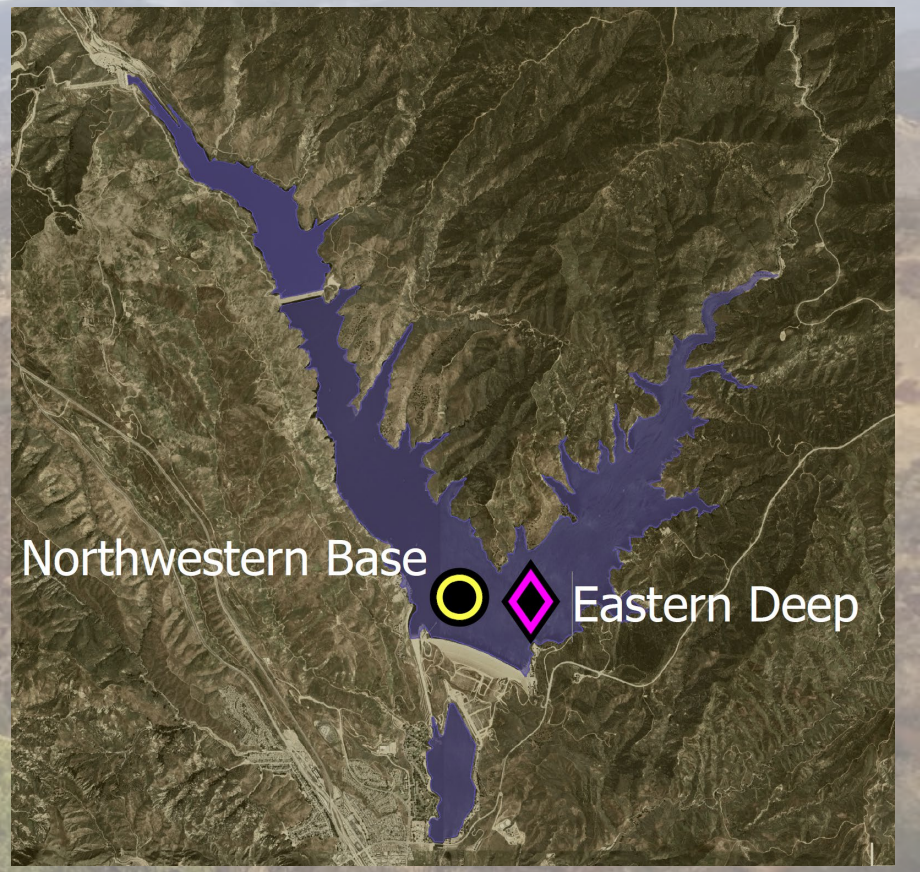
HgT was elevated following storm events, but remained below California Toxic Rule Criteria = 0.50 ng/L

Highest HgT concentrations along streambeds and near the boat launch

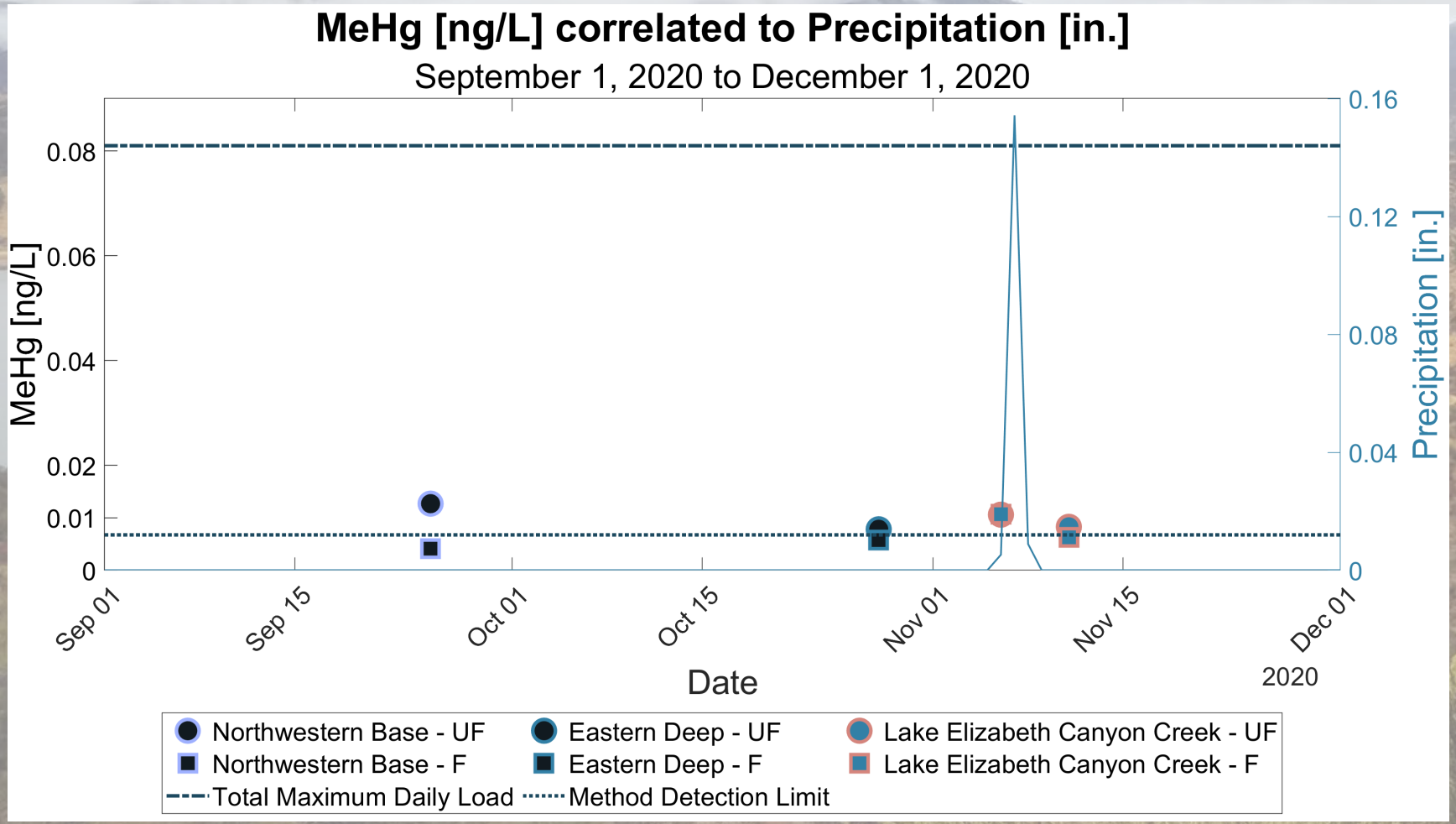


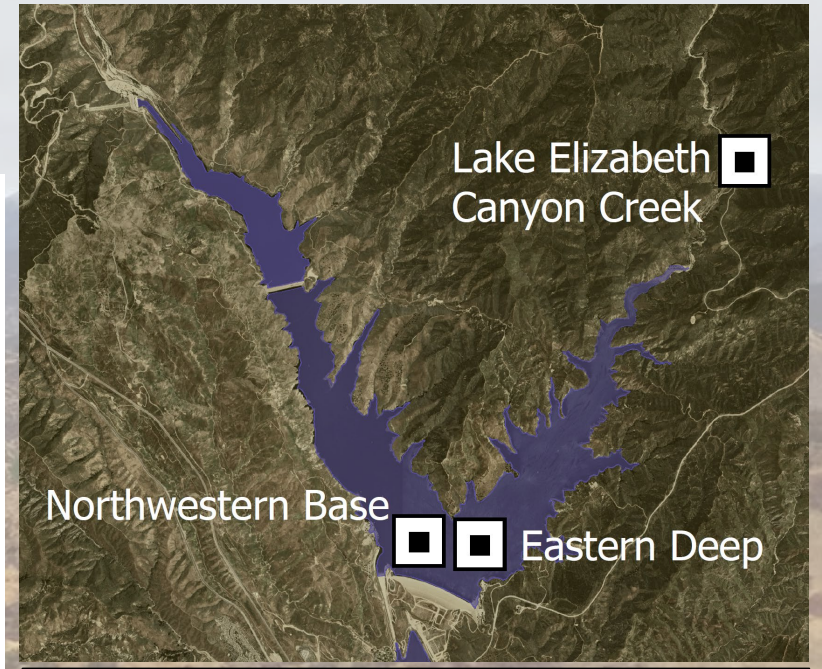
HgT concentrations fluctuate in the water column, but remain close to the detection limit



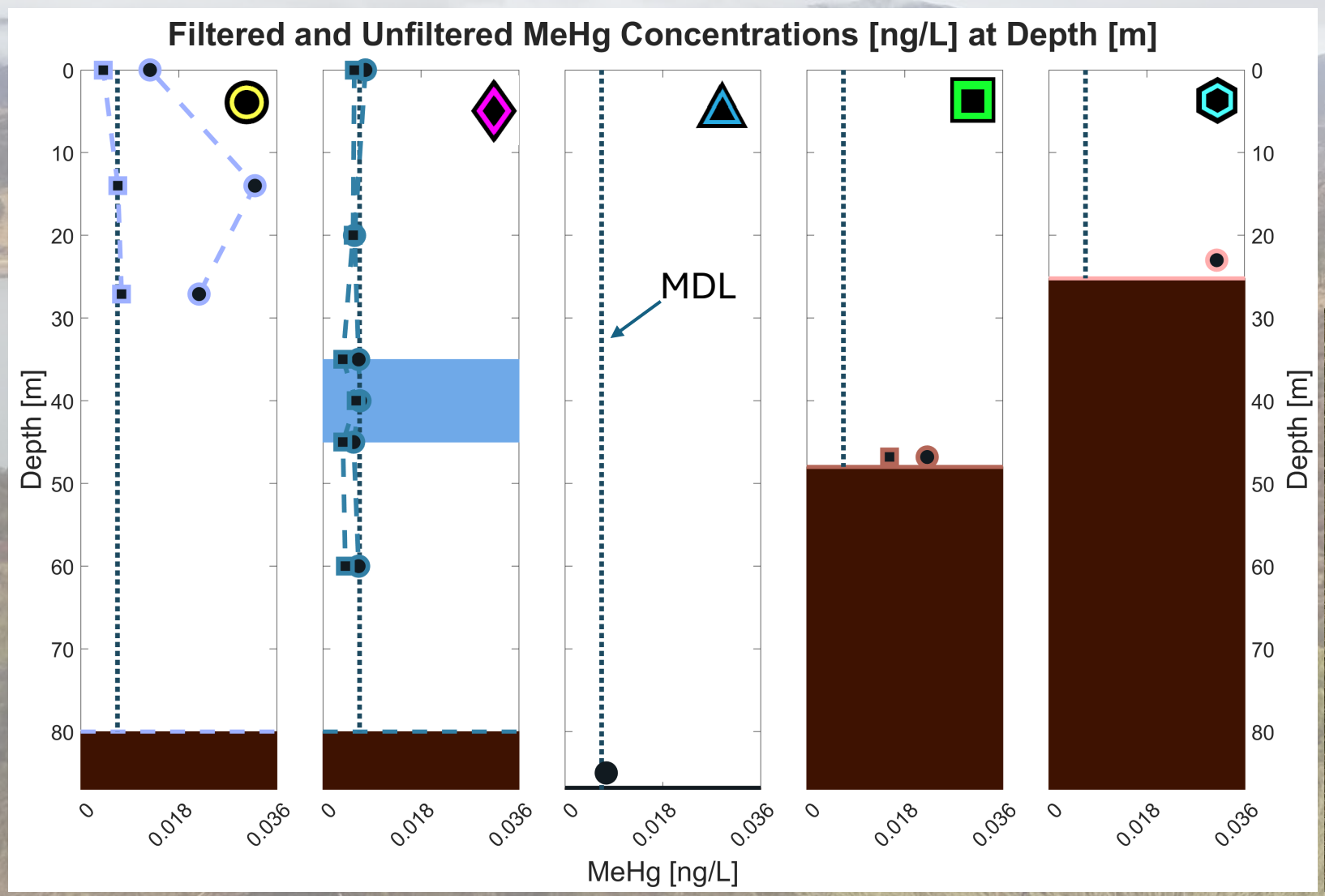


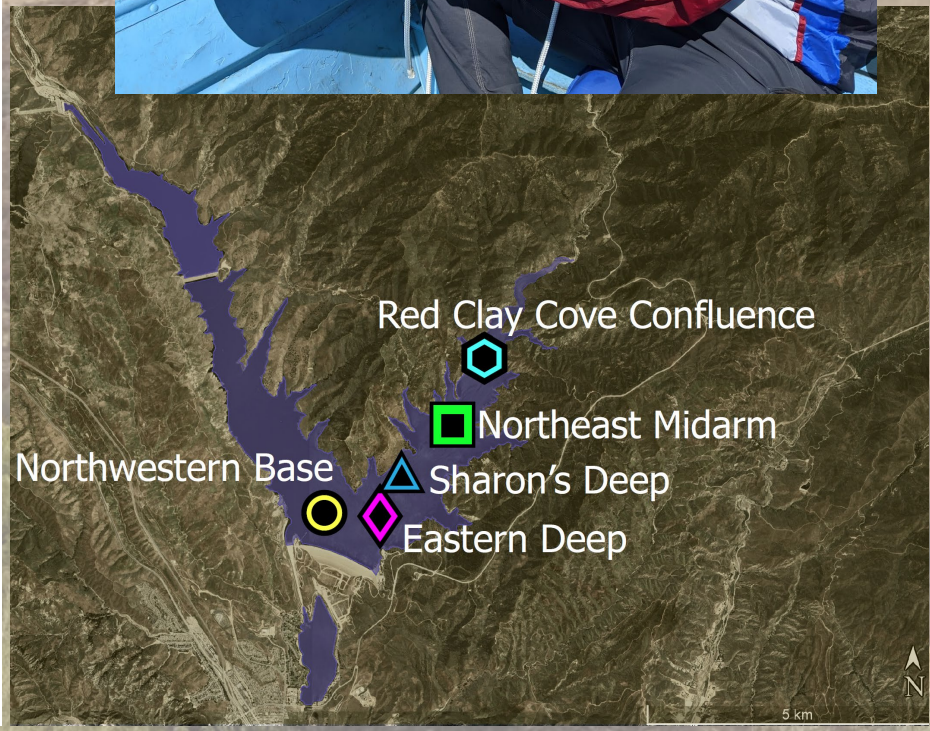
MeHg concentrations were near the MDL (=0.006738 ng/L) and << TMDL = 0.81 ng/L





MeHg concentrations within the water column are at or near the MDL = 0.006738 ng/L



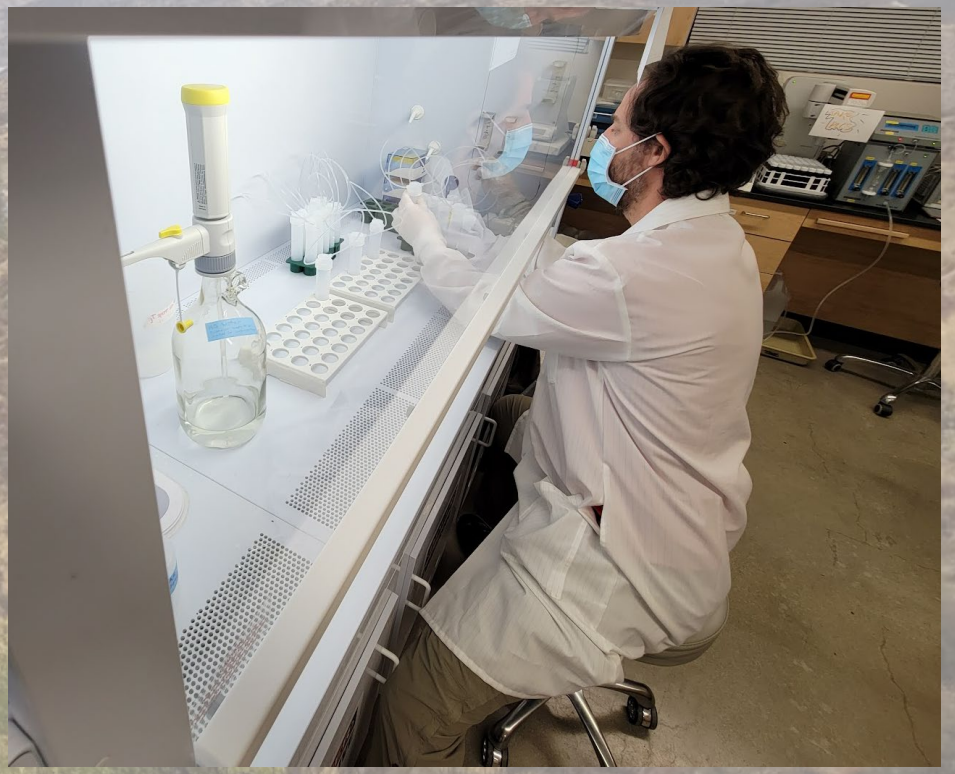


HgT, MeHg, and nutrient concentrations do not indicate methylation occurs in the water column

- Minimal stratification in the water column implies that there is regular mixing occurring, even at depth
- Concentrations of HgT, MeHg, and nutrients, both at the surface and in the water column, are regularly below the designated concentrations of concern
- Raises the question: Is there another source or location by which the fish of the lake derive elevated mercury concentrations?
  - E.g. Coves, HABs, fires, atmospheric deposition, sediment-bound mercury, reservoir elevation changes, quagga mussels, California State Water Project (via Pyramid Lake), former mines, former oil and gas wells

The source of methylmercury to fish does not appear to be in the water column of Castaic Lake

- HgT significantly below the California Toxics Rule Criteria (CA State Water Boards)
- MeHg significantly below the Total Maximum Daily Load (EPA)
- Temperature decrease while moving to depth implies weak thermal stratification around ~35 m, but not significant enough to enforce turnover of the water body
- DO decrease around ~35 m implies minor stratification from oxic to suboxic conditions



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Citations

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