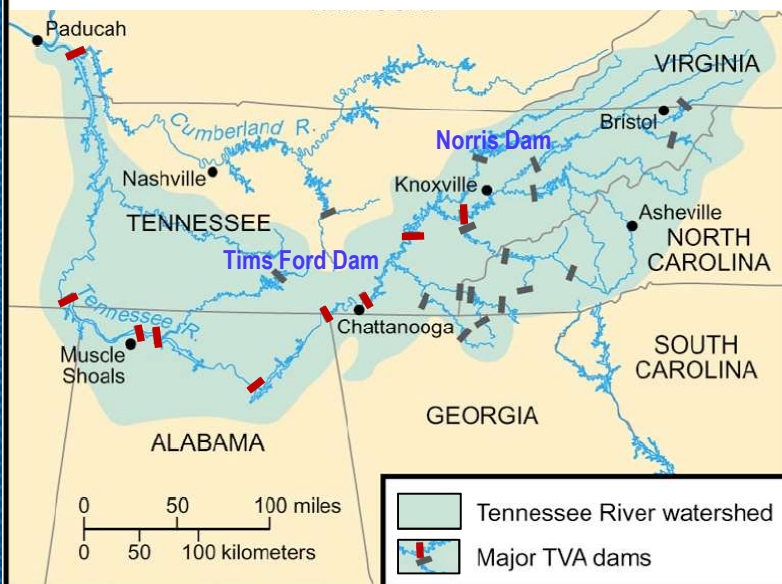


Water Temperature Control at TVA Dams for Environmental Protection & Compliance

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Overview of The Tennessee Valley



Tributary Storage Dams: Tall / deep, small releases. Most are in Eastern part of valley



9 Main River Dams: Shorter/ shallower, have navigation locks, large releases

- TVA has 29 hydro-electric dams and a few non-power dams.
- All but one of TVA's dams were built BEFORE dam releases were regulated for water quality concerns.



Hydro power is an attractive energy source because it is considered **renewable** and **clean**

Renewable as long as it continues to rain and fill the reservoir behind the dam.

Clean because it **does not visibly pollute the air** like a smoke stack

But dams also cause problems that Environmental Engineers now have to fix.

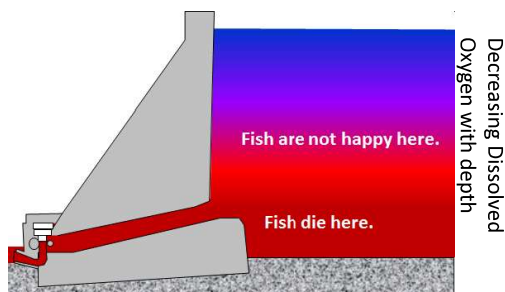
Nobody knew these problems would occur ~50-85 years ago when most of our dams were built.



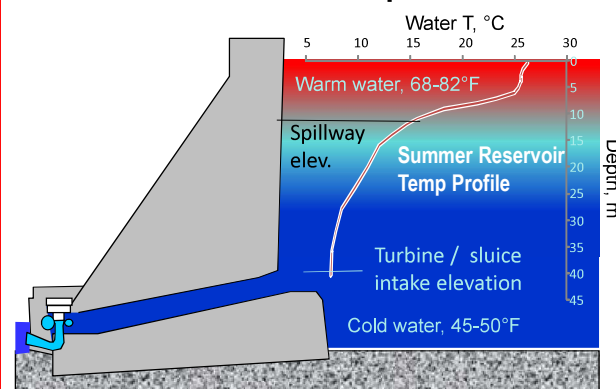
TVA

Some problems dams & reservoirs cause

Oxygen depletion of stored water

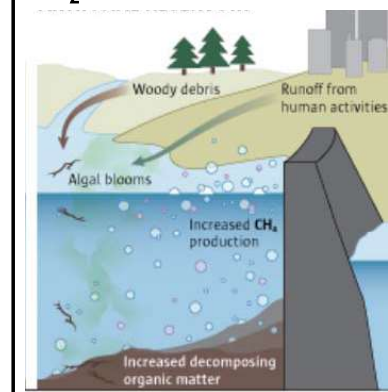


Unnatural water temperatures



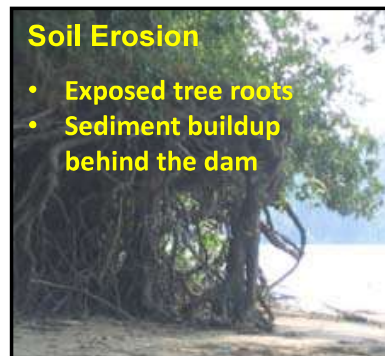
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CO₂ & Methane emissions



Soil Erosion

- Exposed tree roots
- Sediment buildup behind the dam



The Clean Water Act & the Endangered Species Act regulate how we operate our dams & thermal plants



1972: The Clean Water Act (CWA) was created. It established water pollution reduction goals.

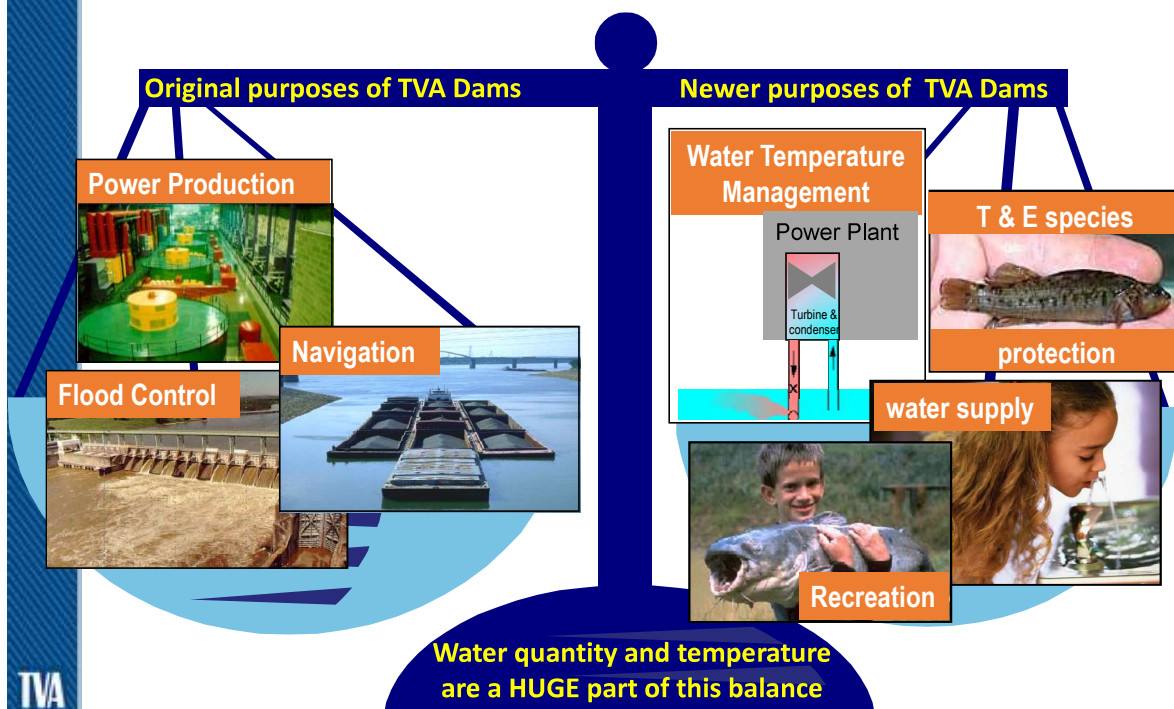
- The CWA set limits on various chemicals & other discharges from industries and power plants to a water body
- Compliance is managed via discharge permits issued by the States

1973: The Endangered Species Act was created to protect and conserve threatened & endangered species and their habitats.

- The US Fish & Wildlife Service oversees compliance with this act.
- When endangered species are discovered near a new or existing industry site, a large study (called a consultation) has to be done to determine the impacts of the project on the species & show how they will be protected.
- TVA has an ongoing consultation with the USFWS related to 29 of our dams.



Managing the TVA River system while ALSO caring for the environment has become a delicate balance



Norris Dam is one of TVA's most important tributary storage dams.

Norris helps the region in many different ways.



Norris Dam provides

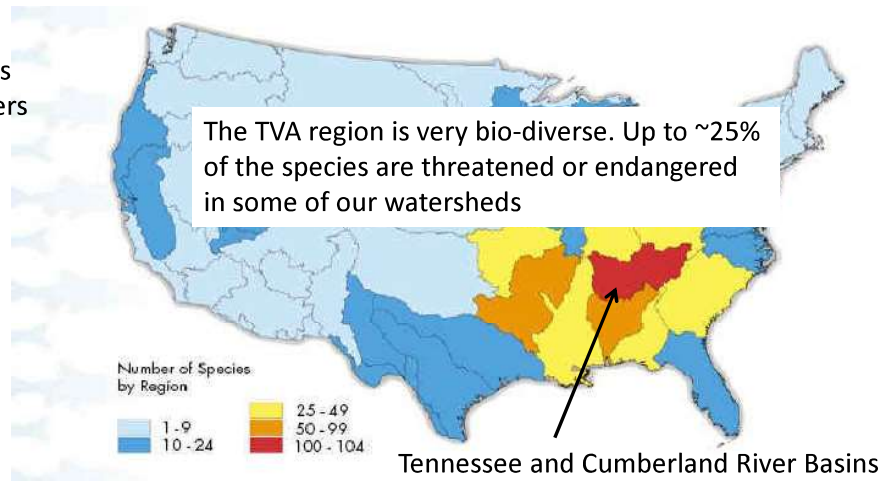
- Flood Control storage (Protects Clinton & Chattanooga)
- Hydropower (electricity production)
- Cold Water Storage for downstream power plants
- Cold water releases for trout habitat downstream
- Downstream minimum flows in summer for other power plants (Bull Run, Kingston, Watts Bar, Sequoyah)
- Water supply for several communities upstream & downstream
- Recreation opportunities (boating, swimming, fishing)

Compared to a natural river, low-level releases from tall dams will be colder in the summer and warmer in the winter.

These temperature changes from ambient, pre-dam conditions can stress or kill species who were used to the natural water temperatures.

Affected aquatic species can include

- Fish
- Mussels
- Water bugs
- Salamanders
- Plants

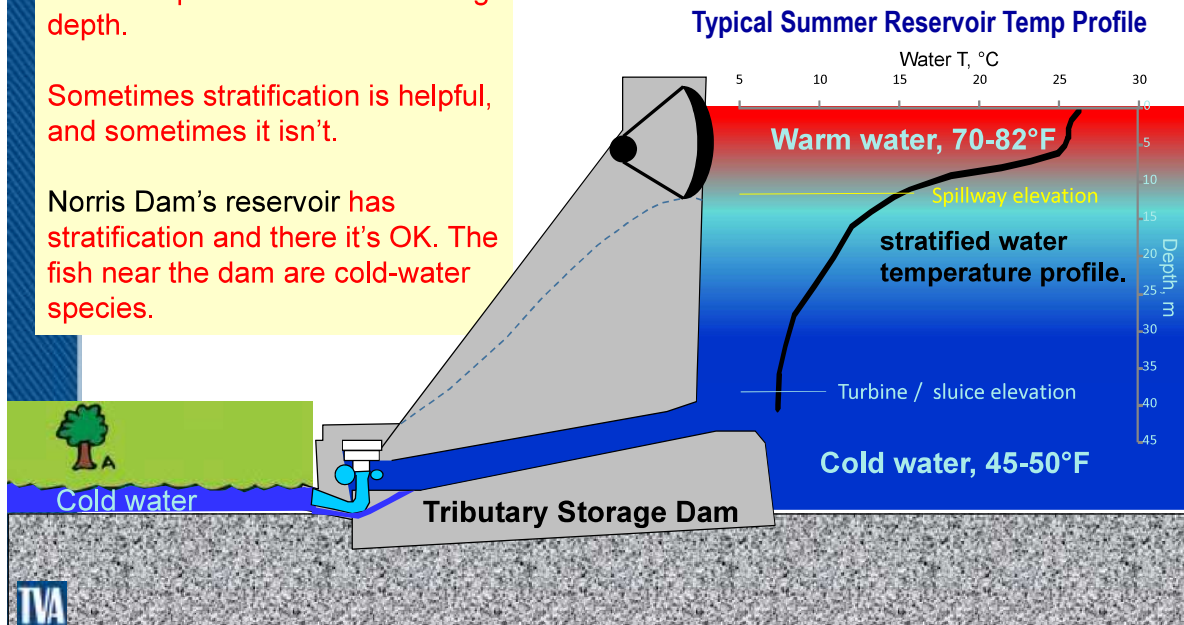


Deep reservoirs like Norris have decreasing water temperatures from top to bottom in summer

Stratification is a decrease in water temperature with increasing depth.

Sometimes stratification is helpful, and sometimes it isn't.

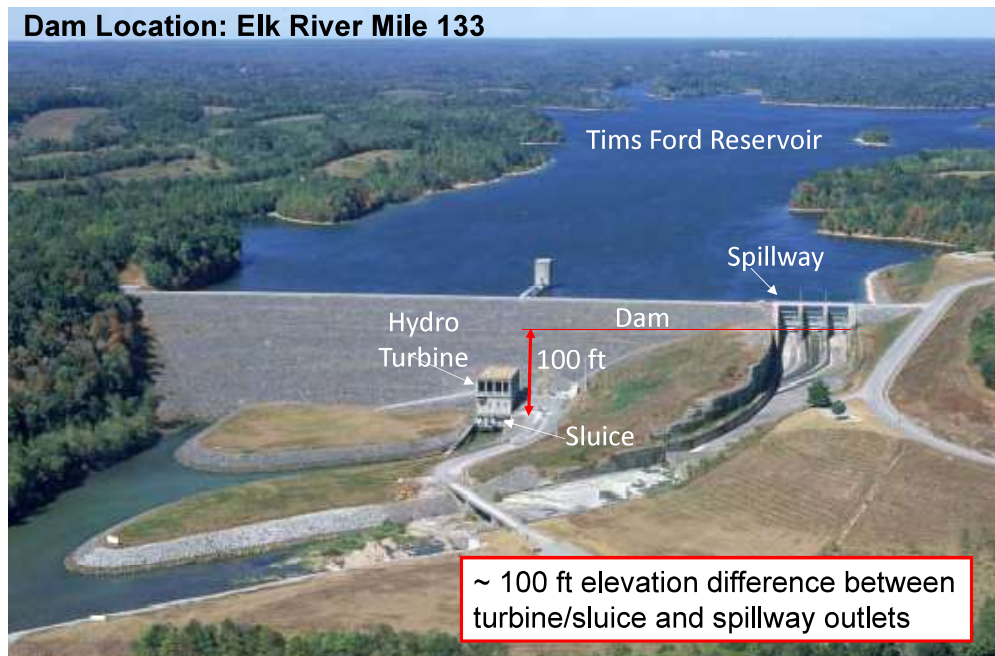
Norris Dam's reservoir has stratification and there it's OK. The fish near the dam are cold-water species.



At Tims Ford Dam, we've had to warm the summer releases to improve habitat downstream of the dam

Tims Ford dam is another tall dam with a deep reservoir behind it.
Deep = cold!

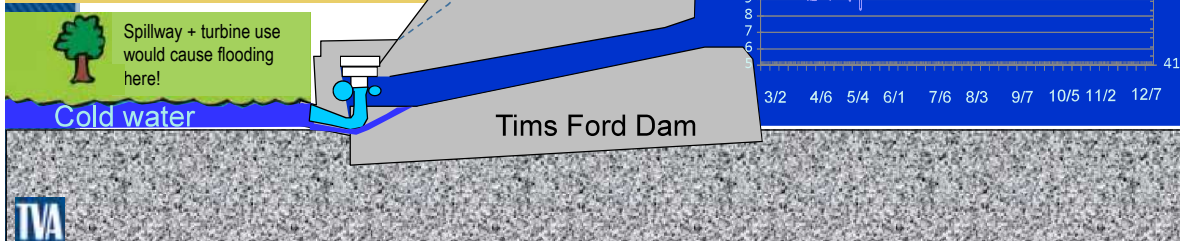
Dam Location: Elk River Mile 133



We have cold- and warm-water fish species downstream of Tims Ford Dam.

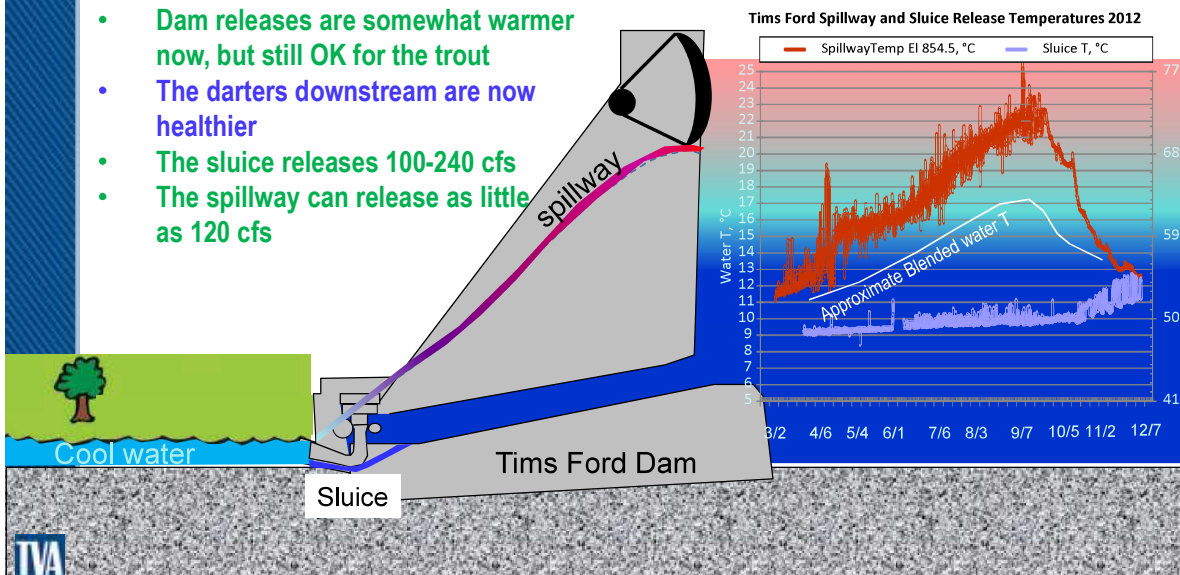
- Trout near the dam need cold water.
- Darters farther downstream need warm water & are endangered species
- The cold water from the turbine is great for the trout but hurts the darters
- Low-level, inflexible turbine: releases ~4000 cfs of cold water & the flow rate isn't adjustable (has vibration issues with other flow rates)
- The spillway flow is very adjustable but its upper level releases are too warm for the trout in summer.
- Trout fishing is good for the economy.
- We have to protect the darters AND we have to protect the trout

- Clearly this is a conflict!
- How did we fix it?



Our solution to protect all of the fish? Stop using the turbine for half of the year.

- We blend the cold low-level sluice release with the warm spillway release to achieve the desired water temperature from April to late October.
- Dam releases are somewhat warmer now, but still OK for the trout
- The darters downstream are now healthier
- The sluice releases 100-240 cfs
- The spillway can release as little as 120 cfs



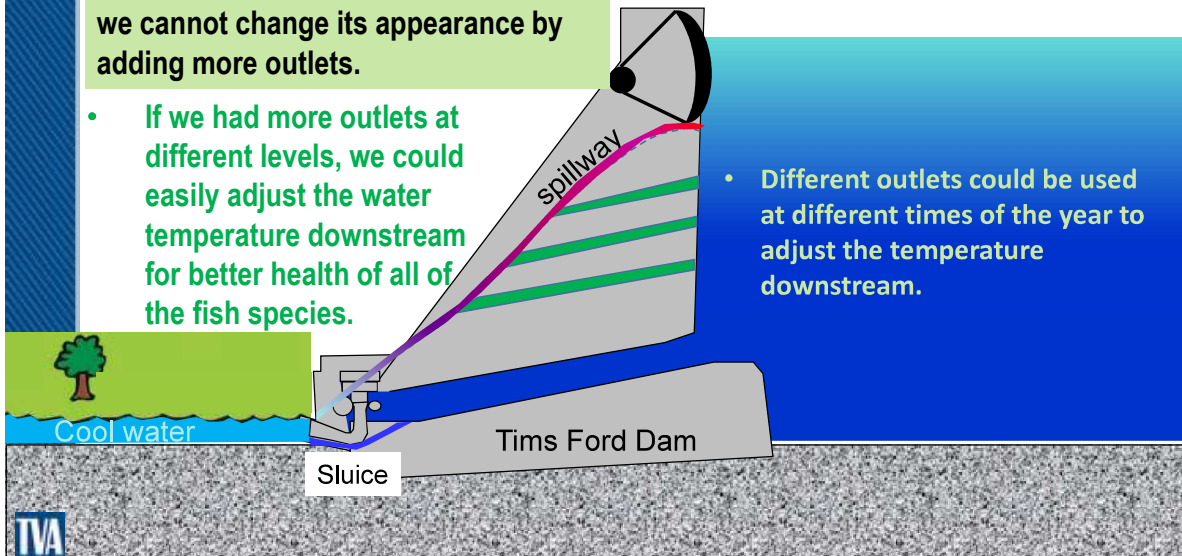
If we knew the problems cold water behind the dam would cause BEFORE we built it, we would have added outlets at more levels for temperature control

It is sometimes hard for us to provide the right release temperature under all flow conditions with ONLY an upper and a lower outlet.

The dam is now a historic landmark so we cannot change its appearance by adding more outlets.

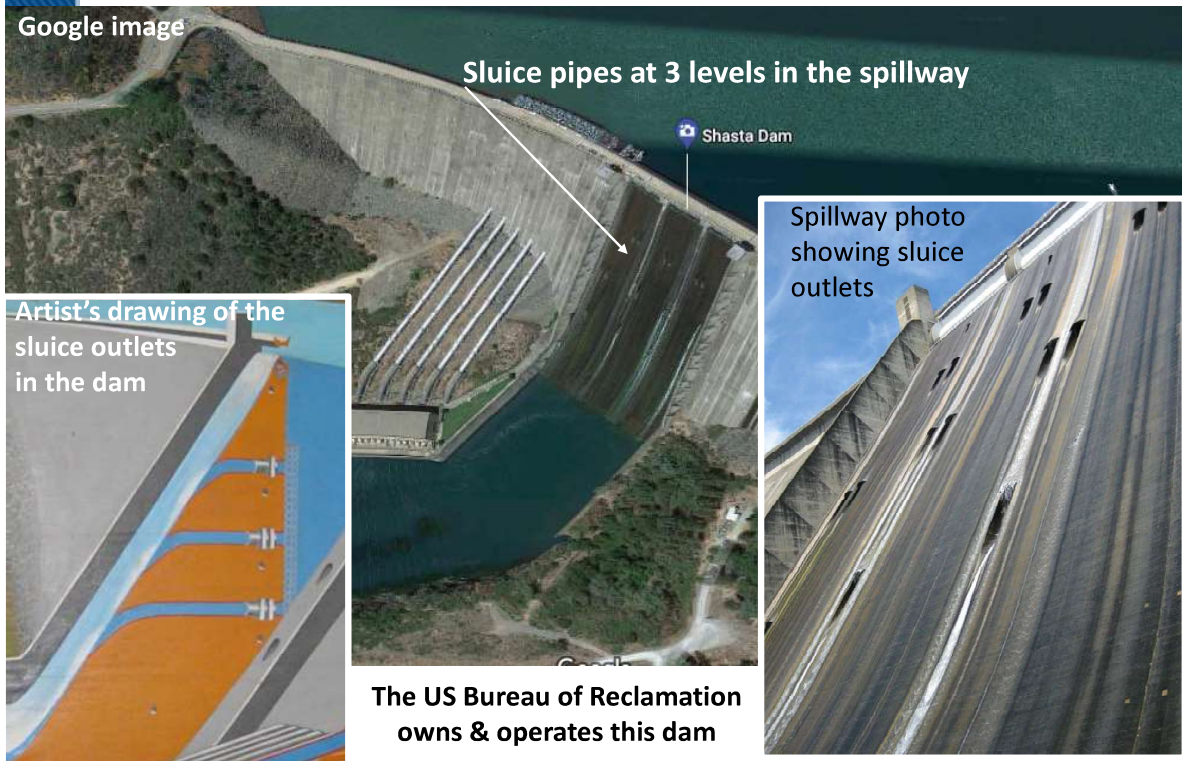
- If we had more outlets at different levels, we could easily adjust the water temperature downstream for better health of all of the fish species.

- Different outlets could be used at different times of the year to adjust the temperature downstream.



A good model for this would be **Shasta Dam**,
(located in Northern California)

Google image



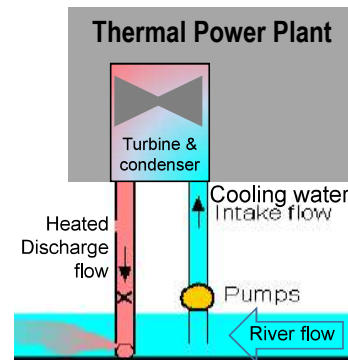
Artist's drawing of the sluice outlets in the dam

Spillway photo showing sluice outlets

The US Bureau of Reclamation owns & operates this dam

On the Tennessee River where we have thermal plants, we try to make the water cooler in the summer

- The cold water stored behind our dams can help us generate more power from our coal and nuclear plants during a hot summer...if we plan the dam releases carefully.
- TVA can adjust the water temperatures in the river **a little bit** by changing the hourly dam releases through the day to be more steady or more variable
- If we need a big temperature change, we can sometimes send a cold water release from Norris Dam (30-120 miles upstream of 4 thermal power plants) to lower the water temperatures at those plants! (There is a long travel time for this)
- This can help keep our thermal plants generating at 100% power in a hot summer instead of having to decrease their generation for fish protection.
- We use models to help us figure this out



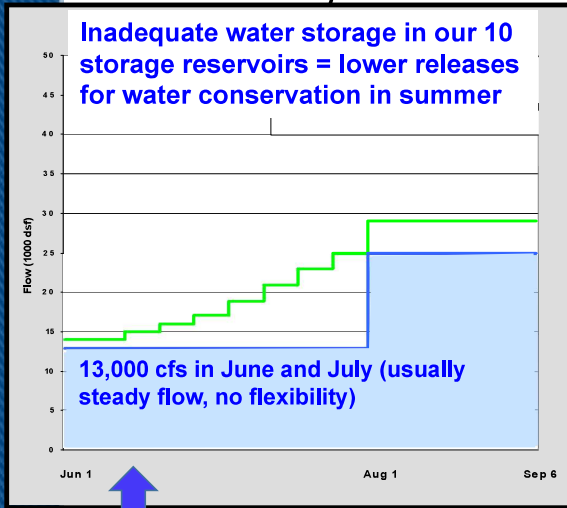
Multi-season climate factors determine how challenging a summer will be for thermal power plants.

Primary climate factors affecting our thermal plants

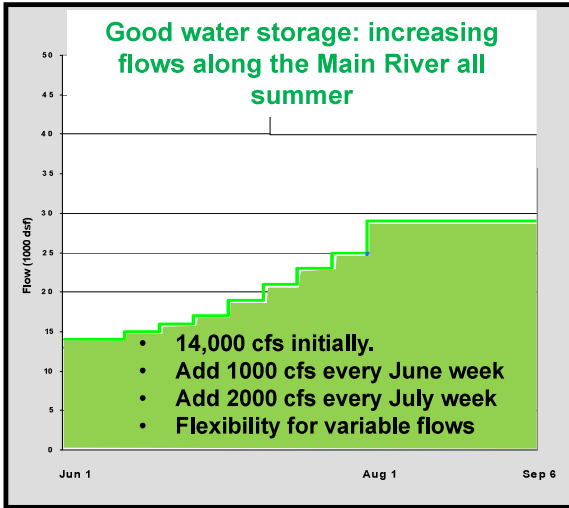
1. **A warm winter** can increase March reservoir water temperatures by 5-8°F (March is when the reservoirs start to stratify)
2. **A large spring flood** flushes away the coldest water stored in the reservoirs before summer (can warm summer water temps 5-8°F)
3. **A dry spring** prevents most TVA storage reservoirs from filling to target levels, restricts summer dam releases to lower-tier, conservation flows
4. **Norris Reservoir did not fill completely** (this happens about 1 in 6 years) Norris is our main cold water source. Usually Norris receives enough rainfall because of its location & the typical weather patterns. (Norris' cold water volume directly affects 4 of our thermal plants)
5. **An unusually hot summer** causes excessive warming of water everywhere

Dry versus normal year dam releases look very different!

Dry year water conservation flows
established By ROS EIS



Normal year flows

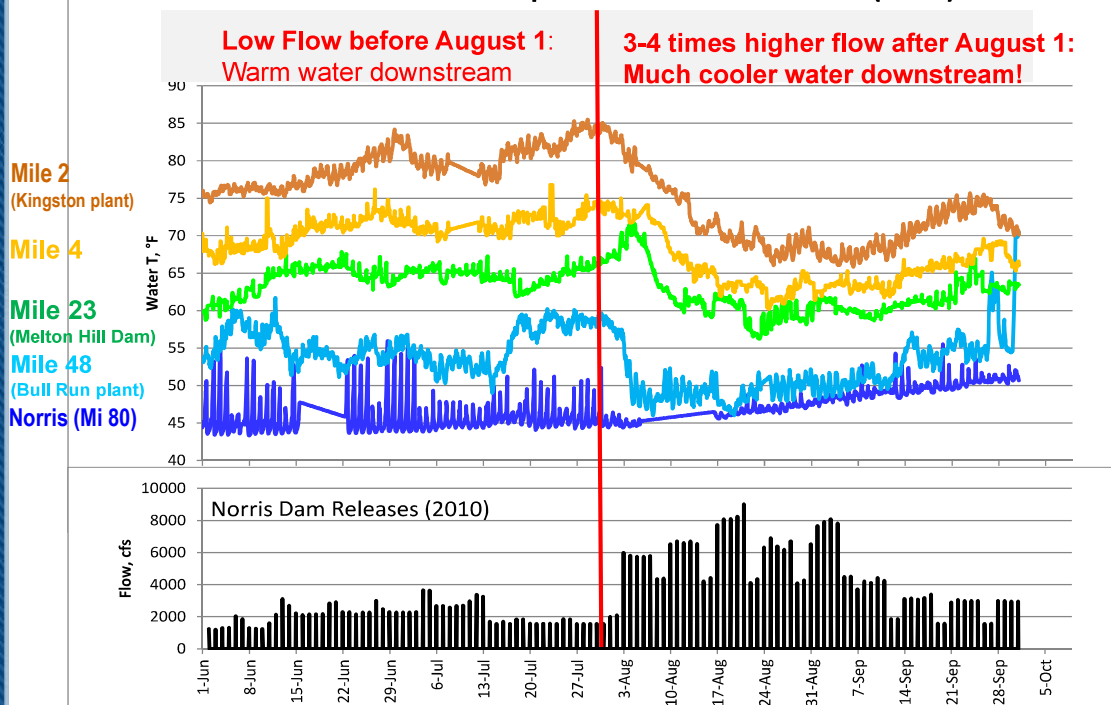


Lower flows produce warmer water temperatures
(lower velocity, more time for solar heating)
Less flexibility on hydro release options with low flow

TVA

Norris Dam Release rate warms or cools Clinch River Water significantly

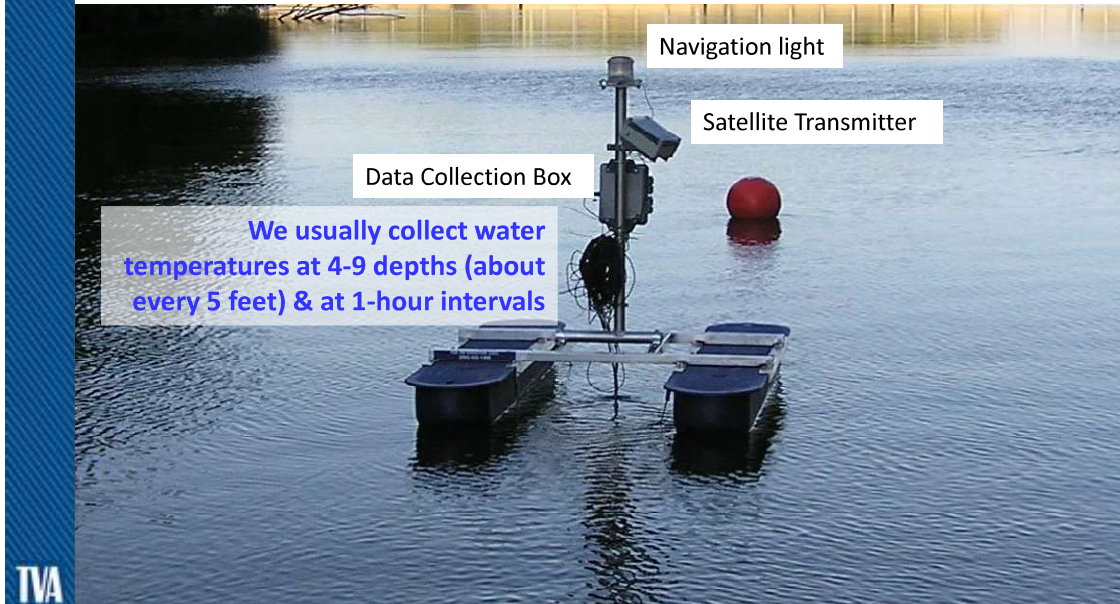
Clinch River Water Temperatures Vs. Norris Flow (2010)



TVA

Data collection along the river and at plant sites is important for decision-making.

- Solar-powered water temperature stations allow us to gather data in remote areas near our thermal plants.
- **The data is sent to us by Satellite & archived in a database.**



Summary

- TVA dams are old and were built before Engineers understood the environmental problems dams can cause.
- Addressing environmental issues is harder after the dam is already built.
- A modern dam can be built to address the major environmental issues like
 - Low dissolved oxygen
 - Unusually cold water temperatures
- Critical animal species impacted by a project need to be identified early, to plan dam construction & operations for their preservation AND for power generation

Some Solutions to these problems

- Install water temperature, DO, and elevation sensors that transmit data to your computer network at dams and other necessary places along the river.
- Archive the data in a database for current and future use.
- Include aeration systems in the turbines and/or the reservoir during construction
- Include selective withdrawal outlets at several different levels in the dam during construction, for water temperature and DO control
- Use hydro turbines designed to operate over a range of flow rates, or use a larger number of small to medium size turbines instead of a few larger ones for greater operating flexibility.
- If possible, have at least one smaller spillway gate to help regulate upper level flows for water mixing downstream.