Data, Tools, and Products to assist in hydropower mitigation

Ryan McManamay

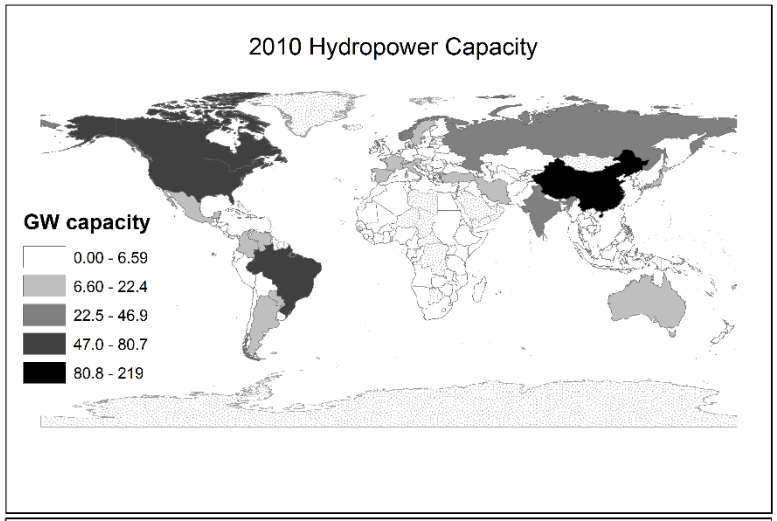
USFS Instream Flow Training

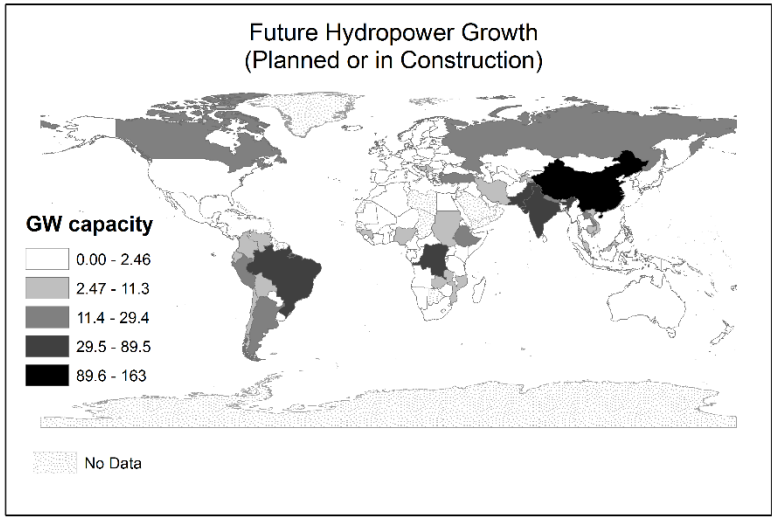
January 10, 2018

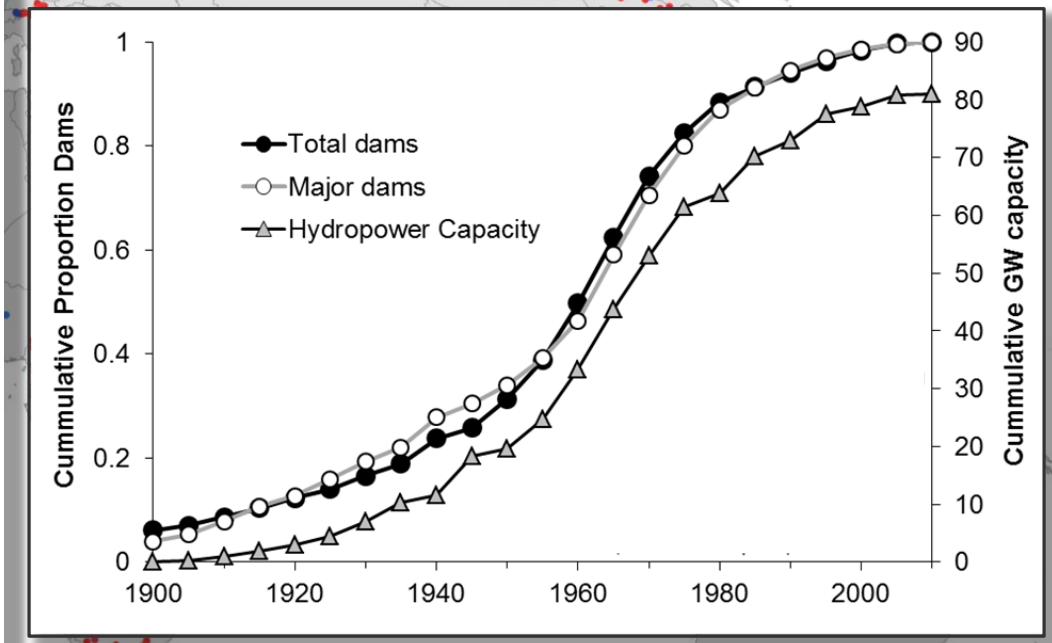
ORNL is managed by UT-Battelle
for the US Department of Energy

OAK RIDGE National Laboratory

Global Hydropower Expansion





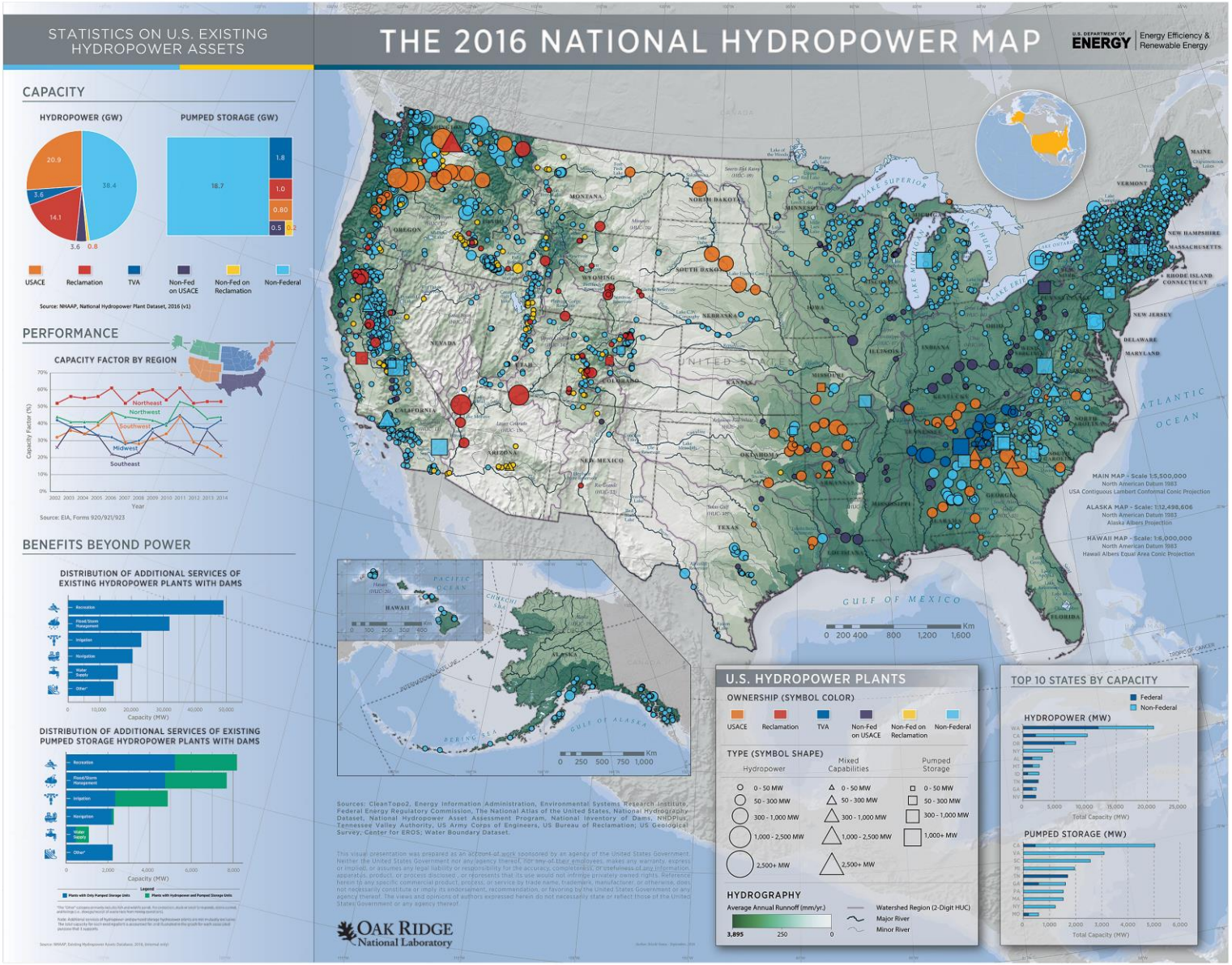


Dams under construction

Dams planned

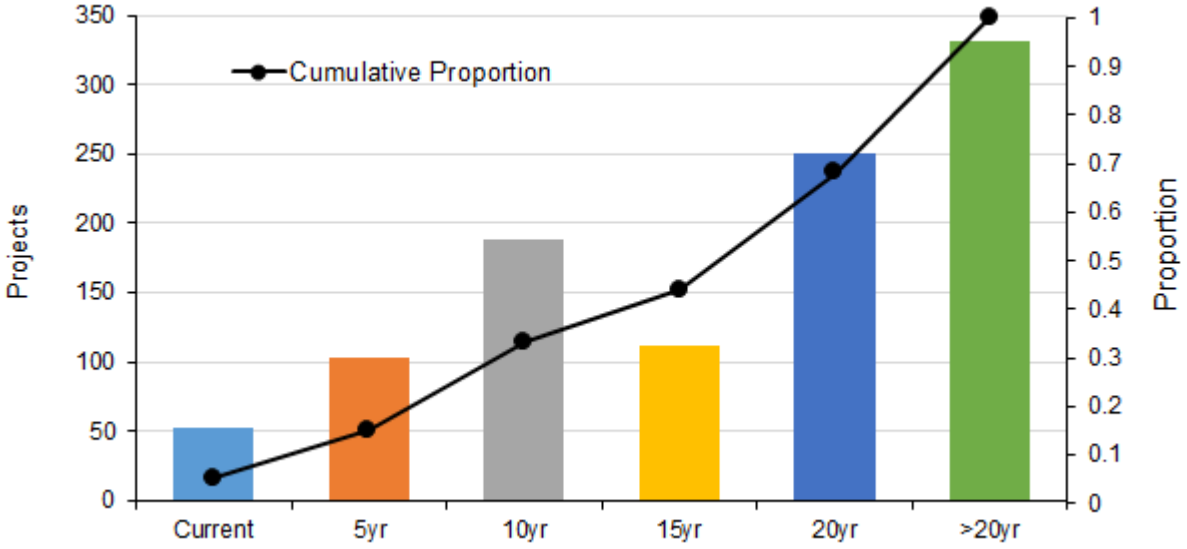
Zarfl et al. 2015 – Aquatic Sciences

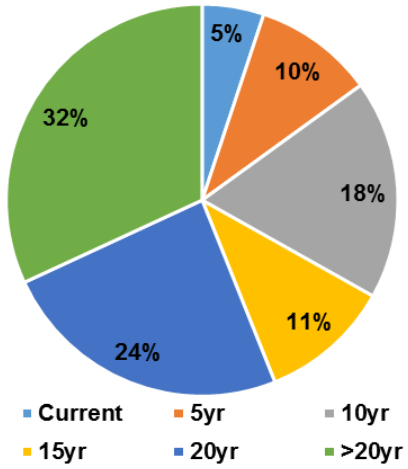
US Hydropower Assets



Near Future of Federal Energy Regulatory Commission (FERC) licensing

- 50% of the FERC hydropower projects with undergo relicensing in the next 15 years
- 70% of the projects will undergo relicensing in the next 20 years
- Doesn't include new licenses





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With the looming relicensing storm…

- Need for data, tools, and frameworks to pre-inform stakeholders prior to engagement in FERC licensing process
- Need for early indicators of mitigation needs

Outline

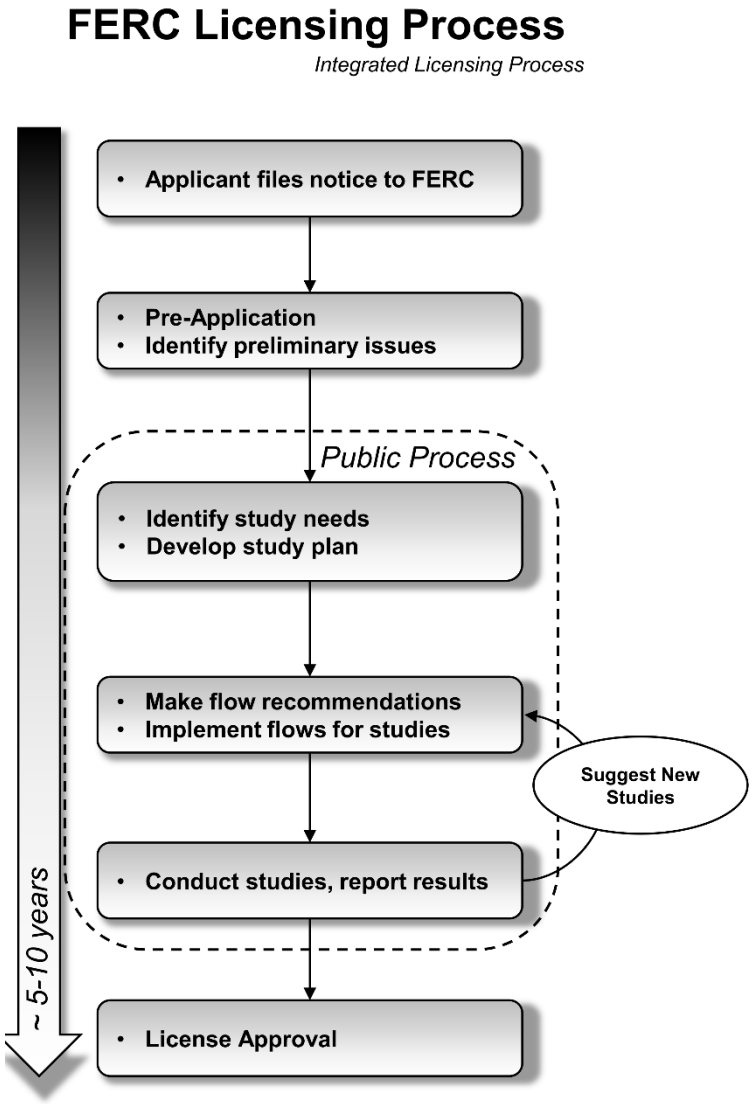
- Steps of FERC licensing
- Present a framework to organize the application of data and tools associated with licensing
- Examples of data, tools and their application
- Brier tour of National Hydropower Asset Assessment Program
- Stream Classification Web Application

McManamay et al. 2016. Env Management

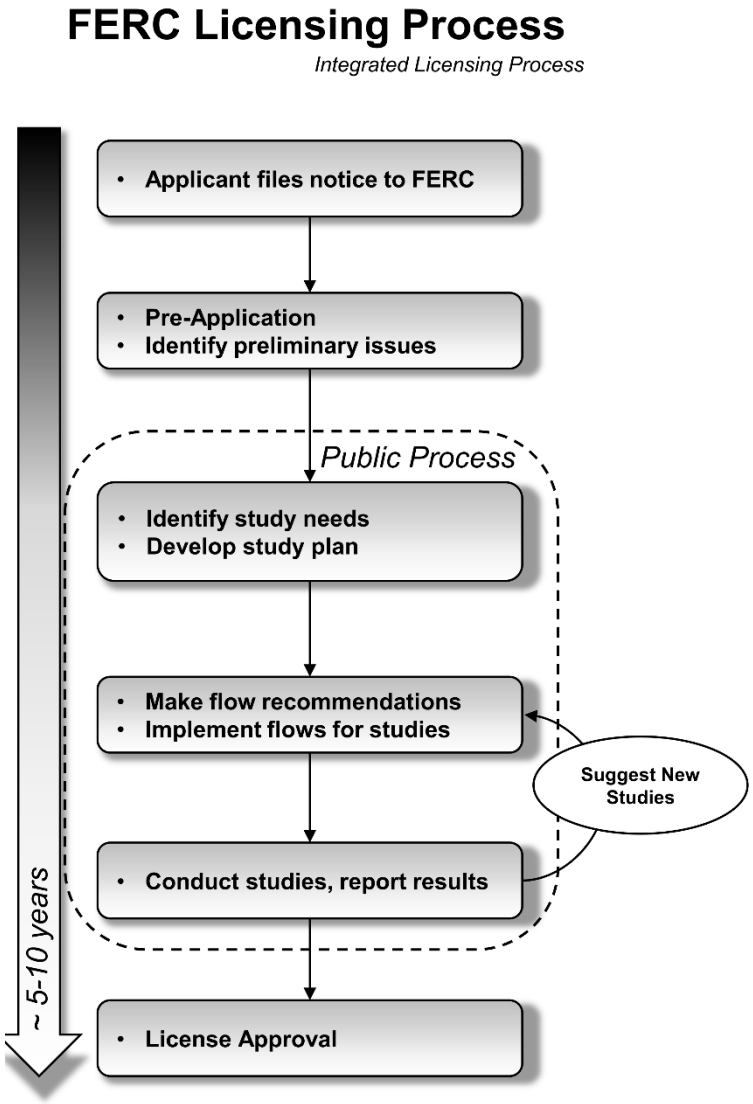
FERC Licensing Procedure Types

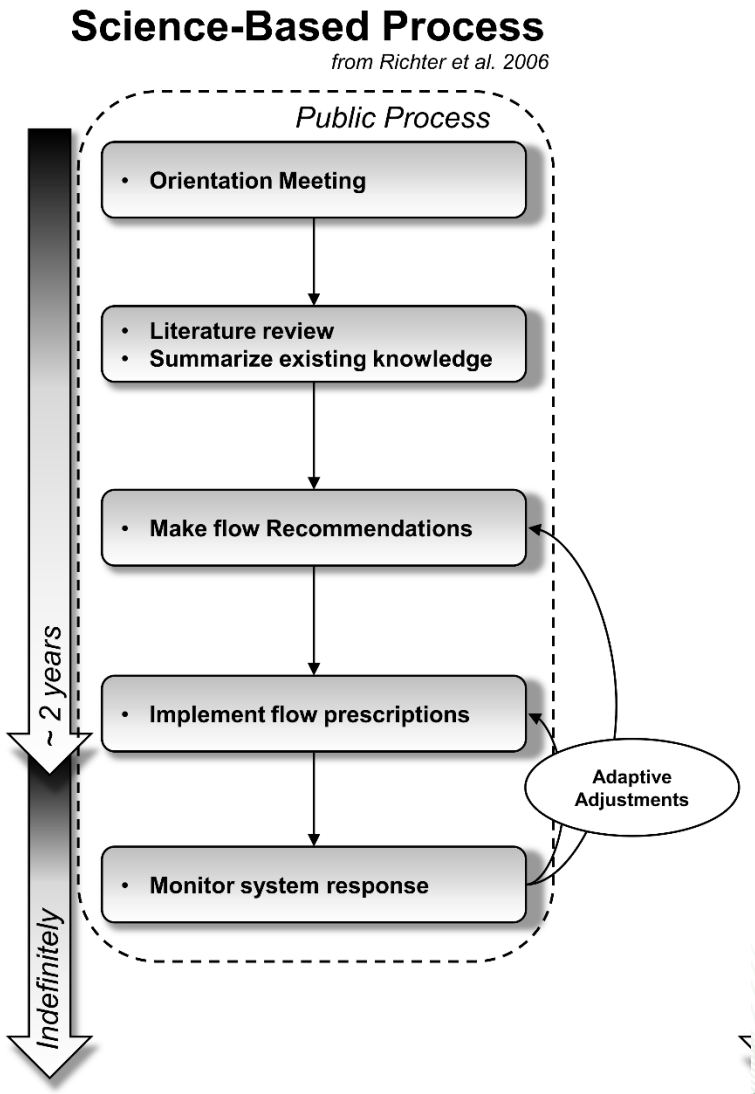
Licensing Process	Description
Traditional Licensing Process (TLP)	Historically, it was the predominant procedure. 3-stage consultation process. Stage 1: NOI, PAD, joint meeting, comments, study proposal disputes. Stage 2: Conduct studies, draft application, stakeholders provide comments/disagreements/resolution. Stage 3: Final application files
Integrated Licensing Process (ILP)	Default procedure. Implemented in 2003 to create efficiency in process. Same as TLP except: • Early issue identification and resolution of studies (fill info gaps), avoiding studies post-filing; • Integration of other stakeholder permitting needs; • Established time frames to complete process steps for all stakeholders, including the Commission.
Alternative Licensing Process (ALP)	Designed to improve communication and flexibility. • Tailor the pre-filing consultation process to each case; • Combine into a single process the pre-filing consultation process and EIS • Allow for prep of draft EIS by an applicant or contractor

Major Steps in FERC Licensing Process



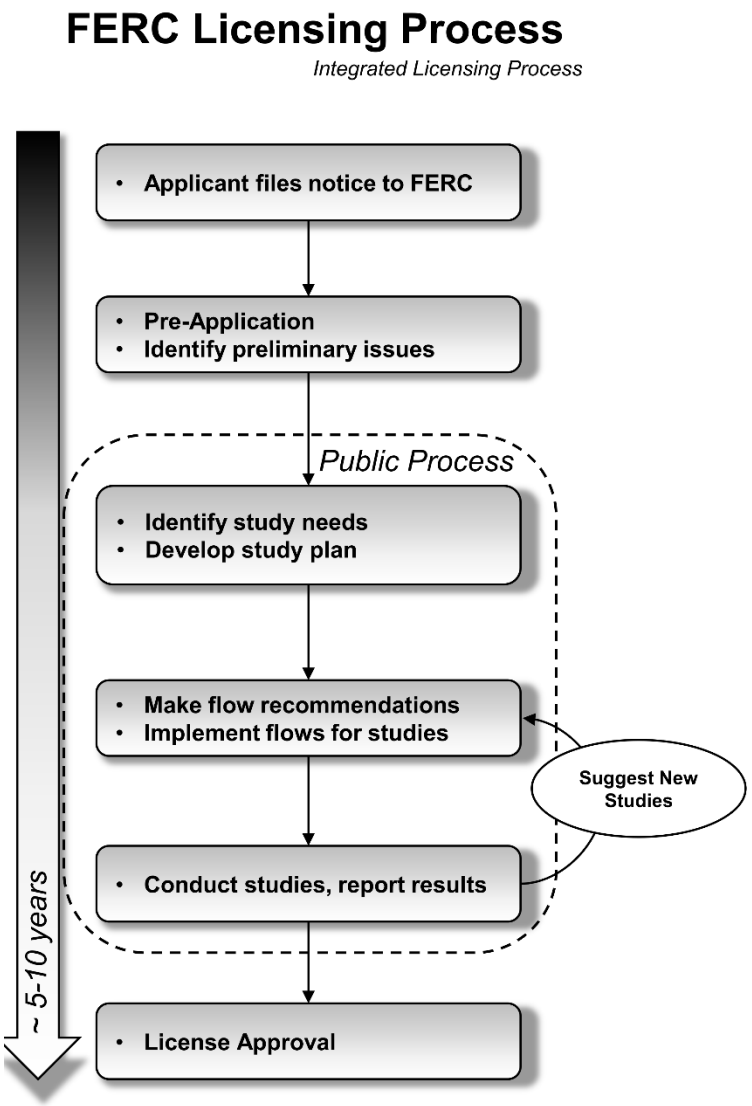
Major Steps in FERC Licensing Process

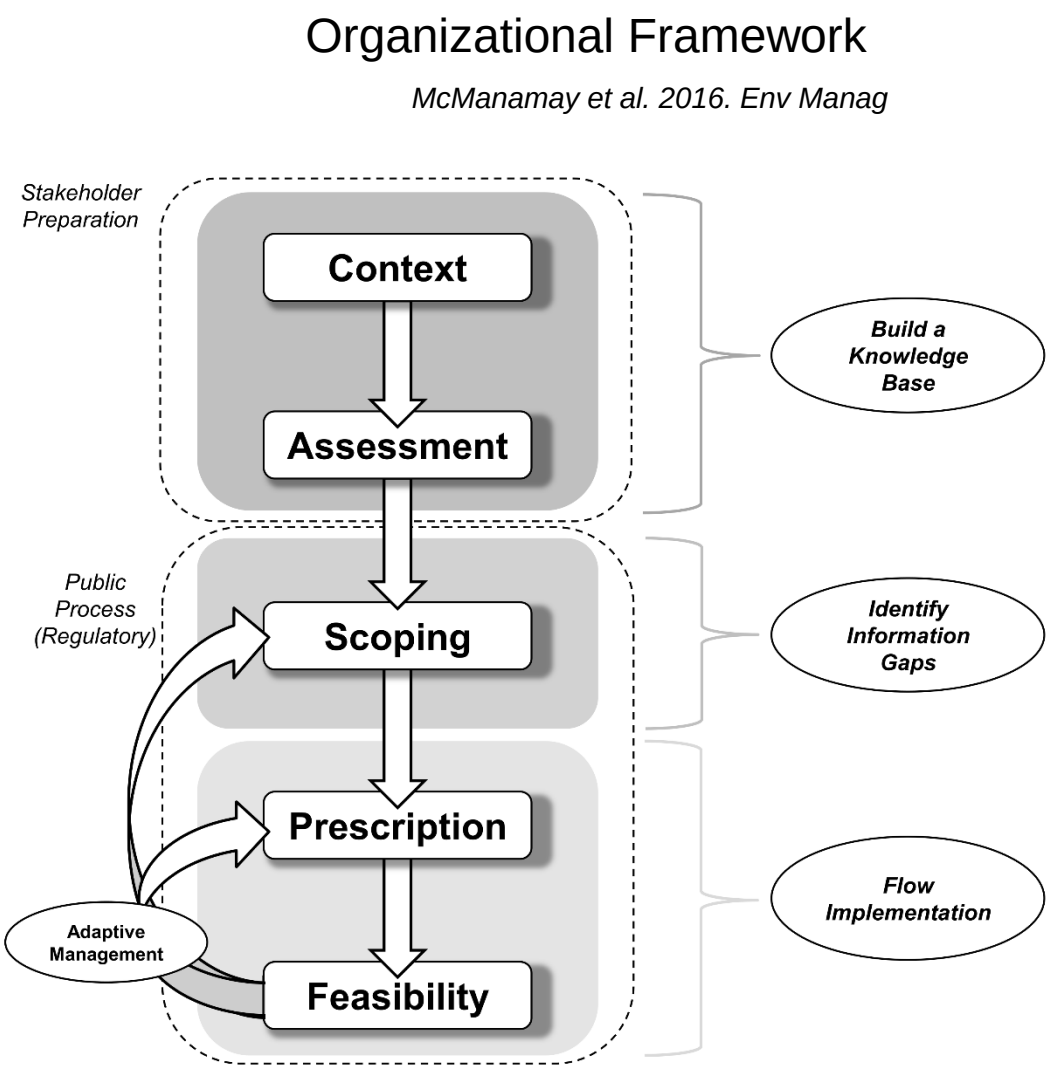




Richter et al. 2006. River Research & Applications

Placing Regulations Into a Meaningful Framework

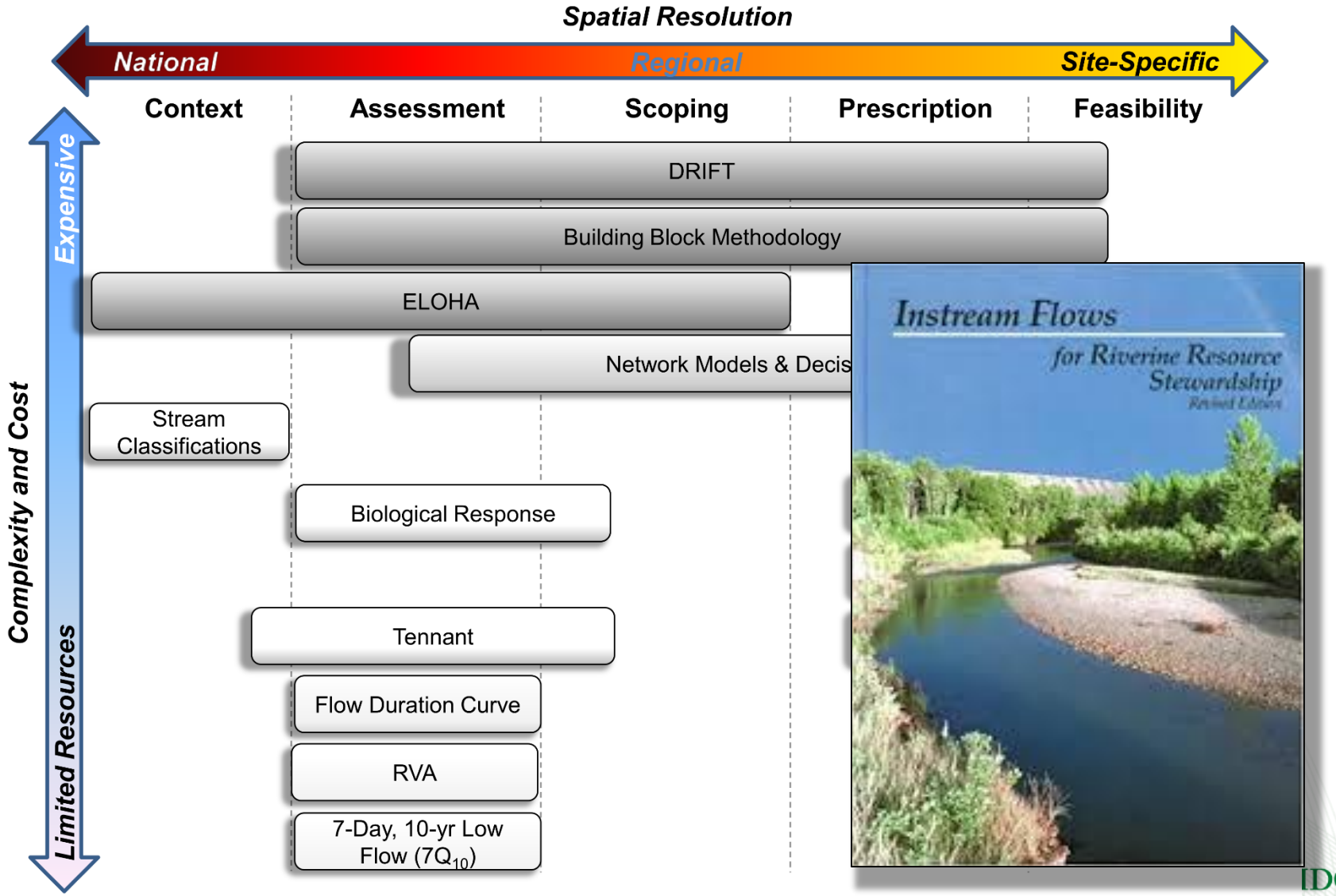




Terminology

- **Context**: provided at basin or regional scales to characterize the biophysical and operational settings around each hydropower project and provides a point of reference to other regulated rivers and reference streams.
- **Assessment**: conducted at national or regional scales and includes fully describing the current hydrologic and ecologic conditions relative to stakeholder determined ecological and hydrologic objectives.
- **Scoping**: used to identify key hydrologic and ecological targets, isolate information gaps, and develop flow-ecology relationships to predict the ecological outcomes of alternative flows.
- **Prescription**: Based upon best available knowledge, prescription presents a series of alternative flow scenarios based on objectives and the knowledge gained within the assessment and scoping stages.
- **Feasibility**: analyses that determine the ecological versus economic impacts of alternative flows at the site-specific scale.

Organizing when and where tools are applicable

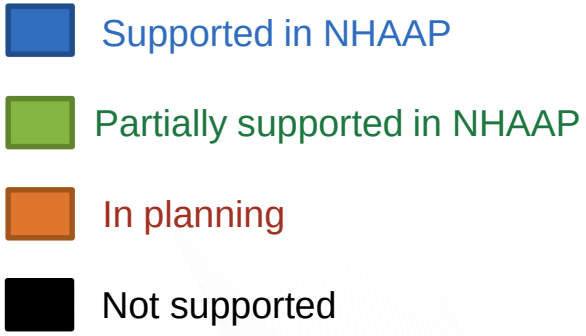


Context

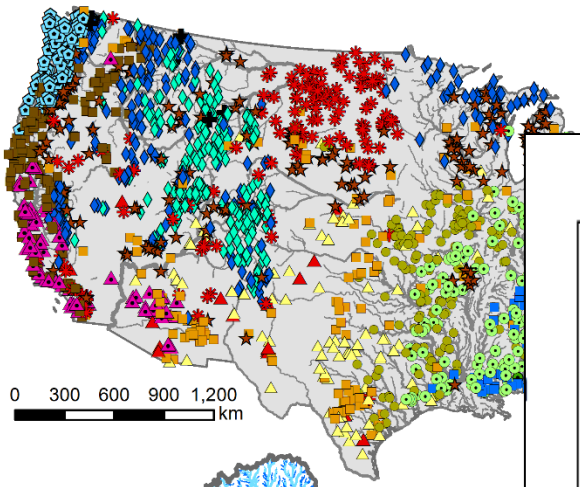
- Provided at basin or regional scales to characterize the biophysical and operational settings around each hydropower project and provides a point of reference to other regulated rivers and reference streams
- This helps to understand the environmental and political setting, as well as the potential opportunities and constraints to environmental mitigation

- Relevant Data
  - Project Infrastructure, Reservoirs, Attributes
  - Land Ownership
  - Project Economics (Generation)
  - Mode of operation
  - Species occurrences
  - Hydrologic gauges, water temperature stations
  - Stream typologies
  - Environmental mitigation requirements

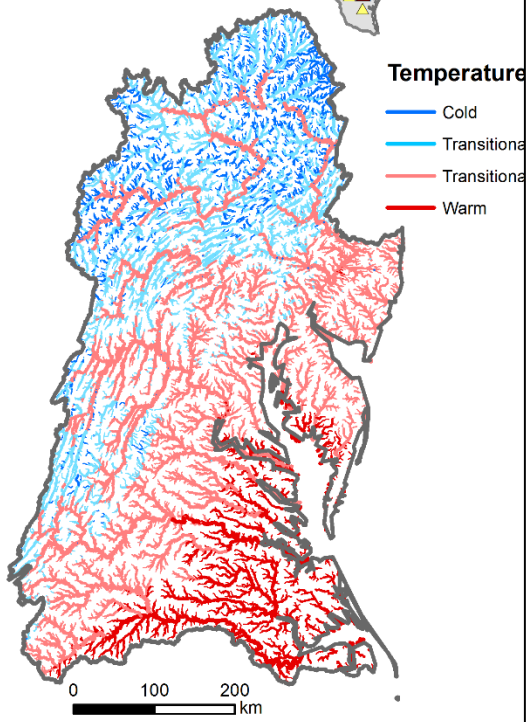
- Relevant Tools
  - Stream Classification Web Application
  - Hydropower Project and Water Resource Mapper
  - Historical Generation
  - River Function Framework

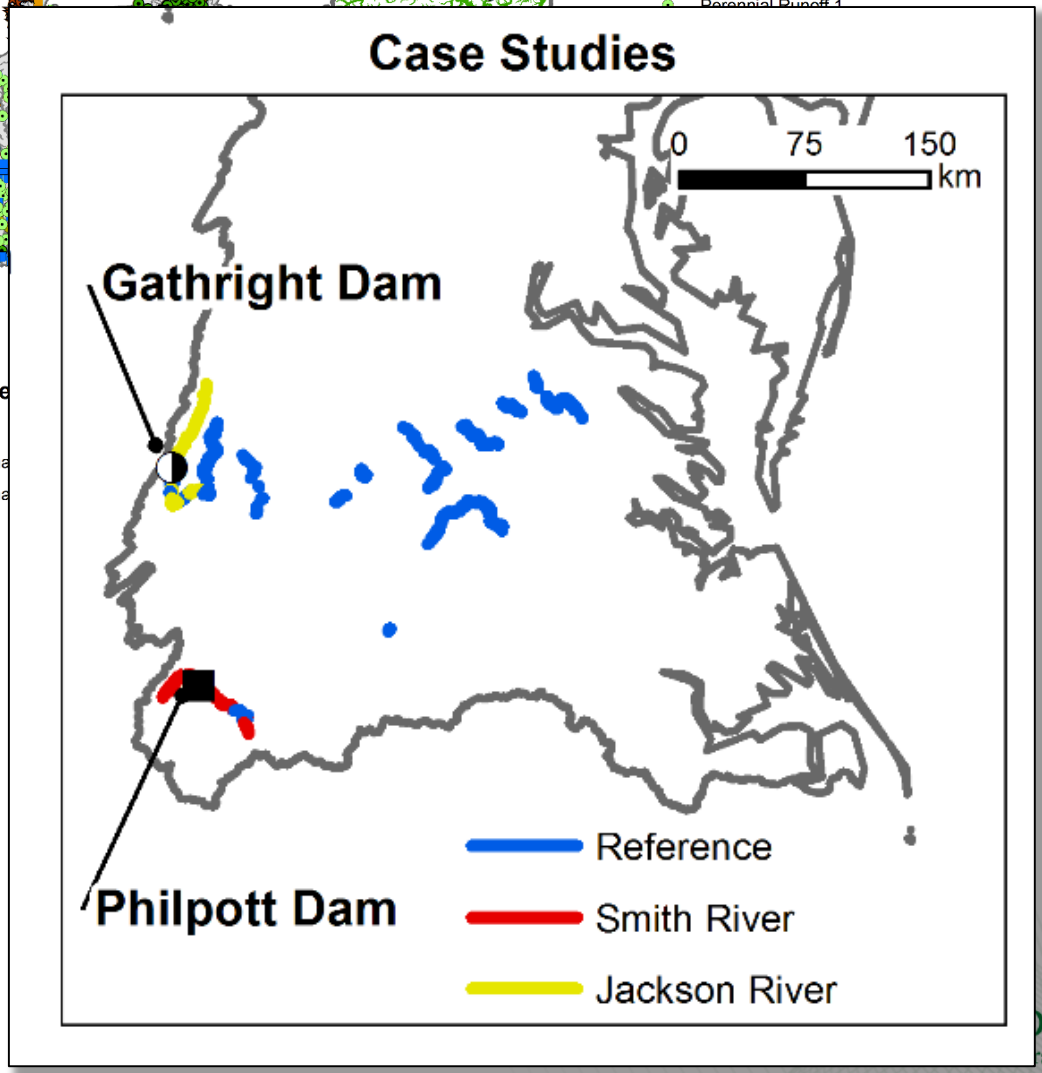


Context


0 300 600 900 1,200
km

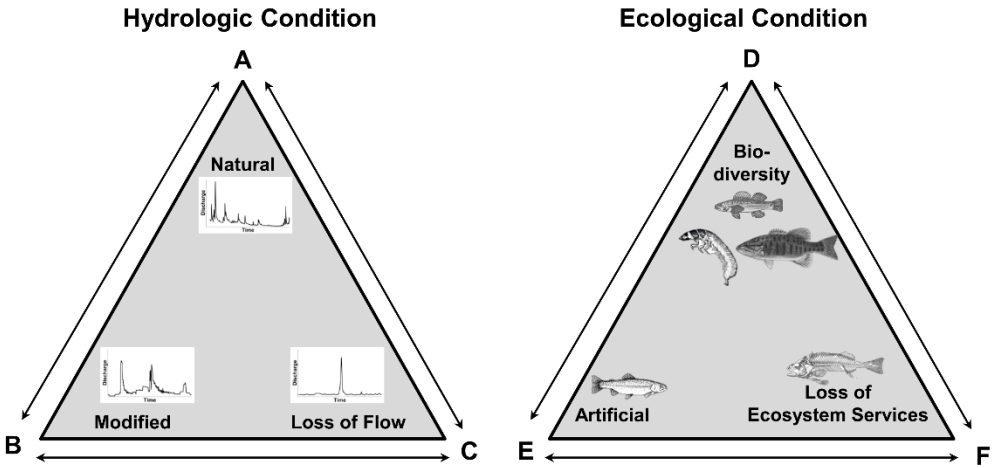

Hydrologic Classes
Intermittent Flashy 1
Unpredictable Perennial


Temperature
Cold
Transitiona
Transitiona
Warm
0 100 200
km


Case Studies
0 75 150
km
Gathright Dam
Philpott Dam
Reference
Smith River
Jackson River

Assessment

- National or regional scales and includes fully describing the current hydrologic and ecologic conditions relative to stakeholder objectives.
- What is the limiting factor(s) in this system?
- Relevant Data
  - Hydrologic Gauges
  - Water Temperature Monitoring
  - Substrate monitoring
  - Hydrologic Alteration Assessment
  - Species Occurrences
  - Observations and Pictures
- Relevant Tools
  - Flow-ecology relationships
  - Stream Classification Web Application
  - Tennant Method
  - IHA and RVA
  - 7Q10



Supported in NHAAP

Partially supported in NHAAP

In planning

Not supported

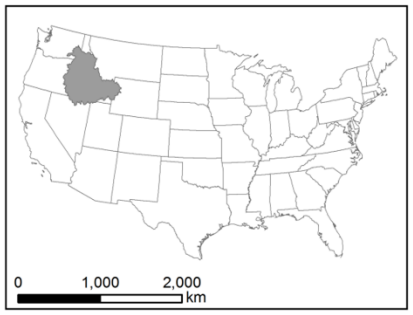
Assessment

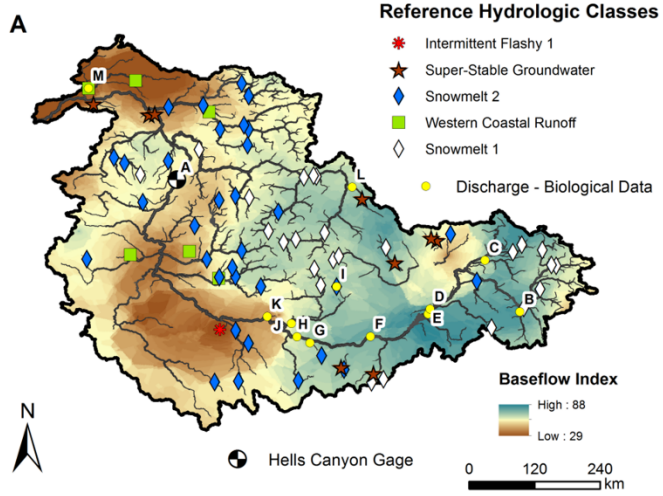
General findings from the 30,000' view:

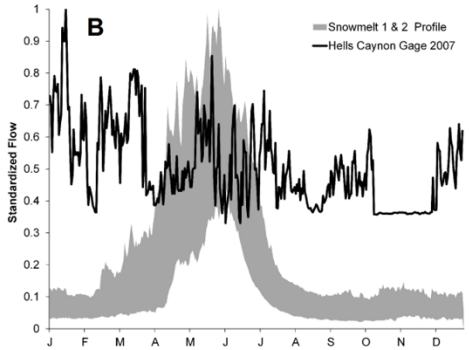
- Complete loss of seasonal profile
- Loss of major timing of peak flows
- Overall loss of flow magnitude, extremely apparent in spring/early summer

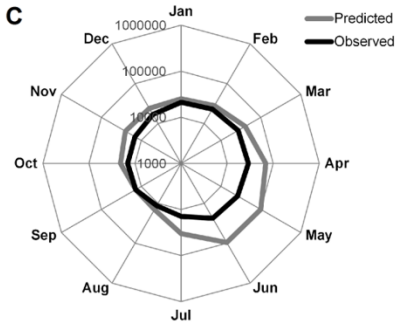
- Hells Canyon displays a loss of flow volume and highly modified flow regime and loss of biodiversity and ecosystem services

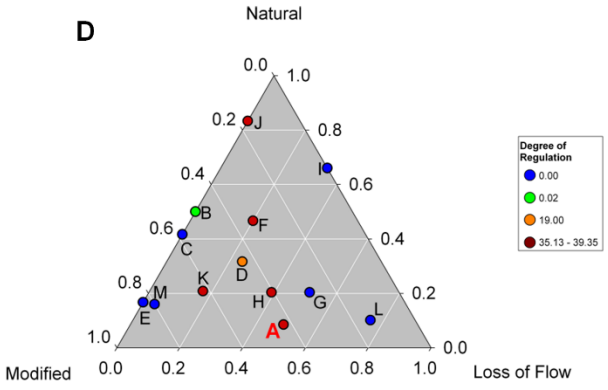
- Comparison to other sites reveals missing ecologically-relevant flow components

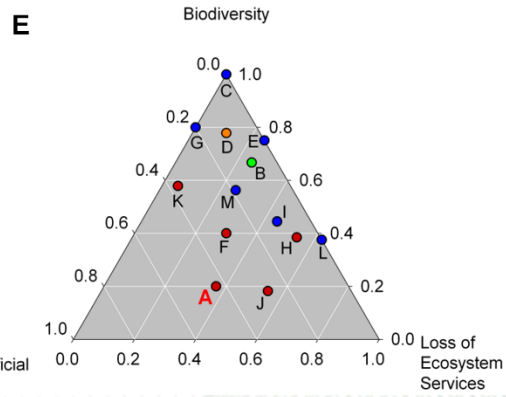












Scoping

- used to identify key hydrologic and ecological targets, isolate information gaps, and develop flow-ecology relationships to predict the ecological outcomes of alternative flows
- What are the knowledge gaps? What studies are needed to fill those gaps?
- Need hard evidence and supporting data
- Relevant Synthesized Data
  - Hydrologic Gauges
  - Water Temperature Monitoring
  - Substrate monitoring
  - Hydrologic Alteration Model
  - Species Occurrences
  - Observations and Pictures
- Relevant Tools
  - Flow-ecology relationships
  - Stream Classification Web Application
  - River Function Framework Checklist

Supported in NHAAP

Partially supported in NHAAP

In planning

Not supported

Prescription

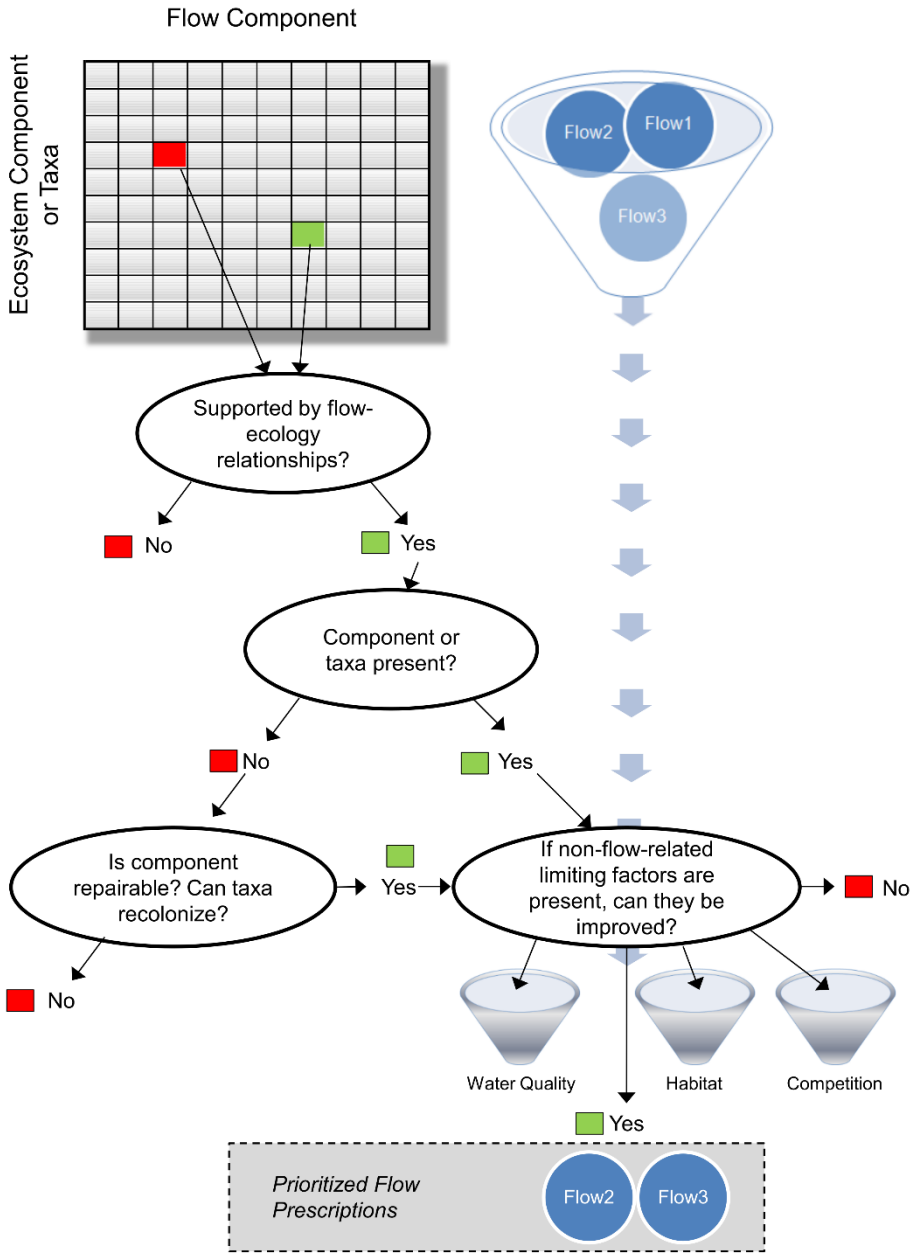
- Based upon best available knowledge, prescription presents a series of alternative flow scenarios based on objectives and the knowledge gained within the assessment and scoping stages
- Relevant Field Data
  - Field observations
  - Cross-sectional profiles
  - Biological surveys
  - Stage/height information
  - Bedload
  - Substrate assessment
- Relevant Tools
  - IFIM (e.g., PHABSIM)
  - Reservoir Operation
  - Floodplain Inundation
  - HECRAS
  - Flushing Flows
  - Flow-ecology relationships

Table 1 Examples of alternative flow scenario components to be tested during feasibility studies for stream reaches below hydropower facilities. Alternative scenarios can represent one to many different flows within each component and/or one to many different combinations of components

Flow scenario component	Description	Potential ecological/societal benefit
Baseflow		
Minimum flow	Constant baseflow supplied year-round between generation	Entire channel perimeter remains inundated and reduces fish stranding following generation. Creates more stable environment
Seasonally variable baseflow	Baseflow magnitude varies according to season	Seasonally fluctuating flow provides enhanced flows during different spawning times for fish and habitat refugia to support varying life stages of macroinvertebrates and riparian vegetation
Flood pulses		
Frequent small flood (rafting release)	Scheduled releases of small flood events periodically during year (5–10 times) during appropriate seasons	Provides channel maintenance such as scouring or flushing sediment, inundating roots, removing encroaching vegetation, and redistributing spawning substrates. Also could provide recreational boating opportunities
Annual large flood (floodplain pulse)	Scheduled large flood event (per 1.5 years)	Creates new habitats by shifting large amounts of substrates, provides organic matter inputs from floodplain, inundates backwater habitats, and provides nursery habitats for fish
Special-events		
Attractant flow	Pulsed flows attract upstream migrating fish to ladders	Enhances fish passage, reproduction, and population viability
Passage flow	Pulsed flows to enhance/protect outmigration	Enhances fish survival, recruitment, and population viability
Subdaily		
Ramping restriction	Restrictions in the rate of change of the rising limb of generation pulse	Creates less disturbance by reducing square-shaped hydrograph. Allows time for behavioral responses to initiation of peak generation
Down-ramping restriction	Restrictions in the rate of change of the falling limb of generation pulse	Prevents fish stranding by providing time for behavioral responses to flow recession
Daily range restriction	Restrictions in range of min/max flows during day	Reduces disturbance and creates more stable environment to enhance feeding and spawning habitats
Diurnal variation in generation	Shifting the timing of generation within a day	Generating during different times of the day may provide more temporal overlapp of hydrologic stability and peak feeding times

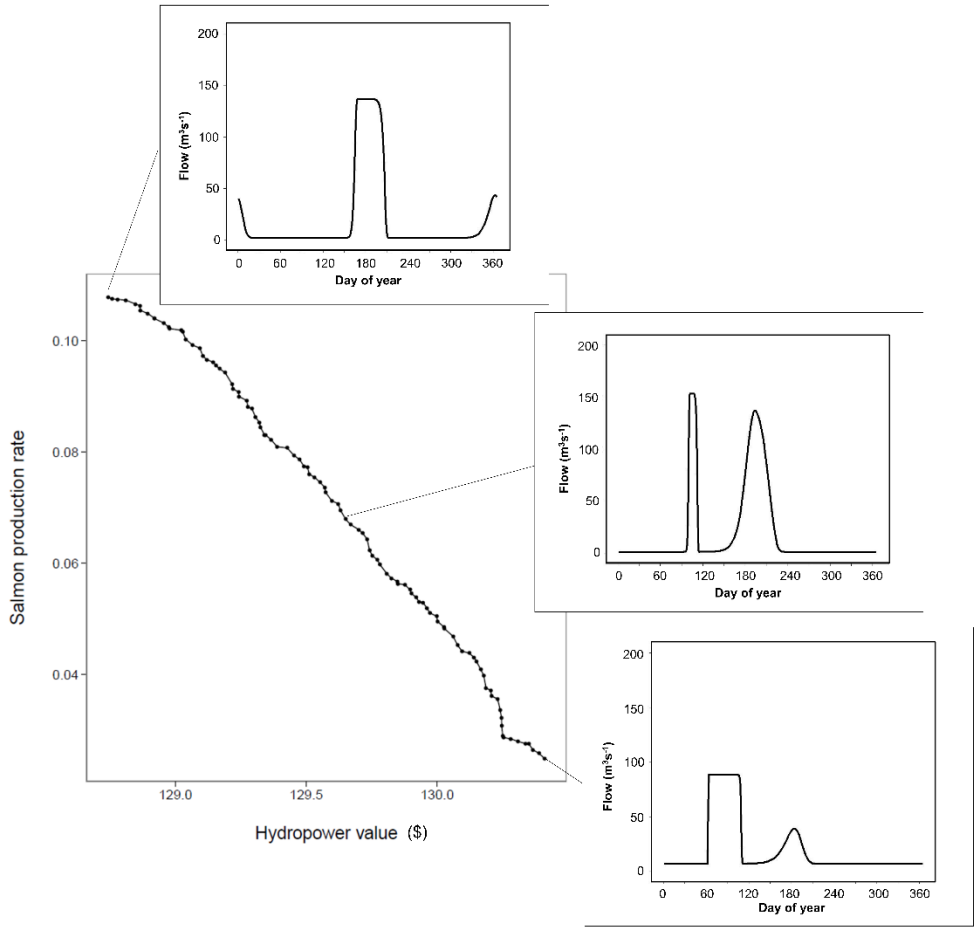
Prescription

- Currently, there is 600 different hydrologic statistics that can be calculated (USGS)
- Need to prioritize components of the flow regime to focus mitigation efforts
- Use a decision-tree approach

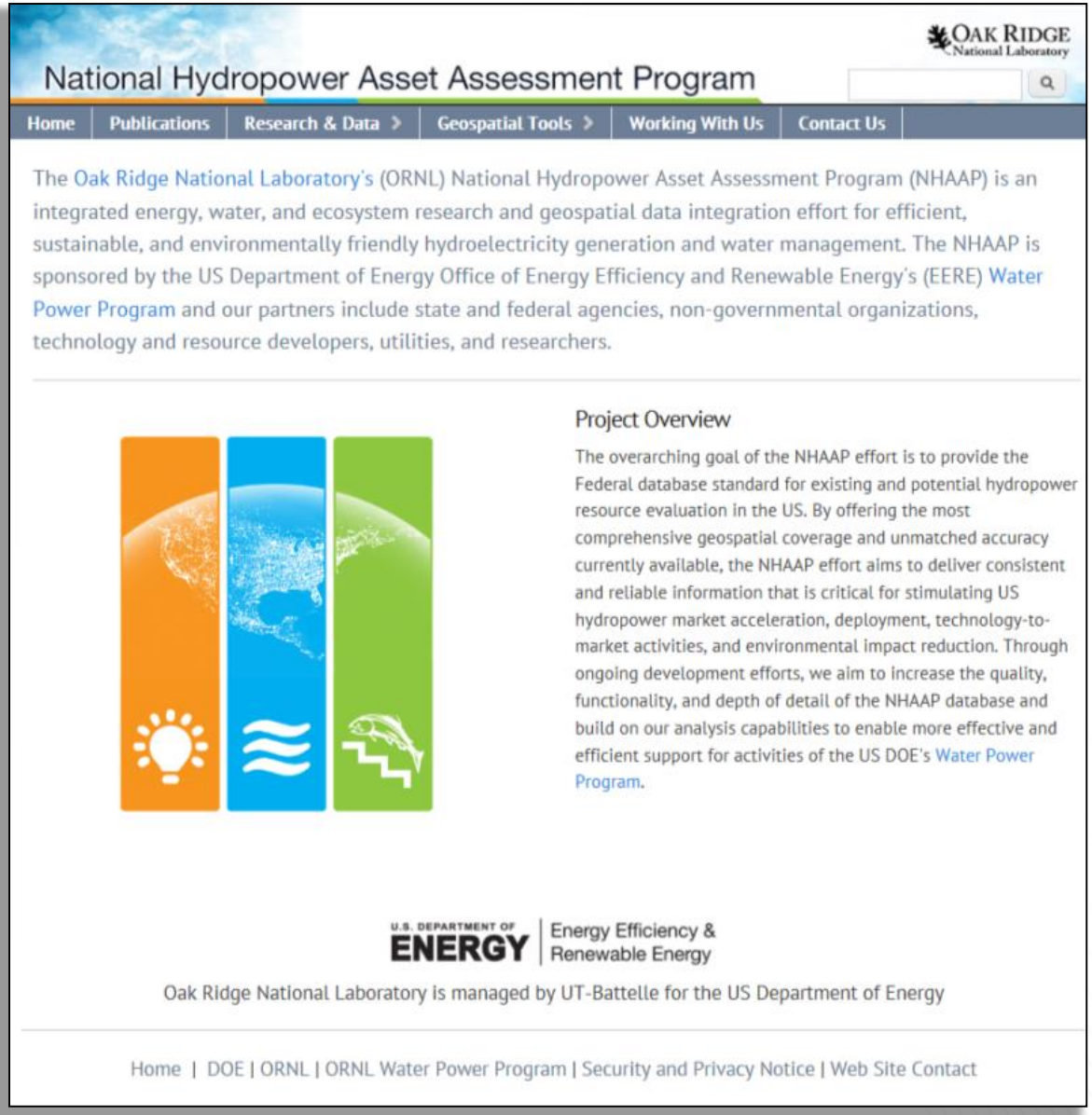


Feasibility

- analyses that determine the ecological versus economic impacts of alternative flows at the site-specific scale
- Relevant Data
  - Project Generation
  - Project infrastructure
  - Synthesized Field Data
  - Observations and Pictures
- Relevant Tools
  - IFIM (e.g., PHABSIM)
  - Reservoir Operation
  - Floodplain Inundation
  - HECRAS
  - Flushing Flows
  - Optimization
  - Flow-ecology relationships



Tour of NHAAP Resources



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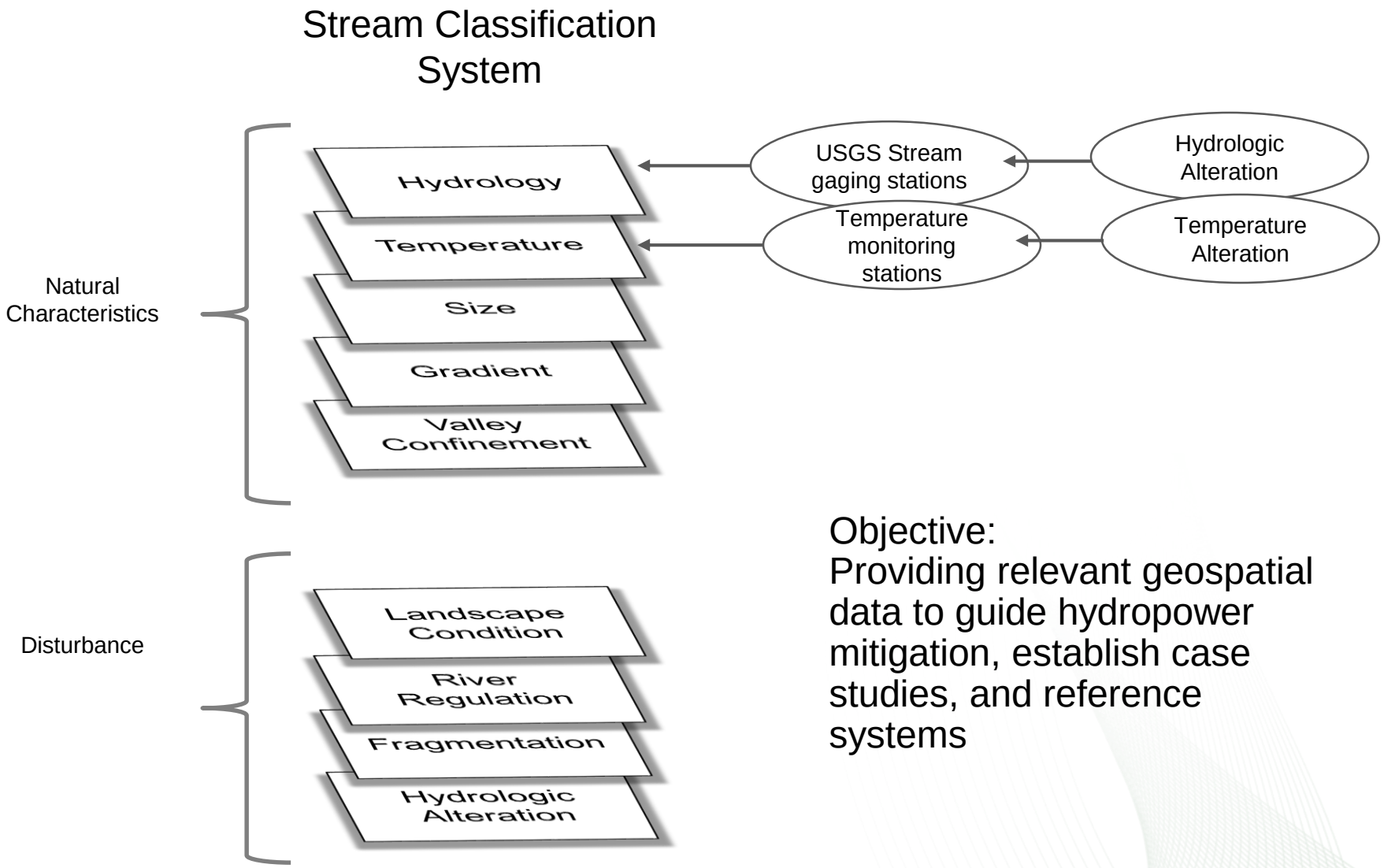
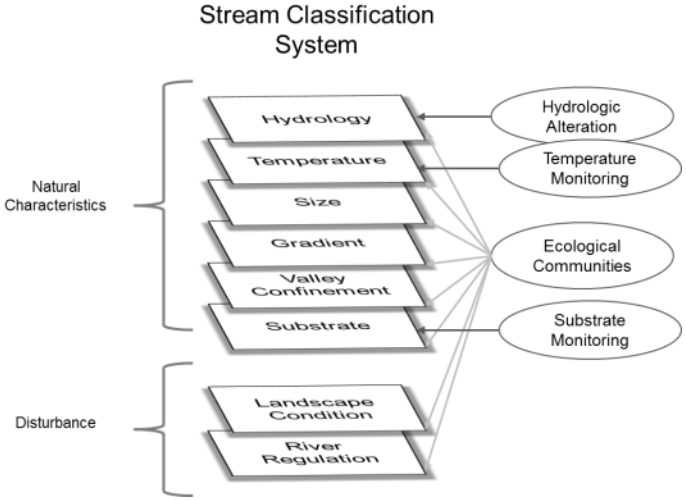
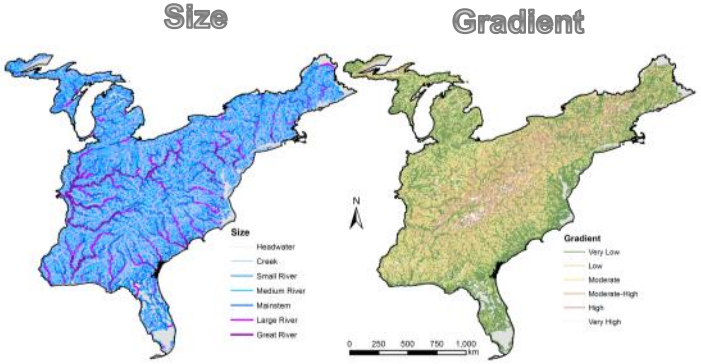
US Stream Classification System

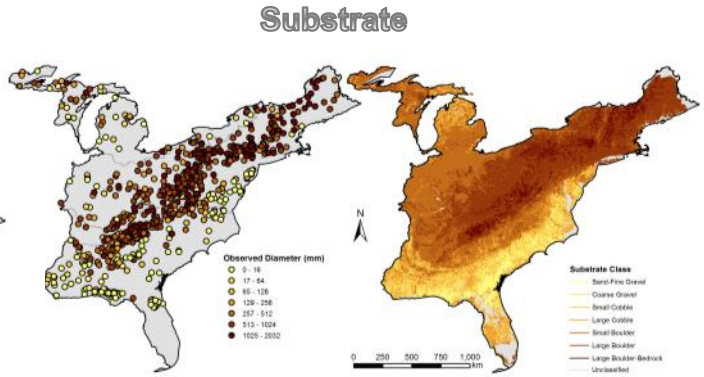


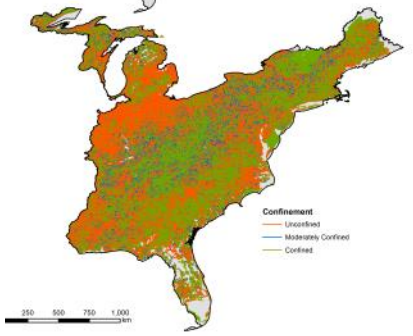
Objective:
Providing relevant geospatial data to guide hydropower mitigation, establish case studies, and reference systems

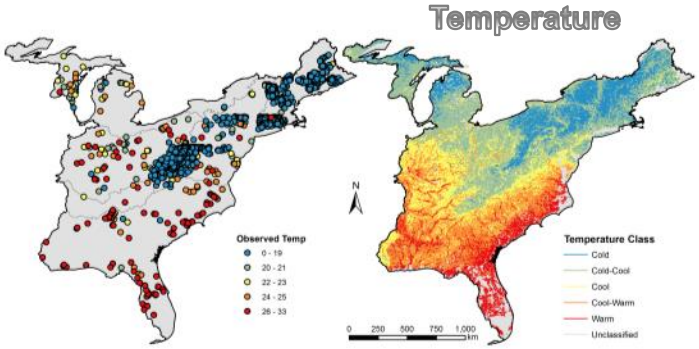
Eastern Stream Classification

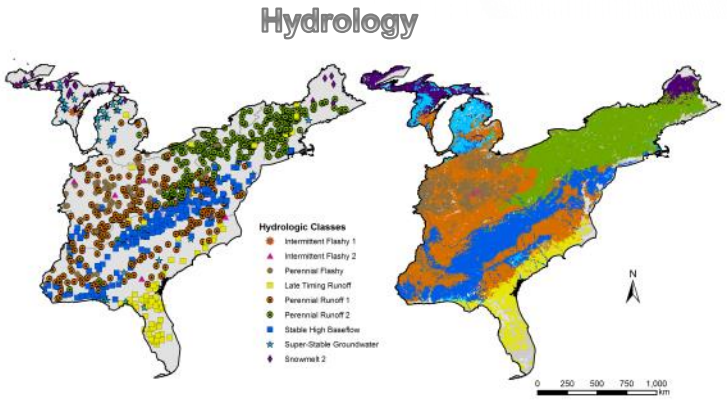


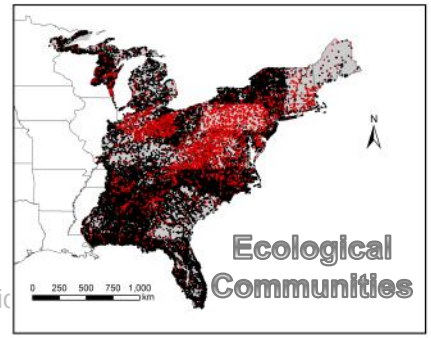












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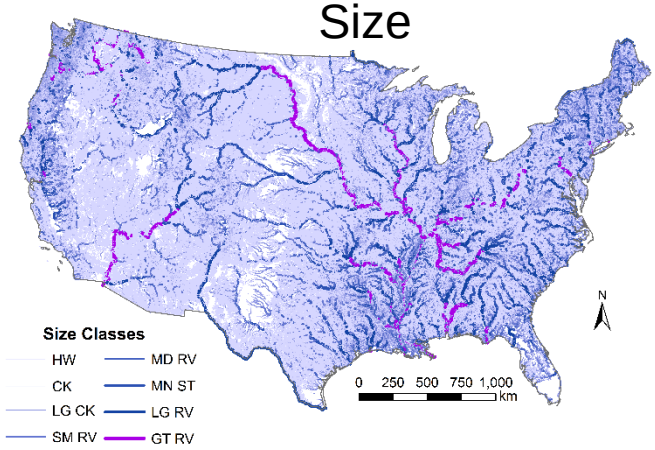
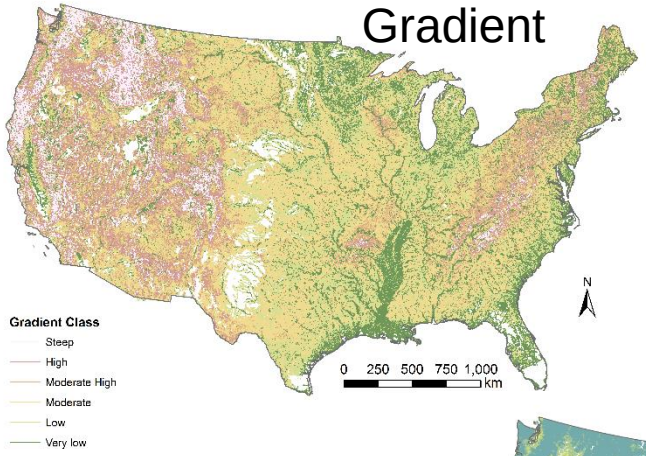
US Stream Classification System

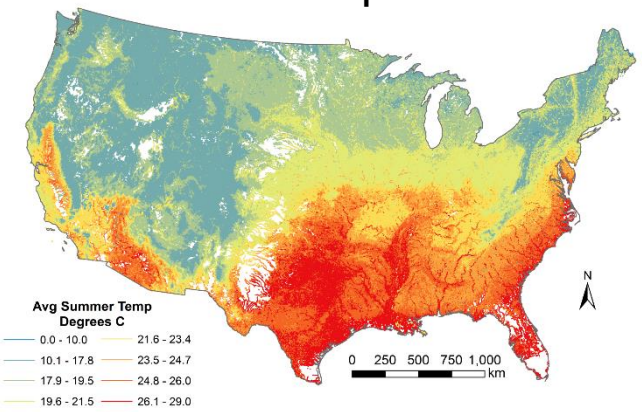
Size



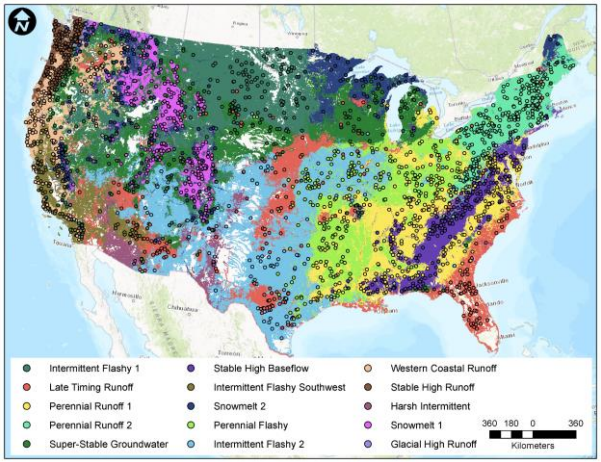
Gradient



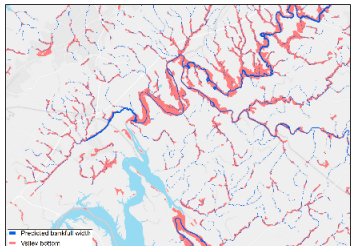
Temperature



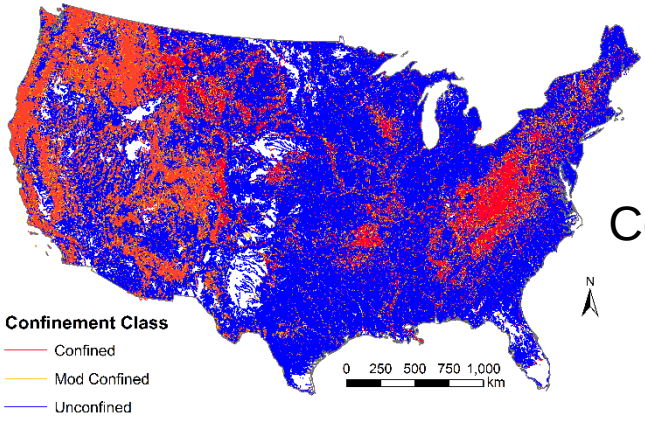
Hydrology



Valley Confinement Closeup



Valley Confinement



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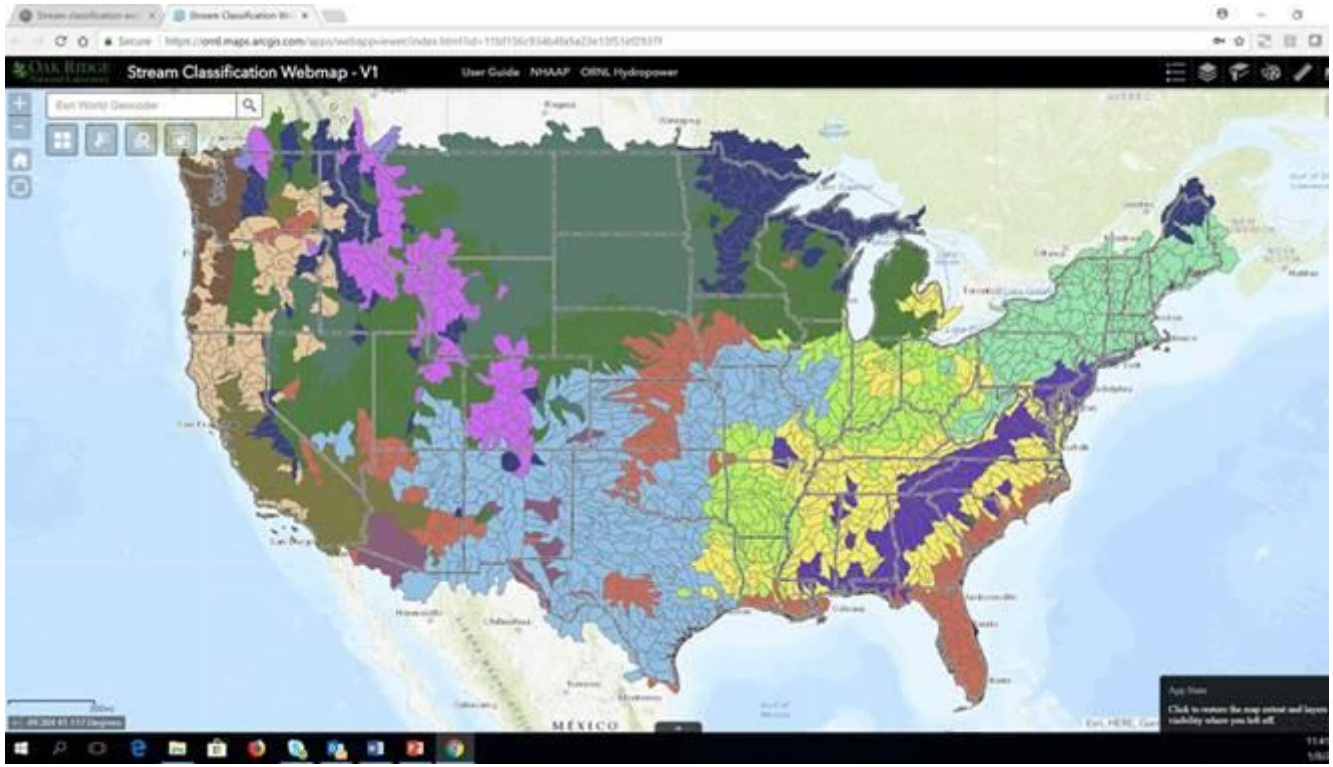
Stream Classification

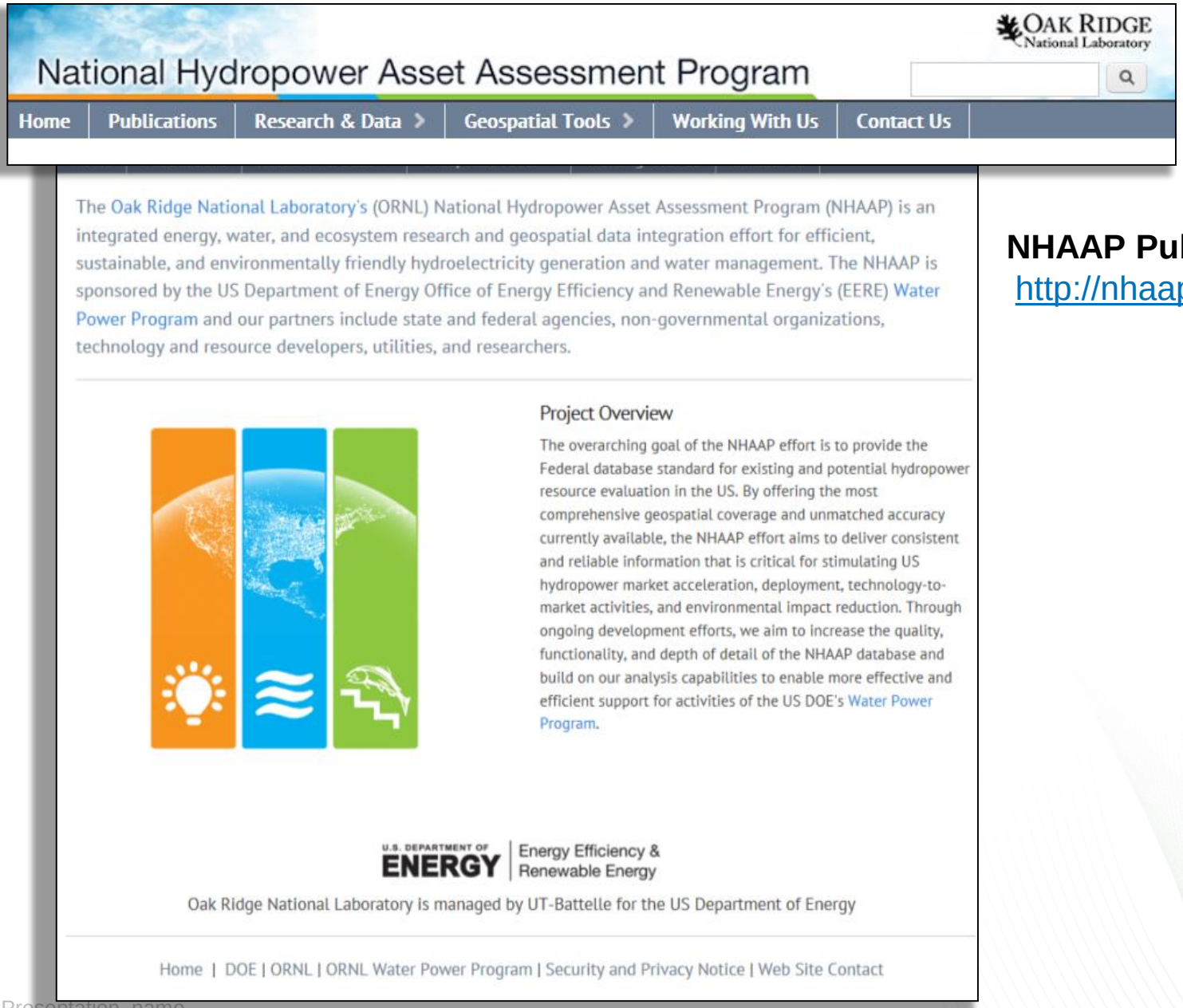
- Identify stream type for hydropower projects, restoration projects, etc
- Identify case studies or reference streams
- Find powerplants or gages on similar stream types
- Assess hydrologic and temperature alteration
- Delineate watersheds

Stream Classification Web Application



Additional Support Slides

Tour of NHAAP Research



NHAAP Public Portal
http://nhaap.ornl.gov/

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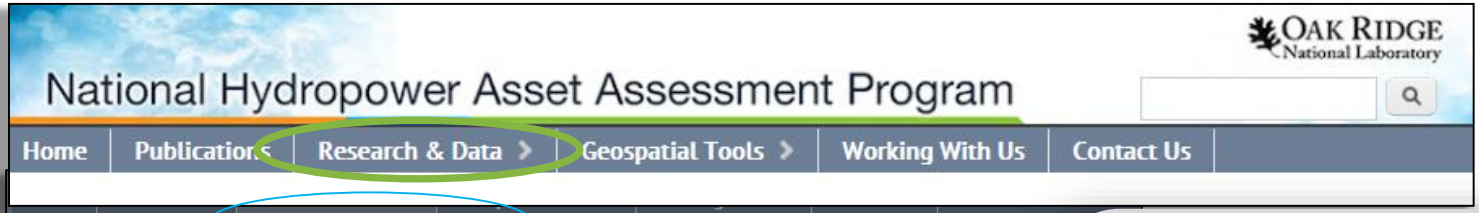
NHAAP Research & Data



Environmental Mitigation
2014 Hydropower Market Report
New Stream-reach Development Resource Assessment
Non-powered Dam Resource Assessment
Climate Change Impact Assessment
Environmental Attribution
Existing Hydropower Assets

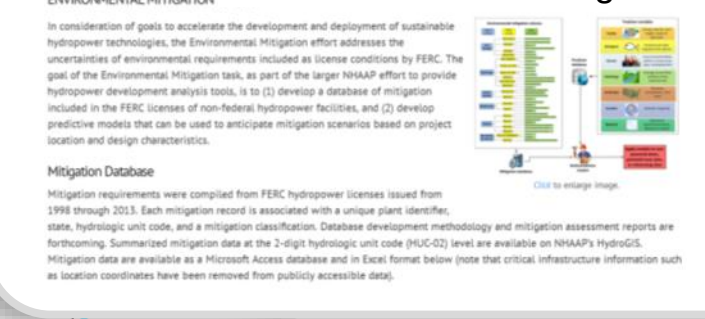
RESEARCH & DATA

The National Hydropower ... (P) was initiated in FY2010, starting with gathering, or... network, facility configuration, historic gen... a necessary to trend the production and capacity of... nt of Energy (DOE) Water Power Program. Given the... te energy, the scope of the NHAAP has been continuo... ssues in the hydropower arena, such as Non-Powered Dam... ts, Pumped Storage, and Environmental Analysis. By... s conceptually and technically from various angles, the g... lutions for using clean hydropower in the most ef... y fashion.

Site Map - Research & Data

- Hydropower Market Report

Environmental Mitigation

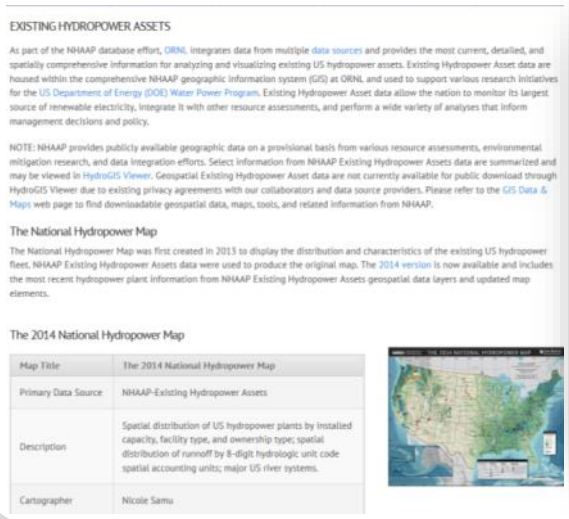

ENVIRONMENTAL MITIGATION

In consideration of goals to accelerate the development and deployment of sustainable hydropower technologies, the Environmental Mitigation effort addresses the uncertainties of environmental requirements included as license conditions by FERC. The goal of the Environmental Mitigation task, as part of the larger NHAAP effort to provide hydropower development analysis tools, is to (1) develop a database of mitigation included in the FERC licenses of non-federal hydropower facilities, and (2) develop predictive models that can be used to anticipate mitigation scenarios based on project location and design characteristics.

Mitigation Database

Mitigation requirements were compiled from FERC hydropower licenses issued from 1998 through 2013. Each mitigation record is associated with a unique plant identifier, state, hydrologic unit code, and a mitigation classification. Database development methodology and mitigation assessment reports are forthcoming. Summarized mitigation data at the 2-digit hydrologic unit code (HUC-02) level are available on NHAAP's HydroGIS. Mitigation data are available as a Microsoft Access database and in Excel format below (note that critical infrastructure information such as location coordinates have been removed from publicly accessible data).

Existing Assets


EXISTING HYDROPOWER ASSETS

As part of the NHAAP database effort, ORNL integrates data from multiple data sources and provides the most current, detailed, and spatially comprehensive information for analyzing and visualizing existing US hydropower assets. Existing Hydropower Asset data are housed within the comprehensive NHAAP geographic information system (GIS) at ORNL and used to support various research initiatives for the US Department of Energy (DOE) Water Power Program. Existing Hydropower Asset data allow the nation to monitor its largest source of renewable electricity, integrate it with other resource assessments, and perform a wide variety of analyses that inform management decisions and policy.

NOTE: NHAAP provides publicly available geographic data on a provisional basis from various resource assessments, environmental mitigation research, and data integration efforts. Select information from NHAAP Existing Hydropower Assets data are summarized and may be viewed in HydroGIS Viewer. Geospatial Existing Hydropower Asset data are not currently available for public download through HydroGIS Viewer due to existing privacy agreements with our collaborators and data source providers. Please refer to the GIS Data & Maps web page to find downloadable geospatial data, maps, tools, and related information from NHAAP.

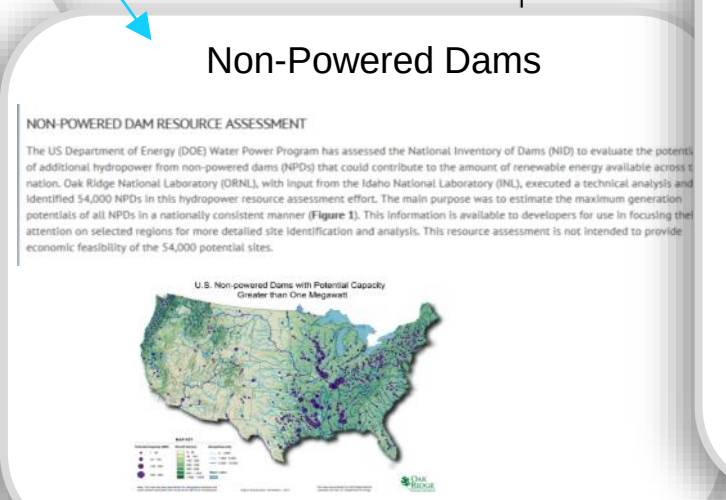
The National Hydropower Map

The National Hydropower Map was first created in 2013 to display the distribution and characteristics of the existing US hydropower fleet. NHAAP Existing Hydropower Assets data were used to produce the original map. The 2014 version is now available and includes the most recent hydropower plant information from NHAAP Existing Hydropower Assets geospatial data layers and updated map elements.

The 2014 National Hydropower Map

Map Title	The 2014 National Hydropower Map
Primary Data Source	NHAAP-Existing Hydropower Assets
Description	Spatial distribution of US hydropower plants by installed capacity, facility type, and ownership type; spatial distribution of runnoff by 8-digit hydrologic unit code spatial accounting units; major US river systems.
Cartographer	Nicole Samu

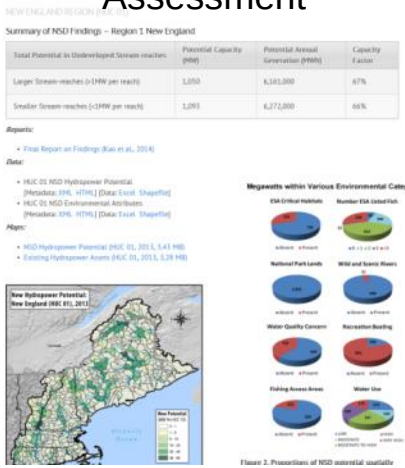
Non-Powered Dams


NON-POWERED DAM RESOURCE ASSESSMENT

The US Department of Energy (DOE) Water Power Program has assessed the National Inventory of Dams (NID) to evaluate the potenti... of additional hydropower from non-powered dams (NPDs) that could contribute to the amount of renewable energy available across t... nation. Oak Ridge National Laboratory (ORNL), with input from the Idaho National Laboratory (INL), executed a technical analysis and identified 54,000 NPDs in this hydropower resource assessment effort. The main purpose was to estimate the maximum generation potentials of all NPDs in a nationally consistent manner (**Figure 1**). This information is available to developers for use in focusing thei... attention on selected regions for more detailed site identification and analysis. This resource assessment is not intended to provide economic feasibility of the 54,000 potential sites.

U.S. Non-powered Dams with Potential Capacity Greater than One Megawatt

New Stream-Reach Assessment


Summary of NSD Findings – Region 1 New England

Total Potential in Undeveloped Stream-reaches	Potential Capacity (MW)	Potential Annual Generation (MWh)	Capacity Factor
Larger Stream-reaches (>1MW per reach)	1,050	6,161,000	67%
Smaller Stream-reaches (<1MW per reach)	1,093	6,272,000	66%

Megawatts within Various Environmental Categories

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http://nhaap.ornl.gov/content/nhaap-research

NHAAP Geospatial Tools

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Stream Classification Tool
Historical Generation
HydroGIS Viewer

GEOSPATIAL TOOLS

ORNL has created the following tools for users to … useful for purposes suc

- Locating and exploring existing hydropower plants, dams, generators, and associated project informati
- Viewing hydrologic and environmental characteristics in relation to existing and potential hydropower
- Exploring hydropower generation trends;
- Identifying and exploring potential for new hydropower development;
- Identifying and removing potential environmental barriers to hydropower development.

Explore Map Layers

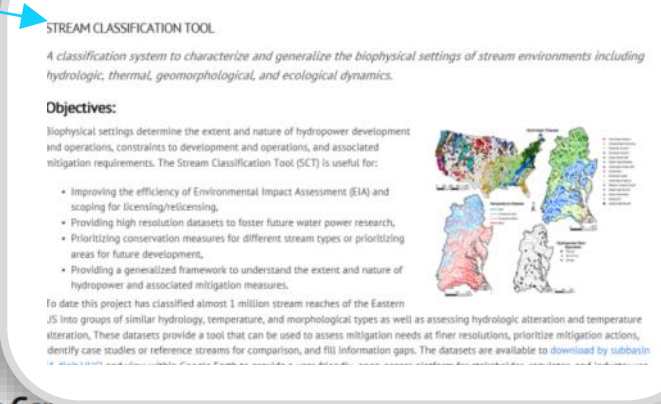
Stream Classification Tool

HydroGIS Viewer

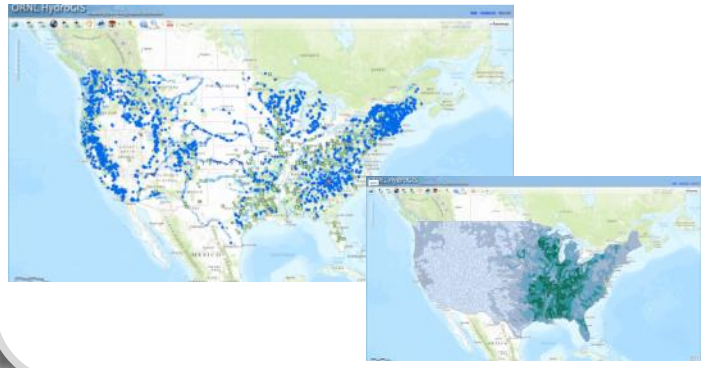
Visualize Generation Trends

Historical Generation Charts

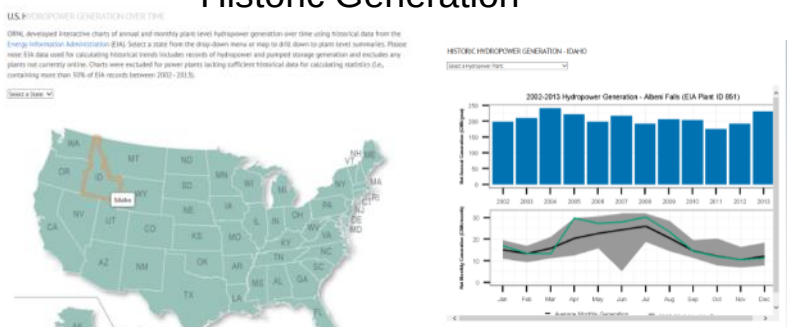
Stream Classification Tool



HydroGIS Viewer



Historic Generation



http://nhaap.ornl.gov/NHAAP-GIS-Data-and-Maps

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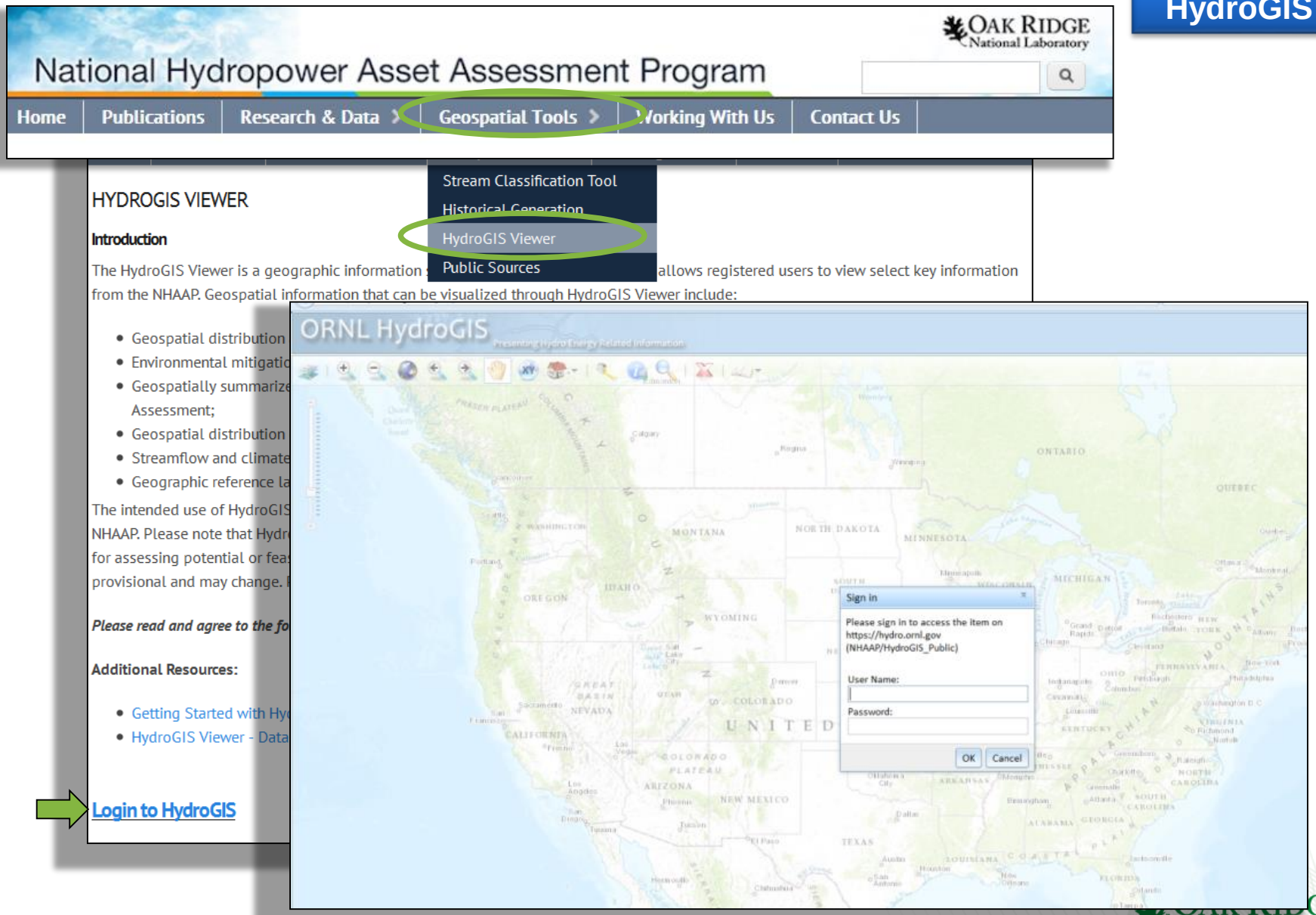
Example: Public Access via HydroGIS

HydroGIS



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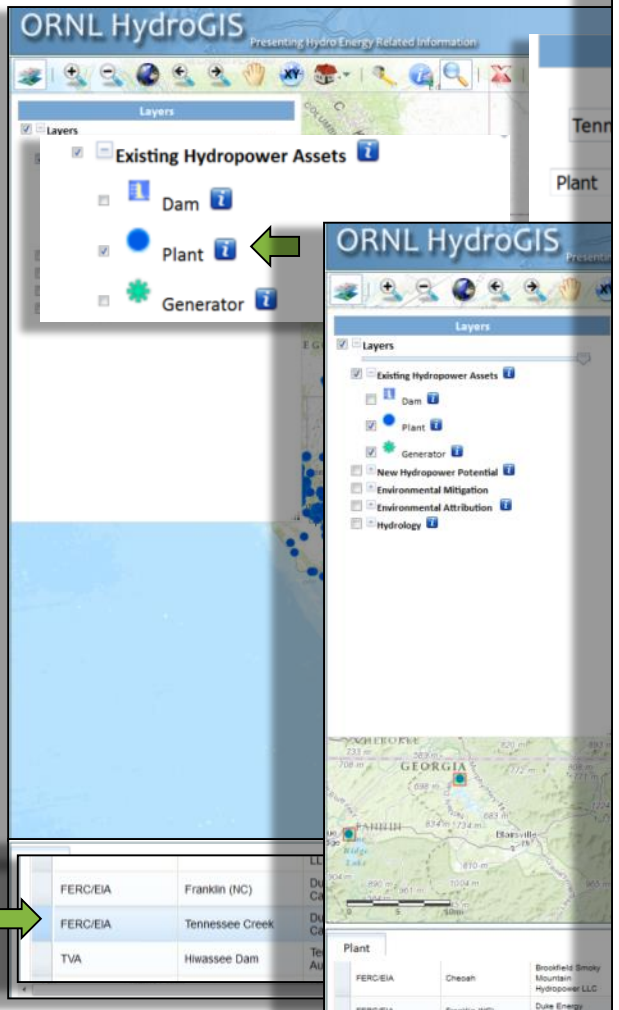
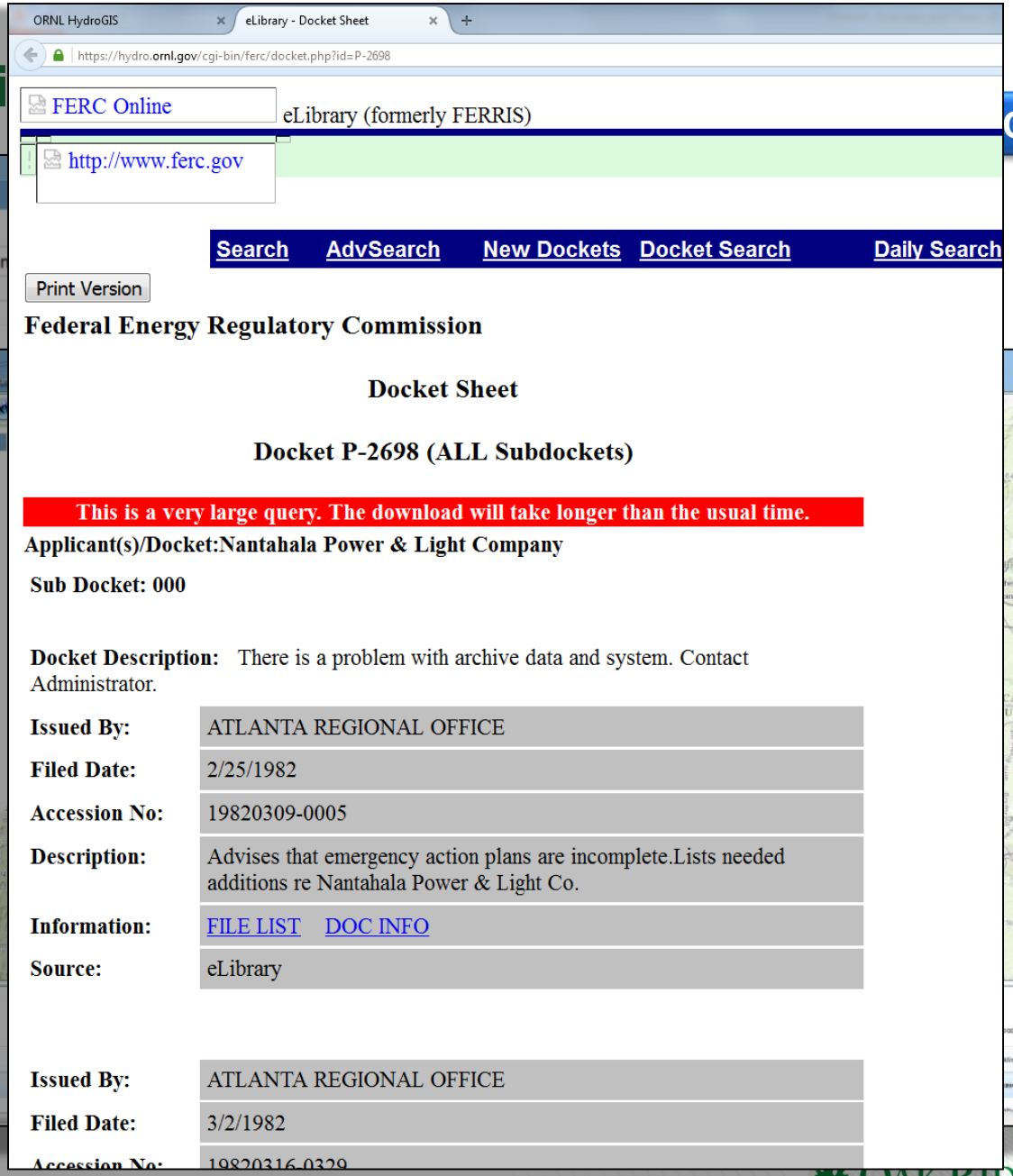
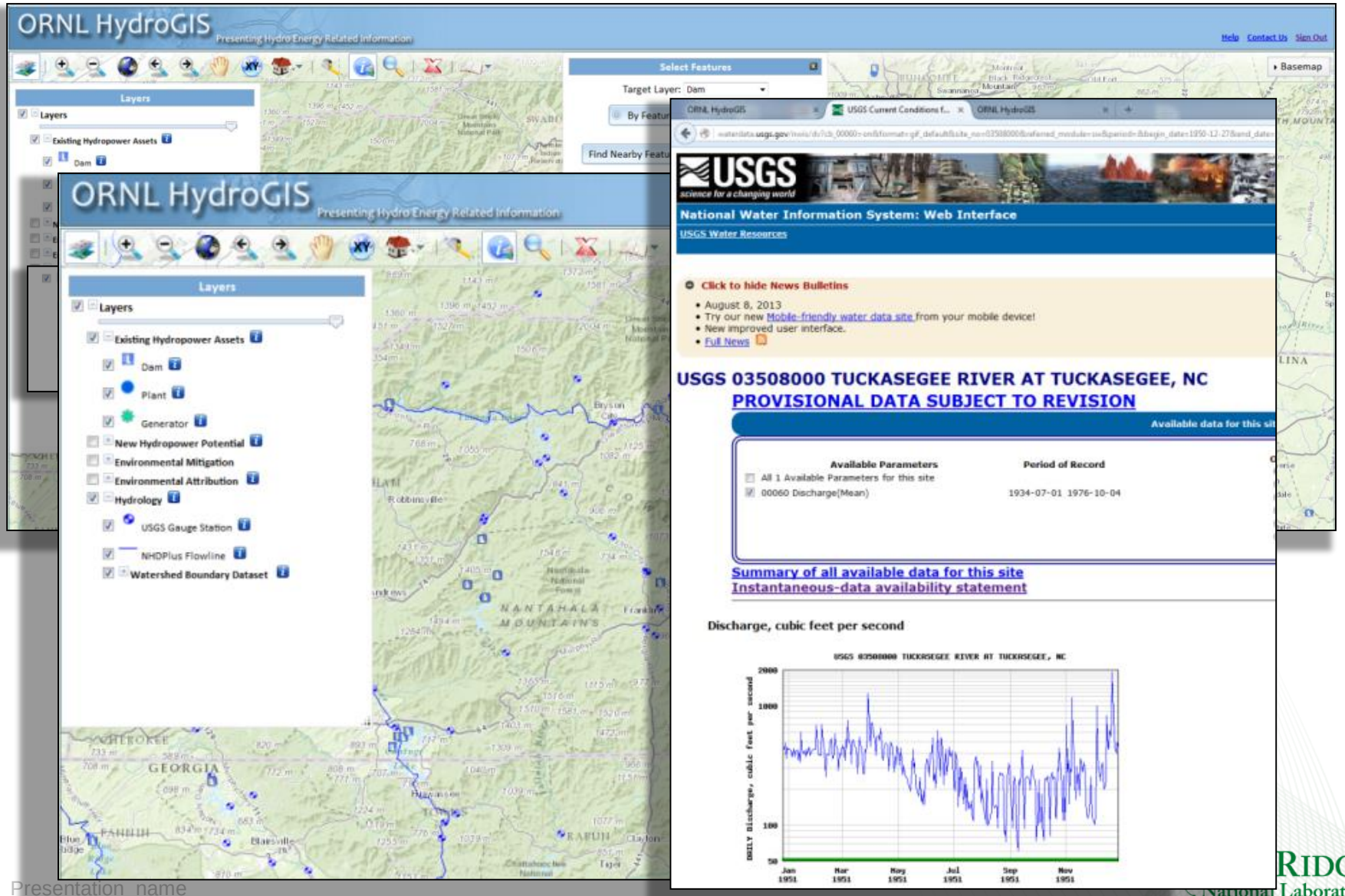
Example: Finding Context for an Exi





Example: Linking water information to hydropower facilities

HydroGIS



Example: Finding Historical Generation for an Existing Hydropower Facility

Historic Generation

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- Stream Classification Tool
- Historical Generation
- HydroGIS Viewer

GEOSPATIAL TOOLS

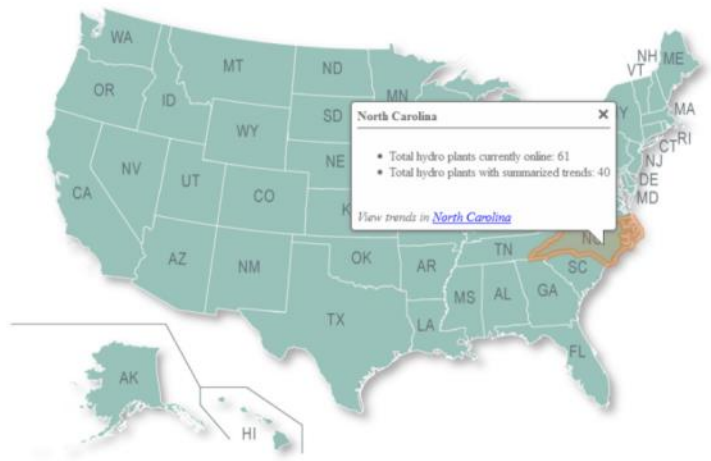
ORNL has created the following tools for users to … useful for purposes such as:

- Locating and exploring existing hydropower plants, dams, generators, and asso…
- Viewing hydrologic and environmental characteristics in relation to existing an…
- Exploring hydropower generation trends;

U.S. HYDROPOWER GENERATION OVER TIME

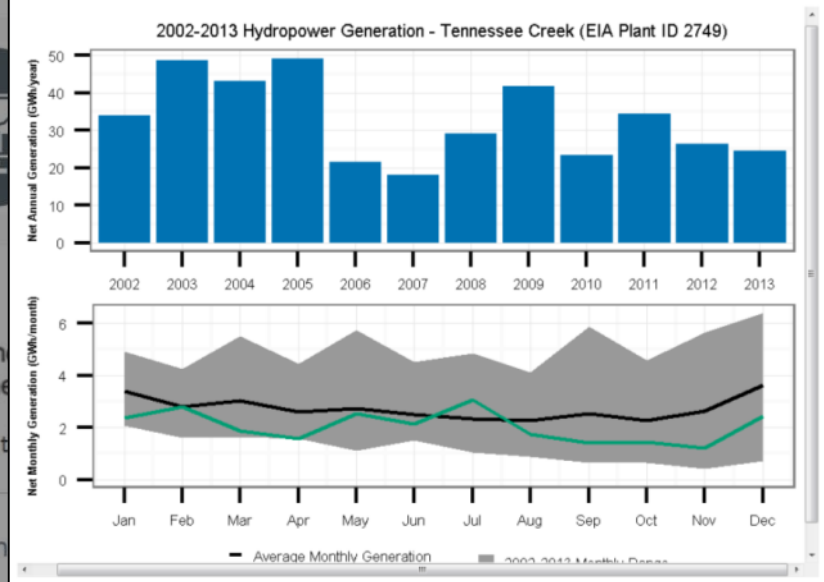
ORNL developed interactive charts of annual and monthly plant-level hydropower generation over time using historical data from the Energy Information Administration (EIA). Select a state from the drop-down menu or map to drill down to plant-level summaries. Please note: EIA data used for calculating historical trends includes records of hydropower and pumped storage generation and excludes any plants not currently online. Charts were excluded for power plants lacking sufficient historical data for calculating statistics (i.e., containing more than 50% of EIA records between 2002 – 2013).

Select a State:



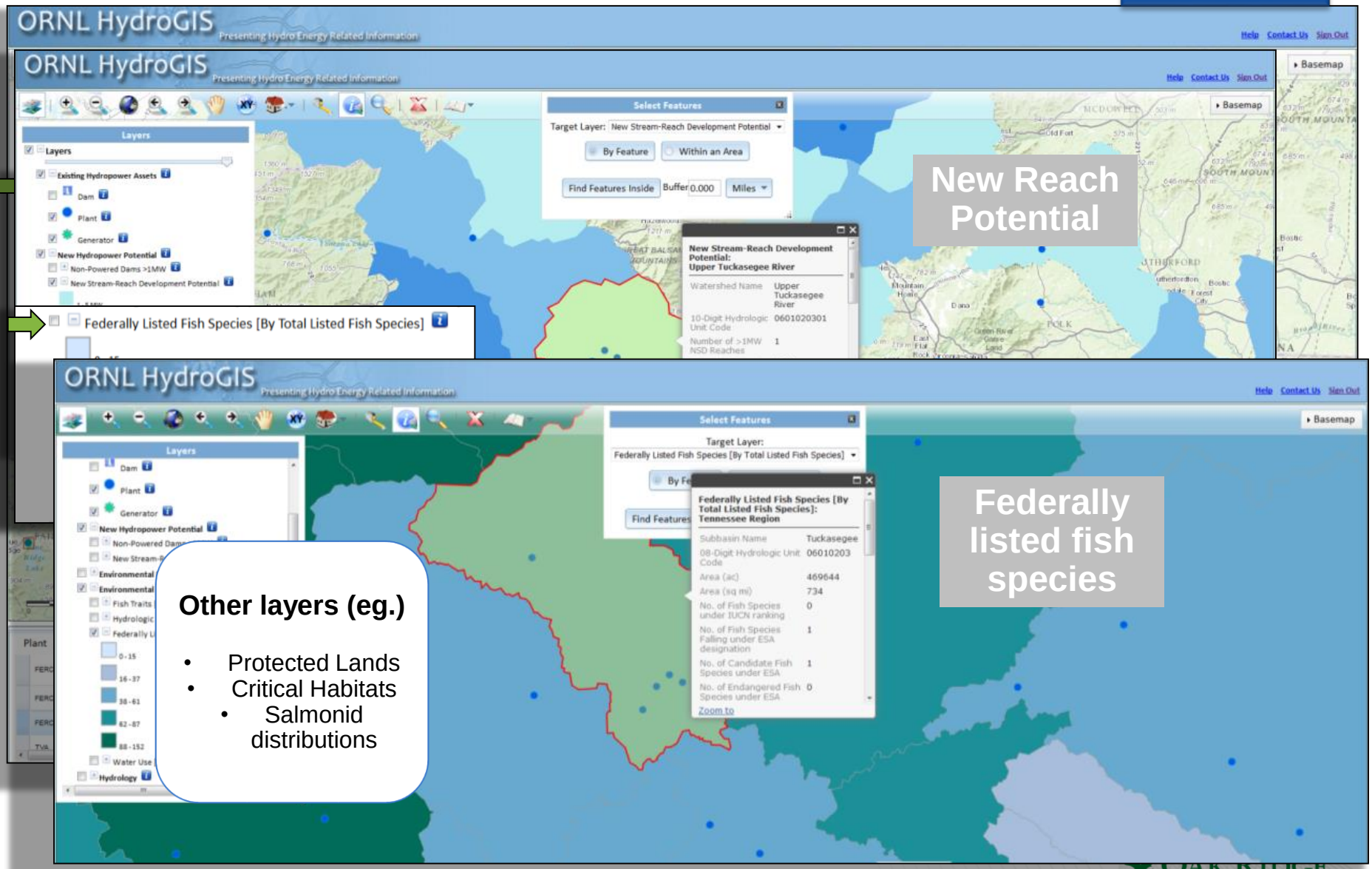
HISTORIC HYDROPOWER GENRATION - NORTH CAROLINA

Tennessee Creek (EIA Plant ID 2749)

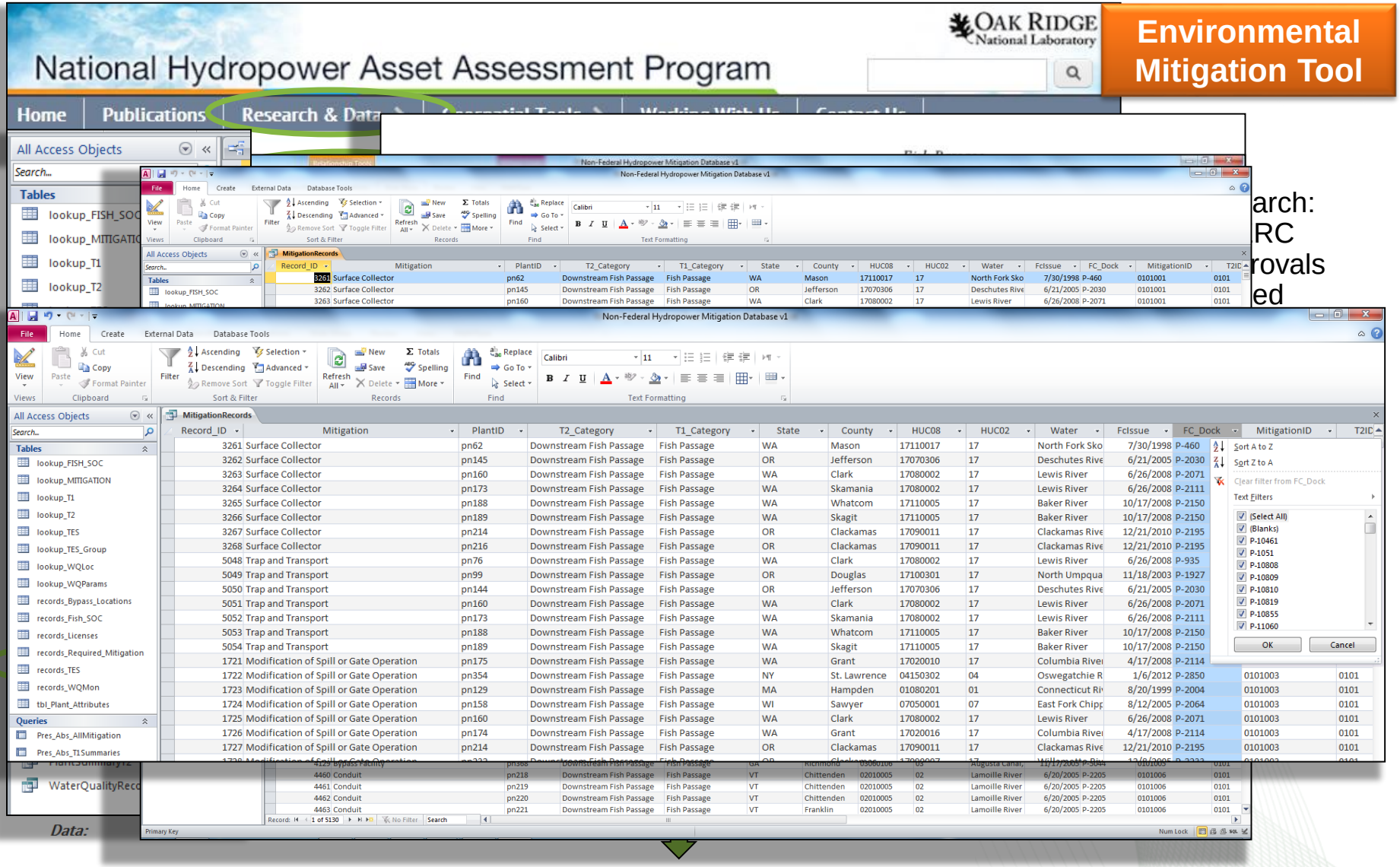


Example: Finding Characteristics of New Stream-reach Development Potential

HydroGIS



Example: Data-Driven Analysis of Environmental Mitigation Requirements



arch:
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- **Mitigation Database** [Data: Access, Excel] [Metadata: Excel] [Classification Structure: PDF]
  [Citation] Bevelhimer, M.S., M.P. Schramm, C.R. DeRolph (2015), Non-Federal Hydropower Mitigation Database, Oak Ridge National Laboratory, available at: http://nhaap.ornl.gov/environmental-mitigation, accessed online: [Month, date, year.]

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New Science – Data-Based Stream Classification for Improved Environmental Assessment

Stream Classification Tool

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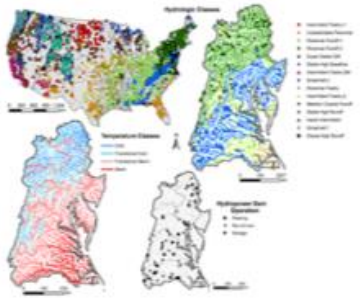
- Stream Classification Tool
- Historical Generation
- HydroGIS Viewer
- Public Sources

STREAM CLASSIFICATION TOOL

A classification system to characterize and ettings of stream environments including hydrologic, thermal, geomorphological, an

Objectives:

Biophysical settings determine the extent and nature of hydropower development and operations, constraints to development and operations, and associated mitigation requirements. The Stream Classification Tool (SCT) is useful for:



- Improving the efficiency of Environmental Impact Assessment (EIA) and scoping for licensing/relicensing,
- Providing high resolution datasets to foster future water power research,
- Prioritizing conservation measures for different stream types or prioritizing areas for future development,
- Providing a generalized framework to understand the extent and nature of hydropower and associated mitigation measures.

To date this project has classified almost 1 million stream reaches of the Eastern US into groups of similar hydrology, temperature, and morphological types as well as assessing hydrologic alteration and temperature alteration, These datasets provide a tool that can be used to assess mitigation needs at finer resolutions, prioritize mitigation actions, identify case studies or reference streams for comparison, and fill information gaps. The datasets are available to download by subbasin (4-digit HUC) and view within Google Earth to provide a user-friendly, open-access platform for stakeholder, regulator, and industry use.

What is a Stream Classification?

At a basic level, stream classifications are an inventory of different types of streams. Classifications help us explore similarities and differences among different types of streams, make inferences regarding stream ecosystem behavior, and communicate the complexities of ecosystem. While classifications aid in understanding fundamental differences among streams, they also have many applied outcomes, such as grouping sites with similar character, stratifying analyses for monitoring and/or experimentation, prioritizing mitigation or aquatic conservation, and generalizing ecological responses to disturbances.

How is it useful to Hydropower?

The SCT is useful to environmental mitigation for hydropower dams in multiple ways. The purpose of the SCT is to create efficiency in the regulatory process by creating an objective and data-rich means to address meaningful mitigation actions. First, the SCT addresses

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STREAM CLASSIFICATION TOOL USER MANUAL: FOR USE IN APPLICATIONS IN HYDROPOWER-RELATED ENVIRONMENTAL MITIGATION

Ryan A. McManamay
Matthew J. Troia
Christopher R. DeRolph
Nicole M. Samu

January 2016

Note: For best results, please view and download data using Google Chrome or Internet Explorer web browsers. Potential errors may occurs with Firefox.

Subregion	HUC	Data | Metadata
+ Upper Tennessee	0601	Updated - 10/21/2015
Sites Temperature	0601	KMZ 2.2 KB
Sites Substrate	0601	KMZ 8.4 KB
Sites Hydrology	0601	KMZ 17.6 KB
Sites Fish	0601	KMZ 8.3 MB
Disturbance	0601	KMZ 8.3 MB
Class Temperature	0601	KMZ 8.3 MB
Class Substrate	0601	KMZ 8.3 MB
Class Size	0601	KMZ 8.3 MB
Class Hydrology	0601	KMZ 8.3 MB
Class Gradient	0601	KMZ 8.3 MB
Class Confinement	0601	KMZ 8.3 MB
+ Middle Tennessee-Hiwassee	0602	Updated - 10/21/2015
+ Middle Tennessee-Elk	0603	Updated - 10/21/2015

+ Middle Tennessee-Hiwassee
+ Middle Tennessee-Elk
+ Lower Tennessee

South Atlantic-Gulf (03)

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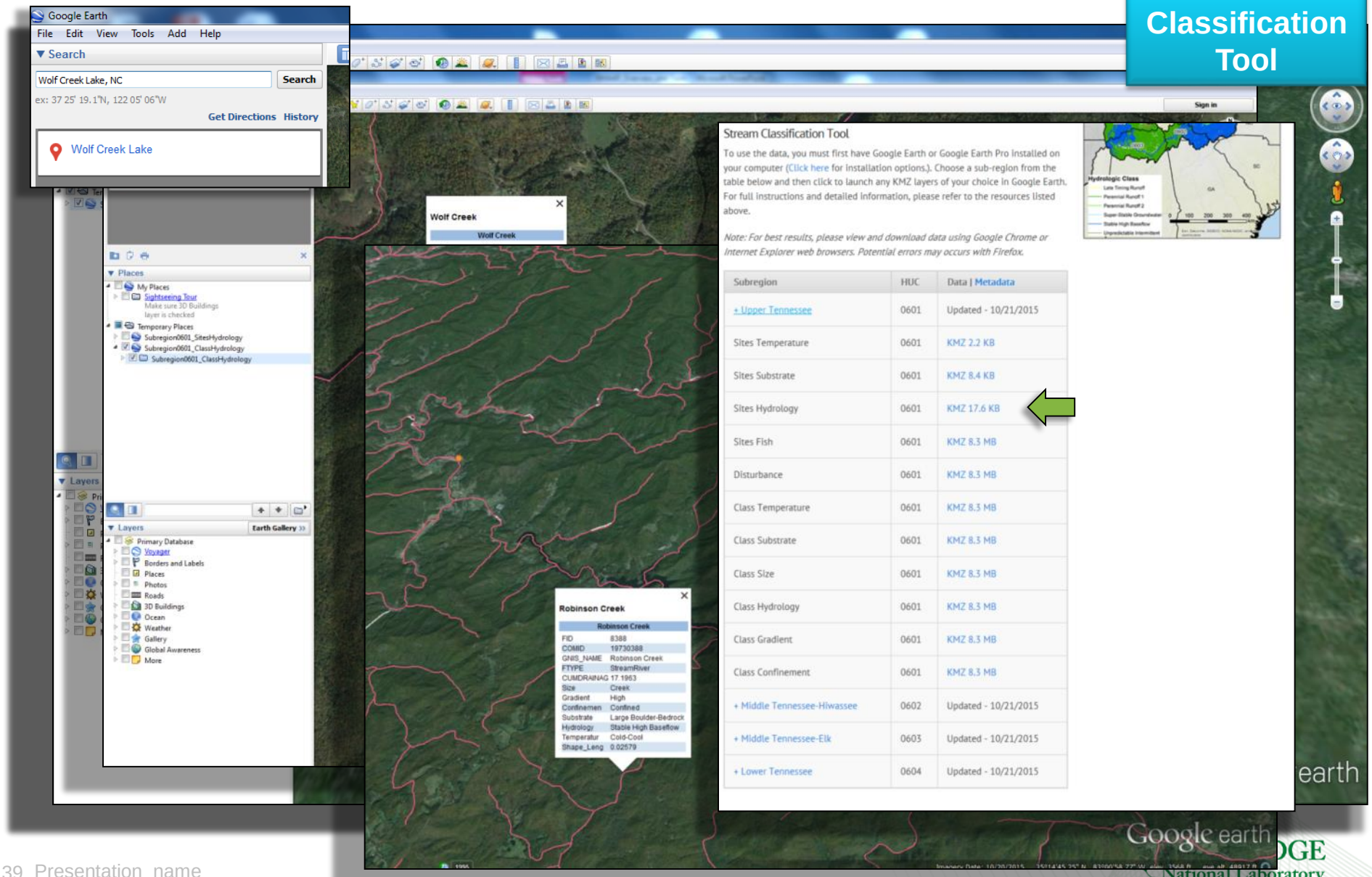
New Science – Data-Based Stream Classification for Improved Environmental Assessment

Stream Classification Tool



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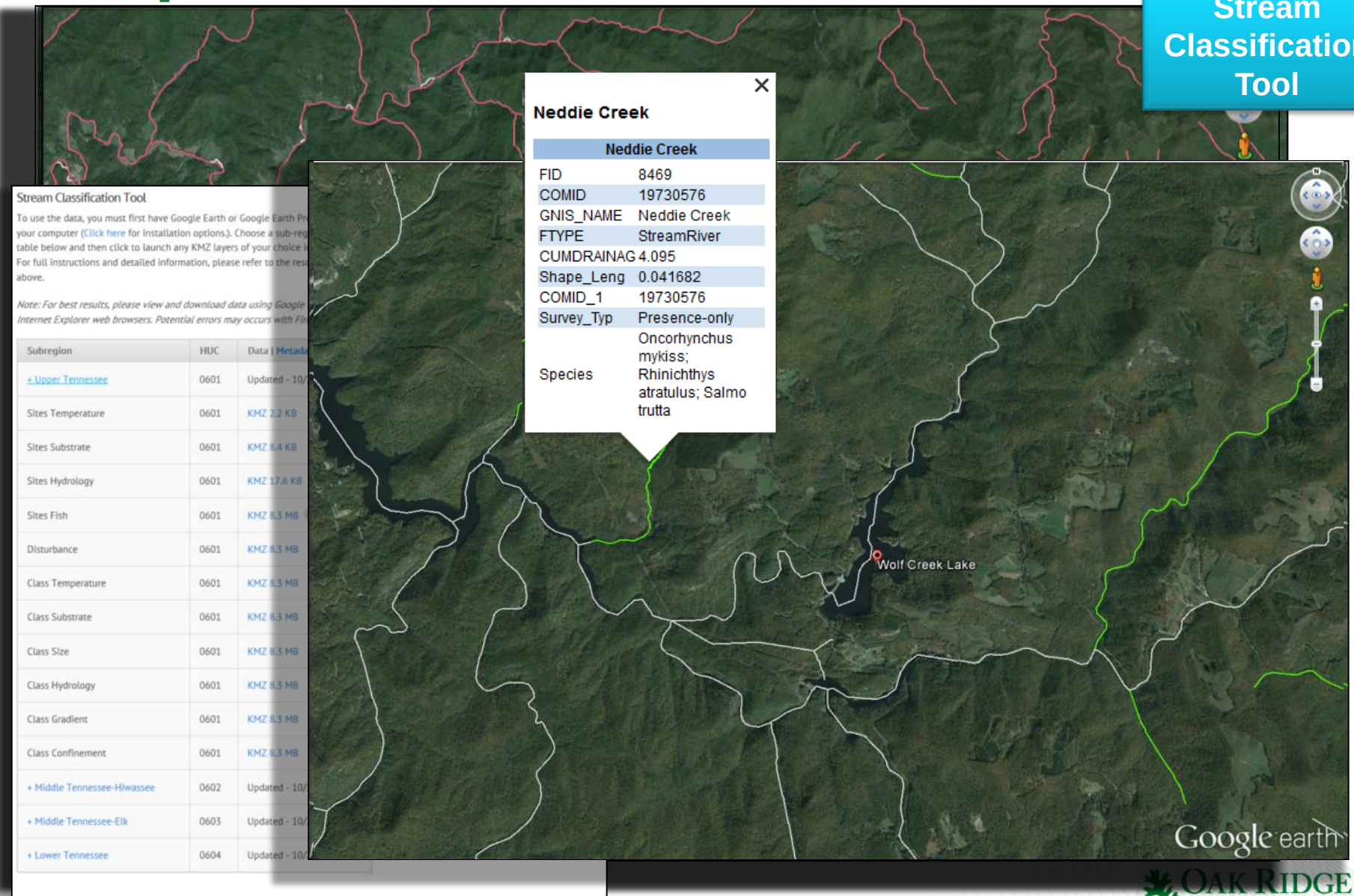

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