SMH Explorer

USER GUIDE

July 2018

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About SMH Explorer

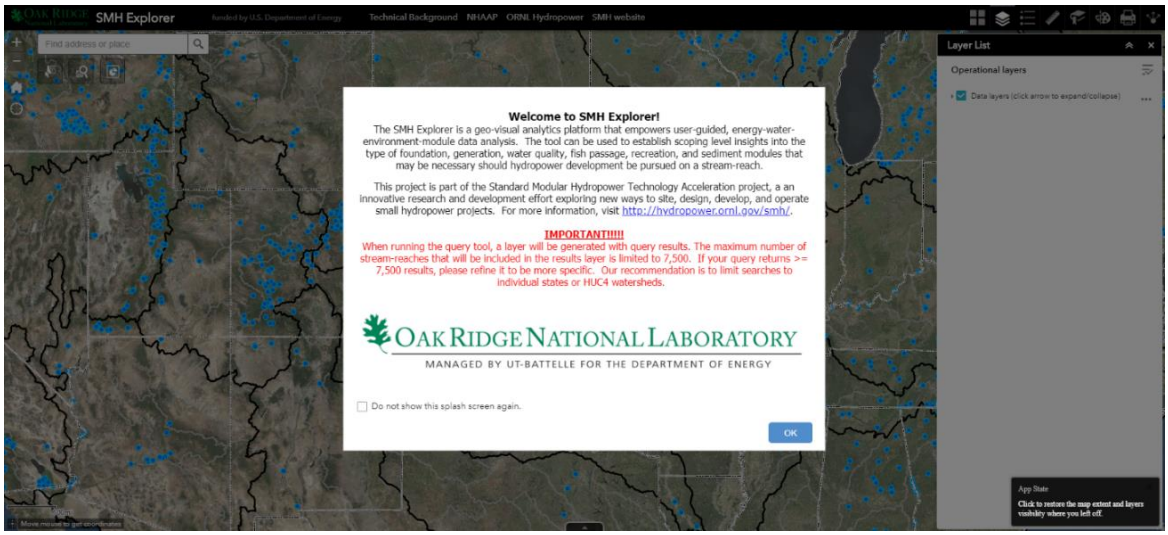
SMH Explorer is a geovisual analytics platform that empowers user-guided energy-water-environment-module data analysis and inquiries in support of the Standard Modular Hydropower (SMH) Technology Acceleration research project. The tool can be used to establish scoping-level insights into the type of foundation, generation, water quality, fish passage, recreation, and sediment modules that may be required if hydropower development is pursued on a stream-reach. For more information on the SMH project, visit https://hydropower.ornl.gov/smh/.

SMH Explorer is built using ArcGIS Online, an ESRI collaborative web geospatial information system (GIS) used to create and share maps, scenes, apps, layers, analytics, and data. The basic functionality of SMH Explorer falls into two categories: data layers and user queries. Data layers provide geospatial information about a particular class of data. For example, a "Substation" data layer provides the location of all substations across the U.S. from an infrastructure data set. The "HUC02" data layer provides the boundaries of all level 2 hydrologic units, the largest-scale regional watersheds in the United States delineated by drainage areas of major rivers. The user queries function allows users to input specific search criteria, visualize results, and download data summaries.

A companion document, *Site Classification for Standard Modular Hydropower Development: Characterizing Stream Reaches by Module Need* [1], provides the technical basis for the web tool results. This preliminary user guide describes the basic tool functionalities, the data underlying the search queries, and how the tool can be used to carry out three basic inquiries.

Accessing the Tool

SMH Explorer and supporting documentation is accessible at https://hydropower.ornl.gov/smh/explorer. Users should see the following splash screen upon successful navigation to SMH Explorer:



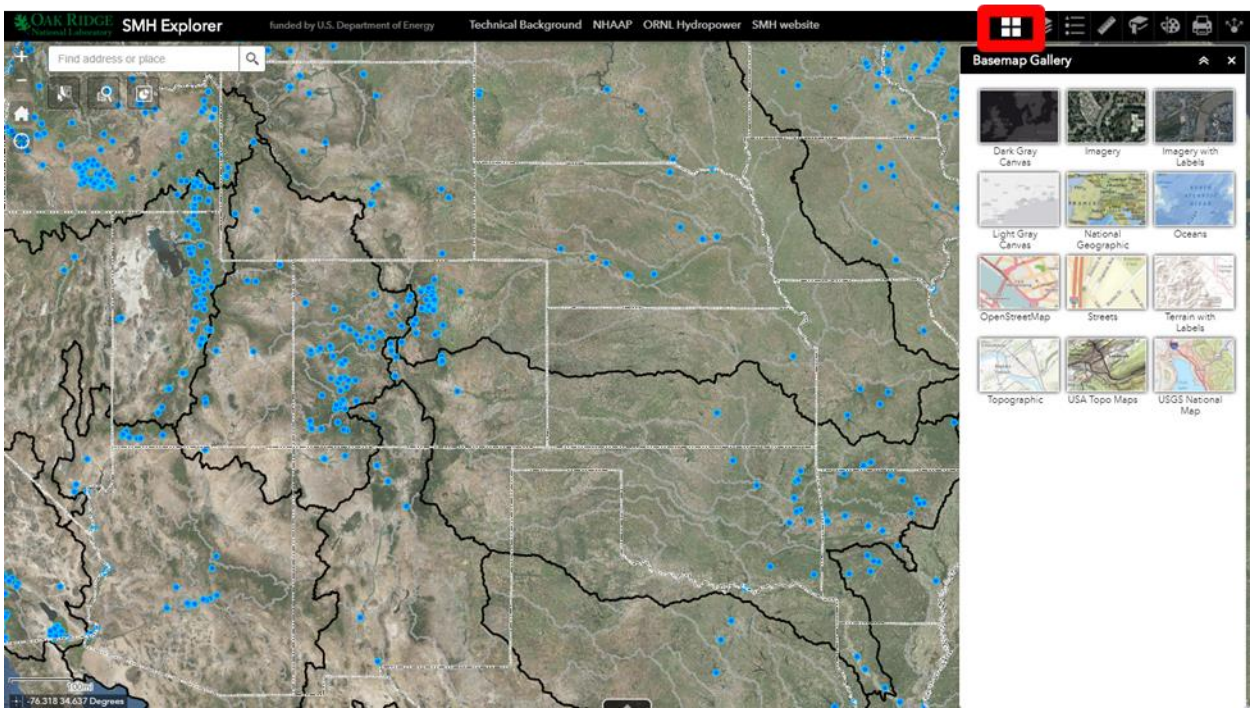
[1] Bevelhimer, M., C. DeRolph, and A. Witt. 2018. *Site Classification for Standard Modular Hydropower Development: Characterizing Stream Reaches by Module Need*, ORNL/TM-2018/898, Oak Ridge National Laboratory. Available at http://hydropower.ornl.gov/smh/docs/SMH_Explorer_Technical_Background.pdf

SMH Explorer Toolbar Features

The following are brief descriptions of the primary features provided in the SMH Explorer toolbar.

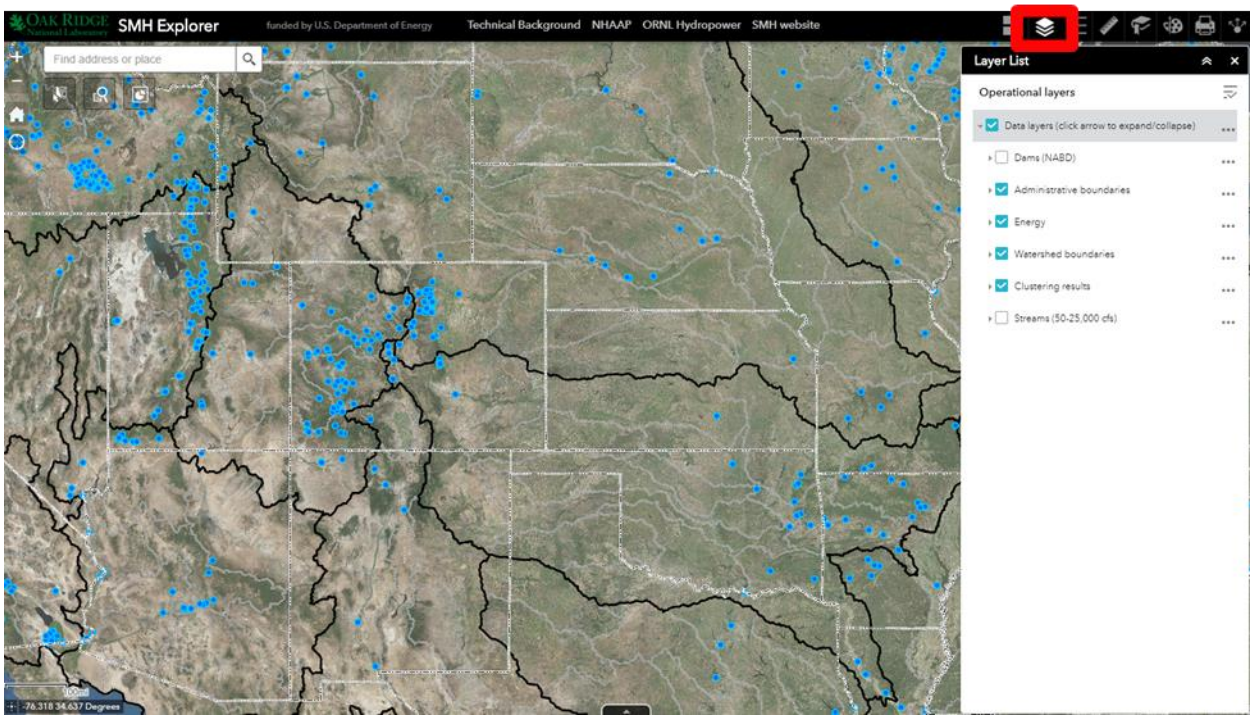
Basemap

Use the **Basemap Gallery** on the **SMH Explorer toolbar** at the top right to select a background map for the SMH Explorer map window.



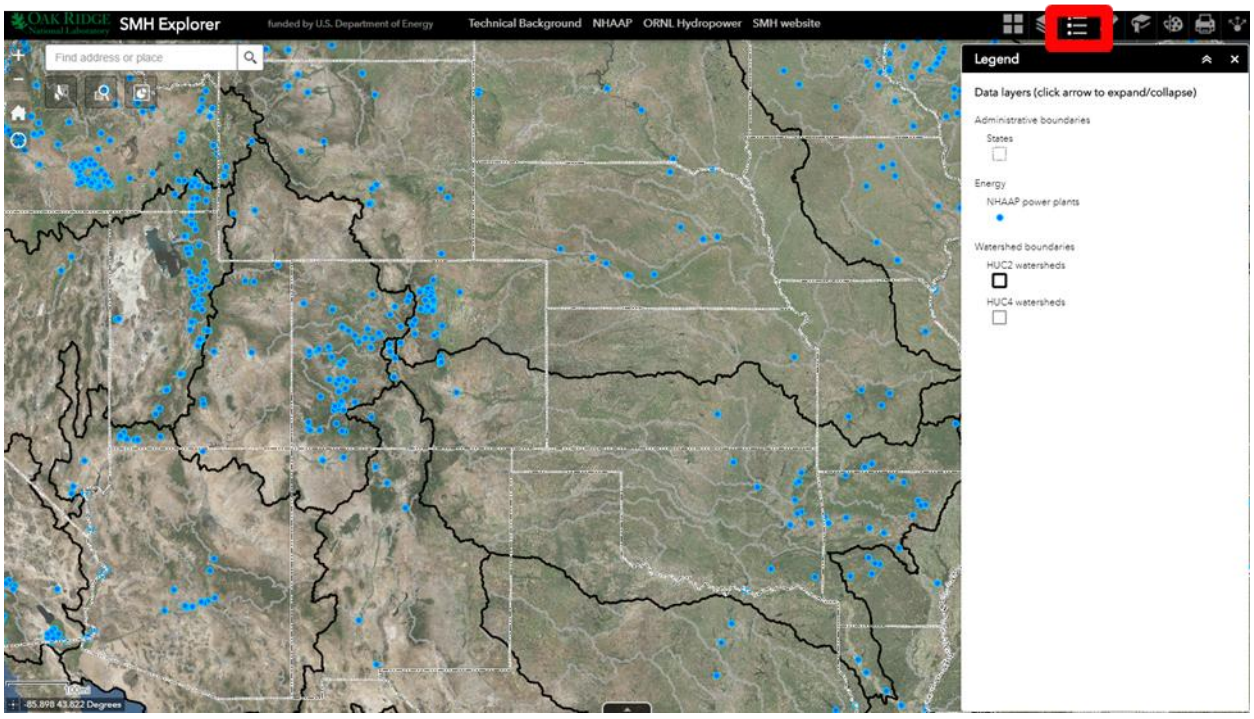
Layers

Click the **Layer List** button at the top right of the **SMH Explorer toolbar** to turn the **Operational layers** panel on or off. In the **Operational layers** panel, individual layers are grouped by themes, and the ► symbol next to each theme can be clicked to expand layers within a theme (click ▼ to contract all layers in a theme). Each layer or theme can be turned on or off individually by checking and unchecking the boxes in the **Layer List**.



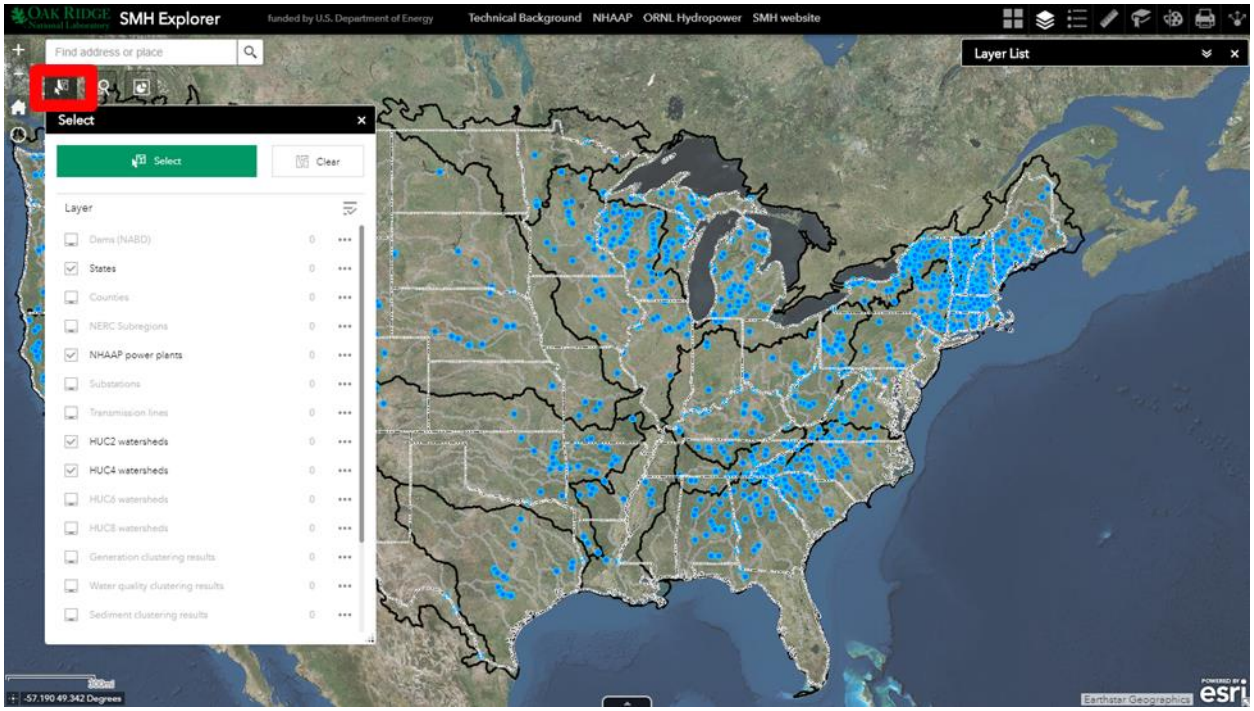
Legend

Click the **Legend** button at the top right of the **SMH Explorer toolbar** to view a description and symbology of each layer currently turned on in the **Layer List**.



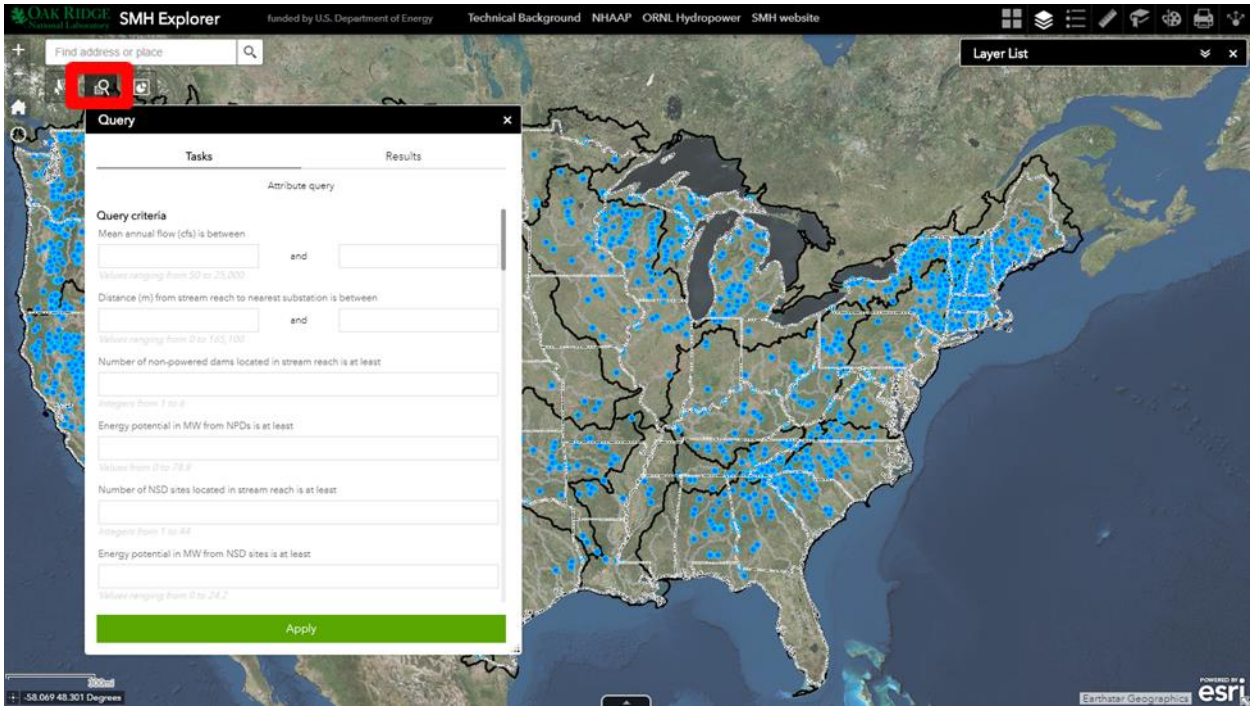
Select Layers for Queries

The **Select** tool is accessed from the top left side of the **SMH Explorer toolbar.** Once it is expanded, a user can click the green **Select** box and then highlight a region on the map for more detailed analysis by left clicking on a location, dragging the mouse within the area of interest, and releasing the mouse. Individual or multiple layers can be selected by checking the box to the left of each layer within the **Select** tool window. If multiple layers are enabled, they will all be highlighted on the map when a region is selected. For example, if the **States** and **HUC2** watersheds boxes are checked, selecting a region on the map will highlight both the state and HUC2 watershed associated with that region. Once a region and layer or set of layers are selected, they form the search region for a user query. It is recommended that users limit selections to a few states or a single HUC2 watershed to ensure the maximum query (see next section) return limit of 7,500 stream-reaches is not exceeded.



Query

The **Query** tool is accessed from the top left side of the **SMH Explorer toolbar.** A set of filter criteria will appear, enabling users to either input specific values or select values from a drop-down menu. These values are applied as filters to all stream-reaches within the selected region. To apply the filter criteria to the region identified using the **Select** tool, the user scrolls to the bottom of the **Query** window, selects the **Related layer** drop-down menu, and uses it to select the layer that corresponds to the one highlighted using the **Select** tool. For example, if several states are highlighted, the **Related layer** is States. The user must check the **Use selected features** box at the bottom of the **Query** tool to link the query to the highlighted region, and then click the green **Apply** button. Stream-reaches that meet the filter criteria will be highlighted in yellow on the map. The results of a **Query** are stored as a data layer in the **Layer List.** If a user desired to initiate a new **Query,** they must uncheck the existing query data layers.


SMH Explorer
funded by U.S. Department of Energy
Technical Background
NHAAP
ORNL Hydropower
SMH website
Find address or place
Layer List
Query
Tasks
Results
Attribute query
Query criteria
Mean annual flow (cfs) is between
and
Distance (m) from stream reach to nearest substation is between
and
Number of non-powered dams located in stream reach is at least
Energy potential in MW from NPDs is at least
Number of NSD sites located in stream reach is at least
Energy potential in MW from NSD sites is at least
Apply
-58.069 48.301 Degrees
Earthstar Geographics
esri

SMH Explorer Data

The SMH explorer tool relies on a variety of data sets to complete the cluster analysis. These data are outlined on the following pages. Hyperlinks to data sources are presented after the table.

Data Table

Field alias	Field name	Description	Source	Data scale	Units
DB_ID	objectid	Unique database identifier		Reach	NA
COMID	comid	Unique stream reach identifier	NHDPlusV2	Reach	NA
Stream name	gnis_name	Stream name	NHDPlusV2	Reach	NA
State	state	State in which the reach lies	ORNL SMH	State	NA
Mean annual flow	qa_ma	Mean annual flow from runoff	NHDPlusV2	Reach	cfs
Generation cluster number	gen10clstr	Generation clusters	ORNL SMH	Reach	NA
Generation cluster description	genclusterdef	Short text description of generation clusters	ORNL SMH	Reach	NA
Water quality cluster number	wq10clstrs	Water quality clusters	ORNL SMH	Reach	NA
Water quality cluster description	wqclusterdef	Short text description of water quality clusters	ORNL SMH	Reach	NA
Sediment cluster number	sed10clstr	Sediment clusters	ORNL SMH	Reach	NA
Sediment cluster description	sedclusterdef	Short text description of sediment clusters	ORNL SMH	Reach	NA

Field alias	Field name	Description	Source	Data scale	Units
Fish passage cluster number	fpsg10clst	Fish passage clusters	ORNL SMH	Reach	NA
Fish passage cluster description	fshclusterdef	Short text description of fish passage clusters	ORNL SMH	Reach	NA
Foundation cluster number	fnd10clstrs	Foundation clusters	ORNL SMH	Reach	NA
Foundation cluster description	fndclusterdef	Short text description of foundation clusters	ORNL SMH	Reach	NA
Recreation cluster number	rec10clstrs	Recreation clusters	ORNL SMH	Reach	NA
Recreation cluster description	recclusterdef	Short text description of recreation clusters	ORNL SMH	Reach	NA
Distance to nearest substation	dist2sub	Distance to nearest substation from reach midpoint	ORNL SMH	Reach	m
NPD count	npd_count	Number of NPDs in reach	ORNL NPD	Reach	Count
NPD MW	npd_mw	Total potential MW from NPDs in reach	ORNL NPD	Reach	MW
NSD count	nsd_count	Number of NSD sites in reach	ORNL NSD	Reach	Count
NSD MW	nsd_mw	Total potential MW from NSD sites in reach	ORNL NSD	Reach	MW
Support RPS	supportrps	Percent of residents within county that support renewable energy portfolio standards	Yale Climate Opinion Maps	County	%
NERC subregion	subregid	NERC subregion ID	EIA	NERC Subregion	NA
Subregion future population	popchngsub	Projected population increase by 2050 in NERC subregion	ORNL LandCast	NERC Subregion	Millions of individuals

Field alias	Field name	Description	Source	Data scale	Units
Population density	popdns10cat	Population density from 2010 census in catchment	StreamCat	Catchment	People per square km
Fish group 1	grp1	Number of ocean-run sturgeon species (Acipenseriformes) within the reach's HUC8	NatureServe	HUC8	Count
Fish group 2	grp2	Number of inland sturgeon/paddlefish species (Acipenseriformes) within the reach's HUC8	NatureServe	HUC8	Count
Fish group 3	grp3	Number of ocean-run clupeid species within the reach's HUC8	NatureServe	HUC8	Count
Fish group 4	grp4	Number of ocean-run eel/lamprey species within the reach's HUC8	NatureServe	HUC8	Count
Fish group 5	grp5	Number of ocean-run salmonid species within the reach's HUC8	NatureServe	HUC8	Count
Fish group 6	grp6	Number of inland salmonid species within the reach's HUC8	NatureServe	HUC8	Count
Fish group 7	grp7	Number of other inland migratory species within the reach's HUC8	NatureServe	HUC8	Count
Fish passage mitigation	huc2prcntfp	Percent of mitigation sites in the mitigation database within the HUC2 that had Tier 1 fish passage mitigation required	ORNL Environmental Mitigation	HUC2	%
303d listed for temperature	d303_temp	Stream listed as impaired for temperature on EPA 303d list	US EPA	Reach	NA
303d listed for sediment	d303_sdmnt	Stream listed as impaired for sediment on EPA 303d list	US EPA	Reach	NA
303d listed for pH	d303_ph	Stream listed as impaired for pH on EPA 303d list	US EPA	Reach	NA

Field alias	Field name	Description	Source	Data scale	Units
303d listed for nutrients	d303_ntrnt	Stream listed as impaired for nutrients on EPA 303d list	US EPA	Reach	NA
303d listed for turbidity	d303_trbdt	Stream listed as impaired for turbidity on EPA 303d list	US EPA	Reach	NA
303d listed for dissolved oxygen	d303_do	Stream listed as impaired for dissolved oxygen on EPA 303d list	US EPA	Reach	NA
Upstream mainstem dams	umct	Upstream mainstem dam count	MSU Dam metrics DB	Mainstem	Count
Upstream dams	unct	Total upstream dam count	MSU Dam metrics DB	Watershed	Count
Downstream mainstem dams	dmct	Downstream mainstem dam count	MSU Dam metrics DB	Downstream flowpath	Count
Total mainstem dam count	tmct	Total mainstem dam count	MSU Dam metrics DB	Mainstem	Count
Distance to upstream mainstem dam	um2d	Distance to upstream mainstem dam	MSU Dam metrics DB	Mainstem	Count
Distance to downstream mainstem dam	dm2d	Distance to downstream mainstem dam	MSU Dam metrics DB	Mainstem	Count
Mainstem dist. between up/down dams	tm2d	Total mainstem distance between upstream and/or downstream mainstem dams	MSU Dam metrics DB	Mainstem	Count
Percentage discharge stored in reservoirs	udor	Percentage of estimated annual discharge stored in upstream reservoirs	MSU Dam metrics DB	Watershed	Count

Field alias	Field name	Description	Source	Data scale	Units
Upstream dam density	damundr	Upstream network dam density per unit stream network length	MSU Dam metrics DB	Watershed	(#/100 km)
Downstream dam density	damdmd	Downstream mainstem dam density per unit downstream mainstem length	MSU Dam metrics DB	Downstream flowpath	(#/100 km)
Depth to bedrock	rckdepcat	Mean depth to bedrock in catchment	USGS WRD NSDI	Catchment	cm
Percent clay in soils	pctclayws	Percent clay content of soils in watershed	StreamCat	Watershed	%
Percent sand in soils	pctsandws	Percent sand content of soils in watershed	StreamCat	Watershed	%
Ground acceleration	grndaccel	Earthquake susceptibility from national seismic hazard map	USGS seismic hazard maps	Reach	NA
K-factor in catchment	kffactcat	The Kffactor - relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall in catchment	StreamCat	Catchment	NA
K-factor in watershed	kffactws	The Kffactor - relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall in watershed	StreamCat	Watershed	NA
UCS low	ucsLow	Unconfined compressive strength of primary lithology - low end of range	UTK Hydraulics and Sedimentation Lab	Geologic unit	NA
UCS high	ucsHigh	Unconfined compressive strength of primary lithology - high end of range	UTK Hydraulics and Sedimentation Lab	Geologic unit	NA

Field alias	Field name	Description	Source	Data scale	Units
Primary lithology	lithlgyprmry	Primary lithology	USGS geologic maps	Geologic unit	NA
Rock type	rocktype	Type of underlying bedrock	UTK Hydraulics and Sedimentation Lab	Geologic unit	NA
Stream order	streamorde	Strahler stream order	NHDPlusV2	Reach	NA
Elevation	minelevsmo	Elevation at downstream end of reach	NHDPlusV2	Reach	cm
Slope	slope	Slope of stream reach	NHDPlusV2	Reach	m/m
Stream power	powerQS	SLOPE * QA_MA	ORNL SMH	Reach	NA
Mean annual velocity	va_ma	Mean annual velocity for QA	NHDPlusV2	Reach	fps
Infiltration-excess overland flow	ieofcat	Mean infiltration-excess overland flow in catchment	USGS WRD NSDI	Catchment	% total stormflow
Runoff in watershed	runoffws	Mean runoff in watershed	StreamCat	Watershed	mm
Flow variation	qa_cv	Coefficient of variation for flow based on monthly averages and annual mean	NHDPlusV2/ORNL	Reach	NA
Elevation change in watershed	elevdiffws	Difference between maximum and minimum elevation in watershed	NHDPlusV2/ORNL	Watershed	cm
Base flow index	bficat	Base flow index is the ratio of base flow to total flow, expressed as a percentage	USGS WRD NSDI	Catchment	%
Agriculture in catchment	pctagcat	Percent agricultural land cover in catchment	StreamCat	Catchment	%

Field alias	Field name	Description	Source	Data scale	Units
Agriculture in watershed	pctagws	Percent agricultural land cover in watershed	StreamCat	Watershed	%
Nitrogen from farms	farmncat	Sum total of nitrogen from farm areas in catchment	USGS WRD NSDI	Catchment	%
Forest/wetlands in catchment	pctforwetcat	Percent forest and wetland land cover in watershed	NLCD 2011	Catchment	%
Forest/wetlands in watershed	pctforwetws	Percent forest and wetland land cover in watershed	NLCD 2011	Watershed	%
Imperviousness in catchment	pctimprv06cat	Percent imperviousness from 2006 in catchment	StreamCat	Catchment	%
Imperviousness in watershed	pctimprv06ws	Percent imperviousness from 2006 in watershed	StreamCat	Watershed	%
Riparian forest in watershed	pctforripws	Percent riparian forest land cover in watershed	StreamCat	Watershed	%
HUC6	huc6	6-digit HUC watershed	USGS WBD	HUC6	NA
Population density in HUC6	popdns10huc6	Mean population density in HUC6	StreamCat/ORNL	HUC6	People per square km
Boat ramps in HUC6	boat_ramp	Number of developed boat ramps in HUC6	Delorme/ORNL	HUC6	Count
Undeveloped boat ramps in HUC6	boat_ramp_undeveloped	Number of undeveloped boat ramps in HUC6	Delorme/ORNL	HUC6	Count
Fishing coldwater	fishing_coldwater	Number of cold water fishing locations in HUC6	Delorme/ORNL	HUC6	Count
Fishing saltwater	fishing_saltwater	Saltwater fishing locations in HUC6	Delorme/ORNL	HUC6	Count

Field alias	Field name	Description	Source	Data scale	Units
Whitewater paddling in HUC6	awhuc6km	Length of stream identified as whitewater paddling runs in HUC6	American Whitewater/ORNL	HUC6	m
Outstanding rivers in HUC6	nrirechuc6km	Length of stream identified as having outstanding recreational value in HUC6	National Rivers Inventory	HUC6	m
Reach length	st_length(shape)	Reach length in m	NHDPlusV2	Reach	m

Data Sources

NHDPlusV2: http://www.horizon-systems.com/nhdplus/NHDPlusV2_home.php

ORNL SMH: https://hydropower.ornl.gov/smh/

ORNL NPD: https://nhaap.ornl.gov/content/non-powered-dam-potential

ORNL NSD: https://nhaap.ornl.gov/nsd

Yale Climate Opinion Maps: http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/

EIA: https://www.eia.gov/maps/layer_info-m.php

ORNL LandCast: http://www.pnas.org/content/112/5/1344

StreamCat: https://www.epa.gov/national-aquatic-resource-surveys/streamcat

NatureServe: http://www.natureserve.org/conservation-tools/data-maps-tools/digital-distribution-native-us-fishes-watershed

ORNL Environmental Mitigation: https://nhaap.ornl.gov/environmental-mitigation

USEPA: https://www.epa.gov/waterdata/waters-geospatial-data-downloads

MSU Dam metrics DB: https://www.sciencedirect.com/science/article/pii/S004896971730308X?via%3Dihub

USGS WRD NSDI: https://water.usgs.gov/lookup/getgislist

USGS seismic hazard maps: https://earthquake.usgs.gov/hazards/hazmaps/

UTK Hydraulics and Sedimentation Lab: http://hsl.engr.utk.edu/

USGS geologic maps: https://mrdata.usgs.gov/geology/state/

NLCD 2011: https://www.mrlc.gov/nlcd2011.php

USGS WBD: https://nhd.usgs.gov/wbd.html

Delorme/ORNL: https://developer.garmin.com/datasets/overview

American Whitewater/ORNL: https://www.americanwhitewater.org/

National Rivers Inventory: https://www.nps.gov/subjects/rivers/data.htm .

SMH Explorer User Tutorial

Getting Started

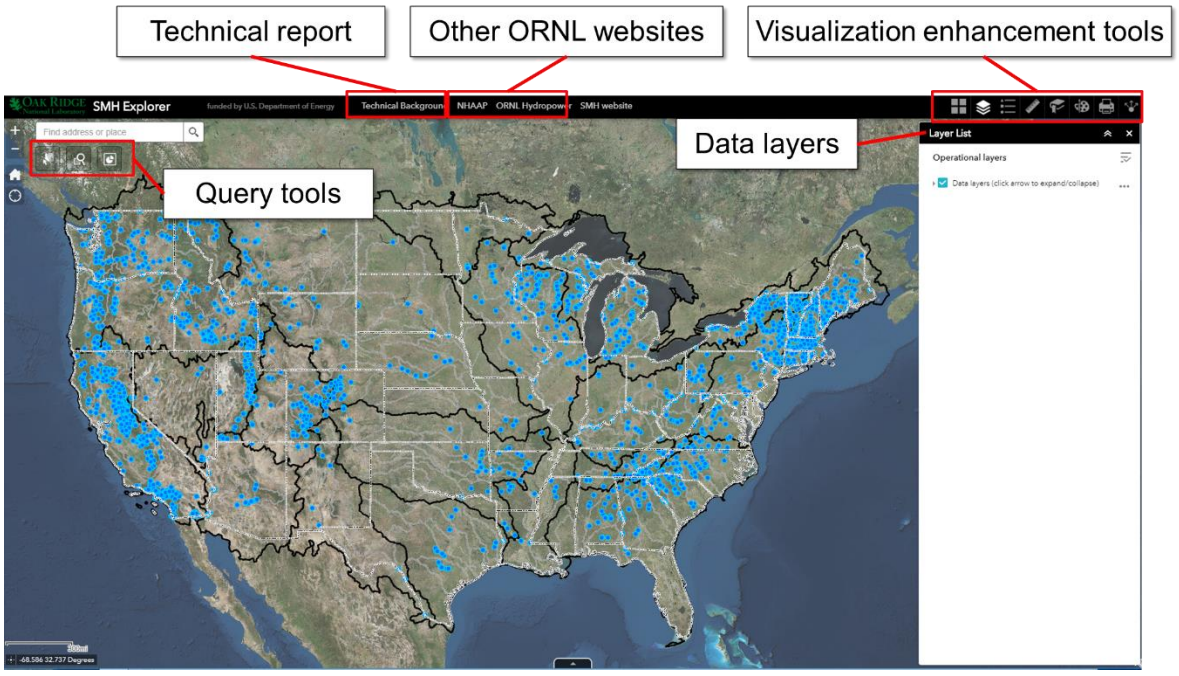
The splash page contains the following important message:

IMPORTANT!!!!!
When running the query tool, a layer will be generated with query results. The maximum number of stream-reaches that will be included in the results layer is limited to 7,500. If your query returns >= 7,500 results, please refine it to be more specific. Our recommendation is to limit searches to individual states or HUC4 watersheds.

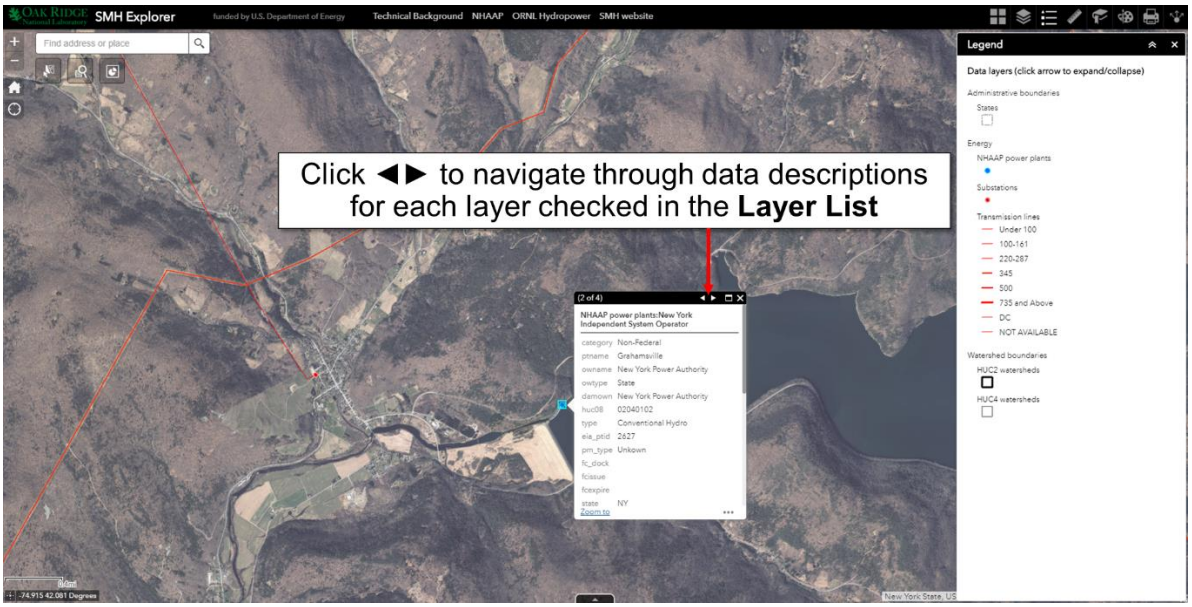
Note that SMH Explorer will display only a maximum of 7,500 features in a layer of query results. If a query is structured so that it results in 7,500 features or more, SMH Explorer will not be able to display all results. Users are thus cautioned to make their searches as specific as is feasible. If the results tab contains greater than 7,500 entries, the user should refine the search with more specific information. This could include focusing on a specific watershed or state, constraining the search to stream-reaches with mean annual flows between a minimum and a maximum value, and/or filtering out stream-reaches that are greater than a certain distance from a substation.

The basic tool layout is shown in the image below. At the upper right-hand side of the screen, the drop-down menu displays data layers that can be toggled on and off. These data are for visualization purposes only and remain visible as the user zooms in and out of specific locations. The upper right corner displays visualization enhancement tools, including different types of background maps, a legend description of each visible data layer, measuring tools, and tools for customizing a map view with text or symbols. The upper portion of the screen contains links to the *Standard Modular Hydropower (SMH): Site Classification Status Report* and other relevant ORNL hydropower websites. The upper left-hand side provides three user query tools:

1. Select allows the user to identify a search region. For example, when a watershed or state is selected, search results will be reported only for that watershed or state.
2. Query allows users to input specific search criteria within the selected region. For example, a user can search for stream-reaches with mean slopes between 0.01 and 0.001.
3. Infographic provides a graphical summary of query results.



Data layers enable users to visualize geospatial relationships between variables and regions of interest. These relationships are important on both the national and local level. For example, the screen capture in the previous image shows all installed hydropower plants as blue dots overlaid on HUC (hydrologic unit code) watershed regions outlined in black. On a national level, users get a sense of how hydropower plants are distributed throughout the nation. Each plant can also be viewed on a local level, with physical features and surrounding environmental context explored in more detail. The example below zooms in on a single dam overlaid with transmission line and substation data layers. Left clicking on the blue dot generates a pop-up window that provides a list of data available for each layer checked in the **Layer List**, offering users an overview of the energy and water context of this specific hydropower plant.



Data layers and query tools are the primary functionalities of SMH Explorer, and their integration into a comprehensive new platform for early scoping of hydropower environmental design is a powerful tool that will be used in numerous ways by the hydropower industry. In the following sections, we highlight three examples of how we envision end users – primarily module technology developers and small hydropower project developers – applying the analytical capabilities of the platform to guide their work.

Use Case 1: Module developer determining application space

A module developer might want to know how much demand there is for a particular module design. This information could be useful for pre-development decision-making and post-development marketing. For example, how many sites or how big of an area might benefit from a fish passage module that passes a particular species group?

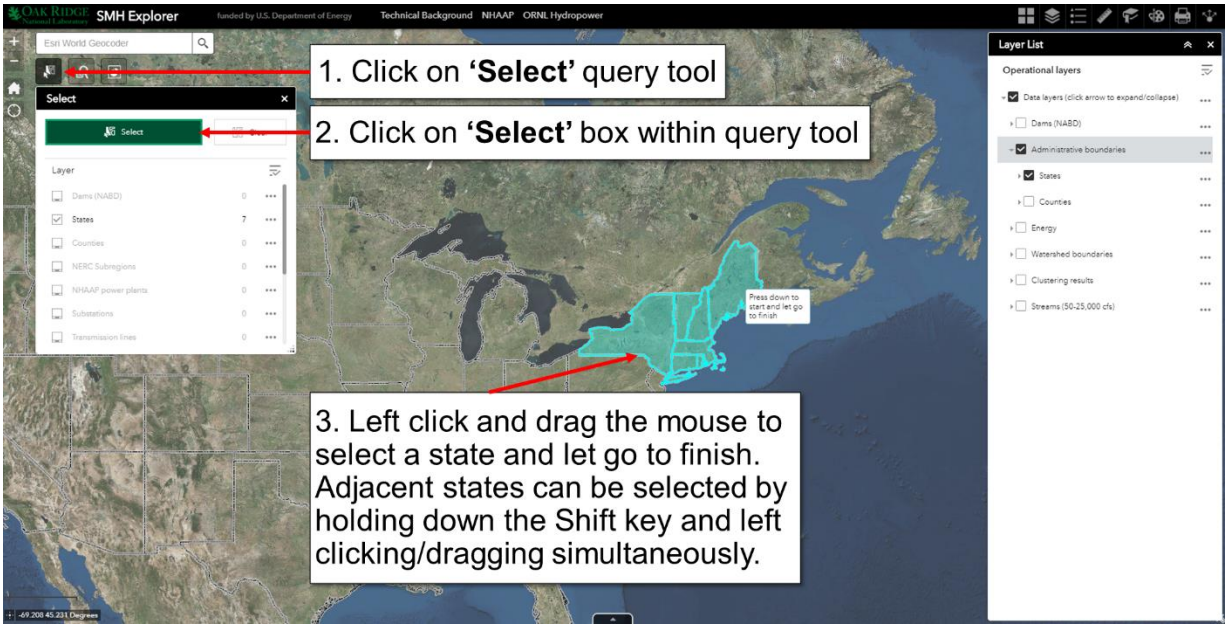
In this example, the search focuses on the Northeast, where fish passage structures are commonly located at existing hydropower facilitates. It also is limited to ocean eel and lamprey, species of concern with specific passage requirements.

Prepare Search

The first step requires the user to highlight only the desired data layers and select a region of interest. Click on **Layer List** in the upper right corner to expand the data layer menu. Next, click on the small arrow to the left of **Data Layers**, then the small arrow next to **Administrative Boundaries** to expand the menu. Check the box next to **Administrative Boundaries** and **States** to display state boundaries on the map. Ensure all other boxes are unchecked in **Layer List**.

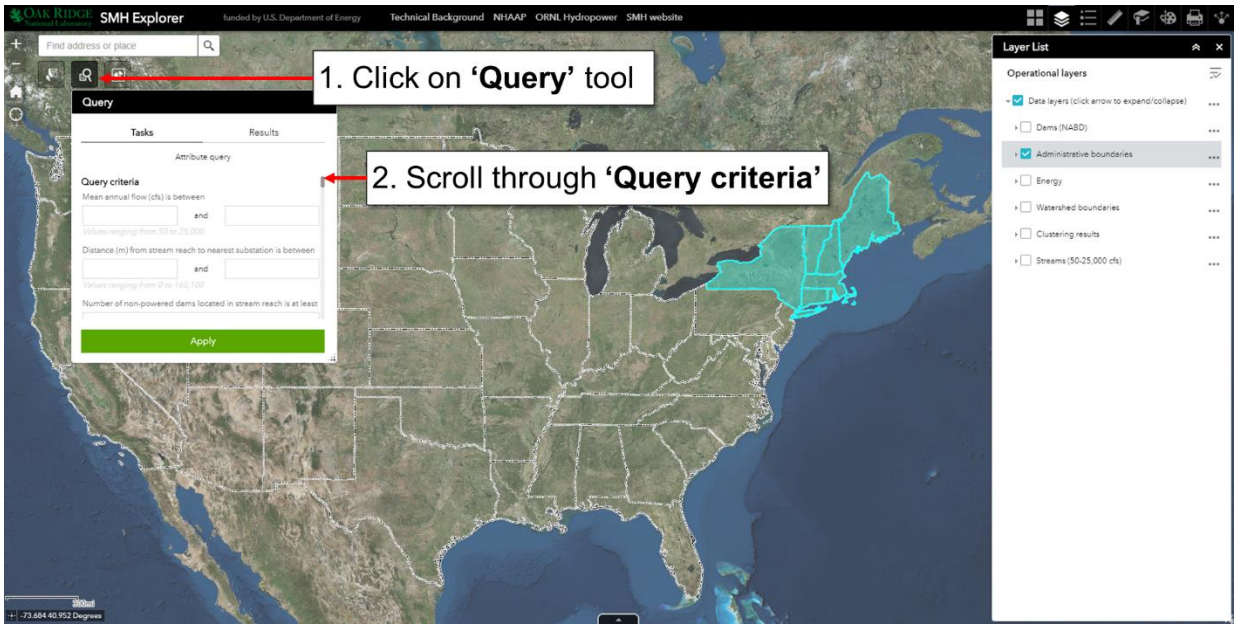
Select Region of Interest

Let's assume a developer is focused on a few states in the Northeast. To select states of interest, click on the **Select** tool, click on the green **Select** box within the query tool, and then left-click anywhere on the map to select a state or region. Multiple adjacent states can be selected by moving the mouse over any part of those states while holding down the left mouse button. Release the left mouse button to complete the selection. Non-adjacent states can be added to the selection by holding down Shift while left-clicking.



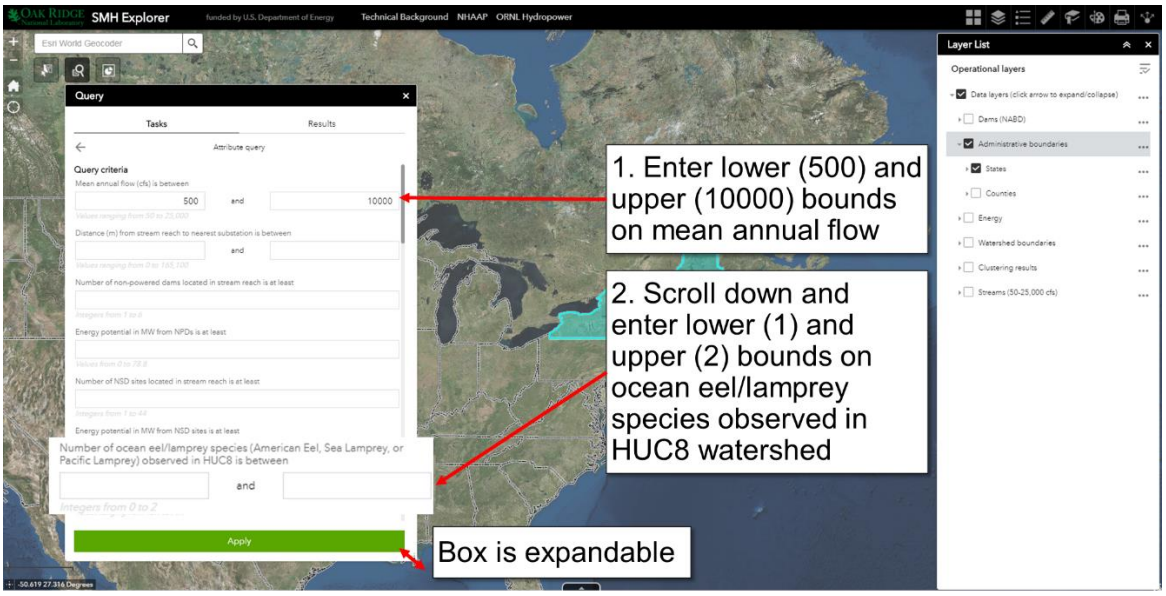
Choose Query Attributes

Next, query stream-reaches by specific attributes to identify locations that may be ideal for a certain kind of fish passage module. Click on the **Query** tool in the upper left corner and scroll through query criteria to view the list of searchable attributes.



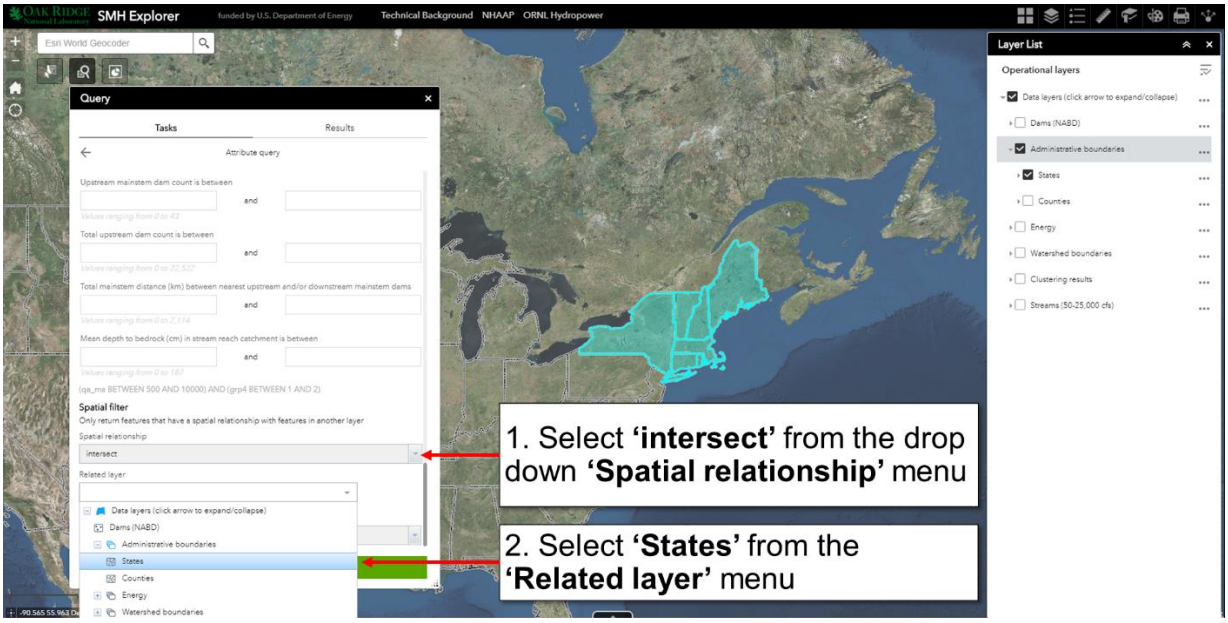
We apply screening criteria to stream-reaches to mimic how a fish passage module developer may seek to identify sites based on a technology feature or limitation. In the **Query** box, assign a mean annual flow between 500 cfs and 10,000 cfs, then scroll down and enter 1 and 2 as lower and upper bounds, respectively, on the number of observed ocean eel/lamprey species in the HUC 8 watershed that contains

the stream-reach. Our search will return only stream reaches with a specific flow value where specific eel and lamprey species have been observed in the HUC8 watershed the stream-reach lies in.



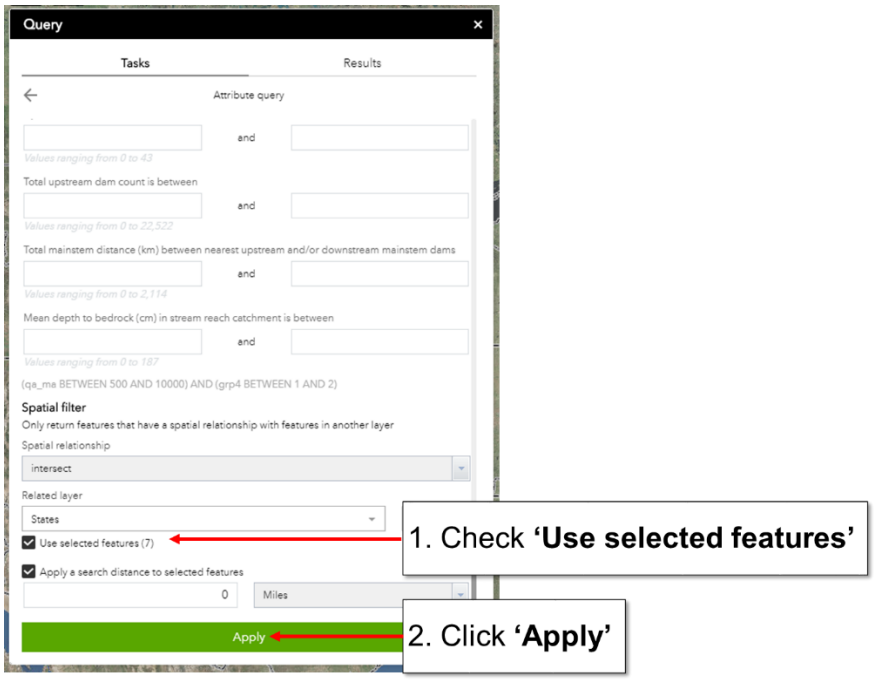
Ensure Results Are Returned for Selected States

The final step in the search procedure is to tell SMH Explorer to search the query attributes only in the desired states. To do so, scroll down to the bottom of the **Query** box. Select **Intersect** from the **Spatial Relationship** menu and **States** from the **Related Layers** menu.



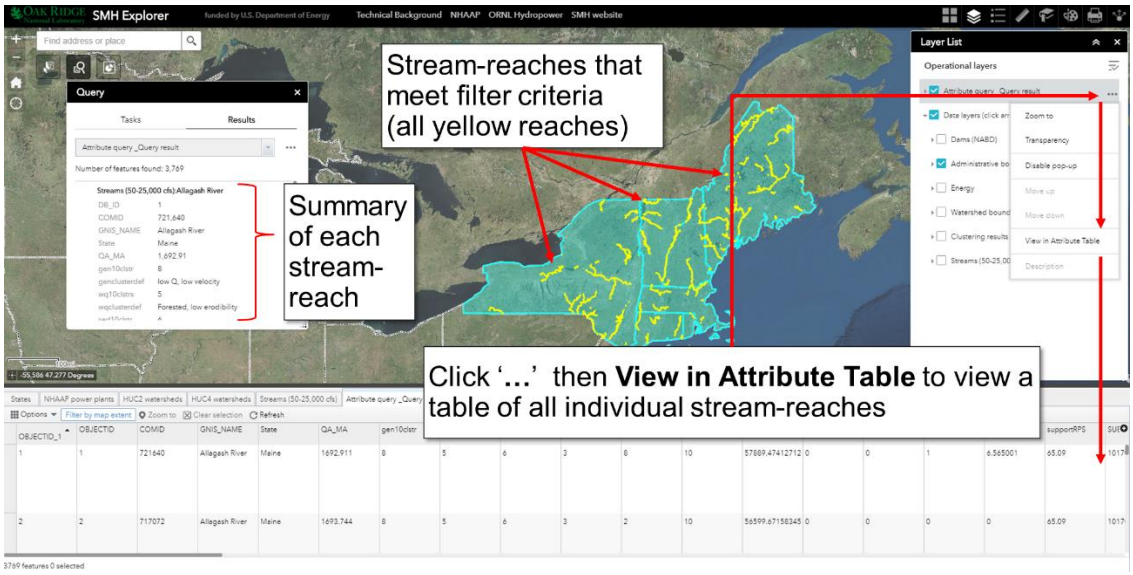
Intersect is required when a user desires to restrict a query to a data layer such as States, NERC Subregions, or HUC2 watersheds. Scroll down further to the bottom of the **Query** box, check **Use selected features**, to ensure the highlighted states are used as filter, and then click the large green **Apply** button.

This search may take a moment as SMH Explorer goes through various layers of data to return only queried results.

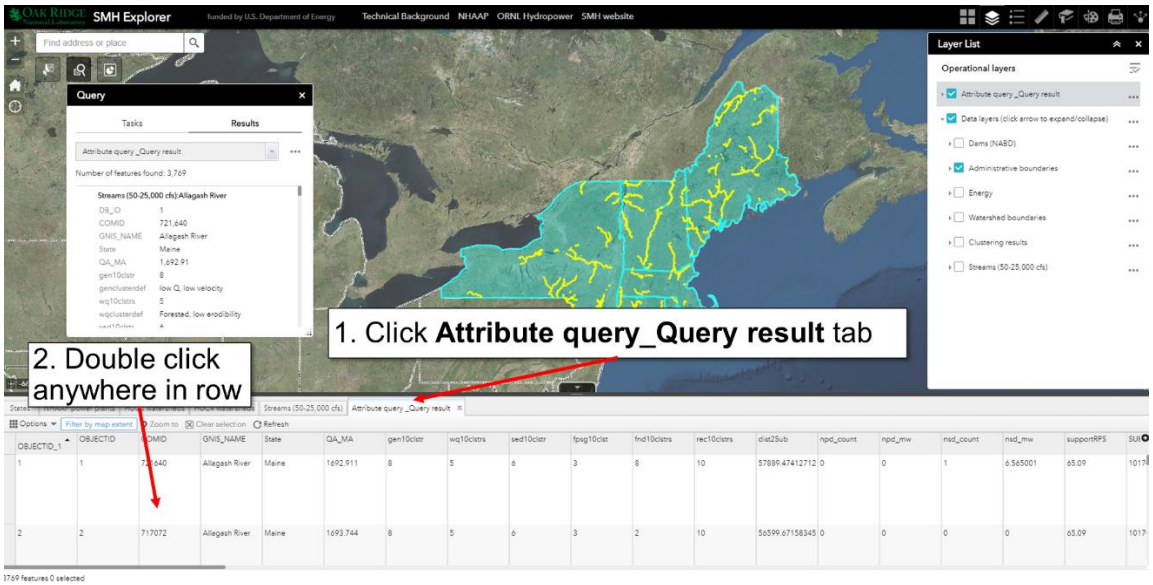


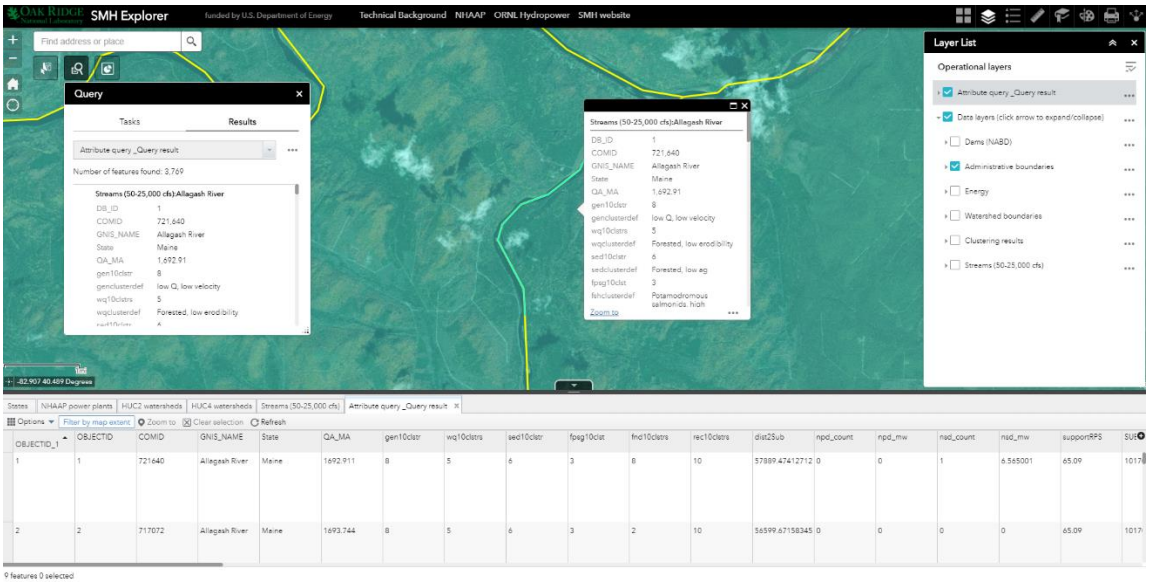
Visualize and Explore Results

SMH Explorer processes user queries and displays the results in three ways: (1) in the **Results** tab of the **Query** window, (2) visually on the underlying basemap as yellow highlighted stream-reaches in the region of interest and (3) in an attribute table at the bottom of the screen. Users can scroll in to regions of interest to explore stream-reaches in more detail or scroll through the attribute table to find all relevant details about all stream-reaches that met all filter criteria.

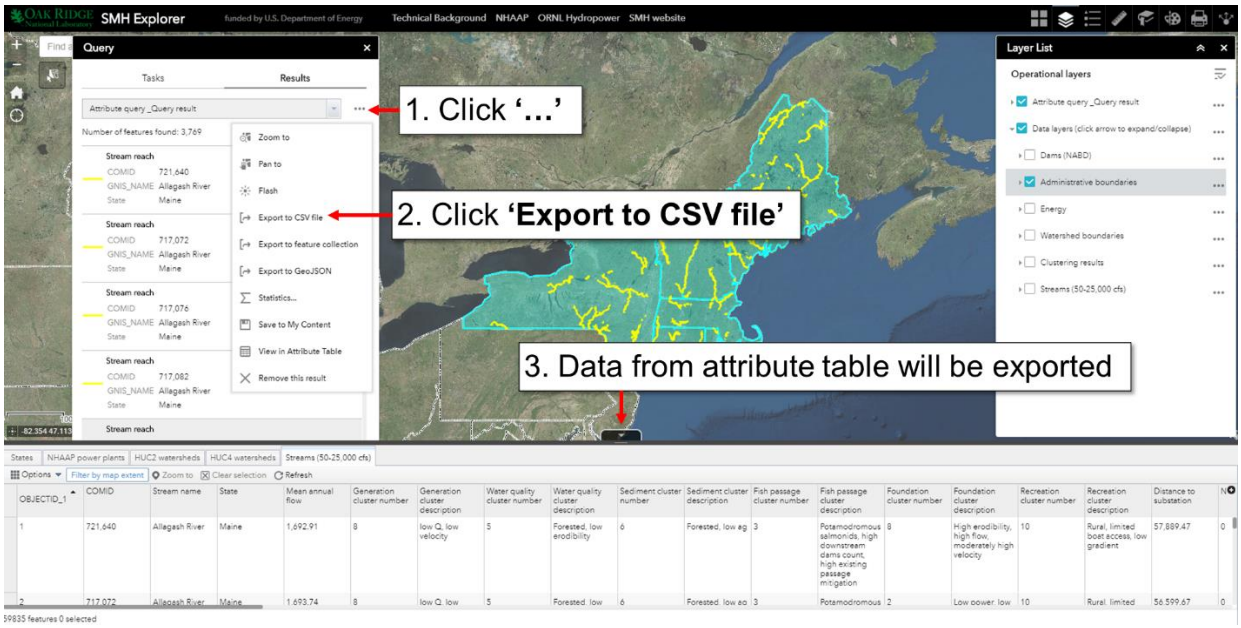


After reviewing the attribute table, a user can zoom to a specific location to view the stream-reach in more detail. Ensure the **Attribute query_Query result** tab is highlighted, then identify a stream-reach of interest in the attribute table, double-click anywhere on the row, and SMH Explorer will zoom to the centroid of the stream-reach, highlight it in light blue, and display the attributes in a pop-up box.

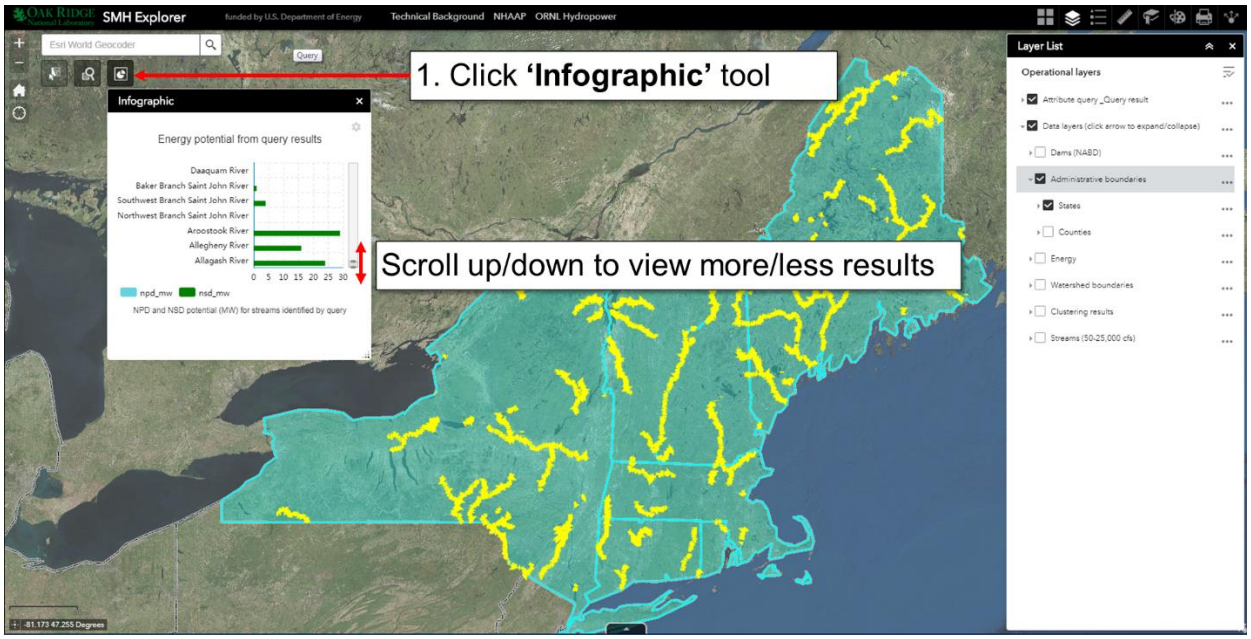




The user can download results and process them using in-house software and analysis tools. To download data returned from a query as a CSV file, click the ellipsis (**…**) on the upper portion of the **Query** box **Results** tab and then select **Export to CSV file**. All results from that query, as shown in the attribute table, will be exported as a CSV file.



A user may also want high-level information about rivers within the query that have high technical potential for non-powered dam (NPD) and new stream-reach development (NSD). To visualize these results, click on the **Infographic** tool at the top left of the screen. A bar plot will display the NSD and NPD potential in each river returned by the query. Users can toggle NPD or NSD potential on or off by clicking on the legend at the bottom left of the **Infographic** window.

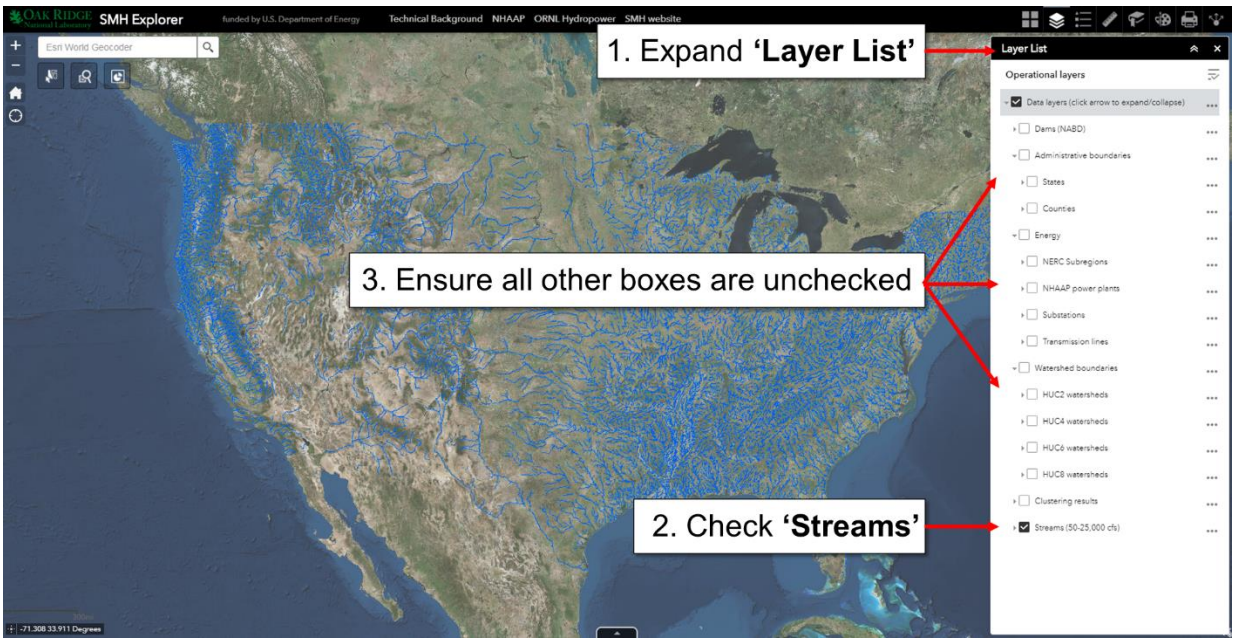


Use Case 2: Module developer design questions

A module developer might want to know the range of conditions within a certain type of project site. For example, a technology developer scoping a specific type of foundation module that ties into bedrock may want to know if stream-reaches with hydropower potential have a mean depth to bedrock in the watershed of less than 1 meter. In this example, the search focuses on all US stream-reaches.

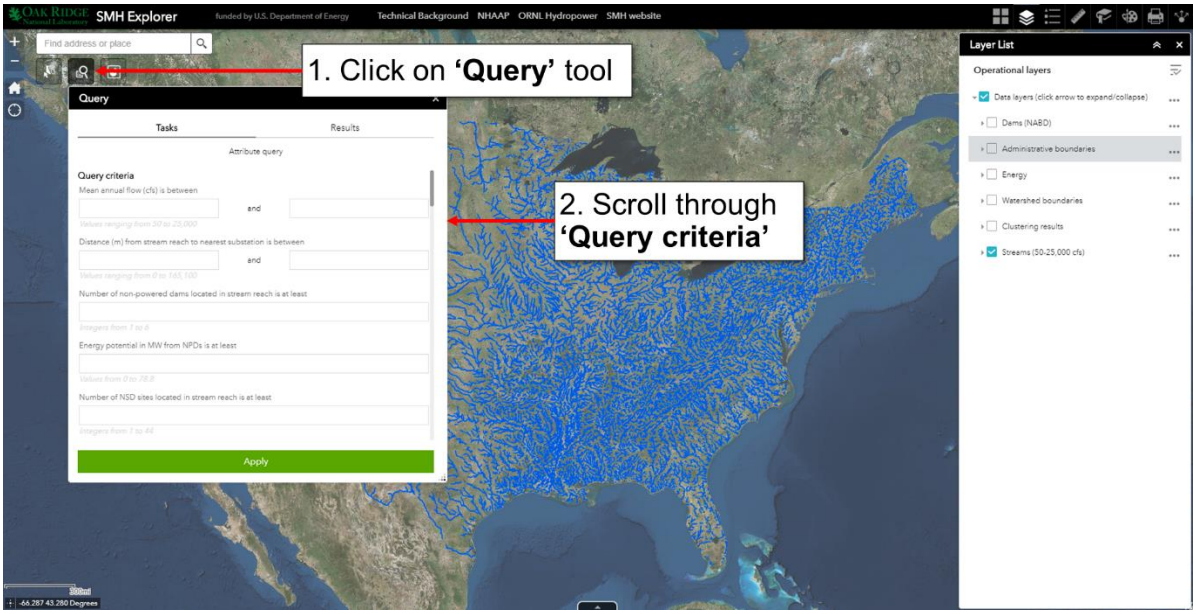
Prepare Search

The first step requires the user to highlight only the desired data layers and select a region of interest. Click on **Layer List** in the upper right corner to expand the data layer menu. Next, click on the small arrow to the left of **Data layers** to expand the menu. Check the box next to **Streams (50–25,000 cfs)** to display US stream-reaches on the map. Uncheck all other boxes in Layer List.

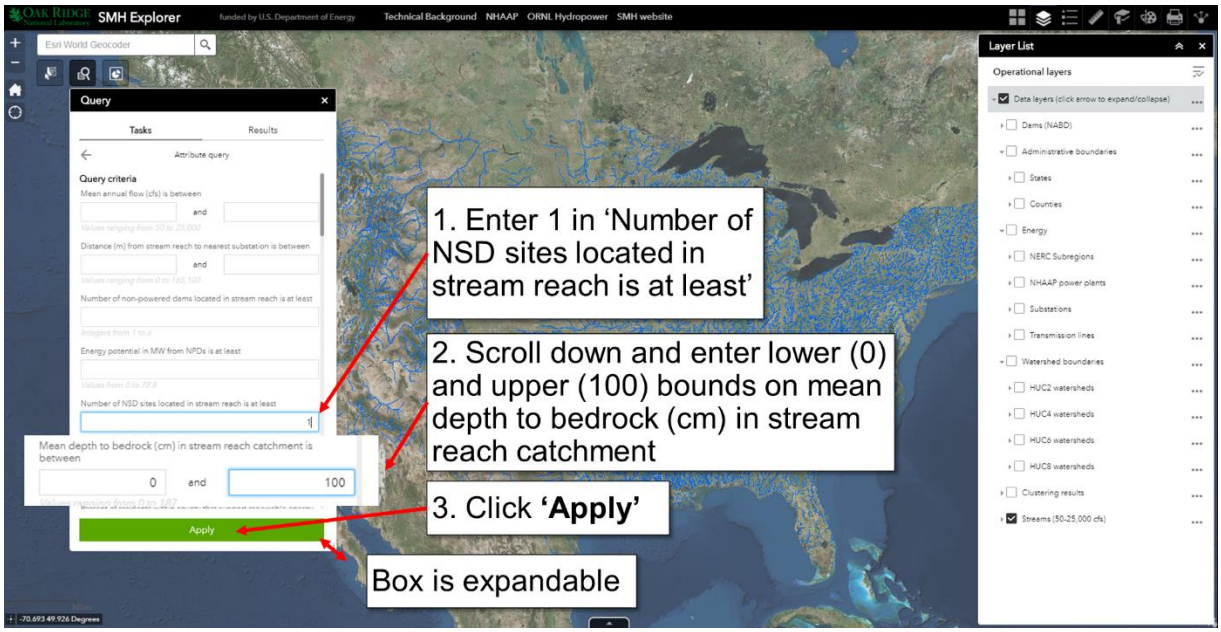


Choose and Apply Query Attributes

Next, query stream-reaches by specific attributes to identify locations with certain energy and foundation module characteristics. Click on the **Query** tool in the upper left corner to expand the list of searchable attributes.



Screening criteria are applied to stream-reaches to determine if the mean depth to bedrock in a given catchment is sufficient to warrant further consideration of a certain type of foundation or geotechnical module. In the **Query** box, enter 1 in **Number of NSD sites located in stream reach is at least** to select stream-reaches with at least 1 potential site that exhibits greater than 1 MW of technical hydropower potential. Then scroll down and enter one and 100 as lower and upper bounds, respectively, in **Mean depth to bedrock (cm) in stream reach catchment**. Finally, click **Apply**. The search will return only stream reaches with NSD potential greater than 1 MW and mean depth to bedrock of less than 100 cm.



Visualize and Explore Results

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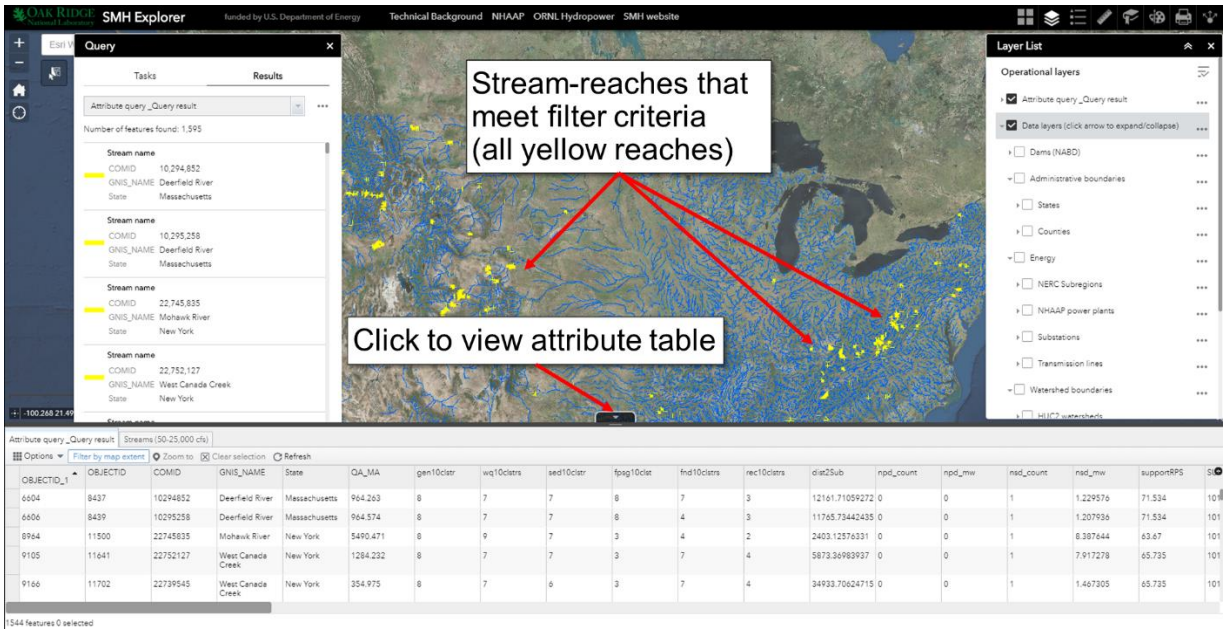
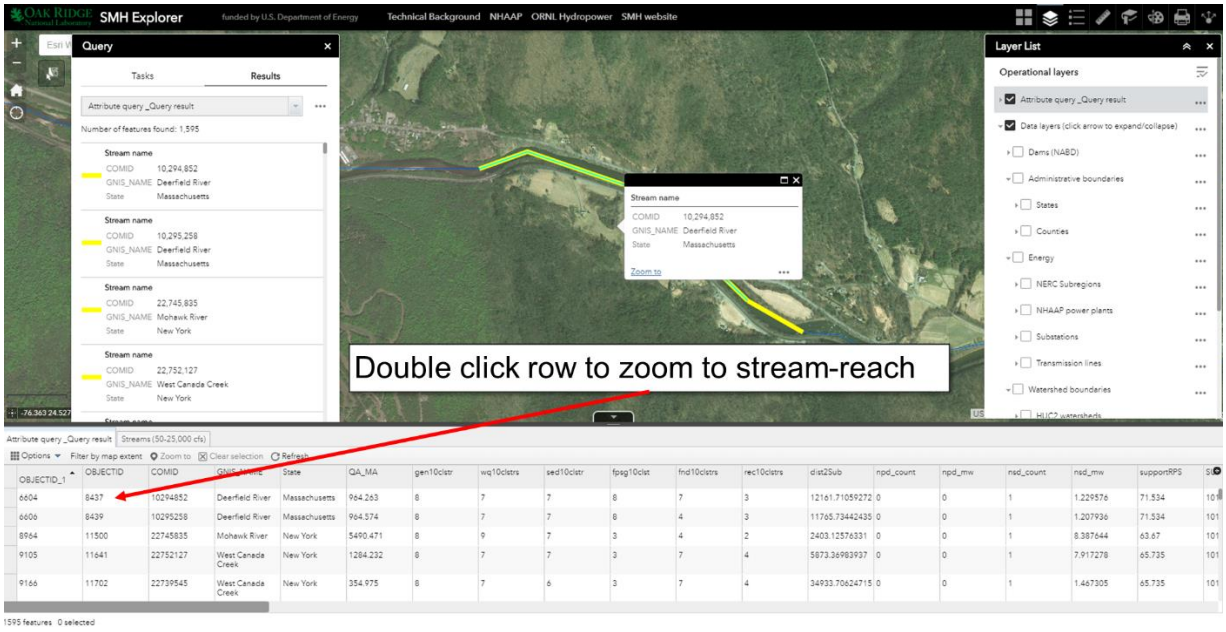
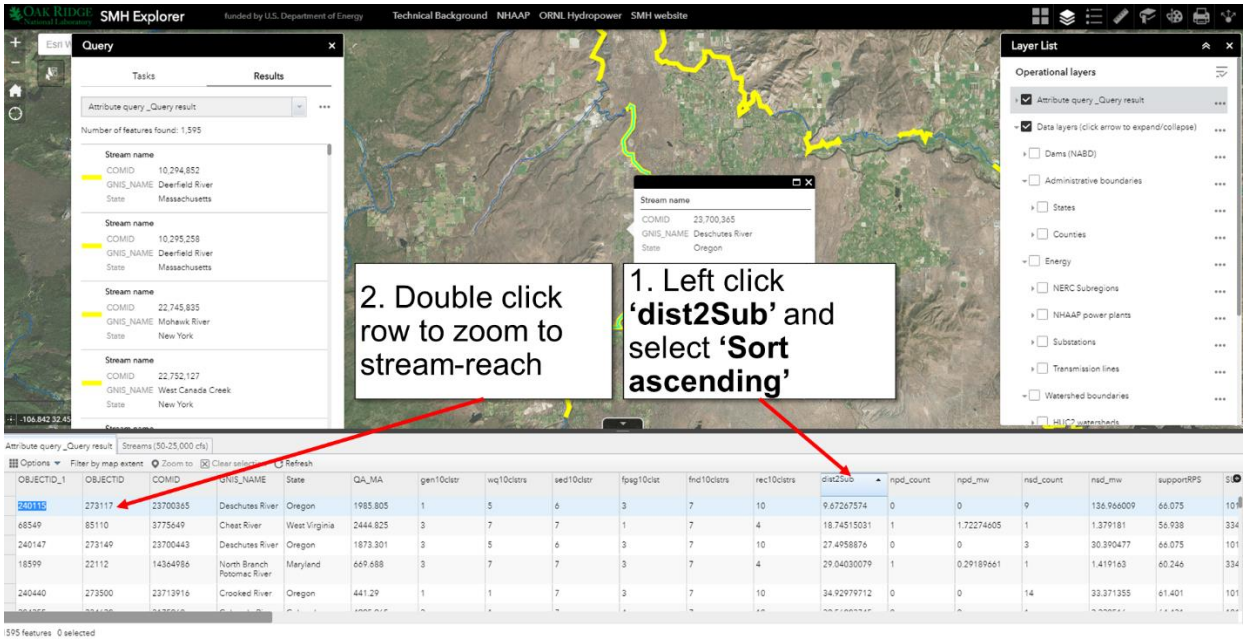


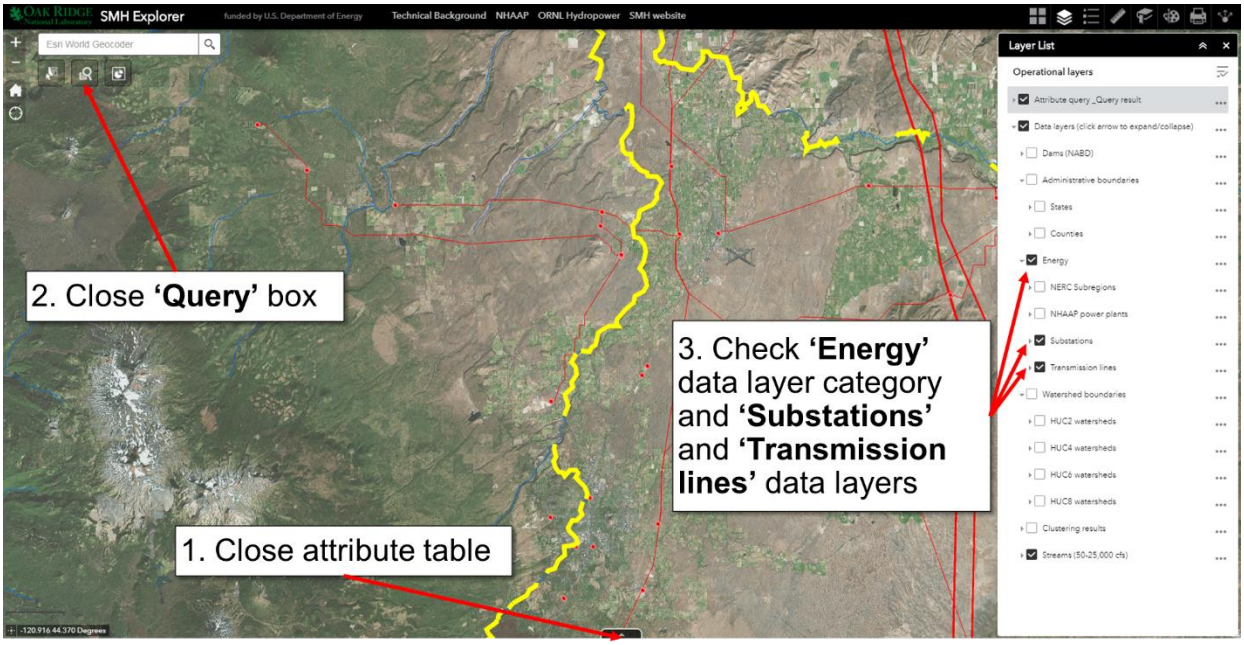
Double-click a row in the attribute table and SMH Explorer will automatically highlight the associated stream-reach and zoom to the precise location.



Users can prioritize specific attributes and search filtered sites in a systematic fashion. For example, a user may want to find the filtered stream-reaches with the shortest distances to substations. Left click on the **dist2Sub** column heading in the attribute table and click **Sort ascending**. The filtered sites are now arranged by their distances from the stream-reach to a substation. Double-click a row in the attribute table and SMH Explorer will automatically highlight the associated stream-reach and zoom to the precise location.



Users can then visualize important attributes of the site to scope preplanning-level feasibility. Close the attribute table and the query box and select the **Energy** data layer theme and the **Substations** and **Transmission Lines** data layers. The stream-reaches with at least one site with NSD potential of >1MW, mean depth to bedrock in the catchment of less than 1 m, and the shortest distances to substations will be shown, along with the locations of transmission lines and substations.

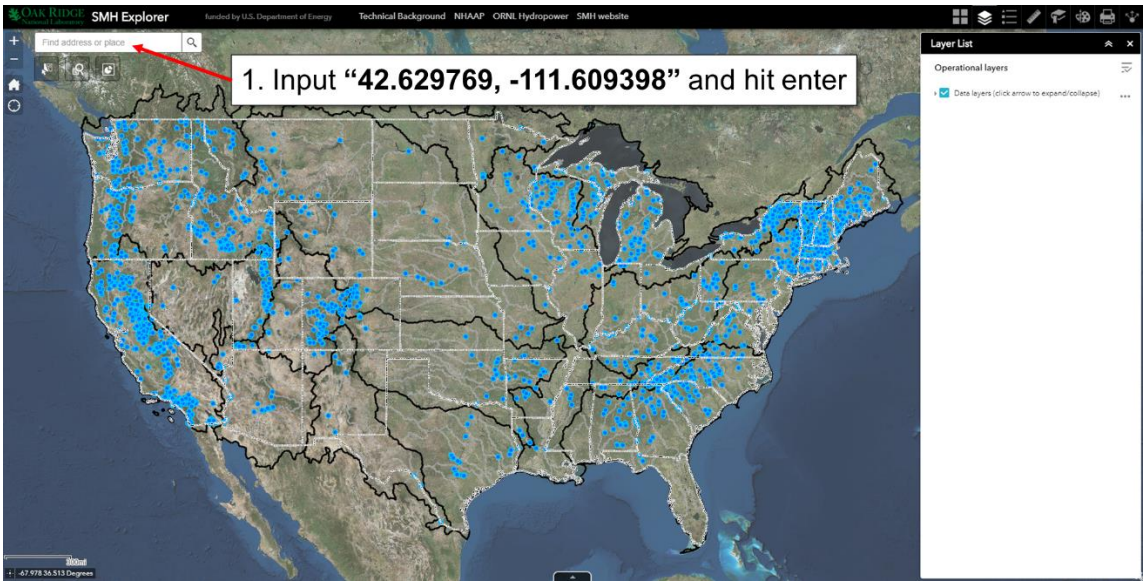

SMH Explorer
funded by U.S. Department of Energy
Technical Background
NHAAP
ORNL Hydropower
SMH website
Esri World Geocoder
Layer List
Operational layers
Attribute query _Query result
Data layers (click arrow to expand/collapse)
Dams (NABD)
Administrative boundaries
States
Counties
Energy
NERC Subregions
NHAAP power plants
Substations
Transmission lines
Watershed boundaries
HUC2 watersheds
HUC4 watersheds
HUC6 watersheds
HUC8 watersheds
Clustering results
Streams (50-25,000 cfs)
2. Close 'Query' box
3. Check 'Energy' data layer category and 'Substations' and 'Transmission lines' data layers
1. Close attribute table

Use Case 3: Project developer assessing module need at site and identifying similar sites

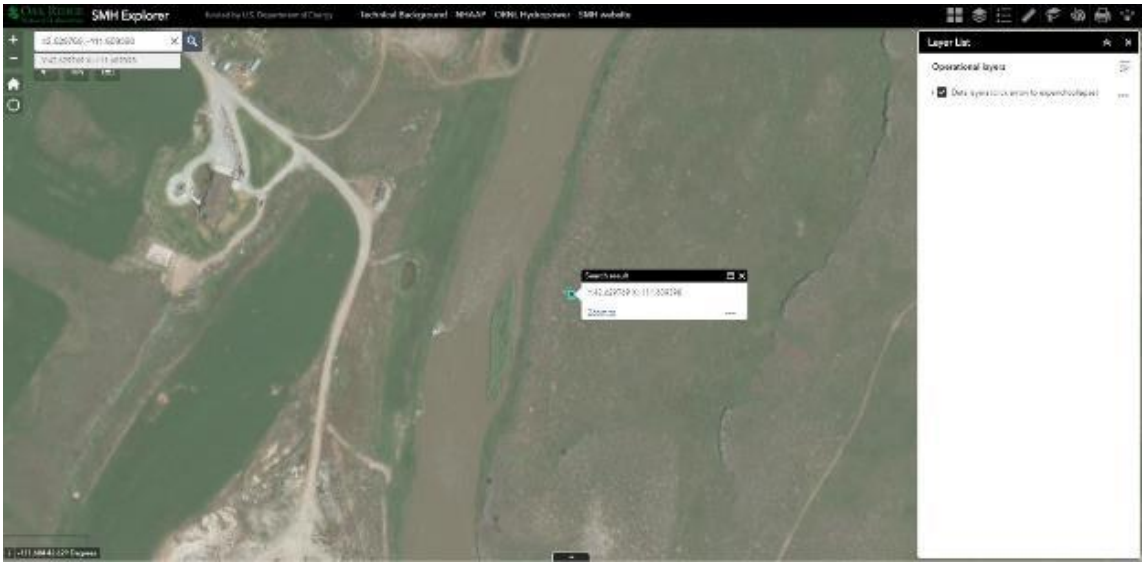
Suppose a project developer has a site it would like to consider for hydropower development and wants to know what modules may be needed, based on the environmental characteristics of the encompassing stream-reach. In this example, we pick an NSD site in the Pacific Northwest, one of the only regions in which NSD has been pursued in the past few decades and a location with significant NSD potential that was deployed within the Hydropower Vision capacity expansion model.

Locate Site

The first step requires the user to input the latitude and longitude of the site. In the upper left search box, input “42.629769, -111.609398” and hit enter.

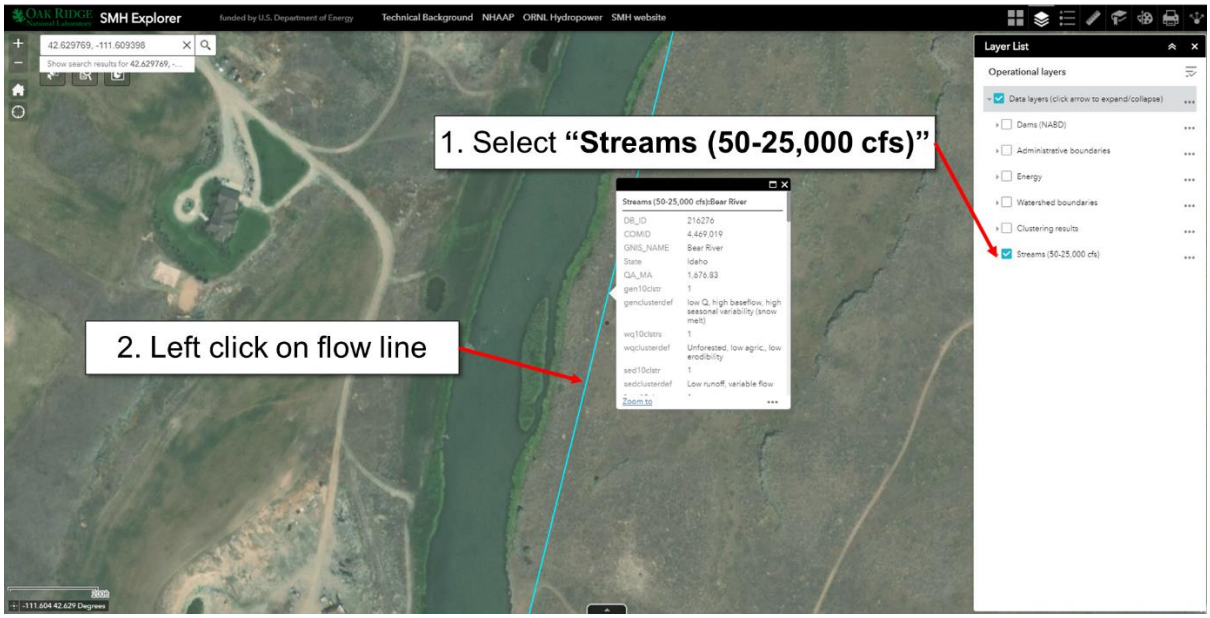


The user will be guided to the exact latitude and longitude coordinates, which in this case are for an NSD site with SMH-like attributes (low head, above 1 MW).



Explore Site Characteristics

Users can quickly get scoping-level information about a particular stream-reach. First, turn on the **Streams (50–25,000 cfs)** data layer from the **Layer List** and turn off all other themes/layers. Next, left-click on the stream-reach line that appears on the screen. A box will appear with individual attributes of the given stream-reach, including energy, environmental, biological, and landscape information. Note that if you have other layers selected (e.g., Administrative boundaries), you can click on the right arrow in upper right corner of the individual attribute box to get the stream-reach attributes.



Of particular interest in this example is the stream-reach site classification cluster identifier for each module. In this example: gen10clstr (generation) = 1, wq10clstrs (water quality) = 1, sed10clstr (sediment) = 1, fpsg10clst (fish passage) = 7, fnd10clstrs (foundation) = 7, and rec10clstrs (recreation) = 10. Referencing the accompanying Technical Background report linked at the top of the page, users can find

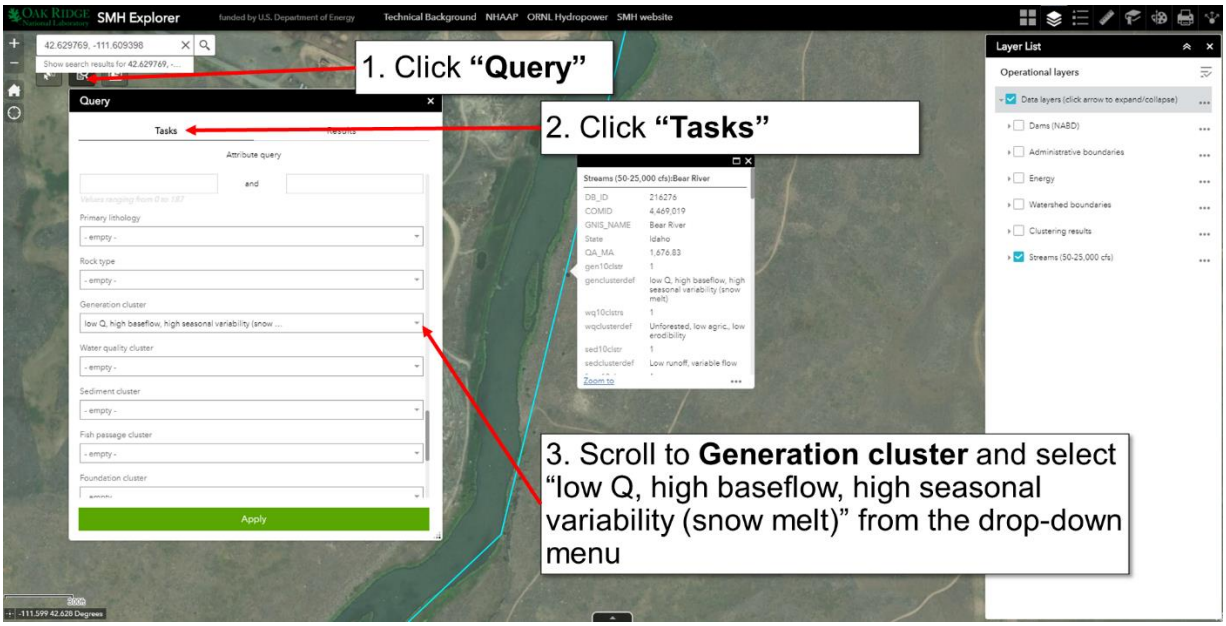
major defining characteristics of these cluster groups. Interpreting these characteristics and converting them into module design requirements is a part of ongoing research.

Module	Cluster number	Number of reaches	Defining characteristics	Locale
Generation	1	37,500	Low Q, high baseflow, high seasonal variability (snow melt)	Rockies, Sierras
Water quality	1	38,238	Unforested, low agricultural, low erodibility	Plains
Sediment	1	34,841	Low runoff, variable flow	Mountain West and Plains
Fish passage	7	94,507	Very low numbers of all major migratory species, low existing passage mitigation	Scattered nationally
Foundation	7	20,837	Moderately high power, high velocity, low erodibility, shallow bedrock	Foothill streams: Pacific NW, Rockies, Appalachians, Maine
Recreation	10	159,406	Rural, limited boat access, low gradient	Ohio and Mississippi River valleys, eastern Great Lakes, Great Plains

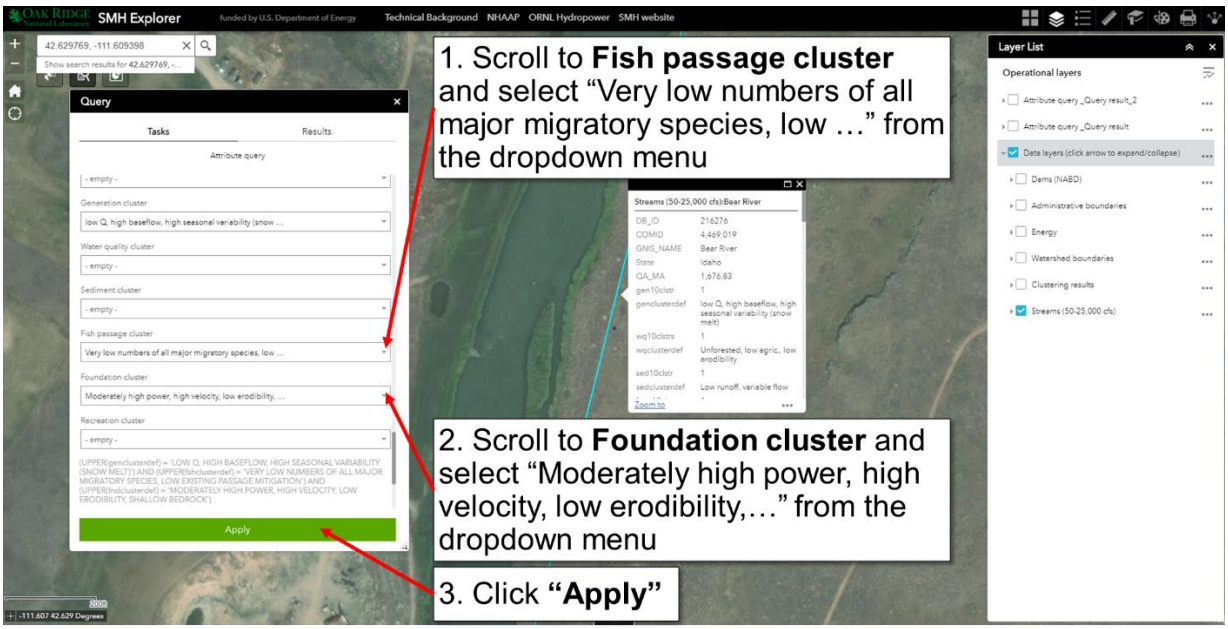
Find Similar Sites

With a known list of module clusters, the developer can now find other sites with similar attributes. This can be helpful for two reasons: (1) to identify additional locations with similar characteristics to develop multiple sites simultaneously and (2) to identify existing hydropower plants to see what types of mitigation measures they employ and explore the potential for using the same measures.

First, identify all stream-reaches with a similar generation cluster. Click the **Query** tool on the upper left hand side, then **Tasks**, then scroll down to the **Generation cluster** dropdown box. Click on **Generation cluster** to see the 10 possible generation module classifications, and select the description that matches that of the highlighted stream-reach, “low Q, high baseflow, high seasonal variability (snow melt)”.

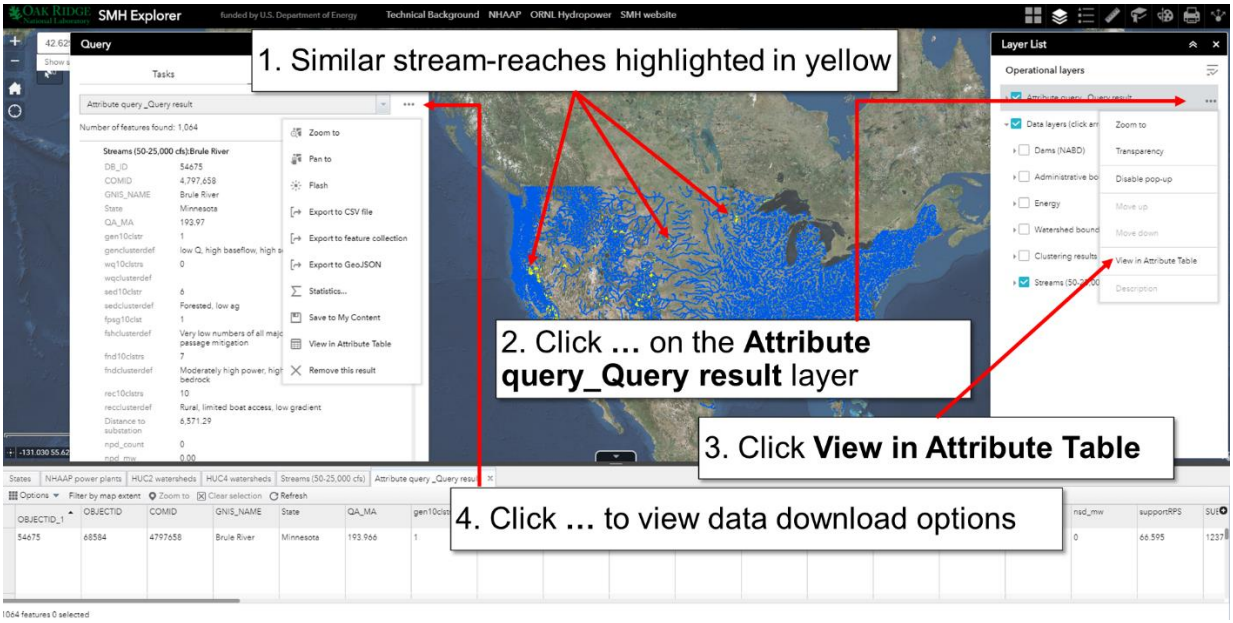


Additional filter criteria may be desired to identify a set of manageable potential sites for further analysis. To further filter sites by similarities in fish passage and foundation characteristics, scroll to **Fish passage cluster** and select "Very low numbers of all major migratory species, low existing passage mitigation", then scroll to **Foundation cluster** and select "Moderately high power, high velocity, low erodibility, shallow bedrock". Scroll down to the bottom of the **Query** box and click **Apply**. Note the **Intersect** feature is not required for this search (see Use Case 1 for use of **Intersect**) because the default **Query** is applied to all stream-reaches.



SMH Explorer will zoom out to the extent of the search results to show where other similar sites are located. In this case, 1,517 other stream-reaches have similar generation, fish passage, and foundation characteristics as the initial site. Users can zoom into these sites to explore them individually, or they can

view the aggregate statistics in the attribute table. In the attribute table, double-clicking on any row will take the user to a close-up view of the stream-reach, as shown in Use Case 2. Data are also available to download for users who wish to conduct their own analysis, as shown in Use Case 1.



Exploring site classification

As expressed through the previous Use Cases, SMH Explorer can be used to establish scoping-level insights into the type of foundation, generation, water quality, fish passage, recreation, and sediment modules that may be required if hydropower development is pursued on a stream-reach. Users are encouraged to interactively explore the existing classification system of stream-reaches by highlighting individual cluster layers, turning on the legend, and exploring national, regional, and local site classifications.