

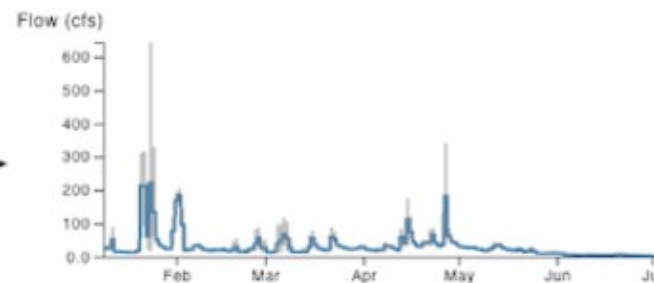
# Streamflow Monitoring with Machine Learning Modeling



Timelapse Photos



Machine Learning  
Models



Continuous Streamflow

*USGS and EPA ORD, R1, R2, R3, R5, R6, R7, R8*

# Background/ Problem



Streams are highly vulnerable to increases in droughts and floods.

It is very **difficult to assess impacts** due to the lack of gages.



**How can we get data in small streams?**

Images from time-lapse trail cameras & machine learning modeling

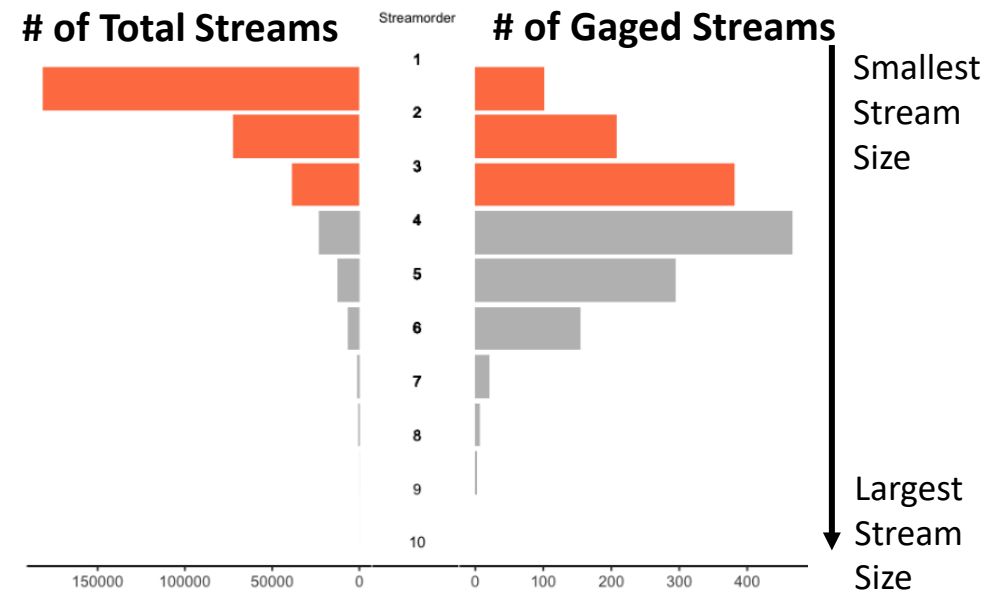


Figure 2: Relative # of USGS gages by stream order for the NE U.S. Headwaters in orange. Source: USGS NWIS and NHD+ Provided by: USGS.

Regular stream gages or hydrological equipment are **difficult to maintain and expensive.**



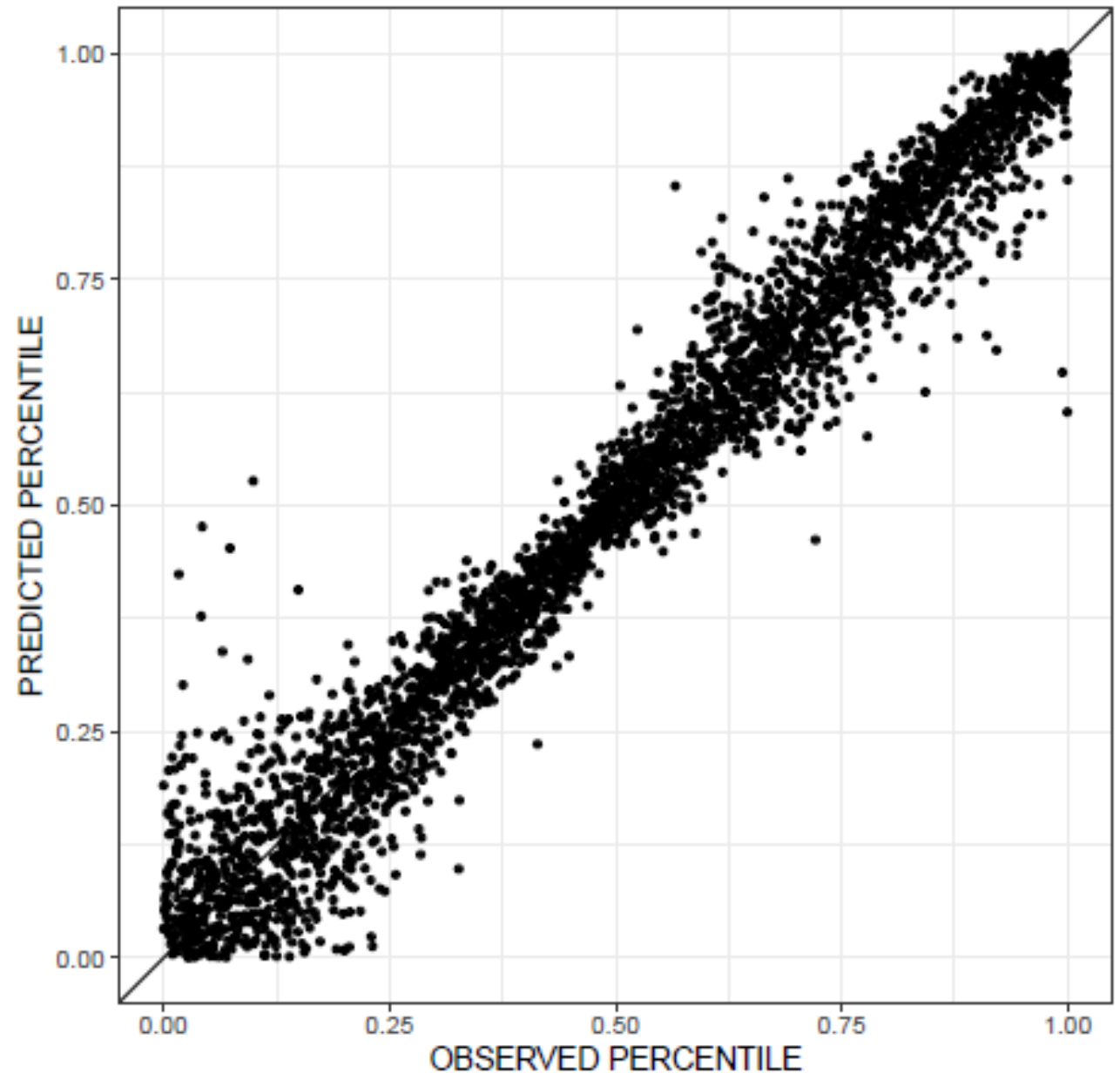
# Project Context

3 key things needed:



1. Input data for models
2. Database of images  
Flow Photo Explorer\*
3. Machine Learning models to  
estimate stream flow  
With local flow data\*  
Without local flow data

\*2018 Innovation Project Products



Machine Learning Modeling Results for Discharge\*  
Provided by USGS and Conservation Science Partners, Inc.



Photo Explorer | Sanderson Brook

BACK TO STATIONS MAP



Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community

Name	Sanderson Brook
Description	Sanderson
Coordinates	42.43641, -72.68598
Affiliation	US Geological Survey, S.O. Conte Anadromous Fish Research Laboratory

Photos Summary	
Period	Apr 1, 2021 to Jul 31, 2021
# Photos	10,795
Source	US Geological Survey, S.O. Conte Anadromous Fish Research Laboratory

[VIEW PHOTO METHODOLOGY](#)

Dataset Summary	
Period	Dec 31, 2019 to Oct 28, 2021
# Days	668
Variables	FLOW_CFS



Photo Timestamp  
Jul 27, 2021 10:45 PM EDT

Instantaneous Flow (Observed)  
15.4 cfs

PLAY Speed

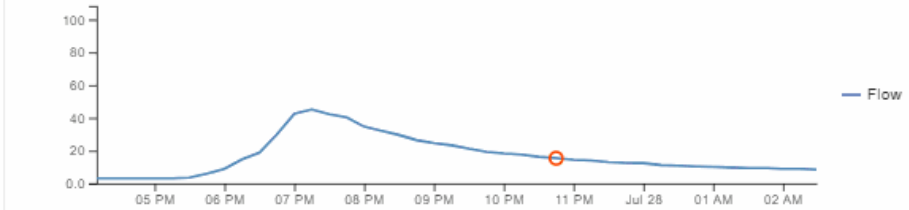
TIMESERIES DISTRIBUTION

Select variable  
Flow (cfs)

Timeseries for Selected Period

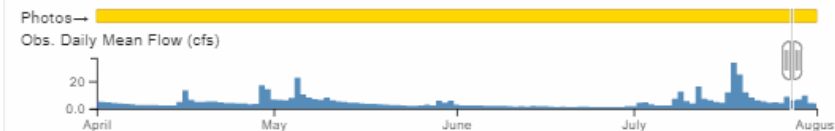
Mode: Instantaneous

Hover to view each photo.



Time Period Selected: Jul 27, 2021 - Jul 28, 2021 (1 days)

Click and drag to focus on a shorter period of time.

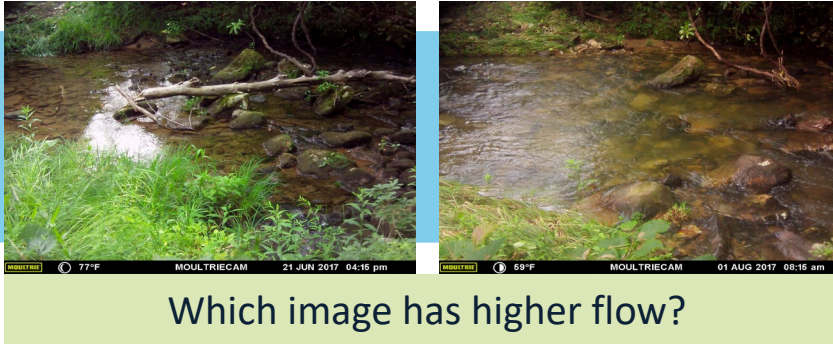


Flow Photo Explorer  
Free, public, interactive, web-based &  
integrated database platform.

# 2022-2023 Project Objectives & Approach

1. Test a novel human-assisted ranking-based machine learning model for estimating flow from photos **when hydrological data is not available** for a variety of different stream types

A person visually compares pairs of images and annotates which image has higher flow in each pair.



Can be done by stakeholders, citizen volunteers, Agency personnel, etc.

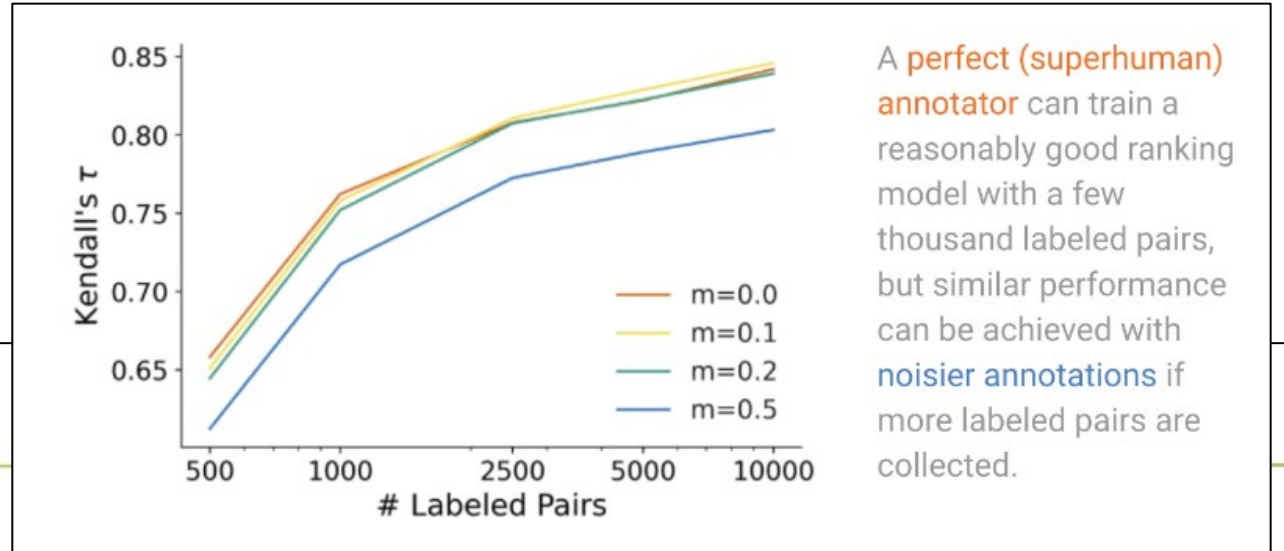
# 2022-2023 Project Objectives & Approach

## 1. Test a novel human-assisted ranking-based machine learning model

A person visually compares pairs of images and annotates which image has higher flow in each pair.



Based on these human annotations, a deep learning model will be trained in order to predict which image has more flow.



-20.9  
1st  
pctile



11.1  
25th  
pctile



157.6  
75th  
pctile



243.3  
99th  
pctile

# 2022-2023 Project Objectives & Approach

## 1. Test a novel human-assisted ranking-based machine learning model

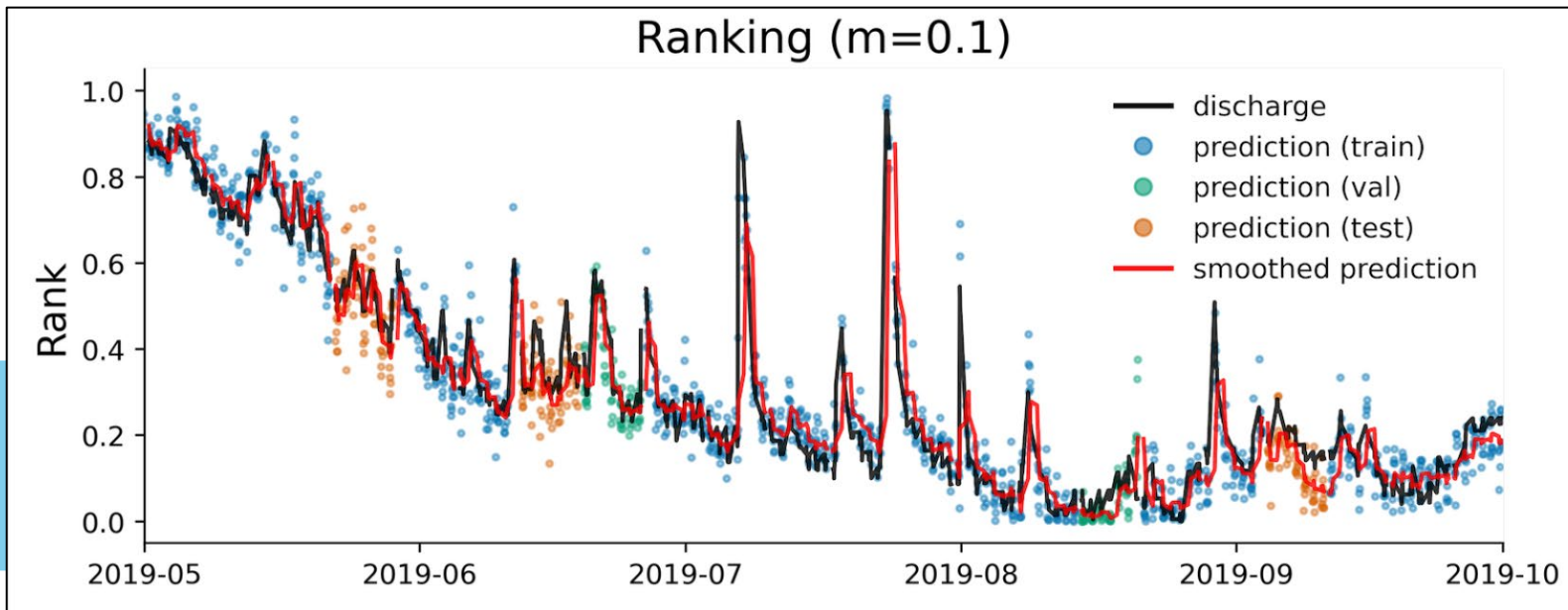
A person visually compares pairs of images and annotates which image has higher flow in each pair.



Based on these human annotations, a deep learning model will be trained in order to predict which image has more flow.



Use the fitted model to assign flow estimates to all images collected at a given location.



# Towards Continuous Streamflow Monitoring with Time-Lapse Cameras and Deep Learning

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## ABSTRACT

Effective water resources management depends on monitoring the volume of water flowing through streams and rivers, but collecting continuous discharge measurements using traditional streamflow gages is prohibitively expensive. Time-lapse cameras offer a low-cost option for streamflow monitoring, but training models for predicting streamflow directly from images requires streamflow data to use as labels, which are often unavailable. We address this data gap by proposing the alternative task of Streamflow Rank Estimation (SRE), in which the goal is to predict *relative* measures of streamflow such as percentile rank rather than *absolute* flow. In particular, we use a learning-to-rank framework to train SRE models using pairs of stream images ranked in order of discharge by an annotator, obviating the need for discharge training data and thus facilitating monitoring streamflow conditions at streams without gages. We also demonstrate a technique for converting SRE model predictions to stream discharge estimates given an estimated streamflow distribution. Using data and images from six small US streams, we compare the performance of SRE with conventional regression models trained to predict absolute discharge. Our results show that SRE performs nearly as well as regression models on relative flow prediction. Further, we observe that the accuracy of absolute discharge estimates obtained by mapping SRE model predictions through a discharge distribution largely depends on how well the assumed discharge distribution matches the field observed data.

## ACM Reference Format:

Amrita Gupta, Tony Chang, Jeffrey D. Walker, and Benjamin H. Letcher. 2022. Towards Continuous Streamflow Monitoring with Time-Lapse Cameras and Deep Learning. In *ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS '22)*, June 29–July 1, 2022, Seattle, WA, USA. ACM, New York, NY, USA, 11 pages. <https://doi.org/10.1145/3530190.3534805>

## 1 INTRODUCTION

Streamflow refers to the volume of water flowing through the cross-section of a river channel per unit time. Also known as discharge, streamflow varies due to natural processes like rainfall, snowmelt, and groundwater seepage, as well as anthropogenic activities like water withdrawals, irrigation returns, and land-use change. It is an essential quantity underpinning short-term and long-term water resources management decisions [13], flood and drought warning systems [26, 41], and aquatic ecosystem health assessments [8]. Streamflow is also a key indicator of climate change [1], and thus tracking the trends and other changes in the magnitude and timing of streamflow is important for understanding the impacts of climate change on water availability, natural hazards, and aquatic habitats [28]. In short, effective management and climate adaptation of our valuable water resources depends on the widespread availability of streamflow monitoring data.



# Research Objectives & Approach

## 2. Enhance Flow Photo Explorer

Add tools for users to supply input data for model training and to explore model predictions.

*\* New for this ROAR project*

Raw Flow Data and Images



Database



*\* Machine Learning Model*



Raw Data Viewer



*\* Image Ranking Tool*

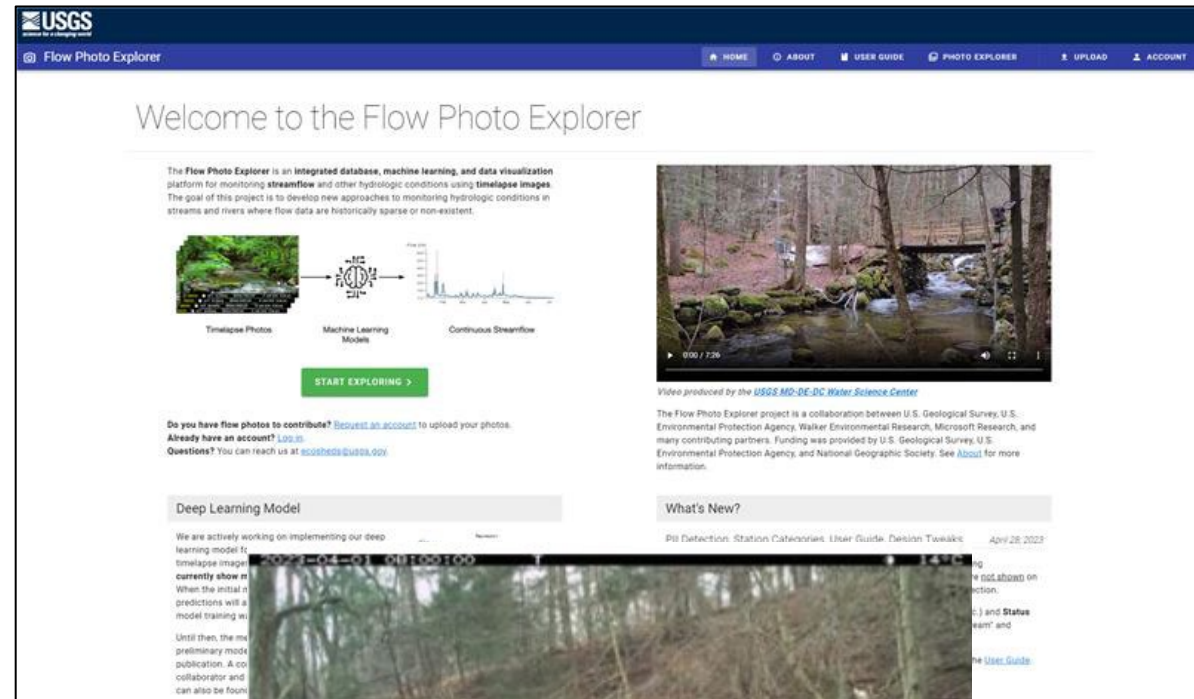


*\* Model Prediction Viewer for Flow Estimates*

# Latest Updates

1. **Redesigned Homepage**, includes "What's New", project video, and updated User Guide.
2. **PII detector**, will screen images, and prevent anything with confidence  $> 0.8$  for person or vehicle from appearing.
3. Stations have **Waterbody Type** and **Status** (*Active* vs *Discontinued*)

*Stream* / *Canal* / *Ditch* / *Tidal Stream* / *Wetland*  
*Lake, Reservoir, Impoundment* / *Estuary* / *Ocean* / *Coastal*



# Roles



Silvio O. Conte Research Laboratory &  
Contractors

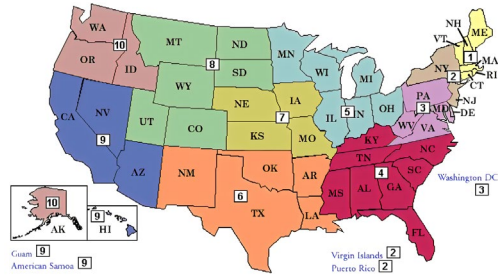
- Develop the machine learning modeling
- Enhance Flow Photo Explorer



- Participate in development
- Ensure protocols and equipment are in place
- Lead coordination and communication



# Roles



## State, Tribal, & Other Collaborators:

- Collect trail camera continuous photos and upload into Flow Photo Explorer
- Provide feedback on developing products
- Rank photos for flow status
- Optionally attend tri-weekly meetings





# Anticipated Results and Impact

1. Interactive data & modeling tool for widespread use
2. Removal of cost & expertise barriers for streamflow characterization
3. Information for stakeholder decisions across many applications:
  - Effects of hydromodifications or their removal (relating to BIL)
  - Effects of installed BMPS or restoration projects
  - WOTUS implications
  - Water quality criteria
  - Assessment decisions
  - Citizen Science and/or ecological studies
  - Tracking flow with extreme weather events/Climate change impacts

What's your use case?

# Participation

## Supplies Needed



Trail Camera  
with timelapse  
mode

Optional  
camera mount/  
Security  
housing



Memory card

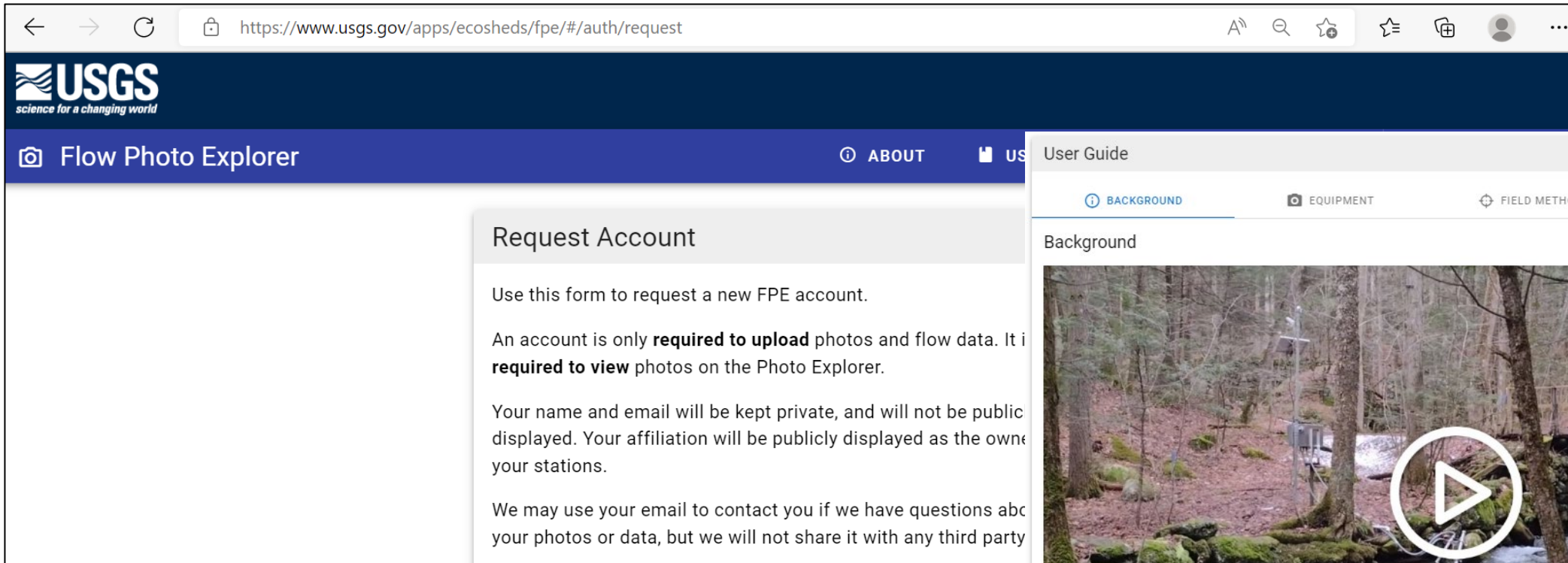
Batteries  
(or solar panel)



Cable lock



# Set up a Flow Photo Explorer account. Create a station.



The screenshot shows the USGS Flow Photo Explorer website. The browser address bar displays <https://www.usgs.gov/apps/ecosheds/fpe/#/auth/request>. The USGS logo is in the top left corner. The main navigation bar includes 'Flow Photo Explorer', 'ABOUT', and 'US'. The central content area is titled 'Request Account' and contains the following text:

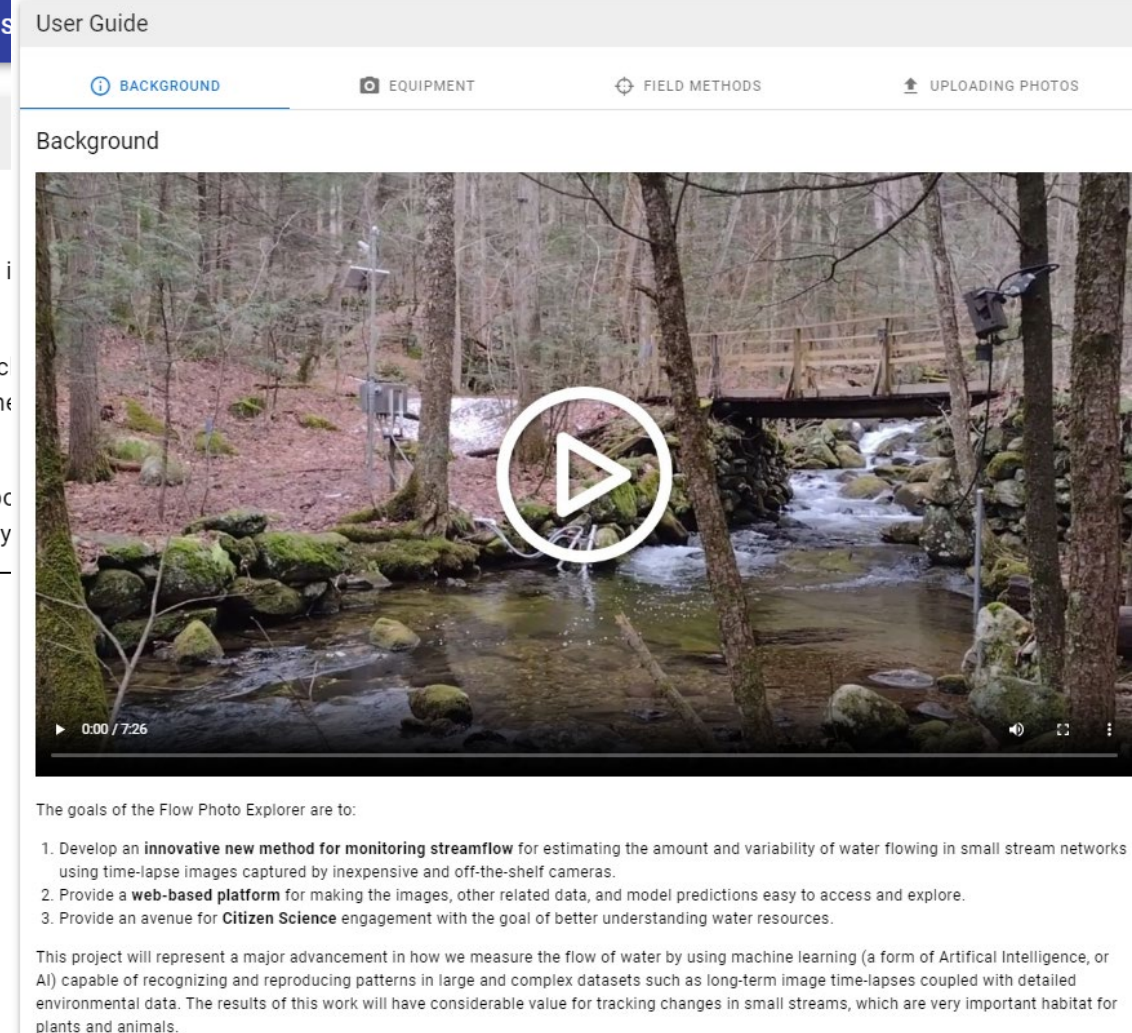
Use this form to request a new FPE account.

An account is only **required to upload** photos and flow data. It is **required to view** photos on the Photo Explorer.

Your name and email will be kept private, and will not be publicly displayed. Your affiliation will be publicly displayed as the owner of your stations.

We may use your email to contact you if we have questions about your photos or data, but we will not share it with any third party.

## Review the User Guide on FPE.



The screenshot shows the 'User Guide' section of the Flow Photo Explorer website. The navigation bar includes 'BACKGROUND', 'EQUIPMENT', 'FIELD METHODS', and 'UPLOADING PHOTOS'. The 'Background' section features a video player with a play button overlay. Below the video, the text reads:

The goals of the Flow Photo Explorer are to:

1. Develop an **innovative new method for monitoring streamflow** for estimating the amount and variability of water flowing in small stream networks using time-lapse images captured by inexpensive and off-the-shelf cameras.
2. Provide a **web-based platform** for making the images, other related data, and model predictions easy to access and explore.
3. Provide an avenue for **Citizen Science** engagement with the goal of better understanding water resources.

This project will represent a major advancement in how we measure the flow of water by using machine learning (a form of Artificial Intelligence, or AI) capable of recognizing and reproducing patterns in large and complex datasets such as long-term image time-lapses coupled with detailed environmental data. The results of this work will have considerable value for tracking changes in small streams, which are very important habitat for plants and animals.



# General Steps



1. Select a site location and install a trail camera.
2. Configure camera with ideal timelapse interval of 15 minutes. Note if daylight savings or standard time.
3. Download images after a period of time (usually 1-3 months) and upload with metadata to FPE website.
4. Participate in the pair-wise image ranking.



# Next Steps

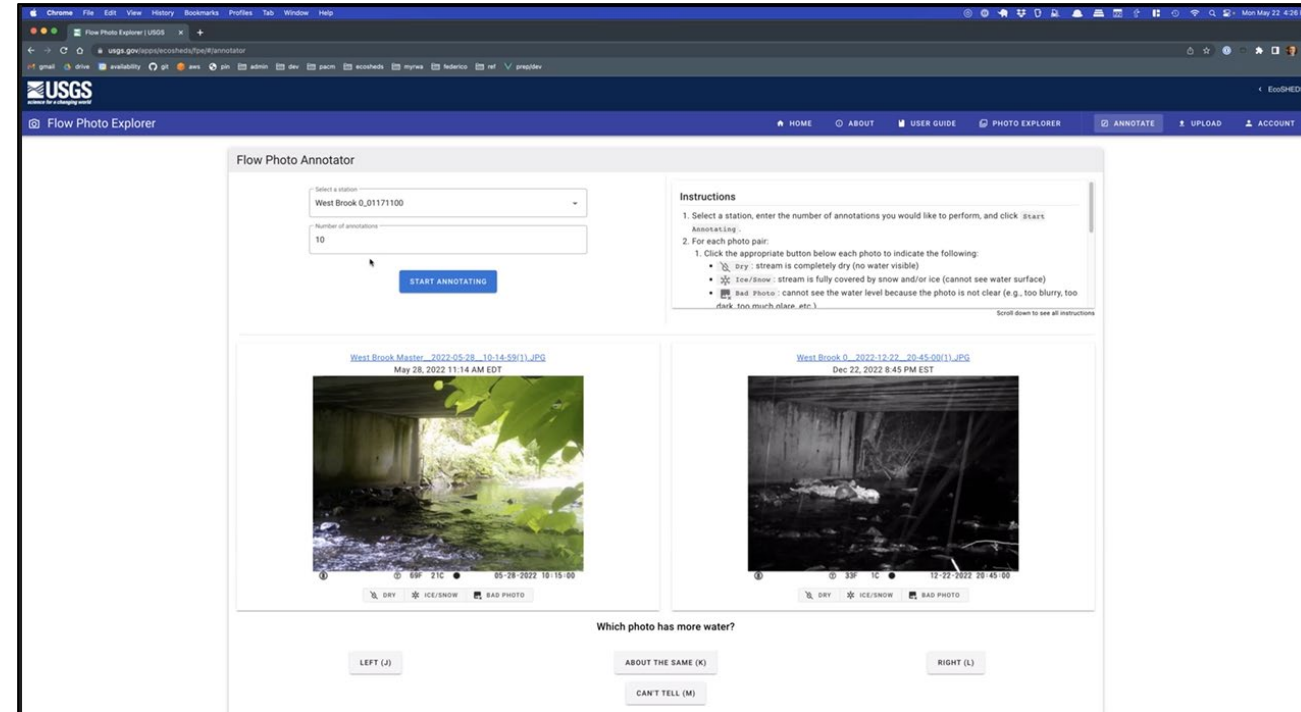
## 1. Near Future

- Ranking Tool on web site
- Testing ranking by different users

FPE does not currently show model predictions, only observed data, until the ranking tool is available and modeling complete for that site.

## 2. Long-Term

- Proposal for lakes and wetlands



Screenshot from Jeff Walker



Photos from Tetra Tech

**Contact Us**  
EPA Region 3

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**Flow Photo Explorer  
Website**



**Modeling Publication &  
Presentation**

