The stage height data is normalized to a mean height of 0. Training occurs for
6,777 images from the Clear Creek site, and 2,348 images from the Auglaize River site
were acquired for this study. Pre-processing in the form of rescaling and random
augmentation was performed on the images before use in the study.

Method
With the data retrieved, the prediction of river stage based on image information can be
formulated as a regression problem. Utilizing Transfer Learning and Image Regression,
we can modify a popular Image Classification model to fit this problem. VGG-16 is
chosen due to its stability in preliminary experiments (Norris et al., 2007) with most cost associated with site inspections and field experiments.

Therefore, a need arises in minimizing the cost for current stream gaging setups.

In addition to their vast stream gaging network, the USGS also maintains a network of
webcams located at many stream gage sites. The webcam images and existing stream
gage data can be utilized to create a new remote sensing method. This study will outline
a method for developing an Image Regression Stream Gaging model that predicts river
height from webcam data. This method will generate approximations of the actual river
height value for some site. These approximations should lie within relative accuracy of
the true height value. We wish to show that this process will create accurate stream gage
results for a sample of USGS sites given sufficient data.

Data
Many USGS stations include live webcam images of the nearby river. Each webcam
captures an image of the water body at a specific time interval. The camera angle, the
position of the camera along the river, and the resolution of the images captured vary
across the sites. Synchronizing the stream gage data and the image would be ideal to train
a DNN to fit a prediction on an image to the actual stage height value. As a constantly
maintained system, this system was able to capture data daily from March 2020 to
January 2021. At the end of this process, 2,861 images from the Milwaukee River site,
6,777 images from the Clear Creek site, and 2,348 images from the Auglaize River site
were acquired for this study. Pre-processing in the form of rescaling and random
augmentation was performed on the images before use in the study.

Conclusion
This study serves as a proof of concept that river stage can be directly
predicted from static images. The presented DNN regression model on
stream gage webcam data shows potential as a general non-contact method of
measuring river flow data, which minimizes the cost and hazards associated
with the current operation. As a data-driven approach, the supervised training
procedure can be universally applied to other sites without specific
knowledge, parameter tuning, or manual calibration of a specific site. This
study demonstrates the strength of machine learning if sufficient data are
available for the learning process.

Results
In the Clear Creek dataset, the minimum MSE score for the validation set is
0.0046 ft² after 20 epochs. For the Milwaukee River dataset, the final MSE is
0.0152 ft². On the Auglaize River, the final MSE score is 0.0116 ft². It is
clear that this model creates an accurate prediction with average error within
a few tenths of a foot. Therefore, the training process is effective at fitting the
image data to predicting water stage.

To show how the model is making water height predictions, Saliency Mapping is employed on the model. Saliency mapping can be utilized to
generate a “heatmap” of the most important pixels in an image. The average
saliency map for the validation set is shown in Figure 2. From the mean
saliency maps, the model tends focus on features with a clear correlation with
the water height including shorelines, static structures, and rocks.

The deployment set is a dataset containing 90% of images gathered after a set
date depending on the site. The goal of the deployment experiment is to
simulate a field deployment and evaluate how the model reacts over time.
Figure 3 shows a Real vs. Predicted values graph for the Training and
Deployment dataset. As expected, the deployment set predictions are not as
accurate as the predictions on the training set. However, all the deployment
set predictions still correlate with the general trend of the time series.

Introduction
The goal of water resource management is to develop methods to monitor and optimally
allocate water resources across the various entities that require the resource. Stream gages
are instruments that are typically capable of tracking the flow discharge and water height
in a river or stream. According to the United States Geographical Survey, average
operation cost was about $14,000 annually per typical continuous stream gage (Norris et al., 2007) with most cost associated with site inspections and field experiments.

Therefore, a need arises in minimizing the cost for current stream gaging setups.

In addition to their vast stream gaging network, the USGS also maintains a network of
webcams located at many stream gage sites. The webcam images and existing stream
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