WEB APPLICATION

USER MANUAL

Revision 1

February 11, 2025

SPEC hardware and software are designed, developed, and manufactured by Deep Analytics, LLC in Montpelier, Vermont.

Visit the public GitLab page for support and documentation.

gitlab.com/deepanalyticsllc/spec

Revision	Date	Summary
Release	February 4, 2025	--
Revision 1	February 11, 2025	Updated figures and directory names; Added missing log

Note to the User:

Setup PIV Edge Camera (SPEC) was a research and development project funded by Next Generation Water Observing System (NGWOS) of the United States Geological Survey (USGS). SPEC is a bank mounted camera system that uses Particle Image Velocimetry (PIV) to calculate the speed at which the water at the surface of a river channel is moving. If something about SPEC doesn't work right, or needs improvement, please let us know.

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CONNECTING TO THE SPEC

Once the SPEC is fully set up and the camera and IMU calibrations are complete, the system is ready to be deployed in the field. Follow these steps to get started:

1. Reboot the SPEC:
    - After completing setup and calibration, restart the SPEC. If you are using a desktop view, you can disconnect the HDMI, mouse, and keyboard at this point.
    - To reboot, simply unplug the SPEC from its power source and reconnect it. Ensure the SPEC is connected to a power source only during operation.
2. Connect to the SPEC Wi-Fi:
    - Once the SPEC powers back on, connect your device to the Wi-Fi access point you previously configured with an SSID and password.
3. Access the Web App:
    - Laptop: Your default browser should automatically open and display the login page.
    - Android Device: After connecting to the Wi-Fi, open a browser, and you should be redirected to the login page.
    - iPhone/iPad:
        - The iOS captive portal browser will pop up upon connecting to the Wi-Fi, displaying the login page.
        - **Note**: The iOS captive portal can slow down the app and may not redirect you to a standard browser. To bypass this:
            - Tap "Cancel" and select "Use Without Internet."
            - Open a browser and enter 192.168.0.1 in the address bar to access the login page.

Once directed you will be able to type in the username and password you selected previously for the webpage. Figure 1 shows the SPEC login page as viewed on different devices.

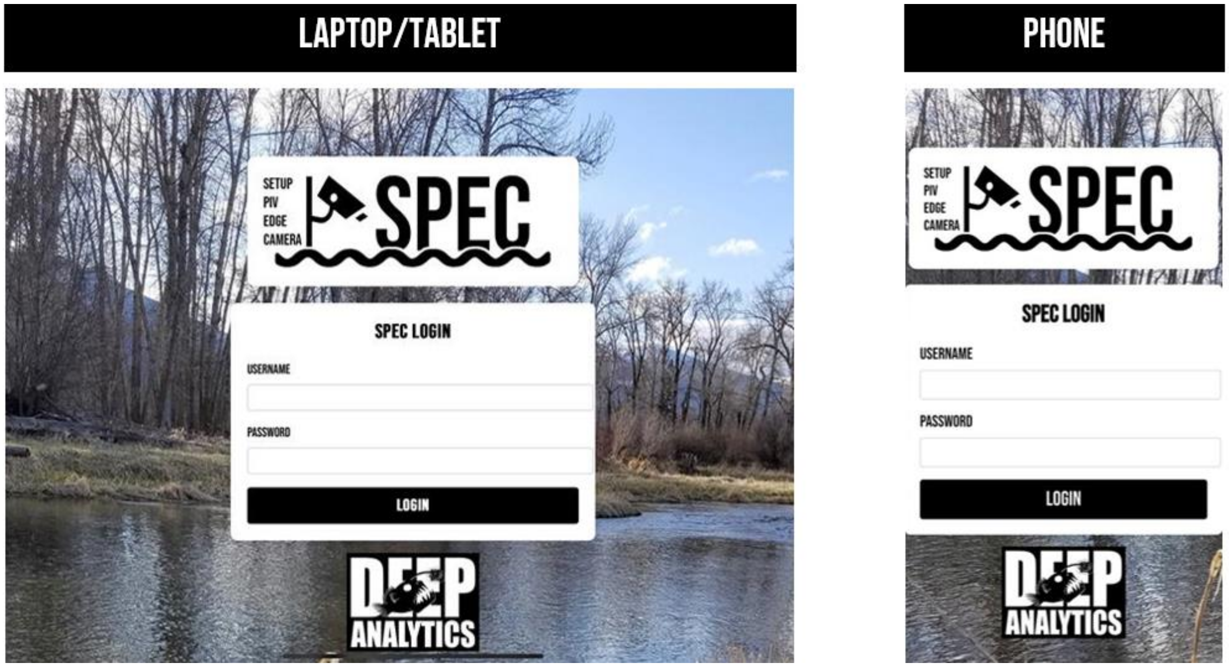

Figure 1. Login page as viewed on a tablet or laptop (left) and phone (right).

Calibration Splash

When you log in, you will be directed to a page called the calibration splash page. On this page, a message will be displayed with either **"DEVICE NEEDS TO BE CALIBRATED"** or **"LAST CALIBRATION: [date]"**, depending on whether the device has been previously calibrated to run PIV. Figure 2 shows the two possible calibration splash page views you will encounter.

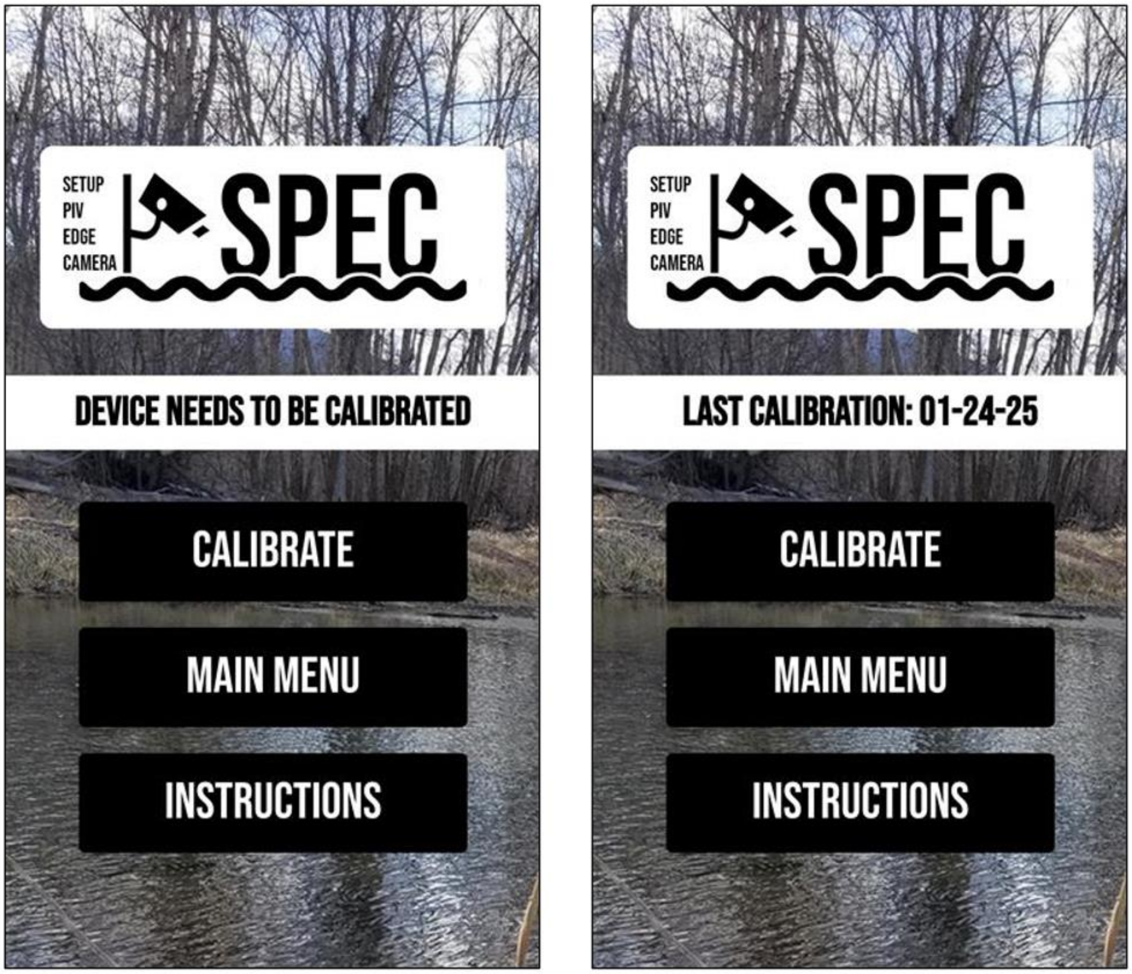

Figure 2 Calibration splash page display showing a non-calibrated system (left) and a calibrated system (right).

Calibrate

The **CALIBRATE** button will guide you through three calibration functions required for the PIV calculations. Each calibration function on the app will present instructions on a page about how to use it. Upon completion of a calibration function, the app prompts you to complete the next one.

There are three main calibration pages:

- **Trapezoid Calibration:** Define the area of interest for PIV.
- **PIV Params Configuration:** Set the parameters for your PIV calculations.
- **Mask Calibration:** Define the area to exclude from PIV analysis.

The same instructions displayed here will also be on the pages before the calibration functions, as well as on the Gitlab for review if needed. To see further information on this process go to the Setup and Calibrations section.

It is recommended that if you have never calibrated the system or want to recalibrate the system, press the **CALIBRATE** button and walk through the steps in order.

MAIN MENU

The first page you will come to is the **MAIN MENU** splash page. On this page, you will have three options to navigate to other sections and a logout button. Additional instructions on using the main menu are provided on that page. Below are the available options and their corresponding functions:

UTILITIES

The utilities page provides services for you to use that are not related to PIV or calibration. Below are the different options available in this section:

SITE INFO

Site Info allows you to manage details about the PIV field site, including:

- **Site Name**: Assign a name to the field site for identification.
- **Site ID**: Assign an ID to uniquely identify the field site.
- **Operator**: Specify the operator's name for tracking purposes.
- **Site Comments**: Add any relevant notes or comments about the field site that can be stored for future reference.

LIVE VIDEO

The Live Video option allows you to view the camera's live feed without any processing. This is simply the raw, undistorted video as seen by the camera.

DATA MANAGEMENT

The Save Data page allows you to save all data to a USB drive, delete data, whether from tests or main PIV runs, and unmount the USB drive. The process works as follows:

- The system will detect if a USB drive is connected.
- If found, it will copy all files from the **save_data** folder, which includes all PIV runs and test files.
- A directory called **Offsite_Processing** will also be saved. This directory contains a script that allows you to reprocess the data offsite if needed.
- You then have the option to delete specific directories.
- ***Important note: to avoid writing a "dirty" bit to the USB drive that will prevent its further use, press the Unmount USB drive button prior to removing the USB drive.***

VIEW LOGS

The View Logs page provides four log options for troubleshooting and diagnostics:

- **App Logs**: Logs related to the overall application performance.

- **PIV Logs**: Logs specific to PIV operations and calculations.
- **Gstreamer Logs**: Logs for the Gstreamer process that streams the camera feed.
- **Loopback Logs**: Logs for the loopback process used to create virtual cameras.
- **Diskspace Logs**: Logs for the disk space manager, will tell what files are deleted if disk becomes full.

CHECK DISK SPACE

This button will display the remaining disk space and the date you will run out of storage based on the size of the last PIV run. If there is no PIV run or the run is still happening, the time until run out will not display. Once the disk space limit is reached (default is 4 GB left), the system will begin deleting the oldest datasets one at a time until there is 4 GB free.

REBOOT SYSTEM

If the system is not functioning correctly (e.g., camera is not on, or errors are occurring), you can use the **REBOOT SYSTEM** option to restart the system. Rebooting can often resolve issues by giving the system a fresh start. All services are programmed to restart automatically after a reboot. If the system starts up incorrectly, a reboot may be required to get everything working properly.

SETUP AND CALIBRATIONS

This page on the main splash will provide the three processes that you need to calibrate your system for PIV calculations.

TRAPEZOID CALIBRATION

This page is used to select the region of the image that you would like to run a PIV calculation. This is not a mask but the area that will be transformed to give a bird's-eye or nadir view of the bank-mounted image for the PIV algorithm to run correctly.

Roll

On this page, you will see a bubble level at the top displaying the roll angle of the SPEC based on the IMU. The roll angle is the angle you tilt the device side to side – see Figure 3 for a visualization of the roll concept. You want the roll angle to be 0°, in other words you want the camera to be level, as other values may introduce errors in PIV calculations. The app provides the bubble level to zero the roll value – see Figure 4.

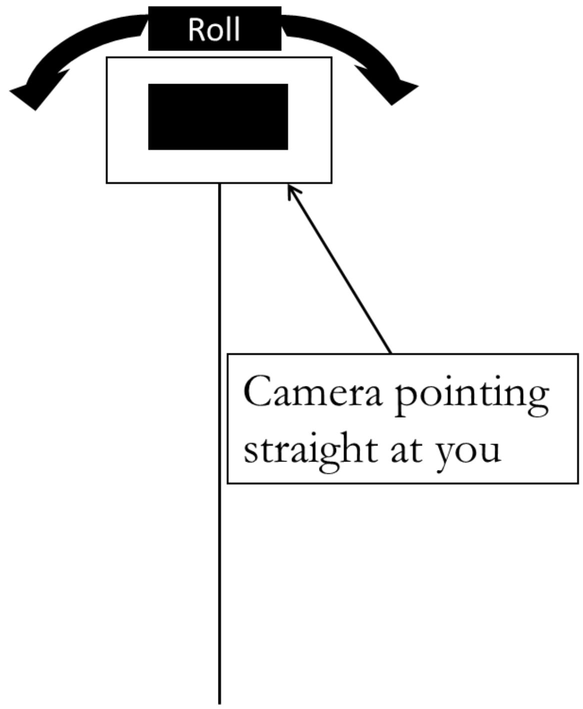

Figure 3 Graphic describing camera roll.

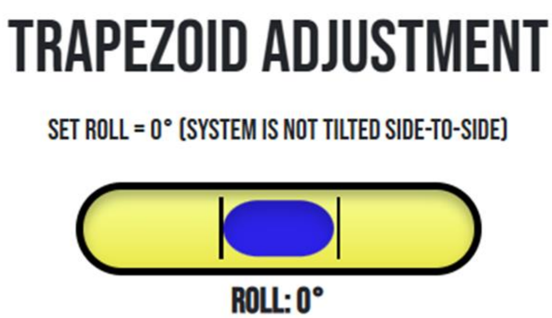

Figure 4 Bubble level display on Trapezoid page, should be 0° for PIV.

Trapezoid View

The next item displayed is a live video with a trapezoid overlaid on it. The area inside the trapezoid will be used for PIV calculations. As you incline the camera up and down, the trapezoid's left and right sides adjust based on the IMU's position relative to nadir. At nadir (pitch=0° or camera pointing straight down), the trapezoid appears rectangular, but as the incline (pitch) approaches 90°, the sides converge as depicted in Figure 5.

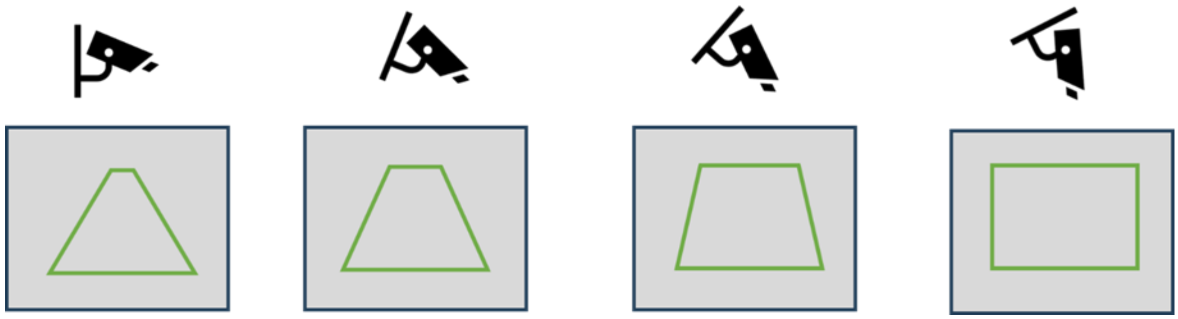

Figure 5 Graphic demonstrating how the sides of the trapezoid changes with the angle of the camera.

To move the trapezoid, use the sliders below the live view – see Figure 6. Adjusting one point recalculates the trapezoid and resets all points. Aim to include as much of the river or PIV region of interest as possible within the trapezoid. Banks or other objects can be masked out later.

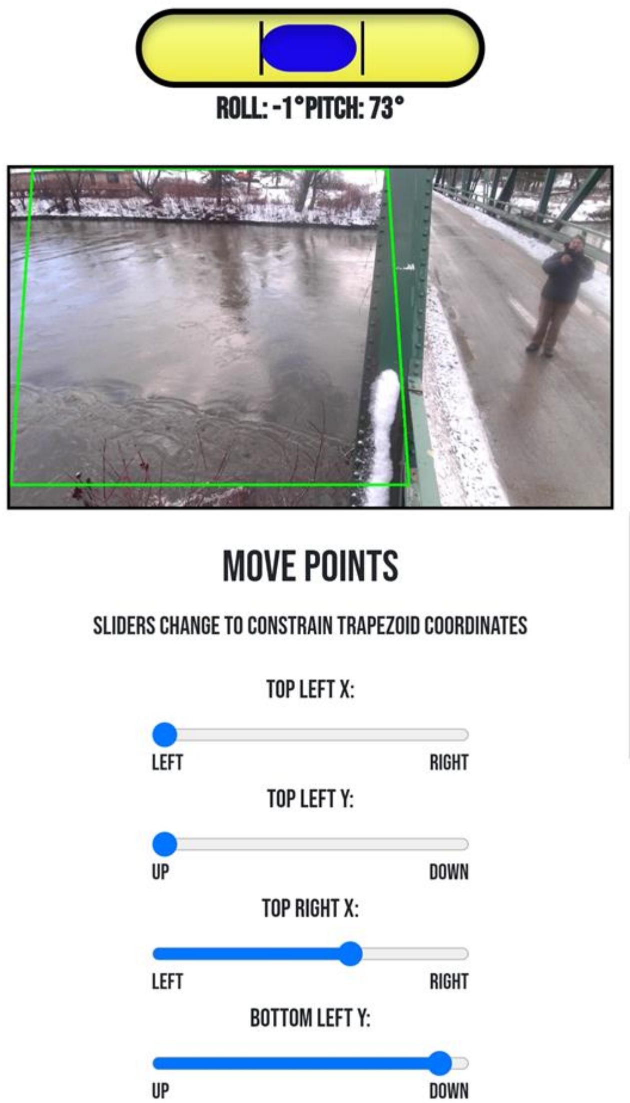

Figure 6 Trapezoid slider display.

Once satisfied with the trapezoid, click SHOW TRANSFORMED IMAGE to view the transformed image. Ensure the desired area for PIV is visible.

Repeat the following steps as needed:

- Adjust camera tilt (up-down angle)
- Set roll (side-to-side angle) to 0°
- Move trapezoid points
- Show transformed image

When finished, click SAVE POINTS to save the trapezoid configuration.

PIV PARAMETERS

The PIV PARAMETERS page is used to input all the parameters needed for your specific PIV situation. These parameters influence the PIV outputs and should be adjusted carefully [1] [2]. The first five parameters in Table 1 are the most important and require special attention.

For the most part, parameters that come after "Pixel Size Ground Sampling Distance" in the table can be left at the default values. However, the **Desired Output Vector Spacing** and **Capture Interval** are important parameters and if after running a test, you are not satisfied with the results, think about adjusting these parameters to assist in collecting good data. There are times that the output spacing is too large or small for a particle to be properly tracked and thus no output is produced. Similarly, the capture interval must allow enough time for features to move a measurable distance (i.e., number of pixels between frames). To get a good understanding of this look into the TIPS feature of TRiVIA [1][3].

Adjust the parameters as needed. Once satisfied, click Update Configuration to save your settings

Table 1. PIV parameters and their descriptions.

PARAMETER	DESCRIPTION
DESIRED OUTPUT VECTOR SPACING	This is the spacing the user wants between vectors in the PIV outputs, this variable affects the output a lot and is key for setting up the system. E.g. input of 1 refers to 1 meter output spacing.
CAPTURE INTERVAL	This is the time between each image capture, e.g. for 10 frames a second user should put 0.1s.
DURATION OF IMAGE SEQUENCE	This is the time you want to capture images for each PIV run. E.g. input of 10 is 10 seconds of image capture.
TIME BETWEEN PIV RUNS	This is the time the system waits between PIV runs. E.g. 15 tells the system to run every 15 minutes.
SENSOR HEIGHT ABOVE WATER	This is the height in meters above the water that the camera stands. Measure from the camera straight down to the water. E.g. input of 1 is 1 meter above the river.
PIXEL SIZE GROUND SAMPLING DISTANCE	This is calculated in the backend based on the sensor height. It is the ground sampling distance of the camera and cannot be modified by the user. It is calculated in meters.
MIN VELOCITY	This is the minimum velocity that is used to post-process the initial PIV output, anything less will be filtered out. Default 0.01 m/s
MAX VELOCITY	This is the maximum velocity used to post-process the initial PIV output, anything more will be filtered out. Default 5 m/s.
STANDARD DEVIATION THRESHOLD	This is the maximum standard deviation used to filter outliers from the initial PIV output. Default is 4
LOCAL MEDIAN THRESHOLD	This is the local median value used to filter outliers from the initial PIV output. Default is 1.5 m/s.
VECTOR INFILLING	Yes: Fill missing vectors in No: Do not fill missing vectors in
VECTOR SMOOTHING	Yes: Smooth vector field No: Do not smooth vector field
MASK	Yes: If plan to use a mask No: If no mask Disclaimer: Yes should almost always be used.

MASKING OPTIONS

The next step in the calibration process is masking. Masking allows us to exclude parts of the transformed image that are not the water, so that the PIV does not run on stationary areas. This can speed up the calculations depending on how much is masked out. Note that you want to mask out everything except the river and include as much of the river as possible to maximize the area with PIV output.

Masking Methods

The first page you will come to when you hit next is a page that asks if you want to digitize or generate a mask – see Figure 7.

Figure 7 Masking options splash page.

DIGITIZE MASK

This is a user-selected custom mask. You will be shown a transformed image and just need to click around the area you want to include in your mask. Start from the top right of the polygon you wish to create and proceed counterclockwise. This will show green dots where you click, and once finished, click **SUBMIT POINTS**. This will perform the masking process in the backend and show you three images: the original transformed image, the binary mask, and the final masked image – see Figure 8 for an example. If you like the mask, hit **SAVE MASK PATH**. The mask will be saved and then used in all following PIV calculations until a new mask is saved. Figure 9 shows an example of the masking process for a river example.

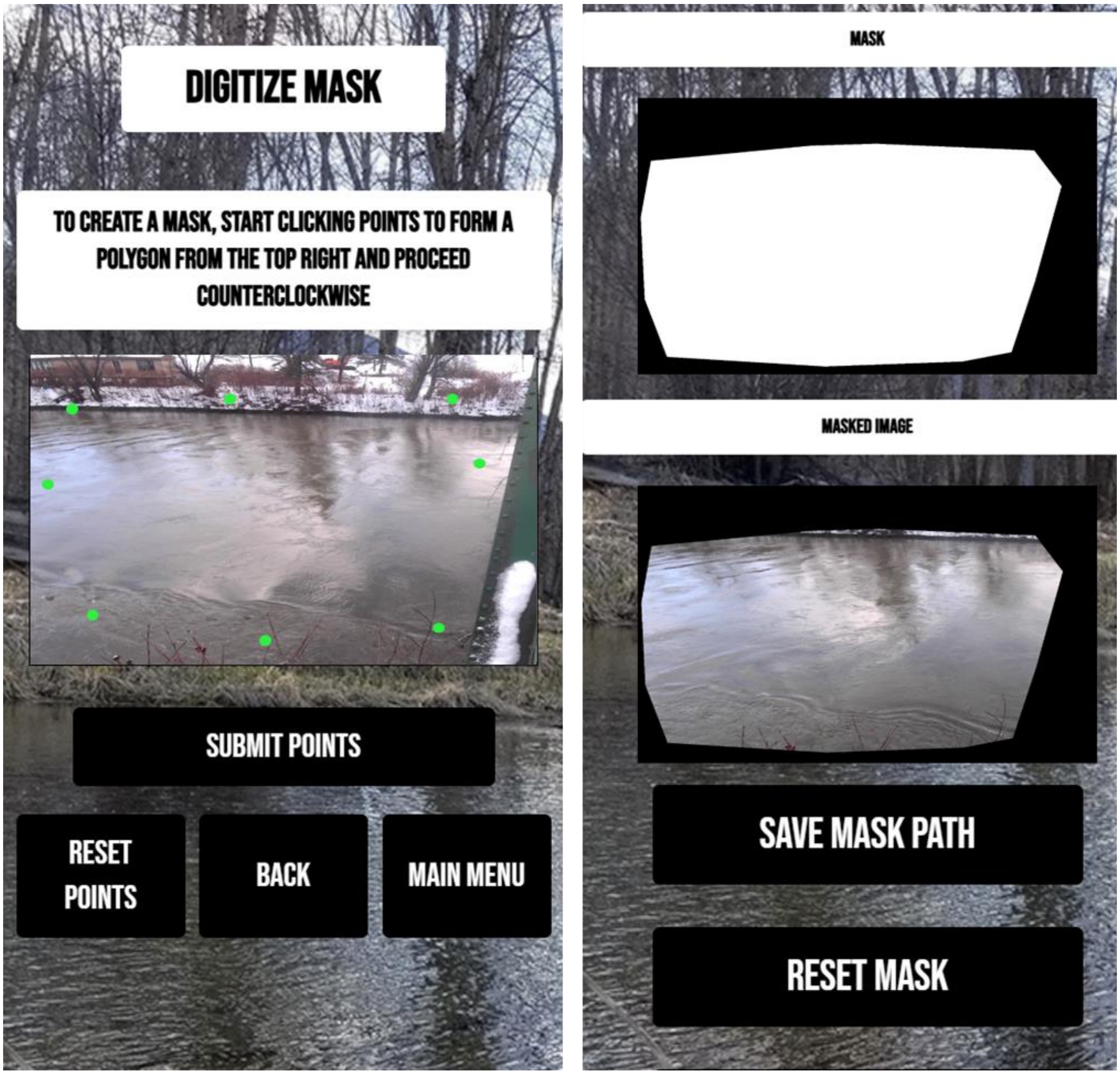

Figure 8 Digitize mask example.

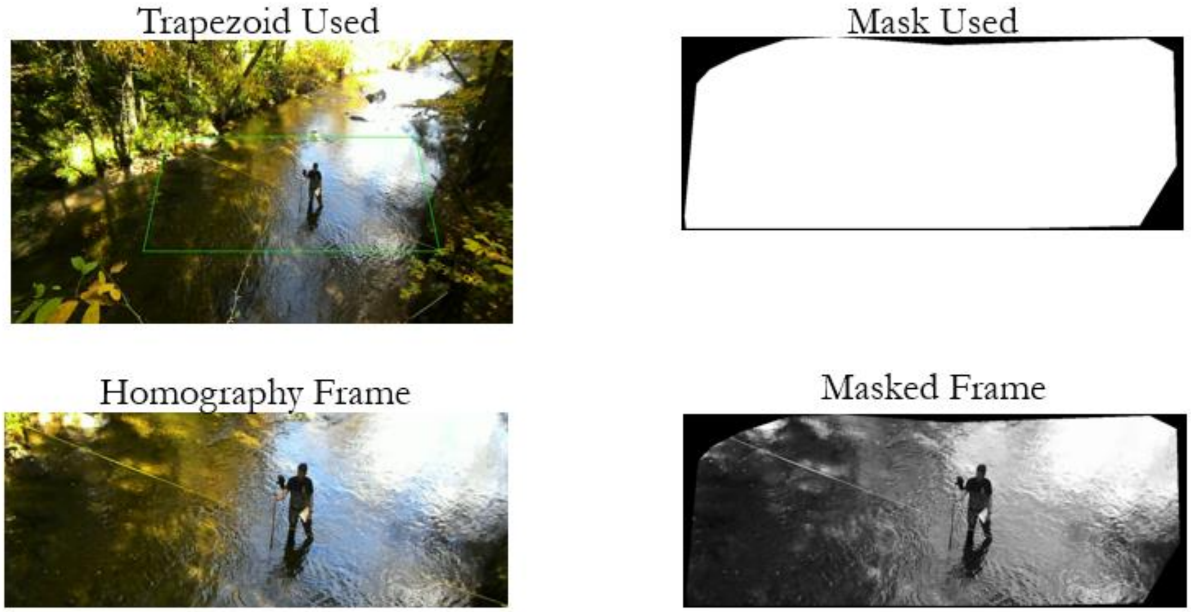

Figure 9 Masking out riverbanks at a field site.

GENERATE MASK

This is an automatic masking process. It creates a mask based on the largest contoured area. If your river is distinctly a different contour than its surroundings, then this is a good option. Once done finding the largest contoured area, it will display three images: the original transformed image, the binary mask, and the final mask. If you like the mask, hit **SAVE MASK PATH.** The mask will be saved and used in all subsequent PIV calculations until a new mask is saved.

CAMERA PARAMETERS

This page is only intended to be set up once, as it is specific to the camera hardware and nothing about the site itself. This page and the camera calibration (as detailed in the set up documentation) must be completed prior to going out to a field site.

This is the place where you put your camera specs: focal length, camera sensor height and width, max array availability, reduced resolution, original sensor pixel size. All these should be specs that you can find online or with your camera or camera sensor datasheet.

PIV FUNCTIONS

This page is where you can view PIV results, run tests, or finally run the main continuous PIV function.

RUN TESTS

This button performs a single PIV calculation based on the selected parameters. This is useful for previewing how PIV outputs will look for the current system configuration.

- Each test generates a new folder of data, enabling comparison between test results.

- During the test, you will be directed to a waiting screen that provides live updates on the calculation process – see Figure 10.
- After completion, you will be redirected to the results page to view the most recent test files.

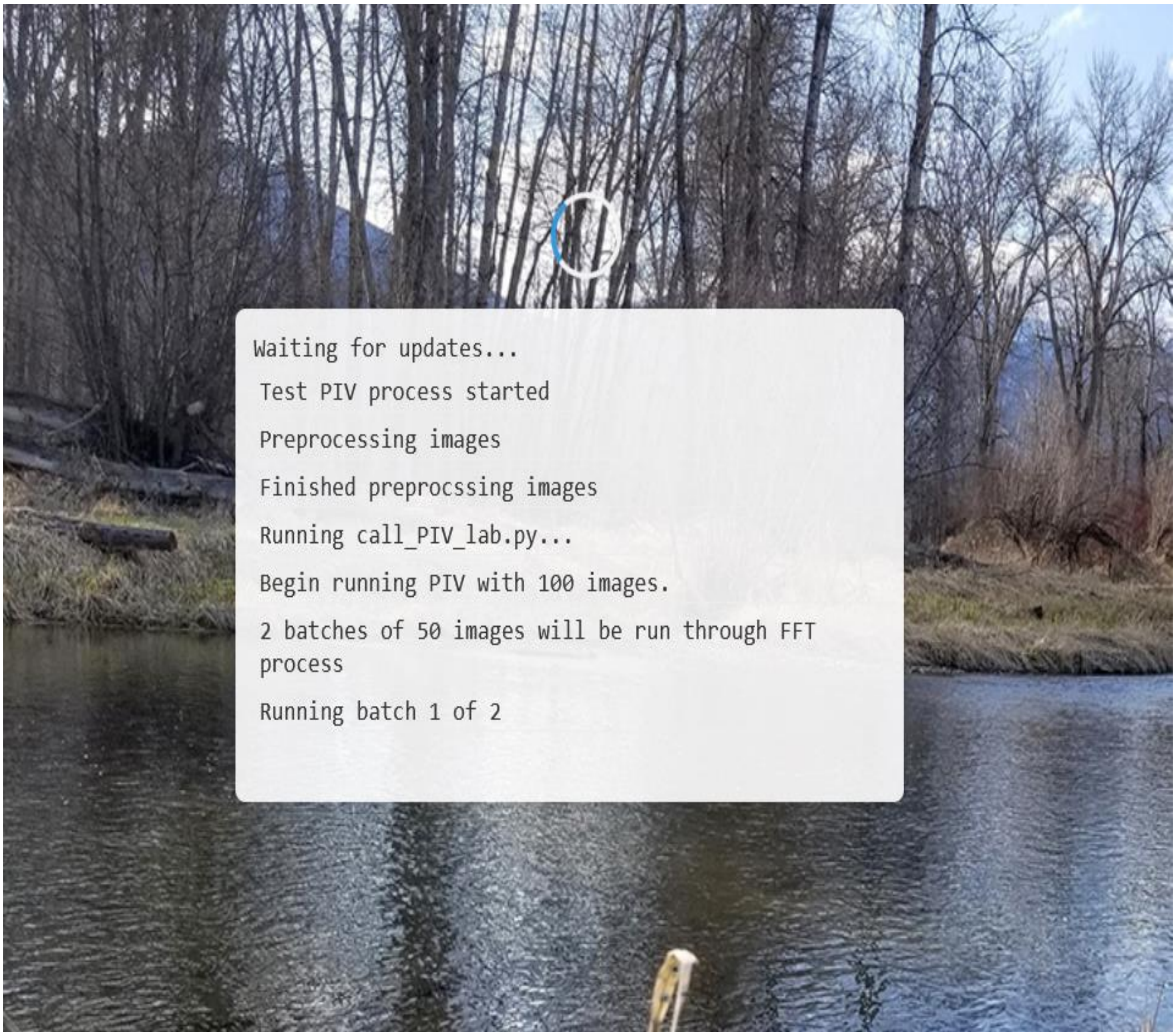

Figure 10 Example of the waiting screen when running a PIV test.

RUN PIV

This button is used for continuous PIV calculations over an extended period. Ensure all parameters are configured correctly before starting.

- A verification page will appear, asking you to confirm and manage test files to optimize disk space.
- You can choose to save test files to a USB or delete them to free up space.

- The system will estimate how long it can run before disk space is full, based on the size of the last test file.
- Once PIV starts, a yellow banner will appear across all pages indicating that PIV is running.

After starting, you will be redirected to a page to view results or return to the main menu.

RESULTS

The Results page allows you to view data stored in the **save_data** folder. By default, it displays the most recent PIV calculation.

- Data are organized by configuration date and run date – see Figure 11.
- Test files include "test" in their filenames and contain a single run.
- Main PIV configurations may include multiple runs with selectable dates.

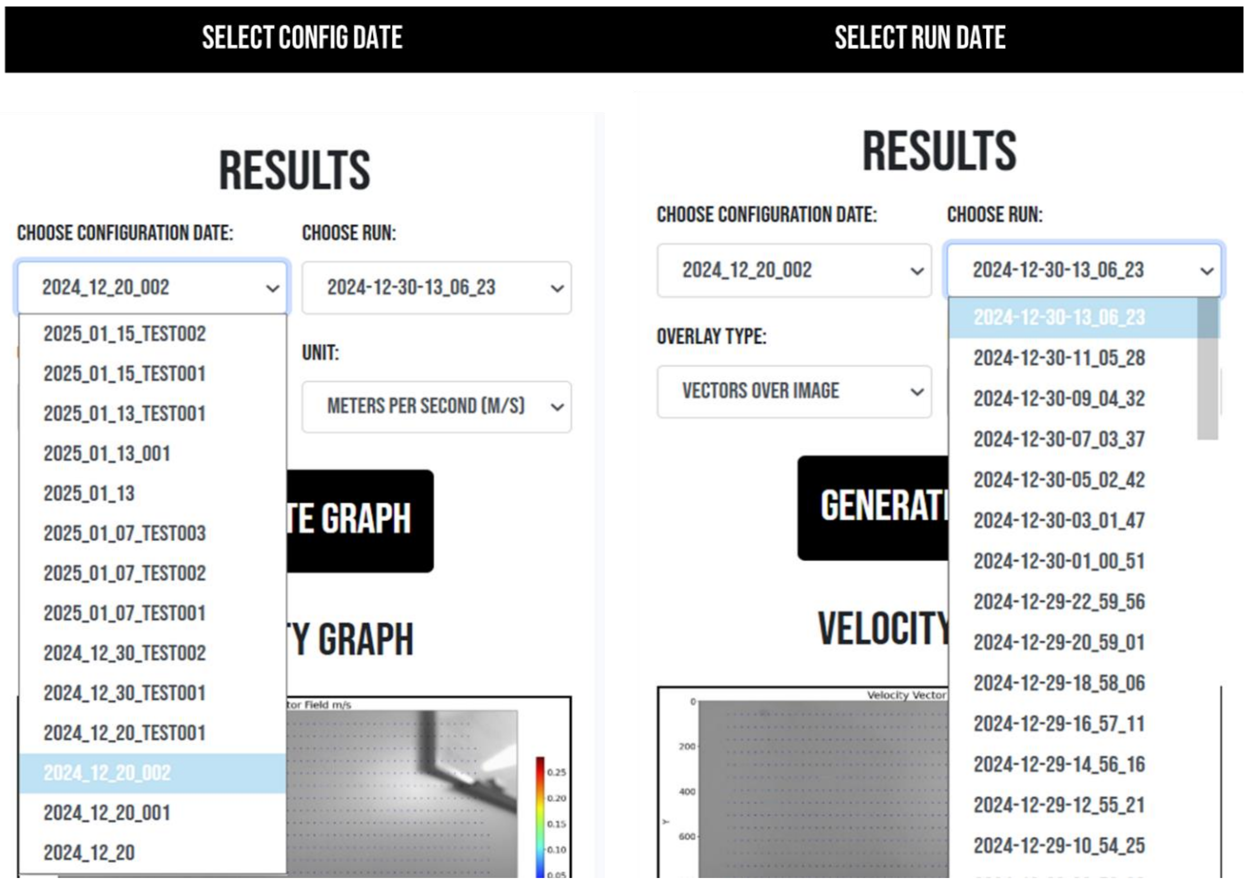

Figure 11 An example of how to select the configuration and PIV run to view its outputs.

You can select the output type and display options:

- **Overlay Type**: Choose between vectors displayed over the river image or over the magnitude color map of the vectors.

- **Unit Type**: Select between meters per second or feet per second.

Once you configure these options, click **GENERATE GRAPH** to display the results. This process may take a few seconds. See Figure 12 for example outputs.

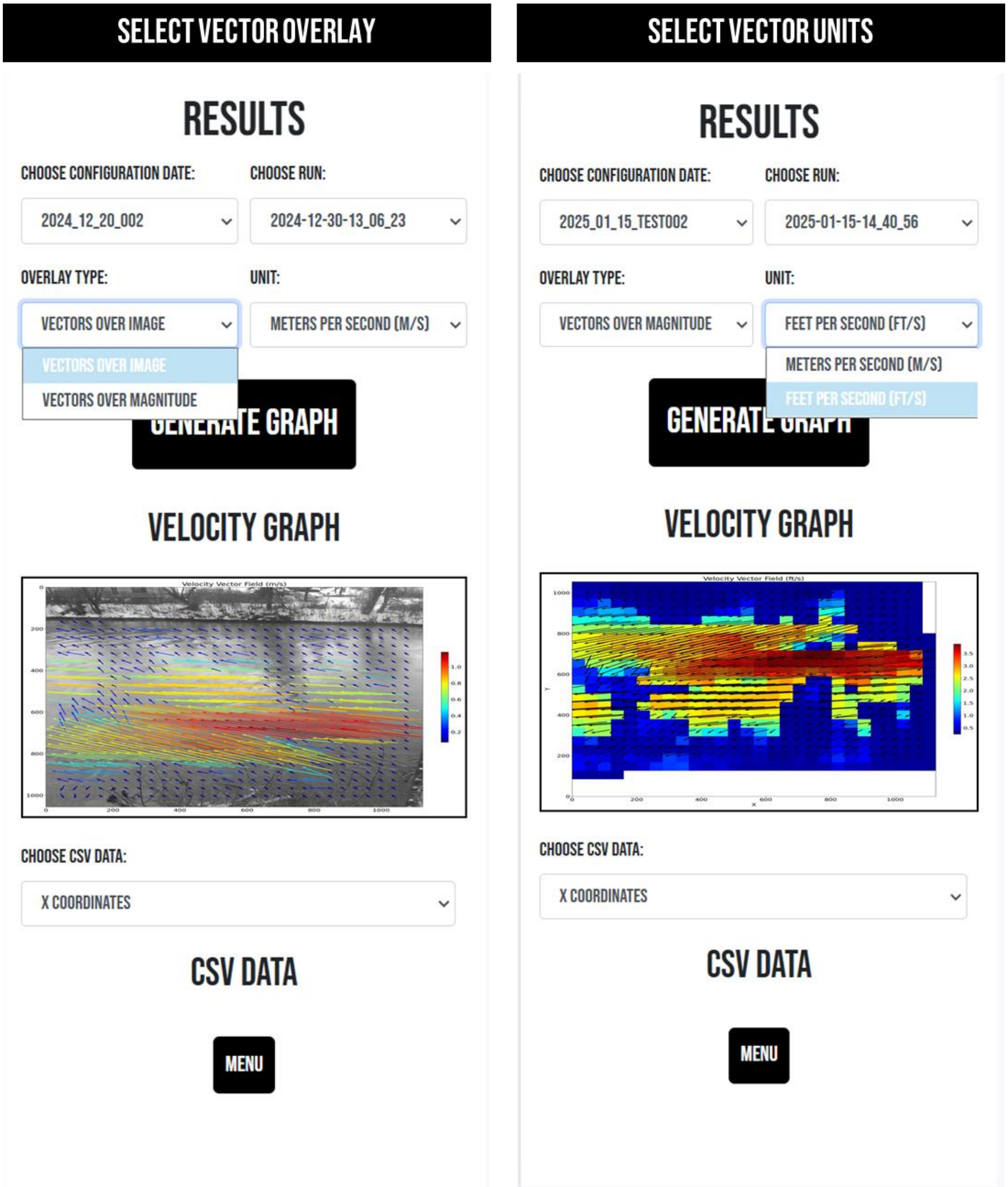

Figure 12 Example of choosing the vector overlay and units you would like displayed.

To view the actual numeric values of the output PIV vectors, select the desired components, and the CSV file will be displayed below the graph – see Figure 13 for an example.

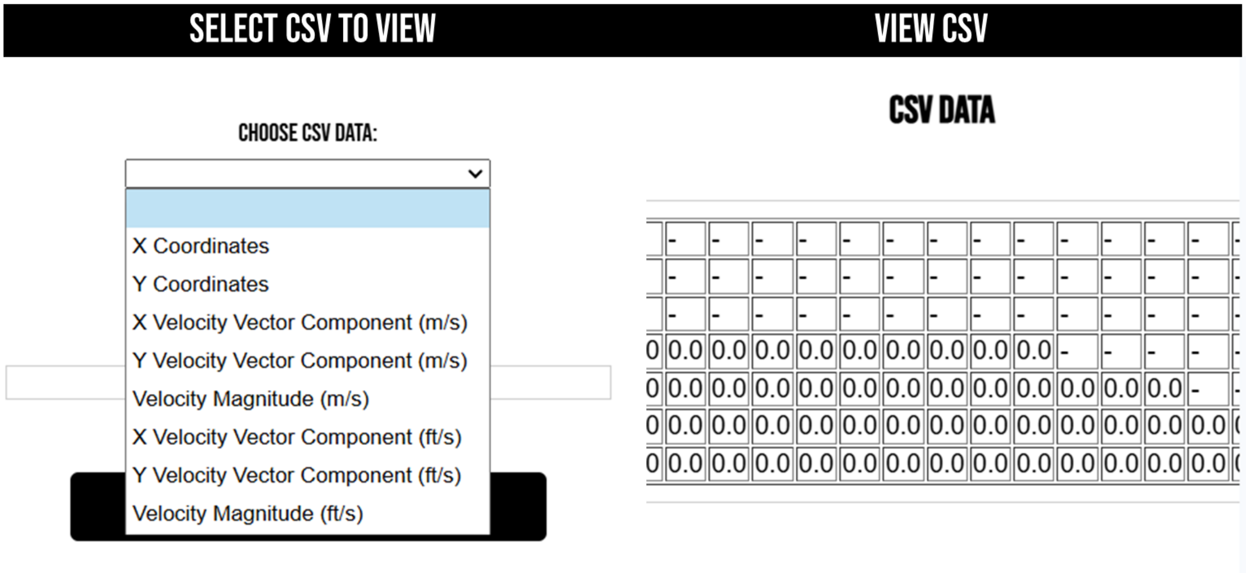

Figure 13 Example showing display of PIV data in CSV format.

OFFSITE PROCESSING

When you choose to save data from the SPEC onto a USB using the web app's save functionality, a directory named Offsite_Processing is included. This directory contains a script called processVideo.py, which enables users to process videos from a PIV run offsite. This functionality provides flexibility to reevaluate data if needed.

The script does not perform the full PIV calculation but instead focuses on transforming the images. It can undistort the images and apply homography transformations based on user-defined trapezoid points. The output can then be used as input to other image velocimetry algorithms. Additionally, users can select the frame extraction rate from the video, with a maximum frame rate of 30 Hz.

To use the script, simply place the video and configuration file into the Offsite_Processing directory. The script will then extract and transform the frames accordingly. If you wish to adjust the frame rate, you can do so by modifying the frameInterval variable in the configuration file. The value of frameInterval represents the time (in seconds) between each frame. For example, to extract frames at 10 frames per second (10 Hz), set the value to 1/10. Figure 14 depicts the post-processing workflow.

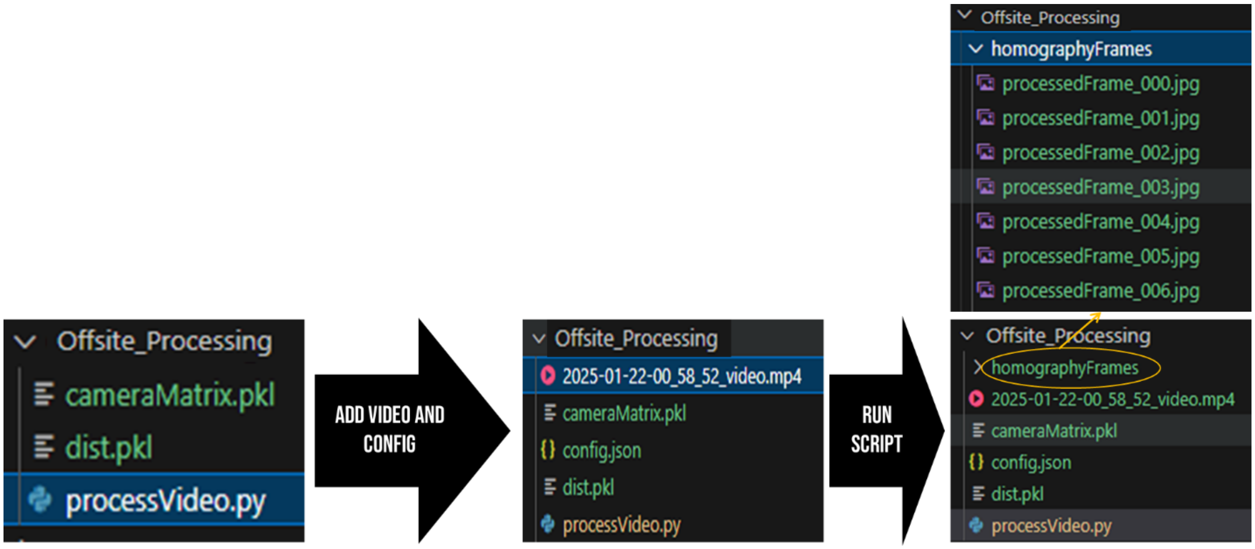

Figure 14 Offsite processing directory process block diagram.

DISCLAIMERS

PIV ACCURACY REQUIREMENTS

For PIV to produce accurate velocity fields, specific conditions must be met:

1. **Distinct Features:**
    - Distinct features or textures that move with the flow of the river need to be present for the algorithm to pick them up.
2. **Minimal Wind and Waves**:
    - High wind or significant waves disrupt the water surface, leading to inaccuracies in the PIV calculation.
    - The algorithm relies on tracking particles consistently across consecutive frames, and surface disturbances can result in erroneous outputs.
3. **Water Clarity**:
    - If the water is too clear, the algorithm may mistakenly track objects or features on the riverbed, skewing the velocity calculations.

Maintaining optimal environmental conditions ensures the PIV algorithm can effectively track surface particles and provide reliable results.

HOMOGRAPHY AND ITS IMPACT

Homography transforms the camera's perspective by stretching the pixels at the top of the image to align with the dimensions of the bottom of the trapezoid. However, this transformation has implications:

1. **Pixel Stretching and Resampling**:
   - As the trapezoid's sides angle inward, the top pixels become increasingly stretched and resampled.
   - This distortion affects the pixel size, particularly near the top of the image.
2. **Impact on Velocity Accuracy**:
   - Pixels closer to the top of the image might deviate further from the actual velocity due to the stretching effect.
   - Beyond a certain angle threshold, the pixel distortion becomes significant enough to compromise the accuracy of the velocity outputs.

This threshold is currently under evaluation to determine the optimal angle range for accurate results.

NIGHTTIME PIV

Currently, there is no system in place to illuminate the river during the night hours. This is also under evaluation.

REFERENCES

[1] C. J. Legleiter and P. J. Kinzel, "An enhanced and expanded Toolbox for River Velocimetry using Images from Aircraft (TRiVIA)," *River Research and Applications,* vol. 40, no. 8, pp. 1602-1612, 2024.

[2] C. J. Legleiter and P. J. Kinzel, "The Toolbox for River Velocimetry using Images from Aircraft (TRiVIA)," *River Research and Applications,* vol. 39, no. 8, pp. 1457-1468, 2023.

[3] C.J Legleiter, "TRiVIA - Toolbox for River Velocimetry using Images from Aircraft," U.S. Geological software release, September 2024. [Online]. Available: https://doi.org/10.5066/P9AD3VT3..