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EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

FISH STREAM

Determining the Surface Velocity Fields near Fish Passages at Hydropower Dams

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HARMONIOUS
UAS for environmental monitoring

MOTIVATION

Over 56% Austrian electricity is hydropower (EEOe, 2018)

Hydropower dams are obstacles for migratory fish (Buadoin et al., 2015)

Habitat defragmentation leads to fish stock decline (Larinier, 2001)

legal obligation to improve river quality till 2027 (WFD)

Fish passages enable upstream migration

An effective fish passage is easy for fish to discover (Larinier, 2002b)

Different key stimuli to attract fish: flow, sound, temperature

Flow pattern at the fish passage entrance influences discoverability (Larinier, 2002a)

Model predictions of flow patterns near fish passages exist, but they are not confirmed by field studies

Clear understanding of actual flow patterns is required

Figure 1. Schematic representation of the project motivation

Research Question

Optical analysis of Surface Velocity Fields (SVFs) near fish passages at hydropower dams from airborne imagery

- **get a better understanding of actual flow patterns near fish passages**
  - potential role in discoverability
  - dependence on different operation modes of hydropower plants
- **provide hydraulic engineers with data for model performance assessment**

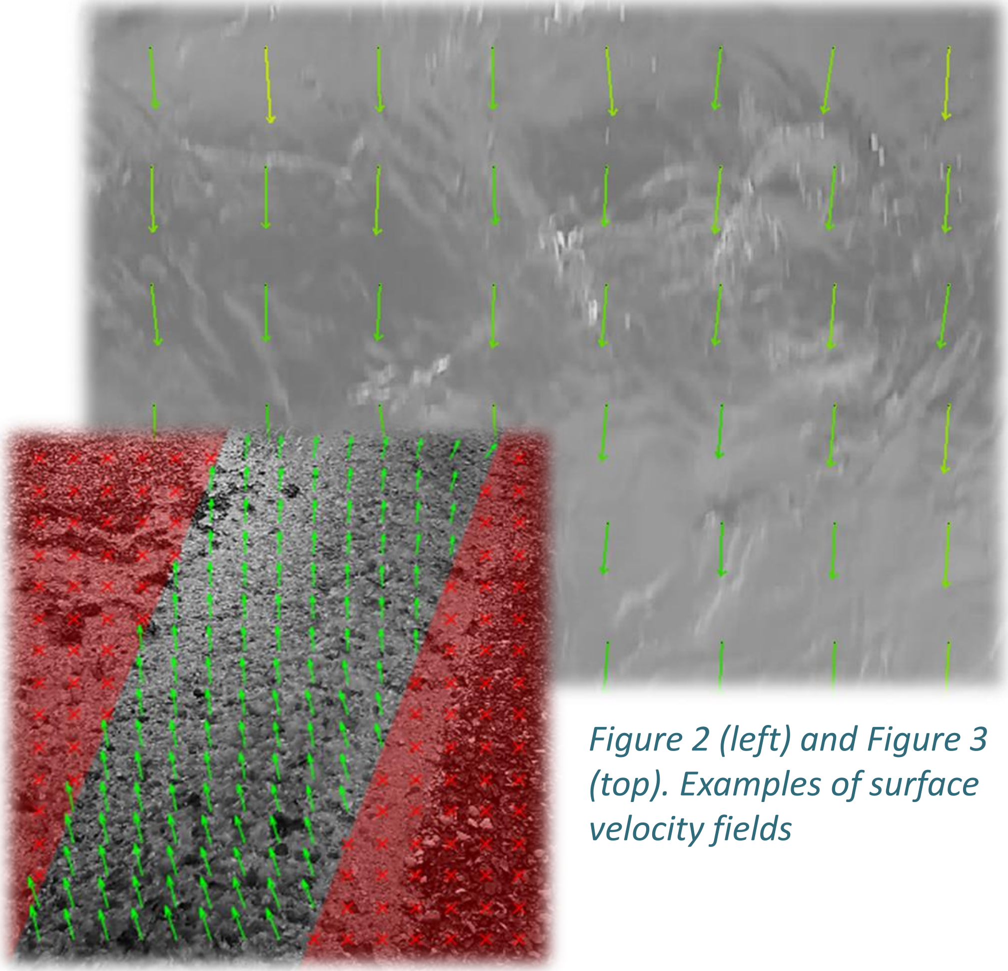


Figure 2 (left) and Figure 3 (top). Examples of surface velocity fields

STATE-OF-THE-ART

Surface Velocity Field estimation

- Capturing video data or image sequences of the flow that contains visually identifiable tracers (natural or artificially introduced)
- Image preprocessing (contrast enhancement, orthorectification, stabilization)
- Pairwise comparison of images, analysis of displacement of tracer particles and vector calculation
- Image scaling, vector validation and filtering
- Comparison with reference data (e.g. obtained with an Acoustic Doppler Current Profiler)

Adrian, 2005; Kim et al., 2008; Le Coz et al., 2010

Software

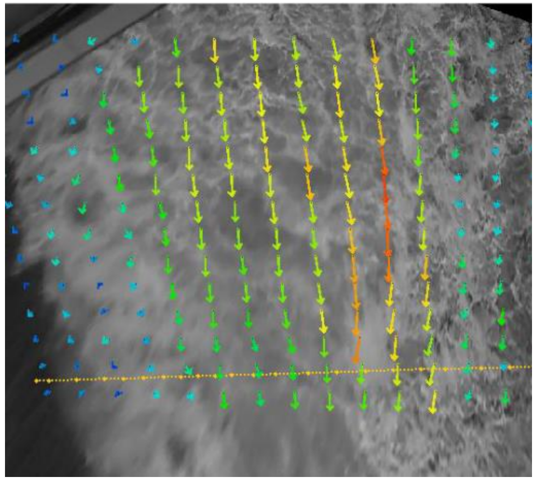
Desktop

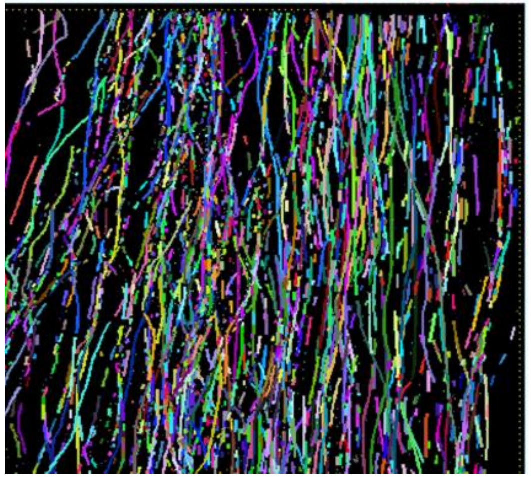
- ADMFlow
- Fudaa-LSPIV
- OpenPIV
- PIVlab

Mobile

- Discharge
- LSPIV App

Methods





Particle Image Velocimetry PIV

Particle Tracking Velocimetry PTV

PIV is most commonly used for river flow analysis

(Nezu & Sanjou, 2011)

Figure 4 (left) An example of PIV application, adopted from Le Coz et al., 2014, S. 26

Figure 5 (right). An example of raw PTV results, adopted from Dal Sasso et al., 2018, Fig. 8b S.460

NOVELTY & CHALLENGES

Figure 6. Scale of the test site

Figure 7. Turbulent flow and a confluence at the test site

1. Large test site dimensions
- Previous studies deal mostly with rivers up to 15 m wide, maximum 35 m*
- Camera height over 50 m - large errors**
- Big volumes of large tracers needed

2. Turbulent flow caused by hydropower plant operation

3. Presence of a confluence
No previous studies in such conditions

** Dal Sasso, Pizarro, Samela, Mita, & Manfreda, 2018; Detert et al., 2017; Kantoush et al., 2011; Tauro et al., 2016; ** Lewis & Rhoads, 2018a, 2018b*

METHODOLOGY

Method: PIV

Camera platform

- Remotely Piloted Aircraft System
- Balloon (at later stages)

hovering at fixed position

- Video of 4096 x 2160 px at 25 fps or imagery of up to 32 mpx at 5 fps in burst mode
- Target image resolution 2-3 cm
- Fixed reference regions for image stabilization

Possible: synchronized use of multiple cameras from multiple platforms

Tools: Desktop Software

- OpenPIV
- PIVlab
- in-house implementations

OpenPIV, PIVlab: Open Source. Tailoring possible.

Tracers

- air bubbles, debris
- wood chips
- eco foam (corn)
- liquid (beetroot juice)

Validation: Reference velocity values provided by the customer

Figure 8. Schematic representation of project methodology

EXPECTED RESULTS

Surface Velocity Fields

- Statically visualized (e.g. Fig. 7)
- Dynamically visualized
- Converted to an exchange format (e.g. netCDF) determined by the customer

Documented procedures

- Data collection and experiment design
- Data storage and metadata
- **Data processing** (image stabilization, preliminary filtering, validation and post-processing)

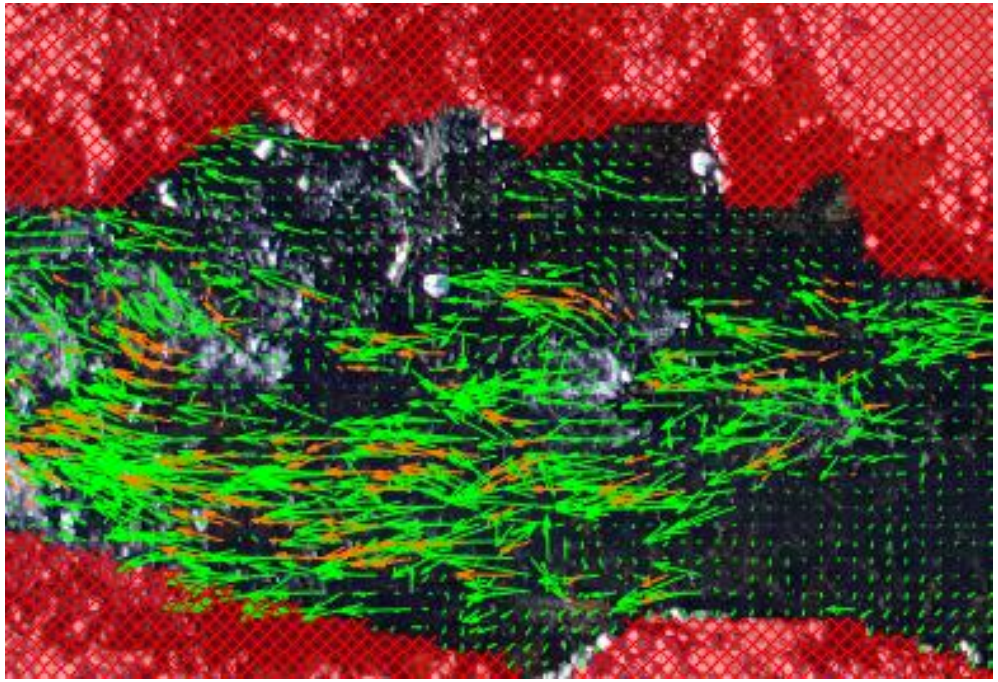


Figure 9. An example of derived static surface velocity field

SMALL-SCALE EXPERIMENT

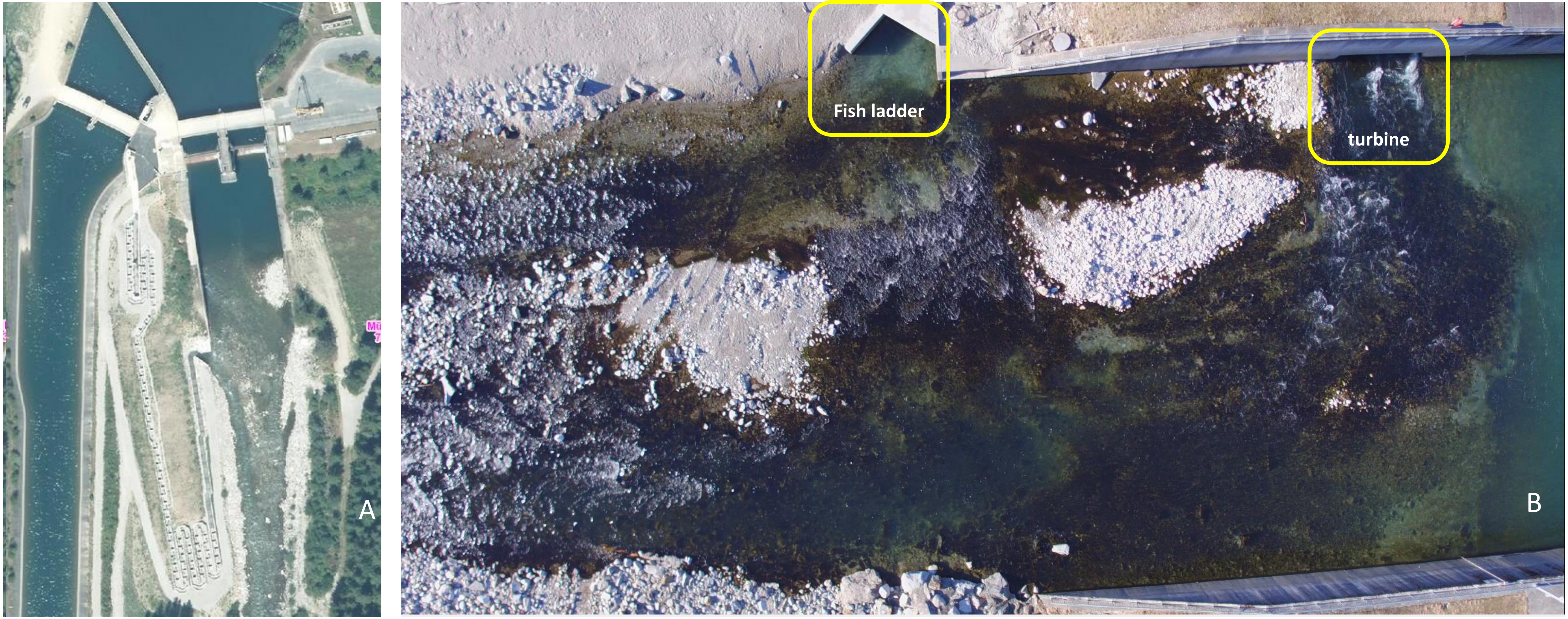
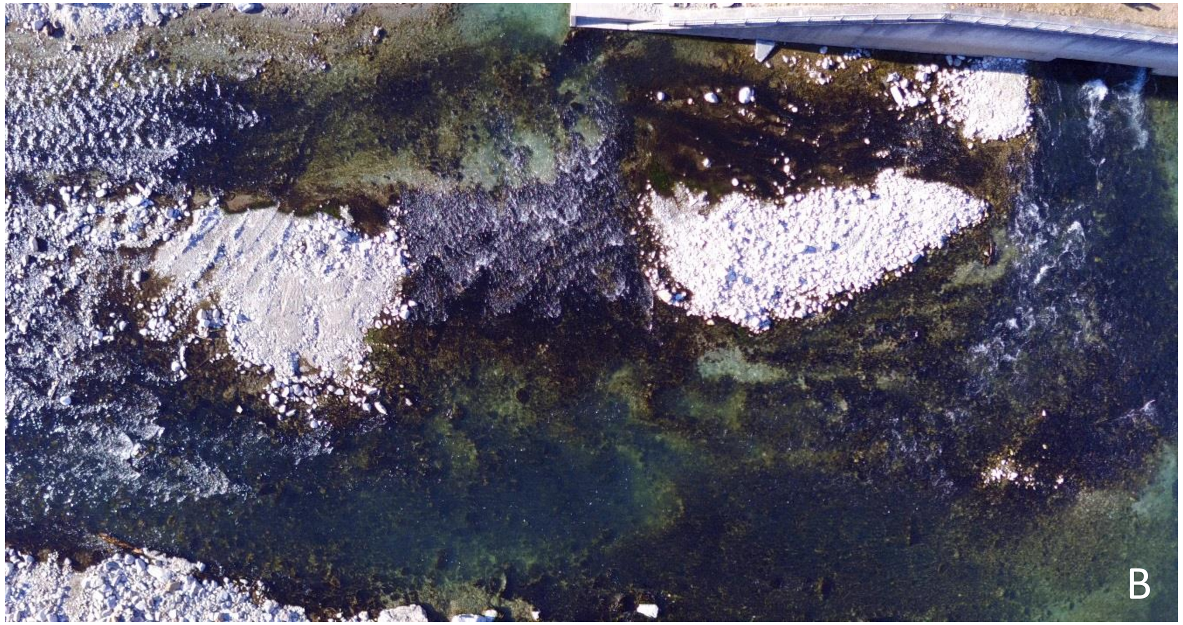


Figure 10. Test site of the small-scale experiment: A. As presented in Kärntner Atlas (https://gis.ktn.gv.at/atlas/); B. Captured during experiments on Jan. 11, 2019

Challenges

River width ~ 40 m

Compromise between the field of view, the resolution and the level of error caused by vibration



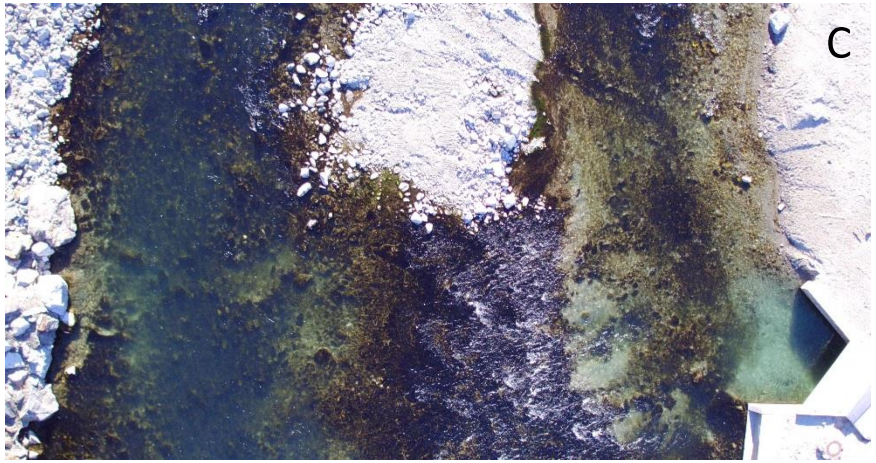


Figure 11. Capturing flow data from 3 different heights. A: height 75m, both banks in the frame; B. height 50m, banks only partially seen, fish ladder entrance not captured; C. height 25m, outflow from the turbine outside of the frame

STABILIZATION (1)

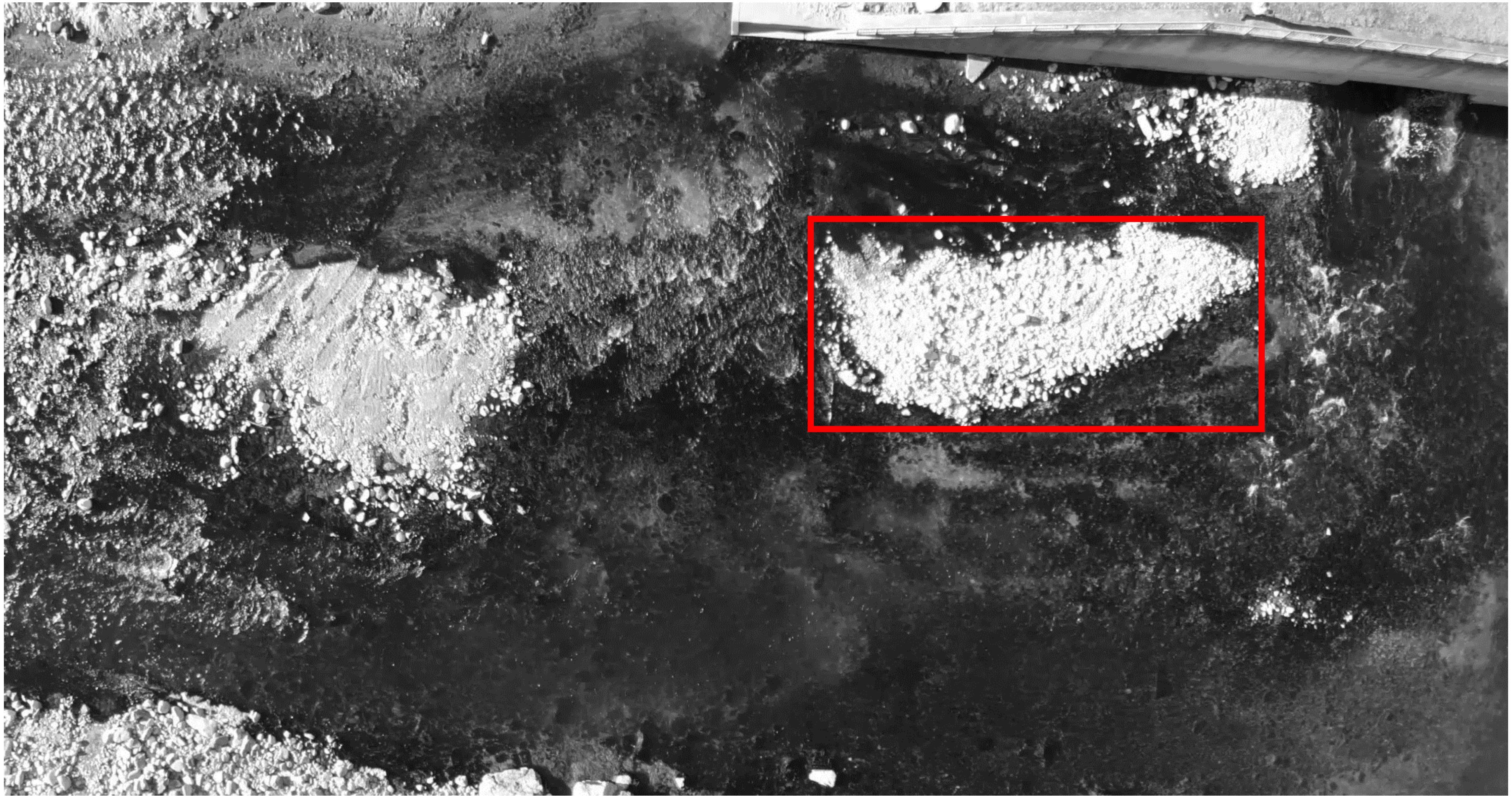


Figure 12. (video) Original footage sped up 5 times

STABILIZATION (2)

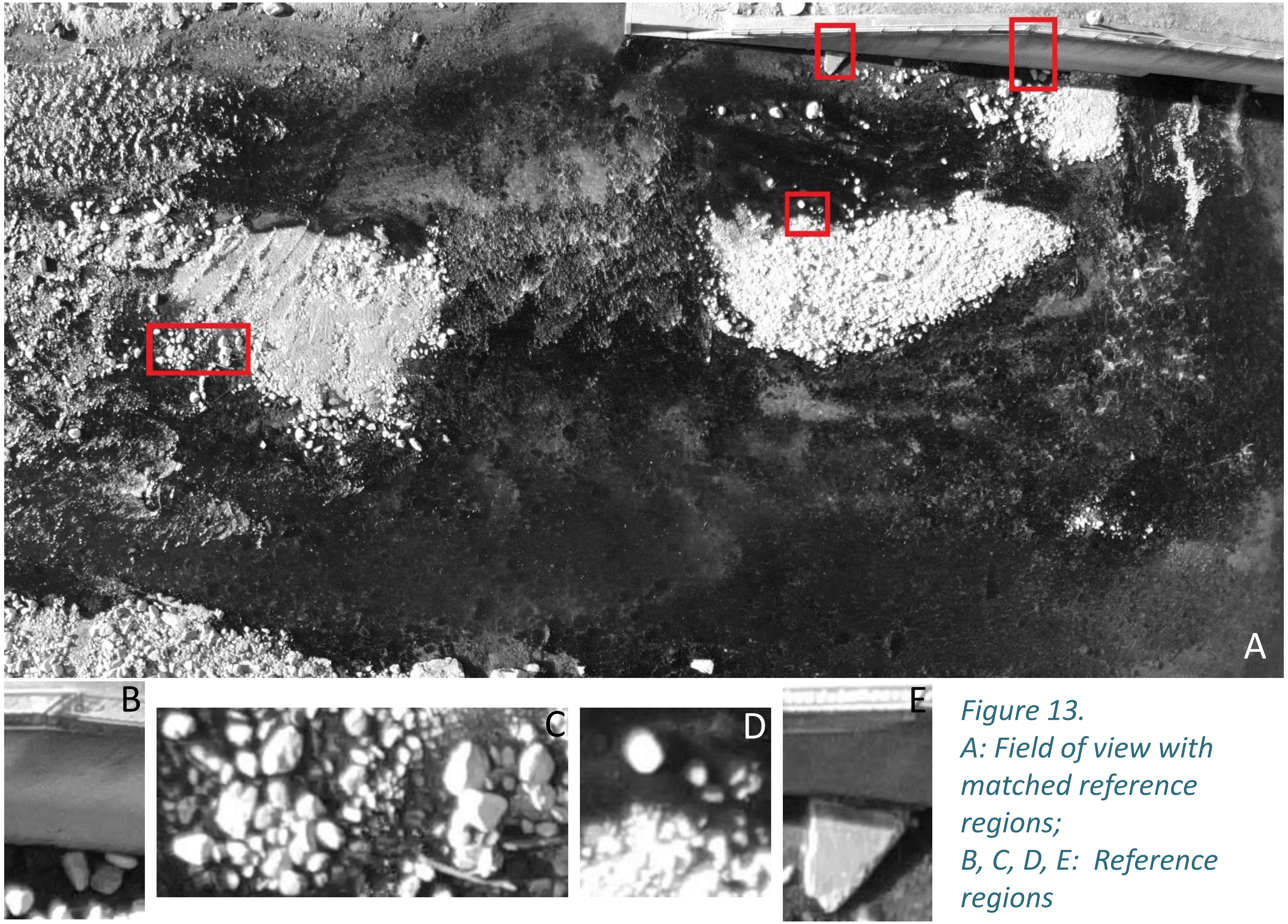


Figure 13.
A: Field of view with matched reference regions;
B, C, D, E: Reference regions

in-house implementation of a video stabilization tool based on OpenCV libraries

1. Find stable reference regions (RRs) present in every frame
2. Locate RRs in the model frame, store locations of their centers as target locations
3. Locate RRs in each consequent frame, storing the displacements between their centers and the target locations
4. Shift and/or rotate each frame respectively to the displacements

FIRST SVF RESULTS BASED ON PIV

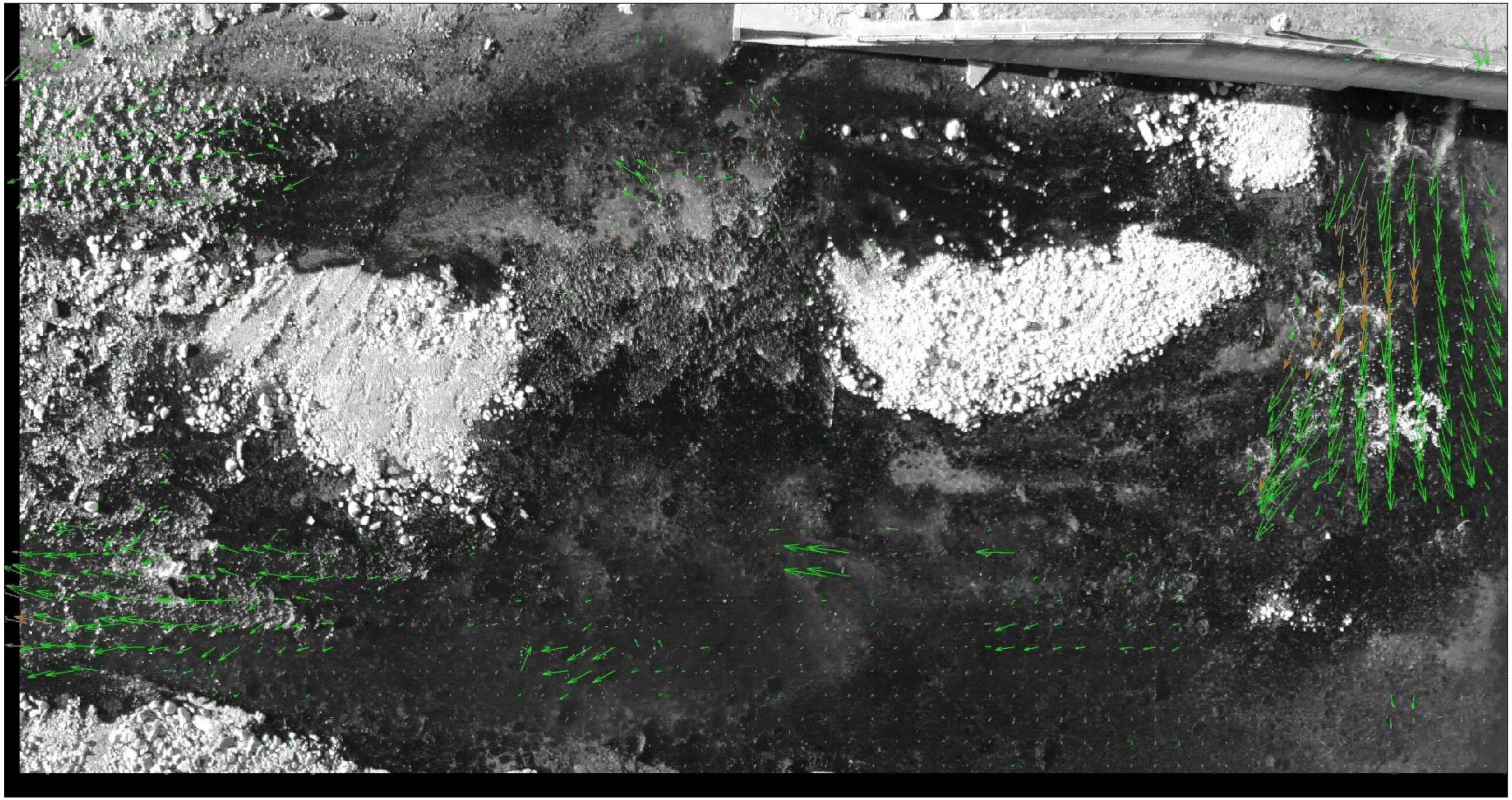


Figure 14. (video) SVFs calculated with PIVlab

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