RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1082

Hydrokinetic Impact Study Update-2013

Prepared for Reclamation's Power Resources Office and Science & Technology Program

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

March 2014

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Hydrokinetic Impact Study Update-2013

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3/31/14
Date

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

March 2014

Background

In recent years much attention has been given to the development of Hydrokinetic Power Generation technologies for use in inland waterways. These hydrokinetic (HK) turbines utilize the velocity of the flowing water to turn a turbine rotor which is connected through a shaft to a generator to produce power. Unlike traditional hydropower, these HK devices do not require a reservoir or head drop to operate. The end goal of many private developers is to eventually have their HK technologies installed in rivers and canal systems throughout the United States.

Since 2011, Reclamation has received requests from private HK developers to install their technology in Reclamation canal systems for demonstration testing. As the impacts of this technology on existing systems are unknown, a study was initiated in early 2013 to determine the hydraulic effects of these devices on existing water delivery and hydropower operations. As part of this effort, Reclamation has partnered with Instream Energy Systems Inc. (Instream) and Sandia National Laboratories (SNL) to study HK performance and hydraulic impacts in canal systems. Results are obtained using Instream's recent HK installation in the Roza Main Canal near Yakima, WA in conjunction with numerical hydraulic modeling. Reclamation engineers from the Technical Service Center's Hydraulic Investigations group are conducting the research in conjunction with Instream and SNL. They are funded jointly by Reclamation's Power Resources Office and Science & Technology Program.

Project Scope and Objectives

While specific objectives for each party are being met through this study, the combined objective of the research team (Instream, SNL, & Reclamation) is to develop a modeling tool to predict HK impacts on water delivery systems. A well-developed numerical model will be a useful tool for both private developers and water system owners to help determine if an HK device could be deployed without impacting existing water delivery operation, before any installations are made. Physical data from the Roza Main Canal are being used to develop the numerical model under a range of canal and HK turbine operating conditions. Initial shakedown of both physical and numerical testing was completed in 2013. It is anticipated that testing at the Roza Canal will continue through 2015 and final results and a general predictive model will be available in 2016.

Physical Data Collection

Initial shakedown testing was completed at the Roza Main Canal in 2013. Test and model extents included a 5 mile stretch of the canal between the two main tunnels (Figure 1). Major milestones in 2013 included installation of water level data loggers in March, Intream's installation and successful operation of their HK turbine in August, and HK impact testing in late August. Data collection included water surface levels and canal velocities at several cross-sections up and downstream from the HK device with both the turbine in and out of the flow. Details of the shakedown field testing data collection and results can be found in the Appendices of this report.

Shakedown testing of the existing Roza hydropower plant, which is fed by the Roza Main Canal, was also completed in 2013. This included a performance test of the single Francis unit with and without the HK device operating in the main canal upstream. Impacts to the unit were not measurable and it was decided that further performance testing was not necessary in 2014. However, hydraulic operation of the power plant will be monitored at the plant throughout the 2014 testing period.

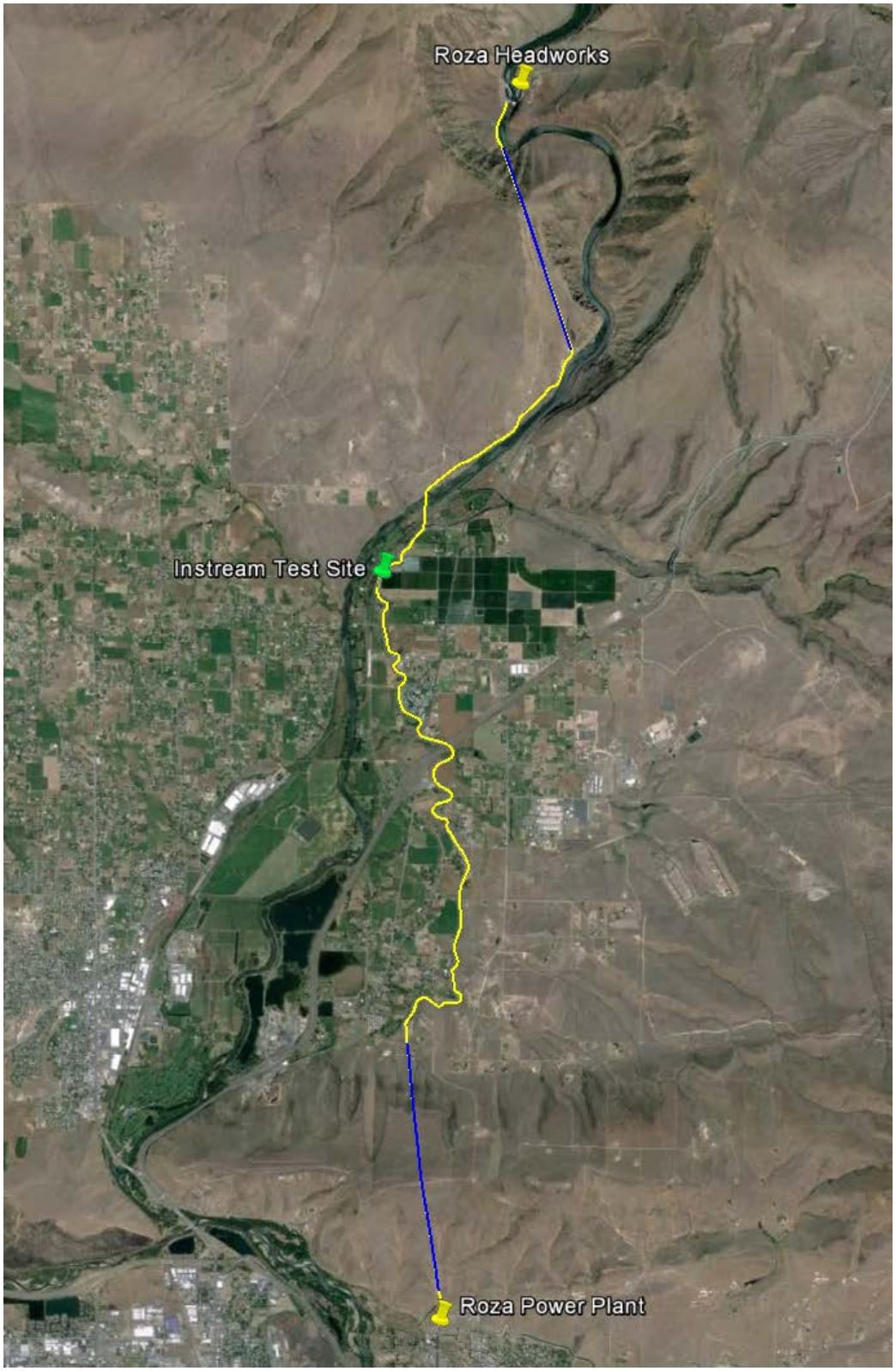

Figure 1 Google Earth image of the Roza Main Canal. Water flows from the head works on the Yakima River (top) to the Roza powerplant (bottom). The blue sections are tunnels and the yellow section is the 5 mile stretch where water level instrumentation was installed. Most of the data were collected near the Instream Test Site.

Numerical Model

Data from the field are being used to calibrate two different numerical models of the canal system with and without an HK installation. The first is a one-dimensional HEC-RAS model of the Roza Canal extents and is being built and calibrated by Reclamation. The main use of the HEC-RAS model will be to determine water level impacts throughout the canal system. The model is being calibrated for an HK device using water level and canal discharge data from the field. HEC-RAS will be developed as the main predictive modeling tool for general hydraulic impacts as it is widely used in industry and is relatively simple to apply. While this model can only be accurately calibrated to the physical data available from the Roza Canal system, it is anticipated that energy loss characteristics of the HK turbine can be applied in other similar canal systems to provide reasonable hydraulic impact predictions using the modeling tool.

The second model used in this study is a quasi-3D Environmental Fluid Dynamics Code (EFDC) that is calibrated by SNL to include HK features. The EFDC model helps characterize HK turbine performance and incorporates cross-sectional velocity data to determine the total energy loss across the HK device. Results from this model will be compared to HEC-RAS results to ensure accurate impact predictions within the range of physical test results. In 2013, basic setups of each model were completed and will continue to be modified to match field data throughout 2014.

Plans for 2014

The research team is preparing for two separate field tests at the Roza Canal in 2014. These tests will occur near the spring and late summer time frames to conduct testing within a full range of canal flows throughout the irrigation season. Also, the HK turbine will be operated at a number of power settings and conditions to characterize the range of hydraulic impacts possible from a single HK unit. These results will be used to continually develop the numerical models throughout 2014. After a single unit deployment has been characterized, and depending on test results, a second HK unit may be installed in the canal. The deployment of the second unit will likely occur in early 2015 depending on the test schedule. Update reports will be submitted for both 2014 and 2015 research efforts and a final report of the study will be completed in 2016.

APPENDIX A

March 2013 Trip Report

RECLAMATION

Managing Water in the West

TR-2013-04

Travel to Yakima Field Office

Installation of test instrumentation for research project 7973 on hydrokinetic turbine impacts to existing canal & power plant operation.

Dates of Travel: March 11 to 15, 2013

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code: 86-68460 Date: March 25, 2013

To: Manager, Hydraulic Investigations and Laboratory Services Group
From: Josh Mortensen, Hydraulic Engineer

Subject: Travel to the Yakima Field Office to begin installation of test instrumentation for research project 7973 on hydrokinetic turbine impacts to existing canal & power plant operation.

1. Travel period: 11 March – 15 March 2013

2. Places or offices visited: Yakima Field Office (Roza canal and power plant).

3. Purpose of trip: The primary purpose of this trip was to install submersible water level data loggers in the Roza canal in preparation for research project #7973. This study will help determine the impacts of hydrokinetic power generators to existing canal and power plant operations. The secondary purpose was to tour the Roza power plant and determine how its operation can be tested and monitored as part of the same research.

4. Synopsis of trip:

Sunday, March 10th: Josh Mortensen and Bryan Heiner flew into Seattle and rented a car to drive to Yakima, arriving Sunday evening.

Monday, March 11th: We first met with Tom Glover to briefly discuss our plans for the week and asked a few questions about the power plant. We then met with Tony Hargroves to discuss equipment and assistance needed to install water level data loggers along the canal. A JHA for the work to install the loggers was reviewed. Tony then drove us along the canal system to the various deployment sites so we could determine safe access and which materials would be needed. Monday afternoon was spent gathering materials needed to deploy the loggers and preparing the deployment pipes.

Tuesday, March 12th: All day was spent installing the HOBO water level data loggers along the main canal section. The loggers were launched at 15 minute recording intervals and deployed in 2-inch PVC pipes that were either clamped to an existing safety ladder (Fig. 1) or anchored to the side wall (Fig. 2). The loggers were lowered into the pipe and secured just a couple of inches from the end of the pipe using a rope tied to the top cap. Water entered the pipe through 3 small holes in the bottom end cap. We started at site #2 just downstream of the first tunnel and finished at site #7 just upstream of the last tunnel. We surveyed each deployment pipe and water surface by setting a benchmark (Fig. 3) and using a survey rod and level. These bench marks still need to

be surveyed with an RTK GPS survey system to obtain accurate elevations.

Wednesday, March 13th: Loggers were installed at the power plant. The forebay logger was deployed in the stilling well (Fig 4). The tailbay logger was deployed in a pipe anchored to the north side of the north wing-wall (Fig. 5). Ron Moores then took us into the power plant where we located pressure taps upstream of the scroll case as well as the Winter-Kennedy flow taps. Ron cracked opened the valves to the flow taps which showed that they were still usable. Josh photographed the wicket gates and control panels to help determine how unit performance might be tested and monitored throughout the study.

Thursday, March 14th: Early Thursday morning we met with Tony Hargroves to discuss work completed this trip as well as plans and coordination for future work. After returning some safety equipment to Tony we departed for Seattle by way of Cle Elum Dam where we took some video for a current physical model in the Hydraulics Lab. Late Thursday afternoon we departed from the Seattle airport.

5. Conclusions:

Roza Canal: All HOBO water level loggers were successfully launched and deployed at the designated sites along the Roza canal. They are to remain in place throughout the irrigation season. They will be pulled out for data download and analysis at a future date. An accurate survey of the benchmarks that were set needs to be completed for accurate analysis of the water level data.

Roza Power Plant: Water level loggers were also deployed in the forebay and tailbay. Pressure and flow taps needed for unit efficiency testing were located. Josh will consult with other TSC and Regional engineers to determine when and how this testing will be conducted.

6. Action correspondence initiated or required:

Tony Hargroves and Tom Glover will keep a log of events on the canal & power plant for documentation which they will forward to Josh (startups, shutdowns, hydrokinetics installed, etc.). They will also help coordinate the power plant testing and/or monitoring.

Josh Mortensen will contact surveyors from the Ephrata Field office about surveying the benchmarks. He will also update and work with Tom regarding the power plant testing.

7. Client feedback received: N/A

cc:
Tony Hargroves (YAK-5410)
Tom Glover (YAK-5210)
Chuck Garner (YAK-5100)
Sid Ottem (YAK-5000)
Erin Foraker (86-69000)
Shanna Durham (86-68420)

SIGNATURES AND SURNAMES FOR:

Travel to: Roza Canal & Power Plant, Yakima, WA

Dates of Travel: March 11 – March 15, 2013

Names and Codes of Travelers: Josh Mortensen, 86-68460 and Bryan Heiner 86-68460

Travelers:

Joshua D Mortensen 3/20/13
Joshua D. Mortensen Date
Hydraulic Investigations and Laboratory Services Group

BHeiner 3/25/13
Bryan J. Heiner Date
Hydraulic Investigations and Laboratory Services Group

Peer Review by:

Tracy B Vermeyen 3/21/13
Tracy B. Vermeyen Date
Hydraulic Investigations and Laboratory Services Group

Noted and Dated by:

Robert F. Einhellig 3/20/2013
Robert F. Einhellig, Manager Date
Hydraulic Investigations and Laboratory Services Group

Figure 1 Site #5 water level logger deployment pipe clamped to the downstream side of the safety ladder.

Figure 2 Site #6 water level logger deployment pipe anchored to the concrete side.

Figure 3 Typical bench mark set at each deployment site marked with a concrete anchor and an X.

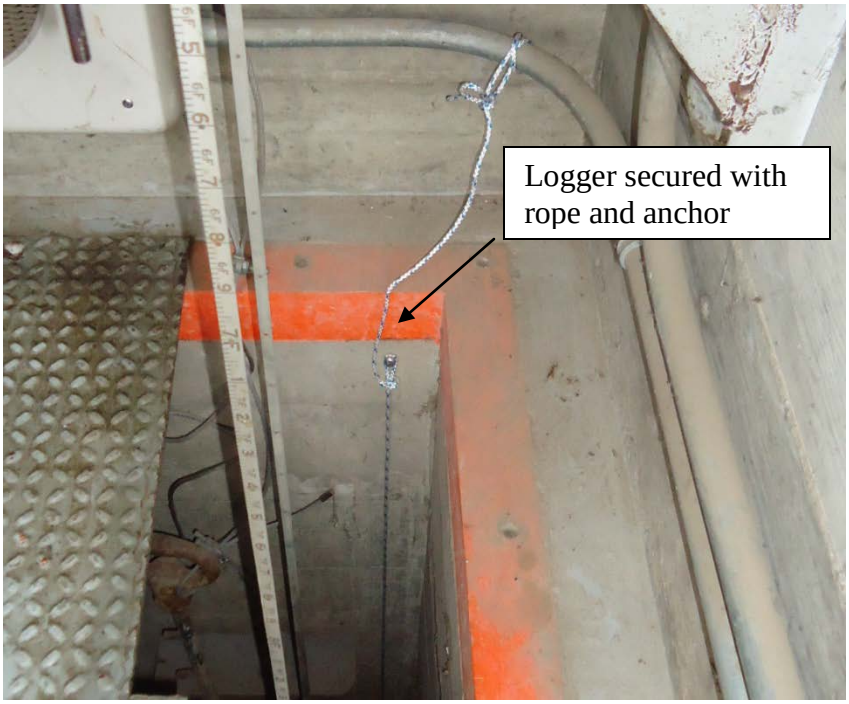

Figure 4 Site #8 Water level logger deployed into the forebay stilling well.

Figure 5 Site #9 Water level logger deployment pipe anchored to the wing wall of the power plant tailbay.

APPENDIX B

August 2013 Trip Report

BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code: 86-68460 Date: December 9, 2013

To: Manager, Hydraulic Investigations and Laboratory Services Group
From: Josh Mortensen, Hydraulic Engineer

Subject: Travel to Roza canal and power plant for shakedown testing of hydrokinetic impacts to existing canal & power plant operation (Science & Technology project 7973).

1. Travel period: 18 August – 24 August 2013

2. Places or offices visited: Yakima Field Office (Roza canal and power plant).

3. Purpose of trip: The primary purpose of this trip was to conduct shakedown testing of hydrokinetic (HK) impacts to the existing canal & power plant operation. In mid-August Instream Energy Systems Inc. deployed their hydrokinetic turbine in the Roza Main Canal, approximately 5 miles upstream from the existing Roza Power Plant. Testing involved deploying water level loggers at the HK test site, collecting canal velocity data using an ADCP, and conducting a performance test on the existing hydropower unit. This testing was a trial run of the planned test approach for future field testing of HK impacts at the Roza canal.

4. Synopsis of trip:

Sunday, August 18th: Josh Mortensen and Bryan Heiner flew into Seattle, WA and rented a car to drive to Yakima, arriving Sunday evening. Work for the testing setup began Monday the 19th.

Monday, August 19th: Josh and Bryan met with Ron Moores at the power plant to go over the job hazard analysis (JHA), acquire safety and survey equipment, and check out a government work truck for the week. Pre-fabricated angle iron used for water level logger deployment was picked up from a local metal shop and then anchored to the canal side wall at the test site (Fig 7).

Tuesday, August 20th: Water level loggers were deployed and surveyed. 12 loggers were deployed at 5, 10, 20, 30, 40, and 50 meters up and downstream from the HK turbine and set to sample at 20 second intervals. 5 additional loggers were deployed at various other locations along the canal for measurements near the river siphon (Fig 1) and near canal geometry transitions to help calibrate numerical models. These loggers were set at 15 minute sample intervals. Also, on Tuesday rebar rods were set to be used for ADCP taglines at the same cross-section as the level loggers.

Wednesday, August 21st: A mobile tagline system was installed and tested with the StreamPro

ADCP unit throughout the morning. The afternoon consisted of installing instrumentation at the Roza Power Plant in preparation for performance testing of the hydropower unit (Figures 12-15). Pressure sensors were installed on the Winter-Kennedy taps for unit flow measurement and on taps from the penstock for pressure data. A string transducer was installed on the servo-motor arm to measure the wicket gate opening. Power data was recorded on a 3-1/2 inch floppy disk through a Monarch Data Chart recorder. Forebay and tailbay elevations were recorded with water level loggers. Wednesday afternoon Ann Dallman and Budi Gunawan from Sandia National Laboratories (SNL) arrived to witness and assist with testing beginning Thursday.

Thursday, August 22nd: Baseline testing with no HK turbine in the canal began at 9:30 MST. Bryan and Budi measured canal velocities at the 12 cross-sections near the HK turbine. Ann and Josh began testing at the power plant about 2 hrs later to allow flow from the HK test site to arrive at the power plant. Data were collected at 5 wicket gate openings (50, 55, 60, 65, and 70 percent open). Plant operators manually operated the spillway emergency gates to maintain a constant forebay elevation. Baseline testing concluded about 1:00 pm MST.

Friday, August 23nd: Thursday's test procedure was repeated with the HK turbine operating in the canal beginning at about 8:30 MST. Velocity measurements at cross-sections downstream of the HK turbine were not possible due to the rough water surface produced by the turbine. Power plant testing was also repeated at the same wicket gate openings with an additional test at 75 percent open due to reduced irrigation demands making additional flow available at the plant. After testing, instrumentation was removed and packaged; loggers were pulled from the canal to download data. Water level loggers were stored in the shop at the power plant. All equipment was returned to the field office and Josh and Bryan drove to Seattle Friday evening to catch an early morning flight on Saturday. Ann and Budi stayed in Yakima.

Saturday, August 24th: Researchers from Reclamation and SNL flew home from Seattle, WA.

5. Conclusions: Test results indicated that with the operation of one vertical axis HK turbine there are hydraulic impacts to the open channel flow of the canal. Water surface elevations upstream of the HK unit were increased by up to 0.12 ft which may only be significant when there are free-board limitations. Increased water surface elevations propagated about 0.5 miles upstream from the HK site. For the power plant, some uncertainties in how the generator power data were measured prevented efficiencies from being calculated. However, hydraulic data at the plant showed that there were no impacts to the operation of the hydropower unit. Fifteen figures (photographs and data) are included as attachments to this report. Test results are shown in (Figures 2-6).

Testing revealed issues using the StreamPro ADCP due to high canal velocities and a rough water surface downstream of the HK turbine. For future testing a larger ADCP vessel (probably the RDI Rio Grande) and a modified tagline system will be used. Shakedown testing also revealed that power plant performance testing may not be necessary because of the negligible impact of the current HK installation. We suggest continuing monitoring hydraulic data at the power plant (unit flow, and forebay/tailbay elevations) until some hydraulic impact is identified with a future HK installation/configuration. If an impact to hydraulic data is noticed during future tests, then performance testing may become necessary.

6. Action correspondence initiated or required: All canal hydraulic data are to be shared with Instream Energy Systems and SNL. TSC researchers will be in contact with the Yakima Field Office and Instream concerning further testing beginning in the spring of 2014.

7. Client feedback received: N/A

cc:
Ron Moores (YAK-5230)
Tom Glover (YAK-5210)
Chuck Garner (YAK-5100)
Erin Foraker (86-69000)
Shanna Durham (86-68420)
Ann Dallman (ardallm@sandia.gov)
Budi Gunawan (bgunawan@sandia.gov)
Shane Grovue (s.grovue@instreamenergy.com)

SIGNATURES AND SURNAMES FOR:

Travel to: Roza Canal & Power Plant, Yakima, WA

Dates of Travel: August 18 – August 24, 2013

Names and Codes of Travelers: Josh Mortensen, 86-68460 & Bryan Heiner 86-68460

Prepared by:

Joshua D. Mortensen 11/21/13

Joshua D. Mortensen, P.E. Date
Hydraulic Investigations and Laboratory Services Group

Peer Review by:

11/21/13

Bryan J. Heiner, P.E. Date
Hydraulic Investigations and Laboratory Services Group

Noted and Dated by:

Robert F. Einhellig 11/21/2013

Robert F. Einhellig, Manager Date
Hydraulic Investigations and Laboratory Services Group

Figure 1 Location of water data loggers on the Roza Main Canal between the upper and lower tunnels. These loggers recorded water surface elevations at 15 minute intervals from March – August 2013. Additional loggers (not shown here) deployed near the Instream Test Site recorded water surface data at 20 second intervals the week of August 19th. Water flows top to bottom of the page. The Roza Power Plant is located downstream of the lower tunnel which is not shown.

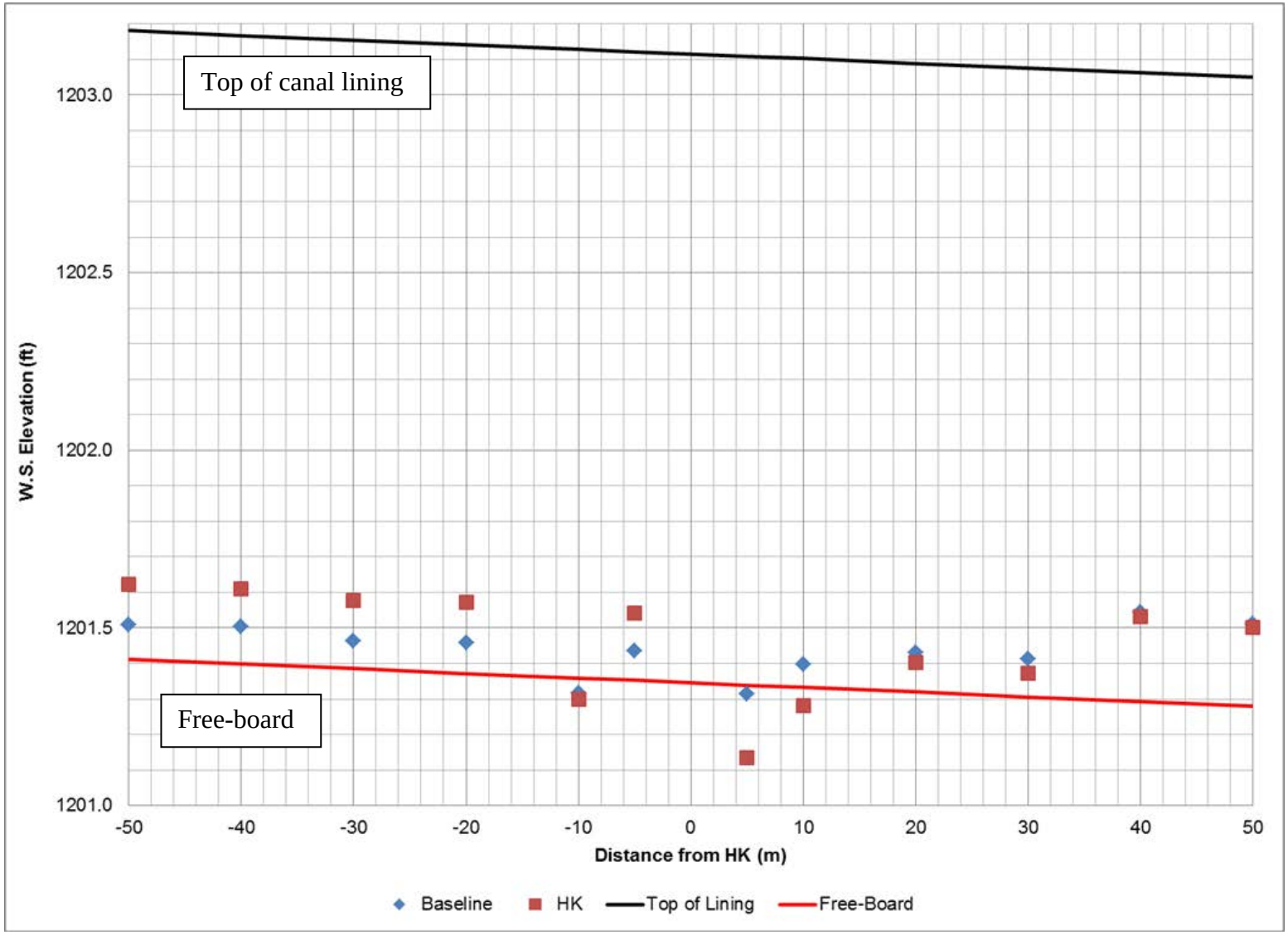

Figure 2 Plot of water surface elevation vs. distance from the HK turbine (negative = u/s and positive = d/s). The u/s water surface increased as expected and the d/s water surface quickly recovered as flow entered the transition to the wider earth lined section of the canal. From this plot, canal operations were already pushing the limits of free-board restrictions prior to operating the HK turbine, likely due to heavy aquatic growth of the unlined sections.

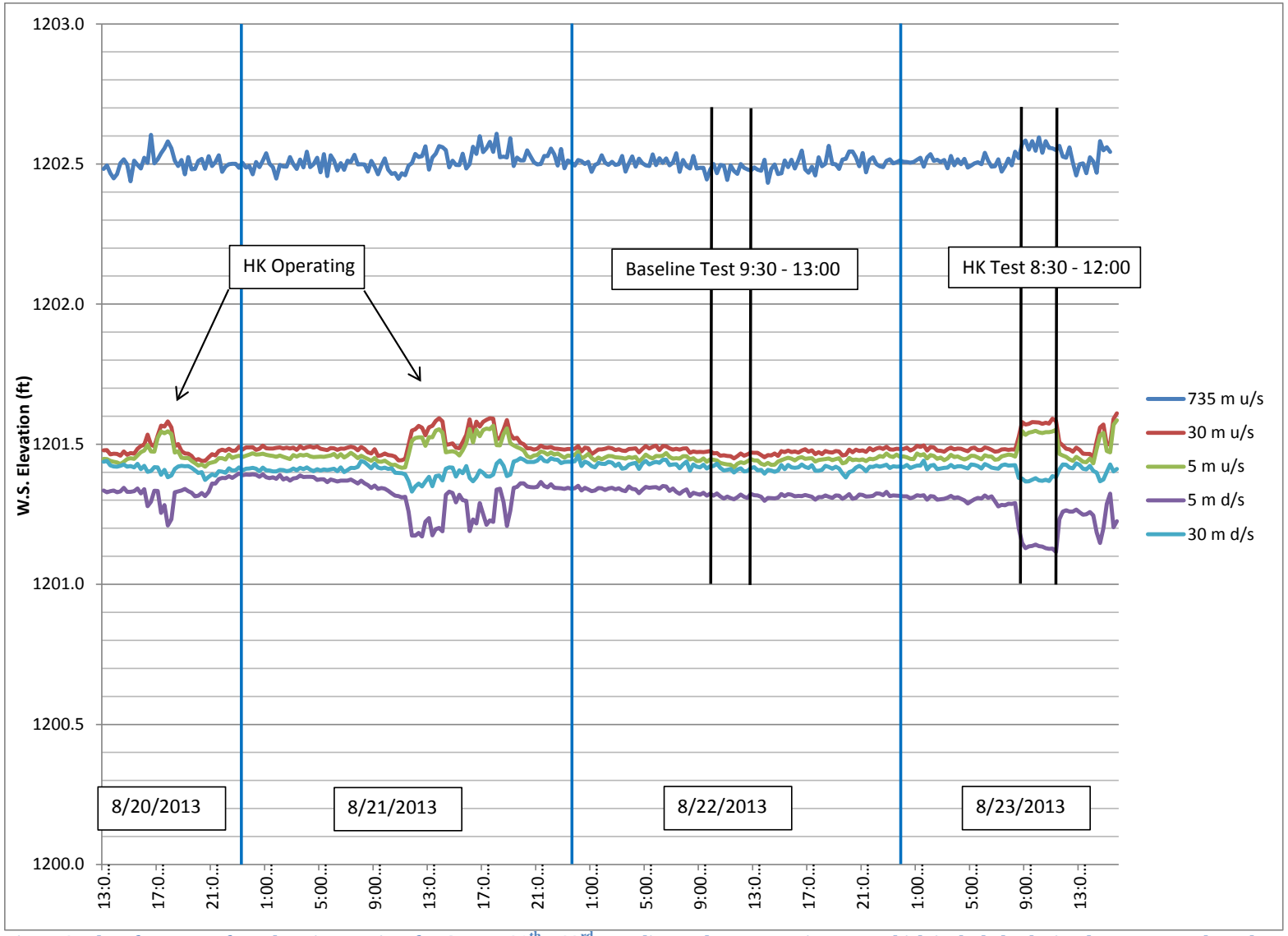

Figure 3 Plot of water surface elevation vs. time for August 20th – 23rd. Baseline and HK operating tests which included velocity data were conducted on the 22nd & 23rd. Water surface increases were observed at all u/s locations including near the river siphon outlet almost 0.5 miles upstream (735 m u/s).

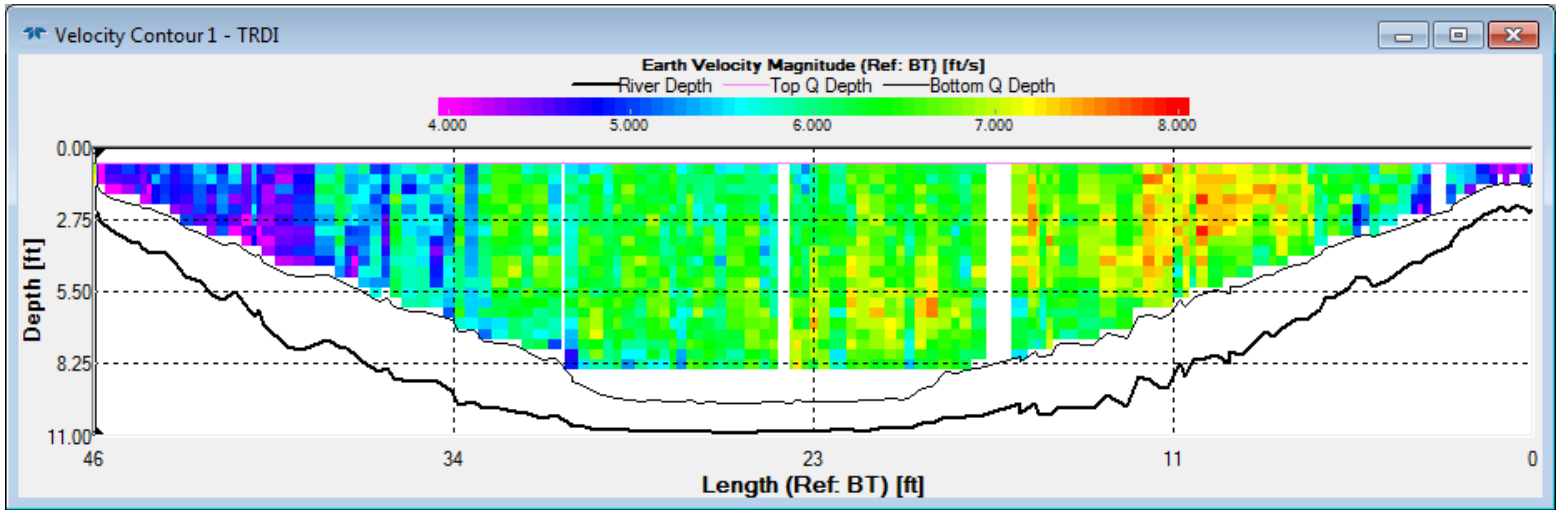

Figure 4 Sample velocity contour - Baseline velocities across cross-section 20 meters upstream of HK turbine.

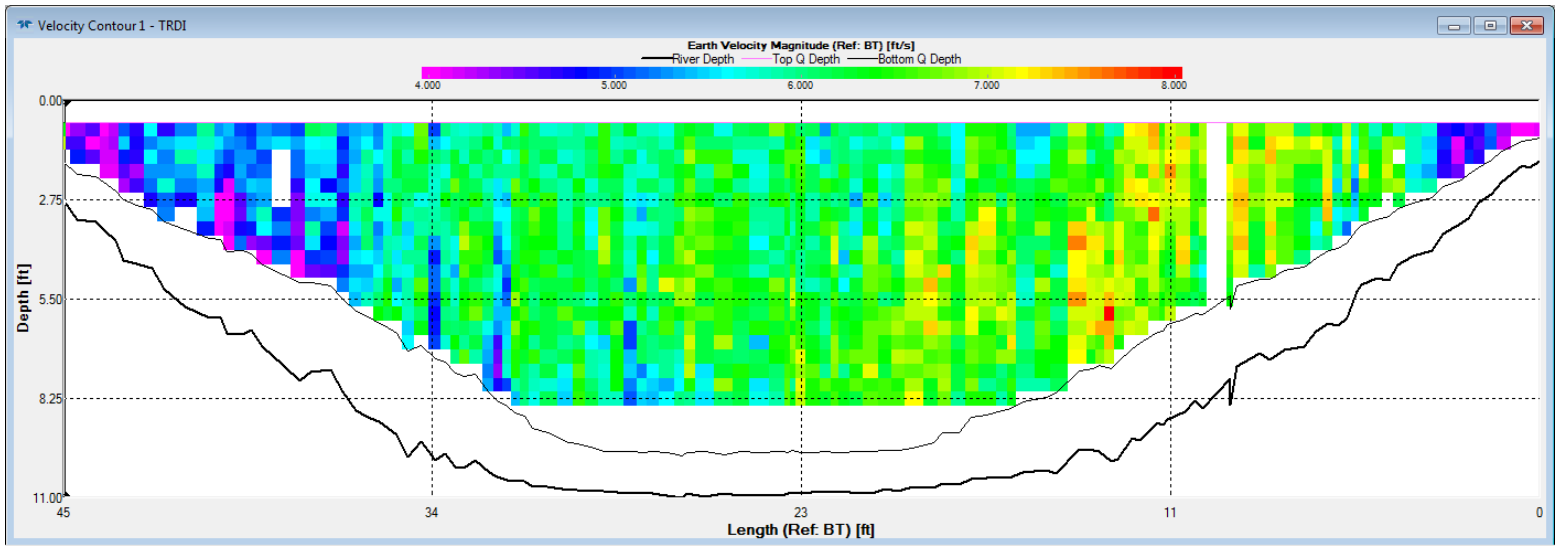

Figure 5 Sample velocity contour - HK operating velocities across cross-section 20 meters upstream of HK turbine. No major differences were seen between the two tests for all u/s velocity measurements. No velocity data from downstream of the HK turbine are available.

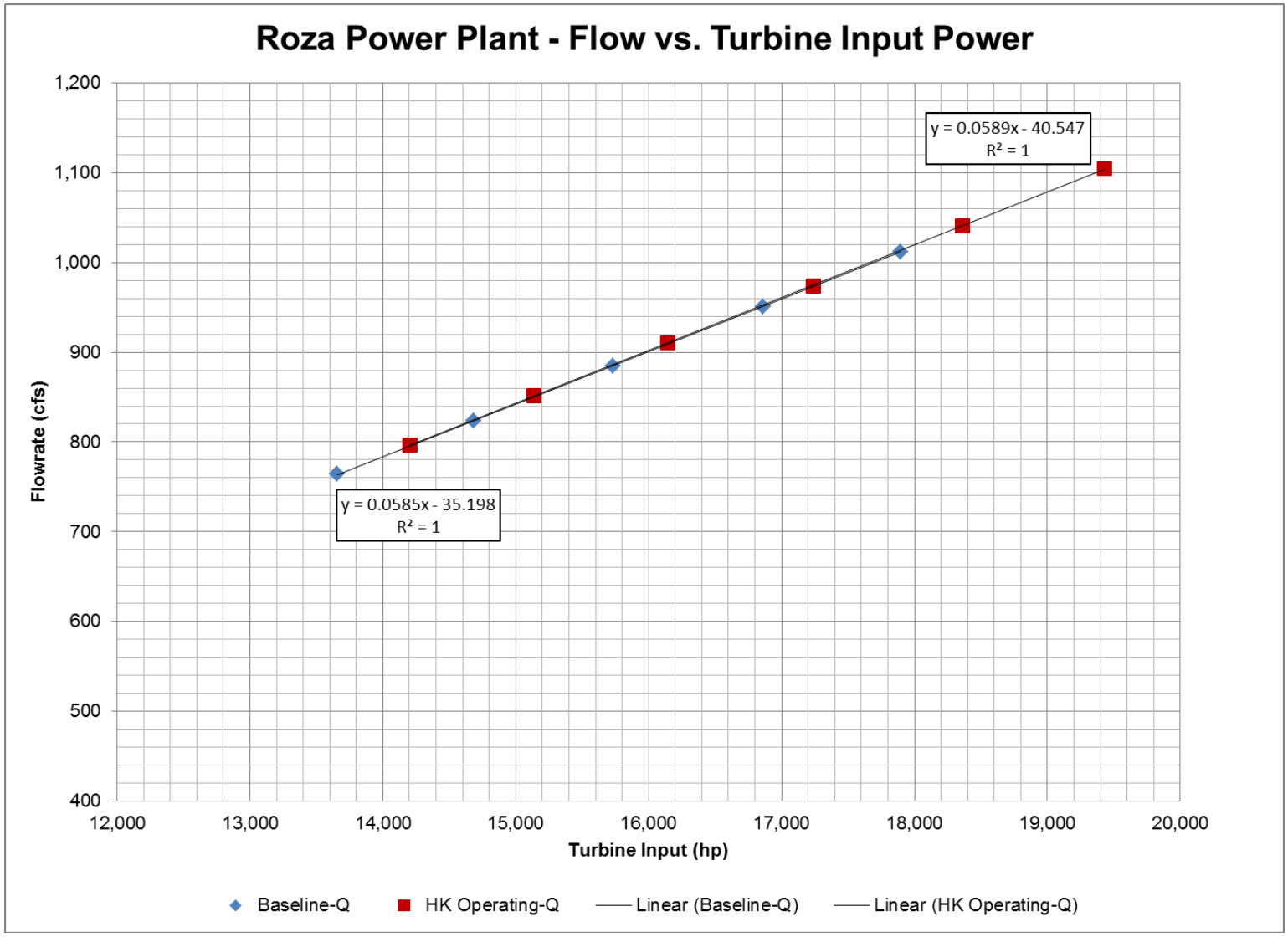

Figure 6 Plot of unit flow vs. power available at the turbine (Turbine Input). This calculation used only hydraulic data and does not include power from the generator. No impact was detected as baseline and HK operating data fall on the same line.

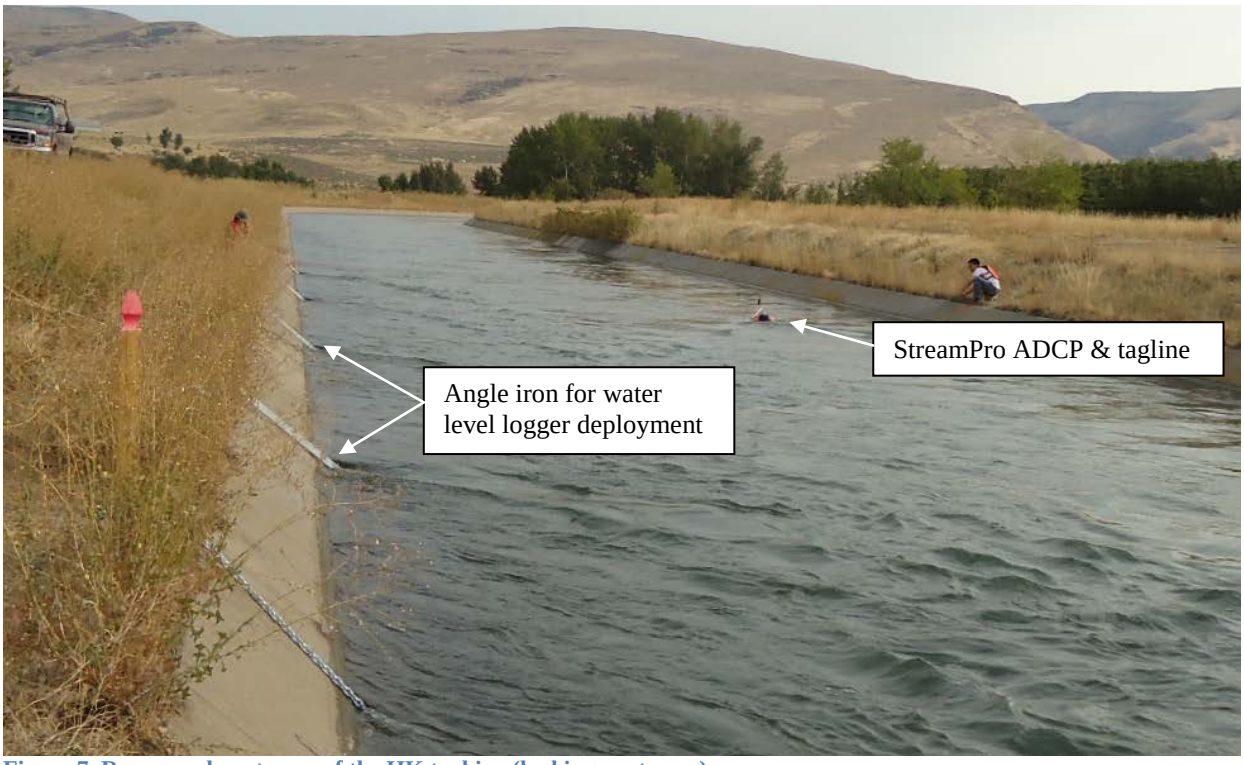

Figure 7 Roza canal upstream of the HK turbine (looking upstream).

Figure 8 Instream's vertical axis HK turbine operating in the canal (looking downstream).

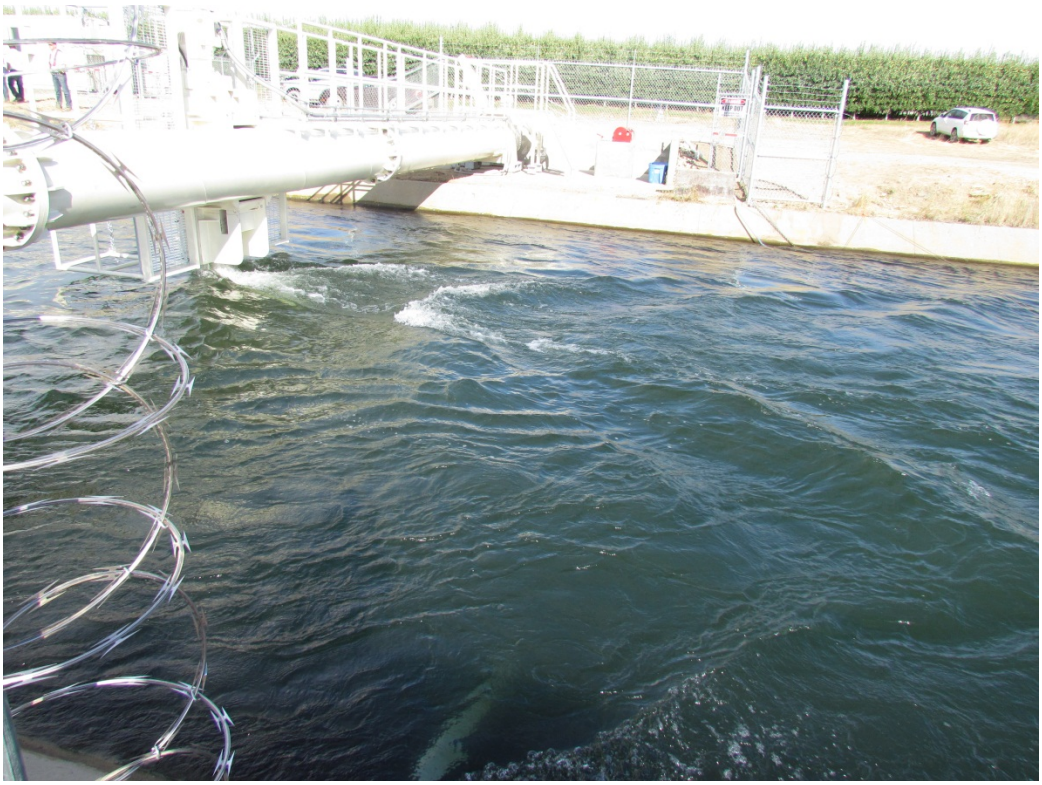

Figure 9 Canal flow immediately downstream of HK turbine.

Figure 10 Rough water surface downstream of HK turbine during operation (looking downstream). Flow is entering a transition from lined canal to a wider unlined section.

Figure 11 Tagline and StreamPro ADCP at a section upstream of the HK turbine. Canal velocities were measured at the same cross-sections as the water level loggers.

Figure 12 Pressure transducers installed on the Winter-Kennedy taps to measure flow through the hydropower unit at the power plant.

Figure 13 String transducer installed on servo-motor arm to measure wicket gate opening.

Figure 14 Pressure transducer installed to measure penstock pressure.

Figure 15 Monarch Data Chart recorder used to log generator power output data.