Micro Hydro Penstock Design

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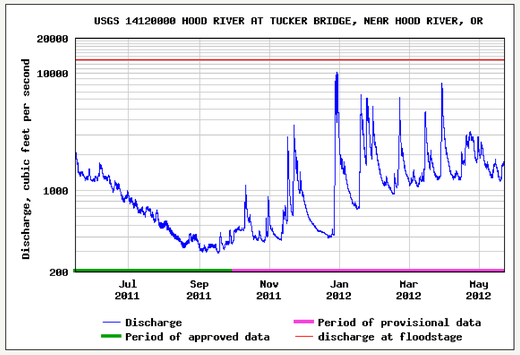
Quantitative analysis of re-routing a high-head, low-flow, run-of-the-river, under-100 kW hydro electric power plant penstock and comparison with the original route for purposes of head loss estimation and available power prediction



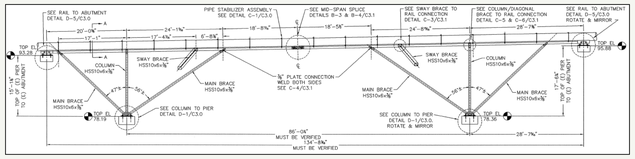
Annual flow variation of the Hood River, for which Tony Creek is a tributary

Available Flow

Estimated Seasonal Flow Variation

Annual Fluctuations

- Minimum – 30 ft^3/s
- Maximum – 1000 ft^3/s
- Year-Round Water rights – 2.5 ft^3/s



Professional drawing of new bridge undergoing installation

Penstock Route

The route of the New Pipeline as measured by different equipment

Total Head

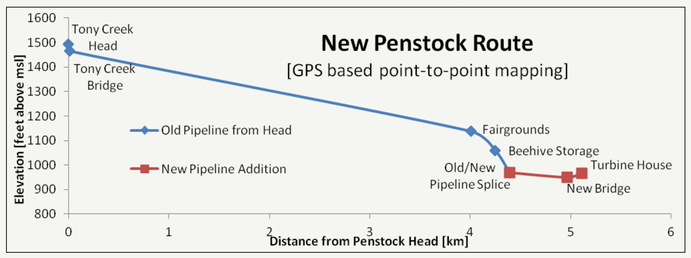
- GPS average estimate – 513 ft
- Skydiver Altimeter – 500 ft
- StaticHead Pressure (205 psi) – 473.1 ft [USED IN CALCULATIONS]

Total Pipeline Distance

- Google Maps – 3.4 miles
- GPS point-to-point – 3.18 miles
- Map Archive – 3.8 miles [USED IN CALCULATIONS]

Pipe Material

- Old and new cast iron
- Old and new steel
- New Plastic
- Welded and joined



Elevation change as a function of distance from the penstock head

Map of the new pipeline route where point 1 corresponds to the Tony Creek screen house (and penstock head), point 5 the splice into the old pipeline, point 6 the west side of the new bridge, and point 7 the turbine house. GPS measurements are overlaid on a satellite image.

Project Overview

- An old mill burned down and part of the disused infrastructure is being turned into an electricity generating station.
- A 4-mile pipeline diverts water from a local stream, called Tony Creek, and routes it to an old shop-cum-turbine house.
- After the original pipeline was damaged by copper thieves, an improved route is being constructed, including a new bridge.
- Verifiable flow and head loss measurements were taken before vandalism occurred.
- Stream flow is sufficient to maintain full water-right draw from Tony Creek year round.
- The two important fish species – steel head and bull trout – will not be affected.
- A turbine must be selected to match anticipated pipeline flow rates and head.

Objectives

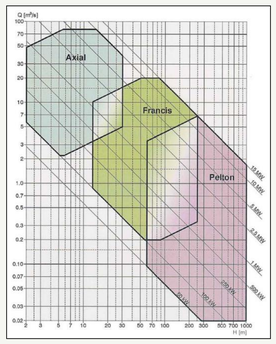
1. Accurately map the old and new penstock routes along with all fittings, elbows, T-joints, and valves. Estimate the pipe inner wall roughness. [COMPLETE]
2. Estimate the head loss and hydro power available from either penstock route based on the mapping. [COMPLETE]
3. Re-work the original flow measurements to account for discrepancies in the experimental set-up. [INPROGRESS]

Head Loss and Power

The predicted head loss and available hydraulic power

	Head Loss at 2.6 CFS [m]			Available Power at 2.6 CFS [kW]		
	Darcy	Hazen	Meas.	Darcy	Hazen	Meas.
Old Route	16.0	28.6	24.6	92.6	83.5	84.8
New Route	9.5	18.9	NA	97.3	90.5	NA

Preliminary Recommendation: Pelton Turbine



Turbine recommendation

Measurements

Tabulated measurements from flow tests

- Performed on the old penstock route in 2001
- Suspected inaccuracy in measurements due to:
  - + unknown nozzle coefficients
  - + location of pressure sensor relative to nozzle
  - + slowly dropping penstock level at high flows

Penstock pressure (psi)	Nozzle diameter (inch)	Calculated flow power (kW)	Calculated flow (ft^3/s)
205	static	0	0
200	1.0	35.6	0.9
193	1.3	56.9	1.5
186	1.5	72.2	2.0
170	1.75	85.8	2.6
153	2.0	95.1	3.3
125	2.5 (female pipe thread)	110	4.7
110	3.0 (3 inch gate valve, open)	131	6.2

Calculations

- Friction Head Loss
  - + Hazen-Williams Method

$$h_f = f\, l\, V_{avg}{}^2 / d\, 2g$$

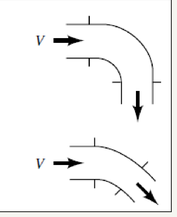
  - + Darcy-Weisbach Method

$$h_f = 10.67\, L\, Q^{1.85} / C^{1.86}\, d^{4.87}$$

- Minor Head Loss

$$h_L = K_L\, V_{avg}{}^2 / 2g$$

Component	K_L
Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4



Minor loss coefficients in elbows

Recommended Next Steps

1. Construct an improved testing apparatus and, if the pipes are flow-worthy, make new flow measurements at multiple locations along either penstock route.
2. Use the new flow measurements to verify the flow predictions.
3. Report the available power from both the old and new penstock routes.