NORTHERN ARIZONA UNIVERSITY

PRESENTATION 2 – HYDROPOWER COLLEGIATE COMPETITION

October 10th, 2023

Riley Frisell
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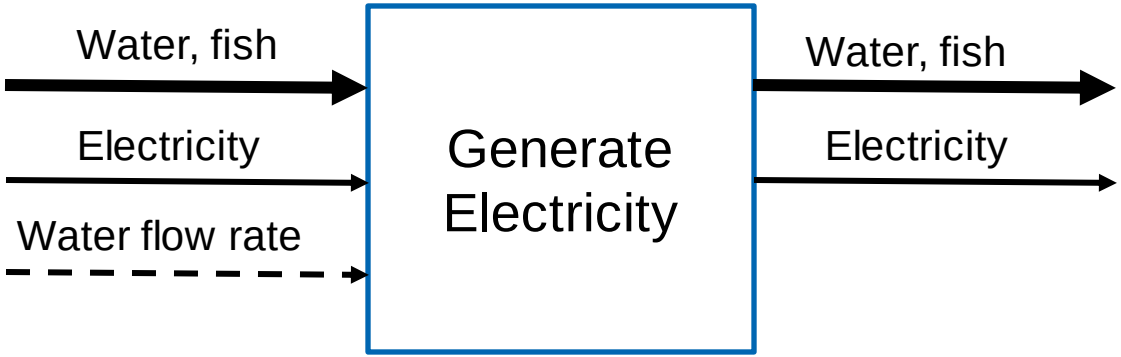
Project Description

- **Problem Statement:** Select and convert a US non-powered dam (NPD) into an efficient source of hydropower to address the nation's clean energy goals

Sponsor: US Department of Energy

Advisor/Client: Dr. Carson Pete

Black Box Model



Specific dam models may include other material flows such as other passengers/cargo, as well as additional signal inputs/outputs depending on dam functions

Fig. 1 – Black Box Model of a simple hydropower plant

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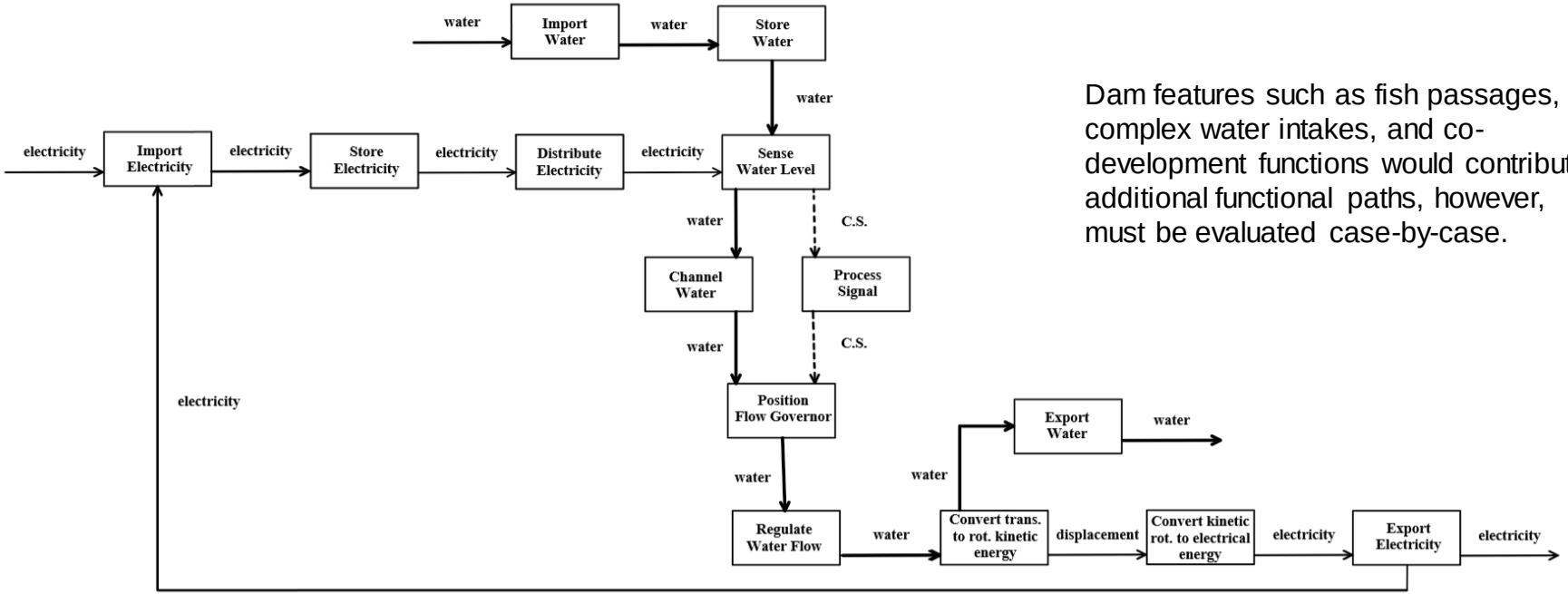
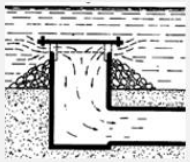
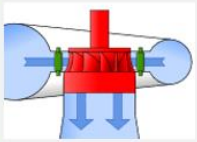
FUNCTIONAL MODEL

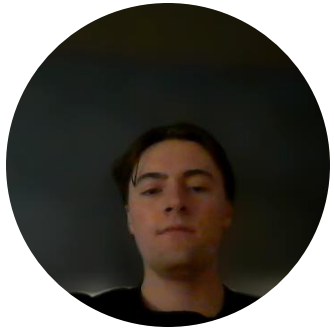


Dam features such as fish passages, complex water intakes, and co-development functions would contribute additional functional paths, however, must be evaluated case-by-case.

Fig. 2 - Functional Model of a simple, single turbine, hydropower plant

Concept Generation – Morphological Matrix

Concept	Option 1	Option 2	Option 3	Option 4
Dam Structure	Arch	Buttress	Rockfill	Gravity
The primary function is to resist the pressure of the water behind it				
Water intake	Capped intake	Intake tower	Direct flow intake structure	
Controlled and efficient utilization of the water coming out of the reservior				
Turbine	Francis	Pelton	Kaplan	
Converts the kinetic energy from the flowing water into mechanical energy for electricity generation				
Fish Passage	Juvenile Bypass System	Fish Ladder	Sluiceways	Spillway with raised Weir
Allows fish to pass through the dam without harming them				



Concept Generation – Pugh Chart

Pugh Chart - Hydropower Collegiate Competition					
Dam Conversion Top Concepts					
		Concept			
		1	2	3	4
		Buttress, Capped Inate, Kaplan, Fish ladder	Arch, Intake Tower, Francis, Sluiceway	Gravity, Direct flow intake, Francis, Spillway with raised weir	Rockfill, Intake tower, Pelton, Juvenile Bypass System
Criteria	Energy Production	S	DATUM	+	-
	Environmental Impact Mitigation	+		+	S
	Community Impact	-		-	S
	Site Interconnectivity	S		-	S
	Cost	+		S	+
	Structure	S		S	-
Sum of +'s		2		2	1
Sum of -'s		1		2	2
Sum of S's		3		2	3
Total		**1**		**0**	**-1**

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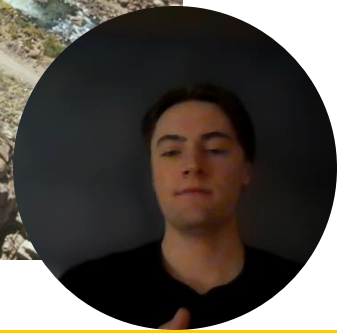
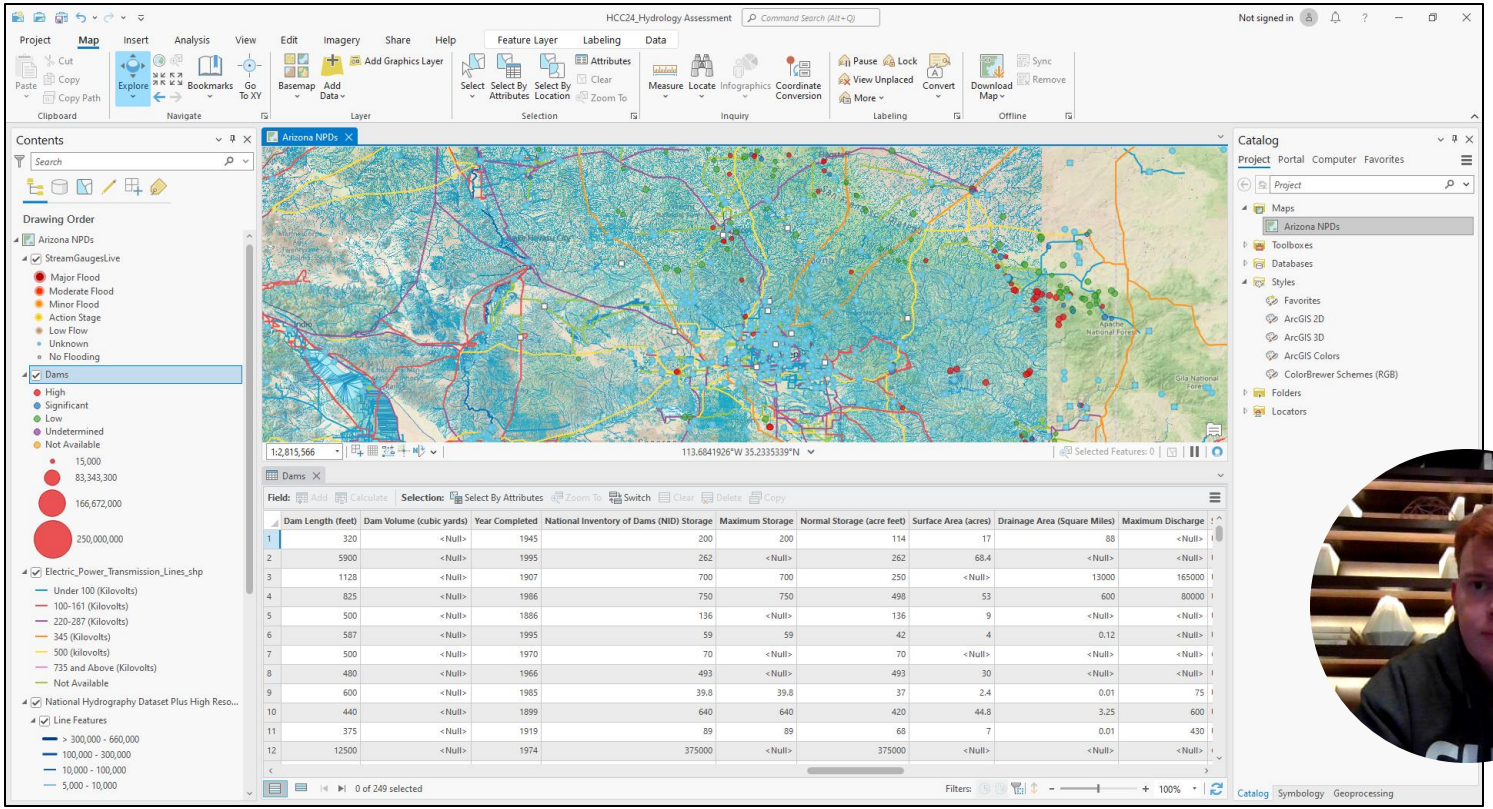
Concept Generation Continued

- **Concept:** Buttress, Capped Intake, Francis, Fish ladder
- **Pros:**
  - Energy production
  - Structure
  - Water storage
  - Site connectivity
  - Access
- **Cons:**
  - Environmental impacts
  - Build challenges
  - Cost

Bartlett Dam, Arizona



ENGINEERING MODEL – ARCGIS PRO



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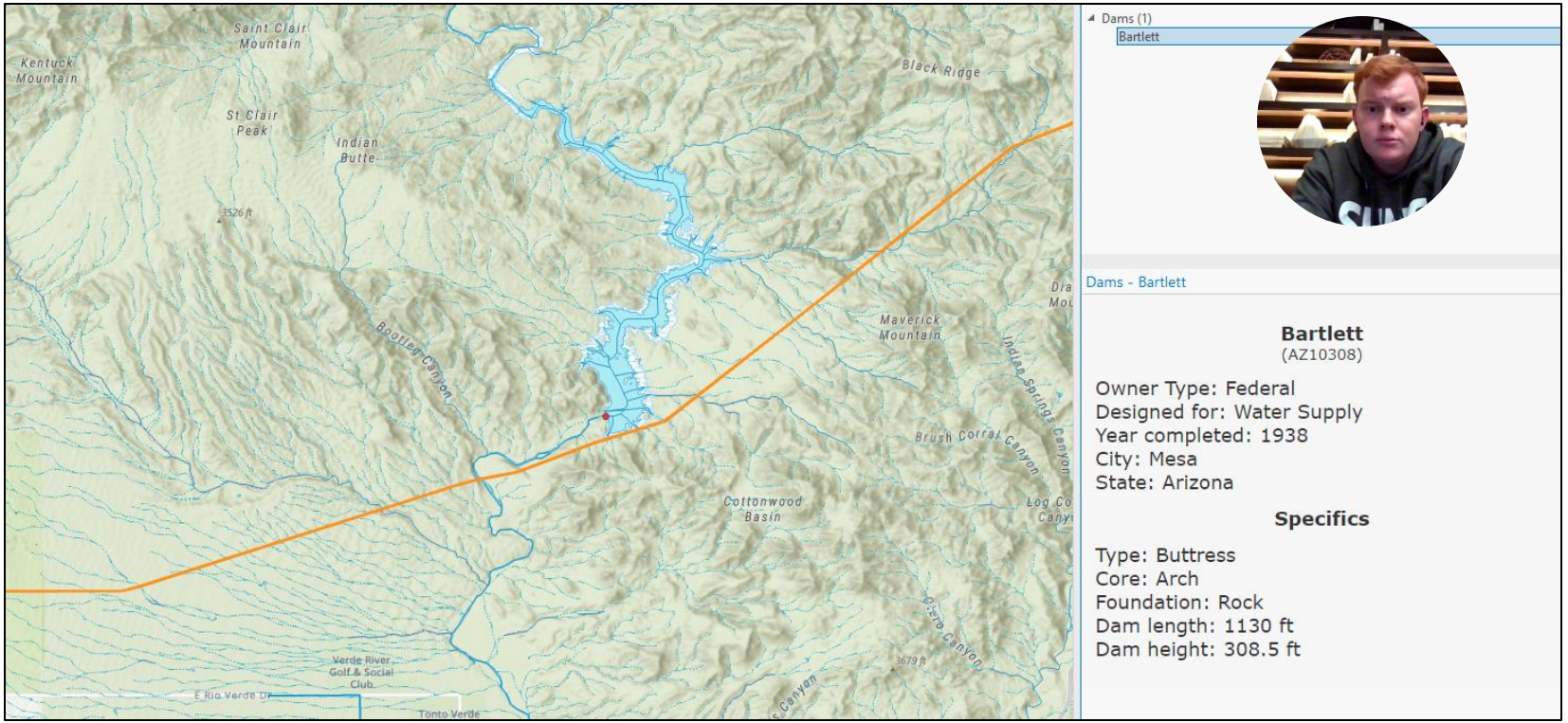
ArcGIS Pro – Continued



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ArcGIS Pro – Continued

Verde River *Connector*

Annual Mean Flow: 692 cfs Annual Mean Velocity: 4.33 f/s
Slope: 14.9%

Data from the National Hydrography Dataset Plus High Resolution

Voltage: 345 (Kilovolts)
(Type: AC; Overhead)

Status: In Service
Owner: Not Available
NAICS Description: Electric Bulk Power Transmission And Control
NAICS Code: 221121
Voltage Classification: 345 (Kilovolts)
Substation 1: Preacher Canyon
Substation 2: Pinnacle Peak Aps

Calculations – Potential Energy Generation

- Hydraulic Head Height
  - Given that Hydraulic Height is not provided, use

$$\Delta H = (\text{NID Height} * 0.7)$$

- Potential Hydropower Generation (MWh)

$$\text{Potential Generation} = (Q * \Delta H * \eta * T) / 11{,}800$$

  - Assume $\eta = 0.85$, ΔH remains constant, all flow may be utilized for generation
- Capacity Factor

$$C_f = \text{Annual Generation} / (\text{Installed Capacity} * 365 * 24)$$

- Potential Capacity (MW)

$$\text{Potential Capacity} = \text{Potential Generation (MWh)} / (C_f * 365 * 24)$$

Input Variables		
Average Flow (Q)	692	ft^3/s
Gross Head (ΔH)	215.95	ft
Generating Efficiency (η)	0.85	(unitless)
Generation Period (T)	8760	hours
Annual Generation	95,000	MWh
Installed Max Capacity	17	MW

Solutions		
Potential Generation	94,298	MWh
Capacity Factor (C_f)	0.6379	(unitless)
Potential Capacity	16.87	MW

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Specification Tables

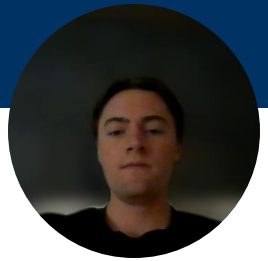

Table 1: Bartlett Dam Specification Table

Estimated Potential Generation	94,298 MW
Estimated Potential Capacity	16.8743 MW
Max Height	308.5 ft
Dam Length	1,130 ft
Max Flow Rate (spill)	287,500 ft^3/s
Annual Mean Flow Rate	692 ft^3/s
Normal Storage	178,000 acre-feet
Built (original)	1936-1939
Renovated/Upgrades	1997
Estimated Turbine Efficiency	0.85 1 Francis Turbine
Federal Agency Owner	Bureau of Reclamation
Hazard Potential Classification	High
Primary Purpose	Irrigation Water Supply

Count of Owner Types County, State	Primary Dam Type	Risk Assessment	Dam Name	Primary Purpose	Total
⊞Apache, Arizona					9
⊞Cochise, Arizona					2
⊞Coconino, Arizona					7
⊞Gila, Arizona					3
⊞Graham, Arizona					6
⊞Greenlee, Arizona					2
⊞Imperial, California					1
⊞La Paz, Arizona					1
⊟Maricopa, Arizona	⊟Buttress	⊟Very High (1)	⊟Bartlett	Water Supply	1
			Bartlett Total		**1**
		Very High (1) Total			1
	Buttress Total				**1**
	⊟Earth	⊟Moderate (3)	⊟Thunderbird Park Reservoir	Water Supply	1
			Thunderbird Park Reservoir Total		**1**
		Moderate (3) Total			1
	Earth Total				**1**
	⊟Gravity	⊟Moderate (3)	⊟Camp Dyer Diversion	Irrigation	1
			Camp Dyer Diversion Total		**1**
		Moderate (3) Total			1
	Gravity Total				**1**
	⊟Rockfill	⊟Very High (1)	⊟Horseshoe	Irrigation	1
			Horseshoe Total		**1**
			⊟New Waddell	Flood Risk Reduction	1
			New Waddell Total		**1**
		Very High (1) Total			2
	Rockfill Total				**2**
Maricopa, Arizona Total					**5**
⊞Mohave, Arizona					1
⊞Navajo, Arizona					8
⊞Pima, Arizona					4
⊞Pinal, Arizona					2
⊞Riverside, California					1
⊞Santa Cruz, Arizona					2
⊞Yavapai, Arizona					9
Grand Total					**63**

Figure 2: AZ NPD Data Summarized in Pivot Tables

Decision Matrix

Criterion	Weight	Bartlett Dam		Dam 2		Dam 3	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	10%	100	10		0		0
2. Flow Rate	10%	95	9.5		0		0
3. Distance to Existing Infrastructure (transmission lines/substations)	10%	90	9		0		0
4. Distance to Alternative Energy Sources	5%		0		0		0
5. Distance to Nearest City	5%	45	2.25		0		0
6. Amount of watershed	7%		0		0		0
7. Dam Ownership Type	3%		0		0		0
8. Potential Environmental Impact	10%		0		0		0
9. Dam Integrity	4%	80	3.2		0		0
10. Cost of Development/Economic Viability	10%		0		0		0
11. Water Storage Capacity	6%	90	5.4		0		0
12. Availability of Historical Flow Data	4%		0		0		0
13. Accessibility (ease of access for construciton and maintenance)	5%		0		0		0
14. Local Community Support	7%		0		0		0
15. Technical Feasibility	4%		0		0		0
Total	**1**		**39.35**		**0**		**0**
Relative Rank			**1**		**2**		**3**

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CAD MODEL – FRANCIS TURBINE ROUGH DRAFT

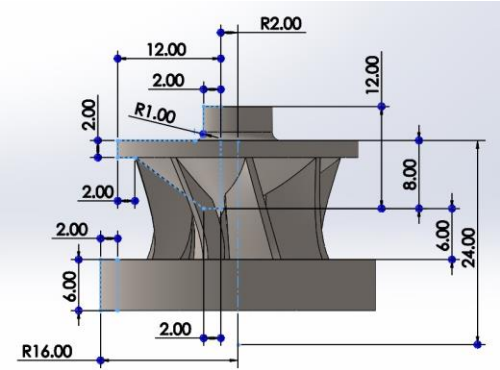


Figure 1: Turbine Dimensions (in)

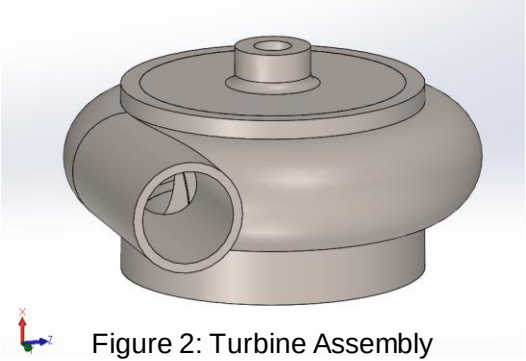


Figure 2: Turbine Assembly

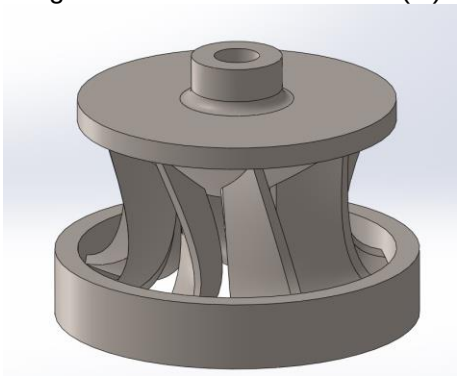


Figure 3: Isometric View Turbine

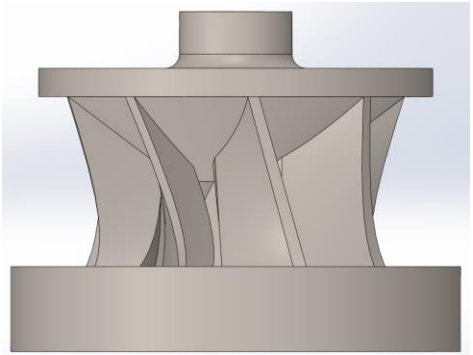


Figure 4: Turbine Side View

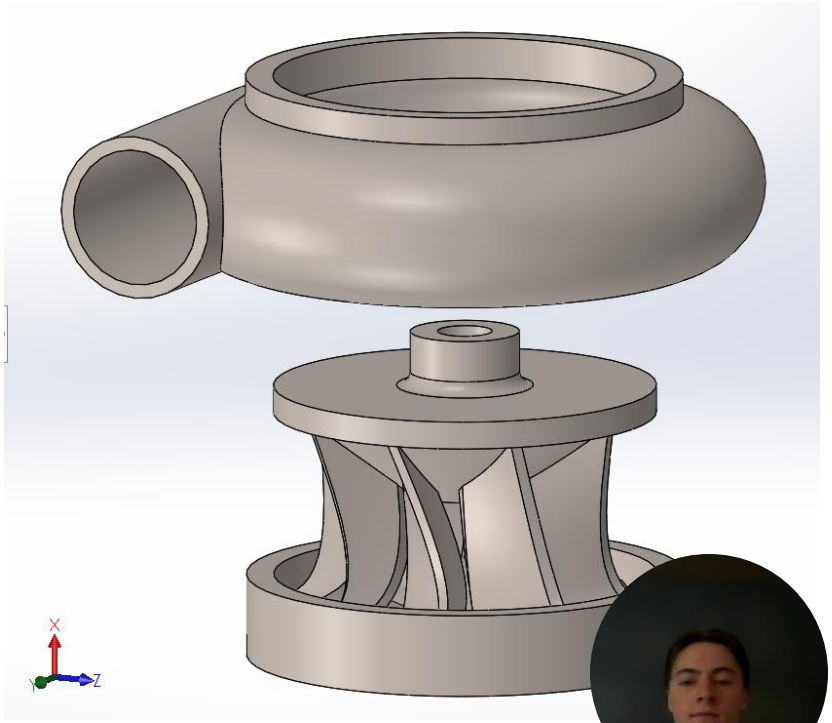
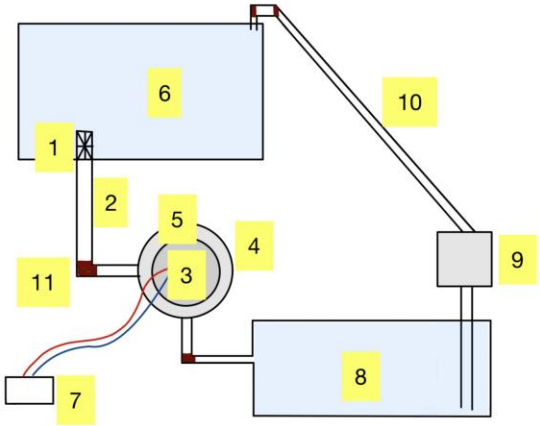


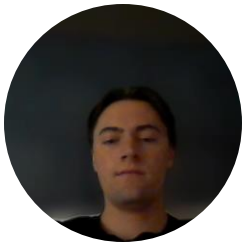
Figure 5: Exploded View

Bill Of Materials

Small scale enclosed hydropower system preliminary design

Item	Description	Specification	Quantity	Estimated Cost Per Part ($)	Estimated Total Cost ($)
1	Intake screen	Woven wire mesh	2	6.69	13.38
2	Penstock	10 ft PVC pipe	1	6.29	6.29
3	Turbine	Material TBD	1	50	50
4	Turbine Casing	Material TBD	1	30	30
5	Generator	Small turbine generator	1	40	40
6	Electrical Components	Wires, etc.		30	0
7	Upper water reservoir	Plastic bin	1	10	10
8	Lower water reservoir	Plastic bin	1	10	10
9	Tubing	Clear vinyl tubing	1	12.99	12.99
10	Pump system	Mini water pump	1	11.89	11.89
11	Pipe clamps and fittings	clamps, PVC elbows, etc.		40	184.55
				Total Cost	369.1





PROJECT BUDGET

Item	Category	Description	Total
NREL Competition Funding	Funds	$5,000 - Application Approval $5,000 - Mid-year Submission $5,000 - Final Submission *$5,000 - Optional Build Submission	20000.00
%10 Self-Raised Funds	Funds		2000.00
		Estimated Funds	22000.00

CLEAN CURRENTS - OHIO [10/09-10/12]	
Item	**Cost**
Flights	1856
Hotel	1022.11
Shuttles	257.6
Total Cost	3135.71

SUMMARY

Estimated Funds = $22,000

Estimated Costs = $5,082.10

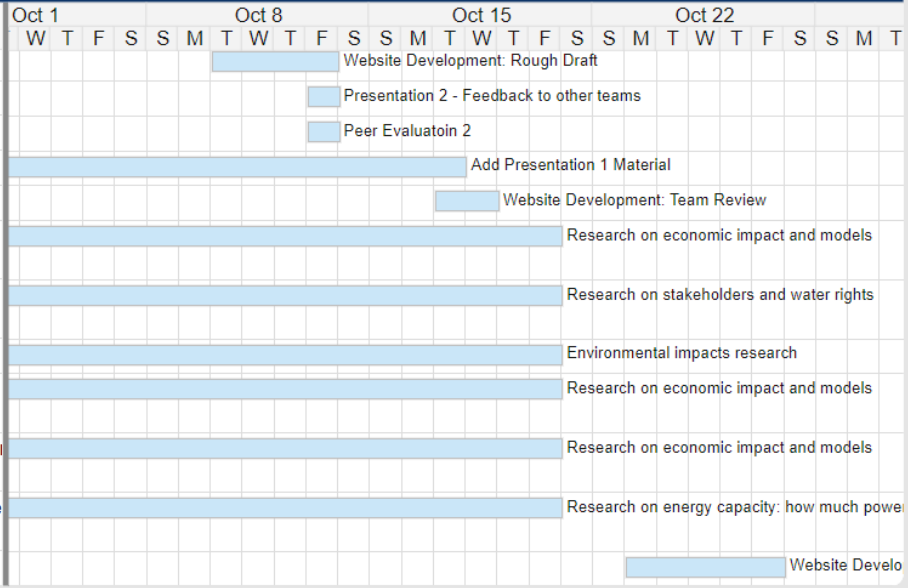
Available Funds = $16,917.90

Item	Category	Description	Unit Cost		Quantity	Cost
Bill of Materials	Materials	*Refer to BOM	369.10		1	369.10
Shuttle Ticket	Travel - IA	Round trip, FLG/PHX [04/29, 05/02]	65.00	/person	7	455.00
Plane Ticket	Travel - IA	Round trip, PHX/DSM [04/29, 05/02]	438.00	/person	7	3066.00
Rental Car	Travel - IA	7 passenger vehicle [04/29 - 05/02]	99.00	/day	3	385.00
Hotel	Travel - IA	3 rooms, 3 nights [04/29 - 05/02]	89.00	/room/night	9	807.00
					Estimated Cost	5082.10

SCHEDULE

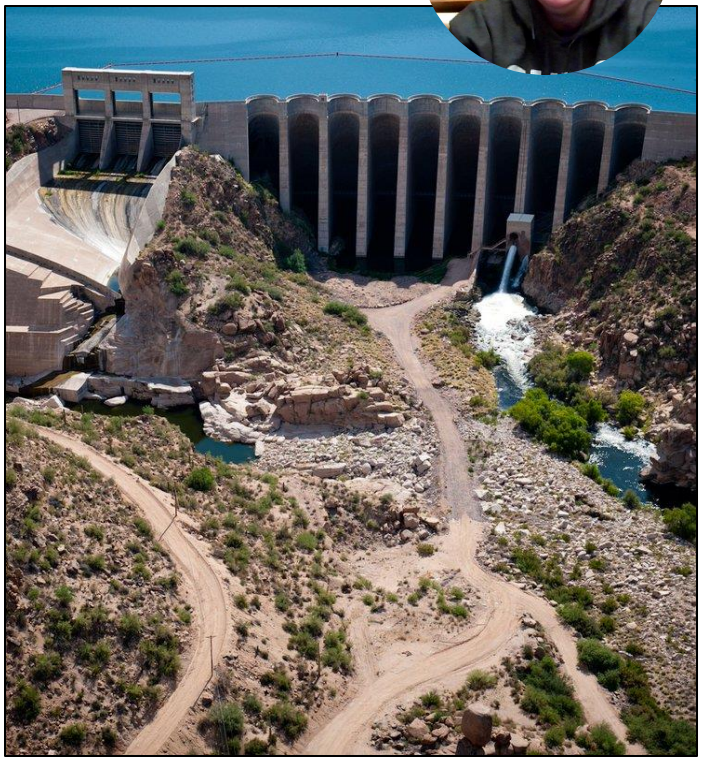
HCC24 - Task Status

Task Name	% Complete	Finish	Health	Assigned To
Website Development: Rough Draft	5%	10/13/23		Trevor Senior
Presentation 2 - Feedback to other teams	0%	10/13/23		Riley Frisell
Peer Evaluatoin 2	0%	10/13/23		
Add Presentation 1 Material	10%	10/17/23		Trevor Senior
Website Development: Team Review	0%	10/18/23		Trevor Senior
Research on economic impact and models	0%	10/20/23		Riley Frisell
Research on stakeholders and water rights	0%	10/20/23		Evan Higgins
Environmental impacts research	0%	10/20/23		Trevor Senior
Research on economic impact and models	0%	10/20/23		Evie Melahn
Research on economic impact and models	0%	10/20/23		Zonghua Ouyai
Research on energy capacity: how much power does a community need/have?	0%	10/20/23		Winston Steele
Website Development: Final Draft	0%	10/27/23		Trevor Senior



CONCLUSION

- ArcGIS mapping efforts have given us a solid foundation and project trajectory
- Significant strides in project catch-up through collaboration
- Next Steps: Focus on finalizing NPD selection and website advancement
- Goals: Use concept generation and research as head start for prototyping



THANK YOU!

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