NORTHERN ARIZONA UNIVERSITY

PRESENTATION 3 – HYDROPOWER COLLEGIATE COMPETITION

November 7th, 2023

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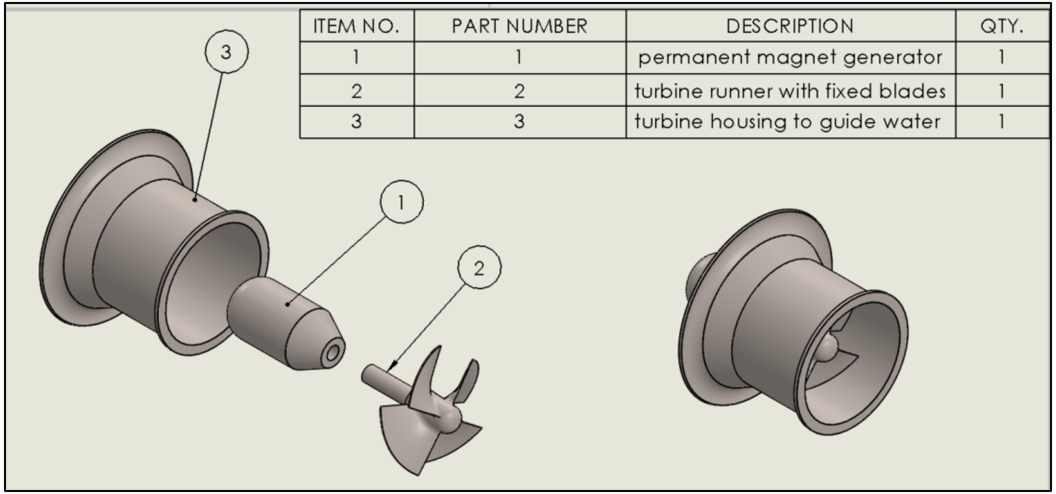
PROJECT DESCRIPTION

- **Problem Statement:** Optimize the conversion of Granite Reef Diversion Dam into a small-scale hydropower facility.

Upcoming Challenges

- Assessing environmental and regulatory considerations
- Interconnection with the power grid
- Ensure long-term viability
- Optimizing turbine design for efficient energy extraction

DESIGN DESCRIPTION



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1	permanent magnet generator	1
2	2	turbine runner with fixed blades	1
3	3	turbine housing to guide water	1

Figure 1: Hydropower turbine assembly

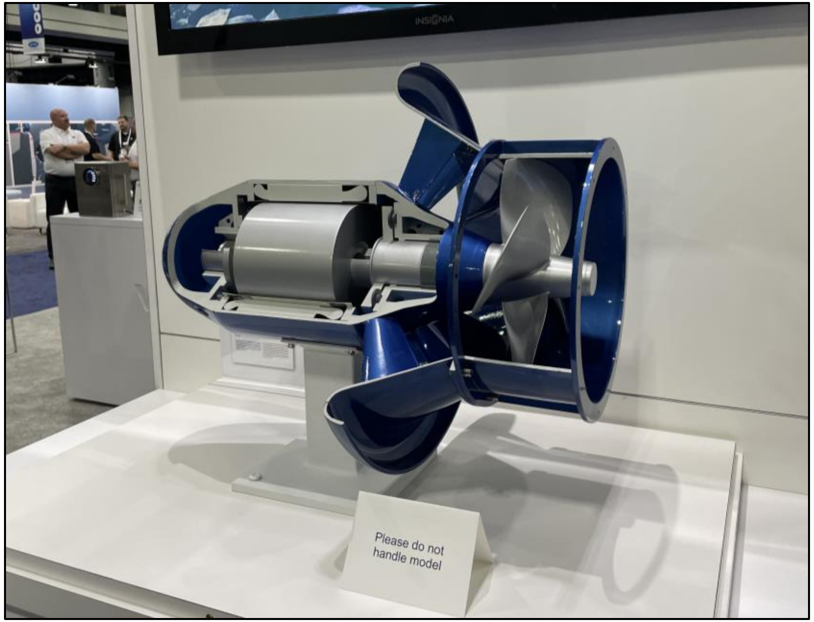


Figure 2: Voith StreamDiver model from Clean Currents Conference 2023

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DESIGN DESCRIPTION

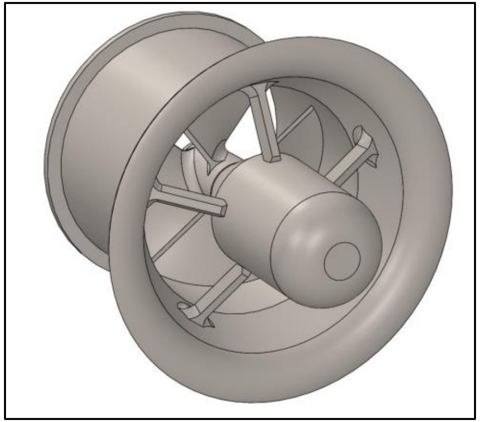

Figure 3: Isometric view of hydropower turbine water inlet

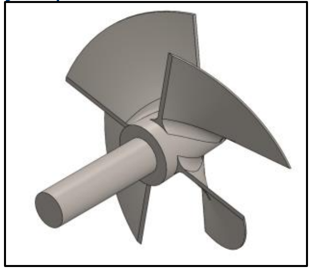

Figure 4: Fixed runner

Hydropower turbine model

- Turbine housing with guide vanes
- Fixed blade runner
- Minimum head 6 ft
- Fish safe blades
- Stainless steel

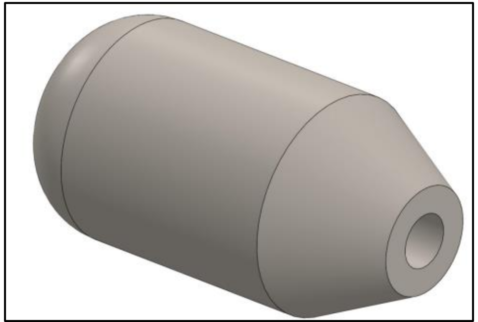

Figure 5: Isometric view of PMG

Permanent Magnet Generator

- Converts mechanical rotation to electricity
- Highly reliable
- No current supply required
- Lifespan greater than 20 years

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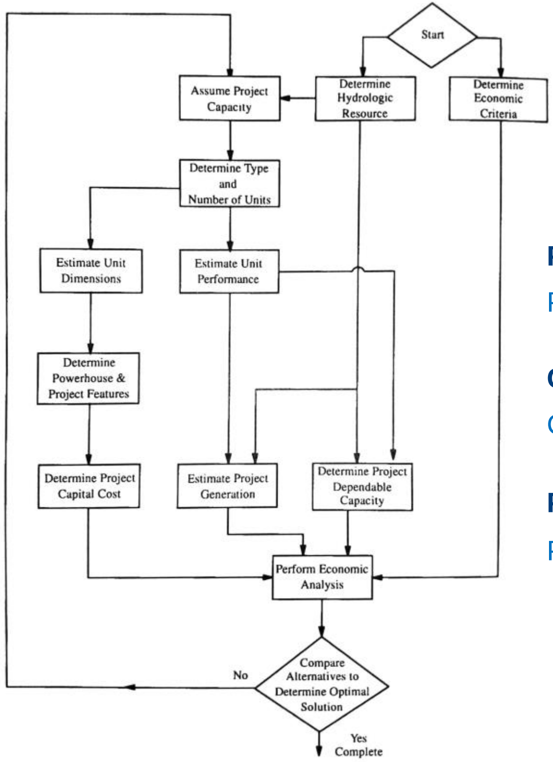
DESIGN REQUIREMENTS – UPDATED QFD

#	Technical Requirement	1	2	3	4	5
1	Mitigated Environmental Impacts					
2	Financial Feasibility	--				
3	Site Interconnectivity	+	++			
4	Co-Development Opportunities	−	++	+		
5	Energy Output		+	++	+	
6	Affected Population	+	+	++	++	++

Legend	
A	Red Rock, IL
B	Lake Livingston, TX
C	Willow Island, WV

#	Customer Needs	Customer Weights	Weight %	Technical Requirements: Mitigated Environmental Impacts	Financial Feasibility	Site Interconnectivity	Co-Development Opportunities	Energy Output	Affected Population	Customer Opinion Survey: 1 *Poor*	*2*	*3 Acceptable*	*4*	*5 Excellent*
1	Environmental Impact Mitigation	10	21.28	9	6	3	6					B	C	A
2	Project Expenditures	9	19.15	6	9	6	6	6	3		A	B		C
3	Accessibility	8	17.02	3	6	9	3	6	3		A	B		C
4	Co-Development Proposal	7	14.89	6	6	6	9		6			C		AB
5	Energy Production	6	12.77		6	3		9	6	A		B	C	
6	Community Engagement	5	10.64		3	3	6	6	9					C
	Technical Requirement Units			%	2023 $	miles	#	MW	#					
	Technical Requirement Targets			↑	↓	↓	↑	(1-10)	↑					
	Absolute Technical Importance			447	600	491	491	396	370					
	Relative Technical Importance			3	1	2	4	2	5					

ENGINEERING CALCULATIONS – CAPACITY



Input Variables		
Average Flow (Q)	1966	cfs
Gross Head (ΔH)	20.3	ft
Generating Efficiency (η)	0.85	(unitless)
Generation Period (T)	8760	hours
Annual Generation	25,184	MWh
Installed Max Capacity	2.874858	MW

Potential Hydropower Generation (MWh)

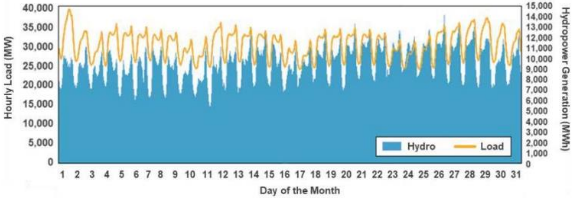
$$\text{Potential Generation (MWh)} = \frac{Q * \Delta H * \eta * T}{11{,}800}$$

Capacity Factor

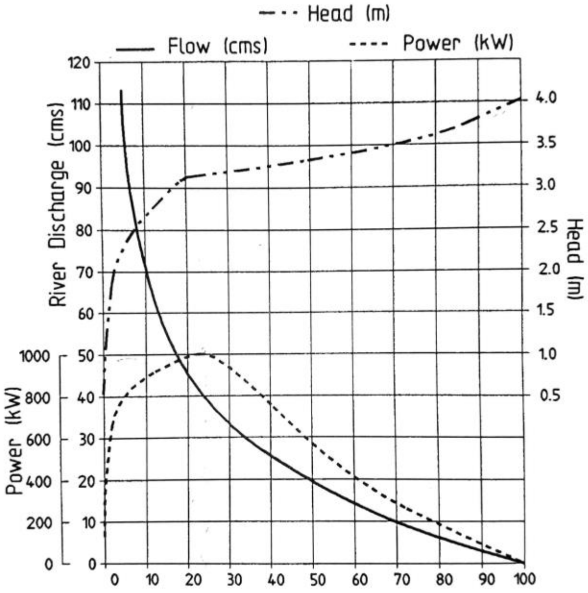
$$CF = \frac{\text{Annual Generation}}{\text{Installed Capacity}}$$

Potential Capacity (MW)

$$\text{Potential Capacity (MW)} = \frac{\text{Potential Generation (MWh)}}{CF * 365 * 24}$$



Solutions		
Potential Generation	25,184	MWh
Capacity Factor (C_f)	1.0000	(unitless)
Potential Capacity	2.87	MW



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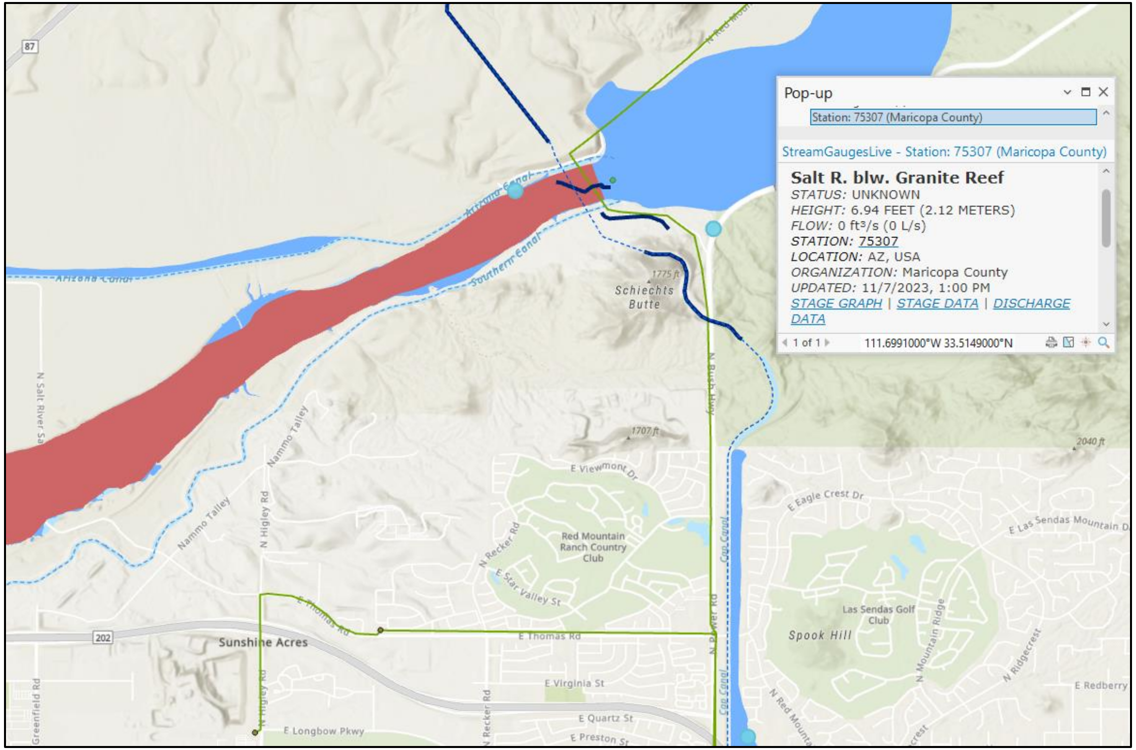
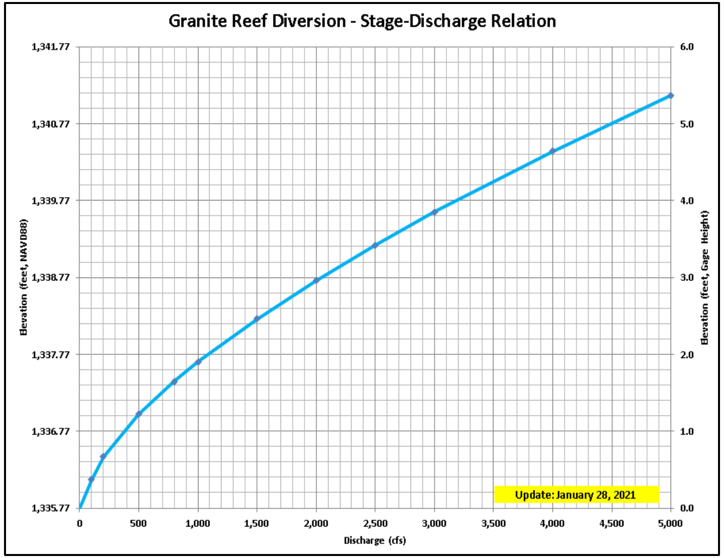
ENGINEERING MODEL – ARCGIS PRO



- Red Area: Floodway
- Blue Area: 100-Year Flood Zone
- Blue Dots: Stream Gages



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ENGINEERING MODEL – ARCGIS PRO

DESIGN VALIDATION – FMEA

Product Name: Granite Reef Dam System Name: Hydropower turbine Subsystem Name: PMG Component Name: Fixed runner		Development Team: HCC24				Page No 1 of 1 FMEA Number: Date: 11/03/2023			
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1: Generator Generate electricity	Shaft in the generator stops rotating, or generator fails	Electricity production would stop	7	Debris or sediment clogging the runner	3	Loading test and efficiency test	2	42	Trash rack to filter out large aquatic animals and debris
2: Fixed runner Capture KE from water	Cavitation	Runner would become less efficient and possibly crack	5	Formation of vapor bubbles round runner bursting, causing pressure changes	4	Material strength and runner vibrations test	2	40	High strenght blade, forward edge blade profile, improve distribution along pressure angle of blade
3: Unit casing Guide water to runner	Leaks or cracks	The casing would suffer from errosion, water leaking around the tube, electrical failure	6	Debris, too high of flow moving abrasive sediments	3	Pressure and flow capacity test. Corrosion resistance inspection	2	36	Strong materials, aerodyncamic design for flow to minimize water force
4: Dam structure Supports the pressure from reservoir	Dam failure, excessive flooding	Downstream flooding, wildlife impacts, and South canal and Arizona canal water supply would stop.	10	High flow water moving abrasive sediments or debris over the dam or thruough the turbine	1	Excessive water assement and test	2	20	Regular inspection, every 3-5 years. Assesment into dam structure before making any alterations

Our completion's optional build and test challenge is focused on a facility conceptual design. Testing and resources required to be determined. [1],[2]

PROJECT BUDGET

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

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
Self-Raised Funds	Funds	EPIC Funding for Clean Currents	3135.71
		Estimated Funds	23135.71

CLEAN CURRENTS - OHIO [10/09-10/12]

Item	Cost
Flights	1856
Hotel	1022.11
Shuttles	257.6
Total Cost	3135.71

SUMMARY

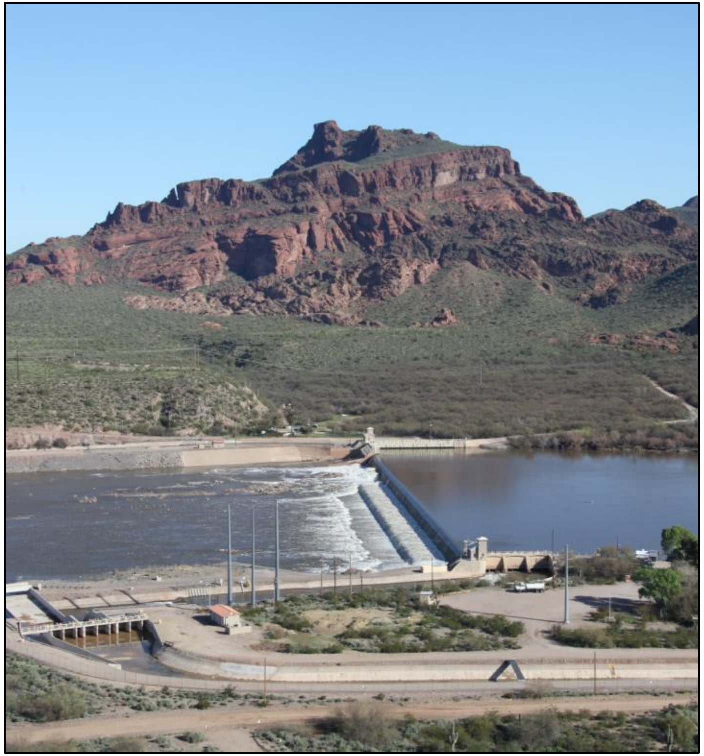
Estimated Funds	23135.71
Estimated Costs	8217.81
Remaing Budget	14917.90

SCHEDULE

1	Week 1 - Project Management	01/16/24	4d	01/19/24
2	Highlight purchasing plan following updates with DOE	01/16/24	4d	01/19/24
2	Alight deliverables with Macabe	01/16/24	4d	01/19/24
1	Week 2 - Engineering Model Summary	01/22/24	5d	01/26/24
2	Highlight testing plan with Voith and SRP	01/22/24	5d	01/26/24
1	Week 3 - Midyear Submission Due	01/22/24	20d	02/16/24
2	Community Connections Challenges	01/22/24	5d	01/26/24
2	Siting Challenge	01/22/24	5d	01/26/24
2	Design Challenge	01/22/24	5d	01/26/24
2	Optional Build and Test Challenge	01/22/24	5d	01/26/24
2	Hardware Status Update - 33% Build	02/12/24	5d	02/16/24
1	Weeks 4-8	02/19/24	15d	03/08/24
2	Follow up on purchase orders	02/19/24	5d	02/23/24
2	Get with Macabe on updated design	02/26/24	5d	03/01/24
2	Get with EE sub-team on electrical components	02/26/24	5d	03/01/24
2	Hardware Status Update - 67% Build	03/04/24	5d	03/08/24
1	Team Photos and Video Submission	03/20/24	4d	03/25/24
1	Weeks 9-13	03/25/24	20d	04/19/24
2	Finalized Testing Plan (testing equipment)	03/25/24	5d	03/29/24
2	Hardware Status Update - 100% Build	04/01/24	5d	04/05/24
2	Initial Testing Results	04/08/24	5d	04/12/24
2	Final Testing Results	04/15/24	5d	04/19/24
1	Submission of Siting and Design Report	01/15/24	73d	04/24/24
1	Head to Competition: Iowa	04/29/24	4d	05/02/24
2	Client Handoff - Spec Sheet and Operation/Ass	04/29/24	4d	05/02/24

CONCLUSION

- With dam selected, we use mapping tools to guide our site assessment
- Moving forward with CAD model to help with preliminary design
- Next Steps: Contact SRP and HDR to gather site-specific data
- Goals: Complete HW04 early to move forward with competition challenges



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THANK YOU!

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References

[1] “Hydropower collegiate competition (HCC),” American Made Challenges ,

https://americanmadechallenges.org/challenges/hydropower-collegiate-competition (accessed Nov.

9, 2023).

[2] U. Dorji et al., “Hydro Turbine Failure Mechanisms: An overview,” Engineering Failure Analysis, https://www.sciencedirect.com/science/article/abs/pii/S1350630714001277 (accessed Nov. 9, 2023).