NAU HCC26

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NAU NORTHERN ARIZONA UNIVERSITY

Project Description

1. Siting Challenge - One of the following site selection challenges is selected - 35%
    a. NPD Conversion (1-10MW)
    b. PSH System Integration (up to 1GW)
    c. In-Conduit System (100KW-10MW)
2. Design Challenge - One of the following tracts is selected - 40%
    a. Facility Conceptual Design
    b. Component Deep Dive
3. Community Connections - Engage with industry and communities - 25%
4. Poster - A poster showcasing the Siting and Design challenges is presented at the Final Event
5. Pitch - 90 second pitch for the project’s takeaways
6. Build and Test (Optional) - Build and test a scaled prototype

Why is this Important?:

- Continually growing energy needs
- Hydropower is a sustainable source of energy
- Prepares next-generation engineers for hydropower industry

Sponsored by Carson Pete

Customer & Engineering Requirements

Customer Requirements (CRs)

(from sponsor expectations + team interpretation)

- Generate renewable, sustainable electricity from a non-powered dam conversion (power, head loss, flow).
- Provide safe, reliable, and low-maintenance operation.
- Long life expectancy,reliability (no water, no dam.)
- Minimize environmental/ecological impact (fish, sediment, water quality).
- Recreational & aesthetic preservation (tourists, farms.)
- Deliver cost-effective power.
- Comply with Regulatory codes.

Engineering Requirements (ERs)

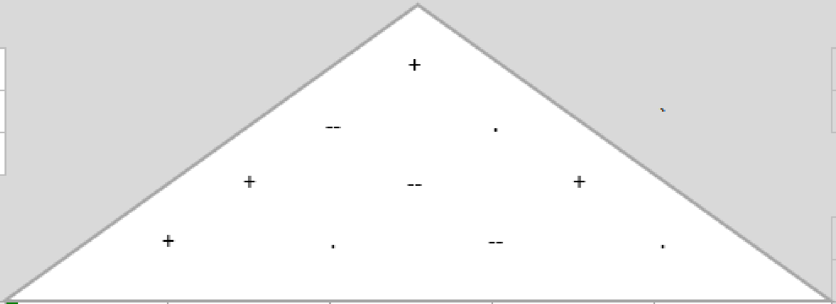
(quantifiable, derived from CRs, project rules)

- Power output range: 1–10 MW
- Net head-loss optimization: %
  Operable head: 1–150 m
- Flow rate: m^3/s
- Uptime reliability: >95%
- Grid Interconnection distance: Km
- Sediment Management: tons/day

Quality Function Deployment

Quality Function Deployment

Project title: HydroJacks
Project leader: Karsten Jones
Date: 9/18/2025



Correlation:

+	.	-
Positive	No correlation	Negative

Relationships:

9	3	1	
Strong	Moderate	Weak	None

1: low, 5: high		Generation Capacity (MW)	Net Headloss Optimization (%)	Design Flow (m^3/s)	Sediment Management (tons/day)	Grid Interconnection (Km)		Competitive evaluation (1: low, 5: high)		
	Desired direction of improvement (↑,0,↓)	0	0	0	0	0				
Customer importance rating	Functional Requirements → / Customer Requirements ↓						Weighted Score	Competitor rating 1	Competitor rating 2	Competitor rating 3
3	Reliable Power Supply	9	9	9	3	9	117	5	4	5
7	Structural Integrity	1	1	3	3	9	119	5	4	4
5	Competitive cost	9	9	9	3	9	195	3	5	4
4	Recreational & Aestetic Preservation	3	1	9	9	3	100	3	4	4
2	Low Enviromental Impact	3	3	9	9	9	66	4	4	4
6	Long Life Expectancy	3	9	9	9	1	186	5	4	4
1	Regulatory Compliance	3	3	9	9	3	27	5	5	4
	Technical importance score	118	146	210	162	174	810			
	Importance %	15%	18%	26%	20%	21%	100%			
	Priorities rank	**5**	**4**	**1**	**3**	**2**				

Background & Benchmarking

- Finnrunner
  - Finnish startup that offers resource-efficient solutions like the adoption of composite materials and additive manufacturing for turbine and equipment production.
- Littoral Power Systems
  - US-based startup that enables small remote hydropower systems to improve their efficiency. Low cost, flexible, low maintenance, adjustable turbine systems.
- Kinetic NRG
  - Australian startup that utilizes an environmentally friendly rotor to produce more power from low-velocity water flow.
- Powerturbines
  - Spanish startup manufacturing a wide range of hydraulic turbines that adapt to various water flow rates and pressures. The startup's nano turbine, battery charging turbines, and grid-tied turbines are installed in parallel with pressure-reducing valves (PRVs).
- RheEnergise
  - UK-based startup that uses a high-density fluid that enables hydroelectric projects to operate on low hills rather than high mountains. This fluid allows smaller project deployment and, in turn, reduces construction costs while minimizing footprint.

Background & Benchmarking

- Redrock Hydroelectric Project
  - -Added 4-5 MW capacity to non-powered section.
  - -uses older but quality retrofit on infrastructure.
  - -Reliable power, but high upfront costs.
- Uniontown Dam Retrofit
  - -Added 5 MW capacity.
  - -low head example with higher flows,smaller river.
  - -modest environmental impact, strong community scale power.
- Holtwood Small Hydro Retrofit
  - -Added 7 MW capacity
  - -Good Cost benefit, minimal visual footprint.

	Redrock Hydroelectric Project	UnionTown Dam Retrofit	Holtwood Small Hydro Retrofit
Reliable Power Supply	5	4	5
Structural Integrity	5	4	4
Competitive cost	3	5	4
Recreational & Aestetic Preservation	3	4	4
Low Enviromental Impact	4	4	4
Long Life Expectancy	5	4	4
Regulatory Compliance	5	5	4

A Literature review

[1] D. P. Billington, D. C. Jackson, M. V. Melosi, *The History of Large Federal Dams: Planning, Design, and Construction in the Era of Big Dams*, U.S. Department of the Interior, 2005. https://www.nps.gov/parkhistory/online_books/nnps/large_dams.pdf

[2] J. D. Rogers, *"Hoover Dam: Evolution of the Dam's Design"*, Missouri University of Science & Technology, Proceedings, https://www.researchgate.net/publication/269084625_Hoover_Dam_Evolution_of_the_Dam%27s_Design

[3] U.S. Department of Energy / ORNL, *"An Assessment of Energy Potential at Non-Powered Dams in the United States"*, ORNL report, https://www1.eere.energy.gov/water/pdfs/npd_report.pdf

[4] C. Hansen, et al., *"Hydropower Development Potential at Non-Powered Dams"*, Renewable Energy (or whatever journal), vol., no., pp., https://www.sciencedirect.com/science/article/pii/S1364032121003476

[5] U.S. Dept. of Energy / Oak Ridge National Lab, *"Non-Powered Dam Retrofit Exemplary Design for Hydropower,"* ORNL, May 2022. https://info.ornl.gov/sites/publications/Files/Pub167488.pdf

[6] S. DeNeale et al., *"An Assessment of Non-Powered Dam Hydropower,"* ORNL, 2022. https://info.ornl.gov/sites/publications/Files/Pub167488.pdf

[7] R. E. Schroeder, et al., *"Development of a procedure and tool for retrofit hydropower potential at South African dams,"* 2023. https://pdfs.semanticscholar.org/459f/cff261950ad3ccf9b8eb8426a24b30dfb1ae.pdf

History of dams → many built for flood control/irrigation, not power [1][2]

NPD potential → thousands retrofittable, 1–10 MW scale [3][4]

Retrofit design → ORNL studies show pathways & examples [5][6]

Global case study → feasibility confirmed internationally [7]

[8]OSHA's standard for confined spaces in construction (29 CFR 1926.1200) applies to any work performed in an area that is large enough for a worker to enter but has limited or restricted entry/exit

A Literature review

Most notable content

- Properties of turbine qualities and aspects.
- Considerations when beginning a hydro electric product.
- Environmental considerations for the project
- Sustainability optimizations and methods.

[8]Federal Energy Regulatory Commission, *Hydropower Primer: A Handbook of Hydropower Basics*, Office of Energy Projects, Washington, DC, Tech. Rep., Feb. 2017. [Online]. Available: https://www.ferc.gov/sites/default/files/2020-05/hydropower-primer.pdf

[9]If dam sediment is contaminated, all cleanup operations must comply with OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) standards (29 CFR 1926.65)

[1] "Hydro Power," *Student Energy*. [Online]. Available: https://studentenergy.org/source/hydro-power/?gad_source=1&gad_campaignid=1654243094&gbraid=0AAAAADmfXHS1brvcEmdjhgh3Bh2-BE8sS&gclid=Cj0KCQjw8p7GBhCjARIsAEhghZ23280bp7kIy7zclB55_iTuTpQ5LtD_TIJClYEDh73TYyiz8Kvf5HUaAuJ1EALw_wcB. [Accessed: 18-Sep-2025].

[2] P. Chapallaz, *Manual on Pump Used as Turbine*. [Online]. Available: https://www.scribd.com/document/408962857/Chapallaz-Manual-on-Pump-used-as-Turbine-pdf. [Accessed: 18-Sep-2025].

[3] L. W. Mays, *Water Resources Engineering*, Wiley, 2010. [Online]. Available: https://dl.watereng.ir/doc/Larry%20W.%20Mays%20-%20Water%20Resources%20Engineering%20_2010,%20Wiley_.pdf. [Accessed: 18-Sep-2025].

[4] "Hydropower in the Context of Sustainable Energy Supply: A Review of Technologies and Challenges," *ResearchGate*. [Online]. Available: https://www.researchgate.net/publication/258404306_Hydropower_in_the_Context_of_Sustainable_Energy_Supply_A_Review_of_Technologies_and_Challenges. [Accessed: 18-Sep-2025].

[5] "Article — ScienceDirect," *ScienceDirect*. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1364032102000060. [Accessed: 18-Sep-2025].

[6] J. P. Ficalora and L. Cohen, *Quality Function Deployment and Six Sigma: A QFD Handbook*, 2nd ed., Upper Saddle River, NJ: Prentice Hall, 2010. OBNB+2Penn State University Libraries Catalog+2

[7] Q. A. Okang, T. H. Bakken, and A. Bor, "Investigation of the Hydroelectric Development Potential of Nonpowered Dams: A Case Study of the Buyuk Menderes River Basin," *Water*, vol. 15, no. 4, article 717, pp. –, Feb. 11, 2023, doi:10.3390/w15040717.

A Literature review

<u>Topics Include:</u>

- Mathematical modeling and design
- Economics of energy
- Industry overviews
- Safety Analysis

[1] G. Gemperline and C. Crane, "Hydraulic Design," in ***Guidelines for Design of Intakes for Hydroelectric Plants***, New York, NY: American Society of CIvil Engineers, pp. 16–105

[2] F. Kreith and J. F. Kreider, "Economics of Energy Generation and Conservation Systems," in *Principles of Sustainable Energy*, Boca Raton, Florida: CRC Press, 2011, pp. 65–115

[3] V. Nelson and K. Starcher, "Water," in *Introduction to Renewable Energy Second Edition*, Boca Raton, Florida: CRC Press, 2016, pp. 279–311

[4] E. Broch, D. K. Lysne, N. Flatabo, and E. Helland-Hansen, "Dam safety and risk analysis," in *Hydropower '97*, Rotterdam/Brookfield: A.A. Balkema, 1997, pp. 349–551

[5] C. C. Warnick, "Hydraulics of Hydropower," in ***Hydropower Engineering***, Englewood Cliffs, NJ: Prentice-Hall Inc., 1984, pp. 24–37

[6] Carly Hansen, Juan Gallego Calderon, Camilo Bastidas Pacheco, Cleve Davis, Rohit Mendadhala, Glenn Russell. 2024. **Technical Potential for Hydropower Capacity at Nonpowered Dams**. Hydrosource. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA. https://doi.org/10.21951/HydroCapacity_NPD/2570407

[7] L. Monition, M. Le Nir, and J. Roux, "Electromechanical Equipment," in *Micro Hydroelectric Power Stations*, Paris: Wiley-Interscience, 1984, pp. 71–121

Standards:

[8] "Hydropower development guidelines," U.S. Department of the Interior, https://www.doi.gov/cupcao/Hydropower (accessed Sep. 18, 2025).

A Literature review

- Current Hydropower systems, statistics, and trends
- Hydrostatic force and pressure acting on a dam

[1] "Hydropower Program," *Energy.gov*. https://www.energy.gov/eere/water/hydropower-program

[2] "Reports & Statistics," *NamUs*. https://namus.nij.ojp.gov/library/reports-and-statistics

[3] "HYDROSTATIC PRESSURE (Fluid Pressure) in 8 Minutes!," *www.youtube.com*. https://www.youtube.com/watch?v=3MvRpp7WnK0

[4] Fluids Explained, "Force and Moment on a Submerged Surface (Dam) Example," *YouTube*, Mar. 27, 2018. https://www.youtube.com/watch?v=lQPDAdgdFkk (accessed Sep. 18, 2025)

[5] S. Insights, "Explore the Top 10 Hydropower Trends in 2023," *StartUs Insights*, Mar. 13, 2023. https://www.startus-insights.com/innovators-guide/hydropower-trends/

[6] "Water Power Technology - Littoral Power - Revolutionizing Water Power Technology Waterpower Done Right," *Littoral Power*, Feb. 20, 2024. https://littoralpower.com/ (accessed Sep. 18, 2025).

[7] BYJU's, "Hydrostatic Pressure - Definition, Formula, Derivation, Problems," *BYJUS*. https://byjus.com/physics/hydrostatic-pressure/

Standards:

[8] The, "The Basement Doctor of Cincinnati," *The Basement Doctor of Cincinnati*, Dec. 03, 2021. https://www.basementdoctorcincy.com/about-us/news-events/41175-5-warning-signs-that-hydrostatic-pressure-is-taking-its-toll-on-your-foundation.html (accessed Sep. 19, 2025).

[9] D. Fitzgerald, "Key Policies for Waterpower," *National Hydropower Association*. https://www.hydro.org/policy/priorities/

Mathematical Modeling

- How strong of a wall or dam do we need?
- Forces and moments pushing on dam as a result of the water
- Knowing theses value indicates our reaction forces and moment needed from a wall or gate

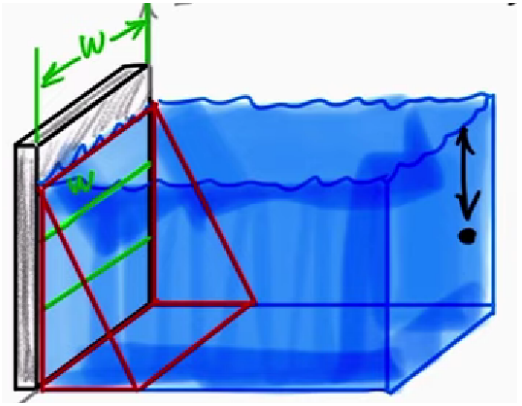
Hydrostatic Force, (N) F = ½ P(h) * A	Height/Depth of Dam, *h* (m)
Hydrostatic Pressure, (Pa) P(h) = ρgh	Gravitational Acceleration, 9.81 g (m/s^2)
Moment of Force at Base, M = F * (h/3)	Density of Water, 1000 ρ (kg/m^3)
Area of the Contact/Dam, *A* (m^2) A = w*h	Width of Dam, *w* (m)

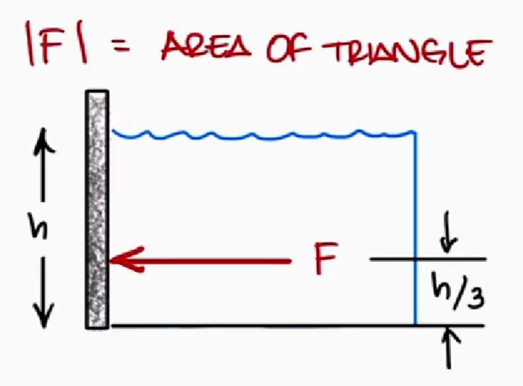
Ex:

- w = 6 m
- h = 3 m

Gives us:

- P = 29.43 kPa
- F = 270 kN
- M = 270 kN*m





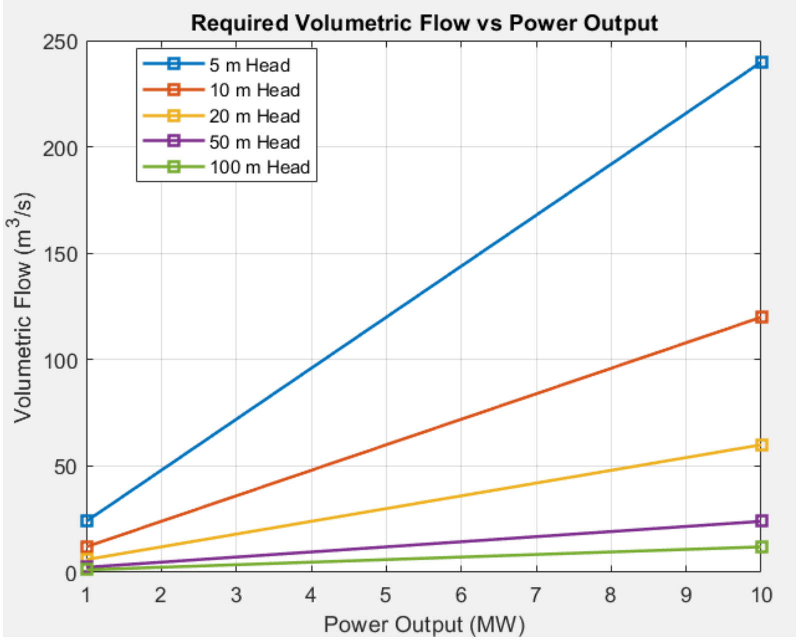
Mathematical Modeling

Modeling Fluid Volumetric Flow Rate,

$$P = \rho g Q H \eta \;\rightarrow Q = P/(\rho g H \eta)$$

Electrical Power Generation, P = *1-10MW*	Net Head(m), $H = 1\text{-}100m$	*Combined Efficiency,* $\eta = \eta_h \eta_g \eta_m \eta_t \eta_{aux} \cong .75$
Volumetric Flow Rate, $Q(m^3/s)$	Water Density, $\rho = 1000(kg/m^3)$	Gravitational Constant, $g = 9.81(m/s^2)$

Head_m	VolFlow_1MW_m3_s	VolFlow_5MW_m3_s	VolFlow_10MW_m3_s
5	23.985	119.93	239.85
10	11.993	59.963	119.93
20	5.9963	29.981	59.963
50	2.3985	11.993	23.985
100	1.1993	5.9963	11.993



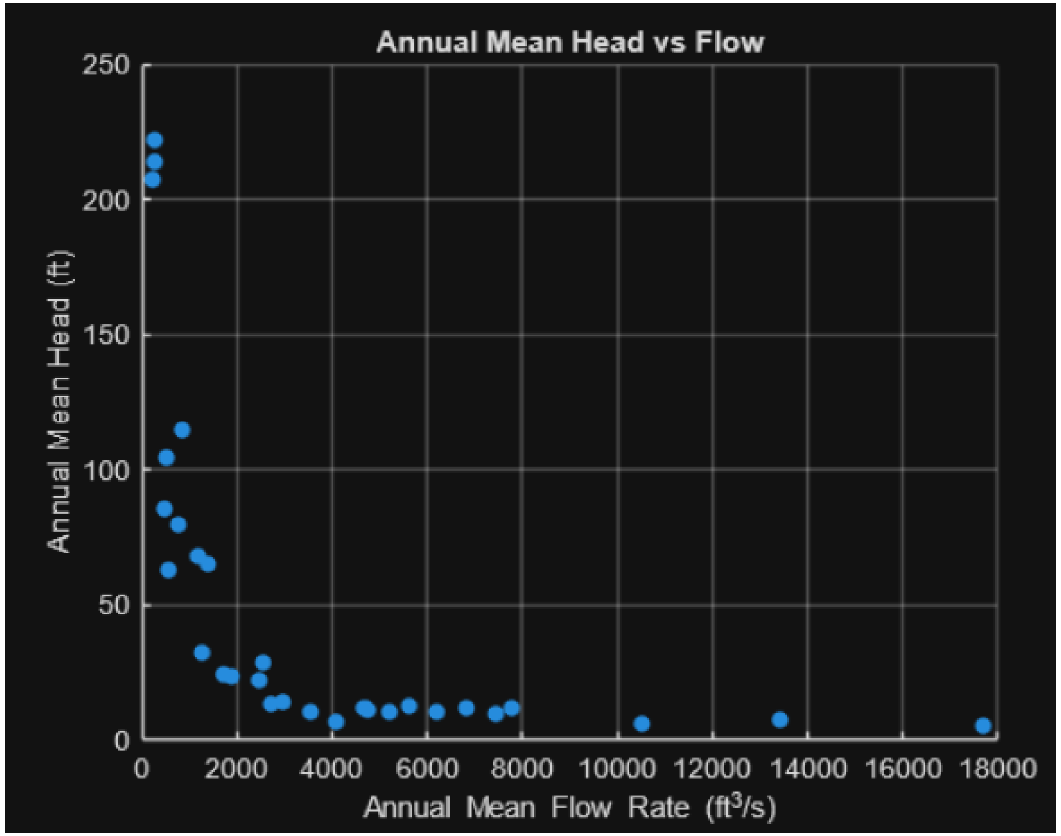
- These answers give us a guideline towards the desired flow rate. as well as site selection
- Validated Using Matlab Code

Mathematical Modeling

Narrowing down the list of potential dams

- 80,000+ NPDs across the country
- Database of ~2500 NPDs with flow rate, head, estimated output, etc.
- Used MatLAB to filter out ~1700 of these entries through criteria of **1<P<10 MW**
- Reduced remaining entries to 31 by filtering out dams with at least 1 month of estimated output outside the 1<P<10 MW range

The 31 remaining dams:
- Estimated yearly output satisfies 1<P<10 MW
- Estimated output by month satisfies 1<P<10MW



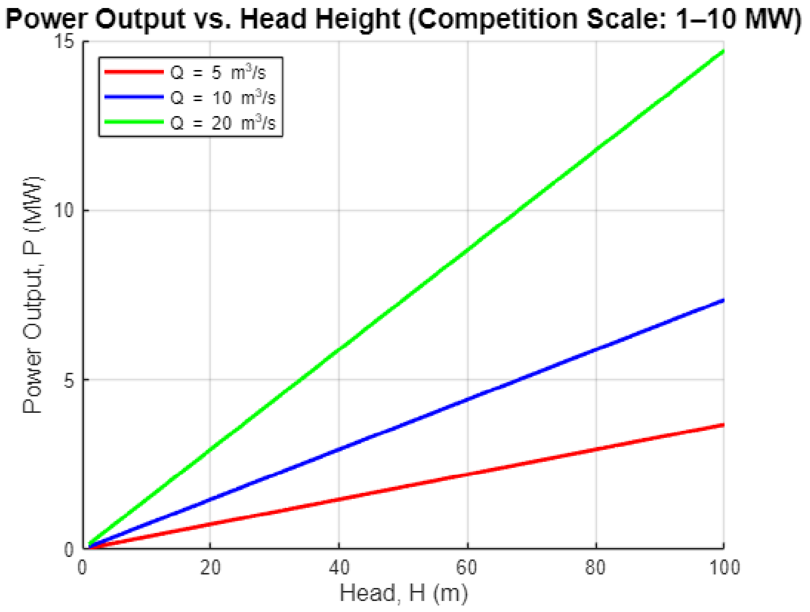
Mathematical Modeling

Power Output vs. Head Height - $P = \eta \rho g Q H$

- Efficiency $\eta = 0.75$
- Density of water $\rho = 1000\ kg/m^3$
- Gravity $g = 9.81\ m/s^2$
- Volumetric Flow Rate $Q\ (m^3/s)$
- Head $H\ (m)$

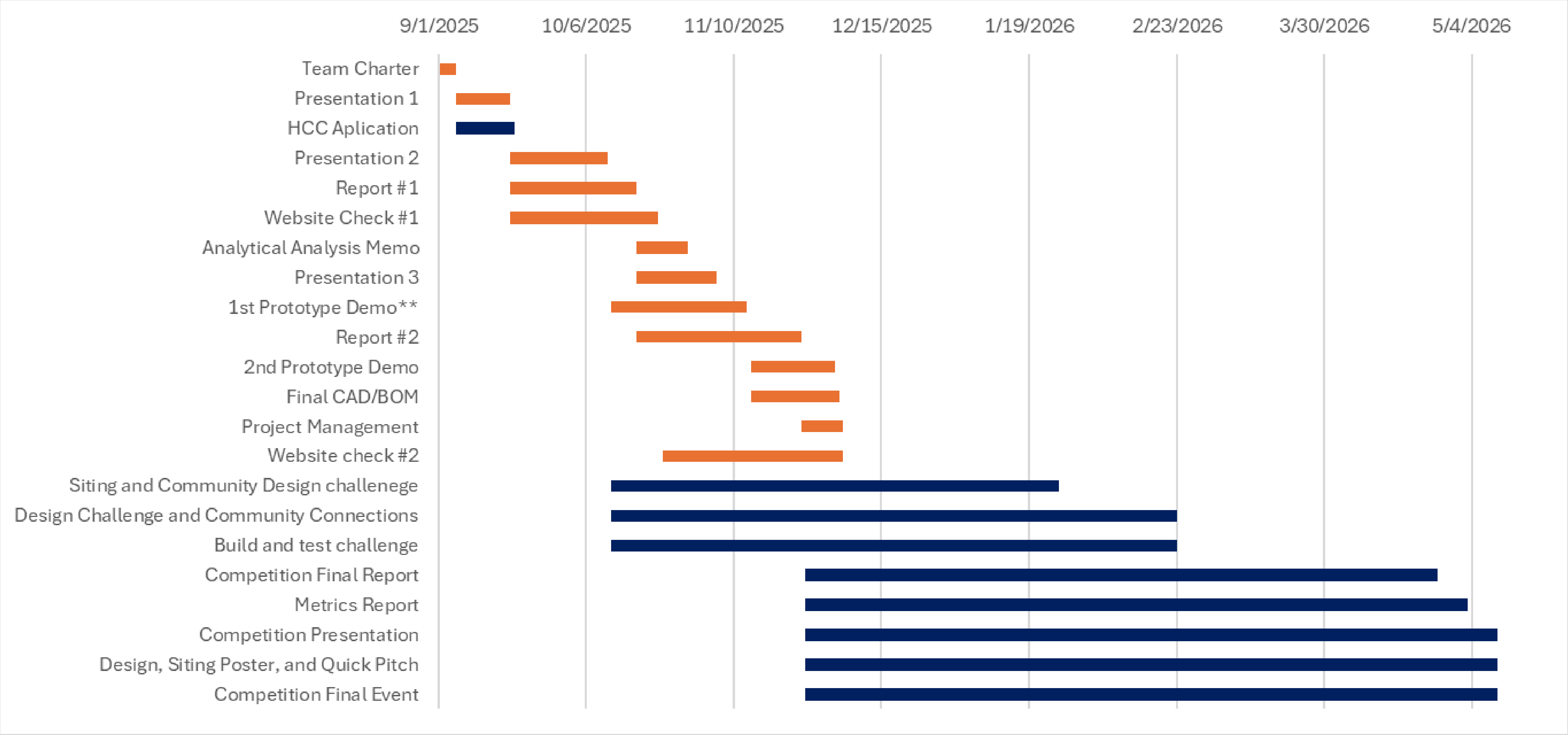
--- Power Output Table (MW) ---

Head_m	Q_5m3s_MW	Q_10m3s_MW	Q_20m3s_MW
5	0.18394	0.36788	0.73575
10	0.36788	0.73575	1.4715
20	0.73575	1.4715	2.943
50	1.8394	3.6787	7.3575
100	3.6787	7.3575	14.715



At realistic flows (10–20 m^3/s) and heads (5–100 m), our system achieves power outputs in the 1–10 MW range, directly aligning with competition requirements.

Schedule (Gantt Chart)

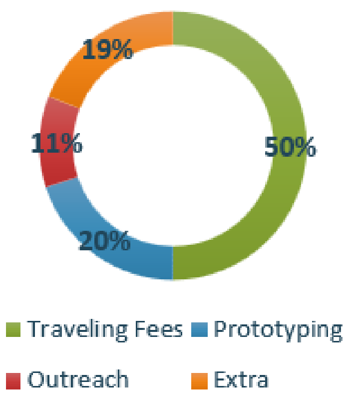


Budget

How much do we have?
Initial Amount
$20,000.00
Total Expenses
$16,200.00
Potential Savings
$3,800.00

Where Do We Want To Allocate Money?

Traveling Fees	50%	$10,000
Prototyping	20%	$4,000
Outreach	11%	$2,200
Extra	19%	$3,800
Total	100%	$20,000



What are our expenses?

Description	Expense amount
In Person Workshops	$2,500.00
In person Conferances	$7,500.00
Prototyping Materials	$3,000.00
Mapping Software	$1,000.00
Community Outreach	$2,200.00
Total Expenses	$16,200.00

Prototype 1	$1,000
prototype 2	$1,000
Final Prototype	$1,000

What is our income?

What is our Income?

Description	Date	Amount
Project Application	9/18/2025	$5,000.00
January Submission	1/26/2026	$5,000.00
Febuary Submission	2/23/2026	
Build & Test Submission	2/23/2026	$3,000.00
Build & Test Presentation	2/23/2026	$2,000.00
Final Event	TBD	$5,000.00
	Total Income	$20,000.00

Fundraising Opportunities

Arizona Snowbowl

SSVEC CoOp

W.L. Gore

- Reaching out to the companies via fliers, as well as an in person pitch

Thank You!

Questions?