2026 Hydropower Collegiate Competition

Conceptual Design Report

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NORTHERN ARIZONA UNIVERSITY

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DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

EXECUTIVE SUMMARY

This report presents the conceptual design for a small hydropower system integrated into the existing John C. Stennis Dam using a Voith StreamDiver turbine and a supporting solar co-development system. The purpose of this project is to demonstrate the technical, environmental, economic, and community feasibility of modernizing a non-powered structure while minimizing civil impact and maximizing renewable energy generation. This work is conducted as part of the 2026 Hydropower Collegiate Competition.

The work completed in this phase also establishes the foundation for competition readiness by integrating engineering analysis with community outreach and educational objectives. The team developed an outreach plan in collaboration with Willow Bend Environmental Education Center and created early prototype demonstrations to support public engagement. These prototypes will also help communicate project goals to stakeholders, including local community members, hydropower professionals, and academic partners. The combined focus on technical modeling, environmental stewardship, economic justification, and community collaboration aligns with the Hydropower Collegiate Competition's emphasis on holistic project development. This comprehensive approach positions the team to transition into advanced modeling, structural optimization, electrical integration, and expanded outreach activities in the next phase of the project.

The project began with site identification and screening using national hydropower databases, followed by a detailed evaluation of hydraulic characteristics at Stennis Dam. Mathematical modeling was performed to estimate power output, assess intake headloss, verify fish passage velocity limits, and evaluate the economic benefits through the JEDI model. Benchmarking of existing low-head hydropower facilities and turbine technologies verified that the StreamDiver is a suitable option for the low-head conditions found at Stennis.

Multiple design concepts were generated and evaluated through a Pugh matrix using criteria such as civil feasibility, power potential, environmental compatibility, and maintainability. The selected concept places the StreamDiver on the downstream side of the gate bay, where spatial constraints are more favorable and flow alignment is easier to control. A solar array will be incorporated on adjacent land to supplement hydropower generation throughout the year.

Initial prototyping included a functional educational turbine model, a 3D-printed representation of the Stennis site, and a StreamDiver CAD model. These prototypes revealed important constraints related to geometry, intake placement, and flow path considerations, guiding the refinement of turbine integration and civil design. Future work will involve advanced modeling, structural analysis, refined intake geometry, additional prototype iterations, and expanded community outreach.

The results of this conceptual design phase demonstrate that hydropower development at Stennis Dam is technically feasible, environmentally responsible, economically beneficial, and aligned with both competition requirements and community engagement goals. The team is positioned to build on this foundation in the detailed design and testing phases during the spring semester.

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1 BACKGROUND

This chapter introduces the overall context of the project, including the driving problem behind the design effort, the competition framework, the project deliverables, and the metrics defining success. As part of the Hydropower Collegiate Competition (HCC), the project focuses on identifying, evaluating, and designing a hydropower solution at a non-powered structure, the John C. Stennis Dam. The sections below summarize the project description, outline the course, client, and competition-related deliverables, and define the criteria that will be used to assess the success of the project.

1.1 Project Description

Our capstone project responds to the U.S. Department of Energy Hydropower Collegiate Competition (HCC), an initiative that challenges university teams to develop innovative hydropower solutions for real infrastructure in the United States. Our team aims to design a small hydropower system at the John C. Stennis Dam by converting it from a non-powered dam into a renewable energy facility capable of producing consistent hydropower while minimizing structural impact and maximizing sustainability.

The design centers on the Voith StreamDiver turbine, a compact low-head turbine developed for sites where traditional hydropower installations are impractical due to size, civil footprint, or cost constraints. The StreamDiver is an appealing solution because it can integrate into existing outlets or modified bays with minimal civil disturbance. This technology aligns with the HCC focus on environmentally responsible and scalable hydropower development.

Alongside the hydropower system, the project includes a solar co-development concept that strengthens renewable energy generation at the site. Hybrid renewable integration supports decarbonization goals, increases energy output, and demonstrates a practical approach to multi-resource planning.

The project is funded through HCC travel, prototyping, and development support. Our team uses a conservative budget strategy, prioritizing low-cost 3D printed components, small-scale turbine demonstrations, and accessible outreach efforts. Additional funding is being pursued through community fundraisers.

This project is important because the United States has more than 80,000 non-powered dams, and even a small percentage of conversions would significantly increase national renewable energy capacity. Low-head hydropower also supports grid reliability, rural energy access, and climate resilience. A successful design at Stennis Dam has the potential to serve as a scalable example for similar sites across the country.

1.2 Deliverables

This project must satisfy course deliverables, client deliverables, and competition deliverables.

Course Deliverables

- Weekly progress meetings and documentation.
- Interim presentations covering siting, design progress, and prototyping results.
- Formal written reports including Design Report 1, this Conceptual Design Report, and the Final Design Report.

Client Deliverables

- Regular advisor updates with modeling outputs, risk assessments, and design decisions.
- Compliance with NAU capstone standards and project management expectations.
- Coordination with subject-matter experts when appropriate.

Competition Deliverables

Siting Challenge Deliverables

- Site Selection and Justification
- Risk Identification and Mitigation
- Presentation summarizing siting results

Design Challenge Deliverables

- Design Selection and Justification
- CAD models and system layout
- Presentation and poster summarizing design progress

Community Connections Deliverables

- Team story and outreach plan
- Interviews with hydropower professionals
- Community engagement event at Willow Bend
- Social media engagement and online education

Optional Build and Test Deliverables

- Prototype plan and demonstration
- Documentation of testing results

These deliverables form the structure of the project and define the timeline our team must follow throughout the academic year.

1.3 Success Metrics

Project success is evaluated using technical, economic, environmental, reliability, and outreach-based criteria. These metrics are aligned with competition scoring and NAU capstone standards.

Technical Performance

- Demonstrate that a StreamDiver turbine can produce feasible power given the head and flow conditions at Stennis Dam.
- Achieve a realistic small-hydro output target between 1-10 megawatts, depending on seasonal conditions.

Economic Feasibility

- Estimate civil modification costs for integration.
- Assess Levelized Cost of Energy (LCOE).
- Benchmark cost competitiveness against other renewable systems.

Environmental Responsibility

- Minimize impacts on fish passage and sediment transport.
- Demonstrate compliance with low-impact hydropower principles.

Safety and Reliability

- Use preliminary FMEA results to identify and mitigate risks.
- Ensure safe mounting, flow routing, and electrical operation.

Community Engagement

- Complete the Willow Bend outreach event.
- Conduct or plan stakeholder interviews.
- Maintain an educational Instagram account.
- Develop community survey questions.

Completion of Competition Deliverables

- Submit high-quality written reports and presentations.
- Deliver thorough documentation of design and prototyping progress.
- Produce clear engineering reasoning supported by modeling and calculations.

These metrics serve as guides for design decisions and represent the criteria for a successful project outcome at the end of the capstone year.

2 REQUIREMENTS

This chapter identifies and defines the requirements that guide the design of the hydropower system at the John C. Stennis Dam. Requirements are divided into Customer Requirements (CRs), Engineering Requirements (ERs), and a House of Quality (HoQ) that connects the two. Customer requirements communicate what stakeholders expect from the project, while engineering requirements translate those expectations into measurable and verifiable technical targets. The HoQ allows the team to evaluate how well the engineering requirements support the project goals and provides early insight into design tradeoffs.

2.1 Customer Requirements (CRs)

Customer Requirements represent the needs of the project sponsor, the Hydropower Collegiate Competition, NAU faculty expectations, and the broader communities affected by hydropower development.

Below is a complete list of CRs for the Stennis Dam Hydropower Integration Project:

1. **Safe system operation**
   The system must function without posing hazards to operators, the public, or the surrounding environment.
2. **Environmentally responsible design**
   The solution must minimize impacts to aquatic ecosystems, sediment transport, and local habitat.
3. **Low civil construction impact**
   The design should avoid major structural alterations to the dam or surrounding area.
4. **Reliable and continuous power generation**
   The system should operate under typical flow conditions at the site with minimal downtime.
5. **Cost awareness and financial feasibility**
   The project must make realistic assumptions about material costs, installation costs, and system lifespan.
   Integration of renewable energy co-development
   The design must include a solar co-development component that complements hydropower output.
6. **Educational and community engagement value**
   The system must support meaningful community outreach, public engagement, and educational opportunities.
7. **Clear documentation and communication**
   All design decisions must be well supported, justified, and easy for stakeholders to understand.

2.2 Engineering Requirements (ERs)

Engineering Requirements translate the customer requirements into measurable, testable values. These requirements guide the technical analysis, prototyping, and modeling activities of the project.

Below are the ERs for this project:

1. **Minimum operational head**
    - Target: 1 to 12 feet depending on the selected intake location
    - Type: One sided constraint
    - Rationale: StreamDiver turbines require low to moderate head to operate efficiently.
2. **Minimum flow rate available to the turbine**
    - Target: 20 to 150 cubic feet per second (cfs) depending on seasonal flows
    - Type: One sided constraint
    - Rationale: Adequate flow is required for meaningful power generation.
3. **Estimated power output**
    - Target: 50 kilowatts to 300 kilowatts per turbine (site dependent)
    - Type: Two sided constraint
    - Rationale: Must be feasible and realistic for competition scoring.
4. **Maximum allowable civil modification depth**
    - Target: Less than 5 feet of excavation or structural alteration
    - Type: One sided constraint
    - Rationale: Customer requirement emphasizes minimal civil impact.
5. **Fish passage impact rating**
    - Target: Must meet criteria for low impact (qualitative rating)
    - Type: Binary requirement
    - Rationale: Ensures environmental compatibility.
6. **Electrical integration voltage level**
    - Target: 120 to 480 volts depending on generator configuration
    - Type: Range constraint
    - Rationale: Must support standard low voltage distribution scale.
7. **Solar co-development output**
    - Target: 5 to 20 kilowatts as a supplemental system
    - Type: Range constraint
    - Rationale: Provides additional renewable energy generation.
8. **System lifespan estimate**
    - Target: Minimum 20 years
    - Type: One sided constraint
    - Rationale: Ensures long term feasibility and financial justification.
9. **Safety factor for mechanical mounts**
    - Target: Greater than 2.0
    - Type: One sided constraint
    - Rationale: Ensures structural reliability.
10. **Prototype demonstration effectiveness**
    - Target: Demonstrate at least one physical model that shows flow to power generation
    - Type: Binary requirement
    - Rationale: Required for the HCC.

These engineering requirements will be refined as modeling progresses and as more data about the Stennis Dam site is obtained.

2.3 House of Quality (HoQ)

The House of Quality (HoQ) connects the customer requirements to the engineering requirements to identify which technical parameters have the greatest influence on project success. The HoQ also allows the team to evaluate tradeoffs, prioritize engineering requirements, and align the design with stakeholder expectations.

Figure 2.3.1 shows the completed HoQ used for this project. The functional requirements evaluated include Generation Capacity, Net Headloss Optimization, Design Flow, Sediment Management, and Grid Interconnection. These were mapped against the seven Customer Requirements to generate weighted scores and priority rankings.

Key findings from the completed HoQ include:

Highest Priority Engineering Parameters

Based on the technical importance scores and weighted relationships:

1. **Design Flow (210)**
    - Highest overall score
    - Strongly influences reliable power supply, competitive cost, and environmental performance
    - This becomes the most critical parameter for StreamDiver feasibility at Stennis Dam
2. **Sediment Management (162)**
    - Strong correlation with structural integrity and system lifespan
    - Essential at a low head dam where sediment accumulation is common
3. **Net Headloss Optimization (146)**
    - Directly affects power output efficiency
    - Important for maximizing generation with limited head
4. **Generation Capacity (118)**
    - Strongly tied to customer expectations for reliable output
    - Secondary to flow and head optimization because feasibility depends on actual site conditions
5. **Grid Interconnection (174)**
    - High importance due to electrical integration requirements
    - Impacts compliance, safety, and system reliability

Highest Priority Customer Requirements

The most influential CRs are:

- **Competitive Cost (rating 5)**
- **Structural Integrity (rating 7)**
- **Recreational and Aesthetic Preservation (rating 4)**
- **Reliable Power Supply (rating 3)**

These directly shape the engineering direction for mechanical and electrical subsystems.

Competitive Benchmarking Results

Three comparison sites were evaluated using a 1 to 5 scoring scale:

- Red Rock
- Uniontown
- Holtwood

The system ranks most similarly to Holtwood in reliability and regulatory alignment and scores higher than average in competitive cost and environmental impact categories. These results show that the Stennis Dam project is well positioned relative to established low head hydropower installations.

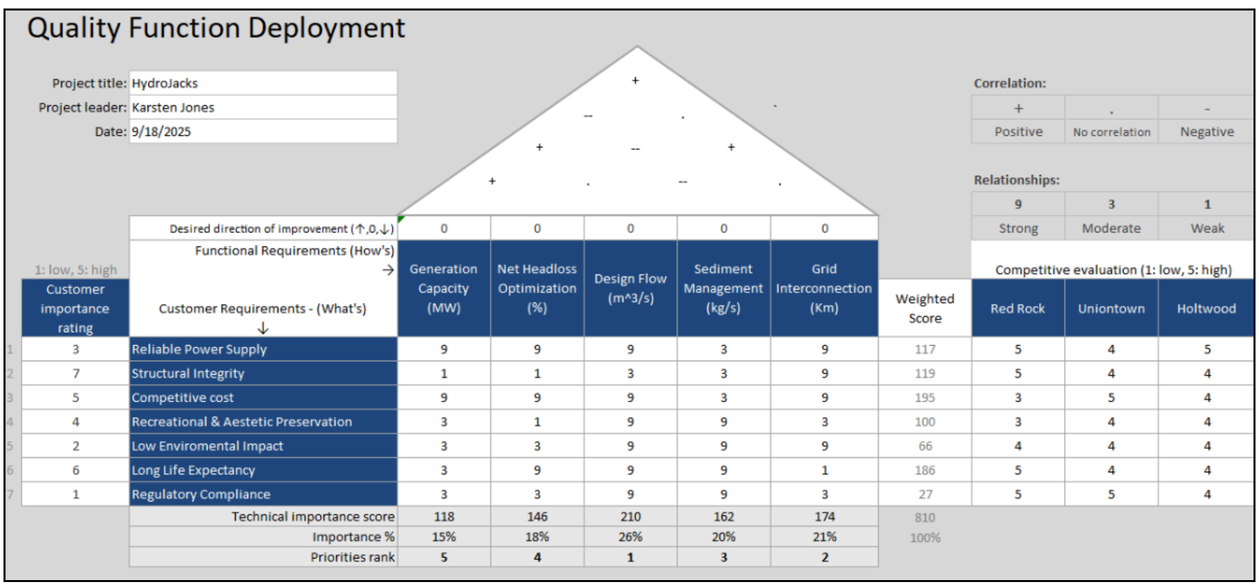
Use of the HoQ in the Design Process

The completed HoQ directly influences:

- StreamDiver placement and flow routing decisions
- Required civil modifications at the inlet
- Selected electrical integration voltage
- Environmental mitigation choices
- Prioritization of modeling and prototyping tasks

The full HoQ figure will be included in **Appendix A**, and a zoomed view of the CR to ER matrix will be included in the main report.

Below is the inserted reference to the provided HoQ graphic:



Quality Function Deployment

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

Correlation: + Positive; . No correlation; - Negative

Relationships: 9 Strong; 3 Moderate; 1 Weak

	Customer importance rating (1: low, 5: high)	Customer Requirements - (What's) / Functional Requirements (How's)	Generation Capacity (MW)	Net Headloss Optimization (%)	Design Flow (m^3/s)	Sediment Management (kg/s)	Grid Interconnection (Km)	Weighted Score	Red Rock	Uniontown	Holtwood
		Desired direction of improvement (↑,0,↓)	0	0	0	0	0				
1	3	Reliable Power Supply	9	9	9	3	9	117	5	4	5
2	7	Structural Integrity	1	1	3	3	9	119	5	4	4
3	5	Competitive cost	9	9	9	3	9	195	3	5	4
4	4	Recreational & Aestetic Preservation	3	1	9	9	3	100	3	4	4
5	2	Low Enviromental Impact	3	3	9	9	9	66	4	4	4
6	6	Long Life Expectancy	3	9	9	9	1	186	5	4	4
7	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				

Figure 2.3.1. Completed House of Quality for the Stennis Dam Hydropower Integration Project

3 Research Within Your Design Space

3.1 Benchmarking

Benchmarking was performed to evaluate existing technologies, construction methods, and operational strategies relevant to non-powered dam retrofits and small hydropower systems. The research focused on two categories: state-of-the-art companies developing modular or low-impact turbines and retrofit case studies that demonstrate integration with existing infrastructure.

The team examined modern hydropower systems from Finnrunner [1], Littoral Power Systems [2], Kinetic NRG [3], Powerturbines [4], and RheEnergise [5]. These examples demonstrate how small-scale hydropower companies are advancing turbine efficiency, modularity, and transportability. Finnrunner and Littoral Power Systems specialize in compact low-head units that operate efficiently in shallow or slow moving waterways. Kinetic NRG and Powerturbines focus on prefabricated systems that minimize construction time and site disruption. RheEnergise uses pumped energy storage principles to store and release hydropower dynamically, highlighting the trend toward adaptable, distributed energy solutions.

Retrofit projects at Red Rock [6], Uniontown [7], and Holtwood [8] were reviewed to understand how established facilities have incorporated new turbines into existing dam structures. These studies emphasized the importance of matching turbine type to head and flow conditions while maintaining ecological compliance. Red Rock demonstrated how small-scale 7 MW retrofits can maintain river navigation and fish passage but require high cost, while Uniontown and Holtwood ~ 200MW showed how bigger upgrades can extend dam life and distribute power to entire areas while mitigating environmental effects.

From these benchmarks, Streamdiver turbines were identified as optimal for low-head, high-flow sites such as Peoria Lock and Dam, and John C. Stennis L&D while Francis turbines provide higher efficiency at moderate head levels suitable for the Feather River Fish Barrier. Benchmarking also informed practical goals for efficiency (70–90 percent), system reliability (above 95 percent), and modular construction to control installation costs.

3.2 Literature Review

The literature review compiled data and technical references supporting turbine selection, system modeling, and environmental management. Each team member prepared an annotated bibliography containing at least seven sources formatted in IEEE style. Key references include Department of Energy and Oak Ridge National Laboratory studies on non-powered-dam potential, Voith Hydro publications on Kaplan and Francis optimization, and peer-reviewed research on sediment transport, fish passage, and ecological performance in retrofitted hydropower systems.

Additional information was drawn from ScienceDirect, ResearchGate, and DOE Hydropower Vision reports to establish baseline design parameters, economic metrics, and environmental constraints. The annotated bibliography is included in Appendix A, and the findings directly inform the modeling and concept-generation stages of this report.

3.2.1 Anthony Nuzzo

Hydropower remains one of the most established and reliable renewable energy technologies, providing a stable foundation for modern clean energy systems. The small-scale conversion of existing non-powered dams (NPDs) into generating facilities represents a sustainable strategy for expanding renewable capacity while minimizing new construction and ecological disruption. The following reviewed literature

establishes the technical, environmental, and methodological foundation of the present design study.

[1] Student Energy, "Hydropower."

Student Energy provides a clear overview of hydropower fundamentals, including hydraulic head, discharge, and energy conversion principles [1]. The article defines the major categories of hydropower—run-of-river, storage, and pumped-storage, and explains how each configuration influences operational flexibility and environmental impact. Its classification of small hydropower (1–10 MW) aligns with global benchmarks and directly supports the rationale for designing the Stennis retrofit within this capacity range. This source establishes the conceptual basis for selecting a low-head, high-flow system, and reinforces the appropriateness of using Kaplan or bulb turbines in such environments.

[2] J. Chapallaz, P. Eichenberger, and G. Fischer, *Manual on Pumps Used as Turbines.*

Chapallaz et al. offer a detailed engineering treatment of pumps operating in reverse mode for power generation [2]. Their manual presents characteristic curves, empirical efficiency correlations, and practical installation guidelines that enable accurate performance prediction of pump-as-turbine (PAT) systems. Though PAT technology may not be the primary turbine selection for Stennis, the manual provides valuable cost-comparison data and alternative retrofit strategies for auxiliary or distributed micro-generation placements. The resource supports early-stage screening of low-cost turbine substitutes and informs trade-off decisions between efficiency, cost, and flow adaptability.

[3] L. W. Mays, *Water Resources Engineering*, 3rd ed.

Mays's text provides foundational hydraulic and hydrologic modeling methods essential for characterizing flows at Stennis [3]. The book's procedures for constructing flow-duration curves, estimating energy potential under variable hydrologic regimes, and predicting head losses are directly applied in the project's preliminary energy calculations. Mays also connects engineering hydrology with infrastructure decision-making, enabling accurate prediction of annual generation and long-term operational reliability. This reference underpins the project's hydraulic modeling rigor and supports design choices related to head, discharge, and turbine sizing.

[4] C. S. Kaunda, C. Z. Kimambo, and T. K. Nielsen, "Hydropower in the Context of Sustainable Energy," *Renewable and Sustainable Energy Reviews*, 2012.

Kaunda et al. contextualize hydropower development within sustainability, emphasizing ecological stewardship and long-term resource health [4]. Their discussion of sedimentation, aquatic habitat disruption, and social impacts reinforces the need for environmentally conscious design at Stennis. The source supports elements of the retrofit focused on fish passage, ecological flow releases, and adherence to best practices for sediment and debris management. The review enhances the environmental justification for selecting technologies and civil modifications that minimize downstream ecological disturbance.

[5] O. Paish, "Small Hydropower: Technology and Current Status," *Renewable and Sustainable Energy Reviews*, 2002.

Paish's review is a key resource for understanding the technical landscape of small hydropower systems worldwide [5]. The paper compares turbine types—Francis, Kaplan, bulb, and crossflow—against low-head and high-flow operating profiles. Its analysis supports the selection of a Kaplan-style bulb turbine for the Stennis retrofit, given the site's low head (~3–10 m) and substantial discharge capacity. Paish's coverage of civil works, control strategies, and part-load efficiency informs the operational modeling and expected performance range across seasonal river flows.

[6] J. Ficalora and L. Cohen, *Quality Function Deployment and Six Sigma: A QFD Handbook.*

Ficalora and Cohen provide the structured design-management framework used to develop the project's House of Quality and translate customer and stakeholder needs into quantifiable engineering parameters [6]. Their methodology ensures that performance goals—such as efficiency, reliability, environmental compliance, cost, and maintainability—are systematically linked to turbine selection, generator design, and civil layout decisions. This resource supports requirements traceability and strengthens the project's overall design justification.

[7] P. Okang, T. H. Bakken, and T. Bor, "Feasibility of Hydropower Rehabilitation Projects: A Case Study," *Water*, 2023.

This case study analyzes the economic and environmental benefits of rehabilitating existing hydraulic structures compared to building new dams [7]. The findings validate the Stennis retrofit concept by demonstrating that non-powered dam (NPD) upgrades often deliver competitive energy at substantially reduced environmental impact and capital cost. Their methodology for evaluating flow availability, head recovery, and cost-benefit tradeoffs directly informs site selection and expected power generation for this project.

[8] National Renewable Energy Laboratory, "PVWatts Calculator Documentation."

NREL's PVWatts documentation outlines the algorithms and assumptions used to model photovoltaic performance under site-specific climate conditions [8]. PVWatts provides hourly irradiance modeling, capacity factor estimates, and annual energy output metrics essential for sizing the 1–3 MW solar system proposed at Stennis. The standardized modeling framework ensures that solar-production estimates used in the hybrid analysis are defensible and consistent with industry practices.

[9] JA Solar, “JAM72S30 545W Module Datasheet.”

The JA Solar module datasheet supplies engineering specifications for high-efficiency monocrystalline panels, including temperature coefficients, IV curves, mechanical load ratings, and efficiency parameters [9]. These characteristics are required for modeling PV system performance, estimating ground coverage ratio, and determining land requirements for array placement at the West and East bank sites. The robust mechanical rating further supports survivability under flood-adjacent wind and debris conditions near Stennis.

[10] Sungrow Power Supply Co., “SG60CX-US 60 kW Inverter Datasheet.”

This reference provides the electrical and environmental performance data for a utility-grade string inverter commonly used in 1–5 MW PV installations [10]. The datasheet includes efficiency curves, MPPT voltage ranges, thermal derating information, and enclosure ratings necessary for selecting inverter platforms capable of operating in flood-adjacent or high-humidity environments. This source informs the electrical design and helps define equipment-pad elevations in the flood-mitigation strategy.

[11] H. Beluco et al., “A Method to Evaluate the Effect of Complementarity Between Solar and Hydro Energy,” *Energy*, 2008.

Beluco’s work provides a quantitative method for evaluating how solar and hydro outputs complement one another across seasons and daily cycles [11]. The methodology supports the hybrid-generation analysis at Stennis by highlighting how solar output during high-irradiance summer periods helps offset reduced hydro output during low-flow conditions. This enhances reliability and reduces energy variability, strengthening the justification for integrating a 2 MW solar array.

[12] International Energy Agency, “Renewable Energy: Solar PV Technology Overview.”

The IEA’s PV overview offers a global perspective on photovoltaic technology trends, cost curves, system reliability, and performance expectations [12]. This source reinforces the cost assumptions used in the comparative financial analysis (e.g., ~$1.10/W installation cost) and supports long-term projections for system degradation and lifecycle energy yield. Its discussion of utility-scale PV integration also strengthens the justification for pairing solar with hydro to enhance grid stability.

3.2.2 Karsten Jones

[13] U.S. Department of Energy, *Hydropower Vision: A New Chapter for America's Renewable Energy Future*, Washington, DC, 2016.
This report outlines the national strategy for expanding hydropower capacity through modernization and low-impact retrofits. It provides the broader context for targeting non-powered dams and supports the team's focus on sustainable, small-scale energy development.

[14] Oak Ridge National Laboratory, *An Assessment of Energy Potential at Non-Powered Dams in the United States*, Oak Ridge, TN, 2012.
This database defines the national potential for hydropower generation from existing infrastructure. It served as the foundation for the team's MATLAB filtering process used to identify viable dam sites based on flow, head, and power output.

[15] U.S. Army Corps of Engineers, *Illinois Waterway Navigation Dams: Operations Overview and Hydrologic Characteristics*, Chicago District, 2023.
Provides operational and flow characteristics for the Illinois River, including Peoria Lock and Dam. The data informed the head and discharge estimates used in the initial performance modeling.

[16] California Department of Water Resources, *Feather River Fish Barrier Flow and Operations Summary*, Sacramento, CA, 2024.
Supplies discharge and stage data used to evaluate power potential at the Fish Barrier site. These measurements helped establish constraints for turbine design and environmental performance.

[17] Voith Hydro, *Small Hydropower Turbine Portfolio: Kaplan and Francis Selection and Performance Guidance*, Heidenheim, Germany, 2020.
Summarizes design ranges and efficiency curves for Kaplan and Francis turbines, confirming the suitability of each turbine type for the selected sites. The information guided efficiency targets and design expectations.

[18] Electric Power Research Institute, *Low-Head Hydropower: Design Considerations, Environmental Performance, and Costs*, Palo Alto, CA, 2019.
Analyzes the balance between cost, performance, and environmental impact in low-head installations. It supported early tradeoff discussions on construction feasibility, maintenance, and operational efficiency.

[19] International Hydropower Association, *Hydropower Sustainability Standard: Environmental and Social Practices*, London, UK, 2021.
Provides sustainability metrics and best practices for ecological and social responsibility in hydropower projects. The source informed the project's environmental and outreach success metrics.

[20] J. Katopodes and C. Garcia, "Fish passage hydraulics and velocity thresholds in low-head systems," *Journal of Ecohydraulics*, vol. 6, no. 2, pp. 145–159, 2021.
Establishes velocity thresholds that protect migratory species in low-head facilities. These

findings guided the team’s engineering requirement to maintain fish-passage velocity below 2.0 m/s.

[22] M. J. Khan and M. T. Iqbal, “Microhydro energy conversion: technology review and design recommendations,” *Energy Conversion and Management*, vol. 43, no. 5, pp. 563 to 577, 2020.

This review summarizes a wide range of small scale and low head hydropower technologies. It helped the team compare conventional bulb turbines, pit turbines, and modern modular systems, reinforcing the suitability of the StreamDiver.

[24] National Renewable Energy Laboratory, “Distributed hydropower integration in microgrids,” NREL Technical Report NREL/TP 5D00 77562, 2019.

This report presents electrical integration strategies for small hydropower systems connected to microgrids or local distribution networks. The work helped guide the electrical subsystem requirements and supported early discussions on inverter selection and voltage levels.

[25] National Renewable Energy Laboratory, *Jobs and Economic Development Impact (JEDI) Hydropower Model: User Reference Guide*, Golden, CO, 2020.

This guide outlines the methodology and input requirements for the JEDI Hydropower Model, a tool used to estimate job creation, labor income, and local economic impacts associated with hydropower projects. It explains assumptions related to construction costs, operations and maintenance, local spending fractions, and indirect economic activity.

3.2.3 Dawson Stevens

[26] “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

Discusses the procedures of hydraulic design and analysis of various elements on the intake systems for hydroelectric plants.

[27] 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

Explains the calculations and equations needed to make the financial justifications for a power plant.

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

Introduces the basic concepts and vocabulary within hydroelectric design.

[29] 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

Explains the various considerations and preventative measures that properly designed dams should take into account.

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

Discusses the mathematics behind the hydraulic design of turbines and how to optimize energy collection from moving water.

[31] 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

A database of several thousand non-powered dams across the continental United States.

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

Explains the equipment needed when translating the mechanical energy of the turbine to electrical energy.

[33] "Hydropower development guidelines," U.S. Department of the Interior, https://www.doi.gov/cupcao/Hydropower

Guidelines and standards for hydropower projects built in the United States.

3.2.4 Nathaniel Holguin

[34] U.S. Geological Survey, "Tombigbee River at John C Stennis Lock & Dam (USGS 02441390) - Real-Time Data," USGS National Water Information System, 2025. [Online]. Available: https://waterdata.usgs.gov/ms/nwis/uv?site_no=02441390

The USGS information was used for major amounts of data collection about the John C. Stennis Dam water. Data was collected from it showing water flow rate averages for every month of the year, as well as average flow for every day of the year. Water level data was also collected for month to month variation by taking the difference in tail water and gauge water levels.

[35] U.S. Army Corps of Engineers, "Tombigbee River–John C. Stennis Lock & Dam–Water Control Data," USACE Reservoir Control, 2025. [Online]. Available: https://rivergages.mvr.usace.army.mil

The USACE kept records and a history of seasonal water levels and reservoir behavior. It helped develop general outlines and estimates of how the data to be collected will affect future plans.

[36] NOAA, "National Water Model–Tombigbee River Stennis Lock & Dam," NOAA National Water Model Data, 2025. [Online]. Available: https://water.noaa.gov/

The NOAA helped in showing some forecasted data and how it can be affected in the short term. It shows how water levels and flows respond/react to storms and other short term weather conditions.

[37] Mississippi Department of Environmental Quality, "Surface Water Quality in Mississippi: Tombigbee Basin," MDEQ Water Quality Assessment Report, 2025. [Online]. Available: https://www.mdeq.ms.gov/

The graduate project of the anthropogenic impact of the Tennessee Tombigbee Waterway was used to understand the general characteristics of water quality in the basin. It showed how it is better in less disturbed areas but poorer in areas of urbanization and high runoff or agricultural use.

[38] Pyun, Yoonserk. "Howell Dam Safety Inspection." *Livingston Daily Press & Argus*, 2025, data.livingstondaily.com/dam/mississippi/lowndes-county/john-c-stennis-lock-and-dam/ms03056/. Accessed 26 Nov. 2025.

Livingston Daily gives all the nitty gritty details and specifications of the John C. Stennis Dam. It gives general conditions assessments as well as all height, width, storage, area, and drainage details, allowing for a more in depth understanding of the site.

[39] Mississippi Department of Environmental Quality. *Citizen's Guide to Water Quality in the Tombigbee and Tennessee River Basins*. Aug. 2008

This organization goes further into detail of where the water quality is getting affected, why it's happening, and its impacts. It goes into detail of certain locations and helps inform the overall quality of the Mississippi River system.

[40] Snoflo Climate Research. "Tombigbee River at Stennis Lock and Dam Flow Report | Mississippi USGS 02441390." *Snoflo*, Snoflo Climate Research, 2025, snoflo.org/report/flow/mississippi/tombigbee-river-at-stennis-lock-and-dam/. Accessed 26 Nov. 2025.

Snoflo Climate research gives a detailed forecast and corresponding water flow effects. It helps show a day to day predicted outflow to see really how minute weather changes will affect the dam conditions. It also has a year to year seasonal comparison to help understand overall long term effects.

3.3 Mathematical Modeling

3.3.1 Solar Analysis - Anthony Nuzzo

Two USACE-managed parcels, AL16 and AL18, were analyzed for solar development feasibility. AL18 on the west bank contains approximately 4–5 acres of cleared land suitable for 1.0–1.6 MW of PV capacity. AL16 on the east bank provides an additional 2–3 acres, supporting 0.5–0.9 MW. Combined, these areas support 1.5–2.5 MW without requiring external land acquisition. Utilizing the SAM model we are able to theoretically construct a PV plant under these assumptions:
Using the SAM model specifically for photovoltaic detailed models, we first started with the following key inputs:
Weather file: NSRDB PSM v3 TMY for Columbus, MS.
Module model: JA Solar JAM72S30-545/MR from the CEC module library.
Inverter model: Sungrow SG60CX-US [480 V] from the CEC inverter library, 20 units.
Array geometry: single subarray, fixed open rack, tilt 25°, azimuth 180°, GCR 0.45.
Bifacial modeling: module marked as bifacial, bifaciality factor 0.70, ground clearance height 1 m, ground albedo ~0.18–0.20.
Modules in a string: 16

Total AC capacity: 1.125 MW_{AC}
Losses: implemented through SAM's Irradiance Losses, DC Losses, AC Losses, and System Availability sections.

The module was selected because it utilizes similar technology to the new 545 W mono-PERC module and similarly the JA models are commonly used in TVA/SE regions per EPC contracts. The inverter model was similar to the paired inverter for the selected module however is slightly unconservative in this run through. The intended module size was not available for the simulation however it is available on the market, named SG125CX-US. This is the bigger more realistic option rated for 125kv, designed for 1-5MW solar farms, and aligns with the plants anticipated 1.125MW_{ac} total.

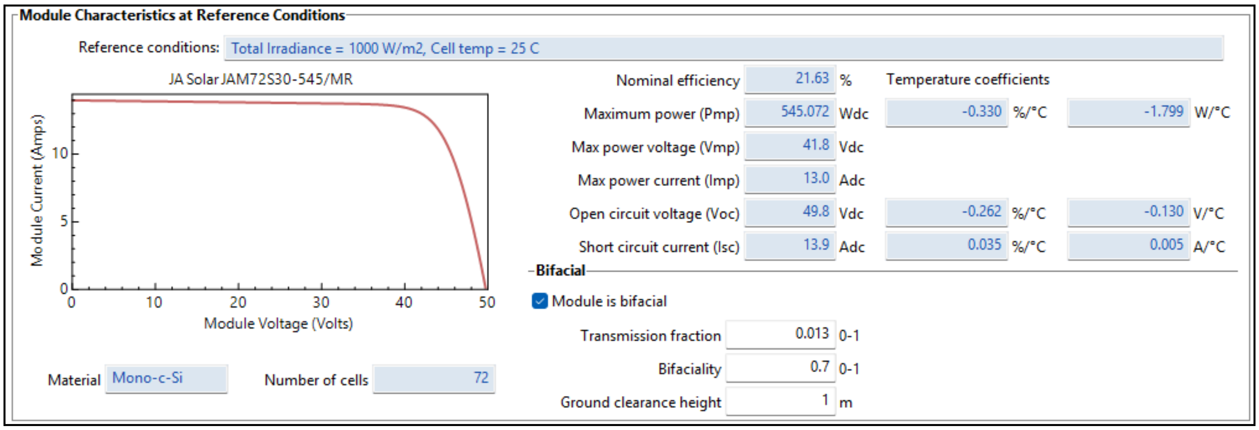


Figure 3.3.1.1 Module Characteristics for JA Solar JAM72S30-545/MR

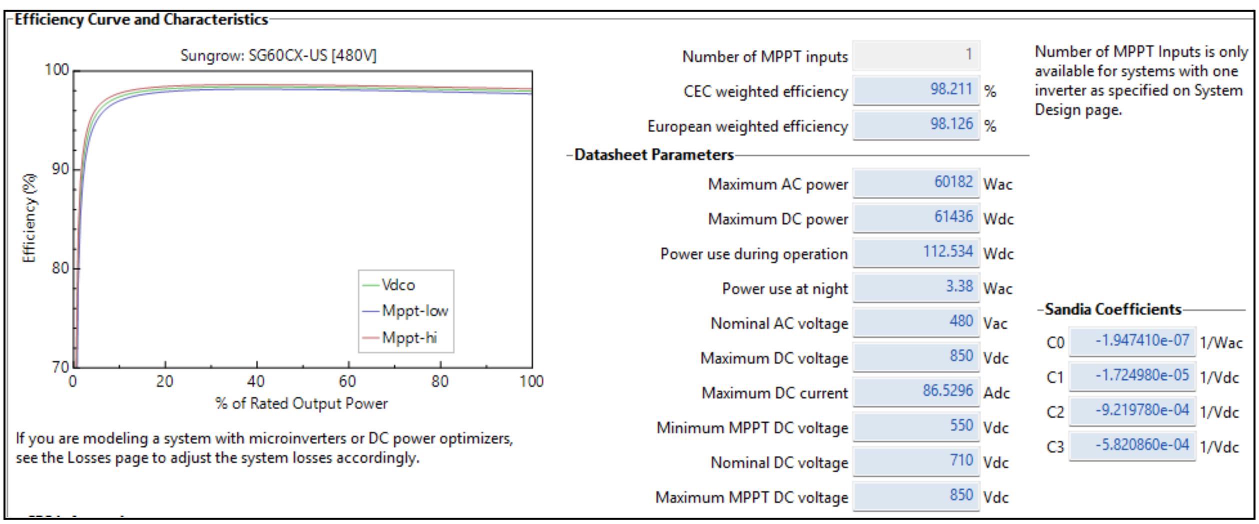


Figure 3.3.1.2 Efficiency Curve of Sungrow SG60CX-US [480 V]

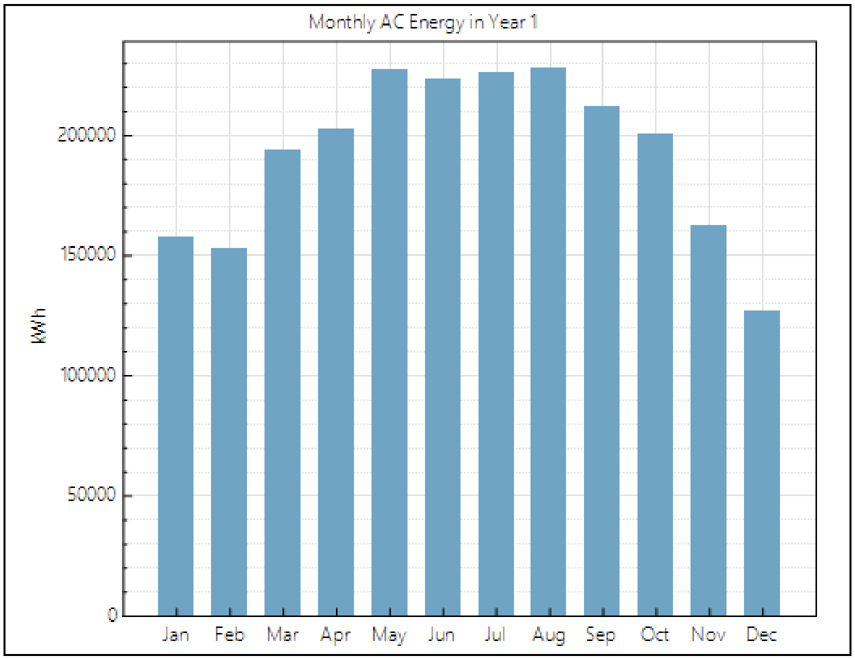


Figure 3.3.1.3 Monthly AC Energy Production

From this simulation we find that our annual energy for the proposed site sits just a 1.51 MW, utilizing either Al16, AL18, Or the East embankment mentioned in APPENDIX C.

When comparing the potential space we have to the land use estimation would show us how much space is required out of the potential sites.

$$A_{Land} = 1.203 * 3 \frac{acres}{MW_{AC}} = 3.61\ acres$$

From this calculation we see that in order to generate 1.5MW of power via solar requires 3.61 acres which is comparable to similar projects near Stennis, Similarly we see that both of our potential sites could house this PV plant. Next, looking at the specific energy yield, capacity factor, and performance ratio calculated within SAM(Appendix C), given by Figure 6.

Metric	Value
Annual AC energy in Year 1	2,311,302 kWh
DC capacity factor in Year 1	17.6%
Energy yield in Year 1	1,541 kWh/kW
Performance ratio in Year 1	0.81

Figure 3.3.1.4 Table Of Resulting Values

Then looking at an annual heatmap for any monthly irregularities,

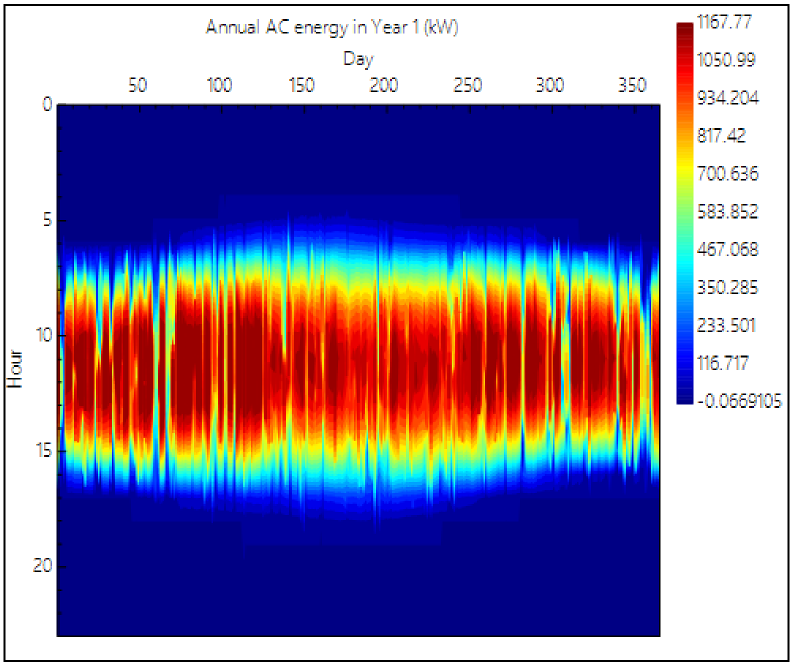


Figure 3.3.1.5 Annual Heat Map Of Stennis Site

From the data depicted we see that the Stennis site is in excellent standing for solar integration. It can confidently deliver at least 1.51 MW under the current assumption of 2752 individual modules. The next course of action is to create an accurate cost representative model to account for costs that will be integrated within the project.

3.3.2 - Environmental Analysis - Dawson Stevens

To conduct this analysis, the Hydropower Environmental Decision Support (EDS) Toolkit, developed by the Oak Ridge National Laboratory (ORNL) and the U.S. Department of Energy, was used. The Hydropower Environmental Decision Toolkit was created for the purposes of streamlining the decision-making process around environmental consideration within the hydropower industry [24]. Below are brief breakdowns of each category:

- Biota & Biodiversity – The site and its reservoir, Columbus Lake, do not contain any endangered or protected species, however, Giant Salvinia, an invasive aquatic plant, is found in the Tennessee-Tombigbee Waterway [23]. Additionally, the lake contains a notably diverse range of algae which should not be disturbed. Otherwise, the biota of Columbus Lake is a mix of durable species, namely catfish, bass, and crappies, that are not incredibly sensitive to minor environmental changes [22][23]. As long as proper precautions and safety measures are taken, the biology of the surrounding water system should not impede construction.
- Hydrology – Due to this project being a renovation project, little change to the hydrology should occur. The only notable issue in this category is the possibility of interrupting the flow of the dam during the construction process. A solution to this would be to schedule the construction during the site's dry season.
- Landscape – Similar to hydrology, there should be minimal effects on the landscape besides that

already affected by the pre-existing structure. The team is currently investigating the co-development of a solar power plant next to the dam. This would occupy more land, potentially interrupting nearby habitats, however a sizable plot of land with minimal vegetation exists alongside the dam. Using this plot would minimize habitat disruption.

- Water Quality – The main concern of water quality has to do with the amount of dissolved oxygen in the tailwater. When water is turbulently discharged through a dam, atmospheric gases can dissolve into it, increasing the oxygenation of downstream water. Currently, it is unclear how much oxygenation occurs with the dam's current structure.
- Geomorphology – Due to the scope of the project, geomorphology will be minimally affected. No further considerations outside of minimizing habitat impact need to be implemented in this regard.
- Connectivity & Fragmentation – The project will have minimal effect on the connectivity of the river as no further fragmentation should occur besides that already caused by the existing dam structure.

Both the reservoir, Columbus Lake, and river, Tombigbee-Tennessee Waterway, contain recreational fisheries. According to the Mississippi Department of Wildlife, Fish, and Parks (MDWFP), the main species that inhabit the reservoir are bass, crappies, and catfish [23]. Fortunately, these species are generalists, which are much less prone to environmental changes than specialist species [22]. The abundance of adaptable fish means that minimal new considerations are needed in regards to fish outside of the already planned measures to prevent fish from entering the turbines.

While the invasive/nuisance species of aquatic plant giant salvinia is present in the lake and waterway, the project has no chance of continuing their spread into new habitats. However, the MDWFP does strongly recommend that recreational boaters thoroughly clean any vehicles that enter the lake afterwards in case it spreads the plant to other bodies of water. For this reason, this report recommends that any equipment that enters the water during the construction of the turbine system is properly clean to prevent the spreading of giant salvinia.

The turbines in the project's plans, as with all hydropower turbines, do have the capability to strike fish that entire them. The team has considered this previously and plans on incorporating fish screens that guide fish passing through the spillway to a fish bypass system. This will allow fish to move through the dam while protecting them from turbine strikes, as well as protect the turbines from potential damage from such strikes [21].

Issue	Solution
Invasive plant life is in the lake and river	Construction equipment will be cleaned to prevent spread into new waterways
Lake contains an active fishery	A fish screen and bypass will be incorporated into the facility's design

Figure 3.3.2: Recommended Environmental Precautions

3.3.3 - Nathaniel Holguin

It is known that the outflow can vary a lot over the course of the year so monthly average data was collected from 1900-2014 excluding a couple of years due to missing data [34]. Taking the average flow rates for each month and putting them into a graph gives the following figure 1. The x axis number is the corresponding month of the year.

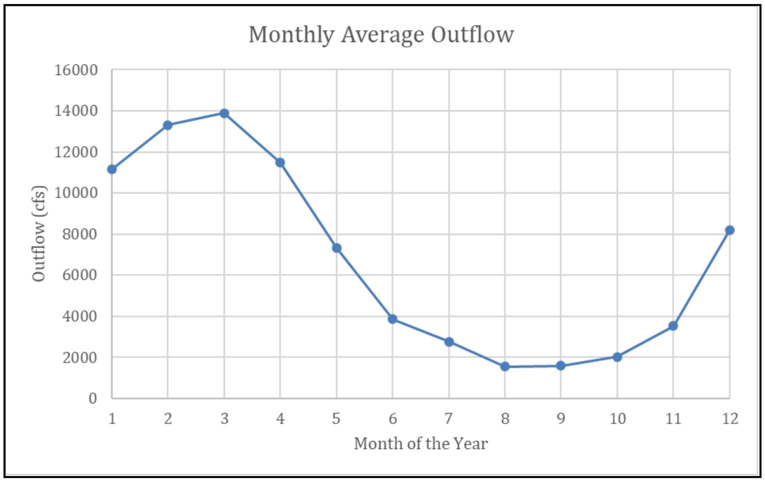


Figure 3.3.3.1: Monthly Average Outflow

As seen in figure 1 the flow at the dam follows a gradual path, having a high December through March and then dipping low May through November. This is due to clear seasonal trends where higher rainfall occurs in the winter and spring months and slows down in the summer and early fall months where precipitation is lower.

This gives the team a good outline to understand how outflow will change throughout the year and how the team might manage that. Even using a turbine that is attuned to capture low flow or a variety of flow, the energy produced during the low season would be insufficient and need a way to counteract it. Some options might include having more turbines run in these months, though that would be a superficial way to keep energy output up. Another option could be being operationally flexible, running as a run of water facility where power is only generated if there is adequate water supply. This might be able to be done seeing as the John C. Stennis Dam has gates that could be used to mitigate how much water flow goes through the system. A similar method to keep up energy through the low season would be to instead of saving water, saving power in a battery of some sorts so that ideally there would always be enough to distribute. There is only so much that can be done about low flow rates though, so in times of low flow the best option might just be to turn off some turbines and save some energy and environmental stability while letting a portion of the turbines do all the work. In this scenario other energy sources would be supplemented so that users would not be affected by seasonal outflow variations.

To understand the total outflow in a given year, data was collected for an average of every day of the year from 1900 to 2014 [34]. This data was used to make a outflow duration curve as seen below in figure 2.

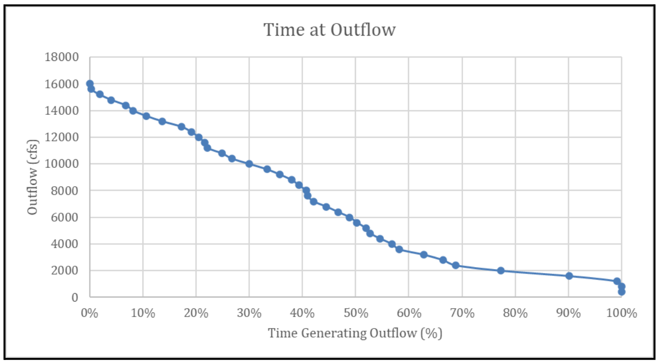


Figure 3.3.3.2: Outflow Duration Curve

The outflow duration curve helps visualize how often outflow will be at different levels so teammates can better understand this topic. As seen on the curve, about 80% of the time outflow will be at least 2000cfs and only 20% of the time it will reach above 12000cfs.

Although outflow is more important, the difference between headwater and tailwater or water drop affects the energy output as well. Below in table 1 is data collected for 9 years [1] of head and tail water.

Table 3.3.3.1: Head and Tail Water

Feet Headwater												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2006	63.17	63.137	63.153	63.155	63.191	63.212	63.241	63.252	63.232	63.206	63.235	63.175
2009	63.185	63.217	63.179	63.2	63.197	63.256	63.294	63.267	63.27	63.16	63.165	63.092
2010	63.168	63.162	63.231	63.204	63.25	63.278	63.269	63.23	63.246	63.265	63.244	63.164
2011	63.186	63.184	63.149	63.157	63.161	63.158	63.155	63.174	63.182	63.149	63.173	63.178
2012	63.188	63.153	63.196	63.141	63.15	63.143	63.173	63.147	63.158	63.169	63.253	63.388
2013	63.383	63.355	63.351	63.374	63.383	63.404	63.39	63.191	63.134	63.238	63.227	63.241
2014	63.217	63.233	63.238	63.264	63.248	63.256	63.233	63.233	63.192	63.207	63.235	63.262
2015	63.205	63.239	63.233	63.298	63.389	63.397	63.429	63.395	63.348	63.28	63.26	63.459
2016	63.295	63.396	63.35	63.333	63.358	63.359	63.379	63.351	63.318	63.348	63.408	63.347
avg	63.22189	63.23067	63.23111	63.23622	63.25856	63.27367	63.28478	63.24889	63.23111	63.22467	63.24444	63.25622
Feet Tailwater												
2006	40.191	40.939	38.137	37.339	37.522	36.573	36.57	36.575	36.579	37.079	37.42	37.037
2009	39.406	37.536	42.277	37.815	40.565	36.792	36.592	36.708	37.453	42.574	38.41	40.071
2010	40.459	39.83	38.66	38.167	39.429	36.885	36.628	36.573	36.453	36.535	36.596	36.597
2011	37.856	37.139	39.505	41.679	37.524	36.437	36.431	36.745	37.178	36.586	36.603	37.668
2012	38.242	38.078	38.861	37.169	36.741	36.641	36.548	36.376	36.531	36.746	36.491	37.864
2013	41.348	39.013	39.235	38.722	38.319	36.731	36.789	36.71	36.775	36.724	36.797	37.613
2014	37.295	38.645	37.34	40.149	37.086	38.047	37.005	36.667	36.63	37.306	37.198	38.641
2015	39.125	38.4	40.558	39.777	38.693	37.265	37.892	36.914	36.705	36.679	37.504	40.715
2016	38.685	39.11	37.591	39.367	36.868	36.518	36.533	36.519	36.402	36.317	36.449	36.682
avg	39.17856	38.74333	39.12933	38.90933	38.083	36.87656	36.77644	36.643	36.74511	37.394	37.052	38.09867
Total Diff	**24.04333**	**24.48733**	**24.10178**	**24.32689**	**25.17556**	**26.39711**	**26.50833**	**26.60589**	**26.486**	**25.83067**	**26.19244**	**25.15756**

Thankfully these values do not have as much seasonal variation as outflow, so the energy output will not be affected too greatly. The total difference in water height at a monthly average sit around 24 to 27 feet, only having about a 3 foot variation. This low variation does not impact the energy output even a percentile as much as the outflow so in turn it will be neglected to deal with the much more pressing issue.

3.3.4 Karsten Jones

This subsection summarizes the mathematical modeling I completed to evaluate the technical and economic feasibility of developing hydropower at the John C. Stennis Dam. The modeling includes hydropower performance calculations, preliminary headloss estimation, scaling analysis for physical prototypes, and economic impact estimation through the JEDI model. These tools supported the engineering requirements listed in Section 2 and helped determine whether the StreamDiver turbine is an appropriate technology for this site.

3.3.4.1 Power Potential Modeling

The first step in evaluating turbine feasibility was calculating the theoretical power available at the site using the standard hydropower equation:

$$P = \rho g Q H \eta$$

Where:

- P = mechanical power output (W)
- ρ = density of water (1000 kg/m³)
- g = gravitational acceleration (9.81 m/s²)
- Q = flow rate (m³/s)
- H = net head available at the selected intake location (m)
- η = overall efficiency (fraction)

For low head conditions at Stennis Dam, assumed values of H=1.0 H = 1.0H=1.0 to 3.03.03.0 meters and flow rates of Q=10Q = 10Q=10 to 404040 m³/s were used. Efficiency values were based on StreamDiver performance data, typically between 0.55 and 0.72 depending on part load operation.

This modeling produced a power envelope used to confirm that a StreamDiver scale installation could produce between 50 and 300 kilowatts depending on final intake location. These results justified continuing with the StreamDiver as the candidate turbine.

3.3.4.2 Net Headloss Estimation

To ensure that the intake and screening system would not significantly reduce available head, I calculated headloss across alternative intake configurations. The loss coefficient method was used:

$$h_L = K\frac{v^2}{2g}$$

Where:

- h_L = headloss (m)
- K = loss coefficient associated with screens or gates
- v = approach velocity (m/s)

Values of K between 0.5 and 2.0 were evaluated, based on data for angled trash racks and low profile screens. By keeping the approach velocity under 0.6 m/s, the estimated headloss remained below 0.1 meters. This satisfied the engineering requirement that intake losses must not significantly reduce effective turbine head.

3.3.4.3 JEDI Economic Impact Modeling

Using the National Renewable Energy Laboratory's JEDI Hydropower Model [25], I evaluated the potential economic and community benefits of a hydropower installation at Stennis Dam. The model uses capital cost inputs, operational spending, labor multipliers, and regional economic data to estimate:

- Direct construction jobs
- Indirect supply chain jobs
- Induced economic activity
- Annual labor income
- Total project economic output

The analysis showed that even a small hydropower installation can contribute measurable benefits to the local economy. This modeling strengthens the justification for renewable energy development at Stennis Dam and supports the community engagement component of the HCC.

4 Design Concepts

4.1 Functional Decomposition

This section describes the process used to generate, evaluate, and select the design concepts for the Hydrojacks hydropower retrofit project. It begins with a functional decomposition outlining the primary and supporting operations required for energy generation and environmental compliance. It then presents the team's top-level and sub-system concepts, including turbine configurations, site strategies, and design features developed from the engineering requirements. The section concludes with a description of the selection criteria and justification of the chosen design, supported by decision matrices and a description of the selected site: John C. Stennis Dam.

4.2 Concept Generation

For this cycle of concept generation, our team primarily focused on the site selection aspect of the project, as the location of our NPD conversion will dictate much of the facility's design. To begin site selection, we found a database of ~2,500 non-powered dams located within the United States from the Oak Ridge National Laboratory that included information such as monthly flow rate, head, and estimated output potential. We used MATLAB to filter the list by selecting dams with estimated power output between 2-25 MW. The reason we did not filter using the 1-10 MW requirement was to ensure the design would be firmly within the range; when inefficiencies are applied, many of the dams with estimated outputs above 10, fall back into range. We also filtered the dams by excluding entries that had especially variable flows. Following this second round of eliminations, we were left with 13 potential candidates.

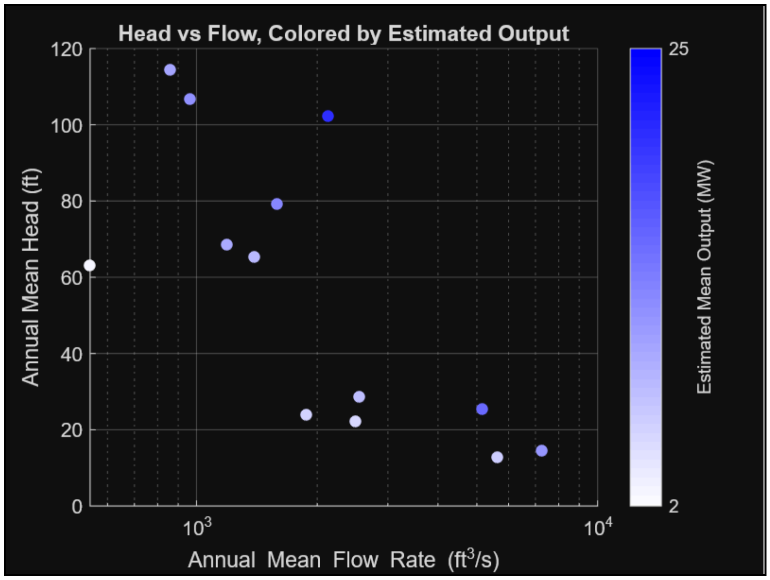


Figure 4.2: Head vs Flow, Colored by Estimated Output

4.3 Selection Criteria

To decide which of the 31 dams would be most fit for our project, we laid out six criteria that would be examined for each dam. Our criteria were as follows:

1. **Flow Rate and Head Consistency** – The consistency of the flow through the dam affects the consistency of a dam's output. An inconsistent output could make financial justification less reliable. To quantify the consistency of flow, we found the coefficient of variance of both flow rate and head for each dam. The dams with especially eccentric flow (i.e. high coefficient of variance) were eliminated.

2. **Proximity to Infrastructure** – Since our dam will need to connect to the local power grid, proximity to relevant electrical infrastructure (most notably powerlines) was considered, with dams more than 5 miles from a transmission line eliminated.

3. **Risk** – Risk encompasses two aspects of danger in a dam. The vulnerability to failure, and the danger a failure presents. To quantify this, we used the National Inventory of Dams' (NID) condition classifications, giving each dam a grade based off the Hazard Potential Classification, Condition Assessment, and Emergency Action Planning preparation. Dams that posed obvious hazards were eliminated.

4. **Ownership/Regulation -** Both ownership of the dam, as well as the applicable regulatory bodies, affect the standards a dam retrofit would need to comply with, and generally, stricter standards become more expensive for construction costs. Additionally, different owners can be more or less willing to work with the team when proceeding to the facility design, therefore

making the design process more arduous and potentially less accurate.

5. **Structure Type** – Several types of dams exist, usually classified by how they are structured and by what material they are built out of. Materials such as earth and infill can be difficult to modify, while concrete and steel dams are more modifiable. Priority was given to dams that were made with either concrete or steel.

6. **Accessibility** – Retrofitting and operating a hydropower dam requires reasonable proximity to developed areas; rural locations make construction more expensive and operation more difficult. Dams further than 10 miles from some sort of population center, highway, etc., were eliminated, and priority was given to more urban sites.

7. **Local Need** – In order to justify a hydropower retrofit, we will need to show that the implementation of a turbine will in some way benefit the local community. This justification can be economic or social. Dams that stood out as highly beneficial to their local community were given priority. After these criteria were applied to the remaining thirty-one dams, four dams stood out as best fit for our project: Fish Barrier, John Sevier Dam, Mississippi River Lock & Dam 3, and Peoria Lock & Dam.

After these criteria were applied to the remaining thirteen dams, three dams stood out as best fit for our project: Fish Barrier, John C. Stennis Lock & Dam, & Coon Rapids Dam

KS00012	39.25713795	-96.591805	NHD	TUTTLE CREEK DAM
NM00404	35.61657592	-106.3178358	NHD	COCHITI DAM
KY03009	36.89341099	-86.12568147	NHD	BARREN RIVER DAM
MS03056	33.51822504	-88.48868317	NHD	JOHN C. STENNIS LOCK AND DAM
WV00701	38.66160057	-80.69293662	NHD	SUTTON DAM
CA00034	39.5205	-121.5478	NID	FISH BARRIER
MN00507	45.14446	-93.3106	NHD	COON RAPIDS
PA00897	39.96722222	-75.18611111	NHD	FAIRMOUNT
WA00555	46.5068	-122.6022	NID	BARRIER DAM
WA00769	48.5394	-121.7437	NID	FISH BARRIER DAM
AZ10002	33.071998	-113.016526	NHD	PAINTED ROCK DAM
AZ10005	32.70500183	-114.7279968	NHD	MORELOS DIVERSION DAM
WV09101	39.31323342	-80.03366043	NHD	TYGART DAM

Figure 4.3: List of 13 Dams, Top 3 Highlighted Green

4.4 Concept Selection

To decide which of the two final dams, our group researched each site in depth, then compared the dams in a decision matrix.

4.4.1 Fish Barrier

Fish Barrier (sometimes referred to as the Feather River Dam) is located in Oroville, California and is part of both the Feather River Salmon Hatchery and the Oroville Complex, a system of dams and canals that run through the town. The most notable advantage of the site is the highly consistent flow rate and head, meaning a turbine system's output would be especially consistent throughout the year. Another benefit of the dam is the lack of a need for fish passage, as the original purpose of the barrier is to prevent salmon from the nearby hatchery going further upstream. The nearest power line is located about 0.5 miles to the east and due to Oroville's pre-existing dam systems, the required construction infrastructure is already present within the area.

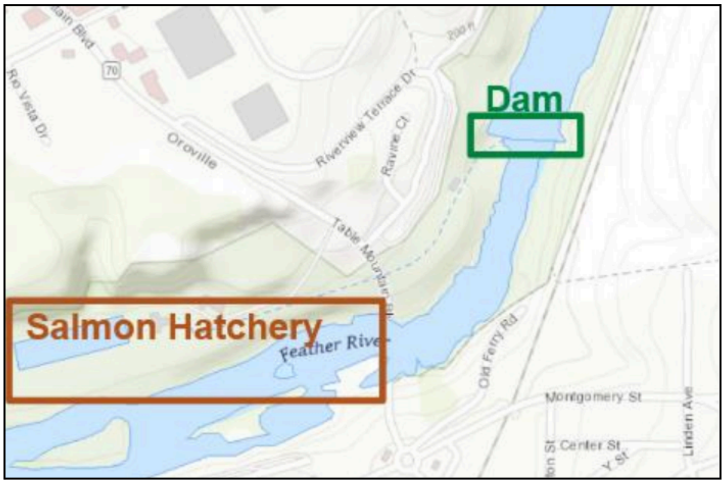


Figure 4.4.3 Fish Barrier and Feather River Hatchery

The downside of its location is that Oroville already has several hydroelectric dams, which could dissuade ownership from adding the relatively small system our team would design. The dam also has a low output potential compared to the other three dams, potentially making financial justification difficult. Additionally, California has especially rigorous standards for hydro projects and finding a contact within the California Department of Water Resources has been difficult for our team thus far. Overall, Fish Barrier has valuable strengths that could be undermined by some of its weaknesses.

4.4.2 John C. Stennis L&D

The John C. Stennis Lock and Dam, located along the Tennessee-Tombigbee Waterway near Columbus, Mississippi, serves primarily as a navigation structure that maintains stable water levels for commercial transport. One of the most notable advantages of this site is its consistent discharge profile, owing to upstream flow regulation across the Tenn-Tom system. This provides a relatively predictable hydraulic environment compared to natural, unregulated rivers, meaning a small hydropower system would experience stable operational conditions throughout most of the year.

Another strength of the Stennis site is its existing U.S. Army Corps of Engineers (USACE) infrastructure, which includes access roads, electrical service points, maintenance areas, and controlled spillways. This significantly reduces the civil works cost typically required for retrofitting a non-powered dam. Additionally, unlike many dams that require major upgrades for fish passage, the Stennis facility is part of a navigation waterway that already accommodates aquatic movement through lock operations, reducing the need for extensive new passage systems. The site also has several USACE-managed land parcels

(AL16, AL18, etc.) near the dam that provide deployable space for integrating supplemental solar generation.

Figure 4.4.2.1 John C Stennis L&D

However, the primary downside of this location is that its available head is relatively low, which limits the maximum capacity and efficiency of conventional turbine systems. This constraint may restrict the overall economic return compared to sites with higher hydraulic head. Another consideration is that the Tennessee-Tombugee Waterway is a federally managed navigation system, meaning that hydropower retrofits require extensive coordination with USACE, including environmental assessments, flood-risk evaluations, and operational scheduling to avoid interfering with commercial traffic. These factors can extend the permitting timeline and introduce additional regulatory complexity.

Despite these challenges, the John C. Stennis site remains a strong candidate for a small-scale hydro retrofit and hybrid solar integration, supported by existing civil structures, consistent flows, accessible land, and reasonable interconnection distances. Overall, the Stennis site presents a balanced mix of strengths and constraints, making it a technically feasible yet carefully managed opportunity for renewable energy development.

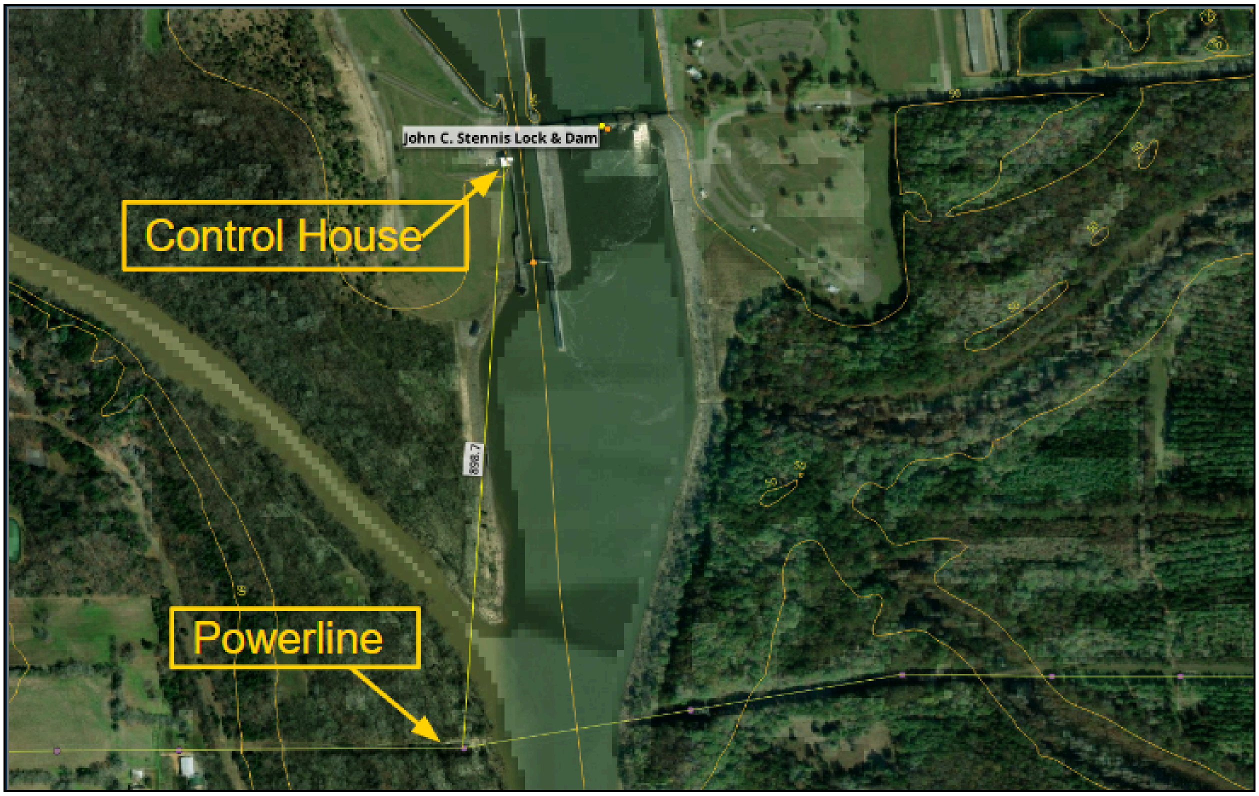


Figure 4.4.2.2 Grid Distance For Stenns Site

4.5 Decision Matrix

Criterion	Weight	Fish Barrier CA00034		John C. Stennis MS03056	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score
Estimated Mean Output	25%	22.68	5.67	100.00	25.00
Flow Rate Consistency (1-CV)	7.50%	98.35	7.38	78.90	5.92
Head Consistency (1-CV)	7.50%	96.33	7.23	76.51	5.74
Poximity to Infrastructure	10%	95.00	9.50	90.00	9.00
Risk	10%	100.00	10.00	70.00	7.00
Ownership and Regulation	10%	60.00	6.00	80.00	8.00
Structure	10%	70.00	7.00	70.00	7.00
Accessibility	10%	90.00	9.00	80.00	8.00
Local Need	10%	60.00	6.00	80.00	8.00
Total	100%		67.77		83.66
Rank					

Figure 4.5: Decision Matrix Version 2

After creating the decision matrix, our team concluded that John C. Stennis Dam is the best choice for our project due to its various strengths. This decision will allow the team to move onto the facility design stage of the project.

5 Schedule and Budget

5.1 Schedule

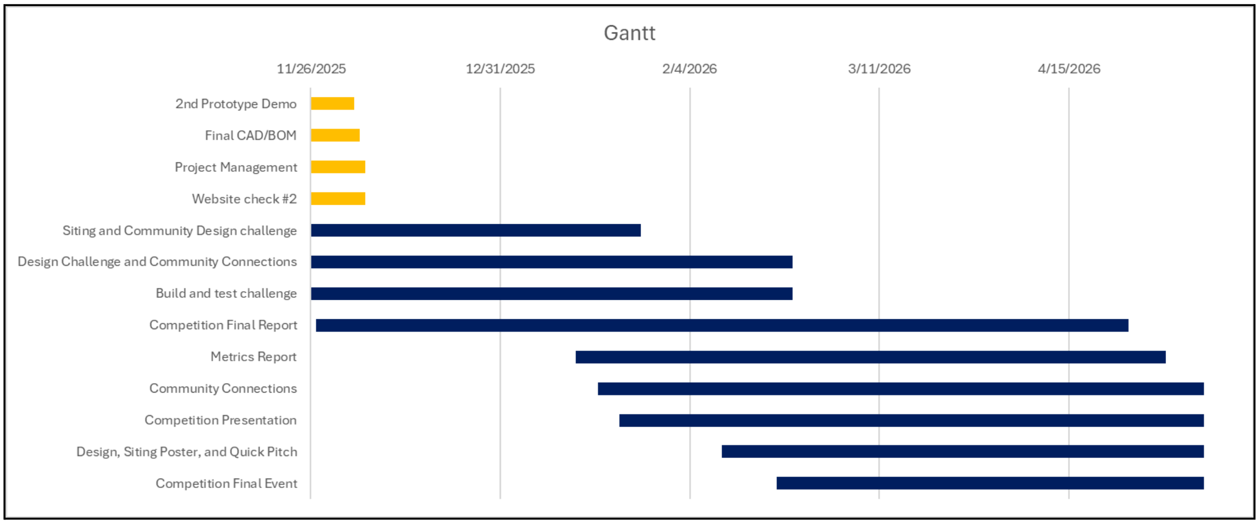


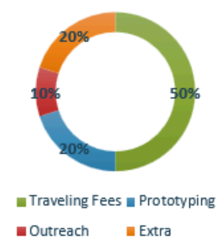
Figure 5.1: Gantt Chart

With the semester coming to an end, most of the major conceptual design milestones have been completed, and only a few remaining capstone assignments are left to finalize. As we move into the spring semester, the focus will shift toward the Siting and Community Design Challenge, which is already well underway and will be completed early in the term. Following this, the team will concentrate on the Community Connections Challenge and the Build and Test Challenge, which together represent the next major phase of work for both the competition and the capstone course. These tasks require more advanced modeling, refined prototyping, and expanded outreach efforts. The remaining HCC deliverables, including the Competition Presentation, Design Reports, and Final Event, extend through April and define the overall trajectory of the project. Based on current progress, the team is well positioned to meet the upcoming deadlines and enter the spring semester with a strong foundation for continued development.

5.2 Budget

For this project scope, the importance of the budget mainly goes towards traveling and prototyping materials. However, due to the feasibility aspect of the project a potential bill of materials is required. This will be demonstrated using a similar size retrofit project that demonstrates similar goals.

How much do we have?	Where Do We Want To Allocate Money?		
Initial Amount			
$15,000.00	Traveling Fees	50%	$7,500
Total Expenses	Prototyping	20%	$3,000
$10,500.00	Outreach	10%	$1,500
Potential Savings	Extra	20%	$3,000
$4,500.00	Total	100%	$15,000



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	4/24/2026	$5,000.00
	Total Income	$20,000.00

What are our expenses?			
Description	Expense amount	Distribution	
In Person Workshops	$1,000.00		
In person Conferances	$7,500.00	Prototype 1	$200
Prototyping Materials	$1,000.00	prototype 2	$200
Mapping Software	$500.00	Final Prototype	$500
Community Outreach	$500.00	Outreach Model	$100
Total Expenses	$10,500.00		$1,000.00

Figure 5.2.1 Expected Income & Expenses

What are our expenses to date?	
Description	Expense amount
3d Printer	$2,882.94
Total Expenses	$2,882.94
True remaining balance	$15,117.06

Figure 5.2.3 Actual Expenses To Date

Looking at the anticipated expenses versus the income we see that we have sufficient funds to utilize and are currently in the process of raising more money for the project.

5.3 Bill of Materials (BoM)

The bill of materials for this project scope would look similar to our competitors however we expect to add solar into our final integration which is not yet modeled but will be in the future. Looking at Figure 5.3.1 we can see the estimated B.O.M for a project of our scope, soon encompassing all of our specific information.

Theoretical B.O.M		
Total Project Cost Estimate		$24,600,000.00
Civil Works	Cofferdams & Dewatering	$1,600,000.00
	Intake Structure,Trash Rack, Stoplogs, Isolation Gate (Vendor)	$1,200,000.00
	Powerhouse bay, crane,rails (Vendor)	$2,500,000.00
	Bulb Pit, Draft Tube Concrete (Vendor)	$1,400,000.00
	Vertical Fish Ladder (Manufacture)	$2,700,000.00
Electromechanical	Kaplan Bulb Turbine Generator Package, Lube, Cooling, Liner, Instalation(Purchase)	$6,900,000.00
	Wicket Gates & Servos (Manufacture)	$800,000.00
	Overhead Crane (Purchase)	$350,000.00
	Automated Trashrack Cleaner (Purchase)	$250,000.00
Electrical and Balance	Generator Switchgear, Protection/SCADA (Purchase)	$900,000.00
	Unit Transformer (Purchase)	$800,000.00
	13.8kV Feeder/POI connections & Intertie (Purchase)	$600,000.00
	Cables, Ductbank, Grounding (Purchase)	$300,000.00
Soft Costs & Contengincy	Permitting, Envirmoantal Studies,CM (Purchase)	$1,800,000.00
	Utility, Legal, Financing (Purchase)	$400,000.00
	Contengincy Construction (Purchase)	$2,100,000.00
Total Price Point		$24,600,000.00

Figure 5.3.1 Bill Of Materials

The Bill of Materials shown in this section represents the major components expected for the final hydropower system and serves as an early outline of the equipment required for the StreamDiver installation. While some items reflect standard components used in typical low head hydropower systems, others will be refined as more detailed modeling and structural analysis are completed. Elements such as the turbine housing, generator, mounting hardware, intake screening, and electrical equipment are directly applicable to the final design, while parts related to civil integration and flow routing may change once site-specific dimensions are confirmed. The future addition of a solar co-development system will also expand the BOM to include photovoltaic panels, mounting structures, inverters, and wiring. Several uncertainties remain at this stage, including final intake geometry, specific electrical interconnection requirements, and the extent of structural reinforcement needed at the chosen installation location. These details will be clarified during the detailed design phase and reflected in an updated and more comprehensive BOM in the final report.

6 Design Validation and Initial Prototyping

6.1 Failure Modes and Effects Analysis (FMEA)

For the team's failure modes and effects analysis, we chose to focus on the turbine system, permanent magnet generator, and the fixed runner component. Modeled in figure 6.1.1 is the FEMA design validation for the system.

Site Name: John C Stennis System Name: Turbine Subsystem Name: PMG Component Name: Fixed Runner		Development Team: HCC26		Page No 1 of 1 FEMA Date: 11/5/2025 RPN scale simplified 1:100	
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
1. Generator Unit, Generates electricity	Generator shaft siezes, or failure	Electical production stops	Debris/sediment clogging the runner,erosion,wildlife	55	Utilize trashrack to filter animals and debris
2. Fixed Runner, Converts KE from water	Caviation	Runner becomes less efficient and in sevire cases cracks appear	Formation of vapor bubbles bursting around runner.extreme pressure fluctuations	40	High strength errosion resistant blades, improve pressure distribution shape of the blade.
3. Unit Casing, guides water to the runner	Leaks or cracks in housing	Electrical failure,erosion, loss of efficiency	Debris, excesive flow, trash	30	Utilize strong materials, trashrack, and aerodynamic design
4. Dam structure, supports water pressure from reservoir	Flooding	Downstream floods, wildlife impacts, components may erode	Irregular water volume moving above dam or through turbine	25	Regular inspection every 2-4 years to assess dam structure and integrity

Figure 6.1.1 FEMA Analysis

Depicted from this table, we see that we chose to analyze the generator unit, fixed runner, unit casing, and dam structure as our functions. We used a simplified 1–100 Risk Priority Number (RPN) scale to compare relative risk and prioritize design actions.

The highest-risk item (RPN = 55) was associated with the generator unit, whose primary failure mode is *shaft seizure or failure*. The effect of this failure is a complete loss of electrical production and potential secondary damage to the turbine and powertrain. The FMEA identified debris and sediment clogging the runner, erosion, and wildlife entrainment as key causes. To mitigate this risk, the design incorporates an upgraded trashrack system at the intake. The rack spacing and bar geometry are selected to block large debris and fish while minimizing head losses. This is paired with improved access for cleaning and inspection so the rack can be maintained without long outages. By addressing debris at the intake rather than accepting it at the turbine, we reduce both the probability of generator shaft loading events and the likelihood of catastrophic failure.

The second critical failure mode (RPN = 40) was cavitation on the fixed runner, which can make the runner less efficient and, in severe cases, cause cracking of the blades. Cavitation is driven by vapor bubble formation and collapse under extreme pressure fluctuations. Our mitigation strategy was primarily materials and geometry: specifying high-strength, erosion-resistant blade material and refining the blade profile to improve pressure distribution and reduce local low-pressure zones. In addition, the operating envelope of the turbine is constrained to avoid extreme off-design flows that produce low pressure at the runner outlet. This combination reduces both the occurrence and severity of cavitation damage.

The unit casing (RPN = 30) can experience leaks or cracks in the housing, leading to electrical failure, erosion, and loss of efficiency. Causes include excessive flow, impact from entrained debris, and long-term fatigue. The design mitigates these risks by using robust, corrosion-resistant casing materials and by aligning the casing geometry with the trashrack and flow-straightening features so that large objects are unlikely to impact the casing at high velocity. We also specify appropriate wall thicknesses and inspection intervals to detect early signs of cracking or coating failure.

Finally, the dam structure itself (RPN = 25) was evaluated for flooding, which could cause downstream flooding, wildlife impacts, and erosion of structural components. While this risk is partly outside the scope of the turbine retrofit, our design decisions still influence it. We assume irregular water volume above the dam or through the turbine as the cause. The mitigation strategy consists of regular structural inspections every 2–4 years, confirmation that the turbine retrofit does not compromise spillway capacity, and controls that prevent the turbine from operating outside safe reservoir levels. These actions keep the retrofit aligned with existing USACE safety margins.

6.2 Risk Trade-Off Analysis

The FMEA also informed several important risk trade-off decisions:

- Trashrack design vs. hydraulic losses: A finer trashrack spacing greatly reduces debris-related failures (lowering the generator and casing RPNs) but increases head loss and reduces available power. Our team selected an intermediate spacing that captures damaging debris and wildlife while keeping additional head loss within an acceptable fraction of total head. This is a deliberate trade-off between maximum efficiency and reliability.
- Runner robustness vs. cost and efficiency: Increasing blade thickness and specifying more expensive, erosion-resistant alloys substantially lowers the cavitation and erosion risk, but raises capital cost and can slightly reduce peak efficiency due to altered blade profiles. We chose a runner design that sacrifices a small amount of maximum efficiency to gain significantly higher durability and reduced maintenance risk over the project life.
- Casing strength vs. construction cost: Over-designing the casing would drive costs unnecessarily high, while under-designing increases the risk of catastrophic leakage or failure. By using the FMEA-derived RPN and realistic load cases, we estimated the sized casing to safely withstand expected operating and transient loads with a suitable factor of safety, rather than simply oversizing each of the components.
- Inspection frequency vs. operational downtime: More frequent inspections lower the chance of undetected damage but increase maintenance cost and downtime. The chosen inspection interval is every 2-4 years for the dam structure and at scheduled outages for turbine components, these reflect a compromise between risk reduction and availability.

Overall, the FMEA allowed the team to identify the generator shaft and runner cavitation as the most critical risks and to justify design features such as rashracks, improved materials, optimized blade geometry, and inspection plans that could reduce those risks to an acceptable level without unnecessarily compromising efficiency or cost.

6.2 Initial Prototyping

6.2.1 Willow Bend Outreach Model

1. Question - Can we develop an effective and engaging educational model that communicates the basic principles of hydropower to students and community members while also supporting our

early engineering learning objectives?

2. Answer - To address this question, the team designed and constructed a simple physical demonstration that combines a small turbine, generator, and visible hydraulic head difference to illustrate how flowing water can be converted into electricity. The model uses accessible materials to create a clear and memorable representation of hydropower fundamentals. Water is delivered to the turbine through a controlled head, causing the spoon turbine to rotate and generate electricity through a small motor functioning as a generator. The design emphasizes visual clarity, physical interaction, and durability so that it can be used repeatedly during outreach events at Willow Bend Environmental Education Center.

   During testing, the model reliably produced measurable electrical output, and its operation was intuitive for younger audiences. Students could observe how changes in head height, flow rate, and turbine geometry influenced performance. The model successfully met its objective as an educational tool and provided the team with valuable hands-on experience working with small scale flow systems.

3. This outreach model provided early insights into the importance of reliability, simplicity, and intuitive flow paths in hydropower system design. While the model operates at a much smaller scale, constructing it allowed the team to develop a better understanding of the relationship between head, flow rate, and turbine performance, which directly informed the assumptions used in hydraulic modeling for the Stennis Dam. The process of designing an educational tool also reinforced the need to clearly communicate design decisions to stakeholders, a skill that is essential in a real hydropower development project.

   The outreach model additionally helped the team recognize the value of visible system components. Watching the turbine spin and produce electricity proved to be highly effective for community engagement, suggesting that transparency and clear visualization should also be considered in presentations and demonstrations for the Hydropower Collegiate Competition. Overall, the Willow Bend model played a significant role in strengthening both the technical and communication aspects of the project and established a foundation for expanded outreach activities in the spring semester.

Figure 6.2.1.1 Outreach Model

Beyond serving as a technical demonstration, the Willow Bend outreach model played an important role in building our partnership with the Willow Bend Environmental Education Center. Their staff provided feedback on how to present hydropower concepts in a clear and engaging way, which helped us refine both the educational message and the physical design of the prototype. Working directly with an established environmental education organization also gave us insight into how younger audiences respond to renewable energy topics and what types of demonstrations are most effective in a classroom setting. This collaboration will continue into next semester as we develop more advanced outreach materials and plan interactive events that support the Community Connections Challenge.

6.2.2 Physical Stennis Site Layout

1. Question - How well does the proposed turbine geometry fit within the dimensional limits of the Stennis Dam gate bay, and can the StreamDiver concept be physically integrated into the layout modeled in the 3D printed prototype?
2. Answer - The physical model showed that the turbine geometry does not align perfectly with the initial assumed gate bay dimensions. The simplified prototype revealed that the StreamDiver housing would not fit ideally on the upstream side of the gate due to limited clearance and interference with the modeled wall thickness. The model also showed that the flow path entering the turbine requires more space than originally expected. These findings indicate that the turbine would be better positioned on the downstream side of the gate or in an adjacent channel where flow straightening and alignment can be improved.
3. The prototype highlighted the need for more accurate dimensional data from Stennis Dam before finalizing turbine placement. It confirmed that the upstream gate configuration is too restrictive and that a downstream or toe-of-river installation is more realistic. The next iteration will include a refined CAD model based on updated measurements and a modified physical layout to better represent the gate recess, sill height, and downstream apron. These improvements will help the team evaluate civil support structures, flow routing, and turbine mounting options with greater accuracy.

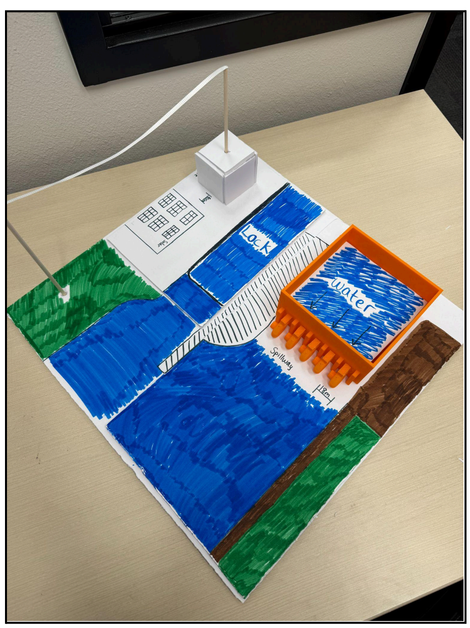


Figure 6.2.2.1 Physical site layout

Figure 6.2.2.2 Close-up of physical site

6.2.3 StreamDiver CAD Model

1. Question - The StreamDiver CAD model was created to determine whether the turbine's geometry, mounting envelope, and component layout can be realistically integrated into the physical constraints of the John C. Stennis Dam. The prototype was also intended to confirm spatial compatibility between the StreamDiver housing, generator, support brackets, and intake alignment. This model helps evaluate how the turbine would physically fit into an existing bay or channel and whether any major civil modifications would be required.
2. Answer - The CAD model showed that the StreamDiver can be positioned within a compact intake channel without interfering with surrounding structures. The generator and support brackets align cleanly behind the turbine housing, and the overall assembly remains shorter than the available length inside a modified intake bay. The exploded view confirmed that all major components can be assembled and accessed for maintenance. The model also demonstrated that the turbine's nose cone and housing do not exceed expected clearances, and that flow can be guided effectively into the runner.
3. The CAD model confirmed that a single StreamDiver unit is physically feasible at the Stennis site and that only minor civil modifications would be required to support the housing and generator. This allows the design team to move forward with intake geometry refinement and structural support modeling. The next iteration will include a fully dimensioned integration model of the turbine inside a site specific channel layout. Additional work will involve adding mounting flanges, evaluating maintenance access, and coordinating the CAD model with electrical routing and sensor placement. The CAD prototype will also be used to validate assumptions in the mechanical subsystem modeling and to prepare for more detailed structural and flow analyses in future phases.

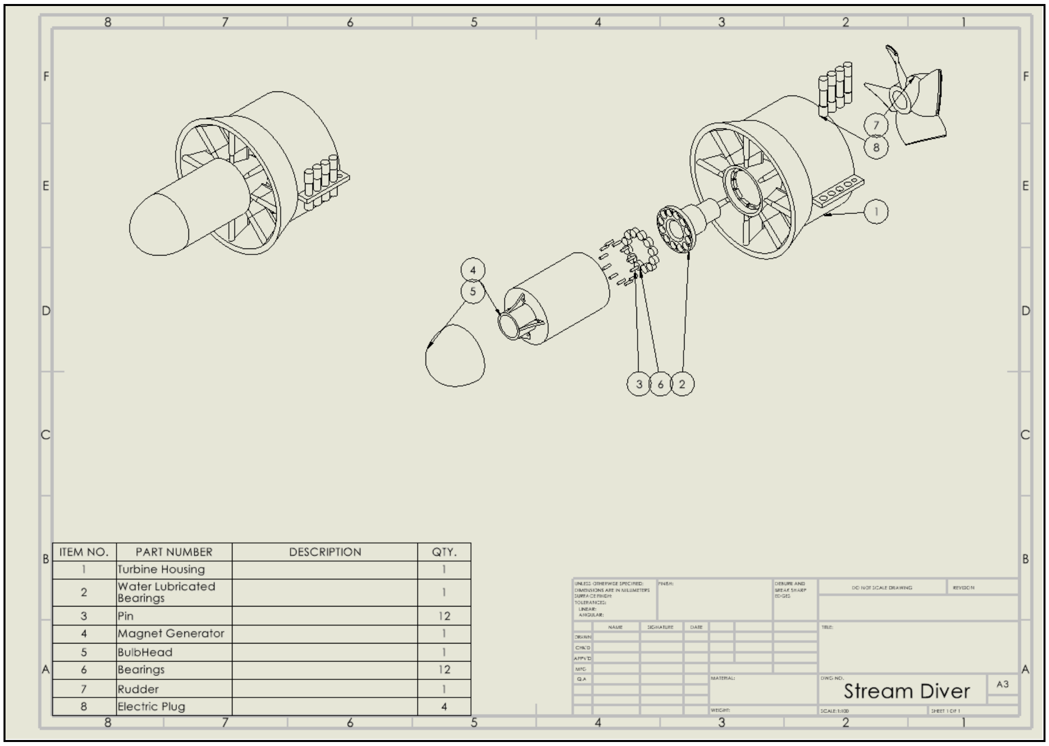


Figure 6.2.3.1 Drawing of StreamDiver model

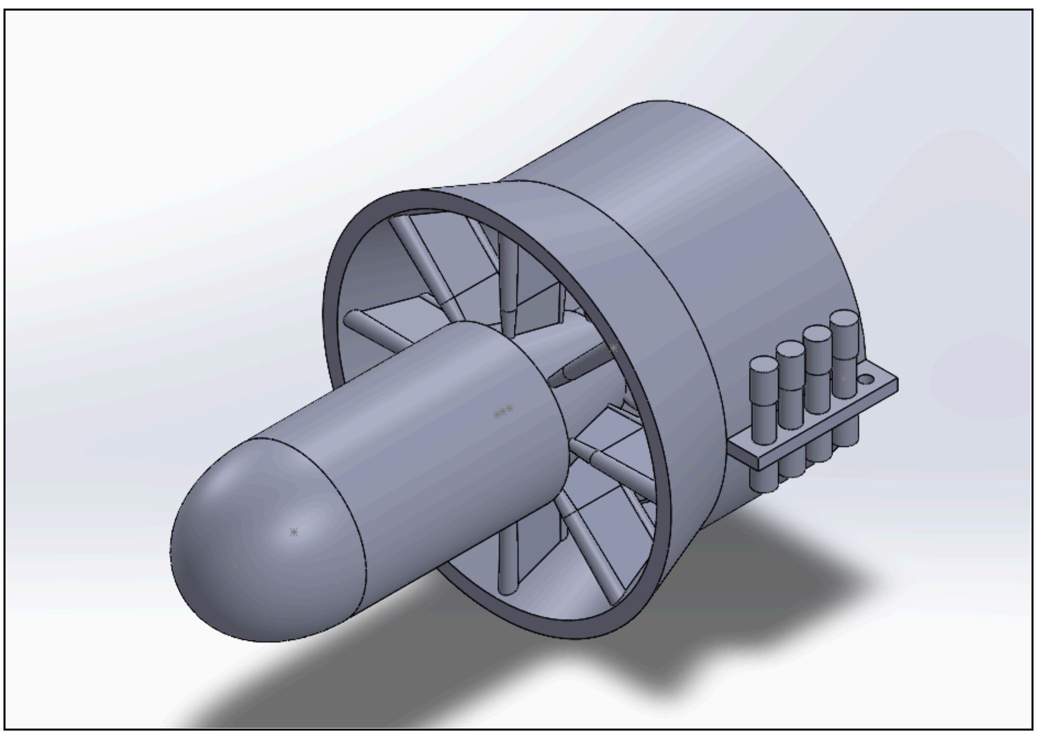


Figure 6.2.3.2 Solidworks view of Stream-Diver design

6.3 Other Engineering Calculations

After the concept selection phase, several engineering calculations were completed to verify the feasibility of installing a StreamDiver turbine at the John C. Stennis Dam and to support the development of the preliminary design. The first set of calculations focused on estimating power output using the available head and flow values associated with the dam's existing hydraulic conditions. Using the standard hydropower equation and efficiency ranges provided by Voith, the expected power generation fell between 50 and 300 kilowatts depending on flow conditions. These results confirmed that the StreamDiver is appropriate for the low head configuration at the site.

Headloss calculations were also performed to determine how intake screens and flow restrictions would affect net head. By applying loss coefficients associated with inclined screens and limiting the approach velocity, the estimated headloss remained below 0.1 meters. This confirmed that the intake design would not significantly reduce available energy. Environmental requirements were evaluated by comparing intake velocities to recommended thresholds for fish passage. All intake concepts analyzed stayed below the 2.0 meters per second limit, supporting the team's goal of minimizing ecological impact.

Geometric clearance checks were conducted using both the CAD assembly and the 3D printed site model. These checks showed that the upstream gate bay does not provide enough space for the StreamDiver housing and generator to fit without interference. The analysis suggested that downstream or toe-of-river placement would be more practical, and this finding will guide future design iterations. Scaling methods were applied to the physical prototypes to better understand flow behavior and turbine placement, providing additional insight into spatial and hydraulic constraints.

Finally, a preliminary JEDI economic assessment was performed to estimate the potential economic benefits of a small hydropower installation at the site. The model indicated positive regional impacts through job creation, operational spending, and related economic activity. These results support the broader community benefit goals required by the HCC.

Overall, these calculations helped validate the technical and economic viability of the proposed design and established a foundation for the next stage of detailed modeling and system integration.

6.4 Future Testing Potential

With the data for seasonal variation flow collected and analyzed it shows that the spring season gets the highest outflow where it will likely exceed 10000cfs and the winter/fall season gets the lowest outflow where it will likely fall below 4000cfs. This will likely be the main contributing factor to seasonal variation of power generation due to the low seen difference in head values. With only a 3 foot variation, outflow ranging over 10000cfs will cause a much larger disturbance in power levels. This information will help the team push forward in turbine development at the John C. Stennis Dam. It allows the group to access the problem accurately and decide a plan moving forward. Ideal options to try and collect consistent power through the year involve saving power from stronger generation months. This could be done by focusing on either the more mechanical side or the more electric side. Having a way to store power so that it can be used later or storing water so that it can generate power later would be likely routes moving forward.

7 CONCLUSIONS

This report presented the conceptual design for a small hydropower system at the John C. Stennis Dam, developed as part of the Hydropower Collegiate Competition. The project goal is to design a renewable energy solution that leverages existing non-powered infrastructure while meeting critical requirements related to low civil impact, environmental responsibility, community value, economic feasibility, and reliable power generation. To meet these requirements, the team selected the Voith StreamDiver turbine for its suitability in low head environments, compact footprint, and minimal construction needs. A solar co-development system was also incorporated to increase overall annual renewable output.

The report documented the complete engineering process completed this semester, including site screening, benchmarking, literature review, mathematical modeling, requirements development, concept generation, prototyping, CAD modeling, and early outreach planning. Modeling provided estimates of expected power output, intake headloss, and fish passage velocities, confirming that the hydraulic conditions at Stennis Dam align well with the StreamDiver's operating range. Prototyping helped clarify spatial constraints around the gate structure and supported the decision to position the turbine on the downstream side of the dam, where installation is more practical.

The outcome of the semester is a validated conceptual design that is technically feasible, environmentally conscious, and aligned with the competition's expectations. The final proposed solution consists of a downstream mounted StreamDiver turbine supported by refined intake geometry, sediment management considerations, and an integrated solar array to enhance annual production. Community engagement efforts were also initiated through partnerships with Willow Bend Environmental Education Center and the development of demonstration prototypes. These accomplishments provide a strong foundation for next semester's detailed design, testing, structural analysis, electrical integration, and expanded outreach activities.

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9 APPENDICES

9.1 Appendix A: General Dam Information

9.1.1 John C Stennis L&D

John C. Stennis Lock and Dam is a concrete navigation and water-control structure located approximately 10 miles north of Columbus, Mississippi, on the Tennessee-Tombigbee Waterway (Tenn-Tom). The dam is owned and operated by the U.S. Army Corps of Engineers (USACE), Mobile District, and forms part of a 234-mile navigational system connecting the Tennessee River to the Gulf of Mexico. Unlike many traditional hydroelectric dams, Stennis was not originally constructed for power generation; its primary function is to maintain navigable pool levels, regulate water elevations, and support commercial barge transport across the Tenn-Tom system.

The structure consists of a navigation lock, a concrete spillway section, and a system of earth embankments extending along the reservoir perimeter. The lock chamber itself is approximately 600 feet long and 110 feet wide, consistent with other Tenn-Tom navigation locks, designed to accommodate towboats and multi-barge formations. The reservoir created upstream of the dam maintains stable pool elevations, producing a relatively consistent head range between 25–35 feet, depending on seasonal conditions and lock operations.

The surrounding USACE-managed lands include several designated parcels—most notably AL16 and AL18—which provide open, accessible ground suitable for renewable energy integration. AL18, located along the west bank near the service and maintenance area, contains roughly 2–3 acres of cleared and graded land, with direct proximity to the dam's control and electrical systems. AL16, on the east bank, includes 1–2 acres of elevated recreational and overflow area that is largely above the flood-prone zone. Combined, these parcels offer 1.5–2.5 MW of feasible solar deployment capacity without requiring external land acquisition.

The dam includes multiple concrete and earth-fill components that direct flow toward the lock and spillway. Its hydraulic control infrastructure—stoplogs, gated sections, and embankment protections—is already in place, reducing the civil works required for a small hydropower retrofit. Additionally, transmission infrastructure is located nearby; the closest distribution tie-in lies within 0.3–0.6 miles of the dam, simplifying potential interconnection for both hydro and solar generation.

However, the Stennis site also presents certain design constraints. The relatively low head limits turbine selection to low-head, high-flow models such as Kaplan bulb units. Navigational priority on the Tenn-Tom imposes strict operational scheduling constraints, requiring that hydropower production never interfere with lock operations or water-level management. As a federal navigation asset, the site is subject to thorough environmental and regulatory review, including evaluation of upstream and downstream aquatic habitats, sediment transport, and flood-risk management. These requirements extend project permitting timelines and necessitate close coordination with USACE during design and deployment.

Overall, the John C. Stennis Lock and Dam offers a technically attractive location for a small hydropower retrofit supplemented by solar generation. The combination of consistent flows, existing civil structures, accessible land parcels (AL16 and AL18), and nearby electrical infrastructure supports an efficient and minimally intrusive renewable-energy installation. When integrated with solar, the site becomes a strong candidate for a hybrid hydro-solar system that improves annual energy output while leveraging federal infrastructure already in place.

Figure 4.4.2.1 John C Stennis L&D

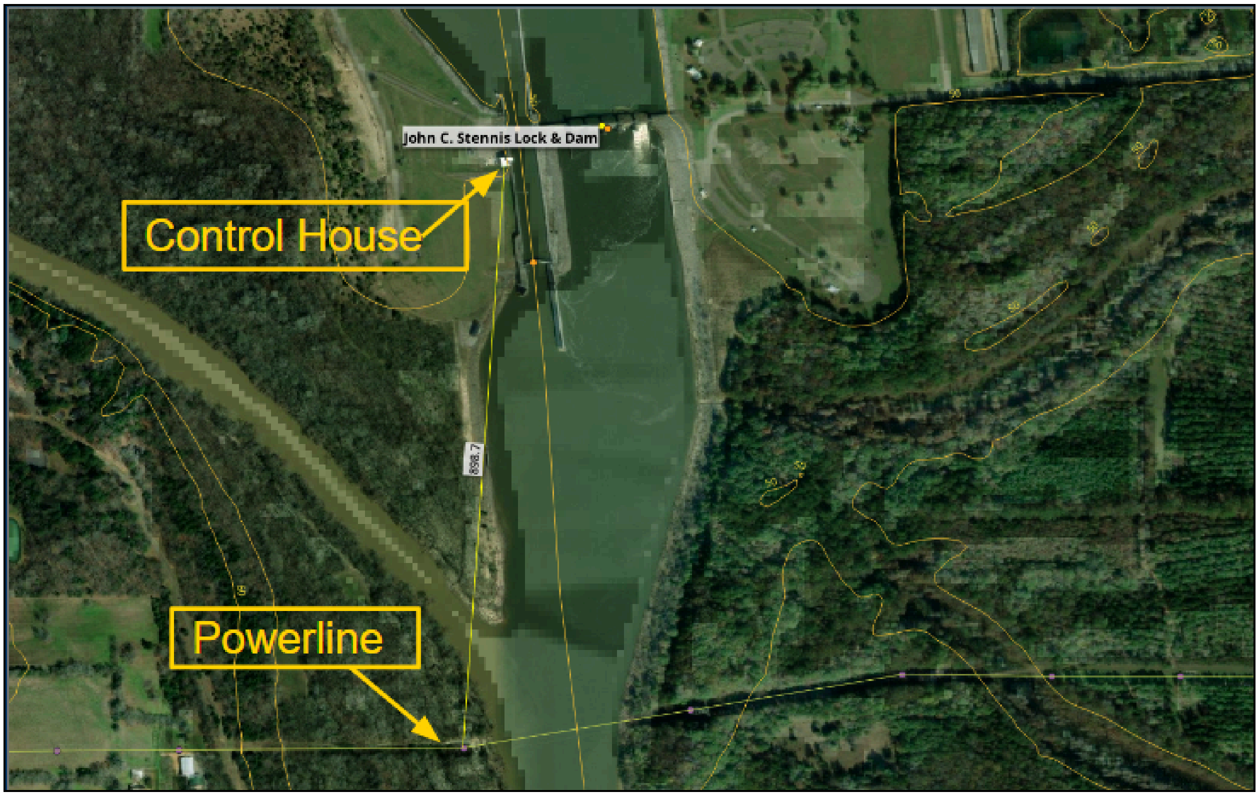

Figure 4.4.2.2 Grid Distance For Stenns Site

9.2 Appendix C: Solar Analysis

To enhance the performance of the proposed John C. Stennis hydropower retrofit, a supplemental solar photovoltaic (PV) system was evaluated. Solar power provides daytime generation that complements the site's flow-dependent hydro output, improves annual energy yield, and reduces reliance on grid imports for operations. This section summarizes the feasibility, land availability, system sizing, and expected performance of a 1–3 MW ground-mounted PV installation.
Land area is denoted as,

$$A_{Land} = P_{AC} * \frac{acres}{MW_{AC}} \tag{1}$$

Where P_{AC} is the AC rating, and the design rule of thumb 3 acres per MW_{AC}

Specific energy yield

$$Y_{spec} = \frac{E_{AC}}{P_{DC}} \tag{2}$$

Where E_{AC} is the annual dc energy and P_{DC} is nameplate capacity.
Capacity factor is given by,

$$CF_{DC} = \frac{E_{AC}}{P_{DC}*8760} \tag{3}$$

Where E_{AC} is the annual AC energy, and P_{DC} is nameplate capacity.
Performance ratio is given by,

$$PR = \frac{E_{AC}}{G_h A_{mod} \eta STC} \quad (4)$$

Where E_{AC} is the annual AC energy, G_h is the annual in-plane radiance, A_{mod} is the total module area, η_{STC} is the efficiency of the selected module.

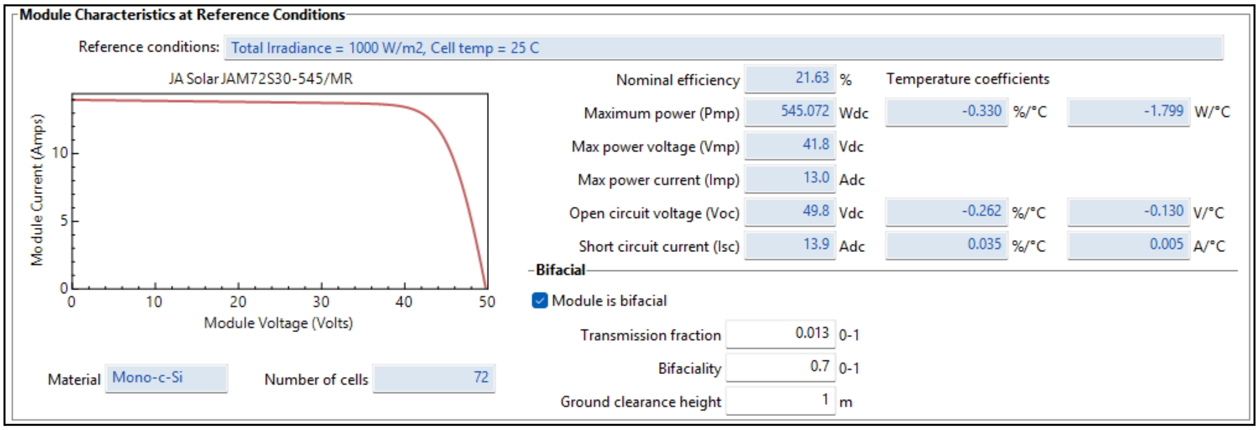

Figure 3.3.1.1 Module Characteristics for JA Solar JAM72S30-545/MR

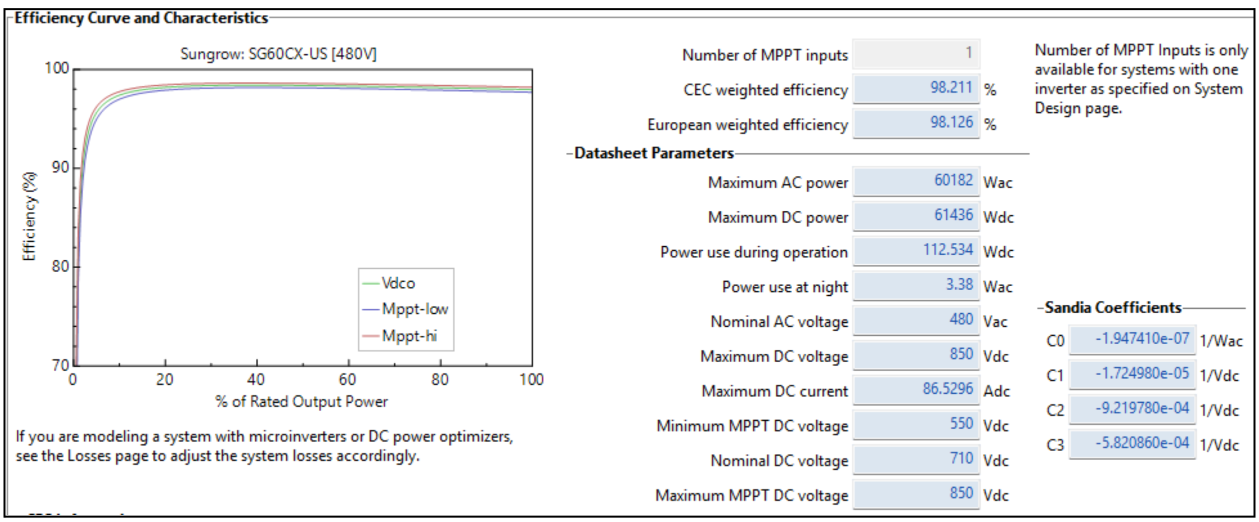

Figure 3.3.1.2 Efficiency Curve of Sungrow SG60CX-US [480 V]

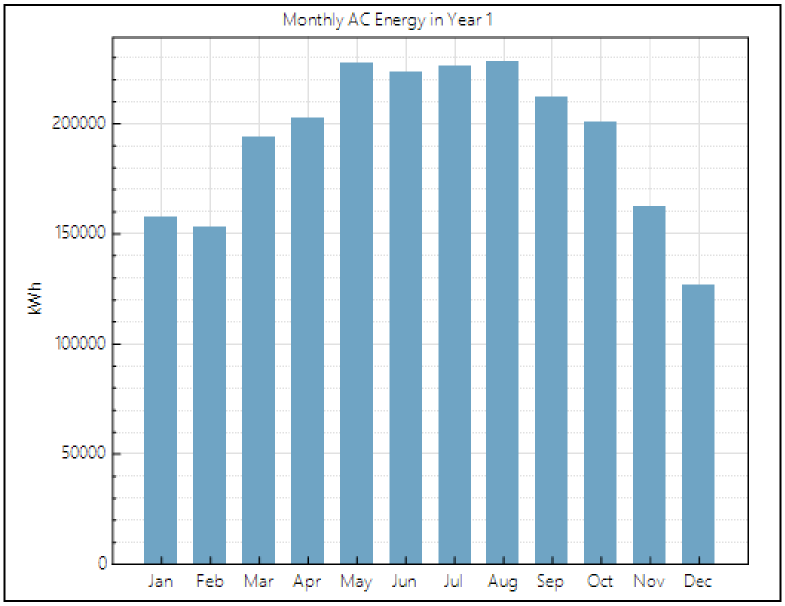

Figure 3.3.1.3 Monthly AC Energy Production

Metric	Value
Annual AC energy in Year 1	2,311,302 kWh
DC capacity factor in Year 1	17.6%
Energy yield in Year 1	1,541 kWh/kW
Performance ratio in Year 1	0.81

Figure 3.3.1.4 Table Of Resulting Values

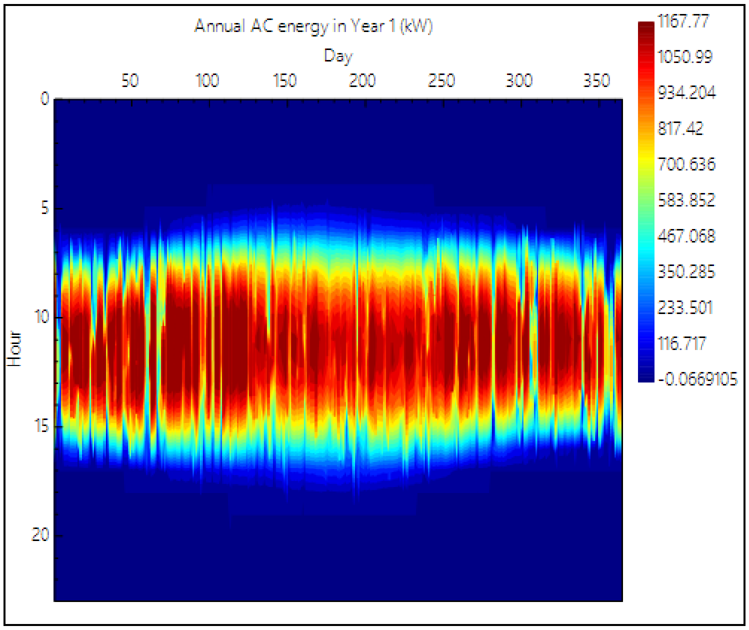

Figure 3.3.1.5 Annual Heat Map Of Stennis Site