# HCC26

# Initial Design Report


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**Fall 2025-Spring 2026**

**Project Sponsor: Carson Pete**

**Instructor: David Willy**

# DISCLAIMER

# EXECUTIVE SUMMARY

Team Hydrojacks represents Northern Arizona University in the 2026 Hydropower Collegiate Competition sponsored by the United States Department of Energy. The project focuses on developing a cost-effective and environmentally responsible retrofit for an existing non-powered dam that can generate between 1 and 10 megawatts of renewable energy. The competition integrates three components: siting analysis, technical design, and community engagement. Together these tasks challenge students to apply engineering judgment, economic reasoning, and public outreach in pursuit of sustainable hydropower solutions.

A database of more than 2500 non-powered dams across the United States was examined using MATLAB to identify locations meeting the necessary head, flow, and power criteria. After screening and benchmarking, two finalists remain under consideration: Peoria Lock and Dam on the Illinois River and the Feather River Fish Barrier in California. Both sites fit the competition's 1–10 MW range and demonstrate favorable characteristics for retrofit development. Peoria offers strong grid access and high discharge, while the Fish Barrier provides a consistent head and moderate flow conditions suitable for medium-scale generation. The team is meeting with the United States Army Corps of Engineers to obtain operational data for Peoria, and the California Department of Water Resources has already shared flow, head, and environmental data for the Fish Barrier site.

Preliminary technical modeling applies the relation $P = \rho g Q H \eta$ to estimate generation potential. Early calculations suggest that a Kaplan turbine could yield approximately 2–6 MW at Peoria, while a Francis turbine is appropriate for the Fish Barrier's head and discharge profile. System efficiency is targeted at roughly 75 percent with reliability greater than 95 percent. Additional analyses address hydrostatic forces on the dam structure, sediment management, and ecological considerations including fish passage and water quality. These parameters will be refined as new site data is obtained.

The project budget is estimated at 20,000 USD. Funds will support modeling software, material procurement, travel, and outreach activities. The team is seeking technical collaboration with Voith Hydro, W. L. Gore, and CFturbo to enhance turbine and system design capabilities. Beyond engineering, the Hydrojacks aim to strengthen public awareness of renewable energy through community involvement. On November 1st, the team will participate in an educational event at the Willow Bend Environmental Education Center in Flagstaff, presenting hydropower demonstrations and engaging with local families, educators, and students.

Success will be determined by accurate modeling of hydropower generation, delivery of all required competition reports and presentations, and positive community engagement outcomes. The Hydrojacks project illustrates how small-scale hydropower retrofits can contribute to reliable clean energy while maintaining environmental balance and promoting public understanding of sustainable engineering.

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# 1 BACKGROUND

This section introduces the project background, objectives, and performance expectations for Team Hydrojacks in the 2026 Hydropower Collegiate Competition. It describes the project's purpose and relevance within the broader field of renewable energy, outlines all major course and competition deliverables, and defines the criteria that will be used to measure success. Together these subsections establish the foundation for later chapters, which expand on the project requirements, research, and design development.

## *1.1 Project Description*

Team Hydrojacks is participating in the 2026 Hydropower Collegiate Competition as part of the Northern Arizona University mechanical engineering capstone program. The competition is sponsored by the United States Department of Energy and focuses on preparing students to address real-world challenges in renewable energy design. The objective of this project is to identify, evaluate, and design a retrofit for an existing non-powered dam that can generate between 1 and 10 megawatts of electrical power while maintaining environmental and community compatibility.

The team is guided by Professor Carson Pete and supervised by Dr. David Willy. After analyzing a national database of more than 2 500 non-powered dams, the team narrowed the options to two finalists for detailed study: Peoria Lock and Dam on the Illinois River in Illinois and the Feather River Fish Barrier in California. Both sites meet the competition's power and head requirements and offer favorable conditions for efficient retrofit development. The United States Army Corps of Engineers has scheduled a meeting with the team to provide site-specific hydraulic and operational data for Peoria, and the California Department of Water Resources has already shared detailed flow and head data for the Fish Barrier site.

The total project budget is estimated at 20 000 USD. The funding supports computational modeling, equipment, travel, and public outreach. The team is pursuing technical and material collaboration with Voith Hydro, W. L. Gore, and CFturbo to improve turbine and system design accuracy. The project aligns with national sustainability goals by promoting renewable power generation while encouraging responsible engineering and public education.

## *1.2 Deliverables*

All course deliverables for the fall 2025 semester align with the Hydropower Collegiate Competition timeline and the Mechanical Engineering capstone schedule. The team will submit Report 1, the Initial Design Report, which documents project background, requirements, research, and early design concepts. Website Check 1 will provide the first public version of the team's website summarizing goals, progress, and outreach. Presentation 3 will communicate preliminary results, site analyses, and early concept evaluations to faculty and sponsors.

Two prototype demonstrations are planned during the semester. The first will display basic hydropower functionality and model testing methods. The second will incorporate improved geometry and instrumentation based on collected site data. Report 2 will document these prototype findings, refined calculations, and modeling updates. The semester will conclude with submission of the final CAD model, final bill of materials, and Website Check 2 to reflect the completed design status.

A project schedule outlining the completion of these deliverables is shown in the Gantt chart and will be updated as progress continues. The schedule divides the semester into research, modeling, prototyping, and reporting phases. These milestones ensure continuous progress toward competition readiness and provide clear checkpoints for faculty and sponsor review.

## *1.3 Success Metrics*

1 - Achieve an electrical-power output between 1 and 10 megawatts under expected operating conditions.
2 - Maintain overall system efficiency near 0.75 and operational reliability above 95 percent.
3 - Comply with DOE, FERC, and OSHA standards for safety and environmental protection.
4 - Limit ecological disturbance by preserving fish migration and controlling sediment transport within acceptable limits.
5 - Complete all competition milestones and outreach events, including the November 1 Willow Bend demonstration, on schedule.

Each metric will be verified through calculations, modeling results, and sponsor feedback. Quantitative success will be confirmed through MATLAB and CFturbo simulations, while qualitative outcomes will be evaluated through community responses and competition scoring.

# 2 REQUIREMENTS

This section identifies the customer and engineering requirements for the Hydrojacks hydropower retrofit project and explains how those requirements guide the technical design process. It summarizes the needs of competition sponsors, regulatory agencies, and community partners, then translates those needs into measurable design parameters. The section concludes with an overview of the House of Quality, which maps the relationships between the two sets of requirements and provides the framework for later design decisions.

## *2.1 Customer Requirements (CRs)*

The customer requirements define the expectations of the Department of Energy, Northern Arizona University, W. L. Gore as a financial sponsor, technical collaborators such as Voith Hydro and CFturbo, and the public audiences who will engage with the project through outreach. These requirements emphasize safety, sustainability, cost-effectiveness, and educational value. The main customer requirements are as follows:

1 - The project must demonstrate a feasible small-scale hydropower retrofit producing between 1 and 10 megawatts of power.
2 - The system must operate safely and reliably while maintaining dam function and river navigation.
3 - The design must minimize ecological disturbance by preserving fish passage and controlling sediment transport.
4 - The project must achieve a competitive energy cost per kilowatt-hour.
5 - The installation and maintenance processes must be simple and economically reasonable.
6 - The design must comply with DOE, FERC, and OSHA safety and environmental standards.
7 - The project must include public engagement through demonstrations and educational outreach, such as the November 1st Willow Bend event.
8 - The final presentation and website must clearly communicate results and community benefits.

## *2.2 Engineering Requirements (ERs)*

1 Power output P: $1 \leq P \leq 10$ MW
2 Head H: $1 \leq H \leq 150$ m (site-dependent)
3 Flow rate Q: 10–300 $m^3/s$ depending on site conditions
4 Overall efficiency $\eta$: target of 0.75 or higher
5 System reliability R: 0.95 or higher
6 Factor of safety (FoS): at least 2.0 for all structural components
7 Sediment throughput: less than or equal to the target threshold established by DOE guidelines
8 Fish-passage velocity: maintained below 2.0 m/s to ensure safe migration
9 Grid interconnection distance: ≤ 5 km
10 Acoustic level at site boundary: ≤ 60 dBA
11 Regulatory compliance: binary verification (yes or no)

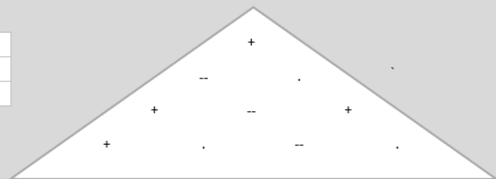
All parameters are expressed in SI units. These requirements will be validated through MATLAB modeling, CFturbo simulations, and comparison with benchmark data from DOE and Voith Hydro case studies.

## 2.3 *House of Quality (HoQ)*

The House of Quality serves as a structured framework that connects stakeholder needs with the specific engineering characteristics of the proposed small-scale hydropower retrofit dam. It begins with identifying the customer requirements, which represent the voices of the primary stakeholders, including the local community, environmental regulators, and utility authority. These requirements emphasize key project goals such as reliable power generation, competitive cost, environmental sustainability, and regulatory compliance. Each of these "what's" expresses what the project must achieve from a user or societal perspective.

Quality Function Deployment

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




Correlation:

| + | . | - |
|---|---|---|
| Positive | No correlation | Negative |

Relationships:

| 9 | 3 | 1 |
|---|---|---|
| Strong | Moderate | Weak |

| | 1: low, 5: high | Desired direction of improvement (↑,0,↓) | 0 | 0 | 0 | 0 | 0 | | Competitive evaluation (1: low, 5: high) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Customer importance rating | Functional Requirements (How's) → / Customer Requirements - (What'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 |
| 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 House of Quality Model

# 3 Research Within Your Design Space

This section summarizes the research, benchmarking, and analytical methods used to define the design space for the Hydrojacks project. It describes comparable hydropower systems, key findings from published studies, and mathematical tools used to model system performance. Together, these subsections provide the technical foundation for later concept development and design selection.

## 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 requires 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, Kaplan turbines were identified as optimal for low-head, high-flow sites such as Peoria Lock and Dam, 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.

The overview presented by *Student Energy* [9] provides an essential background on the principles of hydropower conversion and classification. It clearly explains the relationship between hydraulic head, flow rate, and power generation, while distinguishing between dammed, run-of-river, and pumped-storage systems. This resource establishes the conceptual basis for selecting an appropriate plant configuration and capacity class. The identification of small hydropower (1–10 MW) as a practical and sustainable range supports the decision to target this scale for the John Sevier Dam retrofit, ensuring consistency with global small-hydro benchmarks.

Chapallaz's *Manual on Pumps Used as Turbines* [10] delivers technical depth on the application of standard centrifugal pumps operating in reverse as turbines. Its experimental correlations, efficiency data, and case studies inform cost-effective approaches for low-head energy recovery. The manual's analyses provide quantitative support for evaluating pump-as-turbine (PAT) units as viable alternatives or supplementary generation modules. These insights contribute directly to minimizing capital costs and simplifying mechanical design while maintaining acceptable performance under varying flow conditions.

Mays [11], in *Water Resources Engineering*, offers a comprehensive treatment of hydrologic and hydraulic processes critical to this project's flow assessment and structural design. The text's methods for developing flow-duration curves, estimating head losses, and routing reservoir inflows are directly applicable to predicting energy yield and assessing operational reliability. Mays's integration of hydrology with infrastructure planning ensures that the hydraulic modeling underlying the design is technically robust and consistent with accepted water-resources engineering practice.

The review by Kaunda, Kimambo, and Nielsen [12] situates hydropower within a sustainable energy context, emphasizing both environmental responsibility and long-term resource management. Their analysis highlights the ecological and socio-economic considerations essential to responsible project development, including sedimentation management, habitat preservation, and climate-resilience measures. These findings reinforce the project's emphasis on environmental integration, supporting the inclusion of fish-passage systems and ecological flow control in the retrofit plan.

Paish [13] provides a global perspective on small-hydropower technology and implementation. His review of turbine typologies, civil works, and control systems offers practical benchmarks for efficiency, flow adaptability, and economic viability. The detailed comparisons of Kaplan, Francis, and bulb turbines validate the selection of a Kaplan-style bulb runner for low-head, high-discharge operation. Paish's discussion of control optimization and part-load behavior directly informs strategies to maintain efficiency across seasonal variations in discharge.

The design management and customer-requirement translation processes employed in this project are guided by Ficalora and Cohen [14], whose *Quality Function Deployment and Six Sigma: A QFD Handbook* provides a structured method for converting stakeholder needs into measurable engineering criteria. Their framework underlies the project's House of Quality, ensuring that priorities such as efficiency, cost, safety, and environmental compliance are quantitatively linked to design parameters. This methodological rigor enhances traceability between performance objectives and engineering decisions.

The case study by Okang, Bakken, and Bor [15] in *Water* (2023) delivers the most directly relevant evidence for the technical and economic feasibility of NPD retrofits. Their analysis of the Buyuk Menderes River Basin demonstrates that repowering existing dams can produce competitive energy output with substantially lower environmental and financial costs than greenfield developments. Their methodology for site screening and cost-benefit analysis has been adapted to the present study, validating the retrofit of the John Sevier Dam as both a sustainable and economically justified intervention within regional renewable energy objectives.

### 3.2.2 Karsten Jones

[16] 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.

[17] 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.

[18] 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.

[19] 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.

[20] 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.

[21] 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.

[22] 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.

[23] 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.

### 3.2.3 Dawson Stevens

[24] “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.

[25] 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.

[26] 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.

[27] 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.

[28] 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.

[29] 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.

[30] 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.

[31] “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

[32] “Hydropower Program,” Energy.gov.

The U.S. Department of Energy talks all about hydropower. It talks about the benefits, news, basics and just overall nation wide hydropower information. It also directly links to the Hydropower Collegiate Competition which is what the HCC capstone is based around. This can and was used as a general information extractor to see where things stand in the field. This has been used many times in the process of the project, for example understanding which turbine would be most efficient for the different head heights and flows provided by different dams.

[33] S. Insights, “Explore the Top 10 Hydropower Trends in 2023,” StartUs Insights, Mar. 13, 2023.

All about startups, statistics, and trends in the 2025 hydropower field. Talks about and explains different turbines and generators used all over the world. It takes the top ten trends like novel turbines and explains what they are followed by two linked companies that either currently or recently used them in projects to further their agenda. Using some of these startups as examples we can see what potentially good routes to take the project would be.

[34] “Water Power Technology - Littoral Power - Revolutionizing Water Power Technology Waterpower Done Right,” Littoral Power,

A company that manufactures multiple items like different turbines and systems that helps hydropower projects progress. They also have a software that connects and allows hydropower workers all over the United States to operate efficiently. Seeing how a company can operate and what they can provide is important because we will have most likely work with a company like this to be successful in the competition this year.

[35] BYJU's, “Hydrostatic Pressure - Definition, Formula, Derivation, Problems,” BYJUS.

Explains how hydrostatic pressure works and would or could be applied. With the tools to be able to calculate hydrostatic pressure and dam dimensions the hydrostatic pressure on a dam from the water could show what specifications would be needed for a dam to sustain its water. With these equations the gate that would allow water to pass into a turbine could also be analyzed to see what needs to be done.

[36] The, “The Basement Doctor of Cincinnati,” The Basement Doctor of Cincinnati, Dec. 03, 2021.

This company acts as a standard and lifeline for dam safety being able to withstand pressure forces. They talk about common signs in hydrostatic pressure failures and this could be used to assess the possible risk that a dam might have if we were to visit it. If actually working on a dam and seeing these symptoms the company could be used to get a quote on how much something like this would affect the dam too.

[37] D. Fitzgerald, “Key Policies for Waterpower,” National Hydropower Association.

The National Hydropower Association lays out the rules and regulations that go into the water power industry. They talk about all the federal policies, standards, licensing, and goals that go into this industry no matter what side it’s on. This will be needed to analyze and determine what we as a team are allowed to do and what we should stray away from.

[38] “Water Data - U.S. Army Corps of Engineers,” Army.mil, 2025.

All about Mississippi River Lock and Dam #3, as well as many other dams. Talks about how this dam works, where it is, its specifications like height and water flow, and everything in between. This was used to analyze this site and see how effective it would be as our site in our competition. The main data taken from this was the dam height and water flow over a period of time to get the average water flow. These values and estimated power generated could be calculated to understand this dam's potential for energy production.

[39] "Mississippi River at Red Wing -- Below Lock and Dam #3," Noaa.gov, 2022.

Discusses flow of the Mississippi River Lock and Dam in great detail. Keeps statistics over a long period of time and also reports predicted future flow. Along with this it keeps detail of past incidents in flooding and its effects. With this information we can take into account risk assessment and more broad potential power output.

## *3.3 Mathematical Modeling*

Mathematical modeling supports the quantitative assessment of candidate sites and turbine performance. MATLAB was used to process a national dataset of more than 2 500 non-powered dams. The filtering algorithm applied constraints for head, flow, and power using the standard hydropower Equation [1] $P=\rho gQH\eta$ ,where ρ is water density, g is gravitational acceleration, Q is flow rate, H is head, and η is efficiency. The filter reduced the dataset to 31 viable candidates within the 1–10 MW range. Following this, utilizing Equation [3], $d = 16T/\pi T_{all}$ where d is diameter, T is Torque, and $T_{all}$ is the design Torque. We then estimate a factored diameter to feed into a generator unit will give insight towards material selections. Peoria Lock and Dam and the Feather River Fish Barrier were selected for further analysis based on data availability, infrastructure condition, and environmental suitability.

Hydrostatic and hydrodynamic equations will be used to estimate pressures, forces, and moments on dam surfaces once as built drawings are acquired and accurate water levels are accounted for. These relationships define design loads and guide preliminary structural sizing. MATLAB outputs will be cross-checked with DOE data and site documentation to ensure consistency.

The team is in the process of forming a partnership with **CFturbo** to obtain professional turbine-design support and access to parameterized modeling tools. Once the partnership is confirmed, CFturbo will be used to generate custom Kaplan and Francis turbine geometries based on the team's MATLAB results and site-specific data. These models will later be integrated into SolidWorks for detailed fluid and structural analysis.

The combined benchmarking, literature review, and modeling confirm that both Peoria Lock and Dam and the Feather River Fish Barrier satisfy DOE competition requirements and can achieve the target power range with sustainable environmental performance. As site data are refined and design software access expands, efficiency and geometry estimates will continue to improve in preparation for the detailed design phase.

### 3.3.1 John Sevier Analysis- Anthony Nuzzo

Specific site characteristics utilized in the can be found in Appendix A**.** The engineering calculations for the John Sevier hydropower retrofit establish the expected performance range and guide turbine selection. Using the available site data, an average flow rate of roughly 65 $m^3/s$ and an effective head of 5.5 m, the theoretical power potential was determined from Equation [1] Appendix B, yielding an estimated output of about 3 MW at 85 % efficiency. This value aligns with the target power range for small-scale installations and supports the selection of a Kaplan bulb turbine, known for its efficiency under low-head, high-flow conditions. Supporting calculations using Equation [2] Appendix B further refines this estimate: the rated torque was found to be approximately 162 kN·m, and the design torque, incorporating a 2 times safety factor, reached 324 kN·m using a runner speed of 180rpm. From these parameters, the projected runner diameter was calculated between 314 mm and 320 mm using Equation [3], indicating the appropriate scale for the turbine assembly and confirming mechanical feasibility.

Material and performance assumptions were based on ASTM A743 CA6NM stainless steel for the runner and wicket gates to ensure corrosion resistance and long-term durability. The analysis also identified operational challenges such as potential 30–40% overflow during maximum-flow days and irregular low-flow conditions during dry periods. To mitigate these issues, an active flow-control cap was proposed to stabilize output and protect system efficiency. Overall, these calculations verify that the site's hydraulic characteristics can reliably support a Kaplan bulb configuration while meeting the project's engineering requirements for power generation, environmental compliance, and lifecycle longevity.

### 3.3.2 Peoria Lock & Dam – Karsten Jones

Specific site characteristics utilized in this analysis can be found in Appendix A. The engineering calculations for the Peoria Lock and Dam retrofit establish expected performance ranges and guide turbine and shaft sizing decisions. Using available site data, an average flow rate of approximately 268 $m^3/s$ and an effective head of 3.05 m were applied to Equation [1] in Appendix B, resulting in a theoretical output of about 6 MW at 75 percent efficiency. This value fits within the competition's 1–10 MW range and supports the selection of a Kaplan-style turbine optimized for low-head, high-flow operation.

Supporting calculations using Equation [2] in Appendix B refined this estimate by determining the corresponding torque and angular velocity based on an assumed runner speed of 120 rpm. The rated torque was calculated to be approximately 477 kN·m, with a design torque (applying a safety factor of 2) of about 954 kN·m. These parameters informed the preliminary mechanical design and served as inputs for the shaft sizing analysis.

The required shaft diameter was estimated using Equation [3] from Appendix B. Assuming an allowable shear stress of 60 MPa for the selected steel alloy, the resulting shaft diameter was approximately 0.35 m, indicating feasible manufacturability within the design constraints. These results verify that Peoria's hydraulic characteristics can reliably support a Kaplan configuration while remaining structurally robust and mechanically practical.

Material and performance assumptions were based on stainless steel construction for major components to ensure corrosion resistance and long-term durability in riverine environments. The analysis also accounted for seasonal flow variability and sediment loading, which may influence maintenance intervals and operational stability. Overall, the Peoria analysis confirms that the site's flow and head conditions meet the competition's requirements and provide a strong foundation for continued mechanical and CFD-based design development.

### 3.3.3 Mississippi River Lock and Damn #3 – Nathaniel Holguin

To find the potential power output that bringing a hydropower turbine to the Mississippi River I had to use a multitude of different equations as well as some assumptions. Data was first collected from the "Water Data - U.S. Army Corps of Engineers" [4] being the elevation, tailwater elevation, and water outflow in $ft^3/s$ over the previous month at the time taken. The average value of outflow was determined from the month data to be used for this assessment. The density, gravity, and efficiency were then all assumed because they all generally stay around a certain value. With these assumptions and values found the equations could finally be put to work.

Before getting the power however, the outflow needs to be converted over to $m^2/s$ so that all the units align in the power equation. This gives us our water outflow of the river but only a portion of the river is going to be used to generate power so one more conversion is made being 40% of the outflow to get the runoff outflow usable.  Now using Equation [1] from appendix B the power is calculated to be around 9.5 MW but then reduced to around 8 MW due to the efficiency of the generator, shaft, and turbine in transmitting that power. With the potential average power calculated the next could continue.

Due to the high flow rate and low head of this dam it was determined that the most ideal and efficient turbine would be the Kaplan turbine. Kaplan turbines diameter range in the values of .8-11m and raise fairly linearly with higher power so it was assumed/estimated that the diameter of this Kaplan turbine would be around 6m. With this assumption, the velocity of water going into the turbine could be found using Equation [5] from appendix B. This outputs a velocity of 7.5m/s which can be used to determine the angular velocity and torque. Using Equation [6] from appendix B the angular velocity became 2.5 rad/s which then became a torque of 3762kNm plugging in power to Equation [2] from appendix B. A factor of safety of 2.5 was then used to get a real design torque of 9400kNm.

### 3.3.4 Fish Barrier – Dawson Stevens

Using available site data, an average flow rate of roughly 15.4 $m^3/s$ and an effective head of 19.2 m, the theoretical power potential was determined from Equation [1] Appendix B, yielding an estimated output of about 2.36 MW at 85 % efficiency. Rated and specific speed were also found to be 550 and 827 rpm, respectively, using Equations [4] and [5]. Both the Thumb Rule and Scientific method were then applied to determine which type of turbine would be most fit.

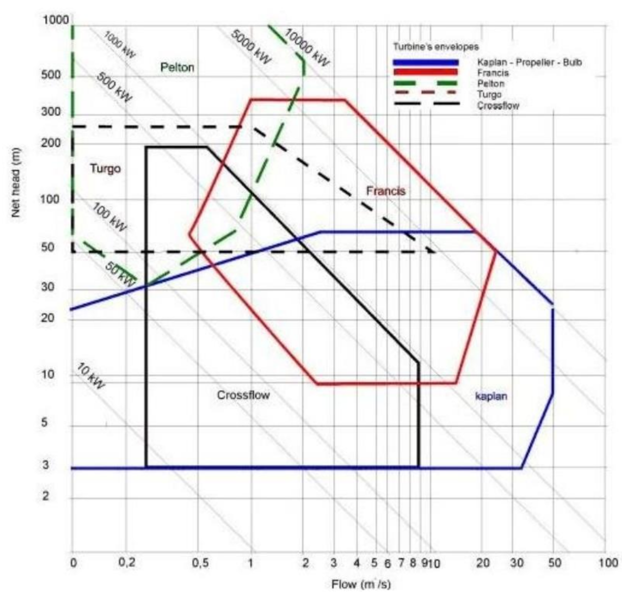



*Figure 3.3.5.1 Turbine Selection based on head and flow rate []*

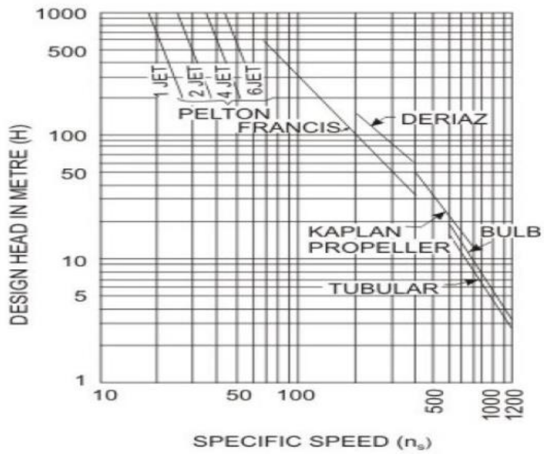



*Figure 3.3.4.2 Chart for determining selection of turbine []*

After applying both methods, it was determined that a Francis turbine would be the most efficient choice. Additionally, Francis turbines present less of a threat to aquatic life than some of the other types of turbines, an important feature for this specific dam.

# 4 Design Concepts

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 comparative analysis between the Peoria Lock and Dam and the Feather River Fish Barrier sites.

## *4.1 Functional Decomposition*

The functional decomposition of the Hydrojacks system identifies the major operations that must occur for a non-powered dam retrofit to generate reliable hydropower. It breaks the overall objective of clean, small-scale power production into a series of mechanical, electrical, and environmental sub-functions. At the highest level, the system must convert the potential energy of water stored behind a dam into rotational and then electrical energy while maintaining flow continuity and minimizing ecological disturbance. This includes the intake of water, its controlled passage through the turbine assembly, and the safe discharge of flow downstream.

The decomposition shown in Figure 4-1 illustrates how these primary operations are divided into subsystems. Flow capture and regulation ensure debris protection and navigational safety; turbine energy conversion achieves high efficiency in a low-head range; and the generator converts mechanical power into stable AC electricity. The power-conditioning system maintains grid compliance, while environmental and structural integration functions support fish passage, sediment control, and dam accessibility. Each function connects directly to a set of engineering requirements—efficiency, reliability, cost, and environmental impact—that together define system performance objectives.

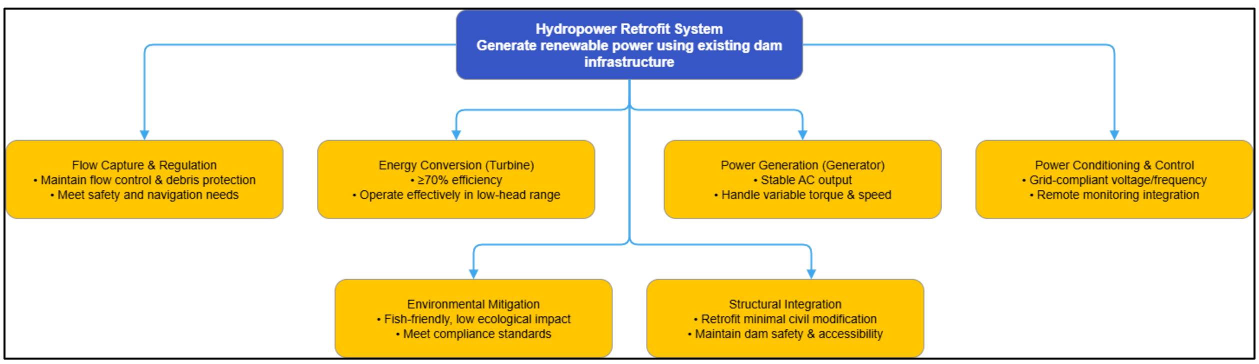



*Figure 4-1. Functional decomposition of the Hydrojacks hydropower retrofit system.*

## *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 then used MATLAB code to filter out dams that had estimated average annual outputs above or below the 1-10 MW output requirements, then further narrowed the list by filtering out any entry with one or more months with estimated outputs outside that range. Following this first round of eliminations, we were left with 31 potential candidates.

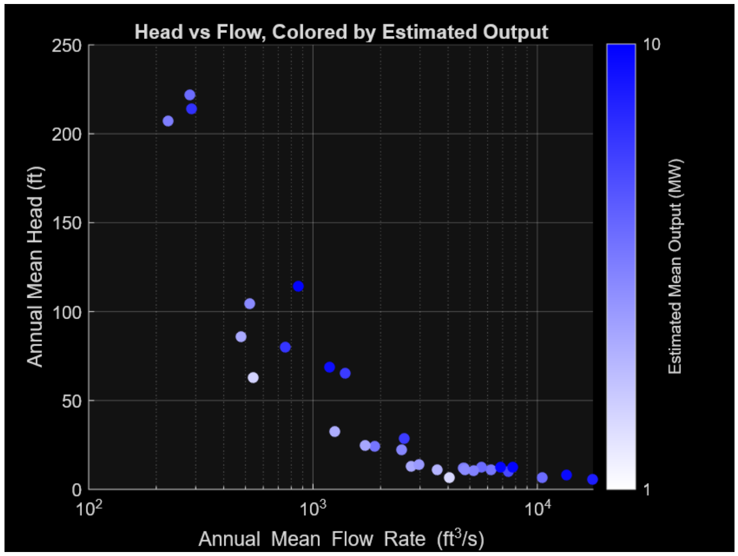



*Figure 4.2 Remaining Dams Plotted by Head vs Flow*

## *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 we're 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.

| | | | | |
|---|---|---|---|---|
| KS00012 | 39.257138 | -96.591805 | NHD | TUTTLE CREEK DAM |
| NM00404 | 35.6165759 | -106.3178358 | NHD | COCHITI DAM |
| OR00624 | 42.0560106 | -123.1149774 | NHD | APPLEGATE DAM |
| CO00357 | 39.208333 | -105.273901 | NHD | CHEESMAN |
| KY03007 | 37.2457146 | -85.33981988 | NHD | GREEN RIVER DAM |
| KY03009 | 36.893411 | -86.12568147 | NHD | BARREN RIVER DAM |
| AZ10308 | 33.8181 | -111.6317 | NHD | BARTLETT DAM |
| AZ10314 | 33.7329348 | -114.5106658 | NHD | PALO VERDE DIVERSION |
| CA00034 | 39.5205 | -121.5478 | NID | FISH BARRIER |
| GA01703 | 33.3724539 | -81.94097879 | NHD | NEW SAVANNAH BLUFF LOCK AND DAM |
| ND00129 | 47.94067 | -97.04886 | NHD | GRAND FORKS RIVERSIDE PARK DAM |
| PA00008 | 41.1122482 | -75.7217298 | NID | FRANCIS E. WALTER DAM |
| PA00897 | 39.9672222 | -75.18611111 | NHD | FAIRMOUNT |
| WA00555 | 46.5068 | -122.6022 | NID | BARRIER DAM |
| WA00769 | 48.5394 | -121.7437 | NID | FISH BARRIER DAM |
| AZ10005 | 32.7050018 | -114.7279968 | NHD | MORELOS DIVERSION DAM |
| CA00226 | 40.5922 | -122.3944 | NID | ANDERSON COTTONWOOD |
| IL00001 | 41.503201 | -88.102898 | NHD | BRANDON ROAD LOCK AND DAM |
| IL01014 | 40.631699 | -89.624496 | NHD | PEORIA LOCK AND DAM |
| KY03004 | 37.2138161 | -86.900057 | NHD | GREEN RIVER LOCK AND DAM 3 |
| MN00093 | 48.49969 | -92.6388 | NHD | KETTLE FALLS |
| MN00595 | 44.6110444 | -92.60995224 | NHD | MISSISSIPPI RIVER LOCK AND DAM 3 |
| MN00738 | 48.59622 | -97.15239 | NHD | RED RIVER DRAYTON |
| MT00585 | 47.6211 | -112.7067 | NHD | SUN RIVER DIVERSION |
| NY00961 | 42.9178 | -74.1408 | NHD | LOCK E10 CRANESVILLE |
| NY00962 | 42.8781 | -74.0425 | NHD | LOCK E9 ROTTERDAM JUNCTION |
| NY00963 | 42.8297 | -73.9908 | NHD | LOCK E8 SCOTIA |
| PA00120 | 40.3905323 | -79.85800091 | NHD | BRADDOCK LOCKS AND DAM |
| PA00122 | 40.1465376 | -79.89950656 | NHD | CHARLEROI LOCKS AND DAM |
| TN07305 | 36.38125 | -82.96584 | NHD | JOHN SEVIER DAM |
| WI00647 | 44.1861061 | -88.4564297 | NHD | NEENAH |

*Figure 4.3 List of 31 dams with top 4 highlighted green*

## 4.4 Concept Selection

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

### 4.4.1 John Sevier Concept

The John Sevier Dam presents a strong opportunity for conversion into a small-scale hydropower facility.

Based on available data, the site maintains an average capped flow of roughly 65 $m^3/s$ and an effective head of around 5.5 m, producing an estimated 3 MW of power at typical turbine efficiencies. These hydraulic conditions fall directly within the operational range for a Kaplan bulb turbine, which is designed for low-head, high-flow environments. One of the greatest advantages of this site (shown in Figure *4.4.1.1*) is the presence of existing infrastructure including the dam, spillway, and flow channels, which reduces the need for major new civil construction. This lowers both project costs and environmental disturbance. The dam's proximity to the TVA power grid and existing road access also simplifies installation, power transmission, and long-term maintenance, further improving project feasibility.

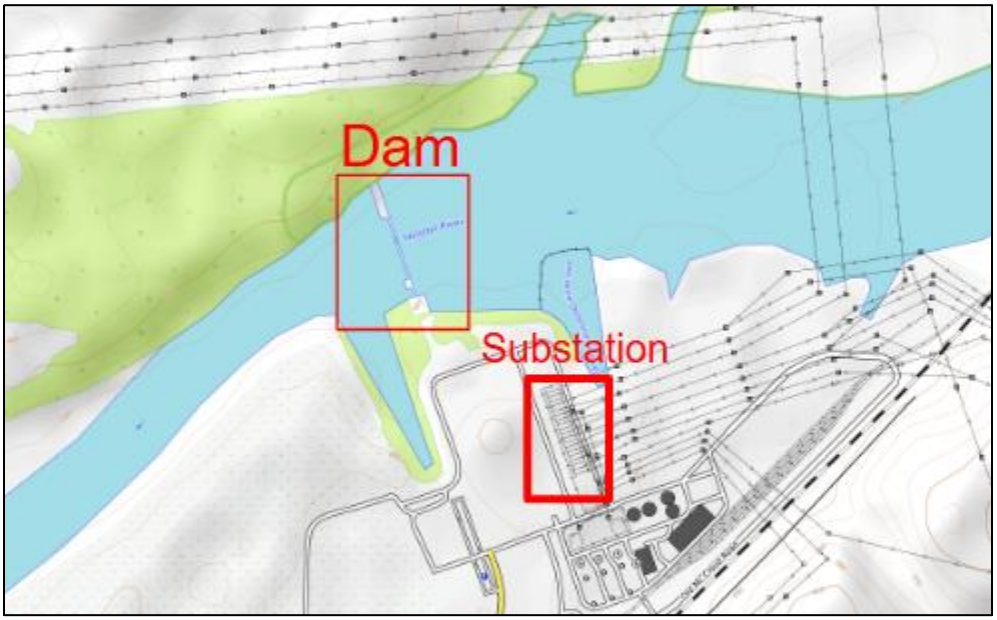



*Figure 4.4.1.1 John Sevier Site*

However, several considerations must be addressed to ensure sustainable and reliable operation. The river's seasonal flow variability, presented in Figure 4.4.1.2 may require an active flow-control or bypass system to prevent turbine overspeed during high inflow conditions and to maintain stable operation during dry periods. Since the dam was not originally designed for power generation, structural reinforcements may be needed around the intake and draft-tube areas to support new mechanical equipment. Environmental factors are also critical, particularly fish passage, sediment transport, and water-quality maintenance, which must comply with FERC and TVA environmental standards. These requirements can extend permitting and construction timelines but are manageable with proper planning and design integration.

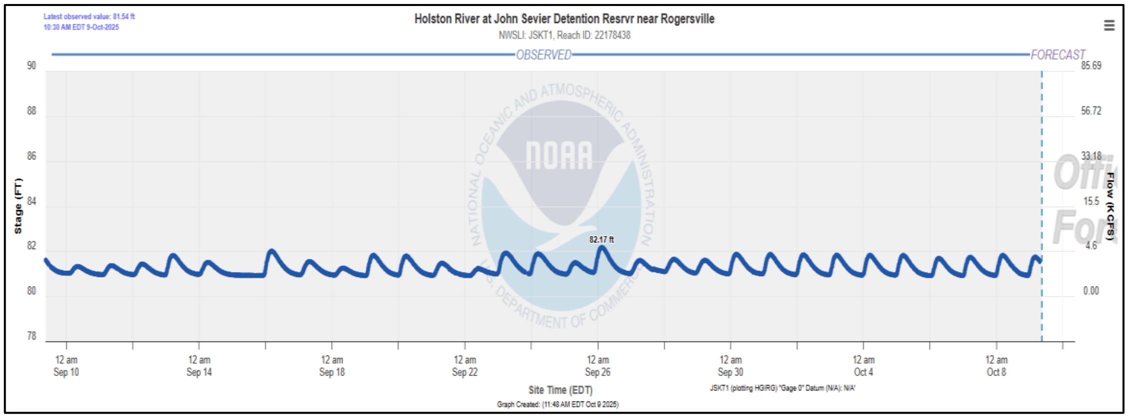



*Figure 4.4.1.2 John Sevier Flow Data*

Overall, the John Sevier site demonstrates mid technical and economic feasibility for a small-scale hydropower retrofit. The combination of steady hydraulic potential, existing infrastructure, and potential straightforward grid access makes it a strong candidate within the 1–10 MW small-hydro range. With modern Kaplan turbine technology and well-designed environmental mitigation, this project could deliver reliable renewable energy while maintaining the ecological balance and recreational value of the surrounding area.

### 4.4.2 Peoria L&D

The concept selection process for the Peoria Lock and Dam focused on identifying a turbine configuration that could effectively utilize the site's low-head, high-flow hydraulic profile within the Hydropower Collegiate Competition's 1–10 MW range. Power estimates from Section 3.3.2, using a head of 3.05 meters and flow of 268 cubic meters per second, indicated a theoretical potential of approximately 6 MW at 75 percent efficiency.

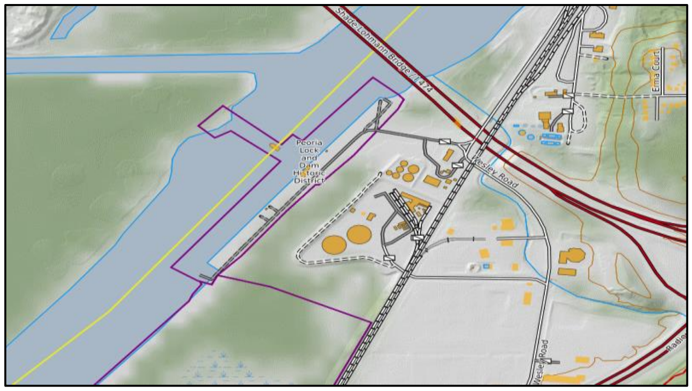



*Figure 4.4.2 Peoria Lock and Dam Site*

Two primary design concepts were evaluated for the Peoria site: a **Kaplan bulb turbine** integrated into one of the existing spillway bays, and a **crossflow turbine** mounted in a reinforced intake channel adjacent to the dam. Both concepts were developed to fit within the 1–10 MW competition range and to minimize structural modifications to the Peoria facility.

Each configuration was assessed against the project's engineering and customer requirements, including hydraulic efficiency, environmental impact, manufacturability, cost, and maintenance accessibility. The Kaplan bulb turbine achieved the higher overall ranking due to its superior efficiency under variable flow conditions, widespread commercial availability, and compact integration potential. The crossflow design offered simplicity and ease of fabrication but was limited by efficiency losses at fluctuating discharge rates and greater flow bypass requirements.

Based on these evaluations, the **Kaplan bulb turbine** was selected as the preferred concept for Peoria. This configuration provides the best balance of efficiency, scalability, and environmental performance while aligning with competition goals and site constraints. The final design phase will incorporate computational modeling through CFturbo and SolidWorks to optimize runner geometry, refine performance under seasonal flow variability, and confirm the structural feasibility of the mounting system.

### 4.4.3 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.

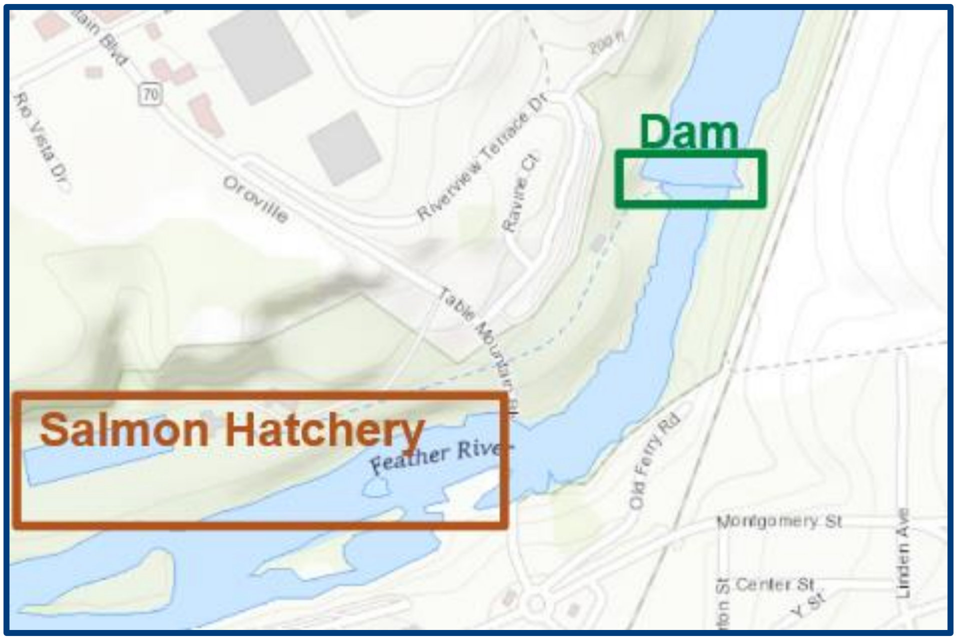



*Figure 4.4.3 Fish Barrier and Feather River Hatchery*

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.

### 4.4.4 Mississippi L&D #3

The Mississippi river Lock and Dam #3 looked to be a promising option for the site selection but had a couple of major drawbacks ultimately holding it back. It is a sturdy and relatively safe dam, both for recreational use of all sorts and fish passage. It also sports a high water outflow over wide dam which would help provide a lot of power.

Figure 4.4.4 Mississippi L&D #3 Power

Unfortunately for this lock and dam system there are a couple of major drawbacks. First of all, one that was not too bad as most other sites had this as well was its low head height. With this a potential turbine could not provide as much power, but it did tell us that a Kaplan Turbine would be the most efficient which is a good small turbine. Another problem with this dam is the miter gate conditions, they are poor and would cause difficulties in implementing a turbine system potentially costing thousands in repairs or replacements. Large floods that would cause potential damages and stop power generation have also becoming increasingly frequent here. There was a major flood in both of the last two years 2023 and 2024 causing high damage to structures and roads. This would put a big damper in any energy production done at this location. It can cost about $10/ft to build a power line which would be needed to use this generated power. Since there is no power line directly next to the dam as seen in figure 4.4.4, about 1500 feet of power line would need to be made costing around $15,000 which would be no easy feat. For these reasons the Mississippi River Lock and Dam was opted out of for the site selection.

### 4.4.5 Decision Matrix

To summarize and quantify the benefits and downsides of each site, a decision matrix was made:

| Criterion | Weight | Fish Barrier CA00034 | | Peoria Lock & Dam IL01014 | | Mississippi River Lock & Dam 3 MN00595 | | John Sevier Dam TN07305 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Score out of 100 | Weighted Score | Score out of 100 | Weighted Score | Score out of 100 | Weighted Score | Score out of 100 | Weighted Score |
| Estimated Mean Output | 25% | 22.68 | 5.67 | 45.58 | 11.40 | 40.42 | 10.11 | 16.50 | 4.13 |
| Flow Rate Consistency (1-CV) | 7.5% | 98.35 | 7.38 | 60.68 | 4.55 | 43.28 | 3.25 | 55.80 | 4.18 |
| Head Consistency (1-CV) | 7.5% | 96.33 | 7.23 | 76.49 | 5.74 | 76.49 | 5.74 | 76.49 | 5.74 |
| Poximity to Infrastructure | 10% | 95.00 | 9.50 | 90.00 | 9.00 | 94.00 | 9.40 | 100.00 | 10.00 |
| Risk | 10% | 100.00 | 10.00 | 65.00 | 6.50 | 65.00 | 6.50 | 65.00 | 6.50 |
| Ownership and Regulation | 10% | 60.00 | 6.00 | 70.00 | 7.00 | 50.00 | 5.00 | 80.00 | 8.00 |
| Structure | 10% | 70.00 | 7.00 | 90.00 | 9.00 | 90.00 | 9.00 | 70.00 | 7.00 |
| Accessibility | 10% | 100.00 | 10.00 | 80.00 | 8.00 | 60.00 | 6.00 | 70.00 | 7.00 |
| Local Need | 10% | 60.00 | 6.00 | 80.00 | 8.00 | 50.00 | 5.00 | 50.00 | 5.00 |
| Total | 100% | | 68.77 | | 69.18 | | 59.99 | | 57.55 |
| Rank | | 2 | | 1 | | 3 | | 4 | |

*Figure 4.4.5 Decision Matrix*

After reviewing each dam and quantifying their strengths and weaknesses, the top two dams were Fish Barrier and Peoria Lock & Dam. Due to their scores being less than one point from each other, we are currently contacting the owners of each dam to gather information that is not otherwise available online.

# 5 CONCLUSIONS

This report summarizes the initial design development of the Hydrojacks team for the 2026 Hydropower Collegiate Competition. The project's objective is to design a small-scale, low-impact hydropower retrofit capable of generating between one and ten megawatts of renewable energy from an existing non-powered dam. The team has identified two primary candidate sites — Peoria Lock and Dam in Illinois and the Feather River Fish Barrier in California — both of which meet the hydraulic and logistical criteria outlined by the Department of Energy competition guidelines.

Research and benchmarking confirmed that modern low-head turbine technologies, particularly Kaplan and Francis configurations, can achieve efficiencies between 70 and 90 percent under appropriate operating conditions. Data from the Department of Energy, Oak Ridge National Laboratory, and Voith Hydro provided reliable baselines for performance modeling and mechanical design. Mathematical analyses verified that both sites possess sufficient head, discharge, and infrastructure accessibility to support efficient small-scale power generation.

Functional decomposition models, site evaluations, and concept comparisons led to the selection of the Kaplan bulb turbine for Peoria and the Francis turbine for the Feather River Fish Barrier. Each design was assessed for efficiency, manufacturability, and environmental compatibility, confirming their suitability for competition requirements and sustainable retrofit objectives.

All planned fall semester deliverables — including this report, the team website, prototype development, and community outreach — will be completed within the current design cycle. The team will continue to refine computational modeling, structural validation, and performance optimization in CFturbo and SolidWorks, ensuring that the final design meets both technical and environmental criteria before the close of the semester.

This project demonstrates the technical and practical potential of retrofitting existing water infrastructure to generate clean energy while engaging the public in renewable technology awareness. Through coordinated engineering, outreach, and design verification, the Hydrojacks aim to deliver a functional, efficient, and environmentally responsible hydropower solution that reflects both the competition's objectives and Northern Arizona University's commitment to sustainable innovation.

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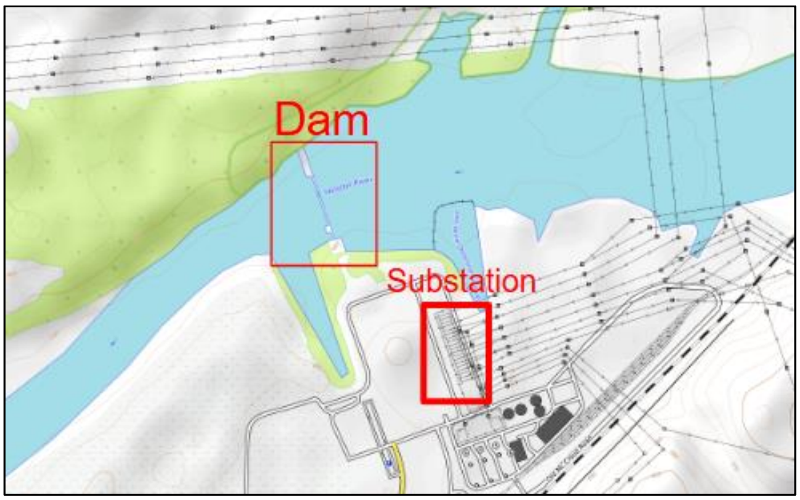
# 7 APPENDICES

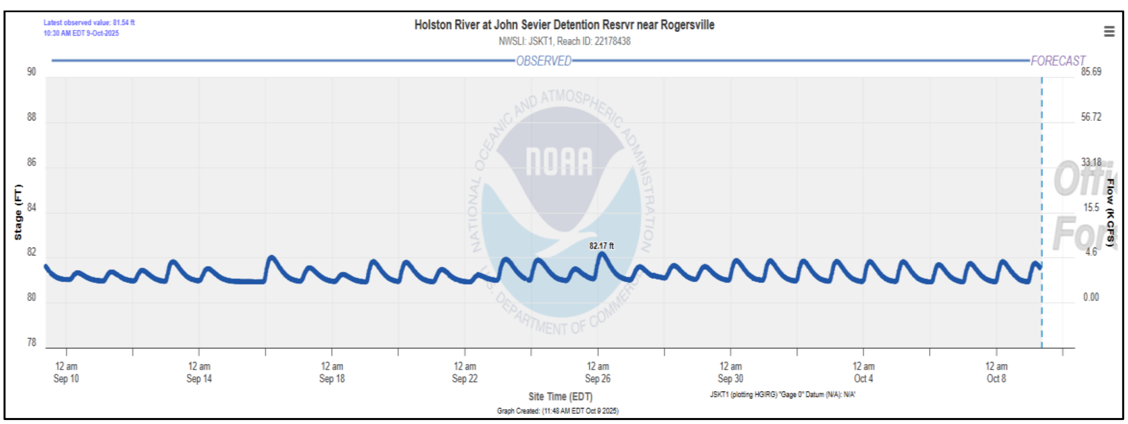
## 7.1 Appendix A: Site Information

### 7.1.1 A.1. John Sevier

John Sevier Dam is a concrete earth gravity dam located about 1 mile from Mccloud, Hawkins, Tennessee. The dam, which is on the Holston River, was primarily built for Water Supply purposes, but also serves benefits. The dam was designed by TVA and commissioned in 1955 and is currently owned by TVA. The John Sevier Dam is approximately 1,110 feet (338 m) long, 20 feet (6 m) high and has a structural volume of 22,000 cubic yards (16,820 cubic meters). The reservoir has a normal storage capacity of 5,500 acre-ft (6,784 mi) and a maximum capacity of 5,500 acre-ft (6,784 mi).The surface area of the reservoir is 660 acres (267 ha), and the total catchment area is 3,006 square miles (7,786 square kilometers).The dam has a 636 feet (194 m) wide uncontrolled spillway with a maximum discharge capacity of 395090 cubic feet per second (11188 cubic meters per second).



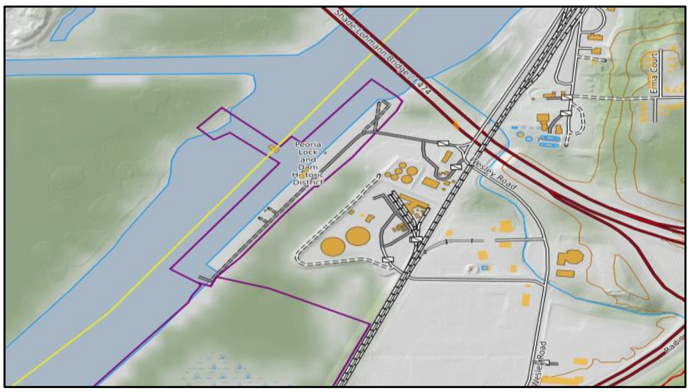

*John Sevier Site, Figure A2*



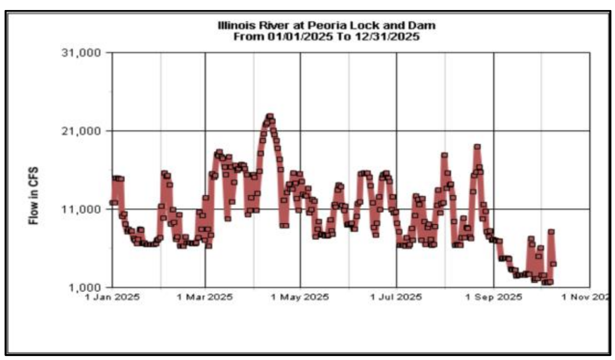

*John Sevier Flow Data, Figure A3*

### 7.1.2 A.2. Peoria L&D

Peoria Lock and Dam is located on the Illinois River near downtown Peoria, Illinois, and is operated by the U.S. Army Corps of Engineers. The structure is a low-head navigation dam designed to maintain river elevation for commercial traffic and flood control purposes. The dam features a tainter gate spillway system and an adjacent lock chamber that provides vessel passage between the Peoria and La Grange pools. The concrete and steel dam spans approximately 1,083 feet (330 m) with a normal head of about 3.05 meters and an average flow rate of 268 cubic meters per second. The surrounding area includes reinforced embankments, a navigation lock, and access roads suitable for small-scale retrofit construction. The Peoria site was selected for analysis due to its consistent flow regime, manageable head, and available structural access for turbine integration. Flow data provided by Peoria site representatives were used to generate the discharge graph shown below, which served as the basis for the hydraulic and power calculations in Section 3.3.2. Site photographs identify potential turbine mounting locations and areas for flow diversion without disrupting navigation operations.



*Peoria Lock and Dam Site, Figure A4*




*Peoria Flow Data, Figure A5*

### 7.1.3 A.3. Fish Barrier

Fish Barrier is located at the northernmost point of the Feather River Salmon Hatchery and ends the transition from the Oroville Complex to the Feather River. Its main purpose is to prevent migratory fish from continuing further upstream. It is a concrete gravity dam and is owned by the California Department of Water Resources. The spillway is 250ft wide and has an average annual head of 63ft and flow rate of 542 $ft^3/s$. A small parking lot and fishing spot are located nearby and the area around the dam is primarily residential. Notable features include a consistent head and flow rate throughout the year and its proximity to relevant infrastructure. Important considerations include maintaining the primary function of the barrier (preventing fish from moving upstream).

*Figure A6 Fish Barrier Dam (Image Credit: calfish.org)*

### 7.1.4 A.4. Mississippi River Lock and Dam #3

Mississippi River Lock and Dam #3 is located near Red Wing, Minnesota, on the Upper Mississippi River at river mile 796.9. The structure is located along the Minnesota side of the river, in the vicinity of Welch, MN. The lock chamber is 110 feet (33.5m) wide by 600 feet (183) long, with a total dam length of 365 feet (111m). The facility also includes four roller gates and an earth embankment over 2,000 feet (610m) long. It has an average head of 5.5 meters and average flow rate of 525 $m^3/s$. Mississippi River Lock and Dam #3 is owned and operated by the U.S. Army Corps of Engineers, specifically the St. Paul District, which is part of the federal government. The Corps is responsible for its maintenance, operation, and the

9-foot navigation channel it helps create on the Upper Mississippi River.

*Figure A7 Mississippi River Lock and Dam #3*


*Figure A8 Monthly Outflow of Lock and Dam #3*


## 7.2 Appendix B: Necessary Equations

$$\boldsymbol{P} = \rho \boldsymbol{gQH}\eta$$

***[1]***

$$\frac{P}{\omega} = T$$

***[2]***

$$d = 16T/\pi T_{allow}$$

***[3]***

$$n_s = \frac{n\sqrt{(1.358P)}}{H^{\frac{5}{4}}}$$

***[4]***

$$v = Q/A \quad [5]$$

$$\omega = v/(d/2) \quad [6]$$