# 67% UPDATE: HYDROPOWER COLLEGIATE COMPETITION

February 28th, 2024

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# PROJECT DESCRIPTION

- **Problem Statement:** Optimize the conversion of Kentucky River Lock & Dam #4 into a small-scale hydropower facility.

*Figure 1: Final site selection aerial view*

## Key Specs

- Estimated Head: 14 ft
- Potential Energy: 1.56 MW
- 0.1 miles from transmission line
- Existing flume

# DAM REMOVAL RISK MITIGATION

- **Overall:** Not enough impact to overcome cost and lack of an interested part to help remove dam
- Heavy risk for communities that depend on dam for municipal water supply and recreation

| Dam Removal Impact Mitigation Matrix | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Proposed Site:** Kentucky River Lock & Dam #4 | | | | | | | | | | | | | |
| **RISK DESCRIPTION** | **Completeness** | | | **Effectiveness** | | | **Efficiency** | | | **Costs** | | | **RISK SCORE** |
| Damages to River | Disruption in local water supply | | | Potential silt buildup could cause environmental catastrophy | | | Will removing the dams benefit local area? | | | Increased flooding could result in long-term costs | | | Max individual 400 |
| | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Total Score |
| | 9 | 10 | 90 | 5 | 9 | 45 | 4 | 9 | 36 | 8 | 10 | 80 | **251** |
| Environmental Impacts | Could result in upstream migration | | | Endangered mussels will still be impacted by other dams | | | Chances of species rehabilitation are low overal | | | Short term cultural resources mitigation costs are anticipated | | | Max individual 400 |
| | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Total Score |
| | 3 | 8 | 24 | 2 | 7 | 14 | 2 | 6 | 12 | 3 | 8 | 24 | **74** |
| Socioeconomic Impacts | Negative impacts to water supply and recreation | | | Potential violation of Property Act constraints | | | Preclude future development in the area | | | Modifying structures and boat ramps would be needed | | | Max individual 400 |
| | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Total Score |
| | 10 | 10 | 100 | 7 | 9 | 63 | 7 | 8 | 56 | 10 | 10 | 100 | **319** |
| Public Safety | Any dam failure worries would be removed | | | Vertical condiitons and drawning hazards would be removed | | | Not Applicable | | | Little to no O&M Costs | | | Max individual 300 |
| | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Chance | Impact | Risk | Total Score |
| | 3 | 5 | 15 | 4 | 6 | 24 | 0 | 0 | 0 | 1 | 2 | 2 | **41** |
| | | | | | | | | | | | | **Total Risk Score (out of 1500)** | **685** |

# COST MODELING

Current Overall Project Cost: **$9,618,191**

Other considerations:

- USDA Grants/Loans
- Tax Incentives
- Return on Investment based on annual generation revenue

| | | | | |
|---|---|---|---|---|
| **Construction Materials and Equipment** | | | | |
| **Civil Works and Structures** | $993,803 | $568 | 10.3% | 100% |
| Civil Subtotal | $993,803 | $568 | 10.3% | |
| **Equipment** | | | | |
| Turbines | $1,740,190 | $994 | 18.1% | 0% |
| Generators | $902,902 | $516 | 9.4% | 0% |
| Balance of Plant - Electrical | $316,016 | $181 | 3.3% | 50% |
| Balance of Plant - Mechanical | $348,038 | $199 | 3.6% | 50% |
| Main Power Transformers | $63,883 | $37 | 0.7% | 0% |
| Switchyard and Interconnection | $87,500 | $50 | 0.9% | 0% |
| Transmission Line | $50,000 | $29 | 0.5% | 0% |
| Equipment Subtotal | $3,508,529 | $2,005 | 36.5% | |
| **Installation/Labor** | | | | |
| Civil Works and Structures | $546,592 | $312 | 5.7% | 100% |
| Turbines | $1,700,000 | $971 | 17.7% | 100% |
| Generators | $127,309 | $73 | 1.3% | 100% |
| Balance of Plant Electrical | $44,558 | $25 | 0.5% | 100% |
| Balance of Plant Mechanical | $49,073 | $28 | 0.5% | 100% |
| Main Power Transformers | $3,084 | $2 | 0.0% | 100% |
| Switchyard and Interconnection | $12,338 | $7 | 0.1% | 100% |
| Transmission Lines | $25,850 | $15 | 0.3% | 100% |
| Installation/Labor Subtotal | $2,508,804 | $1,434 | 26.1% | |
| **Other Costs** | | | | |
| Mitigation | $0 | $0 | 0.0% | 75% |
| Licensing, Permitting and Interconnection Agreement | $1,084,799 | $620 | 11.3% | 75% |
| Engineering and Other Professional Services | $1,258,563 | $719 | 13.1% | 80% |
| Insurance | $0 | $0 | 0.0% | 100% |
| Other Development | $0 | $0 | 0.0% | 80% |
| Other Subtotal | $2,343,361 | $1,339 | 24.4% | |
| **Subtotal** | $9,407,679 | $5,376 | 97.8% | |
| **Sales Tax (Materials & Equipment Purchases)** | $210,512 | $120 | 2.2% | 100% |
| **Total** | $9,618,191 | $5,496 | 100.0% | |



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# COST MODELING

| Annualized Operating and Maintenance Costs | Cost | Cost Per KW | Percent of Total Cost | Local Share (%) |
|---|---|---|---|---|
| **Personnel and Labor** | $66,945 | $38 | 26.7% | 100% |
| **Materials and Services** | | | | |
| Supplies, Tools, Vehicles, etc. | $35,609 | $20 | 14.2% | 100% |
| Insurance | $34,922 | $20 | 13.9% | 100% |
| Taxes and Duties | $0 | $0 | 0.0% | 100% |
| Regulatory Compliance | $35,928 | $21 | 14.3% | 100% |
| Rents/Leases | $0 | $0 | 0.0% | 100% |
| Replacement Parts | $71,218 | $41 | 28.4% | 100% |
| Subtotal | $177,676 | $102 | 70.8% | |
| **Subtotal** | $244,621 | $140 | 97.4% | |
| **Sales Tax (Materials & Equipment Purchases)** | $6,410 | $4 | 2.6% | 100% |
| **Total (without property taxes and debt financing)** | $251,031 | $143 | 100.0% | |



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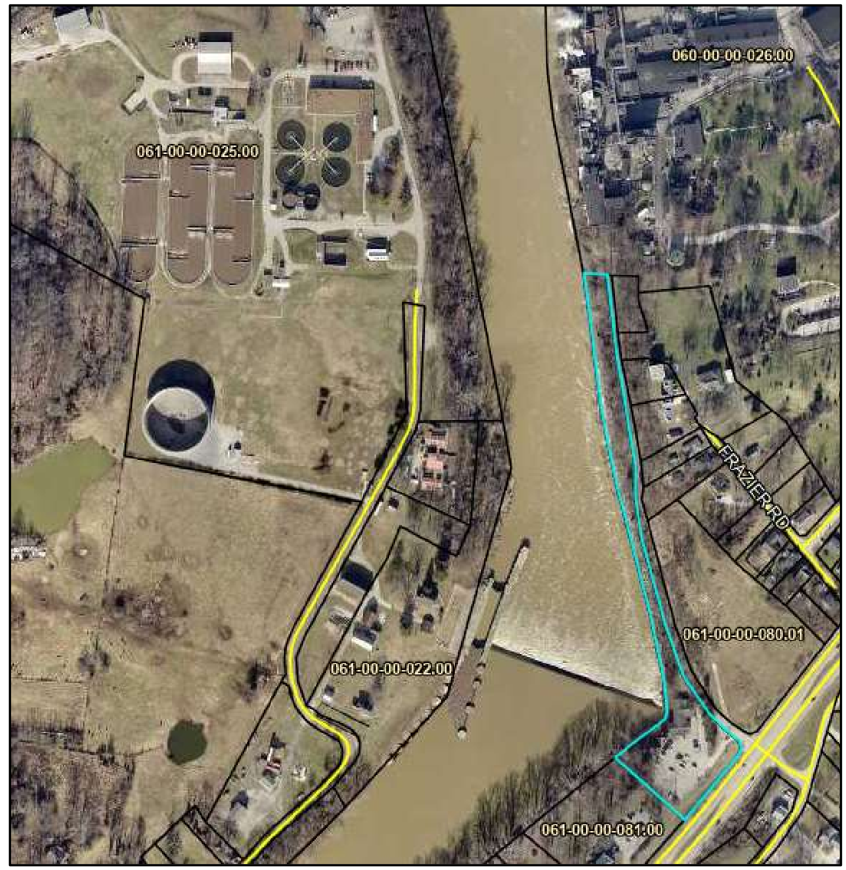
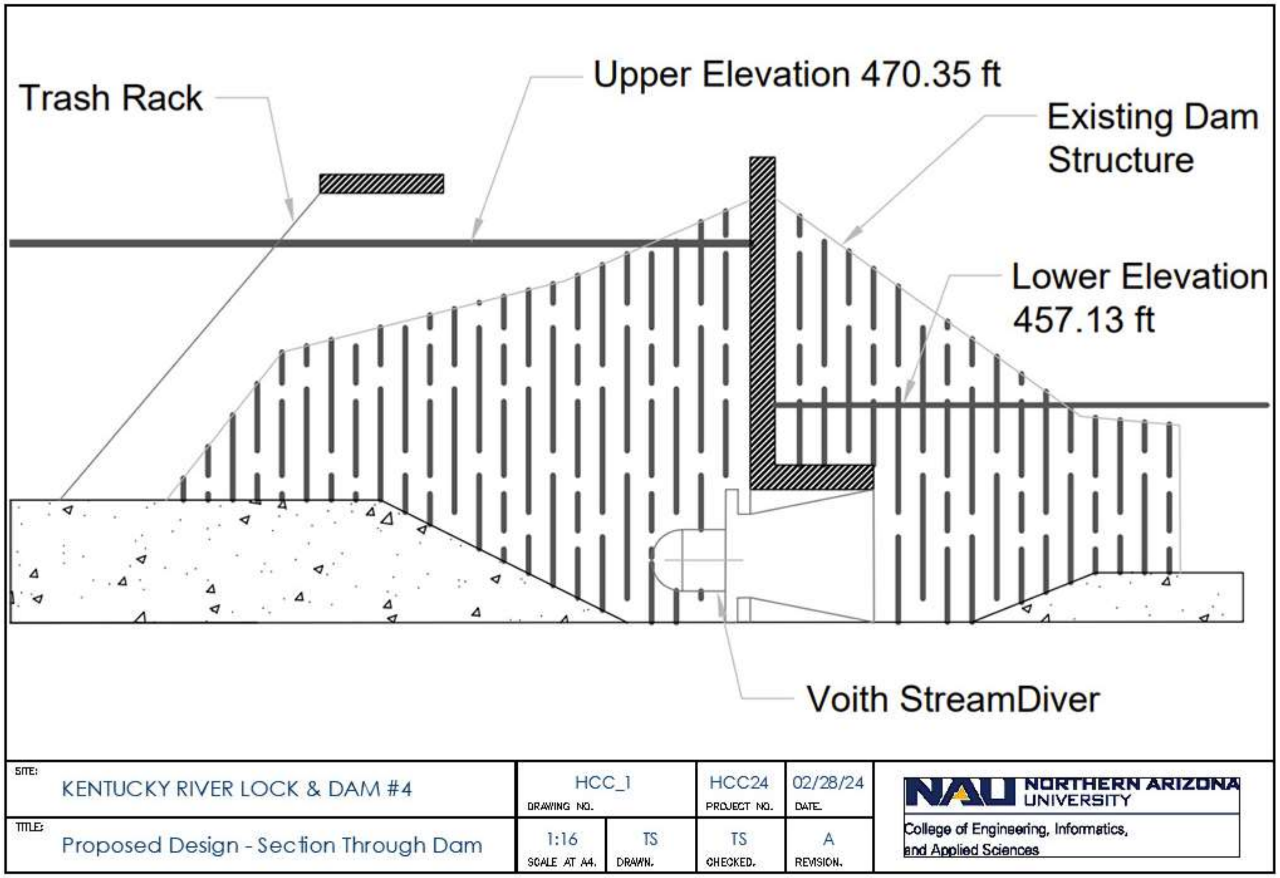
# ROUGH ORDER OF MAGNITUDE (ROM)

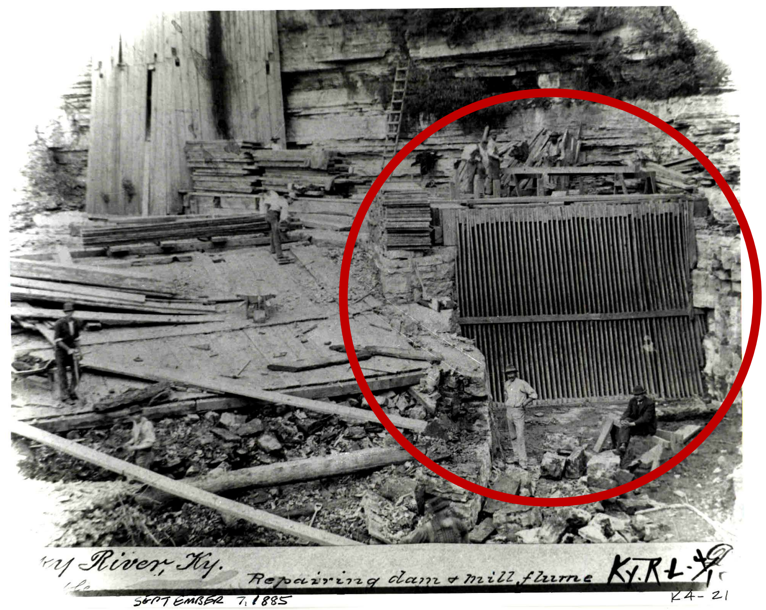
| Map ID | Address | Size (acre) | Land Price | $/acre | Land Use |
|---|---|---|---|---|---|
| 80-00-00-011 | Gregory Rd | 15.12 | $28,000 | $1,852 | VACANT |
| 75-00-00-036 | Hanley Ln | 59.33 | $135,000 | $2,275 | VACANT |
| 76-00-00-036 | Hanley Ln | 59.33 | $135,000 | $2,275 | VACANT |
| 65-00-00-002 | Hanks Ln | 29 | $126,000 | $4,345 | VACANT |
| 62-31-26-019 | Fourth St | 0.164 | $13,400 | $81,707 | LOT |
| 48-00-00-008 | Benson Valley Rd | 28 | $80,000 | $2,857 | VACANT |
| 47-00-00-056.04 | Bald Knob Rd | 2.839 | $25,000 | $8,806 | TELECOM SITE |
| 44-00-00-029.01 | Flat Creek Rd | 13.56 | $25,000 | $1,844 | VACANT |
| 37-00-00-010.01 | Schofield Ln | 1.655 | $36,000 | $21,752 | LOT |
| 35-00-00-024.03 | Hunters Trace | 10.01 | $65,000 | $6,494 | VACANT |
| 47-00-00-117 | Lewis Ferry Rd | 118.5 | $450,000 | $3,797 | FARM |
| 48-00-00-028.13 | Moss Ln | 21.89 | $60,000 | $2,741 | VACANT |
| 61-20-04-009 | Payne St | 0.388 | $5,000 | $12,887 | LOT |
| 61-34-06-008 | Cody Pass | 0.253 | $9,000 | $35,573 | LOT |
| 61-43-05-027 | Murrell St | 0.184 | $1,000 | $5,435 | LOT |
| 64-00-00-002.02 | Old Lawrenceburg | 10.02 | $80,000 | $7,984 | VACANT |
| 73-00-00-024 | US 127 N | 49.655 | $390,000 | $7,854 | FARM |
| 76-00-00-020.02 | Glenns Creek Rd | 1.5 | $15,000 | $10,000 | VACANT |
| 65-00-00-021.02 | Ninevah Rd | 1.919 | $52,500 | $27,358 | VACANT |
| | | | **Average/Acre** | **$13,642** | |
| 74-43-02-003 | Versailles Rd | 4.259 | $155,820 | $36,586 | COMMERCIAL |
| 61-00-00-085 | Wilkinson Blvd | 1.99 | $500,000 | $251,256 | COMMERCIAL |



# CURRENT PROPOSED DESIGN

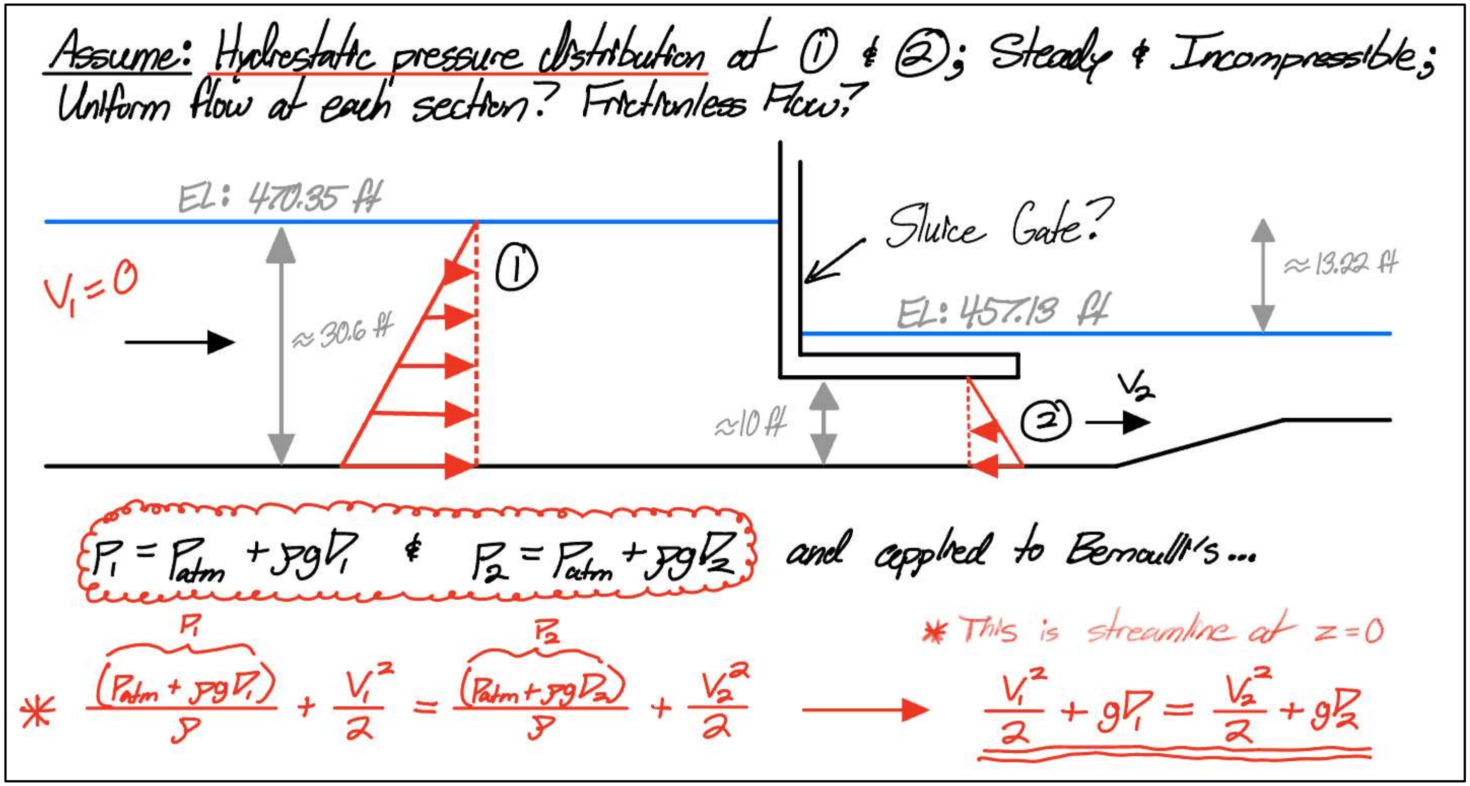



- Use/expand the existing flume to accommodate Voith StreamDiver turbines.



# DAM FLOW ANALYSIS

- **Outlet Velocity:**
  - 36.43 ft/s
- **Outlet Flow Rate:**
  - 364 cfs/foot of width
- Values align with optimal sizing of StreamDiver units



# DAM ENERGY ANALYSIS

The number of turbines in the outlet flume are to be determined through levelized cost of energy calculations.


From the 5-year average flow duration curves, MATLAB was used to calculate flow rate through the flume and potential energy generation.

```
Flow rate in ft^3/s per foot of width in flume = 3.642307
```

```
Cross section area at outlet [m^2] = 1.301
```

```
Power in MW = 1.56018
```

```
Power is in competitions range of 1-10 MW
```

# ENVIRONMENTAL ANALYSIS

1. **Aquatic Habitat –** changes in water flow patterns, sediment transport, and habitat connectivity may affect the distribution and abundance of fish species, including those that are threatened or endangered.
2. **Water Quality –** influenced water quality parameters such as sedimentation rates, nutrient levels, and water temperature may affect the overall health of the river ecosystem and its ability to support aquatic life.
3. **Sediment Transport –** changes in sediment deposition patterns could impact habitat quality, riverbank stability, and channel morphology, with potential downstream consequences.
4. **Erosion and Stability –** increased erosion rates and sediment deposition affect the stability of riverbanks and the surrounding areas.
5. **Terrestrial Habitats –** changes in hydrology or sedimentation may affect habitats adjacent to the Kentucky River, including forests, wetlands, and agricultural lands, and the species they support.

# ENVIRONMENTAL ANALYSIS

**Endangered Mussel Rehabilitation**

Involves habitat restoration, population monitoring, captive breeding, and reintroduction programs

**Approaches and Strategies**

1. **Habitat Restoration -** may involve initiatives such as removing barriers to migration, enhancing water quality, and restoring natural flow regimes.
2. **Propagation and Captive Breeding -** help increase population numbers and genetic diversity, reducing the risk of extinction.
3. **Translocation -** augment existing populations and increase genetic diversity.
4. **Community Engagement and Education -** garner support for recovery efforts.
5. **Regulatory Protections -** may include habitat conservation plans, pollution controls, and enforcement of habitat protection laws.



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# COMMUNITY CONNECTIONS PLAN

- STAR School visit with hydropower informational and hands on activity, end of March.
- Willow Bend Science Saturday, April 6th.
- Hydropower table at Arizona KidWind Challenge with Willow Bend, April 18th.

Willow Bend
environmental
education
center

# PROJECT SCHEDULE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Week 6 | 02/19/24 | 5d | 02/23/24 | | 88% | Complete |
| 2 | Follow up on Website Check #1 | 02/19/24 | 5d | 02/23/24 | | 100% | Complete |
| 2 | Follow up with KidWind | 02/19/24 | 5d | 02/23/24 | | 100% | Complete |
| 2 | Get updates on EE sub-team drafted power model (what's next?) | 02/19/24 | 5d | 02/23/24 | | 100% | Complete |
| 2 | Build out engineering flow diagrams/mock-ups specific to dam operation (transformer? meters? etc.?) | 02/19/24 | 5d | 02/23/24 | | 50% | In Progress |
| 1 | Week 7 | 02/26/24 | 10d | 03/08/24 | | 68% | Not Started |
| 2 | Hardware Status Update - 67% Build | 03/04/24 | 5d | 03/08/24 | | 100% | Complete |
| 2 | Continue power and operational modeling | 02/26/24 | 5d | 03/01/24 | | 40% | In Progress |
| 2 | Build engineering diagrams and potential civil sketches in CAD | 02/26/24 | 5d | 03/01/24 | | 50% | In Progress |
| 2 | Gather environmental data specific for design | 02/26/24 | 5d | 03/01/24 | | 80% | In Progress |
| 1 | Week 8 | 03/04/24 | 5d | 03/08/24 | | 80% | Not Started |
| 2 | Work in CENE 499 on cost modeling for annual g | 03/04/24 | 5d | 03/08/24 | | 80% | In Progress |
| 2 | Meet with Walter and Jonathan to discuss next st | 03/04/24 | 5d | 03/08/24 | | 80% | Not Started |
| 2 | Replace with Testing Plan Deliverable | 03/04/24 | 5d | 03/08/24 | | 80% | Not Started |
| 1 | SPRING BREAK | 03/11/24 | 5d | 03/15/24 | | 80% | Not Started |
| 1 | Week 9 | 03/18/24 | 5d | 03/22/24 | | 0% | Not Started |
| 2 | Start drafting poster for competition | 03/18/24 | 5d | 03/22/24 | | 0% | Not Started |
| | Replace with Testing Plan Deliverable | 03/18/24 | 5d | 03/22/24 | | 0% | Not Started |
| 2 | Complete power modeling and operational modeling | 03/18/24 | 5d | 03/22/24 | | 0% | Not Started |
| 2 | Complete Cost Model on Project Costs | 03/18/24 | 5d | 03/22/24 | | 0% | Not Started |
| 1 | Week 10 | 03/25/24 | 5d | 03/29/24 | | 0% | Not Started |
| 2 | Continue drafting poster for competition | 03/25/24 | 5d | 03/29/24 | | 0% | Not Started |
| | Replace with Testing Plan Deliverable | 03/25/24 | 5d | 03/29/24 | | 0% | Not Started |
| 2 | Complete power modeling and operational modeling | 03/25/24 | 5d | 03/29/24 | | 0% | Not Started |
| 2 | Complete Cost Model - Annual Generatoin | 03/25/24 | 5d | 03/29/24 | | 0% | Not Started |

# THANK YOU!

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# REFERENCES

[1] "StreamDiver | Voith," *voith.com*. https://voith.com/corp-en/hydropower-components/streamdiver.html (accessed Feb. 29, 2024).

[2] R. W. Fox, *Fox And Mcdonald's Introduction To Fluid Mechanics.* S.L.: John Wiley, 2020.