PRODUCT DEMO AND FINAL TESTING RESULTS

Hydropower Collegiate Competition 2024

4/17/2024

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DESIGN REQUIREMENTS SUMMARY

Customer Requirements

CR1 - Mitigated Environmental Impacts

CR2 - Financial Feasibility

CR3 - Site Interconnectivity

CR4 - Co-Development Opportunity

CR5 - Energy Output of 1-10 MW

CR6 - Community Benefits

Engineering Requirements

ER1 - Max/Min Energy Output (MW)

ER2 - Environmental Impact (%)

ER3 - Efficiency (MWh)

ER4 - Quantitative Risk Assessment

ER5 - Feasibility (years)

ER6 - Project Expenditures($)

FINAL TESTING – RISK ASSESSMENT

Design Risk Mitigation Matrix																			
Proposed Site: Kentucky River Lock & Dam #4																			
RISK DESCRIPTION	**Construction and Civil Risk**			**Energy and Grid Risk**			**Technichal/Other Risk**			**Mechanical Risk**			**Enviromental Risk**			**RISK SCORE**		
River Manipulation	Adapting existing flume for StreamDiver			Grid connection disruptions			Construction schedule/planning setbacks			Installation difficulties with turbines/other components			Ecological distrubance			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	500		
	6	8	48	3	6	18	5	8	40	4	6	24	6	9	54	Total Score		
																184		
Power System Installation	Retrofitting existing structures			Integrating with existing grid			Compliance/compatibility issues duirng installation			Mechanical fit and compatibility			Environmental permits for new installation			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	500		
	5	8	40	5	7	35	4	6	24	5	8	40	4	6	24	Total Score		
																163		
Dam Conversion	Conversion while maintaining operations			Energy production variability			Technical retrofitting issues			Downtime/repairs during dam converison			Water rights, permitting, and compliance			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	500		
	6	8	48	4	7	28	5	7	35	5	7	35	6	8	48	Total Score		
																194		
Co-Development	Co-development with Buffalo Trace Distillery			Grid coordination with other current energy projects/infrastructure			Integration with other developments			Not Applicable			Cumulative environmental impact			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	400		
	4	7	28	2	5	10	2	5	10	0	0	0	4	7	28	Total Score		
																76		
Community Incorporation	Encountering high-priority easements in development			Community enery disruption			Local infrastructure adaptations			Not Applicable			Water supply managemnet			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	400		
	3	6	18	2	4	8	2	3	6	0	0	0	4	7	28	Total Score		
																60		
Environment Incorporation	Enivonrmental regulation compliance affecting development			Eco-friendly energy system challenges			Not Applicable			Facility equipment impact on surrounding environment			Ecological system disturbances			Max individual		
	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	Chance	Impact	Risk	400		
	5	8	40	4	7	28	0	0	0	3	6	18	6	9	54	Total Score		
																140		
																Total Risk Score (out of 2200)		**817**

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SUMMARY OF DESIGN

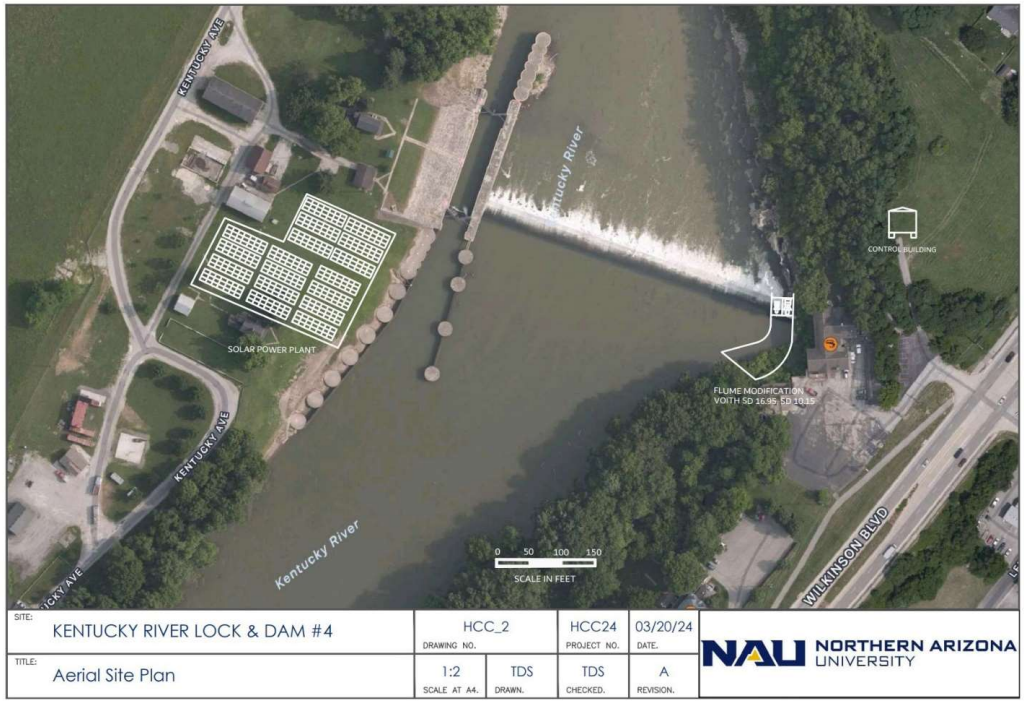


Figure 1: Aerial site plan layout

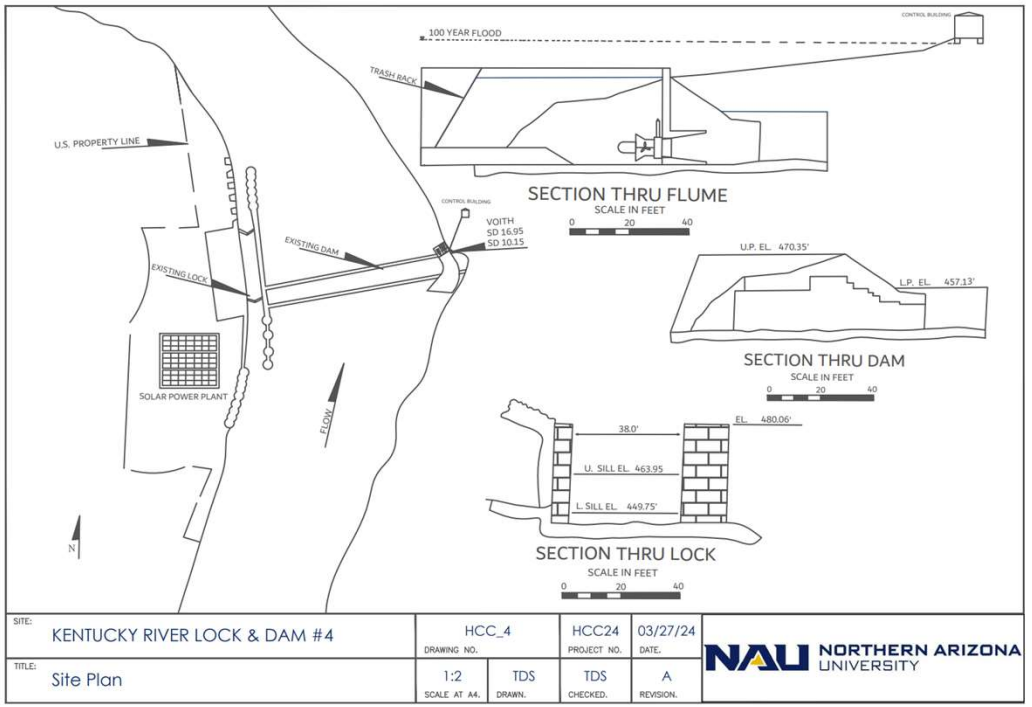


Figure 2: Site plan with through section views

FLUME MATHEMATICAL MODELING

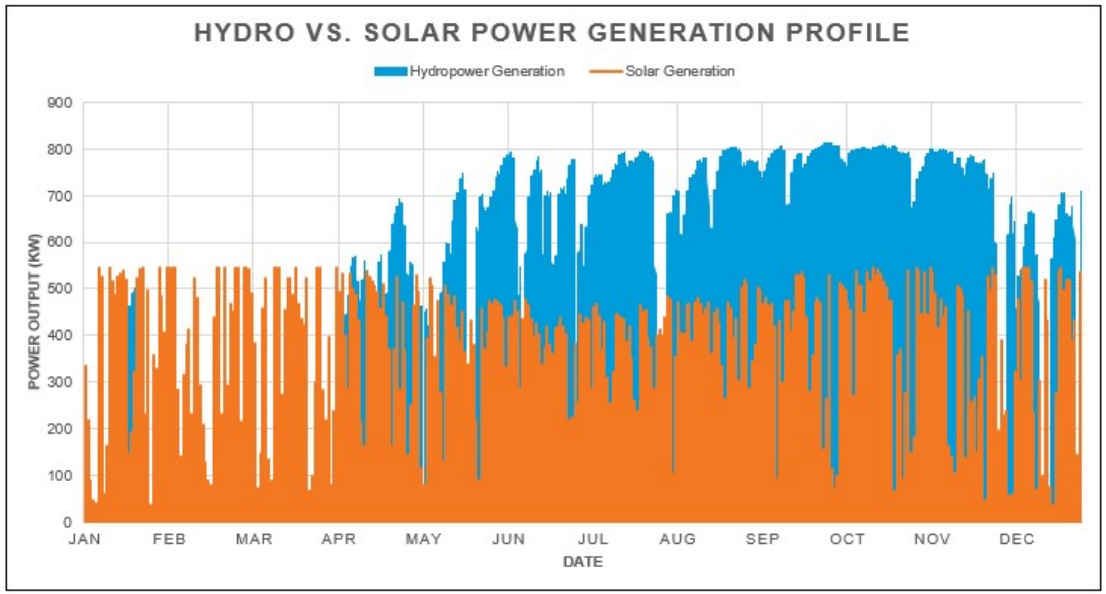
- Using the flow rate through the flume, theoretical power generation was calculated.
- Using the theoretical power, five different contributors to head loss from the flume design were calculated along with the adjusted power output after losses.

Variable	Name	Value	Unit	**Theoretical Power [MW]**
Q	Flow rate	257.8	m^3/s	8.967
m	Mass	257800	kg	Trash Rack Head Loss [m]
g	Gravitaional constant	9.81	m/s^2	3.18E-05
hnet	Net head height	4.029	m	Friction Head Loss [m]
n	Efficiency	0.88	%	0.002
k	Bar shape	1		Hydraulic Gradient Loss [m]
b	Width between bars	0.1016	m	0.00265
t	Bar thickness	0.01905	m	Sudden Contraction Loss [m]
theta	Trash rack angle	60	degrees	0.32
Vo	Approach Velocity	1	m/s	Flume Bends Head Loss [m]
L	Length	40	m	0.3
w	Width	7.62	m	Total Head Loss [m]
D	Depth	7.62	m	0.6245
h	Height	3.048	m	Adjusted Net Head [m]
V	Flow velocity	12.37	m/s	3.4045
e	Flow velocity	0.00018	m	**Power After Losses [MW]**
n	Manning's roughness coefficient	0.014		7.577
Vavg	Average velocity	6.185	m/s	

ESTIMATED ENERGY GENERATION SUMMARY

- Generation was estimated based on:
  - **PVWatts Solar Inputs**
  - **USGS Flow Data**
  - **Hydraulic Profiles of StreamDiver Units (provided by Voith)**
- Peak Generation: 11,906 MWh
  - **Hydropower: 7124 MWh**
  - **Solar: 4783 MWh**
- Peak Capacity: 1.346 MW
  - **Hydropower: 820.1 kW**
  - **Solar: 525.9 kW**
- Losses and shutoff periods for units also accounted for

Overall Power Generation			
	Hydropower	Solar	Overall
Generation (MWh)	4122	883.1	5005
Average Output (MW)	0.4706	0.1008	0.5714
Capacity Factor	57.87%	18.46%	42.45%
LCOE	42.40 ¢/kWh	4.8 ¢/kWh	47.20 ¢/kWh



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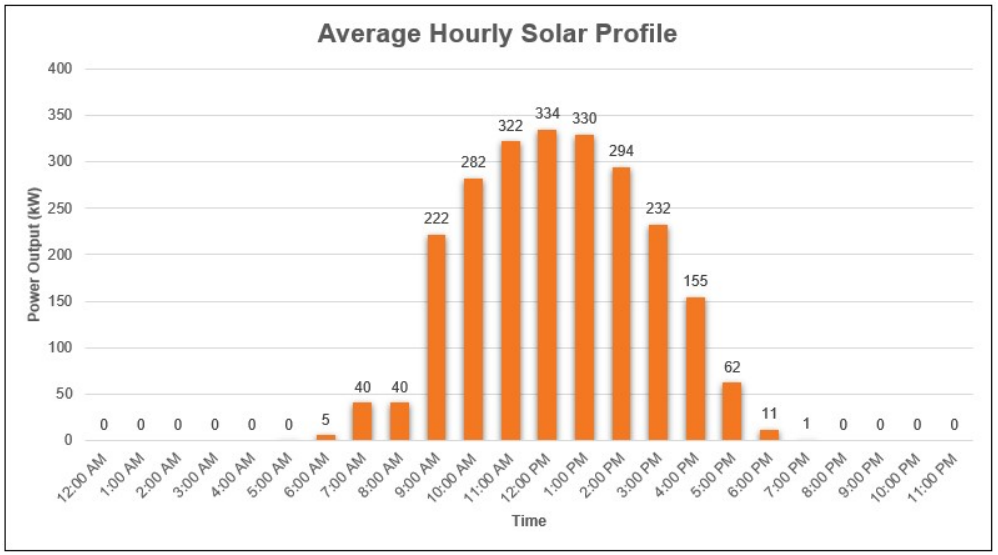
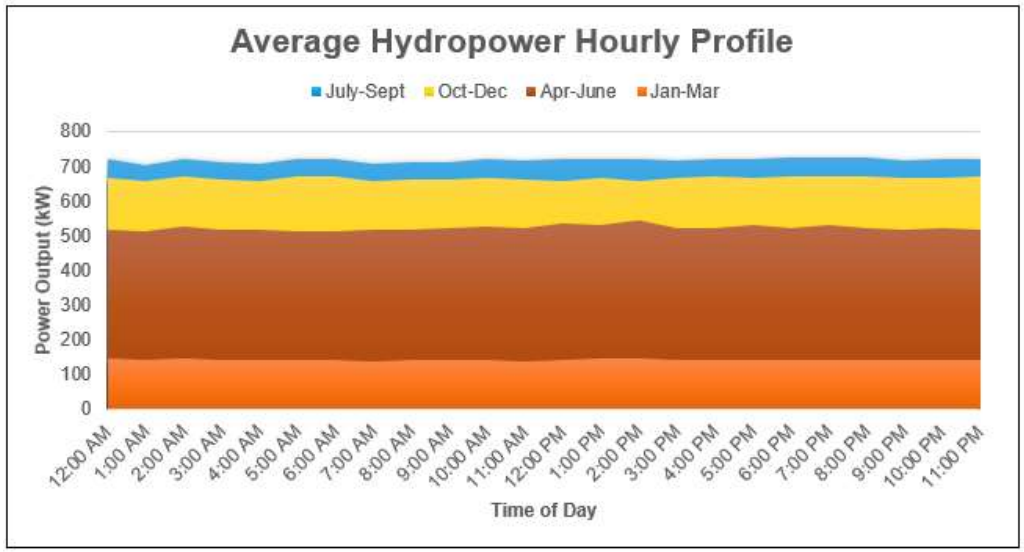
ESTIMATED ENERGY GENERATION SUMMARY

- **Procedure:** Average output at each hour is an aggregate of all corresponding hours from the 365 days
- **Solar Hourly Profile:** Naturally aligns with pattern of sunlight availability
- **Hydropower Hourly Profile:** Consistent hourly output; but varying seasonal production





FINANCIAL FEASIBILITY ANALYSIS SUMMARY

Project Revenue and Operations (2024 Dollars)	
Annual Generation (MWh)	5,005
Power Sales Rate ($/MWh)	72.00
Power Sales Revenue	$ 360,360.00
REC Sale Rate ($/MWh)	28.00
REC Sales Revenues	$ 140,140.00
Total Revenue	**$ 500,500.00**
Annual Operation/Site Expenses (2024 Dollars)	
Property Tax	$ 60,000.00
Liability Insurance	$ 9,000.00
Property Insurance	$ 40,000.00
Professional Accounting Fees + Headwaters Benefit Fee	$ 21,000.00
FERC Fee	$ 1,400.00
KRA Leasing Fee	$ 10,880.00
County Fee	$ 8,000.00
Voith Bearing Replacement (Once every 12 years)	$ 30,000.00
Land lease cost (lease to own - 10 years)	$ 1,044.36
Hydropower O&M	$ 80,000.00
Solar O&M ($15/kW)	$ 9,828.00
Total Annual Expenses (2024)	**$ 241,168.70**
Total Project Net Income	**$ 259,331.30**

- **Overall:** Finalized project cost of $11,652,202
  - Inflated to $13,982,642 to account for cost at end of construction in 2033
- **RUS Loan Analysis:** Proves our project is profitable and investible

RUS Loan Calculation	
Minimum Debt Service Coverage Ratio (DSCR)	1.25
Interest Rate	3.75%
Term (years) - Amortization	25
Loan Amount	$ 5,531,951
Principal and Interest Payments	($207,451.47)
Net Income or Profit	$ 259,331.30
Project DSCR	1.25
Maximum Loan Amount	$ 207,465.04
Profit After Debt	**$ 51,879.83**

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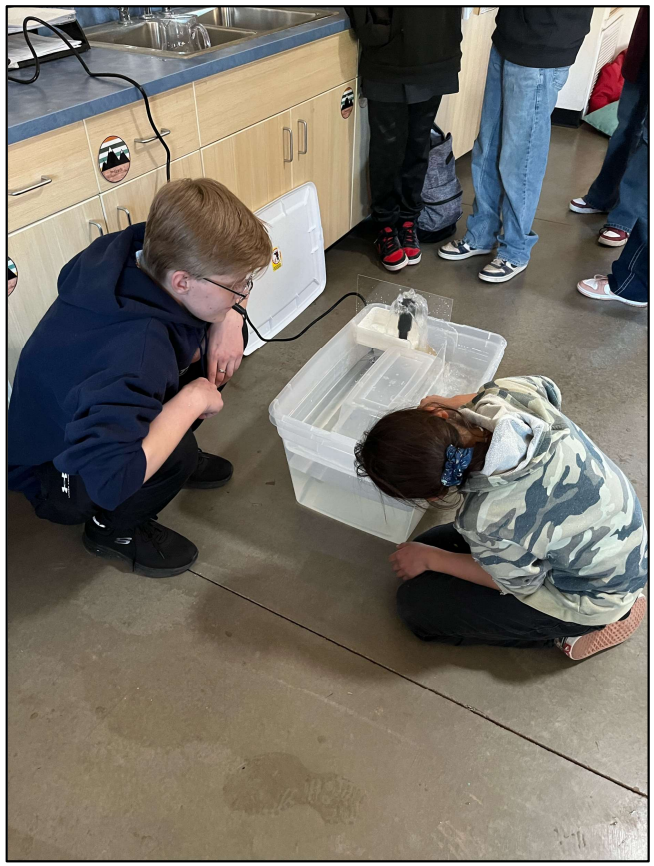
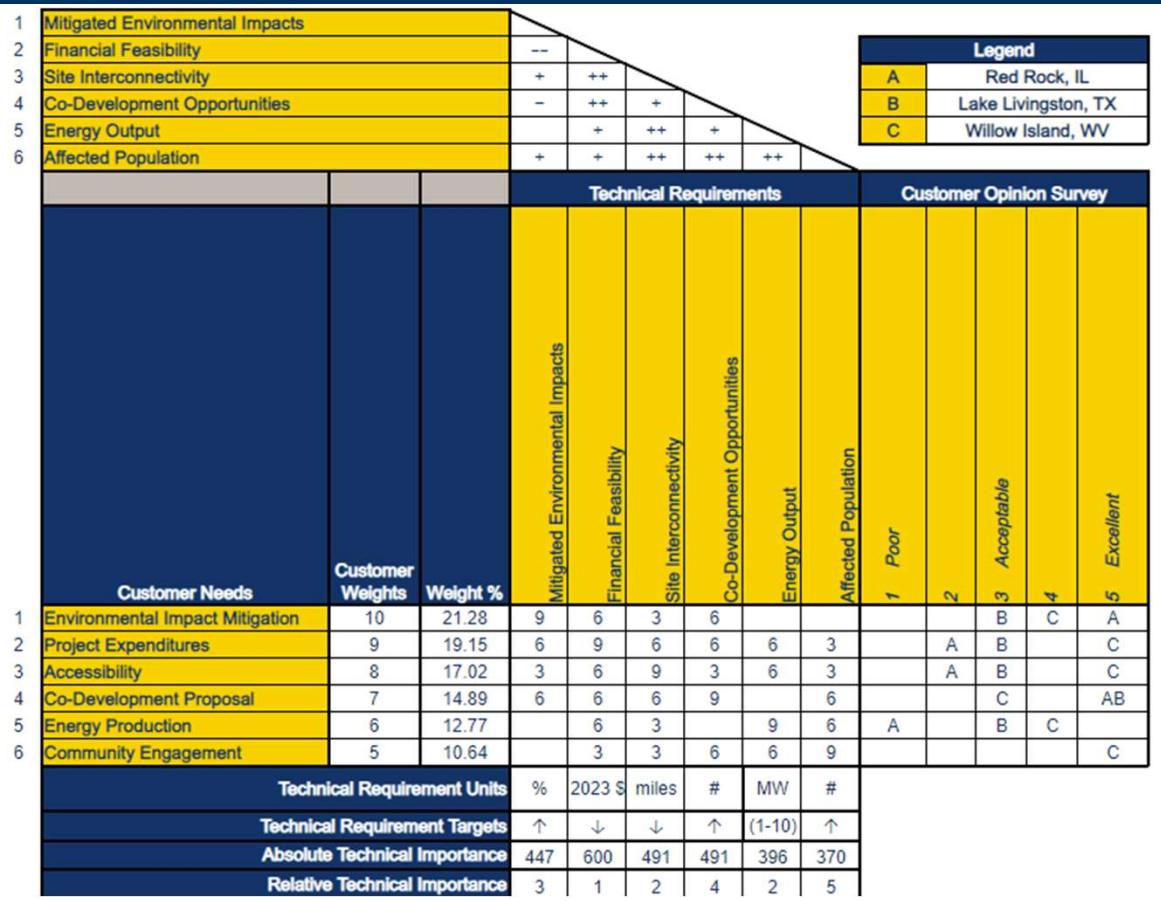
COMMUNITY CONNECTIONS UPDATES/DEMONSTRATION



- Today: Taught a classroom of 16 about hydropower
  - **15 of 16** didn't know what hydropower was prior to event
  - **16 of 16** enjoyed learning about hydropower
  - **10 of 16** wanted to learn more about hydropower
  - **9 of 16** thought "a job in hydropower would be interesting"
- Tomorrow: KidWind Challenge with CWC
  - Tabling as part of a "career fair"
  - Will include metrics from numerous high-schoolers during final report

HOUSE OF QUALITY

- Estimated generation in competition range
- Financially feasible
- Effective outreach



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

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

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

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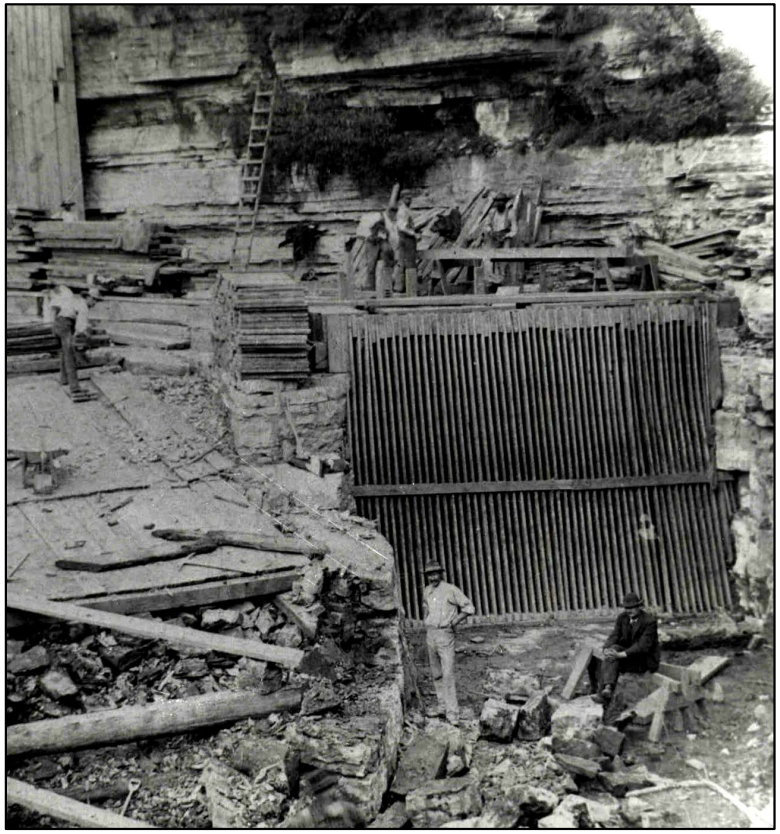
FUTURE WORK

- Review work with UGRADs judges and developers in Kentucky.
- Gather more site-specific data through surveying and inspections.
- Perform more detailed environmental assessment on Kentucky River.
- Obtain appropriate licenses, permits, and right of ways to begin development.



THANK YOU!

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