NAU DRAINAGE PLAN

NAU Water Buffalo Engineering

NAU WATER BUFFALO ENGINEERING

JIANGNAN YI

CONNOR KLEIN

YUZHI ZHANG

YI YANG

PROJECT BACKGROUND

- Drainage Study on NAU's Northern Campus on Eastburn Education (Bldg 27), Cline Library (Bldg 28) and Gammage (Bldg 1)
- Client: NAU Facility Services
- Redesign Hydraulic infrastructure surrounding Bldgs 1,27&28 to mitigate Stormwater damage.

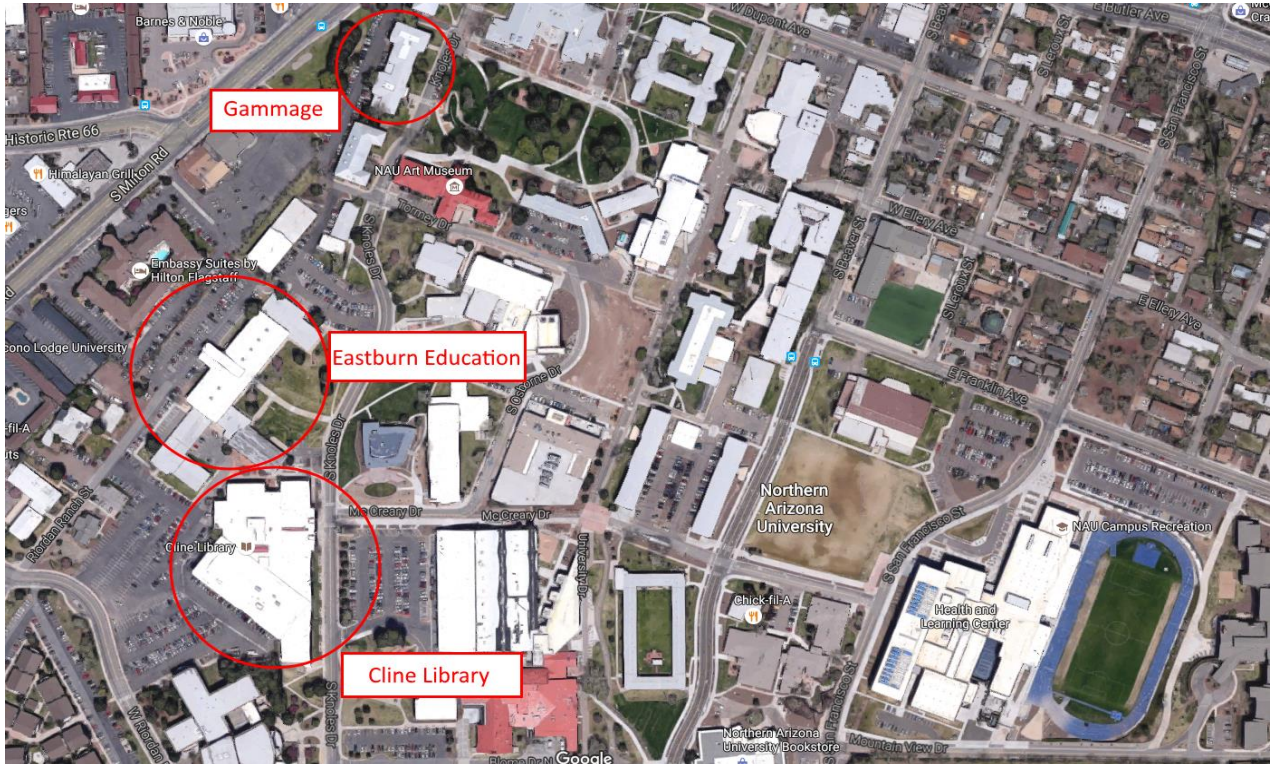


Figure 1: Location of Project Site on NAU's north campus

PRELIMINARY WORK AND SURVEYING

Gammage Survey

Basin Delineation-Gammage

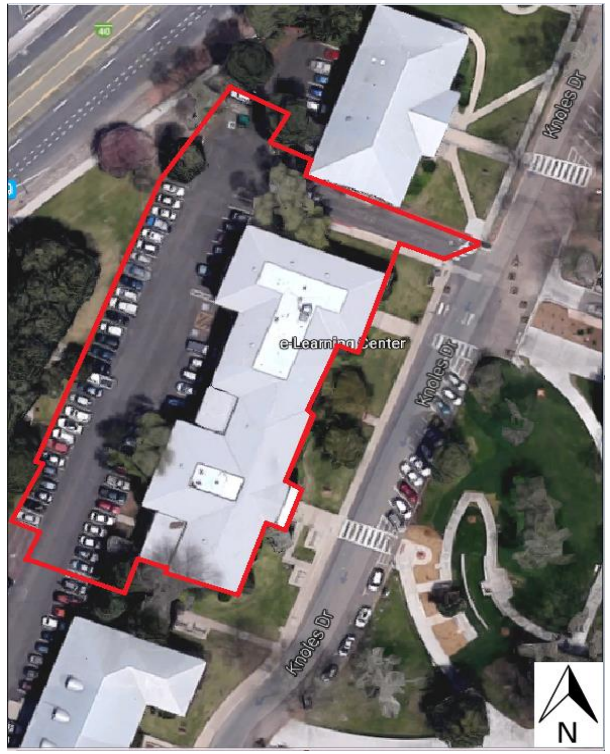


Figure 2: Basin Delineation for Gammage Building

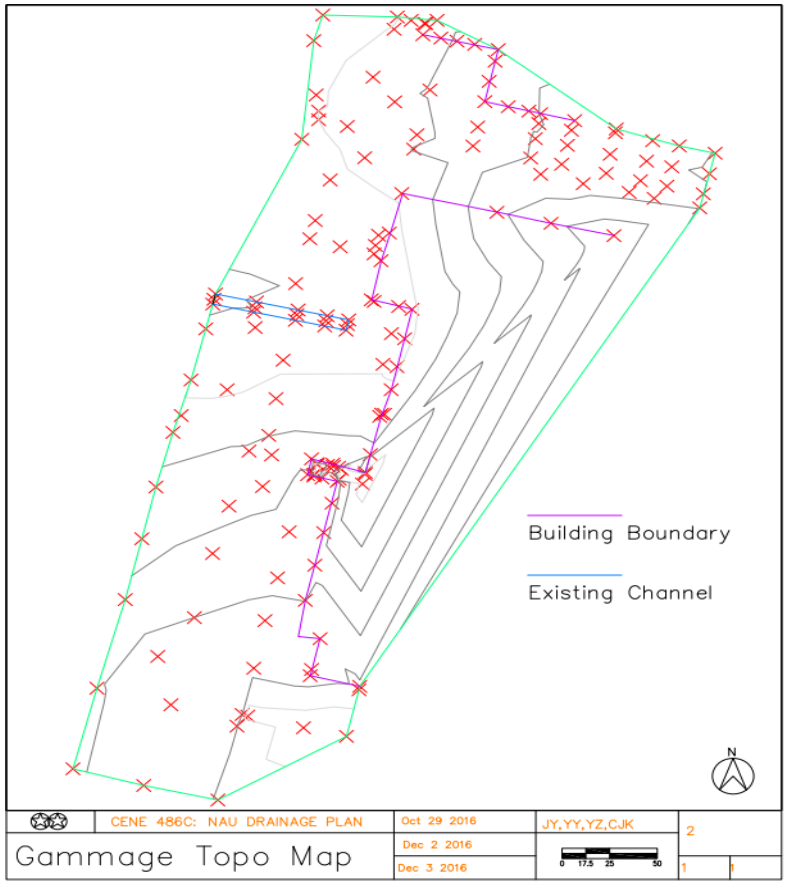


Figure 3: Topo map for Gammage Drainage Basin

PRELIMINARY WORK AND SURVEYING

Cline Library & Eastburn Education Building Survey

Basin Delineation-Eastburn Education & Cline Library

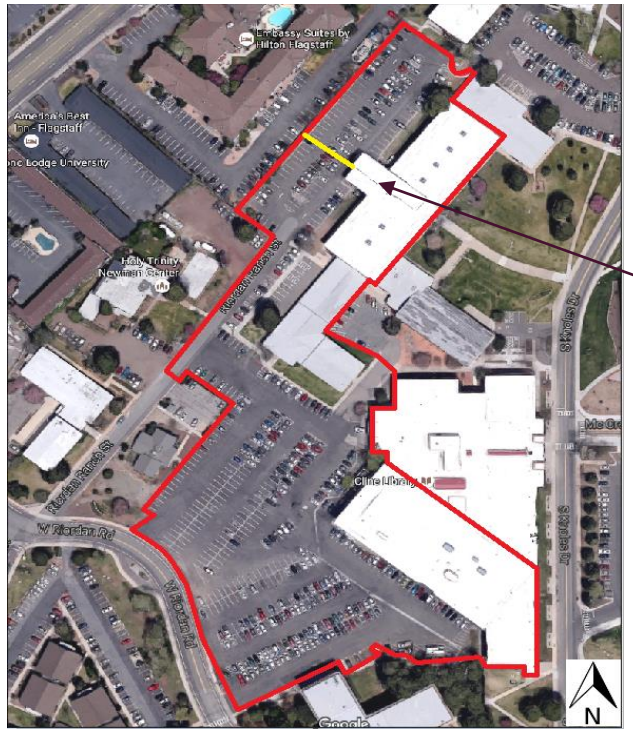


Figure 4: Basin Delineation for Eastburn & Cline Library Building

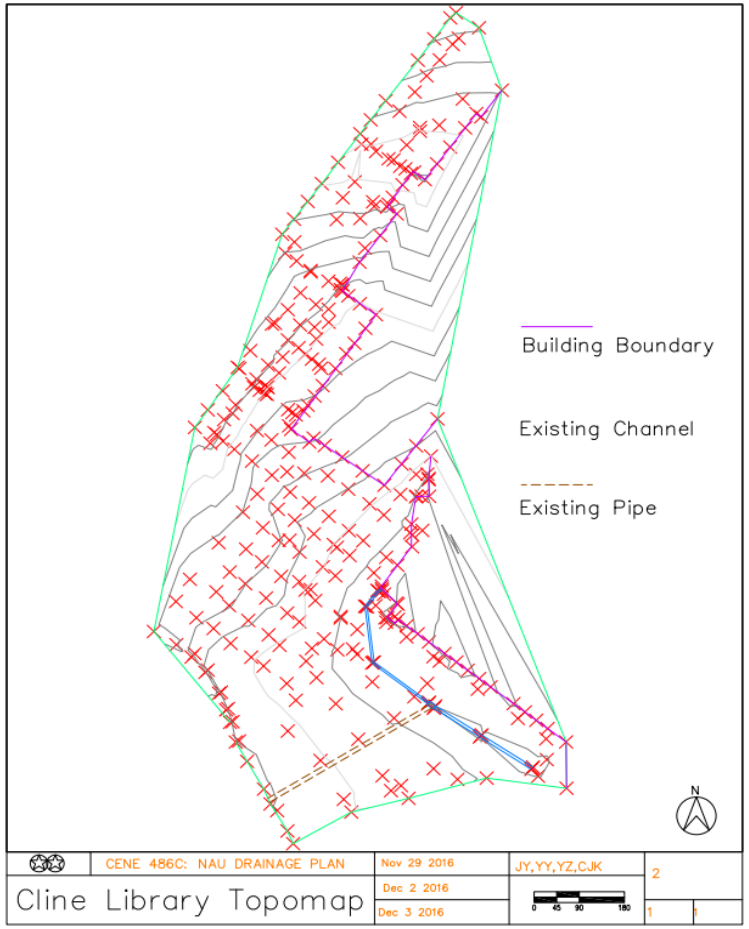


Figure 5: Topo map for Eastburn & Cline Library Building Drainage Basin

HYDROLOGIC ANALYSIS (GAMMAGE)

Gammage Watershed

All hydrologic analysis done through Rational method with weighted curve number as per City of Flagstaff Stormwater Design Manual

Rational Equation:

$Q=C\times I\times A$ x C_f

Q = maximum rate of runoff (cfs)
C_f= antecedent precipitation factor
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area of basin (acres)

Table 1: Rational Method Runoff Calculations for Gammage

	Surface Type 1	Runoff Coefficient "C"	Area (acres)	Surface Type 2	Runoff Coefficient "C"	Area (acres)	Rainfall Intensity (in/hr)	Cf	**Total Flow (cfs)**
10 year	Asphalt Parking Lot	0.95	0.47	Building Roof	0.95	0.42	4.5	1	**3.80**
25 year	Asphalt Parking Lot	0.95	0.47	Building Roof	0.95	0.42	5.34	1.05	**4.74**
50 year	Asphalt Parking Lot	0.95	0.47	Building Roof	0.95	0.42	6	1.05	**5.33**
100 year	Asphalt Parking Lot	0.95	0.47	Building Roof	0.95	0.42	6.66	1.05	**5.91**

Analyze for 25-yr storm

The product of "C" and "C_f" shall not exceed 1

HYDROLOGIC ANALYSIS (CLINE/LIBRARY EASTBURN)

Gammage Watershed

All hydrologic analysis done through Rational method with weighted curve number as per City of Flagstaff Stormwater Design Manual

Rational Equation:

$$Q = C \times I \times A \times C_f$$

Q = maximum rate of runoff (cfs)
C_f= antecedent precipitation factor
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area of basin (acres)

Table 2: Rational Method Runoff Calculations for Cline Library/Eastburn Education Watershed

	Surface Type 1	Runoff Coefficient "C"	Area (acres)	Surface Type 2	Runoff Coefficient "C"	Area (acres)	Surface Type 3	Runoff Coefficient "C"	Area (acres)	Rainfall Intensity (in/hr) "i"	Cf	**Total Flow (cfs)**
10 year	Cline-Eastburn Roof	0.95	2.89	Cline-Eastburn Parking Lot	0.95	4.64	Gravel Parking Lot	0.50	0.26	4.50	1.07	**35.08**
25 year	Cline-Eastburn Roof	0.95	2.89	Cline-Eastburn Parking Lot	0.95	4.64	Gravel Parking Lot	0.50	0.26	5.34	1.07	**41.62**
50 year	Cline-Eastburn Roof	0.95	2.89	Cline-Eastburn Parking Lot	0.95	4.64	Gravel Parking Lot	0.50	0.26	6.00	1.07	**46.77**
100 year	Cline-Eastburn Roof	0.95	2.89	Cline-Eastburn Parking Lot	0.95	4.64	Gravel Parking Lot	0.50	0.26	6.66	1.07	**51.91**

The product of "C" and "C_f" shall not exceed 1

HYDRAULIC ANALYSIS OF CURRENT SYSTEM (GAMMAGE)

Manning's Equation:

$$Q = VA = \left(\frac{k}{n}\right) \times A \times R_h^{\frac{2}{3}} \times \sqrt{S}$$

Q = Flow Rate (cfs)

V = Velocity (ft/s)

A = Cross-Sectional Area (ft^2)

n = Manning's Roughness Coefficient

R_h = Hydraulic Radius (ft)

S = Channel Slope (ft/ft)

k = conversion factor 1.49 for English units

Table 3: Manning's Equation to find capacity of current channel at Gammage

k	n	Channel Hydraulic Radius (ft)	Channel Slope	Channel Cross-Sectional Area (ft^2)	Max Channel Flow (Q) (cfs)
1.49	0.015	0.24	0.012	1.25	**5.26**

	Q (cfs)
25-year Storm	**4.74**

Capacity of current channel exceeds 25-yr storm flow

HYDRAULIC ANALYSIS OF CURRENT SYSTEM (CLINE/EASTBURN)

Manning's Equation:

$$Q = VA = \left(\frac{k}{n}\right) \times A \times R_h^{\frac{2}{3}} \times \sqrt{S}$$

Q = Flow Rate (cfs)

V = Velocity (ft/s)

A = Cross-Sectional Area (ft^2)

n = Manning's Roughness Coefficient

R_h = Hydraulic Radius (ft)

S = Channel Slope (ft/ft)

k = conversion factor 1.49 for English units

Table 4: Manning's Equation to find capacity of 2 ft. Diameter Pipe at Cline Library

k	n	Channel Hydraulic Radius (ft)	Channel Slope	Channel Cross-Sectional Area (ft^2)	Max Channel Flow (Q) (cfs)
1.49	0.027	0.50	0.005	3.14	**7.72**

	Q (cfs)
25-year Storm	41.62

Capacity far less than runoff for 25-year storms within the watershed

DESIGN ALTERNATIVES FOR CLINE LIBRARY/EASTBURN

Design 1 (Enlarge Pipe)

- Increase Pipe Size to Increase Storm Drain Capacity

Figure 6: Corrugated Metal Pipe Storm drain [6]

Design 2 (Green-roof)

- Apply a Green-roof to reduce Building Runoff while improving sustainability

Figure 7: Green roof [7]

Design 3 (Permeable Pavement)

- Repave the large Eastburn/Cline Library Parking Lot with permeable asphalt, decreasing surfaced runoff

Figure 8: Permeable Pavement [8]

DESIGN #1, CLINE LIBRARY (ENLARGE PIPE ONLY)

- Using the 25-year storm runoff from the Rational Method, Manning's Equation is used to back calculate the minimum pipe diameter to convey the flow

Table 5: Manning's Equation for minimum pipe diameter to convey a 25-year storm

Storm Event Flow (cfs)	k	n	Channel Hydraulic Radius	Channel Slope	Channel Cross-Sectional Area	Min Diameter (ft)
41.62	1.49	0.027	0.94	0.005	11.11	**3.76**

Closest Accommodating Pipe size is 48"

DESIGN #2, CLINE LIBRARY (GREEN-ROOF RUNOFF REDUCTION)

- If a Green-roof is applied, the runoff coefficient for all building roofs is reduced (.95 to .2), resulting in a lower Q from the Rational Method.

- Using the newly reduced Runoff flow for a 25-year storm, Manning's equation is used to back calculate the minimum pipe diameter to convey the flow

Table 6: Rational Method to determine 25-year storm for watershed with green-roofs applied to buildings

	Surface Type 1	Runoff Coefficient "C"	Area (acres)	Surface Type 2	Runoff Coefficient "C"	Area (acres)	Surface Type 3	Runoff Coefficient "C"	Area (acres)	Rainfall Intensity (in/hr) "i"	Cf	**Total Flow (cfs)**
25 year	Cline-Eastburn Roof	0.20	2.89	Cline-Eastburn Parking Lot	0.95	4.64	Gravel Parking Lot	0.50	0.26	5.34	1.1	**30.06**

Table 7: Manning's Equation for minimum pipe diameter to convey a 25-year storm after green-roof

Storm Event Flow (cfs)	k	n	Channel Hydraulic Radius	Channel Slope	Channel Cross-Sectional Area	Min Diameter (ft)
30.06	1.49	0.027	0.83	0.005	8.70	**3.33**

Closest Accommodating Pipe size is 42"

DESIGN #3, CLINE LIBRARY (PERMEABLE PAVEMENT REDUCTION)

- If permeable pavement is applied, the runoff coefficient for all parking lots is reduced (.95 to .5), resulting in a lower Q from the Rational Method.

- Using the newly reduced Runoff flow for a 25-year storm, Manning's equation is used to back calculate the minimum pipe diameter to convey the flow

Table 8: Rational Method to determine 25-year storm for watershed with green-roofs applied to buildings

	Surface Type 1	Runoff Coefficient (C)	Area (acres)	Surface Type 2	Runoff Coefficient (C)	Area (acres)	Surface Type 3	Runoff Coefficient (C)	Area (acres)	Rainfall Intensity (in/hr) "i"	Cf	**Total Flow (cfs)**
25 year	Cline-Eastburn Roof	0.95	2.89	Cline-Eastburn Parking Lot	0.5	4.64	Gravel Parking Lot	0.5	0.26	5.34	1.1	**30.53**

Table 9: Manning's Equation for minimum pipe diameter to convey a 25-year storm after permeable pavement reduction

Storm Event Flow (cfs)	k	n	Channel Hydraulic Radius	Channel Slope	Channel Cross-Sectional Area	Min Diameter (ft)
30.53	1.49	0.027	0.84	0.005	8.81	**3.35**

Closest Accommodating Pipe size is 42"

COST ANALYSIS

Table 9: Cost Analysis for All Designs

Cost analysis - Design 1					
Building	**Item**	**Unit Cost**	**Unit**	**Quantity**	**Cost ($)**
EastBurn-Cline Library	Cut/Fill	$2.58	Cubic ft	10452.0	$26,966.2
	Repave	$1.67	Square ft	1608.0	$2,685.4
	Pipe (D 48")	$65.00	ft	268.0	$17,420.0
			Total Cost		$48,596

Cost analysis - Design 2					
Building	**Item**	**Unit Cost**	**Unit**	**Quantity**	**Total Cost ($)**
EastBurn-Cline Library	Cut/Fill	$2.58	Cubic ft	9648.0	$24,891.8
	Repave	$1.67	Square ft	1608.0	$2,685.4
	Pipe (D 42")	$55.00	ft	268.0	$14,740.0
	Green Roof	$10.00	Square ft	125888.4	$1,258,884.0
			Total Cost		$1,485,678

Cost analysis - Design 3					
Building	**Item**	**Unit Cost**	**Unit**	**Quantity**	**Total Cost ($)**
EastBurn-Cline Library	Cut/Fill	$2.58	Cubic ft	9648.0	$24,891.8
	Repave	$1.67	Square ft	1608.0	$2,685.4
	Pipe (D 42")	$55.00	ft	268.0	$14,740.0
	Porous Asphalt (PA)	$0.75	Square ft	213444.0	$160,083.0
			Total Cost		$219,279.6

FINAL DESIGN RECOMMENDATION

- The cost analysis shows that Design 1, where nothing but the pipe size is changed, is the most cost effective and efficient design to control flooding at Cline Library/Eastburn education

Figure 9: 48” Corrugated Metal Pipe Storm drain to be used in parking lot [6]

STAFFING COST ANALYSIS

Table 10: Actual Staffing Cost

Personnel Cost Estimate of Services				
1.0 Personnel	**Classification**	**Hours**	**Rate ($/Hr)**	**Cost**
	SENG	172	135	*$23220*
	ENG	343	75	*$25725*
	LSVR	50	65	*$3250*
	AA	44	50	*$2200*
	Total Personnel			***$54395***
2.0 Equipment	**Hours Used**	**Renting Charge**		**Cost**
	50	$50/hr		***$2500***
Total Cost				***$56895***

SCHEDULE

Legend
Completed Behind Schedule
Completed On Time

Table 11: Project Schedule

Task Name	Start Time	Finish Time
1.0 Site Surveying	**Mon 8/29/16**	**Fri 9/16/16**
2.0 Site Mapping	**Sat 9/23/16**	**Mon 9/26/16**
3.0 Hydrologic Analysis	**Tue 9/27/16**	**Wed 10/5/16**
4.0 Hydraulic Analysis	**Thu 10/6/16**	**Wed 10/19/16**
5.0 Proposed Solutions	**Thu 10/20/16**	**Tue 12/13/16**
6.0 Cost Analysis	**Sat 12/10/16**	**Tue 12/13/16**
6.0 Impact	**Wed 12/14/16**	**Thu 12/15/16**
7.0 Project Management	**Mon 8/29/16**	**Thu 12/15/16**

IMPACTS

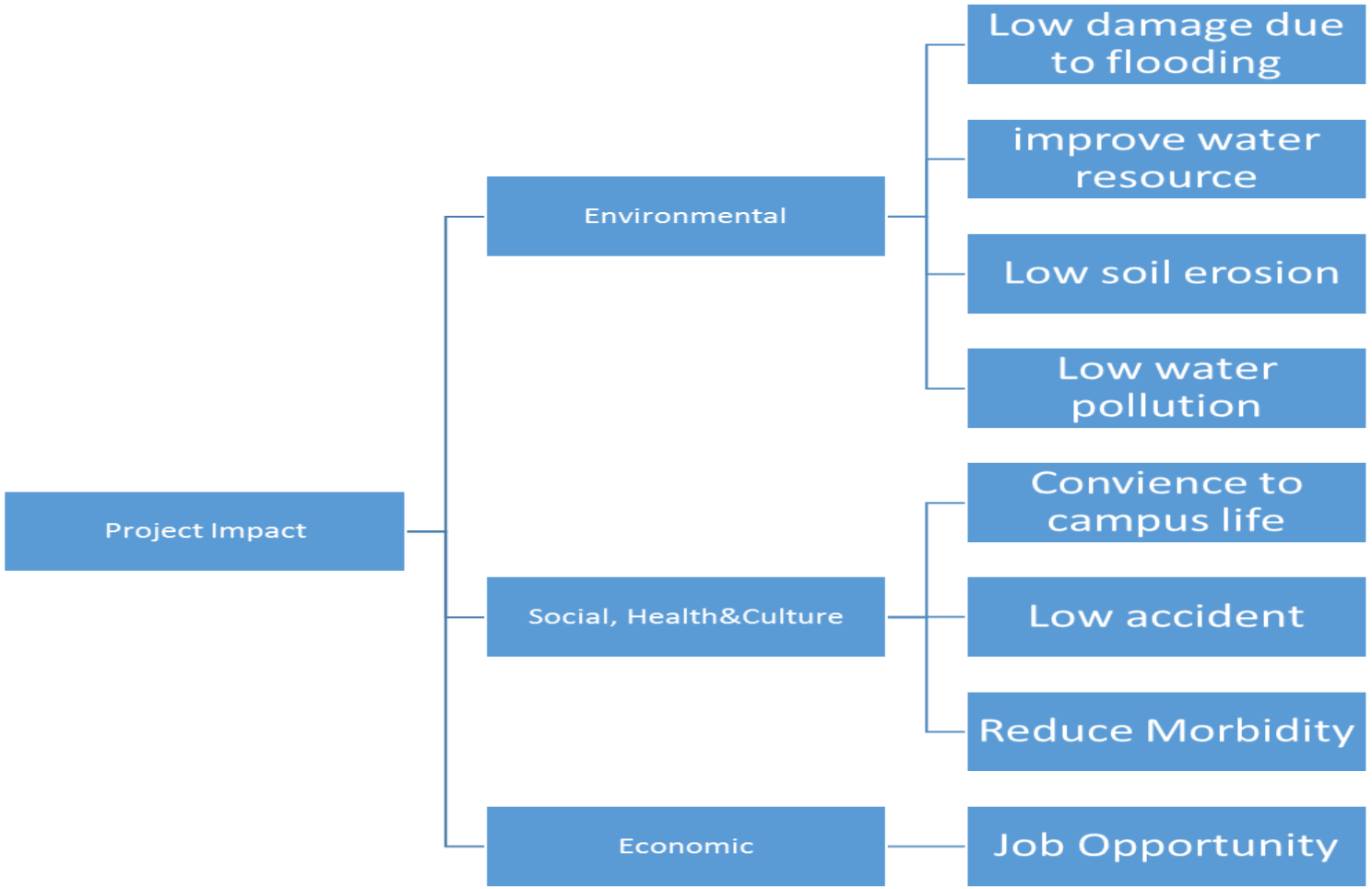
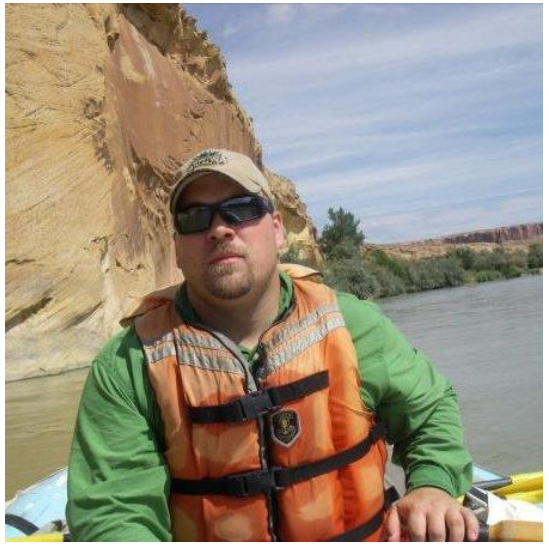


Figure 10: Impact Flowchart

ACKNOWLEDGEMENTS

- Technical Adviser #1
- Grading instructor



- Technical adviser #2

- Client: NAU Facilities

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QUESTIONS?