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NAU Water Buffalo Engineering

DRAINAGE PLAN OF NAU'S EASTBURN EDUCATION AND GAMMAGE BUILDINGS

FINAL PROPOSAL

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1.0 Project Purpose

The NAU department of Engineering and inspection has indicated that the Gammage and Eastburn Education buildings are currently experiencing flooding and in need of immediate flood mitigation. These building sites are susceptible to poor drainage conditions and can consequently suffer moderate flood damage during relatively minor flood events. Accordingly, the drainage plan for the Eastburn Education and Gammage watershed must be analyzed to minimize flood impacts and drain the site area as efficiently as possible. Although the site area lies within the Federal Emergency Management Agency (FEMA) designated floodplain for the Rio De Flag, this drainage study will not include an analysis of the Rio De Flag's 100-year flood plain.

1.1 Project Background

1.1.1 Gammage and Eastburn Education Drainage Issues

The Eastburn Education and Gammage buildings are located in Northern Arizona's (NAU) northern campus in a heavily urbanized area of Flagstaff, Arizona. According to a previous drainage study on NAU's campus performed by "Coe and Van Loo LLC", six buildings on NAU's north campus were marked individually for concern due to flooding risk [1]. Of the six sites designated as "high drainage concern", only Eastburn Education and Gammage have not received any flood mitigation design work. The drainage report lists the primary causes of flooding to be parking lot drainage and roof runoff, resulting in small-scale localized flooding concerns for the site area.

1.1.2 Location within Rio De Flag's Floodplain

NAU's campus is located south of the confluence of the Rio de Flag and Clay Avenue wash, two ephemeral streams draining over 67 square miles of watershed. According to FEMA, the Rio De Flag's 100-year storm floodplain will overflow into a significant portion of NAU's campus. As shown in Figure 1, FEMA's map of the 100-year floodplain of the Rio de Flag, 106 of the 490 acres of NAU's campus currently lies within the floodplain.

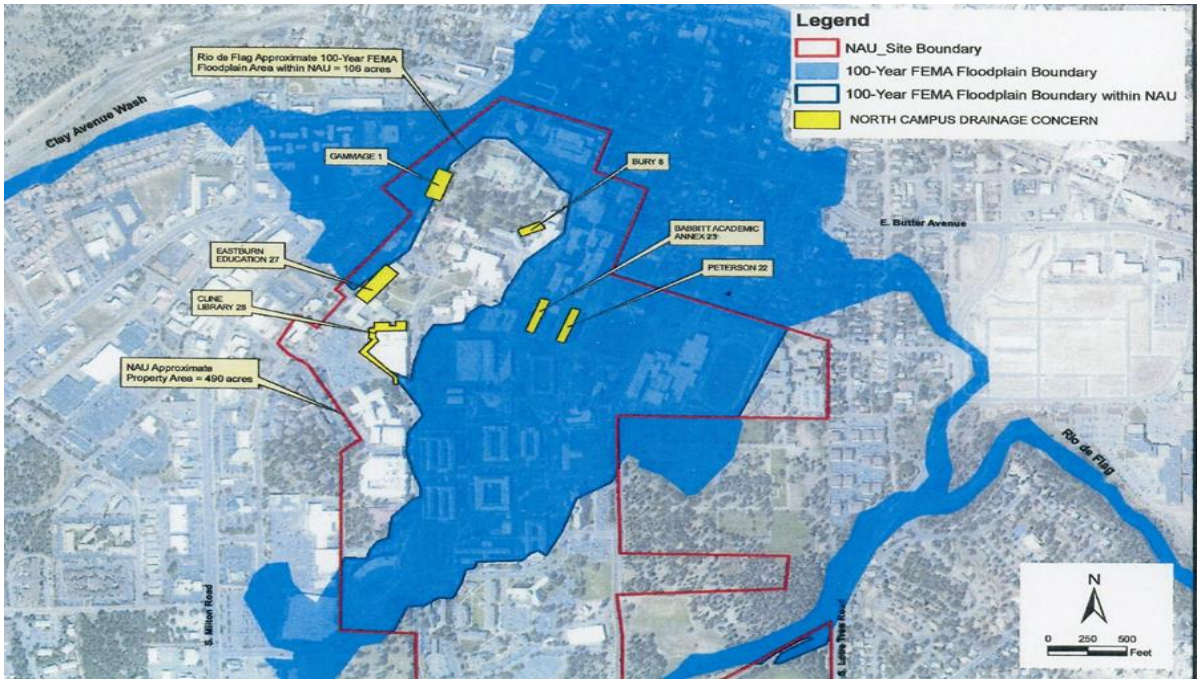

Figure 1: FEMA 100-year floodplain map of Flagstaff

1.2 Technical Considerations

1.2.1 Surveying and Site Mapping

In order to perform hydrologic analysis on the site, a land survey will be needed to determine site topography. Topographic maps allow for 3 dimensional data points of land surface elevation to be inputted into software for hydrologic analysis to determine flow volumes and velocities. Because there are no available topo coordinates suitable for Hydrologic analysis, the team will perform a field survey to create 6" contour maps for the site area. The coordinates obtained from these surveys will form the basis for the entire drainage study.

1.2.2 Evaluation of Current Hydraulic Infrastructure

The purpose of this project is to redesign the current NAU drainage system to function at a level mandated by the City of Flagstaff Storm Water Management Design Manual [2]. However, there are currently numerus pieces of hydraulic infrastructure in place and in use throughout the site. Using GIS files provided by the client, the design team will find all existing hydraulic structures located throughout the campus, where they will then be examined, measured, and evaluated for efficiency in storm water management. After calculations are performed to determine infrastructure capacity, the team will then decide to replace, expand, abandoned, or maintain all pieces of hydraulic infrastructure based on its current effectiveness and efficiency.

1.2.3 Calculation of Surface Runoff

Calculating surface runoff can be done in a variety of ways, however the team will focus on the SCS TR-55 method for determining surface flow. When calculating small catchment areas for

single site analysis, a hand calculated method known as the SCS Curve Number method is used. This method allows for considerably more accurate results than the commonly used rational method, while still being easily performed in the field by hand. The volumes gathered from these calculations will serve as the basis for the sizing of all hydraulic infrastructure.

1.3 Potential Challenges

1.3.1 Potential Sources of Problems

A major challenge that comes with the undertaking of a project of such complexity, is the large volumes of data necessary to be collected for an accurate analysis to take place. Collecting data on site tree cover, soil type, elevation, slope, and precipitation numbers for an area that has never been analyzed before will result in many hours spent in the field. An inventory of all hydraulic infrastructure and building drainage information needs to be gathered through field inspection where it can be documented and measured in 3 dimensions, adding additional field work to an already site intensive project.

1.3.2 Solutions to Potential Challenges

In regards to countering the large amounts of data required to conduct a drainage study, the team is benefited by the fact that the technical adviser, Charles Schlinger P.E., has vast experience in the field of drainage studies in the Flagstaff area and is a capable of providing invaluable insight that cannot be gathered anywhere else. In addition to having a very knowledgeable Technical Adviser, the team's client, Dennis McCarthy P.E., is also very educated in the field of drainage and floodplain management. Mr. McCarthy's office also holds large amounts of GIS files containing a variety of information on campus infrastructure and topography providing the team with valuable sets of data.

1.3 Stakeholders

Flooding events at the NAU campus can result in severe hindrances and a disruption in the daily routines of a significant portion of NAU's students and staff who use the buildings in the flooded area. The surrounding community will also be directed by the change in discharge patterns caused by Stormwater management on the site.

2.0 Scope of Services

This project will perform a drainage study on two flood prone buildings on NAU's north campus, Eastburn Education and Gammage. This project will study the drainage basin surrounding the Eastburn Education and Gammage 1 buildings on the northern end of NAU's campus, an estimated study area of 20 acres. The conducted drainage study will include the following elements:

- Site Surveying
- Site Mapping
- Hydrologic Analysis
- Hydraulic Analysis
- Proposed Solution
- Cost Analysis
- Project Management
- Deliverables (Design Reports, Website, etc)
- Impacts

2.1 Site Surveying

2.1.1 Preliminary Site Evaluation

This task includes visiting the site area and analyzing previously drawn contour maps of the locations to obtain a complete watershed to be surveyed in high detail in the next task.

2.1.2 Inventory of Current Hydraulic infrastructure

The NAU Water Buffalo Engineering team (WBE) will inspect all current pieces of hydraulic infrastructure within the site area during the site visit. This inspection will include measurements and notes regarding structure material, geometry, slope, and condition to be used in topo maps and runoff calculations.

2.1.3 Field Survey

The watershed area previously determined during the site visit will now be surveyed using a total-station based data collection method. This task will involve surveying the watershed to a degree of accuracy needed to perform runoff calculations. In locations where terrain changes frequently, the survey point density will increase to accurately display the change of topography. In areas where elevation change is relatively stagnant, the corresponding survey point density will decrease. The survey will be performed with a total station rented from NAU's engineering department.

2.2 Site Mapping

2.2.1 Preliminary Site Evaluation

Data gathered from the field survey will then be imported into Civil3D for topo-map creation. The site area will be modeled in 6" contours with high-detail displays of building, sidewalk,

road, parking lot, and existing hydraulic infrastructure locations. The final site map will be used to determine runoff volumes experienced by the site.

2.3 Hydrologic Analysis

2.3.1 City of Flagstaff Stormwater Management Design Manual

The City of Flagstaff requires that all 100-yr flooding event hydrologic analysis in urban areas be performed by way of Rational Method, SCS TR-55 Method, or HEC-1 method. In compliance with the Stormwater Management Design Manual, the major watershed will be analyzed with SCS TR-55 method.

2.3.2 Basin Delineation

Newly created topo maps along with satellite imagery and site visits will provide the necessary site makeup information to determine runoff calculations. The high level of terrain detail gathered from the field survey will allow the drainage basin to be divided into several sub-basins within the major drainage basin based upon their topographical makeup. The separate sub-basins will then be classified by their own individual runoff coefficients, slopes, and areas. The runoff volumes taken from the individual sub-basins can then be combined to create a surface runoff flow volume for the site more accurate than any previous method.

2.3.3 Time of Concentration (T_c)

The T_c value is the maximum time for surface runoff to travel from one point of the basin until its collection point. The value for T_c varies on depending on whether the flow is sheet flow, shallow concentrated flow, or open channel flow. The T_c value will be calculated from equations in the Flagstaff Stormwater Management Design Manual, however, if a T_c value of less than 10 minutes is obtained, a conservative value of T_c=10 minutes will be used. a The values necessary to calculate this variable will be obtained from the topo survey for land slope, flow length, and geometry, while the Manning's roughness coefficient "n" will be obtained from an onsite assessment of the basin's land surface.

2.3.4 Weighted Curve Number

Curve Number values will be calculated on a weighted average based upon their sub-basin areas in relation to their percentage of the entire watershed area. The curve numbers for the individual sub-basins will be interpolated from Table 3-4 in the City of Flagstaff Stormwater Management Design Manual.

2.3.5 Rainfall

Rainfall distribution for Flagstaff, Arizona uses a Type II distribution. Rainfall intensities can be determined from Table 3-2 in the City of Flagstaff Stormwater Management Design Manual, and the point precipitation frequency can be determined from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14. Rainfall intensity (I) will be interpolated from the 100-year storm frequency for a time of concentration of 10 minutes.

2.3.6 Model Creation

The Hydrologic study will be modeled in a complete HEC-HMS model encompassing all sections of previous Hydrologic analysis. The output from the HEC-HMS model will serve as the basis of all following hydraulic calculations.

2.4 Hydraulic Analysis

On completion of the hydrologic analysis, the sites current infrastructure will undergo a hydraulic analysis to determine the adequacy of current structures and locate points of flooding where storm water mitigation is necessary.

2.4.1 Existing Hydraulic Infrastructure Adequacy

The volume of surface runoff for the 100-year storm obtained from the Hydrologic analysis will be used as the required flow for conveyance of all infrastructure. Determination of a current hydraulic structure's capacity will be performed via hand calculations. Values for cross sectional area, slope, and roughness coefficients can be gathered from onsite measurements and interpolations from tables presented in the City of Flagstaff Stormwater Management Design Manual. Analysis of the current infrastructure through the FlowMaster Software will provide information concerning locations of inadequacies in the storm water conveyance system and sites for possible flood mitigation design work.

2.5 Proposed Solutions

Hydrologic and Hydraulic analyses will provide the team with sufficient information to propose possible design solutions.

2.5.1 Design Creation

Proposed solutions for flood mitigation will be designed to convey the calculated flows in accordance with the City of Flagstaff Stormwater Management Design Manual. Possible solutions may include modification or addition of storm drains, landscape grading, retention/detention ponds, channel construction, or any other hydraulic infrastructure.

2.5.2 Design Analysis

Proposed design solutions will be introduced into the hydrologic and hydraulic models for the watershed and re-analyzed to determine the effectiveness of the proposed solutions.

2.5.3 Final Design Recommendation

Upon analysis of all design alternatives, the design providing the most cost-effective solution for flood mitigation will be put forth for recommendation.

2.6 Cost Analysis

Analysis into project costs regarding material prices and quantity, construction, and contractor costs.

2.7 Project Management

2.7.1 Scheduling and Coordination

All team deliverables will be presented as they are show in the attached schedule in accordance with the critical path.

2.7.2 Meeting

Team meetings will take place on a weekly basis where ongoing progress on the project can be updated. Technical Adviser and Client meetings will take place on a bi-weekly basis or as needed.

2.8 Deliverables

2.8.1 50% Design Report

The 50% report should complete in the first half of a year and it should followed with client requirements and based on the project schedule. This report include background, project goal alternatives, and cost analysis. This report is due on October 25, 2016.

2.8.2 Final Design Report

The final report will conclude recommended solution, feasibility study and all other aspects related to project design. This report will be due on December 14, 2016.

2.8.3 Final Design Plan Set

The NAU Water Buffalo Engineering team will present the client with the drawings and plans for the proposed solution.

2.8.4 Final Design Presentation

The NAU Water Buffalo Engineering team will present the final design to the client on December 9, 2016.

2.8.5 Website

The project website will include four main pages, consisting of a Homepage, Information Page, Documents page, and an “Other” page. This website will consist of contact information, project description, design documents, and any other miscellaneous information critical to the project. The final website will be available to the public on December 9, 2016.

2.9 Impacts

Analysis into the broader impacts from the drainage plan project in relation to its social, environmental, and economic impacts.

2.10 Exclusions

The following hydrologic events will not be covered by the WBE group and hence forth not bound by any legal means to address or answer the following concerns.

- Flooding damage related to Rio-De-Flag floodplain
- Flooding damage to buildings not located within the designated site area

3.0 Project Schedule

3.0.1 Second Semester

The second semester will consist of actual design implementation. In order for completion of the project on a timely manner, the team will follow the critical path by beginning with a site survey and immediate creation of topography maps, followed by the Hydrologic/Hydraulic analysis resulting in the final design recommendation. The team will present design reports on the 10/25/15 (50% Design Report) and the 12/9/16 (Final Design Report) along with presenting the final design recommendation. Specific tasks and their exact due dates relating to the second semester of work can be found in the attached Gantt chart.

4.0 Staffing and Cost of Engineering Services

Table 1: Project Staff

Staff Positions		
Classification	**Code**	**Responsibilities**
Senior Civil Engineer	SENG	Oversight of all aspects of project design, analysis, implementation, and management.
Civil Engineer	ENG	Responsible for analysis and design work for all components of technical work (Site Mapping, Hydrologic & Hydraulic analysis, etc.)
Land Surveyor	LSVR	Responsible for field survey of site area and required to provide all engineers with survey coordinates necessary for software analysis.
Administrative Assistant	AA	Responsible for all clerical work and document preparation.

Table 2: Personnel Cost Estimate of Engineering Services

Task	SENG Hours	ENG Hours	LSVR Hours	AA Hours	Total Hours
1.0 Site Surveying					***40***
1.1 Preliminary Site Evaluation		8			
1.2 Current Hydraulic Infrastructure		8			
1.3 Field Survey			24		
2.0 Site Mapping					***75***
2.1 Topography Map Creation		75			
3.0 Hydrologic Analysis					***150***
3.1 Basin Delineation	14	35			
3.2 Time of Concentration (T_c)	6	8			
3.3 Weighted Curve Number	6	10			
3.4 Rainfall	6	10			
3.5 Model Creation	12	35			
4.0 Hydraulic Analysis					***101***
4.1 Existing Hydraulic Infrastructure Adequacy	8	24			
4.2 Storm Drain Analysis	24	45			
5.0 Proposed Solution					***120***
5.1 Design Creation	50	30			
5.2 Design Analysis	8	24			
5.3 Final Design Recommendation	8				
6.0 Cost Analysis					***24***
6.1 Materials Cost	2	10			
6.2 Cost of Implementation	2	10			
7.0 Impacts					***8***
7.1 Social, Economic, and Environmental	2	8			
8.0 Project Management					***76***
8.1 Scheduling & Meetings	1			8	
8.2 50% Design Report	4	8		8	
8.3 Final Design Report	8	12		16	
8.4 Final Design Presentation	4	4			
8.5 Website				4	
Total (Hours)					***599***

Table 3: Total Project Cost Estimate

Personnel Cost Estimate of Services				
1.0 Personnel	**Classification**	**Hours**	**Rate ($/Hr)**	**Cost**
	SENG	173	135	*$23,355*
	ENG	372	75	*$27,900*
	LSVR	40	65	*$2,600*
	AA	38	50	*$1,900*
	Total Personnel			***$55,755***
2.0 Equipment	**Hours Used**	**Renting Charge**		**Cost**
	24	$50/hr		***$1200***
Total Cost				***$56,955***

5.0 References

[1] COE AND VAN LOO L.L.C., "Northen Arizona University North Campus Drainage Concerns - Phase I", Flagstaff, 2013.

[2] City of Flagstaff Engineering Division Stormwater Management Section, "CITY OF FLAGSTAFF STORMWATER MANAGEMENT DESIGN MANUAL", *Flagstaffstormwater.com*, 2016. [Online]. Available: http://www.flagstaffstormwater.com/DocumentCenter/View/16. [Accessed: 11- Feb- 2016].