On the Development of a Sustainable Stormwater Management System

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Abstract
In an effort to inculcate independent thinking in students, an opportunity to think creatively on a real world problem-how the occurrence of hurricanes regularly affects various coastal regions was introduced in the water resources engineering course in the undergraduate civil engineering program at our institution. Students were expected to demonstrate a learning methodology that consisted of discussion, examination, elaboration, and fulfillment of the design of a sustainable stormwater management system that aims at reducing a hurricane's impact. The design, assigned as a student term project, consisted of three components: shelterbelt, built-up earth mound and drainage system and was applied to study the protection of agricultural fields in the state of Florida during tropical storms. Students used many sources for retrieving information and developed original thoughts to solve the problem. Students were expected to provide a solution to the stormwater management by applying concepts such as water resources sustainability, surface runoff, stream flow routing, and stormwater control. The design helped in simulating the effect of rainfall intensity on surface runoff and percolation rate while measuring the mitigation of stormwater damages. Students presented their findings in the class regularly, and their work was reviewed, evaluated, and given feedback. At the end of their term-project, students presented a report that detailed their design on stormwater management for real life situations.

Introduction:
Teaching how to design systems is very important in water resources and environmental engineering courses. One of the prime objectives is to show the need for incorporating the subject material covered in traditional environmental engineering courses within a design framework. In this way, the importance, relevance and application of water resources and environmental engineering courses can be highlighted. A Project-Based Learning (PBL) approach is extended wherein the knowledge acquired in the undergraduate water resources engineering course is utilized to devise a stormwater management scheme. The goal of the project is to accentuate the significance of assessing students' designing skills attained in the coursework in the water resources engineering as well as environmental engineering courses. The project also aims to introduce students to the power of internet resources and computer technology, and quickly carry out the many iterative analyses often required at the detailed stages of design. In addition to this, it is recognized that PBL is important in developing student enthusiasm for engineering and can therefore provide a mechanism for maintaining the required levels of interest throughout the course [1].Design projects are often carried out with students working in groups thus helping them develop teamwork and communication skills. One of the major advantages of PBL over traditional formal lecture based approach is that it is student-centered, requiring active learning rather than the passive acquisition of information through lectures. The importance of authenticity in effective design teaching has been highlighted by other authors who argue that the creation of an artifact or system designed is an essential part of the educational process [2].It offers the opportunity of assessing an existing design through an auditorfor producing a new prototype that would not normally be possible within a conventional

lecture course. Project-based teaching, therefore, presents the extra benefit to students of dealing with real problems and it is arguably more tangible than other teaching techniques. Although formal lectures provide an important means for acquiring knowledge, it is suggested that students often have more difficulty in understanding the material and realizing the relevance in course material when it is delivered in this way alone.

The educational purpose of PBL within water resources and environmental engineering courses are not always fully appreciated. Therefore, it is the aim of this paper to discuss the range of objectives and show how they may be achieved within the perspective of a particular stormwater management design project. A shelter belt system along with a stormwater transfer management system was analyzed using calculations and equations taught in the class. The shelter-belt technology is used in Germany and the Netherlands for controlling stormwater[3]. It was combined with the most-advanced Japanese water transfer technology [4]. A group of students worked on stormwater management using different alternatives like shelter-belt technology and rainwater gardens and calculated various parameters. Students were encouraged to search for the information on the internet (scholar.google.com, usepa.gov and uspto.gov) and other sources. The instructor provided the required information and guidance. The project aims to demonstrate the importance of integrating the design process as well as to develop teamwork and communication skills in the water resources and environmental engineering courses.

The design process may be considered to comprise of the following well-established phases: project specifications, common conceptualization, demonstration, and detail. This process pertains largely to original designs, but aspects of the overall process are also relevant. The generation of design solutions requires some consideration of the original design process discussed above. However, the majority of the project is concerned with the detailed design phase. The design project considers a "real world" problem, i.e. stormwater management system and it is argued that such a problem plays an important part in sustaining student commitment which is vital for effective learning. This paper provides an overview of the integration of design skills in a water resources engineering course through a student-focused active learning.

Term-Project on Stormwater Management System

A term-project with the following components was conceived based on the interest of a group of students:

a. Using shelter-by-technology for effective stormwater management.
b. Use of rainwater garden for stormwater management.
c. Designing stormwater management for rural areas.

Students were required to choose their topic at the beginning of the semester and carry out a literature review and seek information by exploring all internet resources.

<u>Objectives:</u> The ultimate aim for the students is to establish a strategy for dealing with stormwater damages due to hurricanes (e.g. Katrina, Harvey). The aim is achieved by ensuring the following specific objectives are met:

- To use rainfall data.
- To estimate runoff based on the current features for a particular site.
- To explore possible solution for the problem.
- To calculate various parameters manually.

The design project is structured in this way to ensure that particular educational objectives are achieved, and these are discussed for each of the above items in a later section.

<u>Methods:</u> The design project is carried out over a period of 15 weeks in the semester system with a total of 36 hours allocated for the project. The project was divided into four phases. The first phase involved the discussion of the project specifications between the instructor and students. Students used the discussion board forum of the Blackboard course management system to discuss topics related to hurricanes. During the third session, students came up with their interested project topic selection. If for any reason students were unable to come up with a topic, the instructor helped them by suggesting alternative topics. Students were given specifications and guidelines on a weekly basis depending on the progress they made on their project. At the beginning of the second session, it is expected that students will generate a conceptual diagram along with data and tables, which can be utilized towards laying out the flow of the project. In the second session, students are expected to identify all the necessary specifications and to comment on their effect on the success of their projects. This is carried out by means of discussions and a detailed literature review during the second session with the instructor. By the start of the third and final sessions, students are required to present their findings in the class. In the fourth session, they were required to write the final report, which received comments by the instructor.

<u>Assessment/feedback:</u> The work of the students is assessed by a term project report that shows details of all the hand calculations and details of the proposed design. A project report instructions and rubric were provided by the instructor to the students in the beginning of the semester when students came up with the project topics. Their final presentation is assessed according to a presentation rubric, which is also posted. Assessment is carried out in particular to identify the following:

- The ability to generate a simple model for a complex stormwater problem to enable realistic operating conditions to be calculated.
- The ability to employ environmental and water resources engineering concepts.
- The ability to interpret the results obtained.
- The ability to produce a well-structured technical report in which arguments are put forward cogently and design decisions are justified.

Feedback to the students takes place throughout the course of the project through discussions with the instructor and detailed comments relating directly to the students' reports.
Educational objectives:

- Use of design, knowledge, and making simplified assumptions.
- USEPA software Stormwater Management Model (SWMM) data generation and manual calculations for verification.

Details:
The use of shelter-belt along with water transfer system can greatly reduce the devastation to agricultural fields caused by hurricanes. Students used Florida coastal county Miami-Dade for their studies and extracted data from a county website. The Miami-Dade County was hit by Hurricane Irma in the fall of 2017. Shelterbelt is an effective technology which can provide an effective barrier against the wind speeds ranging from 39-73 mph in Florida [5].Shelterbelts

consistof trees and shrubs along a farm field to prevent damage caused by strong winds and soil erosion. They work to reduce wind speeds and provide safety to the leeward side of the belt as well as aid in flood control by helping surface water run-off through increasing the rate the water is absorbed into the soil. The design of a shelterbelt is determined by factors including the height, density, row numbers, species composition and spacing. Shelterbelts have been proven to be effective but if designed incorrectly they have detrimental effects on farm productivity. In this project, students designed a shelterbelt on a mound to create a barrier to further protect from flooding. Existing protection systems are not effective and not diverse enough to protect from all the aspects of storms.

Accompanied with an effective shelterbelt, a drainage system would work to protect anagriculture field from storm damage on all angles. Agricultural land drainage consists of technical strategies and hydraulic structures that allow the excess water to be removed. Students used an underground drainage systems designed with perforated piping buried within the mound created under the shelterbelt. Subsurface drainage systems work to lower the water table in unconfined aquifers by collecting water in a drainpipe network where the collected water is removed from the drained area. It will consist of plastic tubes with perforations buried in the mound surrounding the agriculture field and will connect to the drainage system that is already in place for that township. As the piping will be buried within the mound, it will be at ground level and thus easily attached to the existing drainage system.

A subsurface pipe drainage system paired with a shelterbelt surrounding an agricultural field in Florida would work to protect the crops from tropical storm winds and flooding and save a multi-billion dollar industry that is vital to the success of the U.S. economy. Through designing this innovative and flexible flood management system, it is possible to protect the existing agriculture industry in Florida as well as provide a versatile system that can be adapted to use almost anywhere it is needed.

Design and Site Plan

It was taken into consideration the design of the drainage system to surround an agricultural field. The goal of this system is to remove the excess water from the field that occurs during tropical storms as well as maintain the sustainability of the soil to be productive in crop production. This system would be comprised of corrugated polyethylene tubes. This would ensure durability, flexibility and the strength of the pipes as well as allowing the runoff to percolate through the holes. In the project, students used a main drain pipe combined with attached drain pipes to collect the water and drain it into the city's existing drainage system.

Students collected soil information for providing the strong foundation for their project decisions. The soil in this county consists mainly of Candler soil types which fall under the category of a sandy loam soil type. They range from excessively-towell-drained, are comprised largely of sand, and maintain slopes of 0 to 2% grade [6]. For a sandy loam soil with moderately high permeability and excellent drainage such as this, students chose to place drains at a depth of 4.0 to 4.5 feet [7]. The drainage system installed into a mound, therefore to allow for pipes to be at a depth of 4.0 to 4.5 below the surface:our mound should be designed to a height of 5 feet. The drainage coefficient of 0.5 was used because the soil type is mainly mineral. To determine the drain size students used data collected with drainage coefficient of 0.5 in/day with a percent

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grade of 1% with a polyethylene drain type for a 200 acre field. This will give us a required drain size diameter of 15 inches.

This system is installed into a 5-foot mound surrounding the field to protect from flood damages, accompanied by a shelterbelt to be designed on top of the mound to further aid in percolation of water into the soil, soil retention, and protection from wind damage associated with tropical storms. The design of shelterbelt consists of determining the height, density, number of rows, species, and spacing of the trees involved. In order to optimize the effectiveness and height of shelterbelt, the slash pine was chosen as its foundation species. This species is native to Florida and thus will have a higher success rate and high availability. It also reaches the second highest height, reaching 80 feet at mature height. Slash pine also has a fast growth rate and reaches 8 to 10 feet tall at 2 years old [8]. It is successful when spaced between 3 and 6 feet apart;students chose 4 feet as to provide a dense belt without risking the trees being too close to hinder growth. To partner with this species, use of Simpson's stopper is recommended. This species is readily available and reaches heights of 20 feet at maturity and 6 feet after 2 years. They are successful when spaced between 3 and 5 feet which fall in with a chosen spacing of 4 feet. The model requires planting the belt on top a mound to not require an excessive amount of soil, so using two rows of trees spaced 6 feet apart from each other should be enough. This belt will provide a good density of around 40-60% and protect the field from wind damages. It was also found that water infiltration rates are 60 times higher in areas with tree shelterbelts than without; therefore this belt paired with a subsurface drainage system should successfully protect an agricultural field from flood damages.

Table 1: Drain Spacing

		Drain spacing			
Soil type	**Subsoil permeability**	**Fair drainage 1/4 in.**	**Good drainage 3/8 in.**	**Excellent drainage 1/2 in.**	**Drain depth**
			feet		feet
Clay loam	Very low	70	50	35	3.0-3.5
Silty clay loam	Low	95	65	45	3.3-3.5
Silt loam	Moderately low	130	90	60	3.5-4.0
Loam	Moderate	200	140	95	3.8-4.3
Sandy loam	Moderately high	300	210	150	4.0-4.5

Tables retrieved from[9]

The Florida Department of Transportation (FDOT) is responsible for standards for storm drain hydrology and hydraulics. Their drainage manual that goes into effect in January 2018 states their standards and data for Florida storm drainage.

Table 2: Parameters and Requirements by FDOT

Parameter	**Requirement**	**Comments**
Design storm frequencies of storm drain system for general drain	3 years	All structures including mixed systems must meet the three-year design frequency.
Design Tailwater	Elevation of hydraulic grade line of the system at the connection for the design storm event	Used to determine the sizing of the storm drain conduits
Time of concentration	Minimum allowable is 10 minutes	To maintain the response of the watershed to the rain event
Pipe slopes	Minimum of 2.5 f/s & maximum of 15 f/s. Minimum physical slope of 0.1%.	Slope must produce velocity within this range when the storm drain is flowing full
Manning's roughness coefficients	Concrete Box Culverts, n=0.012 Concrete pipes, n=0.012 Re-corrugated metal pipes, n=0.022 PVC smooth interior, n=0.012	To be used in manning's equation to determine other values
Longitudinal Gutter Grade	Minimum grade is 0.3%	Longitudinal gutter grade cannot exceed 0.3% as it would cause flow to be too high
Pipe size	For trunk lines, minimum =18 in. For exfiltration trench pipes, minimum= 24 in.	Does not apply to connections from external, private stormwater management facilities

All data retrieved from[10]

Calculations and Computations

Rainfall Intensity: Stormwater management modeling depends on rainfall intensity, which was calculated as follows:

$$i = \frac{a}{(b+d)}$$

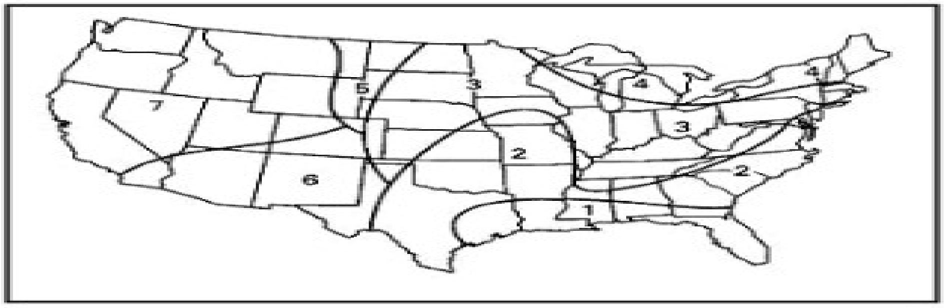
i = rainfall intensity in/h or cm/h; d = duration of storm, min; a, b, = constants varying from place to place

It was determined that the study area falls in Zone 1 of US [11] and has values of a and b as follows:

2 yr return period: a= 209, b=30; 5 yr return period: a=247, b=29; 10 yr return period: a= 300, b=36

25 yr return period: a= 327, b=33; 50 yr return period: a= 315, b=28; 100 yr return period: a= 367, b=33

Based on the data they used Steel equation for calculating rainfall for different periods.



U.S. Regions for STEEL Equation

Using the STEEL equation ($i = a/(d + b)$)

Figure 1: US regions for Steel equation[11]

Table 3: Steel equation constants for USA[11]

Steel Equation Constants for U.S. Regions (i = in/hr)								
return period	Equation Constants	U.S. Region						
		1	2	3	4	5	6	7
2	a	209	140	102	70	70	68	32
	b	30	21	17	13	16	14	11
5	a	247	190	131	97	81	75	48
	b	29	25	19	16	13	12	12
10	a	300	230	170	111	111	122	60
	b	36	29	23	16	17	23	13
25	a	327	260	230	170	130	155	67
	b	33	32	30	27	17	26	10
50	a	315	350	250	187	187	160	65
	b	28	38	27	24	25	21	8
100	a	367	375	290	240	240	210	77
	b	33	36	31	28	29	26	10

Table 4: Duration and Rainfall intensity

			Rainfall Intensity			
Duration	2ys	5yr	10 yr	25yr	50 yr	100yr
0	6.96666667	8.51724138	8.33333333	9.90909091	11.25	11.1212121
5	5.97142857	7.26470588	7.31707317	8.60526316	9.54545455	9.65789474
10	5.225	6.33333333	6.52173913	7.60465116	8.28947368	8.53488372
20	4.18	5.04081633	5.35714286	6.16981132	6.5625	6.9245283
30	3.48333333	4.18644068	4.54545455	5.19047619	5.43103448	5.82539683
40	2.98571429	3.57971014	3.94736842	4.47945205	4.63235294	5.02739726
50	2.6125	3.12658228	3.48837209	3.93975904	4.03846154	4.42168675
60	2.32222222	2.7752809	3.125	3.51612903	3.57954545	3.94623656

In order to understand intensity on a time scale they plotted intensity against duration, which is shown in figure given below:

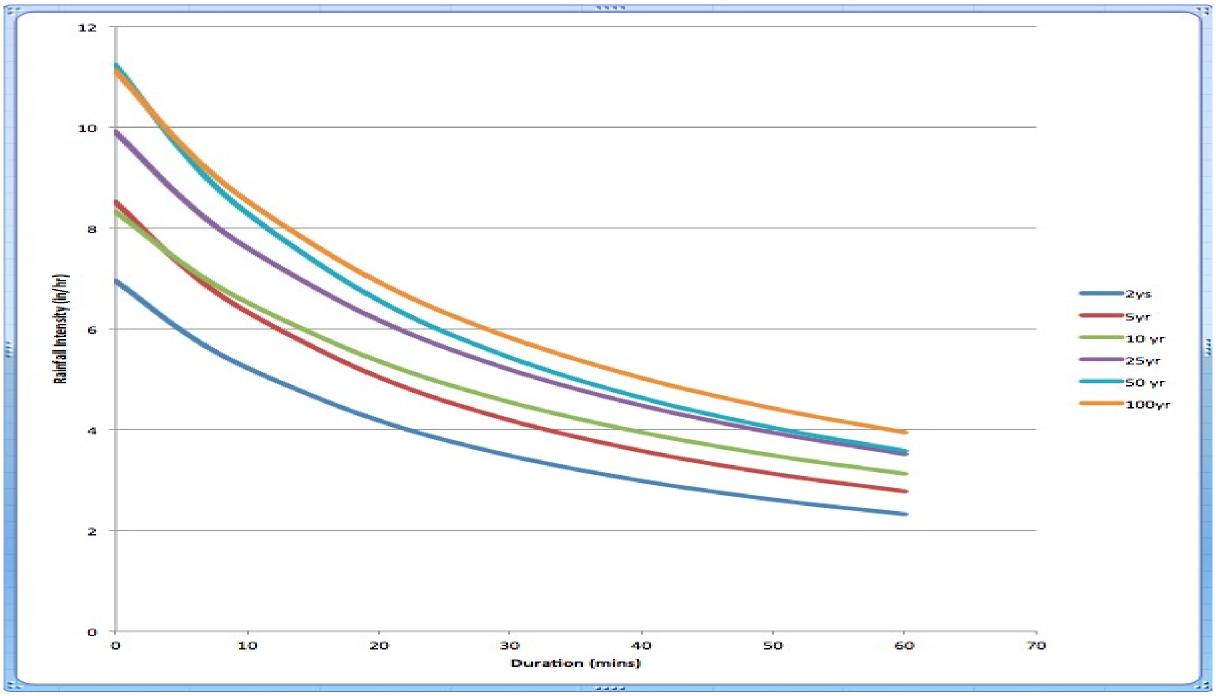


Figure 2: Rainfall intensity vs duration

Time of concentration:In order to understand the relation of rainfall intensity to the stormwater event probability, time of concentration was calculated as follows:

$t = ti + ts$; $ts = L/V$; $ti = C(L/S\ i^2)^{1/3}$

L=distance of overland flow, ft; S=slope of land, ft/ft; i=rainfall intensity, in/h
C=coefficient=0.5 for paved areas; =1-0 for bare earth; =2-5 for turf
V=average flow; L=length

$ti = C(L/S\ i^2)^{1/3}$

C=1.0; L=500 ft (assumed distance to city drainage system); S=1% grade (from soil analysis record); i=5.2 in/hr (use for 25 year return period and average duration of 30 mins)

$ti = 1.0(500/(1 \times 5.2^2)^{1/3}$
ti= 2.65 mins

ts= L/V; L=500 ft (assumed distance to city drainage system);
V=6 ft/sec (average design velocity for storm drains, range from 3 to 10 ft/s)
ts=(500)(6)
ts=3000 sec = 50 mins

T= ti + ts; T= 2.65 +50; T=52.65 mins

It was found that the time of concentration was ~53min, which suggests a need for design ofstormwater management system.

duration	Intensity for 25 yr return period	Time of Concentration (min)
0	9.909090909	51.71110943
5	8.605263158	51.87808722
10	7.604651163	52.03773528
20	6.169811321	52.33927166
30	5.19047619	52.62194361
40	4.479452055	52.88969278
50	3.939759036	53.14521346
60	3.516129032	53.3904499

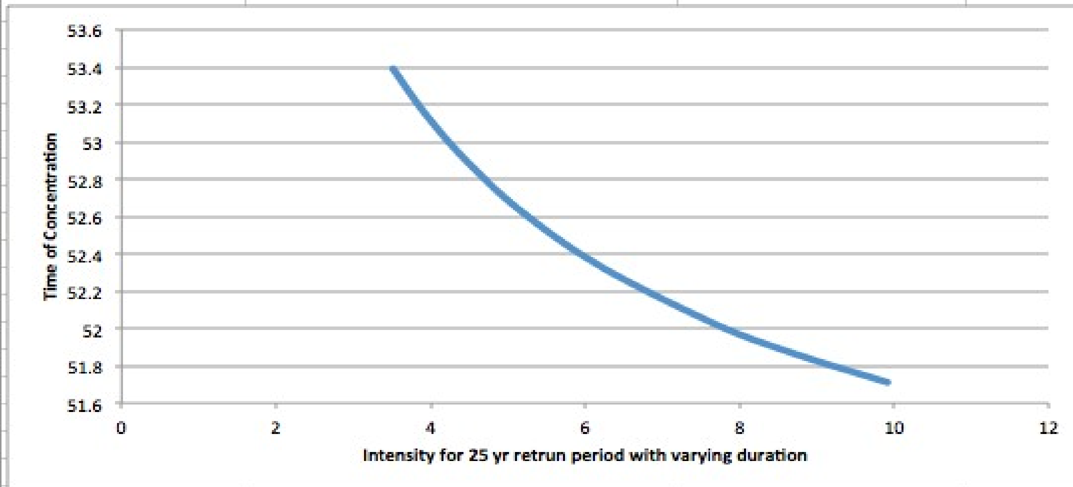


Figure 3: Time of concentration vs duration

Peak Runoff:Peak runoff from rainfall was calculated in order to understand the extreme event of maximum rainfall in the study area.

Q=CIA; Q =peak runoff from rainfall, ft^3/s; C=runoff coefficient, dimensionless

I =rainfall intensity, inches rain/hr

I=5.2 in/hr (use for 25 year-return period and average duration of 30 mins)

A =drainage area, acres; A=200 acres (average area for crop land in Florida)

Q=(1.0)(5.2in/hr)(200acres)

Q=1040 ft^3/s

Water Depth in System:Based on the peak runoff, water depth in system was calculated using the continuity equation:

$Q = VA$, where $V=(k/n)\ (s^{1/2})(A/P)^{2/3}$; Q=stormflow at inlet ($ft^3/s$);

Q=1040 ft^3/s

k=given at 1.49 for English units

n=roughness coefficient; For Corrugated PVC with corrugated inner walls, 0.011

s=longitudinal slope; s=1% grade (soil analysis record)

A=flow area of pipe

$A=\pi(15/2)^2 = 176.7\ in^2 = 1.227\ ft^2$

P=wetted Perimeter of pipe (portion of circumference touching water)

$1040 = (1.49/0.011)\ (0.01^{1/2})(1.227/P)^{2/3}(1.227) \Rightarrow 1040 = 16.6(1.227/P)^{2/3}$

$62.57 = (1.227/P)^{2/3} \Rightarrow 495 = 1.227/P$

$P=0.0025\ ft \Rightarrow P=0.03\ in$ (out of the total circumference of 47 in)

Parshall Flume:

An alternative design of this system could be a mound that covers a larger area of land with a network of drainage systems within that include inlets for collection of stormwater drainage to drain a large area of land, rather than a barrier that prevents water from entering an area with a singular pipe that gathers water through seepage. In this scenario, a raised area of land with dimensions of 100 m long by 100 m wide and 1 m tall consisting of a network of 16 drainage pipes was considered. The computations that follow are working to convert the 16 channels into 3 channel pipes.

Referring to rainfall intensity derived in the beginning of this section. Students will compute the stormflow values in ft^3/s for all duration's periods:

Table 5: Stormwater flow and duration

Duration	Stormflow (Q, ft3/s) for 25 yr return period
0	1981.818182
5	1721.052632
10	1520.930233
20	1233.962264
30	1038.095238
40	895.890411
50	787.9518072
60	703.2258065
	AVERAGE= 1235 ft3/s

This yields values of:

Peak Flow for Florida=1,982 ft^3/s => 56 m^3/s

Average Flow for Florida=1,235 ft^3/s => 35 m^3/s

Minimum Flow for Florida=703 ft^3/s => 20 m^3/s

Flow-through Velocity= 1 ft/s => 0.3 m/s

In order to understand different designs, student calculated a water transfer system using 3 and 16-channel respectively.

$A_{\text{Peak, 3 channel}} = 56/(3 \times 0.3) = 62.2\ m^2$;$A_{\text{Peak, 16 channel}} = 56/(16 \times 0.3) = 11.7\ m^2$

$A_{\text{Average, 16 channel}} = 35/(16 \times 0.3) = 7.3\ m^2$; $A_{\text{Minimum, 16 channel}} = 20/(16 \times 0.3) = 4.2\ m^2$

Using equations:

$Z_o = cw^2$; $A = ⅔\, wZ_o$, where,Z_o = height, w= width, assume starting value of 1.5 m, A=area of parabola, c=constant

For peak through 3 channels,$62.2 = ⅔\,(1.5)Z_o \Rightarrow Z_o = 62.2$ m

$c = 62.2/(1.5^2) \Rightarrow c=27.6$

Now, $Z_o = 27.6w^2$

For peak through 16 channels,

$11.7= ⅔\, w(27.6w^2)$; w=0.86 m

$Z_o = 27.6(0.86^2) \Rightarrow Z_o = 20.4$ m

For average through 16 channels,

$7.3= ⅔\, w(27.6w^2)$; w=0.73 m

$Z_o = 27.6(0.86^2) \Rightarrow Z_o = 14.9$ m

For minimum through 16 channels,

$4.2 = \frac{2}{3} w(27.6w^2)$; $w = 0.61$ m
$Z_o = 27.6(0.86^2) \Rightarrow Z_o = 10.3$ m

Table 6: Area and Stormwater flow

Area (m^2)	w (m)	Z_o (m)	Q (m^3/s)
62.2	1.5	62.2	56 (3 channel)
11.7	0.86	20.4	56 (16 channel)
7.3	0.73	14.9	35 (16 channel)
4.2	0.61	10.3	20 (16 channel)

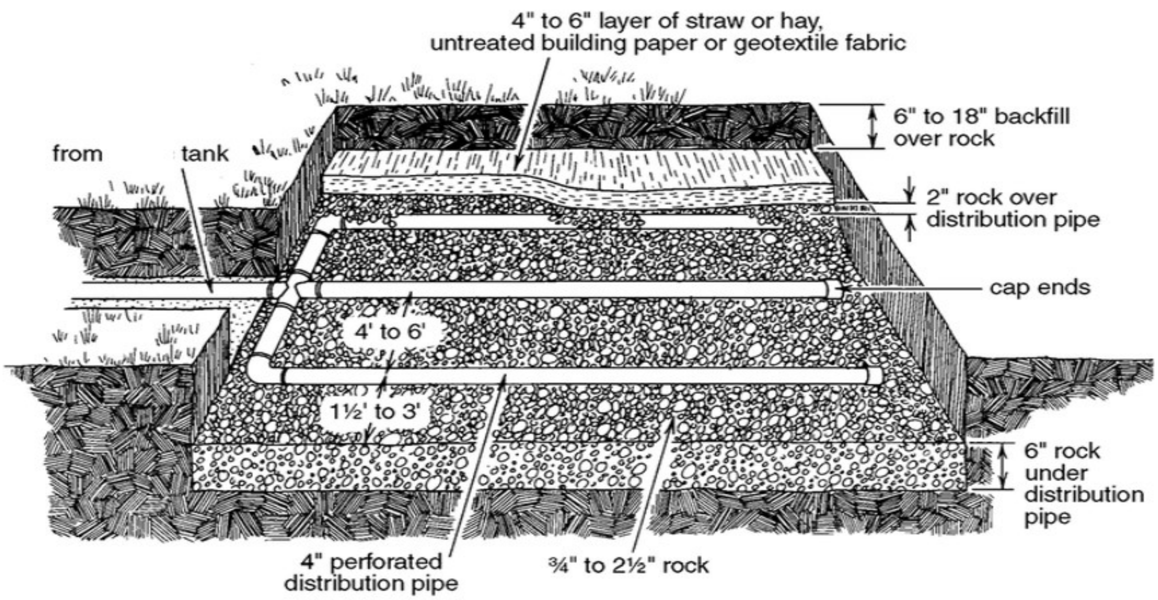


Figure 4: Typical mound configuration

A typical mound configuration based on the literature review is presented in the above figure.

<u>Summary of Parameters/Calculations:</u>
The pipe material and specification were calculated and collected from literature and are compiled in a tabular form as follows:

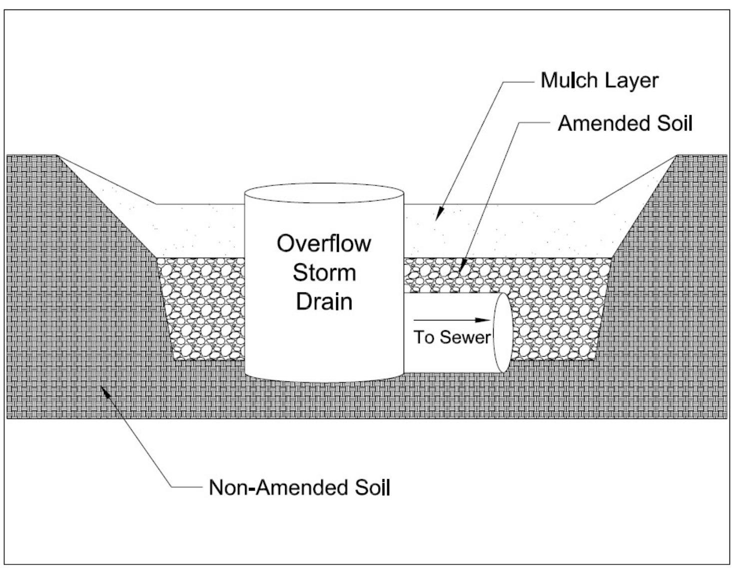
Table 7: Pipe material and specifications

Criteria	Values	Notes
Pipe Material	PVC	
Diameter	200 mm	
Max velocity	2.5 to 3.0 m/s	
Depth to Invert	1.8 to 2.4 m	

Slope	0.0033 m/m	
Q, flow	0.019 m^3/s	(Flowing full)
v, velocity	0.6 m/s	(Flowing full)
mean velocity	0.3 m/s	
Calculated velocity, v	0.2314 m/s	
Calculated flow, Q	0.012 m^3/s	
N	0.013	

Ground Drainage (Water Transfer System)
Water collected from the mound is proposed to join with the city's stormwater system. The drainage calculations are described as below:

I = 355.87 mm/month (according to "Climate Change Knowledge Portal")
  = 355.87 mm/month x (1 month/30 days) x (1 day/24 hrs) = 0.494 mm/hr
A = 10 m x 10 m = 100 m^2 = (1 x 10^{-4}) km^2; c= 1
Q= 0.278 (1)(0.494)(1 x 10^{-4}) = 4.94 x 10^{-2} m^3/hr = 1.37 x 10^{-5} m^3/s



(Figure 5: Design for Shelterbelt-Stormwater management system)
Soil properties were determined using the standard soil textural triangle.

Discussion and conclusions
The design project discussed in this paper had been run for six months, with some modifications as feedback became available. It is argued that the projects are successful in demonstrating the importance of environmental and water resources engineering within a design context. Furthermore, it provides an integrated approach combining computer technology, environmental and water engineering, and design for the consideration of a real design problem. In this way, it

is suggested that it is possible to maintain the students' interest and enthusiasm for environmental and water resource engineering through the use of project work. At the same time, this develops students' understanding of the required engineering and design principle. In addition, it develops students' skills in the use of computer technology.

Environmental and water resources engineering degree courses have been discussed in terms of the need for knowledge acquisition, the skills acquisition, and the development of understanding. The project described in this paper requiresknowledge acquisition, the accumulation of actual information, and the developing understanding of computer skills. The approach presented is effective for the development of understanding because it is student-centered, requiring active learning. It requires the students to express their understanding of concepts to get rapid feedback during the discussion. The process of carrying out design projects in this way is closer,therefore, to a tutorial approach to teaching and learning than to a lecturing approach. The disadvantage of the project-based approach largely relates to instructor and student time requirements. In addition, it is argued that within given design projects, only a limited domain of environmental and water resources engineering can be considered. The PBL approach to student learning, therefore, needs to be run in parallel with more traditional methods but cannot replace them.

The project discussed in this paper is highly suitable. It is argued for inclusion within conventional environmental and water resources engineering courses. This would then fulfill the purposes of both reinforcing the understanding of environmental and water resources engineering principles in a way that maintains the students' interest and enables the courses to be run in an integrated way with the design teaching. The importance of design as an integrating theme running throughout environmental and water resources degree courses has not been established.

There is growing concern among industrialists and employers of graduate environmental and water resources engineers of the way in which computer technology and real world application are used. The design project discussed in this paper addresses this issue directly.

The importance of reality in teaching engineering design has been discussed by several authors [12],since it is found that much greater impact and lasting effect on memory may be achieved if these students see the necessity for what they are doing for the real world. The present design projects considered a stormwater management problem and the students applied their knowledge obtained through several sources.

Students were evaluated and observed on a regular basis using the rubric scheme as mentioned earlier in this paper. All the students were confident in their presentations and their work was comparable to professional quality in the engineering field as evident from their calculations, figures, and their ability to extract information from the internet resources.

Limitations

This course was offered for the first time in Baker College, so we do not have any data to compare with traditional methods and previous courses.

Acknowledgements

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