Stormwater Management Plan

Pleasant Grove, AL

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Submitted To:

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Abstract

On April 27, 2011, Pleasant Grove, AL was hit by a level 4 tornado. In addition to the numerous homes that were lost that day, the community has also lost its stormwater system. This initial system featured a curb and gutter system that carried water to the nearby natural catch basins. Though this method was very effective prior to the storm, the post storm management is not functional. The system now features damaged curbs and gutters, debris filled catch basins, and a loss of the local vegetation. To understand how to fix this system, a computer modeling program, WinSLAMM is used to evaluate a variety of ways to handle this stormwater problem.

After modeling the system, a plan for how to repair the damages was discovered. Fixing the infrastructure must begin with the cleanup of sediment and debris from curbs, gutters, and catch basins. After cleaning the area, vegetation must be added back to the area to prevent new sediment from becoming runoff and clogging the freshly cleaned catch basins, curbs, and gutters. Additional measures, including the addition of bio-swales and additional catch basins, are added to insure that the new system performs at a higher level of functionality. This new system is one that not only succeeds in removing the stormwater, but is also highly effective at removing particulate pollutants from the water.

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1. Introduction

Pleasant Grove, Alabama is a small community located in Jefferson County and is approximately twenty five minutes west of the Birmingham metropolitan area. The cities approximate population is around 10,000 people and the majority of the land within the city is single family homes and undeveloped land. Normal annual rainfall for Pleasant Grove is approximately 59 inches per year with an average monthly precipitation in 2010 of 4.94 in/month. There is little commercial land within the city of Pleasant Grove, including a few shopping areas consisting mostly of grocery items, gas stations, banks, and couple fast food restaurants. The cities topography has many valleys, with the single family homes being situated around the ridge of the land.

2. Background Data

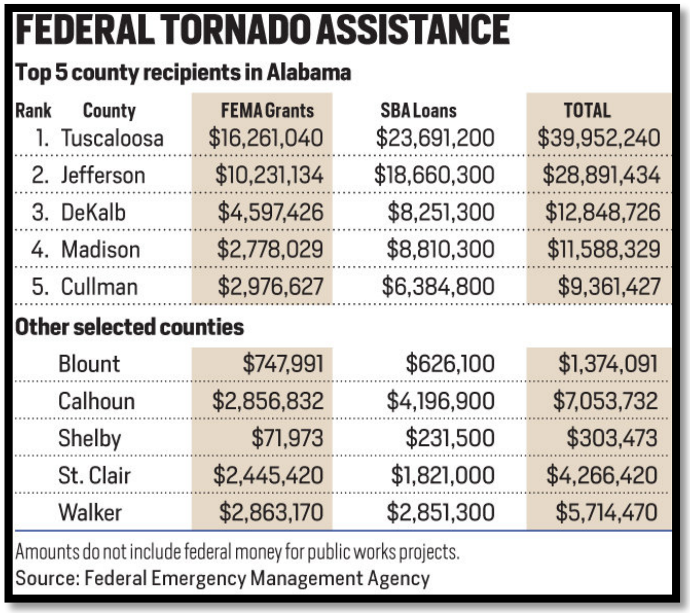
On April 27, 2011, 62 tornadoes travelled through Alabama wreaking havoc in 42 counties (out of 64) counties and caused more than 248 fatalities and 1,700 injuries state-wide. The largest on the record-setting day was a mile-wide F-4 tornado (190 mph wind) that plowed through a populated residential area near the center of Pleasant Grove (Boyd and Cope, 2011). This resulted in 10 deaths, over 700 housing units affected, and over 9.6 million cubic yards of debris. Further information can be found in Table 1.

Table 1: Population Affected by Tornados

	Pleasant Grove	Jefferson County	Alabama
Population Before the Storm	10,014	x*	x
Fatalities	10	21	248
Injuries	x	x	1,700
FEMA Registrants	1,645	2,213	8,330
Housing Units Likely Affected	700-800	962	3,965
Permits Received for House Repair	600	x	x
Permits for Rebuilding from ground up	30	x	x
Vol. of Debris (cubic yards) Generated			+9.6 million
Vol. of Debris Removed by Army Corps of Engineers (cy)			-4.8 million
Ceres Environmental Debris Removed (cy)			-1.0 million

*(x denotes that information was not available)

The number of Federal Emergency Management Agency (FEMA) registrants from Pleasant Grove totaled 1,645, (or 16 % of Pleasant Grove's pre-storm population). Jefferson County received the second highest amount of federal assistance in the state, with FEMA grants totaling $10,231,134 and SBA Loans totaling $18,660,300, for combined value of $28,891,434. (See Figure 1 for more FEMA assistance costs.) These amounts do not include federal money for public works projects.



FEDERAL TORNADO ASSISTANCE

Top 5 county recipients in Alabama

Rank	County	FEMA Grants	SBA Loans	TOTAL
1.	Tuscaloosa	$16,261,040	$23,691,200	$39,952,240
2.	Jefferson	$10,231,134	$18,660,300	$28,891,434
3.	DeKalb	$4,597,426	$8,251,300	$12,848,726
4.	Madison	$2,778,029	$8,810,300	$11,588,329
5.	Cullman	$2,976,627	$6,384,800	$9,361,427
Other selected counties				
	Blount	$747,991	$626,100	$1,374,091
	Calhoun	$2,856,832	$4,196,900	$7,053,732
	Shelby	$71,973	$231,500	$303,473
	St. Clair	$2,445,420	$1,821,000	$4,266,420
	Walker	$2,863,170	$2,851,300	$5,714,470

Amounts do not include federal money for public works projects.
Source: Federal Emergency Management Agency

Figure 1: FEMA Assistance

3. Initial Stormwater Infrastructure

The existing state of the stormwater infrastructure in the area affected by the tornado on April 27, 2011 was underground culverts with curb and gutter drainage and open channel flow. The majority of the land affected was single family homes with lots around 0.25 to 0.5 acres. For the curb and gutter residential area, the houses were located at points of higher elevation and the stormwater was directed into the valleys that are situated in the community. Figure 2 represents the elevation of the land in Pleasant Grove, AL. The darker sections illustrate the valleys located in the city and show the way the water channel flows together.

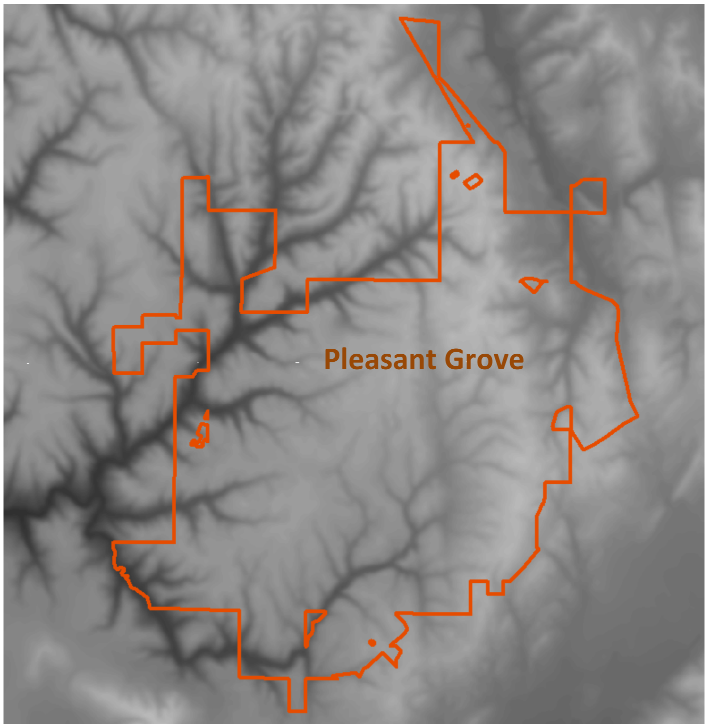


Figure 2: Pleasant Grove Watershed

Pleasant Grove is composed of both new construction neighborhoods and older existing homes. The newer sections of Pleasant Grove were composed of a curb and gutter storm water design, while the older sections in the area are open channel grass swales with cross drains underneath the roads. The area of land was heavily grassed and the valleys of the land were heavily wooded. This allowed for a large amount of ground infiltration and a low amount of runoff. With the topography of the land having so many valleys, the underground culverts were not of very long lengths. The curbs were placed at the obviously low points of the streets, and the majority of these coincided with the entrance of a valley or a cross of the valley.

3.1. Determining Watershed Area

The drainage area calculations were performed using the watershed that will contribute to the project location. This was completed by using the topography map of the area and finding the direction the storm water runoff will flow by using the highest elevation points of the map as a guide to where the water will flow to. The watershed area is shown in the following map, Figure 3, by the tornado path location. An area calculator, Google Maps, was used by drawing a polygon over the tornado area of an aerial shot of the site. This resulted in a total area of the watershed to be approximately 435 acres. This resulting area was then broken into two sections, the Valley Creek Watershed and the Village Creek Watershed.

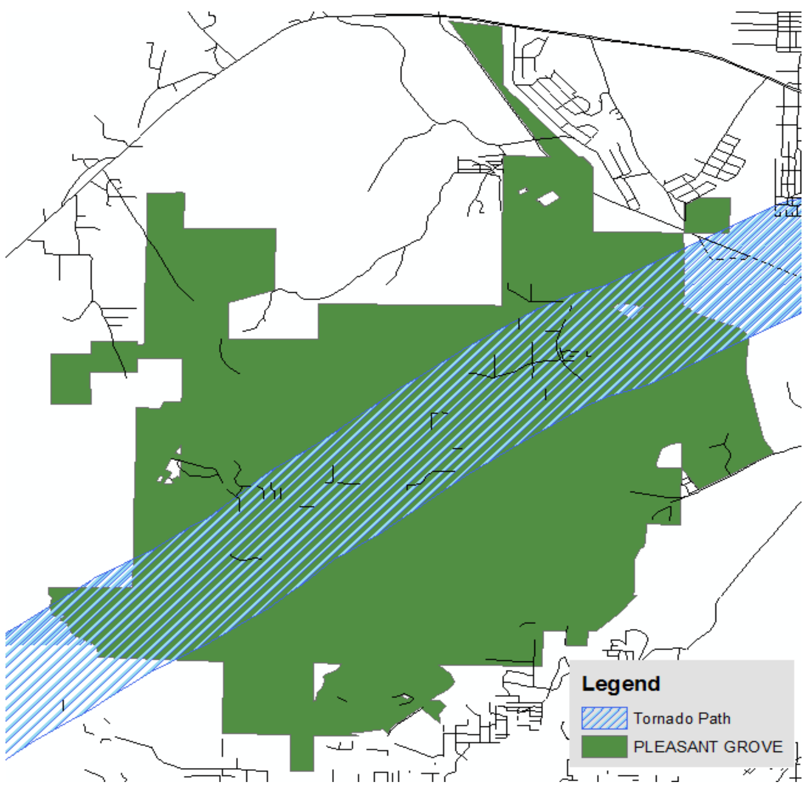


Figure 3: Tornado Path

3.2. Storm Water Quality and Erosion Control

The City of Pleasant Grove ordinances fall under the Jefferson County Department of Health's (JCDH) code of standards. This includes the storm water monitoring, sampling, laboratory analysis, erosion inspection, and education to the general public. The City of Pleasant Grove is required by the 1972 Clean Water Act (CWA), the Alabama Department of Environmental Management (ADEM), and the National Pollution Discharge Elimination System (NPDES) permit to protect the watershed in its city. These will be followed and applied within the new storm water system.

Within the CWA, the Environmental Protection Agency (EPA) has the authority to set effluent limits in order to keep the receiving water within healthy limits. The CWA also requires that any municipality who wants to discharge pollutants must apply for an NPDES permit. Without this permit, all discharge will be considered illegal.

Currently the Jefferson County Department of Health is in charge of monitoring the erosion and sediment control on newly built and construction sites for land area less than 1 acre. However, if there is no residential house being built on the land, there is no permit that says that the land owner has to do any erosion and sediment control procedures. This lack of control is directly increasing the unwanted sediment that enters the watershed.

3.3. Determining the Curve Number

The residential, impervious, and commercial/business areas were calculated to determine the overall areas for each section. For the open space, undeveloped land, a different approach was taken to consider the land area. The land that has a heavy area of trees was considered good conditions because the trees are able to take in the majority of rain that will fall in that area. Next, the poor conditions were calculated by using areas that have no vegetation. These areas will result in more sheet flow rather than infiltration of the water runoff during a storm. The final open space area determined was the fair conditions. Curve numbers are the parameter used to determine the amount of runoff or infiltration of rainfall within different types of land. Curve numbers for the area of each watershed were found for each specific area. After the total areas were calculated for each land use, the corresponding curve number was multiplied by the total area for that section and divided by the sum of all the areas. For the pre-tornado conditions, the curve number was calculated to be 80 for the tornado path area. This same method was used to calculate post-tornado curve numbers. They resulted in similar results as the pre-construction curve numbers with the west watershed resulting in a curve number of 78. Further information can be found in tables 2 and 3.

Table 2: Initial Conditions

Pleasant Grove, AL - Initial Conditions		
P, Precipitation	7.5	in
CN_{II} , Curve Number	80	
S, Storage	2.51	In
$I_{A,}$ Initial Abstractions	0.50	in
P_e, Effective Precipitation	5.15	in
Volume Runoff	186.75	Acre Ft
Volume Runoff	60851.33	Mega Gallons
***P is from a 25-yr, 24-hr storm**		

Table 3: Final Conditions

Pleasant Grove, AL - Final Conditions		
P, Precipitation	7.5	in
CN_{II} , Curve Number	78	
S, Storage	2.78	In
$I_{A,}$ Initial Abstractions	0.56	in
P_e, Effective Precipitation	4.96	in
Volume Runoff	179.67	Acre Ft
Volume Runoff	58544.15	Mega Gallons
***P is from a 25-yr, 24-hr storm**		

3.4. Hydrographs

Hydrographs show the relationship between the flow rate and duration of a given rainfall event over a time period at a particular location within a watershed. The integrated area under the curve represents the runoff volume, and the highest point on the curve represents the peak flow. In order to construct a hydrograph, the Natural Resources Conservation Service (NRCS) Curve Number Method is used. First, the area in acres for each land use type must be determined, see section Determining Watershed Area. Since the soil group is known to be type B, the curve numbers can be determined from the Curve Number Tables for AMC II. Once both areas and curve numbers are determined, they are multiplied to get the products; the curve numbers for ASM II give the maximum possible retention. Finally the initial abstractions can be calculated.

From the method for Coverage of NRCS (SCS) Rainfall Distributions, Jefferson County is determined to be in the Type III rainfall distribution area. For a Type III, 25-year, 24-hour storm in Pleasant Grove, the maximum precipitation of rainfall is 7.5 in. Once the maximum precipitation was found, effective precipitation and total volume of runoff can be determined. Since the soil type of the site is known to be Type III, fractions of the total accumulated rainfall depth for storms with 24-hour durations can be determined from the Soil Conservation Service (SCS) Dimensionless Storm Distributions method; then cumulative and incremental precipitations are calculated. Once incremental precipitations are calculated, discharge can be calculated by multiplying the total area of the watershed by those incremental precipitations. Discharge is then divided by the time interval of one hour. The hydrographs for the area affected can be found in Appendix E through J.

3.5. Time of Concentration and Flow Type

According to TR-55, time of concentration (Tc) is the time for runoff to travel to a point of interest from the most hydraulically remote point in the watershed. It is computed by adding the different travel times for all the individual components of the drainage system. These travel times (Tt) are the times for the runoff to travel from one point to the point of discharge in the watershed. There are 3 main factors that would affect the time of concentration and travel time, and they are surface roughness, channel shape and flow patterns, and slope. Surface roughness decreases the travel time for the runoff through the watershed. This is because the undeveloped areas will flow through more vegetation and then delivered to streets gutters and storm sewers which transport runoff more rapidly and effectively. Channel shape and flow patterns increase runoff velocity and decrease travel time. Because our section is in an urban watershed, the storm water runoff is typically conveyed into a channel as soon as possible.

Runoff moves from one point to another as sheet flow, shallow concentrated flow, open channel flow, or the combination of all of them. Sheet flow flows over the plane surfaces and usually occurs in the headwater of streams. Manning's roughness coefficient (n) is needed to account for the effect of raindrop impact. Different values for sheet flow for different surface condition can be found in Table 3-1 in the TR-55 manual. Shallow concentrated flow is sheet flow of more than 300 feet. The average velocities for estimating travel time for shallow concentrated flow for both paved and unpaved surfaces can be determined from Figure 3-1 in the TR-55 manual when the slope is known. Manning's equation is used to estimate the average flow velocity which is usually determined for the bank elevation. After the field inspection, it was determined that there is no shallow concentrated flow in the area affected by the storms. This means the runoff moves from one point to another as sheet flow and open channel flow.

3.6. Floodplains

The majority of the land surrounding the area in which there was tornado damage place is devoid of floodplains. There is however a small section of land around Mulga Loop Road following the railroad tracks that is considered floodplains. These areas are mostly in the X and AE ranges; with X meaning areas that would be inundated by a 500-year flood and AE meaning an area that would be inundated by a 100-year flood. The floodplain in Pleasant Grove is shown in Appendix E. It is important to know where the floodplains are so that new construction does not take place on them. If construction were to take place in these plains, erosion, loss of property, loss of habitat, and loss of life are likely to occur. By leaving the floodplains in their natural state, the area will be able to hold the excess storm water on its own and allow for ground infiltration.

4. Current Stormwater Infrastructure

The current state of the stormwater infrastructure is sediment filled culverts and drains which have been broken by fallen trees and heavy equipment operation. A shape file was created using ArcMap GIS and field data to show the amount and type of destruction on the storm drains in the tornado effected area. This shape file shows that 11.27% are broken, 61.45% are normally operating, and 22.18% is clogged. Please note that many of the storm drains that were broken are also clogged. The reason for the clogging of drains is due to improper erosion and sediment control. Sedimentation entering the storm drains is the town's biggest problem for their stormwater system. Currently abandoned lots are allowing for large amounts of sediment runoff to come off of the land because the land was left barren due to either the storm or debris removal. This is causing a huge problem for the stormwater system. With the curb receptors being clogged from sediment, the town is facing flooding issues, and the sediment is entering into tributaries located around the city. This is visualized in Appendix A.

5. WinSLAMM Simulation

The target location for the WinSLAMM analysis is Pleasant Grove, Alabama. This area was hit by the April tornado and suffered catastrophic damage to a ¾ mile buffer zone through the middle of the city. This buffer zone was a dense residential area consisting of 700 houses. All of these houses were destroyed by the tornado. The following data, in Table 4, represents the data used in WinSLAMM based on land use type for pre tornado conditions in Pleasant Grove.

Table 4: Pre Tornado Input Data

Lot Area (Acres)	435
Curb-Length (Linear miles)	24.78
Street Area (Acres)	60.07
Drive Way Area (Acres)	43.5
Rooftop Area (Acres)	65.25
Landscaped Area (Acres)	326.25

The lot area represents the total lot area of 700 houses, where 500 houses have .47 acre lots and 200 houses have 1 acre lots, totaling 435 acres for all lots in the buffer zone. Using Google Earth, the curb-length of the streets was found to be 24.78. The width of the roads is 20 feet. By multiplying the length by the width, the street area was found to be 60.07 acres. By using Google Earth's polygon tool it was found that the average driveway was approximately 10% of the lot area, which corresponds to a driveway area of 43.5 acres. Again using the polygon tool, rooftop areas were found be make up approximately 15% of the lot area, giving a rooftop area of 65.25 acres. By subtracting the drive way area and rooftop area from the lot area, the landscaped area was found to be 326.25 acres.

The land use type data was put into a WinSLAMM file with the simple layout of a residential area and outfall area connected by one junction, as shown below in Figure 4.

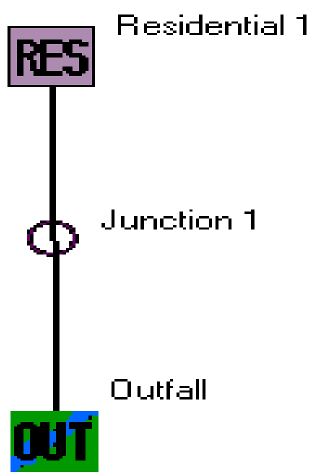


Figure 4: WinSLAMM Layout

The WinSLAMM output file was set to output results for the percent area contribution of run off volume and particulate solids for each land use type. The results were then made into a visual representation as a stacked area graph as shown in Figures 5 and 6 below.

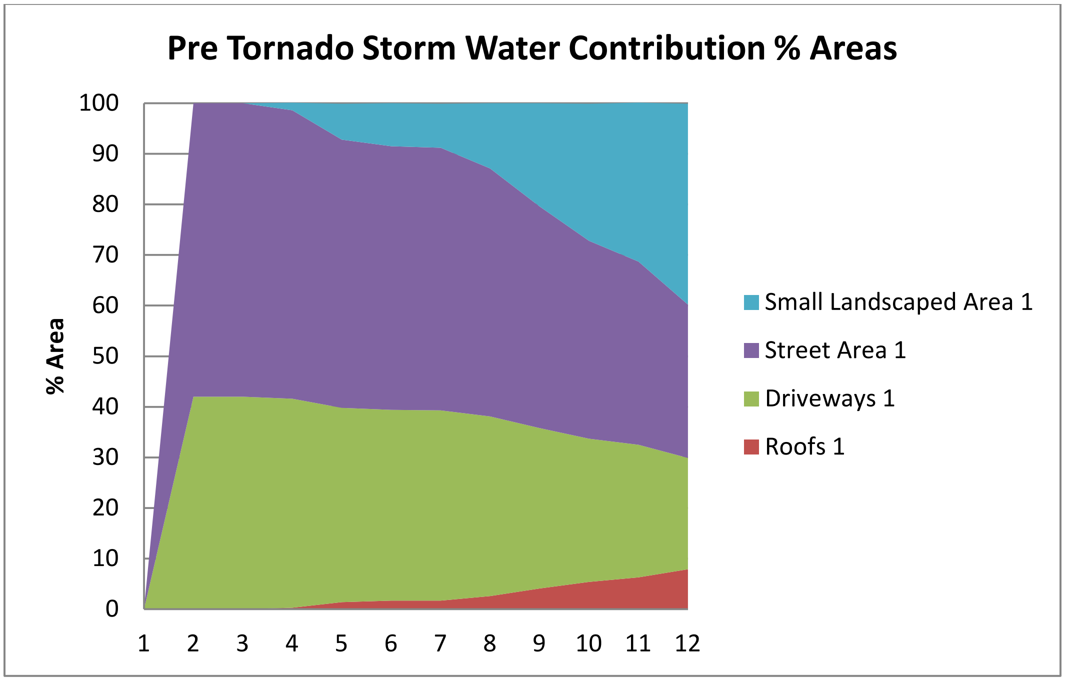


Figure 5: Pre Tornado Storm Water Contribution % Areas

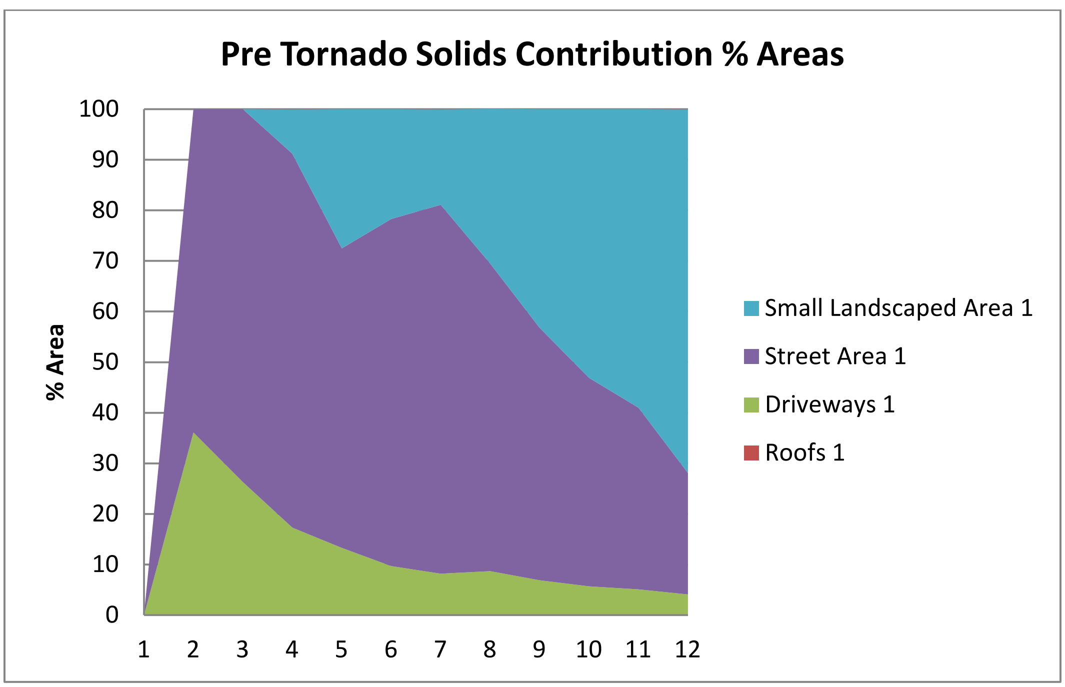


Figure 6: Pre Tornado Solids Contribution % Areas

After the tornado, all 700 houses in the buffer zone were destroyed. The following table, 5, represents the changes in the input data for WinSLAMM for the post tornado scenario.

Table 5: Post Tornado Input Data (ALL Areas in Acres)

Lot Area (Acres)	435
Curb-Length (Linear miles)	24.78
Street Area (Acres)	60.07
Drive Way Area (Acres)	21.75
Rooftop Area (Acres)	0
Landscaped Area (Acres)	413.25

The rooftop area is dropped to zero representing that all the houses were destroyed. The street area is the same as it was for the pre tornado scenario. The drive way area has been decreased to represent that 50% of driveways are covered by the left over highly erodible landscape of the lots after the tornado. The landscaped area is increased by the amount of decrease in from both the rooftop area and driveway area. The post tornado data was put into WinSLAMM and an output file was generated from the same layout as the pre-tornado area. The following figures, 7 and 8, represent the change in percent contribution areas for storm water runoff and particulate solids.

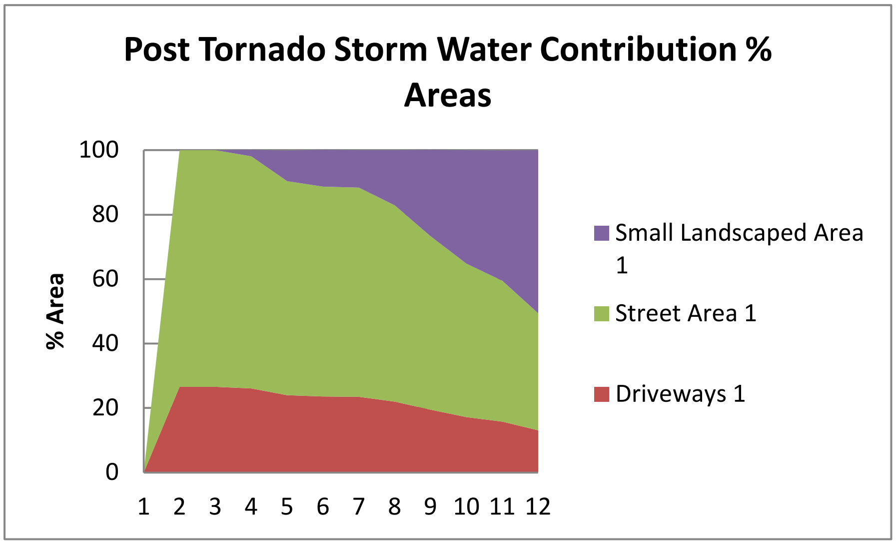
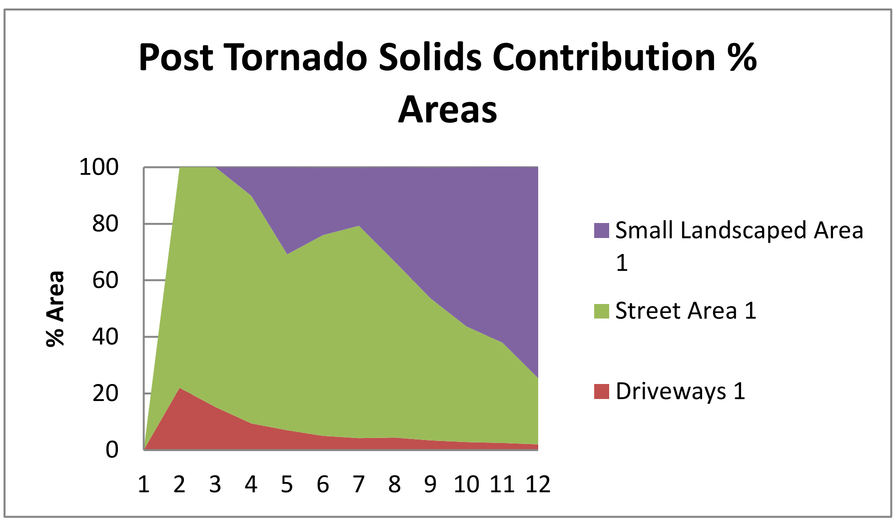


Figure 7: Post Tornado Storm Water Contribution % Areas



Post Tornado Solids Contribution % Areas

The biggest problem with the stormwater currently is the highly erodible residential lots than were destroyed by the tornado and cleared by bulldozers of all debris, vegetation, and topsoil. These problem areas must have control practices implemented in order to reduce the particulate solids. However, in order for these areas to have enforceable storm water best management practices by the governing agency, the Jefferson County Department of Health, the lots must have begun reconstruction on the lots. This means that all the lots that have not begun reconstruction don't have to have any control practices implemented, and therefore, the erosion of sediment from theses lots will continue. The lots that are having houses rebuilt will have control practices such as hay mulching/seeding, gravel exit pads, and silt fences implemented to reduce erosion and sedimentation from these sites.

5.1. Control Practices

5.1.1. Street Cleaning

After a tornado has devastated an area, the first step to recovering the land is to clean the streets. To get heavy machinery into the area to clean up the rest of the damage, the streets need to be cleaned of large debris such as trees, in order to reach all areas affected. In order to model the street cleaning, initial land use type area calculations had to be determined. For the area of Pleasant Grove, AL., the amount of area that is covered by streets is approximately 60.07 acres and a total length of the road to be 24.78 curb-miles with two curb-miles per street mile. The width of the average street is 40 feet. The street texture is assumed to be intermediate due to older, yet well maintained roads. The model's street dirt accumulation and the initial street dirt loading (in pounds/curb-mile) coefficients are both based upon land use and street texture.

For the pre-tornado street cleaning scenario, a cleaning frequency of twice a year was used. Mechanical broom cleaners with a light parking density and no parking controls imposed was used in the street cleaning control device setup. The output data of the street cleaning control device shows a 3.3% reduction in total load and concentration of particulate pollutants, as shown in table 6.

Table 6: WinSLAMM Pre-tornado Output

Total Influent Load (lbs.)	18845
Total Effluent Load (lbs.)	18215
Percent Load Reduction (%)	3.343
Total Influent Concentration (mg/L)	105.9
Total Effluent Concentration (mg/L)	102.3
Percent Conc. Reduction (%)	3.343

For the post-tornado street cleaning scenario, the cleaning frequency was increased from twice a year to once a week, while all other street cleaning control device setup options remained the same. The output data of the street cleaning control device shows a 17% reduction in total load and concentration of particulate pollutants, as shown in table 7.

Table 7: WinSLAMM Post-tornado Output

Total Influent Load (lbs.)	18845
Total Effluent Load (lbs.)	15640
Percent Load Reduction (%)	17
Total Influent Concentration (mg/L)	105.9
Total Effluent Concentration (mg/L)	87.86
Percent Conc. Reduction (%)	17

5.1.2. Catch Basins

Before the tornado hit, Pleasant Grove had a respectable storm water infrastructure for its modest size, consisting of a total of 275 catch basins. WinSLAMM has again been incorporated to model the effects the tornado had on the change in particulate pollutant loadings before and after the tornado hit. This time we will examine the effects of losing 92 out of the 275 catch basins due to severe clogging or broken inlet infrastructure. The WinSLAMM layout for the catch basin modeling is as show in figure 8.

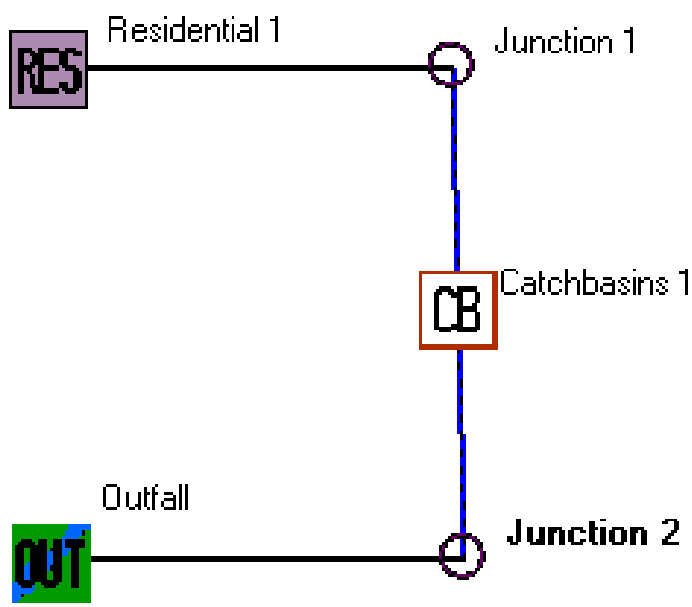


Figure 8: WinSLAMM Catch Basin Layout

The catch basin control device was setup to serve an area equivalent to the disaster zone of pleasant grove, 229 acres, with 257 catch basins, an average sump depth of 7 ft., a typical outlet pipe diameter of 1 ft., and Manning's n of 0.013, a slope of 0.02, a catch basin depth from sump bottom to street level of 9 ft., an inflow hydrograph peak to average flow ratio of 3.8, and a catch basin cleaning frequency of 2 years. The table below, 8, displays the output summary for the catch basin cleaning.

Table 8: WinSLAMM Pre-Tornado Catch Basin Output

Total Influent Load (lbs.)	30229
Total Effluent Load (lbs.)	0
Percent Load Reduction (%)	100
Total Influent Concentration (mg/L)	80.03
Total Effluent Concentration (mg/L)	0
Percent Conc. Reduction (%)	100

According to the table, the entire load is entering the catch basins but the particulate solids leaving the catch basins as effluent is zero. With the total number of catch basins present in the Pleasant Grove tornado affected area, the influent particulate solids is completely managed without releasing any particulate solids in the effluent.

For post tornado conditions, the same results occur. The difference in the catch basin control device model setup is just that there are now only 169 catch basins due to 61 being fully clogged and 31 having broken inlets. The results are shown in Table 9.

Table 9: WinSLAMM Post Tornado Catch Basin Output

Total Influent Load (lbs.)	35615
Total Effluent Load (lbs.)	0
Percent Load Reduction (%)	100
Total Influent Concentration (mg/L)	80.03
Total Effluent Concentration (mg/L)	0
Percent Conc. Reduction (%)	100

The results show an increase in influent load, from 30,229 lbs. to 35,615 lbs., due to a decrease in the number of catch basins. The results expected for the inclusion of a catch basin control device include a decrease in particulate pollutant loadings and concentrations in the effluent, but not a complete removal as shown in the model.

5.1.3. Wet Ponds

5.1.3.1. Pre-Tornado Wet Pond Design

The wet pond designs for Pleasant Grove for the pre-tornado scenario were performed by initially using a 90% suspended solids reduction pond size and shape calculator. The land use types were entered into the calculator. For pre-tornado conditions, there were 60.07 acres of pavement area and 435 acres of medium density residential area. The following table, Table 10, represents the data compiled in the pond size and shape calculator.

Table 10: Pre-tornado Wet Pond Table

Pond Surface Area (acres):			5.282 1	**Radius (ft.):**	271	
Pond Wet Storage Volume (acre-ft.):			10.944			
Pond Storage Depth (ft.)	**Top Surface Area (acres)**	**Radius of Top Area (ft.)**	**Average Side Slope (%)***	**Max Discharge for 5 um (cfs)**	**Max Weir Length (ft.)**	**Max Orifice Diameter (ft.)**
0.25	82.269	1068	0.0	465.9	1119.3	5.50
0.5	38.494	731	0.1	218.0	185.2	3.16
0.75	23.902	576	0.2	135.4	62.7	2.25
1	16.606	480	0.5	94.0	28.4	1.75
1.5	9.310	359	1.7	52.7	8.9	1.18
2	5.662	280	20.9	32.1	3.8	0.86
2.5	3.473	219	-4.9	19.7	2.0	0.63
3	2.014	167	-2.9	11.4	1.3	0.46
3.5	0.972	116	-2.3	5.5	1.0	0.31
4	0.190	51	-1.8	1.1	0.8	0.13

This data was then used to develop a 4 foot deep pond as a control practice in WinSLAMM. The setup for the wet pond design control practice options in WinSLAMM is shown in Figure 9.

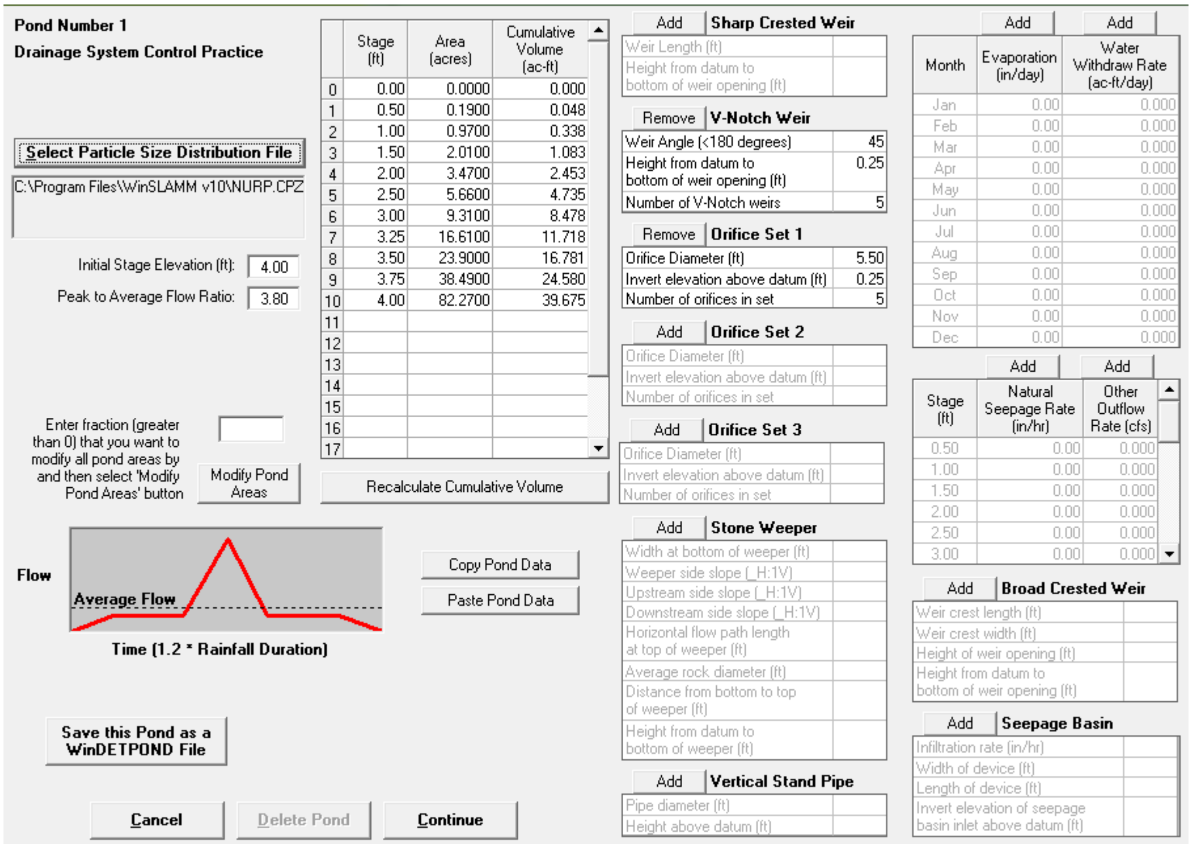


Figure 9: Pre-tornado WinSLAMM Wet Pond

The wet pond design incorporated the use of a V-notched weir at a 45 degree angle at 0.25 feet from the top of the pond and 5 orifices at the same height with a diameter set to the max diameter given from the pond size and shape calculator of 5.50 ft. The results of the control practice being implemented into our pre-tornado scenario are given in Table 11.

Table 11: Pre-tornado WinSLAMM Input

Inflow Volume (cf)	Outflow Volume (cf)	% Volume Reduction	Influent Load (lbs.)	Effluent Load (lbs.)	% Load Reduction
2.04E+07	0	100	117246	0	100

The results of the wet pond control practice show a 100% reduction in volume which means that that for the rainfall event set in WinSLAMM, all the runoff is retained in the pond. Also, the pond will reduce the load by 100%.

In order to see the difference in performance of a wet pond control practice based on its design parameters, several iterations were run with varying volumes and orifice sizes based on the max orifice size determined by the pond size and shape calculator for decreasing areas. These iterations and their resulting data are shown in Table 12.

Table 12: Pre-tornado Wet Pond Output

Iteration	Inflow Vol. (cf)	Outflow Volume (cf)	% Volume Reduction	Influent Load (lbs.)	Effluent Load (lbs.)	% Load Reduction	Orifice Diameter (ft.)	No. of Weirs
1	2.04E+07	0	100	117246	0	100	5.50	1
2	2.04E+07	2.04E+07	0	117246	115314	1.647	0.55	1
3	2.04E+07	2.04E+07	0	117246	115831	1.207	1.23	1
4	2.04E+07	325552	98.41	117246	1324	98.87	1.24	1
5	2.04E+07	7.22E+06	64.65	117246	43509	62.89	1.23	13

From the data in the table above, it can be seen in the first iteration, that by sizing the pond for 100% of the total area in pleasant grove we get a 100% reduction in volume and particulate loading. The second iteration is based on a design for 1% of the original area (1% of 495 acres =

4.95 acres), and the pond overflows giving us a detention pond like design with 0% volume reduction and a 1.6% load reduction. The third iteration is based on the same area, but there is a change in the orifice diameter used in the design. The orifice diameter is increased to 1.23 ft and gives a 1.2% load reduction. However, as shown in iteration four, a slight increase of the orifice diameter to 1.24 ft. now gives a volume reduction of 98% and a load reduction of 99%. In iteration five, the orifice diameter was taken back down to 1.23 ft. and the number of weirs increased from 1 to 13 gives a 65% decrease in volume and 63% load reduction. These iterations show that there are interdependent relationships occurring in the design of a wet pond and that the design should be carefully considered and analyzed to choose the desired volume and pollutant reductions as well as the desired depth, orifice openings, and weirs to be used.

5.1.3.2. Post-Tornado Wet Pond Design

For the post tornado wet pond design, the 90% particulates reduction pond size and shape calculator input area was changed from 435 acres of medium density residential area to 435 acres of construction area to reflect the devastation and unstable soil conditions of the disaster area, while still having the pre-tornado area of 60.07 acres of pavement area. The results of the pond size calculator were input into WinSLAMM. The inputs of the first iteration's wet pond control practice options are shown in Figure 10.

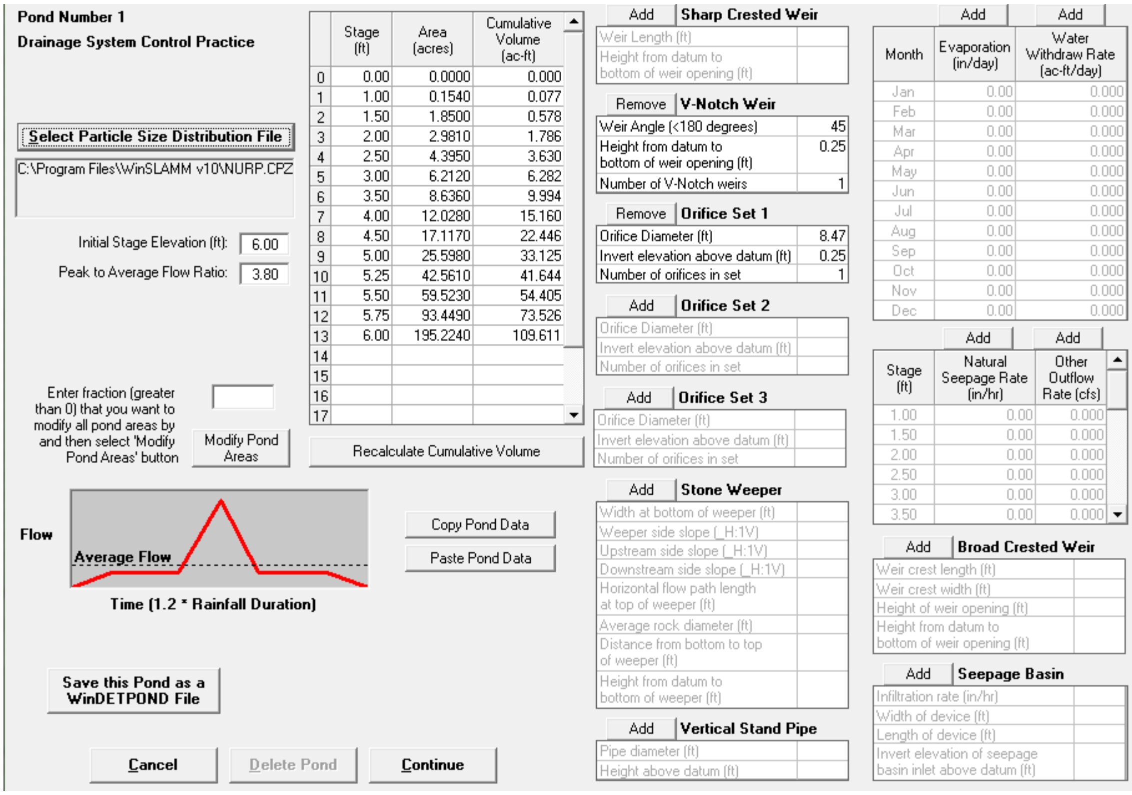


Figure 10: Post-tornado WinSLAMM Input

The pond is 6 feet deep and has a V-notch weir and 1 orifice with a diameter of 8.47 feet.

There were three iterations run for the post tornado scenario, as shown in the Table 13.

Table 13: Post-tornado WinSLAMM Output

Iteration	Inflow Vol. (cf)	Outflow Volume (cf)	% Volume Reduction	Influent Load (lbs.)	Effluent Load (lbs.)	% Load Reduction	Orifice Dia. (ft.)	No. of Orifices
1	1.75E+07	0	100	131079	0	100	8.47	1
2	1.75E+07	1.75E+07	0	131079	129600	1.129	1	5
3	1.75E+07	1.75E+07	0	131079	129779	0.9918	1.4	1

The first iteration represents a pond designed according to the shape and size calculator which gives a 100% reduction in volume and particulate pollutant loadings. The second iteration is designed with a decrease in the orifice diameter from 8.47 feet to 1 foot and has an increase in the number of orifices form 1 to 5. This design does not reduce the volume of storm water at all and only reduces the load by 1.129%. In the third iteration, the number of orifices was reduced back to 1 and the orifice diameter increased to 1.4 feet. This resulted in a lower percent load reduction to 0.9918%. In designing the wet ponds, it was very difficult to find the right combination of orifices and their sizes to get pollutant and volume reductions at 90%, so iteration 1 will be chosen as the best design to be used as the wet pond design control practice for post tornado Pleasant Grove to ensure an adequate amount of volume and pollutant loadings are removed from the storm water.

5.1.4. Bio-filters

5.1.4.1. Pre-Tornado Bio-filter Design

The Bio-filter design for both pre and post-tornado Pleasant Grove will be designed using WinSLAMM. The layout will include the catch basins as used in the previously mentioned WinSLAMM catch basin analysis. The layouts for both pre and post tornado scenario is shown in Figure 11.

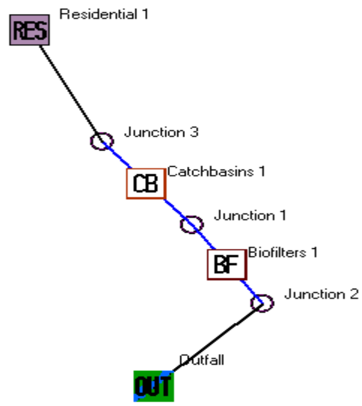


Figure 11: Bio-filter Layout

For the pre-tornado scenario, the first iteration of the bio-filter designs was analyzed in WinSLAMM. The bio-filter control practice options are shown in Figure 12.

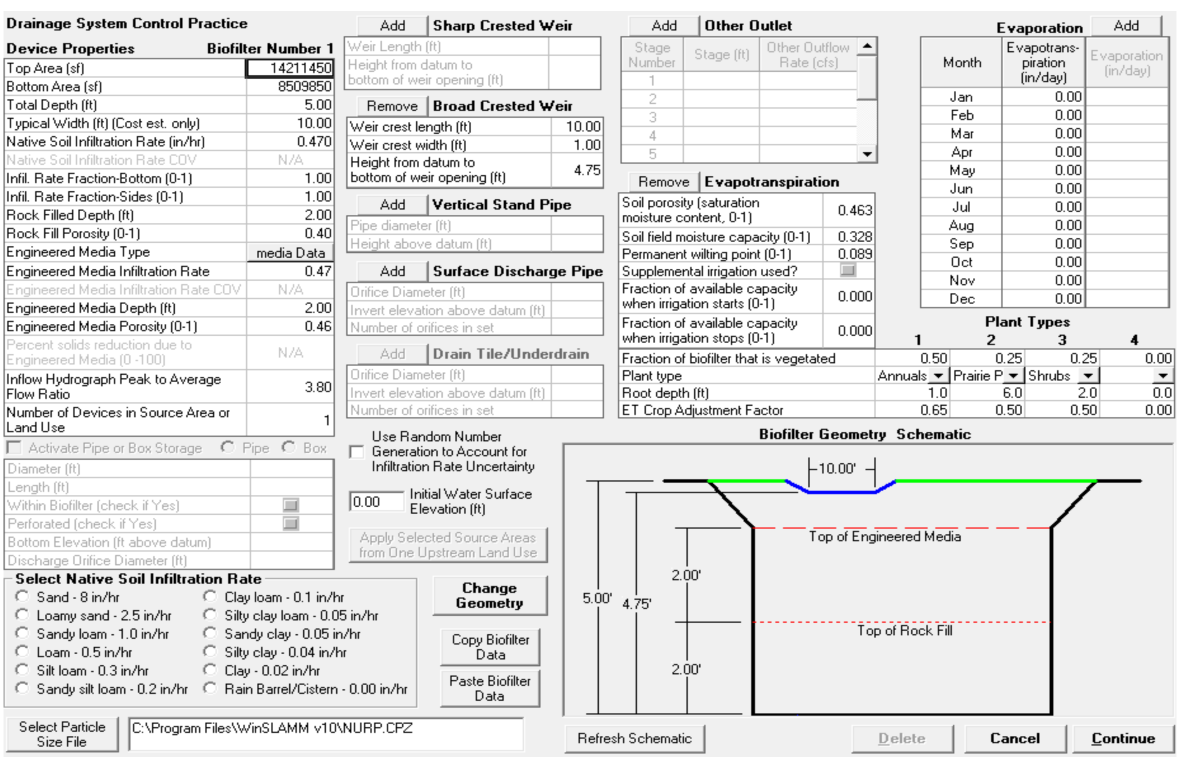


Figure 12: Pre-Tornado Bio-filter Input

The control practice options for the bio-filter include the top area and bottom area of the bio-filter. It was assumed that the bottom area would be 60% of the top area for all bio-filter designs. All bio-filter designs will use a 5 foot depth, 10 foot width, native soil infiltration of 0.47 in/hr; and will have a broad crested weir with a 10 foot length, 1 foot width, and be at a height .25 feet from the top of the filter.

In Table 14 below, shown is a summary of the multiple iterations of bio-filter designs analyzed in WinSLAMM.

Table 9: Pre-Tornado Bio-filter Output

Iteration	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Total Influent Load (lbs)
1	3.04E+07	0	100	0
2	3.04E+07	609630	97.99	0
3	3.04E+07	2.02E+07	33.6	0
4	3.04E+07	4.68E+06	84.58	0

The first iteration considered the entire landscaped area of Pleasant Grove, 326.25 acres (14,211,450 ft.^{2}), being used as the bio-filter surface area. The results show a 100% reduction in volume. There is no pollutant loading to reduce due the catch basins control practice removing

100% as shown in the catch basin section of the report. The second iteration reduces the bio-filter surface area to 10% of the total Pleasant Grove landscaped area and we still have a 98% volume reduction. The third iteration is 1% of the landscaped area and the results show a 33.6% reduction in volume. The fourth and final iteration uses 5% of the landscaped area and gives an 84.58% reduction in volume.

5.1.4.2. Post-Tornado Bio-filter Design

For the bio-filter design of the post tornado scenario, three designs were run in WinSLAMM. The results of these iterations are shown in Table 15.

Table 10: Post-Tornado Bio-filter Output

Iteration	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Influent Load (lbs.)
1	1.75E+07	0	100	0
2	1.75E+07	8.35E+06	52.19	0
3	1.75E+07	1.16E+07	33.31	0

The first iteration is setup to use 10% of the post tornado landscape area (10% of 413.25 acres = 1800117 $ft.^2$) in Pleasant Grove as the top surface area of the bio-filter. The bottom area of the bio-filter is 60% of the top area. This design gives us a 100% volume reduction, and as was the case in the pre-tornado bio-filter setup, the catch basins are reducing the pollutant load by 100%. The second iteration uses 1% of the landscaped area as the top area and gives a volume reduction of 52.19%. The third iteration uses .5% of the landscaped area and gives a volume reduction of 33.31%.

The results show evidence that a larger bio-filter will reduce the storm water volume to a greater extent. However, the choice of bio-filter size should be determined by the volume and pollutant load reductions of the other control practices implemented in a storm water sewer system, as well as the costs associated with the implementing the bio-filters.

6. Proposed Plan to Fix Infrastructure

The tornadoes that passed through Pleasant Grove, Alabama left a large amount of destruction. The scope is to rebuild and recover the stormwater infrastructure of the April 2011 tornado, conscientiously to minimize future design failures and optimum structural capacity. Without proper design and maintenance, stormwater runoff can exacerbate the damage to roads, private and public properties. A large portion of the work involves removal and disposal of debris, securing the erosion and sedimentation and nutrient pollution, stabilize disturbed areas of vegetation and non-vegetation, replacing curb and gutters and culverts that were damaged during the tornado, as well as implementing and/or incorporating Best Management Practices (BMPs) and Low Impact Development (LID) practices.

6.1. Clean up

Street cleaning and catch basin cleaning (Figures 13 and 14) is an integral part of maintaining the functionality of a stormwater system. Since stormwater is not treated before entering local streams, it is imperative to eliminate and reduce pollutants before entering the waterways. Street cleaning and catch basin cleaning prevents debris, oils and greases, and litter from clogging the system. By cleaning these systems, it reduces the waterways sedimentation loads and will help in the preparation for reconstruction of the city.

Figure 13: Catch basin cleaning (Robert Pitt, University of Alabama)

Figure 14: Street cleaning (U.S. Geological Survey)

6.2. Sediment and Erosion Control Common Applications

Prolonged exposure of unprotected sites and service areas to rainy weather can lead to increase sedimentation and erosion deterioration. Practices of containing areas in which are bare soil are essential to decrease further sedimentation entering the stormwater system. Stormwater runoff needs to be diverted from steep slopes that have no vegetation during the reconstruction process by intercepting the runoff to ditches, grass swales, sediment traps or ponds until the slopes have been stabilized from erosion.

Diversion practices will be beneficial to implement because of the locations of the abandoned lots and other unprotected sites situated on higher elevations. Sediment traps are bags consisting of hay, straw, sand, or crushed rock which are designed to trap sediment and also stabilize the route and decrease the flow of the stormwater. Silt fences are a temporary geotextile screen used to pond stormwater and acts as a filter to keep sediment from not filtering through. These fences are put up during the construction process when the sites vegetation has become disrupted.

Ground covers are applications comprised of straw mulch, seeding, or a combination of both. This is an inexpensive and easy way to reduce erosion of a site. An erosion blanket is made up of a mulch material that is surrounded by a plastic netting of mats. This blanket can be put on steep slopes or in bare channels, where mulches and seeding are ineffective.

Construction projects will result in an increase in erosion because soils will be exposed. Construction sites tend to have higher sediment concentrations than runoff from fully urbanized systems. By implementing erosion control, a construction site could reduce the sediment concentration by approximately 80% (Schueler, 90).

6.3. Best Management Practice and Low Impact Development

The U. S. Environmental Protection Agency (EPA) defines a Best Management Practice (BMP) as: "A technique, process, activity, or structure used to reduce the pollutant content of a storm water discharge." BMPs include simple nonstructural methods, including good housekeeping and preventative maintenance. BMPs are most effective when used in combination with each other, and customized to meet the specific needs (drainage, materials, activities, etc.) of a given operation. The focus of EPA's permit is on preventative BMPs, which limit the release of pollutants into storm water discharges. BMPs can also function as treatment controls. It is important for operations and maintenance of stormwater systems constructed in BMPs to be maintained to preserve the construction site. Low Impact Development (LID) designs have become specialized within many engineering disciplines. As stormwater BMPs continue to evolve, implementations of LID will most likely represent the future of stormwater management. LID works by minimizing the amount of impervious area on a site (EPA). LID is a low cost effective landscape feature that utilizes alternatives to stormwater control technologies. The combination of BMPs and LID methods improves site aesthetics, enhances public awareness, urban revitalization areas, potential for reduced taxes and fees and increases in property values. Some LID techniques might not result in an economical route because of the cost of construction/plant materials, site preparation, (hydrology, topography, soil) assessments, pipes and connections to stormwater systems, and other unforeseen costs.

6.4. Low Cost Option

The first step in fixing the damaged infrastructure is to replace or rebuild the destruction created by the tornados. For the curb and gutter residential area, since the residential housing is located on higher grounds of the land, the stormwater runoff will be directed into the valleys. The topography of the land works in the communities favor by easily draining the stormwater with short distances to the resulting drainage valleys. This allows the replacement of the standard curb and gutter by allowing the water to accumulate in catch basin site.

Another option to minimize costs will be simply to plant trees and other native vegetation local to the site seen in the figure 15 below.

Figure 15: Planting Trees - www.google.com

6.5. High Cost Option

Vegetative swales, buffers, filters, and strips are manmade natural sites with built-in features that filter and absorb pollutants, reduce stormwater runoff, and infiltration within a compact design. Stormwater will be able to disperse uniformly across landscaped sites using outlets designed to spread concentrated flow into shallow to sheet-flow. Bio-swales are landscaped depressions that allow stormwater runoff to be diverted and stored. They are designed to function similar to rain gardens, shown in figure 16, but unlike an open channel designs the stormwater treatment exists through the soil. Once the stormwater infiltrates into the soil within the depression, the trees and other vegetation removes nutrient uptake through their roots. Figure 17 illustrates classic BMPs and LID designs.

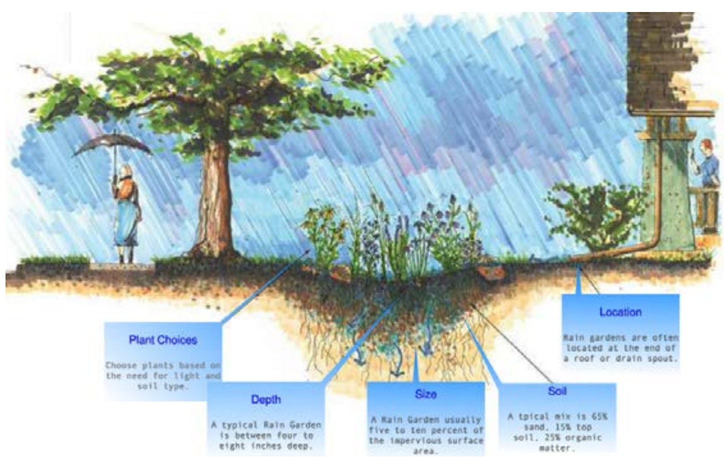


Figure 16: Bio-Swales - www.slideshare.net/CRSsite/the-solution-1923729

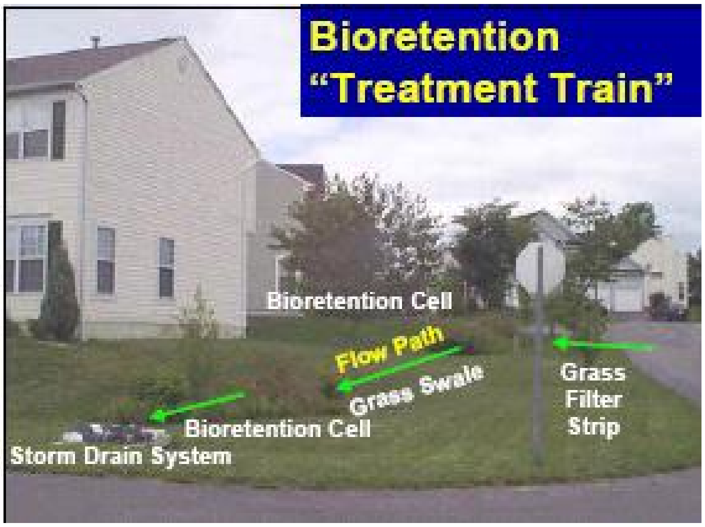


Figure 17: Structural BMP's and LID's - http://advancedmastergardener.org/

7. Actual Cost Breakdown

The costs associated to repair the stormwater system can be analyzed in order to give an estimated cost value for the area that was affected by the tornado. It is nearly impossible to give an accurate estimate due to the fact that many of the curb inlets are reusable and not completely demolished. According to R.S. Means, a four by four foot curb inlet costs approximately $1200 (Appendix A and K). There are ninety two curb inlets in which that are broken or need to be cleaned out. It would not be appropriate to give an estimated numerical cost by multiplying the cost by the amount that need to be fixed because they are not being constructed from scratch.

The majority of these storm drains need to have debris removed done by manpower and a shovel, and have the top replaced. In order to give an estimated number, it was assumed that a team of four municipal workers, cleaning out two storm drains per hour started the cleanout process. Since there are approximately 93 storm drains that need cleanout, with the four men working it will take approximately one week worth of work to complete the cleanout process. With an hourly rate of ten dollars per hour that is an estimated cost of $1600 to clean out the curb inlets.

The cost to replace the thirty-one broken tops of the inlets with approximately measurements of two feet by three feet by four inches thick. The total cost of replacing these tops is according to R.S. means of structural concrete, elevated slab; with a four inch thickness that includes finishing is $26.28. The total cost to replace thirty one of these tops is approximately $814.68. There are approximately 156 culverts that need cleanout. With a four man team, who receives ten dollars an hour, cleaning out approximately one and a half culverts per hour, the total cost to clean out the system will be $4160.With an estimated length of fifteen feet and diameter of twelve inches, the culverts that cross underneath a single road way cost approximately $379.38. With the replacement of four of these culverts an estimated cost for the total cost would be $1,517.40.

8. Water Quality Assessment

Water quality data was taken by the Jefferson County Department of Health at three different locations of Valley Creek within the City limits of Pleasant Grove, AL. There is a trend in the data in which shows an increase in the amount of pollutants that entered the streams. There was mainly an increase in total suspended solids as we saw an increase from 4 mg/L to 17 mg/L in the testing data taken from before and after the storm. This shows that more sediment has entered the creeks due to the greater amount of undeveloped land.

9. Conclusion

As a result of the tornado in April of 2011, Pleasant Grove, AL has lost its stormwater management infrastructure. This is includes the damaged curb and gutter, the debris filled catch basins, and the lack of vegetation preventing the soil from eroding. Through the use of WinSLAMM, a model was created to evaluate a variety of ways to handle this stormwater issue. This is begins with the removal the sediment and debris from curbs, gutters, and catch basins so that they can begin working again. After cleaning the area, it is necessary to add back the lost vegetation and add additional bio-swales. This creates a working stormwater system that removes the water and pollution effectively. Despite having this information, there is still additional information that would be needed to accurately estimate the cost of implementation. At this point, there are too many unknowns surrounding the soil structure of the area.

10. Works Cited

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11. Appendix:

Appendix A:

Curb, Drop Inlet, and Gutter Total Condition

Total: 275			
Sum Normal	169	% Normal	61.45%
Sum Cleanout	61	% Needs Cleanout	22.18%
Sum Broken	31	% Lid Broken	11.27%

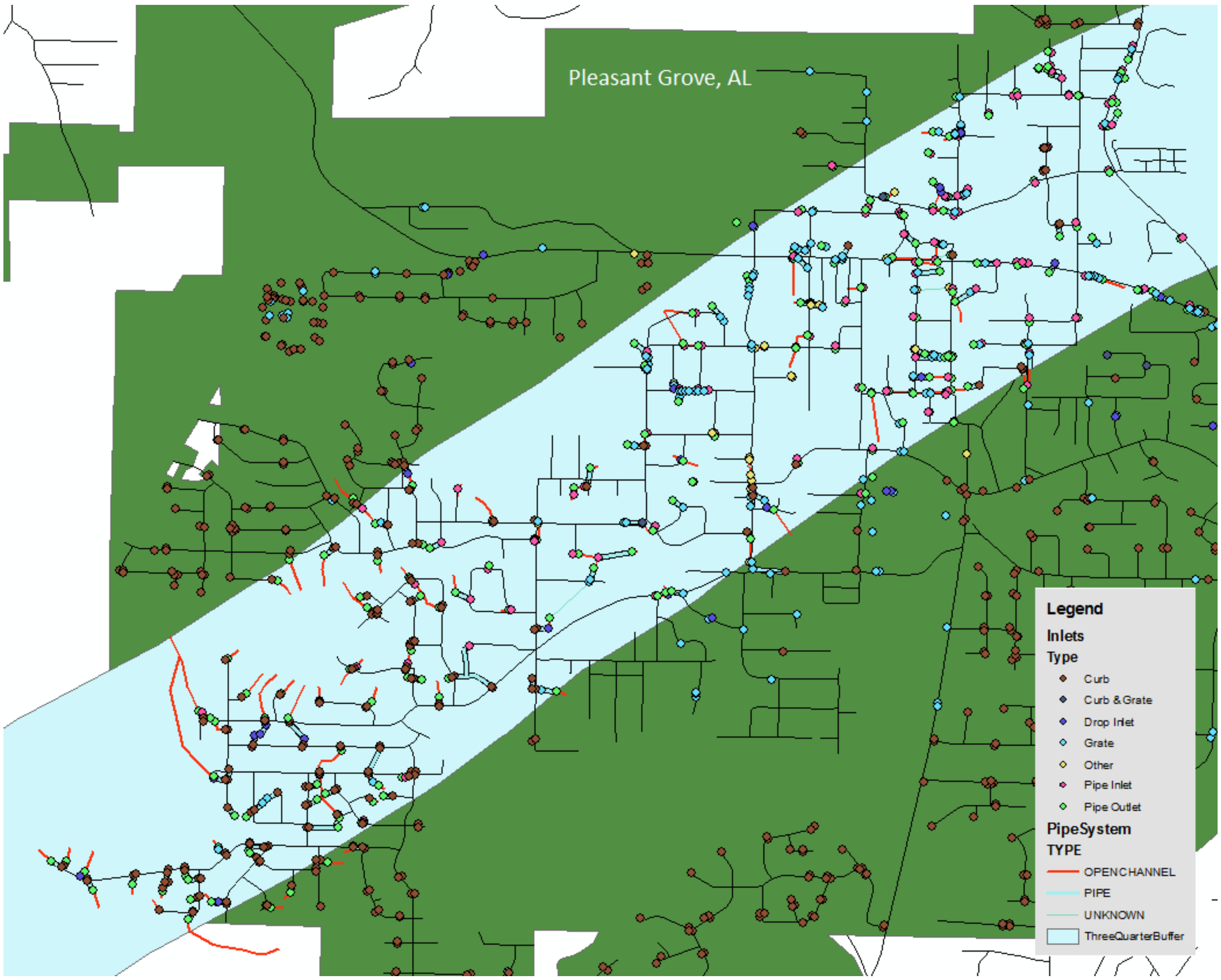
Culvert Total Conditions

Total: 300			
Sum Normal	137	% Normal	45.67%
Sum Cleanout	135	% Needs Cleanout	45.00%
Sum Broken	4	% Lid Broken	1.33%
Sum Buried	21	% Buried	7.00%

Inlet Costs:

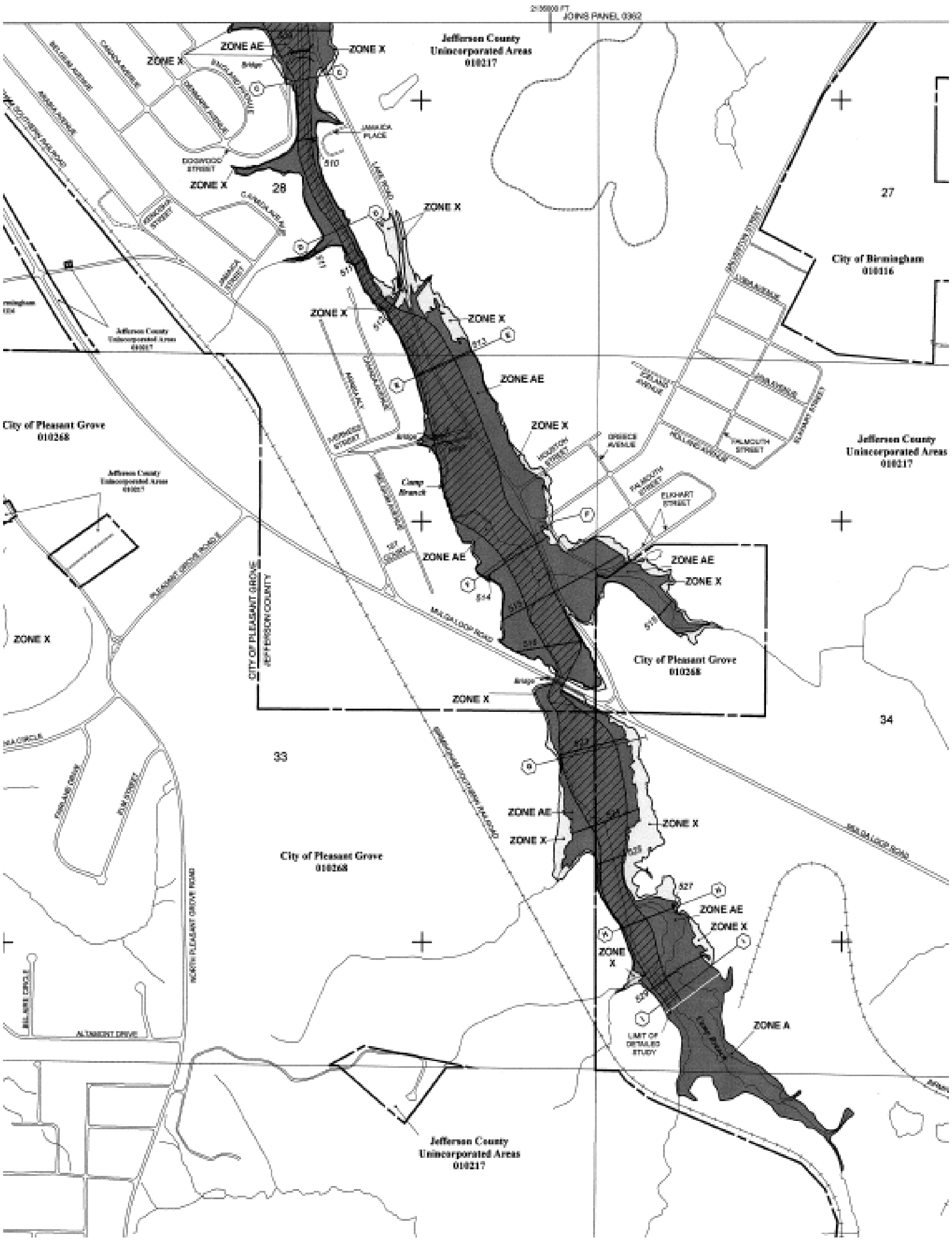
Inside Diameter (ft.)	Depth (ft.)	Cost ($/unit)
4	4	1200
	6	1575
	8	2050
	10	2600
	12	3150
	14	3700
5	4	1275
	6	1800
	8	2300
	10	2894
	12	3488
	14	4082
6	4	2025
	6	2675
	8	3525
	10	4435
	12	5345
	14	6255

Appendix B:


Pleasant Grove, AL
Legend
Inlets
Type
Curb
Curb & Grate
Drop Inlet
Grate
Other
Pipe Inlet
Pipe Outlet
PipeSystem
TYPE
OPENCHANNEL
PIPE
UNKNOWN
ThreeQuarterBuffer

Appendix C:

Appendix D:


JOINS PANEL 0362
ZONE AE
ZONE X
Jefferson County
Unincorporated Areas
010217
28
27
City of Birmingham
010116
ZONE X
ZONE AE
City of Pleasant Grove
010268
Jefferson County
Unincorporated Areas
010217
Camp Branch
MULGA LOOP ROAD
CITY OF PLEASANT GROVE
JEFFERSON COUNTY
33
34
City of Pleasant Grove
010268
ZONE A
LIMIT OF DETAILED STUDY
NORTH PLEASANT GROVE ROAD
ALTAMONT DRIVE
Jefferson County
Unincorporated Areas
010217

Appendix E:

Hyetograph: Pre-tornado Conditions

	Falling P	7.5	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0	0	0
1	0.01	0.075	0.075
2	0.02	0.15	0.075
3	0.031	0.2325	0.0825
4	0.043	0.3225	0.09
5	0.057	0.4275	0.105
6	0.072	0.54	0.1125
7	0.091	0.6825	0.1425
8	0.114	0.855	0.1725
9	0.146	1.095	0.24
10	0.189	1.4175	0.3225
11	0.25	1.875	0.4575
12	0.5	3.75	1.875
13	0.75	5.625	1.875
14	0.811	6.0825	0.4575
15	0.854	6.405	0.3225
16	0.886	6.645	0.24
17	0.91	6.825	0.18
18	0.928	6.96	0.135
19	0.943	7.0725	0.1125
20	0.957	7.1775	0.105
21	0.969	7.2675	0.09
22	0.981	7.3575	0.09
23	0.991	7.4325	0.075
24	1	7.5	0.0675

	Falling P	5.15	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0.00000	0.00000	0.00000
1	0.01000	0.05150	0.05150
2	0.02000	0.10300	0.05150
3	0.03100	0.15965	0.05665
4	0.04300	0.22145	0.06180
5	0.05700	0.29355	0.07210
6	0.07200	0.37080	0.07725
7	0.09100	0.46865	0.09785
8	0.11400	0.58710	0.11845
9	0.14600	0.75190	0.16480
10	0.18900	0.97335	0.22145
11	0.25000	1.28750	0.31415
12	0.50000	2.57500	1.28750
13	0.75000	3.86250	1.28750
14	0.81100	4.17665	0.31415
15	0.85400	4.39810	0.22145
16	0.88600	4.56290	0.16480
17	0.91000	4.68650	0.12360
18	0.92800	4.77920	0.09270
19	0.94300	4.85645	0.07725
20	0.95700	4.92855	0.07210
21	0.96900	4.99035	0.06180
22	0.98100	5.05215	0.06180
23	0.99100	5.10365	0.05150
24	1.00000	5.15000	0.04635

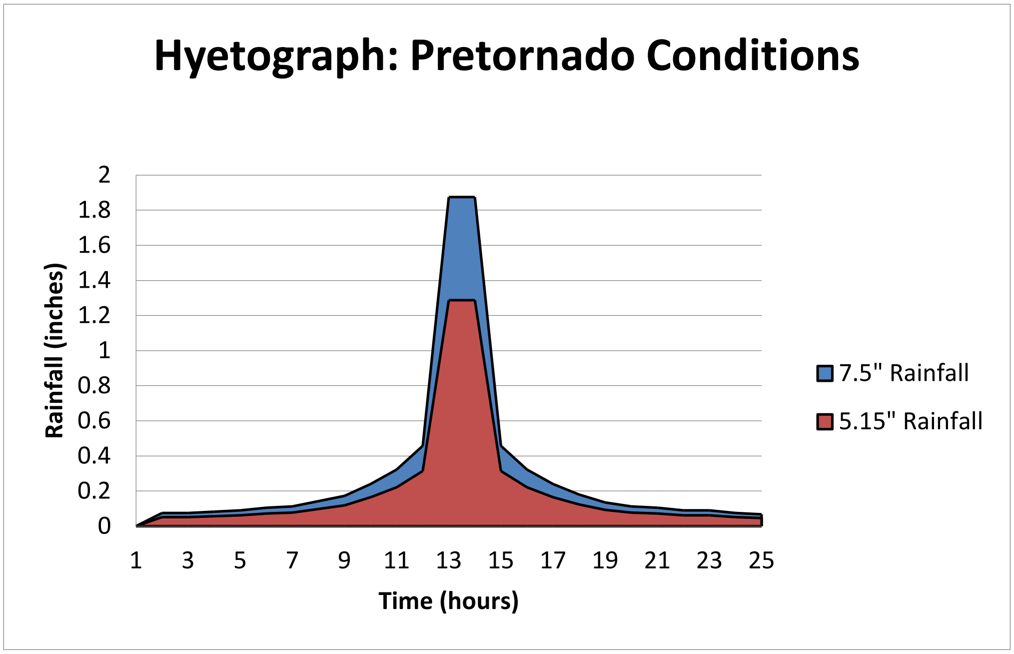
<u>Appendix F</u>:

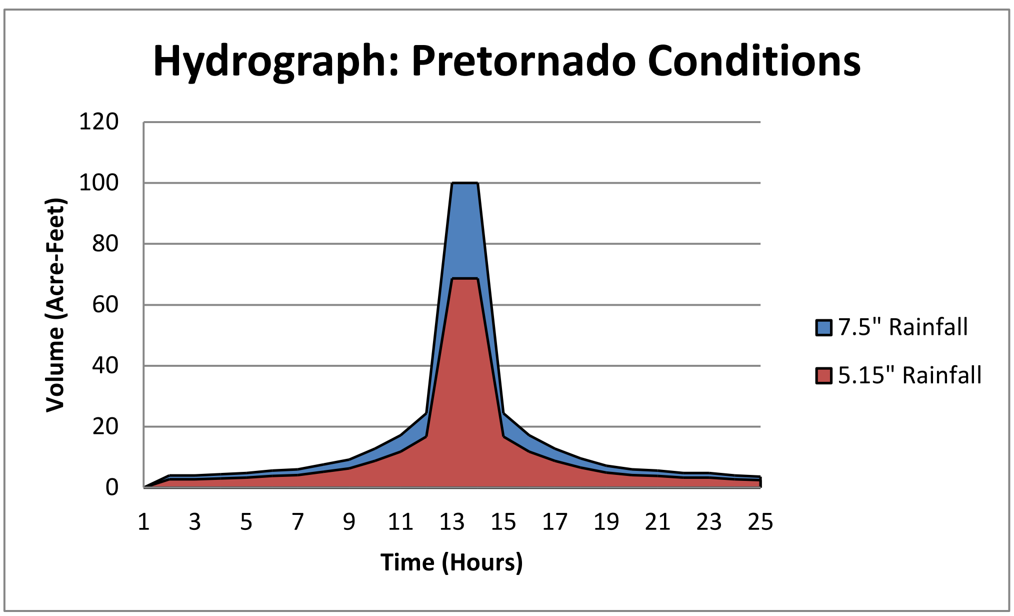
Hydrograph: Pre-tornado Conditions

	Falling P	7.5	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0	0	0
1	0.01	4	4
2	0.02	8	4
3	0.031	12.4	4.4
4	0.043	17.2	4.8
5	0.057	22.8	5.6
6	0.072	28.8	6
7	0.091	36.4	7.6
8	0.114	45.6	9.2
9	0.146	58.4	12.8
10	0.189	75.6	17.2
11	0.25	100	24.4
12	0.5	200	100
13	0.75	300	100
14	0.811	324.4	24.4
15	0.854	341.6	17.2
16	0.886	354.4	12.8
17	0.91	364	9.6
18	0.928	371.2	7.2
19	0.943	377.2	6
20	0.957	382.8	5.6
21	0.969	387.6	4.8
22	0.981	392.4	4.8
23	0.991	396.4	4
24	1	400	3.6

	Falling P	5.15	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0.00000	0.00000	0.00000
1	0.01000	2.74667	2.74667
2	0.02000	5.49333	2.74667
3	0.03100	8.51467	3.02133
4	0.04300	11.81067	3.29600
5	0.05700	15.65600	3.84533
6	0.07200	19.77600	4.12000
7	0.09100	24.99467	5.21867
8	0.11400	31.31200	6.31733
9	0.14600	40.10133	8.78933
10	0.18900	51.91200	11.81067
11	0.25000	68.66667	16.75467
12	0.50000	137.33333	68.66667
13	0.75000	206.00000	68.66667
14	0.81100	222.75467	16.75467
15	0.85400	234.56533	11.81067
16	0.88600	243.35467	8.78933
17	0.91000	249.94667	6.59200
18	0.92800	254.89067	4.94400
19	0.94300	259.01067	4.12000
20	0.95700	262.85600	3.84533
21	0.96900	266.15200	3.29600
22	0.98100	269.44800	3.29600
23	0.99100	272.19467	2.74667
24	1.00000	274.66667	2.47200

Appendix G:


Hyetograph: Pretornado Conditions
Rainfall (inches)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Time (hours)
7.5" Rainfall
5.15" Rainfall


Hydrograph: Pretornado Conditions
Volume (Acre-Feet)
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Time (Hours)
7.5" Rainfall
5.15" Rainfall

Appendix H:

Hyetograph: Post-tornado Conditions

	Falling P	7.5	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0	0	0
1	0.01	0.075	0.075
2	0.02	0.15	0.075
3	0.031	0.2325	0.0825
4	0.043	0.3225	0.09
5	0.057	0.4275	0.105
6	0.072	0.54	0.1125
7	0.091	0.6825	0.1425
8	0.114	0.855	0.1725
9	0.146	1.095	0.24
10	0.189	1.4175	0.3225
11	0.25	1.875	0.4575
12	0.5	3.75	1.875
13	0.75	5.625	1.875
14	0.811	6.0825	0.4575
15	0.854	6.405	0.3225
16	0.886	6.645	0.24
17	0.91	6.825	0.18
18	0.928	6.96	0.135
19	0.943	7.0725	0.1125
20	0.957	7.1775	0.105
21	0.969	7.2675	0.09
22	0.981	7.3575	0.09
23	0.991	7.4325	0.075
24	1	7.5	0.0675

	Falling P	4.96	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0.00000	0.00000	0.00000
1	0.01000	0.04960	0.04960
2	0.02000	0.09920	0.04960
3	0.03100	0.15376	0.05456
4	0.04300	0.21328	0.05952
5	0.05700	0.28272	0.06944
6	0.07200	0.35712	0.07440
7	0.09100	0.45136	0.09424
8	0.11400	0.56544	0.11408
9	0.14600	0.72416	0.15872
10	0.18900	0.93744	0.21328
11	0.25000	1.24000	0.30256
12	0.50000	2.48000	1.24000
13	0.75000	3.72000	1.24000
14	0.81100	4.02256	0.30256
15	0.85400	4.23584	0.21328
16	0.88600	4.39456	0.15872
17	0.91000	4.51360	0.11904
18	0.92800	4.60288	0.08928
19	0.94300	4.67728	0.07440
20	0.95700	4.74672	0.06944
21	0.96900	4.80624	0.05952
22	0.98100	4.86576	0.05952
23	0.99100	4.91536	0.04960
24	1.00000	4.96000	0.04464

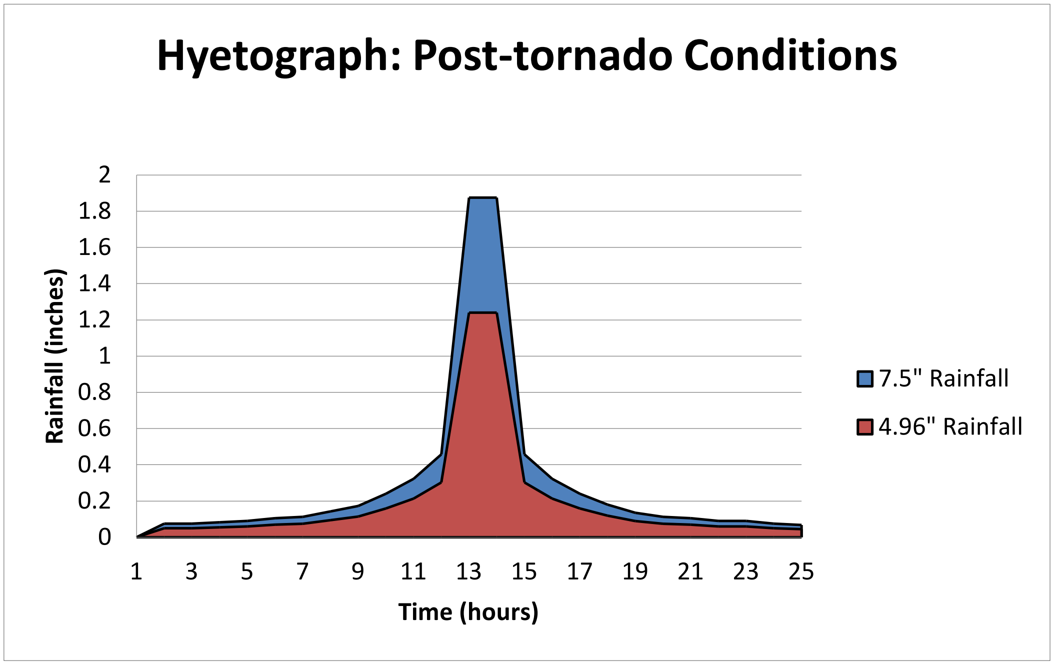
Appendix I:

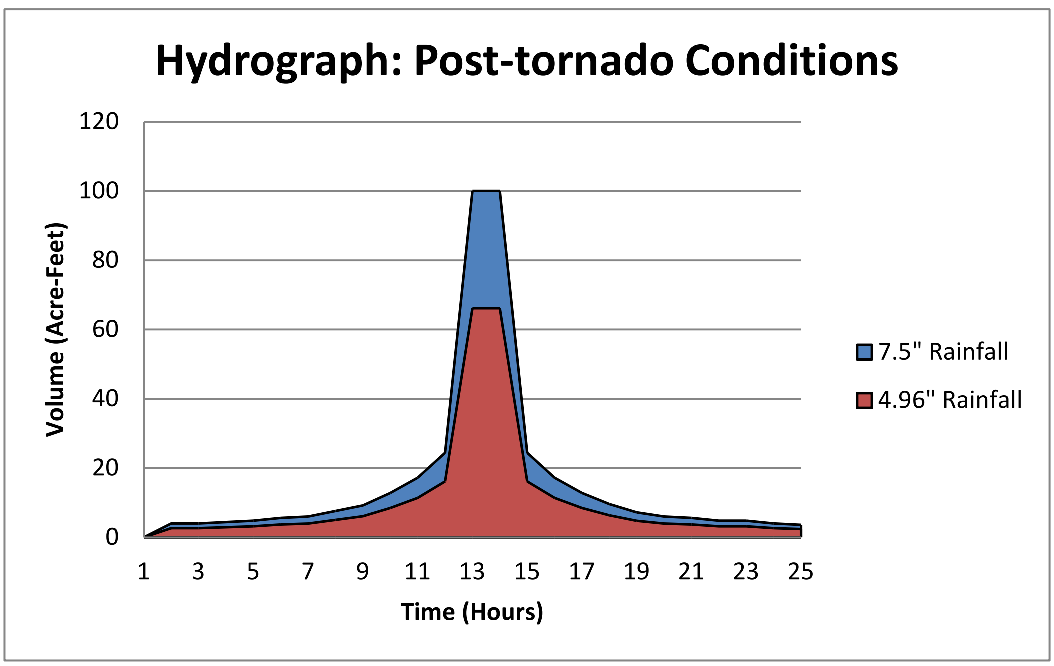
Hydrograph: Post-tornado Conditions

	Falling P	7.5	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0	0	0
1	0.01	4	4
2	0.02	8	4
3	0.031	12.4	4.4
4	0.043	17.2	4.8
5	0.057	22.8	5.6
6	0.072	28.8	6
7	0.091	36.4	7.6
8	0.114	45.6	9.2
9	0.146	58.4	12.8
10	0.189	75.6	17.2
11	0.25	100	24.4
12	0.5	200	100
13	0.75	300	100
14	0.811	324.4	24.4
15	0.854	341.6	17.2
16	0.886	354.4	12.8
17	0.91	364	9.6
18	0.928	371.2	7.2
19	0.943	377.2	6
20	0.957	382.8	5.6
21	0.969	387.6	4.8
22	0.981	392.4	4.8
23	0.991	396.4	4
24	1	400	3.6

	Falling P	4.96	Inches
T (hr)	Type III	Cumulative P	Incremental P
0	0.00000	0.00000	0.00000
1	0.01000	2.64533	2.64533
2	0.02000	5.29067	2.64533
3	0.03100	8.20053	2.90987
4	0.04300	11.37493	3.17440
5	0.05700	15.07840	3.70347
6	0.07200	19.04640	3.96800
7	0.09100	24.07253	5.02613
8	0.11400	30.15680	6.08427
9	0.14600	38.62187	8.46507
10	0.18900	49.99680	11.37493
11	0.25000	66.13333	16.13653
12	0.50000	132.26667	66.13333
13	0.75000	198.40000	66.13333
14	0.81100	214.53653	16.13653
15	0.85400	225.91147	11.37493
16	0.88600	234.37653	8.46507
17	0.91000	240.72533	6.34880
18	0.92800	245.48693	4.76160
19	0.94300	249.45493	3.96800
20	0.95700	253.15840	3.70347
21	0.96900	256.33280	3.17440
22	0.98100	259.50720	3.17440
23	0.99100	262.15253	2.64533
24	1.00000	264.53333	2.38080

Appendix J:


Hyetograph: Post-tornado Conditions
Rainfall (inches)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Time (hours)
7.5" Rainfall
4.96" Rainfall


Hydrograph: Post-tornado Conditions
Volume (Acre-Feet)
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Time (Hours)
7.5" Rainfall
4.96" Rainfall

Appendix K:

Cost for installation and gutter model (RS Means, 2011)

Type	Dimension	Unit Cost-LF
Wood Forms	24 in. wide	22.5
	30 in. wide	25
Steel Forms	24 in. wide	
	Straight	16.4
	Radius	22
	30 in. wide	
	Straight	18.55
	Radius	24.5
Machine Formed	24 in. wide	
	Straight	7.85
	Radius	10.05
	30 in. wide	
	Straight	8.85
	Radius	11.05
Precast (6in.* 18in.)	Straight	14.75
	Radius	34.5

Curb and Gutter Costs (RS Means, 2011)

Inside Diameter (ft)	Depth (ft.)	Unit Cost
4	4	1250
	6	1550
	8	2125
	Depth over 8, add	238
5	4	2125
	6	2725
	8	3300
	Depth over 8, add	340
6	4	3050
	6	4125
	8	5325
	Depth over 8, add	490

*cost excludes footing, excavation, backfill

Precast catch basin inlets (RS Means, 2011)

Grading, Excavation Fill, Common earth with no sheeting or dewatering included, and daily output	Labor/ Equipment	Total including Overhead and Production
1' 4' deep	150/ 0.107	7.8
4'-6' deep	200/0.080	6.15

Selective Clearing	Labor/Equipment	Total including Overhead and Production
Clearing brush with brush with dozer, ball & chain, light clearing	40582	1025

Brushing moving tractor with rotating mover, no removal Heavy density	40551	770

Clearing and Grubbing Land	Labor/Equipment	Total including Overhead & Production
Tree removal, congest area, aerial lift truck (24” diameter)	40643	725
Grub stumps and remove	40567	3275
Cut & chip heavy, tree to 24” diameter	0.3/160	12300

Minor site demolition	Labor/Equipment	Total including Overhead & Production
No hauling	13/ 1.846	117
Catch basin or manhole frames and covers, stored remove and reset	7/ 3.429	218
Roadside delineators, removal only	175/ 0.183	13.1
Remove and reset	100/ 0.320	23