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TECHNICAL MEMORANDUM

CITY OF AMARILLO
MARTIN ROAD LAKE
Storm Water Master Plan Project
Phase II Project Memorandum: Storm Sewer Hydraulic Assessment

Project No.: 0458-022-01

Date: October 9, 2013

Prepared For: Mark Read, P.E., City Engineer

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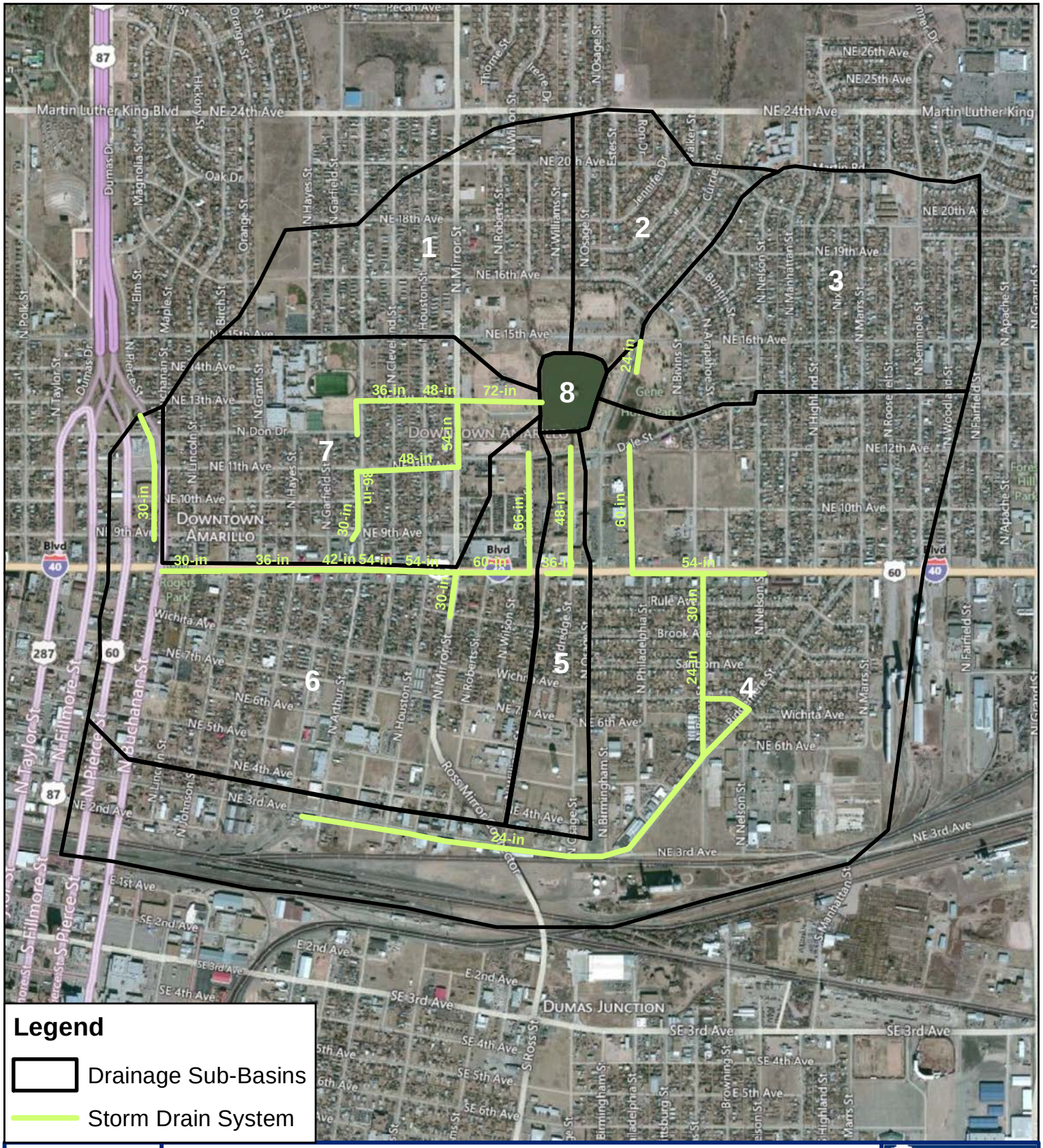
11/26/2013

1. INTRODUCTION

Martin Road Lake is a collection of two playa lakes, divided by Martin Road, located northeast of downtown Amarillo. The drainage area of Martin Road Lake is approximately 1,750 acres, and includes 13 outfalls, over 100 inlets, 7 channels, and more than 3 miles of storm sewer. Previous modeling and limited historical data has indicated there is potential for flooding in the park and the areas surrounding the park. This memorandum is a Phase 2 deliverable, which focuses upon a hydraulic assessment of one of the storm sewer systems that outfall into the lake. Please see the Phase 1 memorandums for the previous analysis and deliverables from the overall Martin Road Lake Storm Water Master Plan.

The overall objective of this memorandum is to provide the City of Amarillo (City) with information on the analysis of the hydraulically modeled storm sewer system. The project scope states that a model will be created of approximately 3,200 linear feet (LF) of storm sewer lines (about 20% of the overall system). Alan Plummer Associates, Inc. (APAI) recommended the west side storm sewer system be evaluated, which is actually about 5,600 LF in length and discharges to the main lake via a 72-inch outfall pipe next to the softball fields. This system drains about 195 acres of the overall 1,750 acres comprising the lake's drainage basin. The streets where inlets and storm sewer pipes are located are Northeast 13th Avenue, Don Drive, Northeast 11th Avenue, Northeast 10th Avenue, and Northeast 9th Avenue all which run in the east/west direction. Also affected are North Mirror Street and North Arthur Street, which run in the north/south direction. They are all local or collector streets as defined by the City criteria. Figure 1 shows the overall drainage basin map of Martin Road Lake (from the Phase I Hydrologic Study). The modeled storm sewer system is show in sub-basin seven on this figure.



Martin Road Lake Stormwater Master Plan
Phase II: Storm Sewer Hydraulic Assessment

FIGURE 1: Sub-Basin Drainage Area Map

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DATE: October 2, 2013

PROJECT NUMBER: 0458-022-01

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2. DRAINAGE CRITERIA

Standards from the City of Amarillo Storm Water Management Criteria Manual (SWMCM) were applied to the analysis of sub-basin seven of the lake's drainage system. Table 1 describes the criteria which apply to this storm sewer evaluation. Comparing the modeled system against this list will reveal any existing system deficiencies and will determine the recommended improvements and final conclusions.

Table 1. City Drainage Criteria Applicable to this Storm Sewer System Evaluation

SWMCM Section	Criteria Description	Method Applied in Model
Section 1.3.3	The area will be evaluated for both a minor and major drainage system. The minor system shall be designed to convey the runoff from a 2-year return period storm. The major system will be designed for the 100-year return period storm.	Minor Storm = 2 year and Major Storm = 100 year
Section 1.3.4	For drainage areas less than 200-acres, the Rational Method or the Amarillo Peak Flow Curve Method may be used for the hydrologic analysis.	Rational Method for Hydrology Calculations
Section 1.3.8	The depth of flow in the receiving playa must be taken into account for backwater computations for both the minor and major runoff events. A starting elevation greater than or equal to that for the same return period assuming a fully developed watershed shall be used.	2-year WSE in lake = 3,607.05-ft, and 100-year WSE in lake = 3,625.15-ft
Section 1.3.10	The street is an important component of an urban drainage system and may be used to convey runoff within the following limits. For a minor runoff event in local and collector streets, the curb shall not be overtopped and flow may spread to the crown of the street. For a major runoff event, the depth of water over the gutter flowline shall not exceed 24-inches and dwellings or buildings shall not be inundated by the runoff. Cross street flow shall not exceed 6-inches of depth for minor events or 24-inches depth for major events in a valley gutter.	Criteria description applies to local and collector streets, which are the street classifications included in the study area.
Section 2.2	The Rational Method can be used to determine runoff for drainage areas less than 200 acres. The runoff coefficient (C) accounts for losses between rainfall and runoff. A range of 0.5 – 0.7 is typical of single family residential land use and 0.65 – 0.95 is typical of neighborhood business districts (commercial use). An adjustment factor of 1.25 will be applied for the 100 year event.	Residential: C_2 year = 0.55 and C_100 year = 0.69 Commercial: C_2 year = 0.65 and C_100 year = 0.81
Section 5.2.2	The storm sewer shall have a minimum average full pipe velocity of 2.0 feet per second (ft. /sec) to prevent deposition of solids. The maximum allowable velocity of collector storm sewer lines is 15 ft. /sec, while the maximum allowable velocity of main trunklines is 12 ft. /sec. The purpose of this upper limit is to help prevent excessive erosion.	Agree.
Section 5.2.3	A minimum pipe diameter of 18-inches should be used for gravity flow storm sewer lines in the City's system.	Agree.

3. MODEL DEVELOPMENT

The software, Bentley StormCAD version V8i was used to construct the hydraulic model. This program can model runoff, inlet capacity and capture efficiency as well as the hydraulics of the storm sewer pipe system. It also takes into account the tail water effect from the lake level per each storm event. The majority of the geometric and connectivity information was taken from the following construction drawings of the system:

- City of Amarillo Storm Sewer Improvements, North Mirror Street Project, July 1963.
- City of Amarillo Martin Road Lake Improvements, BOR Project No. 48-00121, September 1972.

Construction drawing information was supplemented using survey data from this project, where available, and the City's 2-foot contour GIS data set to develop runoff paths. All vertical elevations are presented in the North American Vertical Datum (NAVD) 1988. The following sections further discuss model development with respect to the hydrology and hydraulics of the system.

3.1. Model Hydraulics

APAI input the inlets and storm sewer pipes in the model according to information from the original construction drawings. There are 20 storm sewer inlets in the system with the physical characteristics shown in Table 2. There is a total of 5,223 LF of storm sewer trunkline in the system, which varies from 21 to 72-inches in diameter at the outfall. Additionally, there is 360 LF of lateral pipes which connect the trunkline to the inlets. These vary between 12 and 24-inches in diameter. Figure 2 shows the storm sewer pipe network configuration overlaid on the drainage area map.

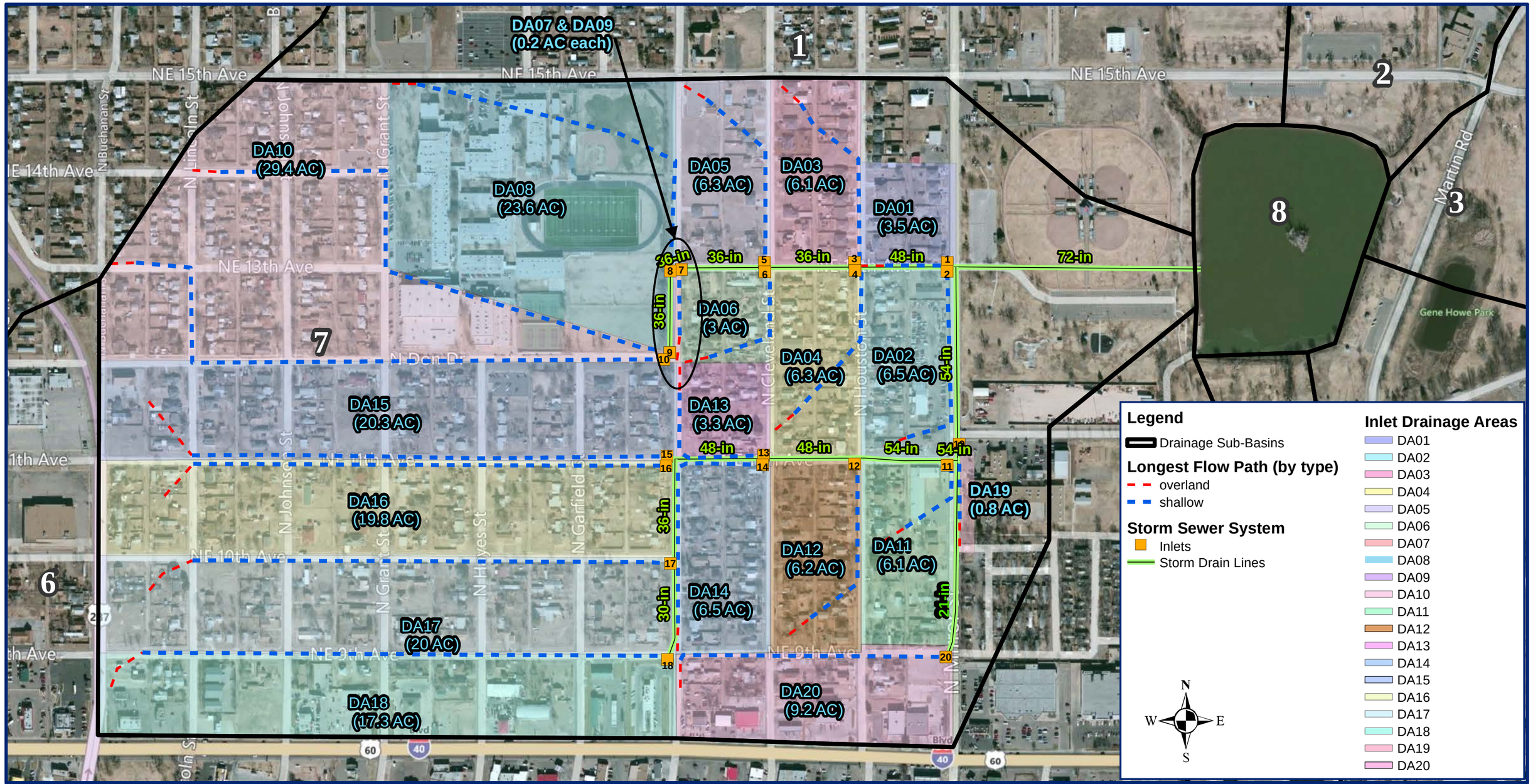
The next section discussed the hydrologic inputs to this modeled system. Then, hydraulic results from the model are discussed in Section 4.

Table 2. Storm Sewer System: Inlets

Inlet ID	Inlet Type [A]	Inlet Location [B]	Gutter Elevation (ft.)	Invert Elevation (ft.)
Inlet 1	Curb Inlet Type B-6	On Grade	3,625.60	3,623.43
Inlet 2	Curb Inlet Type B-8	On Grade	3,625.60	3,623.43
Inlet 3	Curb Inlet Type B-10	On Grade	3,627.84	3,625.40
Inlet 4	Curb Inlet Type B-8	On Grade	3,627.90	3,625.73
Inlet 5	Curb Inlet Type B-10	On Grade	3,630.76	3,628.32
Inlet 6	Curb Inlet Type B-4	On Grade	3,630.42	3,628.25
Inlet 7	Curb Inlet Type B-10	On Grade	3,633.89	3,631.46
Inlet 8	Curb Inlet Type B-5	On Grade	3,634.36	3,628.93
Inlet 9	Curb Inlet Type B-10	On Grade	3,635.10	3,630.75
Inlet 10	Curb Inlet Type B-10	On Grade	3,635.38	3,632.90
Inlet 11	Curb Inlet Type B-8	On Grade	3,628.44	3,626.00
Inlet 12	Curb Inlet Type B-8	On Grade	3,629.75	3,627.81
Inlet 13	Curb Inlet Type B-4	On Grade	3,630.37	3,628.70
Inlet 14	Curb Inlet Type B-8	On Grade	3,630.82	3,628.88
Inlet 15	Curb Inlet Type B-20	On Grade	3,634.38	3,631.63
Inlet 16	Curb Inlet Type B-20	On Grade	3,634.70	3,631.95
Inlet 17	Curb Inlet Type B-5	On Grade	3,636.30	3,633.55
Inlet 18	Curb Inlet Type B-5	On Grade	3,637.75	3,634.20
Inlet 19	Curb Inlet Type B-4	On Grade	3,628.00	3,625.93
Inlet 20	Curb Inlet Type B-10	On Grade	3,632.02	3,627.52

A. The inlet type describes the length of the opening of the curb inlet.

B. On-grade means the inlet is on a sloped surface instead of in a low point (sag).



Legend

Drainage Sub-Basins

Longest Flow Path (by type)

overland

shallow

Storm Sewer System

Inlets

Storm Drain Lines

Inlet Drainage Areas

DA01
DA02
DA03
DA04
DA05
DA06
DA07
DA08
DA09
DA10
DA11
DA12
DA13
DA14
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Martin Road Lake Stormwater Master Plan
Phase II: Storm Sewer Hydraulic Assessment
FIGURE 2: Drainage Area Map

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0 280 560 Feet
1 inch = 375 feet

SOURCE: ESRI BASE DATA, WORLD IMAGERY

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3.2. Model Hydrology

APAI delineated drainage areas for each inlet in the system (shown on Figure 2). The total drainage area contributing to this storm sewer system is 195 acres with the westernmost drainage areas being the largest. The land all generally slopes toward Martin Road Lake, which will have room per the Phase I recommendations to store runoff through the 100-year storm event.

Once drainage areas are defined, the next step is to determine runoff from the minor (2-year) and major (100-year) storm events per the City drainage criteria. Since the total drainage area is just less than 200 acres, the Rational Method is used to calculate runoff for these two storm events. The Rational Method takes into account the following hydrologic factors:

- **Runoff Coefficient, C (unitless):** Accounts for losses between rainfall and runoff that are caused by infiltration into the ground, interception by vegetation, retention in surface depressions, evaporation, and transpiration. Recommended Runoff Coefficient values from the City drainage criteria were compared to land uses for each inlet's drainage area and assigned a representative value (see Table 1). An average C-value was determined for drainage areas with multiple land uses. An adjustment factor of 1.25 was applied to the 2-year C-value to determine the 100-year event C-value.
- **Time of Concentration, Tc (minutes):** This is the time it takes for runoff to travel from the most hydraulically remote (furthest away by travel time, not distance) part of the drainage area to that areas storm sewer inlet. Figure 2 shows the longest flow paths used to determine the Tc for each drainage area. Appendix A contains detailed calculations which take into account the flow type (overland or shallow concentrated flow), length of the flow path, gradient of the flow path, and land surface.
- **Average Rainfall Intensity, i (inches per hour):** This variable reflects the average rate of rainfall for each storm event. It is selected based upon statistical parameters given for each storm based upon local rainfall conditions. The graph in Figure 3 (equivalent data in Table 3) shows the rainfall intensity curves from the City drainage criteria. To determine runoff to each inlet's drainage area, the intensity that is equal to each area's Tc is used in the Rational Method runoff calculations.

A summary of these runoff calculations for each inlet's drainage area are provided in Table 4.

Figure 3. Amarillo Intensity v. Storm Duration Curves for Minor and Major Storm Events

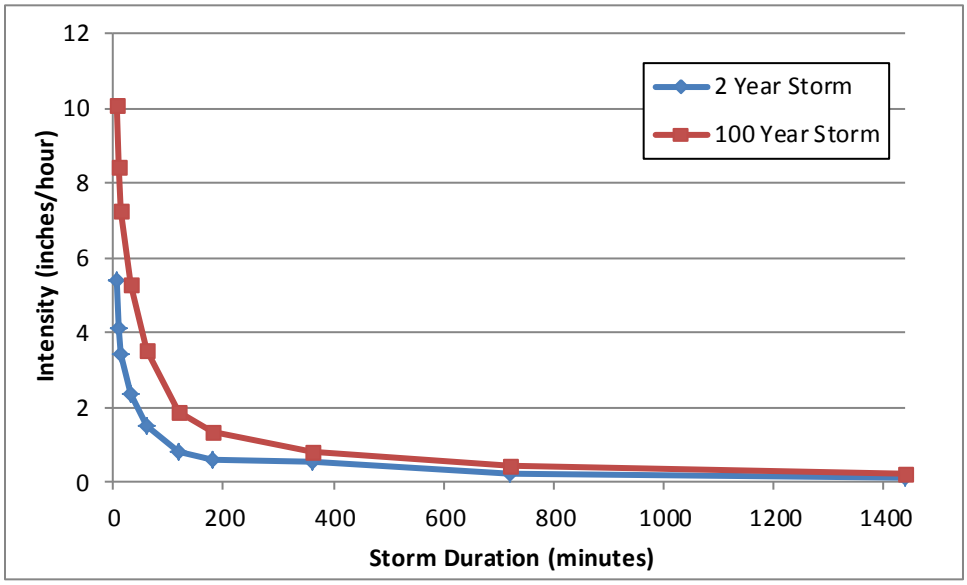


Table 3. Amarillo Intensity v. Storm Duration in Tabular Format

Duration (min)	Intensity (in/hour)	
	2-Year Storm	100-Year Storm
5	5.4	10.08
10	4.14	8.46
15	3.4	7.24
30	2.36	5.3
60	1.52	3.52
120	0.825	1.9
180	0.6	1.337
360	0.538	0.783
720	0.2	0.433
1,440	0.113	0.241

Table 4. Summary of Hydrologic Inputs

Drainage Area ID	Area (acres)	Tc (min)	Land Use	C Values		Intensity (in/hr)		Peak Flow (cfs)	
				2-yr	100-yr	2-yr	100-yr	2-yr	100-yr
1	3.52	5.0	Residential	0.55	0.69	5.40	10.08	10.5	24.6
2	6.52	11.2	Residential & Neighborhood Business	0.59	0.74	3.96	8.17	15.4	39.6
3	6.07	11.5	Residential	0.55	0.69	3.92	8.10	13.2	34.1
4	6.25	14.4	Residential	0.55	0.69	3.50	7.40	12.1	32.0
5	6.34	11.2	Residential	0.55	0.69	3.97	8.18	13.9	35.9
6	3.04	8.6	Residential	0.55	0.69	4.49	8.90	7.6	18.8
7	0.19	5.0	Neighborhood Business	0.65	0.81	5.40	10.07	0.7	1.6
8	23.63	17.4	Neighborhood Business	0.65	0.81	3.24	6.93	50.1	134.2
9	0.17	5.0	Neighborhood Business	0.65	0.81	5.40	10.08	0.6	1.4
10	29.38	21.8	Residential & Neighborhood Business	0.57	0.71	2.93	6.36	49.4	134.2
11	6.09	9.3	Residential & Neighborhood Business	0.57	0.71	4.32	8.69	15.1	38.0
12	6.23	13.2	Residential	0.55	0.69	3.66	7.67	12.7	33.1
13	3.26	7.7	Residential	0.55	0.69	4.72	9.21	8.5	20.8
14	6.49	14.4	Residential	0.55	0.69	3.49	7.39	12.6	33.3
15	20.32	23.3	Residential	0.55	0.69	2.83	6.17	31.8	86.9
16	19.82	19.4	Residential	0.55	0.69	3.10	6.67	34.0	91.7
17	20.04	21.2	Residential	0.55	0.69	2.97	6.44	33.0	89.4
18	17.29	23.3	Residential & Neighborhood Business	0.63	0.79	2.83	6.17	31.0	84.7
19	0.83	5.7	Neighborhood Business	0.65	0.81	5.22	9.85	2.8	6.7
20	9.20	14.8	Residential & Neighborhood Business	0.61	0.76	3.42	7.28	19.4	51.5

Table 4 shows the peak flows from each drainage area (DA) to each inlet. Notice that some of these peak flows are quite high, the greatest being DA 10 which has a 2-year peak flow of almost 50 cfs and a 100-year peak flow of 134 cfs. A drainage inlet, even with a large capacity could not contain these flows, so much of the water will pond in the street. Modeled results, in greater depth, are discussed in Section 4.

The final key model input is the Martin Road Lake tailwater boundary conditions. In this case, the recommendations from the Phase I deliverables are applied. The tailwater elevations take into account the proposed improvements for the lake which were recommended to contain the 100-year floodplain within the lake's storage pool. A tailwater elevation of 3,607.05-feet was used for the 2-year storm and 3,625.15-feet was used for the 100-year storm.

4. MODEL RESULTS

Results from the StormCAD model are compared with the City drainage criteria to determine if the existing system meets City standards for the minor and major storm events. Model results are divided into three sections for discussion (storm sewer pipe capacity, inlet capacity, and street capacity) since these components each have a part to play in overall system performance.

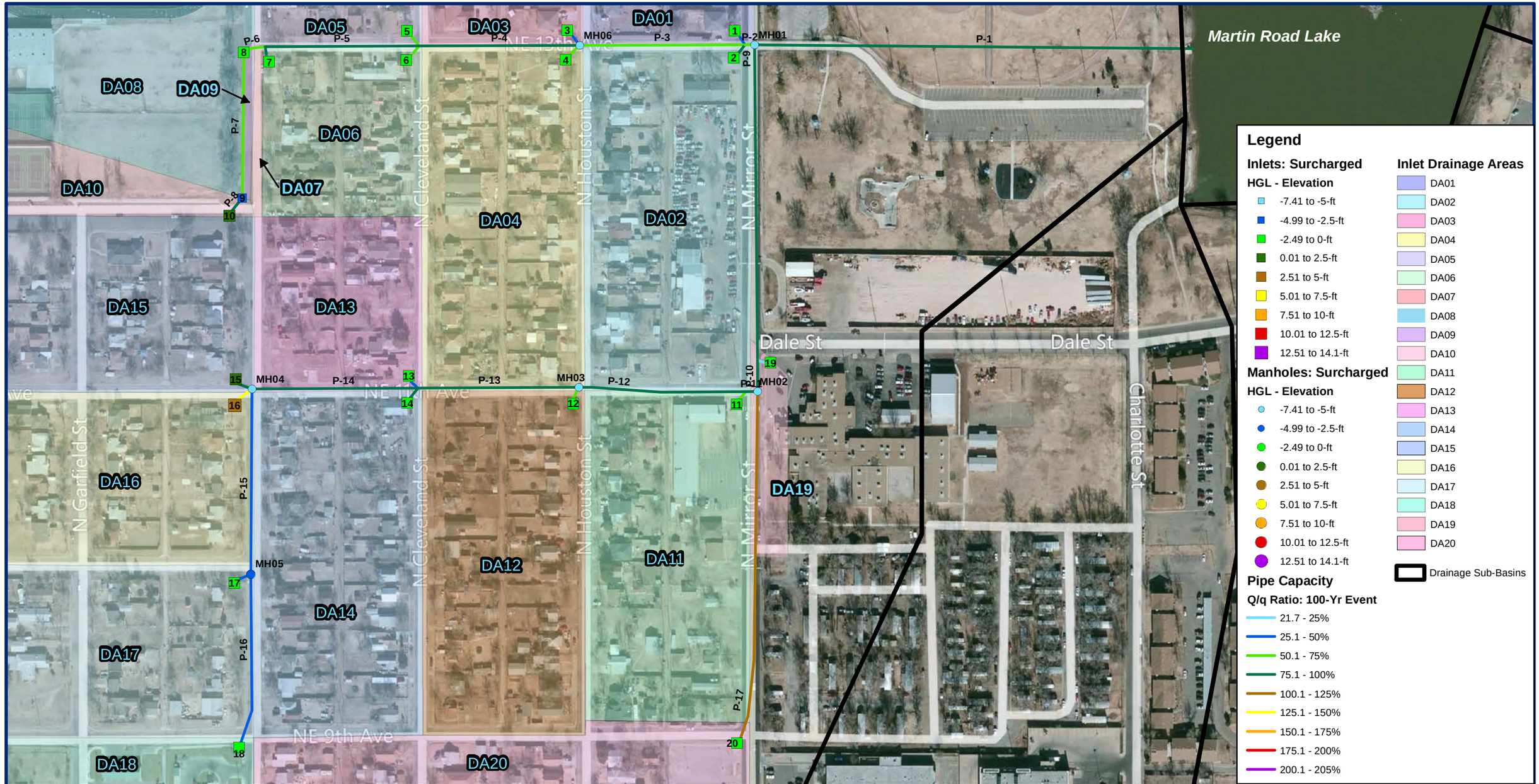
4.1. Storm Sewer Pipe Capacity

APAI evaluated the storm sewer pipe's capacity according to the following factors.

- **Q/q Ratio:** The flow through each pipe (Q) divided by the pipe's full flow capacity (q) is a useful indicator to determine if each pipe segment is adequately sized. A ratio greater than 1.0 means that the flow exceeds the pipe's capacity and surcharging occurs. A ratio less than 1.0 means that the flow is contained within the pipe.
- **Hydraulic Grade Line (HGL):** The HGL is the modeled water surface elevation (WSE) of the storm sewer system. When the Q/q is greater than one or significant headlosses occur, the HGL may be above the ground elevation showing that water will escape the system from any openings (inlets and manholes) to the air.

It is important to consider these parameters within the guidance set by the SWMCM. A Q/q ratio that is too low means that the pipes may be oversized or that their capacity is not being efficiently used. A Q/q ratio that is too high means surcharging of the pipe occurs, which is acceptable when still meeting the design criteria. Table 1 stated the street curb shall not be overtopped and flow may spread to the crown of the street in the minor runoff event of local and collector streets. Therefore, the depth of the 2-year storm cannot exceed 6-inches. For a major runoff event, the depth of water over the gutter flowline shall not exceed 24-inches and dwellings or buildings shall not be inundated by the runoff.

Figures 4 and 5 present the pipe capacity and HGL surcharge analysis for the 2-year and 100-year storm events, respectively. Additionally, tabular results are included in Appendix B. For the 2-year event, these figures show that the q/Q ratios vary from 21.7% to 137.6%. Only one line, the lateral to Inlet 16, significantly exceeds a ratio of 1.0 (Q/q = 137.6%). The next greatest Q/q value is for Pipe 17, which just exceeds the pipe capacity at 100.8%. For the 100-year event, the Q/q ratios vary from 32.7% to 204.8% with 81% of the entire system (by length) having a Q/q greater than 1.0. These figures and tabular results also show that the HGL escapes the system at three inlet locations (inlets 10, 15, and 16) for the 2-year event. However, for the 100-year event, the HGL escapes the system at all but one inlet (#18) and one manhole (#5). These two parameters show that flow exceeds pipe capacity for the majority of the system and that there may be significant street flooding during the 100-year storm event. Section 4.3 discusses the street flooding issue within the drainage criteria framework.



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Martin Road Lake Stormwater Master Plan
Phase II: Storm Sewer Hydraulic Assessment
FIGURE 4: Pipe Capacity and HGL Surcharge Results for 2-year Storm Event

Note: Lateral pipe IDs not shown on this map due to space constraints. IDs are numbered according to the inlet they serve. i.e. L-1, L-2, etc.

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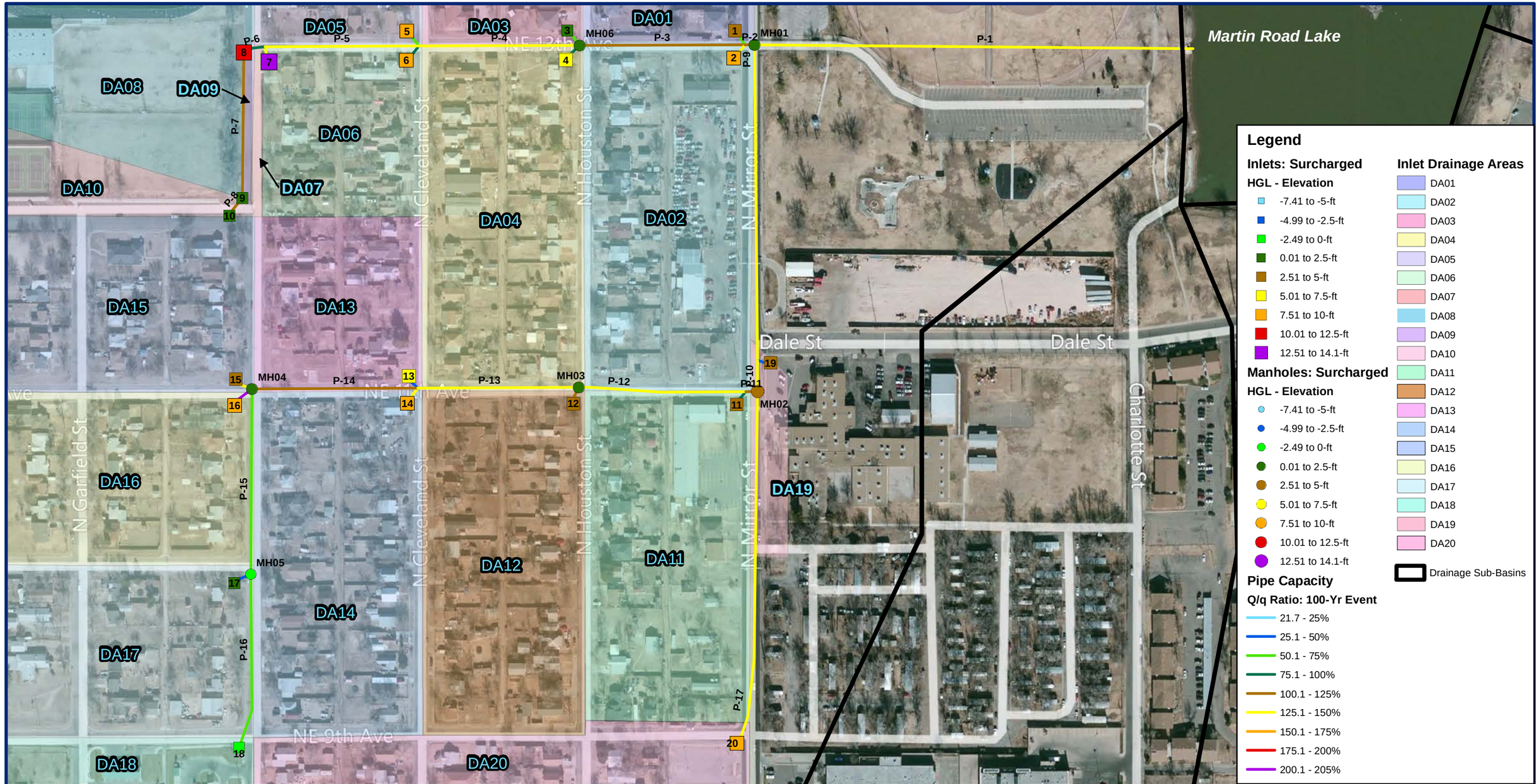

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Martin Road Lake Stormwater Master Plan
Phase II: Storm Sewer Hydraulic Assessment
FIGURE 5: Pipe Capacity and HGL Surcharge Results for 100-year Storm Event

Note: Lateral pipe IDs not shown on this map due to space constraints. IDs are numbered according to the inlet they serve. i.e. L-1, L-2, etc.

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It is important to note that StromCAD is a one dimensional (not two dimensional) hydraulic model. It can calculate the HGL or WSE within the storm sewer system, but once the HGL escapes the system the reported results are no longer accurate. For example, Figure 5 shows that the greatest amount of surcharging occurs at inlet 7 with an HGL 14.1-ft above the inlet's gutter line. This result is a one dimensional calculated value and does not mean that 14.1-feet of water is ponded in this location for the 100-year event. This is a limitation of StormCAD and a two dimensional model would be required to tell the true depth and spread of water here.

4.2. Inlet Capacity

Section 4.1 discussed the pipe capacity of the existing system and how the HGL calculated by the model for each storm event and can show if storm water is escaping from the system via manholes or inlets. This section discusses the capacity of the inlets to determine which inlets can accommodate the amount of runoff they are receiving from each drainage area. Flow that the inlet cannot capture is bypassed to the next inlet via gutter flow to be potentially captured or passed along further. Ultimately, some bypassed flow may never be captured by any inlets in the system. In this case, it will continue to flow east through the park area as overland flow and ultimately into Martin Road Lake.

Table 5 shows each inlet, its bypass target if applicable, and the performance data for the minor and major storm events. The table shows that for the 2-year event, the gutter depth exceeds 6-inches for half of the inlets. The gutter spread also shows that water will pond across half the street or more, which is allowable per the City's drainage criteria. For the 100-year event, the greatest gutter depth is 12.6-inches, which is well below the allowable limit of 24-inches for the major storm event.

The most important result shown in this table is the low capture efficiency of each inlet and the significant amount of flow bypassed to the next downstream inlet in the system. The amount of flow intercepted by each inlet is typical of inlets on grade, with those inlets having a larger opening or located on a gentler slope capturing more flow. However, the large amount of flow bypassed, even for the 2-year storm event, shows that there are not enough inlets along the streets. The drainage areas contribute more runoff than the inlets can physically capture. Figure 4 showed with the Q/q analysis that there is some extra capacity in the pipe system that is not being fully utilized for the 2-year storm event.

Section 4.3 will discuss the street capacity to determine if the bypassed flows can be adequately contained.

Table 5. Inlet Performance Summary

Inlet ID [A]	Length of Opening (ft)	Bypass Target	2-Year: Minor Storm Event					100-Year: Minor Storm Event				
			Gutter Depth (in) [B]	Gutter Spread (ft)	Flow Intercepted (cfs)	Flow Bypassed (cfs)	Capture Efficiency (%)	Gutter Depth (in) [C]	Gutter Spread (ft)	Flow Intercepted (cfs)	Flow Bypassed (cfs)	Capture Efficiency (%)
1	6	Lake	3.6	15.2	5.6	31.4	15.1	4.9	20.5	7.8	74.3	9.5
2	8	Lake	6.1	25.5	13.3	134.1	9.0	8.7	36.2	19.8	355.3	5.3
3	10	Inlet 1	3.5	14.7	8.6	17.3	33.1	4.8	19.9	12.3	46.2	21.1
4	8	Inlet 2	6.0	24.8	12.9	113.9	10.2	8.5	35.3	19.2	304.5	5.9
5	10	Inlet 3	3.4	14.2	8.0	9.5	45.7	4.5	18.6	11.2	24.7	31.2
6	4	Inlet 4	6.3	26.1	6.9	113.0	5.7	8.6	35.7	9.8	266.6	3.5
7	10	Inlet 6	6.8	28.3	18.6	131.1	12.4	9.0	37.5	25.7	290.3	8.1
8	5	Inlet 7	8.9	37.2	12.9	83.2	13.4	12.4	51.5	18.9	209.5	8.3
9	10	Inlet 8	9.5	39.7	26.5	55.9	32.2	12.6	52.6	37.7	137.0	21.6
10	10	Inlet 9	6.6	27.5	17.5	44.3	28.3	8.8	36.8	24.9	109.3	18.5
11	8	Lake	5.7	23.6	12.1	95.8	11.2	8.3	34.4	18.7	276.4	6.3
12	8	Inlet 11	5.8	24.2	12.5	75.5	14.2	8.6	35.7	19.5	226.9	7.9
13	4	Inlet 4	3.6	15.1	3.7	29.3	11.2	5.3	22.0	5.7	85.6	6.2
14	8	Inlet 12	8.3	34.4	18.5	68.9	21.1	12.0	49.9	28.8	205.5	12.3
15	20	Inlet 13	5.8	24.1	26.4	13.4	66.3	7.7	32.2	39.7	47.2	45.7
16	20	Inlet 14	8.2	34.0	42.9	63.5	40.3	11.2	46.5	63.8	181.5	26.0
17	5	Inlet 16	7.2	29.8	10.0	61.2	14.0	9.8	40.6	14.3	148.2	8.8
18	5	Inlet 17	7.5	31.2	10.3	28.5	26.5	10.0	41.8	14.7	70.0	17.3
19	4	Lake	5.2	21.7	5.5	14.4	27.5	7.3	30.6	8.2	41.5	16.5
20	10	Inlet 19	5.6	23.4	13.5	10.7	55.9	7.5	31.1	19.7	31.8	38.2

A. All inlets are curb inlets on grade (on a slope).
B. Gutter depth may not exceed curb height (6-inches) for the minor storm event.
C. Gutter depth may not exceed 24-inches depth for the major storm event or may not inundate structures.

4.3. Street Capacity

The capacity of each street to convey flow was calculated using the methodology described in the City of Amarillo Drainage Utility Study (RPS Espey, December 2011) and equation 3.1 of the SWMCM. This method assumes a street cross-slope of 3.33% and a 2% grade of the right-of-way sloped to the street producing a cross-section that can convey flow. Note, not enough detailed elevation data of the street right-of-ways was available to verify this assumption. Table 6 shows the results of street capacity calculations (detailed calculations are included in Appendix C) compared with the amount of bypassed flows presented in Table 5.

Table 6 shows that flow exceeds the street capacity for both storm events at over half of the inlet locations. This means there may be potential for the flooding of structures near these locations. As stated previously a two dimensional analysis would provide better results to determine the spread of runoff/flooding with more refined elevation data. All of the bypassed flows will reach Martin Road Lake, which is the drainage basin's outfall. The recommendations provided in Phase I of this Storm Water Master Plan will ensure the lake has the capacity to contain the 100-year flows once they reach the lake. Section 5 of this memorandum provides a summary of all recommendations.

Table 6. Street Capacity Summary & Comparison to Inlet Bypassed Flows

Inlet ID	Street Name	Street Width (ft)	Minimum Width Between Structures (ft)	Street Capacity [A] (cfs)	Right-of-way Capacity (cfs)	Total Capacity [B] (cfs)	Flow Bypassed (cfs)		Flow Bypassed - Street Capacity [C] (cfs)	
							2-Year	100-Year	2-Year	100-Year
1	Northeast 13th Ave.	30	80	26	49	75	31.4	74.3	5.5	-0.8
2	Northeast 13th Ave.	30	80	26	49	75	134.1	355.3	108.2	280.2
3	Northeast 13th Ave.	30	80	30	56	86	17.3	46.2	-12.3	-39.7
4	Northeast 13th Ave.	30	80	30	56	86	113.9	304.5	84.2	218.6
5	Northeast 13th Ave.	30	80	34	64	98	9.5	24.7	-24.4	-73.4
6	Northeast 13th Ave.	30	80	34	64	98	113.0	266.6	79.2	168.5
7	North Arthur St.	40	120	20	55	75	131.1	290.3	110.9	215.6
8	North Arthur St.	40	120	16	43	59	83.2	209.5	67.4	150.7
9	North Arthur St.	40	120	18	50	68	55.9	137.0	37.5	68.6
10	North Don Dr.	45	85	34	82	115	44.3	109.3	10.4	-6.2
11	Northeast 11th Ave.	30	80	20	38	57	95.8	276.4	76.1	219.1
12	Northeast 11th Ave.	30	65	18	31	49	75.5	226.9	57.6	178.3
13	Northeast 11th Ave.	30	60	33	55	88	29.3	85.6	-4.0	-2.5
14	Northeast 11th Ave.	30	60	33	55	88	68.9	205.5	35.6	117.4
15	Northeast 11th Ave.	30	85	35	68	103	13.4	47.2	-21.2	-55.4
16	Northeast 11th Ave.	30	85	35	68	103	63.5	181.5	28.9	78.9
17	Northeast 10th Ave.	35	90	20	44	65	61.2	148.2	40.8	83.3
18	Northeast 9th Ave.	35	60	30	54	84	28.5	70.0	-1.6	-14.4
19	North Miror St.	40	120	24	65	89	14.4	41.5	-9.6	-47.2
20	Northeast 9th Ave.	35	63	20	62	82	10.7	31.8	-9.6	-50.7

A. The 2-year (minor) event should be contained within the street per City drainage criteria.
B. The 100-year (major) event should be contained with right-of-way per City drainage criteria.
C. The highlighted red cells are the locations where flows exceed the capacity of the street or street plus right-of-way.

5. RECOMMENDATIONS

The purpose of this Phase II Storm Sewer Hydraulic Assessment was to assist the City of Amarillo by creating a hydraulic model of a portion of the storm sewer system discharging to Martin Road Lake. The western drainage basin encompassing about 195 acres was selected for modeling. This drainage basin is primarily residential, although it also includes Palo Duro High School and some light commercial businesses north along East Amarillo Boulevard. The storm sewer system serving this area is comprised of 20 inlets, almost 5,600 LF of storm sewer pipe, and has the largest outfall (72-inches) into the lake. APAI developed a StormCAD hydraulic model, which required drainage area calculations and hydrologic inputs. Model results were evaluated against the City's drainage criteria manual for the minor (2-year) and major (100-year) storm events. The following list summarizes the results from this evaluation.

- The key result of this evaluation is that the Q/q (pipe flow/pipe capacity) analysis showed that not all pipe capacity is being utilized in the 2-year storm event. This coupled with the amount of bypassed flow at inlets for the 2-year event shows that the system could use more inlets to capture and convey flow through the storm sewer system. Since this area is well established, it is recommended that adding inlets only be done if other upgrades or street construction are taking place or if the City becomes aware of localized flooding issues that could be alleviated.
- Another key result is that the amount of bypassed flow by the inlets often exceeds the street and right-of-way capacity, sometimes by a whole order of magnitude. It is recommended that the City consider any localized flooding issues at the locations where the bypassed flow exceeds the street/right-of-way capacity by the greatest margin. A more detailed evaluation of these areas could be performed using two dimensional modeling techniques. An evaluation of the right-of-way grade to street in these areas would also be useful to determine if the capacity assumptions used in this evaluation are accurate and if the near-by structures are located sufficiently above the 24-inch allowable water depth above the gutter elevation for the 100-year storm event.
- The existing system does not meet the City's drainage criterion with respect to minimum pipe diameter, which is 18-inches. The purpose of this criterion is to select a size large enough to help prevent debris or trash from obstructing the pipes. The existing system has 252 LF of 12-inch and 15-inch diameter pipe (12 laterals). Again, APAI does not recommend tearing out and replacing this pipe, but if other construction activities present the opportunity or repeated obstructions is a problem in an area, they upgrades are recommended.
- Several pipes in the storm sewer system exceed the maximum allowable velocity for collector lines, which is 15 ft. /sec. The trunklines do meet the criteria for maximum allowable velocity of 12 ft. /sec. The purpose of this upper limit is to help prevent excessive erosion. If laterals are replaced with larger diameter lines, then velocities will decrease or the lateral's slope can be adjusted, but only if other construction activities are taking place.

It is important to consider that the peak flows and subsequent hydraulic results and analysis presented in this memorandum were calculated using the Rational Method. This method is used to determine peak storm water runoff rates and is often used for the design of storm sewer systems. Some of the results showed that the peak flows greatly exceeded the street capacity. These peak flows should occur only for a short duration[1] over the course of the storm event. APAI did not recommend any capital projects per this storm sewer hydraulic assessment because there was no significant history of complaints in this area. One complaint was recorded in 2008 from 922 North Houston Street stating the street floods whenever it rains. This house is on a side street between inlets 11 and 12, which both see significant bypassed flow since they are on the lakeside edge of the drainage area. The City should monitor this location and those of future complaints near any of the inlets or bypassed flow locations. If these localized flooding issues continue after the Martin Road Lake improvements, the City should revisit this report and consider increasing inlet sizes or quantity. A more detailed analysis of the street and right-of-way capacity at any problem locations could be performed to see if improvements are needed.

Appendices

Appendix A – Hydrology Calculations for Time of Concentration

Appendix B – Hydraulic Modeling Results

Appendix C – Street and Right-of-way Capacity Calculations

Electronic Deliverables

Electronic Deliverable 1 - Storm CAD Hydraulic Model

[1] The peak runoff duration is assumed to be equal to the time of concentration of each drainage area. The model results are shown at the time when the entire drainage area is contributing runoff to the system.

Appendix A

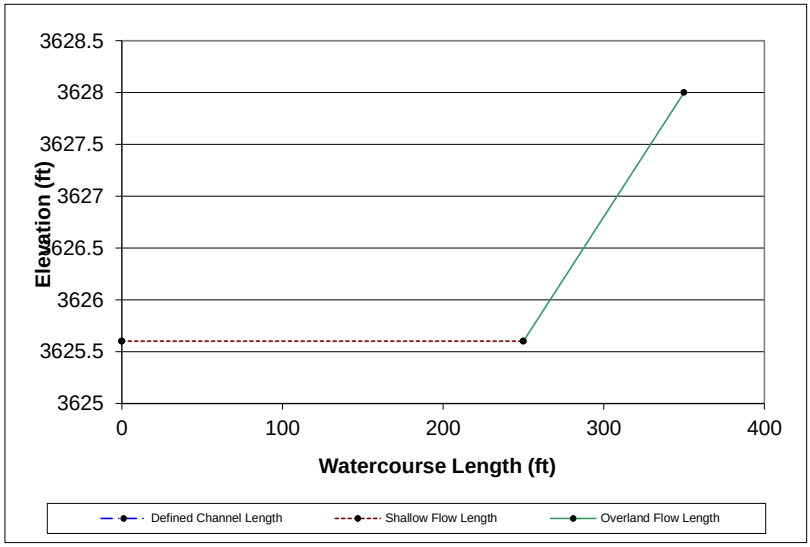
Time of Concentration Calculations

APAI, Inc.

DA-1

Total Watercourse length	350	ft
Defined Channel Length	0	ft
Shallow Flow Length	250	ft
Overland Flow Length	100	ft
Starting Elevation	3628	ft
Elevation after 100 feet	3625.6	ft
Starting Channel Elevation	3625.6	ft
Ending Channel Elevation	3625.6	ft
County	Randall	
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.035	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.03	1.79
Shallow	0.00	0.00
Channel	0.00	0.00
TOTAL	**0.03**	**1.79**
T_{lag}	**0.02**	**1.07**



Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 100 ft	

	Overland	Shallow Flow	Channel	Average
Watercourse slope:	2.40%	0.00%	N/A	0.69%
Watercourse velocity:	0.93 fps	N/A	N/A	3.26 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

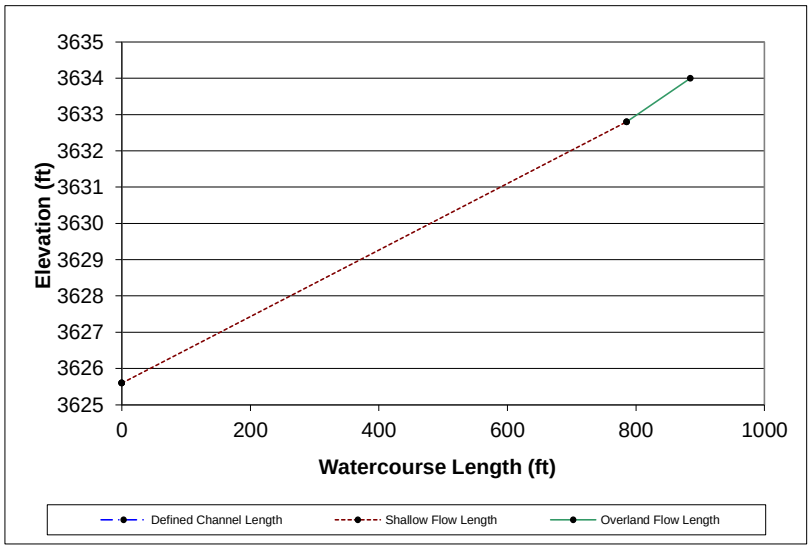
Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-2

Total Watercourse length	885	ft
Defined Channel Length	0	ft
Shallow Flow Length	786	ft
Overland Flow Length	99	ft
Starting Elevation	3634	ft
Elevation after 99 feet	3632.8	ft
Starting Channel Elevation	3625.6	ft
Ending Channel Elevation	3625.6	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.02	
Hydraulic Radius of channel	3.09	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.04	2.66
Shallow	0.14	8.53
Channel	0.00	0.00
TOTAL	**0.19**	**11.19**
T_{lag}	**0.11**	**6.71**



Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 99 ft	

	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.21%	0.92%	N/A	0.95%
Watercourse velocity:	0.62 fps	1.54 fps	N/A	1.32 fps

Channel Geometry		
Bottom Width	12	ft
Estimated Depth	5	ft
Side Slopes (Hoz / Vert)	3	ft/ft
Hydraulic Radius	3.09	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

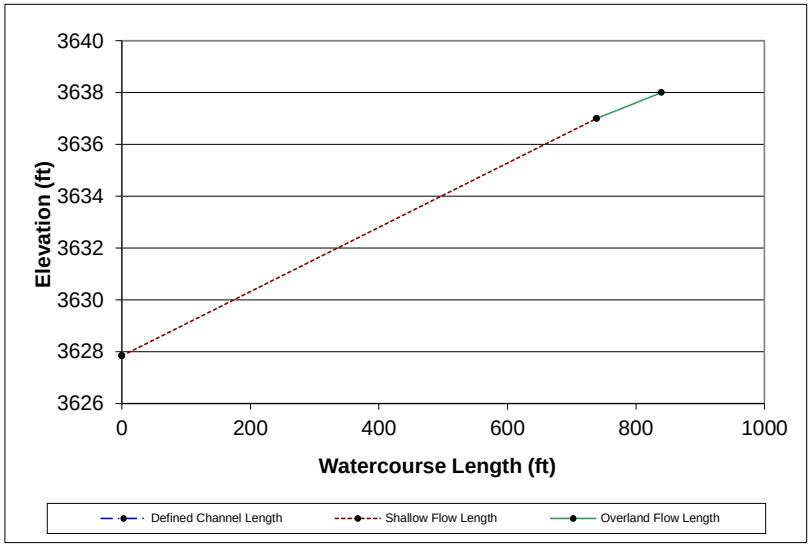
Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	#VALUE!	fps	

Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-3

Total Watercourse length	840	ft
Defined Channel Length	0	ft
Shallow Flow Length	739	ft
Overland Flow Length	101	ft
Starting Elevation	3638	ft
Elevation after 101 feet	3637	ft
Starting Channel Elevation	3627.84	ft
Ending Channel Elevation	3627.84	ft
	Randall	
County		
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.08	4.58
Shallow	0.11	6.89
Channel	0.00	0.00
TOTAL	**0.19**	**11.47**
T_{lag}	**0.11**	**6.88**



Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 101 ft	

	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.99%	1.24%	N/A	1.21%
Watercourse velocity:	0.37 fps	1.79 fps	N/A	1.22 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

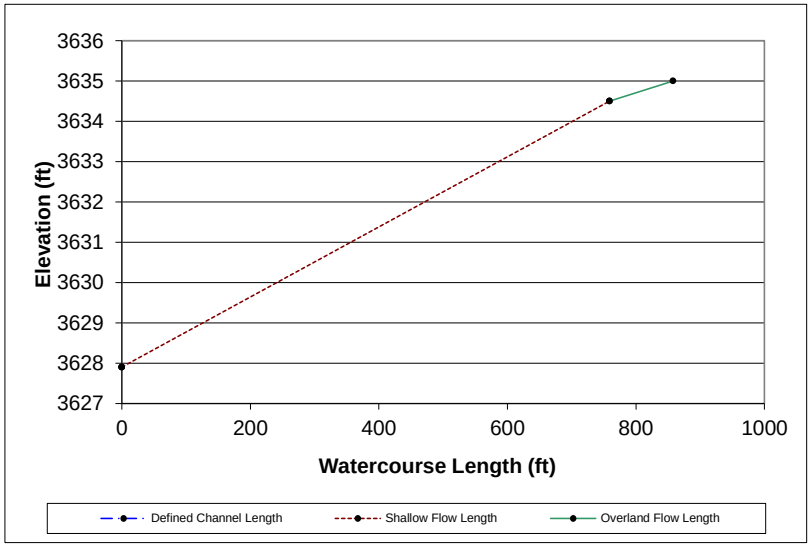
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-4

Total Watercourse length	858	ft
Defined Channel Length	0	ft
Shallow Flow Length	759	ft
Overland Flow Length	99	ft
Starting Elevation	3635	ft
Elevation after 99 feet	3634.5	ft
Starting Channel Elevation	3627.9	ft
Ending Channel Elevation	3627.9	ft
	Randall	
County		
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.10	5.90
Shallow	0.14	8.46
Channel	0.00	0.00
TOTAL	**0.24**	**14.36**
T_{lag}	**0.14**	8.62

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 99 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.51%	0.87%	N/A	0.83%
Watercourse velocity:	0.28 fps	1.5 fps	N/A	1 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

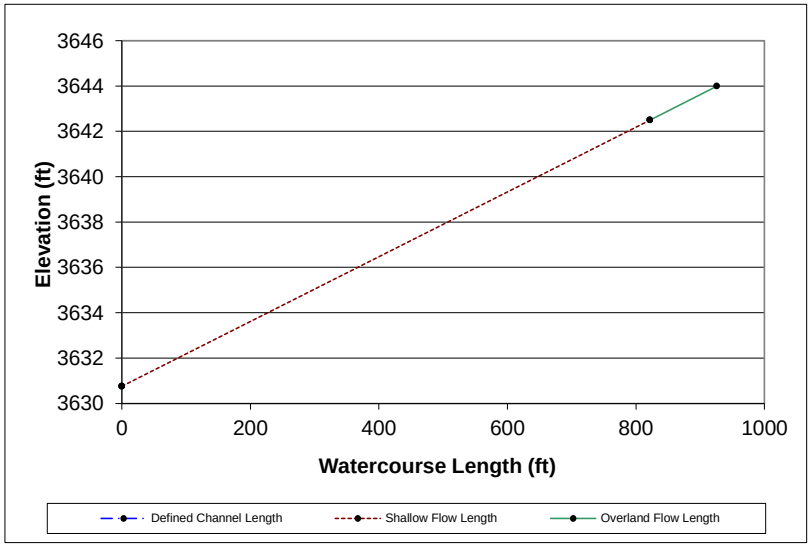
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-5

Total Watercourse length	926	ft
Defined Channel Length	0	ft
Shallow Flow Length	822	ft
Overland Flow Length	104	ft
Starting Elevation	3644	ft
Elevation after 104 feet	3642.5	ft
Starting Channel Elevation	3630.76	ft
Ending Channel Elevation	3630.76	ft
County	Randall	
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.07	4.03
Shallow	0.12	7.13
Channel	0.00	0.00
TOTAL	**0.19**	**11.17**
T_{lag}	**0.11**	6.70

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 104 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.44%	1.43%	N/A	1.43%
Watercourse velocity:	0.43 fps	1.92 fps	N/A	1.38 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

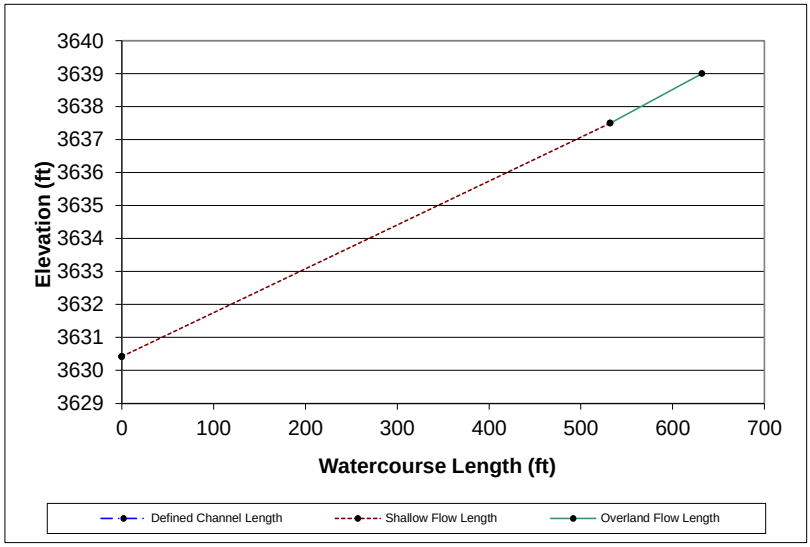
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-6

Total Watercourse length	632	ft
Defined Channel Length	0	ft
Shallow Flow Length	532	ft
Overland Flow Length	100	ft
Starting Elevation	3639	ft
Elevation after 100 feet	3637.5	ft
Starting Channel Elevation	3630.42	ft
Ending Channel Elevation	3630.42	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.85
Shallow	0.08	4.78
Channel	0.00	0.00
TOTAL	**0.14**	**8.63**
T_{lag}	**0.09**	5.18

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 100 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.50%	1.33%	N/A	1.36%
Watercourse velocity:	0.43 fps	1.85 fps	N/A	1.22 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

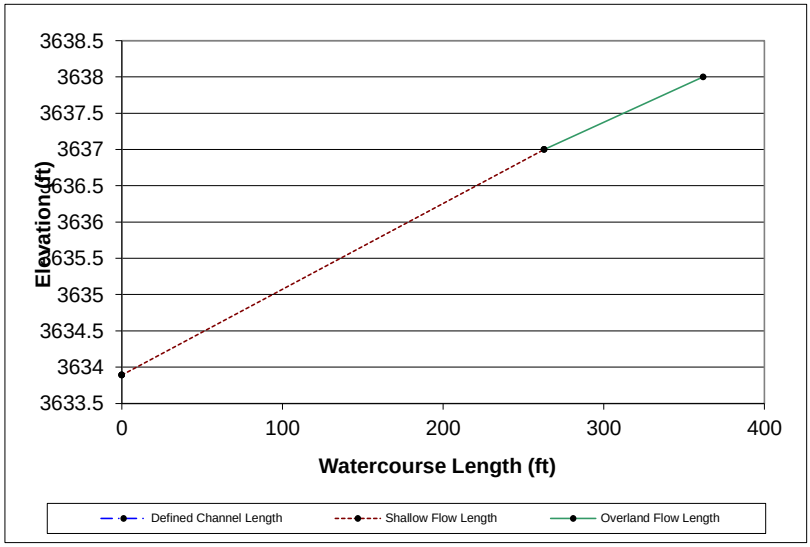
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-7

Total Watercourse length	362	ft
Defined Channel Length	0	ft
Shallow Flow Length	263	ft
Overland Flow Length	99	ft
Starting Elevation	3638	ft
Elevation after 99 feet	3637	ft
Starting Channel Elevation	3633.89	ft
Ending Channel Elevation	3633.80	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.04	2.51
Shallow	0.04	2.51
Channel	0.00	0.00
TOTAL	**0.08**	**5.02**
T_{lag}	**0.05**	3.01

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 99 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.01%	1.18%	N/A	1.14%
Watercourse velocity:	0.66 fps	1.75 fps	N/A	1.2 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation		
Runoff Coefficient, C**		
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

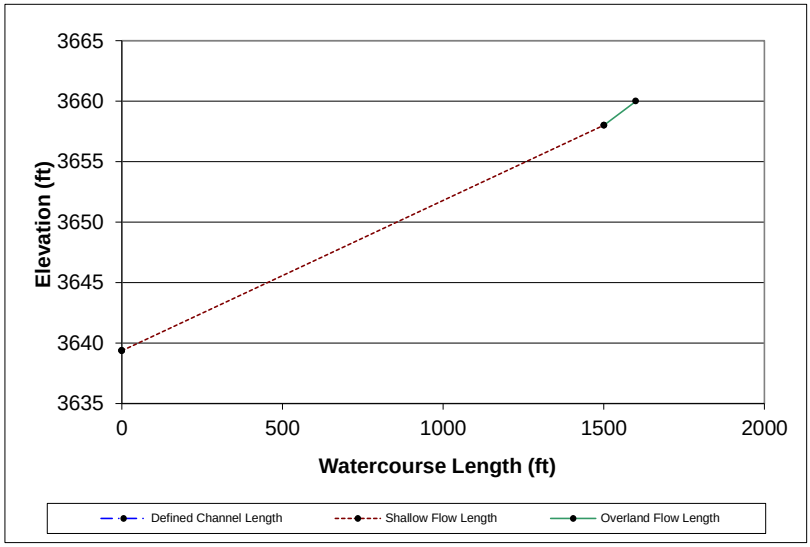
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-8

Total Watercourse length	1600	ft
Defined Channel Length	0	ft
Shallow Flow Length	1501	ft
Overland Flow Length	99	ft
Starting Elevation	3660	ft
Elevation after 99 feet	3658	ft
Starting Channel Elevation	3639.36	ft
Ending Channel Elevation	3639.36	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.39
Shallow	0.23	13.98
Channel	0.00	0.00
TOTAL	**0.29**	**17.37**
T_{lag}	**0.17**	10.42

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 99 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	2.02%	1.24%	N/A	1.29%
Watercourse velocity:	0.49 fps	1.79 fps	N/A	1.54 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

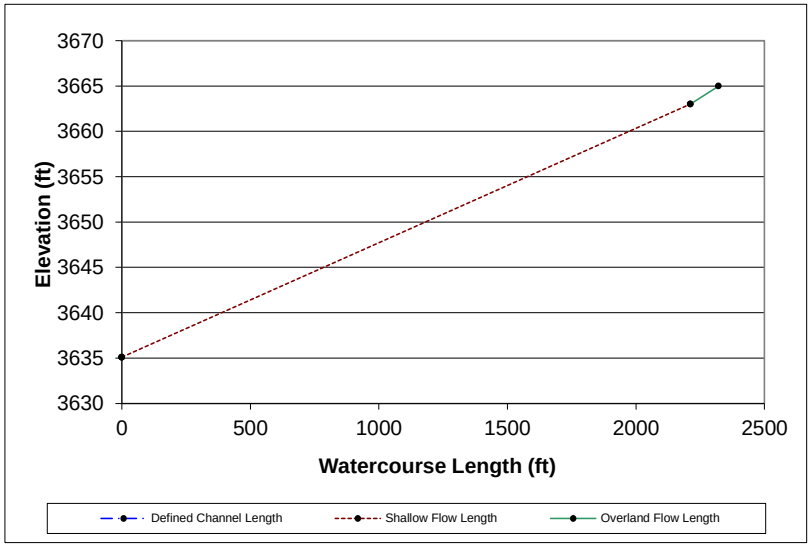
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-9

Total Watercourse length	2322	ft
Defined Channel Length	0	ft
Shallow Flow Length	2212	ft
Overland Flow Length	110	ft
Starting Elevation	3665	ft
Elevation after 110 feet	3663	ft
Starting Channel Elevation	3635.1	ft
Ending Channel Elevation	3635.1	ft
County	Randall	
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.85
Shallow	0.34	20.44
Channel	0.00	0.00
TOTAL	**0.40**	**24.28**
T_{lag}	**0.24**	14.57

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 110 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.82%	1.26%	N/A	1.29%
Watercourse velocity:	0.48 fps	1.8 fps	N/A	1.59 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

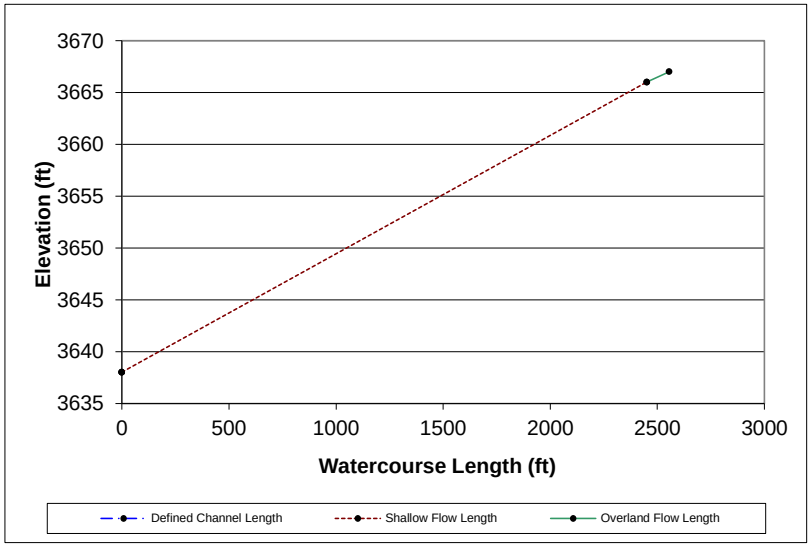
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-10

Total Watercourse length	2556	ft
Defined Channel Length	0	ft
Shallow Flow Length	2452	ft
Overland Flow Length	104	ft
Starting Elevation	3667	ft
Elevation after 104 feet	3666	ft
Starting Channel Elevation	3638	ft
Ending Channel Elevation	3638	ft
County	Randall	
◉ Shallow Area Paved ○ Shallow Area Not Paved	Y	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.02	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.05	3.03
Shallow	0.31	18.79
Channel	0.00	0.00
TOTAL	**0.36**	**21.82**
T_{lag}	**0.22**	13.09

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	NO	
County	Randall	
Length Notes:	Shallow flow = 104 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.96%	1.14%	N/A	1.13%
Watercourse velocity:	0.57 fps	2.18 fps	N/A	1.95 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

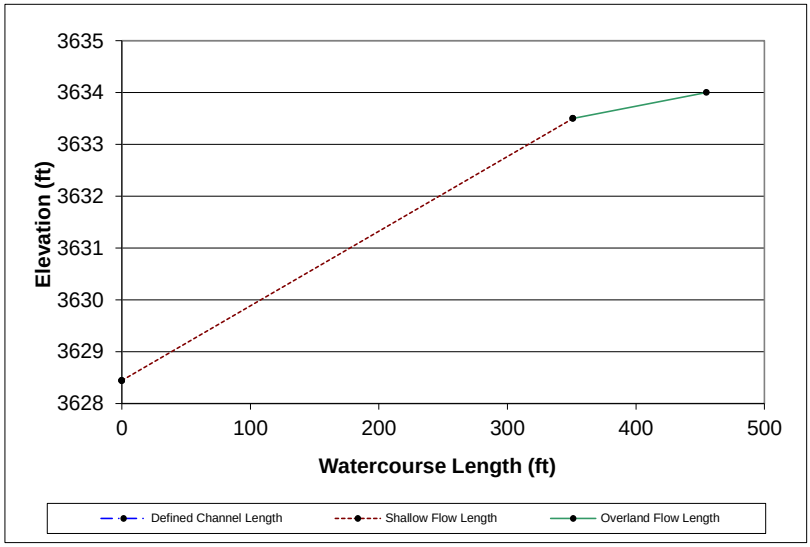
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-11

Total Watercourse length	455	ft
Defined Channel Length	0	ft
Shallow Flow Length	351	ft
Overland Flow Length	104	ft
Starting Elevation	3634	ft
Elevation after 104 feet	3633.5	ft
Starting Channel Elevation	3628.44	ft
Ending Channel Elevation	3628.44	ft
	Randall	
County		
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.10	6.26
Shallow	0.05	3.03
Channel	0.00	0.00
TOTAL	**0.15**	**9.29**
T_{lag}	**0.09**	5.57

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 104 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.48%	1.44%	N/A	1.22%
Watercourse velocity:	0.28 fps	1.93 fps	N/A	0.82 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

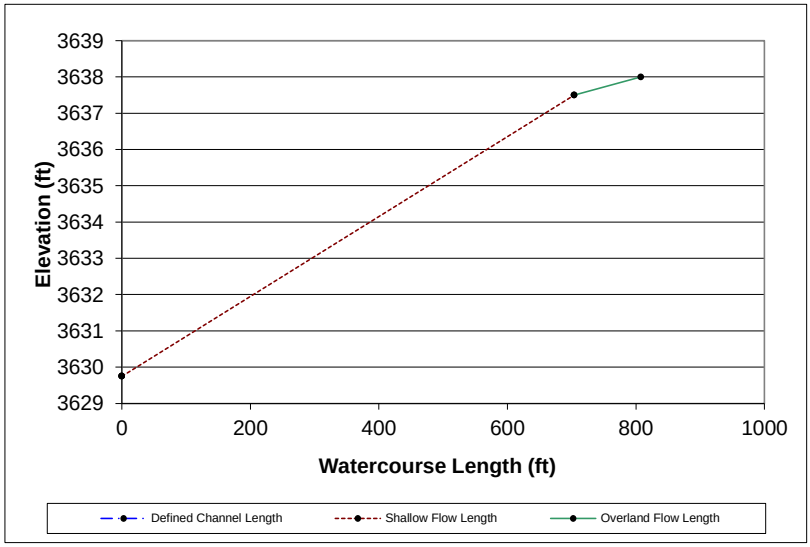
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-12

Total Watercourse length	808	ft
Defined Channel Length	0	ft
Shallow Flow Length	704	ft
Overland Flow Length	104	ft
Starting Elevation	3638	ft
Elevation after 104 feet	3637.5	ft
Starting Channel Elevation	3629.75	ft
Ending Channel Elevation	3629.75	ft
County	Randall	
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.035	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.10	6.26
Shallow	0.12	6.97
Channel	0.00	0.00
TOTAL	**0.22**	**13.23**
T_{lag}	**0.13**	7.94

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 104 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.48%	1.10%	N/A	1.02%
Watercourse velocity:	0.28 fps	1.68 fps	N/A	1.02 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

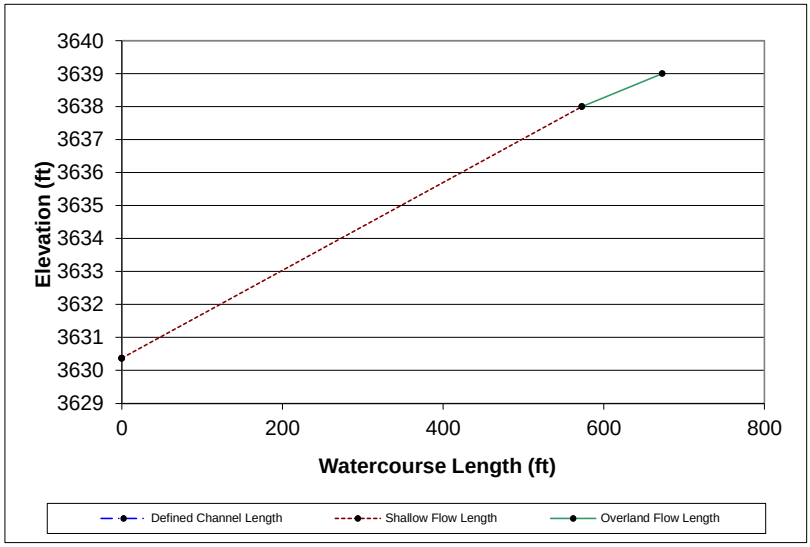
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-13

Total Watercourse length	673	ft
Defined Channel Length	0	ft
Shallow Flow Length	573	ft
Overland Flow Length	100	ft
Starting Elevation	3639	ft
Elevation after 100 feet	3638	ft
Starting Channel Elevation	3630.37	ft
Ending Channel Elevation	3630.37	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.04	2.54
Shallow	0.09	5.15
Channel	0.00	0.00
TOTAL	**0.13**	**7.69**
T_{lag}	**0.08**	4.61

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 100 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.00%	1.33%	N/A	1.28%
Watercourse velocity:	0.66 fps	1.85 fps	N/A	1.46 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

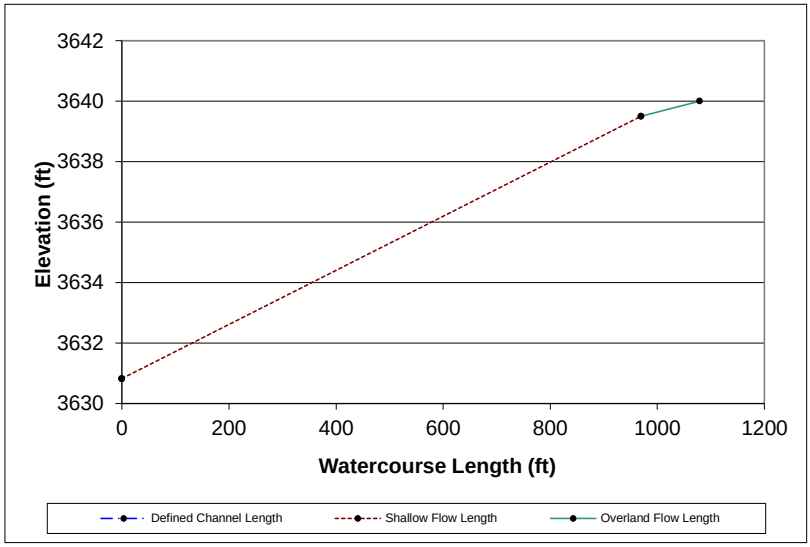
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-14

Total Watercourse length	1079	ft
Defined Channel Length	0	ft
Shallow Flow Length	970	ft
Overland Flow Length	109	ft
Starting Elevation	3640	ft
Elevation after 109 feet	3639.5	ft
Starting Channel Elevation	3630.82	ft
Ending Channel Elevation	3630.82	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.72
Shallow	0.18	10.66
Channel	0.00	0.00
TOTAL	**0.24**	**14.37**
T_{lag}	**0.14**	8.62

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 109 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.46%	0.89%	N/A	0.85%
Watercourse velocity:	0.49 fps	1.52 fps	N/A	1.25 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

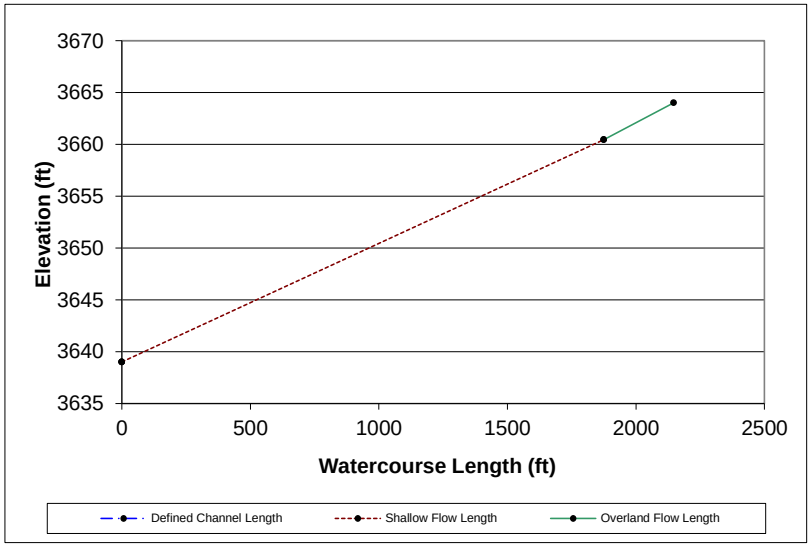
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-15

Total Watercourse length	2147.5	ft
Defined Channel Length	0	ft
Shallow Flow Length	1875.5	ft
Overland Flow Length	272	ft
Starting Elevation	3664	ft
Elevation after 272 feet	3660.45	ft
Starting Channel Elevation	3639	ft
Ending Channel Elevation	3639	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.08	5.08
Shallow	0.30	18.20
Channel	0.00	0.00
TOTAL	**0.39**	**23.29**
T_{lag}	**0.23**	13.97

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 272 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.31%	1.14%	N/A	1.16%
Watercourse velocity:	0.89 fps	1.72 fps	N/A	1.54 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

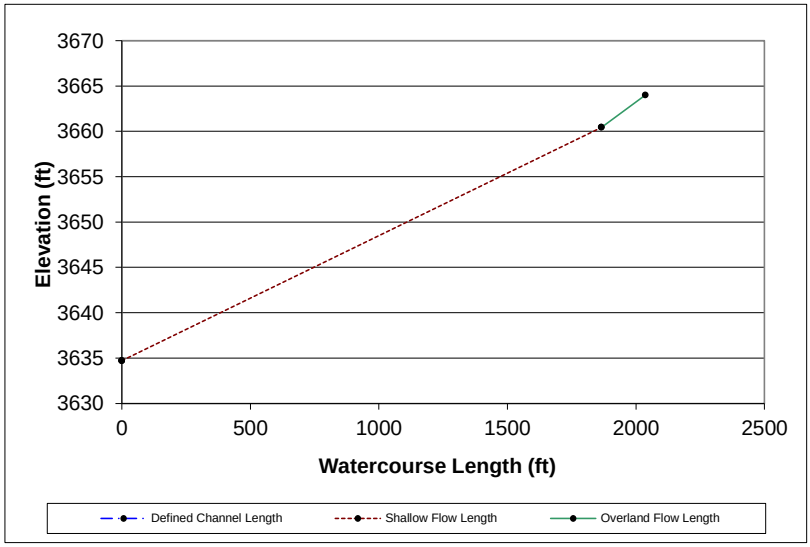
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-16

Total Watercourse length	2037	ft
Defined Channel Length	0	ft
Shallow Flow Length	1866.5	ft
Overland Flow Length	170.5	ft
Starting Elevation	3664	ft
Elevation after 171 feet	3660.45	ft
Starting Channel Elevation	3634.7	ft
Ending Channel Elevation	3634.7	ft
	Randall	
County		
○ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.05	2.90
Shallow	0.27	16.48
Channel	0.00	0.00
TOTAL	**0.32**	**19.38**
T_{lag}	**0.19**	11.63

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 170.5 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	2.08%	1.38%	N/A	1.44%
Watercourse velocity:	0.98 fps	1.89 fps	N/A	1.75 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

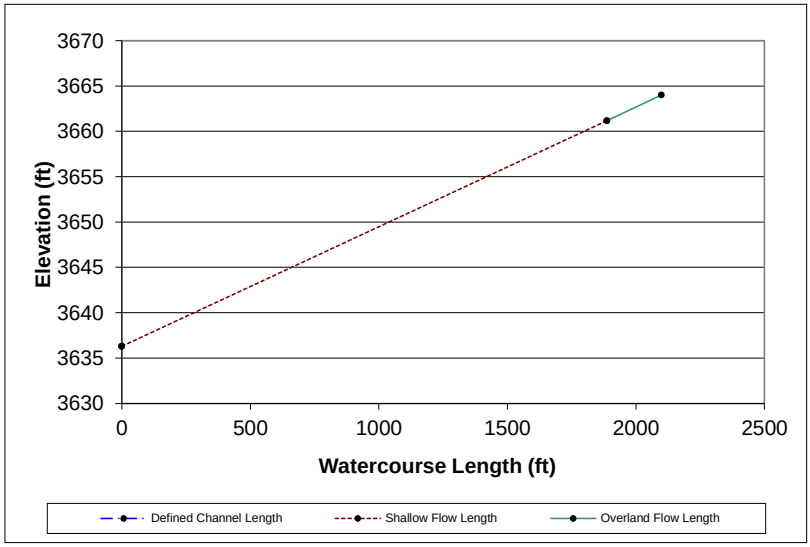
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-17

Total Watercourse length	2099.5	ft
Defined Channel Length	0	ft
Shallow Flow Length	1887.5	ft
Overland Flow Length	212	ft
Starting Elevation	3664	ft
Elevation after 212 feet	3661.17	ft
Starting Channel Elevation	3636.3	ft
Ending Channel Elevation	3636.2	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.07	4.13
Shallow	0.28	17.06
Channel	0.00	0.00
TOTAL	**0.35**	**21.19**
T_{lag}	**0.21**	12.71

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 212 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.33%	1.32%	N/A	1.32%
Watercourse velocity:	0.86 fps	1.84 fps	N/A	1.65 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

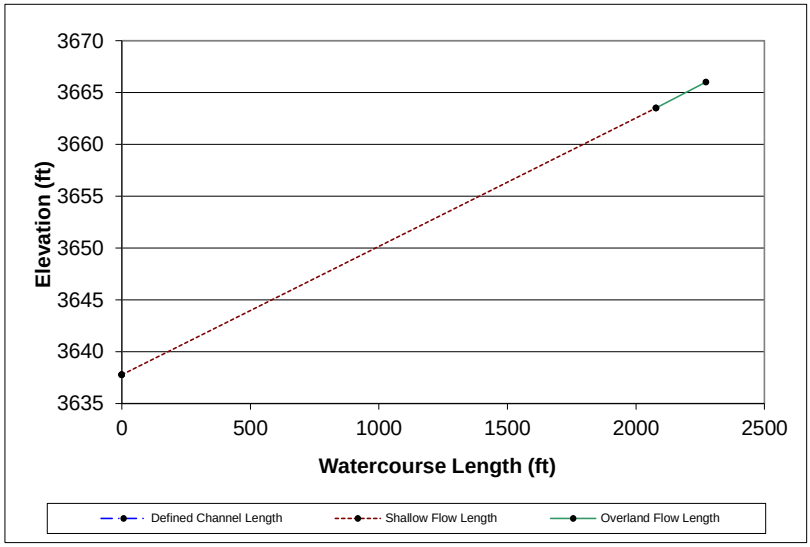
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-18

Total Watercourse length	2273	ft
Defined Channel Length	0	ft
Shallow Flow Length	2079	ft
Overland Flow Length	194	ft
Starting Elevation	3666	ft
Elevation after 194 feet	3663.5	ft
Starting Channel Elevation	3637.75	ft
Ending Channel Elevation	3637.75	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.90
Shallow	0.32	19.38
Channel	0.00	0.00
TOTAL	**0.39**	**23.28**
T_{lag}	**0.23**	13.97

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 194 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.29%	1.24%	N/A	1.24%
Watercourse velocity:	0.83 fps	1.79 fps	N/A	1.63 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override			
Velocity	5.0*	fps	*Leave blank to ignore
Sugg.	n.a	fps	

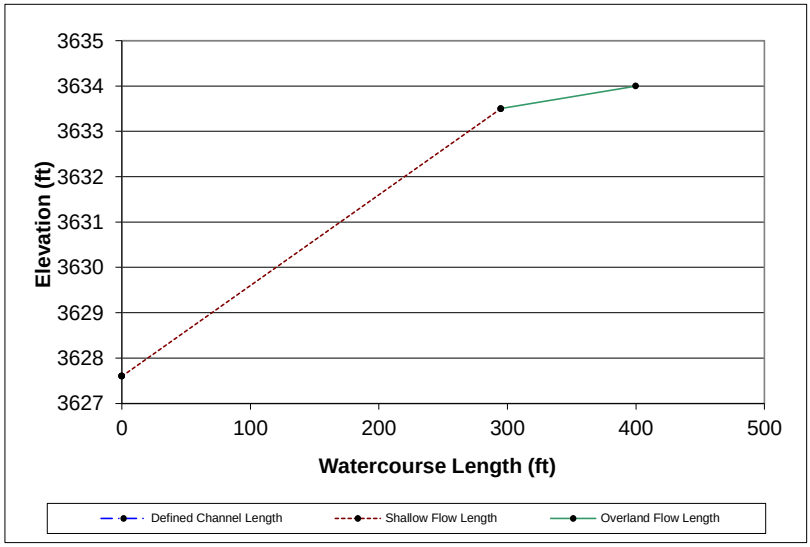
Discharge Calculation		
Runoff Coefficient, C**		**Table 15.1.1, Applied Hydrology (Chow, et al)
Intensity, I (in/hr)		
Area, A (ac)		
Discharge, Q (cfs)	0	
Discharge, Q (gpm)	0	
Discharge, Q (mgd)	0	

DA-19

Total Watercourse length	400	ft
Defined Channel Length	0	ft
Shallow Flow Length	295	ft
Overland Flow Length	105	ft
Starting Elevation	3634	ft
Elevation after 105 feet	3633.5	ft
Starting Channel Elevation	3627.6	ft
Ending Channel Elevation	3627.6	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.06	3.55
Shallow	0.04	2.16
Channel	0.00	0.00
TOTAL	**0.10**	**5.71**
T_{lag}	**0.06**	3.43

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 105 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	0.48%	2.00%	N/A	1.60%
Watercourse velocity:	0.49 fps	2.28 fps	N/A	1.17 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

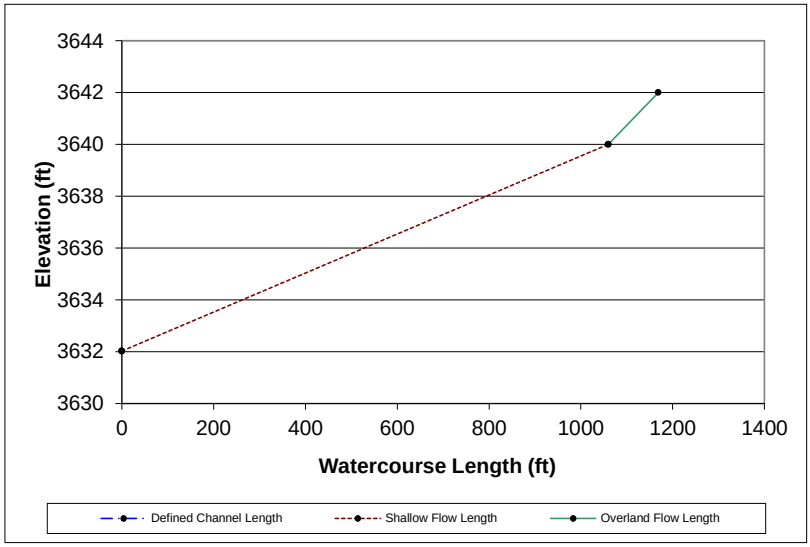
**Table 15.1.1, Applied Hydrology (Chow, et al)

DA-20

Total Watercourse length	1169	ft
Defined Channel Length	0	ft
Shallow Flow Length	1060	ft
Overland Flow Length	109	ft
Starting Elevation	3642	ft
Elevation after 109 feet	3640	ft
Starting Channel Elevation	3632.02	ft
Ending Channel Elevation	3632.02	ft
County	Randall	
◯ Shallow Area Paved ◉ Shallow Area Not Paved	N	
Manning's 'n' value of channel	0.03	
Manning's 'n' value of overland area	0.017	
Hydraulic Radius of channel	0.00	ft

T_c RESULTS	Hours	Minutes
Overland Flow	0.04	2.13
Shallow	0.21	12.71
Channel	0.00	0.00
TOTAL	**0.25**	**14.84**
T_{lag}	**0.15**	8.90

Notes:	OK	
2-Yr, 24 Hour rainfall depth:	2.54	in
Unpaved Road	YES	
County	Randall	
Length Notes:	Shallow flow = 109 ft	



	Overland	Shallow Flow	Channel	Average
Watercourse slope:	1.83%	0.75%	N/A	0.85%
Watercourse velocity:	0.85 fps	1.39 fps	N/A	1.31 fps

Channel Geometry		
Bottom Width		ft
Estimated Depth		ft
Side Slopes (Hoz / Vert)		ft/ft
Hydraulic Radius	0.00	ft
Hydraulic Radius Override		ft
Barrels		
Span		ft
Rise		ft
Hydraulic Radius	0.00	ft

Channel Velocity Override		
Velocity	5.0*	fps
Sugg.	n.a	fps

*Leave blank to ignore

Discharge Calculation	
Runoff Coefficient, C**	
Intensity, I (in/hr)	
Area, A (ac)	
Discharge, Q (cfs)	0
Discharge, Q (gpm)	0
Discharge, Q (mgd)	0

**Table 15.1.1, Applied Hydrology (Chow, et al)

Appendix B

Hydraulic Modeling Results

APAI, Inc.

Appendix B: Model Drainage Area Summary

2-Year Storm Event

Label	Area (acres)	Time of Concentration (min)	Rational C	Catchment CA (acres)	Catchment Intensity (in/h)	Catchment Rational Flow (ft^3/s)
DA01	3.52	5	0.688	2.42	5.4	13.17
DA02	6.52	11.19	0.738	4.808	3.964	19.21
DA03	6.07	11.47	0.688	4.173	3.922	16.5
DA04	6.25	14.36	0.688	4.297	3.495	15.14
DA05	6.34	11.17	0.688	4.359	3.967	17.43
DA06	3.04	8.63	0.688	2.09	4.485	9.45
DA07	0.19	5.02	0.813	0.154	5.395	0.84
DA08	23.63	17.37	0.813	19.199	3.236	62.62
DA09	0.17	5	0.813	0.138	5.4	0.75
DA10	29.38	21.82	0.713	20.933	2.927	61.76
DA11	6.09	9.29	0.713	4.339	4.319	18.89
DA12	6.23	13.23	0.688	4.283	3.662	15.81
DA13	3.26	7.69	0.688	2.241	4.722	10.67
DA14	6.49	14.37	0.688	4.462	3.493	15.71
DA15	20.32	23.29	0.688	13.97	2.825	39.78
DA16	19.82	19.38	0.688	13.626	3.096	42.53
DA17	20.04	21.19	0.688	13.778	2.971	41.26
DA18	17.29	23.28	0.788	13.616	2.826	38.79
DA19	0.83	5.71	0.813	0.674	5.221	3.55
DA20	9.2	14.84	0.763	7.015	3.424	24.21

100-Year Storm Event

Label	Area (acres)	Time of Concentration (min)	Rational C	Catchment CA (acres)	Catchment Intensity (in/h)	Catchment Rational Flow (ft^3/s)
DA01	3.52	5	0.688	2.42	10.08	24.59
DA02	6.52	11.19	0.738	4.808	8.17	39.6
DA03	6.07	11.47	0.688	4.173	8.101	34.08
DA04	6.25	14.36	0.688	4.297	7.396	32.03
DA05	6.34	11.17	0.688	4.359	8.175	35.92
DA06	3.04	8.63	0.688	2.09	8.904	18.76
DA07	0.19	5.02	0.813	0.154	10.074	1.57
DA08	23.63	17.37	0.813	19.199	6.933	134.18
DA09	0.17	5	0.813	0.138	10.08	1.4
DA10	29.38	21.82	0.713	20.933	6.358	134.16
DA11	6.09	9.29	0.713	4.339	8.69	38.01
DA12	6.23	13.23	0.688	4.283	7.672	33.12
DA13	3.26	7.69	0.688	2.241	9.208	20.8
DA14	6.49	14.37	0.688	4.462	7.394	33.25
DA15	20.32	23.29	0.688	13.97	6.168	86.85
DA16	19.82	19.38	0.688	13.626	6.674	91.66
DA17	20.04	21.19	0.688	13.778	6.439	89.43
DA18	17.29	23.28	0.788	13.616	6.169	84.67
DA19	0.83	5.71	0.813	0.674	9.85	6.7
DA20	9.2	14.84	0.763	7.015	7.279	51.47

Appendix B: Model Inlet Summary

2-Year Storm Event

Label	Inlet Type	Catalog Inlet Type	Catalog Inlet	Flow (Total Intercepted) (ft^3/s)	Flow (Total Bypassed) (ft^3/s)	Bypass Target	Capture Efficiency (Calculated) (%)	Gutter Depth (in)	Gutter Spread (ft)
Inlet 1	Catalog Inlet	Curb	Amarillo Inlet Type B-6	5.57	31.42	Outfall Parking Lot	15.1	3.6	15.2
Inlet 2	Catalog Inlet	Curb	Amarillo Inlet Type B-8	13.28	134.06	Outfall Parking Lot	9	6.1	25.5
Inlet 3	Catalog Inlet	Curb	Amarillo Inlet Type B-10	8.55	17.3	Inlet 1	33.1	3.5	14.7
Inlet 4	Catalog Inlet	Curb	Amarillo Inlet Type B-8	12.87	113.85	Inlet 2	10.2	6	24.8
Inlet 5	Catalog Inlet	Curb	Amarillo Inlet Type B-10	7.97	9.46	Inlet 3	45.7	3.4	14.2
Inlet 6	Catalog Inlet	Curb	Amarillo Inlet Type B-4	6.89	113	Inlet 4	5.7	6.3	26.1
Inlet 7	Catalog Inlet	Curb	Amarillo Inlet Type B-10	18.57	131.06	Inlet 6	12.4	6.8	28.3
Inlet 8	Catalog Inlet	Curb	Amarillo Inlet Type B-5	12.87	83.24	Inlet 7	13.4	8.9	37.2
Inlet 9	Catalog Inlet	Curb	Amarillo Inlet Type B-10	26.5	55.9	Inlet 8	32.2	9.5	39.7
Inlet 10	Catalog Inlet	Curb	Amarillo Inlet Type B-10	17.51	44.26	Inlet 9	28.3	6.6	27.5
Inlet 11	Catalog Inlet	Curb	Amarillo Inlet Type B-8	12.14	95.84	Outfall Parking Lot	11.2	5.7	23.6
Inlet 12	Catalog Inlet	Curb	Amarillo Inlet Type B-8	12.49	75.54	Inlet 11	14.2	5.8	24.2
Inlet 13	Catalog Inlet	Curb	Amarillo Inlet Type B-4	3.72	29.33	Inlet 4	11.2	3.6	15.1
Inlet 14	Catalog Inlet	Curb	Amarillo Inlet Type B-8	18.46	68.9	Inlet 12	21.1	8.3	34.4
Inlet 15	Catalog Inlet	Curb	Amarillo Inlet Type B-20	26.39	13.39	Inlet 13	66.3	5.8	24.1
Inlet 16	Catalog Inlet	Curb	Amarillo Inlet Type B-20	42.85	63.51	Inlet 14	40.3	8.2	34
Inlet 17	Catalog Inlet	Curb	Amarillo Inlet Type B-5	9.97	61.24	Inlet 16	14	7.2	29.8
Inlet 18	Catalog Inlet	Curb	Amarillo Inlet Type B-5	10.3	28.49	Inlet 17	26.5	7.5	31.2
Inlet 19	Catalog Inlet	Curb	Amarillo Inlet Type B-4	5.46	14.37	Outfall Parking Lot	27.5	5.2	21.7
Inlet 20	Catalog Inlet	Curb	Amarillo Inlet Type B-10	13.53	10.68	Inlet 19	55.9	5.6	23.4

Appendix B: Model Inlet Summary

100-Year Storm Event

Label	Inlet Type	Catalog Inlet Type	Catalog Inlet	Flow (Total Intercepted) (ft^3/s)	Flow (Total Bypassed) (ft^3/s)	Bypass Target	Capture Efficiency (Calculated) (%)	Gutter Depth (in)	Gutter Spread (ft)
Inlet 1	Catalog Inlet	Curb	Amarillo Inlet Type B-6	7.82	74.27	Outfall Parking Lot	9.5	4.9	20.5
Inlet 2	Catalog Inlet	Curb	Amarillo Inlet Type B-8	19.79	355.28	Outfall Parking Lot	5.3	8.7	36.2
Inlet 3	Catalog Inlet	Curb	Amarillo Inlet Type B-10	12.34	46.21	Inlet 1	21.1	4.8	19.9
Inlet 4	Catalog Inlet	Curb	Amarillo Inlet Type B-8	19.21	304.5	Inlet 2	5.9	8.5	35.3
Inlet 5	Catalog Inlet	Curb	Amarillo Inlet Type B-10	11.22	24.7	Inlet 3	31.2	4.5	18.6
Inlet 6	Catalog Inlet	Curb	Amarillo Inlet Type B-4	9.81	266.6	Inlet 4	3.5	8.6	35.7
Inlet 7	Catalog Inlet	Curb	Amarillo Inlet Type B-10	25.67	290.29	Inlet 6	8.1	9	37.5
Inlet 8	Catalog Inlet	Curb	Amarillo Inlet Type B-5	18.89	209.5	Inlet 7	8.3	12.4	51.5
Inlet 9	Catalog Inlet	Curb	Amarillo Inlet Type B-10	37.71	136.96	Inlet 8	21.6	12.6	52.6
Inlet 10	Catalog Inlet	Curb	Amarillo Inlet Type B-10	24.87	109.29	Inlet 9	18.5	8.8	36.8
Inlet 11	Catalog Inlet	Curb	Amarillo Inlet Type B-8	18.66	276.39	Outfall Parking Lot	6.3	8.3	34.4
Inlet 12	Catalog Inlet	Curb	Amarillo Inlet Type B-8	19.47	226.92	Inlet 11	7.9	8.6	35.7
Inlet 13	Catalog Inlet	Curb	Amarillo Inlet Type B-4	5.7	85.56	Inlet 4	6.2	5.3	22
Inlet 14	Catalog Inlet	Curb	Amarillo Inlet Type B-8	28.77	205.54	Inlet 12	12.3	12	49.9
Inlet 15	Catalog Inlet	Curb	Amarillo Inlet Type B-20	39.67	47.19	Inlet 13	45.7	7.7	32.2
Inlet 16	Catalog Inlet	Curb	Amarillo Inlet Type B-20	63.79	181.47	Inlet 14	26	11.2	46.5
Inlet 17	Catalog Inlet	Curb	Amarillo Inlet Type B-5	14.29	148.21	Inlet 16	8.8	9.8	40.6
Inlet 18	Catalog Inlet	Curb	Amarillo Inlet Type B-5	14.67	70	Inlet 17	17.3	10	41.8
Inlet 19	Catalog Inlet	Curb	Amarillo Inlet Type B-4	8.23	41.48	Outfall Parking Lot	16.5	7.3	30.6
Inlet 20	Catalog Inlet	Curb	Amarillo Inlet Type B-10	19.69	31.78	Inlet 19	38.2	7.5	31.1

Appendix B: Model Conduit Data

2-Year Storm Event

Label	Diameter (in)	Length (ft)	Slope (ft/ft)	Start Node	Stop Node	Velocity (Ave.) (ft/s)	Invert (Upstream) (ft)	Invert (Downstream) (ft)	Elevation Ground (Start) (ft)	Elevation Ground (Stop) (ft)	HGL (In) (ft)	HGL (Out) (ft)	Flow (Link) (ft^3/s)	Capacity (Full Flow) (ft^3/s)	Flow / Capacity (Full) (%)
L-1	12	24	0.169	Inlet 1	Junction 1, 2	17.38	3,623.43	3,619.38	3,625.60	3,626.20	3,623.86	3,620.38	5.57	14.63	38.1
L-2	12	24	0.169	Inlet 2	Junction 1, 2	21.1	3,623.43	3,619.38	3,625.60	3,626.20	3,624.18	3,620.38	13.28	14.63	90.8
L-3	15	22	0.1	Inlet 3	MH06	15.9	3,625.40	3,623.20	3,627.84	3,628.80	3,625.96	3,623.76	8.55	20.43	41.8
L-4	12	20	0.145	Inlet 4	MH06	19.65	3,625.73	3,622.83	3,627.90	3,628.80	3,626.51	3,623.61	12.87	13.57	94.8
L-5	15	24	0.057	Inlet 5	Junction 5, 6	6.5	3,628.32	3,626.96	3,630.76	3,631.30	3,629.62	3,629.26	7.97	15.38	51.8
L-6	12	20	0.101	Inlet 6	Junction 5, 6	8.77	3,628.25	3,626.23	3,630.42	3,631.30	3,630.01	3,629.26	6.89	11.32	60.8
L-7	15	16	0.094	Inlet 7	Junction 7	15.13	3,631.46	3,629.96	3,633.89	3,631.60	3,632.99	3,631.66	18.57	19.78	93.9
L-11	15	25	0.138	Inlet 11	Junction 11	19.6	3,626.00	3,622.56	3,628.44	3,629.20	3,626.63	3,624.27	12.14	23.96	50.7
L-12	15	30	0.08	Inlet 12	MH03	16.05	3,627.81	3,625.40	3,629.75	3,630.60	3,628.57	3,626.16	12.49	18.31	68.2
L-13	12	16	0.142	Inlet 13	Junction 13, 14	14.63	3,628.70	3,626.42	3,630.37	3,631.40	3,629.06	3,627.74	3.72	13.45	27.6
L-14	15	23	0.103	Inlet 14	Junction 13, 14	19.13	3,628.88	3,626.50	3,630.82	3,631.40	3,629.80	3,627.74	18.46	20.78	88.8
L-15	24	35	0.017	Inlet 15	MH04	10.58	3,631.63	3,631.04	3,634.38	3,636.10	3,633.11	3,632.52	26.39	29.37	89.9
L-16	24	48	0.019	Inlet 16	MH04	13.64	3,631.95	3,631.04	3,634.70	3,636.10	3,634.74	3,633.02	42.85	31.15	137.6
L-17	24	25	0.017	Inlet 17	MH05	8.51	3,633.55	3,633.12	3,636.30	3,637.00	3,634.35	3,633.92	9.97	29.67	33.6
L-19	12	8	0.5	Inlet 19	Junction 19	25.62	3,625.93	3,621.93	3,628.00	3,628.60	3,626.25	3,622.82	5.46	25.19	21.7
P-1	72	214	0.003	MH01	Outfall 72" at Lake	9.17	3,614.14	3,613.50	3,625.90	3,623.20	3,618.33	3,617.69	193.15	231.59	83.4
P-2	48	32.5	0.007	Junction 1, 2	MH01	10.32	3,616.40	3,616.18	3,626.20	3,625.90	3,619.35	3,619.35	88.68	118.18	75
P-3	48	364.5	0.007	MH06	Junction 1, 2	9.9	3,618.78	3,616.40	3,628.80	3,626.20	3,621.17	3,620.38	77.68	116.07	66.9
P-4	36	360	0.013	Junction 5, 6	MH06	11.99	3,625.27	3,620.59	3,631.30	3,628.80	3,627.33	3,622.65	62.03	76.04	81.6
P-5	36	381	0.007	Junction 7	Junction 5, 6	7.49	3,628.00	3,625.27	3,631.60	3,631.30	3,631.66	3,629.26	52.97	56.46	93.8
P-6	36	65.4	0.014	Inlet 8	Junction 7	6.04	3,628.93	3,628.00	3,634.36	3,631.60	3,631.93	3,631.66	42.72	79.53	53.7
P-7	36	310	0.005	Inlet 9	Inlet 8	7.16	3,630.75	3,629.20	3,635.10	3,634.36	3,632.56	3,632.34	31.84	47.16	67.5
P-8	21	30	0.02	Inlet 10	Inlet 9	10.31	3,632.90	3,632.30	3,635.38	3,635.10	3,634.06	3,633.46	17.51	22.41	78.1
P-9	54	620	0.004	Junction 19	MH01	9.26	3,618.40	3,615.69	3,628.60	3,625.90	3,621.76	3,619.35	118.05	130	90.8
P-10	54	140	0.005	MH02	Junction 19	9.84	3,619.11	3,618.40	3,628.80	3,628.60	3,622.82	3,622.82	116.21	140.03	83
P-11	54	30	0.005	Junction 11	MH02	6.7	3,619.25	3,619.11	3,629.20	3,628.80	3,623.80	3,623.71	106.53	134.33	79.3
P-12	54	360	0.003	MH03	Junction 11	6.42	3,620.47	3,619.25	3,630.60	3,629.20	3,625.24	3,624.27	102.05	114.47	89.2
P-13	48	360	0.006	Junction 13, 14	MH03	9.94	3,623.17	3,621.01	3,631.40	3,630.60	3,627.06	3,625.57	94.79	111.26	85.2
P-14	48	362.6	0.005	MH04	Junction 13, 14	8.95	3,624.98	3,623.17	3,636.10	3,631.40	3,628.69	3,627.74	80.33	101.48	79.2
P-15	36	407.4	0.005	MH05	MH04	6.55	3,632.12	3,629.88	3,637.00	3,636.10	3,633.42	3,631.18	19.13	49.45	38.7
P-16	30	398	0.004	Inlet 18	MH05	4.98	3,634.20	3,632.61	3,637.75	3,637.00	3,635.30	3,633.71	10.3	25.92	39.7
P-17	21	788	0.007	Inlet 20	MH02	5.63	3,627.52	3,621.86	3,632.02	3,628.80	3,629.29	3,623.71	13.53	13.43	100.8

Appendix B: Model Conduit Data

100-Year Storm Event

Label	Diameter (in)	Length (ft)	Slope (ft/ft)	Start Node	Stop Node	Velocity (Ave.) (ft/s)	Invert (Upstream) (ft)	Invert (Downstream) (ft)	Elevation Ground (Start) (ft)	Elevation Ground (Stop) (ft)	Hydraulic Grade	Hydraulic Grade	Flow (Link) (ft^3/s)	Capacity (Full Flow) (ft^3/s)	Flow / Capacity (Full) (%)
L-1	12	24	0.169	Inlet 1	Junction 1, 2	9.96	3,623.43	3,619.38	3,625.60	3,626.20	3,628.72	3,627.57	7.82	14.63	53.5
L-2	12	24	0.169	Inlet 2	Junction 1, 2	25.19	3,623.43	3,619.38	3,625.60	3,626.20	3,634.97	3,627.57	19.79	14.63	135.2
L-3	15	22	0.1	Inlet 3	MH06	10.06	3,625.40	3,623.20	3,627.84	3,628.80	3,629.60	3,628.80	12.34	20.43	60.4
L-4	12	20	0.145	Inlet 4	MH06	24.45	3,625.73	3,622.83	3,627.90	3,628.80	3,634.61	3,628.80	19.21	13.57	141.6
L-5	15	24	0.057	Inlet 5	Junction 5, 6	9.14	3,628.32	3,626.96	3,630.76	3,631.30	3,639.00	3,638.28	11.22	15.38	72.9
L-6	12	20	0.101	Inlet 6	Junction 5, 6	12.49	3,628.25	3,626.23	3,630.42	3,631.30	3,639.79	3,638.28	9.81	11.32	86.6
L-7	15	16	0.094	Inlet 7	Junction 7	20.91	3,631.46	3,629.96	3,633.89	3,631.60	3,648.00	3,645.47	25.67	19.78	129.8
L-11	15	25	0.138	Inlet 11	Junction 11	15.2	3,626.00	3,622.56	3,628.44	3,629.20	3,632.19	3,630.10	18.66	23.96	77.9
L-12	15	30	0.08	Inlet 12	MH03	15.87	3,627.81	3,625.40	3,629.75	3,630.60	3,633.33	3,630.60	19.47	18.31	106.3
L-13	12	16	0.142	Inlet 13	Junction 13, 14	7.26	3,628.70	3,626.42	3,630.37	3,631.40	3,635.87	3,635.46	5.7	13.45	42.4
L-14	15	23	0.103	Inlet 14	Junction 13, 14	23.44	3,628.88	3,626.50	3,630.82	3,631.40	3,640.02	3,635.46	28.77	20.78	138.4
L-15	24	35	0.017	Inlet 15	MH04	12.63	3,631.63	3,631.04	3,634.38	3,636.10	3,637.18	3,636.10	39.67	29.37	135.1
L-16	24	48	0.019	Inlet 16	MH04	20.3	3,631.95	3,631.04	3,634.70	3,636.10	3,639.92	3,636.10	63.79	31.15	204.8
L-17	24	25	0.017	Inlet 17	MH05	4.55	3,633.55	3,633.12	3,636.30	3,637.00	3,636.98	3,636.88	14.29	29.67	48.2
L-19	12	8	0.5	Inlet 19	Junction 19	10.47	3,625.93	3,621.93	3,628.00	3,628.60	3,632.77	3,632.34	8.23	25.19	32.7
P-1	72	214	0.003	MH01	Outfall 72" at Lake	10.5	3,614.14	3,613.50	3,625.90	3,623.20	3,626.20	3,625.15	296.92	231.59	128.2
P-2	48	32.5	0.007	Junction 1, 2	MH01	10.95	3,616.40	3,616.18	3,626.20	3,625.90	3,626.20	3,625.90	137.57	118.18	116.4
P-3	48	364.5	0.007	MH06	Junction 1, 2	9.53	3,618.78	3,616.40	3,628.80	3,626.20	3,630.10	3,627.57	119.77	116.07	103.2
P-4	36	360	0.013	Junction 5, 6	MH06	13.49	3,625.27	3,620.59	3,631.30	3,628.80	3,636.16	3,628.80	95.38	76.04	125.4
P-5	36	381	0.007	Junction 7	Junction 5, 6	11.45	3,628.00	3,625.27	3,631.60	3,631.30	3,643.89	3,638.28	80.95	56.46	143.4
P-6	36	65.4	0.014	Inlet 8	Junction 7	9.18	3,628.93	3,628.00	3,634.36	3,631.60	3,646.09	3,645.47	64.9	79.53	81.6
P-7	36	310	0.005	Inlet 9	Inlet 8	6.88	3,630.75	3,629.20	3,635.10	3,634.36	3,636.01	3,634.36	48.61	47.16	103.1
P-8	21	30	0.02	Inlet 10	Inlet 9	10.34	3,632.90	3,632.30	3,635.38	3,635.10	3,635.84	3,635.10	24.87	22.41	111
P-9	54	620	0.004	Junction 19	MH01	11.28	3,618.40	3,615.69	3,628.60	3,625.90	3,631.00	3,625.90	179.38	130	138
P-10	54	140	0.005	MH02	Junction 19	11.05	3,619.11	3,618.40	3,628.80	3,628.60	3,633.46	3,632.34	175.77	140.03	125.5
P-11	54	30	0.005	Junction 11	MH02	10.14	3,619.25	3,619.11	3,629.20	3,628.80	3,629.00	3,628.80	161.33	134.33	120.1
P-12	54	360	0.003	MH03	Junction 11	9.55	3,620.47	3,619.25	3,630.60	3,629.20	3,632.25	3,630.10	151.94	114.47	132.7
P-13	48	360	0.006	Junction 13, 14	MH03	11.12	3,623.17	3,621.01	3,631.40	3,630.60	3,634.01	3,630.60	139.74	111.26	125.6
P-14	48	362.6	0.005	MH04	Junction 13, 14	9.26	3,624.98	3,623.17	3,636.10	3,631.40	3,637.84	3,635.46	116.37	101.48	114.7
P-15	36	407.4	0.005	MH05	MH04	3.83	3,632.12	3,629.88	3,637.00	3,636.10	3,636.77	3,636.10	27.04	49.45	54.7
P-16	30	398	0.004	Inlet 18	MH05	2.99	3,634.20	3,632.61	3,637.75	3,637.00	3,637.39	3,636.88	14.67	25.92	56.6
P-17	21	788	0.007	Inlet 20	MH02	8.18	3,627.52	3,621.86	3,632.02	3,628.80	3,640.62	3,628.80	19.69	13.43	146.6

Appendix C

Street Capacity Calculations

APAI, Inc.

Appendix C: Street Capacity Calculations

Inlet ID	Street Name	Street Width (ft)	Minimum Width Between Structures (ft)	Length (ft) (GIS)	Elevation Upstream (ft) (plans)	Elevation Downstream (ft) (plans)	Slope (ft/ft)	Manning's n in Street (SWCM Table 3-2)	Curb Depth (ft)	Zstreet (typ 1/Sx)	Street Capacity* Minor Event (cfs)	Manning's n in Right-of-way (light turf grass)	Allowable Depth in Street ROW (ft)	k	Cross Sectional Area (sf)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Right-of-way Capacity** (cfs)	Total Capacity (Street + Right-of-way) Major Event (cfs)
Example		30	80				0.004	0.016	0.50	30.00	20.9	0.200	1.50	1.49	82.50	80.09	1.03	39.6	60.5
1	Northeast 13th Ave.	30	80	364	3,627.84	3,625.60	0.006	0.016	0.50	30.00	25.9	0.200	1.50	1.49	82.50	80.09	1.03	49.2	75.1
2	Northeast 13th Ave.	30	80	364	3,627.84	3,625.60	0.006	0.016	0.50	30.00	25.9	0.200	1.50	1.49	82.50	80.09	1.03	49.2	75.1
3	Northeast 13th Ave.	30	80	355	3,630.76	3,627.90	0.008	0.016	0.50	30.00	29.6	0.200	1.50	1.49	82.50	80.09	1.03	56.3	85.9
4	Northeast 13th Ave.	30	80	355	3,630.76	3,627.90	0.008	0.016	0.50	30.00	29.6	0.200	1.50	1.49	82.50	80.09	1.03	56.3	85.9
5	Northeast 13th Ave.	30	80	330	3,633.89	3,630.42	0.011	0.016	0.50	30.00	33.8	0.200	1.50	1.49	82.50	80.09	1.03	64.3	98.1
6	Northeast 13th Ave.	30	80	330	3,633.89	3,630.42	0.011	0.016	0.50	30.00	33.8	0.200	1.50	1.49	82.50	80.09	1.03	64.3	98.1
7	North Arthur St.	40	120	325	3,635.10	3,633.89	0.004	0.016	0.50	30.00	20.1	0.200	1.50	1.49	120.00	120.06	1.00	54.5	74.7
8	North Arthur St.	40	120	321	3,635.10	3,634.36	0.002	0.016	0.50	30.00	15.8	0.200	1.50	1.49	120.00	120.06	1.00	42.9	58.8
9	North Arthur St.	40	120	410	3,636.38	3,635.10	0.003	0.016	0.50	30.00	18.4	0.200	1.50	1.49	120.00	120.06	1.00	49.9	68.4
10	North Don Dr.	45	85	380	3,642.00	3,638.00	0.011	0.016	0.50	30.00	33.9	0.200	1.50	1.49	97.50	85.11	1.15	81.6	115.4
11	Northeast 11th Ave.	30	80	365	3,629.75	3,628.44	0.004	0.016	0.50	30.00	19.8	0.200	1.50	1.49	82.50	80.09	1.03	37.6	57.3
12	Northeast 11th Ave.	30	65	362	3,630.82	3,629.75	0.003	0.016	0.50	30.00	17.9	0.200	1.50	1.49	71.25	65.13	1.09	30.6	48.6
13	Northeast 11th Ave.	30	60	381	3,634.70	3,630.82	0.010	0.016	0.50	30.00	33.3	0.200	1.50	1.49	67.50	60.15	1.12	54.8	88.1
14	Northeast 11th Ave.	30	60	381	3,634.70	3,630.82	0.010	0.016	0.50	30.00	33.3	0.200	1.50	1.49	67.50	60.15	1.12	54.8	88.1
15	Northeast 11th Ave.	30	85	364	3,641.00	3,637.00	0.011	0.016	0.50	30.00	34.6	0.200	1.50	1.49	86.25	85.08	1.01	68.0	102.6
16	Northeast 11th Ave.	30	85	364	3,641.00	3,637.00	0.011	0.016	0.50	30.00	34.6	0.200	1.50	1.49	86.25	85.08	1.01	68.0	102.6
17	Northeast 10th Ave.	35	90	378	3,637.75	3,636.30	0.004	0.016	0.50	30.00	20.4	0.200	1.50	1.49	93.75	90.08	1.04	44.4	64.9
18	Northeast 9th Ave.	35	60	360	3,643.00	3,640.00	0.008	0.016	0.50	30.00	30.1	0.200	1.50	1.49	71.25	60.18	1.18	54.2	84.4
19	North Miror St.	40	120	841	3,632.02	3,627.60	0.005	0.016	0.50	30.00	23.9	0.200	1.50	1.49	120.00	120.06	1.00	64.8	88.7
20	Northeast 9th Ave.	35	63	310	3,636.20	3,635.03	0.004	0.016	0.50	30.00	20.3	0.200	1.50	2.49	73.50	63.16	1.16	62.2	82.5

* $$Q = 0.56 \left[\frac{Z}{n}\right] S^{0.5} d^{2.67}$$

* Using Equation 3.1, Storm Sewer Criteria Manual

** Manning's Equation

NOTE: All street and ROW capacities consider total inlet capacity at a given cross-section location

Calculated Values