Notice of a Meeting
Dalworthington Gardens Planning and Zoning Commission

February 1, 2024 at 6:00 p.m.
City Hall Council Chambers, 2600 Roosevelt Drive, Dalworthington Gardens, Texas

The Planning and Zoning Commission reserves the right to adjourn into closed session at any time during the course of this meeting as authorized by Texas Government Code, Section 551.071 (Consultation with Attorney).

1. Call to Order

2. Citizens who wish to speak to the Planning & Zoning Commission Members will be heard at this time. In compliance with the Texas Open Meetings Act, unless the subject matter of the presentation is on the agenda, the City staff and Planning and Zoning Commission Members are prevented from discussing the subject and may respond only with statements of factual information or existing policy.

3. Discussion and possible recommendation regarding a planned development concept plan application for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11X of Block A an addition to the City of Dalworthington Gardens, Tarrant County, Texas.
   i. Conduct public hearing
   ii. Discussion and recommendation

4. Discussion and possible recommendation regarding Final Plan for for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11X of Block A an addition to the City of Dalworthington Gardens, Tarrant County, Texas.
   i. Conduct public hearing
   ii. Discussion and recommendation

5. Discussion and possible recommendation regarding Preliminary Plat application for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11X of Block A an addition to the City of Dalworthington Gardens, Tarrant County, Texas.
   i. Conduct public hearing
   ii. Discussion and recommendation

6. Discussion and possible recommendation request for a concept plan with a Bowen Road planned developemnt overlay for property located at 2500 and 2512 California Lane, Dalworthington Gardens, Tarrant County, Texas
   i. Conduct public hearing
   ii. Discussion and recommendation

7. Consideration of a Special Exception Application for motor vehicle sales – indoor: Showroom wholly within a building; no vehicle display visible from outside the building; detailing for sale but no mechanical work allowed; no outside storage, in accordance with the City of Dalworthington Garden's Zoning Ordinance subsection (a) (15) of Section 14.02.224. Business located at 2209 Michigan Ave, Dalworthington Gardens.
   i. Conduct public hearing
   ii. Discussion and recommendation

8. Discussion and possible action to potentially change P&Z meeting date and time.

9. Future agenda items.

10. Adjourn

CERTIFICATION

This is to certify that a copy of the **February 1, 2024,** Planning and Zoning Commission Agenda was posted on the City Hall bulletin board, a place convenient and readily accessible to the general public at all times, and to the City's website, www.cityofdwg.net, in compliance with Chapter 551, Texas Government Code.

DATE OF POSTING: ________________TIME OF POSTING: ___________________TAKEN DOWN: ___________________

____
Sandra Ma, City Secretary

Staff Agenda Report

Agenda Subject: Discussion and possible recommendation regarding a planned development concept plan application for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas, to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11 X of Block A, an addition to the City of Dalworthington Gardens, Tarrant County, Texas.

Background Information: An application for a change in zoning was submitted by Cannon Clark on December 4, 2024. A Concept Plan was submitted with the application showing the proposed improvements and highlighting the proposed deviations from the base zoning district requirements. The proposed deviations from the requirements of the base zoning district are included in the "Residential Use Criteria" table shown on the Concept Plan.

The Concept Plan was forwarded to the city engineer for review. On January 23, 2024 the city engineer conducted his final review of the Concept Plan and determined that the Concept Plan conforms with the City's ordinance.

Notifications of tonight's public hearing were sent to all property owners within 200' of the subject property as well as being posted in the Commercial Recorder. Of the 24 property owner notifications sent, 0 were returned with comments. 0 were returned in favor of the zoning change and 0 were returned in opposition of the zoning change. All comments included on the notifications returned will be read during the public hearing.

As the application submitted contains all required documents and the concept plan conforms with the City's ordinance, staff recommends approval of the proposed zoning change.

Recommended Action/Motion: Motion to recommend approval planned development concept plan application for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas, to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11 X of Block A, an addition to the City of Dalworthington Gardens, Tarrant County, Texas.

Attachments:

Zoning Change Application
Concept Plan
Letter of conformance

THE DWG GARDENS

PLAT Application

CITY OF DALWORTHINGTON GARDENS

2600 Roosevelt
TEL. 817-274-7368 FAX 817-265-4401
www.cityofdwg.net

☐ Replat ☐ Amending Plat ☐ Preliminary Plat ☐ Final Plat

Applicant's Name: Roosevelt Estates, LLC

Address: 2000 Prairie Holly Lane Aledo TX 76008

Applicant Contact Number: (682) 802 0250

Applicant Email: [illegible]@Highwater Development.com

Surveyor: Shield Engineering

Address: PO Box 470636 Fort Worth TX 76147

I have purchased or have access to the City of Dalworthington Gardens Subdivision Ordinance which specifies requirements for plat submissions.

☑ Yes ☐ No

The attached submission complies with all applicable requirements of the City Subdivision Ordinance.

☑ Yes ☐ No

Signature: [signature]

Date: 12/4/2023

For Office Use Only

Fee: $4500.00 **Date Paid:** 12/4/2023 **Receipt #** CK 248338

P & Z Scheduled ______ **Public Hearing Published:** ______

Council Scheduled: ______ **Public Hearing Published:** ______

Pro-Rata Paid: $______ **Date:** ______

12/4/2023 - Sent email to Brandon amount received to proceed. [initials]

DEC 04 2023

BY C.Newbell

City of DWG
817-274-7368
***** R E P R I N T   R E C E I P T*****

REC#: 00248338   12/04/2023   11:36 AM
OPER: CARLA TERM: 002
REF#: WINDOW/CK1038
PAID BY:

TRAN: PLATTING   PLATTING CHARGE
ROOSEVLET ESTATES LLC
110-00.4455
Chrg For Service-Pl   4,500.00CR

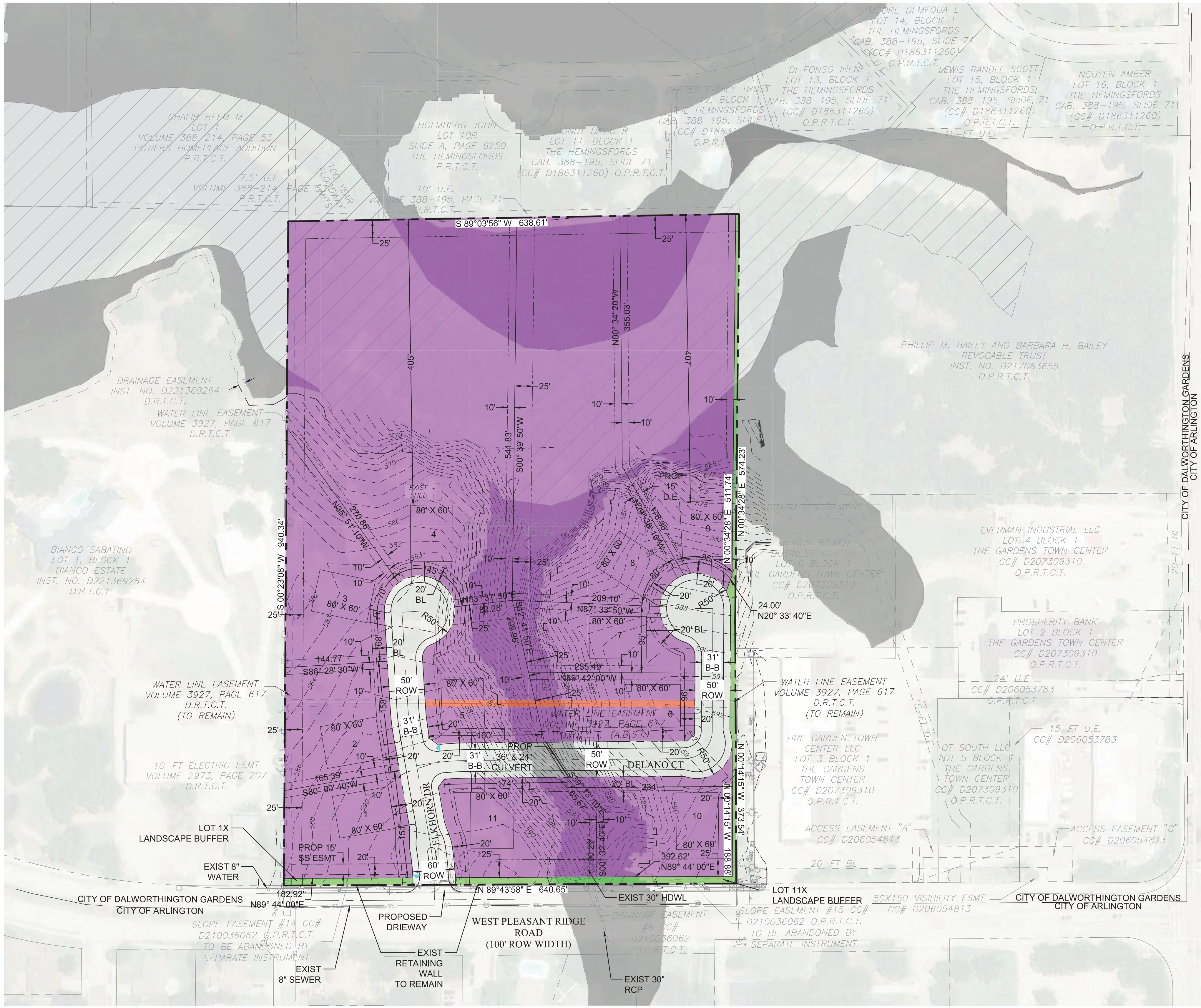
TENDERED: 4,500.00   CHECK
APPLIED: 4,500.00-

CHANGE: 0.00

LAND USE DATA

TOTAL ACRES = 13.825 ACRES
RESIDENTIAL = 13.584 ACRES
OPEN SPACE = 0.241 ACRES

- 0.5 ACRE MIN = **11 LOTS**
- OPEN SPACE/LANDSCAPE AREA
- EASEMENT & WATER LINE TO BE ABADONED
- FEMA FLOODWAY
- FEMA FLOODPLAIN ZONE A



RESIDENTIAL USE CRITERIA

PROVISION	SF	PROPOSED PD
MINIMUM LOT AREA	21,780 SF	21,780 SF
MINIMUM LIVING AREA	1,250 SF	1,250 SF
MAXIMUM BUILDING COVERAGE	25%	25%
MINIMUM LOT WIDTH	80 FEET	80 FEET
MINIMUM LOT FRONT YARD	50 FEET	20 FEET
MINIMUM LOT SIDE YARD	25 FEET	10 FEET
MINIMUM LOT SIDE YARD FOR CORNER LOT	35 FEET	20 FEET
MINIMUM REAR YARD	25 FEET	25 FEET
MAX STRUCTURE HEIGHT	35 FEET	35 FEET

SHIELD ENGINEERING GROUP
TBPE FIRM #F-11039 · TBPLS FIRM #10193890

0 80 160 240
GRAPHIC SCALE IN FEET
1" = 80'

CITY OF DALWORTHINGTON GARDENS, TEXAS

ROOSEVELT ESTATES

CONCEPT PLAN

DESIGNED: JGD	SCALE:	DATE:	SHEET:
DRAWN: JGD	1" = 80'	JAN 2024	1OF 1

Kimley»Horn

January 23, 2024

Sandra Ma
Interim City Secretary
City of Dalworthington Gardens
2600 Roosevelt Drive
Dalworthington Gardens, TX 76016

RE: Fourth Concept Plan Submittal Review
Roosevelt Estates
KHA No. 068302505

Dear Sandra:

We have completed our review of the fourth submittal of the Concept Plan for the above referenced project. The Concept Plan was received via email for review on January 22, 2024.

All previous comments have been adequately addressed. The Concept Plan as submitted conforms to the technical requirements listed in the Dalworthington Gardens Code of Ordinances.

Please remember that the adequacy of the design work reflected in the plans reviewed and the responsibility to adhere to all applicable ordinances and codes remains with the design engineer.

Sincerely,

KIMLEY-HORN AND ASSOCIATES, INC.

Brandon Bell, P.E.

Brandon Bell, P.E.

Staff Agenda Report

Agenda Subject: Discussion and possible recommendation regarding Final Plan for for property located at 2611 W. Pleasant Ridge Road, Dalworthington Gardens, Texas to be known as Roosevelt Estates Lots 1 – 11, 1X, and 11X of Block A an addition to the City of Dalworthington Gardens, Tarrant County, Texas.

Background Information: A Final Plan was submitted by Jose De Leon on January 22, 2024 showing the proposed improvements and highlighting the proposed deviations from the base zoning district requirements. The proposed deviations from the requirements of the base zoning district are included in the "Residential Use Criteria" table shown on the Final Plan.

Typically the Final Plan for a development within the Planned Development zoning district does not come before the Commission until City Council has approved the zoning change and the Concept Plan. In this case, because the Final Plan is being presented to the Commission prior to Council's decision, if a recommendation of approval is to be provided, it shall be contingent on City Council's approval of the zoning change from Single Family to Planned Development.

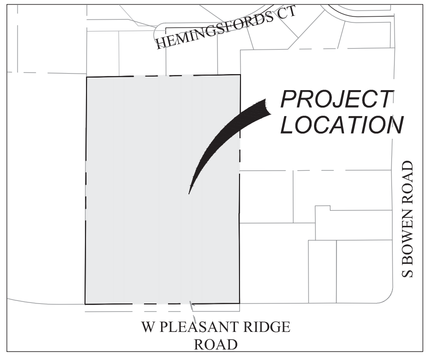
The Final Plan was forwarded to the city engineer for review. On January 23, 2024 the city engineer conducted his final review and determined that if City Council approves the proposed zoning change, the Final Plan conforms with the City's ordinance and therefore recommends approval.

City staff also recommends approval.

Recommended Action/Motion: Motion to recommend approval of the Final Plan for the property located at 2611 W. Pleasant Ridge Road contingent on City Council's approval of the proposed zoning change of the property from Single Family to Planned Development.

Attachments:

Final Plan
Preliminary Drainage Study
Letter of Recommendation

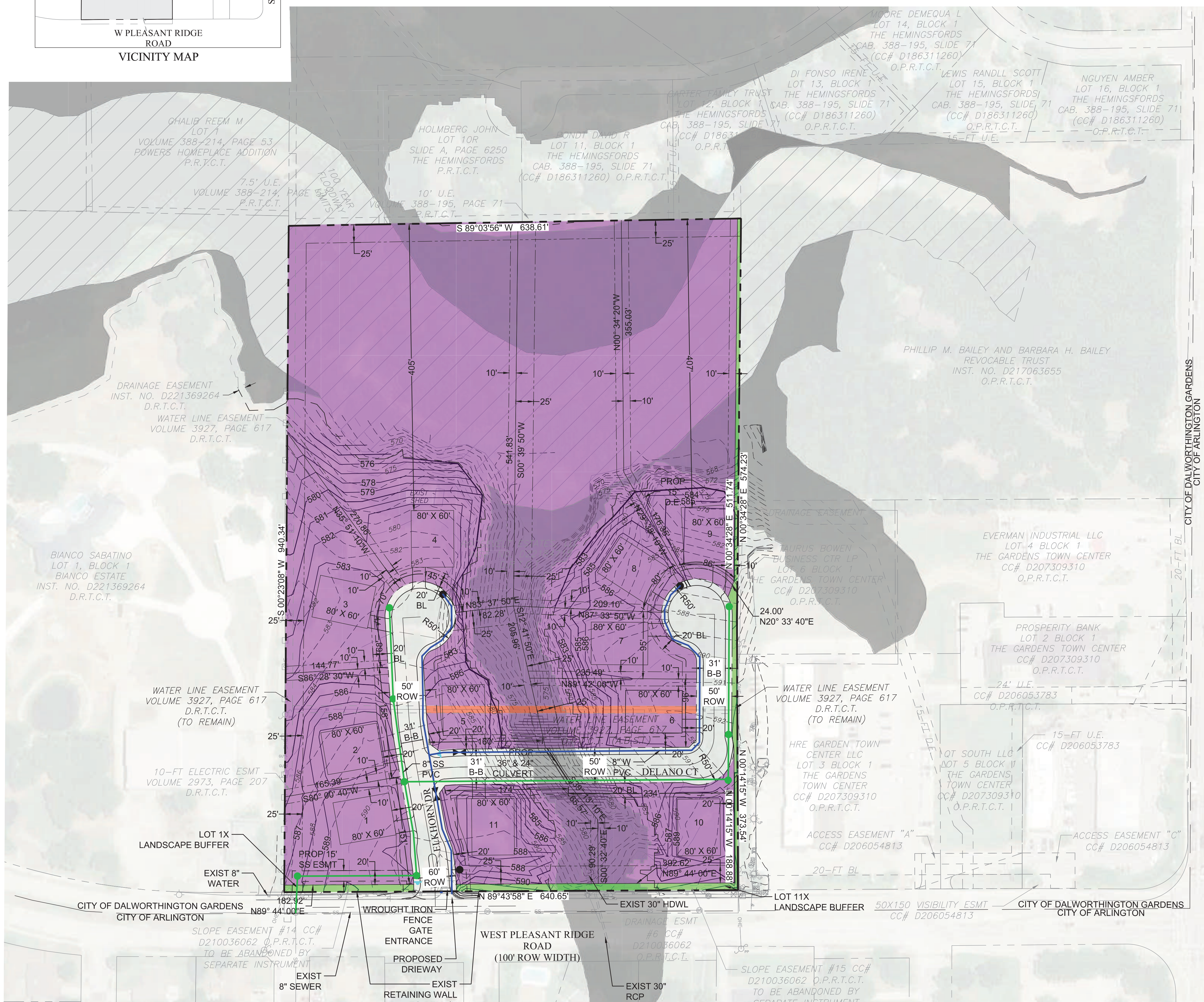


VICINITY MAP

LAND USE DATA

TOTAL ACRES = 13.825 ACRES
RESIDENTIAL = 13.584 ACRES
OPEN SPACE = 0.241 ACRES

- 0.5 ACRE MIN = **11 LOTS**
- OPEN SPACE/LANDSCAPE AREA
- EASEMENT & WATER LINE TO BE ABADONED
- FEMA FLOODWAY
- FEMA FLOODPLAIN ZONE A



RESIDENTIAL USE CRITERIA

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MINIMUM LOT SIDE YARD FOR CORNER LOT	35 FEET	20 FEET
MINIMUM REAR YARD	25 FEET	25 FEET
MAX STRUCTURE HEIGHT	35 FEET	35 FEET
MAX SITE COVERAGE	25%	25%
LOT DENSITY	---	.80 UNITS PER ACRE

DEVELOPMENT SCHEDULE

GRADING	FEB 1
WET UTILITIES	FEB 15
PAVING	MAR 1
DRY UTILITES	MAR 24
BACKFILL AND LADSCAPE	APR 15
FINAL INSPECTION	MAY 1

SHIELD ENGINEERING GROUP
TBPE FIRM #F-11039 · TBPLS FIRM #10193890

N
0 80 160 240
GRAPHIC SCALE IN FEET
1" = 80'

CITY OF DALWORTHINGTON GARDENS, TEXAS

ROOSEVELT ESTATES

FINAL PLAN

DESIGNED: JGD	SCALE:	DATE:	SHEET:
DRAWN: JGD	1" = 80'	JAN 2024	1OF 1

SHIELD
ENGINEERING GROUP

TECHNICAL MEMORANDUM

Roosevelt Estates Preliminary Drainage Study

Dalworthington Gardens, Texas

June 2023

STATE OF TEXAS
JACOB B. WADLEY
142451
LICENSED
PROFESSIONAL ENGINEER

06/02/2023

1600 W. 7th Street, Suite 400, Fort Worth, Texas 76102 | 817.810.0696
Shield Engineering Group, PLLC

info@shield-engineering.com | www.SHIELDENGINEERINGGROUP.com
TBPE FIRM #F-11039 | TBPLS FIRM #10193890

Table of Contents

Appendixes

Introduction

The purpose of this Preliminary Drainage Study Technical Memorandum is to support the Roosevelt Estates Project. This Preliminary Drainage Study Technical Memorandum includes a downstream assessment and culvert design narrative. The proposed ±14-acre single-family residential development includes 1-acre single family lots with associated improvements (see project layout sheets in Appendix D). The project is located northwest of the West Pleasant Ridge Road and Bowen Road intersection in Dalworthington Gardens, Texas (see Exhibit B-1 in Appendix B). The property is north of West Pleasant Ridge Road and is bound by existing developments on the west, east, and north. Twin Springs Draw, a tributary to Rush Creek, runs through the northern portion of the property. Twin Springs Draw Tributary 2 runs through the center of the property and proposed project layout. The project is located approximately 1600 ft upstream of the Twin Springs Draw and Rush Creek confluence. The following describes the approach, methodology, and results to establish the impacts of the proposed development and provide preliminary sizing of a culvert system.

Previous Study

The Downstream Assessment portion of this study was based on the Rush Creek Watershed Study prepared by Halff Associates, Inc. in 2012 and includes hydrology and hydraulic modeling. This study is categorized as preliminary data and not within FEMA's effective database. The City of Arlington provided the Rush Creek study, as well as associated models and supplemental files to Shield Engineering, PLLC on March 31st, 2023 (see Appendix C for Rush Creek Watershed Study report). See Exhibit B-2 for the Twin Springs Draw watershed delineation.

Downstream Assessment

Hydrology Design Methodology

The modeling approach for the downstream assessment was kept consistent with the Rush Creek Watershed Study. The Rush Creek Watershed Study hydrology was developed using the following methodology and assumptions:

- SCS methodology was used to determine flow rates throughout the watershed.
- Hydrology Analysis was performed using USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS version 3.5)
- The Natural Resource Conservation Services (NRCS) Soil Survey was used to evaluate hydrologic soil groups. Good condition soil was used to determine curve numbers throughout the watershed.
- Percent Impervious values were calculated based on watershed conditions. Percent Impervious values were calculated assuming existing conditions.
- Time of concentration and lag time calculations were performed using NRCS TR-55 methodology.
- Rainfall data was obtained from TP-40 (Hershfield, 1961) for the 24-hour events.

The total watershed square mileage at the project outfall is 1.17 square miles. The project area contributes 2% to the total watershed. Analysis points were defined by junctions along Twin

Springs Draw and all project boundary outfalls. Existing and Proposed conditions analyses were performed for the 10%, 4%, and 1% annual chance events to confirm no adverse impacts (see Tables A1 and A2 for a summary of hydrologic parameters).

Analysis Point Summary	
Junction	Description
C_TWI_000_002	Project outfall at Twin Springs Draw
J_B1	Project outfall along western property boundary
C_TWI_000_003	Confluence along Twin Springs Draw upstream of project
J_B_TWI_000_100_B1	Confluence between Twin Springs Draw and Rush Creek

For existing conditions, drainage area delineations and parameters were updated based on topographic data and 2019 TNRIS LiDAR to basins B_TWI_000_100, B_TWI_000_090, and B_TWI_003_010. Drainage area B_TW_002_010 was split into EX-A1, OS-A1, and EX-B1 to accurately model flow through the project site (see Exhibit B-3 for the existing conditions drainage area map). Hydrologic parameters were updated assuming good condition soil and open space land use (see Tables A3, A4, and A5 for hydrologic parameter calculations). See Exhibits B-5 and B-6 for the soils map and existing land use coverage, respectively.

The proposed development comprises basins PR-A1, PR-A2, and PR-B1 (see Exhibit B-4 for the proposed conditions drainage area map). From existing to proposed conditions, the percent impervious increased from approximately 5% to 25% (see Exhibit B-7 for the proposed conditions land use coverage). The hydrologic study demonstrated an increase in flow at C_TWI_000_002, the confluence with Twin Springs Draw (see Tables A6 and A7 for a summary of discharges and comparison at project outfalls). This comparison was made assuming offsite areas were unchanged between existing and proposed conditions.

Hydraulics Design Methodology

Due to the minimal contribution of the project area to the total watershed and proximity to Twin Springs Draw, a hydraulic comparison was performed to show no increases in water surface elevation along Twin Springs Draw. The Twin Springs Draw Hydraulic Model developed with the Rush Creek Watershed Study was used for the comparison and was developed using the following methodology and assumptions:

1. Hydraulic Analysis was performed using USACE Hydrologic Engineering Center River Analysis System (HEC-RAS version 4.1).
2. The HEC-RAS analysis utilized unsteady flow computations.

The Rush Creek HEC-HMS model did not utilize routing reaches along Twin Springs Draw Mainstem. Uniform Hydrograph and Lateral Inflow Hydrograph flow data was updated in the HEC-RAS model based on hydrology updates for existing and proposed conditions. The hydraulic study comparison demonstrated no rises in water surface elevation from the project outfall to the Tributary Springs Draw to the confluence with Rush Creek (See Table A-8 for a comparison of water surface elevations).

Culvert Design

Hydrology Design Methodology

The proposed project includes a culvert and roadway crossing along Tributary Springs Draw Tributary 2. Design flow rates were determined using rational method in accordance with Chapter 10 Section 10.02.274 of Dalworthington Garden's City Ordinances. See Tables A9 and A10 for rational method and weighted runoff coefficient calculations.

Hydraulics Design Methodology

The USACE HEC-River Analysis System (HEC-RAS version 6.3) was used for hydraulic modeling of the stream and proposed culvert (see Exhibit B-8 for a hydraulic workmap). Rational method discharges for the 1% annual chance event were used as steady flow data in the hydraulic analysis. Topography collected in 2022 by Shield Engineering Group surveying was used in conjunction with Texas Natural Resources Information System (TNRIS) LiDAR 2019 to generate cross section data and map floodplains. A Manning's roughness coefficient of 0.05 was used to represent natural channel areas with light brush. A Manning's roughness coefficient of 0.08 was used to represent natural channel areas with heavy brush and tree growth. Bank stations were set to represent the change in the channel from light brush to heavy tree growth.

The preliminary culvert size was determined to be 36". The preliminary design provides more than 1' of freeboard to the proposed roadway and doesn't impact existing upstream storm drain infrastructure. See Table A11 for a comparison of existing and proposed water surface elevations along Twin Springs Draw Tributary 2. See Table A12 for a comparison between the proposed 100-year water surface elevation and top of bank/roadway.

Conclusion

The goal of this report was to demonstrate no adverse impacts downstream of the project site to adjacent properties and Twin Springs Draw due to the proposed development and provide preliminary sizing of a culvert system. The hydrology study determined that the proposed development increased the percent impervious value of the onsite drainage area from approximately 5% to 25%. This resulted in a discharge increase at the project outfall along Twin Springs Draw and no increase in water surface elevation along Twin Springs Draw to the confluence with Rush Creek. No increases in discharge were observed at project outfalls draining to adjacent properties. Results from the preliminary hydraulic study indicate that a 36" culvert will convey onsite and offsite flow with adequate freeboard and cause no adverse impacts to upstream storm drain infrastructure.

SHIELD ENGINEERING GROUP

APPENDIX A: TABLES AND CALCULATIONS

Roosevelt Estates Downstream Assessment					
Table A1 - Sumary of Parameters - Existing Conditions					
Basin	Acres	SQ Mile	CN	Percent Impervious	Lag Time
EX-A1	5.075	0.008	77	3	7.0
EX-B1	1.758	0.003	61	8	9.5
OS-A1	6.499	0.010	76	50	5.9
TWI_003_010	27.259	0.043	80	55	Previous Study
TWI_000_090	20.735	0.032	80	35	Previous Study
TWI_000_100	33.076	0.052	68	34	Previous Study

Table A2 - Sumary of Parameters - Proposed Conditions					
Basin	Acres	SQ Mile	CN	Percent Impervious	Lag Time
PR-A1	2.007	0.003	76	25	4.5
PR-A2	4.464	0.007	73	25	5.0
PR-B1	0.683	0.001	61	31	4.1
OS-A1	6.499	0.010	76	50	5.9
TWI_003_010	26.525	0.041	80	57	Previous Study
TWI_000_090	21.147	0.033	81	36	2.0
TWI_000_100	33.076	0.052	68	34	Previous Study

ROOSEVELT ESTATES DOWNSTREAM ASSESSMENT																			
TABLE A3 - TIME OF CONCENTRATION CALCULATIONS																			
1	2					3				4								5	6
	SHEET FLOW					SHALLOW CONCENTRATED FLOW				CHANNEL / PIPE FLOW									
Drainage Area ID	Sheet Flow Length (ft)	P_2 (in)	Land Slope (ft/ft)	n	t_{sheet} (min)	Shallow Flow Length (ft)	Shallow Flow Slope (ft/ft)	Average Velocity (ft/sec)	$t_{shallow}$ (min)	Channel Length (ft)	Channel Slope (ft/ft)	n	Cross Sectional Area (sf)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Average Velocity (ft/sec)	$t_{channel}$ (min)	SCS Method T_c (min)	SCS Method t_{lag} (min)
Existing Conditions																			
EX-A1	100	3.95	0.0237	0.15	8.24	-	-	-	-	655.6	-	-	-	-	-	3.20	3.41	11.65	6.99
EX-B1	100	3.95	0.0065	0.15	13.82	333	0.0278	2.69	2.07	-	-	-	-	-	-	-	-	15.89	9.53
OS-A1	100	3.95	0.0589	0.15	5.73	697	0.0359	3.05	3.80	106	0.0040	0.013	-	-	-	6.00	0.29	9.82	5.89
Proposed Conditions																			
PR-A1	100	3.95	0.0465	0.15	6.29	-	-	-	-	230.09	-	-	-	-	-	3.20	1.20	7.49	4.49
PR-A2	69.44	3.95	0.0163	0.15	7.15	527	0.0127	2.29	3.83	210.58	-	-	-	-	-	3.20	1.10	8.25	4.95
PR-B1	100	3.95	0.0437	0.15	6.45	16	0.0019	0.70	0.37	-	-	-	-	-	-	-	-	6.82	4.09
TWI_000_090	50	3.95	0.0050	0.011	1.09	353	0.0374	3.93	1.50	-	-	-	-	-	-	-	-	3.41	2.05
						149	0.0351	3.02	0.82	-	-	-	-	-	-	-	-		
NOTE: CITE SOURCE OF MANNING'S N VALUES USED.																			

ROOSEVELT ESTATES DOWNSTREAM ASSESSMENT				
TABLE A4 - CURVE NUMBER AND PERCENT IMPERVIOUS CALCULATION EXISTING CONDITIONS				
Basin	Total Area (Acres)	Total Area (sq. mi)	[1]Weighted CN	[1]Weighted / Percent Impervious
EX-A1	5.08	0.0079	77	3
EX-B1	1.76	0.0027	61	8
OS-A1	6.50	0.0102	76	50
TWI_000_090	20.74	0.0324	80	35
TWI_000_100	33.08	0.0517	68	34
TWI_003_010	27.26	0.0426	80	55
TWI_000_070	96.93	0.1515	-	57
TWI_000_030	67.34	0.1052	-	51

ROOSEVELT ESTATES DOWNSTREAM ASSESSMENT				
TABLE A5 - CURVE NUMBER AND PERCENT IMPERVIOUS CALCULATION PROPOSED CONDITIONS				
Basin	Total Area (Acres)	Total Area (sq. mi)	[1]Weighted CN	[1]Weighted / Percent Impervious
PR-A1	2.01	0.0031	76	25
PR-A2	4.46	0.0070	73	25
PR-B1	0.68	0.0011	61	31
OS-A1	6.50	0.0102	76	50
TWI_000_090	21.15	0.0330	81	36
TWI_000_100	33.08	0.0517	68	34
TWI_003_010	26.53	0.0414	80	57
TWI_000_070	96.93	0.1515	-	57
TWI_000_030	67.34	0.1052	-	51

Notes:
1. Weighted CN and Percent Impervious values calculated using Intersect and Dissolve Geoprocessing Tools in ArcPro

Roosevelt Estates Downstream Assessment						
Table A6 - Summary of Discharges						
Junction	10% ACE		4% ACE		1% ACE	
	Existing Flow	Proposed Flow	Existing Flow	Proposed Flow	Existing Flow	Proposed Flow
Project Site Junction Outfalls						
C_TWI_000_002	60.8	68.7	75.5	85.1	101	114.2
J_B1	5.2	2.8	7.1	3.6	10.6	5
Junctions Downstream through ZOI						
C_TWI_000_003	168.8	161.8	204.4	195.7	265.5	253.9
J_B_TWI_000_100_B1	127.5	123.9	161	156	220.9	213.4

Roosevelt Estates Downstream Assessment			
Table A7 - Discharge Impacts			
Basin	1-yr Comparison	5-yr Comparison	100-yr Comparison
Project Site Junction Outfalls			
C_TWI_000_002	7.9	9.6	13.2
J_B1	-2.4	-3.5	-5.6
Junctions Downstream through ZOI			
C_TWI_000_003	-7	-8.7	-11.6
J_B_TWI_000_100_B1	-3.6	-5	-7.5

Roosevelt Estates Downstream Assessment											
Table A8 - Twin Springs Draw Water Surface Elevation Comparison											
Reach	River	Cross Section	10% ACE Event			4% ACE Event			1% ACE Event		
			Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Twin Springs Draw											
TWI000A	TSD	6594	609.14	609.14	0	609.25	609.25	0	609.43	609.43	0
TWI000A	TSD	6562	608.23	608.23	0	608.38	608.38	0	608.63	608.63	0
TWI000A	TSD	6532	607.8	607.8	0	607.9	607.9	0	608.26	608.26	0
TWI000A	TSD	6498	607.09	607.09	0	607.33	607.33	0	608.08	608.08	0
TWI000A	TSD	6438	606.49	606.49	0	606.95	606.95	0	607.99	607.99	0
TWI000A	TSD	6319	606.38	606.38	0	606.85	606.85	0	607.96	607.96	0
TWI000A	TSD	6249	604.34	604.34	0	605	605	0	605.74	605.74	0
TWI000A	TSD	6218	604.63	604.63	0	605.18	605.18	0	606.05	606.05	0
TWI000A	TSD	6179	604.53	604.53	0	605.05	605.05	0	605.86	605.86	0
TWI000A	TSD	6133	604.29	604.29	0	604.75	604.75	0	605.47	605.47	0
TWI000A	TSD	6059	603.95	603.95	0	604.34	604.34	0	604.92	604.92	0
TWI000A	TSD	5935	602.83	602.83	0	603.3	603.3	0	604.04	604.04	0
TWI000A	TSD	5676	601.16	601.16	0	601.69	601.69	0	602.5	602.5	0
TWI000A	TSD	5466	599.57	599.57	0	600.05	600.05	0	600.79	600.79	0
TWI000A	TSD	5296	598.02	598.02	0	598.48	598.48	0	599.18	599.18	0
TWI000A	TSD	5079	596.18	596.18	0	596.61	596.61	0	597.37	597.37	0
TWI000A	TSD	4954	595.18	595.18	0	595.71	595.71	0	596.64	596.64	0
TWI000A	TSD	4851	594.72	594.72	0	595.39	595.39	0	596.45	596.45	0
TWI000A	TSD	4630	594.32	594.32	0	595.1	595.1	0	596.26	596.26	0
TWI000A	TSD	4515	593.61	593.61	0	594.4	594.4	0	595.53	595.53	0
TWI000A	TSD	4315	591.53	591.53	0	592.04	592.04	0	592.87	592.87	0
TWI000A	TSD	4239	591.04	591.04	0	591.57	591.57	0	592.38	592.38	0
TWI000A	TSD	4155	590.98	590.98	0	591.55	591.55	0	592.43	592.43	0
TWI000A	TSD	3981	589.62	589.62	0	590.07	590.07	0	590.75	590.75	0
TWI000A	TSD	3902	588.54	588.54	0	589.05	589.05	0	589.82	589.82	0
TWI000A	TSD	3556	584.09	584.09	0	584.68	584.68	0	585.68	585.68	0
TWI000A	TSD	3490	583.5	583.5	0	584.02	584.02	0	584.86	584.86	0
TWI000A	TSD	3161	581.24	581.24	0	581.72	581.72	0	582.35	582.35	0
TWI000A	TSD	3010	580.32	580.32	0	580.72	580.72	0	581.16	581.16	0
TWI000A	TSD	2970	580.3	580.3	0	580.65	580.65	0	580.97	580.97	0
TWI000A	TSD	2668	576.75	576.75	0	577.28	577.28	0	578.08	578.08	0
TWI000A	TSD	2599	576.04	576.04	0	576.54	576.54	0	577.31	577.31	0
TWI000A	TSD	2389	574.65	574.65	0	575.18	575.18	0	576	576	0
TWI000A	TSD	2202	573.77	573.77	0	574.31	574.31	0	575.1	575.1	0
TWI000A	TSD	2201	0	0	0	0	0	0	0	0	0
TWI000A	TSD	2108	573.28	573.28	0	573.79	573.79	0	574.56	574.56	0
TWI000A	TSD	1959	572.69	572.69	0	573.22	573.22	0	573.97	573.97	0
TWI000A	TSD	1815	572.42	572.42	0	572.96	572.96	0	573.7	573.7	0
TWI000A	TSD	1704	572.36	572.35	-0.01	572.89	572.88	-0.01	573.6	573.6	0
TWI000A	TSD	1522	572.26	572.26	0	572.78	572.77	-0.01	573.45	573.45	0
TWI000A	TSD	1354	572.16	572.16	0	572.66	572.66	0	573.3	573.3	0
TWI000A	TSD	1241	571.58	571.57	-0.01	572.06	572.06	0	572.63	572.63	0
TWI000A	TSD	1205	571.07	571.07	0	571.46	571.46	0	572	572	0
TWI000A	TSD	1115	570.82	570.82	0	571.26	571.26	0	571.83	571.83	0
TWI000A	TSD	1076.5	0	0	0	0	0	0	0	0	0
TWI000A	TSD	1038	570.82	570.82	0	571.26	571.26	0	571.83	571.83	0
TWI000A	TSD	1011	570.82	570.82	0	571.26	571.26	0	571.83	571.83	0
TWI000A	TSD	897	570.81	570.81	0	571.24	571.24	0	571.8	571.8	0
TWI000A	TSD	736	570.81	570.81	0	571.25	571.24	-0.01	571.81	571.8	-0.01
TWI000A	TSD	585	570.8	570.8	0	571.24	571.24	0	571.79	571.79	0
TWI000A	TSD	549	570.66	570.66	0	571.04	571.03	-0.01	571.51	571.51	0
TWI000A	TSD	544	0	0	0	0	0	0	0	0	0
TWI000A	TSD	437	554.15	554.15	0	554.85	554.85	0	555.94	555.94	0
TWI000A	TSD	390	554.25	554.24	-0.01	554.99	554.99	0	555.99	555.99	0
TWI000A	TSD	329	554.24	554.24	0	554.98	554.98	0	555.97	555.96	-0.01
TWI000A	TSD	237	554.25	554.25	0	555	554.99	-0.01	555.99	555.99	0
TWI000A	TSD	179	554.24	554.23	-0.01	554.98	554.98	0	555.97	555.96	-0.01
TWI000A	TSD	165	554.05	554.05	0	554.78	554.77	-0.01	555.7	555.7	0
TWI000A	TSD	143	0	0	0	0	0	0	0	0	0
TWI000A	TSD	106	548.07	548.06	-0.01	548.93	548.93	0	550.79	550.79	0
TWI000A	TSD	87	548.24	548.24	0	549.44	549.43	-0.01	551.13	551.12	-0.01

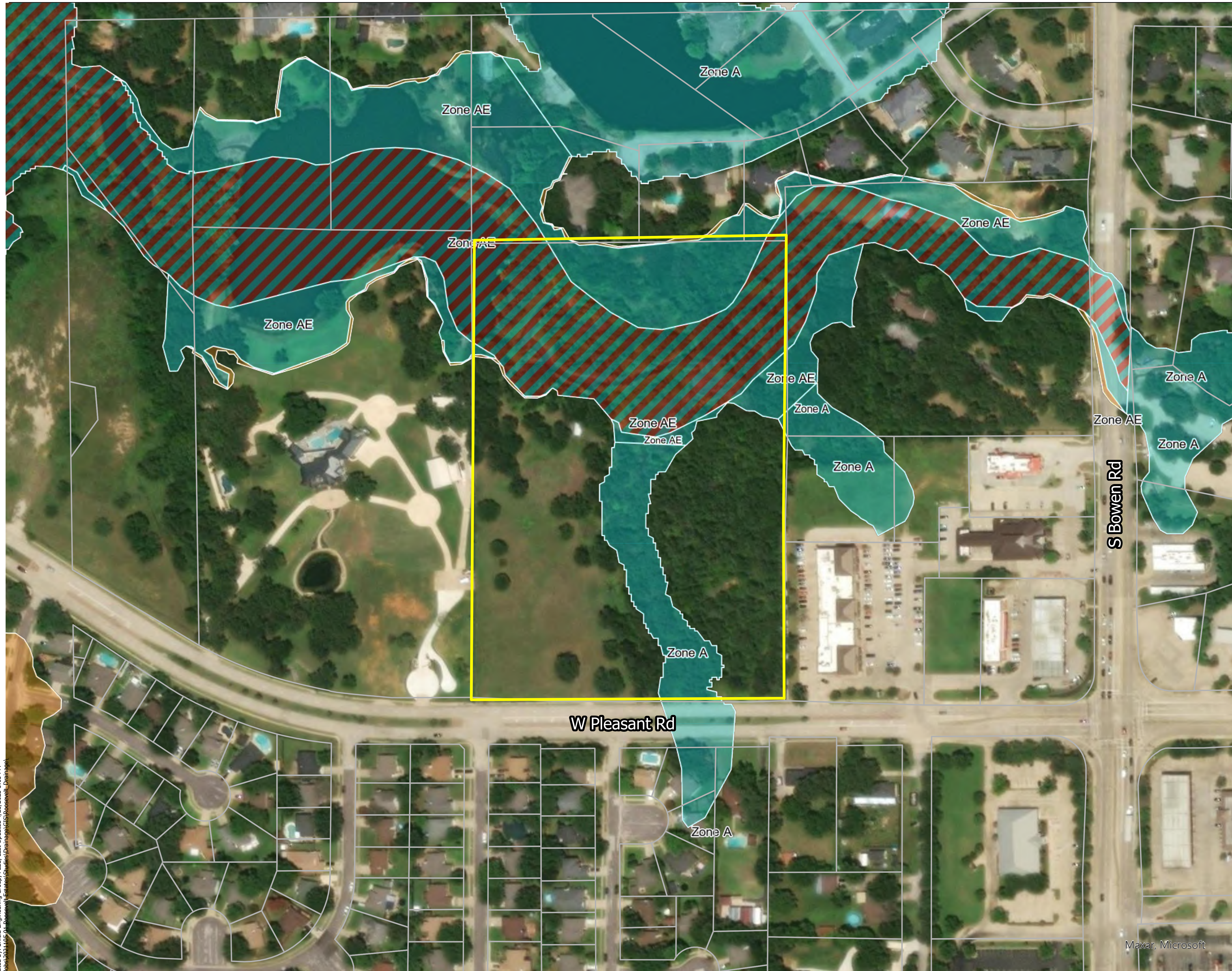
ROOSEVELT ESTATES DOWNSTREAM ASSESSMENT										
Table A9 - Culvert Design Rational Method Calculations										
25 and 100-Year Design Frequency										
1	2	3	4	5	6	7	8	9	10	11
Drainage Area ID	Area (ac)	Land Use Description	Runoff Coefficient C	CA	Total Tc (Min)	I25	Runoff Q25 (cfs)	I100	Runoff Q100 (cfs)	Outfall DesignPoint #
PR-A1	2.007	Residential	0.56	1.13	7.49	8.75	10.84	10.95	15.42	1
PR-A2	4.464	Residential	0.55	2.47	8.25	8.45	22.92	10.58	32.61	1
OS-A1	6.499	Residential	0.56	3.63	9.82	7.91	31.61	9.89	44.94	1
NOTE: TABLE 10.02.274-2. RUNOFF COEFFICIENT - DWG DRAINAGE ORDINANCE										
Q25 AND Q100 INCLUDE ANTECEDENT PRECIPITATION FACTORS OF 1.1 AND 1.25, RESPECTIVELY.										

ROOSEVELT ESTATES DOWNSTREAM ASSESSMENT								
TABLE A10 - COMPOSITE RUNOFF COEFFICIENT CALCULATIONS								
Drainage Area ID	Total Area (ac)	Residnetial - Type B Soil		Residnetial - Type C Soil		Residnetial - Type D Soil		Composite C
		C	Area (ac)	C	Area (ac)	C	Area (ac)	
PR-A1	2.007	0.52	0.234	0.55	0.806	0.58	0.968	0.56
PR-A2	4.464	0.52	1.527	0.55	1.046	0.58	1.89	0.55
OS-A1	6.499	0.52	0	0.55	4.445	0.58	2.05	0.56
NOTE: TABLE 10.02.274-2. RUNOFF COEFFICIENT - DWG DRAINAGE ORDINANCE								

Roosevelt Estates Downstream Assessment														
Table A11 - Water Surface Elevation Comparison														
Reach	River	Cross Section	Water Surface Elevation Comparison						Velocity Comparison					
			4% ACE Event			1% ACE Event			4% ACE Event			1% ACE Event		
			Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Twin Springs Draw 2														
Reach 1	1	627	585.43	585.43	0	585.57	585.57	0	4.03	4.03	0	4.42	4.42	0
Reach 1	1	590	581.34	581.34	0	581.52	581.52	0	4.46	4.43	-0.03	4.77	4.77	0
Reach 1	1	544	577.67	577.9	0.23	577.84	578.98	1.14	4.38	3.05	-1.33	4.75	1.43	-3.32
Reach 1	1	517	575.9	577.5	1.6	576.07	578.65	2.58	2.37	4.31	1.94	2.66	4.17	1.51
Reach 1	1	407	573.52	573.53	0.01	573.68	573.7	0.02	4.19	4.6	0.41	4.55	5.2	0.65
Reach 1	1	379	572.95	572.96	0.01	573.15	573.16	0.01	2.65	2.61	-0.04	2.96	2.91	-0.05
Reach 1	1	336	571.88	571.88	0	572.03	572.03	0	4.1	4.1	0	4.49	4.49	0
Reach 1	1	273	571.4	571.39	-0.01	571.8	571.79	-0.01	0.84	1.3	0.46	0.89	1.38	0.49
Reach 1	1	208	571.4	571.4	0	571.8	571.8	0	0.24	0.37	0.13	0.3	0.47	0.17
Reach 1	1	150	571.4	571.4	0	571.8	571.8	0	0.16	0.25	0.09	0.21	0.32	0.11
Reach 1	1	89	571.4	571.4	0	571.8	571.8	0	0.09	0.13	0.04	0.11	0.17	0.06
Reach 1	1	57	571.4	571.4	0	571.8	571.8	0	0.06	0.1	0.04	0.08	0.13	0.05

Roosevelt Estates Downstream Assesment					
Table A12 Twin Springs Draw Tributary 2 Freeboard					
Reach	River	Cross Section	Proposed 100-Yr WSEL (ft)	Bank Station Elevation (ft)	Freeboard (ft)
Reach 1	1	627	585.57	589.77	4.2
Reach 1	1	590	581.52	585.39	3.87
Reach 1	1	544	578.98	582.87	3.89
Reach 1	1	517	578.65	582.15	3.5
Reach 1	1	407	573.7	582.15	8.45
Reach 1	1	379	573.16	582.61	9.45
Reach 1	1	336	572.03	581.29	9.26
Reach 1	1	273	571.79	580.89	9.1
Reach 1	1	208	571.8	582.37	10.57
Reach 1	1	150	571.8	582.67	10.87
Reach 1	1	89	571.8	582.59	10.79
Reach 1	1	57	571.8	577.76	5.96

APPENDIX B: EXHIBITS AND WORKMAPS



Legend
- Project Location
- Parcels

Flood Hazard Boundaries
- Limit Lines
- SFHA / Flood Zone Boundary

Flood Hazard Zones
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee
- Area with Risk Due to Levee

N

200 100 0 200 US Feet

Scale: 1":200'

Exhibit B-1
Project Location Map

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:05 PM
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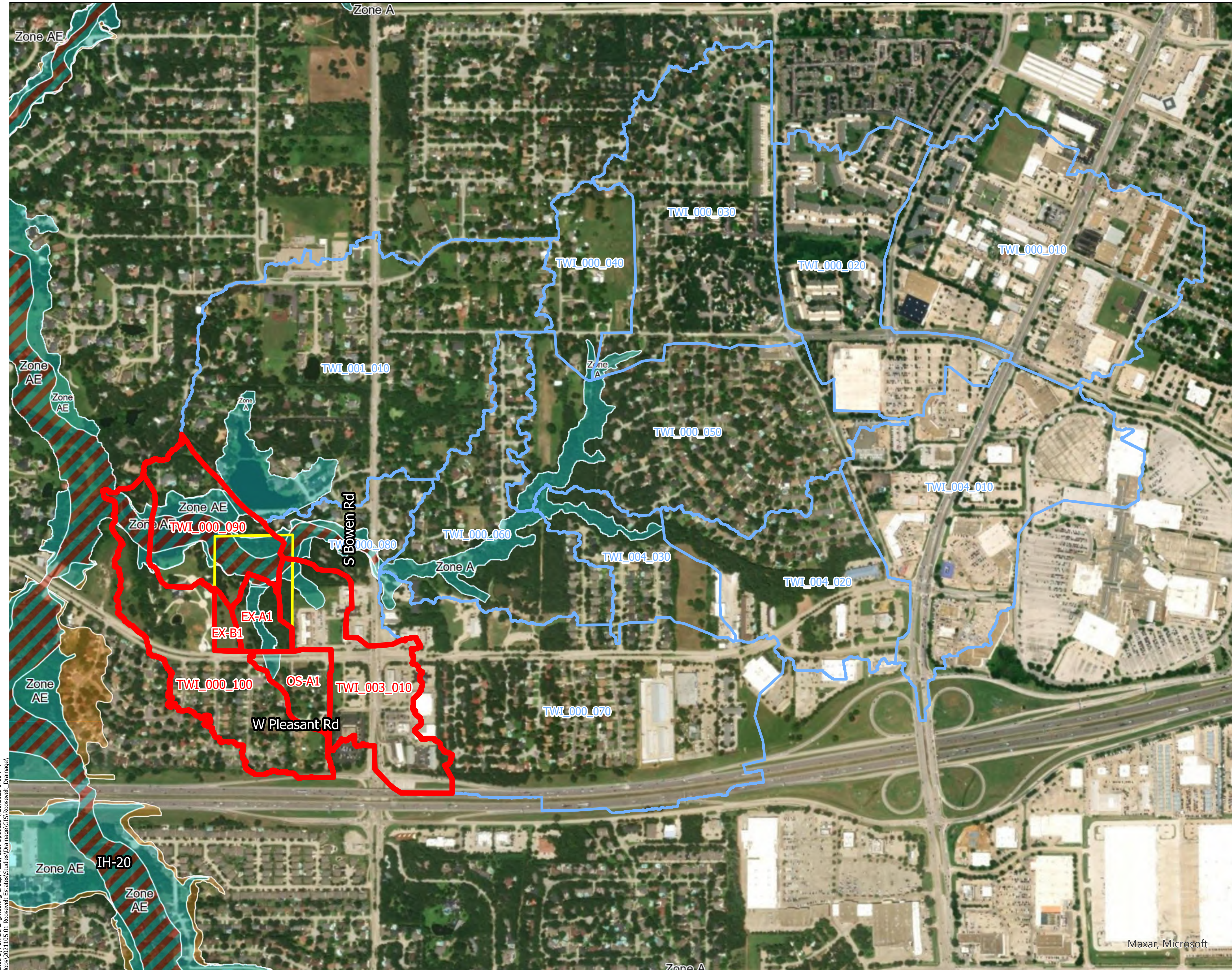

SHIELD ENGINEERING GROUP

Legend

- Project Location
- Existing Drainage Areas
- Twin Springs Draw Drainage Areas

Flood Hazard Boundaries

- Limit Lines
- SFHA / Flood Zone Boundary

Flood Hazard Zones

- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee
- Area with Risk Due to Levee

N

800 400 0 800 US Feet

Scale: 1":800'

Exhibit B-2
Overall Watershed

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:05 PM
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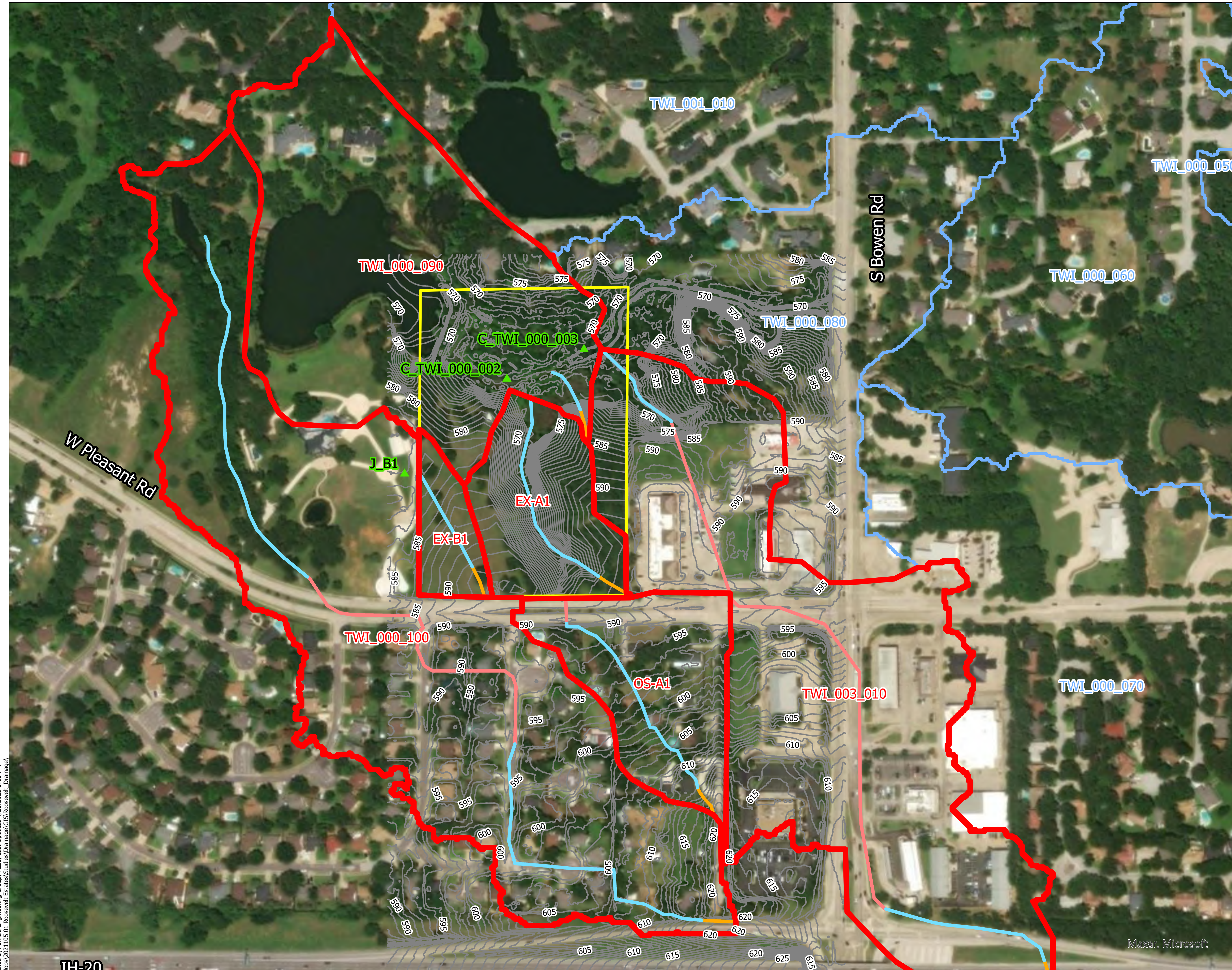

Legend

- Junction
- Project Location

Existing Longest Flowpath

FlowType

- Channel Flow
- Shallow Concentrated Flow
- Overland Flow
- Pipe Flow
- LiDAR
- Survey_Contours
- Existing Drainage Areas
- Twin Springs Draw Drainage Areas

N

300 150 0 300 US Feet

Scale: 1":300'

Exhibit B-3 Existing Drainage Area Map

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:05 PM.
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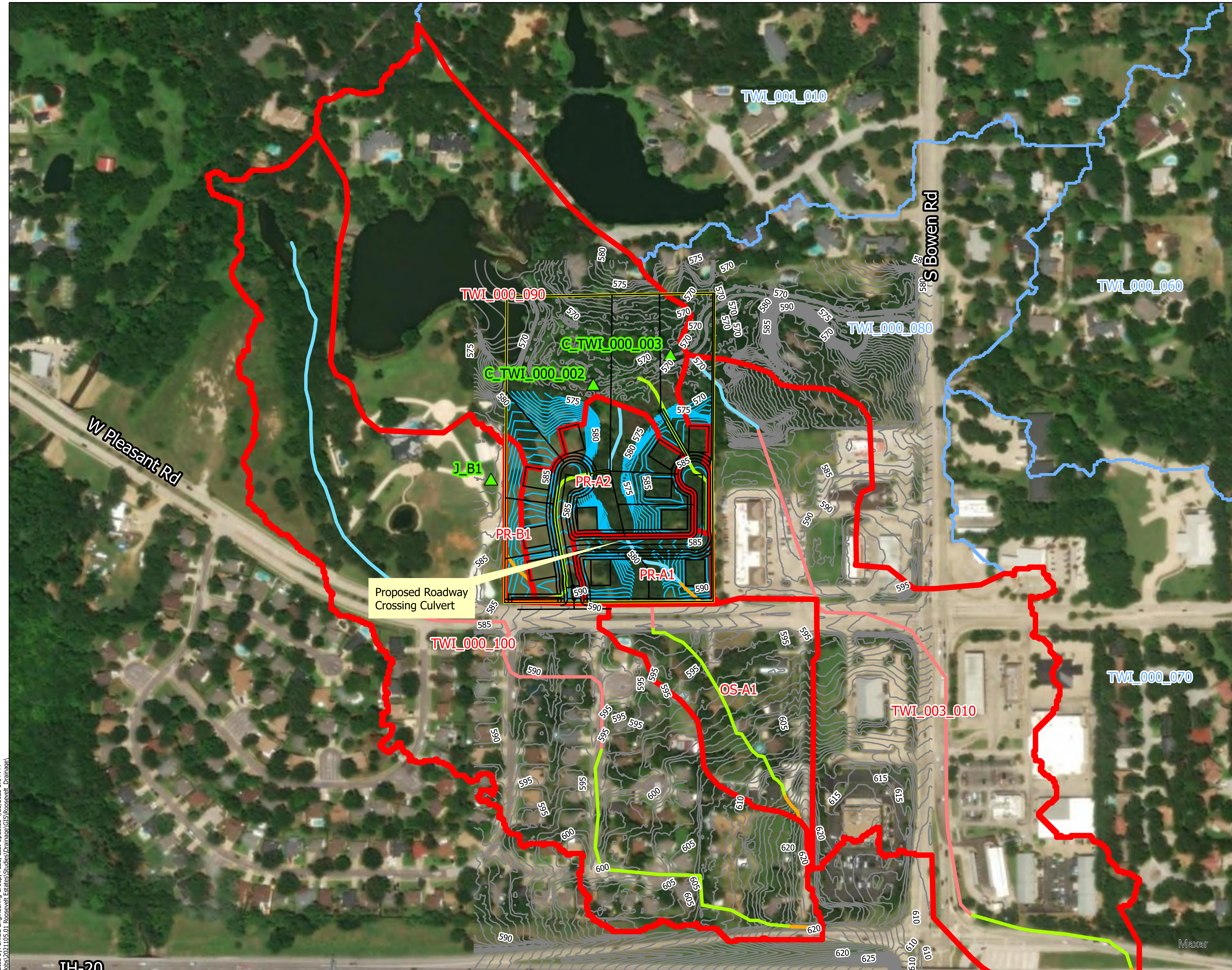

SHIELD
ENGINEERING GROUP

Legend
- Layout
- Project Location
- Proposed Drianage Areas
- Twin Springs Draw Drainage Areas

Proposed Longest Flowpath

FlowType
- Channel Flow
- Shallow Concentrated Flow
- Overland Flow
- Pipe Flow
- Preliminary Grading
- LiDAR
- Junction

N

300 150 0 300 US Feet

Scale: 1":300'

Exhibit B-4
Proposed Drainage Area Map

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:14 PM
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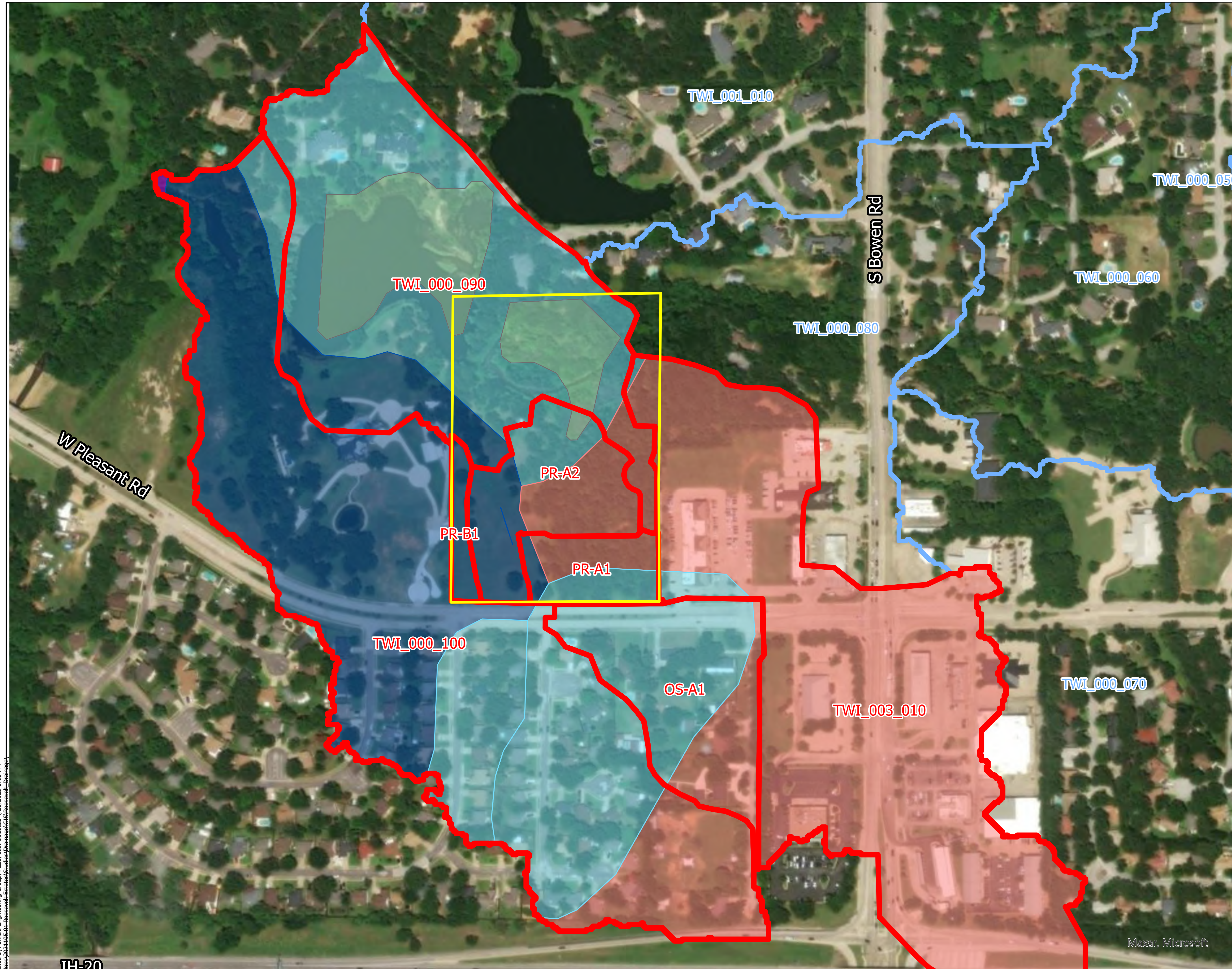

SHIELD ENGINEERING GROUP

Legend

- Project Location

Soil Type

HSG

- A
- B
- C
- D
- Water
- Twin Springs Draw Drainage Areas
- Proposed Drianage Areas

N

300 150 0 300 US Feet

Scale: 1":300'

Exhibit B-5
Soils Map

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:05 PM
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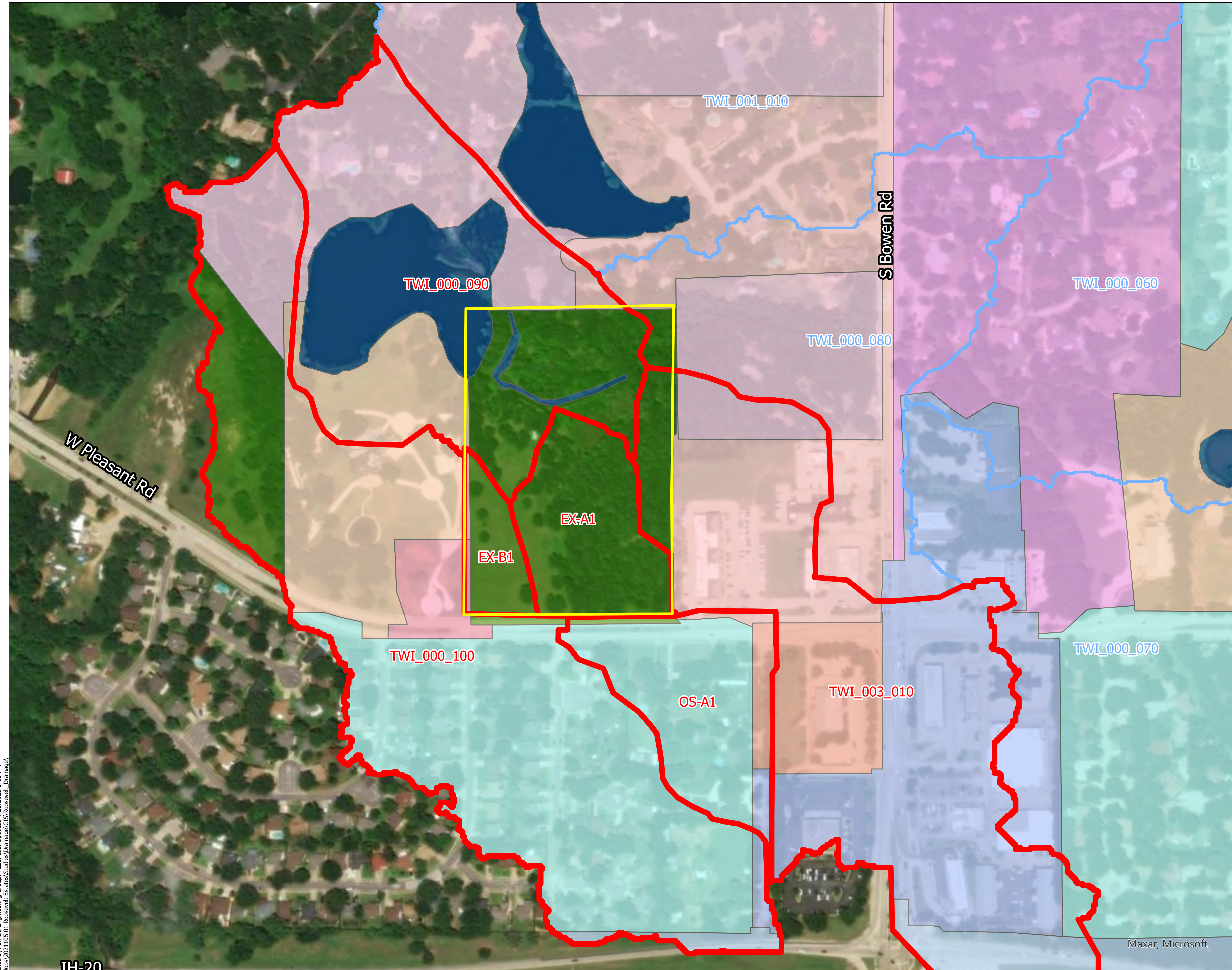

SHIELD ENGINEERING GROUP

Legend

- Project Location

Existing Land Use

Type

- Extremely Low Density
- Group Quarters
- High Density Residential
- Hotel/Motel
- Industrial
- Institutional
- Low Density Residential
- Major Roads
- Medium Density Residential
- Mobile Home
- Multi Family
- Office
- Parks/Recreation
- Retail
- Under Construction
- Utilities
- Vacant
- Very Low Density Residential
- Water
- Existing Drainage Areas
- Twin Springs Draw Drainage Areas

N

300 150 0 300 US Feet

Scale: 1":300'

Exhibit B-6
Existing Land Use Map

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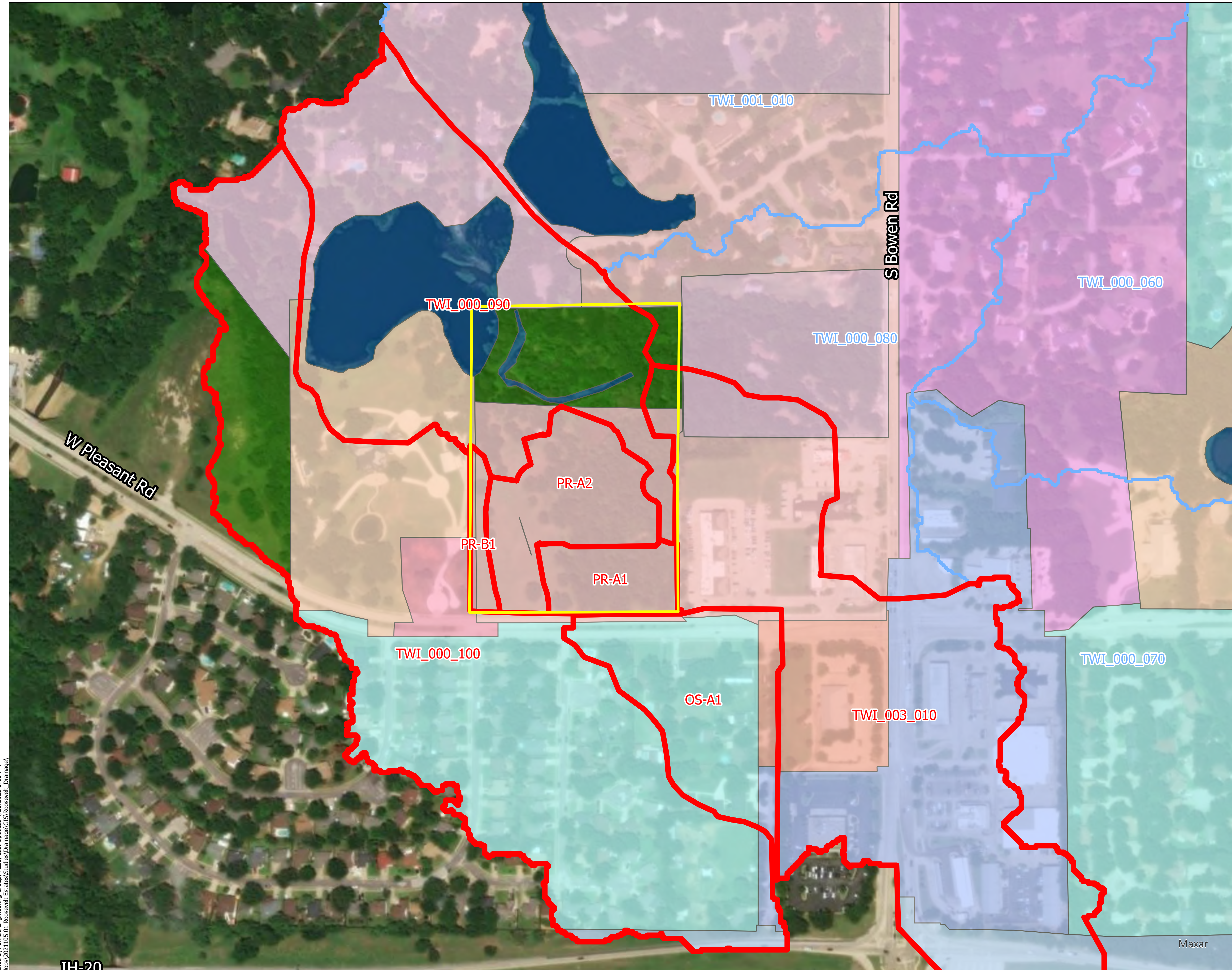
Exhibit B-7
Proposed Land Use Map



SHIELD ENGINEERING GROUP

Legend

- Project Location

Proposed Land Use

Type

- Extremely Low Density
- Group Quarters
- High Density Residential
- Hotel/Motel
- Industrial
- Institutional
- Low Density Residential
- Major Roads
- Medium Density Residential
- Mobile Home
- Multi Family
- Office
- Parks/Recreation
- Retail
- Under Construction
- Utilities
- Vacant
- Very Low Density Residential
- Water
- Proposed Drianage Areas
- Twin Springs Draw Drainage Areas

N

300 150 0 300 US Feet

Scale: 1":300'

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:05 PM
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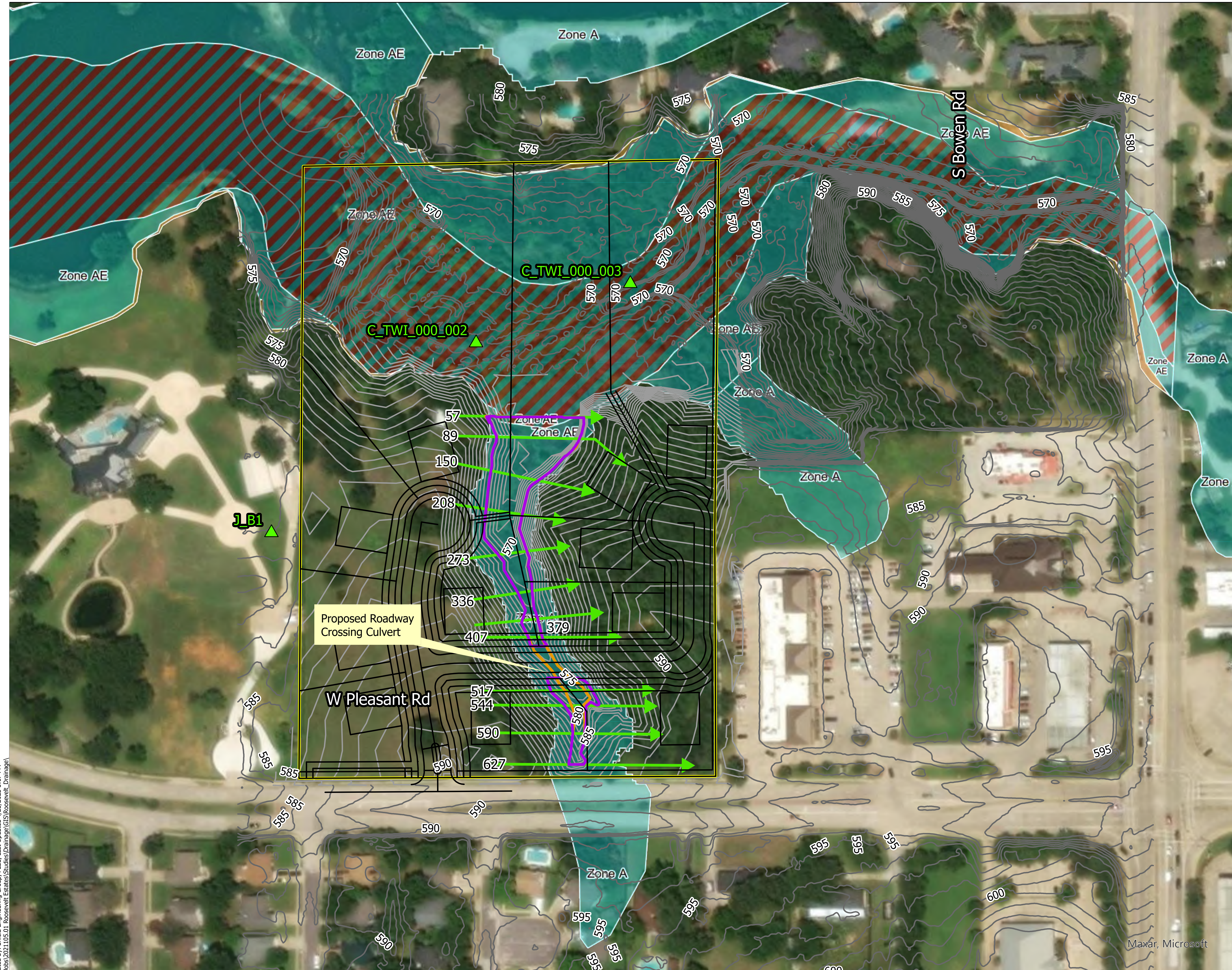

SHIELD ENGINEERING GROUP

Legend
- Layout
- Project Location
- LiDAR
- Survey_Contours
- Existing 100-yr Inundation
- Proposed 100-yr Inundation
- HEC-RAS Cross Sections

Flood Hazard Boundaries
- Limit Lines
- SFHA / Flood Zone Boundary

Flood Hazard Zones
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee
- Area with Risk Due to Levee
- Junction

N

150 75 0 150 US Feet

Scale: 1":150'

Exhibit 8
Hydraulic Workmap

Created by: Shield Engineering Group, PLLC, Last Updated 4/25/2023 5:17 PM
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SHIELD
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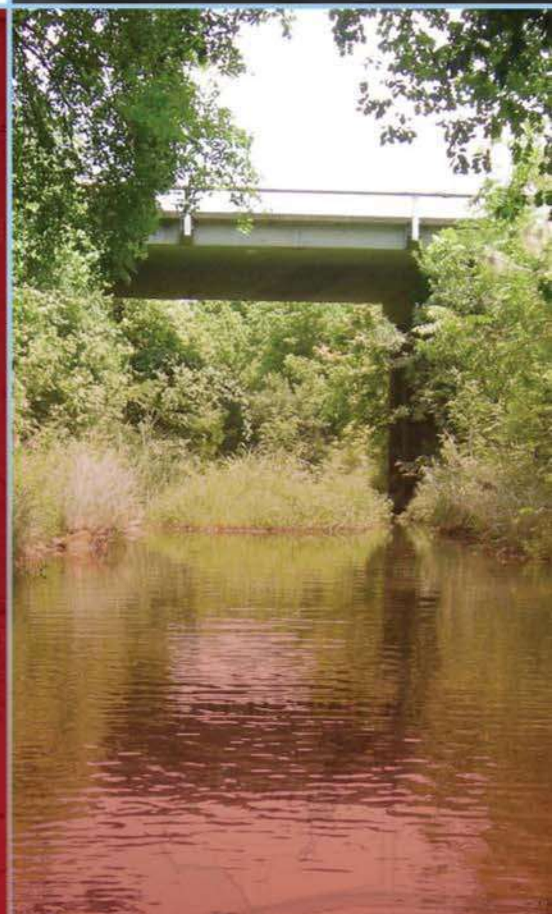
APPENDIX C: PREVIOUS STUDY (2012 RUSH CREEK STUDY)

RUSH CREEK
City of Arlington
Watershed Study

Rush Creek Watershed Study Hydrology Report

July 2012



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5/15/2013
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CDM Smith

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HALFF

CONTENTS

APPENDIX

FIGURES

TABLES

1. Executive Summary

1. Executive Summary

The Rush Creek watershed is the largest watershed in Arlington and includes portions of Kennedale, Mansfield, and Fort Worth and the entirety of Pantego and Dalworthington Gardens. The watershed encompasses approximately 35 square miles of contributing drainage area. It has developed significantly over the past 40 years from the time when the original floodplain mapping was produced by the Federal Emergency Management Agency (FEMA) and this development has had a significant impact on floodplains and creeks.

The City of Arlington has undertaken a comprehensive watershed study to update information regarding flooding characteristics and flows in Rush Creek. The purpose of the watershed study is to 1) update the FEMA flood maps so that flooding risk is better defined for Arlington residents; 2) reduce risks by formulating flood management projects; and 3) assess channel erosion risks.

This report summarizes the study methods and results of the hydrologic modeling effort performed by Halff Associates, Inc. As part of this effort, the Rush Creek watershed was divided into the following major sub-watersheds: Kee Branch, Lower Rush Creek, Middle Rush Creek, Stream RC-1, and Upper Rush Creek. HEC-HMS v3.5 was utilized to create hydrologic models for each sub-watershed. The results of this modeling effort will be utilized to develop unsteady hydraulic models to determine flood elevations corresponding to the 50, 20, 10, 4, 2, 1 and 0.2%-annual-chance (2-, 5-, 10-, 25-, 50-, 100- and 500-year) storm events. Figure 1-1 is a map of the Rush Creek study area.

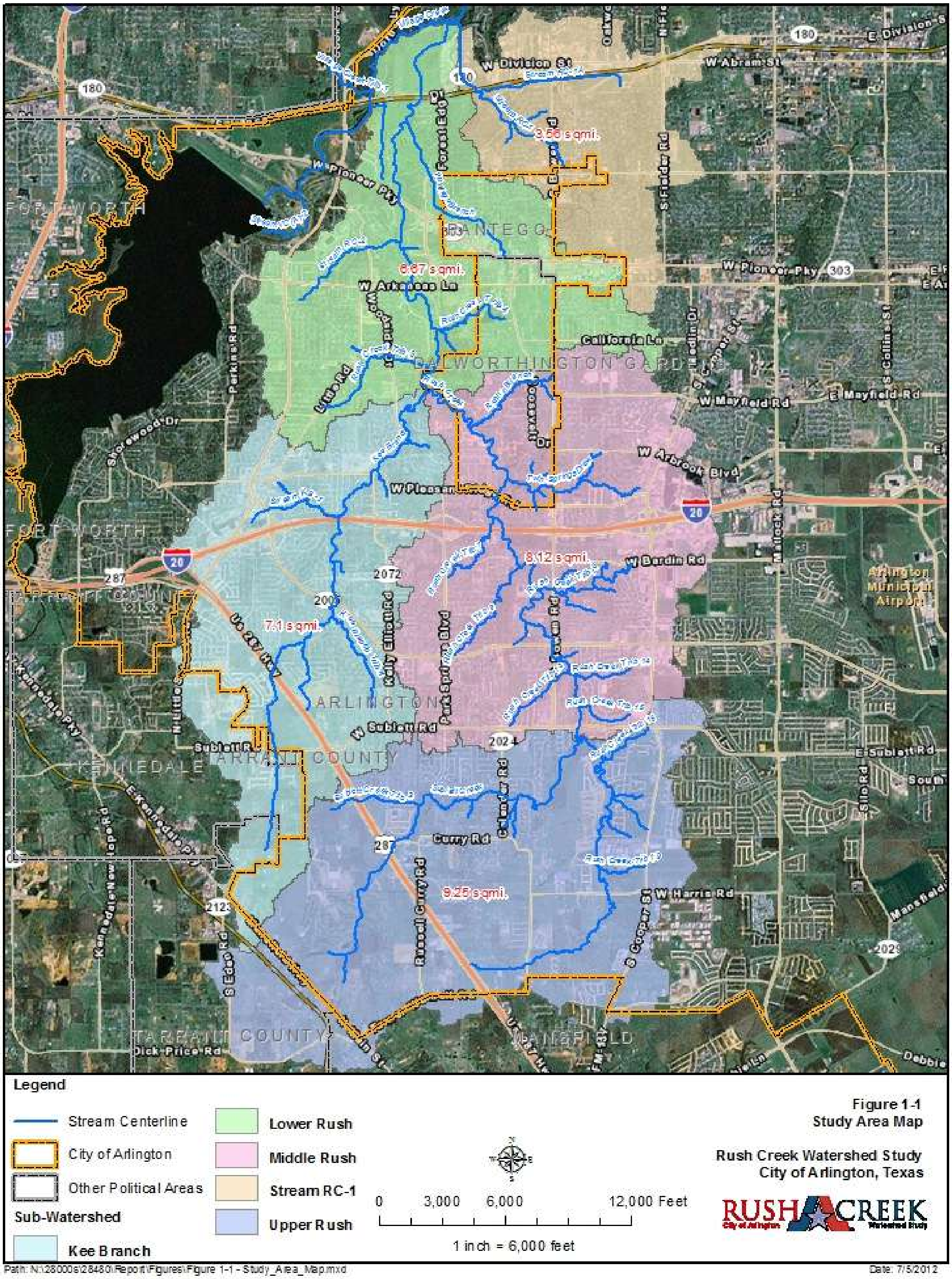


Figure 1-1. Study Area Map

2. Hydrologic Study

2. Hydrologic Study

2.1 Study Area Characteristics

2.1.1 Hydrologic Region

The Rush Creek watershed is located in the Lower West Fork Trinity hydrologic region and is bordered by the Village Creek watershed to the west, the Walnut Creek watershed to the southeast, Fish Creek watershed to the east, Johnson Creek watershed to the northeast. The characteristics of the Lower West Fork Trinity hydrologic region include generally flat terrain and impermeable soils.

2.1.2 Watershed Size

At its outlet, the Rush Creek watershed drainage area measures 34.69 square miles. The Rush Creek watershed was divided into the following five major sub-watersheds:

- *Kee Branch*
- *Lower Rush Creek*
- *Middle Rush Creek*
- *Stream RC-1*
- *Upper Rush Creek*

Figure A-1, Vicinity Map, shows the Rush Creek watershed boundary and the surrounding area.

2.1.3 Soils

The Natural Resource Conservation Service (NRCS) Soil Survey of Tarrant County (2009) was used to evaluate the hydrologic soils in the Rush Creek watershed. The most prevalent soil type in the watershed is Group D which consists of clayey soils with slow infiltration rates and high potential for runoff. The second most prevalent soil type is Group B which consists of soils characterized as having some content of gravelly sand with moderate infiltration rates and low/moderate runoff potential. The third most prevalent soil type in the watershed is Group C which indicates soils having moderately fine to fine texture and slow infiltration rates. A small percentage of soils in the watershed are identified as Group A which indicates soils having high infiltration rates and low runoff potential. Table 2.1 includes a list of the NRCS Soil Survey Geographic Database (SSURGO) Hydrologic Soil Group (HSG) classifications for each Rush Creek sub-watershed.

The hydrologic soils for the Rush Creek watershed are illustrated in Figure A-2, Soils Map.

The antecedent moisture condition (AMC) defines the soil moisture condition prior to a storm. AMC-II, average soil moisture conditions, was used for the watershed study.

Table 2.1 - Watershed Soil Classification				
SSURGO Database Classification	Hydrologic Soil Type Percentage			
	A	B	C	D
Kee Branch	3%	38%	29%	30%
Lower Rush Creek	13%	43%	18%	26%
Middle Rush Creek	4%	25%	18%	53%
Stream RC-1	2%	41%	28%	28%
Upper Rush Creek	3%	29%	17%	50%

2.1.4 Land Use

Land use for the Rush Creek watershed has been determined for both existing and ultimate conditions. Table 2.2 shows the land use categories and corresponding impervious percentages used for this study. Refer to the Technical Standards (May 21, 2012) developed by CDM Smith for sources of these impervious area percentages. Watershed conditions dictated that the recommended percent impervious values provided in the Technical Guidelines be revised to the values shown in Table 2.2 for Extremely Low Density Residential, Very Low Density Residential, Major Transportation, Institutional, and Mobile Home land use categories. A composite percentage of impervious area was computed for each sub-basin for both existing and ultimate land use conditions.

Table 2.2 - Land Use and Percent Impervious	
Land Use Description	Impervious (%) Condition
Extremely Low Density Res (2+ac lots)	15
Very Low Density Res (1 ac lots)	25
Low Density Res (1/2 ac lots)	40
Medium Density Res (1/3 ac lots)	45
High Density Res (1/4 ac lots)	50
Major Transportation	50
Industrial	72
Institutional	50
Group Quarters	40
Hotel/Motel	85
Mobile Home	35
Multi Family	65
Office	85
Parks/Recreation	6
Retail	85
Under Construction	50
Utilities	60
Vacant	3
Water	100

2.1.4.1 *Existing Conditions Land Use*

The existing land use conditions were based on 2005 North Central Texas Council of Governments (NCTCOG) existing land use data provided in shapefile format. The land use shapefile was updated to reflect current development conditions shown on the City of Arlington aerial photography (2011). The existing conditions land use for the Rush Creek watershed is illustrated in Figure A-3, Existing Land Use Map.

2.1.4.2 *Ultimate Conditions Land Use*

Ultimate conditions land use data was not available for the project area. Based on discussion with the project team and the City of Arlington, an impervious area value of 75 percent was applied to all vacant and extremely low density residential land use to estimate the ultimate build out conditions of the watershed. All other land use remained consistent with the existing land use conditions.

2.1.5 Sub-basins

Sub-basin delineations were generated in ESRI's ArcGIS Version 10.0 based on the Texas Natural Resource Information Systems (TNRIS) 2009 Light Detection And Ranging (LiDAR) Terrain Data. Digital storm sewer lines supplied by the City of Arlington, supported by current aerial photography, aided in the sub-basin delineation process. See Figure A-4, Sub-basin Workmap, for sub-basin delineations.

2.1.5.1 *Topographic Data Acquisition and Evaluation*

Topographic data covering the project extent was obtained from the TNRIS 2009 LiDAR acquisition project. This data was available as LiDAR point clouds in the American Society of Photogrammetry and Remote Sensing (ASPRS) common LiDAR Data Exchange Format (LAS 1.1) with 1.0 meter post spacing.

Data was acquired in March 2009 by Fugro Earth Data, Inc. The LiDAR QA Report provided by Dewberry is included in Appendix E of this report. This data was acquired and processed to meet 0.185 meter Root Mean Square Error (RMSEz) vertical accuracy and was tested to have an RMSEz of 0.040 meters using National Standards for Spatial Data Accuracy (NSSDA) and FEMA methodology (see Table 1 of the LiDAR QA Report).

2.1.5.2 *Terrain Processing*

The LiDAR data was processed with Esri's ArcGIS software. The LiDAR data was acquired in Universal Transverse Mercator (UTM), North American Datum of 1983, (NAD83 Meters) with heights in the 1988 North American Vertical Datum (NAVD88 Meters). Each LiDAR tile was projected to Stateplane NAD83, Texas North Central zone with horizontal units of feet and the vertical units were also converted from meters to feet. The projected LiDAR point clouds were then processed in ArcGIS and the ground points were placed into a multipoint feature class within a file geodatabase. The multipoint feature class was then used to generate a seamless terrain dataset within the same file geodatabase. From the terrain dataset, a ground surface Digital Elevation Model (DEM) was generated to support basin delineations and hydrologic modeling.

2.2 Approach and Methodology

2.2.1 Methodology

Hydrologic analyses have been conducted for the Rush Creek watershed as part of the comprehensive watershed study and model updates. The entire watershed has been analyzed for the following hydrologic scenarios:

- *Existing Land Use Conditions*
- *Ultimate Land Use Conditions*

Significant rainfall events considered for the hydrologic models were the 2-, 5-, 10-, 25-, 50-, 100- and 500-year frequency floods. Detailed watershed delineations, existing and ultimate land use determinations, and the hydrologic soil coverage were used to develop HEC-HMS hydrologic computer models for the respective tributaries' watershed. The Rush Creek Watershed Technical Standards (May 21, 2012) along with Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55) Second Edition were used as guidelines for the new 2012 hydrologic analyses.

2.2.1.1 *Rainfall*

Rainfall data was obtained from TP-40 (Hershfield, 1961) for the 24-hour storm events corresponding to the 50, 20, 10, 4, 2, 1 and 0.2%-annual-chance (2-, 5-, 10-, 25-, 50-, 100- and 500-year) storm events.

The rainfall data is summarized below in Table 2.3

Table 2.3 - Rainfall Data (inches)

Recurrence Interval (Percent Annual Chance)	Storm Duration							
	5 Min	15 Min	1 Hr	2 Hr	3 Hr	6 Hr	12 Hr	24 Hr
50%	0.40	1.02	1.77	2.15	2.37	2.86	3.43	3.95
20%	0.54	1.38	2.39	2.90	3.19	3.86	4.63	5.33
10%	0.64	1.64	2.84	3.44	3.79	4.58	5.49	6.32
4%	0.76	1.94	3.35	4.06	4.48	5.41	6.49	7.47
2%	0.86	2.19	3.79	4.59	5.06	6.12	7.34	8.45
1%	0.96	2.46	4.25	5.15	5.67	6.86	8.23	9.47
0.2%	1.16	2.98	5.15	6.24	6.87	8.31	9.96	11.47

2.2.1.2 *Rainfall Losses*

The loss rate of rainfall, caused by evaporation, interception, depression, storage, and infiltration, is typically evaluated and subtracted from the rainfall to determine rainfall excess for each time increment of a storm. For this study, the SCS Curve Number Method, developed by the Natural Resources Conservation Service (NRCS), was used to develop flood hydrographs based on land use, soil classification, and antecedent moisture conditions. Baseline Curve Numbers were obtained from TR-55, Table 2.2c, for pasture, grassland, or range for AMC-II, average soil moisture conditions. Curve Numbers (CN) were computed based on a composite percentage of soil types within each sub-basin. Group A soils were defined as having a CN of 39, Group B soils were defined as having CN as 61, Group C soils were defined as having CN as 74, and Group D soils were defined as having CN as 80.

The initial abstraction (I.A.) for all watersheds was computed for AMC-II, average soil conditions using the following equation from TR-55:

$$IA = 0.2\left(\frac{1000}{CN} - 10\right)$$

2.2.1.3 Sub-basin Response

The SCS Dimensionless Unit Hydrograph method was used and SCS lag times were computed for each sub-basin to generate runoff hydrographs. A different time of concentration was computed for existing and ultimate conditions. Both were based on the NRCS TR-55 methodology for overland (sheet) flow, shallow concentrated flow, and channel flow. Overland flow length was limited to a maximum of 100 feet for unpaved surfaces and 50 feet for paved surfaces.

Travel times for channel flow were based on velocities from the HEC-RAS routing models, where available. Channel flows for non-routed reaches were estimated based on Manning's equation, assuming a bankfull depth that was selected based on the channel geometry and the elevation corresponding to the natural channel banks. For improved channels, it was often difficult to estimate the bankfull depth from the channel geometry and some consideration was given to the expected bankfull (2-year) discharges and anticipated velocities associated with bankfull flow. Storm drain velocities were assumed to be 6 feet per second for the purposes of this study.

Based on the recommendation of the project team, the stream channels being modeled using unsteady HEC-RAS were removed from the time of concentration calculations. A memorandum, entitled “Flow paths for estimating Basin Lag Time”, supporting this decision is provided in Appendix D.

The time of concentration is the summation of these phases, where:

$$T_c = t_{sheet} + t_{shallow\ concentrated} + t_{storm\ drain} + t_{channel}$$

Lag times were computed using the following equation:

$$T_p = 0.6 * T_c$$

The Ultimate Conditions times of concentration were estimated by changing overland flow located in vacant land use to be a maximum of 50 feet and paved. All shallow concentrated flow was changed to paved for ultimate conditions. These two changes were intended to estimate the impacts of future development to times of concentration.

Studies have shown that the square root of area can provide a good prediction of time of concentration. Graphs showing the comparison of the estimated times of concentration to the sub-basin area are included in Appendix B of this report.

2.2.1.4 Routing

Channel reaches for which there will be no new unsteady hydraulic study were routed in the hydrologic model. The Modified Puls method was used for open channel reaches. HEC-RAS v4.1 was used to develop elevation-storage-discharge relationships for these reaches to route flows in the HEC-HMS model. The HEC-RAS models were generated using cross sections based on the TNRIS LiDAR data. The subreaches (routing step) calculations are provided in Appendix B of this report.

The Muskingum-Cunge method was used to route flows through storm drain reaches outside of the new unsteady hydraulic study reaches. An equivalent pipe diameter size was calculated for most reaches based on a weighted average of the pipe size and length through the reach. The equivalent pipe diameter was input in the HEC-HMS models and a note was added in the description of these routing reaches to specify when this method was applied.

2.2.1.5 External Input Hydrographs

There were no external input hydrographs entered into the Rush Creek Hydrology models.

2.2.1.6 Reservoir Storage

Two ponds were modeled as reservoirs in HEC-HMS for the Rush Creek watershed. The first is near the intersection of Briarwood Blvd and Winewood Ln in the RC-1 sub-watershed. The second is west of Green Oaks Blvd near the intersection of Fireside Drive in the Lower Rush sub-watershed. The elevation-area-discharge method was used to model these reservoirs in HEC-HMS. Record drawings received from the City of Arlington were utilized to develop elevation-discharge ratings for the outlet structures of these reservoirs. The TNRIS LiDAR data was used to develop the elevation-area tables for each reservoir.

2.2.2 Stream Gages

There are no stream gages in the Rush Creek watershed.

2.2.3 Calibration

Rainfall data was obtained from the National Weather Service (NWS) for the following historical storms:

- *January 24-25, 2012*
- *September 7-9, 2010 (Tropical Storm Hermine)*

Multisensory precipitation estimator (MPE) rainfall data was used to generate the historical rainfall data. This rainfall data is a mosaic of radar, satellite imagery, and rainfall gauge data that is generated on an hourly time-step by the National Weather Service (NWS). The data is available on a 4km x 4km grid (HRAP grid) and provides high-quality temporal and spatial distribution of the rainfall during each storm event. The gridded rainfall product was distributed to the sub-basins by calculating a weighted average for each grid cell and corresponding rainfall depth within each sub-basin. Figure 2.1 below shows the precipitation map of total rainfall from Tropical Storm Hermine courtesy of the NWS.

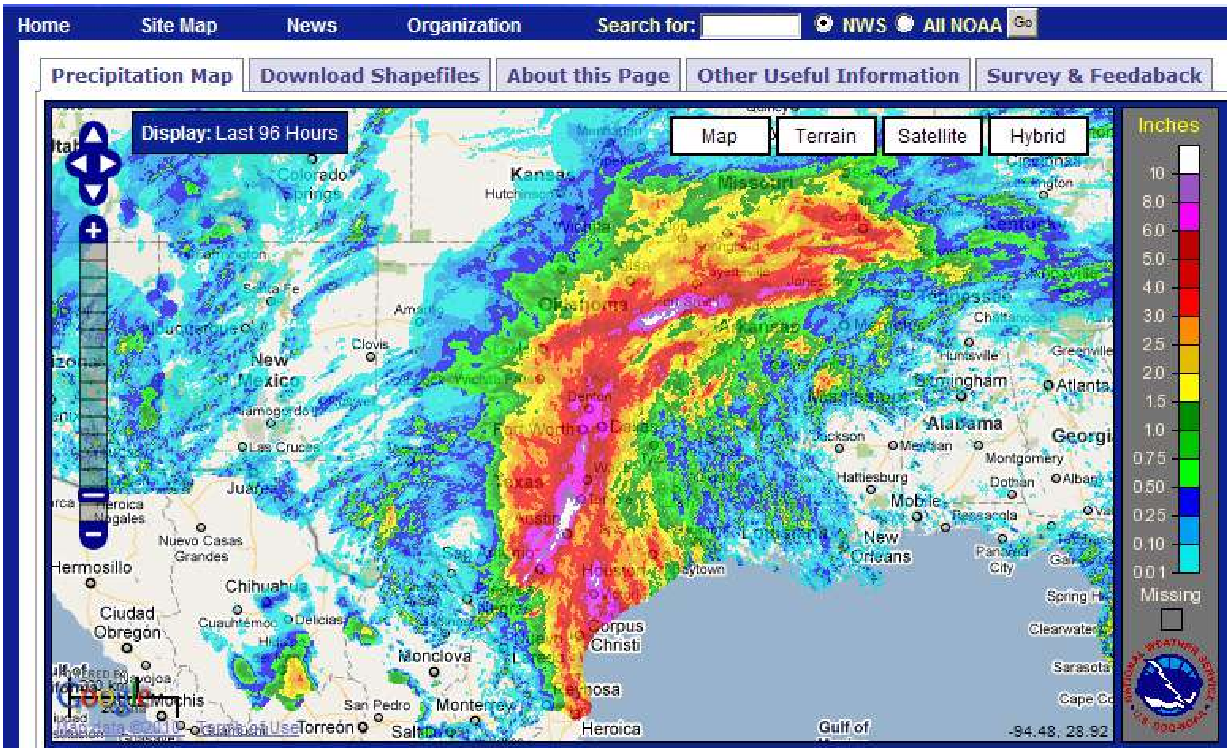


Figure 2-1. Tropical Storm Hermine Total Rainfall

In the absence of stream gage data and watershed wide routing data, the HEC-HMS models have not been calibrated to either storm event at this point. It is anticipated highwater marks documented during these storm events will be used to confirm study results following the completion of the unsteady hydraulic modeling.

2.3 Discharge Comparison

2.3.1 Computed Discharges

Computed discharges will be compared to the effective discharges following the development of the unsteady hydraulic models for the Rush Creek watershed. Previous studies with comparable hydrologic conditions were used to validate the results of the hydrologic models. Discharge comparison graphs are included in Appendix B of this report. The comparison is only conceptually applicable since travel time through unsteady modeled streams was omitted for many of the Rush Creek sub-basins resulting in calculated peak discharges that were higher compared to other sub-basins of similar size. It is anticipated that these discharges will compare favorably after the unsteady routing is utilized to route the hydrographs through the studied reaches. Refer to Appendix D for correspondence documenting technical support for the time of concentration methodology.

2.3.2 Effective Discharges

The current FEMA effective discharges from the September 25, 2009 FEMA Flood Insurance Study (FIS) for Tarrant County are listed in Table 2.4 below.

Table 2.4 - FEMA Effective Discharges

Flooding Source and Approximate Location	Basin Area (sq. mi.)	Peak Discharge (cfs)			
		10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
KEE BRANCH					
At confluence with Rush Creek	7.23	6,810	9,490	10,920	13,900
Downstream of confluence of Stream KB-1	6.96	6,210	8,720	9,970	12,470
At Interstate Route 20	4.44	4,360	6,400	7,300	9,070
Downstream of confluence of Tributary K-2	3.55	3,680	4,660	6,420	7,880
Upstream of confluence of Tributary K-2	2.85	2,980	4,400	5,020	6,190
Downstream of confluence of Tributary K-3	1.4	1,340	1,880	2,140	2,650
At U. S. Route 287	1.09	1,030	1,450	1,640	2,020
At Kennenda1e Sublett Road	0.89	1,230	1,650	1,840	2,230
STREAM KB-1					
At confluence with Kee Branch	1.52	2,500	3,310	3,670	4,440
At Oak Springs Road	1.26	2,160	2,890	3,120	3,750
PANTEGO BRANCH					
At confluence with Rush Creek	1.68	2,460	3,320	3,710	4,490
At West Park Row	1.43	2,190	2,940	3,310	4,030
At Smith-Barry Road	0.94	1,550	2,070	2,290	2,840
RUSH CREEK					
At confluence of Pantego Branch	29.01	3,670	4,233	4,704	5,799
At State Route 303	28.77	15,400	23,280	27,060	34,770
At Woodland Park Boulevard	27.59	15,240	22,990	26,670	34,170
At Arkansas Lane	27.17	15,540	23,460	27,180	34,770
Below confluence of Kee Branch	25.24	14,680	21,904	25,280	32,290
At confluence of Kee Branch	18.01	9,920	14,550	16,850	21,650
Below confluence of Tributary R-8	17.83	9,980	14,690	16,950	21,730
Above Kee Branch	17.52	9,600	15,000	17,600	25,000
At confluence of Tributary R-8	16.57	9,710	14,150	16,350	20,900
Below confluence of Tributary R-7	16.3	9,770	14,140	16,340	20,800
At confluence of Tributary R-7	15.16	9,350	13,590	15,700	19,980

Table 2.4 - FEMA Effective Discharges

Flooding Source and Approximate Location	Basin Area (sq. mi.)	Peak Discharge (cfs)			
		10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Downstream of confluence of Tributary R-5 and R-6	14.74	9,400	13,670	15,780	20,010
At Interstate Route 20	13.07	8,860	12,820	14,770	18,680
Downstream of confluence of Tributary R-4	12.78	9,000	13,170	15,190	19,130
At confluence of Tributary R-4	11.51	8,380	12,250	14,010	17,510
At Green Oaks Boulevard	10.82	8,350	12,179	13,890	17,260
Downstream of confluence of Sublett Creek	9.51	8,210	11,620	13,179	16,340
At confluence of Sublett Creek	4.22	4,000	5,560	6,270	7,740
Downstream of confluence of Tributary R-11	3.04	3,520	4,880	5,490	6,820
At confluence of Tributary R-11	2.54	2,990	4,120	4,610	5,690
Below confluence with Tributary R-10	1.9	2,520	3,440	3,850	4,720
At confluence of Tributary R-I	1	1,290	1,770	1,980	2,450
FOREST PARK TRIBUTARY OF RUSH CREEK					
At confluence with Rush Creek	0.18	**	**	610	**
NORTHEAST TRIBUTARY OF RUSH CREEK					
At confluence with Rush Creek	0.11	**	**	361	**
RUSH CREEK RELIEF CHANNEL					
Upstream of convergence with Village Creek	**	15,728	25,147	30,374	40,972
STREAM RC-1					
At confluence with Rush Creek	3.56	4,810	6,220	6,850	8,130
Immediately upstream of Union Pacific Railroad	1.95	2,640	3,310	3,630	4,280
STREAM RC-1(A)					
At confluence with Stream RC-I	1.36	2,210	2,870	3,180	3,810
At headwaters	0.93	1,710	2,240	2,480	3,010
STREAM RC-2					
At confluence with Rush Creek	1.18	1,970	2,520	2,790	3,370
At headwaters	0.64	1,350	1,750	1,930	2,410
RYAN'S BRANCH					

Table 2.4 - FEMA Effective Discharges					
Flooding Source and Approximate Location	Basin Area (sq. mi.)	Peak Discharge (cfs)			
		10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
At confluence with Rush Creek	1.29	2,000	2,750	3,100	3,900
At Roosevelt Drive	0.99	1,850	2,500	2,800	3,550
SUBLETT CREEK					
At confluence with Rush Creek	5.29	4,620	6,630	7,500	9,100
At Calendar Road	4.57	4,520	6,310	7,060	8,320
SUBLETT CREEK					
Downstream of U.S. Route 287	3.66	3,790	5,230	5,790	6,620
At U.S. Route 287	2.99	3,520	4,790	5,170	5,790
Downstream of Tributary 1	1.83	2,510	3,400	3,800	4,610
TWIN SPRINGS DRAW					
At confluence with Rush Creek	1.17	1,850	2,550	2,850	3,550

3. Exceptions

3. Exceptions

3.1 Explanation of Deviations from the Standard Procedures

This section documents exceptions to the FEMA study standards, FEMA Guidelines and Specifications, or to the procedures described above.

3.1.1 Data Capture Standards (DCS) Submittal

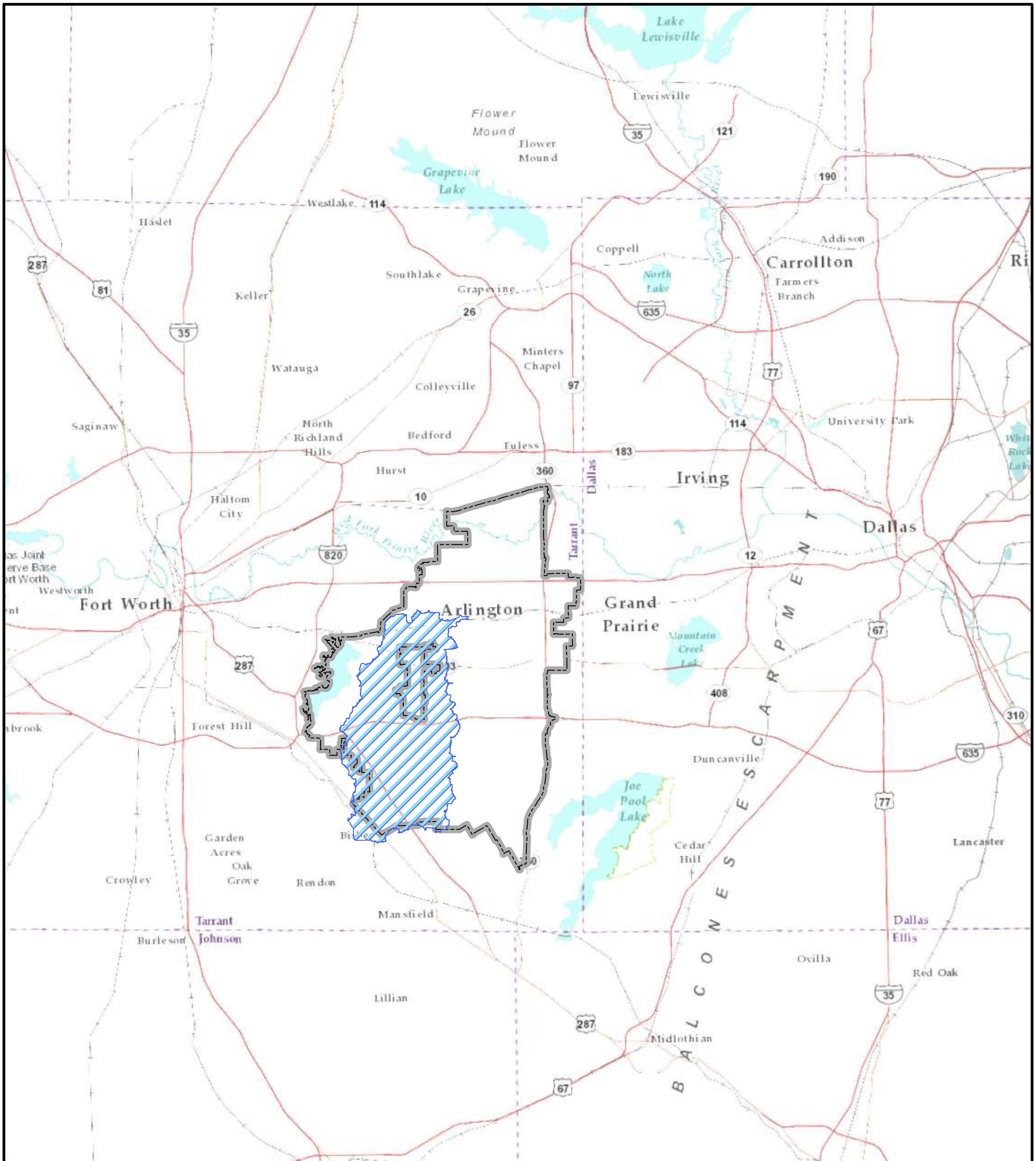
The data submitted for this study follows the FEMA Appendix M Data Capture Standards dated March 2009. All required spatial files and tables, as listed in the Mapping Information Index in Appendix A, will be submitted with this report with the exception of those listed in Table 3.1 below.

Table 3.1 DCS Omitted Digital Files

DCS Feature or Table	Exception
L_Summary_Elevations	This table was not populated because there are no summary elevations associated with any lakes in this watershed.
L_Summary_Discharges	This table was not populated because the data is not yet available. Data will be available in final submittal when unsteady hydraulic models are complete.
S_Nodes	This layer was not populated because routing for unsteady modeling is still in progress and will be populated when finalized.

Appendix A
Figures

Figure A-1 - Vicinity Map



Legend

Rush Creek Watershed

City of Arlington

0 15,000 30,000 60,000 Feet

1 inch = 30,000 feet

Figure A-1
Vicinity Map

Rush Creek Watershed Study
City of Arlington, Texas

RUSH CREEK City of Arlington Watershed Study

Figure A-2 - Soils Map

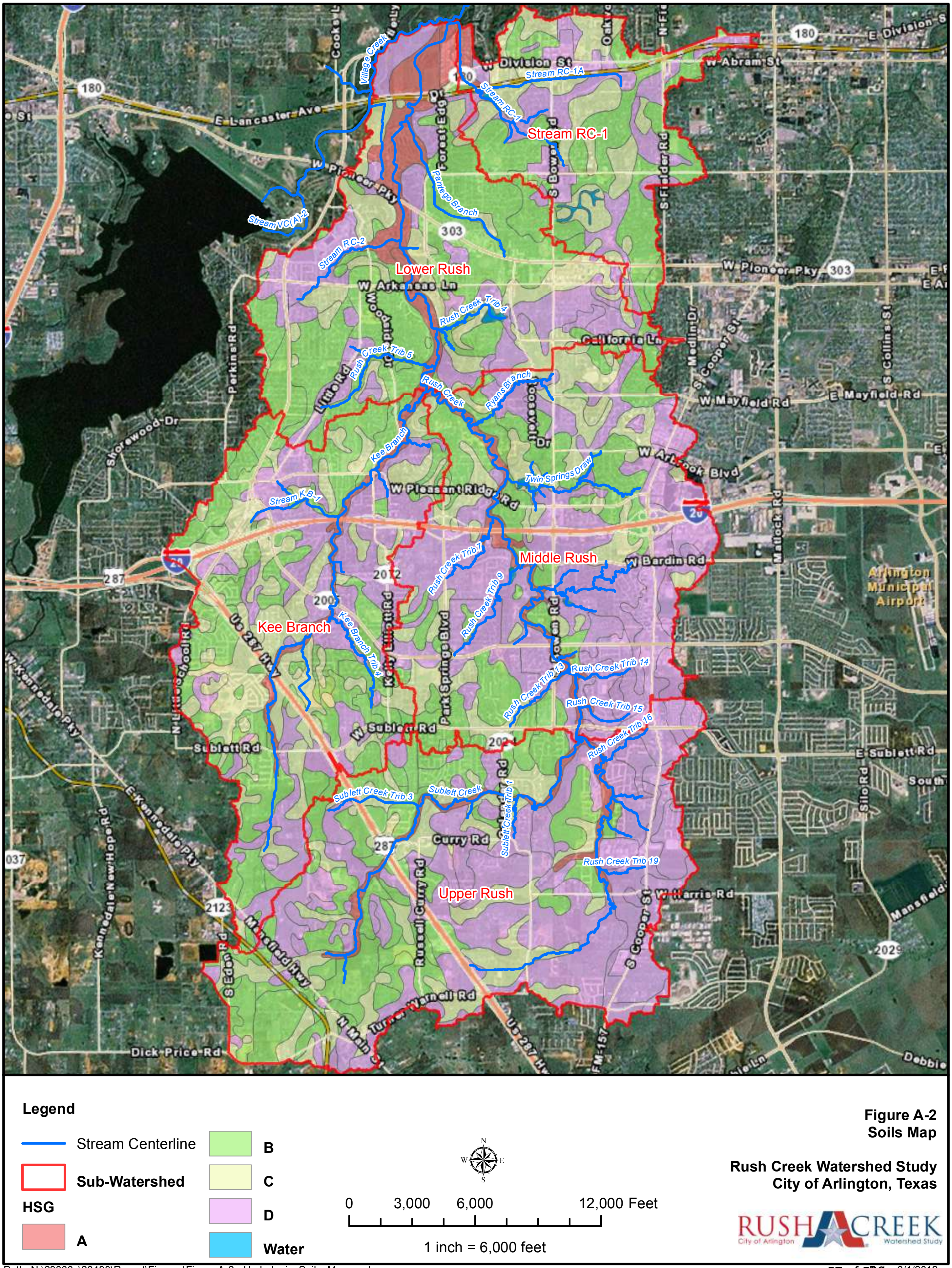
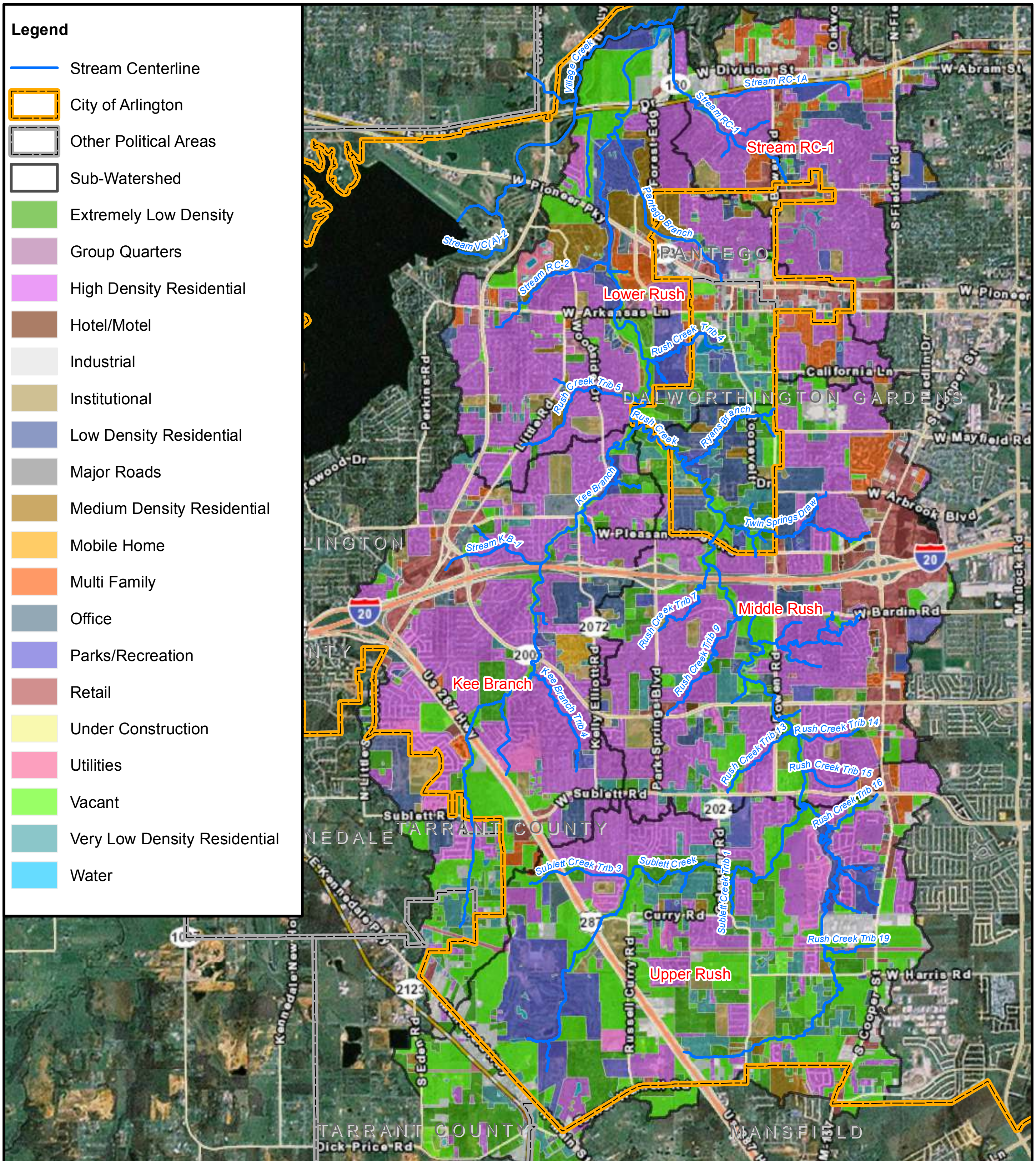


Figure A-3 - Existing Land Use Map



Notes:

An impervious percentage of 75 was applied to all vacant and extremely low density residential to estimate the ultimate build out conditions of the watershed.

0 3,000 6,000 12,000 Feet

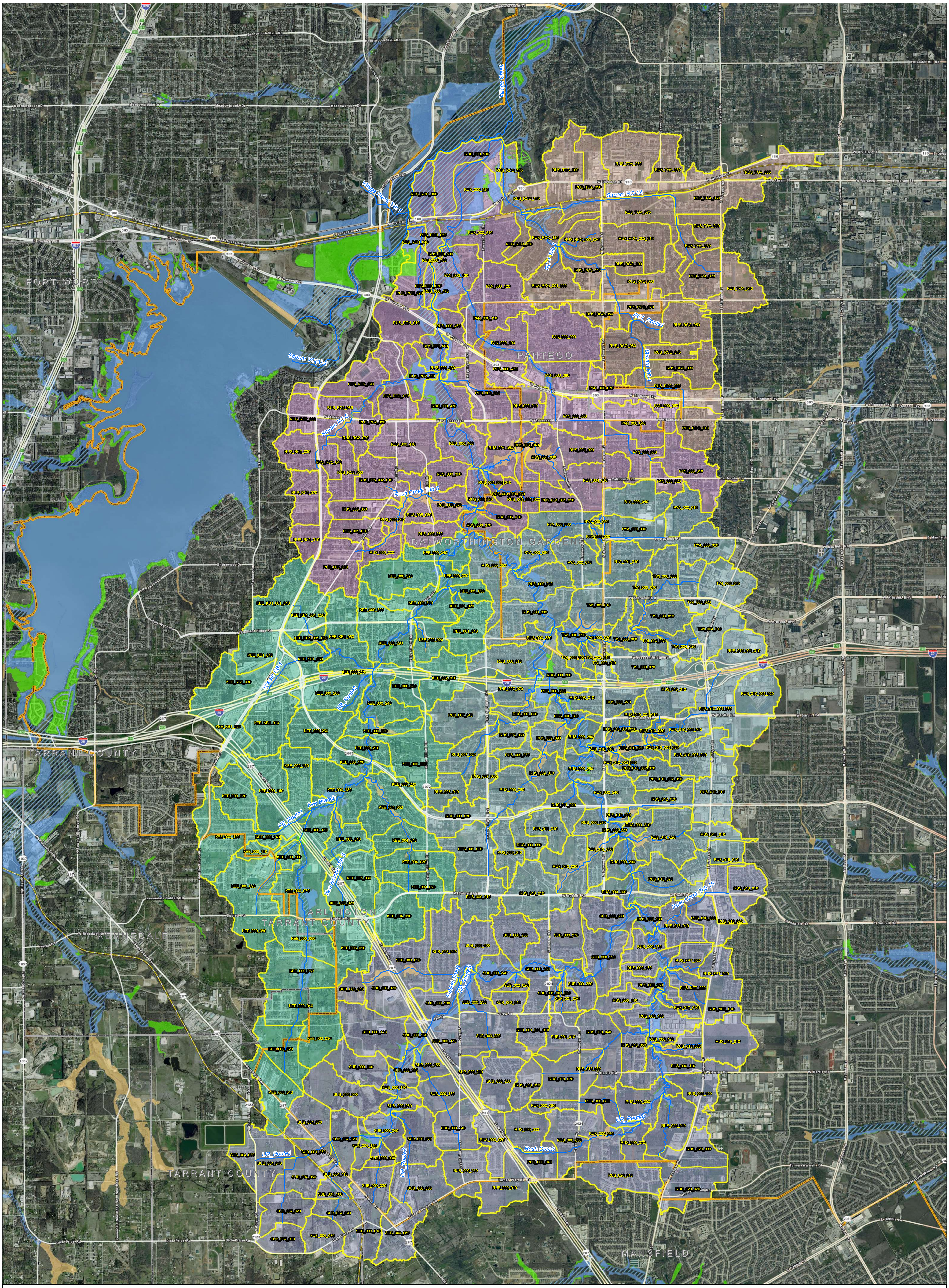
1 inch = 6,000 feet

Figure A-3
Existing Land Use Map

Rush Creek Watershed Study
City of Arlington, Texas

RUSH CREEK City of Arlington Watershed Study

Path: N:\28000s\28480\Report\Figures\Figure A-3 - Existing_Land_Use_Map.mxd Date: 6/1/2012



Legend

- City of Arlington
- Other Political Areas
- Stream Centerline

SUBWTRSHD

- KB
- LR
- MR
- RC1
- UR

FLOOD ZONE

- A
- AE
- FLOODWAY
- X500

0 2,000 4,000 8,000 Feet

Figure A-4
Sub-basin Workmap

Rush Creek Watershed Study
City of Arlington, Texas

RUSH CREEK
City of Arlington
Watershed Study

Appendix B
Hydrologic Data

Appendix B-1
Sub-basin Summary

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
KEE_000_010	KB	105.24	0.164	0	0%	59	56%	14	13%	32	30%	0	0%	68	51	68	18	26	25	-1
KEE_000_020	KB	90.75	0.142	0	0%	58	64%	3	4%	30	33%	0	0%	68	26	66	39	21	20	-1
KEE_000_030	KB	83.06	0.130	0	0%	11	14%	17	21%	54	65%	0	0%	76	20	67	47	12	12	0
KEE_000_040	KB	101.65	0.159	0	0%	27	27%	18	18%	56	56%	0	0%	74	18	59	40	8	3	-5
KEE_000_050	KB	114.66	0.179	0	0%	67	58%	30	26%	18	16%	0	0%	67	22	64	42	10	8	-2
KEE_000_060	KB	93.74	0.147	6	6%	51	55%	22	23%	15	16%	0	0%	66	41	51	10	17	15	-2
KEE_000_070	KB	138.70	0.217	23	17%	33	24%	57	41%	24	18%	0	0%	66	19	69	51	17	14	-3
KEE_000_080	KB	52.05	0.081	0	0%	23	44%	15	30%	14	26%	0	0%	70	18	63	46	18	17	-1
KEE_000_090	KB	137.00	0.214	0	0%	49	35%	73	54%	15	11%	0	0%	70	45	45	0	13	13	0
KEE_000_100	KB	22.51	0.035	3	16%	0	0%	19	84%	0	0%	0	0%	69	56	56	0	7	7	0
KEE_000_110	KB	30.05	0.047	1	3%	3	10%	26	85%	0	2%	0	0%	72	51	51	0	13	11	-2
KEE_000_120	KB	141.48	0.221	0	0%	60	43%	41	29%	40	29%	0	0%	70	36	54	18	13	13	0
KEE_000_130	KB	80.53	0.126	0	0%	65	81%	14	18%	1	1%	0	0%	64	47	52	4	11	10	-1
KEE_000_140	KB	24.43	0.038	0	0%	6	25%	18	75%	0	0%	0	0%	71	52	62	9	13	13	0
KEE_000_150	KB	123.70	0.193	0	0%	41	33%	73	59%	10	8%	0	0%	70	39	57	18	10	10	0
KEE_000_160	KB	85.00	0.133	1	1%	14	16%	65	76%	6	7%	0	0%	72	47	51	4	12	12	0
KEE_000_170	KB	71.26	0.111	13	19%	11	15%	41	58%	6	9%	0	0%	66	35	60	26	13	13	0
KEE_000_180	KB	111.92	0.175	12	11%	7	6%	61	54%	33	29%	0	0%	71	33	61	28	17	16	-1
KEE_000_190	KB	35.25	0.055	3	10%	0	0%	6	18%	25	72%	0	0%	75	38	57	19	8	8	0
KEE_000_200	KB	25.48	0.040	0	0%	13	51%	0	0%	12	49%	0	0%	70	52	52	0	7	7	0
KEE_000_210	KB	44.68	0.070	6	13%	0	1%	7	15%	31	70%	0	0%	73	39	43	4	6	6	0
KEE_000_220	KB	139.16	0.218	0	0%	41	29%	11	8%	87	62%	0	0%	74	44	47	3	10	10	0
KEE_000_230	KB	48.42	0.076	3	7%	1	2%	13	28%	31	64%	0	0%	75	46	50	4	10	10	0
KEE_000_240	KB	85.05	0.133	14	17%	0	0%	20	23%	51	60%	0	0%	72	41	51	10	12	12	0
KEE_000_250	KB	103.25	0.161	0	0%	33	32%	29	28%	41	39%	0	0%	72	49	50	0	7	7	0
KEE_000_260	KB	105.08	0.164	4	3%	26	25%	25	24%	50	48%	0	0%	73	51	57	6	10	10	0
KEE_000_270	KB	12.02	0.019	3	21%	0	3%	0	0%	9	76%	0	0%	71	48	51	3	13	13	0
KEE_000_280	KB	56.23	0.088	1	1%	0	0%	13	24%	42	75%	0	0%	78	46	47	1	6	6	0
KEE_000_290	KB	100.62	0.157	16	16%	39	39%	8	8%	37	37%	0	0%	66	40	53	13	14	13	-1
KEE_000_300	KB	52.46	0.082	1	3%	37	70%	14	27%	0	0%	0	0%	64	69	69	1	10	10	0
KEE_000_310	KB	80.84	0.126	16	20%	24	29%	25	31%	16	19%	0	0%	64	47	53	6	9	9	0
KEE_000_320	KB	108.89	0.170	4	3%	83	76%	23	21%	0	0%	0	0%	63	49	50	1	16	15	-1
KEE_000_330	KB	29.28	0.046	10	35%	3	11%	15	51%	1	3%	0	0%	60	22	31	9	9	9	0
KEE_000_340	KB	61.30	0.096	15	24%	34	56%	12	20%	0	0%	0	0%	58	36	54	18	8	8	0
KEE_001_010	KB	80.96	0.127	0	0%	34	42%	39	48%	8	10%	0	0%	69	47	52	5	10	10	0
KEE_001_020	KB	13.08	0.020	0	0%	0	0%	4	28%	9	72%	0	0%	78	43	55	12	8	8	0
KEE_001_030	KB	28.66	0.045	0	0%	11	40%	1	3%	16	57%	0	0%	72	17	73	57	7	7	0
KEE_002_010	KB	87.19	0.136	0	0%	3	3%	10	12%	74	85%	0	0%	79	55	56	1	11	10	-1
KEE_002_020	KB	56.93	0.089	1	2%	7	13%	14	25%	34	60%	0	0%	75	37	58	21	13	13	0
KEE_004_010	KB	116.35	0.182	0	0%	37	32%	41	35%	38	33%	0	0%	72	42	52	10	13	13	0
KEE_004_020	KB	68.25	0.107	0	0%	48	71%	6	9%	14	20%	0	0%	66	48	49	1	7	7	0
KEE_004_030	KB	86.57	0.135	0	0%	42	49%	34	40%	10	12%	0	0%	68	41	44	3	16	15	-1
KEE_004_040	KB	68.46	0.107	0	0%	49	72%	12	17%	8	11%	0	0%	65	50	50	0	7	7	0
KEE_004_050	KB	113.23	0.177	0	0%	63	56%	1	1%	49	44%	0	0%	69	50	50	0	4	4	0
KEE_005_010	KB	87.32	0.136	0	0%	47	54%	11	12%	30	34%	0	0%	69	41	72	31	12	11	-1
KEE_005_020	KB	64.52	0.101	0	0%	1	2%	36	56%	27	42%	0	0%	76	29	63	35	8	8	0

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
KEE_005_030	KB	85.63	0.134	0	0%	48	55%	28	32%	10	12%	0	0%	68	40	56	16	11	10	-1
KEE_005_040	KB	62.15	0.097	0	1%	23	38%	38	62%	0	0%	0	0%	69	47	52	4	4	4	0
KEE_KB1_001_010	KB	110.82	0.173	0	0%	110	100%	0	0%	0	0%	0	0%	61	48	52	3	6	6	0
KEE_KB1_001_020	KB	71.35	0.112	0	0%	16	22%	9	13%	46	65%	0	0%	75	64	71	7	10	10	0
KEE_KB1_001_030	KB	20.72	0.032	0	0%	4	18%	1	5%	16	77%	0	0%	76	42	73	31	6	6	0
KEE_KB1_010	KB	120.84	0.189	0	0%	50	42%	37	30%	34	28%	0	0%	70	57	58	1	6	6	0
KEE_KB1_020	KB	103.66	0.162	0	0%	42	41%	38	37%	23	23%	0	0%	70	62	63	1	14	10	-4
KEE_KB1_030	KB	115.86	0.181	0	0%	70	60%	46	40%	0	0%	0	0%	66	56	66	10	13	13	0
KEE_KB1_040	KB	98.82	0.154	0	0%	54	54%	32	33%	13	13%	0	0%	68	67	67	0	8	8	0
KEE_KB1_050	KB	57.20	0.089	0	0%	5	9%	3	5%	49	86%	0	0%	78	53	61	8	5	5	0
KEE_KB1_060	KB	128.10	0.200	0	0%	33	26%	25	19%	70	55%	0	0%	74	46	51	5	9	9	0
PAN_000_010	LR	114.57	0.179	0	0%	39	34%	23	20%	52	46%	0	0%	72	50	51	1	15	15	0
PAN_000_020	LR	34.76	0.054	0	0%	15	42%	11	31%	9	27%	0	0%	70	45	55	10	13	12	-1
PAN_000_030	LR	68.21	0.107	0	0%	8	12%	1	2%	59	86%	0	0%	78	59	61	2	12	12	0
PAN_000_040	LR	89.71	0.140	0	0%	0	0%	46	51%	44	49%	0	0%	77	66	69	3	13	13	0
PAN_000_050	LR	94.42	0.148	0	0%	54	58%	35	37%	5	6%	0	0%	67	61	80	19	11	11	0
PAN_000_060	LR	55.37	0.087	0	0%	10	18%	30	54%	16	28%	0	0%	73	72	74	2	14	14	0
PAN_000_070	LR	57.09	0.089	0	0%	42	74%	12	21%	3	5%	0	0%	65	63	67	4	11	11	0
PAN_000_080	LR	80.19	0.125	0	0%	75	94%	5	6%	0	0%	0	0%	62	41	50	9	12	12	0
PAN_000_090	LR	163.11	0.255	0	0%	146	89%	8	5%	9	6%	0	0%	63	46	51	4	14	14	0
PAN_000_100	LR	79.18	0.124	0	0%	74	93%	5	7%	0	0%	0	0%	62	46	50	5	15	15	0
PAN_000_110	LR	81.57	0.127	0	0%	79	97%	0	0%	3	3%	0	0%	62	47	48	1	12	12	0
PAN_000_120	LR	90.84	0.142	1	1%	76	84%	7	7%	7	8%	0	0%	63	47	47	0	11	11	0
PAN_000_130	LR	107.77	0.168	59	55%	5	5%	0	0%	44	41%	0	0%	57	19	20	2	18	18	0
RUS_000_360	LR	51.18	0.080	1	2%	32	62%	6	12%	12	23%	0	0%	67	50	50	0	8	8	0
RUS_000_370	LR	39.84	0.062	15	38%	13	32%	4	11%	8	19%	0	0%	58	11	67	56	9	8	-1
RUS_000_380	LR	36.94	0.058	16	44%	12	33%	2	4%	7	19%	0	0%	55	20	60	40	5	5	0
RUS_000_390	LR	46.87	0.073	0	1%	47	99%	0	0%	0	0%	0	0%	61	49	50	1	11	11	0
RUS_000_400	LR	82.33	0.129	37	45%	27	33%	18	22%	0	0%	0	0%	54	18	65	47	3	3	0
RUS_000_410	LR	131.27	0.205	0	0%	113	86%	10	7%	8	6%	0	0%	63	42	54	12	13	13	0
RUS_000_420	LR	99.02	0.155	41	41%	23	24%	35	35%	0	0%	0	0%	56	30	40	11	9	9	0
RUS_000_430	LR	30.15	0.047	16	52%	2	8%	12	38%	1	2%	0	0%	55	45	49	3	4	4	0
RUS_000_440	LR	27.73	0.043	17	61%	0	0%	11	38%	0	1%	0	0%	53	33	33	0	5	5	0
RUS_000_450	LR	77.92	0.122	6	8%	57	73%	0	0%	15	20%	0	0%	63	70	73	3	21	14	-7
RUS_000_460	LR	36.80	0.058	8	21%	3	9%	0	0%	26	69%	0	0%	70	44	45	1	8	8	0
RUS_000_470	LR	4.34	0.007	4	100%	0	0%	0	0%	0	0%	0	0%	39	48	48	0	6	6	0
RUS_000_480	LR	1.31	0.002	1	100%	0	0%	0	0%	0	0%	0	0%	39	66	66	0	6	6	0
RUS_000_500	LR	2.62	0.004	3	100%	0	0%	0	0%	0	0%	0	0%	39	32	53	22	6	6	0
RUS_000_510	LR	134.12	0.210	38	29%	28	21%	28	21%	39	29%	0	0%	63	42	56	15	11	11	0
RUS_000_520	LR	97.04	0.152	93	96%	2	2%	0	0%	2	2%	0	0%	40	38	73	35	8	8	0
RUS_000_530	LR	110.22	0.172	66	60%	0	0%	0	0%	44	40%	0	0%	55	21	55	34	41	35	-6
RUS_003_010	LR	51.93	0.081	0	0%	45	86%	0	0%	7	14%	0	0%	64	47	65	18	6	6	0
RUS_003_020	LR	98.45	0.154	1	1%	66	67%	24	24%	8	8%	0	0%	65	57	61	3	8	8	0
RUS_004_001_010	LR	42.36	0.066	0	0%	2	5%	8	18%	33	77%	0	0%	78	31	46	15	15	15	0
RUS_004_001_020	LR	25.87	0.040	0	0%	12	48%	4	16%	9	36%	0	0%	70	19	58	38	9	8	-1
RUS_004_001_030	LR	28.87	0.045	0	0%	12	41%	17	59%	0	0%	0	0%	69	17	22	5	5	5	0

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
RUS_004_001_040	LR	14.64	0.023	0	0%	8	53%	7	46%	0	0%	0	0%	67	7	10	4	5	4	-1
RUS_004_010	LR	111.14	0.174	0	0%	4	3%	68	61%	40	36%	0	0%	76	30	55	24	15	15	0
RUS_004_020	LR	56.31	0.088	0	0%	0	0%	9	16%	47	84%	0	0%	79	20	69	49	20	18	-2
RUS_004_030	LR	74.01	0.116	0	0%	17	23%	15	21%	30	40%	11	15%	77	40	54	14	12	7	-5
RUS_004_040	LR	37.24	0.058	0	0%	15	42%	16	43%	6	16%	0	0%	70	35	46	11	14	13	-1
RUS_004_050	LR	82.61	0.129	0	0%	37	45%	23	28%	21	26%	1	1%	70	11	18	7	9	5	-4
RUS_005_002_010	LR	87.86	0.137	0	0%	58	66%	5	5%	26	29%	0	0%	67	49	49	0	9	9	0
RUS_005_010	LR	108.52	0.170	0	0%	74	68%	1	1%	34	32%	0	0%	67	45	53	8	10	10	0
RUS_005_020	LR	41.86	0.065	0	0%	31	74%	4	9%	7	17%	0	0%	65	46	53	7	6	6	0
RUS_005_030	LR	54.13	0.085	0	0%	27	50%	0	0%	27	50%	0	0%	70	44	50	6	13	13	0
RUS_005_040	LR	34.25	0.054	0	0%	19	55%	5	14%	11	31%	0	0%	69	46	47	1	8	8	0
RUS_005_050	LR	49.69	0.078	0	0%	39	78%	1	1%	10	21%	0	0%	65	49	52	3	14	14	0
RUS_005_060	LR	57.28	0.090	0	0%	42	74%	7	13%	8	13%	0	0%	65	50	50	0	12	12	0
RUS_005_070	LR	56.21	0.088	4	6%	53	94%	0	0%	0	0%	0	0%	60	44	53	9	3	3	0
RUS_006_010	LR	39.55	0.062	0	1%	5	14%	8	21%	25	64%	0	0%	76	21	58	37	7	6	-1
RUS_RC2_010	LR	70.41	0.110	0	0%	64	92%	6	8%	0	0%	0	0%	62	44	51	6	14	13	-1
RUS_RC2_020	LR	68.02	0.106	0	0%	61	90%	7	10%	0	0%	0	0%	62	47	49	2	10	10	0
RUS_RC2_030	LR	65.28	0.102	0	0%	46	71%	2	4%	16	25%	0	0%	66	46	50	4	12	12	0
RUS_RC2_040	LR	35.40	0.055	0	0%	8	23%	6	16%	22	61%	0	0%	75	50	51	1	9	9	0
RUS_RC2_050	LR	58.41	0.091	0	0%	40	69%	8	14%	10	18%	0	0%	66	50	50	0	13	13	0
RUS_RC2_060	LR	74.27	0.116	0	0%	4	6%	9	12%	61	82%	0	0%	78	54	59	5	8	8	0
RUS_RC2_070	LR	33.18	0.052	0	0%	0	0%	24	72%	2	7%	0	0%	75	58	59	1	6	6	0
RUS_RC2_080	LR	30.18	0.047	0	0%	2	6%	15	49%	14	45%	0	0%	76	48	54	6	7	6	-1
RUS_RC2_085	LR	35.52	0.056	0	0%	0	0%	0	0%	43	120%	0	0%	80	58	61	3	6	6	0
RUS_RC2_090	LR	97.48	0.152	0	0%	11	11%	7	7%	80	82%	0	0%	77	44	61	17	14	14	0
RUS_RC2_100	LR	97.10	0.152	2	2%	38	39%	28	29%	29	30%	0	0%	70	47	47	0	7	7	0
RUS_RC2_110	LR	45.47	0.071	24	52%	11	23%	11	25%	0	0%	0	0%	53	34	34	0	5	5	0
RUS_RCH_010	LR	93.98	0.147	18	19%	10	11%	49	52%	16	17%	0	0%	67	17	61	44	9	6	-3
RUS_RCH_020	LR	66.07	0.103	24	37%	0	0%	28	43%	14	21%	0	0%	62	29	59	30	12	7	-5
RUS_RCH_030	LR	15.41	0.024	15	100%	0	0%	0	0%	0	0%	0	0%	39	12	18	7	6	6	0
RUS_RCH_040	LR	26.39	0.041	0	0%	0	0%	26	98%	0	2%	0	0%	74	23	70	47	14	13	-1
RUS_RCH_050	LR	29.52	0.046	17	57%	0	0%	9	32%	3	11%	0	0%	55	9	66	56	6	6	0
RUS_RCH_060	LR	50.04	0.078	7	14%	0	0%	0	0%	43	86%	0	0%	74	4	74	71	9	8	-1
RUS_000_190	MR	66.36	0.104	8	12%	19	29%	0	0%	39	59%	0	0%	69	31	61	30	11	11	0
RUS_000_200	MR	44.34	0.069	13	30%	5	12%	0	0%	26	58%	0	0%	65	19	67	48	11	4	-7
RUS_000_210	MR	26.71	0.042	3	12%	4	14%	0	0%	20	74%	0	0%	73	40	54	14	8	8	0
RUS_000_220	MR	8.79	0.014	8	89%	1	10%	0	0%	0	1%	0	0%	42	8	72	64	10	3	-7
RUS_000_230	MR	34.22	0.053	5	14%	0	1%	0	0%	29	85%	0	0%	74	45	52	7	7	7	0
RUS_000_240	MR	75.76	0.118	11	14%	27	35%	16	22%	22	29%	0	0%	66	34	52	18	9	9	0
RUS_000_250	MR	64.17	0.100	16	25%	21	33%	5	7%	23	35%	0	0%	63	34	63	29	5	5	0
RUS_000_260	MR	34.97	0.055	8	22%	15	42%	1	4%	11	32%	0	0%	63	23	77	54	5	3	-2
RUS_000_270	MR	50.28	0.079	0	0%	8	15%	2	3%	41	82%	0	0%	77	48	52	5	18	17	-1
RUS_000_280	MR	33.76	0.053	12	37%	5	14%	3	9%	13	40%	0	0%	62	26	63	36	7	6	-1
RUS_000_290	MR	28.42	0.044	12	41%	5	17%	2	8%	10	34%	0	0%	59	42	54	12	8	8	0
RUS_000_300	MR	45.92	0.072	8	17%	26	58%	5	12%	6	13%	0	0%	61	48	51	3	4	4	0
RUS_000_310	MR	107.92	0.169	11	10%	13	12%	42	39%	42	39%	0	0%	71	40	58	17	18	18	0

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
RUS_000_320	MR	49.32	0.077	5	9%	17	35%	27	54%	1	1%	0	0%	66	27	61	35	11	7	-4
RUS_000_330	MR	102.55	0.160	12	12%	39	38%	43	42%	8	8%	0	0%	65	28	54	25	16	16	0
RUS_000_340	MR	88.59	0.138	17	19%	60	68%	11	13%	0	0%	0	0%	58	30	42	12	12	10	-2
RUS_000_350	MR	128.31	0.201	25	20%	83	65%	20	16%	0	0%	0	0%	59	23	56	33	22	19	-3
RUS_007_010	MR	47.38	0.074	0	0%	16	34%	16	34%	15	32%	0	0%	71	42	50	8	11	11	0
RUS_007_020	MR	68.53	0.107	0	0%	14	21%	12	17%	43	62%	0	0%	75	48	51	3	11	11	0
RUS_007_030	MR	47.96	0.075	0	0%	7	14%	33	68%	9	18%	0	0%	73	41	49	8	21	20	-1
RUS_007_040	MR	129.96	0.203	0	0%	0	0%	3	2%	127	98%	0	0%	80	30	56	26	11	11	0
RUS_007_050	MR	43.72	0.068	0	0%	0	0%	3	6%	41	94%	0	0%	80	50	50	0	7	7	0
RUS_007_060	MR	35.77	0.056	0	0%	0	0%	0	0%	36	100%	0	0%	80	50	50	0	5	5	0
RUS_007_070	MR	68.39	0.107	10	15%	0	0%	14	20%	45	66%	0	0%	73	41	55	14	13	13	0
RUS_008_010	MR	49.96	0.078	4	8%	8	16%	3	7%	34	69%	0	0%	73	50	53	3	17	17	0
RUS_009_010	MR	96.57	0.151	0	0%	90	94%	5	6%	1	1%	0	0%	62	44	50	7	7	7	0
RUS_009_020	MR	104.43	0.163	0	0%	32	31%	65	62%	8	7%	0	0%	70	50	50	0	13	13	0
RUS_009_030	MR	83.53	0.131	0	0%	20	24%	11	14%	52	62%	0	0%	75	53	56	3	9	9	0
RUS_009_040	MR	55.65	0.087	0	0%	10	17%	16	29%	30	54%	0	0%	75	50	50	0	15	15	0
RUS_009_050	MR	45.15	0.071	0	0%	28	62%	11	24%	6	14%	0	0%	67	43	50	7	11	11	0
RUS_009_060	MR	93.54	0.146	0	0%	21	22%	4	4%	69	73%	0	0%	76	48	55	7	4	4	0
RUS_009_070	MR	45.12	0.071	0	0%	0	0%	0	0%	45	100%	0	0%	80	33	56	23	7	7	0
RUS_009_080	MR	38.66	0.060	0	0%	1	3%	2	4%	36	93%	0	0%	79	50	50	1	8	8	0
RUS_009_090	MR	49.83	0.078	0	0%	2	5%	0	0%	43	87%	4	8%	81	54	56	2	2	2	0
RUS_010_001_010	MR	28.33	0.044	0	0%	0	0%	11	37%	18	63%	0	0%	78	50	50	1	7	7	0
RUS_010_001_020	MR	28.06	0.044	0	0%	0	0%	0	0%	28	100%	0	0%	80	48	48	0	10	10	0
RUS_010_002_010	MR	51.39	0.080	0	0%	0	1%	1	1%	50	98%	0	0%	80	49	49	0	8	8	0
RUS_010_002_020	MR	17.95	0.028	0	0%	0	0%	3	14%	15	86%	0	0%	79	50	50	0	3	3	0
RUS_010_002_030	MR	12.72	0.020	0	0%	0	0%	0	0%	10	80%	3	20%	84	59	59	0	4	4	0
RUS_010_003_010	MR	81.10	0.127	0	0%	0	0%	0	0%	81	100%	0	0%	80	66	67	1	8	8	0
RUS_010_003_020	MR	13.03	0.020	0	0%	0	0%	0	0%	13	100%	0	0%	80	50	50	0	2	2	0
RUS_010_004_010	MR	76.27	0.119	0	0%	0	0%	1	1%	76	99%	0	0%	80	79	79	0	13	13	0
RUS_010_004_020	MR	79.94	0.125	0	0%	0	0%	1	1%	79	99%	0	0%	80	59	77	18	11	11	0
RUS_010_004_030	MR	149.77	0.234	0	0%	11	7%	21	14%	118	79%	0	0%	78	57	57	0	23	23	0
RUS_010_004_040	MR	56.79	0.089	0	0%	0	0%	1	2%	56	98%	0	0%	80	55	60	5	6	6	0
RUS_010_010	MR	109.01	0.170	0	0%	34	32%	54	50%	20	19%	0	0%	71	64	64	0	19	19	0
RUS_010_020	MR	13.63	0.021	0	0%	0	0%	0	0%	14	100%	0	0%	80	38	56	18	10	1	-9
RUS_010_030	MR	36.73	0.057	0	0%	0	0%	0	0%	37	100%	0	0%	80	50	50	0	5	5	0
RUS_010_040	MR	29.72	0.046	2	7%	8	26%	0	1%	20	66%	0	0%	72	30	60	30	8	8	0
RUS_011_010	MR	56.26	0.088	0	0%	29	51%	0	0%	28	49%	0	0%	70	27	56	30	11	10	-1
RUS_011_020	MR	51.86	0.081	0	1%	1	1%	7	13%	44	84%	0	0%	79	32	48	16	8	8	0
RUS_012_010	MR	105.30	0.165	0	0%	0	0%	0	0%	105	100%	0	0%	80	68	68	0	11	10	-1
RUS_012_020	MR	60.58	0.095	0	0%	4	6%	0	0%	57	94%	0	0%	79	37	53	16	17	16	-1
RUS_012_030	MR	12.97	0.020	5	36%	8	64%	0	0%	0	0%	0	0%	53	32	60	28	1	1	0
RUS_013_010	MR	122.21	0.191	0	0%	72	59%	42	34%	9	7%	0	0%	67	31	46	15	11	11	0
RUS_013_020	MR	92.60	0.145	0	0%	53	57%	15	16%	25	27%	0	0%	68	28	63	35	16	14	-2
RUS_013_030	MR	55.42	0.087	3	6%	23	41%	0	0%	29	53%	0	0%	70	43	54	11	4	4	0
RUS_014_010	MR	46.82	0.073	0	0%	0	0%	0	0%	47	100%	0	0%	80	51	70	20	13	13	0
RUS_014_020	MR	119.19	0.186	3	3%	0	0%	0	0%	116	97%	0	0%	79	48	50	2	11	11	0

Appendix B-1

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
RUS_015_010	MR	67.74	0.106	0	0%	0	0%	0	0%	68	100%	0	0%	80	48	63	16	15	15	0
RUS_015_020	MR	80.60	0.126	4	5%	0	0%	0	0%	77	95%	0	0%	78	53	54	1	10	10	0
RYA_000_010	MR	66.67	0.104	0	0%	32	48%	8	12%	27	41%	0	0%	70	53	53	0	10	10	0
RYA_000_020	MR	99.78	0.156	0	0%	46	46%	21	21%	32	32%	0	0%	70	58	60	1	20	19	-1
RYA_000_030	MR	63.29	0.099	0	0%	11	17%	36	57%	16	26%	0	0%	73	41	62	21	16	15	-1
RYA_000_040	MR	92.99	0.145	0	0%	23	25%	68	74%	1	1%	0	0%	71	39	67	29	9	9	0
RYA_000_050	MR	5.45	0.009	0	0%	0	0%	2	34%	4	66%	0	0%	78	3	75	72	6	1	-5
RYA_000_060	MR	81.23	0.127	0	0%	5	6%	21	25%	56	68%	0	0%	77	29	51	22	11	5	-6
RYA_000_070	MR	77.62	0.121	0	0%	36	46%	0	0%	42	54%	0	0%	71	34	47	13	14	7	-7
RYA_000_080	MR	52.02	0.081	3	6%	21	41%	6	12%	21	41%	0	0%	69	30	34	4	8	8	0
RYA_001_010	MR	77.35	0.121	0	0%	4	5%	43	55%	31	40%	0	0%	76	42	53	11	11	11	0
RYA_001_020	MR	12.94	0.020	0	0%	1	5%	7	51%	6	44%	0	0%	76	10	75	65	8	3	-5
TWI_000_010	MR	87.86	0.137	0	0%	0	0%	14	16%	73	84%	0	0%	79	76	76	0	12	12	0
TWI_000_020	MR	55.13	0.086	0	0%	8	15%	26	48%	20	37%	0	0%	74	68	72	4	5	5	0
TWI_000_030	MR	67.34	0.105	0	0%	22	33%	20	29%	25	38%	0	0%	72	48	52	4	14	14	0
TWI_000_040	MR	20.95	0.033	0	0%	1	7%	11	51%	9	42%	0	0%	76	41	41	0	12	10	-2
TWI_000_050	MR	75.53	0.118	0	0%	53	70%	5	7%	18	24%	0	0%	66	47	47	0	9	9	0
TWI_000_060	MR	43.53	0.068	0	0%	18	42%	10	23%	15	35%	0	0%	71	37	37	0	16	15	-1
TWI_000_070	MR	96.93	0.151	0	0%	32	33%	9	9%	56	58%	0	0%	73	51	57	6	21	21	0
TWI_000_080	MR	18.60	0.029	0	0%	6	30%	6	33%	7	37%	0	0%	72	28	52	24	9	9	0
TWI_000_090	MR	20.73	0.032	0	0%	3	15%	11	54%	0	0%	6	30%	80	35	70	35	3	1	-2
TWI_000_100	MR	34.00	0.053	0	0%	20	58%	10	30%	4	12%	0	0%	67	32	50	18	13	13	0
TWI_001_010	MR	111.24	0.174	0	0%	72	65%	29	26%	7	7%	3	2%	67	33	47	15	15	15	0
TWI_002_010	MR	12.24	0.019	0	0%	0	3%	7	59%	4	37%	0	1%	76	30	60	30	8	7	-1
TWI_003_010	MR	27.44	0.043	0	0%	0	0%	0	2%	27	98%	0	0%	80	56	65	9	6	6	0
TWI_004_010	MR	77.75	0.122	0	0%	8	11%	10	13%	60	77%	0	0%	77	80	80	0	10	10	0
TWI_004_020	MR	42.92	0.067	0	0%	34	80%	4	10%	4	10%	0	0%	64	63	69	7	7	7	0
TWI_004_030	MR	21.68	0.034	0	0%	10	48%	2	10%	9	42%	0	0%	70	35	50	15	4	4	0
RUS_RCO_001_010	RC1	101.70	0.159	0	0%	88	87%	0	0%	13	13%	0	0%	63	54	55	1	19	18	-1
RUS_RCO_002_010	RC1	111.56	0.174	0	0%	42	38%	44	39%	26	23%	0	0%	70	52	53	1	19	19	0
RUS_RCO_002_020	RC1	57.70	0.090	0	0%	15	25%	3	6%	40	69%	0	0%	75	50	50	0	12	12	0
RUS_RCO_010	RC1	69.60	0.109	0	0%	45	65%	8	11%	16	23%	0	0%	67	56	57	1	17	17	0
RUS_RCO_020	RC1	90.89	0.142	0	0%	48	53%	23	25%	20	22%	0	0%	68	59	65	5	11	11	0
RUS_RCO_030	RC1	82.01	0.128	0	0%	57	70%	8	10%	17	20%	0	0%	66	44	46	2	14	14	0
RUS_RCO_040	RC1	36.63	0.057	0	0%	16	42%	14	37%	8	21%	0	0%	70	50	50	0	11	11	0
RUS_RCO_050	RC1	84.98	0.133	0	0%	33	39%	21	25%	30	36%	0	0%	71	52	52	0	18	18	0
RUS_RCO_060	RC1	123.32	0.193	0	0%	49	39%	54	43%	7	6%	14	11%	72	53	55	2	20	19	-1
RUS_RCO_070	RC1	55.66	0.087	0	0%	34	61%	11	20%	10	18%	0	0%	67	62	67	6	9	9	0
RUS_RCO_080	RC1	48.51	0.076	0	0%	17	36%	2	5%	29	59%	0	0%	73	59	64	5	11	11	0
RUS_RCO_090	RC1	109.44	0.171	0	0%	55	50%	41	37%	14	13%	0	0%	68	57	59	2	21	21	0
RUS_RCO_100	RC1	34.89	0.055	0	0%	18	53%	16	45%	1	2%	0	0%	67	51	54	3	14	14	0
RUS_RCO_110	RC1	54.88	0.086	0	0%	32	59%	0	0%	23	41%	0	0%	69	63	63	0	12	12	0
RUS_RCO_120	RC1	109.92	0.172	0	0%	32	29%	51	46%	20	18%	7	6%	73	51	51	0	14	14	0
RUS_RCO_130	RC1	24.94	0.039	1	2%	1	3%	10	39%	14	56%	0	0%	76	46	47	1	12	12	0
RUS_RCO_140	RC1	46.75	0.073	8	17%	8	18%	15	31%	16	34%	0	0%	68	52	71	18	12	7	-5
RUS_RCO_150	RC1	39.91	0.062	35	87%	0	0%	0	0%	5	13%	0	0%	44	45	58	12	10	7	-3

Rush Creek Sub-basin Summary

NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
RUS_TOA_010	RC1	105.76	0.165	0	0%	76	72%	2	2%	28	27%	0	0%	66	35	36	1	20	19	-1
RUS_TOA_020	RC1	74.43	0.116	0	0%	21	28%	17	23%	36	49%	0	0%	73	50	50	0	8	8	0
RUS_TOA_030	RC1	45.81	0.072	0	0%	22	49%	13	29%	10	22%	0	0%	69	48	48	0	15	15	0
RUS_TOA_040	RC1	39.09	0.061	0	0%	18	45%	7	18%	14	37%	0	0%	70	46	47	0	13	12	-1
RUS_TOA_050	RC1	107.96	0.169	0	0%	56	52%	0	0%	52	48%	0	0%	70	51	59	7	21	21	0
RUS_TOA_055	RC1	107.75	0.168	0	0%	53	49%	4	4%	51	47%	0	0%	70	65	74	9	31	29	-2
RUS_TOA_060	RC1	52.45	0.082	0	0%	21	41%	24	46%	7	13%	0	0%	69	47	61	14	19	18	-1
RUS_TOA_070	RC1	95.18	0.149	0	0%	5	5%	57	60%	33	35%	0	0%	75	39	46	7	18	18	0
RUS_TOA_080	RC1	156.21	0.244	0	0%	3	2%	76	49%	77	49%	0	0%	77	62	67	5	15	15	0
RUS_TOA_090	RC1	100.69	0.157	0	0%	18	18%	57	57%	25	25%	0	0%	73	51	68	16	14	9	-5
RUS_TOA_100	RC1	109.41	0.171	1	1%	43	40%	61	55%	4	4%	0	0%	69	54	63	9	10	10	0
RUS_000_010	UR	84.84	0.133	0	0%	0	0%	45	53%	40	47%	0	0%	77	12	72	60	29	20	-9
RUS_000_020	UR	78.66	0.123	0	0%	36	45%	2	2%	41	53%	0	0%	71	44	59	15	7	7	0
RUS_000_030	UR	70.31	0.110	0	0%	2	3%	30	42%	38	55%	0	0%	77	22	58	36	27	24	-3
RUS_000_040	UR	51.38	0.080	0	0%	0	0%	32	63%	19	37%	0	0%	76	35	66	30	12	10	-2
RUS_000_050	UR	87.61	0.137	0	0%	0	0%	48	55%	40	45%	0	0%	77	40	52	11	13	13	0
RUS_000_060	UR	76.71	0.120	0	0%	0	0%	19	25%	57	75%	0	0%	78	34	56	21	12	5	-7
RUS_000_070	UR	38.12	0.060	0	0%	0	0%	2	5%	36	95%	0	0%	80	9	67	58	20	18	-2
RUS_000_080	UR	24.57	0.038	0	0%	0	0%	4	17%	20	83%	0	0%	79	39	49	10	17	16	-1
RUS_000_085	UR	52.59	0.082	0	0%	4	7%	1	3%	47	90%	0	0%	79	17	68	51	21	12	-9
RUS_000_090	UR	81.90	0.128	0	0%	2	3%	5	6%	75	92%	0	0%	79	12	66	54	19	17	-2
RUS_000_100	UR	71.48	0.112	0	0%	0	0%	0	0%	71	100%	0	0%	80	36	72	36	16	15	-1
RUS_000_110	UR	90.67	0.142	7	8%	13	14%	8	9%	63	69%	0	0%	74	20	66	46	16	14	-2
RUS_000_120	UR	16.75	0.026	3	17%	1	6%	0	0%	13	77%	0	0%	72	33	72	40	6	5	-1
RUS_000_130	UR	76.02	0.119	9	12%	16	22%	12	16%	39	51%	0	0%	70	54	60	7	12	12	0
RUS_000_140	UR	49.17	0.077	4	8%	29	59%	13	27%	3	7%	0	0%	64	34	53	20	14	13	-1
RUS_000_150	UR	45.29	0.071	10	22%	28	61%	0	0%	8	17%	0	0%	59	38	39	1	11	10	-1
RUS_000_160	UR	40.00	0.063	9	23%	12	29%	0	0%	19	48%	0	0%	65	40	40	0	6	6	0
RUS_000_170	UR	43.90	0.069	10	22%	18	40%	0	0%	16	37%	0	0%	63	38	38	0	11	11	0
RUS_000_180	UR	26.37	0.041	9	33%	0	0%	0	0%	18	67%	0	0%	67	21	44	22	9	9	0
RUS_016_010	UR	64.82	0.101	0	0%	0	0%	0	0%	65	100%	0	0%	80	48	55	7	11	11	0
RUS_016_020	UR	63.32	0.099	0	0%	0	0%	0	0%	63	100%	0	0%	80	73	73	0	12	12	0
RUS_016_030	UR	62.11	0.097	0	0%	0	0%	0	0%	62	100%	0	0%	80	49	68	19	6	6	0
RUS_016_040	UR	66.48	0.104	1	1%	0	0%	0	0%	66	99%	0	0%	79	41	53	12	5	5	0
RUS_017_010	UR	22.61	0.035	0	1%	6	24%	0	0%	17	75%	0	0%	75	27	38	12	9	9	0
RUS_018_010	UR	48.17	0.075	0	0%	0	0%	20	42%	28	58%	0	0%	78	24	61	37	15	14	-1
RUS_018_020	UR	83.21	0.130	0	0%	0	0%	34	41%	49	59%	0	0%	78	10	72	61	21	20	-1
RUS_018_030	UR	34.02	0.053	0	0%	6	18%	8	23%	20	59%	0	0%	75	20	60	39	15	7	-8
RUS_018_040	UR	104.39	0.163	7	6%	18	17%	6	6%	74	71%	0	0%	74	21	64	44	19	10	-9
RUS_018_050	UR	58.72	0.092	9	15%	29	50%	3	6%	17	29%	0	0%	64	38	54	16	15	15	0
RUS_019_010	UR	97.54	0.152	0	0%	0	0%	0	0%	98	100%	0	0%	80	25	74	49	19	17	-2
RUS_019_020	UR	42.19	0.066	1	3%	0	0%	0	0%	41	97%	0	0%	79	39	69	30	7	7	0
RUS_020_010	UR	102.82	0.161	0	0%	0	0%	27	27%	75	73%	0	0%	78	36	56	20	25	23	-2
RUS_020_020	UR	115.59	0.181	0	0%	0	0%	0	0%	116	100%	0	0%	80	29	71	42	29	26	-3
RUS_020_030	UR	71.22	0.111	0	0%	0	0%	0	0%	71	100%	0	0%	80	38	72	35	24	22	-2
RUS_020_040	UR	94.50	0.148	0	0%	0	0%	0	0%	95	100%	0	0%	80	20	69	49	19	18	-1

Rush Creek Sub-basin Summary

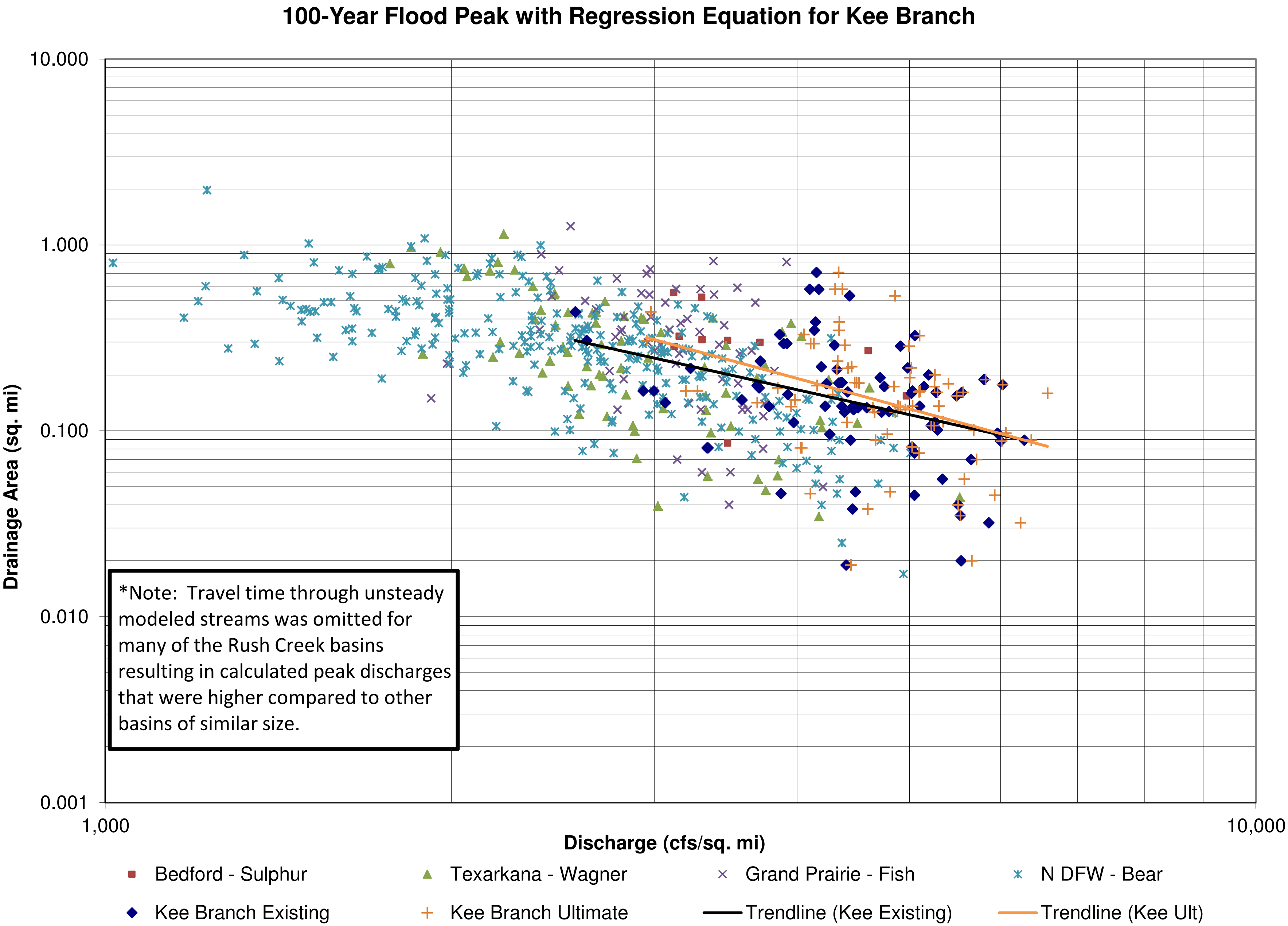
NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
RUS_FPT_010	UR	73.59	0.115	0	0%	0	0%	0	0%	74	100%	0	0%	80	41	58	17	8	8	0
RUS_FPT_020	UR	42.95	0.067	0	1%	0	0%	0	0%	43	99%	0	0%	80	37	43	5	8	7	-1
RUS_NET_010	UR	29.41	0.046	0	0%	0	0%	0	0%	29	100%	0	0%	80	42	65	23	6	6	0
RUS_NET_020	UR	46.69	0.073	1	2%	5	10%	0	0%	41	89%	0	0%	78	18	20	2	3	3	0
SUB_000_010	UR	80.66	0.126	0	0%	9	11%	34	43%	37	46%	0	0%	75	39	66	27	21	19	-2
SUB_000_020	UR	57.96	0.091	0	0%	54	92%	3	5%	2	3%	0	0%	62	15	41	26	11	10	-1
SUB_000_030	UR	22.77	0.036	0	1%	23	99%	0	0%	0	0%	0	0%	61	6	12	6	3	2	-1
SUB_000_040	UR	48.35	0.076	9	18%	25	51%	1	2%	14	28%	0	0%	63	6	24	18	12	12	0
SUB_000_050	UR	92.01	0.144	0	0%	7	7%	23	25%	62	67%	0	0%	77	33	66	33	25	22	-3
SUB_000_060	UR	100.61	0.157	0	0%	50	50%	23	22%	28	28%	0	0%	69	28	61	34	18	17	-1
SUB_000_070	UR	90.86	0.142	1	1%	70	77%	6	7%	14	15%	0	0%	64	10	54	44	19	17	-2
SUB_000_080	UR	24.34	0.038	4	16%	6	27%	2	7%	12	49%	0	0%	68	8	8	0	8	7	-1
SUB_000_090	UR	119.82	0.187	2	1%	19	16%	23	20%	76	63%	0	0%	75	8	39	31	26	23	-3
SUB_000_100	UR	81.51	0.127	1	1%	28	35%	0	0%	52	64%	0	0%	73	8	19	11	13	8	-5
SUB_000_110	UR	25.10	0.039	12	46%	6	26%	0	0%	7	29%	0	0%	56	6	6	0	8	8	0
SUB_000_115	UR	33.57	0.052	9	26%	16	47%	0	0%	9	27%	0	0%	60	9	32	23	10	9	-1
SUB_000_120	UR	131.30	0.205	1	1%	41	32%	24	18%	65	49%	0	0%	73	17	44	26	19	17	-2
SUB_000_130	UR	83.72	0.131	0	0%	39	47%	15	18%	29	35%	0	0%	70	26	55	28	17	16	-1
SUB_000_140	UR	84.94	0.133	0	0%	74	88%	8	9%	3	3%	0	0%	63	22	67	45	14	13	-1
SUB_000_150	UR	59.59	0.093	0	0%	20	34%	20	34%	19	32%	0	0%	72	6	57	50	13	6	-7
SUB_000_155	UR	37.43	0.058	1	3%	20	53%	0	1%	16	43%	0	0%	69	23	59	36	12	7	-5
SUB_000_160	UR	21.05	0.033	4	18%	14	64%	2	11%	1	7%	0	0%	60	6	73	67	9	4	-5
SUB_000_170	UR	92.62	0.145	4	4%	28	31%	23	25%	37	40%	0	0%	71	50	50	1	16	16	0
SUB_000_180	UR	54.74	0.086	11	20%	26	47%	18	33%	0	0%	0	0%	61	29	61	33	7	7	0
SUB_000_190	UR	73.49	0.115	5	7%	63	86%	2	3%	3	5%	0	0%	61	41	55	13	10	10	0
SUB_000_200	UR	82.97	0.130	0	0%	4	4%	12	15%	67	81%	0	0%	78	41	62	21	19	17	-2
SUB_000_210	UR	34.11	0.053	0	0%	16	46%	0	0%	18	54%	0	0%	71	14	71	57	9	8	-1
SUB_000_220	UR	118.42	0.185	0	0%	10	8%	23	20%	86	72%	0	0%	77	32	65	32	22	13	-9
SUB_000_230	UR	44.83	0.070	2	5%	0	0%	29	64%	14	31%	0	0%	74	14	65	50	11	11	0
SUB_000_240	UR	55.81	0.087	13	23%	2	3%	22	39%	20	35%	0	0%	68	21	63	42	7	7	0
SUB_000_250	UR	76.62	0.120	1	1%	48	63%	9	11%	19	25%	0	0%	67	44	50	6	13	13	0
SUB_000_260	UR	98.56	0.154	7	7%	19	19%	28	28%	45	46%	0	0%	72	27	55	27	11	11	0
SUB_000_270	UR	83.06	0.130	0	0%	48	57%	35	42%	1	1%	0	0%	66	24	27	3	15	13	-2
SUB_000_280	UR	55.00	0.086	7	13%	5	9%	11	19%	32	59%	0	0%	72	24	68	45	10	9	-1
SUB_000_290	UR	100.99	0.158	15	15%	23	23%	26	25%	38	37%	0	0%	68	25	64	39	8	8	0
SUB_000_300	UR	79.88	0.125	10	12%	56	70%	0	0%	14	18%	0	0%	62	35	57	21	11	11	0
SUB_001_001_010	UR	50.71	0.079	0	0%	0	0%	7	13%	44	87%	0	0%	79	46	53	7	16	8	-8
SUB_001_001_020	UR	13.14	0.021	0	0%	3	26%	9	66%	1	9%	0	0%	71	22	68	46	6	6	0
SUB_001_010	UR	65.94	0.103	0	0%	0	0%	0	0%	66	100%	0	0%	80	33	61	28	13	8	-5
SUB_001_020	UR	25.67	0.040	0	0%	0	0%	6	23%	20	77%	0	0%	79	37	58	21	4	4	0
SUB_002_010	UR	31.92	0.050	0	0%	1	2%	10	31%	21	67%	0	0%	78	23	39	16	6	5	-1
SUB_002_020	UR	18.11	0.028	0	1%	4	24%	5	29%	8	46%	0	0%	73	25	35	10	10	9	-1
SUB_003_010	UR	34.69	0.054	0	0%	23	67%	1	3%	11	30%	0	0%	67	33	60	27	10	10	0
SUB_003_020	UR	101.45	0.159	0	0%	57	56%	16	16%	28	28%	0	0%	68	36	64	29	13	12	-1
SUB_003_030	UR	96.22	0.150	0	0%	55	57%	34	35%	7	7%	0	0%	67	42	55	13	10	10	0
SUB_003_040	UR	107.96	0.169	0	0%	79	73%	11	11%	18	17%	0	0%	66	50	50	0	16	16	0

Rush Creek Sub-basin Summary

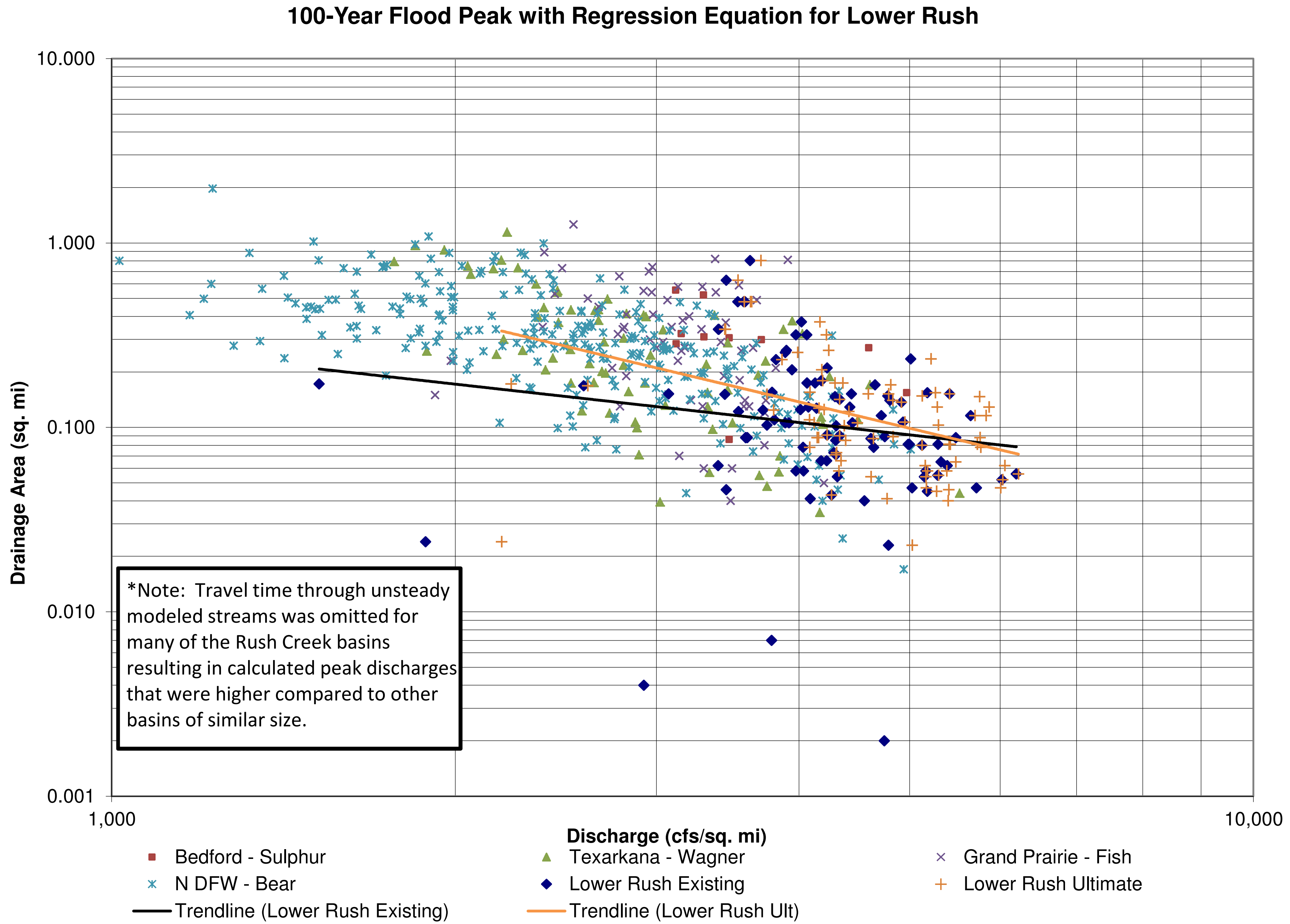
NAME	SUBWTRSHD	AREA	AREA	Area_A	Percent_A	Area_B	Percent_B	Area_C	Percent_C	Area_D	Percent_D	Area_Water	Percent_Wa	CN	EX_IMP	ULT_IMP	Difference	Existing Lag Time	Ultimate Lag Time	Difference
		Ac	SQ. MI.	Ac		Ac		Ac		Ac		Ac			%	%	%	Min	Min	Min
SUB_004_010	UR	50.88	0.080	0	0%	44	87%	6	12%	1	1%	0	0%	63	19	70	51	24	21	-3
SUB_004_020	UR	74.87	0.117	0	0%	68	91%	2	3%	4	5%	0	0%	62	22	74	52	15	14	-1
SUB_004_030	UR	42.07	0.066	0	0%	16	37%	14	34%	12	28%	0	0%	71	18	68	51	13	7	-6
SUB_004_040	UR	90.58	0.142	0	0%	57	63%	33	36%	1	1%	0	0%	66	11	74	64	23	21	-2
SUB_004_050	UR	72.87	0.114	0	0%	54	75%	11	15%	7	10%	0	0%	65	19	71	52	16	11	-5
SUB_004_060	UR	26.26	0.041	0	0%	5	20%	8	30%	13	50%	0	0%	74	68	72	4	13	12	-1
SUB_004_070	UR	83.44	0.130	0	0%	26	32%	3	3%	54	65%	0	0%	74	46	71	25	16	16	0
SUB_004_080	UR	60.12	0.094	0	0%	28	47%	32	52%	1	1%	0	0%	68	23	71	47	8	7	-1
SUB_004_090	UR	51.19	0.080	0	0%	32	63%	16	31%	3	5%	0	0%	66	21	69	48	13	10	-3
SUB_004_100	UR	21.95	0.034	0	0%	19	88%	3	12%	0	0%	0	0%	63	35	46	12	14	7	-7
SUB_004_110	UR	26.34	0.041	0	0%	20	75%	6	22%	1	3%	0	0%	64	49	67	17	24	22	-2
SUB_004_120	UR	62.68	0.098	1	1%	24	39%	27	44%	10	17%	0	0%	70	9	47	38	19	17	-2
SUB_004_130	UR	32.38	0.051	6	19%	22	67%	4	13%	0	0%	0	0%	59	5	48	43	13	8	-5

Appendix B-2
Discharge Comparisons

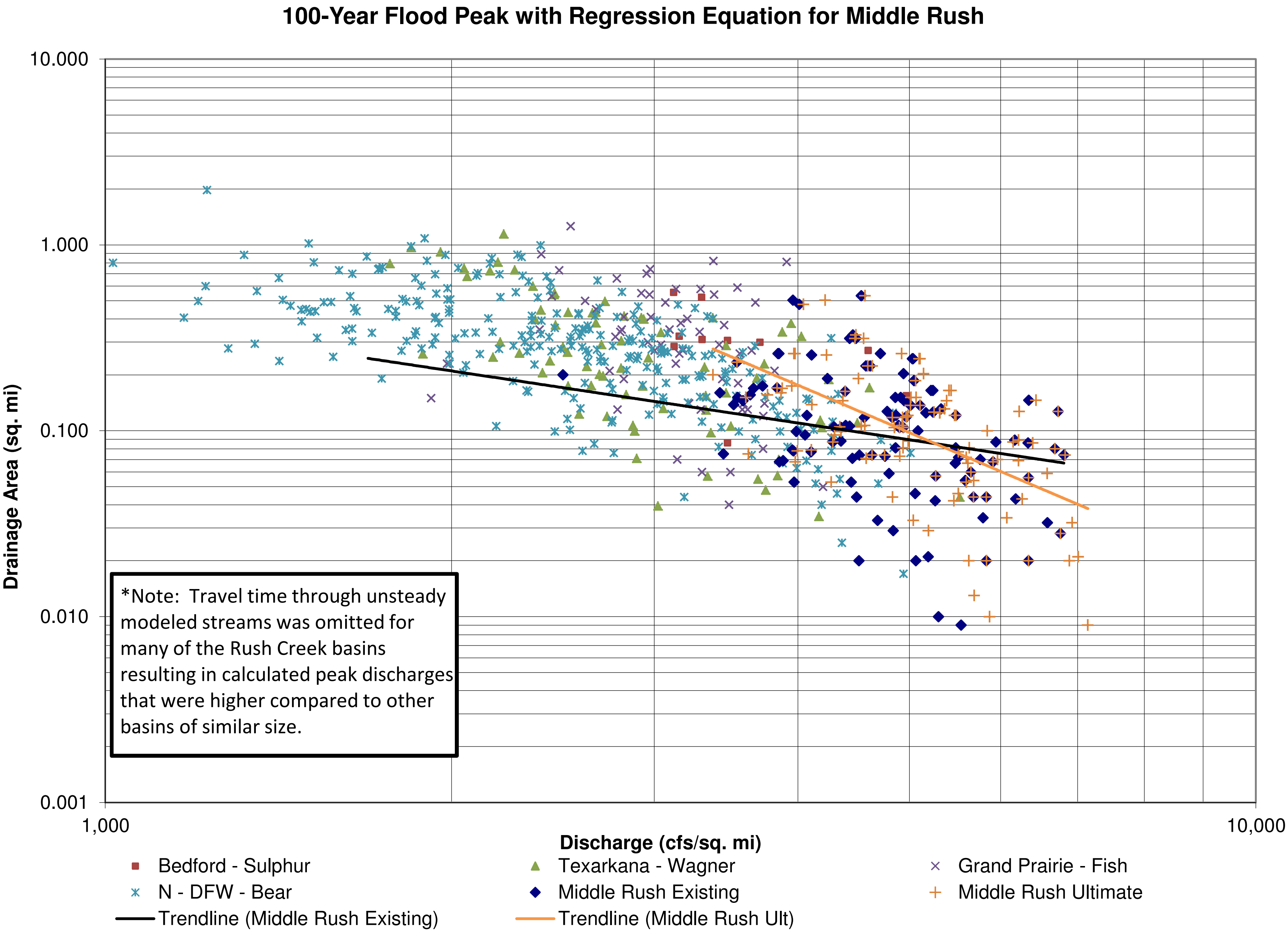
Discharge Comparison



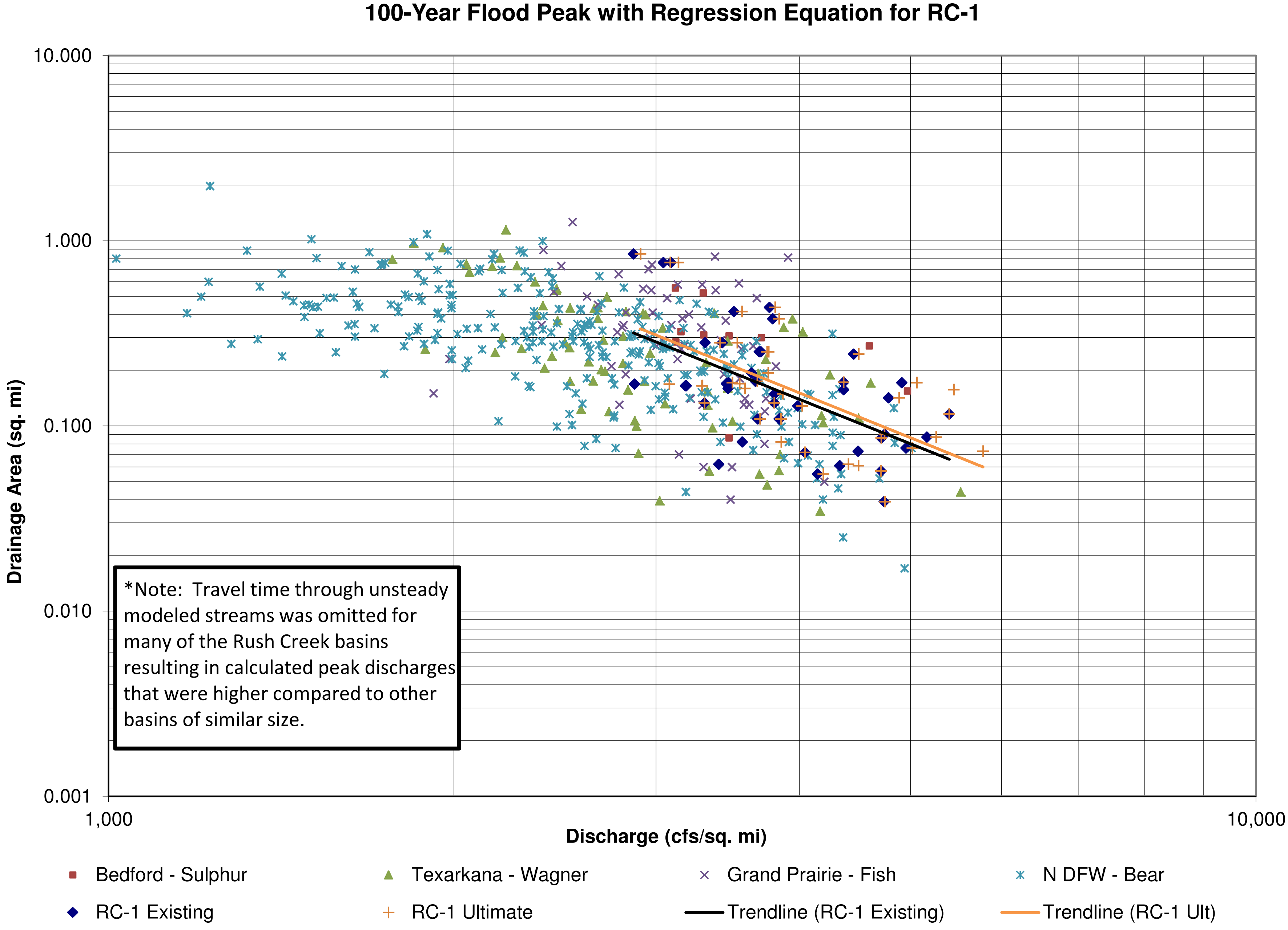
Discharge Comparison



Discharge Comparison

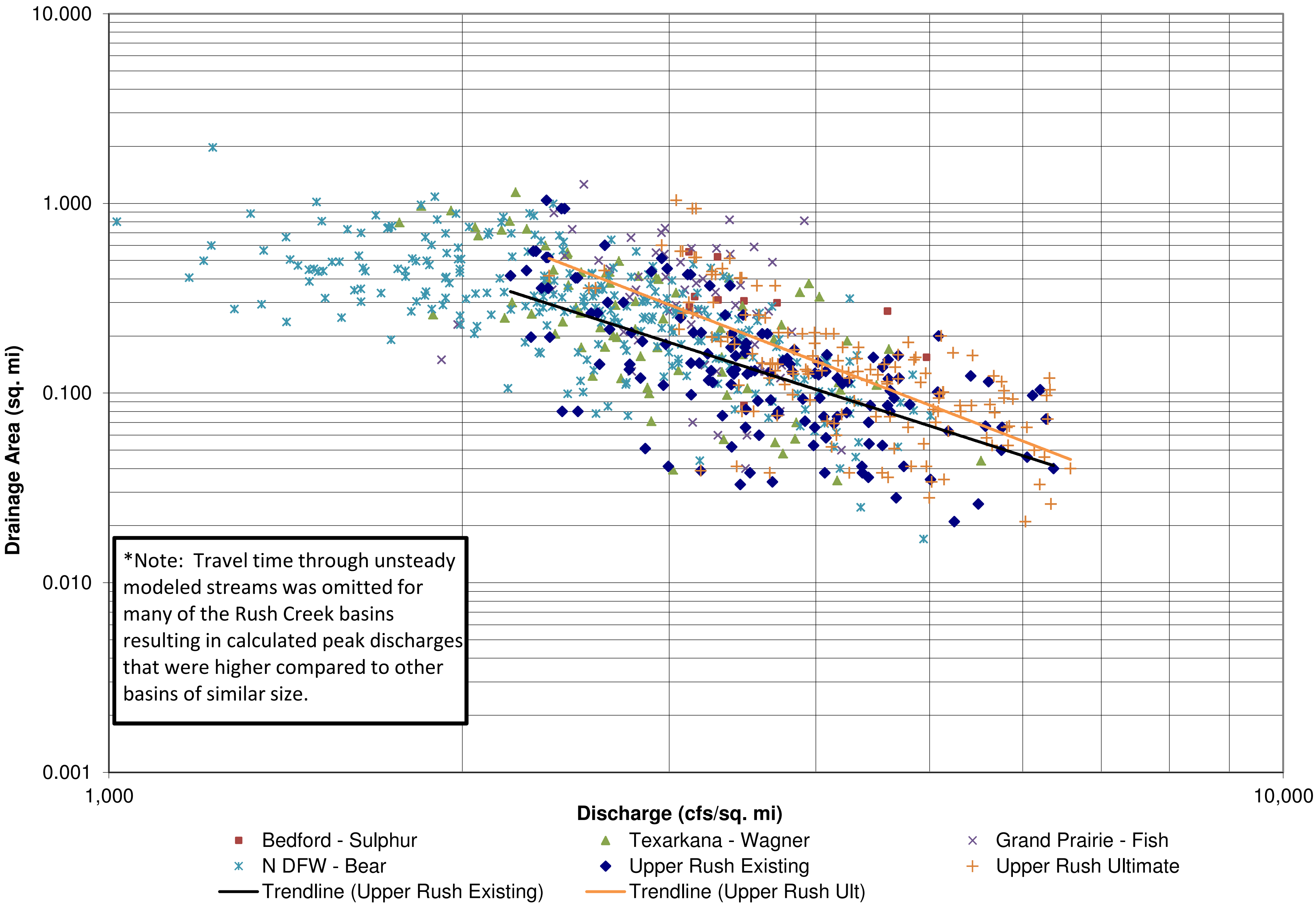


Discharge Comparison

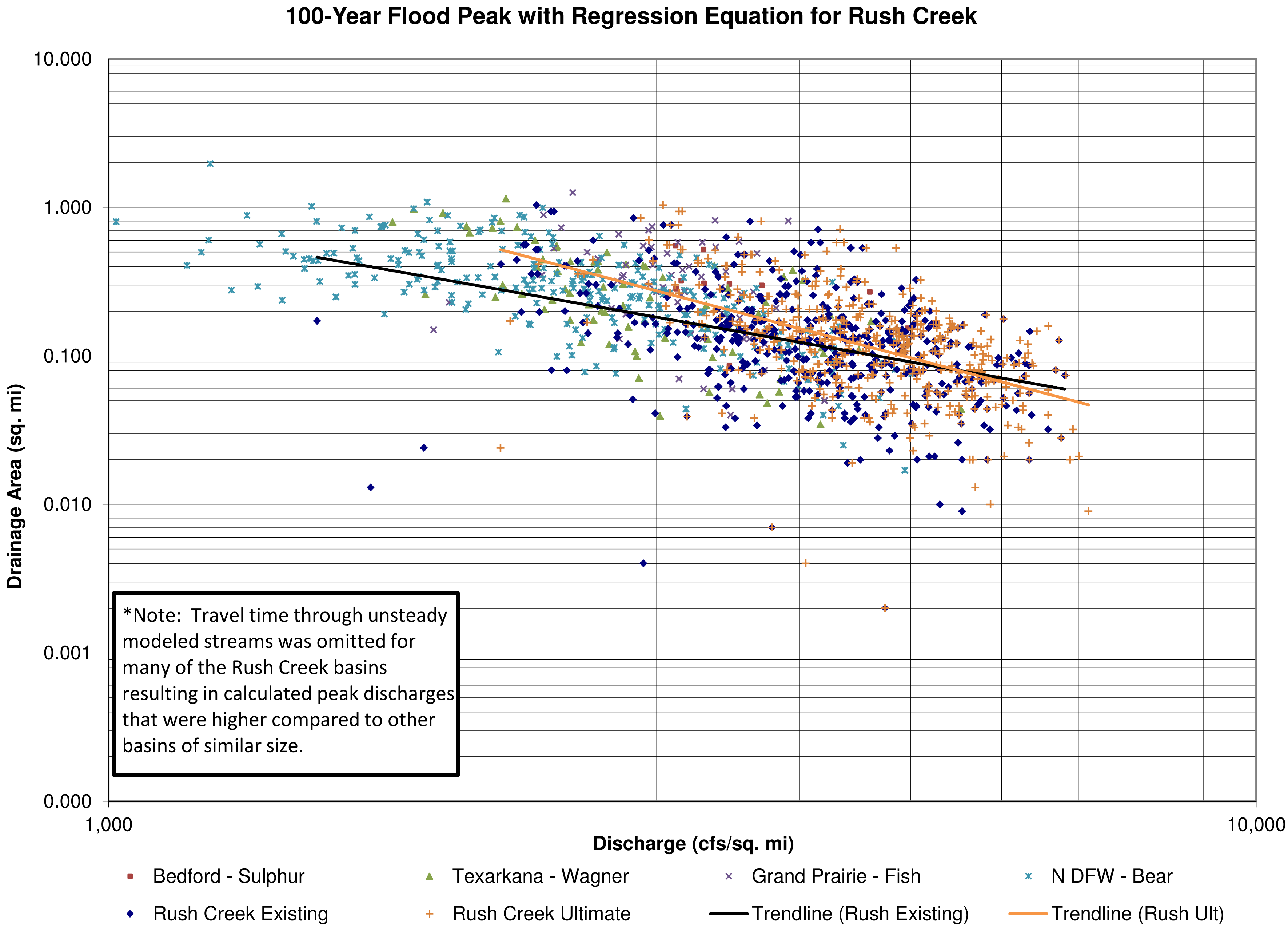


Discharge Comparison

100-Year Flood Peak with Regression Equation for Upper Rush



Discharge Comparison



Appendix B-3
Time of Concentration Calculations

Kee Branch Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
KEE_000_010		3,087	100	0.150	Grass-Short Grass Prairie	4.900	3.95	6.2																			KEE_000_010	6.2	25.9	0.43
									832	0.921	1.55	Unpaved	8.96															9.0		
														2,155	0.675	4.8	15.0	0.045	1.28		1.28	28.11						28.1		
KEE_000_020		4,034	100	0.150	Grass-Short Grass Prairie	0.690	3.95	13.5																			KEE_000_020	13.5	21.0	0.35
									663	1.437	1.93	Unpaved	5.71															5.7		
														1,092	2.116	5.9	10.7	0.045	3.24		3.24	5.62						5.6		
														2,179	0.588				3.58	3.58	3.58	10.14						10.1		
KEE_000_030		2,234	54	0.150	Grass-Short Grass Prairie	2.034	3.95	5.4																			KEE_000_030	5.4	12.3	0.21
									641	0.772	1.79	Paved	5.98															6.0		
														1,538	1.048	5.5	7.4	0.045	2.78		2.78	9.23						9.2		
KEE_000_040		1,299	100	0.150	Grass-Short Grass Prairie	3.510	3.95	7.0																			KEE_000_040	7.0	7.6	0.13
									572	2.811	2.71	Unpaved	3.52															3.5		
														628	2.524	17.4	19.3	0.045	4.92		4.92	2.13						2.1		
KEE_000_050		1,757	100	0.150	Grass-Short Grass Prairie	2.962	3.95	7.5																			KEE_000_050	7.5	9.7	0.16
									417	2.557	2.58	Unpaved	2.69															2.7		
														1,241	2.807	5.4	10.7	0.045	3.52		3.52	5.87						5.9		
KEE_000_060		3,065	100	0.150	Grass-Short Grass Prairie	2.965	3.95	7.5																			KEE_000_060	7.5	16.8	0.28
									487	3.404	2.98	Unpaved	2.73															2.7		
									2,268	1.273	2.29	Paved	16.48															16.5		
														210	1.455	7.7	13.8	0.045	2.70		2.70	1.30						1.3		
KEE_000_070		3,566	100	0.150	Grass-Short Grass Prairie	11.424	3.95	4.4																			KEE_000_070	4.4	16.9	0.28
									2,853	1.794	2.16	Unpaved	22.00															22.0		
														613	1.330	17.9	5.4	0.065	5.89		5.89	1.73						1.7		
KEE_000_080		2,338	100	0.150	Grass-Short Grass Prairie	2.610	3.95	7.9																			KEE_000_080	7.9	18.0	0.30
									1,517	2.118	2.35	Unpaved	10.77															10.8		
														721	0.552	13.0	45.9	0.045	1.06		1.06	11.33						11.3		
KEE_000_090		3,947	100	0.150	Grass-Short Grass Prairie	2.650	3.95	7.9																			KEE_000_090	7.9	13.5	0.22
									60	5.609	3.82	Unpaved	0.26															0.3		
									742	3.436	3.77	Paved	3.28															3.3		
														1,214	1.388	8.5	10.4	0.045	3.42		3.42	5.92						5.9		
																							1,831	6	6.00	5.1		5.1		
KEE_000_100		1,777	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.017	3.95	0.8																			KEE_000_100	0.8	6.6	0.11
									695	0.674	1.67	Paved	6.94															6.9		
																							862	6	6.00	2.4		2.4		
														170	0.631	33.7	11.6	0.065	3.72		3.72	0.76						0.8		
KEE_000_110		3,519	100	0.150	Grass-Short Grass Prairie	5.080	3.95	6.1																			KEE_000_110	6.1	12.5	0.21
									1,546	2.758	2.68	Unpaved	9.62															9.6		
																							1,874	6	6.00	5.2		5.2		
KEE_000_120		4,341	100	0.150	Grass-Short Grass Prairie	2.208	3.95	8.5																			KEE_000_120	8.5	13.0	0.22
									94	3.605	3.06	Unpaved	0.51															0.5		
									818	2.235	3.04	Paved	4.49															4.5		
																							1,289	6	6.00	3.6		3.6		
														2,040	1.426	5.6	11.7	0.015	7.29		7.29	4.66						4.7		
KEE_000_130		3,538	100	0.150	Grass-Short Grass Prairie	6.001	3.95	5.7																			KEE_000_130	5.7	10.9	0.18
									627	3.096	2.84	Unpaved	3.68															3.7		
									459	2.576	3.26	Paved	2.34															2.3		
																							2,351	6	6.00	6.5		6.5		
KEE_000_140		1,799	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			KEE_000_140	15.4	12.8	0.21
									344	1.009	2.04	Paved	2.81															2.8		
																							552	6	6.00	1.5		1.5		
														803	0.768				8.33	8.33	8.33	1.61						1.6		
KEE_000_150		4,517	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	7.139	3.95	0.4																			KEE_000_150	0.4	10.2	0.17
									1,044	2.939	3.49	Paved	4.99															5.0		
																							1,498	6	6.00	4.2		4.2		
														443	0.875	6.0	10.5	0.015	6.37		6.37	1.16						1.2		
														1,482	1.334	17.1	16.4	0.045	3.93		3.93	6.28						6.3		
KEE_000_160		4,517	60	0.150	Grass-Short Grass Prairie	5.796	3.95	3.8																			KEE_000_160	3.8	11.6	0.19
									1,732	3.077	3.57	Paved	8.10															8.1		
																							2,518	6	6.00	7.0		7.0		
														208	0.525				7.26	7.26	7.26	0.48						0.5		
KEE_000_170		2,524	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.440	3.95	0.4																			KEE_000_170	0.4	13.0	0.22
														2,474	0.860	11.8	23.5	0.045	1.94		1.94	21.25						21.3		
KEE_000_180		2,661	100	0.150	Grass-Short Grass Prairie	1.856	3.95	9.1																			KEE_000_180	9.1	17.5	0.29
									1,466	1.436	1.93	Unpaved	12.64															12.6		
														1,095	1.316	7.7	14.7	0.045	2.47		2.47	7.39						7.4		
KEE_000_190		2,588	100	0.150	Grass-Short Grass Prairie	7.600	3.95	5.2																			KEE_000_190	5.2	7.9	0.13
									993	4.530	4.33	Paved	3.83															3.8		
																							1,495	6	6.00	4.2		4.2		
KEE_000_200		3,249	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.191	3.95	0.8																			KEE_000_200	0.8	6.6	0.11
									398	1.732	2.68	Paved	2.48															2.5		
																							2,801	6	6.00	7.8		7.8		
KEE_000_210		1,254	100	0.150	Grass-Short Grass Prairie	4.450	3.95	6.4																			KEE_000_210	6.4	6.5	0.11
									1,023	4.303	4.22	Paved	4.04															4.0		
																							131	6	6.00	0.4		0.4		
KEE_000_220		5,107	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.505	3.95	1.1																			KEE_000_220	1.1	9.6	0.16
									325	2.255	3.05	Paved	1.77															1.8		
																							2,301	6	6.00	6.4		6.4		
														530	0.952	22.7	11.2	0.050	4.67		4.67	1.89						1.9		
														310	2.812	2.7	4.6	0.015	11.70		11.70	0.44						0.4		
																							1,592	6	6.00	4.4		4.4		
KEE_000_230		3,201	100	0.150	Grass-Short Grass Prairie	5.898	3.95	5.7																			KEE_000_230	5.7	10.2	0.17
									279	2.645	3.31	Paved	1.41															1.4		
														1,817	2.361	1.3	7.3	0.015	4.89		4.89	6.20						6.2		

Kee Branch Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
																							286	6	6.00	0.8		0.8		
														720	1.506	16.8	9.2	0.065	4.19		4.19	2.87						2.9		
KEE_000_240		2,832	100	0.150	Grass-Short Grass Prairie	4.426	3.95	6.4																			KEE_000_240	6.4	12.3	0.20
									756	3.744	3.12	Unpaved	4.04															4.0		
									1,590	2.170	2.99	Paved	8.85															8.8		
																							109	6	6.00	0.3		0.3		
														277	2.964	23.3	14.1	0.065	5.52		5.52	0.84						0.8		
KEE_000_250		3,233	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	7.220	3.95	0.4																			KEE_000_250	0.4	6.6	0.11
									1,454	4.093	4.11	Paved	5.89															5.9		
																							1,729	6	6.00	4.8		4.8		
KEE_000_260		4,376	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	5.026	3.95	0.4																			KEE_000_260	0.4	9.9	0.16
									2,638	3.363	3.73	Paved	11.79															11.8		
																							144	6	6.00	0.4		0.4		
														1,545	1.122				6.71	6.71	6.71	3.84						3.8		
KEE_000_270		3,616	50	0.150	Grass-Short Grass Prairie	0.500	3.95	8.8																			KEE_000_270	8.8	12.7	0.21
														3,313	2.212	15.0	16.0	0.045	4.71		4.71	11.72						11.7		
																							253	6	6.00	0.7		0.7		
KEE_000_280		3,496	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.999	3.95	0.8																			KEE_000_280	0.8	6.4	0.11
									69	0.795	1.81	Paved	0.63															0.6		
																							1,688	6	6.00	4.7		4.7		
														452	2.424	1.5	3.5	0.015	8.72		8.72	0.86						0.9		
																							678	6	6.00	1.9		1.9		
														558	2.041	7.7	5.5	0.050	5.33		5.33	1.75						1.7		
KEE_000_290		2,617	100	0.150	Grass-Short Grass Prairie	1.000	3.95	11.6																			KEE_000_290	11.6	14.1	0.24
									733	1.173	1.75	Unpaved	6.99															7.0		
																							1,784	6	6.00	5.0		5.0		
KEE_000_300		3,375	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.367	3.95	0.6																			KEE_000_300	0.6	9.7	0.16
									780	1.743	2.68	Paved	4.84															4.8		
																							505	6	6.00	1.4		1.4		
									1,065	1.768	2.70	Paved	6.57															6.6		
																							976	6	6.00	2.7		2.7		
KEE_000_310		2,056	100	0.150	Grass-Short Grass Prairie	10.600	3.95	4.5																			KEE_000_310	4.5	8.5	0.14
									1,744	2.453	3.18	Paved	9.13															9.1		
																							212	6	6.00	0.6		0.6		
KEE_000_320		5,147	60	0.150	Grass-Short Grass Prairie	7.099	3.95	3.5																			KEE_000_320	3.5	16.4	0.27
									1,321	1.910	2.81	Paved	7.84															7.8		
									1,642	1.903	2.23	Unpaved	12.30															12.3		
														1,946	2.147	1.0	1.8	0.015	9.78		9.78	3.32						3.3		
														177	2.605	56.7	16.6	0.065	8.38		8.38	0.35						0.4		
KEE_000_330		1,743	100	0.150	Grass-Short Grass Prairie	1.485	3.95	9.9																			KEE_000_330	9.9	9.4	0.16
														1,643	3.018	8.0	10.5	0.045	4.79		4.79	5.71						5.7		
KEE_000_340		2,174	30	0.150	Grass-Short Grass Prairie	2.694	3.95	3.0																			KEE_000_340	3.0	7.7	0.13
									738	1.273	2.29	Paved	5.36															5.4		
														1,228	3.625	4.1	6.6	0.045	4.62		4.62	4.43						4.4		
														178	11.612	16.9	6.3	0.065												
KEE_001_010		3,375	100	0.150	Grass-Short Grass Prairie	6.151	3.95	5.6																			KEE_001_010	5.6	10.4	0.17
									1,063	3.256	3.67	Paved	4.83															4.8		
														218	1.637	1.5	4.7	0.045	1.99		1.99	1.83						1.8		
														526	0.799	7.8	7.9	0.015	8.81		8.81	1.00						1.0		
																							1,468	6	6.00	4.1		4.1		
KEE_001_020		1,554	100	0.150	Grass-Short Grass Prairie	3.210	3.95	7.3																			KEE_001_020	7.3	7.7	0.13
									867	3.248	3.66	Paved	3.94															3.9		
																							100	6	6.00	0.3		0.3		
														486	2.993	54.2	30.5	0.065	5.82		5.82	1.39						1.4		
KEE_001_030		1,340	100	0.150	Grass-Short Grass Prairie	4.670	3.95	6.3																			KEE_001_030	6.3	7.4	0.12
									634	2.329	2.46	Unpaved	4.29															4.3		
														606	1.393	15.4	8.3	0.045	5.92		5.92	1.71						1.7		
KEE_002_010		2,469	100	0.150	Grass-Short Grass Prairie	1.870	3.95	9.1																			KEE_002_010	9.1	10.7	0.18
									626	3.214	2.89	Unpaved	3.61															3.6		
														655	3.682	12.2	9.4	0.065	5.22		5.22	2.09						2.1		
																							1,088	6	6.00	3.0		3.0		
KEE_002_020		1,349	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			KEE_002_020	15.4	12.9	0.22
									179	1.891	2.22	Unpaved	1.34															1.3		
									465	1.488	2.48	Paved	3.13															3.1		
																							605	6	6.00	1.7		1.7		
KEE_004_010		3,383	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.300	3.95	0.7																			KEE_004_010	0.7	13.5	0.22
									2,242	1.156	2.19	Paved	17.10															17.1		
														314	1.003	3.9	5.6	0.015	7.88		7.88	0.66						0.7		
									311	0.665	1.66	Paved	3.13															3.1		
														466	1.303	4.5	6.3	0.015	9.02		9.02	0.86						0.9		
KEE_004_020		3,028	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.630	3.95	0.7																			KEE_004_020	0.7	6.9	0.12
									1,199	2.240	3.04	Paved	6.57															6.6		
																							1,066	6	6.00	3.0		3.0		
														713	0.635				9.01	9.01	9.01	1.32						1.3		
KEE_004_030		3,428	100	0.150	Grass-Short Grass Prairie	1.682	3.95	9.5																			KEE_004_030	9.5	15.6	0.26
									546	2.474	2.54	Unpaved	3.59															3.6		
									1,024	1.090	2.12	Paved	8.04															8.0		
																							1,757	6	6.00	4.9		4.9		
KEE_004_040		1,473	87	0.150	Grass-Short Grass Prairie	3.045	3.95	6.7																			KEE_004_040	6.7	7.1	0.12
									138	2.116	2.35	Unpaved	0.98															1.0		
									170	1.563	2.54	Paved	1.11															1.1		
																							1,078	6	6.00	3.0		3.0		
KEE_004_050		1,412	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.520	3.95	0.7																			KEE_004_050	0.7	3.9	0.06
									894	2.662	3.32	Paved	4.49															4.5		
																							468	6	6.00	1.3		1.3		
KEE_005_010		3,260	100	0.150	Grass-Short Grass Prairie	2.370	3.95	8.2																			KEE_005_010	8.2	11.7	0.20
									404	1.556	2.01	Unpaved	3.35															3.3		
														483	2.007	58.5	23.7	0.065	5.94		5.94	1.36						1.4		
														463	0.970	84.0	38.7	0.050	4.93		4.93	1.57						1.6		
																							1,811	6	6.00	5.0		5.0		

Kee Branch Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
KEE_005_020		3,664	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.000	3.95	0.8																			KEE_005_020	0.8	**7.9**	**0.13**
														906	1.467	29.3	31.9	0.045	3.80		3.80	3.98						4.0		
																							867	6	6.00	2.4		2.4		
														1,840	1.124	30.1	17.2	0.045	5.09		5.09	6.03						6.0		
KEE_005_030		3,020	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.980	3.95	0.5																			KEE_005_030	0.5	**10.5**	**0.18**
									305	1.304	2.32	Paved	2.19															2.2		
									774	1.280	1.83	Unpaved	7.07															7.1		
																							589	6	6.00	1.6		1.6		
														802	0.753	10.3	6.1	0.065	2.83		2.83	4.72						4.7		
																							500	6	6.00	1.4		1.4		
KEE_005_040		1,614	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.500	3.95	0.7																			KEE_005_040	0.7	**3.7**	**0.06**
									1,171	4.716	4.41	Paved	4.42															4.4		
																							393	6	6.00	1.1		1.1		
KEE_KB1_001_010		2,967	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.847	3.95	0.6																			KEE_KB1_001_010	0.6	**5.9**	**0.10**
									453	2.351	3.12	Paved	2.42															2.4		
																							2,464	6	6.00	6.8		6.8		
KEE_KB1_001_020		2,885	100	0.150	Grass-Short Grass Prairie	4.280	3.95	6.5																			KEE_KB1_001_020	6.5	**10.1**	**0.17**
									94	4.891	3.57	Unpaved	0.44															0.4		
									629	1.486	2.48	Paved	4.23															4.2		
														97	1.107	5.9	10.5	0.015	7.14		7.14	0.23						0.2		
																							237	6	6.00	0.7		0.7		
														451	0.747	2.9	3.5	0.015	7.46		7.46	1.01						1.0		
														532	1.340				5.50	5.50	5.50	1.61						1.6		
														426	1.319				9.20	9.20	9.20	0.77						0.8		
														318	1.195				3.90	3.90	3.90	1.36						1.4		
KEE_KB1_001_030		696	100	0.150	Grass-Short Grass Prairie	3.406	3.95	7.1																			KEE_KB1_001_030	7.1	**5.9**	**0.10**
									596	5.342	3.73	Unpaved	2.66															2.7		
KEE_KB1_010		3,559	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.067	3.95	0.8																			KEE_KB1_010	0.8	**6.2**	**0.10**
									647	5.107	4.59	Paved	2.35															2.3		
																							703	6	6.00	2.0		2.0		
														1,234	1.280	3.5	6.3	0.015	7.61		7.61	2.70						2.7		
																							925	6	6.00	2.6		2.6		
KEE_KB1_020		4,817	85	0.150	Grass-Short Grass Prairie	2.810	3.95	6.8																			KEE_KB1_020	6.8	**13.6**	**0.23**
									734	1.529	2.51	Paved	4.87															4.9		
																							3,998	6	6.00	11.1		11.1		
KEE_KB1_030		4,936	50	0.150	Grass-Short Grass Prairie	4.172	3.95	3.8																			KEE_KB1_030	3.8	**13.1**	**0.22**
									810	2.627	3.29	Paved	4.10															4.1		
																							129	6	6.00	0.4		0.4		
														2,566	1.746	8.7	9.0	0.045	4.26		4.26	10.03						10.0		
														232	1.415	1.6	2.7	0.015	8.34		8.34	0.46						0.5		
																							1,149	6	6.00	3.2		3.2		
KEE_KB1_040		3,426	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.843	3.95	0.9																			KEE_KB1_040	0.9	**7.9**	**0.13**
									1,487	3.011	3.53	Paved	7.03															7.0		
																							1,890	6	6.00	5.3		5.3		
KEE_KB1_050		2,596	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.620	3.95	1.0																			KEE_KB1_050	1.0	**5.3**	**0.09**
														872	2.111	17.5	18.4	0.045	4.66		4.66	3.12						3.1		
																							1,674	6	6.00	4.7		4.7		
KEE_KB1_060		3,711	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.080	3.95	0.5																			KEE_KB1_060	0.5	**9.5**	**0.16**
									231	0.917	1.95	Paved	1.98															2.0		
									149	5.852	3.90	Unpaved	0.64															0.6		
														493	0.637	1.8	5.9	0.015	3.57		3.57	2.30						2.3		
														1,246	1.791	4.8	6.5	0.045	3.63		3.63	5.72						5.7		
														371	2.868	4.0	3.4	0.065	4.35		4.35	1.42						1.4		
																							1,171	6	6.00	3.3		3.3		

Lower Rush Existing Time of Concentration Calculations

HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Overland Flow: Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Shallow Concentrated Flow: Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Channel Flow: Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Flow: Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Totals: Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
PAN_000_010		4,143	100	0.150	Grass-Short Grass Prairie	3.879	3.95	6.8																			PAN_000_010	6.8	15.2	0.25
									702	2.327	2.46	Unpaved	4.75															4.8		
									804	0.925	1.96	Paved	6.85															6.9		
																							2,535	6.00	6.00	7.0		7.0		
PAN_000_020		2,536	100	0.150	Grass-Short Grass Prairie	1.424	3.95	10.1																			PAN_000_020	10.1	13.0	0.22
									962	1.806	2.17	Unpaved	7.39															7.4		
																							1,474	6.00	6.00	4.1		4.1		
PAN_000_030		4,382	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.843	3.95	0.9																			PAN_000_030	0.9	11.6	0.19
									1,377	0.938	1.97	Paved	11.66															11.7		
														2,352	0.667			0.015	7.63	7.63	7.63	5.14						5.1		
																							604	6.00	6.00	1.7		1.7		
PAN_000_040		4,196	100	0.150	Grass-Short Grass Prairie	6.914	3.95	5.4																			PAN_000_040	5.4	12.9	0.22
									113	8.527	4.71	Unpaved	0.40															0.4		
									1,282	1.628	2.59	Paved	8.24															8.2		
																							2,698	6.00	6.00	7.5		7.5		
PAN_000_050		4,121	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.571	3.95	1.0																			PAN_000_050	1.0	10.5	0.18
									491	0.544	1.50	Paved	5.46															5.5		
																							2,846	6.00	6.00	7.9		7.9		
														734	0.704			0.065	3.86	3.86	3.86	3.17						3.2		
PAN_000_060		6,759	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.284	3.95	0.5																			PAN_000_060	0.5	14.4	0.24
									1,691	2.112	2.95	Paved	9.54															9.5		
																							5,018	6.00	6.00	13.9		13.9		
PAN_000_070		5,912	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.579	3.95	1.0																			PAN_000_070	1.0	11.4	0.19
									732	2.560	3.25	Paved	3.75															3.8		
																							5,130	6.00	6.00	14.3		14.3		
PAN_000_080		2,612	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			PAN_000_080	1.1	11.8	0.20
									2,221	1.112	2.14	Paved	17.27															17.3		
														341	4.360	16.3	17.5	0.065	4.57		4.57	1.24						1.2		
PAN_000_090		5,232	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.011	3.95	0.6																			PAN_000_090	0.6	13.5	0.23
									854	0.500	1.44	Paved	9.90															9.9		
																							4,328	6.00	6.00	12.0		12.0		
PAN_000_100		2,042	100	0.150	Grass-Short Grass Prairie	0.748	3.95	13.1																			PAN_000_100	13.1	15.4	0.26
									258	0.786	1.43	Unpaved	3.01															3.0		
									1,685	2.054	2.91	Paved	9.64															9.6		
PAN_000_110		2,848	100	0.150	Grass-Short Grass Prairie	2.376	3.95	8.2																			PAN_000_110	8.2	12.3	0.20
									958	1.160	2.19	Paved	7.29															7.3		
																							1,790	6.00	6.00	5.0		5.0		
PAN_000_120		2,917	100	0.150	Grass-Short Grass Prairie	2.420	3.95	8.2																			PAN_000_120	8.2	10.9	0.18
									228	3.247	2.91	Unpaved	1.31															1.3		
									714	2.717	3.35	Paved	3.55															3.6		
																							1,876	6.00	6.00	5.2		5.2		
PAN_000_130		3,301	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.457	3.95	0.7																			PAN_000_130	0.7	18.4	0.31
									601	3.667	3.89	Paved	2.57															2.6		
														2,650	0.886	10.4	27.8	0.045	1.61		1.61	27.39						27.4		
RUS_000_360		3,176	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_000_360	1.1	8.0	0.13
									1,427	2.340	3.11	Paved	7.65															7.6		
																							1,497	6.00	6.00	4.2		4.2		
														202	8.113	17.4	14.8	0.065	7.28		7.28	0.46						0.5		
RUS_000_370		2,146	100	0.150	Grass-Short Grass Prairie	3.750	3.95	6.9																			RUS_000_370	6.9	9.5	0.16
									121	8.763	4.78	Unpaved	0.42															0.4		
														1,927	3.223	6.1	12.1	0.045	3.77		3.77	8.53						8.5		
RUS_000_380		674	100	0.150	Grass-Short Grass Prairie	4.730	3.95	6.2																			RUS_000_380	6.2	5.0	0.08
									573	7.984	4.56	Unpaved	2.09															2.1		
RUS_000_390		2,658	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.672	3.95	1.0																			RUS_000_390	1.0	11.0	0.18
									1,257	0.579	1.55	Paved	13.54															13.5		
																							1,352	6.00	6.00	3.8		3.8		
RUS_000_400		1,435	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.646	3.95	1.0																			RUS_000_400	1.0	3.1	0.05
									478	5.274	4.67	Paved	1.71															1.7		
																							907	6.00	6.00	2.5		2.5		
RUS_000_410		4,837	100	0.150	Grass-Short Grass Prairie	3.876	3.95	6.8																			RUS_000_410	6.8	12.9	0.22
									1,216	3.291	3.69	Paved	5.50															5.5		
																							508	6.00	6.00	1.4		1.4		
														2,220	1.962	1.7	5.2	0.015	6.48		6.48	5.71						5.7		
																							791	6.00	6.00	2.2		2.2		
RUS_000_420		2,655	50	0.150	Grass-Short Grass Prairie	1.100	3.95	6.4																			RUS_000_420	6.4	8.8	0.15
									375	2.429	3.17	Paved	1.97															2.0		
																							2,231	6.00	6.00	6.2		6.2		
RUS_000_430		1,770	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.928	3.95	0.4																			RUS_000_430	0.4	4.3	0.07
									1,220	3.529	3.82	Paved	5.32															5.3		
																							501	6.00	6.00	1.4		1.4		
RUS_000_440		391	100	0.150	Grass-Short Grass Prairie	3.155	3.95	7.3																			RUS_000_440	7.3	5.5	0.09
									287	2.680	2.64	Unpaved	1.81															1.8		
RUS_000_450		5,802	100	0.150	Grass-Short Grass Prairie	1.109	3.95	11.2																			RUS_000_450	11.2	21.1	0.35
									879	0.722	1.37	Unpaved	10.69															10.7		
																							4,822	6.00	6.00	13.4		13.4		
RUS_000_460		2,409	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.526	3.95	1.1																			RUS_000_460	1.1	7.6	0.13
									653	0.621	1.60	Paved	6.79															6.8		
																							1,707	6.00	6.00	4.7		4.7		

Lower Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_470														1,965	0.500	100.4	58.2	0.050	3.03		3.03	10.80					RUS_000_470	10.8	6.5	0.11
RUS_000_480														297	0.500	104.1	60.6	0.065	2.32		2.32	2.13					RUS_000_480	10.0	6.0	0.10
RUS_000_500		856												856	1.719	140.3	36.4	0.065	7.39		7.39	1.93					RUS_000_500	10.0	6.0	0.10
RUS_000_510		3,401	50	0.150	Grass-Short Grass Prairie	3.981	3.95	3.8																			RUS_000_510	3.8	10.5	0.18
									1,647	4.446	4.29	Paved	6.40															6.4		
														1,704	1.624	2.5	2.8	0.045	3.89		3.89	7.30						7.3		
RUS_000_520		689	100	0.150	Grass-Short Grass Prairie	1.650	3.95	9.5																			RUS_000_520	9.5	8.0	0.13
									589	2.603	2.60	Unpaved	3.77															3.8		
RUS_000_530		5,641	100	0.150	Grass-Short Grass Prairie	7.835	3.95	5.1																			RUS_000_530	5.1	40.9	0.68
									3,227	0.500	1.14	Unpaved	47.14															47.1		
														2,315	0.500	105.9	58.3	0.065	2.41		2.41	15.99						16.0		
RUS_003_010		2,458	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.628	3.95	1.0																			RUS_003_010	1.0	5.7	0.10
									731	2.369	3.13	Paved	3.89															3.9		
																							1,676	6.00	6.00	4.7		4.7		
RUS_003_020		3,664	98	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.191	3.95	1.0																			RUS_003_020	1.0	7.8	0.13
									740	2.179	3.00	Paved	4.11															4.1		
																							2,826	6.00	6.00	7.9		7.9		
RUS_004_001_010		2,717	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.713	3.95	0.9																			RUS_004_001_010	0.9	14.8	0.25
														2,666	0.585	9.2	14.4	0.045	1.88		1.88	23.68						23.7		
RUS_004_001_020		2,250	100	0.150	Grass-Short Grass Prairie	5.307	3.95	6.0																			RUS_004_001_020	6.0	8.7	0.14
									560	2.970	2.78	Unpaved	3.36															3.4		
														455	1.358	8.0	10.2	0.045	3.27		3.27	2.32						2.3		
														1,135	0.777			0.065	6.66	6.66	6.66	2.84						2.8		
RUS_004_001_030		2,222	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.375	3.95	0.7																			RUS_004_001_030	0.7	5.1	0.09
														891	3.344	5.5	13.7	0.045	3.29		3.29	4.52						4.5		
														1,278	2.228			0.065	6.43	6.43	6.43	3.31						3.3		
RUS_004_001_040		592	100	0.150	Grass-Short Grass Prairie	5.366	3.95	5.9																			RUS_004_001_040	5.9	4.5	0.08
									494	10.075	5.12	Unpaved	1.61															1.6		
RUS_004_010		3,537	77	0.150	Grass-Short Grass Prairie	3.850	3.95	5.5																			RUS_004_010	5.5	15.3	0.26
									100	2.405	2.50	Unpaved	0.67															0.7		
									614	0.914	1.94	Paved	5.27															5.3		
																							515	6.00	6.00	1.4		1.4		
														2,231	0.537	23.8	17.9	0.045	2.94		2.94	12.65						12.7		
RUS_004_020		2,424	100	0.150	Grass-Short Grass Prairie	1.256	3.95	10.6																			RUS_004_020	10.6	20.1	0.33
									1,076	0.506	1.15	Unpaved	15.63															15.6		
														1,246	0.850	8.3	9.0	0.045	2.89		2.89	7.19						7.2		
RUS_004_030		1,793	49	0.150	Grass-Short Grass Prairie	1.391	3.95	5.8																			RUS_004_030	5.8	11.5	0.19
									1,188	1.434	1.93	Unpaved	10.25															10.2		
														556	0.500			0.055	2.87	2.87	2.87	3.23						3.2		
RUS_004_040		1,909	100	0.150	Grass-Short Grass Prairie	2.384	3.95	8.2																			RUS_004_040	8.2	14.2	0.24
									726	0.500	1.14	Unpaved	10.61															10.6		
														1,084	3.061			0.045	3.73	3.73	3.73	4.84						4.8		
RUS_004_050		2,011	100	0.150	Grass-Short Grass Prairie	3.174	3.95	7.3																			RUS_004_050	7.3	8.9	0.15
									596	3.614	3.07	Unpaved	3.24															3.2		
									638	1.985	2.86	Paved	3.71															3.7		
														677	2.910	311.4	137.2	0.024	18.29		18.29	0.62						0.6		
RUS_005_002_010		3,287	60	0.150	Grass-Short Grass Prairie	9.203	3.95	3.2																			RUS_005_002_010	3.2	8.9	0.15
									1,438	3.112	3.59	Paved	6.68															6.7		
																							1,789	6.00	6.00	5.0		5.0		
RUS_005_010		3,228	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.900	3.95	0.6																			RUS_005_010	0.6	9.7	0.16
									1,760	1.571	2.55	Paved	11.51															11.5		
																							1,417	6.00	6.00	3.9		3.9		
RUS_005_020		1,426	56	0.150	Grass-Short Grass Prairie	8.478	3.95	3.1																			RUS_005_020	3.1	6.5	0.11
									755	2.282	3.07	Paved	4.10															4.1		
									615	3.197	2.88	Unpaved	3.55															3.6		
RUS_005_030		3,299	81	0.150	Grass-Short Grass Prairie	1.329	3.95	8.8																			RUS_005_030	8.8	13.4	0.22
									1,672	2.126	2.96	Paved	9.40															9.4		
																							1,257	6.00	6.00	3.5		3.5		
														289	2.204	1.4	3.6	0.015	7.83		7.83	0.62						0.6		
RUS_005_040		1,121	100	0.150	Grass-Short Grass Prairie	4.480	3.95	6.4																			RUS_005_040	6.4	7.7	0.13
									804	1.240	2.26	Paved	5.92															5.9		
																							217	6.00	6.00	0.6		0.6		
RUS_005_050		4,115	100	0.150	Grass-Short Grass Prairie	5.308	3.95	6.0																			RUS_005_050	6.0	14.4	0.24
														2,095	1.936	1.9	4.0	0.045	2.76		2.76	12.67						12.7		
																							1,921	6.00	6.00	5.3		5.3		
RUS_005_060		1,894	100	0.150	Grass-Short Grass Prairie	3.446	3.95	7.1																			RUS_005_060	7.1	12.3	0.20
									1,441	0.916	1.95	Paved	12.34															12.3		
																							354	6.00	6.00	1.0		1.0		
RUS_005_070		671	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.864	3.95	0.9																			RUS_005_070	0.9	2.6	0.04
									621	2.199	3.01	Paved	3.43															3.4		
RUS_006_010		2,750	38	0.150	Grass-Short Grass Prairie	5.841	3.95	2.6																			RUS_006_010	2.6	7.3	0.12
									677	3.792	3.96	Paved	2.85															2.9		
														2,035	2.914	45.5	30.9	0.065	5.06		5.06	6.70						6.7		
RUS_RC2_010		4,624	100	0.150	Grass-Short Grass Prairie	5.259	3.95	6.0																			RUS_RC2_010	6.0	13.6	0.23
									1,085	2.477	2.54	Unpaved	7.12															7.1		
																							3,440	6.00	6.00	9.6		9.6		
RUS_RC2_020		3,281	49	0.150	Grass-Short Grass Prairie	3.496	3.95	4.0																			RUS_RC2_020	4.0	10.0	0.17
														1,238	2.750	3.3	8.5	0.045	2.90		2.90	7.11						7.1		
																							1,994	6.00	6.00	5.5		5.5		
RUS_RC2_030		2,943	100	0.150	Grass-Short Grass Prairie	3.122	3.95	7.4																			RUS_RC2_030	7.4	11.5	0.19
														1,631	1.945	4.2	7.2	0.045	3.21		3.21	8.46						8.5		
																							1,212	6.00	6.00	3.4		3.4		

RUSH CREEK
City of Arlington Watershed Study

Lower Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_RC2_040		2,905	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_040	1.1	9.0	0.15
									1,470	1.426	2.43	Paved	10.09															10.1		
																							1,385	6.00	6.00	3.8		3.8		
RUS_RC2_050		3,579	100	0.150	Grass-Short Grass Prairie	4.446	3.95	6.4																			RUS_RC2_050	6.4	13.2	0.22
									398	2.553	2.58	Unpaved	2.57															2.6		
									963	1.234	2.26	Paved	7.11															7.1		
																							2,117	6.00	6.00	5.9		5.9		
RUS_RC2_060		3,143	65	0.150	Grass-Short Grass Prairie	8.975	3.95	3.4																			RUS_RC2_060	3.4	8.3	0.14
									860	4.128	4.13	Paved	3.47															3.5		
																							1,110	6.00	6.00	3.1		3.1		
														740	2.606	14.8	11.5	0.065	4.39		4.39	2.81						2.8		
																							369	6.00	6.00	1.0		1.0		
RUS_RC2_070		2,142	42	0.150	Grass-Short Grass Prairie	20.469	3.95	1.7																			RUS_RC2_070	1.7	6.4	0.11
									1,843	3.404	3.75	Paved	8.19															8.2		
																							257	6.00	6.00	0.7		0.7		
RUS_RC2_080		1,482	100	0.150	Grass-Short Grass Prairie	7.150	3.95	5.3																			RUS_RC2_080	5.3	6.6	0.11
									418	5.026	3.62	Unpaved	1.93															1.9		
									612	2.960	3.50	Paved	2.92															2.9		
														353	6.538	10.7	7.9	0.065	7.17		7.17	0.82						0.8		
RUS_RC2_085		2,259	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_085	1.1	6.0	0.10
									762	1.644	2.61	Paved	4.87															4.9		
																							1,448	6.00	6.00	4.0		4.0		
RUS_RC2_090		3,894	83	0.150	Grass-Short Grass Prairie	8.486	3.95	4.3																			RUS_RC2_090	4.3	13.6	0.23
									1,159	3.169	3.62	Paved	5.34															5.3		
																							238	6.00	6.00	0.7		0.7		
														1,893	1.779	19.5	21.2	0.065	2.90		2.90	10.89						10.9		
																							522	6.00	6.00	1.5		1.5		
RUS_RC2_100		2,889	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.922	3.95	0.6																			RUS_RC2_100	0.6	6.9	0.12
									1,351	2.673	3.32	Paved	6.77															6.8		
																							1,489	6.00	6.00	4.1		4.1		
RUS_RC2_110		1,928	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_110	1.1	4.8	0.08
									1,114	3.655	3.89	Paved	4.78															4.8		
																							764	6.00	6.00	2.1		2.1		
RUS_RCH_010		3,584	100	0.150	Grass-Short Grass Prairie	7.263	3.95	5.3																			RUS_RCH_010	5.3	9.0	0.15
														1,730	4.622	19.8	14.9	0.065	5.95		5.95	4.84						4.8		
																							1,755	6.00	6.00	4.9		4.9		
RUS_RCH_020		1,780	100	0.150	Grass-Short Grass Prairie	2.105	3.95	8.6																			RUS_RCH_020	8.6	12.0	0.20
									64	4.464	3.41	Unpaved	0.31															0.3		
									759	0.523	1.47	Paved	8.60															8.6		
																							855	6.00	6.00	2.4		2.4		
RUS_RCH_030		0		0.150	Grass-Short Grass Prairie	0.500																					RUS_RCH_030	10.0	6.0	0.10
RUS_RCH_040		1,724	100	0.150	Grass-Short Grass Prairie	1.610	3.95	9.6																			RUS_RCH_040	9.6	13.7	0.23
									798	0.721	1.73	Paved	7.71															7.7		
									826	2.342	2.47	Unpaved	5.57															5.6		
RUS_RCH_050		0		0.150	Grass-Short Grass Prairie	0.500																					RUS_RCH_050	10.0	6.0	0.10
RUS_RCH_060		2,902	100	0.150	Grass-Short Grass Prairie	10.150	3.95	4.6																			RUS_RCH_060	4.6	8.5	0.14
									471	3.547	3.04	Unpaved	2.58															2.6		
														2,331	0.500	1224.8	249.1	0.055	5.54		5.54	7.01						7.0		

Appendix B-3

Middle Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_190		3,167	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.910	3.95	0.6																			RUS_000_190	0.6	10.7	0.18
									1,512	0.949	1.98	Paved	12.73															12.7		
																							1,605	6.00	6.00	4.5		4.5		
RUS_000_200		1,447	100	0.150	Grass-Short Grass Prairie	1.039	3.95	11.5																			RUS_000_200	11.5	10.8	0.18
									1,348	4.474	3.41	Unpaved	6.58															6.6		
RUS_000_210		2,148	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.878	3.95	0.9																			RUS_000_210	0.9	8.4	0.14
									1,259	0.960	1.99	Paved	10.54															10.5		
																							420	6.00	6.00	1.2		1.2		
														417	3.442	31.0	24.1	0.065	5.03		5.03	1.38						1.4		
RUS_000_220		845	100	0.150	Grass-Short Grass Prairie	1.137	3.95	11.1																			RUS_000_220	11.1	9.8	0.16
									748	2.197	2.39	Unpaved	5.21															5.2		
RUS_000_230		1,908	45	0.150	Grass-Short Grass Prairie	3.872	3.95	3.6																			RUS_000_230	3.6	6.8	0.11
									1,391	3.055	3.55	Paved	6.52															6.5		
																							471	6.00	6.00	1.3		1.3		
RUS_000_240		1,677	100	0.150	Grass-Short Grass Prairie	1.499	3.95	9.9																			RUS_000_240	9.9	9.5	0.16
									205	3.455	3.00	Unpaved	1.14															1.1		
									221	1.293	2.31	Paved	1.59															1.6		
																							1,150	6.00	6.00	3.2		3.2		
RUS_000_250		754	100	0.150	Grass-Short Grass Prairie	5.941	3.95	5.7																			RUS_000_250	5.7	4.9	0.08
									655	7.526	4.43	Unpaved	2.47															2.5		
RUS_000_260		514	100	0.150	Grass-Short Grass Prairie	5.690	3.95	5.8																			RUS_000_260	5.8	4.6	0.08
									414	5.398	3.75	Unpaved	1.84															1.8		
RUS_000_270		3,893	100	0.150	Grass-Short Grass Prairie	1.409	3.95	10.1																			RUS_000_270	10.1	18.2	0.30
									752	1.894	2.22	Unpaved	5.64															5.6		
														1,417	2.138	10.5	18.3	0.065	2.31		2.31	10.22						10.2		
																							1,381	6.00	6.00	3.8		3.8		
														243	9.110	11.9	8.3	0.065	8.85		8.85	0.46						0.5		
RUS_000_280		1,435	50	0.150	Grass-Short Grass Prairie	10.595	3.95	2.6																			RUS_000_280	2.6	6.6	0.11
									1,004	1.550	2.53	Paved	6.61															6.6		
									380	4.793	3.53	Unpaved	1.79															1.8		
RUS_000_290		1,931	100	0.150	Grass-Short Grass Prairie	8.438	3.95	5.0																			RUS_000_290	5.0	8.4	0.14
									157	1.504	1.98	Unpaved	1.32															1.3		
														1,673	3.209	2.0	4.1	0.045	3.64		3.64	7.65						7.7		
RUS_000_300		2,275	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.076	3.95	0.6																			RUS_000_300	0.6	4.4	0.07
									37	3.386	3.74	Paved	0.16															0.2		
									118	3.832	3.16	Unpaved	0.62															0.6		
														2,068	3.722	1.3	7.4	0.015	5.86		5.86	5.89						5.9		
RUS_000_310		3,314	100	0.150	Grass-Short Grass Prairie	0.624	3.95	14.1																			RUS_000_310	14.1	17.6	0.29
														1,362	1.210	19.7	28.6	0.045	2.84		2.84	8.01						8.0		
																							407	6.00	6.00	1.1		1.1		
														1,142	1.393	62.0	39.7	0.065	3.64		3.64	5.23						5.2		
																							301	6.00	6.00	0.8		0.8		
RUS_000_320		3,334	100	0.150	Grass-Short Grass Prairie	4.808	3.95	6.2																			RUS_000_320	6.2	10.7	0.18
									193	8.064	4.58	Unpaved	0.70															0.7		
									538	1.977	2.86	Paved	3.14															3.1		
														328	1.141	6.8	7.9	0.045	3.23		3.23	1.69						1.7		
																							2,174	6.00	6.00	6.0		6.0		
RUS_000_330		3,501	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.668	3.95	0.6																			RUS_000_330	0.6	16.2	0.27
									1,910	0.530	1.48	Paved	21.51															21.5		
																							847	6.00	6.00	2.4		2.4		
														694	0.500	152.2	33.1	0.065	4.49		4.49	2.58						2.6		
RUS_000_340		2,466	100	0.150	Grass-Short Grass Prairie	5.297	3.95	6.0																			RUS_000_340	6.0	11.6	0.19
									861	4.878	3.56	Unpaved	4.03															4.0		
									691	3.183	3.63	Paved	3.18															3.2		
									814	1.818	2.18	Unpaved	6.24															6.2		
RUS_000_350		3,685	100	0.150	Grass-Short Grass Prairie	6.822	3.95	5.4																			RUS_000_350	5.4	22.3	0.37
									1,104	2.368	2.48	Unpaved	7.41															7.4		
														1,357	0.659	0.7	2.9	0.045	1.03		1.03	21.97						22.0		
																							590	6.00	6.00	1.6		1.6		
														535	4.495	70.0	89.0	0.024	11.21		11.21	0.80						0.8		
RUS_007_010		2,493	100	0.150	Grass-Short Grass Prairie	2.146	3.95	8.6																			RUS_007_010	8.6	11.3	0.19
									807	2.173	2.38	Unpaved	5.66															5.7		
														138	0.547	4.1	10.1	0.015	4.00		4.00	0.58						0.6		
																							1,448	6.00	6.00	4.0		4.0		
RUS_007_020		3,709	28	0.150	Grass-Short Grass Prairie	1.228	3.95	3.9																			RUS_007_020	3.9	11.0	0.18
									1,293	1.397	2.40	Paved	8.97															9.0		
																							171	6.00	6.00	0.5		0.5		
														1,837	1.419			0.015	7.83	7.83	7.83	3.91						3.9		
																							380	6.00	6.00	1.1		1.1		

RUSH CREEK City of Arlington Watershed Study

Middle Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_007_030		3,847	100	0.150	Grass-Short Grass Prairie	1.065	3.95	11.3																			RUS_007_030	11.3	21.3	0.35
									1,090	0.691	1.34	Unpaved	13.55															13.5		
									791	1.474	2.47	Paved	5.34															5.3		
																							1,867	6.00	6.00	5.2		5.2		
RUS_007_040		3,613	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.497	3.95	0.5																			RUS_007_040	0.5	10.7	0.18
									273	0.714	1.72	Paved	2.65															2.6		
														1,182	2.760	4.7	11.2	0.045	3.09		3.09	6.38						6.4		
														2,106	1.153	80.2	35.5	0.065	4.24		4.24	8.28						8.3		
RUS_007_050		2,081	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_007_050	1.1	6.6	0.11
									1,310	1.877	2.79	Paved	7.84															7.8		
																							722	6.00	6.00	2.0		2.0		
RUS_007_060		972	53	0.150	Grass-Short Grass Prairie	3.873	3.95	4.1																			RUS_007_060	4.1	5.1	0.09
									777	2.448	3.18	Paved	4.07															4.1		
																							142	6.00	6.00	0.4		0.4		
RUS_007_070		3,594	100	0.150	Grass-Short Grass Prairie	5.870	3.95	5.7																			RUS_007_070	5.7	13.2	0.22
														2,102	1.452	15.5	27.5	0.045	2.73		2.73	12.85						12.9		
																							767	6.00	6.00	2.1		2.1		
														625	3.995	36.3	15.3	0.065	8.17		8.17	1.28						1.3		
RUS_008_010		4,459	100	0.150	Grass-Short Grass Prairie	0.755	3.95	13.0																			RUS_008_010	13.0	17.4	0.29
														1,283	1.961	2.4	4.6	0.045	3.03		3.03	7.07						7.1		
																							2,450	6.00	6.00	6.8		6.8		
														620	2.319	13.9	8.6	0.065	4.83		4.83	2.14						2.1		
RUS_009_010		3,279	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_009_010	1.1	7.1	0.12
									471	1.550	2.53	Paved	3.10															3.1		
																							2,758	6.00	6.00	7.7		7.7		
RUS_009_020		3,793	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.672	3.95	1.0																			RUS_009_020	1.0	13.0	0.22
									1,970	1.058	2.09	Paved	15.70															15.7		
																							1,774	6.00	6.00	4.9		4.9		
RUS_009_030		3,660	51	0.150	Grass-Short Grass Prairie	5.576	3.95	3.4																			RUS_009_030	3.4	9.2	0.15
									223	0.526	1.47	Paved	2.52															2.5		
																							3,387	6.00	6.00	9.4		9.4		
RUS_009_040		3,486	49	0.150	Grass-Short Grass Prairie	2.375	3.95	4.7																			RUS_009_040	4.7	14.5	0.24
									1,374	0.886	1.91	Paved	11.97															12.0		
														751	2.041	1.3	2.7	0.045	2.89		2.89	4.33						4.3		
																							435	6.00	6.00	1.2		1.2		
														878	1.504	1.4	3.3	0.015	7.01		7.01	2.09						2.1		
RUS_009_050		3,246	32	0.150	Grass-Short Grass Prairie	4.626	3.95	2.5																			RUS_009_050	2.5	11.1	0.19
									601	0.863	1.89	Paved	5.30															5.3		
																							409	6.00	6.00	1.1		1.1		
														1,290	1.118	38.9	52.1	0.045	2.88		2.88	7.46						7.5		
														914	1.796	1.1	2.8	0.015	7.24		7.24	2.11						2.1		
RUS_009_060		517	50	0.150	Grass-Short Grass Prairie	2.845	3.95	4.4																			RUS_009_060	4.4	4.1	0.07
									467	2.501	3.21	Paved	2.42															2.4		
RUS_009_070		1,305	100	0.150	Grass-Short Grass Prairie	3.928	3.95	6.7																			RUS_009_070	6.7	6.5	0.11
														1,205	2.904	11.8	14.8	0.045	4.85		4.85	4.14						4.1		
RUS_009_080		2,650	44	0.150	Grass-Short Grass Prairie	9.012	3.95	2.5																			RUS_009_080	2.5	8.3	0.14
									1,042	1.494	2.48	Paved	6.99															7.0		
																							1,563	6.00	6.00	4.3		4.3		
RUS_009_090		762	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_009_090	1.1	2.3	0.04
									712	4.332	4.23	Paved	2.80															2.8		
RUS_010_001_010		2,007	31	0.150	Grass-Short Grass Prairie	8.518	3.95	1.9																			RUS_010_001_010	1.9	6.7	0.11
									1,076	1.754	2.69	Paved	6.66															6.7		
																							900	6.00	6.00	2.5		2.5		
RUS_010_001_020		1,631	100	0.150	Grass-Short Grass Prairie	2.568	3.95	8.0																			RUS_010_001_020	8.0	10.0	0.17
									329	1.345	1.87	Unpaved	2.93															2.9		
									656	1.566	2.54	Paved	4.30															4.3		
																							546	6.00	6.00	1.5		1.5		
RUS_010_002_010		3,151	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.478	3.95	0.7																			RUS_010_002_010	0.7	7.8	0.13
									1,207	2.020	2.89	Paved	6.96															7.0		
																							1,892	6.00	6.00	5.3		5.3		
RUS_010_002_020		729	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.895	3.95	0.5																			RUS_010_002_020	0.5	2.7	0.05
									489	1.276	2.30	Paved	3.55															3.5		
																							185	6.00	6.00	0.5		0.5		
RUS_010_002_030		268	100	0.150	Grass-Short Grass Prairie	3.992	3.95	6.7																			RUS_010_002_030	6.7	4.4	0.07
									169	7.631	4.46	Unpaved	0.63															0.6		
RUS_010_003_010		3,676	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_010_003_010	1.1	8.0	0.13
									332	0.979	2.01	Paved	2.75															2.8		
																							2,801	6.00	6.00	7.8		7.8		
														493	2.674	8.4	5.6	0.065	4.95		4.95	1.66						1.7		
RUS_010_003_020		782	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.740	3.95	0.9																			RUS_010_003_020	0.9	2.3	0.04
									732	4.394	4.26	Paved	2.86															2.9		
RUS_010_004_010		3,696	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.845	3.95	0.6																			RUS_010_004_010	0.6	13.0	0.22
									2,116	1.071	2.10	Paved	16.76															16.8		
																							1,530	6.00	6.00	4.3		4.3		
RUS_010_004_020		2,840	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_010_004_020	1.1	10.7	0.18
									1,248	0.837	1.86	Paved	11.18															11.2		
														695	0.500	87.1	32.9	0.055	3.67		3.67	3.16						3.2		
																							846	6.00	6.00	2.4		2.4		
RUS_010_004_030		5,070	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_010_004_030	15.4	23.5	0.39
														2,154	0.945	13.7	23.5	0.045	2.25		2.25	15.95						15.9		
																							2,815	6.00	6.00	7.8		7.8		

Middle Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_010_004_040		1,541	41	0.150	Grass-Short Grass Prairie	2.765	3.95	3.8																			RUS_010_004_040	3.8	6.1	0.10
									977	2.681	3.33	Paved	4.89															4.9		
																							523	6.00	6.00	1.5		1.5		
RUS_010_010		4,841	100	0.150	Grass-Short Grass Prairie	4.537	3.95	6.4																			RUS_010_010	6.4	19.4	0.32
									213	3.976	3.22	Unpaved	1.10															1.1		
														2,090	1.163	3.5	9.2	0.045	1.89		1.89	18.47						18.5		
																							1,312	6.00	6.00	3.6		3.6		
														646	1.756	0.7	1.6	0.015	7.25		7.25	1.49						1.5		
																							480	6.00	6.00	1.3		1.3		
RUS_010_020		343	100	0.150	Grass-Short Grass Prairie	0.525	3.95	15.1																			RUS_010_020	15.1	9.6	0.16
									241	6.397	4.08	Unpaved	0.98															1.0		
RUS_010_030		1,321	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.663	3.95	0.6																			RUS_010_030	0.6	4.5	0.08
									1,271	2.209	3.02	Paved	7.01															7.0		
RUS_010_040		1,759	100	0.150	Grass-Short Grass Prairie	4.802	3.95	6.2																			RUS_010_040	6.2	7.7	0.13
									602	1.730	2.67	Paved	3.75															3.8		
																							1,059	6.00	6.00	2.9		2.9		
RUS_011_010		2,319	100	0.150	Grass-Short Grass Prairie	2.369	3.95	8.2																			RUS_011_010	8.2	11.0	0.18
									789	2.589	2.60	Unpaved	5.07															5.1		
														1,432	1.614	56.0	26.8	0.065	4.76		4.76	5.02						5.0		
RUS_011_020		1,738	71	0.150	Grass-Short Grass Prairie	3.175	3.95	5.6																			RUS_011_020	5.6	8.0	0.13
														1,299	3.035	3.9	9.5	0.045	3.18		3.18	6.80						6.8		
																							368	6.00	6.00	1.0		1.0		
RUS_012_010		4,330	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.660	3.95	0.7																			RUS_012_010	0.7	11.2	0.19
									219	1.260	2.28	Paved	1.60															1.6		
									927	1.540	2.00	Unpaved	7.72															7.7		
																							3,133	6.00	6.00	8.7		8.7		
RUS_012_020		4,124	100	0.150	Grass-Short Grass Prairie	0.813	3.95	12.6																			RUS_012_020	12.6	16.8	0.28
									540	1.611	2.05	Unpaved	4.39															4.4		
									464	2.235	3.04	Paved	2.54															2.5		
																							3,020	6.00	6.00	8.4		8.4		
RUS_012_030		423	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.381	3.95	0.5																			RUS_012_030	0.5	1.3	0.02
									375	3.338	3.71	Paved	1.68															1.7		
RUS_013_010		2,469	100	0.150	Grass-Short Grass Prairie	1.827	3.95	9.1																			RUS_013_010	9.1	11.5	0.19
									743	1.962	2.26	Unpaved	5.48															5.5		
																							1,625	6.00	6.00	4.5		4.5		
RUS_013_020		1,511	100	0.150	Grass-Short Grass Prairie	0.590	3.95	14.4																			RUS_013_020	14.4	15.5	0.26
									1,410	1.593	2.04	Unpaved	11.54															11.5		
RUS_013_030		1,261	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_013_030	1.1	4.0	0.07
									1,212	3.168	3.62	Paved	5.58															5.6		
RUS_014_010		3,428	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.947	3.95	0.5																			RUS_014_010	0.5	12.6	0.21
														1,756	0.732	14.4	21.2	0.045	2.19		2.19	13.37						13.4		
																							528	6.00	6.00	1.5		1.5		
														1,099	1.577	11.1	16.0	0.045	3.26		3.26	5.62						5.6		
RUS_014_020		2,053	100	0.150	Grass-Short Grass Prairie	4.554	3.95	6.3																			RUS_014_020	6.3	11.4	0.19
									131	5.140	3.66	Unpaved	0.60															0.6		
									475	1.609	2.58	Paved	3.07															3.1		
									467	0.546	1.19	Unpaved	6.53															6.5		
																							882	6.00	6.00	2.5		2.5		
RUS_015_010		3,692	100	0.150	Grass-Short Grass Prairie	2.397	3.95	8.2																			RUS_015_010	8.2	15.5	0.26
									432	0.582	1.55	Paved	4.64															4.6		
																							638	6.00	6.00	1.8		1.8		
														889	1.588	22.2	56.4	0.045	2.24		2.24	6.61						6.6		
																							1,634	6.00	6.00	4.5		4.5		
RUS_015_020		2,629	100	0.150	Grass-Short Grass Prairie	2.181	3.95	8.5																			RUS_015_020	8.5	10.2	0.17
									56	2.495	2.55	Unpaved	0.37															0.4		
									388	1.870	2.78	Paved	2.33															2.3		
																							2,085	6.00	6.00	5.8		5.8		
RYA_000_010		2,853	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RYA_000_010	1.1	10.0	0.17
									1,121	0.714	1.72	Paved	10.88															10.9		
																							1,681	6.00	6.00	4.7		4.7		
RYA_000_020		5,389	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RYA_000_020	15.4	19.6	0.33
									709	2.571	2.59	Unpaved	4.57															4.6		
																							4,581	6.00	6.00	12.7		12.7		
RYA_000_030		4,581	100	0.150	Grass-Short Grass Prairie	2.566	3.95	8.0																			RYA_000_030	8.0	16.4	0.27
									1,191	1.453	1.94	Unpaved	10.21															10.2		
																							3,290	6.00	6.00	9.1		9.1		
RYA_000_040		4,283	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.387	3.95	0.7																			RYA_000_040	0.7	8.7	0.14
									575	1.727	2.67	Paved	3.59															3.6		
																							3,657	6.00	6.00	10.2		10.2		
RYA_000_050		456	100	0.150	Grass-Short Grass Prairie	2.022	3.95	8.8																			RYA_000_050	8.8	6.5	0.11
									357	3.319	2.94	Unpaved	2.02															2.0		
RYA_000_060		1,480	100	0.150	Grass-Short Grass Prairie	1.520	3.95	9.8																			RYA_000_060	9.8	11.3	0.19
									1,000	2.134	2.36	Unpaved	7.07															7.1		
									381	4.080	3.26	Unpaved	1.95															1.9		
RYA_000_070		3,198	100	0.150	Grass-Short Grass Prairie	1.235	3.95	10.7																			RYA_000_070	10.7	14.0	0.23
									937	2.236	2.41	Unpaved	6.47															6.5		
														416	2.751	23.4	15.2	0.065	5.06		5.06	1.37						1.4		
																							1,744	6.00	6.00	4.8		4.8		
RYA_000_080		1,688	100	0.150	Grass-Short Grass Prairie	2.993	3.95	7.5																			RYA_000_080	7.5	8.3	0.14
									614	3.984	4.06	Paved	2.52															2.5		
														668	1.829	1.1	7.3	0.015	3.85		3.85	2.89						2.9		
																							301	6.00	6.00	0.8		0.8		
RYA_001_010		3,045	47	0.150	Grass-Short Grass Prairie	4.536	3.95	3.5																			RYA_001_010	3.5	11.1	0.18
									1,943	1.879	2.79	Paved	11.62															11.6		
																							428	6.00	6.00	1.2		1.2		

Middle Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
														628	0.866	91.4	26.9	0.065	4.83		4.83	2.17						2.2		
RYA_001_020		1,206	100	0.150	Grass-Short Grass Prairie	1.416	3.95	10.1																			RYA_001_020	10.1	8.5	0.14
									272	2.860	2.73	Unpaved	1.66															1.7		
																							834	6.00	6.00	2.3		2.3		
TWI_000_010		3,106	35	0.150	Grass-Short Grass Prairie	5.166	3.95	2.6																			TWI_000_010	2.6	12.0	0.20
									1,530	0.931	1.96	Paved	13.00															13.0		
																							294	6.00	6.00	0.8		0.8		
														334	1.700	28.3	16.5	0.065	4.28		4.28	1.30						1.3		
																							528	6.00	6.00	1.5		1.5		
														385	1.504	6.0	10.7	0.015	8.26		8.26	0.78						0.8		
TWI_000_020		2,662	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.476	3.95	0.6																			TWI_000_020	0.6	5.3	0.09
									613	3.063	3.56	Paved	2.87															2.9		
																							1,169	6.00	6.00	3.2		3.2		
														831	1.287			0.065	6.27	6.27	6.27	2.21						2.2		
TWI_000_030		3,151	81	0.150	Grass-Short Grass Prairie	3.009	3.95	6.3																			TWI_000_030	6.3	13.7	0.23
									1,162	0.675	1.67	Paved	11.60															11.6		
																							1,294	6.00	6.00	3.6		3.6		
														613	0.900			0.065	8.10	8.10	8.10	1.26						1.3		
TWI_000_040		1,403	100	0.150	Grass-Short Grass Prairie	2.163	3.95	8.5																			TWI_000_040	8.5	11.7	0.20
									1,302	1.493	1.97	Unpaved	11.01															11.0		
TWI_000_050		3,239	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.756	3.95	0.7																			TWI_000_050	0.7	8.7	0.15
									1,619	1.929	2.82	Paved	9.56															9.6		
																							1,570	6.00	6.00	4.4		4.4		
TWI_000_060		1,818	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			TWI_000_060	15.4	15.6	0.26
									123	1.082	1.68	Unpaved	1.22															1.2		
									1,596	1.899	2.80	Paved	9.50															9.5		
TWI_000_070		4,548	100	0.150	Grass-Short Grass Prairie	0.846	3.95	12.4																			TWI_000_070	12.4	20.9	0.35
														1,040	0.500	16.7	29.1	0.045	1.61		1.61	10.73						10.7		
														350	3.561	2.7	5.1	0.015	12.41		12.41	0.47						0.5		
									689	1.863	2.77	Paved	4.14															4.1		
																							1,544	6.00	6.00	4.3		4.3		
														825	1.486	87.4	36.7	0.065	4.98		4.98	2.76						2.8		
TWI_000_080		1,292	100	0.150	Grass-Short Grass Prairie	1.766	3.95	9.3																			TWI_000_080	9.3	9.1	0.15
									348	2.510	2.56	Unpaved	2.27															2.3		
									626	2.994	3.52	Paved	2.97															3.0		
																							219	6.00	6.00	0.6		0.6		
TWI_000_090		248	100	0.150	Grass-Short Grass Prairie	12.420	3.95	4.2																			TWI_000_090	4.2	3.0	0.05
									149	3.507	3.02	Unpaved	0.82															0.8		
TWI_000_100		3,353	100	0.150	Grass-Short Grass Prairie	2.027	3.95	8.8																			TWI_000_100	8.8	12.9	0.22
									371	3.046	2.82	Unpaved	2.20															2.2		
									675	1.958	2.84	Paved	3.96															4.0		
																							1,054	6.00	6.00	2.9		2.9		
														1,154	2.465	88.5	50.1	0.065	5.25		5.25	3.66						3.7		
TWI_001_010		3,147	100	0.150	Grass-Short Grass Prairie	2.091	3.95	8.7																			TWI_001_010	8.7	14.7	0.25
														1,404	0.664	16.2	21.9	0.045	2.21		2.21	10.58						10.6		
																							1,266	6.00	6.00	3.5		3.5		
														378	0.703	50.4	25.4	0.055	3.59		3.59	1.76						1.8		
TWI_002_010		1,046	100	0.150	Grass-Short Grass Prairie	3.380	3.95	7.1																			TWI_002_010	7.1	7.6	0.13
									491	4.489	3.42	Unpaved	2.39															2.4		
									456	1.497	2.49	Paved	3.06															3.1		
TWI_003_010		2,713	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.596	3.95	0.5																			TWI_003_010	0.5	6.2	0.10
									536	4.721	4.42	Paved	2.02															2.0		
																							1,811	6.00	6.00	5.0		5.0		
														318	0.500	15.5	12.2	0.065	1.90		1.90	2.79						2.8		
TWI_004_010		3,365	26	0.150	Grass-Short Grass Prairie	6.863	3.95	1.8																			TWI_004_010	1.8	9.6	0.16
									1,111	1.285	2.30	Paved	8.04															8.0		
																							2,228	6.00	6.00	6.2		6.2		
TWI_004_020		1,374	100	0.150	Grass-Short Grass Prairie	3.757	3.95	6.9																			TWI_004_020	6.9	7.3	0.12
									678	2.389	3.14	Paved	3.60															3.6		
																							597	6.00	6.00	1.7		1.7		
TWI_004_030		1,291	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.534	3.95	0.5																			TWI_004_030	0.5	4.2	0.07
									70	4.908	4.50	Paved	0.26															0.3		
									779	2.512	2.56	Unpaved	5.08															5.1		
																							394	6.00	6.00	1.1		1.1		

Stream RC-1 Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel Flow	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_RCO_001_010		2,640	100	0.150	Grass-Short Grass Prairie	0.880	3.95	12.2																			RUS_RCO_001_010	12.2	18.7	0.31
									1,101	1.360	1.88	Unpaved	9.75															9.8		
									1,270	1.419	2.42	Paved	8.74															8.7		
																							169	6	6.00	0.5		0.5		
RUS_RCO_002_010		4,461	76	0.150	Grass-Short Grass Prairie	2.473	3.95	6.5																			RUS_RCO_002_010	6.5	18.8	0.31
									1,586	0.597	1.57	Paved	16.83															16.8		
														633	0.500	9.7	14.5	0.015	5.40		5.40	1.95						2.0		
																							2,166	6	6.00	6.0		6.0		
RUS_RCO_002_020		938	100	0.150	Grass-Short Grass Prairie	1.260	3.95	10.6																			RUS_RCO_002_020	10.6	11.8	0.20
									37	8.935	4.82	Unpaved	0.13															0.1		
									761	0.500	1.44	Paved	8.82															8.8		
																							40	6	6.00	0.1		0.1		
RUS_RCO_010		3,067	44	0.150	Grass-Short Grass Prairie	0.500	3.95	8.0																			RUS_RCO_010	8.0	17.0	0.28
									1,226	0.500	1.44	Paved	14.22															14.2		
																							1,267	6	6.00	3.5		3.5		
														530	0.604	111.4	42.6	0.065	3.38		3.38	2.61						2.6		
RUS_RCO_020		5,143	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.260	3.95	0.6																			RUS_RCO_020	0.6	10.8	0.18
									623	0.894	1.92	Paved	5.40															5.4		
																							3,093	6	6.00	8.6		8.6		
														1,377	0.566					6.81	6.81	3.37						3.4		
RUS_RCO_030		4,440	43	0.150	Grass-Short Grass Prairie	2.596	3.95	4.0																			RUS_RCO_030	4.0	14.0	0.23
									2,084	1.737	2.68	Paved	12.96															13.0		
																							2,239	6	6.00	6.2		6.2		
														74	0.701	15.0	17.0	0.015	7.65		7.65	0.16						0.2		
RUS_RCO_040		2,647	100	0.150	Grass-Short Grass Prairie	2.280	3.95	8.4																			RUS_RCO_040	8.4	11.1	0.18
									159	8.315	4.65	Unpaved	0.57															0.6		
									993	2.107	2.95	Paved	5.61															5.6		
																							1,396	6	6.00	3.9		3.9		
RUS_RCO_050		3,439	100	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_RCO_050	14.9	18.5	0.31
									82	2.425	2.51	Unpaved	0.54															0.5		
									2,551	2.552	3.25	Paved	13.09															13.1		
																							280	6	6.00	0.8		0.8		
														426	0.501	5.0	9.1	0.015	4.71		4.71	1.51						1.5		
RUS_RCO_060		2,387	100	0.150	Grass-Short Grass Prairie	1.550	3.95	9.8																			RUS_RCO_060	9.8	19.8	0.33
									526	0.547	1.19	Unpaved	7.35															7.3		
									1,273	0.510	1.45	Paved	14.61															14.6		
																							488	6	6.00	1.4		1.4		
RUS_RCO_070		4,161	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.740	3.95	0.4																			RUS_RCO_070	0.4	9.1	0.15
									2,074	3.498	3.80	Paved	9.09															9.1		
																							2,037	6	6.00	5.7		5.7		
RUS_RCO_080		2,228	100	0.150	Grass-Short Grass Prairie	2.225	3.95	8.5																			RUS_RCO_080	8.5	10.5	0.18
									1,001	1.922	2.82	Paved	5.92															5.9		
																							1,128	6	6.00	3.1		3.1		
RUS_RCO_090		4,509	87	0.150	Grass-Short Grass Prairie	2.008	3.95	7.9																			RUS_RCO_090	7.9	20.7	0.35
									3,099	1.224	2.25	Paved	22.97															23.0		
																							1,324	6	6.00	3.7		3.7		
RUS_RCO_100		2,499	49	0.150	Grass-Short Grass Prairie	0.500	3.95	8.7																			RUS_RCO_100	8.7	13.7	0.23
									1,120	0.782	1.80	Paved	10.38															10.4		
																							1,330	6	6.00	3.7		3.7		
RUS_RCO_110		2,443	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.700	3.95	1.0																			RUS_RCO_110	1.0	11.7	0.20
									1,940	0.845	1.87	Paved	17.30															17.3		
																							453	6	6.00	1.3		1.3		
RUS_RCO_120		2,934	100	0.150	Grass-Short Grass Prairie	2.150	3.95	8.6																			RUS_RCO_120	8.6	14.3	0.24
									25	9.370	4.94	Unpaved	0.08															0.1		
									2,810	2.300	3.08	Paved	15.19															15.2		
RUS_RCO_130		2,380	100	0.150	Grass-Short Grass Prairie	2.210	3.95	8.5																			RUS_RCO_130	8.5	11.7	0.19
									41	7.259	4.35	Unpaved	0.16															0.2		
									2,128	2.748	3.37	Paved	10.52															10.5		
																							111	6	6.00	0.3		0.3		
RUS_RCO_140		2,218	100	0.150	Grass-Short Grass Prairie	2.020	3.95	8.8																			RUS_RCO_140	8.8	12.1	0.20
									83	2.624	2.61	Unpaved	0.53															0.5		
									844	0.807	1.83	Paved	7.70															7.7		
									109	10.417	5.21	Unpaved	0.35															0.3		
														1,082	4.248	87.8	54.3	0.065	6.51		6.51	2.77						2.8		
RUS_RCO_150		1,740	100	0.150	Grass-Short Grass Prairie	5.250	3.95	6.0																			RUS_RCO_150	6.0	10.2	0.17
									696	5.939	3.93	Unpaved	2.95															3.0		
									812	0.761	1.77	Paved	7.63															7.6		
																							132	6	6.00	0.4		0.4		
RUS_TOA_010		3,284	100	0.150	Grass-Short Grass Prairie	0.990	3.95	11.7																			RUS_TOA_010	11.7	19.5	0.33
									101	1.302	1.84	Unpaved	0.91															0.9		
									1,287	0.500	1.44	Paved	14.92															14.9		
																							1,795	6	6.00	5.0		5.0		
RUS_TOA_020		2,315	100	0.150	Grass-Short Grass Prairie	4.880	3.95	6.2																			RUS_TOA_020	6.2	7.6	0.13
									131	3.939	3.20	Unpaved	0.68															0.7		
														346	4.051	37.2	51.7	0.045	5.35		5.35	1.08						1.1		
														114	2.516	12.4	36.3	0.015	7.70		7.70	0.25						0.2		
																							1,624	6	6.00	4.5		4.5		
RUS_TOA_030		3,613	100	0.150	Grass-Short Grass Prairie	0.830	3.95	12.5																			RUS_TOA_030	12.5	14.9	0.25

Stream RC-1 Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel Flow	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
									46	8.211	4.62	Unpaved	0.17															0.2		
									1,353	3.017	3.53	Paved	6.39															6.4		
																							240	6	6.00	0.7		0.7		
														1,874	0.970	0.6	2.1	0.015	4.25	6.09	6.09	5.13						5.1		
RUS_TOA_040		2,776	100	0.150	Grass-Short Grass Prairie	1.170	3.95	10.9																			RUS_TOA_040	10.9	**12.5**	**0.21**
									192	3.440	2.99	Unpaved	1.07															1.1		
									785	2.437	3.17	Paved	4.12															4.1		
																							1,698	6	6.00	4.7		4.7		
RUS_TOA_050		4,900	100	0.150	Grass-Short Grass Prairie	0.860	3.95	12.4																			RUS_TOA_050	12.4	**21.3**	**0.36**
									34	7.690	4.47	Unpaved	0.13															0.1		
									1,787	0.985	2.02	Paved	14.76															14.8		
																							2,979	6	6.00	8.3		8.3		
RUS_TOA_055		7,994	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.820	3.95	0.9																			RUS_TOA_055	0.9	**30.8**	**0.51**
									1,191	0.825	1.47	Unpaved	13.54															13.5		
														6,753	0.908	27.9	21.8	0.055	3.05		3.05	36.92						36.9		
RUS_TOA_060		2,926	100	0.150	Grass-Short Grass Prairie	3.350	3.95	7.2																			RUS_TOA_060	7.2	**19.4**	**0.32**
									651	0.500	1.14	Unpaved	9.51															9.5		
									2,175	1.286	2.30	Paved	15.73															15.7		
RUS_TOA_070		2,587	100	0.150	Grass-Short Grass Prairie	1.070	3.95	11.3																			RUS_TOA_070	11.3	**18.1**	**0.30**
									1,500	0.584	1.55	Paved	16.09															16.1		
																							987	6	6.00	2.7		2.7		
RUS_TOA_080		5,019	100	0.150	Grass-Short Grass Prairie	3.001	3.95	7.5																			RUS_TOA_080	7.5	**14.8**	**0.25**
									1,098	1.873	2.78	Paved	6.58															6.6		
																							3,623	6	6.00	10.1		10.1		
														204	3.945	24.7	13.3	0.065	6.88		6.88	0.49						0.5		
RUS_TOA_090		3,864	100	0.150	Grass-Short Grass Prairie	1.660	3.95	9.5																			RUS_TOA_090	9.5	**14.2**	**0.24**
									608	4.924	3.58	Unpaved	2.83															2.8		
									41	0.879	1.91	Paved	0.36															0.4		
														398	2.856	4.6	6.4	0.045	4.49		4.49	1.48						1.5		
																							303	6	6.00	0.8		0.8		
														504	1.092	6.2	12.1	0.045	2.21		2.21	3.80						3.8		
																							1,202	6	6.00	3.3		3.3		
														709	2.154	134.2	35.6	0.065	8.15		8.15	1.45						1.4		
RUS_TOA_100		4,958	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.980	3.95	0.6																			RUS_TOA_100	0.6	**9.8**	**0.16**
									713	2.022	2.89	Paved	4.11															4.1		
																							2,960	6	6.00	8.2		8.2		
														542	1.081	17.8	8.5	0.045	5.63		5.63	1.60						1.6		
														693	3.696	42.8	24.6	0.065	6.38		6.38	1.81						1.8		

Upper Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_010		3,581	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_000_010	49	**29.5**	**0.49**
									1,480	0.697	1.35	Unpaved	18.31																	
														2,001	0.981	55.2	88.3	0.050	2.16		2.16	15.45								
RUS_000_020		2,722	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.320	3.95	0.7																			RUS_000_020	12	**7.4**	**0.12**
														2,672	0.964	27.0	21.0	0.045	3.84		3.84	11.58								
RUS_000_030		3,258	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_000_030	45	**27.0**	**0.45**
									2,660	1.091	1.69	Unpaved	26.30																	
														498	0.500	121.5	110.5	0.045	2.49		2.49	3.33								
RUS_000_040		1,419	100	0.150	Grass-Short Grass Prairie	1.970	3.95	8.9																			RUS_000_040	19	**11.5**	**0.19**
									1,031	1.437	1.93	Unpaved	8.88																	
														288	0.625	53.4	22.5	0.065	3.22		3.22	1.49								
RUS_000_050		2,882	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.276	3.95	0.7																			RUS_000_050	21	**12.5**	**0.21**
									1,679	0.864	1.89	Paved	14.81																	
																							375	6	6.00	1.0				
														778	0.966	52.9	59.3	0.045	3.02		3.02	4.30								
RUS_000_060		2,425	100	0.150	Grass-Short Grass Prairie	1.115	3.95	11.1																			RUS_000_060	19	**11.6**	**0.19**
									594	2.216	2.40	Unpaved	4.12																	
																							1,053	6	6.00	2.9				
														678	1.563	115.4	87.2	0.024	9.36		9.36	1.21								
RUS_000_070		2,113	100	0.150	Grass-Short Grass Prairie	0.505	3.95	15.3																			RUS_000_070	33	**20.1**	**0.33**
									2,013	1.313	1.85	Unpaved	18.15																	
RUS_000_080		2,523	100	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_000_080	28	**16.8**	**0.28**
									673	1.797	2.16	Unpaved	5.19																	
														1,749	0.692	5.7	3.7	0.045	3.70		3.70	7.89								
RUS_000_085		3,636	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_000_085	35	**20.7**	**0.35**
									574	2.162	2.37	Unpaved	4.03																	
														2,962	0.935					3.26	3.26	15.14								
RUS_000_090		2,192	100	0.150	Grass-Short Grass Prairie	0.564	3.95	14.6																			RUS_000_090	32	**19.5**	**0.32**
									2,092	1.468	1.96	Unpaved	17.83																	
RUS_000_100		4,764	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.820	3.95	0.9																			RUS_000_100	26	**15.8**	**0.26**
									831	1.203	1.77	Unpaved	7.83																	
																							1,845	6	6.00	5.1				
														2,037	1.009	131.6	131.6	0.055	2.72		2.72	12.48								
RUS_000_110		3,764	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.540	3.95	1.1																			RUS_000_110	26	**15.7**	**0.26**
									1,699	1.018	1.63	Unpaved	17.39																	
																							262	6	6.00	0.7				
														1,753	1.778	40.8	44.7	0.045	4.15		4.15	7.03								
RUS_000_120		1,360	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.060	3.95	0.6																			RUS_000_120	10	**5.9**	**0.10**
									1,310	2.172	2.38	Unpaved	9.18																	
RUS_000_130		2,066	100.0	0.150	Grass-Short Grass Prairie	0.760	3.95	13.0																			RUS_000_130	20	**12.0**	**0.20**
														1,966	2.272	6.7	7.4	0.045	4.65		4.65	7.04								
RUS_000_140		2,863	100.0	0.150	Grass-Short Grass Prairie	1.270	3.95	10.6																			RUS_000_140	23	**14.0**	**0.23**
									928	1.585	2.03	Unpaved	7.61																	
																							1,835	6	6.00	5.1				
RUS_000_150		2,761	100.0	0.150	Grass-Short Grass Prairie	2.107	3.95	8.6																			RUS_000_150	18	**10.5**	**0.18**
									446	1.850	2.77	Paved	2.69																	
																							2,001	6	6.00	5.6				
														214	5.486	31.9	29.5	0.065	5.66		5.66	0.63								
RUS_000_160		1,865	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.940	3.95	0.8																			RUS_000_160	11	**6.4**	**0.11**
									1,089	1.328	2.34	Paved	7.75																	
																							726	6	6.00	2.0				
RUS_000_170		1,952	100.0	0.150	Grass-Short Grass Prairie	0.810	3.95	12.7																			RUS_000_170	19	**11.4**	**0.19**
									383	2.035	2.90	Paved	2.20																	
																							1,469	6	6.00	4.1				
RUS_000_180		747	100.0	0.150	Grass-Short Grass Prairie	0.940	3.95	11.9																			RUS_000_180	16	**9.4**	**0.16**
									647	3.321	2.94	Unpaved	3.67																	
RUS_016_010		2,662	100.0	0.150	Grass-Short Grass Prairie	2.835	3.95	7.7																			RUS_016_010	18	**11.0**	**0.18**
									693	1.080	2.11	Paved	5.47																	
																							1,869	6	6.00	5.2				
RUS_016_020		3,161	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.705	3.95	1.0																			RUS_016_020	20	**12.2**	**0.20**
									2,082	1.064	2.10	Paved	16.55																	
																							1,030	6	6.00	2.9				
RUS_016_030		2,587	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.680	3.95	1.0																			RUS_016_030	9	**5.6**	**0.09**
									504	2.282	3.07	Paved	2.74																	
																							2,033	6	6.00	5.6				
RUS_016_040		2,434	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.328	3.95	0.4																			RUS_016_040	9	**5.2**	**0.09**
									707	3.158	3.61	Paved	3.26																	
																							1,199	6	6.00	3.3				
														477	2.307	57.3	35.8	0.065	4.77		4.77	1.67								
RUS_017_010		677	100.0	0.150	Grass-Short Grass Prairie	0.940	3.95	11.9																			RUS_017_010	15	**8.8**	**0.15**
									145	2.091	2.33	Unpaved	1.04																	
														432	1.238	115.9	65.0	0.055	4.43		4.43	1.62								
RUS_018_010		2,702	100.0	0.150	Grass-Short Grass Prairie	1.611	3.95	9.6																			RUS_018_010	25	**15.2**	**0.25**
									1,064	1.266	1.82	Unpaved	9.77																	
														884	0.500	70.0	37.8	0.045	3.53		3.53	4.17								
																							654	6	6.00	1.8				
RUS_018_020		2,891	100.0	0.150	Grass-Short Grass Prairie	0.970	3.95	11.8																			RUS_018_020	35	**21.2**	**0.35**
									1,383	1.595	2.04	Unpaved	11.31																	
														1,408	0.795	49.3	81.0	0.050	1.91		1.91	12.29								
RUS_018_030		2,585	100.0	0.150	Grass-Short Grass Prairie	0.742	3.95	13.1																			RUS_018_030	25	**14.7**	**0.25**
									851	2.307	2.45	Unpaved	5.79																	
														1,634	1.004					4.86	4.86	5.60								
RUS_018_040		2,976	100.0	0.150	Grass-Short Grass Prairie	0.730	3.95	13.2																			RUS_018_040	31	**18.8**	**0.31**
									1,774	1.860	2.20	Unpaved	13.44																	
														1,102	0.645					3.96	3.96	4.64								

Upper Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_018_050		3,423	100.0	0.150	Grass-Short Grass Prairie	2.870	3.95	7.6																			RUS_018_050	25	14.7	0.25
									1,647	1.569	2.55	Paved	10.78																	
																							585	6	6.00	1.6				
														1,091	0.806					4.07	4.07	4.47								
RUS_019_010		2,630	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_019_010	31	18.7	0.31
									1,333	1.403	1.91	Unpaved	11.63																	
														1,197	1.247	208.7	106.6	0.055	4.73		4.73	4.21								
RUS_019_020		1,706	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.399	3.95	0.6																			RUS_019_020	11	6.9	0.11
									1,313	1.153	2.18	Paved	10.03																	
														343	3.086	46.1	28.9	0.055	6.49		6.49	0.88								
RUS_020_010		4,272	100.0	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_020_010	42	25.0	0.42
									1,285	0.500	1.14	Unpaved	18.77																	
																							2,887	6	6.00	8.0				
RUS_020_020		4,387	100.0	0.150	Grass-Short Grass Prairie	0.671	3.95	13.7																			RUS_020_020	49	29.4	0.49
									2,493	0.784	1.43	Unpaved	29.08																	
																							692	6	6.00	1.9				
														535	0.778	29.9	18.9	0.045	3.96		3.96	2.25								
														350	0.500	30.1	23.2	0.015	8.34		8.34	0.70								
														217	0.500	52.3	45.4	0.045	2.57		2.57	1.41								
RUS_020_030		3,118	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_020_030	40	23.8	0.40
									1,974	1.221	1.78	Unpaved	18.46																	
																							175	6	6.00	0.5				
														870	0.500	81.3	67.1	0.045	2.66		2.66	5.45								
RUS_020_040		4,060	100.0	0.150	Grass-Short Grass Prairie	1.630	3.95	9.6																			RUS_020_040	31	18.8	0.31
									545	2.494	2.55	Unpaved	3.56																	
														3,415	0.621					3.13	3.13	18.18								
RUS_FPT_010		3,184	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.720	3.95	0.9																			RUS_FPT_010	13	7.9	0.13
									990	1.628	2.59	Paved	6.36																	
																							1,560	6	6.00	4.3				
														585	0.500	141.8	78.1	0.024	6.54		6.54	1.49								
RUS_FPT_020		2,432	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_FPT_020	13	7.7	0.13
									1,403	2.614	2.61	Unpaved	8.96																	
																							979	6	6.00	2.7				
RUS_NET_010		2,119	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_NET_010	10	6.2	0.10
									396	0.500	1.44	Paved	4.59																	
																							1,673	6	6.00	4.6				
RUS_NET_020		710	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.380	3.95	0.4																			RUS_NET_020	5	3.3	0.05
									660	1.809	2.17	Unpaved	5.07																	
SUB_000_010		2,952	100.0	0.150	Grass-Short Grass Prairie	0.624	3.95	14.1																			SUB_000_010	36	21.3	0.36
									1,990	1.658	2.08	Unpaved	15.96																	
														862	0.500	54.1	34.2	0.055	2.60		2.60	5.53								
SUB_000_020		2,349	100.0	0.150	Grass-Short Grass Prairie	2.216	3.95	8.5																			SUB_000_020	18	10.6	0.18
									669	3.707	3.11	Unpaved	3.59																	
														1,579	0.699					4.71	4.71	5.59								
SUB_000_030		751	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.084	3.95	0.5																			SUB_000_030	5	2.8	0.05
									701	3.020	2.80	Unpaved	4.17																	
SUB_000_040		1,108	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			SUB_000_040	21	12.4	0.21
									1,008	3.731	3.12	Unpaved	5.39																	
SUB_000_050		3,726	100.0	0.150	Grass-Short Grass Prairie	0.861	3.95	12.4																			SUB_000_050	42	25.2	0.42
									2,717	1.114	1.70	Unpaved	26.59																	
														909	1.239	27.8	17.5	0.045	5.02		5.02	3.02								
SUB_000_060		3,046	100.0	0.150	Grass-Short Grass Prairie	0.725	3.95	13.2																			SUB_000_060	30	18.1	0.30
									388	1.749	2.13	Unpaved	3.03																	
														1,609	1.009	30.0	30.0	0.055	2.72		2.72	9.85								
																							371	6	6.00	1.0				
														577	0.500					3.13	3.13	3.07								
SUB_000_070		4,044	100.0	0.150	Grass-Short Grass Prairie	2.269	3.95	8.4																			SUB_000_070	31	18.8	0.31
									1,623	2.069	2.32	Unpaved	11.66																	
														2,321	0.688					3.45	3.45	11.21								
SUB_000_080		1,251	100.0	0.150	Grass-Short Grass Prairie	4.950	3.95	6.1																			SUB_000_080	13	7.9	0.13
									1,151	2.888	2.74	Unpaved	7.00																	
SUB_000_090		4,935	100.0	0.150	Grass-Short Grass Prairie	2.225	3.95	8.5																			SUB_000_090	44	26.3	0.44
									2,607	1.188	1.76	Unpaved	24.70																	
														2,228	1.010	117.4	81.9	0.055	3.46		3.46	10.72								
SUB_000_100		3,603	100.0	0.150	Grass-Short Grass Prairie	1.862	3.95	9.1																			SUB_000_100	22	13.4	0.22
									853	2.248	2.42	Unpaved	5.88																	
																							2,650	6	6.00	7.4				
SUB_000_110		1,188	100.0	0.150	Grass-Short Grass Prairie	5.241	3.95	6.0																			SUB_000_110	13	7.7	0.13
									1,088	2.712	2.66	Unpaved	6.82																	
SUB_000_115		1,627	100.0	0.150	Grass-Short Grass Prairie	4.390	3.95	6.4																			SUB_000_115	17	10.2	0.17
									1,527	2.211	2.40	Unpaved	10.61																	
SUB_000_120		4,452	100.0	0.150	Grass-Short Grass Prairie	1.910	3.95	9.0																			SUB_000_120	31	18.7	0.31
									1,388	1.701	2.10	Unpaved	10.99																	
														2,964	1.129	52.1	27.2	0.055	4.44		4.44	11.12								
SUB_000_130		2,603	100.0	0.150	Grass-Short Grass Prairie	0.558	3.95	14.7																			SUB_000_130	28	17.0	0.28
									1,125	1.420	1.92	Unpaved	9.75																	
																							1,378	6	6.00	3.8				
SUB_000_140		2,769	100.0	0.150	Grass-Short Grass Prairie	1.720	3.95	9.4																			SUB_000_140	23	13.8	0.23
									795	2.961	2.78	Unpaved	4.77																	
														1,873	0.500					3.52	3.52	8.87								
SUB_000_150		2,065	100.0	0.150	Grass-Short Grass Prairie	1.166	3.95	10.9																			SUB_000_150	22	13.1	0.22
									858	2.360	2.48	Unpaved	5.77																	
														1,107	0.961					3.65	3.65	5.05								
SUB_000_155		2,374	100.0	0.150	Grass-Short Grass Prairie	1.673	3.95	9.5																			SUB_000_155	21	12.4	0.21
									979	2.472	2.54	Unpaved	6.43																	
														1,296	1.214					4.50	4.50	4.80								

Upper Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
SUB_000_160		1,428	100.0	0.150	Grass-Short Grass Prairie	5.050	3.95	6.1																			SUB_000_160	14	8.6	0.14
									1,328	2.789	2.69	Unpaved	8.21																	
SUB_000_170		4,539	100.0	0.150	Grass-Short Grass Prairie	0.760	3.95	13.0																			SUB_000_170	27	16.5	0.27
														4,057	1.095	60.1	34.1	0.045	5.05		5.05	13.38								
																							382	6	6.00	1.1				
SUB_000_180		2,240	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.639	3.95	1.0																			SUB_000_180	12	7.3	0.12
									768	0.976	2.01	Paved	6.38																	
																							713	6	6.00	2.0				
														709	3.297	40.2	39.5	0.065	4.21		4.21	2.80								
SUB_000_190		3,147	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.975	3.95	0.8																			SUB_000_190	16	9.8	0.16
									2,056	1.796	2.72	Paved	12.58																	
																							1,041	6	6.00	2.9				
SUB_000_200		3,651	100.0	0.150	Grass-Short Grass Prairie	1.627	3.95	9.6																			SUB_000_200	32	19.0	0.32
									1,716	1.266	1.82	Unpaved	15.75																	
																							719	6	6.00	2.0				
														798	0.717	14.7	9.3	0.015	11.40		11.40	1.17								
														318	0.500	32.8	39.8	0.055	1.68		1.68	3.15								
SUB_000_210		2,926	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.600	3.95	0.7																			SUB_000_210	15	8.7	0.15
									1,139	2.044	2.31	Unpaved	8.23																	
														1,737	1.113	23.7	9.7	0.055	5.17		5.17	5.60								
SUB_000_220		3,608	100.0	0.150	Grass-Short Grass Prairie	0.970	3.95	11.8																			SUB_000_220	37	22.0	0.37
									2,227	1.681	2.09	Unpaved	17.74																	
														1,281	0.500			0.055		3.01	3.01	7.09								
SUB_000_230		3,351	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.382	3.95	0.5																			SUB_000_230	18	11.0	0.18
									499	1.903	2.80	Paved	2.97																	
														1,659	0.930			0.055		3.15	3.15	8.78								
														1,143	0.764			0.024		3.15	3.15	6.05								
SUB_000_240		808	100.0	0.150	Grass-Short Grass Prairie	2.188	3.95	8.5																			SUB_000_240	12	7.3	0.12
									199	2.898	2.75	Unpaved	1.21																	
									510	2.798	3.40	Paved	2.50																	
SUB_000_250		4,052	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.954	3.95	0.8																			SUB_000_250	22	13.3	0.22
									1,369	0.907	1.94	Paved	11.79																	
																							1,947	6	6.00	5.4				
														686	0.500	25.1	19.5	0.045	2.77		2.77	4.13								
SUB_000_260		3,034	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			SUB_000_260	18	11.0	0.18
									1,007	0.500	1.44	Paved	11.68																	
																							1,977	6	6.00	5.5				
SUB_000_270		3,885	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.059	3.95	0.5																			SUB_000_270	25	14.8	0.25
									427	0.668	1.66	Paved	4.28																	
									1,399	0.940	1.56	Unpaved	14.90																	
														585	0.500	32.1	19.5	0.015	9.80		9.80	0.99								
																							1,423	6	6.00	4.0				
SUB_000_280		904	100.0	0.150	Grass-Short Grass Prairie	1.560	3.95	9.7																			SUB_000_280	16	9.8	0.16
									804	1.604	2.04	Unpaved	6.56																	
SUB_000_290		2,946	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			SUB_000_290	14	8.4	0.14
									1,206	1.448	2.45	Paved	8.22																	
																							1,690	6	6.00	4.7				
SUB_000_300		2,628	100.0	0.150	Grass-Short Grass Prairie	2.520	3.95	8.0																			SUB_000_300	18	10.8	0.18
									775	1.557	2.54	Paved	5.09																	
																							1,752	6	6.00	4.9				
SUB_001_001_010		3,113	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			SUB_001_001_010	27	16.5	0.27
									1,389	2.257	3.05	Paved	7.58																	
																							1,624	6	6.00	4.5				
SUB_001_001_020		651	100.0	0.150	Grass-Short Grass Prairie	4.907	3.95	6.2																			SUB_001_001_020	10	6.0	0.10
									551	2.216	2.40	Unpaved	3.82																	
SUB_001_010		3,004	100.0	0.150	Grass-Short Grass Prairie	2.600	3.95	7.9																			SUB_001_010	21	12.6	0.21
									1,073	2.633	2.62	Unpaved	6.83																	
																							826	6	6.00	2.3				
														1,005	0.701	155.8	61.4	0.055	4.22		4.22	3.97								
SUB_001_020		1,504	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.060	3.95	0.8																			SUB_001_020	6	3.8	0.06
									656	2.658	3.31	Paved	3.30																	
																							798	6	6.00	2.2				
SUB_002_010		1,878	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.000	3.95	0.5																			SUB_002_010	10	5.9	0.10
									1,004	3.108	2.84	Unpaved	5.88																	
														824	1.055	36.3	21.2	0.055	3.98		3.98	3.45								
SUB_002_020		876	100.0	0.150	Grass-Short Grass Prairie	1.160	3.95	11.0																			SUB_002_020	16	9.8	0.16
									776	2.300	2.45	Unpaved	5.29																	
SUB_003_010		1,857	100.0	0.150	Grass-Short Grass Prairie	1.299	3.95	10.5																			SUB_003_010	17	10.0	0.17
									326	1.666	2.62	Paved	2.07																	
																							503	6	6.00	1.4				
														928	1.088	15.3	5.4	0.055	5.66		5.66	2.73								
SUB_003_020		3,531	100.0	0.150	Grass-Short Grass Prairie	2.835	3.95	7.7																			SUB_003_020	22	13.1	0.22
									756	1.938	2.25	Unpaved	5.61																	
																							1,941	6	6.00	5.4				
														735	0.872	17.7	12.7	0.045	3.86		3.86	3.17								
SUB_003_030		2,118	54.0	0.150	Grass-Short Grass Prairie	1.130	3.95	6.8																			SUB_003_030	17	10.1	0.17
														2,064	1.087	25.7	26.0	0.045	3.43		3.43	10.03								
SUB_003_040		3,148	100.0	0.150	Grass-Short Grass Prairie	1.235	3.95	10.7																			SUB_003_040	26	15.6	0.26
									1,344	1.078	2.11	Paved	10.61																	
																							1,704	6	6.00	4.7				
SUB_004_010		2,840	100.0	0.150	Grass-Short Grass Prairie	2.056	3.95	8.7																			SUB_004_010	40	24.2	0.40
									1,389	1.503	1.98	Unpaved	11.70																	
														1,351	0.500	17.7	38.9	0.055	1.13		1.13	19.89								
SUB_004_020		2,607	100.0	0.150	Grass-Short Grass Prairie	1.223	3.95	10.7																			SUB_004_020	25	15.1	0.25
									1,471	2.471	2.54	Unpaved	9.67																	

Upper Rush Existing Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
														1,037	0.692					3.63	3.63	4.76								
SUB_004_030		1,858	100.0	0.150	Grass-Short Grass Prairie	1.710	3.95	9.4																			SUB_004_030	21	**12.9**	**0.21**
									1,247	1.819	2.18	Unpaved	9.55																	
														511	0.535	17.2	10.6	0.045	3.34		3.34	2.55								
SUB_004_040		3,401	100.0	0.150	Grass-Short Grass Prairie	0.770	3.95	12.9																			SUB_004_040	39	**23.4**	**0.39**
									2,165	1.524	1.99	Unpaved	18.11																	
														1,136	0.500					2.36	2.36	8.02								
SUB_004_050		2,930	100.0	0.150	Grass-Short Grass Prairie	3.040	3.95	7.5																			SUB_004_050	27	**16.4**	**0.27**
									1,202	0.887	1.52	Unpaved	13.19																	
														1,628	1.014					4.03	4.03	6.73								
SUB_004_060		1,854	100.0	0.150	Grass-Short Grass Prairie	5.133	3.95	6.0																			SUB_004_060	21	**12.8**	**0.21**
									1,023	1.224	1.79	Unpaved	9.55																	
														730	0.594					2.15	2.15	5.66								
SUB_004_070		2,708	100.0	0.150	Grass-Short Grass Prairie	2.518	3.95	8.0																			SUB_004_070	26	**15.7**	**0.26**
									2,111	1.351	2.36	Paved	14.89																	
														497	1.657					2.54	2.54	3.26								
SUB_004_080		2,193	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.160	3.95	0.8																			SUB_004_080	14	**8.3**	**0.14**
									980	1.330	1.86	Unpaved	8.78																	
														1,163	1.518	38.9	24.6	0.055	4.53		4.53	4.28								
SUB_004_090		2,238	100.0	0.150	Grass-Short Grass Prairie	1.645	3.95	9.5																			SUB_004_090	22	**13.2**	**0.22**
									1,034	3.480	3.01	Unpaved	5.73																	
														1,104	0.500					2.71	2.71	6.79								
SUB_004_100		1,932	100.0	0.150	Grass-Short Grass Prairie	1.507	3.95	9.9																			SUB_004_100	23	**13.9**	**0.23**
									1,832	2.006	2.29	Unpaved	13.36																	
SUB_004_110		3,333	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			SUB_004_110	40	**24.3**	**0.40**
									1,518	0.807	1.45	Unpaved	17.45																	
														1,716	0.734					3.72	3.72	7.69								
SUB_004_120		3,147	100.0	0.150	Grass-Short Grass Prairie	3.897	3.95	6.8																			SUB_004_120	31	**18.8**	**0.31**
									2,122	1.617	2.05	Unpaved	17.24																	
														925	0.500					2.09	2.09	7.38								
SUB_004_130		1,986	100.0	0.150	Grass-Short Grass Prairie	2.640	3.95	7.9																			SUB_004_130	21	**12.7**	**0.21**
									1,140	2.854	2.73	Unpaved	6.97																	
														746	1.432	24.8	52.8	0.055	1.96		1.96	6.34								

Kee Branch Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
KEE_000_010		3,087	100	0.150	Grass-Short Grass Prairie	4.900	3.95	6.2																			KEE_000_010	6.2	24.8	0.41
									832	0.921	1.95	Paved	7.11															7.1		
														2,155	0.675	4.8	15.0	0.045	1.28		1.28	28.11						28.1		
KEE_000_020		4,034	100	0.150	Grass-Short Grass Prairie	0.690	3.95	13.5																			KEE_000_020	13.5	20.3	0.34
									663	1.437	2.44	Paved	4.54															4.5		
														1,092	2.116	5.9	10.7	0.045	3.24		3.24	5.62						5.6		
														2,179	0.588				3.58	3.58	3.58	10.14						10.1		
KEE_000_030		2,234	54	0.150	Grass-Short Grass Prairie	2.034	3.95	5.4																			KEE_000_030	5.4	12.3	0.21
									641	0.772	1.79	Paved	5.98															6.0		
														1,538	1.048	5.5	7.4	0.045	2.78		2.78	9.23						9.2		
KEE_000_040		1,299	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.510	3.95	0.5																			KEE_000_040	0.5	3.4	0.06
									622	2.811	3.41	Paved	3.04															3.0		
														628	2.524	17.4	19.3	0.045	4.92		4.92	2.13						2.1		
KEE_000_050		1,757	50	0.150	Grass-Short Grass Prairie	2.962	3.95	4.3																			KEE_000_050	4.3	7.6	0.13
									467	2.557	3.25	Paved	2.39															2.4		
														1,241	2.807	5.4	10.7	0.045	3.52		3.52	5.87						5.9		
KEE_000_060		3,065	50	0.150	Grass-Short Grass Prairie	2.965	3.95	4.3																			KEE_000_060	4.3	14.7	0.24
									537	3.404	3.75	Paved	2.39															2.4		
									2,268	1.273	2.29	Paved	16.48															16.5		
														210	1.455	7.7	13.8	0.045	2.70		2.70	1.30						1.3		
KEE_000_070		3,566	100	0.150	Grass-Short Grass Prairie	11.424	3.95	4.4																			KEE_000_070	4.4	14.2	0.24
									2,853	1.794	2.72	Paved	17.46															17.5		
														613	1.330	17.9	5.4	0.065	5.89		5.89	1.73						1.7		
KEE_000_080		2,338	100	0.150	Grass-Short Grass Prairie	2.610	3.95	7.9																			KEE_000_080	7.9	16.7	0.28
									1,517	2.118	2.96	Paved	8.55															8.5		
														721	0.552	13.0	45.9	0.045	1.06		1.06	11.33						11.3		
KEE_000_090		3,947	100	0.150	Grass-Short Grass Prairie	2.650	3.95	7.9																			KEE_000_090	7.9	13.4	0.22
									60	5.609	4.81	Paved	0.21															0.2		
									742	3.436	3.77	Paved	3.28															3.3		
														1,214	1.388	8.5	10.4	0.045	3.42		3.42	5.92						5.9		
																							1,831	6	6.00	5.1		5.1		
KEE_000_100		1,777	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.017	3.95	0.8																			KEE_000_100	0.8	6.6	0.11
									695	0.674	1.67	Paved	6.94															6.9		
																							862	6	6.00	2.4		2.4		
														170	0.631	33.7	11.6	0.065	3.72		3.72	0.76						0.8		
KEE_000_110		3,519	100	0.150	Grass-Short Grass Prairie	5.080	3.95	6.1																			KEE_000_110	6.1	11.3	0.19
									1,546	2.758	3.38	Paved	7.63															7.6		
																							1,874	6	6.00	5.2		5.2		
KEE_000_120		4,341	100	0.150	Grass-Short Grass Prairie	2.208	3.95	8.5																			KEE_000_120	8.5	13.0	0.22
									94	3.605	3.86	Paved	0.41															0.4		
									818	2.235	3.04	Paved	4.49															4.5		
																							1,289	6	6.00	3.6		3.6		
														2,040	1.426	5.6	11.7	0.015	7.29		7.29	4.66						4.7		
KEE_000_130		3,538	100	0.150	Grass-Short Grass Prairie	6.001	3.95	5.7																			KEE_000_130	5.7	10.5	0.17
									627	3.096	3.58	Paved	2.92															2.9		
									459	2.576	3.26	Paved	2.34															2.3		
																							2,351	6	6.00	6.5		6.5		
KEE_000_140		1,799	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			KEE_000_140	15.4	12.8	0.21
									344	1.009	2.04	Paved	2.81															2.8		
																							552	6	6.00	1.5		1.5		
														803	0.768				8.33	8.33	8.33	1.61						1.6		
KEE_000_150		4,517	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	7.139	3.95	0.4																			KEE_000_150	0.4	10.2	0.17
									1,044	2.939	3.49	Paved	4.99															5.0		
																							1,498	6	6.00	4.2		4.2		
														443	0.875	6.0	10.5	0.015	6.37		6.37	1.16						1.2		
														1,482	1.334	17.1	16.4	0.045	3.93		3.93	6.28						6.3		
KEE_000_160		4,517	60	0.150	Grass-Short Grass Prairie	5.796	3.95	3.8																			KEE_000_160	3.8	11.6	0.19
									1,732	3.077	3.57	Paved	8.10															8.1		
																							2,518	6	6.00	7.0		7.0		
														208	0.525				7.26	7.26	7.26	0.48						0.5		
KEE_000_170		2,524	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.440	3.95	0.4																			KEE_000_170	0.4	13.0	0.22
														2,474	0.860	11.8	23.5	0.045	1.94		1.94	21.25						21.3		
KEE_000_180		2,661	100	0.150	Grass-Short Grass Prairie	1.856	3.95	9.1																			KEE_000_180	9.1	15.9	0.27
									1,466	1.436	2.44	Paved	10.03															10.0		
														1,095	1.316	7.7	14.7	0.045	2.47		2.47	7.39						7.4		
KEE_000_190		2,588	100	0.150	Grass-Short Grass Prairie	7.600	3.95	5.2																			KEE_000_190	5.2	7.9	0.13
									993	4.530	4.33	Paved	3.83															3.8		
																							1,495	6	6.00	4.2		4.2		
KEE_000_200		3,249	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.191	3.95	0.8																			KEE_000_200	0.8	6.6	0.11
									398	1.732	2.68	Paved	2.48															2.5		
																							2,801	6	6.00	7.8		7.8		
KEE_000_210		1,254	100	0.150	Grass-Short Grass Prairie	4.450	3.95	6.4																			KEE_000_210	6.4	6.5	0.11
									1,023	4.303	4.22	Paved	4.04															4.0		
																							131	6	6.00	0.4		0.4		
KEE_000_220		5,107	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.505	3.95	1.1																			KEE_000_220	1.1	9.6	0.16
									325	2.255	3.05	Paved	1.77															1.8		
																							2,301	6	6.00	6.4		6.4		
														530	0.952	22.7	11.2	0.050	4.67		4.67	1.89						1.9		
														310	2.812	2.7	4.6	0.015	11.70		11.70	0.44						0.4		
																							1,592	6	6.00	4.4		4.4		
KEE_000_230		3,201	100	0.150	Grass-Short Grass Prairie	5.898	3.95	5.7																			KEE_000_230	5.7	10.2	0.17
									279	2.645	3.31	Paved	1.41															1.4		
														1,817	2.361	1.3	7.3	0.015	4.89		4.89	6.20						6.2		

Kee Branch Ultimate Time of Concentration Calculations

HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Overland Flow: Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Shallow Concentrated Flow: Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Channel Flow: Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Flow: Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Totals: Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
																							286	6	6.00	0.8		0.8		
														720	1.506	16.8	9.2	0.065	4.19		4.19	2.87						2.9		
KEE_000_240		2,832	100	0.150	Grass-Short Grass Prairie	4.426	3.95	6.4																			KEE_000_240	6.4	11.8	0.20
									756	3.744	3.93	Paved	3.20															3.2		
									1,590	2.170	2.99	Paved	8.85															8.8		
																							109	6	6.00	0.3		0.3		
														277	2.964	23.3	14.1	0.065	5.52		5.52	0.84						0.8		
KEE_000_250		3,233	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	7.220	3.95	0.4																			KEE_000_250	0.4	6.6	0.11
									1,454	4.093	4.11	Paved	5.89															5.9		
																							1,729	6	6.00	4.8		4.8		
KEE_000_260		4,376	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	5.026	3.95	0.4																			KEE_000_260	0.4	9.9	0.16
									2,638	3.363	3.73	Paved	11.79															11.8		
																							144	6	6.00	0.4		0.4		
														1,545	1.122				6.71	6.71	6.71	3.84						3.8		
KEE_000_270		3,616	50	0.150	Grass-Short Grass Prairie	0.500	3.95	8.8																			KEE_000_270	8.8	12.7	0.21
														3,313	2.212	15.0	16.0	0.045	4.71		4.71	11.72						11.7		
																							253	6	6.00	0.7		0.7		
KEE_000_280		3,496	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.999	3.95	0.8																			KEE_000_280	0.8	6.4	0.11
									69	0.795	1.81	Paved	0.63															0.6		
																							1,688	6	6.00	4.7		4.7		
														452	2.424	1.5	3.5	0.015	8.72		8.72	0.86						0.9		
																							678	6	6.00	1.9		1.9		
														558	2.041	7.7	5.5	0.050	5.33		5.33	1.75						1.7		
KEE_000_290		2,617	100	0.150	Grass-Short Grass Prairie	1.000	3.95	11.6																			KEE_000_290	11.6	13.3	0.22
									733	1.173	2.20	Paved	5.55															5.5		
																							1,784	6	6.00	5.0		5.0		
KEE_000_300		3,375	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.367	3.95	0.6																			KEE_000_300	0.6	9.7	0.16
									780	1.743	2.68	Paved	4.84															4.8		
																							505	6	6.00	1.4		1.4		
									1,065	1.768	2.70	Paved	6.57															6.6		
																							976	6	6.00	2.7		2.7		
KEE_000_310		2,056	100	0.150	Grass-Short Grass Prairie	10.600	3.95	4.5																			KEE_000_310	4.5	8.5	0.14
									1,744	2.453	3.18	Paved	9.13															9.1		
																							212	6	6.00	0.6		0.6		
KEE_000_320		5,147	60	0.150	Grass-Short Grass Prairie	7.099	3.95	3.5																			KEE_000_320	3.5	14.9	0.25
									1,321	1.910	2.81	Paved	7.84															7.8		
									1,642	1.903	2.80	Paved	9.76															9.8		
														1,946	2.147	1.0	1.8	0.015	9.78		9.78	3.32						3.3		
														177	2.605	56.7	16.6	0.065	8.38		8.38	0.35						0.4		
KEE_000_330		1,743	100	0.150	Grass-Short Grass Prairie	1.485	3.95	9.9																			KEE_000_330	9.9	9.4	0.16
														1,643	3.018	8.0	10.5	0.045	4.79		4.79	5.71						5.7		
KEE_000_340		2,174	30	0.150	Grass-Short Grass Prairie	2.694	3.95	3.0																			KEE_000_340	3.0	7.8	0.13
									738	1.273	2.29	Paved	5.36															5.4		
														1,228	3.625	4.1	6.6	0.045	4.62		4.62	4.43						4.4		
														178	11.612	16.9	6.3	0.065	15.05		15.05	0.20						0.2		
KEE_001_010		3,375	100	0.150	Grass-Short Grass Prairie	6.151	3.95	5.6																			KEE_001_010	5.6	10.4	0.17
									1,063	3.256	3.67	Paved	4.83															4.8		
														218	1.637	1.5	4.7	0.045	1.99		1.99	1.83						1.8		
														526	0.799	7.8	7.9	0.015	8.81		8.81	1.00						1.0		
																							1,468	6	6.00	4.1		4.1		
KEE_001_020		1,554	100	0.150	Grass-Short Grass Prairie	3.210	3.95	7.3																			KEE_001_020	7.3	7.7	0.13
									867	3.248	3.66	Paved	3.94															3.9		
																							100	6	6.00	0.3		0.3		
														486	2.993	54.2	30.5	0.065	5.82		5.82	1.39						1.4		
KEE_001_030		1,340	100	0.150	Grass-Short Grass Prairie	4.670	3.95	6.3																			KEE_001_030	6.3	6.8	0.11
									634	2.329	3.10	Paved	3.41															3.4		
														606	1.393	15.4	8.3	0.045	5.92		5.92	1.71						1.7		
KEE_002_010		2,469	100	0.150	Grass-Short Grass Prairie	1.870	3.95	9.1																			KEE_002_010	9.1	10.2	0.17
									626	3.214	3.64	Paved	2.86															2.9		
														655	3.682	12.2	9.4	0.065	5.22		5.22	2.09						2.1		
																							1,088	6	6.00	3.0		3.0		
KEE_002_020		1,349	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			KEE_002_020	15.4	12.7	0.21
									179	1.891	2.80	Paved	1.07															1.1		
									465	1.488	2.48	Paved	3.13															3.1		
																							605	6	6.00	1.7		1.7		
KEE_004_010		3,383	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.300	3.95	0.7																			KEE_004_010	0.7	13.5	0.22
									2,242	1.156	2.19	Paved	17.10															17.1		
														314	1.003	3.9	5.6	0.015	7.88		7.88	0.66						0.7		
									311	0.665	1.66	Paved	3.13															3.1		
														466	1.303	4.5	6.3	0.015	9.02		9.02	0.86						0.9		
KEE_004_020		3,028	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.630	3.95	0.7																			KEE_004_020	0.7	6.9	0.12
									1,199	2.240	3.04	Paved	6.57															6.6		
																							1,066	6	6.00	3.0		3.0		
														713	0.635				9.01	9.01	9.01	1.32						1.3		
KEE_004_030		3,428	100	0.150	Grass-Short Grass Prairie	1.682	3.95	9.5																			KEE_004_030	9.5	15.1	0.25
									546	2.474	3.20	Paved	2.85															2.8		
									1,024	1.090	2.12	Paved	8.04															8.0		
																							1,757	6	6.00	4.9		4.9		
KEE_004_040		1,473	87	0.150	Grass-Short Grass Prairie	3.045	3.95	6.7																			KEE_004_040	6.7	6.9	0.12
									138	2.116	2.96	Paved	0.78															0.8		
									170	1.563	2.54	Paved	1.11															1.1		
																							1,078	6	6.00	3.0		3.0		
KEE_004_050		1,412	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.520	3.95	0.7																			KEE_004_050	0.7	3.9	0.06
									894	2.662	3.32	Paved	4.49															4.5		
																							468	6	6.00	1.3		1.3		
KEE_005_010		3,260	100	0.150	Grass-Short Grass Prairie	2.370	3.95	8.2																			KEE_005_010	8.2	11.3	0.19
									404	1.556	2.54	Paved	2.66															2.7		
														483	2.007	58.5	23.7	0.065	5.94		5.94	1.36						1.4		
														463	0.970	84.0	38.7	0.050	4.93		4.93	1.57						1.6		
																							1,811	6	6.00	5.0		5.0		

Kee Branch Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
KEE_005_020		3,664	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.000	3.95	0.8																			KEE_005_020	0.8	**7.9**	**0.13**
														906	1.467	29.3	31.9	0.045	3.80		3.80	3.98						4.0		
																							867	6	6.00	2.4		2.4		
														1,840	1.124	30.1	17.2	0.045	5.09		5.09	6.03						6.0		
KEE_005_030		3,020	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.980	3.95	0.5																			KEE_005_030	0.5	**9.6**	**0.16**
									305	1.304	2.32	Paved	2.19															2.2		
									774	1.280	2.30	Paved	5.61															5.6		
																							589	6	6.00	1.6		1.6		
														802	0.753	10.3	6.1	0.065	2.83		2.83	4.72						4.7		
																							500	6	6.00	1.4		1.4		
KEE_005_040		1,614	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.500	3.95	0.7																			KEE_005_040	0.7	**3.7**	**0.06**
									1,171	4.716	4.41	Paved	4.42															4.4		
																							393	6	6.00	1.1		1.1		
KEE_KB1_001_010		2,967	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.847	3.95	0.6																			KEE_KB1_001_010	0.6	**5.9**	**0.10**
									453	2.351	3.12	Paved	2.42															2.4		
																							2,464	6	6.00	6.8		6.8		
KEE_KB1_001_020		2,885	100	0.150	Grass-Short Grass Prairie	4.280	3.95	6.5																			KEE_KB1_001_020	6.5	**10.0**	**0.17**
									94	4.891	4.50	Paved	0.35															0.3		
									629	1.486	2.48	Paved	4.23															4.2		
														97	1.107	5.9	10.5	0.015	7.14		7.14	0.23						0.2		
																							237	6	6.00	0.7		0.7		
														451	0.747	2.9	3.5	0.015	7.46		7.46	1.01						1.0		
														532	1.340				5.50	5.50	5.50	1.61						1.6		
														426	1.319				9.20	9.20	9.20	0.77						0.8		
														318	1.195				3.90	3.90	3.90	1.36						1.4		
KEE_KB1_001_030		696	100	0.150	Grass-Short Grass Prairie	3.406	3.95	7.1																			KEE_KB1_001_030	7.1	**5.5**	**0.09**
									596	5.342	4.70	Paved	2.11															2.1		
KEE_KB1_010		3,559	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.067	3.95	0.8																			KEE_KB1_010	0.8	**6.2**	**0.10**
									647	5.107	4.59	Paved	2.35															2.3		
																							703	6	6.00	2.0		2.0		
														1,234	1.280	3.5	6.3	0.015	7.61		7.61	2.70						2.7		
																							925	6	6.00	2.6		2.6		
KEE_KB1_020		4,817	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.810	3.95	0.5																			KEE_KB1_020	0.5	**10.1**	**0.17**
									770	1.529	2.51	Paved	5.11															5.1		
																							3,998	6	6.00	11.1		11.1		
KEE_KB1_030		4,936	50	0.150	Grass-Short Grass Prairie	4.172	3.95	3.8																			KEE_KB1_030	3.8	**13.1**	**0.22**
									810	2.627	3.29	Paved	4.10															4.1		
																							129	6	6.00	0.4		0.4		
														2,566	1.746	8.7	9.0	0.045	4.26		4.26	10.03						10.0		
														232	1.415	1.6	2.7	0.015	8.34		8.34	0.46						0.5		
																							1,149	6	6.00	3.2		3.2		
KEE_KB1_040		3,426	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.843	3.95	0.9																			KEE_KB1_040	0.9	**7.9**	**0.13**
									1,487	3.011	3.53	Paved	7.03															7.0		
																							1,890	6	6.00	5.3		5.3		
KEE_KB1_050		2,596	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.620	3.95	1.0																			KEE_KB1_050	1.0	**5.3**	**0.09**
														872	2.111	17.5	18.4	0.045	4.66		4.66	3.12						3.1		
																							1,674	6	6.00	4.7		4.7		
KEE_KB1_060		3,711	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.080	3.95	0.5																			KEE_KB1_060	0.5	**9.4**	**0.16**
									231	0.917	1.95	Paved	1.98															2.0		
									149	5.852	4.92	Paved	0.51															0.5		
														493	0.637	1.8	5.9	0.015	3.57		3.57	2.30						2.3		
														1,246	1.791	4.8	6.5	0.045	3.63		3.63	5.72						5.7		
														371	2.868	4.0	3.4	0.065	4.35		4.35	1.42						1.4		
																							1,171	6	6.00	3.3		3.3		

Lower Rush Ultimate Time of Concentration Calculations

HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Overland Flow: Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Shallow Concentrated Flow: Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Channel Flow: Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Flow: Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Totals: Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
PAN_000_010		4,143	100	0.150	Grass-Short Grass Prairie	3.879	3.95	6.8																			PAN_000_010	6.8	14.7	0.24
									702	2.327	3.10	Paved	3.77															3.8		
									804	0.925	1.96	Paved	6.85															6.9		
																							2,535	6.00	6.00	7.0		7.0		
PAN_000_020		2,536	100	0.150	Grass-Short Grass Prairie	1.424	3.95	10.1																			PAN_000_020	10.1	12.0	0.20
									962	1.806	2.73	Paved	5.87															5.9		
																							1,474	6.00	6.00	4.1		4.1		
PAN_000_030		4,382	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.843	3.95	0.9																			PAN_000_030	0.9	11.6	0.19
									1,377	0.938	1.97	Paved	11.66															11.7		
														2,352	0.667			0.015	7.63	7.63	7.63	5.14						5.1		
																							604	6.00	6.00	1.7		1.7		
PAN_000_040		4,196	100	0.150	Grass-Short Grass Prairie	6.914	3.95	5.4																			PAN_000_040	5.4	12.9	0.21
									113	8.527	5.94	Paved	0.32															0.3		
									1,282	1.628	2.59	Paved	8.24															8.2		
																							2,698	6.00	6.00	7.5		7.5		
PAN_000_050		4,121	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.571	3.95	1.0																			PAN_000_050	1.0	10.5	0.18
									491	0.544	1.50	Paved	5.46															5.5		
																							2,846	6.00	6.00	7.9		7.9		
														734	0.704			0.065	3.86	3.86	3.86	3.17						3.2		
PAN_000_060		6,759	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.284	3.95	0.5																			PAN_000_060	0.5	14.4	0.24
									1,691	2.112	2.95	Paved	9.54															9.5		
																							5,018	6.00	6.00	13.9		13.9		
PAN_000_070		5,912	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.579	3.95	1.0																			PAN_000_070	1.0	11.4	0.19
									732	2.560	3.25	Paved	3.75															3.8		
																							5,130	6.00	6.00	14.3		14.3		
PAN_000_080		2,612	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			PAN_000_080	1.1	11.8	0.20
									2,221	1.112	2.14	Paved	17.27															17.3		
														341	4.360	16.3	17.5	0.065	4.57		4.57	1.24						1.2		
PAN_000_090		5,232	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.011	3.95	0.6																			PAN_000_090	0.6	13.5	0.23
									854	0.500	1.44	Paved	9.90															9.9		
																							4,328	6.00	6.00	12.0		12.0		
PAN_000_100		2,042	100	0.150	Grass-Short Grass Prairie	0.748	3.95	13.1																			PAN_000_100	13.1	15.1	0.25
									258	0.786	1.80	Paved	2.39															2.4		
									1,685	2.054	2.91	Paved	9.64															9.6		
PAN_000_110		2,848	100	0.150	Grass-Short Grass Prairie	2.376	3.95	8.2																			PAN_000_110	8.2	12.3	0.20
									958	1.160	2.19	Paved	7.29															7.3		
																							1,790	6.00	6.00	5.0		5.0		
PAN_000_120		2,917	100	0.150	Grass-Short Grass Prairie	2.420	3.95	8.2																			PAN_000_120	8.2	10.8	0.18
									228	3.247	3.66	Paved	1.04															1.0		
									714	2.717	3.35	Paved	3.55															3.6		
																							1,876	6.00	6.00	5.2		5.2		
PAN_000_130		3,301	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.457	3.95	0.7																			PAN_000_130	0.7	18.4	0.31
									601	3.667	3.89	Paved	2.57															2.6		
														2,650	0.886	10.4	27.8	0.045	1.61		1.61	27.39						27.4		
RUS_000_360		3,176	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_000_360	1.1	8.0	0.13
									1,427	2.340	3.11	Paved	7.65															7.6		
																							1,497	6.00	6.00	4.2		4.2		
														202	8.113	17.4	14.8	0.065	7.28		7.28	0.46						0.5		
RUS_000_370		2,146	50	0.150	Grass-Short Grass Prairie	3.750	3.95	3.9																			RUS_000_370	3.9	7.8	0.13
									171	8.763	6.02	Paved	0.47															0.5		
														1,927	3.223	6.1	12.1	0.045	3.77		3.77	8.53						8.5		
RUS_000_380		674	100	0.150	Grass-Short Grass Prairie	4.730	3.95	6.2																			RUS_000_380	6.2	4.7	0.08
									573	7.984	5.74	Paved	1.66															1.7		
RUS_000_390		2,658	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.672	3.95	1.0																			RUS_000_390	1.0	11.0	0.18
									1,257	0.579	1.55	Paved	13.54															13.5		
																							1,352	6.00	6.00	3.8		3.8		
RUS_000_400		1,435	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.646	3.95	1.0																			RUS_000_400	1.0	3.1	0.05
									478	5.274	4.67	Paved	1.71															1.7		
																							907	6.00	6.00	2.5		2.5		
RUS_000_410		4,837	100	0.150	Grass-Short Grass Prairie	3.876	3.95	6.8																			RUS_000_410	6.8	12.9	0.22
									1,216	3.291	3.69	Paved	5.50															5.5		
																							508	6.00	6.00	1.4		1.4		
														2,220	1.962	1.7	5.2	0.015	6.48		6.48	5.71						5.7		
																							791	6.00	6.00	2.2		2.2		
RUS_000_420		2,655	50	0.150	Grass-Short Grass Prairie	1.100	3.95	6.4																			RUS_000_420	6.4	8.8	0.15
									375	2.429	3.17	Paved	1.97															2.0		
																							2,231	6.00	6.00	6.2		6.2		
RUS_000_430		1,770	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.928	3.95	0.4																			RUS_000_430	0.4	4.3	0.07
									1,220	3.529	3.82	Paved	5.32															5.3		
																							501	6.00	6.00	1.4		1.4		
RUS_000_440		391	100	0.150	Grass-Short Grass Prairie	3.155	3.95	7.3																			RUS_000_440	7.3	5.5	0.09
									287	2.680	2.64	Unpaved	1.81															1.8		
RUS_000_450		5,802	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.109	3.95	0.8																			RUS_000_450	0.8	13.9	0.23
									929	0.722	1.73	Paved	8.96															9.0		
																							4,822	6.00	6.00	13.4		13.4		
RUS_000_460		2,409	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.526	3.95	1.1																			RUS_000_460	1.1	7.6	0.13
									653	0.621	1.60	Paved	6.79															6.8		
																							1,707	6.00	6.00	4.7		4.7		

Lower Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_470														1,965	0.500	100.4	58.2	0.050	3.03		3.03	10.80					RUS_000_470	10.8	6.5	0.11
RUS_000_480														297	0.500	104.1	60.6	0.065	2.32		2.32	2.13					RUS_000_480	10.0	6.0	0.10
RUS_000_500		856												856	1.719	140.3	36.4	0.065	7.39		7.39	1.93					RUS_000_500	10.0	6.0	0.10
RUS_000_510		3,401	50	0.150	Grass-Short Grass Prairie	3.981	3.95	3.8																			RUS_000_510	3.8	10.5	0.18
									1,647	4.446	4.29	Paved	6.40															6.4		
														1,704	1.624	2.5	2.8	0.045	3.89		3.89	7.30						7.3		
RUS_000_520		689	100	0.150	Grass-Short Grass Prairie	1.650	3.95	9.5																			RUS_000_520	9.5	7.5	0.13
									589	2.603	3.28	Paved	2.99															3.0		
RUS_000_530		5,641	100	0.150	Grass-Short Grass Prairie	7.835	3.95	5.1																			RUS_000_530	5.1	35.1	0.59
									3,227	0.500	1.44	Paved	37.42															37.4		
														2,315	0.500	105.9	58.3	0.065	2.41		2.41	15.99						16.0		
RUS_003_010		2,458	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.628	3.95	1.0																			RUS_003_010	1.0	5.7	0.10
									731	2.369	3.13	Paved	3.89															3.9		
																							1,676	6.00	6.00	4.7		4.7		
RUS_003_020		3,664	98	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.191	3.95	1.0																			RUS_003_020	1.0	7.8	0.13
									740	2.179	3.00	Paved	4.11															4.1		
																							2,826	6.00	6.00	7.9		7.9		
RUS_004_001_010		2,717	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.713	3.95	0.9																			RUS_004_001_010	0.9	14.8	0.25
														2,666	0.585	9.2	14.4	0.045	1.88		1.88	23.68						23.7		
RUS_004_001_020		2,250	100	0.150	Grass-Short Grass Prairie	5.307	3.95	6.0																			RUS_004_001_020	6.0	8.3	0.14
									560	2.970	3.50	Paved	2.66															2.7		
														455	1.358	8.0	10.2	0.045	3.27		3.27	2.32						2.3		
														1,135	0.777			0.065	6.66	6.66	6.66	2.84						2.8		
RUS_004_001_030		2,222	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.375	3.95	0.7																			RUS_004_001_030	0.7	5.1	0.09
														891	3.344	5.5	13.7	0.045	3.29		3.29	4.52						4.5		
														1,278	2.228			0.065	6.43	6.43	6.43	3.31						3.3		
RUS_004_001_040		592	100	0.150	Grass-Short Grass Prairie	5.366	3.95	5.9																			RUS_004_001_040	5.9	4.3	0.07
									494	10.075	6.45	Paved	1.28															1.3		
RUS_004_010		3,537	77	0.150	Grass-Short Grass Prairie	3.850	3.95	5.5																			RUS_004_010	5.5	15.2	0.25
									100	2.405	3.15	Paved	0.53															0.5		
									614	0.914	1.94	Paved	5.27															5.3		
																							515	6.00	6.00	1.4		1.4		
														2,231	0.537	23.8	17.9	0.045	2.94		2.94	12.65						12.7		
RUS_004_020		2,424	100	0.150	Grass-Short Grass Prairie	1.256	3.95	10.6																			RUS_004_020	10.6	18.1	0.30
									1,076	0.506	1.45	Paved	12.40															12.4		
														1,246	0.850	8.3	9.0	0.045	2.89		2.89	7.19						7.2		
RUS_004_030		1,793	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.391	3.95	0.7																			RUS_004_030	0.7	7.3	0.12
									1,188	1.434	2.43	Paved	8.13															8.1		
														556	0.500			0.055	2.87	2.87	2.87	3.23						3.2		
RUS_004_040		1,909	100	0.150	Grass-Short Grass Prairie	2.384	3.95	8.2																			RUS_004_040	8.2	12.9	0.21
									726	0.500	1.44	Paved	8.42															8.4		
														1,084	3.061			0.045	3.73	3.73	3.73	4.84						4.8		
RUS_004_050		2,011	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.174	3.95	0.5																			RUS_004_050	0.5	4.6	0.08
									646	3.614	3.86	Paved	2.79															2.8		
									638	1.985	2.86	Paved	3.71															3.7		
														677	2.910	311.4	137.2	0.024	18.29		18.29	0.62						0.6		
RUS_005_002_010		3,287	60	0.150	Grass-Short Grass Prairie	9.203	3.95	3.2																			RUS_005_002_010	3.2	8.9	0.15
									1,438	3.112	3.59	Paved	6.68															6.7		
																							1,789	6.00	6.00	5.0		5.0		
RUS_005_010		3,228	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.900	3.95	0.6																			RUS_005_010	0.6	9.7	0.16
									1,760	1.571	2.55	Paved	11.51															11.5		
																							1,417	6.00	6.00	3.9		3.9		
RUS_005_020		1,426	56	0.150	Grass-Short Grass Prairie	8.478	3.95	3.1																			RUS_005_020	3.1	6.0	0.10
									755	2.282	3.07	Paved	4.10															4.1		
									615	3.197	3.63	Paved	2.82															2.8		
RUS_005_030		3,299	81	0.150	Grass-Short Grass Prairie	1.329	3.95	8.8																			RUS_005_030	8.8	13.4	0.22
									1,672	2.126	2.96	Paved	9.40															9.4		
																							1,257	6.00	6.00	3.5		3.5		
														289	2.204	1.4	3.6	0.015	7.83		7.83	0.62						0.6		
RUS_005_040		1,121	100	0.150	Grass-Short Grass Prairie	4.480	3.95	6.4																			RUS_005_040	6.4	7.7	0.13
									804	1.240	2.26	Paved	5.92															5.9		
																							217	6.00	6.00	0.6		0.6		
RUS_005_050		4,115	100	0.150	Grass-Short Grass Prairie	5.308	3.95	6.0																			RUS_005_050	6.0	14.4	0.24
														2,095	1.936	1.9	4.0	0.045	2.76		2.76	12.67						12.7		
																							1,921	6.00	6.00	5.3		5.3		
RUS_005_060		1,894	100	0.150	Grass-Short Grass Prairie	3.446	3.95	7.1																			RUS_005_060	7.1	12.3	0.20
									1,441	0.916	1.95	Paved	12.34															12.3		
																							354	6.00	6.00	1.0		1.0		
RUS_005_070		671	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.864	3.95	0.9																			RUS_005_070	0.9	2.6	0.04
									621	2.199	3.01	Paved	3.43															3.4		
RUS_006_010		2,750	38	0.011	Smooth Surface (concrete, asphalt, bare earth)	5.841	3.95	0.3																			RUS_006_010	0.3	5.9	0.10
									677	3.792	3.96	Paved	2.85															2.9		
														2,035	2.914	45.5	30.9	0.065	5.06		5.06	6.70						6.7		
RUS_RC2_010		4,624	100	0.150	Grass-Short Grass Prairie	5.259	3.95	6.0																			RUS_RC2_010	6.0	12.7	0.21
									1,085	2.477	3.20	Paved	5.65															5.7		
																							3,440	6.00	6.00	9.6		9.6		
RUS_RC2_020		3,281	49	0.150	Grass-Short Grass Prairie	3.496	3.95	4.0																			RUS_RC2_020	4.0	10.0	0.17
														1,238	2.750	3.3	8.5	0.045	2.90		2.90	7.11						7.1		
																							1,994	6.00	6.00	5.5		5.5		
RUS_RC2_030		2,943	100	0.150	Grass-Short Grass Prairie	3.122	3.95	7.4																			RUS_RC2_030	7.4	11.5	0.19
														1,631	1.945	4.2	7.2	0.045	3.21		3.21	8.46						8.5		

Lower Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
																							1,212	6.00	6.00	3.4		3.4		
RUS_RC2_040		2,905	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_040	1.1	9.0	0.15
									1,470	1.426	2.43	Paved	10.09															10.1		
																							1,385	6.00	6.00	3.8		3.8		
RUS_RC2_050		3,579	100	0.150	Grass-Short Grass Prairie	4.446	3.95	6.4																			RUS_RC2_050	6.4	12.9	0.21
									398	2.553	3.25	Paved	2.04															2.0		
									963	1.234	2.26	Paved	7.11															7.1		
																							2,117	6.00	6.00	5.9		5.9		
RUS_RC2_060		3,143	65	0.150	Grass-Short Grass Prairie	8.975	3.95	3.4																			RUS_RC2_060	3.4	8.3	0.14
									860	4.128	4.13	Paved	3.47															3.5		
																							1,110	6.00	6.00	3.1		3.1		
														740	2.606	14.8	11.5	0.065	4.39		4.39	2.81						2.8		
																							369	6.00	6.00	1.0		1.0		
RUS_RC2_070		2,142	42	0.150	Grass-Short Grass Prairie	20.469	3.95	1.7																			RUS_RC2_070	1.7	6.4	0.11
									1,843	3.404	3.75	Paved	8.19															8.2		
																							257	6.00	6.00	0.7		0.7		
RUS_RC2_080		1,482	100	0.150	Grass-Short Grass Prairie	7.150	3.95	5.3																			RUS_RC2_080	5.3	6.3	0.11
									418	5.026	4.56	Paved	1.53															1.5		
									612	2.960	3.50	Paved	2.92															2.9		
														353	6.538	10.7	7.9	0.065	7.17		7.17	0.82						0.8		
RUS_RC2_085		2,259	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_085	1.1	6.0	0.10
									762	1.644	2.61	Paved	4.87															4.9		
																							1,448	6.00	6.00	4.0		4.0		
RUS_RC2_090		3,894	83	0.150	Grass-Short Grass Prairie	8.486	3.95	4.3																			RUS_RC2_090	4.3	13.6	0.23
									1,159	3.169	3.62	Paved	5.34															5.3		
																							238	6.00	6.00	0.7		0.7		
														1,893	1.779	19.5	21.2	0.065	2.90		2.90	10.89						10.9		
																							522	6.00	6.00	1.5		1.5		
RUS_RC2_100		2,889	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.922	3.95	0.6																			RUS_RC2_100	0.6	6.9	0.12
									1,351	2.673	3.32	Paved	6.77															6.8		
																							1,489	6.00	6.00	4.1		4.1		
RUS_RC2_110		1,928	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_RC2_110	1.1	4.8	0.08
									1,114	3.655	3.89	Paved	4.78															4.8		
																							764	6.00	6.00	2.1		2.1		
RUS_RCH_010		3,584	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	7.263	3.95	0.4																			RUS_RCH_010	0.4	6.1	0.10
														1,780	4.622	19.8	14.9	0.065	5.95		5.95	4.98						5.0		
																							1,755	6.00	6.00	4.9		4.9		
RUS_RCH_020		1,780	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.105	3.95	0.6																			RUS_RCH_020	0.6	7.2	0.12
									114	4.464	4.29	Paved	0.44															0.4		
									759	0.523	1.47	Paved	8.60															8.6		

Appendix B-3

Middle Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_190		3,167	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.916	3.95	0.6																			RUS_000_190	0.6	**10.7**	**0.18**
									1,512	0.949	1.98	Paved	12.73															12.7		
																							1,605	6.00	6.00	4.5		4.5		
RUS_000_200		1,447	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.039	3.95	0.8																			RUS_000_200	0.8	**3.7**	**0.06**
									1,398	4.474	4.30	Paved	5.42															5.4		
RUS_000_210		2,148	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.882	3.95	0.9																			RUS_000_210	0.9	**8.4**	**0.14**
									1,259	0.960	1.99	Paved	10.54															10.5		
																							420	6.00	6.00	1.2		1.2		
														417	3.444	31.0	24.1	0.065	5.03		5.03	1.38						1.4		
RUS_000_220		845	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.145	3.95	0.8																			RUS_000_220	0.8	**3.1**	**0.05**
									798	2.196	3.01	Paved	4.42															4.4		
RUS_000_230		1,908	45	0.150	Grass-Short Grass Prairie	3.872	3.95	3.6																			RUS_000_230	3.6	**6.8**	**0.11**
									1,391	3.055	3.55	Paved	6.52															6.5		
																							471	6.00	6.00	1.3		1.3		
RUS_000_240		1,677	100	0.150	Grass-Short Grass Prairie	1.500	3.95	9.9																			RUS_000_240	9.9	**9.4**	**0.16**
									205	3.455	3.78	Paved	0.90															0.9		
									221	1.290	2.31	Paved	1.60															1.6		
																							1,150	6.00	6.00	3.2		3.2		
RUS_000_250		754	100	0.150	Grass-Short Grass Prairie	5.942	3.95	5.7																			RUS_000_250	5.7	**4.6**	**0.08**
									655	7.526	5.58	Paved	1.96															2.0		
RUS_000_260		514	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	5.690	3.95	0.4																			RUS_000_260	0.4	**3.2**	**0.05**
									1,414	5.398	4.72	Paved	4.99															5.0		
RUS_000_270		3,893	100	0.150	Grass-Short Grass Prairie	1.409	3.95	10.1																			RUS_000_270	10.1	**17.4**	**0.29**
									752	1.895	2.80	Paved	4.48															4.5		
														1,417	2.138	10.5	18.3	0.065	2.31		2.31	10.22						10.2		
																							1,381	6.00	6.00	3.8		3.8		
														243	13.051	11.9	8.3	0.065	10.59		10.59	0.38						0.4		
RUS_000_280		1,435	50	0.150	Grass-Short Grass Prairie	10.597	3.95	2.6																			RUS_000_280	2.6	**6.4**	**0.11**
									1,004	1.551	2.53	Paved	6.61															6.6		
									380	4.792	4.45	Paved	1.42															1.4		
RUS_000_290		1,931	100	0.150	Grass-Short Grass Prairie	8.440	3.95	5.0																			RUS_000_290	5.0	**8.2**	**0.14**
									157	1.502	2.49	Paved	1.05															1.1		
														1,673	3.209	2.0	4.1	0.045	3.64		3.64	7.65						7.7		
RUS_000_300		2,275	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.074	3.95	0.6																			RUS_000_300	0.6	**4.3**	**0.07**
									37	3.377	3.74	Paved	0.17															0.2		
									118	3.837	3.98	Paved	0.49															0.5		
														2,068	3.722	1.3	7.4	0.015	5.86		5.86	5.89						5.9		
RUS_000_310		3,314	100	0.150	Grass-Short Grass Prairie	0.621	3.95	14.1																			RUS_000_310	14.1	**17.6**	**0.29**
														1,362	1.210	19.7	28.6	0.045	2.84		2.84	8.01						8.0		
																							407	6.00	6.00	1.1		1.1		
														1,142	1.393	62.0	39.7	0.065	3.64		3.64	5.23						5.2		
																							301	6.00	6.00	0.8		0.8		
RUS_000_320		3,334	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.801	3.95	0.4																			RUS_000_320	0.4	**7.2**	**0.12**
									243	8.064	5.77	Paved	0.70															0.7		
									538	1.979	2.86	Paved	3.14															3.1		
														328	1.140	6.8	7.9	0.045	3.23		3.23	1.70						1.7		
																							2,174	6.00	6.00	6.0		6.0		
RUS_000_330		3,501	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.676	3.95	0.6																			RUS_000_330	0.6	**16.2**	**0.27**
									1,910	0.530	1.48	Paved	21.51															21.5		
																							847	6.00	6.00	2.4		2.4		
														694	0.500	152.2	33.1	0.065	4.49		4.49	2.58						2.6		
RUS_000_340		2,466	100	0.150	Grass-Short Grass Prairie	5.295	3.95	6.0																			RUS_000_340	6.0	**10.4**	**0.17**
									861	4.877	4.49	Paved	3.20															3.2		
									691	3.183	3.63	Paved	3.18															3.2		
									814	1.818	2.74	Paved	4.95															4.9		
RUS_000_350		3,685	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.820	3.95	0.4																			RUS_000_350	0.4	**18.6**	**0.31**
									1,154	2.369	3.13	Paved	6.15															6.1		
														1,357	0.659	0.7	2.9	0.045	1.03		1.03	21.97						22.0		
																							590	6.00	6.00	1.6		1.6		
														535	4.495	70.0	89.0	0.024	11.21		11.21	0.80						0.8		
RUS_007_010		2,493	100	0.150	Grass-Short Grass Prairie	2.155	3.95	8.6																			RUS_007_010	8.6	**10.6**	**0.18**
									807	2.173	3.00	Paved	4.49															4.5		
														138	0.543	4.1	10.1	0.015	3.98		3.98	0.58						0.6		
																							1,448	6.00	6.00	4.0		4.0		
RUS_007_020		3,709	28	0.150	Grass-Short Grass Prairie	1.232	3.95	3.9																			RUS_007_020	3.9	**11.0**	**0.18**
									1,293	1.397	2.40	Paved	8.97															9.0		
																							171	6.00	6.00	0.5		0.5		
														1,837	1.419			0.015	7.83	7.83	7.83	3.91						3.9		
																							380	6.00	6.00	1.1		1.1		

Middle Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_007_030		3,847	100	0.150	Grass-Short Grass Prairie	1.067	3.95	11.3																			RUS_007_030	11.3	19.6	0.33
									1,090	0.691	1.69	Paved	10.75															10.8		
									791	1.475	2.47	Paved	5.34															5.3		
																							1,867	6.00	6.00	5.2		5.2		
RUS_007_040		3,613	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.499	3.95	0.5																			RUS_007_040	0.5	10.7	0.18
									273	0.712	1.72	Paved	2.65															2.7		
														1,182	2.761	4.7	11.2	0.045	3.09		3.09	6.38						6.4		
														2,106	1.153	80.2	35.5	0.065	4.24		4.24	8.28						8.3		
RUS_007_050		2,081	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_007_050	1.1	6.6	0.11
									1,310	1.878	2.79	Paved	7.84															7.8		
																							722	6.00	6.00	2.0		2.0		
RUS_007_060		972	53	0.150	Grass-Short Grass Prairie	3.872	3.95	4.1																			RUS_007_060	4.1	5.1	0.09
									777	2.448	3.18	Paved	4.07															4.1		
																							142	6.00	6.00	0.4		0.4		
RUS_007_070		3,594	100	0.150	Grass-Short Grass Prairie	5.870	3.95	5.7																			RUS_007_070	5.7	13.2	0.22
														2,102	1.452	15.5	27.5	0.045	2.73		2.73	12.85						12.9		
																							767	6.00	6.00	2.1		2.1		
														625	3.995	36.3	15.3	0.065	8.17		8.17	1.28						1.3		
RUS_008_010		4,459	100	0.150	Grass-Short Grass Prairie	0.750	3.95	13.1																			RUS_008_010	13.1	17.4	0.29
														1,283	1.961	2.4	4.6	0.045	3.03		3.03	7.07						7.1		
																							2,450	6.00	6.00	6.8		6.8		
														620	2.319	13.9	8.6	0.065	4.83		4.83	2.14						2.1		
RUS_009_010		3,279	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_009_010	1.1	7.1	0.12
									471	1.549	2.53	Paved	3.10															3.1		
																							2,758	6.00	6.00	7.7		7.7		
RUS_009_020		3,793	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.675	3.95	1.0																			RUS_009_020	1.0	13.0	0.22
									1,970	1.058	2.09	Paved	15.70															15.7		
																							1,774	6.00	6.00	4.9		4.9		
RUS_009_030		3,660	51	0.150	Grass-Short Grass Prairie	5.583	3.95	3.4																			RUS_009_030	3.4	9.2	0.15
									223	0.525	1.47	Paved	2.52															2.5		
																							3,387	6.00	6.00	9.4		9.4		
RUS_009_040		3,486	49	0.150	Grass-Short Grass Prairie	2.355	3.95	4.7																			RUS_009_040	4.7	14.6	0.24
									1,374	0.886	1.91	Paved	11.97															12.0		
														751	2.041	1.3	2.7	0.045	2.89		2.89	4.33						4.3		
																							435	6.00	6.00	1.2		1.2		
														878	1.504	1.4	3.3	0.015	7.01		7.01	2.09						2.1		
RUS_009_050		3,246	32	0.150	Grass-Short Grass Prairie	4.626	3.95	2.5																			RUS_009_050	2.5	11.1	0.19
									601	0.863	1.89	Paved	5.30															5.3		
																							409	6.00	6.00	1.1		1.1		
														1,290	1.118	38.9	52.1	0.045	2.88		2.88	7.46						7.5		
														914	1.797	1.1	2.8	0.015	7.24		7.24	2.10						2.1		
RUS_009_060		517	50	0.150	Grass-Short Grass Prairie	2.840	3.95	4.4																			RUS_009_060	4.4	4.1	0.07
									467	2.501	3.21	Paved	2.42															2.4		
RUS_009_070		1,305	100	0.150	Grass-Short Grass Prairie	3.928	3.95	6.7																			RUS_009_070	6.7	6.5	0.11
														1,205	2.903	11.8	14.8	0.045	4.85		4.85	4.14						4.1		
RUS_009_080		2,650	44	0.150	Grass-Short Grass Prairie	9.014	3.95	2.5																			RUS_009_080	2.5	8.3	0.14
									1,042	1.494	2.48	Paved	6.99															7.0		
																							1,563	6.00	6.00	4.3		4.3		
RUS_009_090		762	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_009_090	1.1	2.3	0.04
									712	4.333	4.23	Paved	2.80															2.8		
RUS_010_001_010		2,007	31	0.150	Grass-Short Grass Prairie	8.520	3.95	1.9																			RUS_010_001_010	1.9	6.7	0.11
									1,076	1.754	2.69	Paved	6.66															6.7		
																							900	6.00	6.00	2.5		2.5		
RUS_010_001_020		1,631	100	0.150	Grass-Short Grass Prairie	2.562	3.95	8.0																			RUS_010_001_020	8.0	9.7	0.16
									329	1.347	2.36	Paved	2.32															2.3		
									656	1.565	2.54	Paved	4.30															4.3		
																							546	6.00	6.00	1.5		1.5		
RUS_010_002_010		3,151	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.465	3.95	0.7																			RUS_010_002_010	0.7	7.8	0.13
									1,207	2.020	2.89	Paved	6.96															7.0		
																							1,892	6.00	6.00	5.3		5.3		
RUS_010_002_020		729	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.894	3.95	0.5																			RUS_010_002_020	0.5	2.7	0.05
									489	1.275	2.30	Paved	3.55															3.6		
																							185	6.00	6.00	0.5		0.5		
RUS_010_002_030		268	100	0.150	Grass-Short Grass Prairie	3.989	3.95	6.7																			RUS_010_002_030	6.7	4.3	0.07
									169	7.628	5.61	Paved	0.50															0.5		
RUS_010_003_010		3,676	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_010_003_010	1.1	8.0	0.13
									332	0.978	2.01	Paved	2.75															2.8		
																							2,801	6.00	6.00	7.8		7.8		
														493	2.675	8.4	5.6	0.065	4.95		4.95	1.66						1.7		
RUS_010_003_020		782	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.729	3.95	0.9																			RUS_010_003_020	0.9	2.3	0.04
									732	4.395	4.26	Paved	2.86															2.9		
RUS_010_004_010		3,696	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.845	3.95	0.6																			RUS_010_004_010	0.6	13.0	0.22
									2,116	1.071	2.10	Paved	16.76															16.8		
																							1,530	6.00	6.00	4.3		4.3		
RUS_010_004_020		2,840	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_010_004_020	1.1	10.7	0.18
									1,248	0.837	1.86	Paved	11.18															11.2		
														695	0.500	87.1	32.9	0.055	3.67		3.67	3.16						3.2		
																							846	6.00	6.00	2.4		2.4		
RUS_010_004_030		5,070	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_010_004_030	15.4	23.5	0.39
														2,154	0.945	13.7	23.5	0.045	2.25		2.25	15.95						15.9		
																							2,815	6.00	6.00	7.8		7.8		

Middle Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_010_004_040		1,541	41	0.150	Grass-Short Grass Prairie	2.760	3.95	3.8																			RUS_010_004_040	3.8	6.1	0.10
									977	2.681	3.33	Paved	4.89															4.9		
																							523	6.00	6.00	1.5		1.5		
RUS_010_010		4,841	100	0.150	Grass-Short Grass Prairie	4.538	3.95	6.4																			RUS_010_010	6.4	19.3	0.32
									213	3.979	4.05	Paved	0.88															0.9		
														2,090	1.163	3.5	9.2	0.045	1.89		1.89	18.47						18.5		
																							1,312	6.00	6.00	3.6		3.6		
														646	1.756	0.7	1.6	0.015	7.25		7.25	1.49						1.5		
																							480	6.00	6.00	1.3		1.3		
RUS_010_020		343	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.520	3.95	1.1																			RUS_010_020	1.1	1.2	0.02
									291	6.399	5.14	Paved	0.94															0.9		
RUS_010_030		1,321	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.650	3.95	0.6																			RUS_010_030	0.6	4.5	0.08
									1,271	2.210	3.02	Paved	7.01															7.0		
RUS_010_040		1,759	100	0.150	Grass-Short Grass Prairie	4.801	3.95	6.2																			RUS_010_040	6.2	7.7	0.13
									602	1.729	2.67	Paved	3.75															3.8		
																							1,059	6.00	6.00	2.9		2.9		
RUS_011_010		2,319	100	0.150	Grass-Short Grass Prairie	2.375	3.95	8.2																			RUS_011_010	8.2	10.4	0.17
									789	2.588	3.27	Paved	4.02															4.0		
														1,432	1.614	56.0	26.8	0.065	4.76		4.76	5.02						5.0		
RUS_011_020		1,738	71	0.150	Grass-Short Grass Prairie	3.174	3.95	5.6																			RUS_011_020	5.6	8.0	0.13
														1,299	3.035	3.9	9.5	0.045	3.18		3.18	6.80						6.8		
																							368	6.00	6.00	1.0		1.0		
RUS_012_010		4,330	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.659	3.95	0.7																			RUS_012_010	0.7	10.3	0.17
									219	1.259	2.28	Paved	1.60															1.6		
									927	1.540	2.52	Paved	6.12															6.1		
																							3,133	6.00	6.00	8.7		8.7		
RUS_012_020		4,124	100	0.150	Grass-Short Grass Prairie	0.808	3.95	12.7																			RUS_012_020	12.7	16.3	0.27
									540	1.612	2.58	Paved	3.49															3.5		
									464	2.235	3.04	Paved	2.54															2.5		
																							3,020	6.00	6.00	8.4		8.4		
RUS_012_030		423	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.373	3.95	0.5																			RUS_012_030	0.5	1.3	0.02
									375	3.337	3.71	Paved	1.68															1.7		
RUS_013_010		2,469	100	0.150	Grass-Short Grass Prairie	1.822	3.95	9.2																			RUS_013_010	9.2	10.8	0.18
									743	1.961	2.85	Paved	4.35															4.4		
																							1,625	6.00	6.00	4.5		4.5		
RUS_013_020		1,511	100	0.150	Grass-Short Grass Prairie	0.587	3.95	14.4																			RUS_013_020	14.4	14.1	0.24
									1,410	1.594	2.57	Paved	9.16															9.2		
RUS_013_030		1,261	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_013_030	1.1	4.0	0.07
									1,212	3.168	3.62	Paved	5.58															5.6		
RUS_014_010		3,428	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.951	3.95	0.5																			RUS_014_010	0.5	12.6	0.21
														1,756	0.731	14.4	21.2	0.045	2.19		2.19	13.38						13.4		
																							528	6.00	6.00	1.5		1.5		
														1,099	1.577	11.1	16.0	0.045	3.26		3.26	5.62						5.6		
RUS_014_020		2,053	100	0.150	Grass-Short Grass Prairie	4.552	3.95	6.3																			RUS_014_020	6.3	10.5	0.18
									131	5.141	4.61	Paved	0.47															0.5		
									475	1.609	2.58	Paved	3.07															3.1		
									467	0.546	1.50	Paved	5.18															5.2		
																							882	6.00	6.00	2.5		2.5		
RUS_015_010		3,692	100	0.150	Grass-Short Grass Prairie	2.398	3.95	8.2																			RUS_015_010	8.2	15.5	0.26
									432	0.584	1.55	Paved	4.63															4.6		
																							638	6.00	6.00	1.8		1.8		
														889	1.588	22.2	56.4	0.045	2.24		2.24	6.61						6.6		
																							1,634	6.00	6.00	4.5		4.5		
RUS_015_020		2,629	100	0.150	Grass-Short Grass Prairie	2.179	3.95	8.5																			RUS_015_020	8.5	10.2	0.17
									56	2.488	3.21	Paved	0.29															0.3		
									388	1.870	2.78	Paved	2.33															2.3		
																							2,085	6.00	6.00	5.8		5.8		
RYA_000_010		2,853	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RYA_000_010	1.1	10.0	0.17
									1,121	0.715	1.72	Paved	10.87															10.9		
																							1,681	6.00	6.00	4.7		4.7		
RYA_000_020		5,389	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RYA_000_020	15.4	19.0	0.32
									709	2.572	3.26	Paved	3.62															3.6		
																							4,581	6.00	6.00	12.7		12.7		
RYA_000_030		4,581	100	0.150	Grass-Short Grass Prairie	2.571	3.95	8.0																			RYA_000_030	8.0	15.1	0.25
									1,191	1.453	2.45	Paved	8.10															8.1		
																							3,290	6.00	6.00	9.1		9.1		
RYA_000_040		4,283	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.398	3.95	0.7																			RYA_000_040	0.7	8.7	0.14
									575	1.726	2.67	Paved	3.59															3.6		
																							3,657	6.00	6.00	10.2		10.2		
RYA_000_050		456	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.020	3.95	0.6																			RYA_000_050	0.6	1.5	0.02
									407	3.320	3.70	Paved	1.83															1.8		
RYA_000_060		1,480	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.517	3.95	0.7																			RYA_000_060	0.7	4.9	0.08
									1,050	2.133	2.97	Paved	5.89															5.9		
									381	4.081	4.11	Paved	1.55															1.5		
RYA_000_070		3,198	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.228	3.95	0.8																			RYA_000_070	0.8	7.4	0.12
									987	2.236	3.04	Paved	5.41															5.4		
														416	2.752	23.4	15.2	0.065	5.06		5.06	1.37						1.4		
																							1,744	6.00	6.00	4.8		4.8		
RYA_000_080		1,688	100	0.150	Grass-Short Grass Prairie	2.998	3.95	7.5																			RYA_000_080	7.5	8.2	0.14
									614	3.984	4.06	Paved	2.52															2.5		
														668	1.829	1.1	7.3	0.015	3.85		3.85	2.89						2.9		
																							301	6.00	6.00	0.8		0.8		
RYA_001_010		3,045	47	0.150	Grass-Short Grass Prairie	4.536	3.95	3.5																			RYA_001_010	3.5	11.1	0.18
									1,943	1.879	2.79	Paved	11.62															11.6		

RUSH CREEK City of Arlington Watershed Study

Middle Rush Ultimate Time of Concentration Calculations

HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Overland Flow: Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Shallow Concentrated Flow: Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Channel Flow: Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Flow: Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Totals: Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
																							428	6.00	6.00	1.2		1.2		
														628	0.867	91.4	26.9	0.065	4.83		4.83	2.17						2.2		
RYA_001_020		1,206	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.413	3.95	0.7																			RYA_001_020	0.7	2.8	0.05
									322	2.861	3.44	Paved	1.56															1.6		
																							834	6.00	6.00	2.3		2.3		
TWI_000_010		3,106	35	0.150	Grass-Short Grass Prairie	5.162	3.95	2.6																			TWI_000_010	2.6	12.0	0.20
									1,530	0.931	1.96	Paved	13.00															13.0		
																							294	6.00	6.00	0.8		0.8		
														334	1.700	28.3	16.5	0.065	4.28		4.28	1.30						1.3		
																							528	6.00	6.00	1.5		1.5		
														385	1.506	6.0	10.7	0.015	8.26		8.26	0.78						0.8		
TWI_000_020		2,662	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.470	3.95	0.6																			TWI_000_020	0.6	5.3	0.09
									613	3.063	3.56	Paved	2.87															2.9		
																							1,169	6.00	6.00	3.2		3.2		
														831	1.287			0.065	6.27	6.27	6.27	2.21						2.2		
TWI_000_030		3,151	81	0.150	Grass-Short Grass Prairie	3.007	3.95	6.3																			TWI_000_030	6.3	13.7	0.23
									1,162	0.675	1.67	Paved	11.60															11.6		
																							1,294	6.00	6.00	3.6		3.6		
														613	0.900			0.065	8.10	8.10	8.10	1.26						1.3		
TWI_000_040		1,403	100	0.150	Grass-Short Grass Prairie	2.161	3.95	8.5																			TWI_000_040	8.5	10.4	0.17
									1,302	1.493	2.48	Paved	8.74															8.7		
TWI_000_050		3,239	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.753	3.95	0.7																			TWI_000_050	0.7	8.7	0.15
									1,619	1.929	2.82	Paved	9.56															9.6		
																							1,570	6.00	6.00	4.4		4.4		
TWI_000_060		1,818	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			TWI_000_060	15.4	15.5	0.26
									123	1.085	2.12	Paved	0.97															1.0		
									1,596	1.899	2.80	Paved	9.50															9.5		
TWI_000_070		4,548	100	0.150	Grass-Short Grass Prairie	0.854	3.95	12.4																			TWI_000_070	12.4	20.9	0.35
														1,040	0.500	16.7	29.1	0.045	1.61		1.61	10.73						10.7		
														350	3.562	2.7	5.1	0.015	12.41		12.41	0.47						0.5		
									689	1.862	2.77	Paved	4.14															4.1		
																							1,544	6.00	6.00	4.3		4.3		
														825	1.487	87.4	36.7	0.065	4.98		4.98	2.76						2.8		
TWI_000_080		1,292	100	0.150	Grass-Short Grass Prairie	1.770	3.95	9.3																			TWI_000_080	9.3	8.8	0.15
									348	2.511	3.22	Paved	1.80															1.8		
									626	2.993	3.52	Paved	2.97															3.0		
																							219	6.00	6.00	0.6		0.6		
TWI_000_090		248	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	12.423	3.95	0.3																			TWI_000_090	0.3	0.7	0.01
									199	3.506	3.81	Paved	0.87															0.9		
TWI_000_100		3,353	100	0.150	Grass-Short Grass Prairie	2.026	3.95	8.8																			TWI_000_100	8.8	12.6	0.21
									371	3.047	3.55	Paved	1.74															1.7		
									675	1.959	2.85	Paved	3.95															4.0		
																							1,054	6.00	6.00	2.9		2.9		
														1,154	2.465	88.5	50.1	0.065	5.25		5.25	3.66						3.7		
TWI_001_010		3,147	100	0.150	Grass-Short Grass Prairie	2.089	3.95	8.7																			TWI_001_010	8.7	14.7	0.25
														1,404	0.664	16.2	21.9	0.045	2.21		2.21	10.58						10.6		
																							1,266	6.00	6.00	3.5		3.5		
														378	0.703	50.4	25.4	0.055	3.59		3.59	1.76						1.8		
TWI_002_010		1,046	100	0.150	Grass-Short Grass Prairie	3.373	3.95	7.2																			TWI_002_010	7.2	7.3	0.12
									491	4.489	4.31	Paved	1.90															1.9		
									456	1.497	2.49	Paved	3.06															3.1		
TWI_003_010		2,713	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.591	3.95	0.5																			TWI_003_010	0.5	6.2	0.10
									536	4.720	4.42	Paved	2.02															2.0		
																							1,811	6.00	6.00	5.0		5.0		
														318	0.500	15.5	12.2	0.065	1.90		1.90	2.79						2.8		
TWI_004_010		3,365	26	0.150	Grass-Short Grass Prairie	6.863	3.95	1.8																			TWI_004_010	1.8	9.6	0.16
									1,111	1.285	2.30	Paved	8.04															8.0		
																							2,228	6.00	6.00	6.2		6.2		
TWI_004_020		1,374	100	0.150	Grass-Short Grass Prairie	3.762	3.95	6.8																			TWI_004_020	6.8	7.3	0.12
									678	2.388	3.14	Paved	3.60															3.6		
																							597	6.00	6.00	1.7		1.7		
TWI_004_030		1,291	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.544	3.95	0.5																			TWI_004_030	0.5	3.5	0.06
									70	4.900	4.50	Paved	0.26															0.3		
									779	2.512	3.22	Paved	4.03															4.0		
																							394	6.00	6.00	1.1		1.1		

Stream RC-1 Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel Flow	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_RCO_001_010		2,640	100	0.150	Grass-Short Grass Prairie	0.880	3.95	12.2																			RUS_RCO_001_010	12.2	17.5	0.29
									1,101	1.360	2.37	Paved	7.74															7.7		
									1,270	1.419	2.42	Paved	8.74															8.7		
																							169	6	6.00	0.5		0.5		
RUS_RCO_002_010		4,461	76	0.150	Grass-Short Grass Prairie	2.473	3.95	6.5																			RUS_RCO_002_010	6.5	18.8	0.31
									1,586	0.597	1.57	Paved	16.83															16.8		
														633	0.500	9.7	14.5	0.015	5.40		5.40	1.95						2.0		
																							2,166	6	6.00	6.0		6.0		
RUS_RCO_002_020		938	100	0.150	Grass-Short Grass Prairie	1.260	3.95	10.6																			RUS_RCO_002_020	10.6	11.8	0.20
									37	8.935	6.08	Paved	0.10															0.1		
									761	0.500	1.44	Paved	8.82															8.8		
																							40	6	6.00	0.1		0.1		
RUS_RCO_010		3,067	44	0.150	Grass-Short Grass Prairie	0.500	3.95	8.0																			RUS_RCO_010	8.0	17.0	0.28
									1,226	0.500	1.44	Paved	14.22															14.2		
																							1,267	6	6.00	3.5		3.5		
														530	0.604	111.4	42.6	0.065	3.38		3.38	2.61						2.6		
RUS_RCO_020		5,143	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.260	3.95	0.6																			RUS_RCO_020	0.6	10.8	0.18
									623	0.894	1.92	Paved	5.40															5.4		
																							3,093	6	6.00	8.6		8.6		
														1,377	0.566					6.81	6.81	3.37						3.4		
RUS_RCO_030		4,440	43	0.150	Grass-Short Grass Prairie	2.596	3.95	4.0																			RUS_RCO_030	4.0	14.0	0.23
									2,084	1.737	2.68	Paved	12.96															13.0		
																							2,239	6	6.00	6.2		6.2		
														74	0.701	15.0	17.0	0.015	7.65		7.65	0.16						0.2		
RUS_RCO_040		2,647	100	0.150	Grass-Short Grass Prairie	2.280	3.95	8.4																			RUS_RCO_040	8.4	11.0	0.18
									159	8.315	5.86	Paved	0.45															0.5		
									993	2.107	2.95	Paved	5.61															5.6		
																							1,396	6	6.00	3.9		3.9		
RUS_RCO_050		3,439	100	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_RCO_050	14.9	18.4	0.31
									82	2.425	3.17	Paved	0.43															0.4		
									2,551	2.552	3.25	Paved	13.09															13.1		
																							280	6	6.00	0.8		0.8		
														426	0.501	5.0	9.1	0.015	4.71		4.71	1.51						1.5		
RUS_RCO_060		2,387	100	0.150	Grass-Short Grass Prairie	1.550	3.95	9.8																			RUS_RCO_060	9.8	18.9	0.32
									526	0.547	1.50	Paved	5.83															5.8		
									1,273	0.510	1.45	Paved	14.61															14.6		
																							488	6	6.00	1.4		1.4		
RUS_RCO_070		4,161	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	4.740	3.95	0.4																			RUS_RCO_070	0.4	9.1	0.15
									2,074	3.498	3.80	Paved	9.09															9.1		
																							2,037	6	6.00	5.7		5.7		
RUS_RCO_080		2,228	100	0.150	Grass-Short Grass Prairie	2.225	3.95	8.5																			RUS_RCO_080	8.5	10.5	0.18
									1,001	1.922	2.82	Paved	5.92															5.9		
																							1,128	6	6.00	3.1		3.1		
RUS_RCO_090		4,509	87	0.150	Grass-Short Grass Prairie	2.008	3.95	7.9																			RUS_RCO_090	7.9	20.7	0.35
									3,099	1.224	2.25	Paved	22.97															23.0		
																							1,324	6	6.00	3.7		3.7		
RUS_RCO_100		2,499	49	0.150	Grass-Short Grass Prairie	0.500	3.95	8.7																			RUS_RCO_100	8.7	13.7	0.23
									1,120	0.782	1.80	Paved	10.38															10.4		
																							1,330	6	6.00	3.7		3.7		
RUS_RCO_110		2,443	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.700	3.95	1.0																			RUS_RCO_110	1.0	11.7	0.20
									1,940	0.845	1.87	Paved	17.30															17.3		
																							453	6	6.00	1.3		1.3		
RUS_RCO_120		2,934	100	0.150	Grass-Short Grass Prairie	2.150	3.95	8.6																			RUS_RCO_120	8.6	14.3	0.24
									25	9.370	6.22	Paved	0.07															0.1		
									2,810	2.300	3.08	Paved	15.19															15.2		
RUS_RCO_130		2,380	100	0.150	Grass-Short Grass Prairie	2.210	3.95	8.5																			RUS_RCO_130	8.5	11.7	0.19
									41	7.259	5.48	Paved	0.12															0.1		
									2,128	2.748	3.37	Paved	10.52															10.5		
																							111	6	6.00	0.3		0.3		
RUS_RCO_140		2,218	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.020	3.95	0.6																			RUS_RCO_140	0.6	7.2	0.12
									133	2.624	3.29	Paved	0.67															0.7		
									844	0.807	1.83	Paved	7.70															7.7		
									109	10.417	6.56	Paved	0.28															0.3		
														1,082	4.248	87.8	54.3	0.065	6.51		6.51	2.77						2.8		
RUS_RCO_150		1,740	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	5.250	3.95	0.4																			RUS_RCO_150	0.4	6.6	0.11
									746	5.939	4.95	Paved	2.51															2.5		
									812	0.761	1.77	Paved	7.63															7.6		
																							132	6	6.00	0.4		0.4		
RUS_TOA_010		3,284	100	0.150	Grass-Short Grass Prairie	0.990	3.95	11.7																			RUS_TOA_010	11.7	19.4	0.32
									101	1.302	2.32	Paved	0.73															0.7		
									1,287	0.500	1.44	Paved	14.92															14.9		
																							1,795	6	6.00	5.0		5.0		
RUS_TOA_020		2,315	100	0.150	Grass-Short Grass Prairie	4.880	3.95	6.2																			RUS_TOA_020	6.2	7.5	0.13
									131	3.939	4.03	Paved	0.54															0.5		
														346	4.051	37.2	51.7	0.045	5.35		5.35	1.08						1.1		
														114	2.516	12.4	36.3	0.015	7.70		7.70	0.25						0.2		
																							1,624	6	6.00	4.5		4.5		
RUS_TOA_030		3,613	100	0.150	Grass-Short Grass Prairie	0.830	3.95	12.5																			RUS_TOA_030	12.5	14.9	0.25

Stream RC-1 Ultimate Time of Concentration Calculations

HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Overland Flow: Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Shallow Concentrated Flow: Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Channel Flow: Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel Flow	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Flow: Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Totals: Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
									46	8.211	5.83	Paved	0.13															0.1		
									1,353	3.017	3.53	Paved	6.39															6.4		
																							240	6	6.00	0.7		0.7		
														1,874	0.970	0.6	2.1	0.015	4.25	6.09	6.09	5.13						5.1		
RUS_TOA_040		2,776	100	0.150	Grass-Short Grass Prairie	1.170	3.95	10.9																			RUS_TOA_040	10.9	**12.4**	**0.21**
									192	3.440	3.77	Paved	0.85															0.8		
									785	2.437	3.17	Paved	4.12															4.1		
																							1,698	6	6.00	4.7		4.7		
RUS_TOA_050		4,900	100	0.150	Grass-Short Grass Prairie	0.860	3.95	12.4																			RUS_TOA_050	12.4	**21.3**	**0.35**
									34	7.690	5.64	Paved	0.10															0.1		
									1,787	0.985	2.02	Paved	14.76															14.8		
																							2,979	6	6.00	8.3		8.3		
RUS_TOA_055		7,994	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.820	3.95	0.9																			RUS_TOA_055	0.9	**29.1**	**0.49**
									1,191	0.825	1.85	Paved	10.75															10.8		
														6,753	0.908	27.9	21.8	0.055	3.05		3.05	36.92						36.9		
RUS_TOA_060		2,926	100	0.150	Grass-Short Grass Prairie	3.350	3.95	7.2																			RUS_TOA_060	7.2	**18.3**	**0.30**
									651	0.500	1.44	Paved	7.55															7.5		
									2,175	1.286	2.30	Paved	15.73															15.7		
RUS_TOA_070		2,587	100	0.150	Grass-Short Grass Prairie	1.070	3.95	11.3																			RUS_TOA_070	11.3	**18.1**	**0.30**
									1,500	0.584	1.55	Paved	16.09															16.1		
																							987	6	6.00	2.7		2.7		
RUS_TOA_080		5,019	100	0.150	Grass-Short Grass Prairie	3.001	3.95	7.5																			RUS_TOA_080	7.5	**14.8**	**0.25**
									1,098	1.873	2.78	Paved	6.58															6.6		
																							3,623	6	6.00	10.1		10.1		
														204	3.945	24.7	13.3	0.065	6.88		6.88	0.49						0.5		
RUS_TOA_090		3,864	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.660	3.95	0.7																			RUS_TOA_090	0.7	**8.6**	**0.14**
									658	4.924	4.51	Paved	2.43															2.4		
									41	0.879	1.91	Paved	0.36															0.4		
														398	2.856	4.6	6.4	0.045	4.49		4.49	1.48						1.5		
																							303	6	6.00	0.8		0.8		
														504	1.092	6.2	12.1	0.045	2.21		2.21	3.80						3.8		
																							1,202	6	6.00	3.3		3.3		
														709	2.154	134.2	35.6	0.065	8.15		8.15	1.45						1.4		
RUS_TOA_100		4,958	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.980	3.95	0.6																			RUS_TOA_100	0.6	**9.8**	**0.16**
									713	2.022	2.89	Paved	4.11															4.1		
																							2,960	6	6.00	8.2		8.2		
														542	1.081	17.8	8.5	0.045	5.63		5.63	1.60						1.6		
														693	3.696	42.8	24.6	0.065	6.38		6.38	1.81						1.8		

Upper Rush Ultimate Time of Concentration Calculations

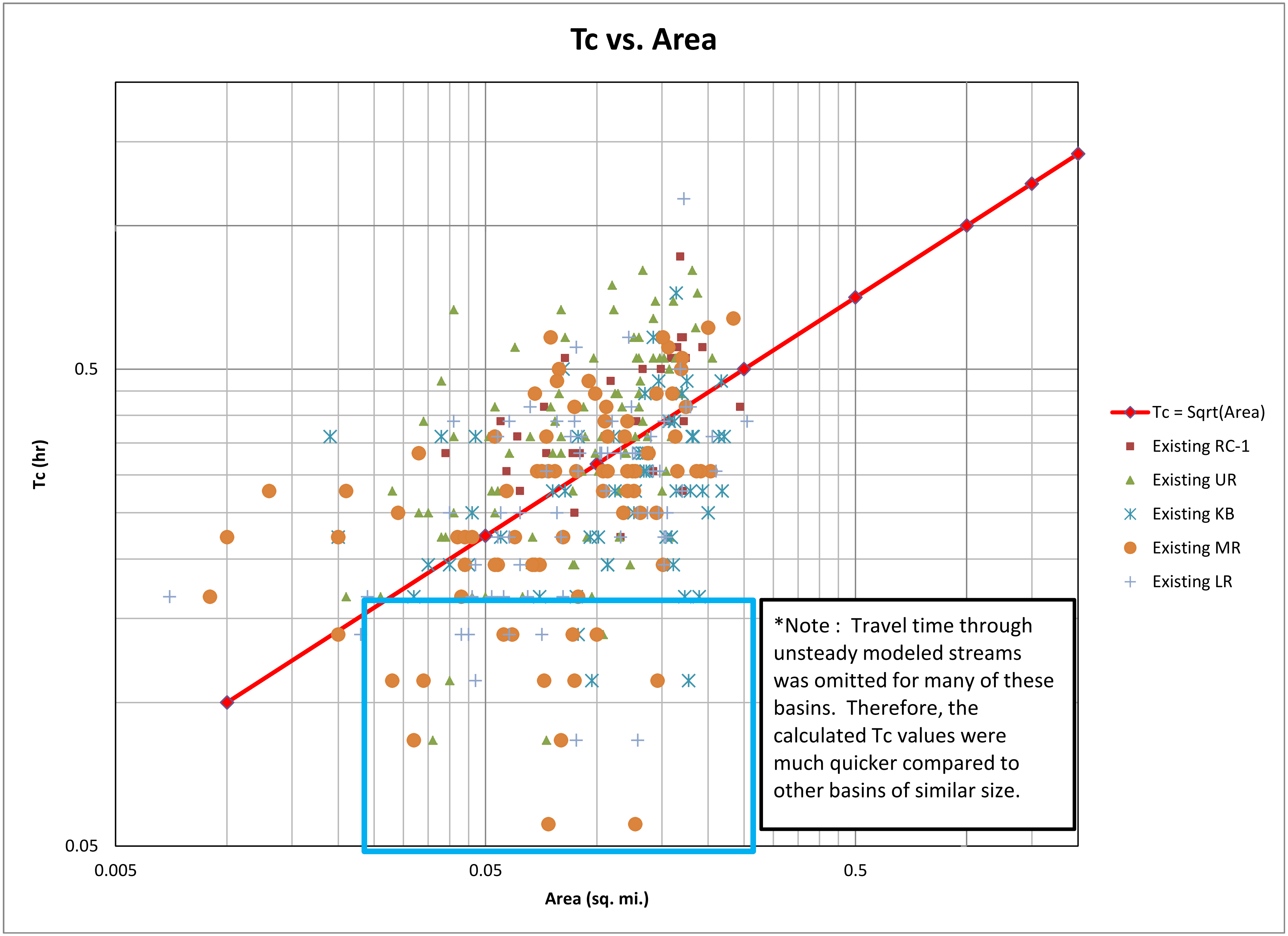
			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_000_010		3,581	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_000_010	33	19.9	0.33
									1,530	0.700	1.70	Paved	14.99																	
														2,001	0.980	55.2	88.3	0.055	1.96		1.96	17.01								
RUS_000_020		2,722	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.320	3.95	0.7																			RUS_000_020	12	7.4	0.12
														2,672	0.960	27.0	21.0	0.045	3.84		3.84	11.61								
RUS_000_030		3,258	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_000_030	40	24.2	0.40
									2,660	1.090	2.12	Paved	20.89																	
														498	0.500	121.5	110.5	0.055	2.04		2.04	4.07								
RUS_000_040		1,419	100	0.150	Grass-Short Grass Prairie	1.970	3.95	8.9																			RUS_000_040	17	10.4	0.17
									1,031	1.440	2.44	Paved	7.04																	
														288	0.630	53.4	22.5	0.065	3.23		3.23	1.48								
RUS_000_050		2,882	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.280	3.95	0.7																			RUS_000_050	21	12.6	0.21
									1,679	0.860	1.89	Paved	14.84																	
																							375	6	6.00	1.0				
														778	0.970	52.9	59.3	0.045	3.02		3.02	4.29								
RUS_000_060		2,425	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	1.120	3.95	0.8																			RUS_000_060	8	5.1	0.08
									644	2.210	3.02	Paved	3.55																	
																							1,053	6	6.00	2.9				
														678	1.563	115.4	87.2	0.024	9.36		9.36	1.21								
RUS_000_070		2,113	100	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_000_070	30	17.9	0.30
									2,013	1.310	2.33	Paved	14.42																	
RUS_000_080		2,523	100	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_000_080	27	16.1	0.27
									673	1.800	2.73	Paved	4.11																	
														1,750	0.690	5.7	3.7	0.045	3.69		3.69	7.90								
RUS_000_085		3,636	100	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.9																			RUS_000_085	20	12.1	0.20
									574	2.162	2.99	Paved	3.20																	
														2,962	0.935					3.26	3.26	15.14								
RUS_000_090		2,192	100	0.150	Grass-Short Grass Prairie	0.570	3.95	14.6																			RUS_000_090	29	17.2	0.29
									2,092	1.470	2.46	Paved	14.15																	
RUS_000_100		4,764	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.820	3.95	0.9																			RUS_000_100	25	14.8	0.25
									831	1.200	2.23	Paved	6.22																	
																							1,845	6	6.00	5.1				
														2,037	1.010	131.6	131.6	0.055	2.72		2.72	12.47								
RUS_000_110		3,764	50	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.540	3.95	1.1																			RUS_000_110	23	13.6	0.23
									1,699	1.020	2.05	Paved	13.79																	
																							262	6	6.00	0.7				
														1,753	1.780	40.8	44.7	0.045	4.16		4.16	7.03								
RUS_000_120		1,360	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.060	3.95	0.6																			RUS_000_120	8	4.7	0.08
									1,310	2.170	2.99	Paved	7.29																	
RUS_000_130		2,066	100.1	0.150	Grass-Short Grass Prairie	0.760	3.95	13.0																			RUS_000_130	20	12.0	0.20
														1,966	2.270	6.7	7.4	0.045	4.65		4.65	7.05								
RUS_000_140		2,863	100.0	0.150	Grass-Short Grass Prairie	1.270	3.95	10.6																			RUS_000_140	22	13.0	0.22
									928	1.580	2.56	Paved	6.05																	
																							1,835	6	6.00	5.1				
RUS_000_150		2,761	100.0	0.150	Grass-Short Grass Prairie	2.100	3.95	8.6																			RUS_000_150	17	10.5	0.17
									446	1.850	2.76	Paved	2.69																	
																							2,001	6	6.00	5.6				
														214	5.486	31.9	29.5	0.055	6.69		6.69	0.53								
RUS_000_160		1,865	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.940	3.95	0.8																			RUS_000_160	11	6.4	0.11
									1,089	1.330	2.34	Paved	7.74																	
																							726	6	6.00	2.0				
RUS_000_170		1,952	100.0	0.150	Grass-Short Grass Prairie	0.810	3.95	12.7																			RUS_000_170	19	11.4	0.19
									383	2.040	2.90	Paved	2.20																	
																							1,469	6	6.00	4.1				
RUS_000_180		747	100.0	0.150	Grass-Short Grass Prairie	0.940	3.95	11.9																			RUS_000_180	15	8.9	0.15
									647	3.320	3.70	Paved	2.91																	
RUS_016_010		2,662	100.0	0.150	Grass-Short Grass Prairie	2.830	3.95	7.7																			RUS_016_010	18	11.0	0.18
									693	1.080	2.11	Paved	5.47																	
																							1,869	6	6.00	5.2				
RUS_016_020		3,161	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.700	3.95	1.0																			RUS_016_020	20	12.2	0.20
									2,082	1.060	2.09	Paved	16.58																	
																							1,030	6	6.00	2.9				
RUS_016_030		2,587	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.680	3.95	1.0																			RUS_016_030	9	5.6	0.09
									504	2.280	3.07	Paved	2.74																	
																							2,033	6	6.00	5.6				
RUS_016_040		2,434	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.320	3.95	0.4																			RUS_016_040	9	5.2	0.09
									707	3.160	3.61	Paved	3.26																	
																							1,199	6	6.00	3.3				
														477	2.310	57.3	35.8	0.065	4.77		4.77	1.67								
RUS_017_010		678	100.8	0.150	Grass-Short Grass Prairie	0.900	3.95	12.2																			RUS_017_010	15	8.8	0.15
									145	2.090	2.94	Paved	0.82																	
														432	1.240	115.9	65.0	0.055	4.44		4.44	1.62								
RUS_018_010		2,702	100.0	0.150	Grass-Short Grass Prairie	1.610	3.95	9.6																			RUS_018_010	23	14.0	0.23
									1,064	1.270	2.29	Paved	7.74																	
														884	0.500	70.0	37.8	0.045	3.53		3.53	4.17								
																							654	6	6.00	1.8				
RUS_018_020		2,891	100.0	0.150	Grass-Short Grass Prairie	0.970	3.95	11.8																			RUS_018_020	33	19.8	0.33
									1,383	1.600	2.57	Paved	8.96																	
														1,408	0.800	49.3	81.0	0.050	1.91		1.91	12.26								
RUS_018_030		2,585	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.740	3.95	0.9																			RUS_018_030	11	6.8	0.11
									901	2.310	3.09	Paved	4.86																	
														1,634	1.000					4.86	4.86	5.60								
RUS_018_040		2,976	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.730	3.95	0.9																			RUS_018_040	17	9.9	0.17
									1,824	1.860	2.77	Paved	10.97																	
														1,102	0.640					3.96	3.96	4.64								

Upper Rush Ultimate Time of Concentration Calculations

			Overland Flow						Shallow Concentrated Flow					Channel Flow									Pipe Flow				Totals			
HMS Program Basin Name	Notes	Longest Flowpath (ft) (1)	Length (ft) (2)	n-Value (3)	Land Use/Surface Description (4)	Slope (%) (5)	Rainfall (in) (6b)	TcOverland (min) (7)	Length 1 (ft) (8)	Slope 1 (%) (9)	V1 (ft/s) (10)	Assumption for V1 (Paved/Unpaved) (11)	Tc Shallow Concentrated (min) (12)	Length 2 (ft) (13)	Slope 2 (%) (14)	Bankfull Area (ft^2) (15)	Bankfull Wet Peri (ft) (16)	Channel n-Value (17)	V2 (ft/s) Manning's (18)	V2 (ft/s) from RAS Model (19)	Selected Velocity (ft/s) (20)	Tc Channel (min) (21)	Pipe Length (ft) (23)	Pipe Velocity Other Source (ft/s) (26)	Selected Velocity (ft/s) (27)	Tc Pipe (min) (28)	Sub-basin	Final Tc (min) (29)	Tlag (min) (30)	Tlag (hr)
RUS_018_050		3,423	100.0	0.150	Grass-Short Grass Prairie	2.870	3.95	7.6																			RUS_018_050	25	**14.7**	**0.25**
									1,647	1.570	2.55	Paved	10.78																	
																							585	6	6.00	1.6				
														1,091	0.810					4.07	4.07	4.47								
RUS_019_010		2,630	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_019_010	29	**17.3**	**0.29**
									1,333	1.400	2.41	Paved	9.24																	
														1,197	1.250	208.7	106.6	0.055	4.74		4.74	4.21								
RUS_019_020		1,706	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	2.400	3.95	0.6																			RUS_019_020	12	**6.9**	**0.12**
									1,313	1.150	2.18	Paved	10.04																	
														343	3.086	46.1	28.9	0.055	6.49		6.49	0.88								
RUS_020_010		4,272	100.0	0.150	Grass-Short Grass Prairie	0.540	3.95	14.9																			RUS_020_010	38	**22.7**	**0.38**
									1,285	0.500	1.44	Paved	14.90																	
																							2,887	6	6.00	8.0				
RUS_020_020		4,387	100.0	0.150	Grass-Short Grass Prairie	0.670	3.95	13.7																			RUS_020_020	43	**25.8**	**0.43**
									2,493	0.780	1.80	Paved	23.14																	
																							692	6	6.00	1.9				
														535	0.780	29.9	18.9	0.045	3.97		3.97	2.25								
														350	0.500	30.1	23.2	0.015	8.34		8.34	0.70								
														217	0.500	52.3	45.4	0.045	2.57		2.57	1.41								
RUS_020_030		3,118	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			RUS_020_030	36	**21.6**	**0.36**
									1,974	1.220	2.25	Paved	14.65																	
																							175	6	6.00	0.5				
														870	0.500	81.3	67.1	0.045	2.66		2.66	5.45								
RUS_020_040		4,060	100.0	0.150	Grass-Short Grass Prairie	1.630	3.95	9.6																			RUS_020_040	31	**18.4**	**0.31**
									545	2.490	3.21	Paved	2.83																	
														3,415	0.620					3.13	3.13	18.18								
RUS_FPT_010		3,184	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.720	3.95	0.9																			RUS_FPT_010	13	**7.9**	**0.13**
									990	1.630	2.60	Paved	6.36																	
																							1,560	6	6.00	4.3				
														585	0.500	141.8	78.1	0.024	6.54		6.54	1.49								
RUS_FPT_020		2,432	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_FPT_020	11	**6.6**	**0.11**
									1,403	2.610	3.28	Paved	7.12																	
																							979	6	6.00	2.7				
RUS_NET_010		2,119	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	0.500	3.95	1.1																			RUS_NET_010	10	**6.2**	**0.10**
									396	0.500	1.44	Paved	4.59																	
																							1,673	6	6.00	4.6				
RUS_NET_020		710	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	6.380	3.95	0.4																			RUS_NET_020	4	**2.6**	**0.04**
									660	1.810	2.73	Paved	4.02																	
SUB_000_010		2,952	100.0	0.150	Grass-Short Grass Prairie	0.620	3.95	14.1																			SUB_000_010	31	**18.8**	**0.31**
									1,990	1.660	2.62	Paved	12.66																	
														862	0.500	54.1	34.2	0.045	3.18		3.18	4.52								
SUB_000_020		2,349	100.0	0.150	Grass-Short Grass Prairie	2.220	3.95	8.5																			SUB_000_020	17	**10.1**	**0.17**
									669	3.710	3.92	Paved	2.85																	
														1,579	0.700					4.71	4.71	5.59								
SUB_000_030		751	50.0	0.011	Smooth Surface (concrete, asphalt, bare earth)	3.100	3.95	0.5																			SUB_000_030	4	**2.3**	**0.04**
									701	3.020	3.53	Paved	3.31																	
SUB_000_040		1,108	100.0	0.150	Grass-Short Grass Prairie	0.500	3.95	15.4																			SUB_000_040	20	**11.8**	**0.20**
									1,008	3.730	3.93	Paved	4.28																	
SUB_000_050		3,726	100.0	0.150	Grass-Short Grass Prairie	0.860	3.95	12.4																			SUB_000_050	37	**22.3**	**0.37**
									2,717	1.110	2.14	Paved	21.14																	
														909	1.240	27.8	17.5	0.055	4.11		4.11	3.69								
SUB_000_060		3,046	100.0	0.150	Grass-Short Grass Prairie	0.720	3.95	13.3																			SUB_000_060	28	**16.7**	**0.28**
									388	1.750	2.69	Paved	2.40																	
														1,609	1.010	30.0	30.0	0.045	3.33		3.33	8.06								
																							371	6	6.00	1.0				
														577	0.500					3.13	3.13	3.07								
SUB_000_070		4,044	100.0	0.150	Grass-Short Grass Prairie	2.260	3.95	8.4																			SUB_000_070	29	**17.3**	**0.29**
									1,623	2.070	2.92	Paved	9.25																	
														2,321	0.690					3.45	3.45	11.21								
SUB_000_080		1,251	100.0	0.150	Grass-Short Grass Prairie	4.950	3.95	6.1																			SUB_000_080	12	**7.0**	**0.12**
									1,151	2.890	3.46	Paved	5.55																	

RUSH CREEK City of Arlington Watershed Study

Appendix B-4
Time of Concentration Graphs


Tc vs. Area
Tc (hr)
0.5
0.05
0.005
0.05
0.5
Area (sq. mi.)
Tc = Sqrt(Area)
Existing RC-1
Existing UR
Existing KB
Existing MR
Existing LR
*Note : Travel time through unsteady modeled streams was omitted for many of these basins. Therefore, the calculated Tc values were much quicker compared to other basins of similar size.

Appendix B-5
Modified Puls Subreach Calculations

Modified Puls Subreach Calculations
Kee Branch

Time Step (min) = 1

Creek/River	Reach Name	Length	Average Velocity	Steps	Rounded Steps
Kee Branch	R_KEE_000_020	2161	3.58	10.06	10.0
KB_Route1	R_KEE_000_140	1958	8.33	3.92	4.0
	R_KEE_000_160	361	7.26	0.83	1.0
KB_Route2	R_KEE_000_260	2290	6.71	5.69	6.0
Kee Branch Trib 4	R_KEE_004_020	741	9.01	1.37	2.0
Kee Branch Trib 5	R_KEE_005_020	1589	2.81	9.44	10.0
Stream KB-1.1	R_KEE_KB1_001_020	1428	6.99	3.40	4.0

Notes:
(1) Length of the main channel
(2) Average channel velocity calculated in the time of concentration spreadsheet (V2)
(3) Number of Routing Steps = (River Length / Channel Velocity) * (1 / 60 min/s) / Time Step
(4) Rounded Steps = the number or routing steps rounded up

Modified Puls Subreach Calculations
Lower Rush

Time Step (min) = 1

Creek/River	Reach Name	Length	Average Velocity	Steps	Rounded Steps
Pantego	R_PAN_000_030b	2870	7.63	6.27	7.0
	R_PAN_000_050a	687	3.86	2.97	3.0
Rush Creek Trib 3	R_RUS_003_020b	908	5.28	2.87	3.0
Rush Creek Trib 4.1	R_RUS_004_001_020	1140	6.66	2.85	3.0
	R_RUS_004_001_030	1161	6.43	3.01	4.0
LR_Route1	R_RUS_004_030a	1041	2.87	6.05	7.0
Rush Creek Trib 4	R_RUS_004_030b	382	3.73	1.71	2.0

Notes:
(1) Length of the main channel
(2) Average channel velocity calculated in the time of concentration spreadsheet (V2)
(3) Number of Routing Steps = (River Length / Channel Velocity) * (1 / 60 min/s) / Time Step
(4) Rounded Steps = the number or routing steps rounded up

Appendix B-5

Modified Puls Subreach Calculations
Middle Rush

Time Step (min) = 1

Creek/River	Reach Name	Length	Average Velocity	Steps	Rounded Steps
Rush Creek Trib 7	R_RUS_007_020	1857	7.83	3.95	4.0
Rush Creek Trib 9	R_RUS_009_030	332	10.29	0.54	1.0
Twin Springs Draw	R_TWI_000_020	1012	6.27	2.69	3.0
	R_TWI_000_030	1572	8.10	3.24	4.0

Notes:
(1) Length of the main channel
(2) Average channel velocity calculated in the time of concentration spreadsheet (V2)
(3) Number of Routing Steps = (River Length / Channel Velocity) * (1 / 60 min/s) / Time Step
(4) Rounded Steps = the number or routing steps rounded up

Appendix B-5

Modified Puls Subreach Calculations
Stream RC-1

Time Step (min) = 1

Creek/River	Reach Name	Length	Average Velocity	Steps	Rounded Steps
Stream RC-1	R_RUS_RCO_020a	1381	6.81	3.38	4.0
	R_RUS_RCO_030	279	8.14	0.57	1.0
	R_RUS_RCO_070	1230	7.43	2.76	3.0
Stream RC-1A	R_RUS_TOA_030	2177	6.09	5.96	6.0

Notes:
(1) Length of the main channel
(2) Average channel velocity calculated in the time of concentration spreadsheet (V2)
(3) Number of Routing Steps = (River Length / Channel Velocity) * (1 / 60 min/s) / Time Step
(4) Rounded Steps = the number or routing steps rounded up

Appendix B-5

Modified Puls Subreach Calculations
Upper Rush

Time Step (min) = 1

Creek/River	Reach Name	Length	Average Velocity	Steps	Rounded Steps
UR_Route6	R_RUS_000_085	3143	3.26	16.07	10.0
Rush Creek Trib 18	R_RUS_018_020	2026	4.90	6.89	7.0
	R_RUS_018_030	1252	4.86	4.29	5.0
	R_RUS_018_040	1183	3.96	4.98	5.0
	R_RUS_018_050	1126	4.07	4.61	5.0
Rush Creek Trib 20	R_RUS_020_040	3245	3.13	17.28	10.0
Sublett Creek	R_SUB_000_020	1566	4.71	5.54	6.0
UR_Route 3	R_SUB_000_060	1715	3.13	9.13	10.0
	R_SUB_000_070	2505	3.45	12.10	10.0
UR_Route 4	R_SUB_000_140	1644	3.52	7.78	8.0
	R_SUB_000_150	1859	3.65	8.49	9.0
	R_SUB_000_155	1269	4.50	4.70	5.0
UR_Route 5	R_SUB_000_220	2003	3.01	11.09	10.0
	R_SUB_000_230	2137	3.15	11.31	10.0
Sublett Creek Trib 4	R_SUB_004_020	1219	3.63	5.60	6.0
UR_Route 1	R_SUB_004_040	1634	2.36	11.54	10.0
	R_SUB_004_050a	301	4.03	1.24	2.0
	R_SUB_004_050b	2233	4.03	9.23	10.0
	R_SUB_004_060	794	2.15	6.16	7.0
	R_SUB_004_070	504	2.54	3.31	4.0
UR_Route 2	R_SUB_004_090	1654	2.71	10.17	10.0
	R_SUB_004_100	1194	2.91	6.84	7.0
	R_SUB_004_110	1384	3.72	6.20	7.0
	R_SUB_004_120	1149	2.09	9.16	10.0

Notes:
(1) Length of the main channel
(2) Average channel velocity calculated in the time of concentration spreadsheet (V2)
(3) Number of Routing Steps = (River Length / Channel Velocity) * (1 / 60 min/s) / Time Step
(4) Rounded Steps = the number or routing steps rounded up

Appendix C
QAQC Documentation

RUSH CREEK
City of Arlington Watershed Study

QA/QC Review Certification

Product Name: Final Hydrologic Models

Level: ☐ Internal/Subproduct ☑ Deliverable ☐ Audit

Type: ☐ Checklist ☐ Monthly Model Review ☑ Engineer Deliverables

Checklist Category: ☐ Survey ☑ Hydrology ☐ Hydraulic ☐ Mapping

WBS Code: 4.3

Date: 6/22/2012 Status: ☐ Draft ☐ Revision ☑ Final

Originator/Firm: Ben Plyant/Halff Associates, Inc.

QC Reviewer/Firm: Tom Nye/CDM Smith, Inc.

General Comments: Based on comparisons to the aerial photographs in several areas, the percent impervious based on land use may be high, especially for the very low density land use type. The PMC contends that the aerial photography does not always support the argument that large amounts of impervious area is not included in the GIS impervious cover shapefiles. As discussed in the weekly Rush Creek Watershed Study team meeting of 6/11/2012, the PMC accepts these results pending hydraulic model calibration, at which time the percent impervious values may need to be revisited.

Subbasin delineations may also need to be revisited after hydraulic model calibration. As documented in the PMC review of draft subbasin delineations, it was recommened That some subbasin delineations be modified to account for differences between the topography and the anticipated actual flow path (accounting for momentum in the 100-year stormwater flow and depth of funoff from relatively large areas that will be unlikely to funnel into narrow openings without a buildup of depth).

In most cases though, the long "fingers" have been removed from the Tc Calculations. The PMC accepts the subbasin delineations pending hydraulic model calibration.

Additional Review Comments Attached: ☐ Yes ☑ No

Recommendation:

☑ Approved as is ☐ Approved with Minor Corrections ☐ Resubmittal Required

Review Completed By:

Tom Nye/CDM Smith, Inc. *Date: 6 / 2 2 / 2 0 1 2*

Resubmittal Date (if required):

Approved as Final by: [signature] *Date:* 6/27/12

RUSH CREEK
City of Arlington Watershed Study

QA/QC Review Certification

Product Name: Draft Hydrology Report

Level: ☐ Internal/Subproduct ☑ Deliverable ☐ Audit

Type: ☐ Checklist ☐ Monthly Model Review ☑ Engineer Deliverables

Checklist Category: ☐ Survey ☑ Hydrology ☐ Hydraulic ☐ Mapping

WBS Code: 4.4.1

Date: 6/22/2012 Status: ☑ Draft ☐ Revision ☐ Final

Originator/Firm: Ben Plyant/Halff Associates, Inc.

QC Reviewer/Firm: Tom Nye/CDM Smith, Inc.

General Comments: Remove Appendix C, or at least remove all but the signed QC Page. Internal review notes, comments and responses are Internal work products that should not be published as part of the final document.
Most of Appendix B should be submitted in electronic form only. We could submit this appendix in electronic form or print just the figures and move the tables to a CD/DVD in order to keep the appendices as labeled.
Other minor edits/comments as noted in the attached scan.

Additional Review Comments Attached: ☑ Yes ☐ No

Recommendation:

☐ Approved as is ☑ Approved with Minor Corrections ☐ Resubmittal Required

Review Completed By:

Tom Nye, CDM Smith, Inc. Date: 6/22/2012

Resubmittal Date (if required): N/A

Approved as Final by: [signature] Date: 6/22/2012

Appendix D
Correspondence

Draft Memorandum

To: *Hydrology File*

From: *Eric Loucks, P.E., Ph.D.*

Date: *May 31, 2012*

Subject: *Flow paths for estimating Basin Lag Time*

1. Purpose

This memo clarifies the procedure for defining the subbasin flow path to be used for estimating basin lag time in the Rush Creek hydrologic model. For the Rush Creek hydrology we have selected the SCS unit hydrograph method to convert the subbasin runoff volumes into a runoff hydrograph. The SCS unit hydrograph method uses a single input parameter: the basin lag time, T_L.

Runoff hydrographs are either routed downstream in HEC-HMS or directly loaded into HEC-RAS. There are three different applications for each hydrograph generated in HEC-HMS.

1. It is used in a downstream routing or junction in the HEC-HMS model.
2. It is loaded to the HEC-RAS model as a point flow
3. It is loaded to the HEC-RAS model as a distributed flow

The primary purpose of this memo is to describe the need for using different flow paths when defining basin lag time in cases 2 & 3 above. Generally case 1 is the same application as case 2, but that can depend on how routings through basins are handled in HEC-HMS.

2. Discussion

For the Rush Creek hydrology we have selected the SCS unit hydrograph method to convert the subbasin runoff volumes into a runoff hydrograph. The SCS unit hydrograph method uses a single input parameter: the basin lag time, T_L.

Basin lag time for a storm event is defined as the time from the centroid of the effective rainfall to the peak of the outflow hydrograph. There are several empirical methods for estimating T_L (McCuen, 1989) and one of the most popular uses the time of concentration, T_c even though there is no physical connection between the two. Time of concentration is the time it takes for a drainage area to become 100 percent effective in contributing runoff from the start of a runoff producing rainfall. There are also many empirical methods for estimating T_c (Xing, et al., 2005). One of the most popular, the SCS velocity method, involves selecting the longest flow path within the drainage basin and using estimates of flow velocity to determine the travel time to traverse the entire flow path. In a basin with no internal sinks, topology dictates that the longest flow path end at the basin outlet.

Virtually all methods for estimating either T_L or T_c use a flow path that is extended to the basin outlet. The implication is that the flow path ends where the hydrograph is being determined. The technical literature does not say this explicitly, possibly because the point is obvious. The recommendation for the Rush Creek study is to terminate the flow path at the location where the flow path meets a channel that is being modeled in HEC-RAS, or at the basin outlet if the flow path never meets a HEC-RAS channel.

In a HEC-RAS model, there are two types of hydrograph input, point inflow or distributed inflow along a reach. It is worth noting that, on a computational level, all input is the same. As illustrated in *Figure 2-1*, each computational element receives up to three inflows; one lateral inflow along with inflows each adjacent computational elements. In HEC-RAS, each computational element corresponds to a model cross-section. In reaches with distributed inflows, the inflow hydrograph is allocated proportionally among the elements. Distributed inflow to a reach that has just one cross-section, behaves identically to a point inflow.

The inflow hydrographs are computed in HEC-HMS. The locations of HEC-HMS basin outlets must be carefully defined to correspond to the input points in the HEC-RAS model. An example is illustrated in schematic form in *Figure 2-2*. As indicated, the subbasin KEE_000_040 is being loaded as a headwaters point inflow at cross-section 30699.74; therefore it follows that the calculation of basin lag time should terminate where the flow path intersects this cross-section, which is also the basin outlet. Therefore the flowpath for KEE_000_040 does include the main channel segment.

Subbasin KEE_000_050 is loaded as a distributed inflow between 30699.74 and 28906. In HEC-RAS, the inflow will be represented as seven inflow hydrographs, one for each of the seven cross-sections in the reach. In the actual Kee Branch channel, inflows will occur at various points on each side of the channel through small tributaries and storm sewer outfalls. Of course, it is beyond the scale of this modeling effort to individually account for each one of these sources. The longest flow path for subbasin KEE_000_050 is shown in *Figure 2-3*. The flow path used to estimate T_L for this hydrograph should not include the portion of the channel that is modeled in unsteady HEC-RAS. The east-west flow path segment shown in the figure will be used to approximate the travel time for all of the lateral inflow hydrographs in the subbasin.

Discharge from subbasin KEE_000_060 has characteristics of both a distributed and point inflow to the Kee Branch main channel. As shown in *Figure 2-4*, the longest flow path drains a large area that discharges through an outfall.

It is up to the hydraulic modeler to decide how a given subbasin should be represented. While the choice of approach has some local effect, the impact on overall results will be minor. This is especially true in the Rush Creek Watershed Study because we have elected to use small subbasins, minimizing the effect of the modeling approach on each particular subbasin. Subbasin KEE_000_070 will be loaded as a distributed inflow. The longest flow path for this subbasin is also shown in *Figure 2-4*. Again the portion that overlaps the main channel should be excluded from the basin lag time calculation. This is because routing through the main channel is modeled in HEC-RAS so including it would duplicate this travel time and storage and because the truncated flow path is more representative of all the flow paths leading to the main channel from Subbasin KEE_000_070.

3. Conclusion

The primary conclusion of this memo is a procedural guideline to exclude any portion of the channel modeled in unsteady HEC-RAS from the flow path used to determine basin lag time. This essentially defines a clear boundary between HEC-RAS and HEC-HMS at the point where the HEC-HMS hydrograph enters the HEC-RAS channel model. This is a situation that arises when unsteady HEC-RAS is used because channel routing can occur in both models and it seems appropriate to ensure that not only is no portion of any modeled channel double-counted, but also that the entire channel is used. In other words, HMS-routing should end right where HEC-RAS routing begins. In the examples presented, it has been demonstrated that there is no clean break in subbasins with distributed lateral inflow to the channel due to the fact that there are multiple inflows from these basins. However the recommended approach of excluding the main channel for calculating basin lag will, on average, provide an appropriate path length.

References

Franz, D. D. and C. S. Melching. Full Equations Model for the Solution of the Full, Dynamic Equations of Motion for One-Dimensional Unsteady Flow in Open Channels and Through Control Structures, USGS WRI Report 96-4240, 1997.

McCuen, Richard H., Hydrologic Analysis and Design, Prentice Hall, 1989.

Xing, Fang, Pradhan, P., Malla, R., Cleveland, Theodore, and David Thompson, “Estimating Time of Concentration for Texas Watersheds,” 2005.

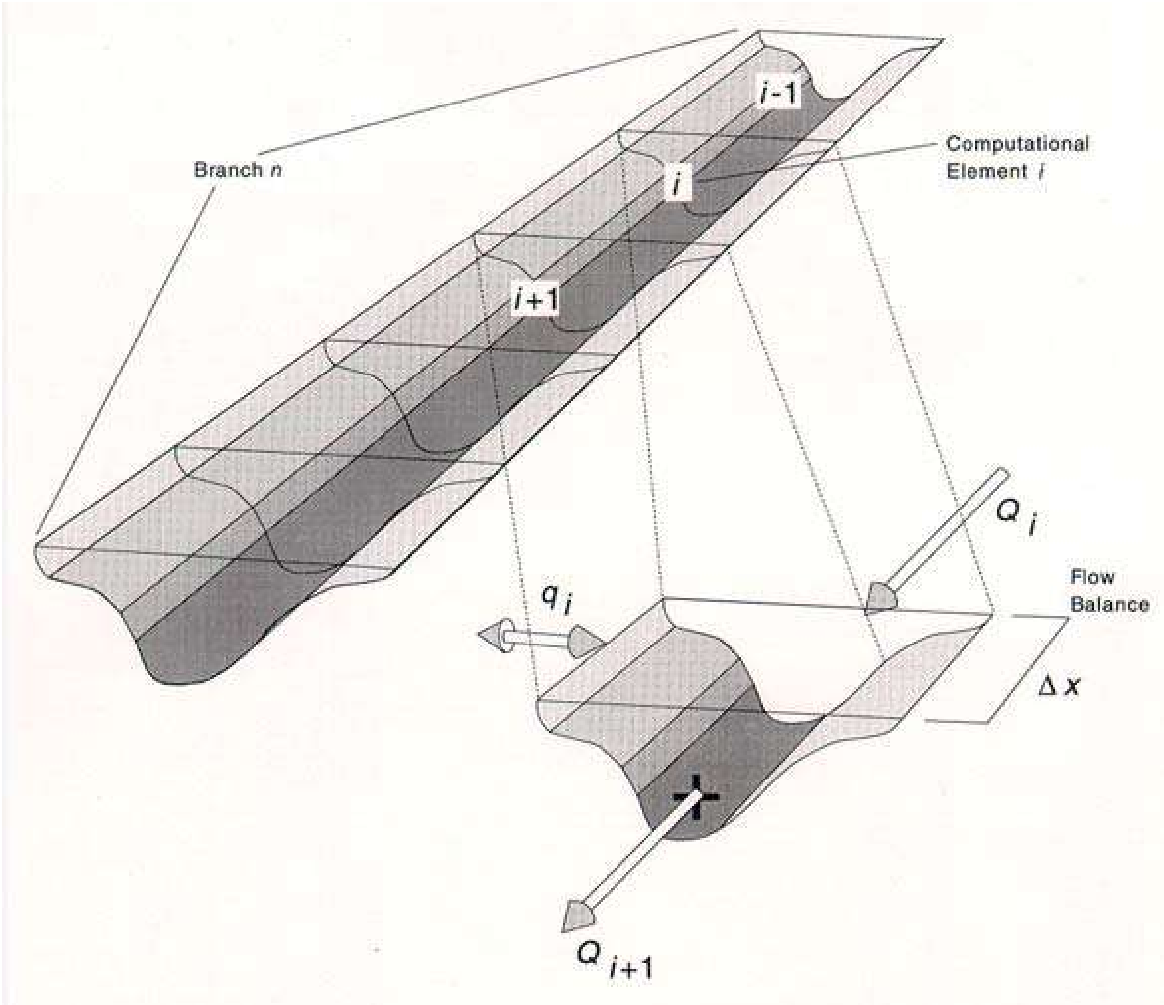


Figure 2-1. Computational elements in an unsteady Flow Model (Franz and Melching, 1996)

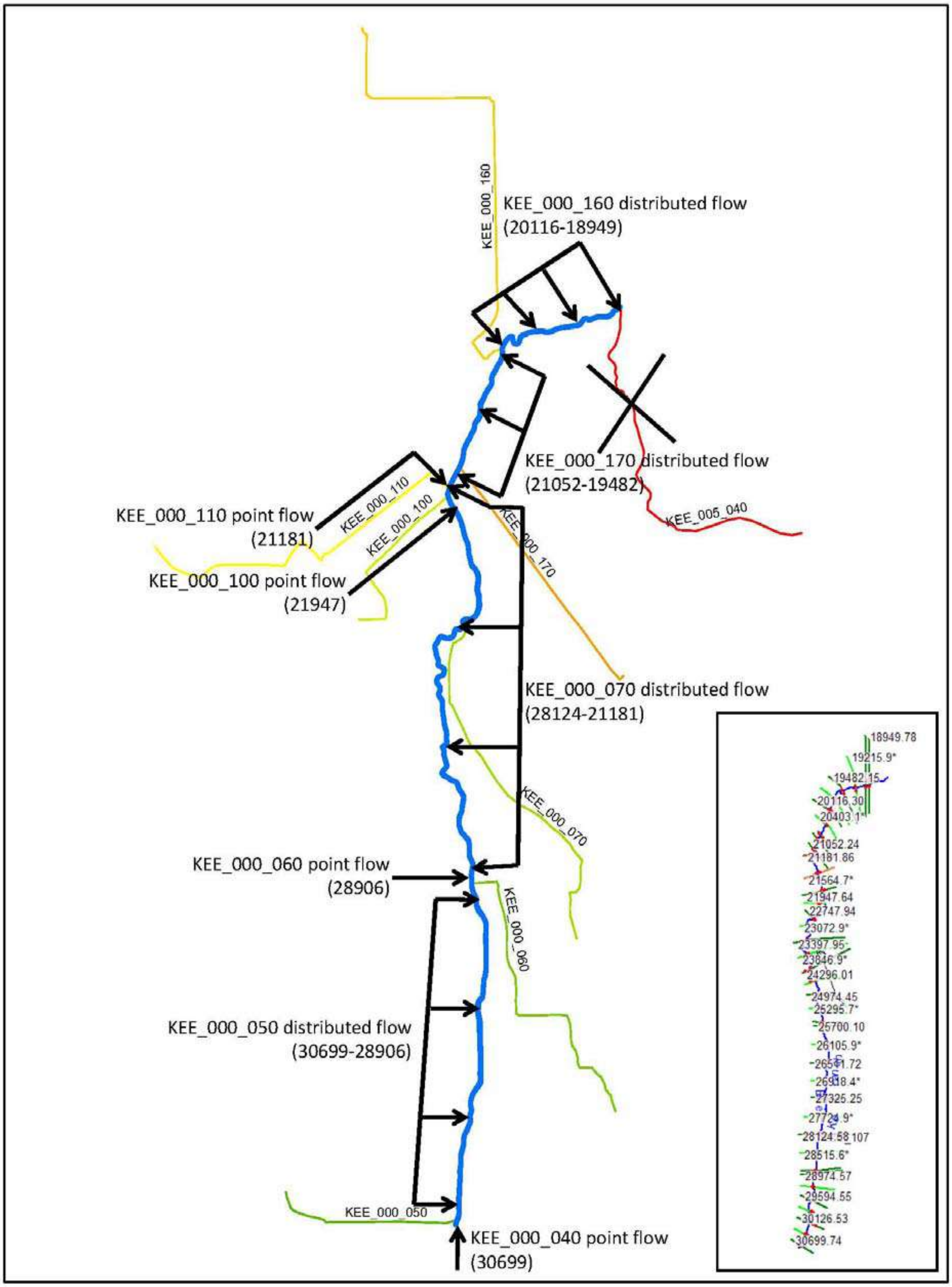


Figure 2-2. Point flow and distributed flow schematics.

Figure 2-3. Longest flow paths for subbasins at the Kee branch Headwaters.

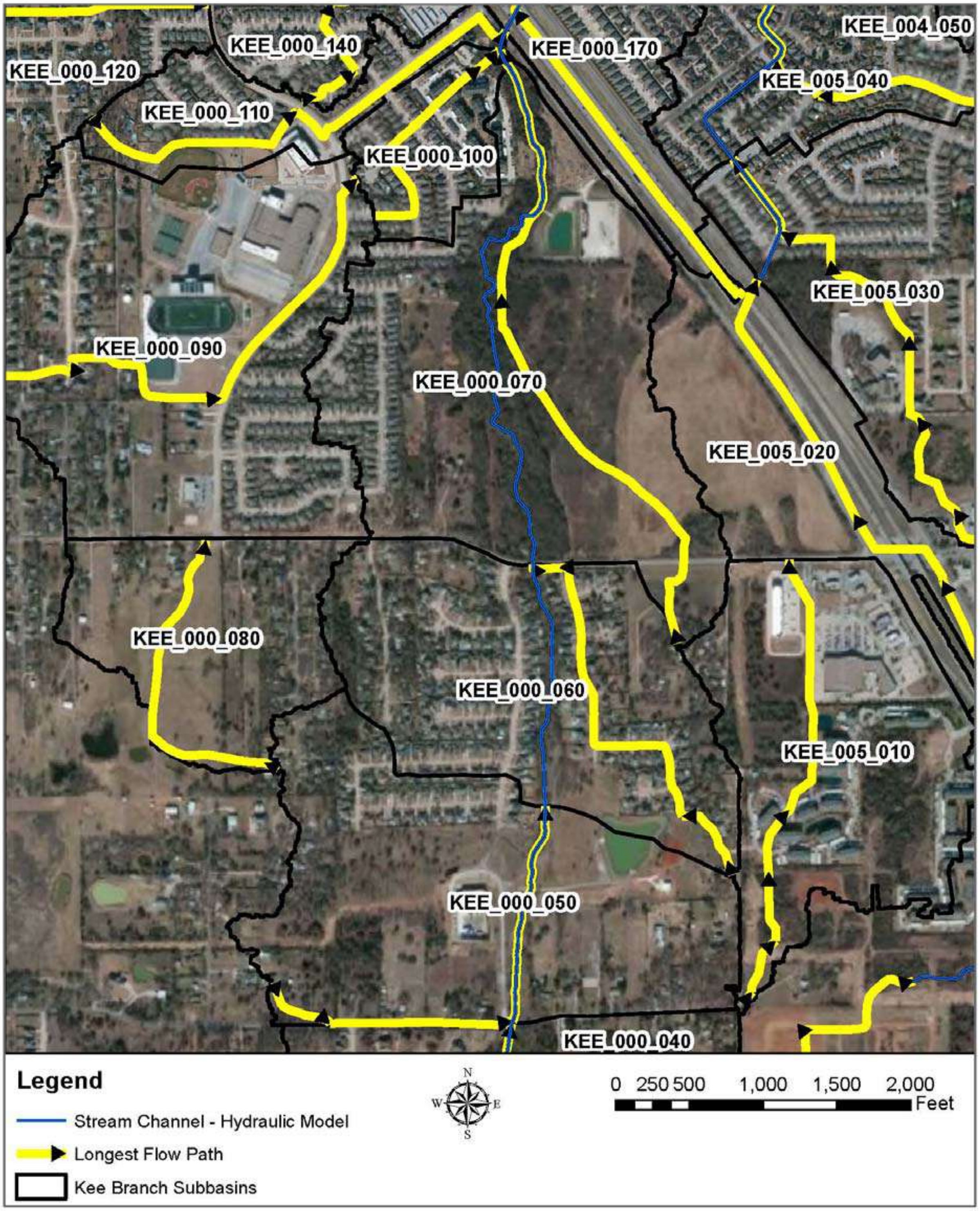


Figure 2-4. Additional KEE_000 Subbasins

Appendix E
LiDAR QA Report

LiDAR Quality Assurance (QA) Report
Fort Worth, Texas
Texas Water Development Board
May 10, 2010

Submitted to:
Texas Water Development Board

Prepared by:
Dewberry
Fairfax, VA

Table of Contents

Executive Summary

Reference: Texas Water Development Board Contract 580-09-0824

This report documents Dewberry's assessment of the quality of the LiDAR deliverables for Fort Worth, Texas, developed under contract to the Texas Water Development Board (TWDB). The LiDAR data and supplemental deliverables were acquired and processed by Fugro Earth Data, Inc. (FEDI) beginning in March 2009. The area consists of 322 tiles of LiDAR data in LAS format 1.1, classified into eight classes as follows.

- Class 1 – Unclassified
- Class 2 – Ground
- Class 3 – Low Vegetation
- Class 4 – Medium Vegetation
- Class 5 – High Vegetation
- Class 6 – Building
- Class 7 – Noise
- Class 9 – Water

The data were reviewed quantitatively for statistical errors and vertical accuracy, and qualitatively for completeness and visual anomalies.

The LiDAR data are of good quality; however, some issues exist in the supplemental products including the breakline dataset, hydro-enforced Digital Elevation Models (DEMs), and metadata products.

- Breakline Dataset - There are topology and completeness issues, albeit minimal, in the breakline dataset. The end user should make note of these errors; however, they do not render the data unusable.
- Hydro-enforced DEMs - The hydro-enforced DEMs contain data voids and incomplete tile edges due to processing errors. The specific tiles containing data voids are documented in this report and must be corrected before use.
- Metadata - Errors exist in the metadata for all products: LAS, breakline, intensity, and DEM. Dewberry has provided suggestions for improvement later in this report.

Completeness: The LiDAR data were required to contain multiple returns per pulse with an intensity value recorded for each point. Dewberry verified that the LAS files adhere to these specifications. Furthermore, the spatial extent of each tile was required to conform to a 1/16th 7.5-minute quadrangle, otherwise known as the USGS Quarter-Quarter-Quad. The internal tiles contain a 50-meter overlap between tiles, while those that line the project boundary contain a 300-meter buffer on all sides. The LAS data were projected to NAD83 UTM Zone 14N and NAVD 88, Geoid 03, meters.

Quantitative Assessment: One of the first steps in assessing the quality of the LAS dataset is a vertical accuracy assessment of the ground models in comparison to the survey checkpoints. Using the checkpoints provided by Dewberry's surveyor, Dewberry tested the $RMSE_Z$ per FEMA/NSSDA and NDEP/ASPRS specifications. The checkpoints were collected in a total of four land cover types (Open Terrain, Urban Terrain, Weeds/Crop, and Forest). The LAS dataset conforms to the vertical accuracy requirements using 100% of the

original 72 checkpoints. Table 1 provides the accuracy results in open terrain based on the FEMA/NSSDA methodology ($RMSE_z$ x 1.960).
Table 2 contains the results measured at the 95% confidence level in the Fundamental Vertical Accuracy (FVA) and the 95th percentile for the Consolidated and Supplemental Vertical Accuracies (CVA and SVA).

Table 1 – Vertical accuracy assessment summary (FEMA/NSSDA)

Criterion	Number of Checkpoints	Accuracy Specification(m)	Results(m)
$RMSE_Z$	24	0.185	0.040
FVA	24	0.363	0.078

Table 2 – Vertical accuracy assessment summary (NDEP/ASPRS)

Criterion	Number of Checkpoints	Accuracy Specification(m)	Results(m)
Consolidated	72	0.363	0.084
FVA – Open Terrain	24	0.363	0.078
SVA – Open Terrain	24	0.363	0.076
SVA – Weeds/Crop	11	0.363	0.075
SVA – Forest	12	0.363	0.480
SVA – Urban	25	0.363	0.072

- Tested 0.084 m consolidated vertical accuracy at 95% confidence level in all land cover categories (NDEP/ASPRS methodology)
- Tested 0.078 m fundamental vertical accuracy at 95% confidence level in Open Terrain using $RMSE_Z$ x 1.9600 (FEMA/NSSDA and NDEP/ASPRS methodologies)
- Tested 0.076 m supplemental vertical accuracy at 95th percentile in Open Terrain category (NDEP/ASPRS methodology)
- Tested 0.075 m supplemental vertical accuracy at 95th percentile in Weeds/Crop category (NDEP/ASPRS methodology)
- Tested 0.480 m supplemental vertical accuracy at 95th percentile in Forest category (NDEP/ASPRS methodology)
- Tested 0.072 m supplemental vertical accuracy at 95th percentile in Urban category (NDEP/ASPRS methodology)

Qualitative Assessment: Dewberry conducted a visual inspection of 100% of the data on a tile-by-tile basis. The data do not contain any major anomalies or data voids. The bare earth model is very clean, but contains some minor anomalies. It is 98% free of artifacts, which exceeds expectations (the acceptable limit is 95%). Very few divots and flight line ridges were identified in the ground models. There are misclassification errors in the dataset, specifically within classes 3, 4, 5, and 6; however, these types of errors are to be expected. Overall, Dewberry can confirm that the LiDAR data is of good quality.

QA Report

1 Introduction

The goal of the TWDB LiDAR Task Order is to provide high accuracy elevation datasets of multiple deliverable products including LAS, intensity imagery, hydro-enforced DEMs, and 3D breaklines for the State of Texas. The project area spans 322 tiles covering 1,061 square miles and will support the National Flood Insurance Program in the development of accurate flood zone maps as well as the USGS's efforts in maintaining its National Elevation Data.

Dewberry had previously reviewed data provided by FEDI with both satisfactory and unsatisfactory results. In summary, the LiDAR data passed the quantitative assessment, however the Quality Assurance (QA) review recommended minor corrections. The original breakline dataset did not pass completeness and qualitative checks, and the data contained topology and other quantitative errors. Dewberry identified that the intensity imagery did not contain a defined projection. Lastly, Dewberry identified errors in the LAS metadata and proposed a set of recommendations to improve the overall quality.

The first review of the Fort Worth data did not consist of all deliverables. The following deliverables were not initially included:

- Hydro-enforced DEMs
- Intensity Metadata
- DEM Metadata
- Breakline Metadata

Dewberry performed a final review of all data products, which included completeness checks, vertical accuracy testing, and qualitative reviews. This report documents the results and defines whether or not each deliverable meets specifications. Special notes have been documented where improvements were made.

The sensor used to acquire the data was the Leica ALS-50. Refer to Figure 1 for the flight line trajectories. The trajectories were provided in shapefile format and include the required information: the aircraft position, attitude and GPS time.

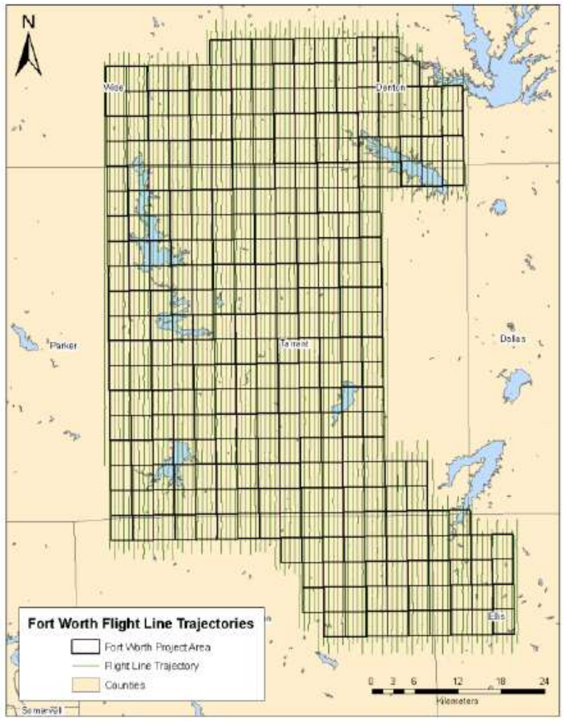


Figure 1 – Map of Fort Worth project area displaying complete coverage by trajectories

2 LAS

2.1 Completeness

The LAS datasets were provided in format 1.1, in 322 tiles as defined by USGS 1/16th 7.5 minute quadrangles. The tiles that fall on the project boundary have a 300-meter buffer while those that fall within the boundary contain a 50-meter overlap between tiles.

2.1.1 Methodology

Dewberry conducted a statistical analysis of the LiDAR data to ensure its completeness. The tool used to perform the analysis reports the relevant information specific to LAS data in format 1.1. This information includes the following:

- Number of points per tile;
- ASPRS classes used throughout the dataset;
- Projection and datum;
- Scan angle of the sensor;
- Elevation values per tile;
- Swath overlap; and
- Other criteria.

2.1.2 Assessment Results

Dewberry verified that the LAS contained the appropriate information in each of the aforementioned categories. One point to note is the amount of swath overlap. The scope of work requires a nominal sidelap of 50% on adjoining swaths, meaning that all of the data should have 100% double coverage. The tile in Figure 2 colored by individual flight lines amounts to 34% of overlap on either side. This same characteristic is present throughout the dataset.

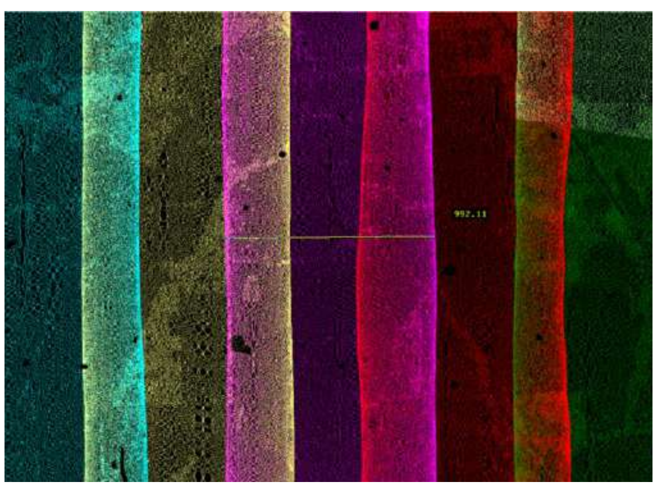


Figure 2 - Tile u339760_2_a; LAS Source data showing flight line overlap. The yellow line defines the width of one flight line.

The LAS data follow the USGS tile naming system and are classified by the following ASPRS classes:

- Class 1 – Unclassified

- Class 2 – Ground
- Class 3 – Low Vegetation
- Class 4 – Medium Vegetation
- Class 5 – High Vegetation
- Class 6 – Building
- Class 7 – Low Point/Noise
- Class 9 – Water

Figure 3 illustrates the total number of LiDAR points collected per tile. The tiles along the project boundary with the highest number of points reflect the 300-meter buffer. This is to be expected.

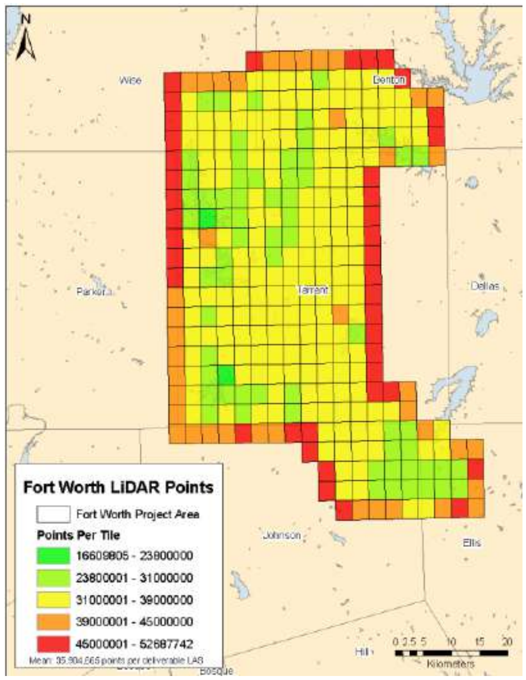


Figure 3 – Map illustrating the total number of LiDAR points per tile

The figures provided below illustrate the minimum and maximum elevation values of the ground class. The lowest z-minimum values depicted by Figure 4 exist in the eastern portion of the project area and elevate toward the west. The same pattern is recognized in Figure 5 as the lowest of the z-maximum values originate in the east and gradually heighten toward the west. The maps also verify that null or extraneous z-values in the ground class do not exist.

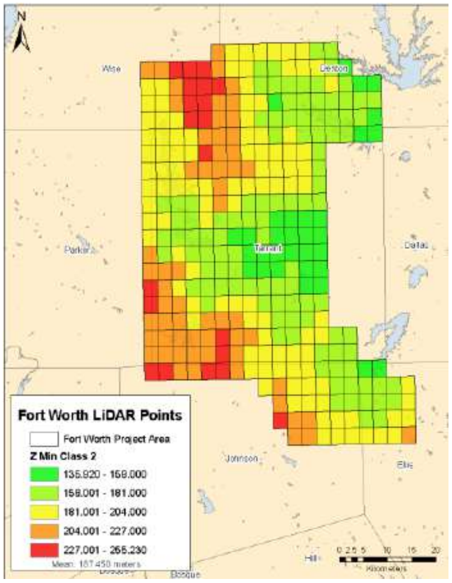


Figure 4 – Map of Z-minimum values in the ground class

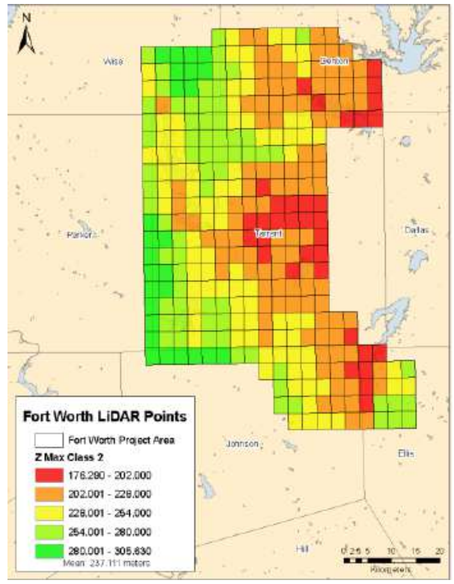


Figure 5 – Map of Z-maximum values in the ground class

2.2 Quantitative Assessment

Dewberry performed an analysis that compared the elevation values of ground survey checkpoints against the LiDAR data to ensure the vertical accuracy of the LiDAR data.

2.2.1 Methodology

Dewberry used 72 surveyed checkpoints, chosen to fall into the following land cover categories:

- Urban Terrain – 25 points
- Open Terrain – 24 points
- Forest – 12 points
- Weeds/Crops – 11 points

The checkpoints were spread across the 1,061 square mile project area in an effort to survey as many flight lines as possible. To verify accuracy of the survey, 50% of the checkpoints were re-surveyed. The re-surveyed values match the initial surveyed positions within the 95% confidence level. Figure 6 illustrates the locations of the checkpoints throughout the project area colored by their respective land cover types.

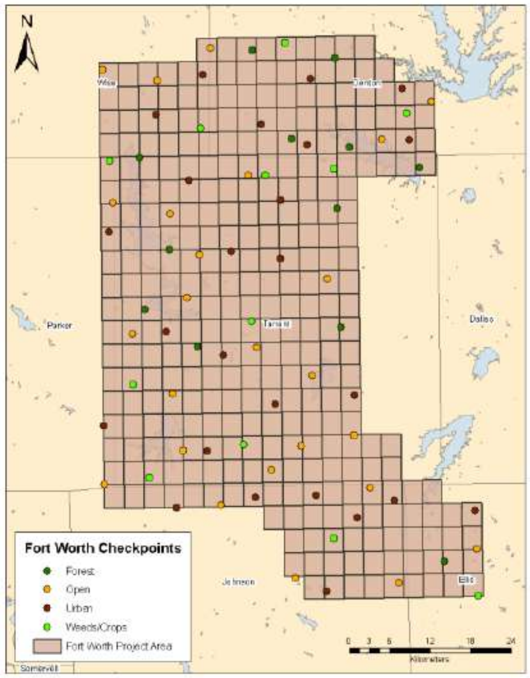


Figure 6 – Map displaying spatial location of 72 survey checkpoints

The GPS technique used to survey the data was connected to Real Time Kinematic (RTK) network. This network is composed of highly accurate GPS reference stations that compare the survey checkpoints against published coordinates. It is linked to create a Virtual Reference Station (VRS) system. The VRS functions as a network of points that send corrections to the survey checkpoints, solving for ionospheric and tropospheric conditions. Additionally, six National Geodetic Survey monuments were used to validate the accuracy of the VRS network. These monuments also acted as the primary project control monuments.

Dewberry's methodology for testing vertical accuracy used the orthometric heights of the survey checkpoints compared against the bare-earth LiDAR elevations at the same horizontal locations. The survey checkpoints were overlaid on the Triangulated Irregular Network (TIN) created by the LiDAR ground points and the interpolated Z value from the TIN at that point was subtracted from the survey checkpoint elevation. The differences in Z values were recorded, and represent the amount of error between the two measurements.

2.2.2 Assessment Results

The LAS data passed the quantitative assessment using 100% of the survey checkpoints with a consolidated RMSE of 0.112m as shown in Table 3.

Table 3 – RMSE method for testing vertical accuracy

100% of Totals	RMSE (m) Spec=0.185m	Mean (m)	Median (m)	Skew	Std Dev	# of Points	Min (m)	Max (m)
Consolidated	0.112	-0.008	0.009	-6.635	0.113	72	-0.875	0.089
Open Terrain	0.040	0.006	0.003	-0.506	0.040	24	-0.092	0.077
Weeds/Crop	0.041	0.028	0.023	0.344	0.032	11	-0.022	0.089
Forest	0.259	-0.091	0.005	-3.172	0.254	12	-0.875	0.033
Urban	0.041	0.004	0.009	-0.294	0.041	25	-0.080	0.075

The result of the FVA assessment shown in Table 4 provides the best summary of the data, as it describes how well the sensor worked in open terrain - the land cover type with the least amount of induced error. With an FVA value of 7.8 cm and a threshold of 36.3 cm, it can be concluded that the LAS data were collected with accuracy. As a result, we expect that the sensor functioned appropriately in all other land cover types. The CVA and SVA assessments report the RMSE value that 95 percent of the errors fall on or below, known as the 95th percentile. The remaining 5 percent of the errors lie above the stated CVA and SVA values.

Table 4 – Fundamental, Consolidated, and Supplemental Vertical Accuracies

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy	CVA — Consolidated Vertical Accuracy	SVA — Supplemental Vertical Accuracy
Consolidated	72		0.084	
Open Terrain	24	0.078		0.076
Weeds/Crop	11			0.075
Forest	12			0.480
Urban	25			0.072

The following graph illustrates the RMSE results of the survey checkpoints separated by land cover type. The majority of errors are distributed just above and below zero with one outlier in the forest category.

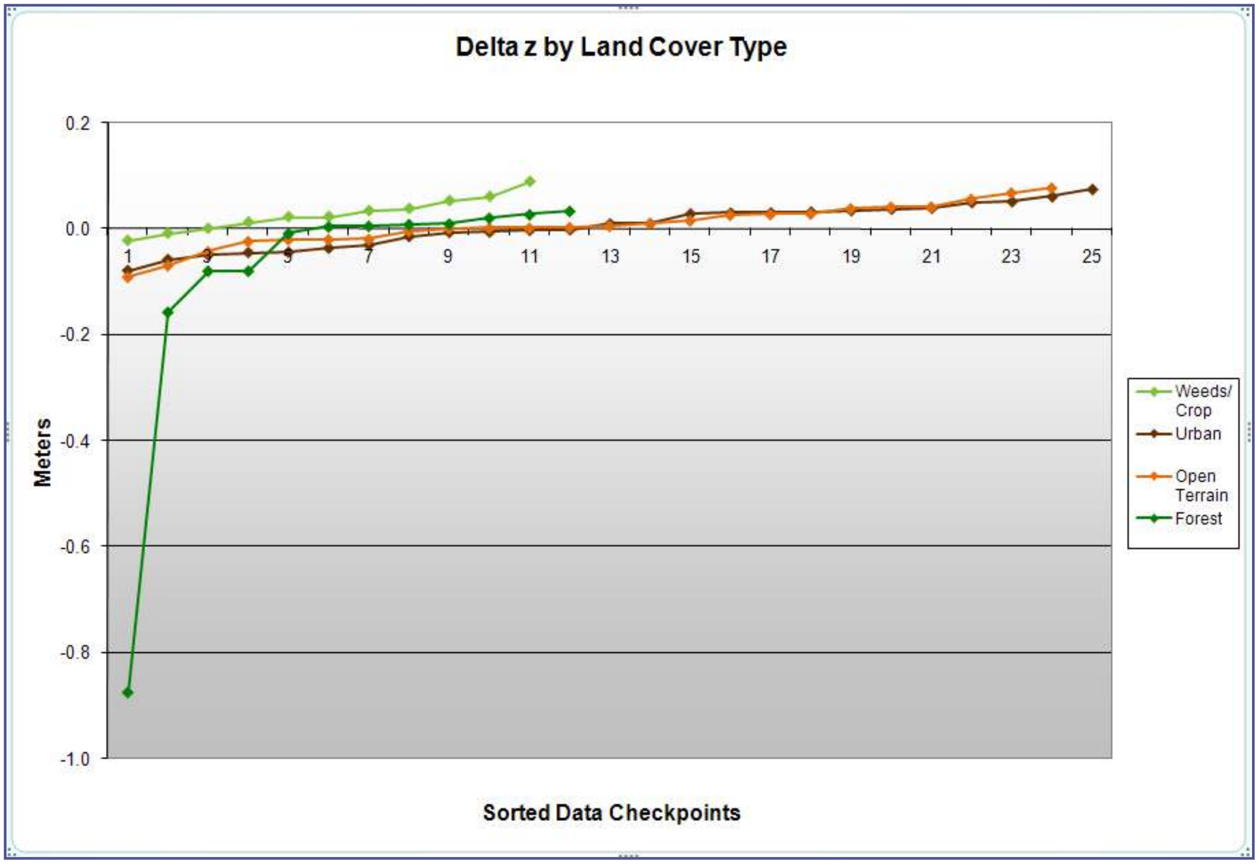


Figure 7 – Display of RMSE value of 72 checkpoints based on land cover type

The RMSE value using the 95% best checkpoints was computed. Table 5 identifies the four points that were removed.

Table 5 – The least accurate 5% of checkpoints

Point	Easting	Northing	Elevation	Z LiDAR	Land Cover Type	DeltaZ
W-612-F	685304.402	3592474.073	218.637	217.762	Forest	-0.875
W-506-VTF	662641.773	3654876.960	175.717	175.560	Forest	-0.157
OT-628	652252.904	3600719.460	245.930	245.838	Open Terrain	-0.092
B-19-VTV	679674.813	3658657.342	178.733	178.822	Weeds/Crop	0.089

The RMSE using the 95% of the best checkpoints is **0.037m,** as shown in Table 6. The most notable improvements exist in the Forest and Weeds/Crop categories.

Table 6 – RMSE method for testing vertical accuracy at 95%

100 % of Totals	RMSE (m) Spec=0.185m	Mean (m)	Median (m)	Skew	Std Dev	# of Points	Min (m)	Max (m)
Consolidated	0.037	0.007	0.007	-0.485	0.036	68	-0.080	0.077
Open Terrain	0.035	0.009	0.003	-0.096	0.034	23	-0.070	0.077
Weeds/Crop	0.031	0.019	0.022	0.076	0.026	10	-0.022	0.061
Forest	0.036	-0.005	0.005	-1.568	0.037	10	-0.079	0.033
Urban	0.041	0.004	0.009	-0.294	0.041	25	-0.080	0.075

Improvements are made in the FVA, CVA, and SVA values using the best 95% of the checkpoints.

Table 7 - Fundamental, Consolidated, and Supplemental Vertical Accuracies

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600)	CVA — Consolidated Vertical Accuracy (95th Percentile)	SVA — Supplemental Vertical Accuracy (95th Percentile)
Consolidated	68		0.076	
Open Terrain	23	0.069		0.069
Weeds/Crop	10			0.057
Forest	10			0.079
Urban	25			0.072

2.3 Qualitative Assessment

Dewberry performed a micro-level qualitative analysis on 100% of the LAS data by performing a visual analysis of ground models, full point cloud models, and raw LiDAR points. Below is a discussion of the discrepancies identified in the dataset. Appendix A contains a complete list of LiDAR calls. While corrective actions could have been made, the LiDAR data pass the qualitative assessment.

Artifacts

In any dataset it is not uncommon to find artifacts left in the ground models. Typically, artifacts are caused by misclassification of points. As an example, points that should have been classified as a building (class 6) may be left in the ground class (class 2). Dewberry identified a total of four artifacts in the bare-earth LiDAR models throughout the entire Ft. Worth project area. In the Acceptance Criterion, Dewberry requires 95% removal of artifacts. This dataset meets the accuracy specifications, as 98% of the ground models are free of artifacts.

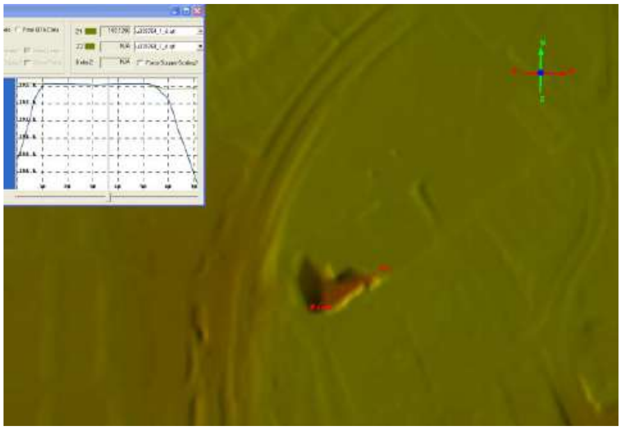


Figure 8 - Tile u329764_1_d; Partial building left in the ground model

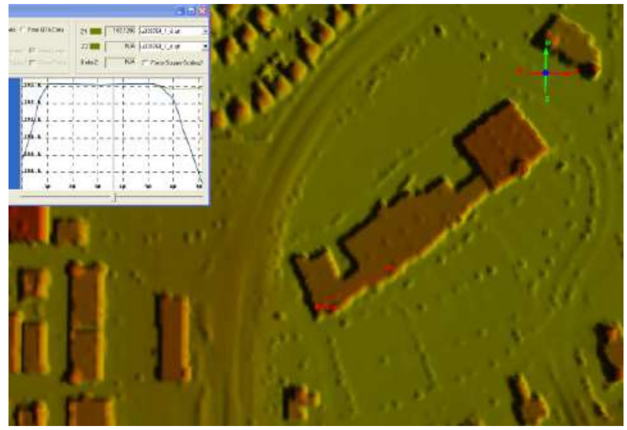


Figure 9 – Full point cloud model showing entire building

Inconsistent Editing

Dewberry identified a few cases in the dataset where inconsistent editing occurred. This type of error may be visible in the removal of buildings, bridges, highway ramps or vegetation. The example below shows a highway ramp that was incorrectly removed from the ground. It is evident when analyzing the full point cloud model that both ramps on either side of the overpass are similar, thus the ground points should have been edited in the same manner. Placing ground points back in the ground class would have improved data quality; however, due to the minimal number of inconsistent edits in the ground models (1.8%), the data meets the requirements.

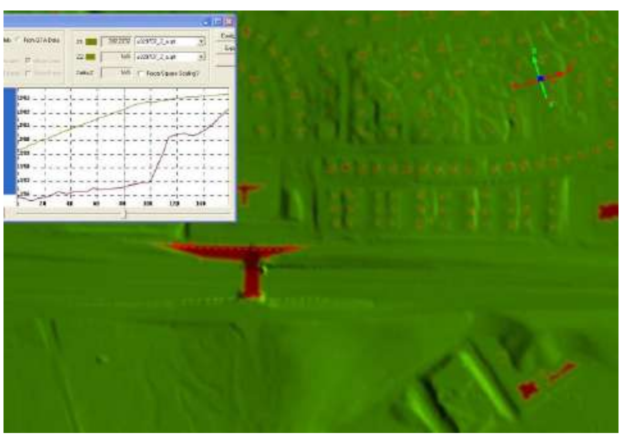


Figure 10 – Tile u329707_2_a; Inconsistent editing of the ground class

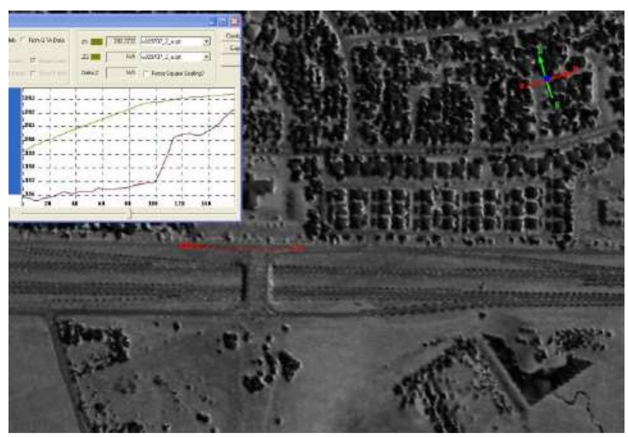


Figure 11 – Full point cloud intensity model showing that the highway ramp and overpass features

Divots

Divots in the dataset are caused by the misclassification of points. As an example, points that should exist in class 7 (noise) may instead be classified as class 2 (ground points). These points lie well below the true ground and may be overlooked during the classification process. Five examples of divots were identified in the ground models. Since the data are largely free of such outliers, Dewberry did not ask for correction.

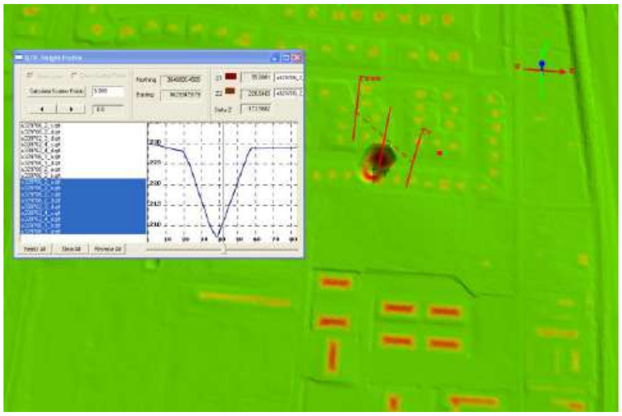


Figure 12 – Tile u329706_2_d; Ground density model of divot

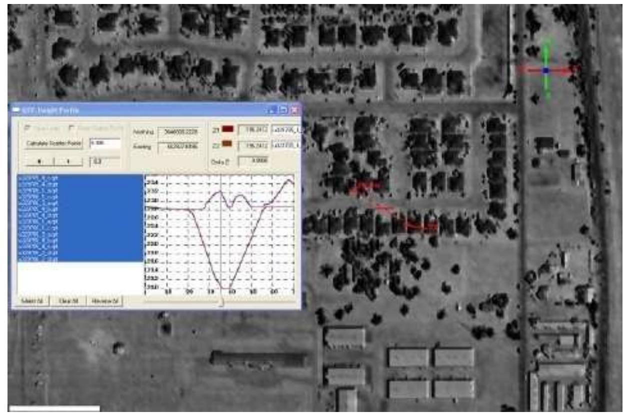


Figure 13 – Full point cloud intensity model

Misclassification

Throughout the dataset there are many examples of the misclassification of LiDAR points in classes 3, 4, 5, and 6. The image below displays an area populated by trailers. Although the trailers should be classified as buildings, they are classified as high vegetation (Figure 14, shown in purple). However, the ground is not affected by this type of misclassification as illustrated by Figure 15. Dewberry is not concerned with this anomaly, as it does not affect the usability of the bare-earth data; it is simply an observation.

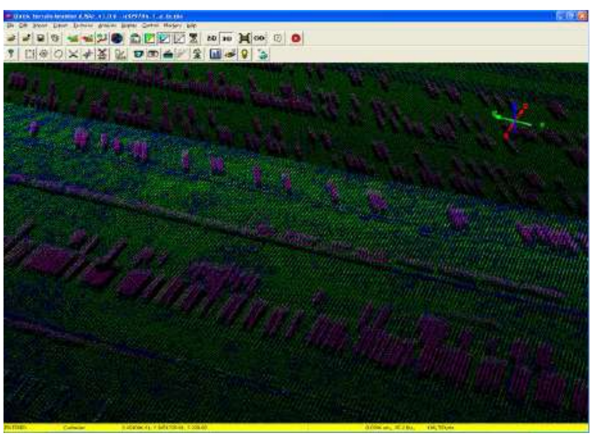


Figure 14 - Tile u329706_1_a; LAS showing trailers classified as high vegetation points

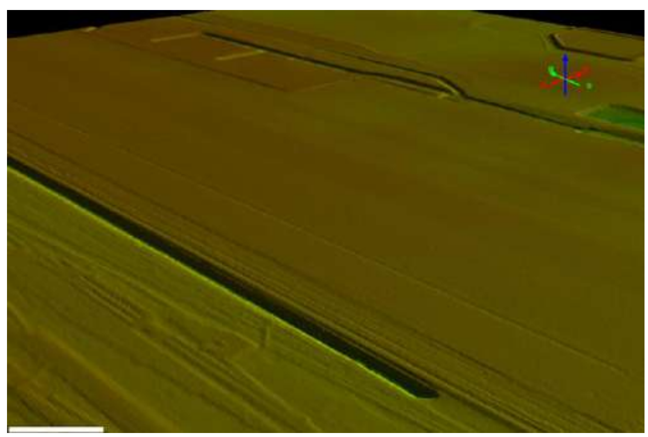


Figure 15 – Tile u329706_1_a; model showing correct classification of ground despite misclassification of trailers

Flight Line Ridges

Minimal flight line ridges, amounting to mismatches of 20-centimeters, were identified in the dataset. The Acceptance Criterion specifies the correction of seam line mismatches that are greater than 20-centimeters. These do not require corrective measures.

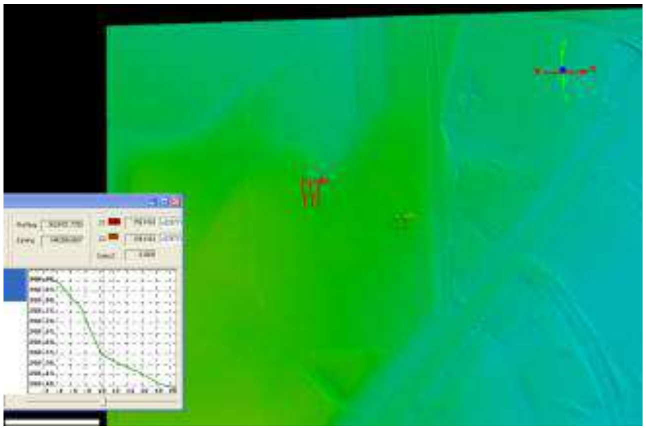


Figure 16 – Tile u329721_2_a; Ground model of flight line ridge

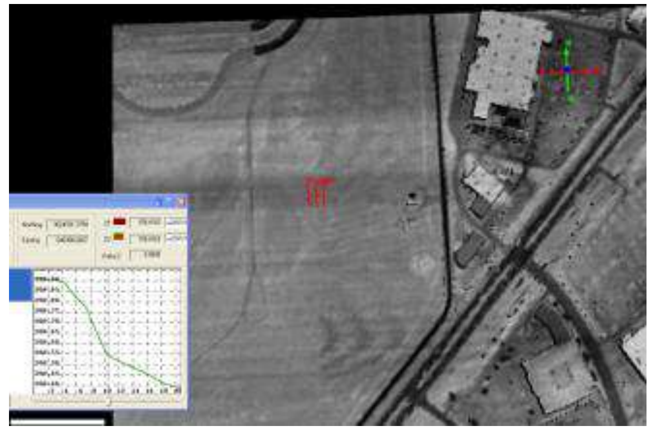


Figure 17 – Intensity image illustrates the boundary between flight lines

3 Breaklines

Dewberry conducted a thorough quantitative and qualitative analysis of the breakline dataset. The breaklines were examined a second time to determine if they met project requirements for completeness, topology (including monotonicity – ensuring that each stream flows downhill), and vertical accuracy. Dewberry assessed the dataset for hydro-enforcement of the hydrolines, the topology of the dataset, and the completeness of the watershed.

In a previous memo, Dewberry provided a list of edit calls and common issues found in the breakline dataset and recommended their correction. After reviewing the most recent geodatabase, it is evident that FEDI has made many improvements to the data. Some outstanding issues still remain that are detailed in the qualitative analysis section below.

3.1 Inventory

Dewberry received an ESRI Geodatabase that included the following feature classes:

- Culvert
- Single Stream
- Stream Polygon
- Stream Connector
- Stream Island Polygon
- Waterbody Polygon
- Waterbody Connector
- Waterbody Island Polygon

3.2 Topology

An important requirement of hydro breaklines intended for modeling is valid topology. Dewberry tested the topology using ESRI's PLTS to ensure that breakline vertices snapped together, that hydro lines were monotonic within a tolerance, that all waterbodies were flat, and that all breaklines had defined elevations. The issues identified during the review are listed below.

- Duplicate geometry:
  - 9 waterbody to waterbody islands
  - 5 stream to stream islands
- Dangles:
  - 1 stream dangle

3.3 Vertical Accuracy Assessment

In order to test the relative accuracy of the breaklines compared to the LiDAR, Dewberry compared a sample of the breakline vertices to the LiDAR masspoints. This is not a definitive test; it is used as an internal guideline to determine how well the breaklines fit the LiDAR. We expect in some cases that the data will not fit, which may be due to the distribution of points or the difficulty in collecting a bankline on a steep slope, for example. Therefore, we use this check as an indication of the vertical consistency between the two products.

3.3.1 Methodology

Dewberry tests the vertical accuracy of the breaklines by comparing the elevation of a sample of the breakline vertices to the surrounding LiDAR points. The vertices of polyline breaklines are converted to points while a GeoTerrain is created from the LiDAR masspoints using only the ground classification. The elevation of the LiDAR is derived by extracting the Z-value of the terrain at the same X/Y-values of the "checkpoints". Finally, an analysis of the elevation comparison between the checkpoints and the terrain is conducted to determine the accuracy of the breakline collection. Due to the enforced montonicity of the breaklines, Dewberry set a criterion of twice the RMSE to allow room for acceptable errors.

A slightly modified version of the process described above was implemented for the analysis of the waterbody features. Since the waterbody breakline vertices are all equal, the purpose of the vertical accuracy assessment is to determine if LiDAR masspoints surrounding the breakline are lower in elevation than the breakline. If there are masspoints with lower elevations, then the horizontal placement of the breakline may need to be adjusted. Dewberry set a criterion that if 20% of the vertices are higher in elevation or "float above" the surrounding masspoints, then the feature is marked as an error.

3.3.2 Assessment Results

The breakline vertex samples were tested for the individual feature classes against the masspoints. Table 1 shows the raw $RMSE_Z$ values, the vertical accuracy value at the 95^{th} percentile, and the vertical accuracy value and percentile level at which the breaklines reach the accuracy of less than twice the $RMSE_Z$ or 0.363 m.

Table 8 – Vertical Accuracy Results

Breakline Feature Class	Vertical Accuracy at 95^{th} Percentile	Percentile at which the vertical accuracy is less than twice the $RMSE_Z$, Spec= 0.363 m
Single Line Stream	0.351	95th
Dual Line Stream	0.852	79th

Table 2 illustrates the results of the vertical accuracy assessment performed on the waterbody feature vertices. Dewberry tested 1,319 breaklines and found that 14 features have at least 20% of their vertices with higher elevations than the surrounding masspoints.

Table 9 – Vertical Accuracy Results of the Water body Feature Class

Total Waterbodies floating (based on 20% criterion)	14
Total Waterbodies	1319
Percent of Water bodies floating	1%

The waterbody feature class achieved the poorest vertical accuracy rating using this method. Of the total feature count, 1% of the waterbody features float above the masspoints. Please note that this analysis does not take into account the distance of the vertices above the terrain, only that a certain percentage of the vertices are in error. However, after the visual review, Dewberry only identified waterbodies floating by 0.35m or less. Dewberry did not identify any major anomalies that would cause concern. Based on the very small percentage of waterbodies floating, and the small degree by which they float, Dewberry is confident in the level of vertical consistency between the waterbodies and the LiDAR masspoints.

3.4 Qualitative Assessment

Dewberry performed a second visual qualitative analysis of the breaklines against intensity imagery as well as a terrain created using LiDAR masspoints. The purpose of this check is to verify the completeness of each feature class. The analysts check for feature coding errors and missing features. They also verify that breaklines are compiled to the correct project boundary, and that features are captured without overlap.

In the previous dataset, a general call was placed to snap all breaklines to the project boundary. It appears that issues still remain, as several breaklines extend past the boundary while others stop short of the boundary. Figure 18 illustrates this issue. All breaklines should be snapped to the project boundary.

Figure 18 – Tile u329704_4_c; waterbody extends past project boundary

Waterbody Feature Class

As defined by the breakline specifications, any waterbody greater than or equal to 1 acre is to be captured. Previously, Dewberry identified 100+ missing waterbodies in the dataset. FEDI made many improvements to the waterbody feature class; however, there are waterbodies that meet the criteria that have not been collected. Figure 19 and Figure 20 identify a waterbody in the intensity and terrain that is 1.4 acres.

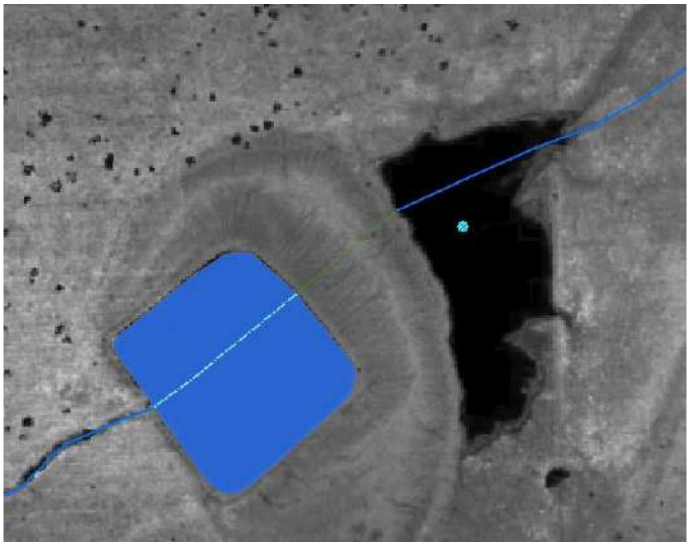


Figure 19 – Tile u339754_4_d; Intensity supports initial claim that a waterbody is missing

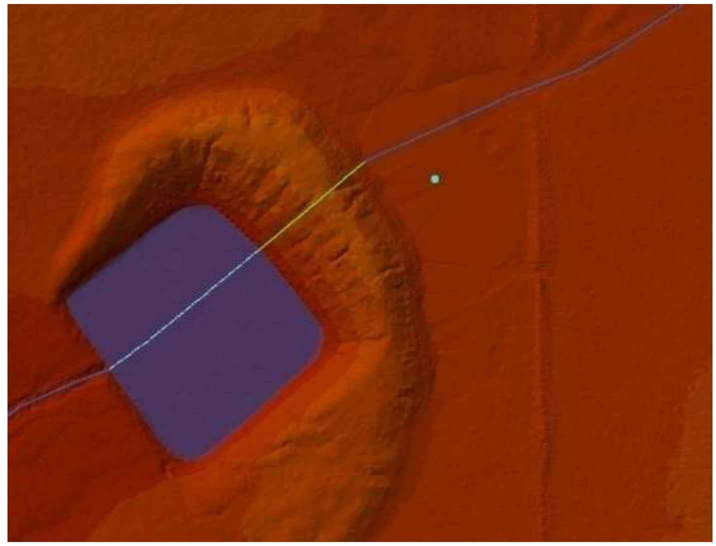


Figure 20 – Flatness of terrain due to absence of masspoints supports the collection of the waterbody

There are very minimal feature coding errors that affect the waterbody feature class. In Figure 21, a single line stream runs through a waterbody. Instead, this feature should have been coded as a waterbody connector.

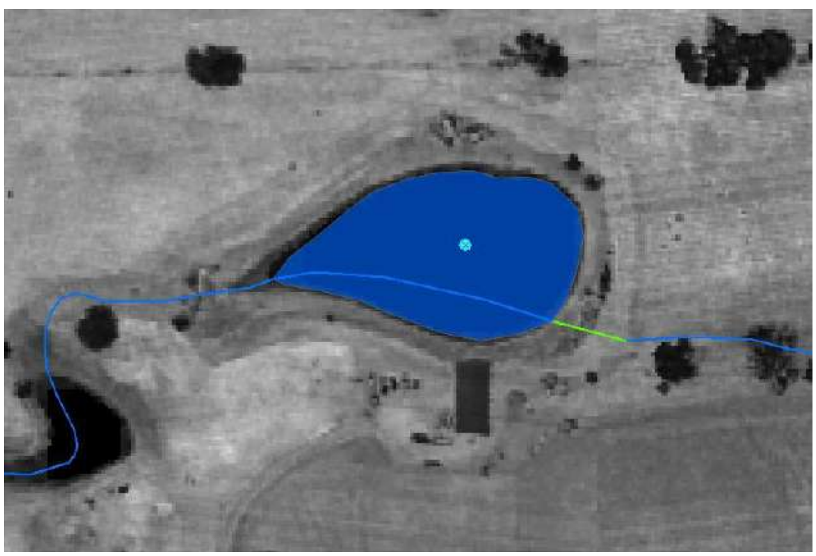


Figure 21 – Tile u339762_2_c; Stream passing through waterbody should be coded as a waterbody connector

Hydrographic Features

Many inconsistencies in the collection of hydrographic features existed in the previous dataset. However, FEDI heeded many of Dewberry's recommendations and as a result the hydrographic features have significantly improved. Some discrepancies may exist - it can be debatable if a feature should be a waterbody or a stream, for example. However, overall the hydrographic feature class is of good quality in terms of both capture methods and horizontal placement of the breaklines.

Below is an example of one error that was also called in the previous dataset. The major waterbody in blue should have two dual line streams (purple) that feed into the waterbody from the west. The single line stream to the north, highlighted by the yellow arrow, should be captured and coded as a dual line stream for two reasons: it is greater than 40ft wide, and the feature to the south that has the same characteristics was treated as a dual line stream.

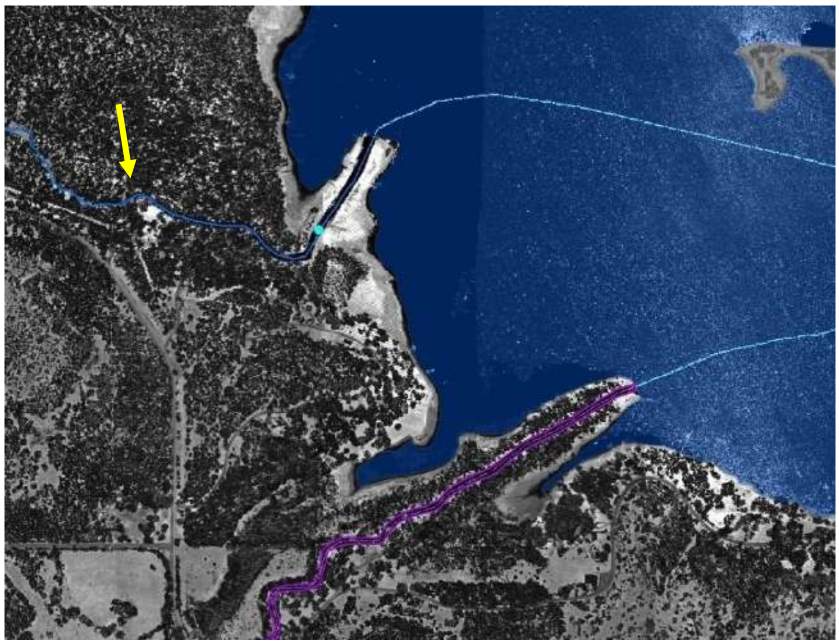


Figure 22 – Stream denoted by yellow arrow should be coded as a dual line instead

Waterbody Island Feature Class

Dewberry placed calls that requested the delineation of water body islands in the previously submitted dataset. In their response, FEDI stated that island feature classes less than one acre did not require collection. However, there are island features greater than 1 acre that were not compiled. Figure 23 shows three islands that are between 1 and 2 acres in size that were not collected.

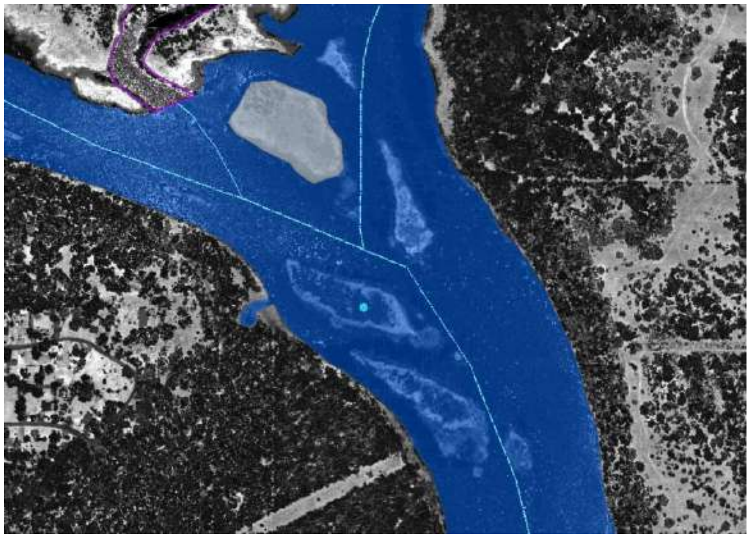


Figure 23 – Tile u329713_1_d; waterbody islands up to 2 acres not collected

Culverts

The purpose of culverts is to connect hydrographic features when they are interrupted by a road. The difficulty in using culverts consistently throughout the dataset is in determining the type of feature underneath which they pass. If the stream is running under a bridge, it should remain a stream. However, if the stream passes under a road as a culvert, then it should be coded as such. It is not always easy to judge if the feature is a road or bridge based on intensity imagery. Therefore, it is possible that one reviewer may interpret the feature as a bridge while the other sees a road. Dewberry took this into account when placing calls that asked for streams to be coded as culverts, and Fugro either made the appropriate changes or provided justifications.

After completing the review of culverts, Dewberry did not identify any major discrepancies that require resolution.

4 Intensity

Dewberry received a complete delivery of LiDAR intensity images. The data were required to meet the following specifications:

- Raster images in GeoTIFF format of 1st-return
- 1-meter pixel size
- 1/4th USGS 7.5-minute quadrangle

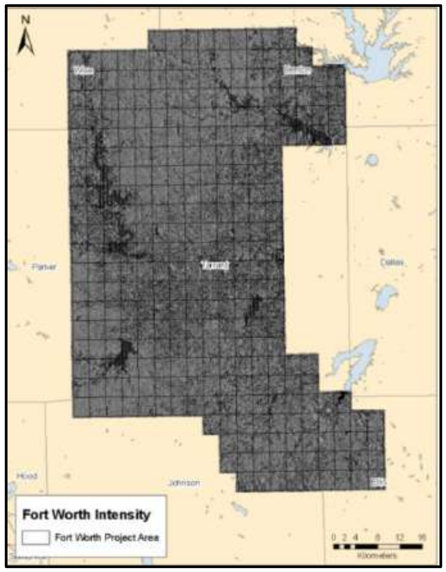


Figure 24 - Complete delivery of Fort Worth Intensity

With the exception of the tile grid, all 322 files were delivered in accordance with the requirements. The intensity are tiled based on the 1/16th USGS 7.5-minute quadrangle. They follow the same tiling scheme as the LAS data; that is, the internal tiles have a 50-meter overlap between tiles and those that line the project boundary have a 300-meter buffer.

Dewberry verified that the pixel values in the areas of overlap are the same. However, Dewberry could not verify that the intensity data are projected. FEDI stated that the projection has been defined using a different set of definitions that ArcGIS cannot read as shown in Figure 25. It appears that the projection may be defined by the number 3721, as opposed to a text format definition. Dewberry recommends that the projection be defined so that it may be validated in ArcGIS.

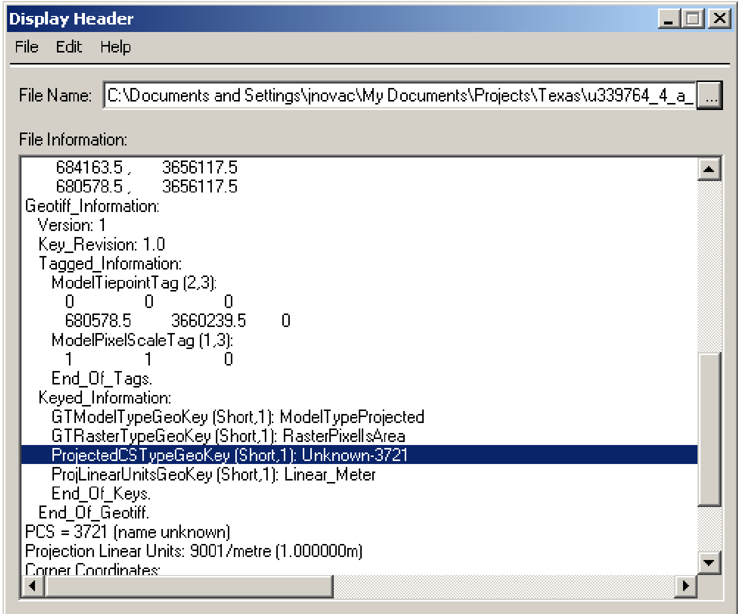


Figure 25 - Intensity header example

5 Hydro-Enforced DEMs

To verify the accuracy and completeness of the hydro-enforced DEMs, Dewberry performed a series of checks on the data, beginning with a visual analysis. This analysis was performed on each DEM, on a tile-by-tile basis in an effort to identify any major anomalies in the data, specifically data voids. Furthermore, each DEM was processed to create a hillshade as a second visual check. Hillshades provide an illuminated view of the ground surface created from a hypothetical light source, which gives analysts an image in which data voids are easier to see during the assessment process.

The DEMs are required to be free of artifacts, gaps, or smoothing at tile boundaries. Upon completion of the visual analysis, Dewberry identified the following discrepancies:

Table 10 – Complete list of errors identified in the hydro-enforced DEMs

DEM Tile	Error Type
u329704_4_b_be	data void
u329704_4_d_be	data void
u329707_4_c_be	data void
u339762_2_b_be	data void
u329633_1_a_be	incomplete tile edge
u329705_3_c_be	incomplete tile edge
u329708_1_b_be	incomplete tile edge
u329712_4_c_be	incomplete tile edge
u329728_2_a_be	incomplete tile edge
u329729_4_b_be	incomplete tile edge
u329732_1_a_be	incomplete tile edge
u339753_4_d_be	incomplete tile edge
u339764_2_c_be	incomplete tile edge

Figure 26 and Figure 27 illustrate the data void identified in tile u329707_4_a. Since the DEMs are composed of LiDAR ground points and hydro-enforced breaklines, a data void of this magnitude would cause suspicion of the quality of the ground points. However, Dewberry verified that the ground points are complete in this particular tile, as illustrated in Figure 28. As a result, Dewberry attributes this error to DEM processing. This is true for all tiles that contain errors, as listed in Table 10. Dewberry verified the integrity of the ground points from the LAS source, and concluded that all errors resulted from the processing steps. Dewberry strongly encourages that these errors be corrected before the data is used.

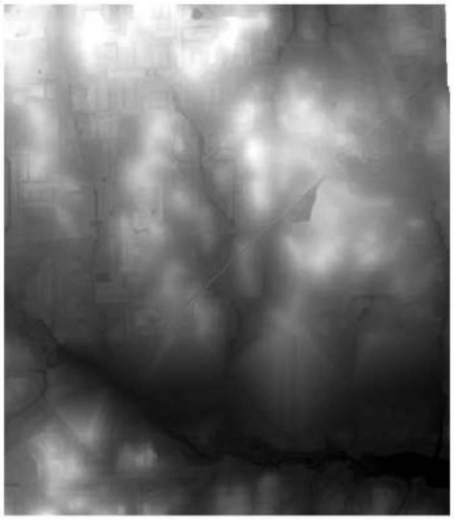


Figure 26 – Tile u329707_4_a; data void in bottom half of DEM

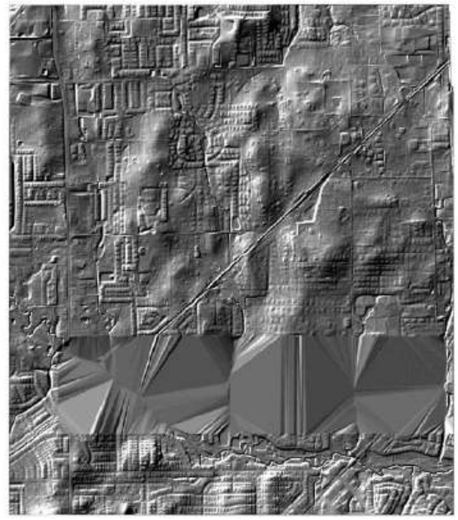


Figure 27 – Data void illustrated by hillshade model

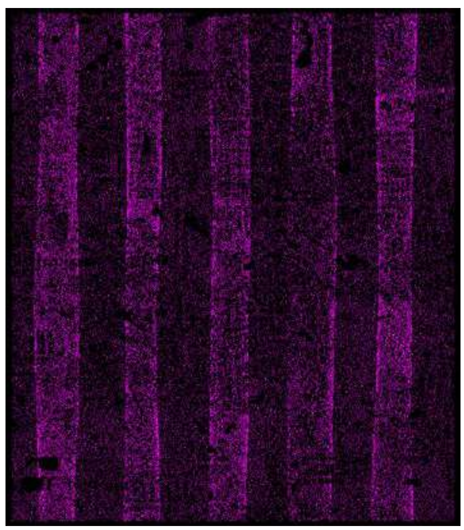


Figure 28 – Ground LiDAR points from source LAS are complete throughout the tile

6 Metadata

Dewberry received tile-based LAS, DEM, and intensity metadata, as well as breakline metadata provided in the geodatabase. Dewberry reviewed the metadata, checking for accuracy and completeness based on Federal Geographic Data Committee (FGDC) requirements.

6.1 LAS Metadata

In the previous delivery, Dewberry received LAS metadata and proposed a set of corrections. Many improvements have been made to the LAS metadata. There are three recommendations remaining:

1. The *Theme* states *intensity image.* This should be removed.
2. *Who created the data* and *who completed this document* is FEDI, instead of the TWDB.
3. The *Horizontal Coordinate System* does not state the projection: UTM Zone 14N

6.2 Intensity Metadata

This is the first review that Dewberry has performed on the intensity metadata. Below are recommendations to improve the metadata quality:

1. *Who created the data* and *who completed this document* is FEDI, instead of the TWDB.
2. *Type of data* reads LAS. This is incorrect and it should be Intensity.
3. The *Horizontal Coordinate System* does not state the projection: UTM Zone 14N
4. The *FGDC lineage process steps* should only contain step 3. Steps 1 and 2 are not needed. The *source* information should reference the LAS ground files.
5. The *Attributes* tab lists LAS 1.1 format. This should be removed.

6.3 DEM Metadata

This is the first review that Dewberry has performed on the DEM metadata. Below are recommendations to improve the metadata quality:

1. *Who created the data* and *who completed this document* is FEDI, instead of the TWDB.
2. *Type of data* reads LAS. This is incorrect. It is DEM data delivered in ESRI grid format.
3. The *Horizontal Coordinate System* does not state the projection: UTM Zone 14N
4. The *FGDC lineage process steps* 1 and 2 are not needed.
5. The *Vertical positional accuracy* states the LiDAR accuracy, which is different from the accuracy of the DEMs.
6. The *Attributes* tab lists LAS 1.1 format and GeoTiff. This should be removed as it is DEM data in ESRI grid format.

6.4 Breakline *Meta*data

The breakline metadata was delivered per feature class. Dewberry reviewed each of the eight feature class metadata files for accuracy and completeness. The following issues were identified:

1. The *Theme* specifies *waterbody* for each feature class. This is incorrect for every feature classes with the exception of the waterbody feature class
2. The *FGDC lineage process step* 1 defines the criteria for capturing a single line stream as any hydro feature less than 50 feet, when in fact the breakline specification states 40 feet.

7 Optional Deliverables

7.1 ASCII Ground Point List

Dewberry received 322 ASCII text files that list the x, y, and z coordinates of all ground points, class 2. The models follow the 1/16th USGS 7.5-minute quadrangle tiling scheme. To ensure the correct number of ground points in each file, Dewberry compared the count of the ground class from the LAS to the count from the ASCII text files. In each comparison, Dewberry found consistency between the two types of models. Secondly, Dewberry created ground models of all 322 ASCII files as a second check to verify that data is present in each tile. Dewberry then conducted a macro level assessment of the ground models and did not find any major anomalies.

7.2 First-Return Surface Model

Dewberry performed a qualitative analysis on 322 models in ESRI Grid format. The models are to be created from the first-return of the LiDAR pulse, using either a 1-meter or 2-meter cell size, and following the 1/4th USGS 7.5-minute quadrangle tiling scheme. Dewberry used a random sample of LAS data to create 1-meter gridded models using only the first-return LiDAR pulses. Dewberry queried the pixel values to ensure consistency between the deliverable and the sample model created by Dewberry. This process is used to verify that the raster models conform to the specifications. Figure 29 is an example of a first-return model.

Figure 29 - Tile u329705_2_b; an example of first-return model showing NoData areas in bright blue

8 Conclusion

The LiDAR data for Fort Worth, Texas was thoroughly examined by Dewberry for accuracy, completeness, and conformity to project specifications. Because the data meet the vertical accuracy requirements and are free of major anomalies, Dewberry is confident in the quality and integrity of the LiDAR data for general geographic use and for hydrographic modeling.

The hydrographic breaklines are also of good quality with some minor issues. The breaklines pass the completeness and topology requirements; however, there are vertical accuracy errors in the dataset that should be noted. A specific tolerance (twice the RMSE) was utilized as a baseline to allow for small amounts of vertical accuracy error due to compiler error and monotonicity enforcement, but in this dataset some errors are outside this threshold. As previously stated, this is not a definitive check; however it is important for the end user to be aware of minor discrepancies in vertical accuracy.

The hydro-enforced DEMs require corrective actions before the data can be used. This is due to processing errors that resulted in data voids. Secondly, the DEMs do not have a defined projection. This should be corrected. This deliverable did not meet project specifications.

Although FEDI stated that the intensity are projected, Dewberry strongly encourages that the data have their projection defined in such a way that is readable by ArcGIS.

Lastly, Dewberry identified that the metadata for the LAS, intensity, and DEMs are not FGDC compliant, as they lack a defined projection. Additional recommendations have been provided for improvements to the overall metadata quality.

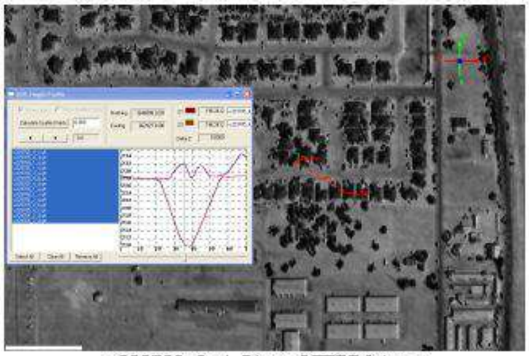
In summary, the following list illustrates the deliverables that meet project specifications:

- ✓ All-Return LAS Point Cloud Data
- ✓ Hydrographic Breaklines
- ✓ Intensity Imagery
- ✓ First-Return Surface Model
- ✓ ASCII Ground Point List
- ✓ Breakline Metadata

The data that require correction include:

- ➢ Hydro-Enforced DEMs
- ➢ LAS Metadata
- ➢ Intensity Metdata
- ➢ DEM Metadata

Appendix A



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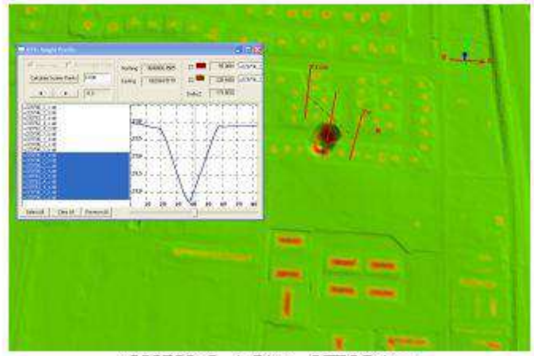

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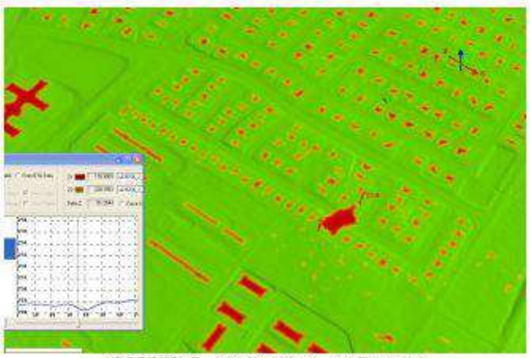

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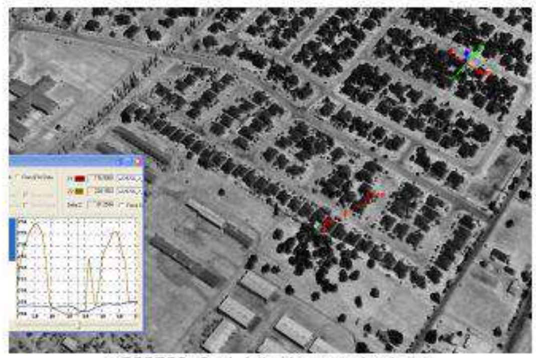

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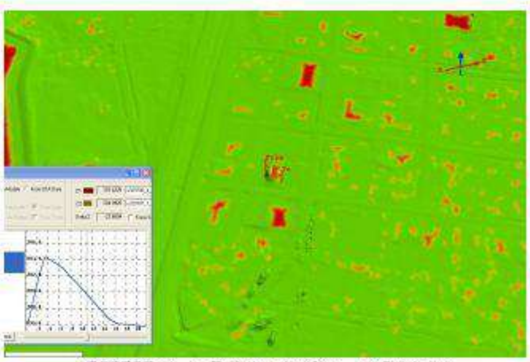

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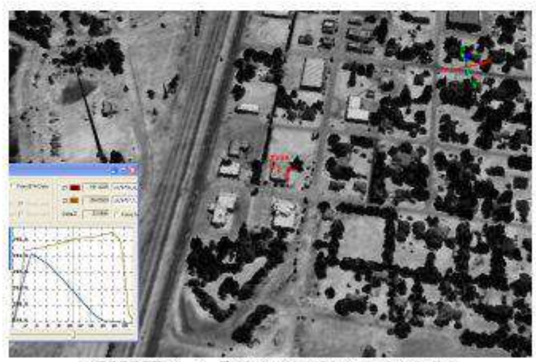

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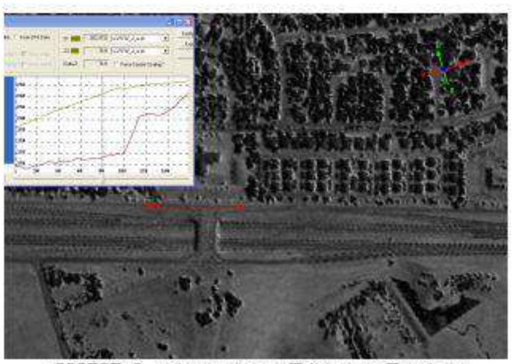

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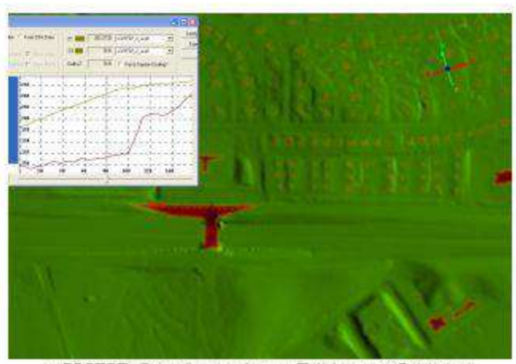

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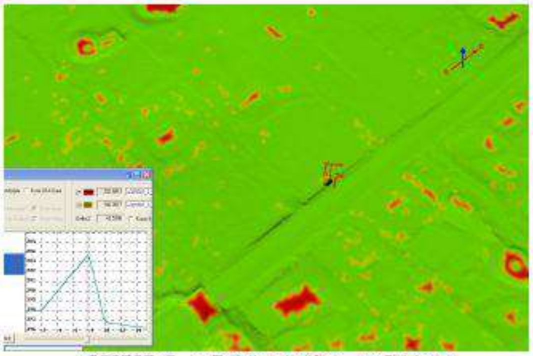
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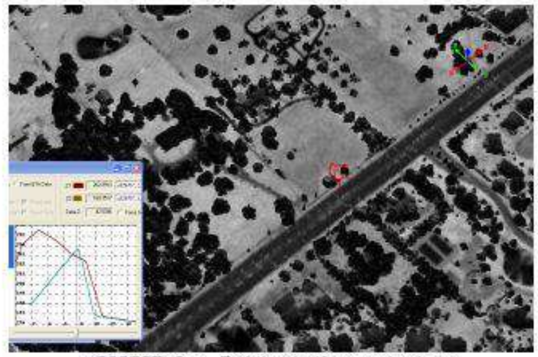
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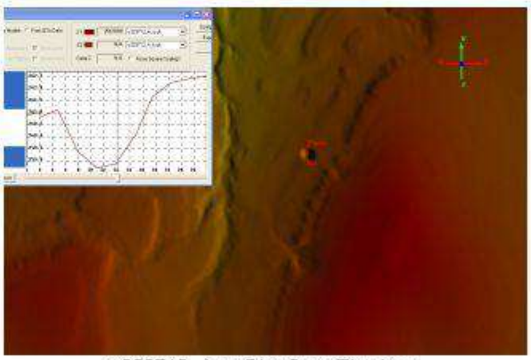
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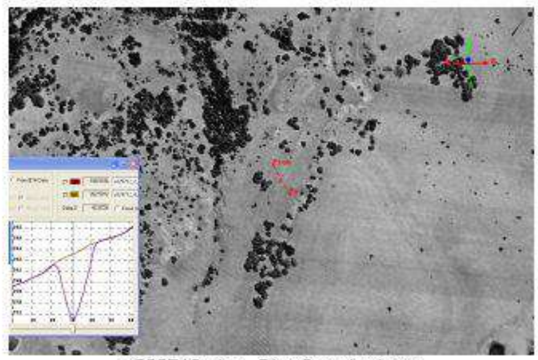
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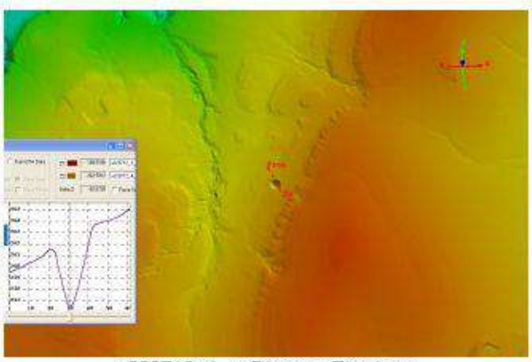
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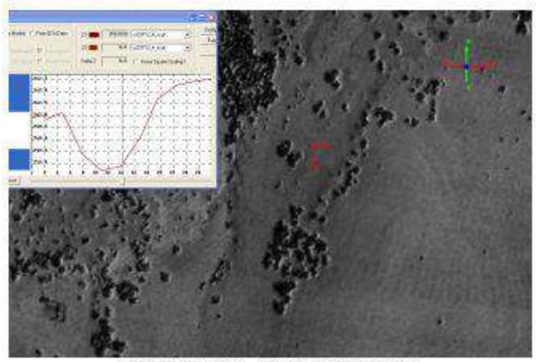
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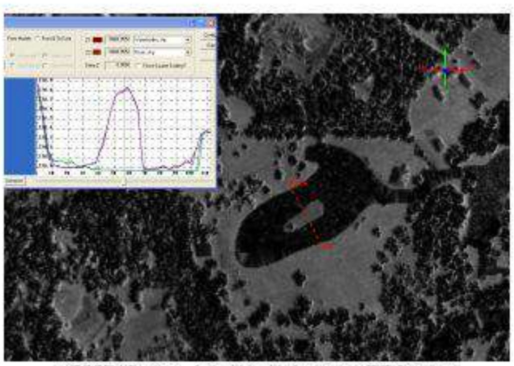
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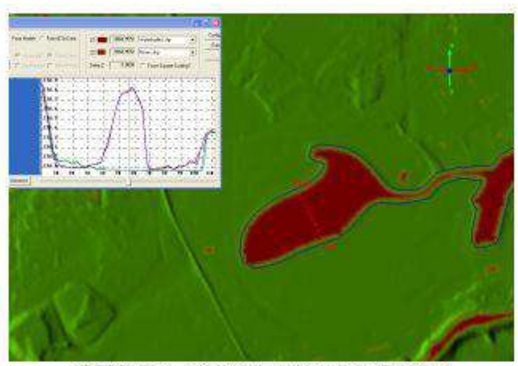
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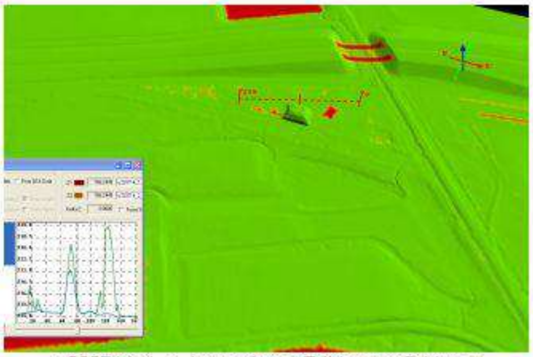
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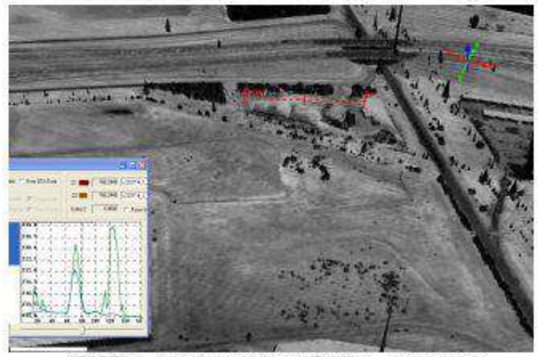
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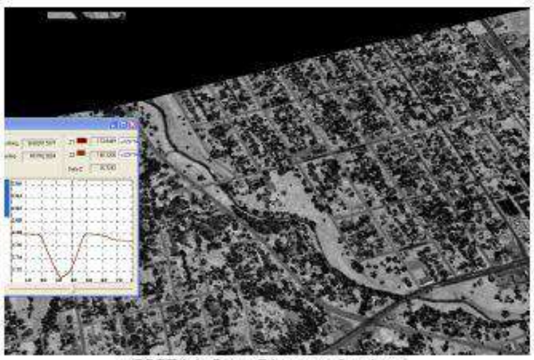
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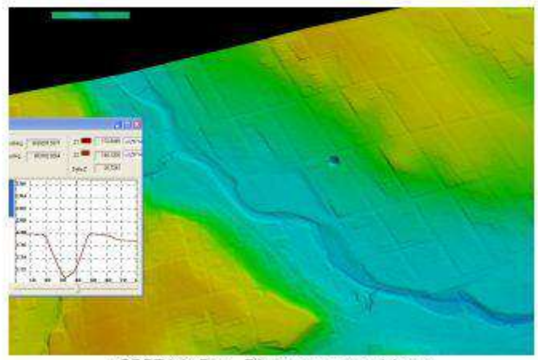
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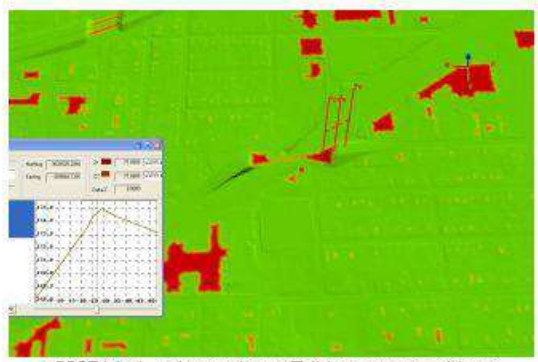
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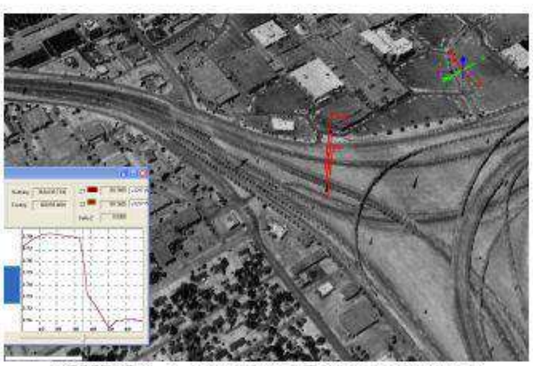
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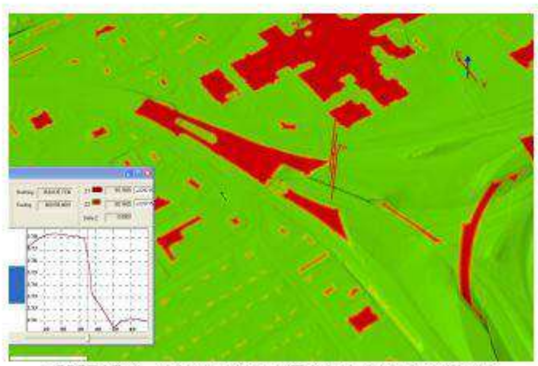
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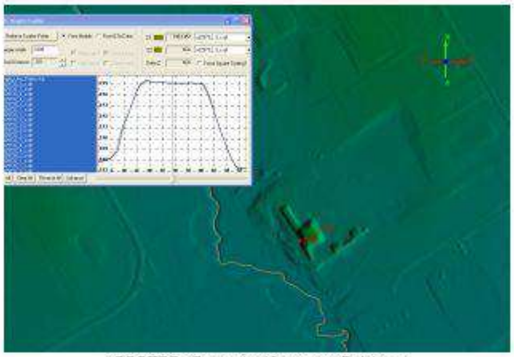
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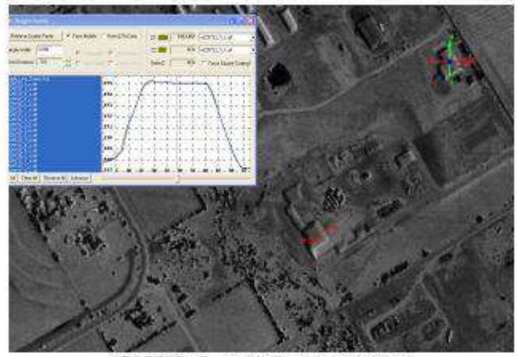
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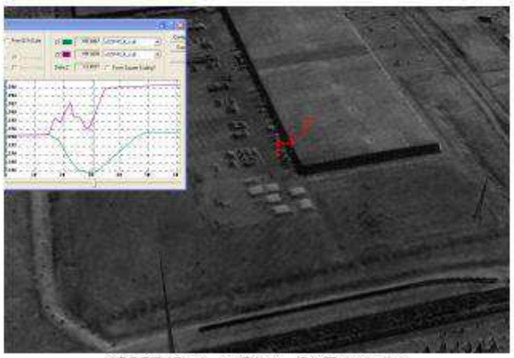
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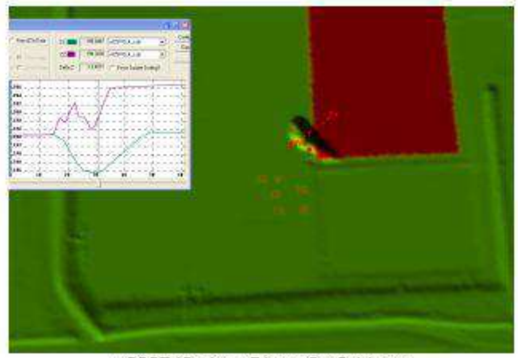
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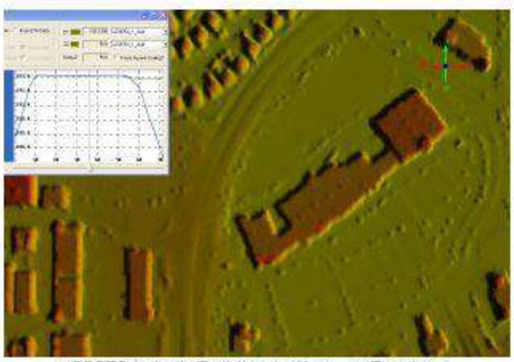
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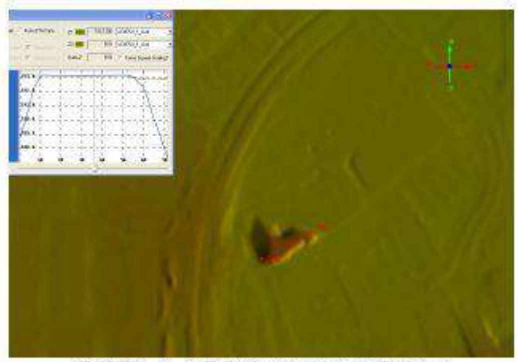
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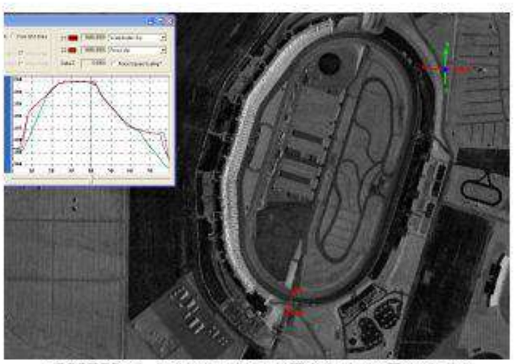
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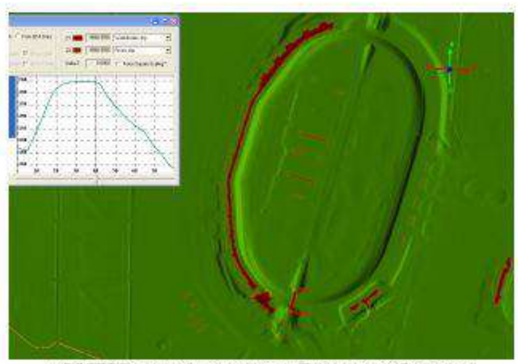
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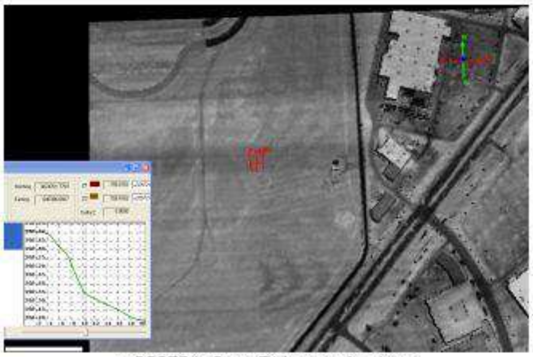
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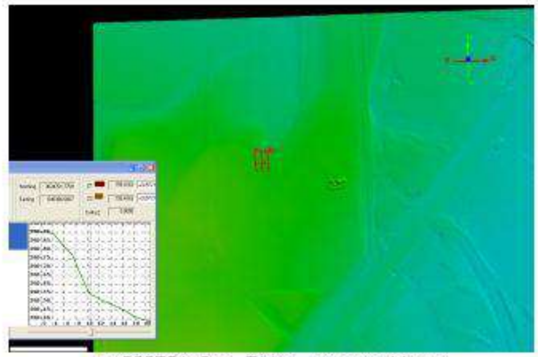
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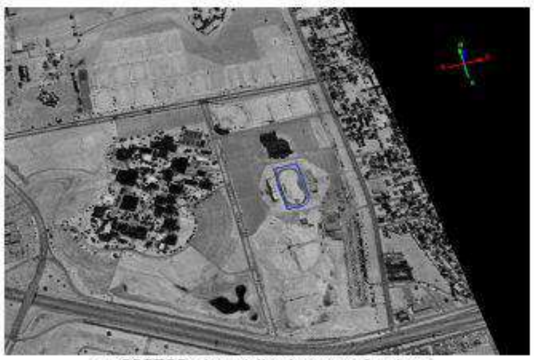
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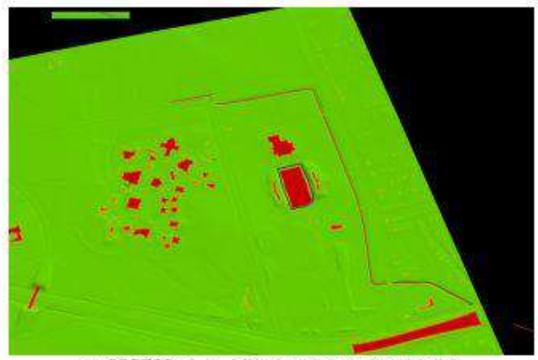
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