Desert Mountain Flood Modeling Showdown

MANAGING FLOODS WHERE MOUNTAINS MEET THE DESERT

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Taylor Leahy , P.E

June 20, 2018

CDM Smith

WATER + ENVIRONMENT + TRANSPORTATION + ENERGY + FACILITIES

Presentation Outline

- Similar Desert / Arid Region Floods Study
- KSA Field Recon Experience
- Hydrologic Modeling Techniques
- Be Better Than Average
- Hydrologic/Hydraulic Modeling Sensitivity

Streams in Desert/Arid Region

Las Cruces Arroyo, AZ

Flash Flood in Gobi Desert

Flood Mitigation Study in Kingdom of Saudi Arabia

Flooding also happens in the Kingdom of Saudi Arabia

Neighborhood Floods in Riyadh

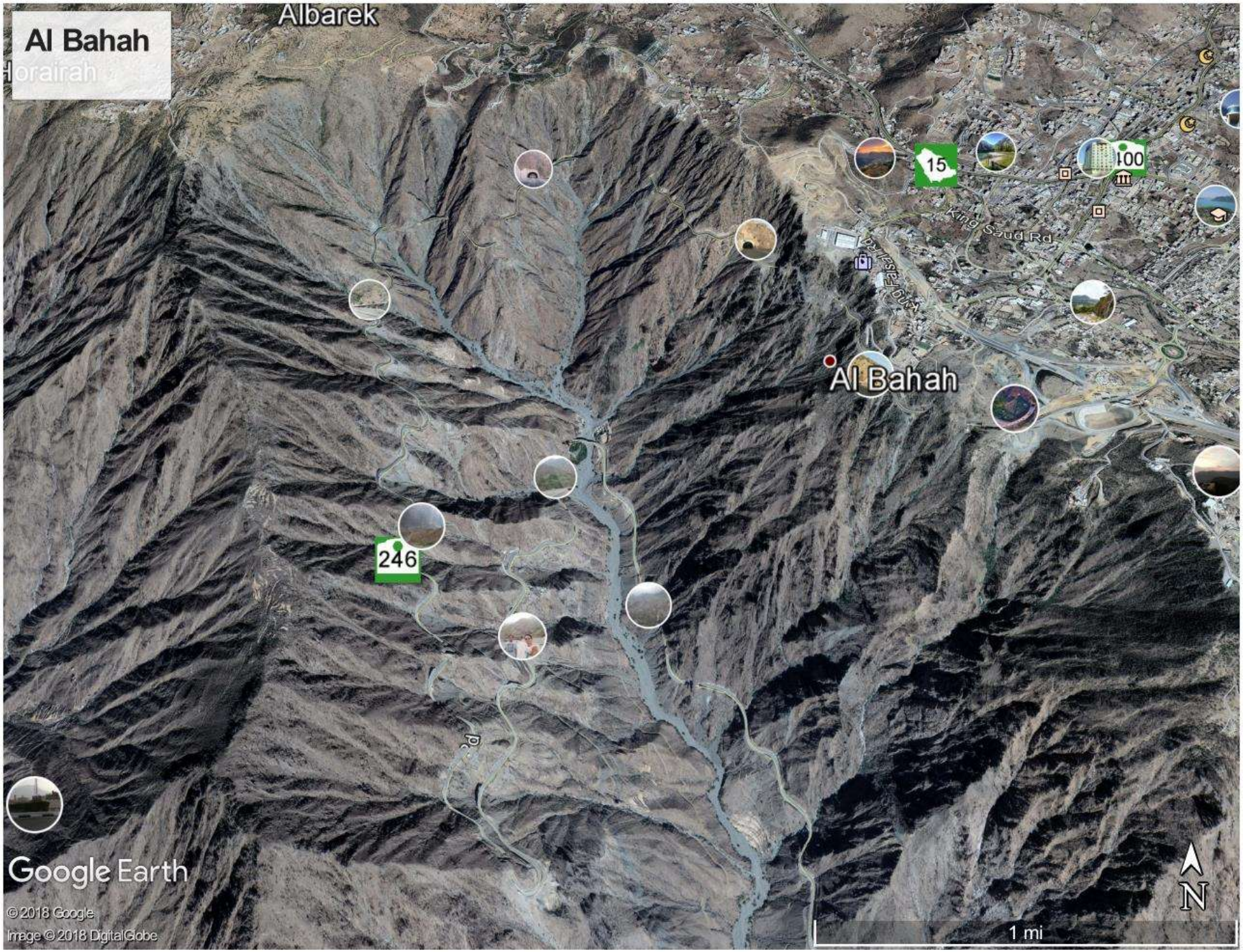
Roadway Floods in Baha

Flooding also happens in the Kingdom of Saudi Arabia

During a Flooding Event in Ad Dair

The Same Culvert Crossing in Dry Day

Saudi Arabia
Field Recon Photos
(March 2014)


Al Bahah
Albarek
15
King Saud Rd
King Faisal Rd
Al Bahah
246
Google Earth
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03/03/2014


03/08/2014


03/04/2014


03/08/2014


03/09/2014


03/09/2014


03/10/2014


03/10/2014


03/09/2014


998
نحو مجتمع آمن
2014
المملكة العربية السعودية
وزارة الداخلية
المديرية العامة للدفاع المدني
مديرية الدفاع المدني بمنطقة عسير
إدارة محايل عسير
بإهمال قواعد السلامة
قد تتحول الرحلة البرية
إلى مأساة
مع تحيات إدارة الدفاع المدني بمحايل
03/03/2014

Flood Protection Project
Muhail, Saudi Arabia

Wadi	Wadi Tayyah						Unnamed Tributary to Wadi Tayyah		
	U/S of Tributary				D/S of Tributary		U/S of culvert	D/S of culvert	At mouth
HEC-RAS Model Cross-section	XS-11388	XS-9485	XS-7232	XS-5614	XS-4029	XS-1719	XS-1927	XS-1148	XS-511
Flow (cms)	3,379	3,379	3,379	3,379	3,569	3,576	108	108	108
Depth of Flow (m)	5.5	4.4	7.2	6.7	7	6.5	3.5	3.3	1.5
Flow Velocity (m/s)	5.1	3.4	6.1	4.7	7.5	6.8	1.3	3	2.1

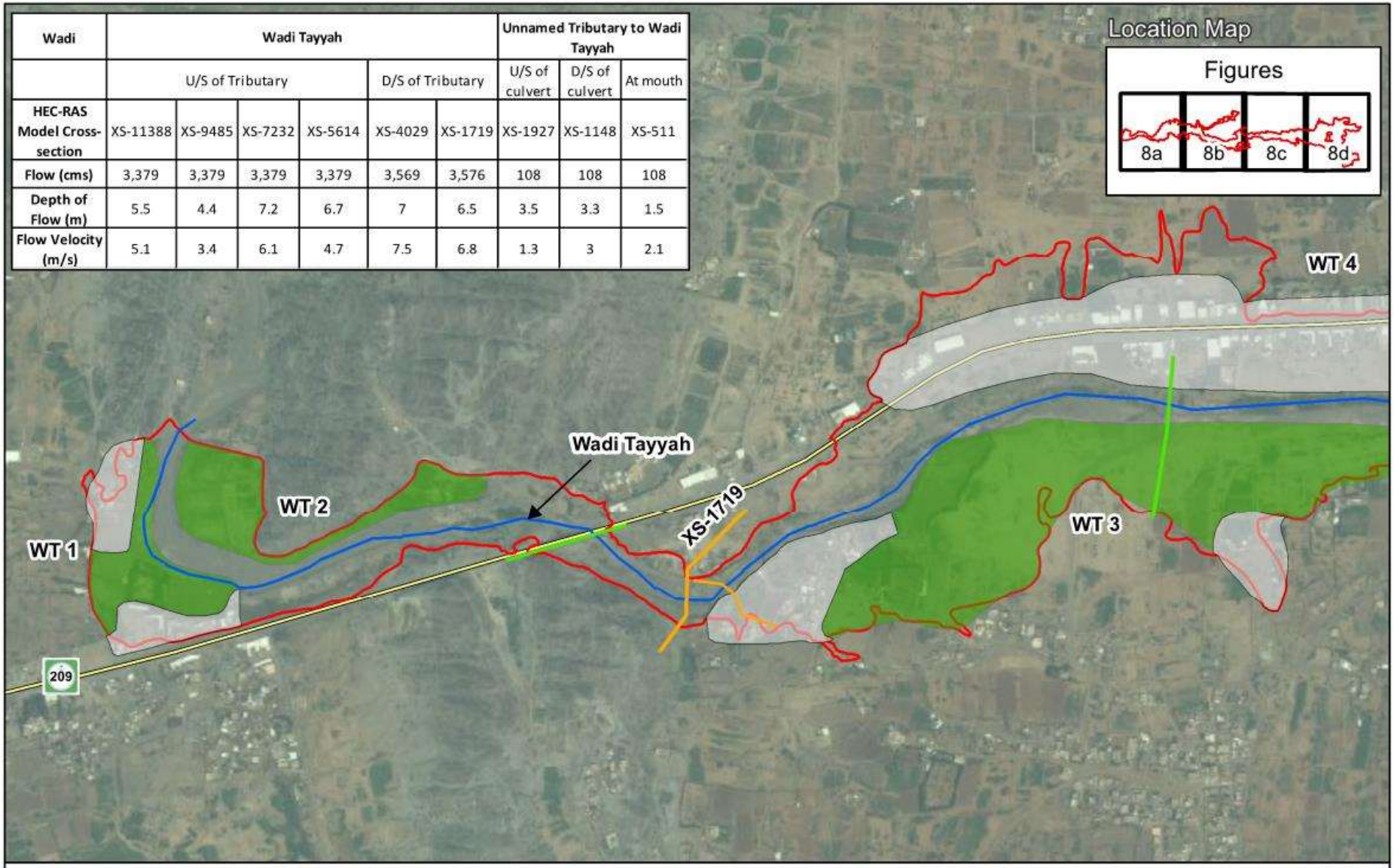

Figure 8a: Existing Conditions Water Depths, Velocities, and Flows

Wadi	Wadi Tayyah						Unnamed Tributary to Wadi Tayyah		
	U/S of Tributary				D/S of Tributary		U/S of culvert	D/S of culvert	At mouth
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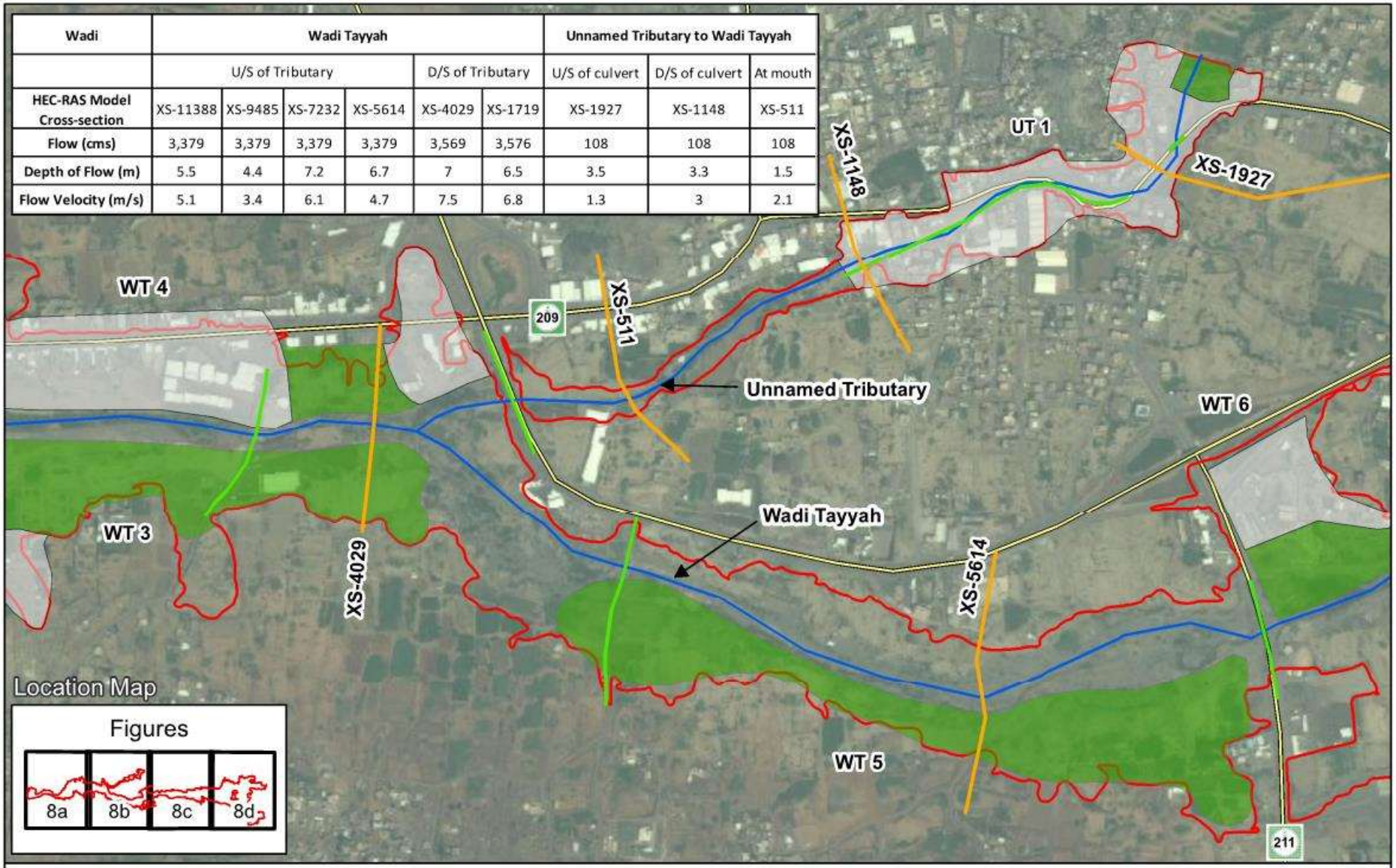
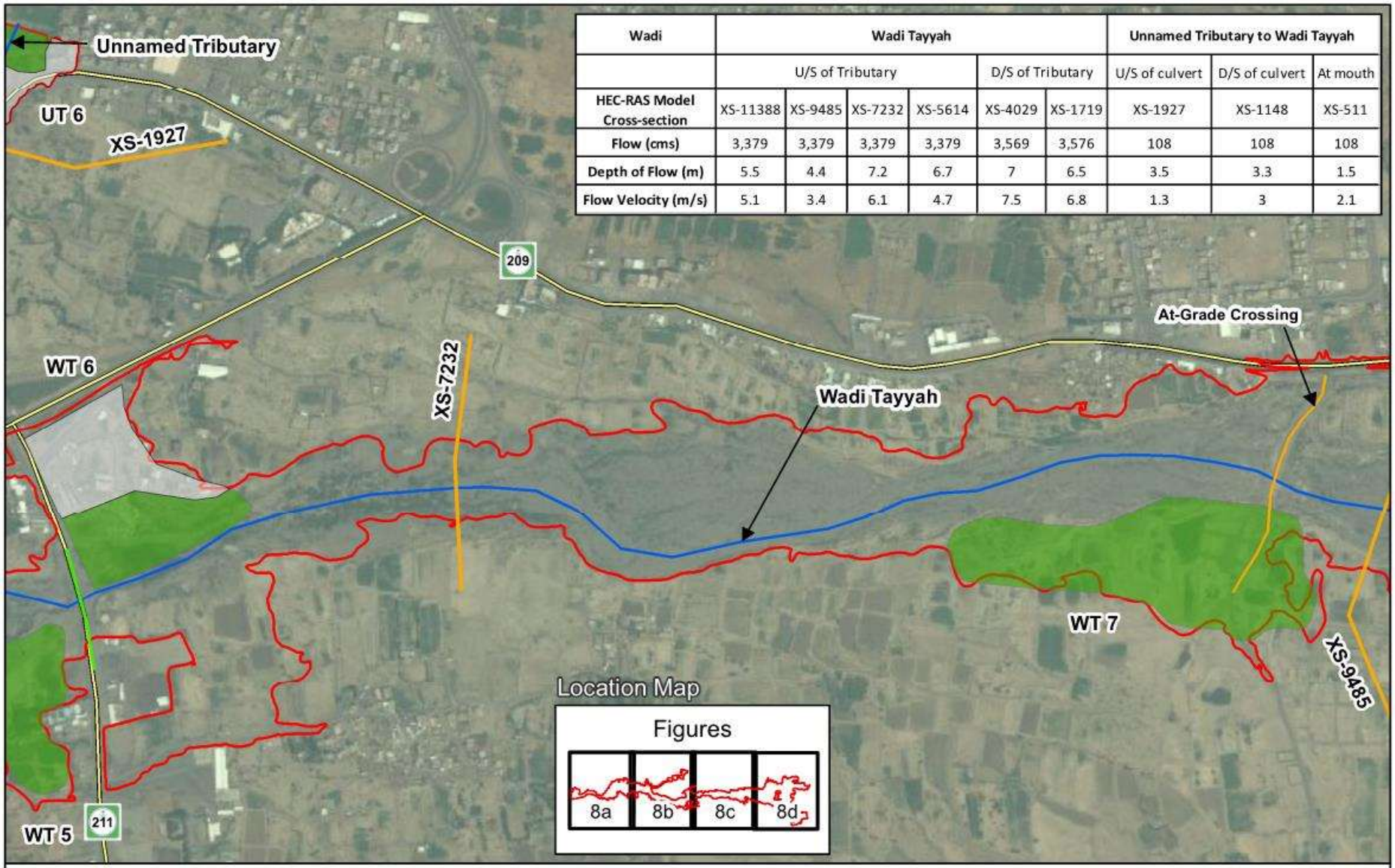


0 0.15 0.3 0.6 Kilometers

Legend

- At-Grade Crossings
- Bridges and Culverts
- Drainage Lines
- Major Roads
- HEC-RAS Model Cross-Sections
- Floodprone Area - Urban
- Floodprone Area - Agriculture
- 100-year Floodplain

Figure 8b: Existing Conditions Water Depths, Velocities, and Flows



Wadi	Wadi Tayyah						Unnamed Tributary to Wadi Tayyah		
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N

0 0.15 0.3 0.6 Kilometers

Legend

- At-Grade Crossings
- Bridges and Culverts
- Drainage Lines
- Major Roads
- HEC-RAS Model Cross-Sections
- Floodprone Area - Urban
- Floodprone Area - Agriculture
- 100-year Floodplain

Figure 8c: Existing Conditions Water Depths, Velocities, and Flows

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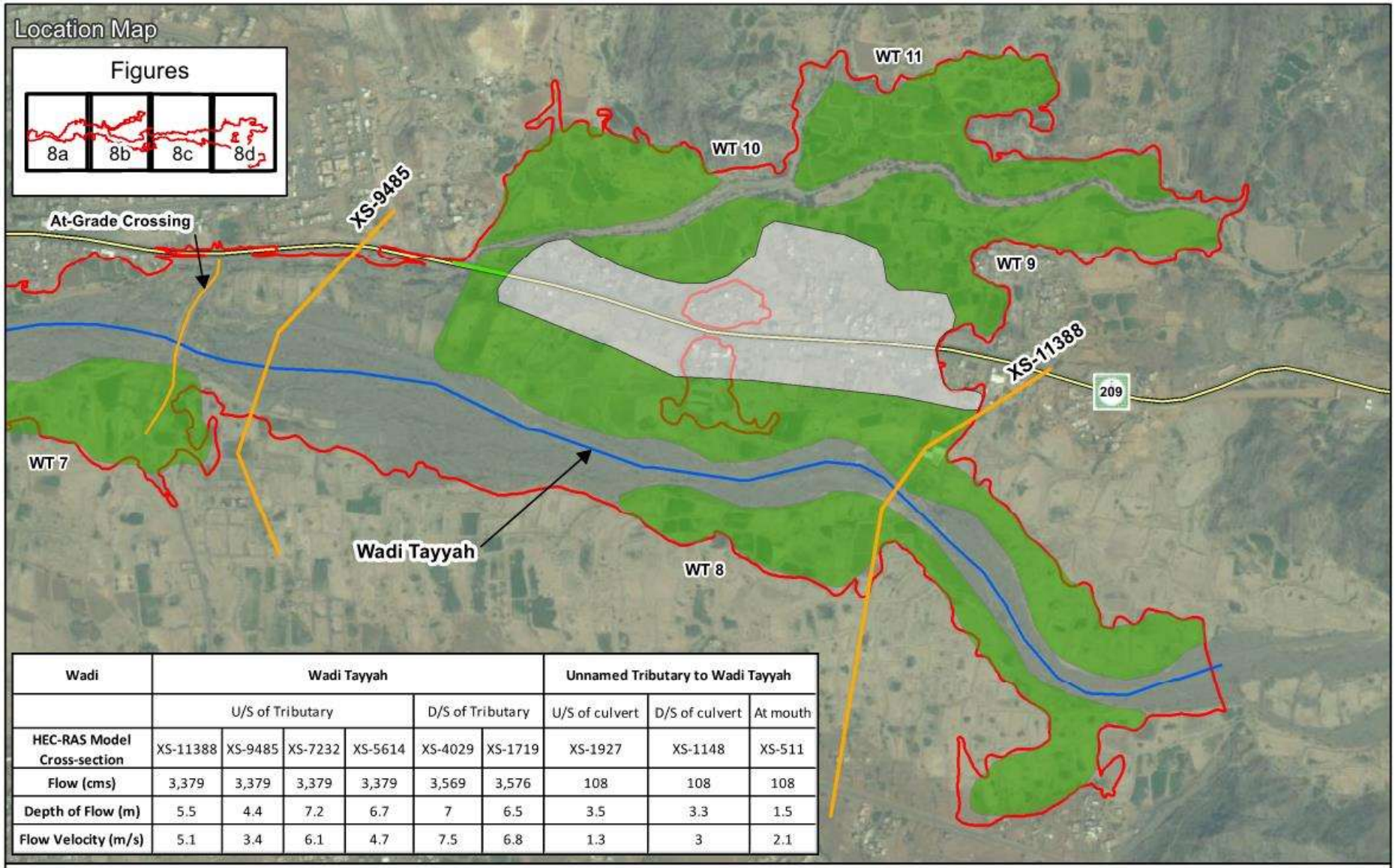

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N

0 0.15 0.3 0.6 Kilometers

Legend

- At-Grade Crossings
- Bridges and Culverts
- Drainage Lines
- Major Roads
- HEC-RAS Model Cross-Sections
- Floodprone Area - Urban
- Floodprone Area - Agriculture
- 100-year Floodplain

Figure 8d: Existing Conditions Water Depths, Velocities, and Flows

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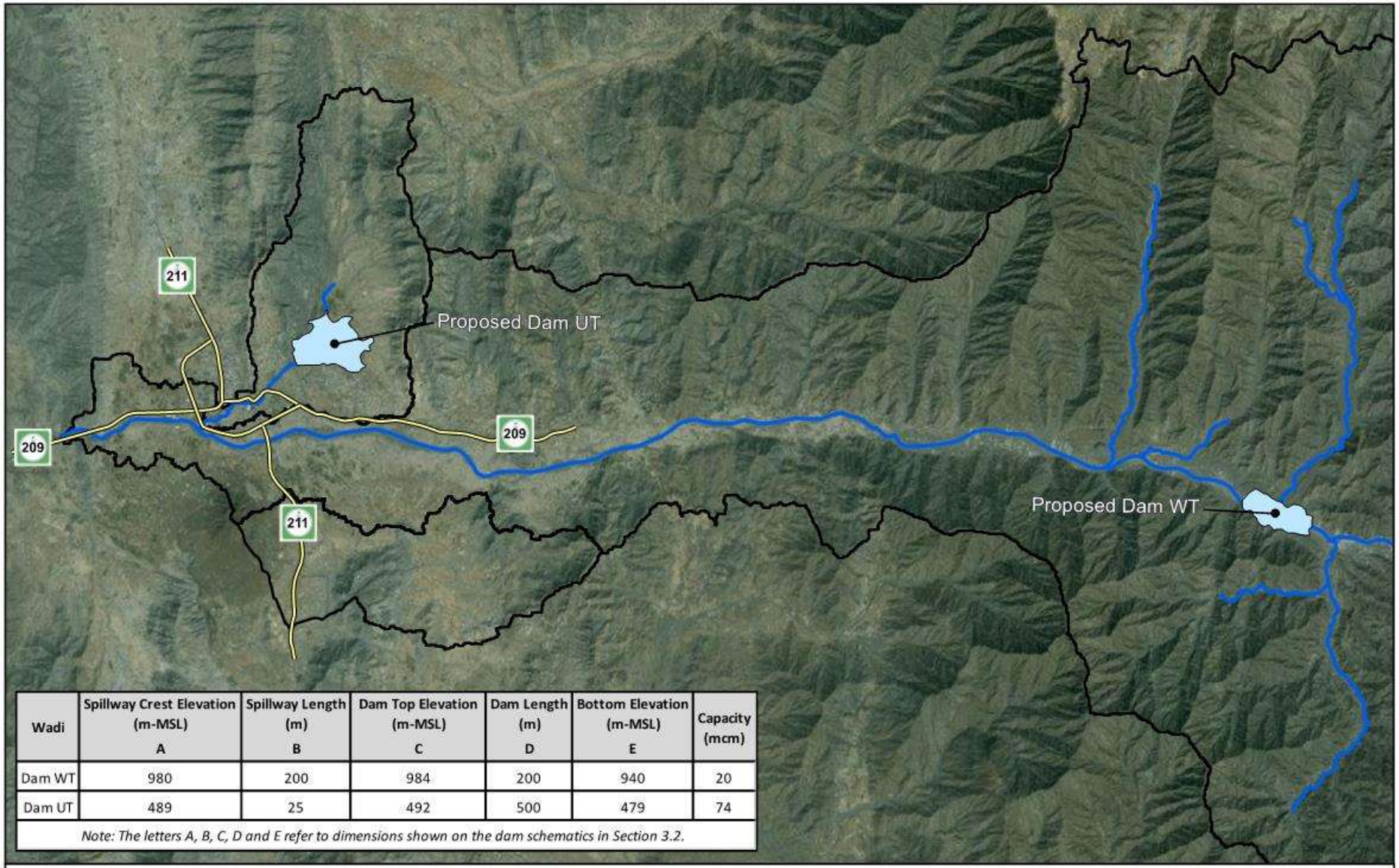
وزارة المياه والكهرباء



Wadi	Spillway Crest Elevation (m-MSL) A	Spillway Length (m) B	Dam Top Elevation (m-MSL) C	Dam Length (m) D	Bottom Elevation (m-MSL) E	Capacity (mcm)
Dam WT	980	200	984	200	940	20
Dam UT	489	25	492	500	479	74

Note: The letters A, B, C, D and E refer to dimensions shown on the dam schematics in Section 3.2.

Figure 10: Alternative 1 Dam/Reservoir Locations

0 2 4 8 Kilometers

Legend

Drainage Lines

Major Roads

Proposed Reservoir/Detention Basin

Catchment Boundaries and HMS Model Extent

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Wadi	Wadi Tayyah						Unnamed Tributary to Wadi Tayyah		
	U/S of Tributary				D/S of Tributary		U/S of culvert	D/S of culvert	At mouth
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Flow (cms)	1,843	1,843	1,843	1,843	1,940	1,944	33	33	33
Depth of Flow (m)	4	3.4	5.8	4.9	5.6	4.6	2.2	2.2	0.9
Flow Velocity (m/s)	4.9	4	2.8	4.1	6.1	5.8	1.5	2.2	1.4

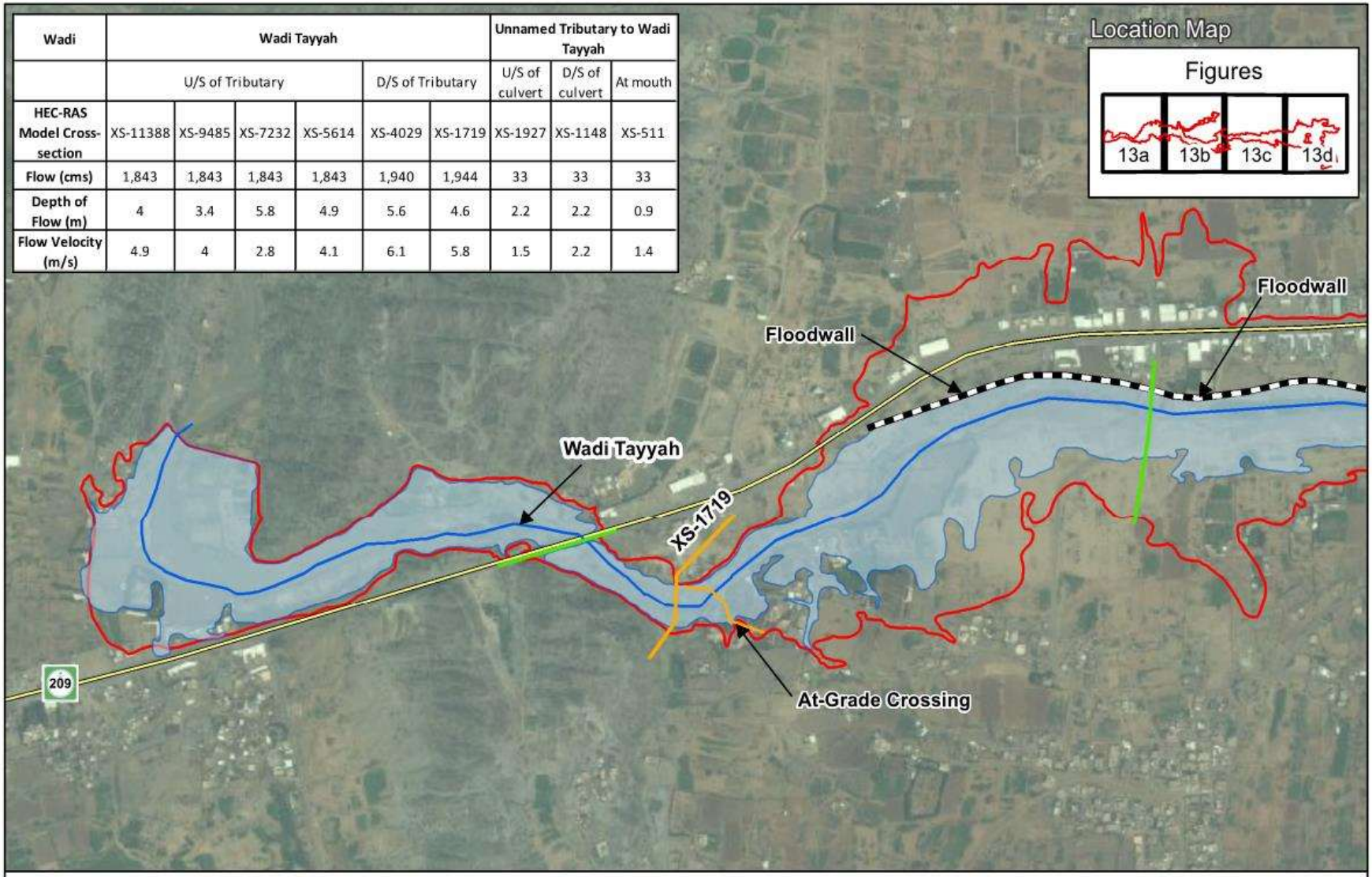

Figure 13a: Alternative 1 100-year Comparisons

Wadi	Wadi Tayyah						Unnamed Tributary to Wadi Tayyah		
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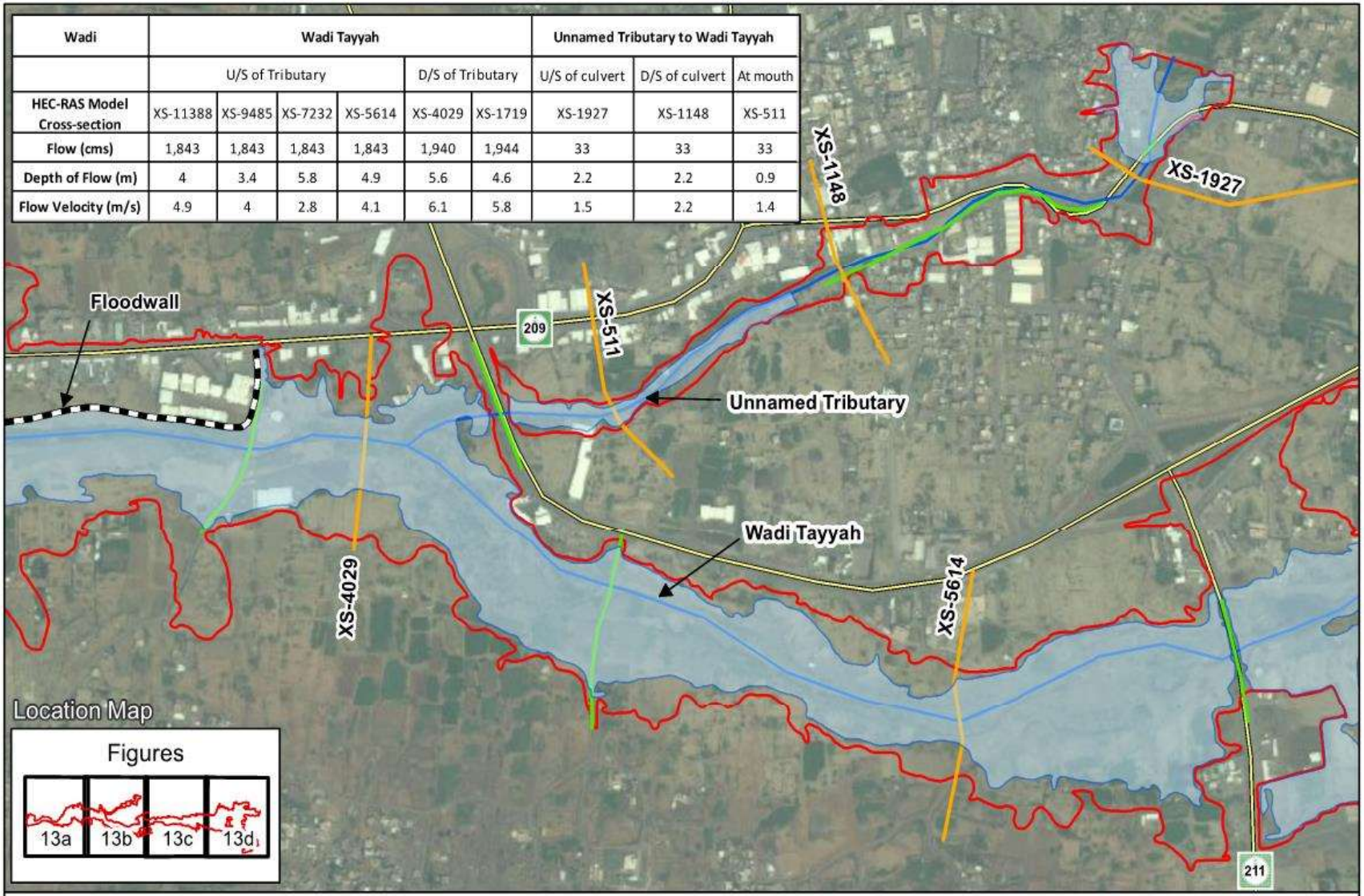


N

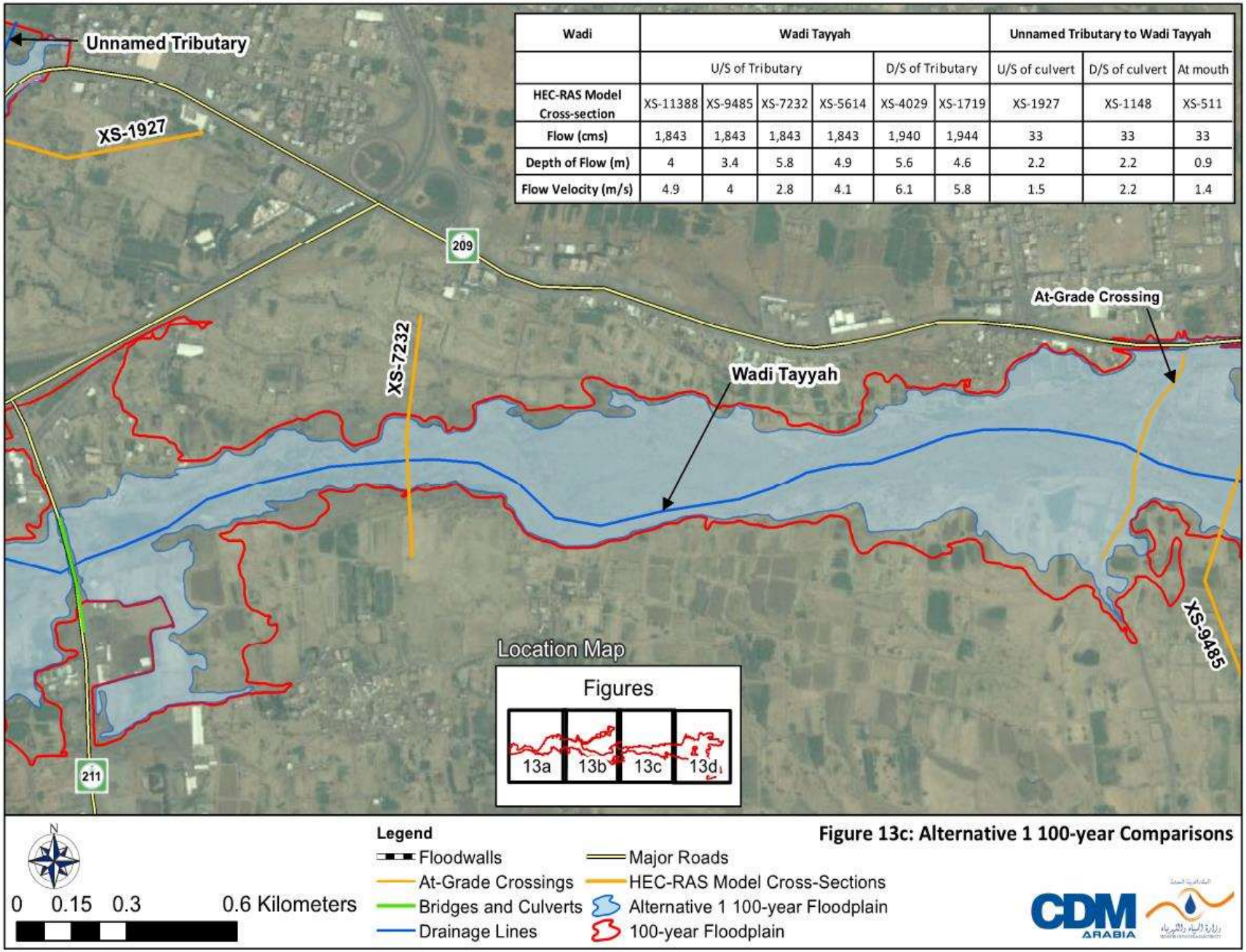
0 0.15 0.3 0.6 Kilometers

Legend

- Floodwalls
- At-Grade Crossings
- Bridges and Culverts
- Drainage Lines
- Major Roads
- HEC-RAS Model Cross-Sections
- Alternative 1 100-year Floodplain
- 100-year Floodplain

Figure 13b: Alternative 1 100-year Comparisons

CDM ARABIA



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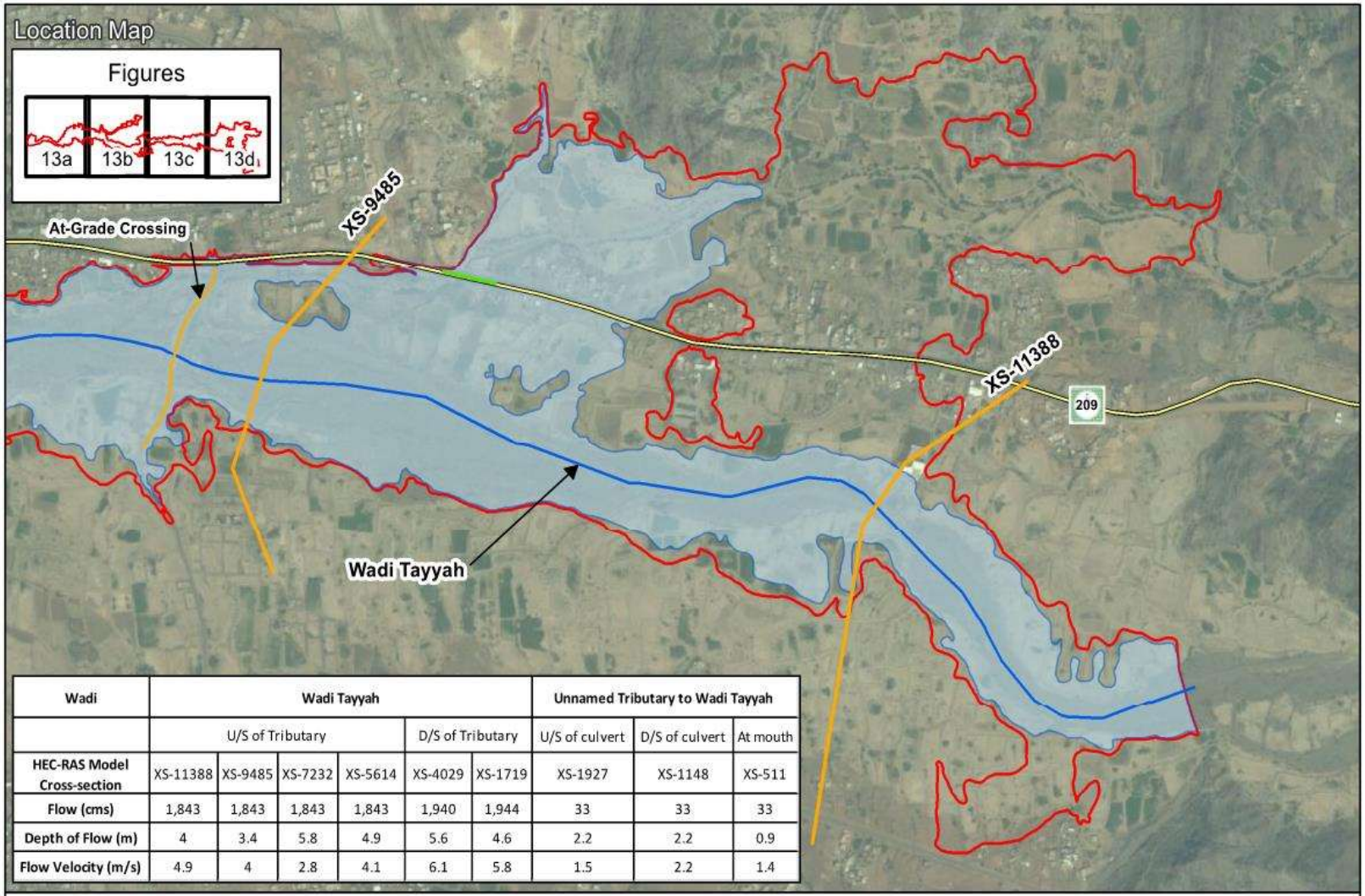
Flow Velocity (m/s)	4.9	4	2.8	4.1	6.1	5.8	1.5	2.2	1.4

Figure 13c: Alternative 1 100-year Comparisons



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N

0 0.15 0.3 0.6 Kilometers

Legend

- Floodwalls
- At-Grade Crossings
- Bridges and Culverts
- Drainage Lines
- Major Roads
- HEC-RAS Model Cross-Sections
- Alternative 1 100-year Floodplain
- 100-year Floodplain

Figure 13d: Alternative 1 100-year Comparisons

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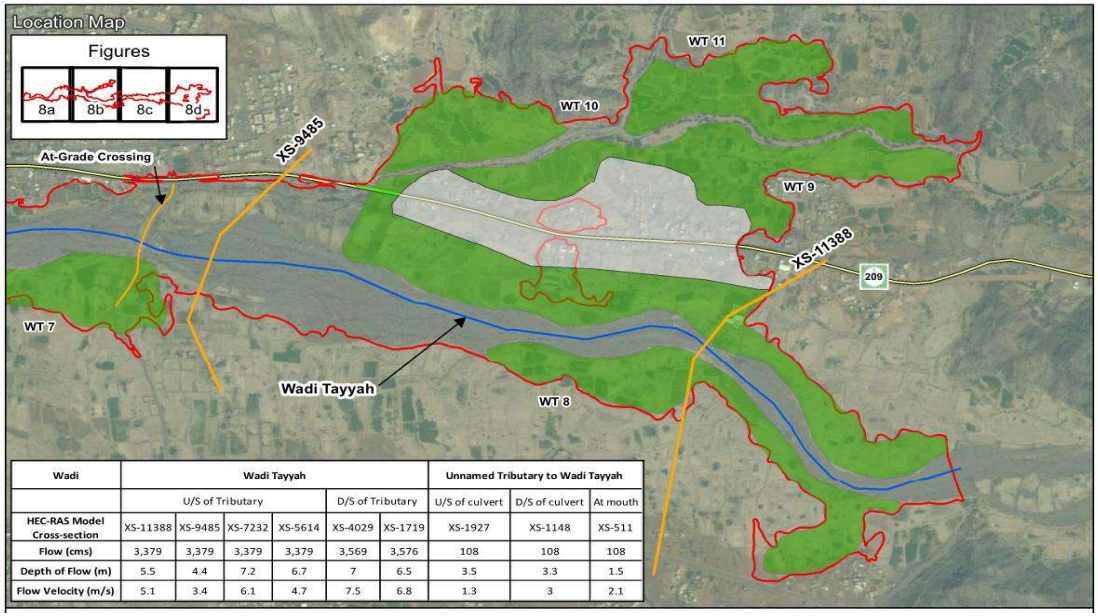

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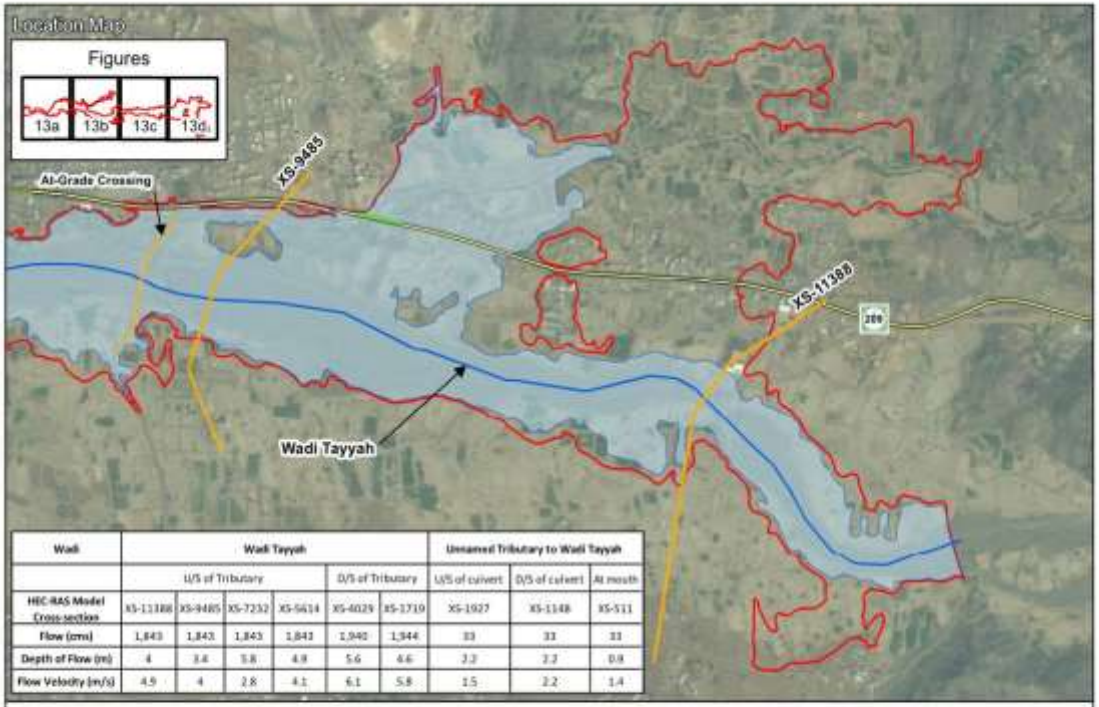

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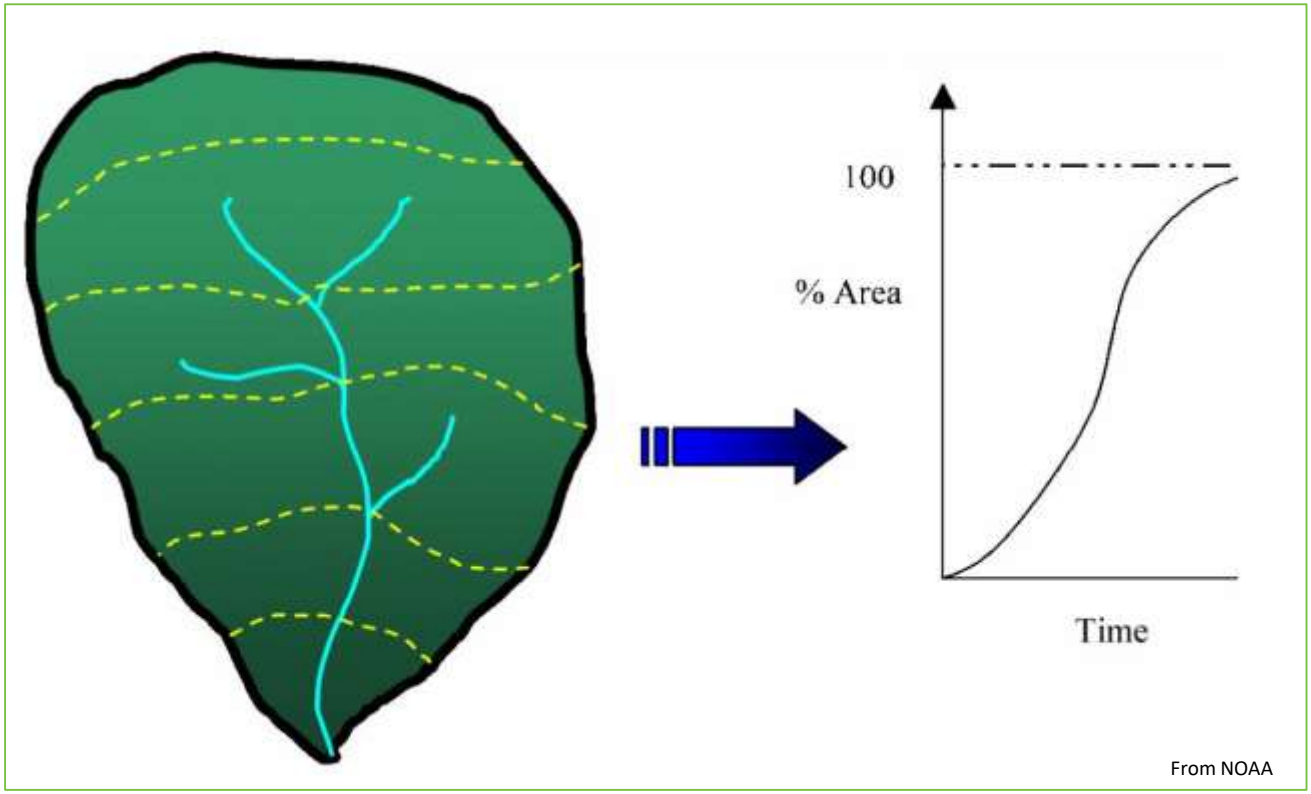
Flow Velocity (m/s)	4.9	4	2.8	4.1	6.1	5.8	1.5	2.2	1.4

Figure 13d: Alternative 1 100-year Comparisons

Time of Concentration

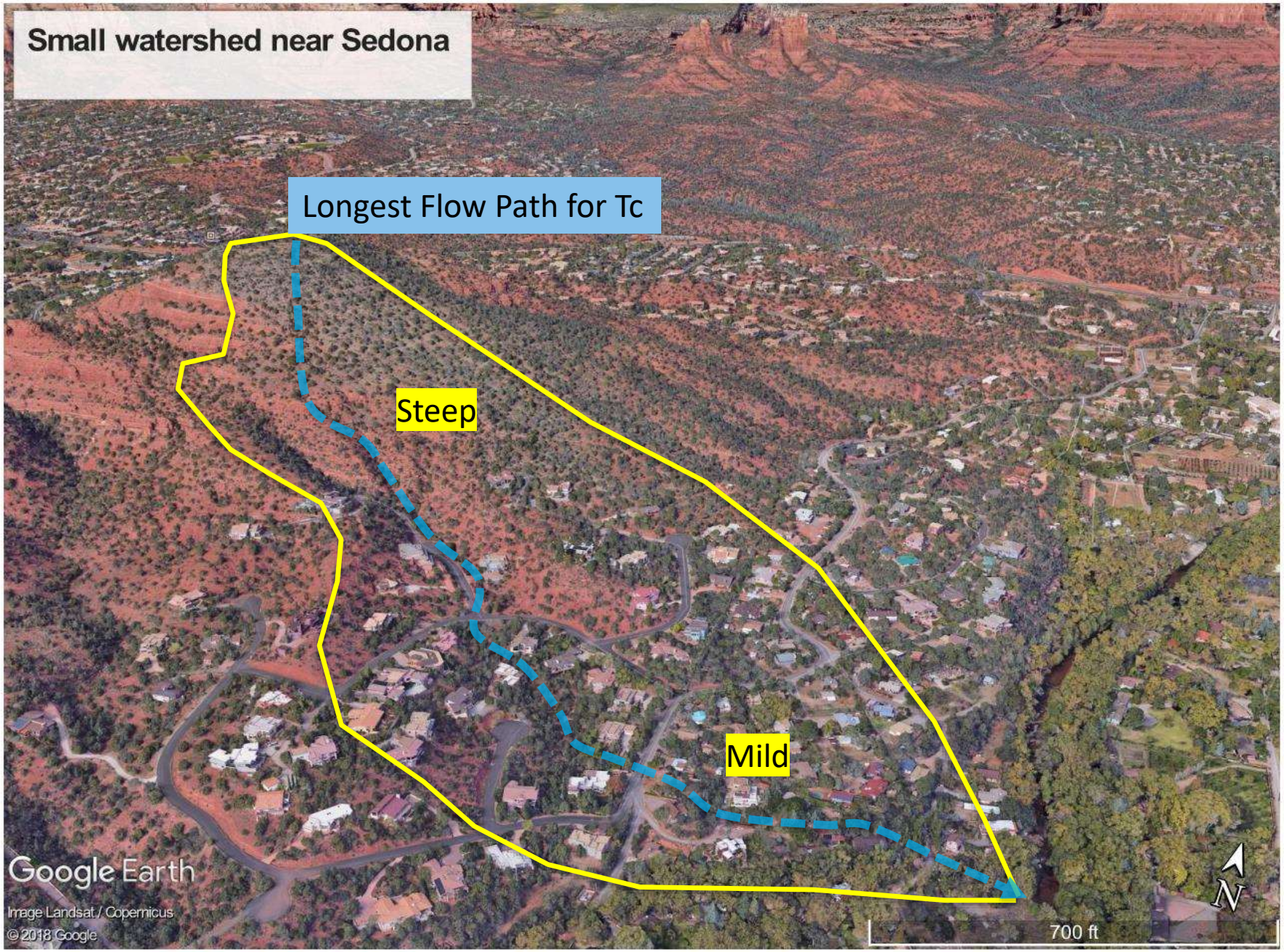
What is the Time of Concentration?

- Time of concentration (Tc) is the time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet. USDA-NRCS
- Sheet Flow, Shallow Concentrated Flow, & Open Channel Flow



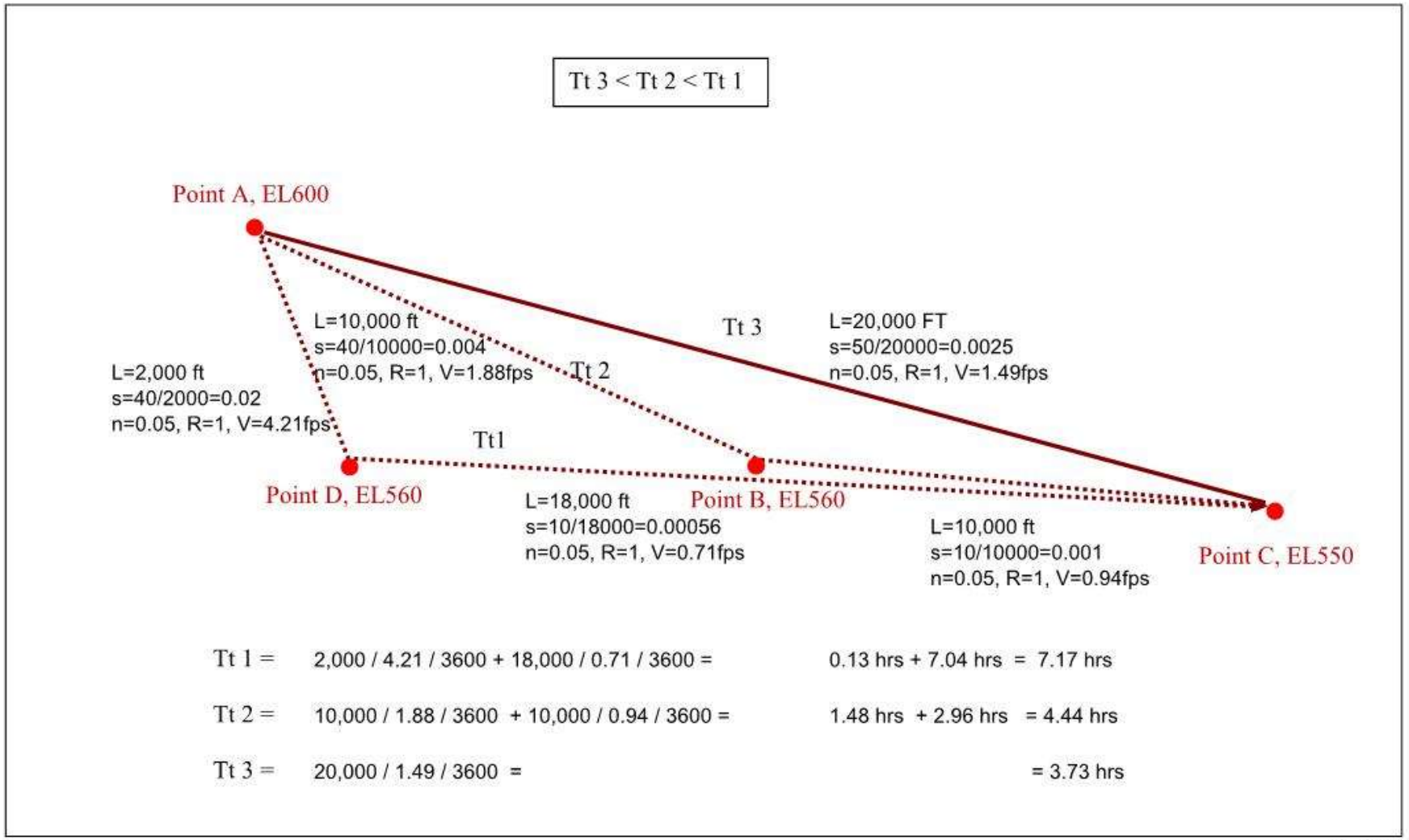
From NOAA

Is using average slope reasonable?


Small watershed near Sedona
Longest Flow Path for Tc
Steep
Mild
Google Earth
Image Landsat / Copernicus
© 2018 Google
700 ft
N

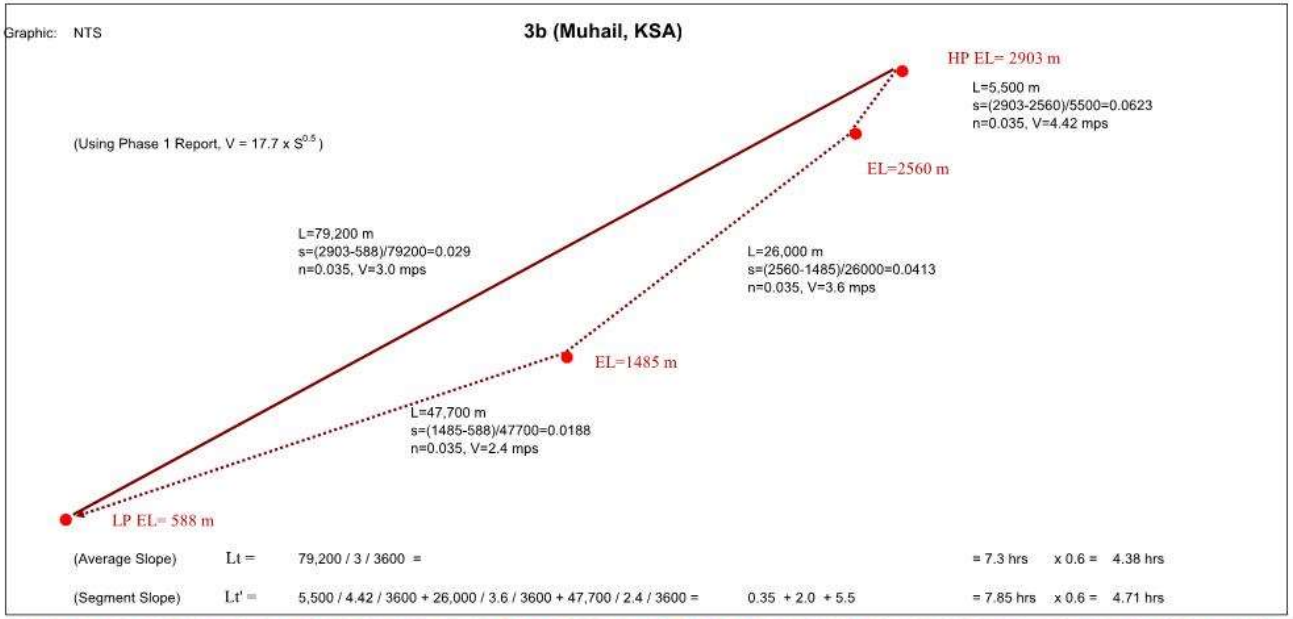
Did you know that an averaged slope in a channel is the fastest way of travel?

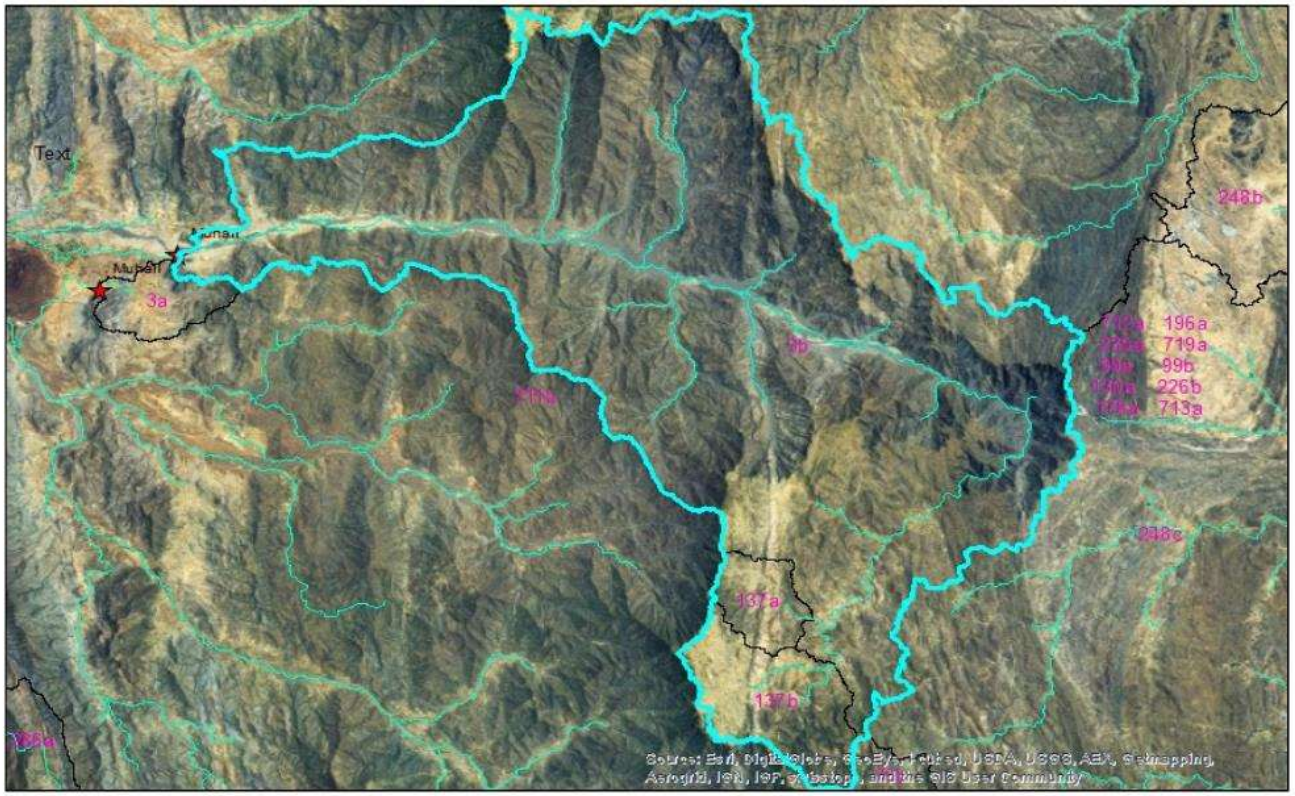
Using Average Slope is Reasonable?



S. Song

Direct Application


Graphic: NTS
3b (Muhail, KSA)
HP EL= 2903 m
L=5,500 m
s=(2903-2560)/5500=0.0623
n=0.035, V=4.42 mps
(Using Phase 1 Report, V = 17.7 x S^0.5)
EL=2560 m
L=79,200 m
s=(2903-588)/79200=0.029
n=0.035, V=3.0 mps
L=26,000 m
s=(2560-1485)/26000=0.0413
n=0.035, V=3.6 mps
EL=1485 m
L=47,700 m
s=(1485-588)/47700=0.0188
n=0.035, V=2.4 mps
LP EL= 588 m
(Average Slope) Lt = 79,200 / 3 / 3600 = = 7.3 hrs x 0.6 = 4.38 hrs
(Segment Slope) Lt' = 5,500 / 4.42 / 3600 + 26,000 / 3.6 / 3600 + 47,700 / 2.4 / 3600 = 0.35 + 2.0 + 5.5 = 7.85 hrs x 0.6 = 4.71 hrs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Muhail
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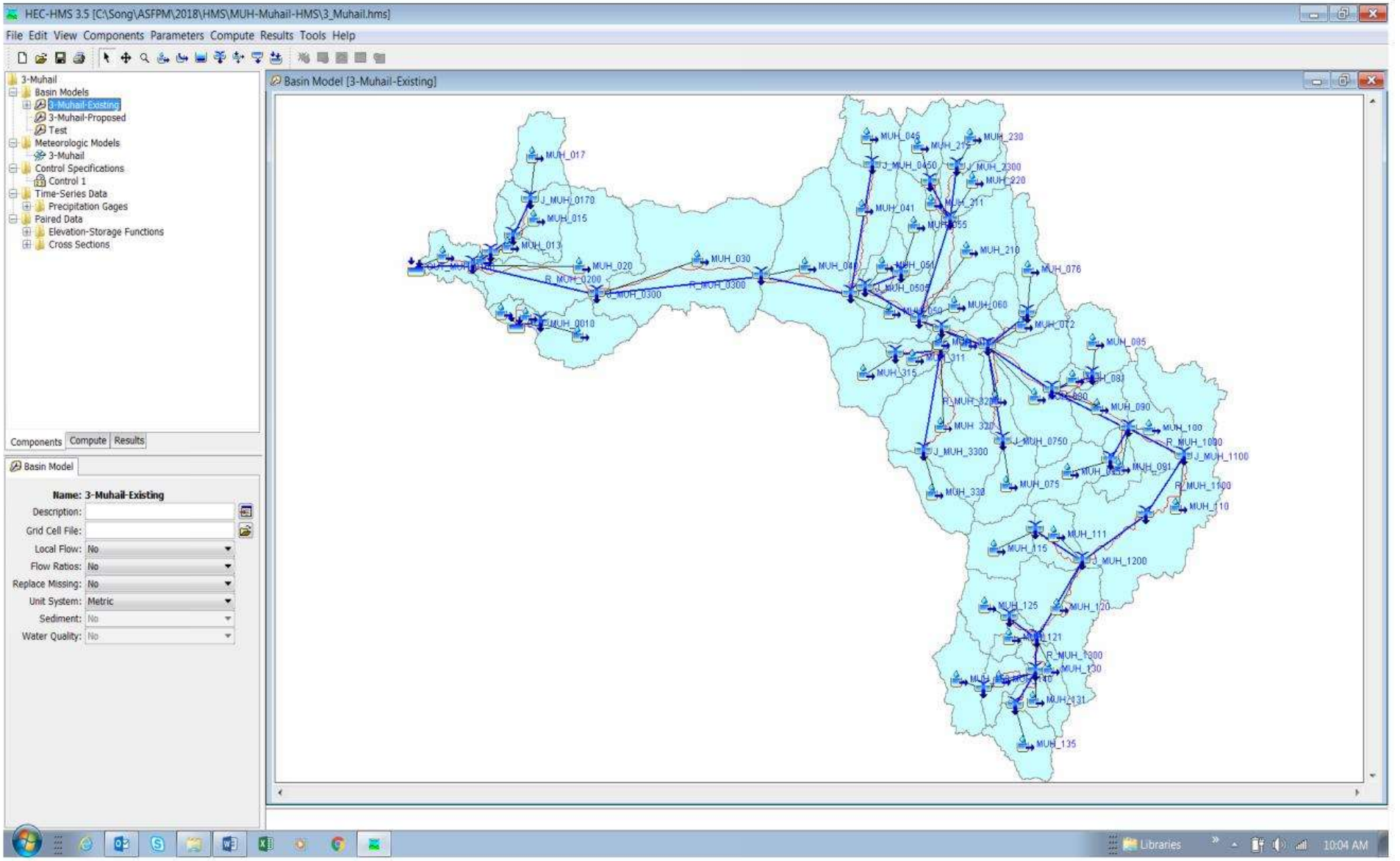
719a
99b
226b
713a
248c
137a
137b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File Edit View Components Parameters Compute Results Tools Help
3-Muhail
Basin Models
3-Muhail-Existing
3-Muhail-Proposed
Test
Meteorologic Models
3-Muhail
Control Specifications
Control 1
Time-Series Data
Precipitation Gages
Paired Data
Elevation-Storage Functions
Cross Sections
Components
Compute
Results
Basin Model
Name: 3-Muhail-Existing
Description:
Grid Cell File:
Local Flow: No
Flow Ratios: No
Replace Missing: No
Unit System: Metric
Sediment: No
Water Quality: No
Basin Model [3-Muhail-Existing]
MUH_017
J_MUH_0170
MUH_015
MUH_013
MUH_020
R_MUH_0200
J_MUH_0300
R_MUH_0300
MUH_0010
MUH_030
MUH_040
MUH_045
MUH_230
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J_MUH_2300
MUH_220
MUH_041
MUH_211
MUH_055
MUH_210
MUH_076
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MUH_050
MUH_060
MUH_072
MUH_095
MUH_315
MUH_090
MUH_100
R_MUH_1000
J_MUH_1100
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J_MUH_3300
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MUH_075
MUH_330
R_MUH_1100
MUH_110
MUH_111
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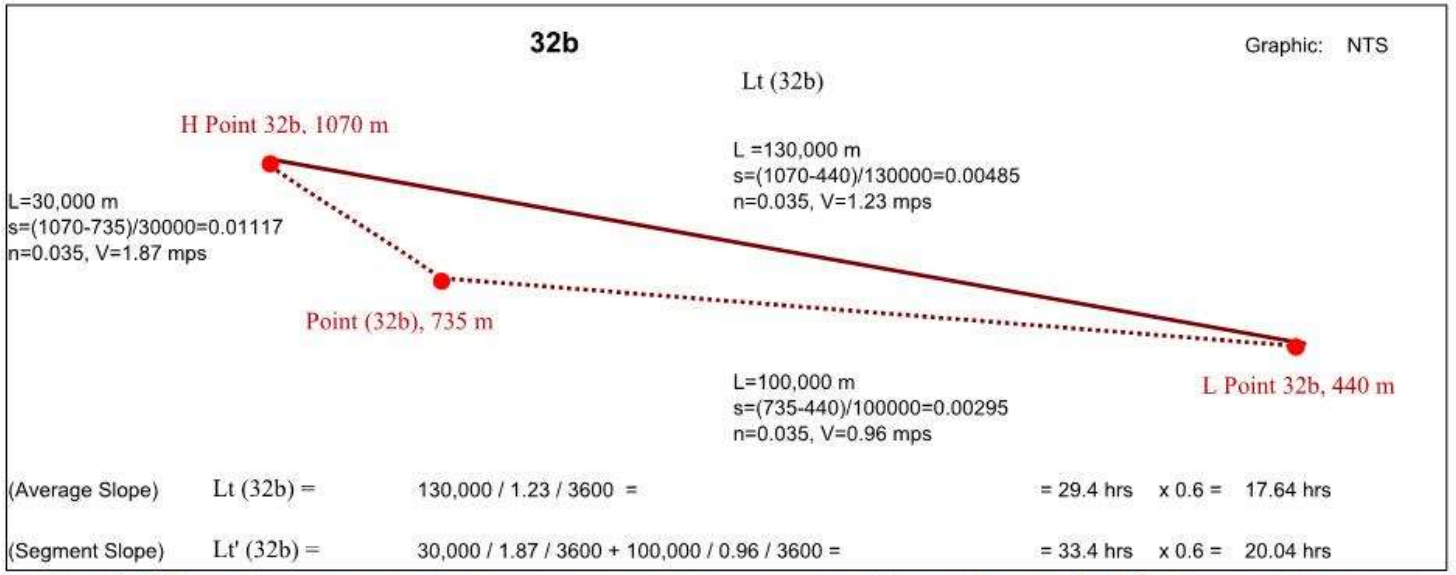
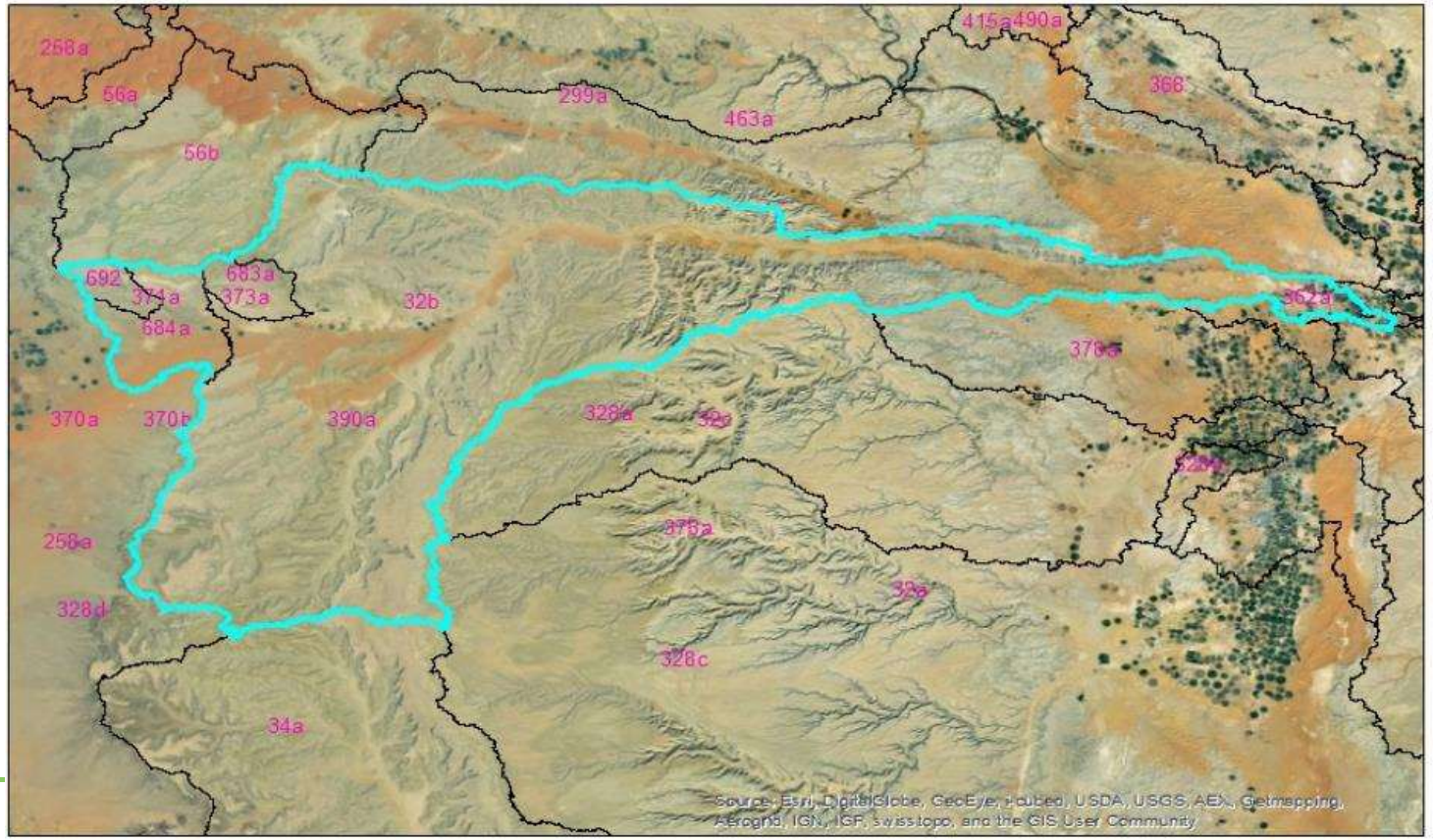

32b
Graphic: NTS
Lt (32b)
H Point 32b, 1070 m
L =130,000 m
s=(1070-440)/130000=0.00485
n=0.035, V=1.23 mps
L=30,000 m
s=(1070-735)/30000=0.01117
n=0.035, V=1.87 mps
Point (32b), 735 m
L=100,000 m
s=(735-440)/100000=0.00295
n=0.035, V=0.96 mps
L Point 32b, 440 m
(Average Slope) Lt (32b) = 130,000 / 1.23 / 3600 = = 29.4 hrs x 0.6 = 17.64 hrs
(Segment Slope) Lt' (32b) = 30,000 / 1.87 / 3600 + 100,000 / 0.96 / 3600 = = 33.4 hrs x 0.6 = 20.04 hrs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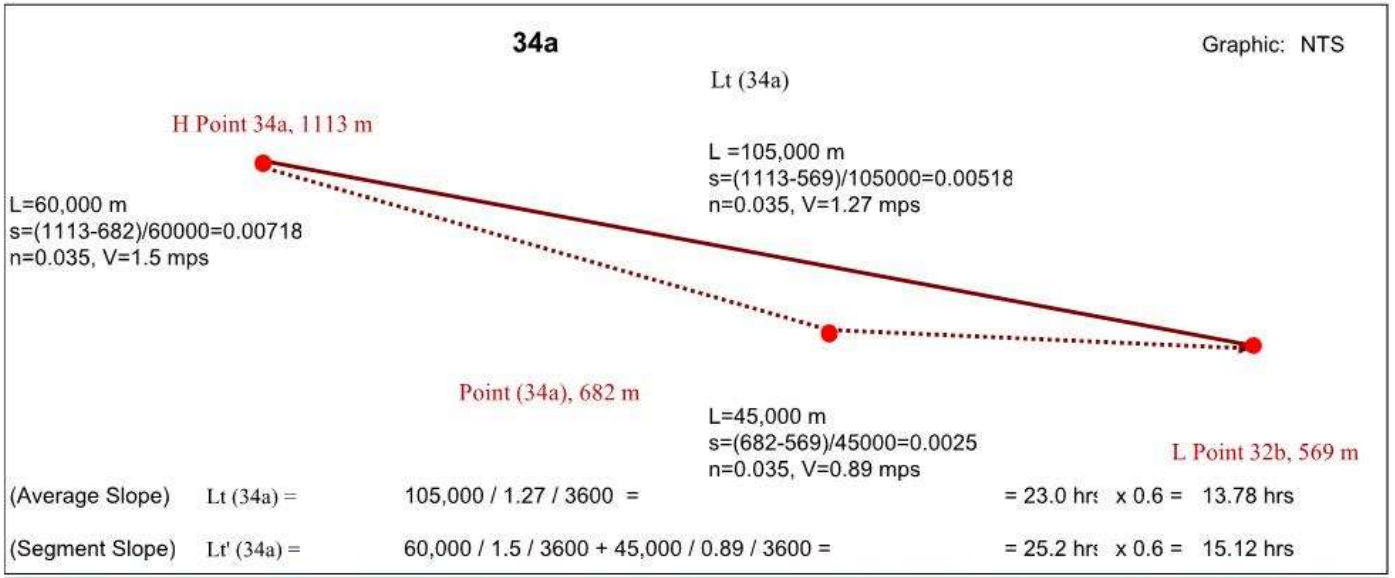
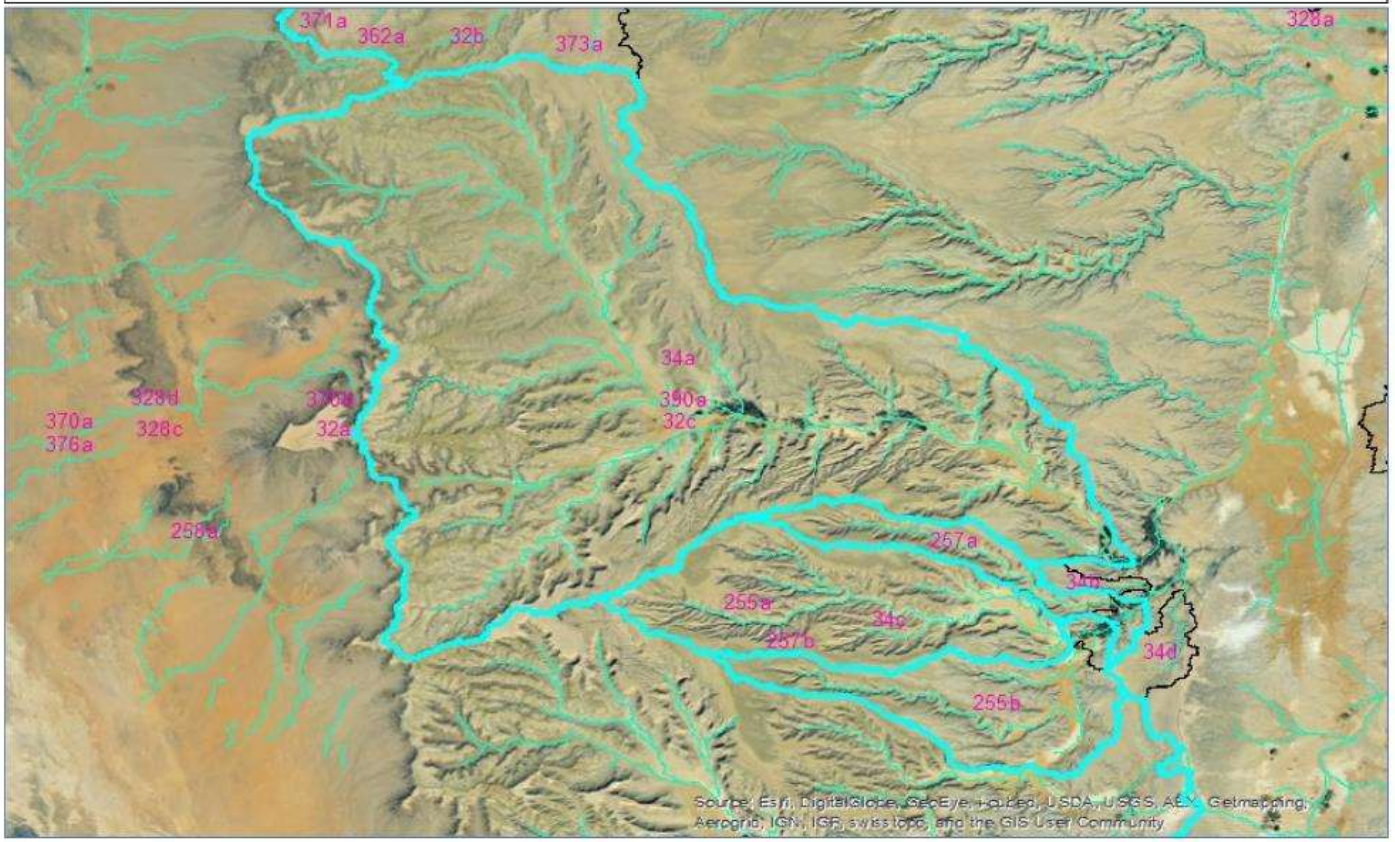
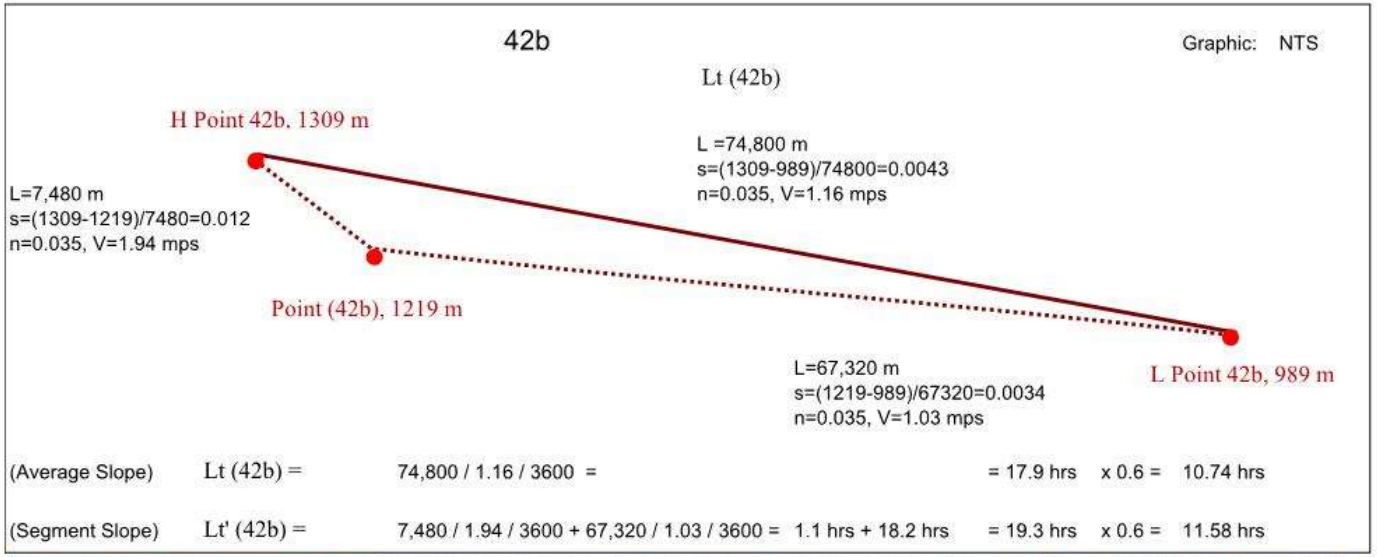
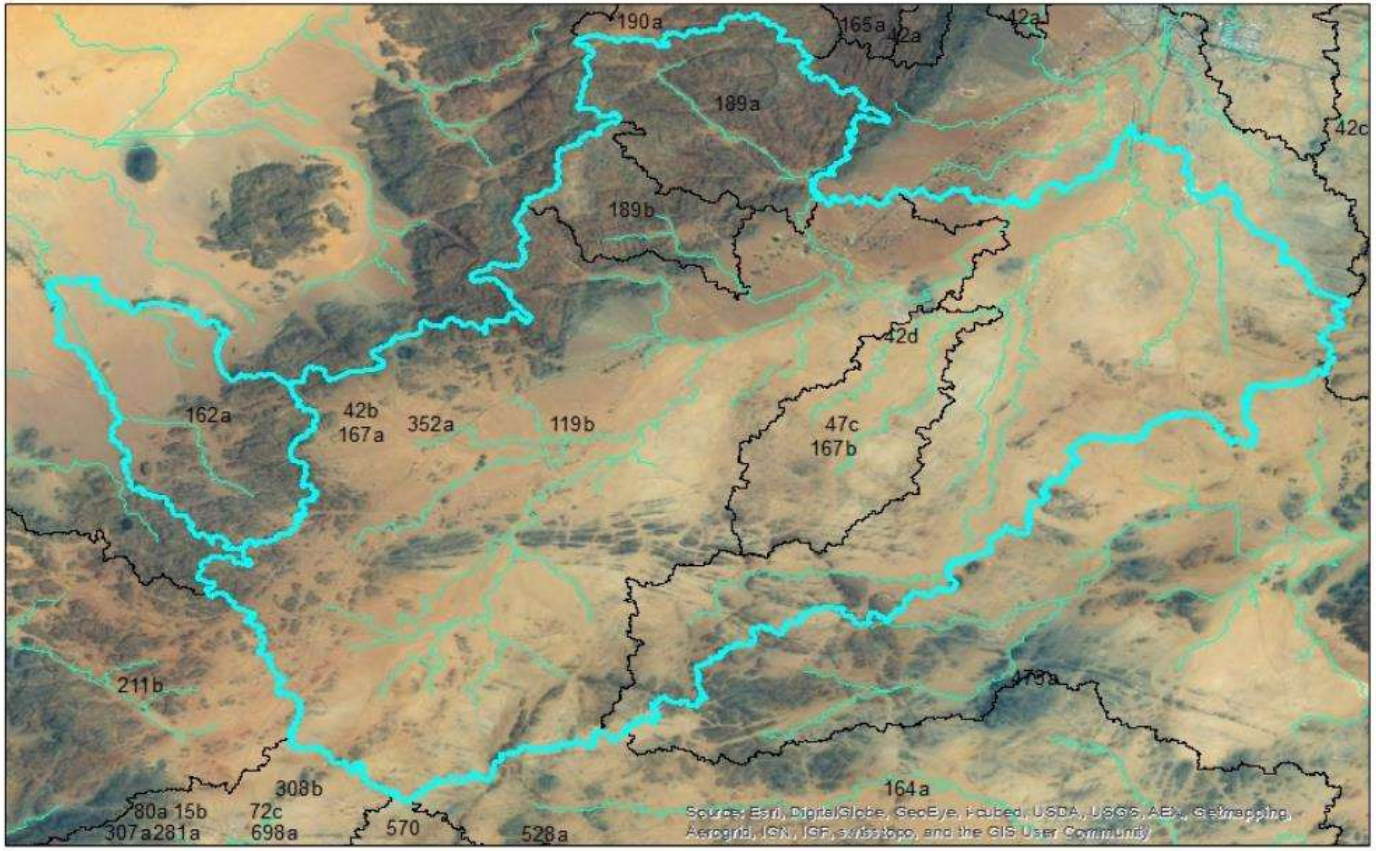
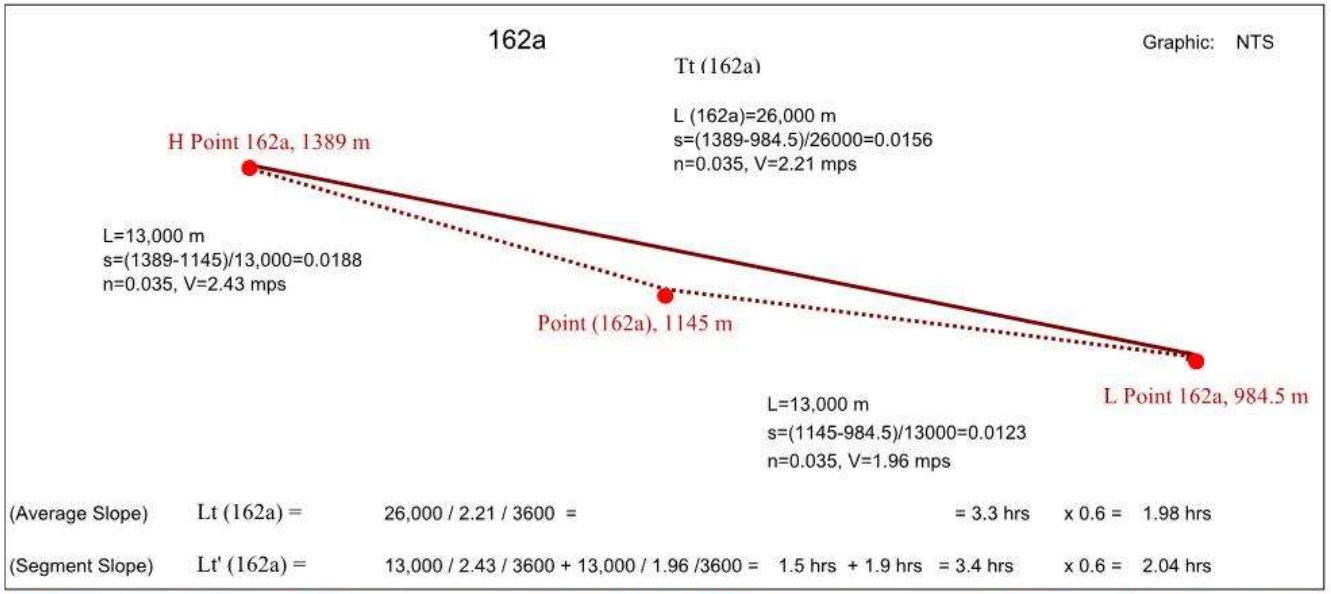
56b
299a
463a
415a
490a
368
692
373a
32b
362a
370a
370b
390a
328a
376a
328d
328c
34a
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, IGP, swisstopo, and the GIS User Community

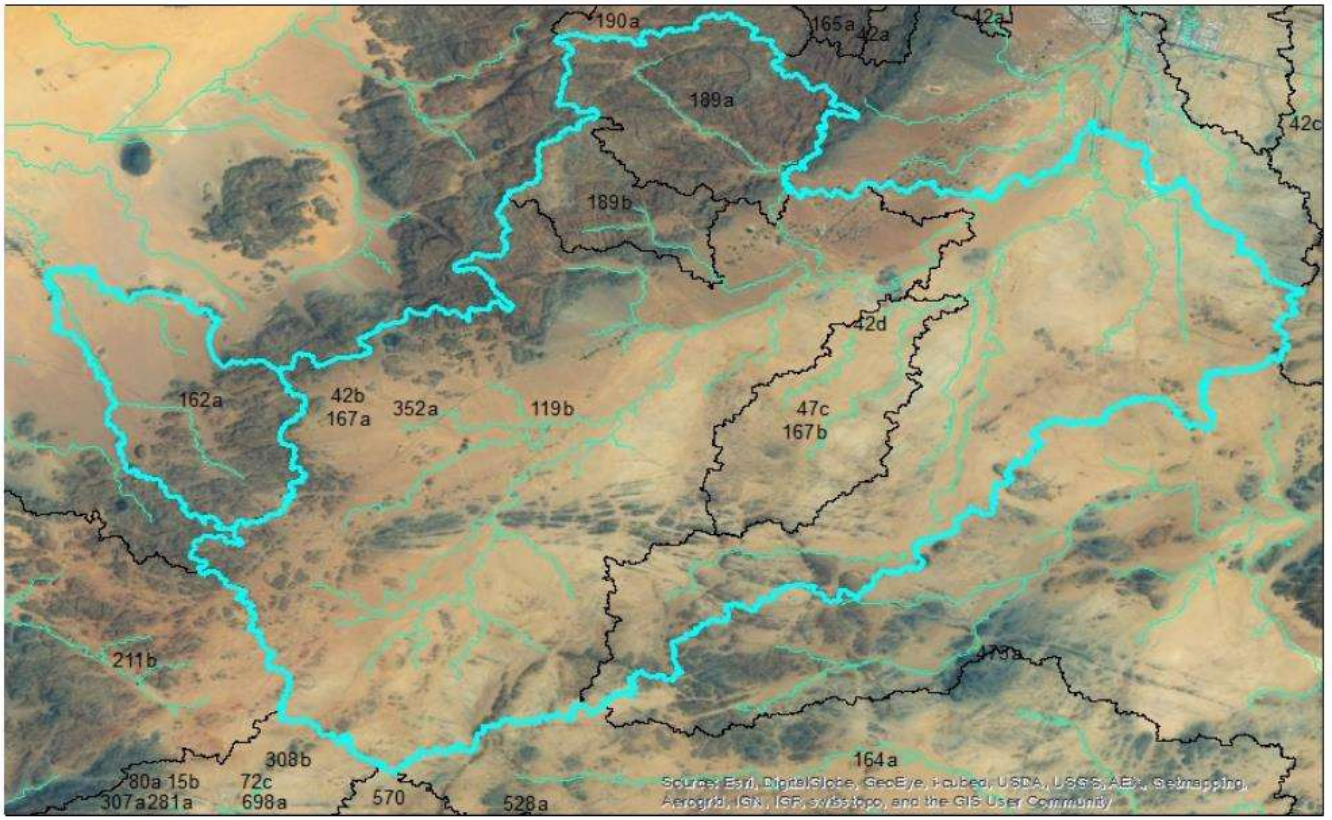

34a
Graphic: NTS
Lt (34a)
H Point 34a, 1113 m
L =105,000 m
s=(1113-569)/105000=0.00518
n=0.035, V=1.27 mps
L=60,000 m
s=(1113-682)/60000=0.00718
n=0.035, V=1.5 mps
Point (34a), 682 m
L=45,000 m
s=(682-569)/45000=0.0025
n=0.035, V=0.89 mps
L Point 32b, 569 m
(Average Slope) Lt (34a) = 105,000 / 1.27 / 3600 = = 23.0 hrs x 0.6 = 13.78 hrs
(Segment Slope) Lt' (34a) = 60,000 / 1.5 / 3600 + 45,000 / 0.89 / 3600 = = 25.2 hrs x 0.6 = 15.12 hrs


371a
362a
32b
373a
328a
34a
328d
370a
376a
328c
32a
350a
32c
258a
257a
255a
257b
34c
34d
255b
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, IGP, swisstopo, and the GIS User Community


42b
Graphic: NTS
Lt (42b)
H Point 42b, 1309 m
L =74,800 m
s=(1309-989)/74800=0.0043
n=0.035, V=1.16 mps
L=7,480 m
s=(1309-1219)/7480=0.012
n=0.035, V=1.94 mps
Point (42b), 1219 m
L=67,320 m
s=(1219-989)/67320=0.0034
n=0.035, V=1.03 mps
L Point 42b, 989 m
(Average Slope) Lt (42b) = 74,800 / 1.16 / 3600 = = 17.9 hrs x 0.6 = 10.74 hrs
(Segment Slope) Lt' (42b) = 7,480 / 1.94 / 3600 + 67,320 / 1.03 / 3600 = 1.1 hrs + 18.2 hrs = 19.3 hrs x 0.6 = 11.58 hrs


190a
165a
42a
42a
189a
42c
189b
42d
162a
42b
167a
352a
119b
47c
167b
211b
308b
80a 15b
307a281a
72c
698a
570
528a
164a
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


162a
Graphic: NTS
Tt (162a)
L (162a)=26,000 m
s=(1389-984.5)/26000=0.0156
n=0.035, V=2.21 mps
H Point 162a, 1389 m
L=13,000 m
s=(1389-1145)/13,000=0.0188
n=0.035, V=2.43 mps
Point (162a), 1145 m
L Point 162a, 984.5 m
L=13,000 m
s=(1145-984.5)/13000=0.0123
n=0.035, V=1.96 mps
(Average Slope) Lt (162a) = 26,000 / 2.21 / 3600 = = 3.3 hrs x 0.6 = 1.98 hrs
(Segment Slope) Lt' (162a) = 13,000 / 2.43 / 3600 + 13,000 / 1.96 /3600 = 1.5 hrs + 1.9 hrs = 3.4 hrs x 0.6 = 2.04 hrs


190a
165a
42a
189a
42c
189b
42d
162a
42b
167a
352a
119b
47c
167b
211b
308b
80a 15b
307a281a
72c
698a
570
528a
164a
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

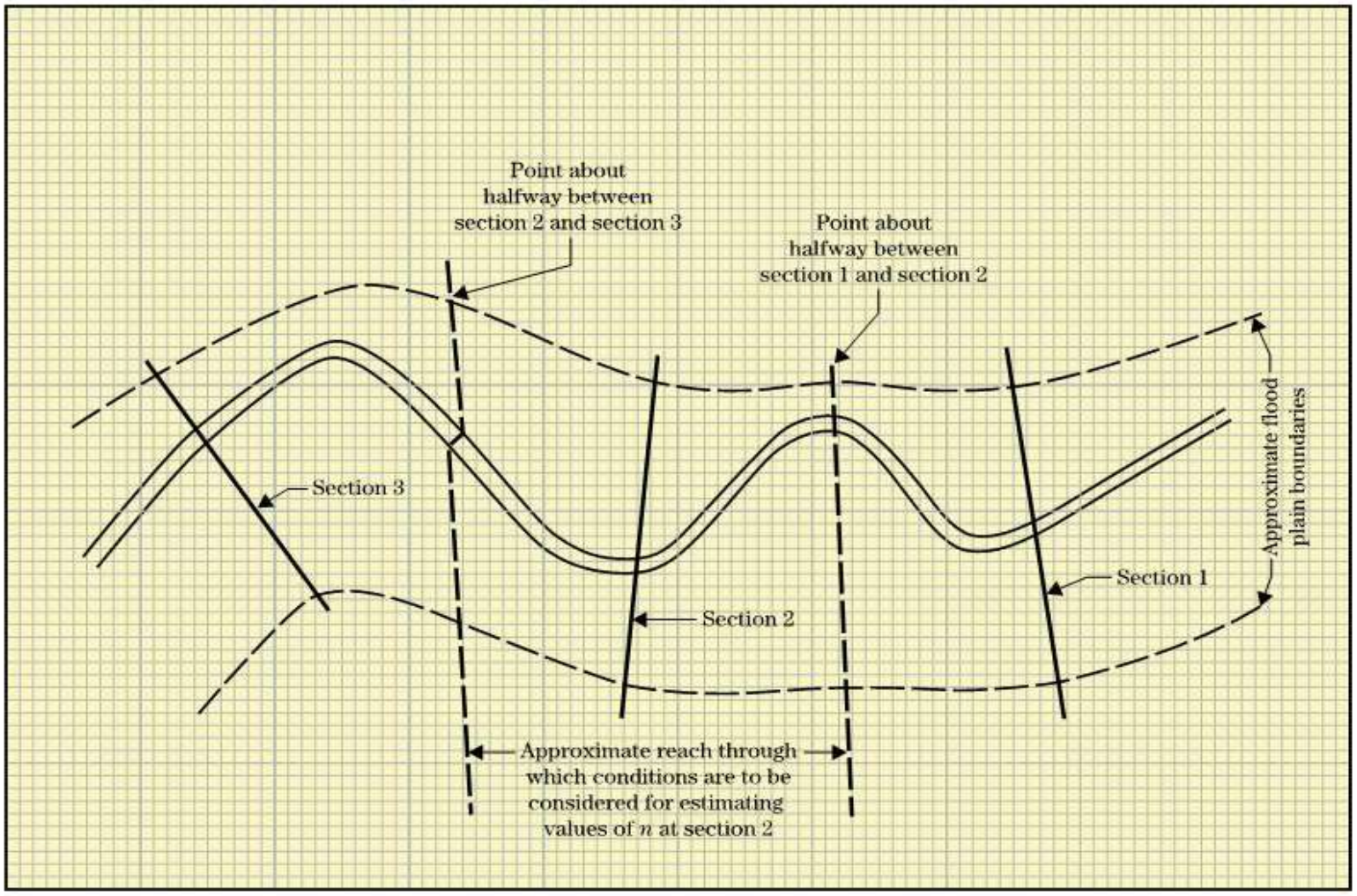
KSA, Flood Protection Study

UH Method, Average-Segment Lag Time Sensitivity Test

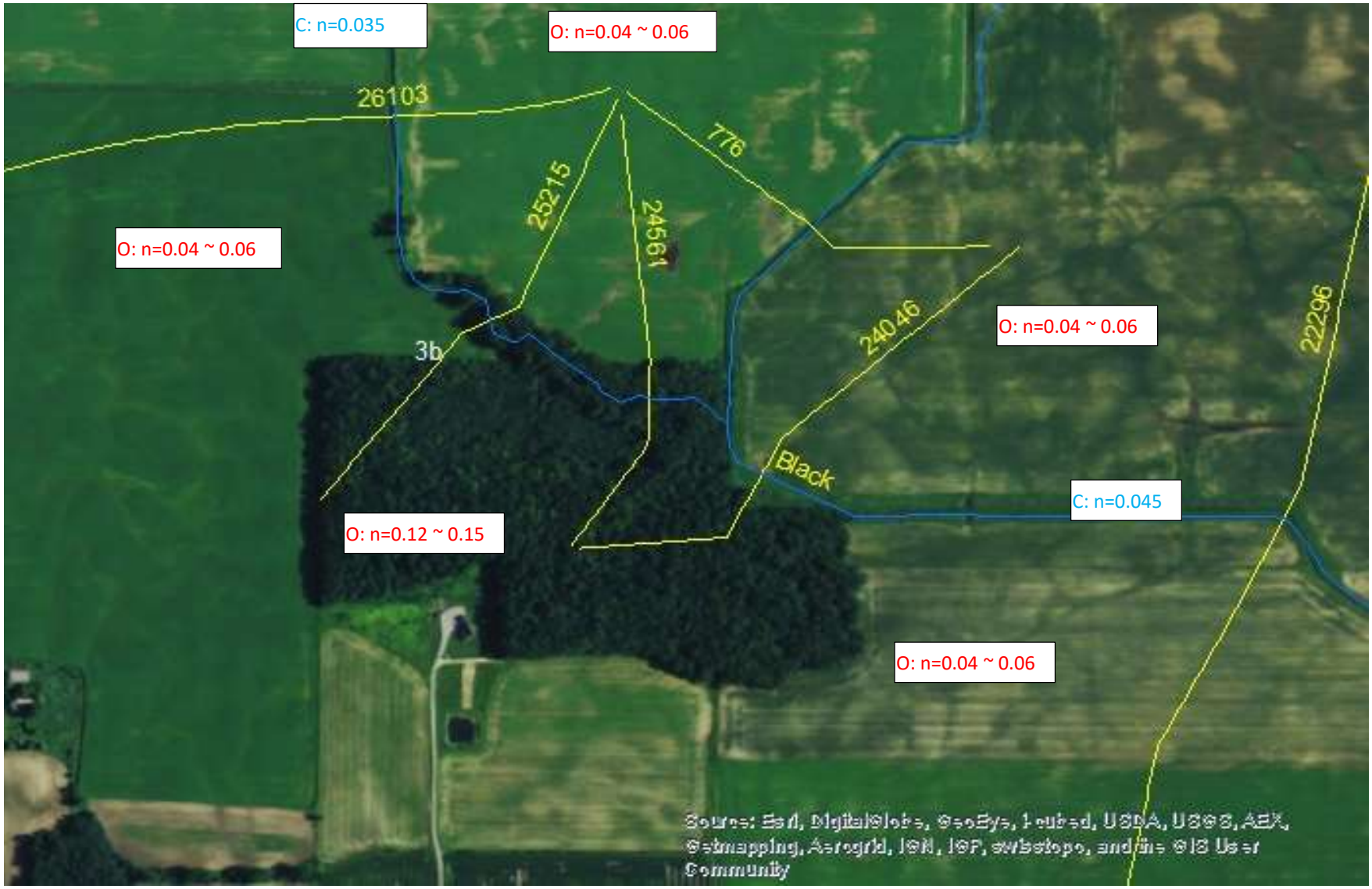
Site No.	L (m)	S (m/m)	S (m/km)	Avg SL Lag (hrs)	Segment SL Lag (hrs)	DA (sq.km)	CN	P (mm)	SCS UH (Avg Lag) Q (cms)	SCS UH (Seg Lag) Q (cms)
3b	79200	0.0293	29.230	4.38	4.71	556	79.2	144.3	1562	1600
32b	130000	0.0048	4.846	17.64	20.04	1867	66.4	90.7	399	648
34	105000	0.0052	5.181	13.78	15.12	2361	67.1	90.0	654	737
42b	74800	0.0043	4.278	10.74	11.58	1049	77.7	98.0	728	1134
162a	26000	0.0156	15.558	1.98	2.04	91	72.3	95.1	173	157

Manning's N

Did you know that averaged Manning's roughness coefficient is applied between the two cross sections, and roughness coefficient changes should be considered in cross section placement?



National Engineering Handbook


C: n=0.035
O: n=0.04 ~ 0.06
26103
776
25215
24561
O: n=0.04 ~ 0.06
24046
O: n=0.04 ~ 0.06
22296
3b
Black
C: n=0.045
O: n=0.12 ~ 0.15
O: n=0.04 ~ 0.06
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Edit Manning's n or k Values

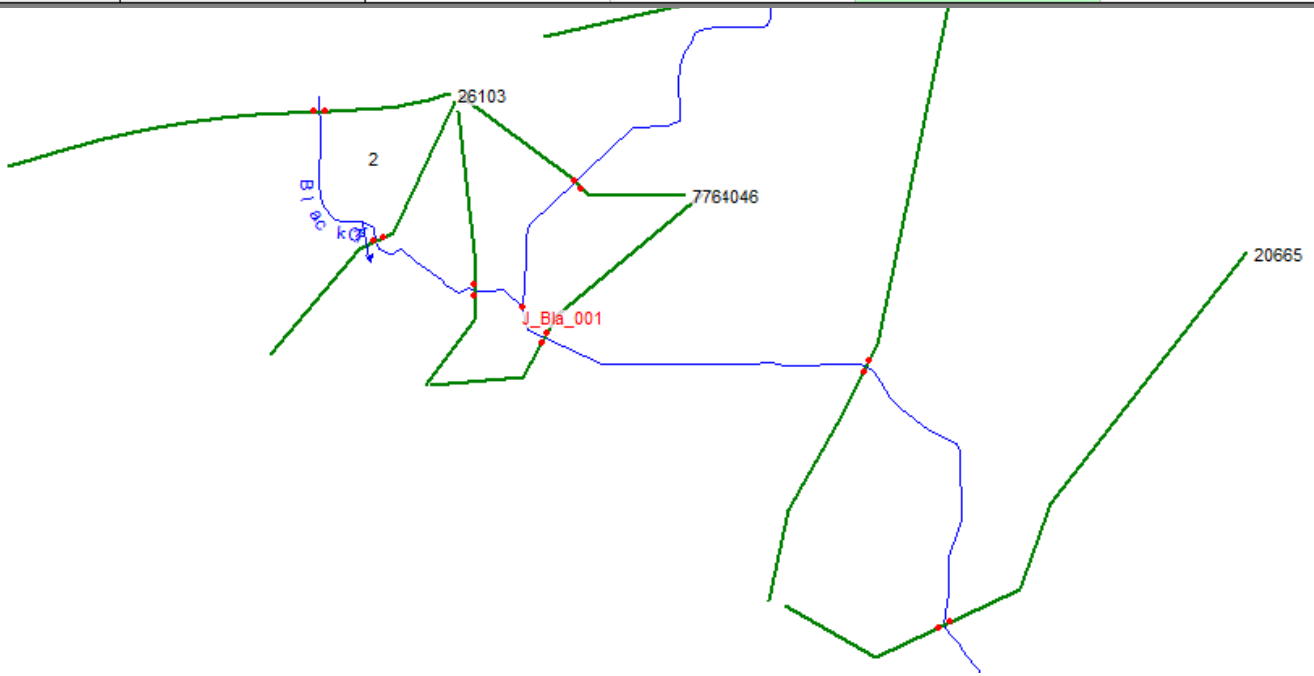
River: BlackCrk | Edit Interpolated XS's | Channel n Values have a light green background

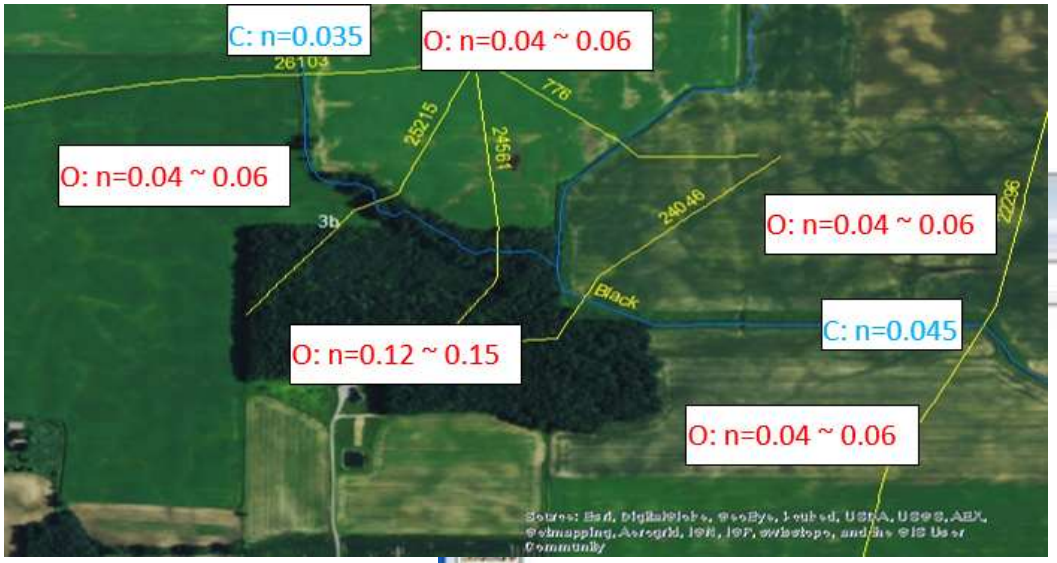
Reach: (All Reaches) | All Regions

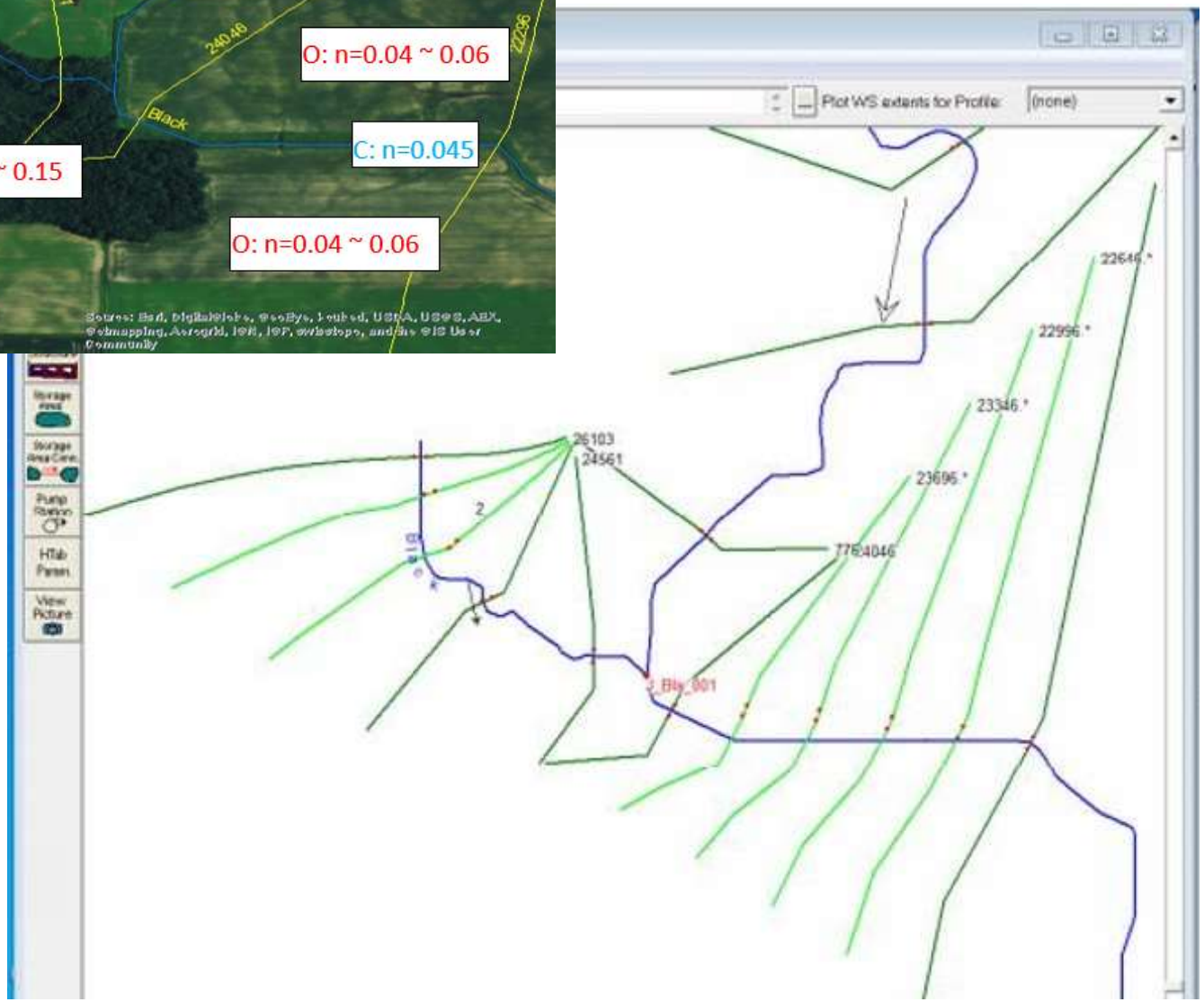
Selected Area Edit Options

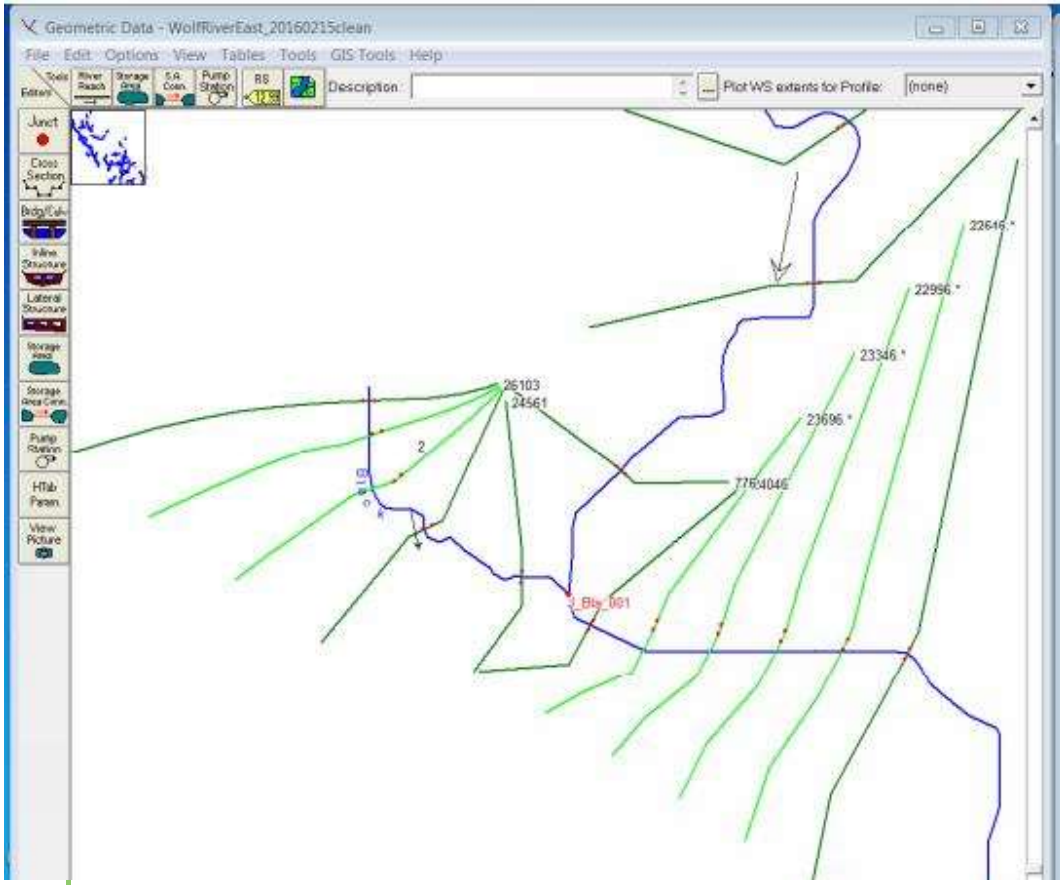
Add Constant ... | Multiply Factor ... | Set Values ... | Replace ... | Reduce to L Ch R ...

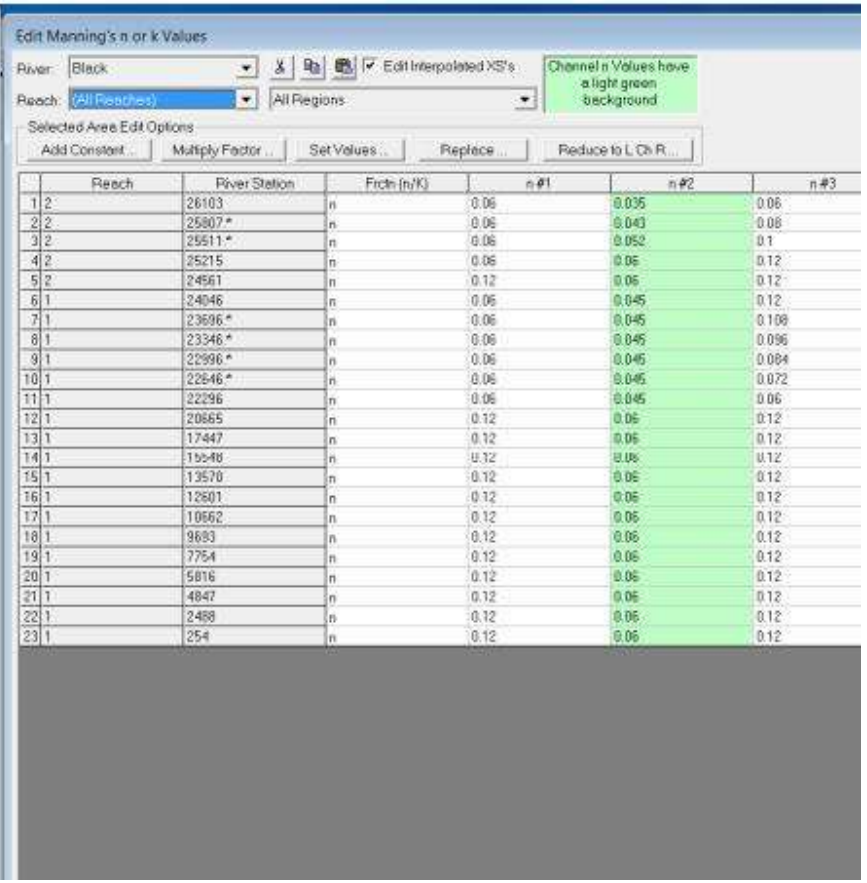
	Reach	River Station	Frctn (n/K)	n #1	n #2	n #3
1	2	26103	n	0.06	0.045	0.06
2	2	25215	n	0.06	0.045	0.15
3	2	24561	n	0.06	0.045	0.15
4	1	24046	n	0.06	0.045	0.15
5	1	22296	n	0.06	0.045	0.06
6	1	20665	n	0.06	0.045	0.06
7	1	17447	n	0.06	0.045	0.06
8	1	15548	n	0.06	0.045	0.06
9	1	13570	n	0.06	0.045	0.06
10	1	12601	n	0.06	0.045	0.06
11	1	10662	n	0.06	0.045	0.06
12	1	9693	n	0.06	0.045	0.06
13	1	7754	n	0.06	0.045	0.06
14	1	5816	n	0.06	0.045	0.06
15	1	4847	n	0.06	0.045	0.06
16	1	2488	n	0.06	0.045	0.06
17	1	254	n	0.06	0.045	0.06




C: n=0.035
O: n=0.04 ~ 0.06
26104
776
25215
24561
O: n=0.04 ~ 0.06
3b
24046
O: n=0.04 ~ 0.06
22296
Black
C: n=0.045
O: n=0.12 ~ 0.15
O: n=0.04 ~ 0.06


Plot WS extents for Profile:
(none)
22646 *
22996 *
23346 *
23695 *
26103
24561
2
776
4046
Storage Area
Pump Station
HTab Param
View Picture





	Reach	River Station	Frctn (n/K)	n #1	n #2	n #3
1	2	26103	n	0.06	0.035	0.06
2	2	25807 *	n	0.06	0.043	0.08
3	2	25511 *	n	0.06	0.052	0.1
4	2	25215	n	0.06	0.06	0.12
5	2	24561	n	0.12	0.06	0.12
6	1	24046	n	0.06	0.045	0.12
7	1	23696 *	n	0.06	0.045	0.108
8	1	23346 *	n	0.06	0.045	0.096
9	1	22996 *	n	0.06	0.045	0.084
10	1	22646 *	n	0.06	0.045	0.072
11	1	22296	n	0.06	0.045	0.06
12	1	20665	n	0.12	0.06	0.12
13	1	17447	n	0.12	0.06	0.12
14	1	15548	n	0.12	0.06	0.12
15	1	13570	n	0.12	0.06	0.12
16	1	12601	n	0.12	0.06	0.12
17	1	10662	n	0.12	0.06	0.12
18	1	9693	n	0.12	0.06	0.12
19	1	7754	n	0.12	0.06	0.12
20	1	5816	n	0.12	0.06	0.12
21	1	4847	n	0.12	0.06	0.12
22	1	2488	n	0.12	0.06	0.12
23	1	254	n	0.12	0.06	0.12

Conclusion – **Be Better Than Average**

- Learned How to Improve Better Than Average

1. Time of Concentration – Add Additional Segments Per Slope Conditions

2. Manning's Roughness Coefficients – Insert necessary additional Cross Section Placement

Thanks for your attention

- Questions?
- Contact:

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leahyt@cdmsmith.com
312-346-5000