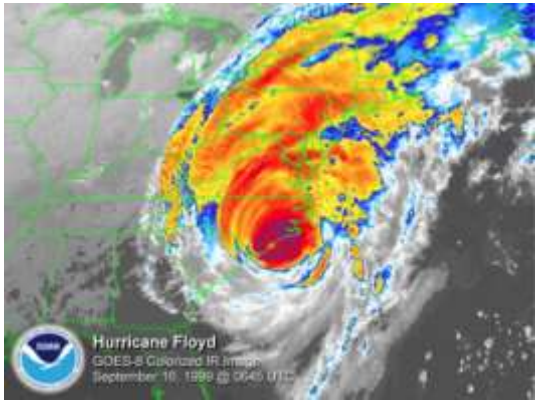


Evaluating the Role of Urban Stream Restoration for Improving Transportation Resilience to Extreme Rainfall Events

Jack Kurki-Fox, PhD, PE[1], Barbara Doll, PhD, PE[1,2], and Dan Line, PE[2],

[1-] NC State University Bio&Ag Engineering
[2-] North Carolina Sea Grant

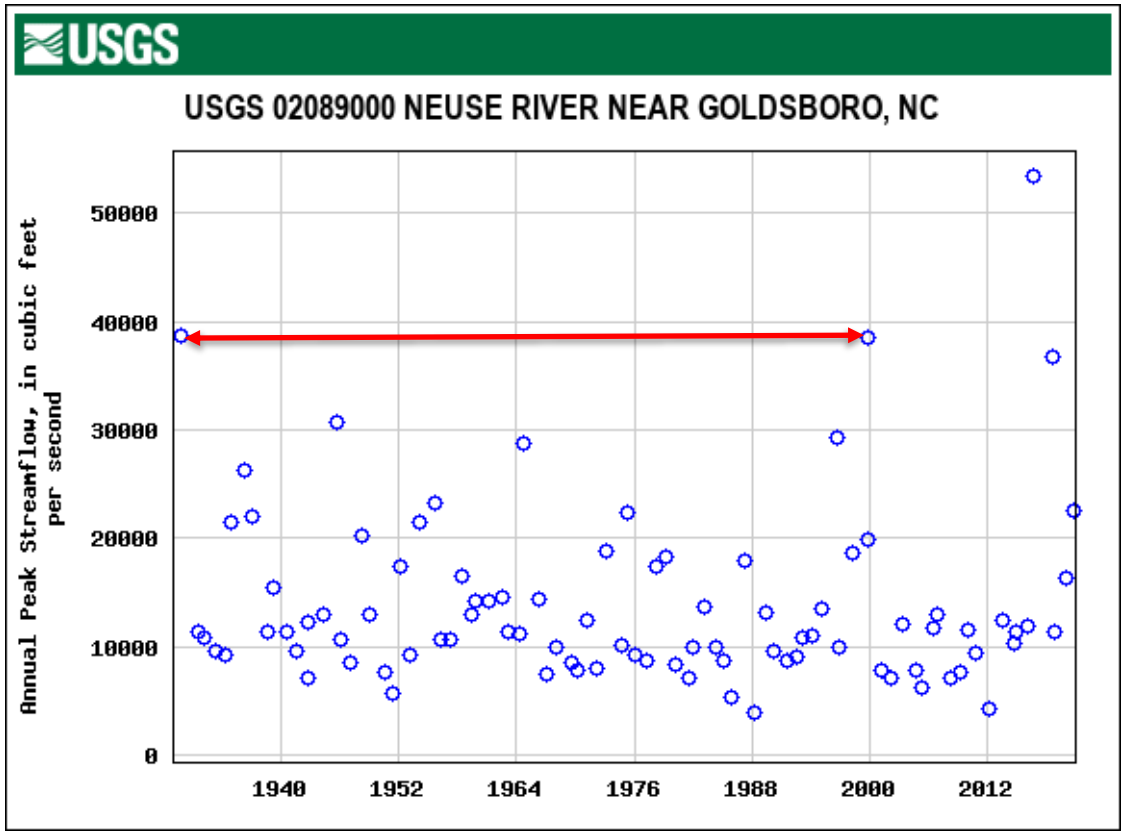
Flooding in Eastern N.C.

- Floyd (1999) – $3 billion in damages; 35 deaths, 1500 rescues; 56,000 homes damaged
- Matthew (2016) - $4.8 billion in damages; 31 deaths, 2336 rescues; 100,000 homes damaged
- Florence (2018) - $16.7 billion in damages; 42 deaths, 74,563 structures flooded, 5214 rescues

Neuse Sport Shop, Kinston, Public Radio East

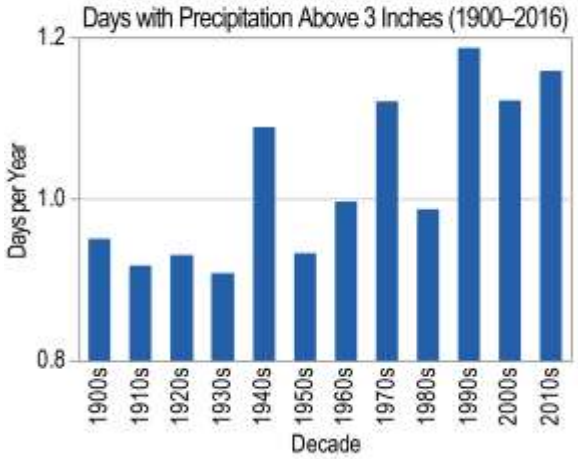
Photo by Jocelyn Augustino/FEMA

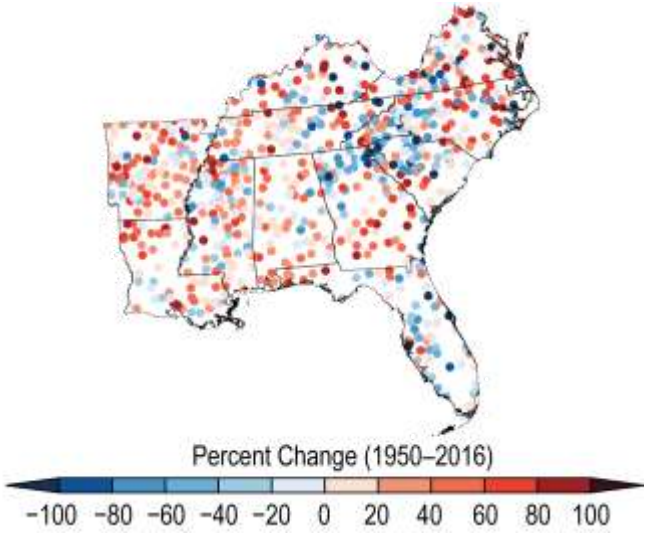
Flooding in Eastern N.C.



Flooding in Eastern NC

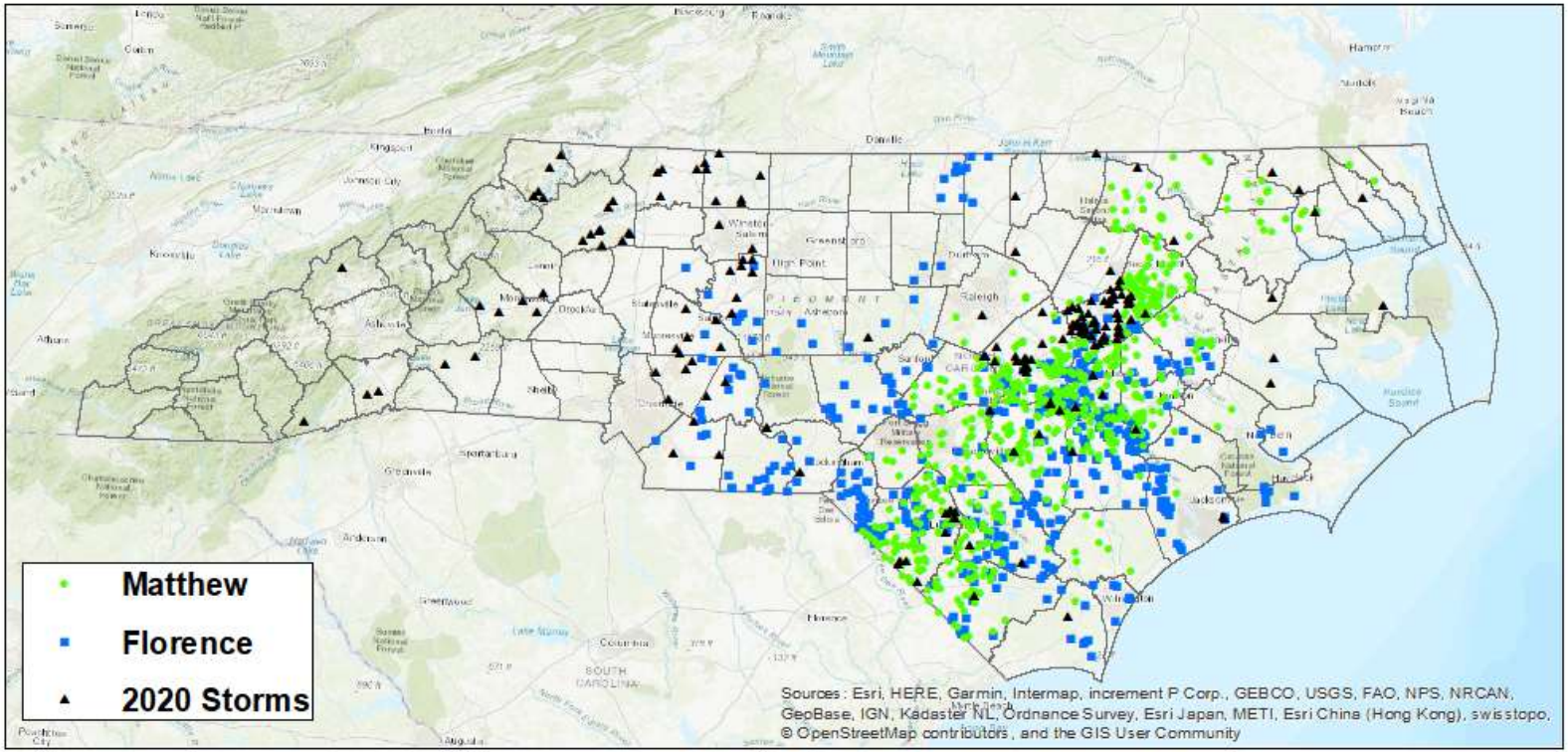
- Severe flooding from extreme events + increased flash flooding





Globalchange.gov

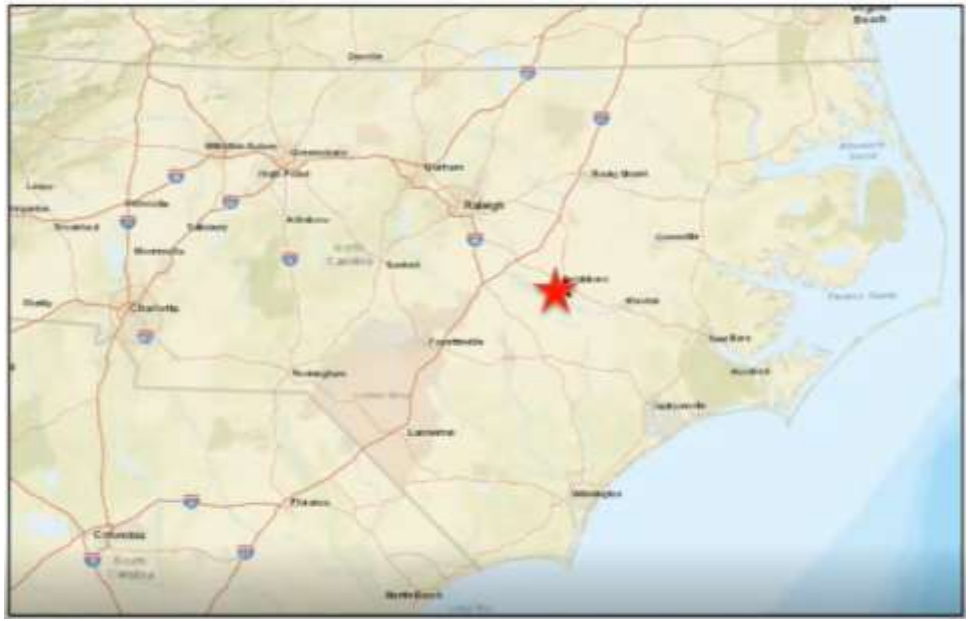
Flooding - Transportation Impacts



Small Municipalities in Eastern NC

- Infrastructure designed in 1800s and 1900s
  - Prevailing wisdom suggested streams should be deepened, straightened, and armored to increase conveyance and allow building along waterways
  - Newer development designed for 10-25 year event
  - Increased rainfall intensity + more extreme events =
    - Increased frequency of historical return period events

Goldsboro, NC



NC COOPERATIVE EXTENSION

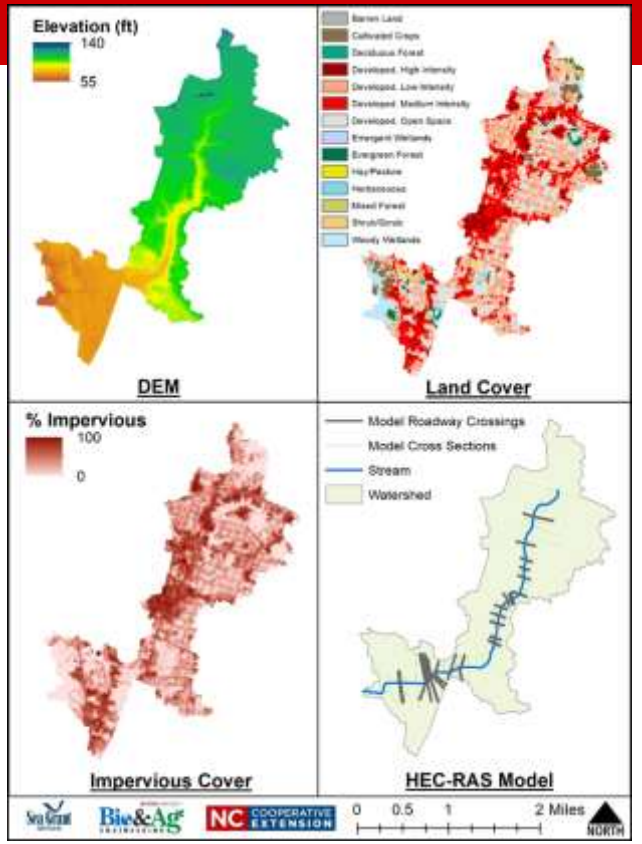
N.C. A&T STATE UNIVERSITY

NC STATE UNIVERSITY

Big Ditch, Goldsboro

Stream

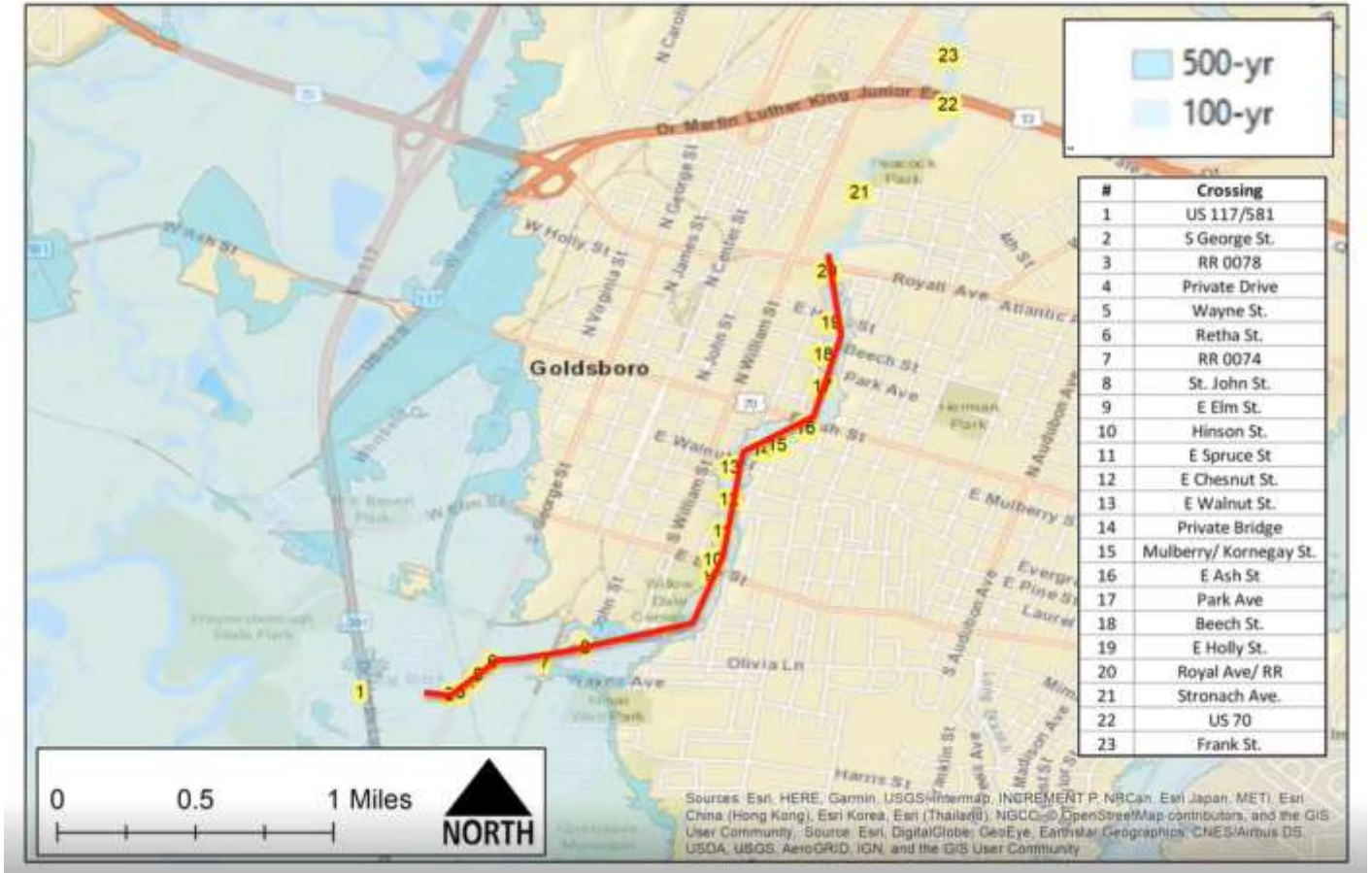
- Channel has been straightened and armored with concrete
- Floodplain developed
- 22 road crossings
  - Many undersized (16 overtopped in the 10-yr storm)



Watershed

- 3 square miles
- 93% Developed
- 35% Impervious

Big Ditch



#	Crossing
1	US 117/581
2	S George St.
3	RR 0078
4	Private Drive
5	Wayne St.
6	Retha St.
7	RR 0074
8	St. John St.
9	E Elm St.
10	Hinson St.
11	E Spruce St
12	E Chesnut St.
13	E Walnut St.
14	Private Bridge
15	Mulberry/ Kornegay St.
16	E Ash St
17	Park Ave
18	Beech St.
19	E Holly St.
20	Royal Ave/ RR
21	Stronach Ave.
22	US 70
23	Frank St.

HEC-RAS Model

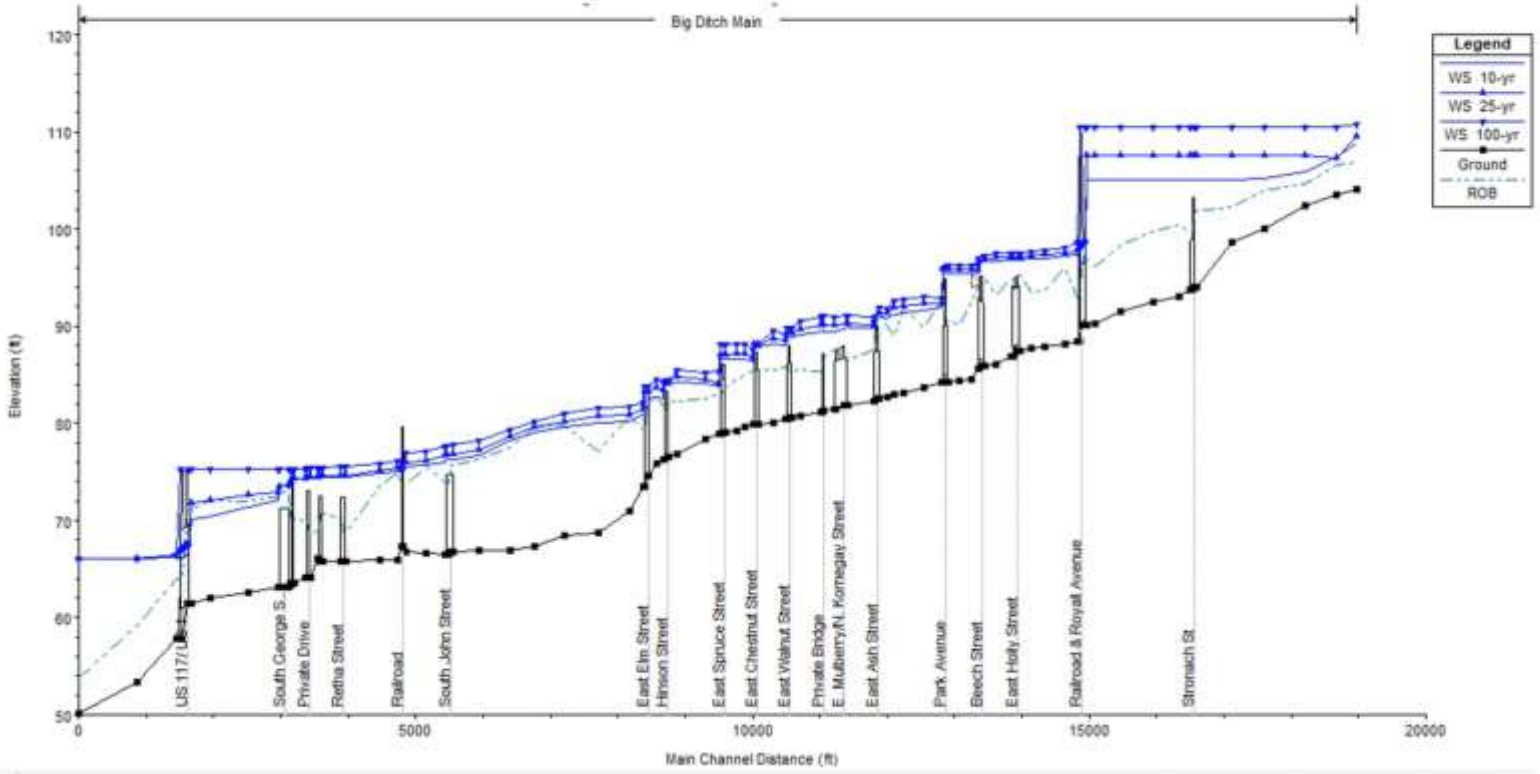
MODEL

- Combined NC EM floodplain mapping models
- Updated with recent LiDAR
- Calibrated to USGS gage

Table 7. Discharge values used in the HEC-RAS model (all values in cfs).

Return Period	*Location and Drainage Area*					
	US 70 Bypass (0.28 sq. mi.)	*Royal Ave (1.08 sq. mi.)*	*Downstream of Royal Ave (1.27 sq. mi.)*	*Upstream of E Ash St (1.53 sq. mi.)*	*Downstream of E Elm St (2.00 sq. mi.)*	*Upstream of Retha St (2.50 sq. mi.)*
10-yr	209	588	684	747	898	1005
25-yr	280	753	865	953	1139	1276
50-yr	340	887	1010	1117	1332	1494
100-yr	407	1031	1164	1294	1538	1727
500-yr	580	1390	1548	1737	2054	2310

Big Ditch


Big Ditch Main
Legend
WS 10-yr
WS 25-yr
WS 100-yr
Ground
ROB
Elevation (ft)
120
110
100
90
80
70
60
50
0
5000
10000
15000
20000
Main Channel Distance (ft)
US 117/I-95
South George St.
Private Drive
Rethia Street
Railroad
South John Street
East Elm Street
Hinson Street
East Spruce Street
East Chestnut Street
East Walnut Street
Private Bridge
E. Mulberry/N. Kornegay Street
East Ash Street
Park Avenue
Beech Street
East Holly Street
Railroad & Royall Avenue
Stronach St

Study Questions

Questions

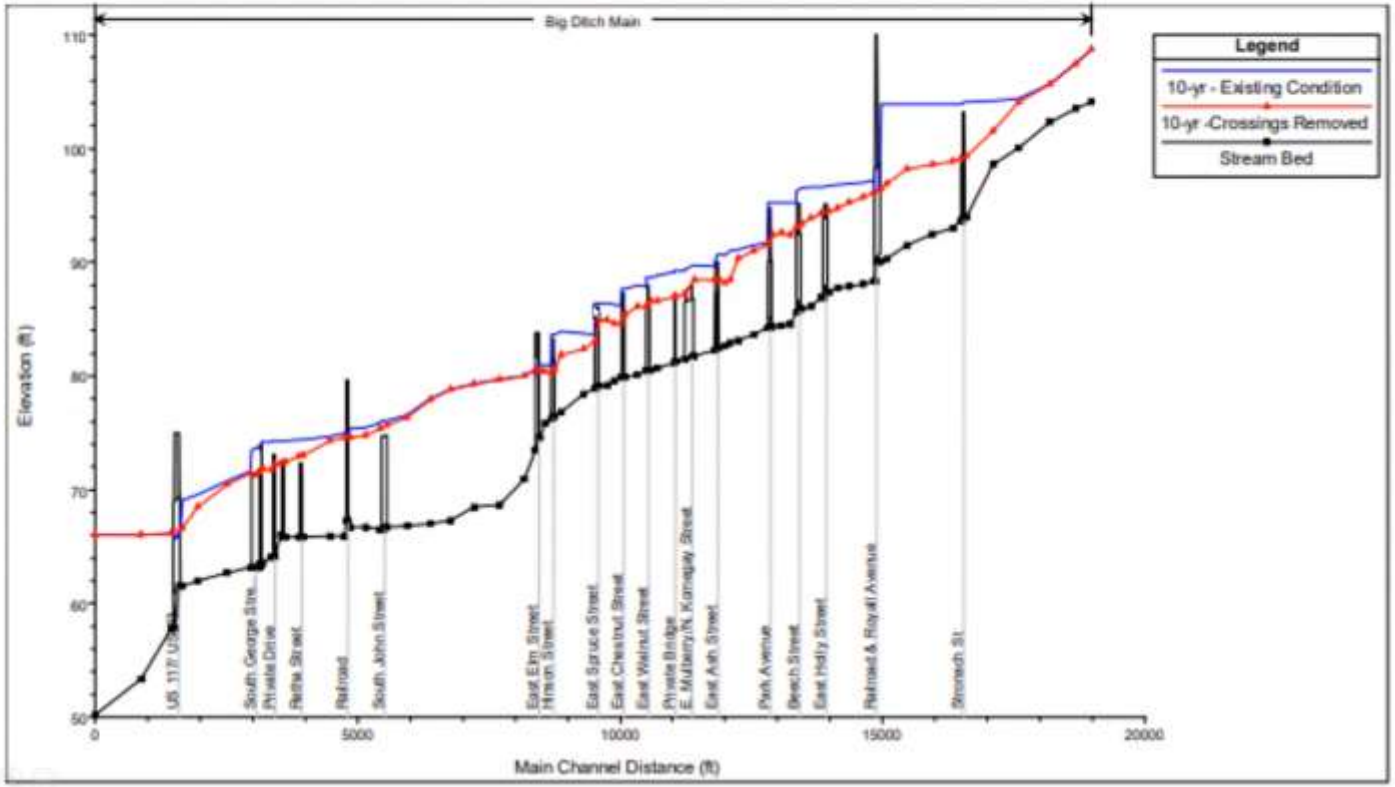
- Where could changes to crossing and/or stream restoration provide substantial benefits?

- Where to invest limited resources?

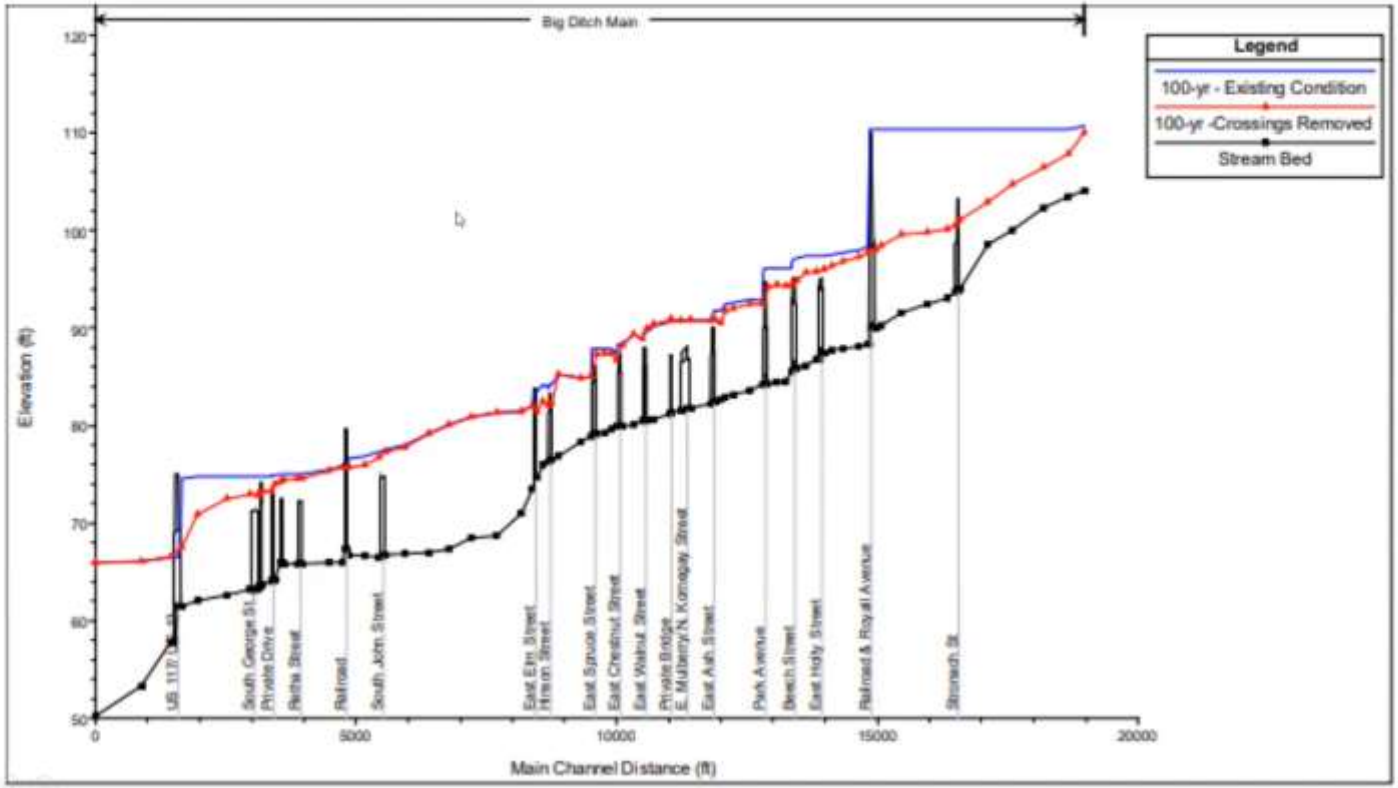
Approach

- **Model Scenarios**
  - **Crossing Modifications** – impact of bridges and culverts
  - **Stream Restoration –** Impact of channel size
  - **Stream Restoration and Crossing Removed** – maximum potential benefits
  - **Floodplain Restoration with Strategic Crossing Modification**

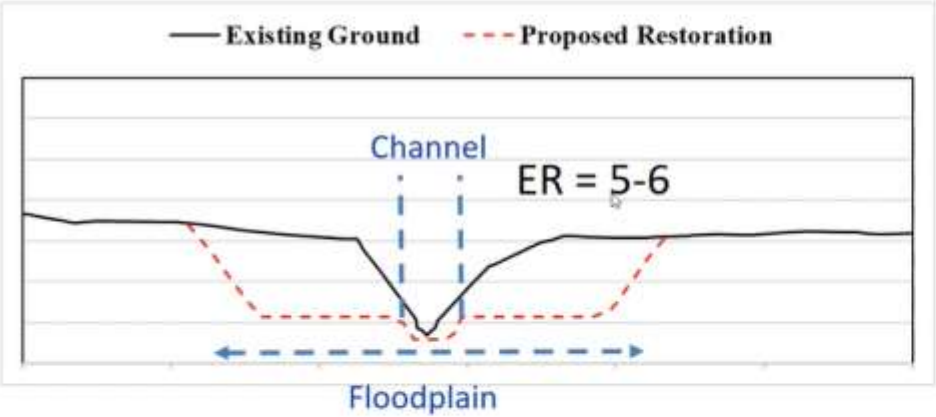
All Culverts & Bridges Removed – 10-yr

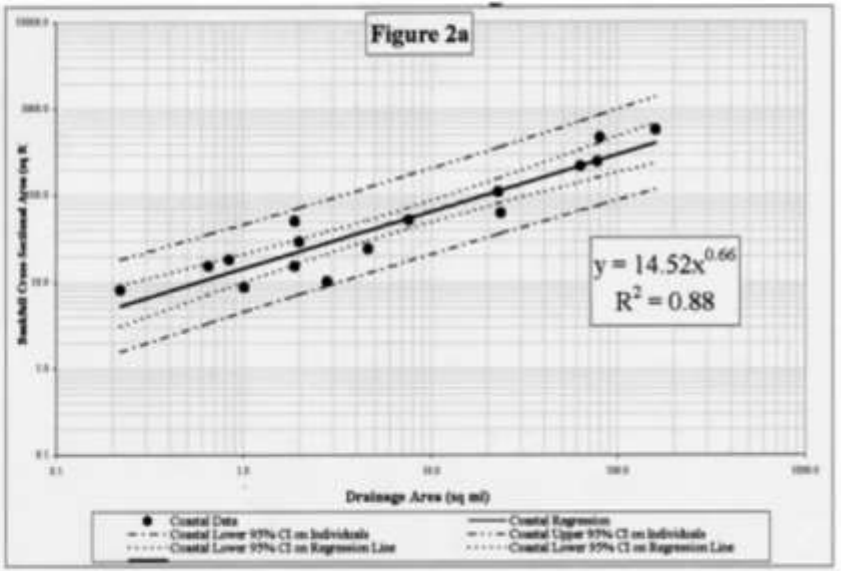


All Culverts & Bridges Removed – 100-yr

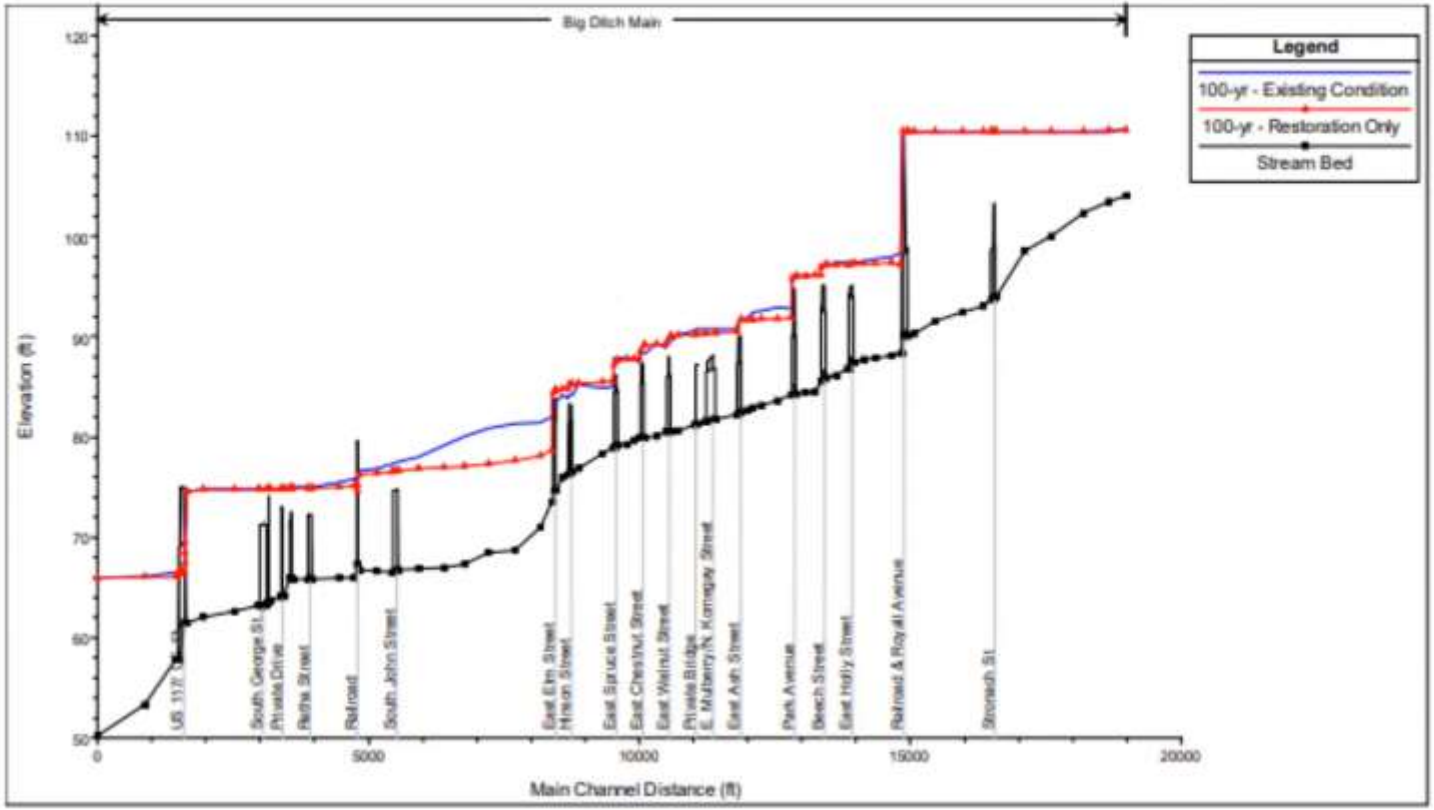


Stream and Floodplain Restoration

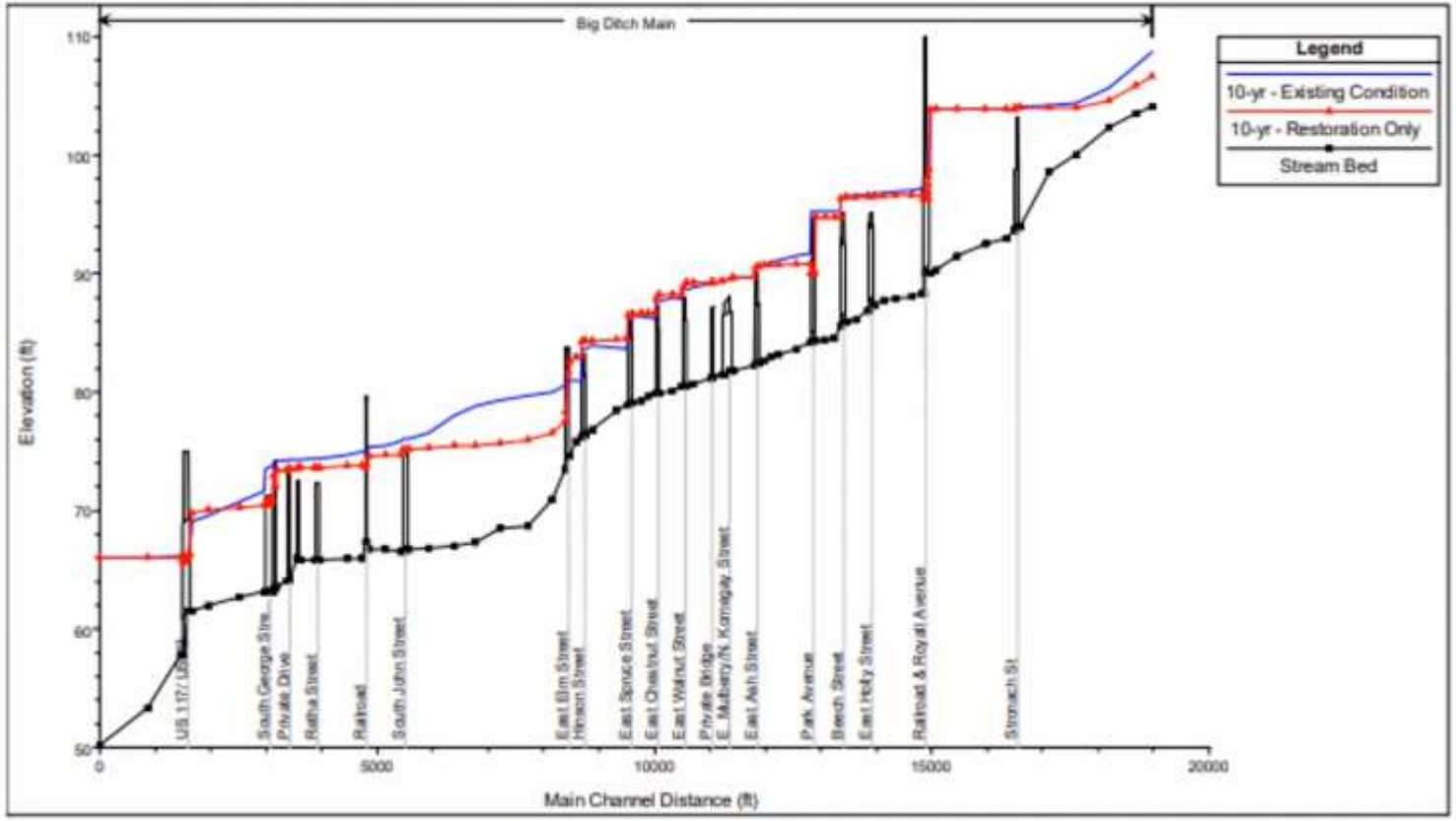




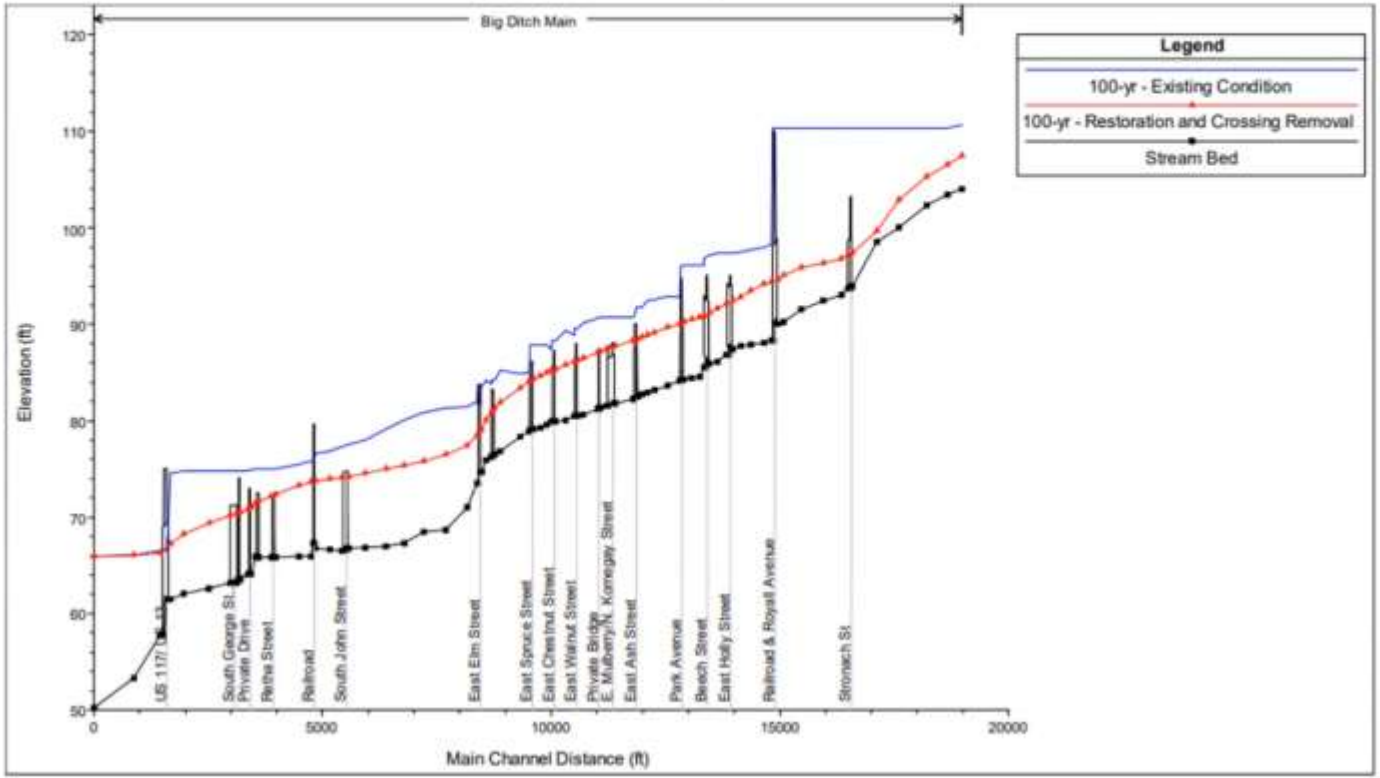
Floodplain Restoration Only – 100-yr



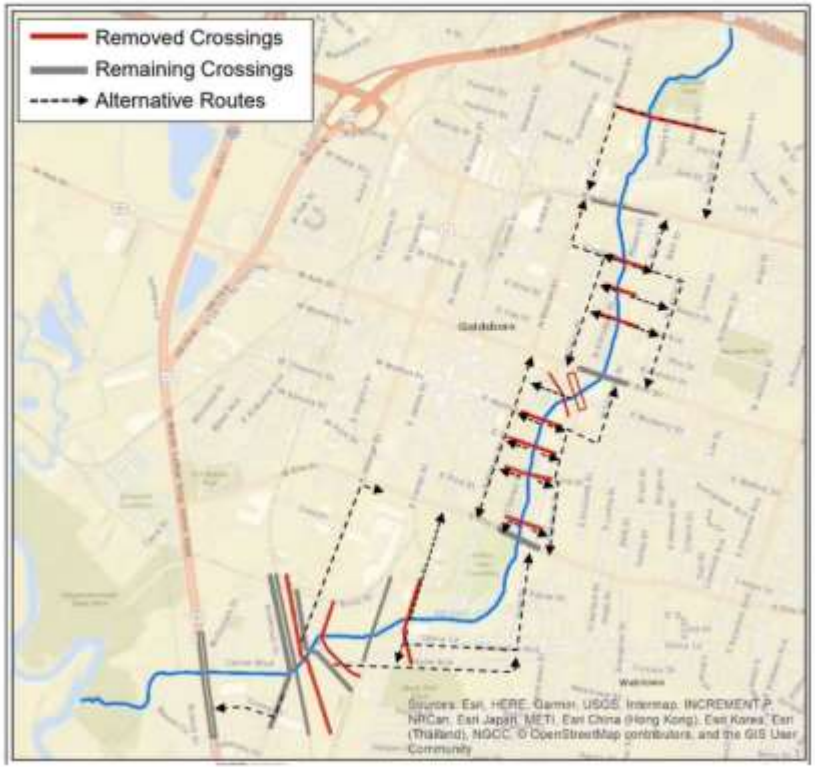
Floodplain Restoration Only – 10-yr



What are maximum possible changes?
- Remove all crossing and implement stream restoration

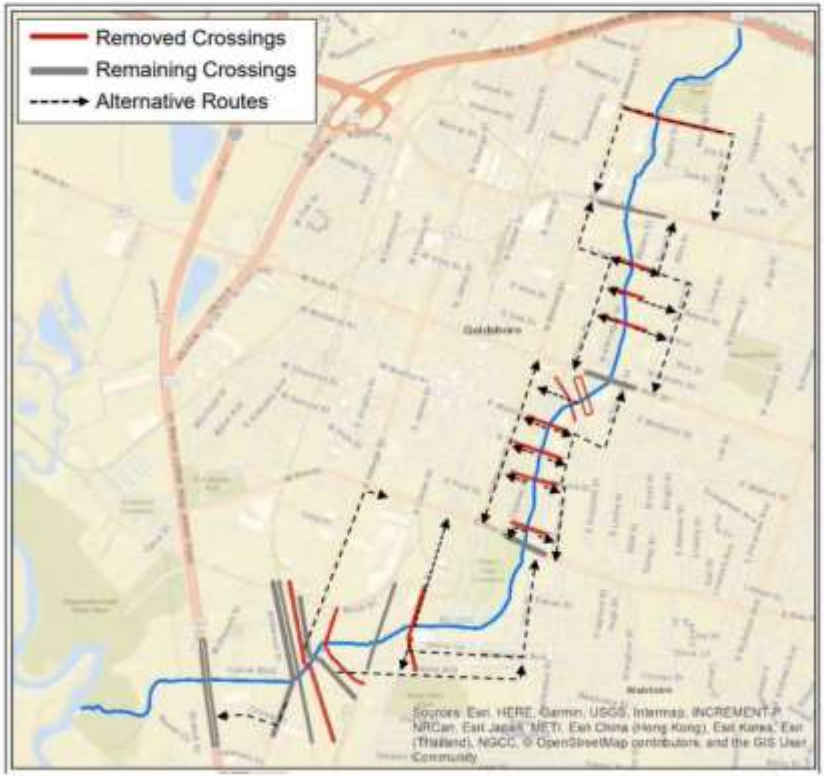


Combine stream restoration with strategic crossing removal/replacement

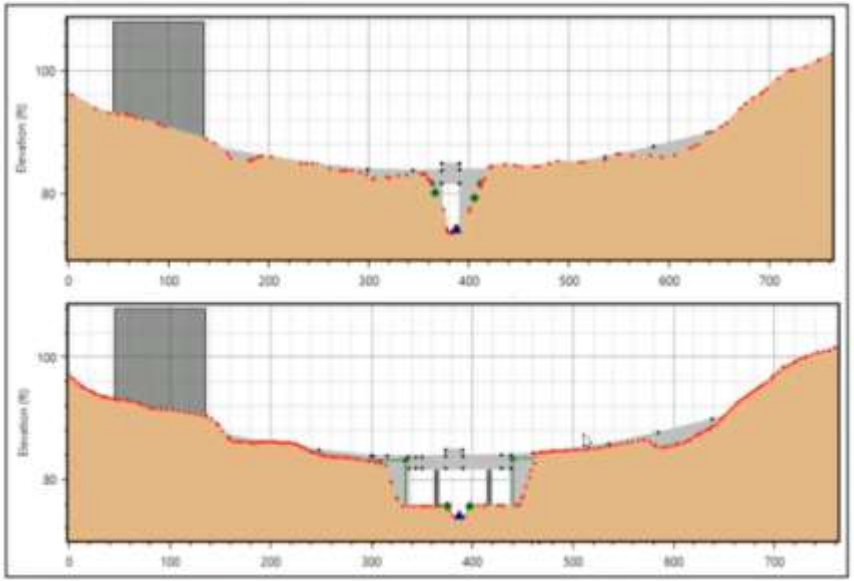


- 7 crossings enlarged
- 15 redundant crossings removed
- ER of 5-6

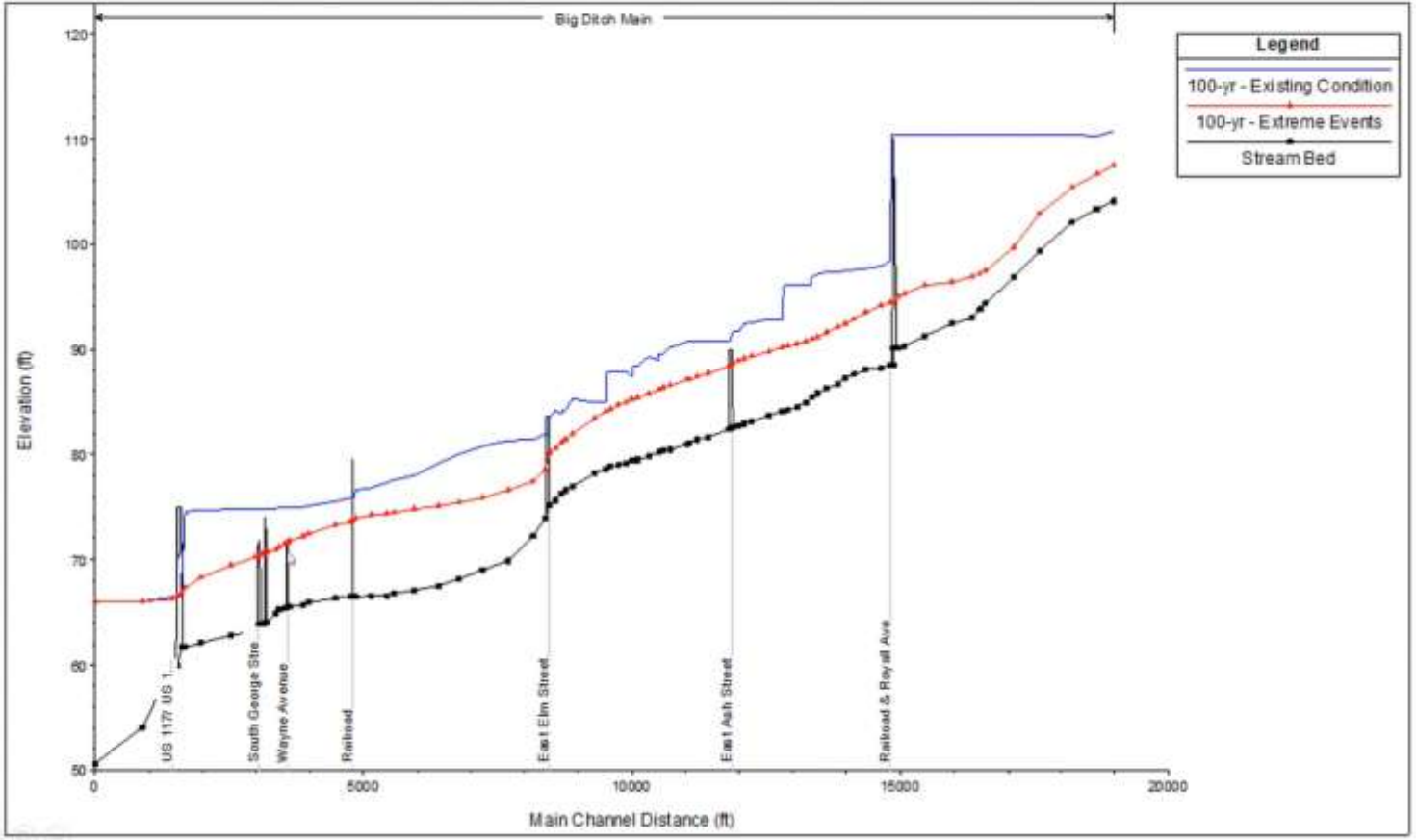
Combine stream restoration with strategic crossing removal/replacement



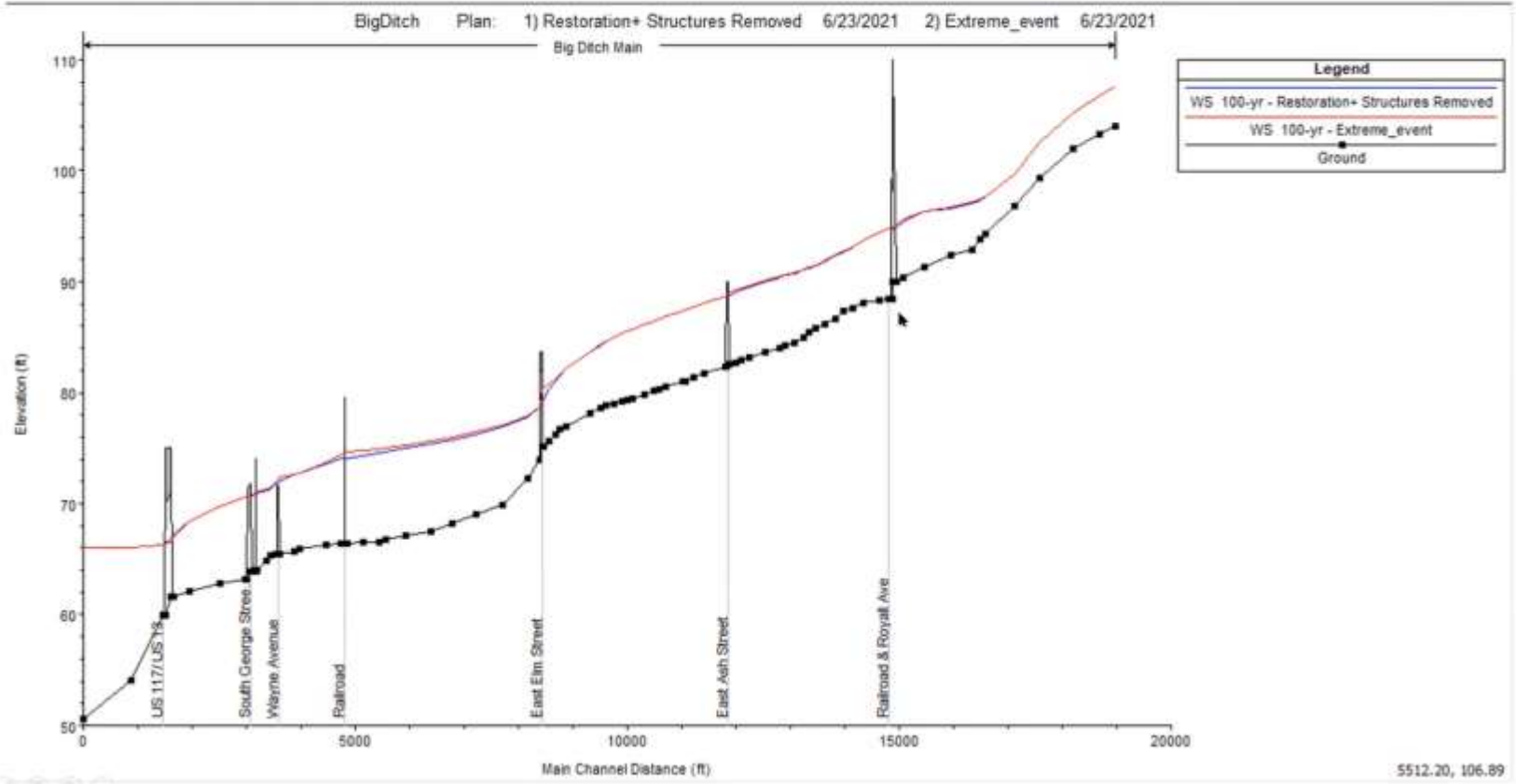
- 7 crossings enlarged
- 15 redundant crossings removed
- ER of 5-6



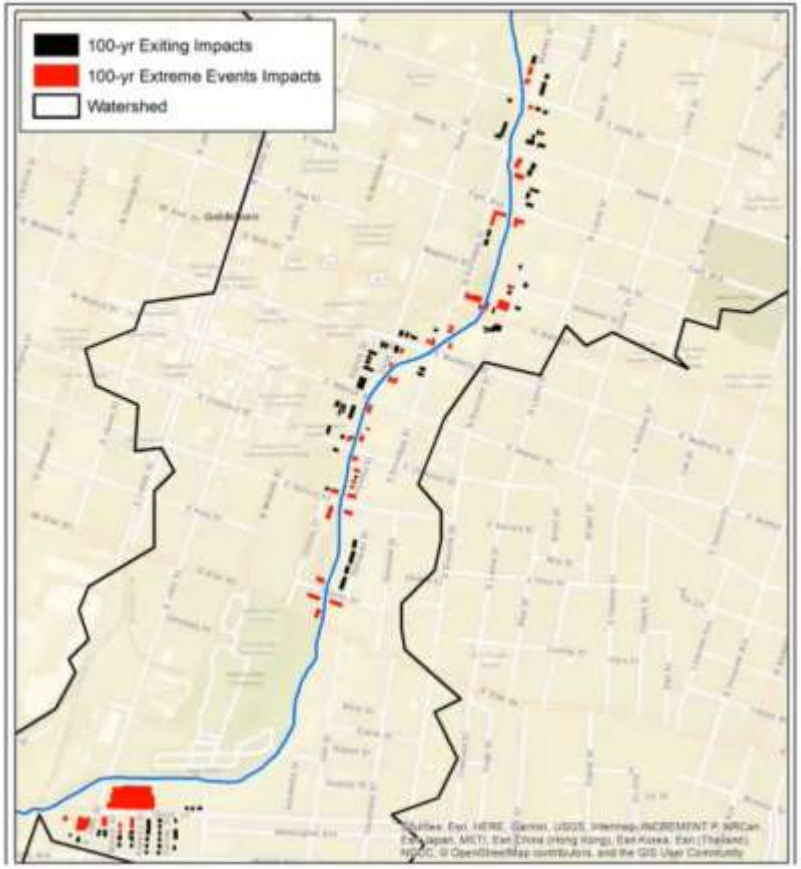
Combined Measures (100-year)



Combined Measures (100-year)



Big Ditch – Combined Measures



Summary

- This approach would be expensive to implement
  - But repeated flooding and damage is expensive too!
    - 4 – 100-yr + events in 20 years
  - Existing conditions present substantial safety risk
  - NC legislature allocated $35 million to target flooding mitigation in Goldsboro
  - Targeted interventions would provide limited benefits and not resolve flooding problems

Summary

Adapting to increased flooding (Wilby and Keenan, 2012)

- (1) Defending against floods with traditional infrastructure
- (2) Accommodating and living with floods
- (3) Withdrawing from floodprone areas

Appropriate level of risk

- Assumption of stationarity – i.e. using past rainfall and discharge to design infrastructure
  - Likely not valid with climate change
- Larger design storms or climate change projections

Responding to flooding

- Is it better to make investments now vs. reacting to storm damage?

Questions?

Jack Kurki-Fox - jjkurkif@ncsu.edu

Barbara Doll – bdoll@ncsu.edu

@NCState_Streams

Doll, B. A., Kurki-Fox, J. J., & Line, D. E. (2020). A framework for planning and evaluating the role of urban stream restoration for improving transportation resilience to extreme rainfall events. *Water*, *12*(6), 1620.

Funding: