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Consequences of Changing Climate and Land Use to 100-Year Flooding

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5th Annual Lamprey River Symposium
January 6, 2012

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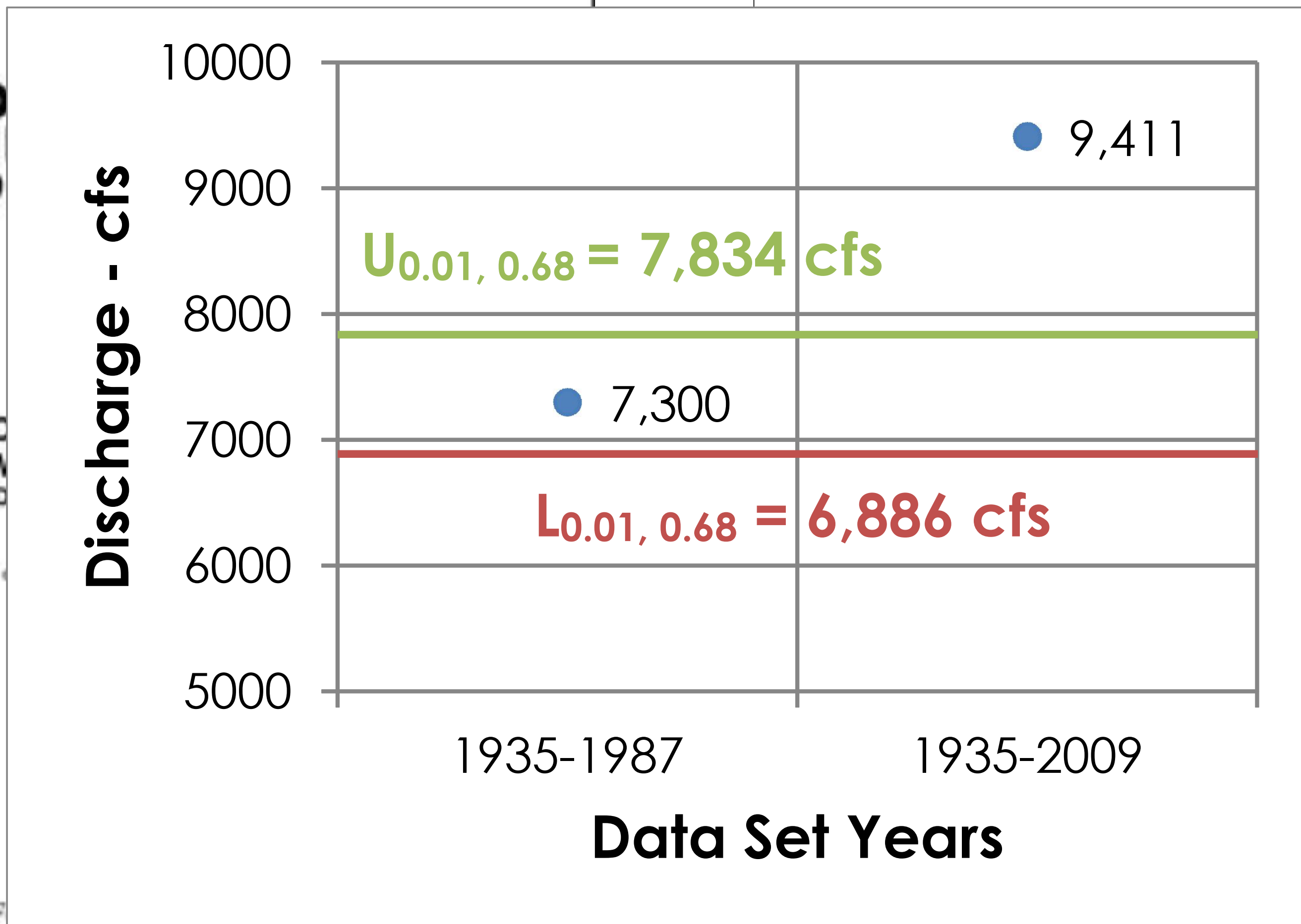
Funding by NOAA Cooperative Institute for
Coastal and Estuarine Environmental Technology

Project Objectives

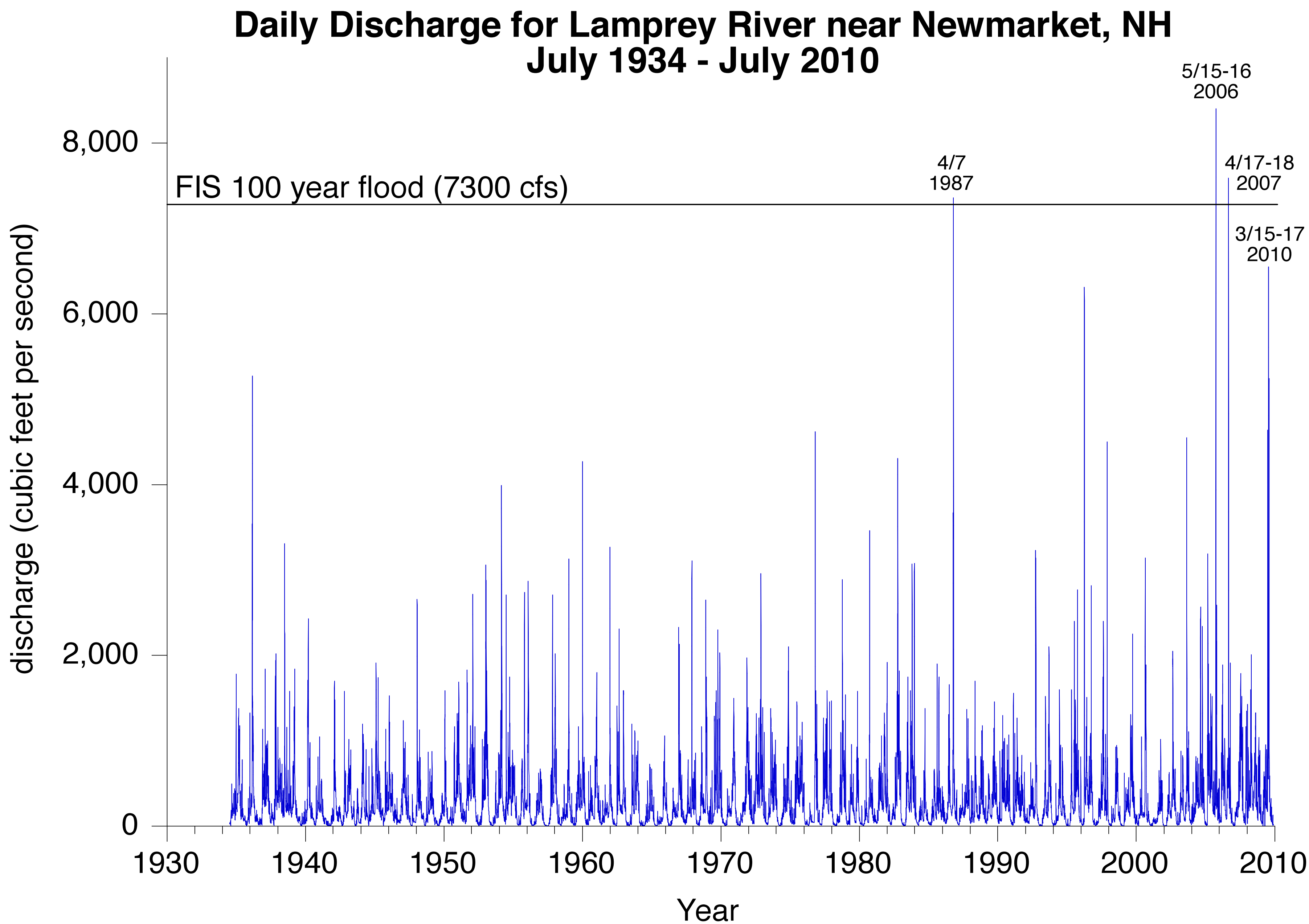
- Update hydrologic and hydraulic model for the watershed and river respectively based on current climate and land use
- Update base flood elevations and flood risk areas
- Assess flood risk associated with <u>combined</u> future development and climate change
- Engage municipal and regional planners in project and discuss land use management strategies to mitigate runoff volumes

Lamprey River Studies

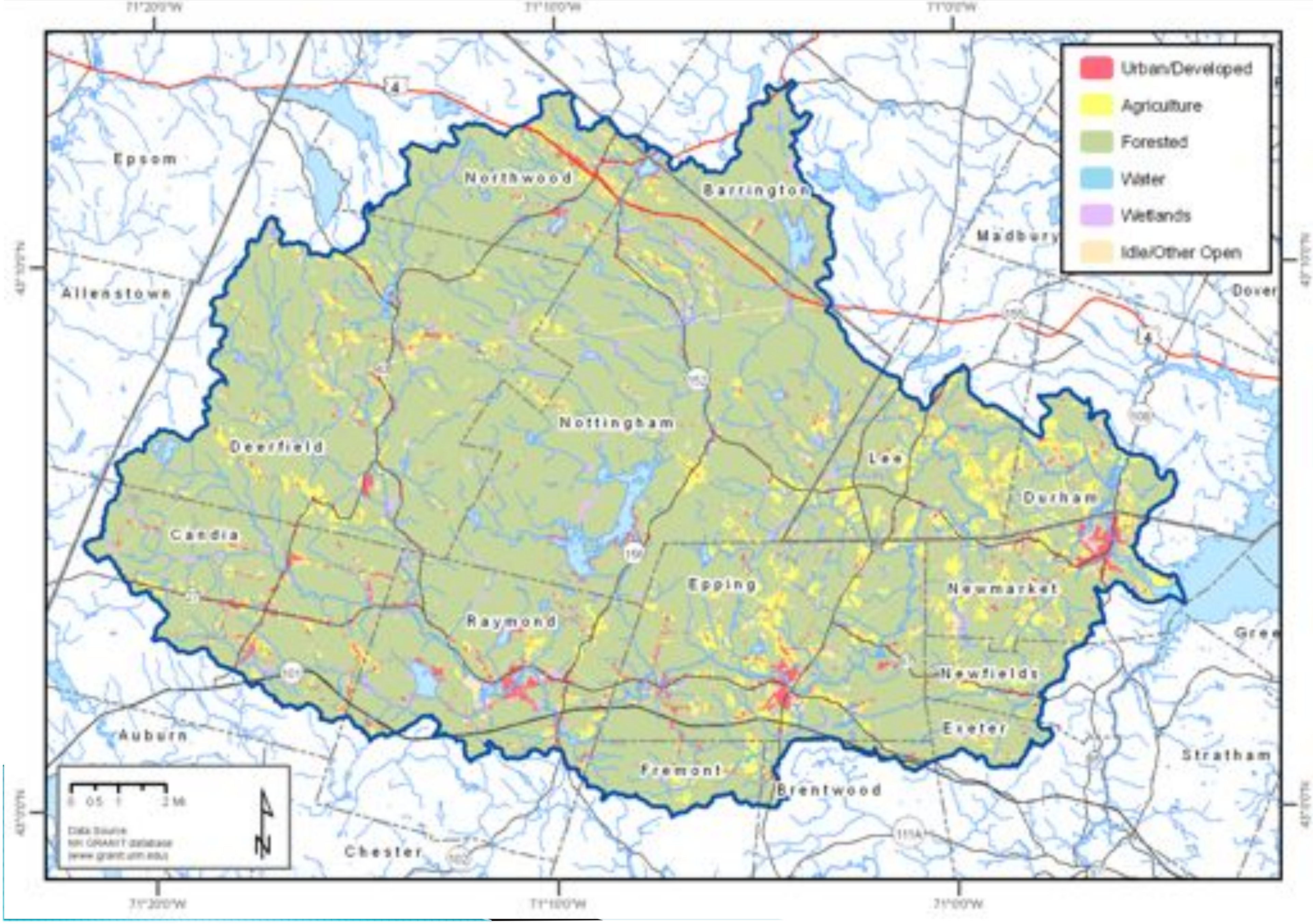


Lee	No published study available		
Durham	May 3, 1990	SCS	September 1987
	August 23, 2001	USGS	April 1998
Newmarket	May 2, 1991	USGS	August 1989

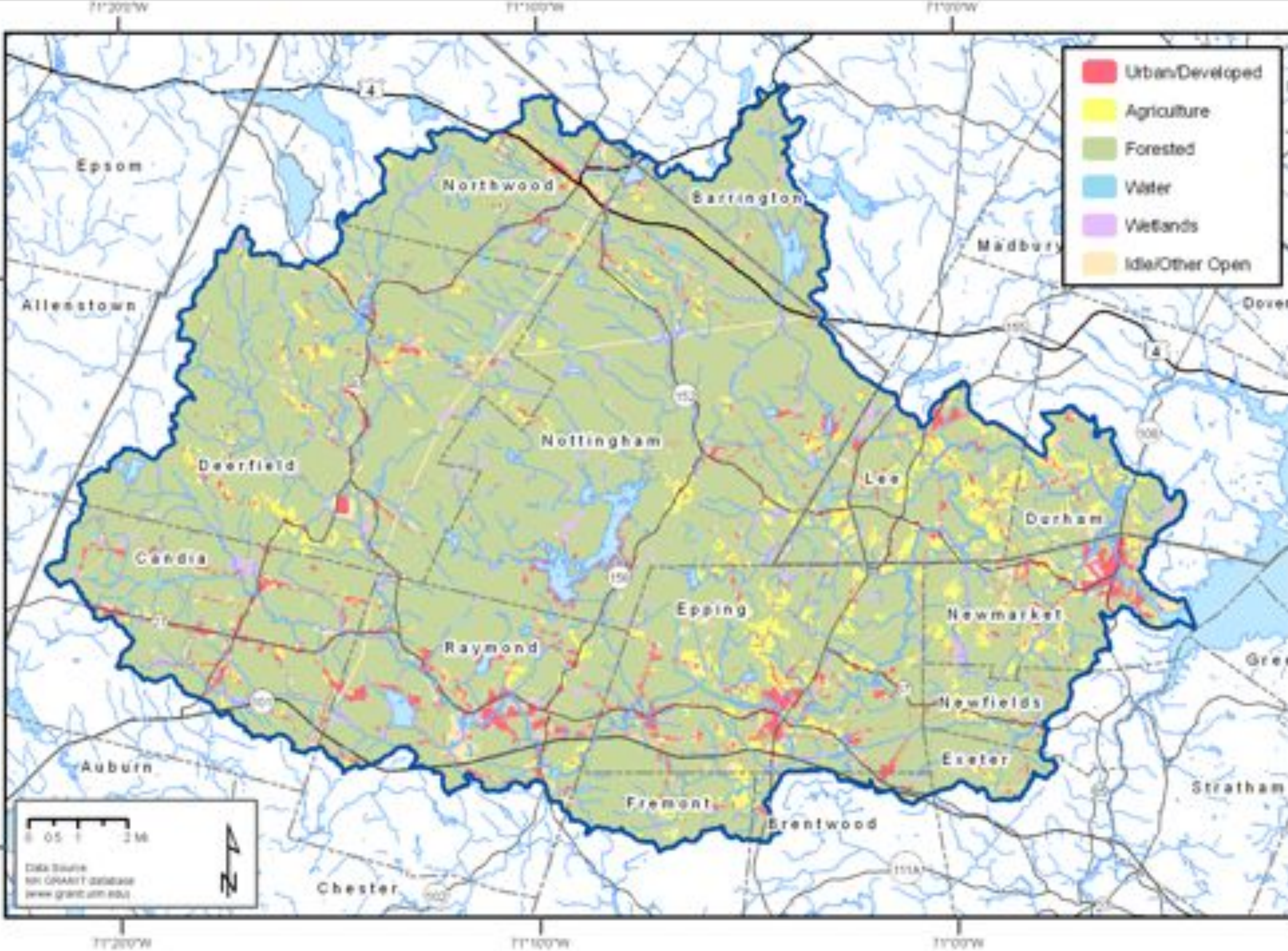
Assessing Flood Risk - Lamprey River Watershed



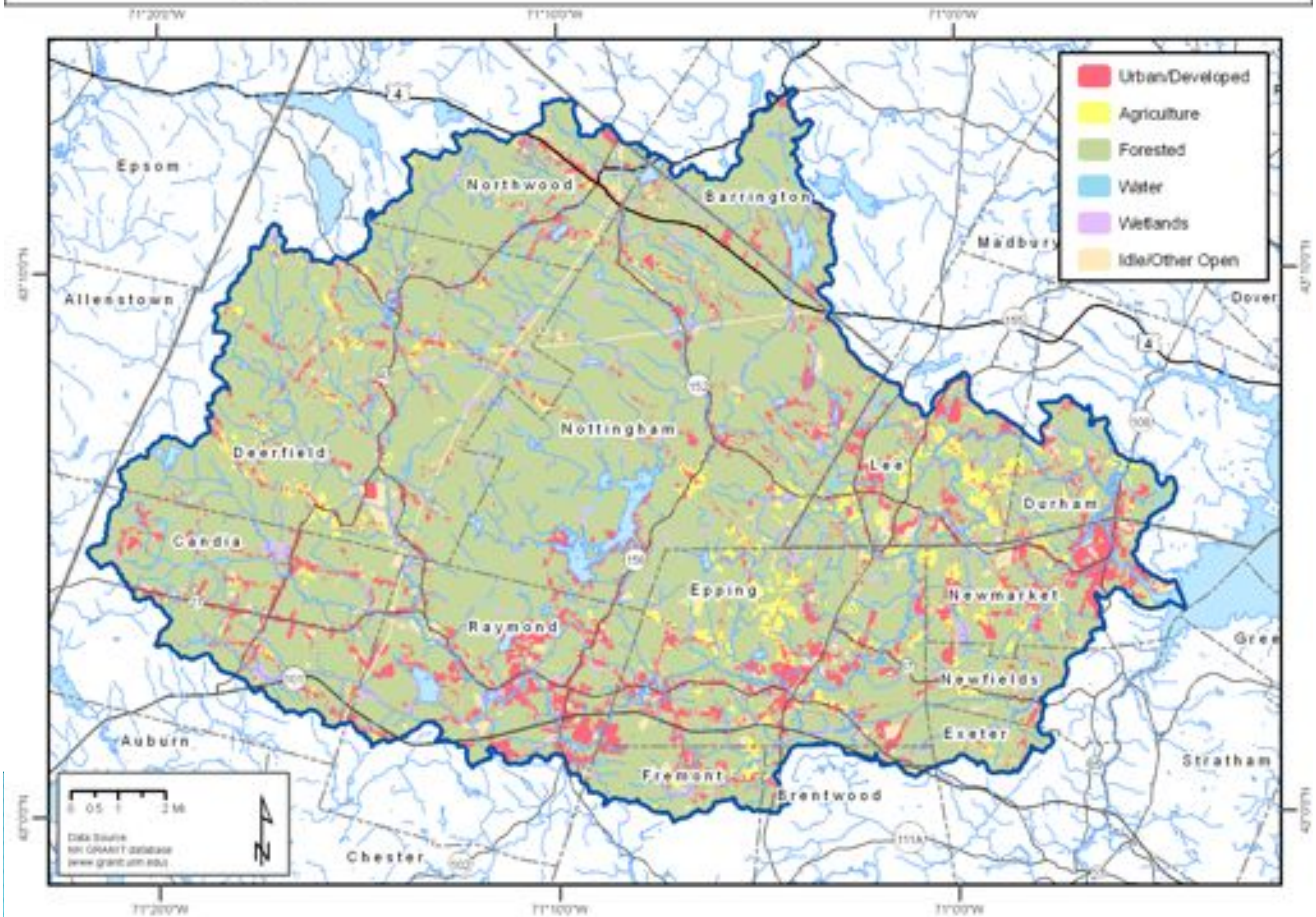
Lamprey River Watershed Generalized Land Use - 1962



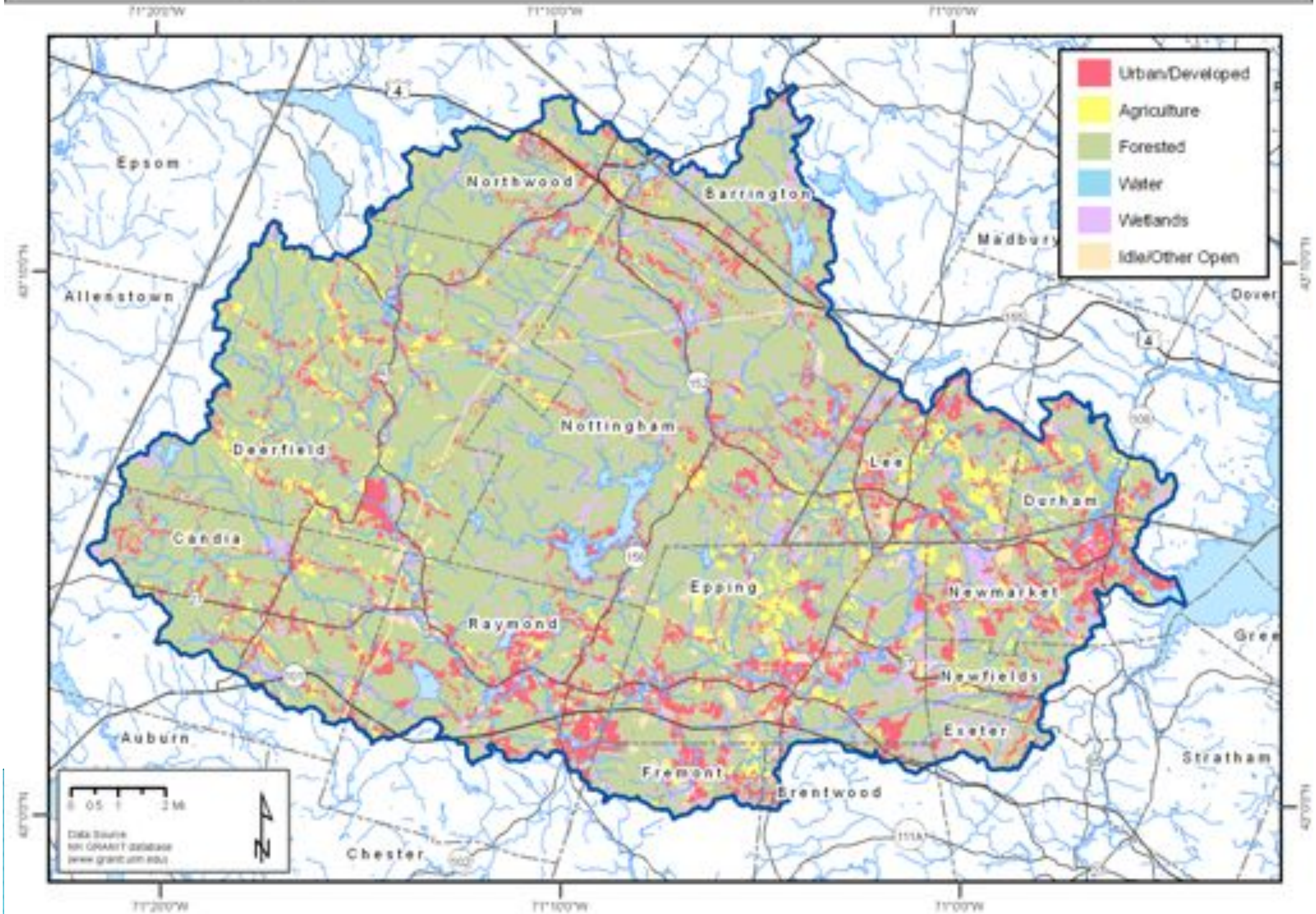
Lamprey River Watershed Generalized Land Use - 1974

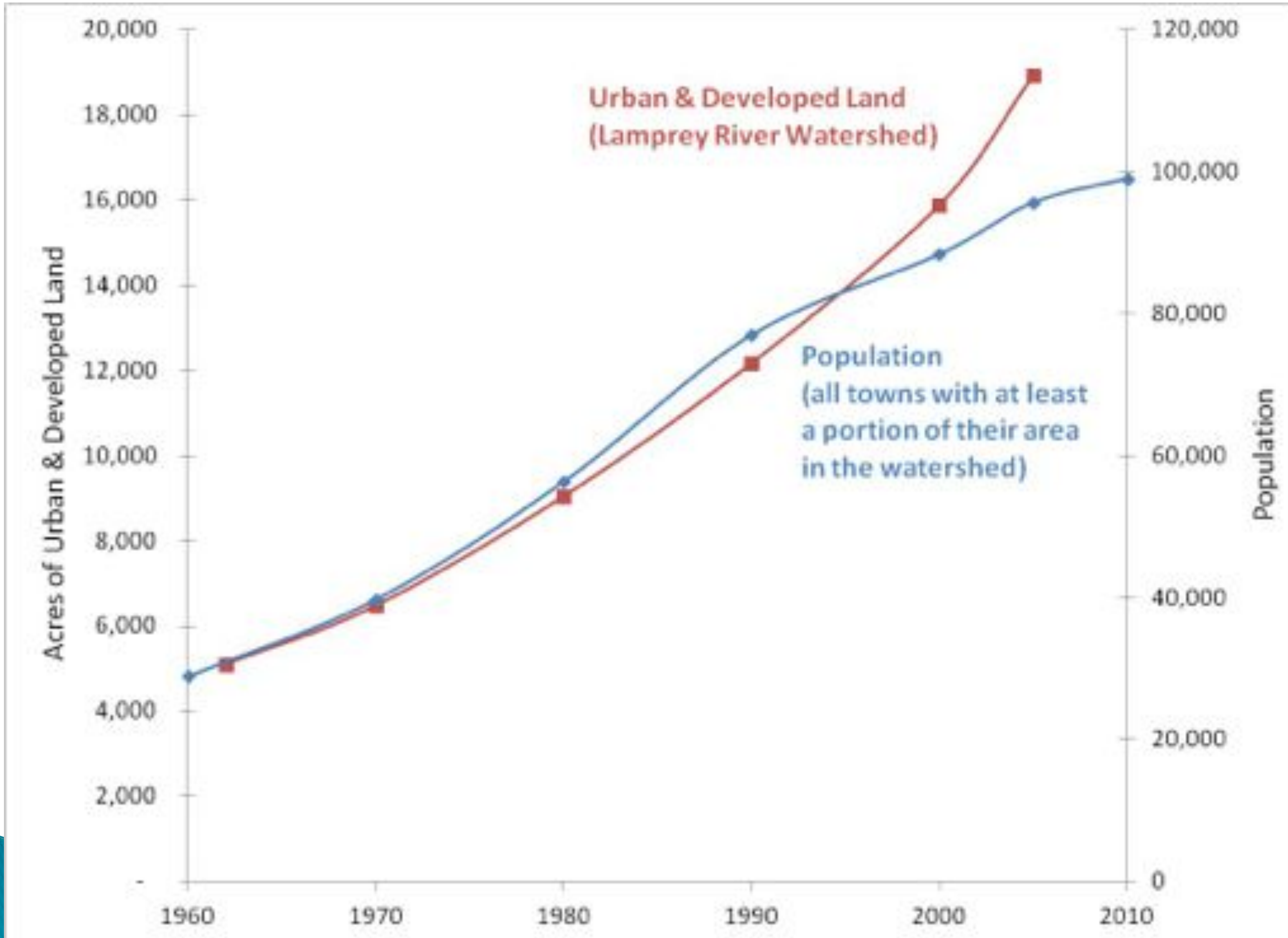


Lamprey River Watershed Generalized Land Use - 1998

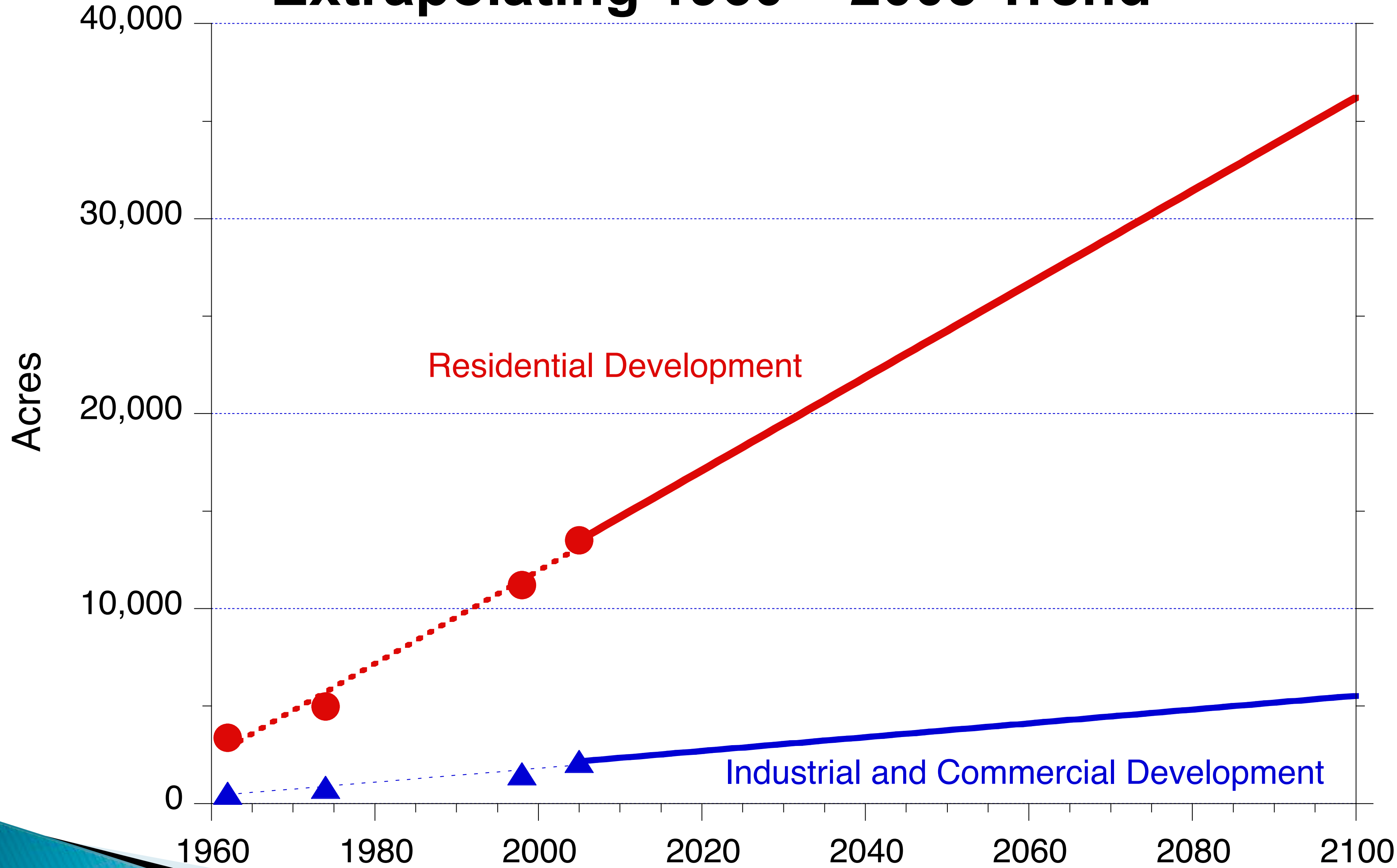


Lamprey River Watershed Generalized Land Use - 2005

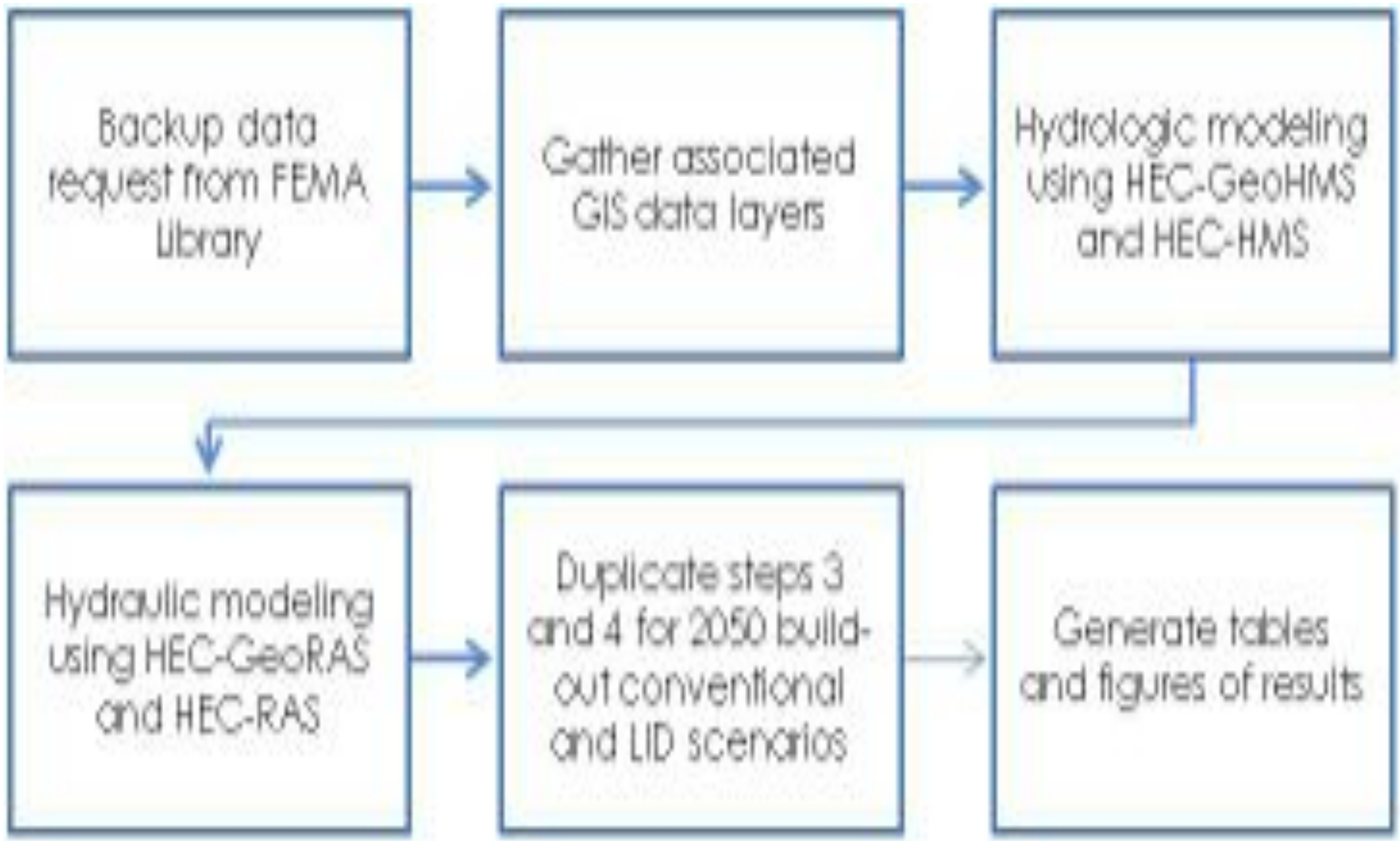



Urban & Developed Land
(Lamprey River Watershed)
Population
(all towns with at least
a portion of their area
in the watershed)
Acres of Urban & Developed Land
Population
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
120,000
100,000
80,000
60,000
40,000
20,000
0
1960
1970
1980
1990
2000
2010

Lamprey River Watershed Buildout
Extrapolating 1960 – 2005 Trend



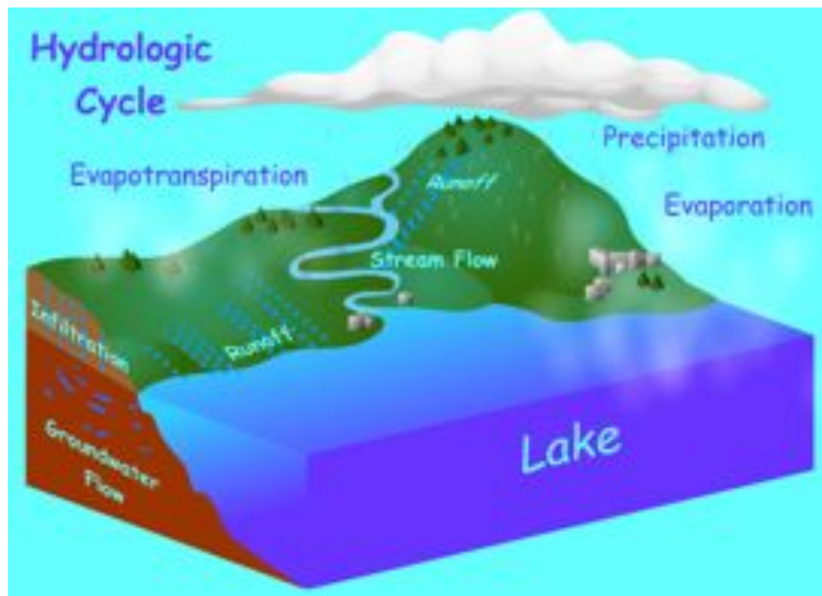
Project overview



Hydrologic Methodology

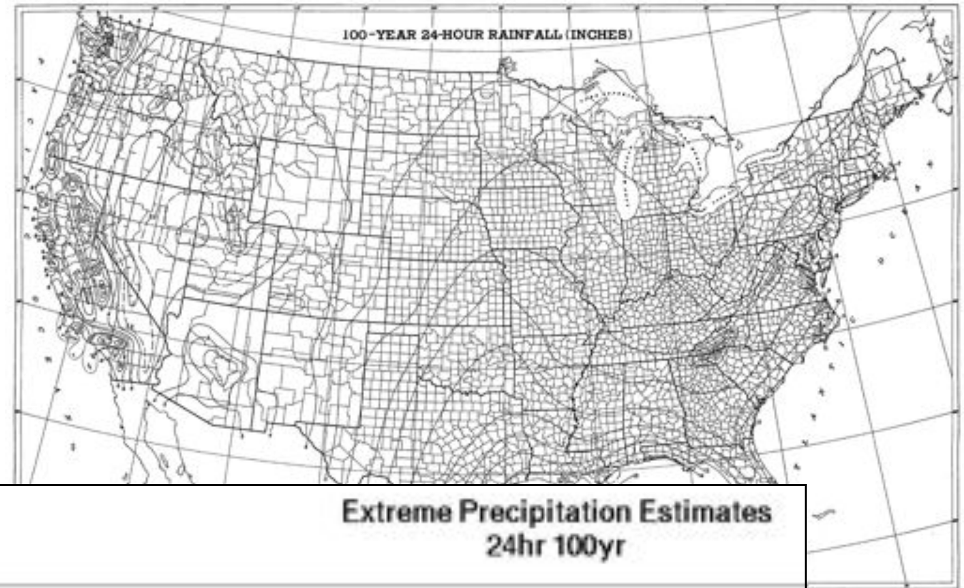
- FIS:
  - Annual peak flow frequency analysis
    - peak annual stream flow
    - standard deviation
    - weighted coefficient of skewness.

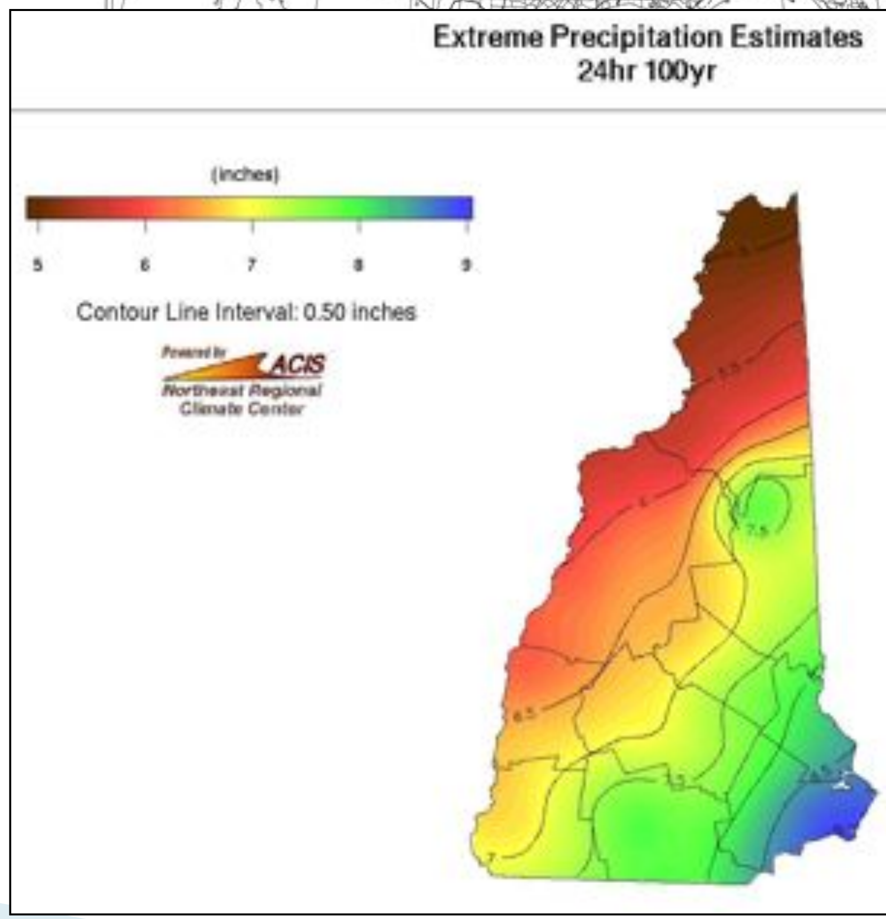
- Current Project
  - Rainfall-Runoff
    - Watershed area
    - Time of concentration
    - Runoff curve number (CN)



Precipitation

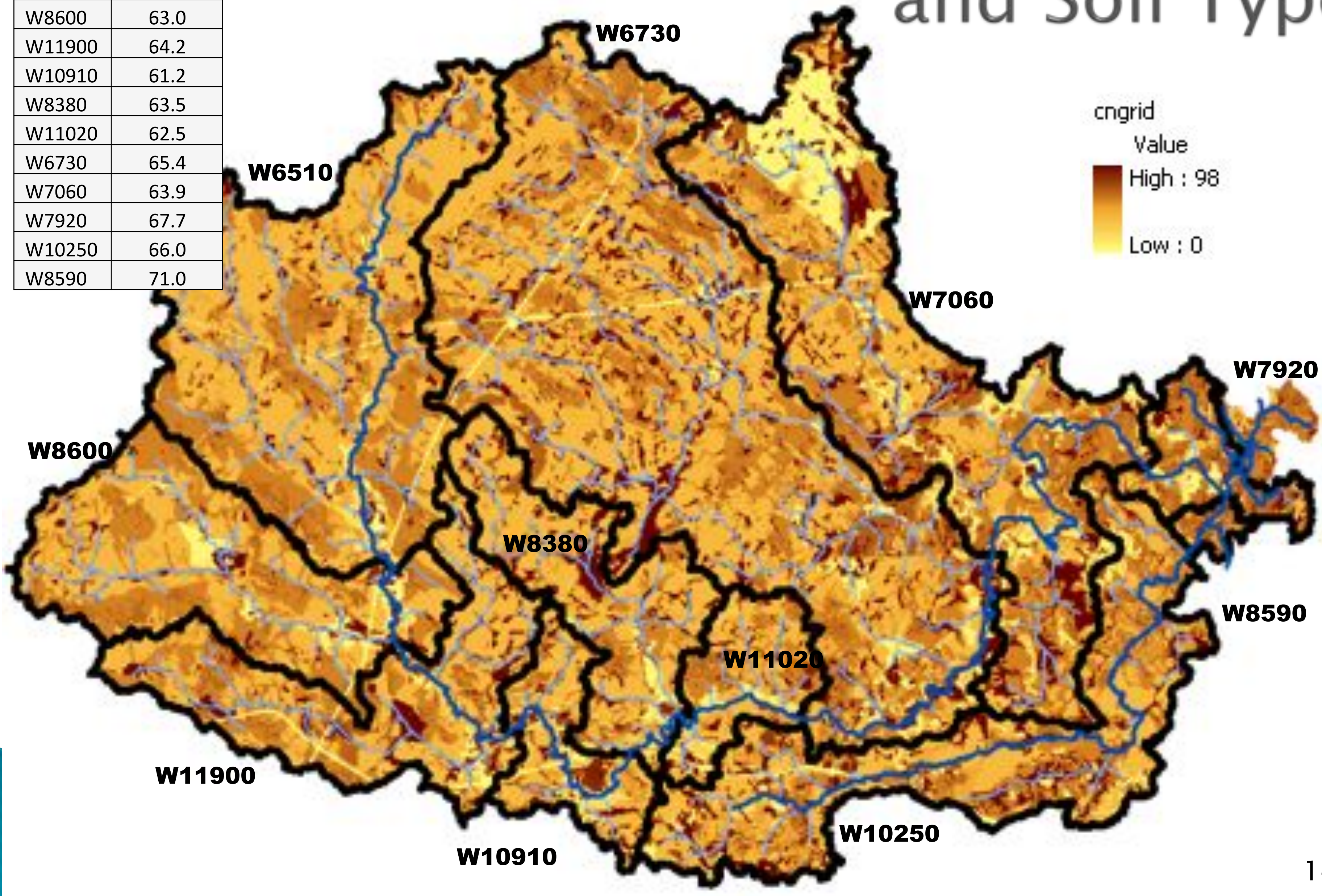
- Rainfall
  - Depth-duration-frequency
    - ➢TP-40 Rainfall Frequency Atlas of the United States is being used for effective conditions
    - ➢Northeast Regional Climate Center (NRCC) Atlas for Extreme Precipitation. FEMA guidelines for re-delineation indicate the need to use <u>current</u> depth duration frequency data.



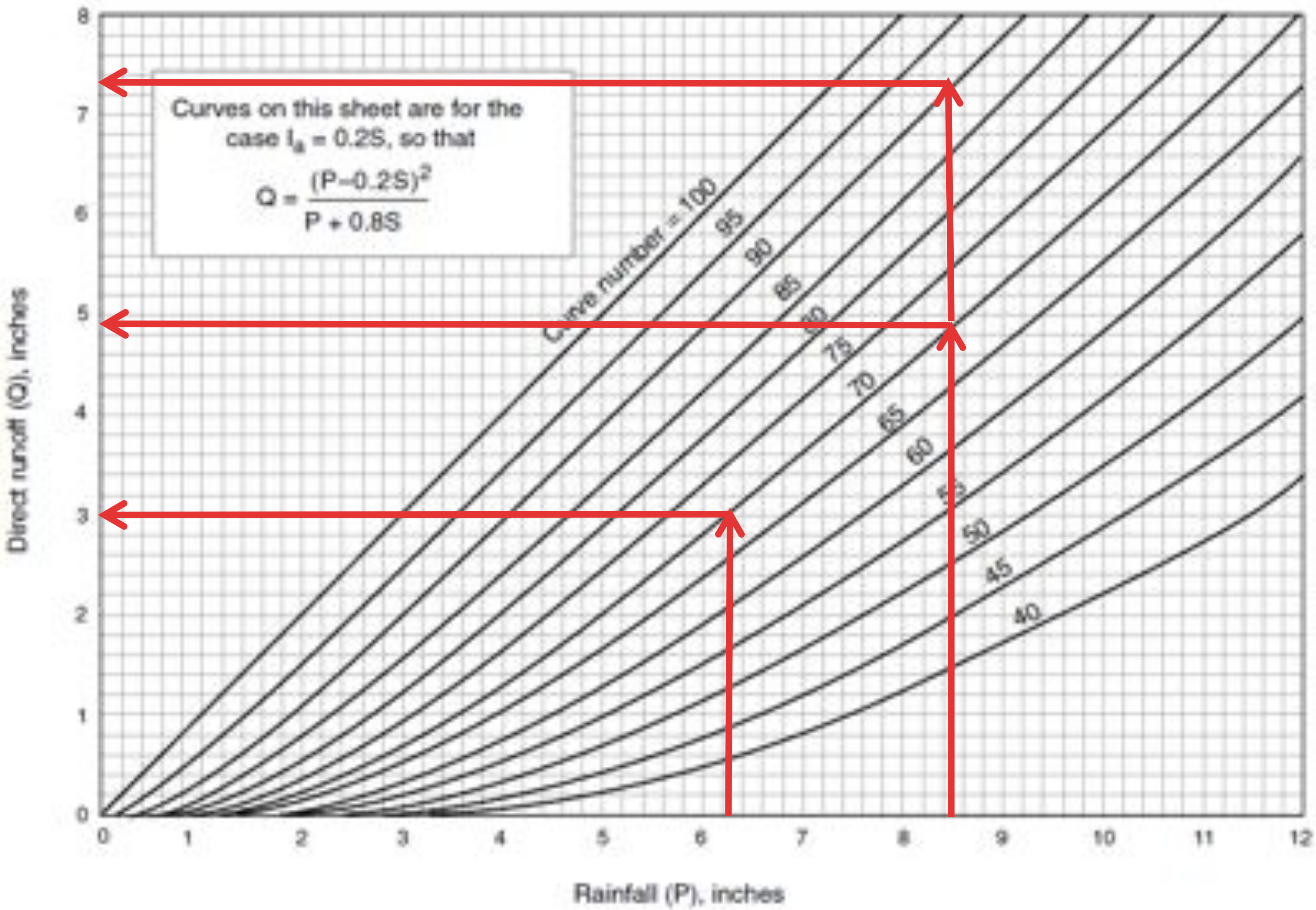


Curve Number based on Land Use and Soil Type

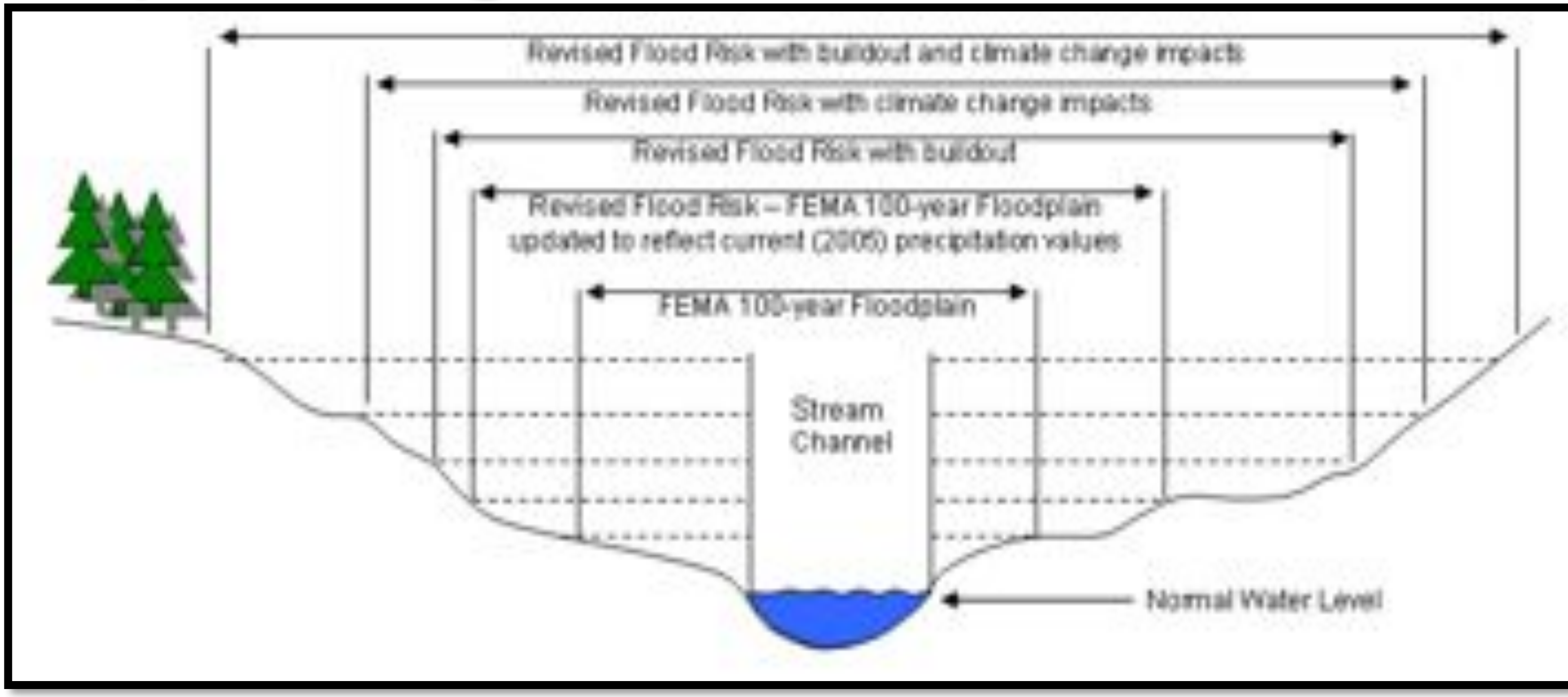
Subbasin	CN
W6510	62.5
W8600	63.0
W11900	64.2
W10910	61.2
W8380	63.5
W11020	62.5
W6730	65.4
W7060	63.9
W7920	67.7
W10250	66.0
W8590	71.0



Rainfall – Runoff Equation

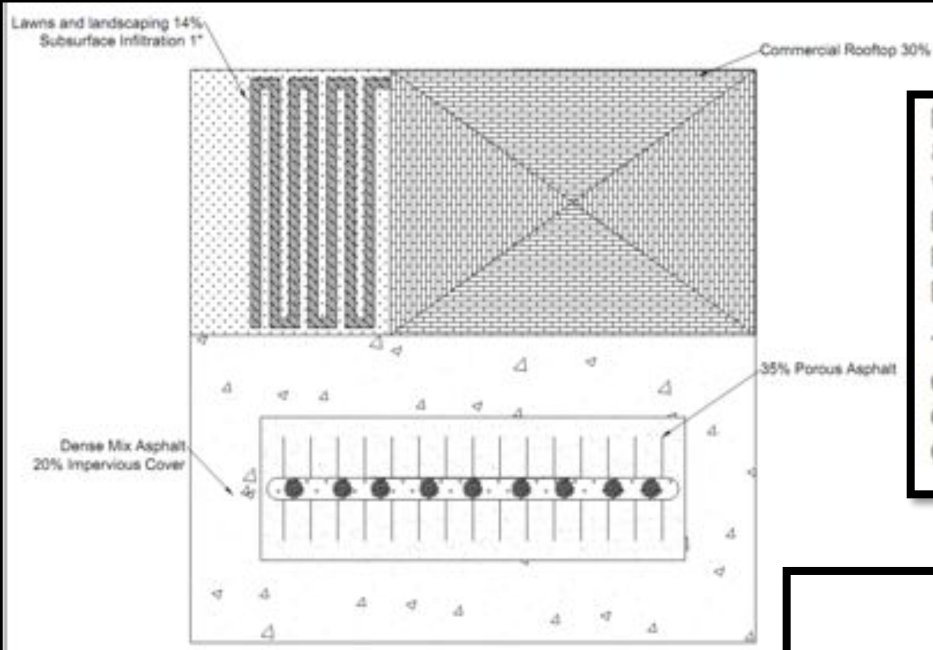


Hydrologic Model Scenarios



Project Models			
Land Use Conditions	Rainfall Rates and Global Change Model Scenario		
	Rainfall Atlas		Climate Period 2035-2069
	TP-40	NRCC	RCM
	6.3 in/24 hr	8.5 in/24 hr	8.5 in/24 hr
2005 Current	X	X	
2050 Build-out			X
2050 LID/Build-out			X

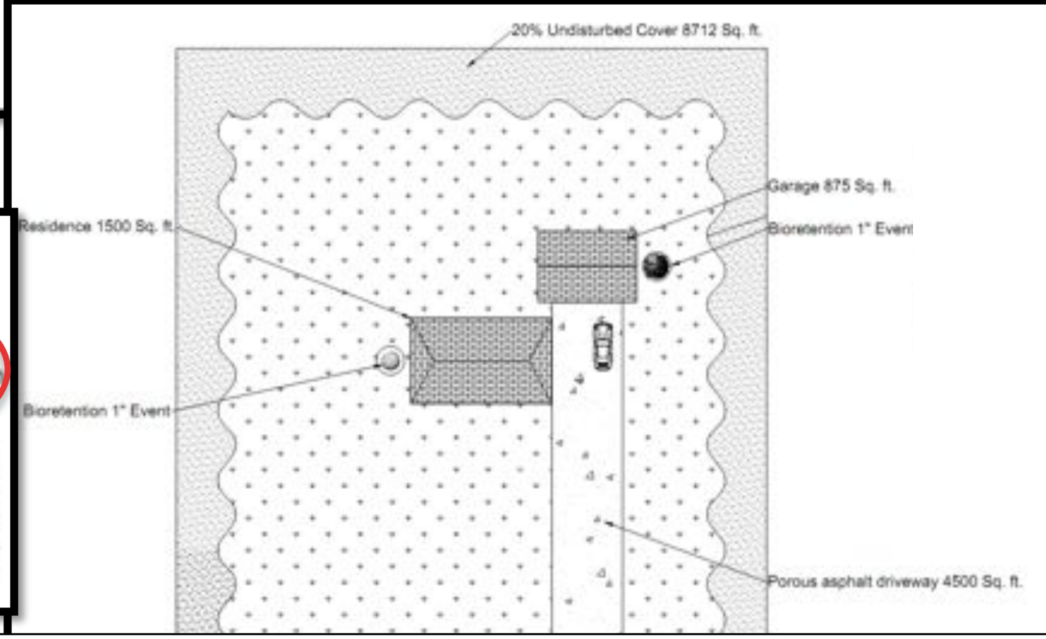
Implementing LID



Commercial Zoning

Notes:
85% IC 0% EIC
WQV = 1"
Rooftop Infiltration
Porous asphalt for parking only
Bioretention for drive lanes of standard asphalt

Type	A	B	C	D
CN Predevelopment	38	55	70	77
CN Conventional	84	89	92	94
CN LID	64	73	80	83



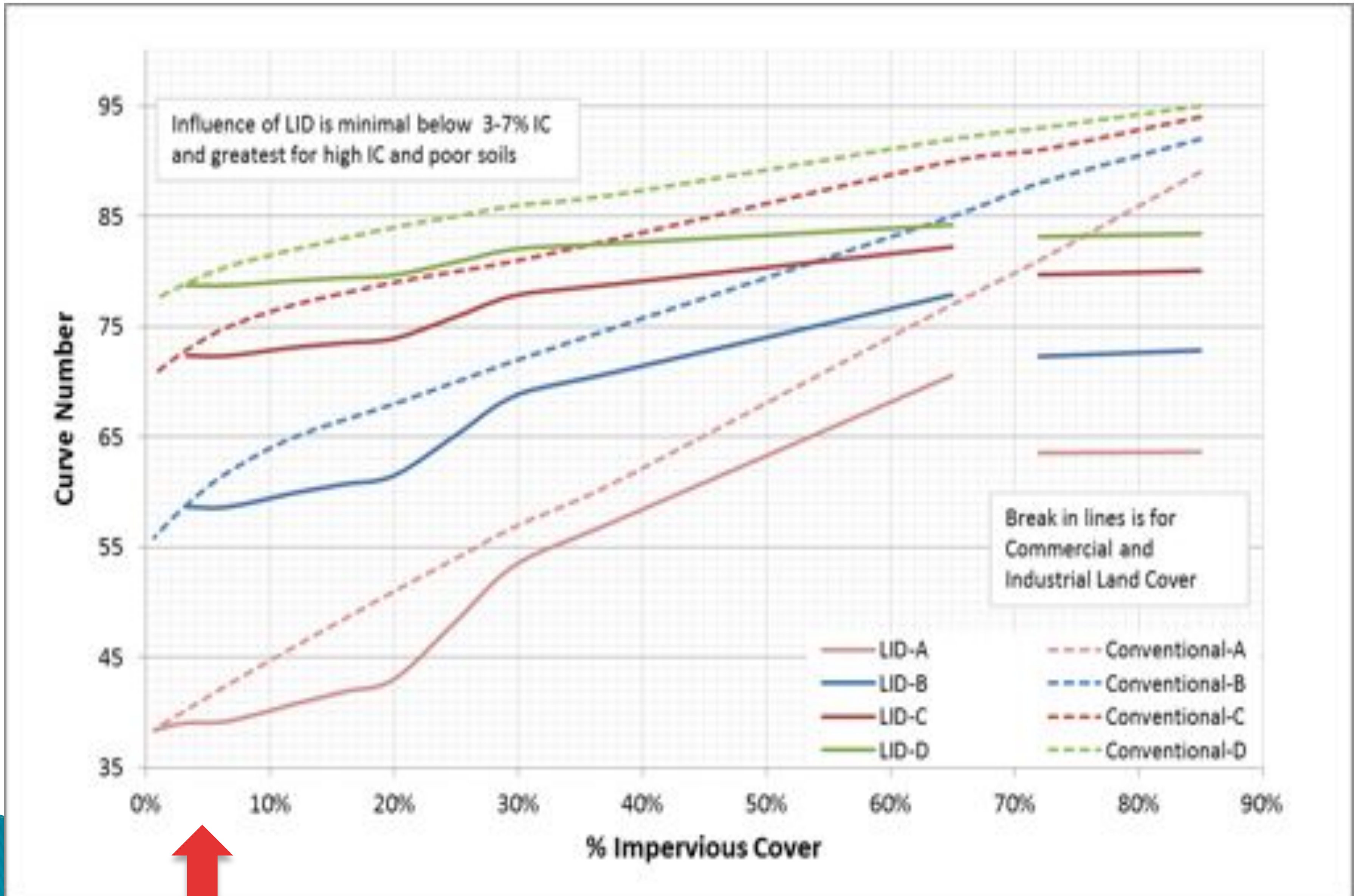
One Acre Residential

Notes:
19% IC 0% EIC
WQV = 1"
Rooftop and garage bioretention
Associated impervious surface biorentention
Porous asphalt driveway

Type	A	B	C	D
CN Predevelopment	38	55	70	77
CN Conventional	51	68	79	84
CN LID	43	62	74	80

Runoff Curve Number Reduction Method from : 1. McCuen, R. and M. D. E. (1983). Changes in Runoff Curve Number Method; 2. Maryland Department of Environment (2008). Maryland Stormwater Design Manual, Supplement No. 1.

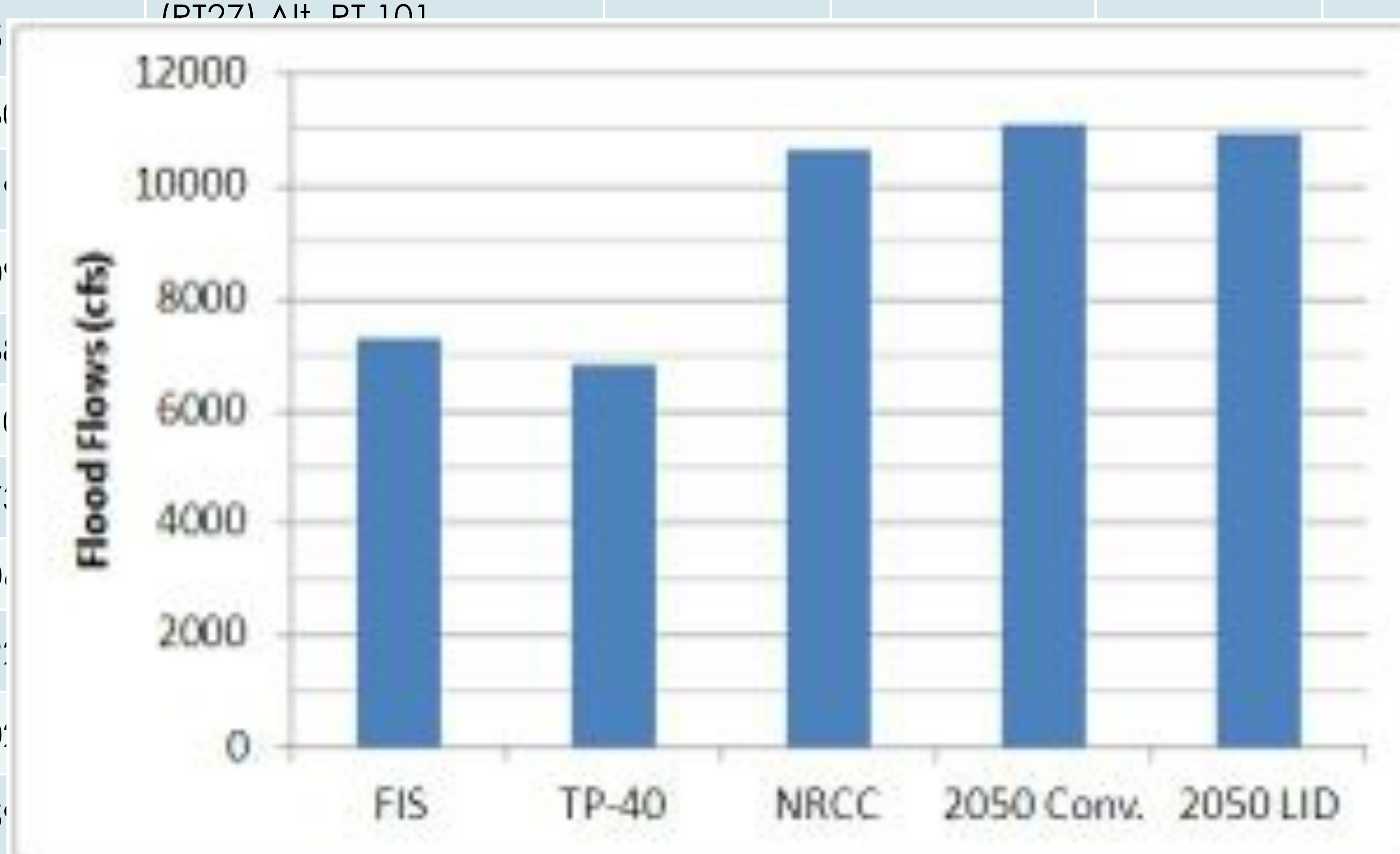
Implementing LID



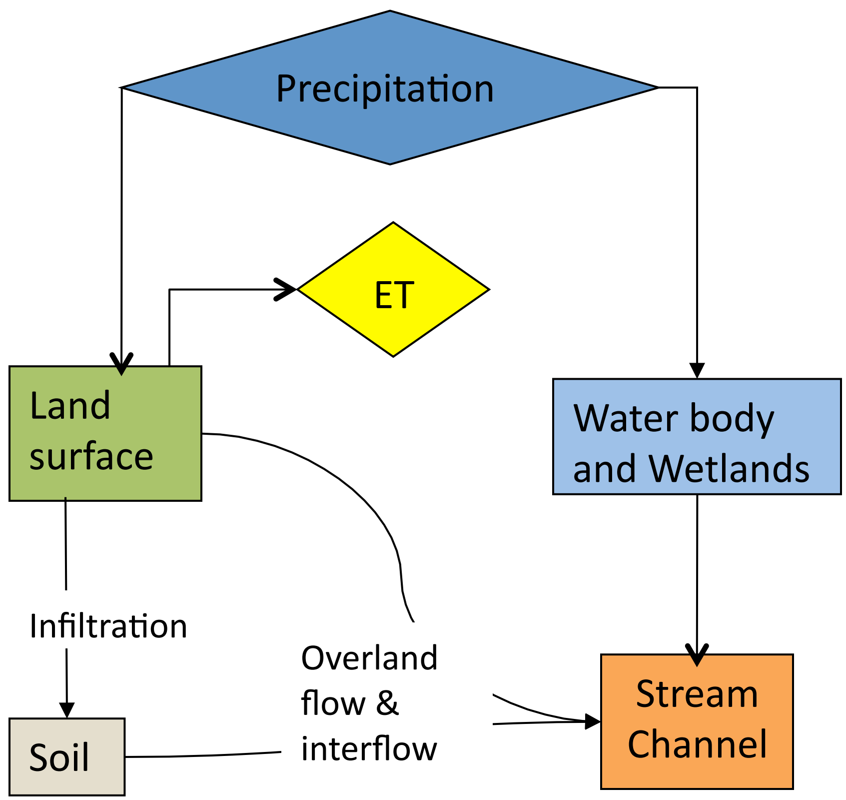
Watershed scale CN values and runoff differences

SCS 'Q' = HMS 'R'

Sub basin	Boundary Condition (Catchment)	Current 2005 CN	2050 Conventional Build-out	2050 LID Build-out	Build-out ∆R (in)
W65	(PT27) Alt. PT 101				).08
W86(					).14
W11'					).10
W10'					).24
W83:					).06
W11(					).09
W67:					).11
W70.					).14
W79:					).08
W10:					).20
W85'					).05



Watershed scale CN



Typical representation of watershed runoff

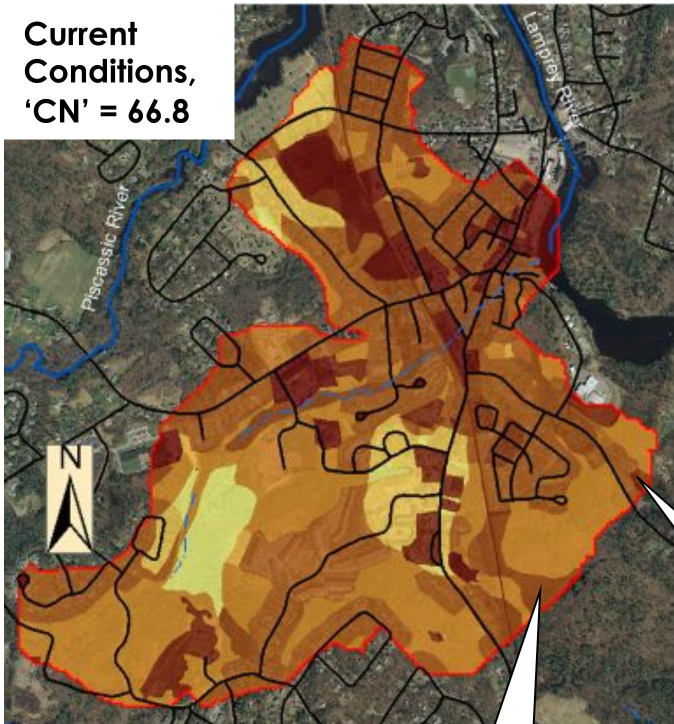
No change in conditions:
11.5% (25 sq.mi.) is water/wetlands

Future build-out
45% (95 sq. mi.) still forested and open space

Watershed communities require at least two (2) acre lot size for single residential use
(12% impervious cover/lot)

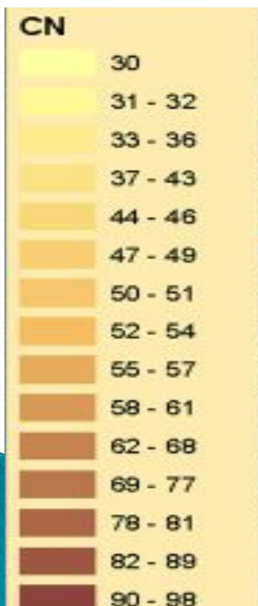
Moonlight Brook, Newmarket

Current Conditions, 'CN' = 66.8

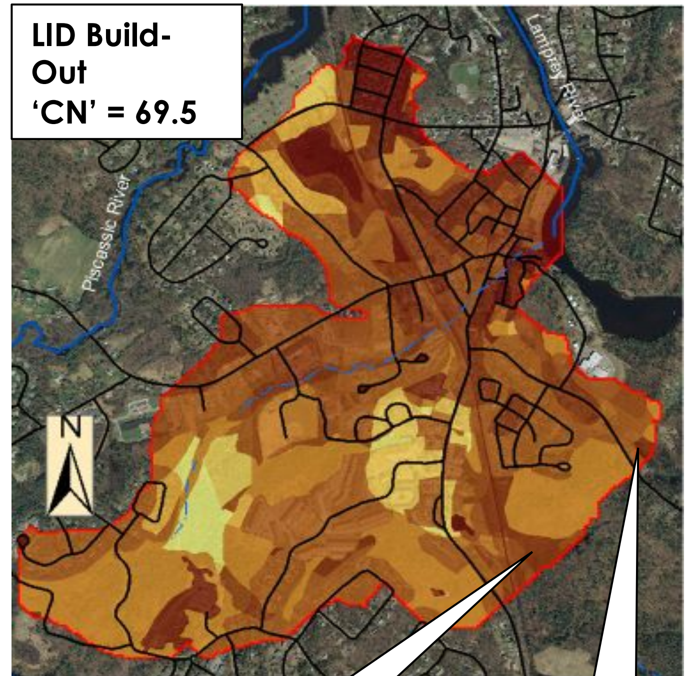


Forested Type D soil CN = 77

Forested Type C soil CN = 70



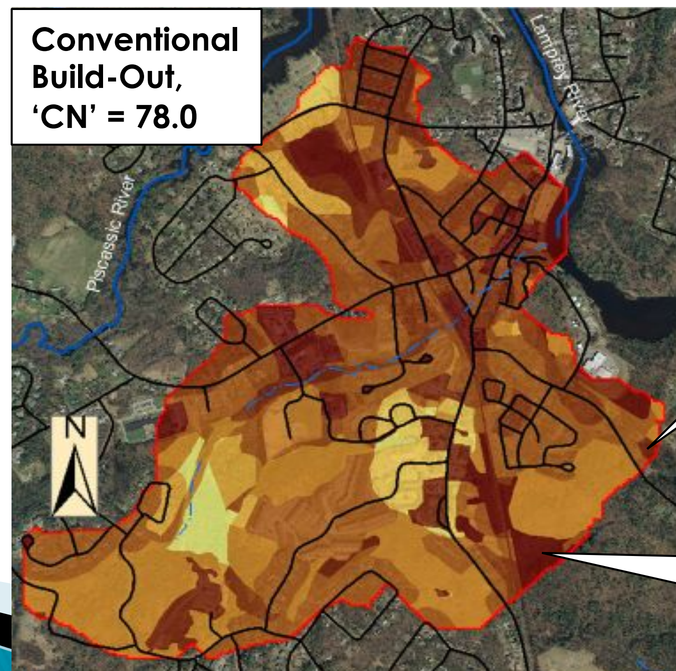
LID Build-Out 'CN' = 69.5



Comm./ Ind.Type D soil CN = 80

Residential Type D soil CN = 80

Conventional Build-Out, 'CN' = 78.0



Residential Type D soil CN = 84

Comm./ Ind.Type D soil CN = 94

Urban scale composite CNs, runoff, and discharge

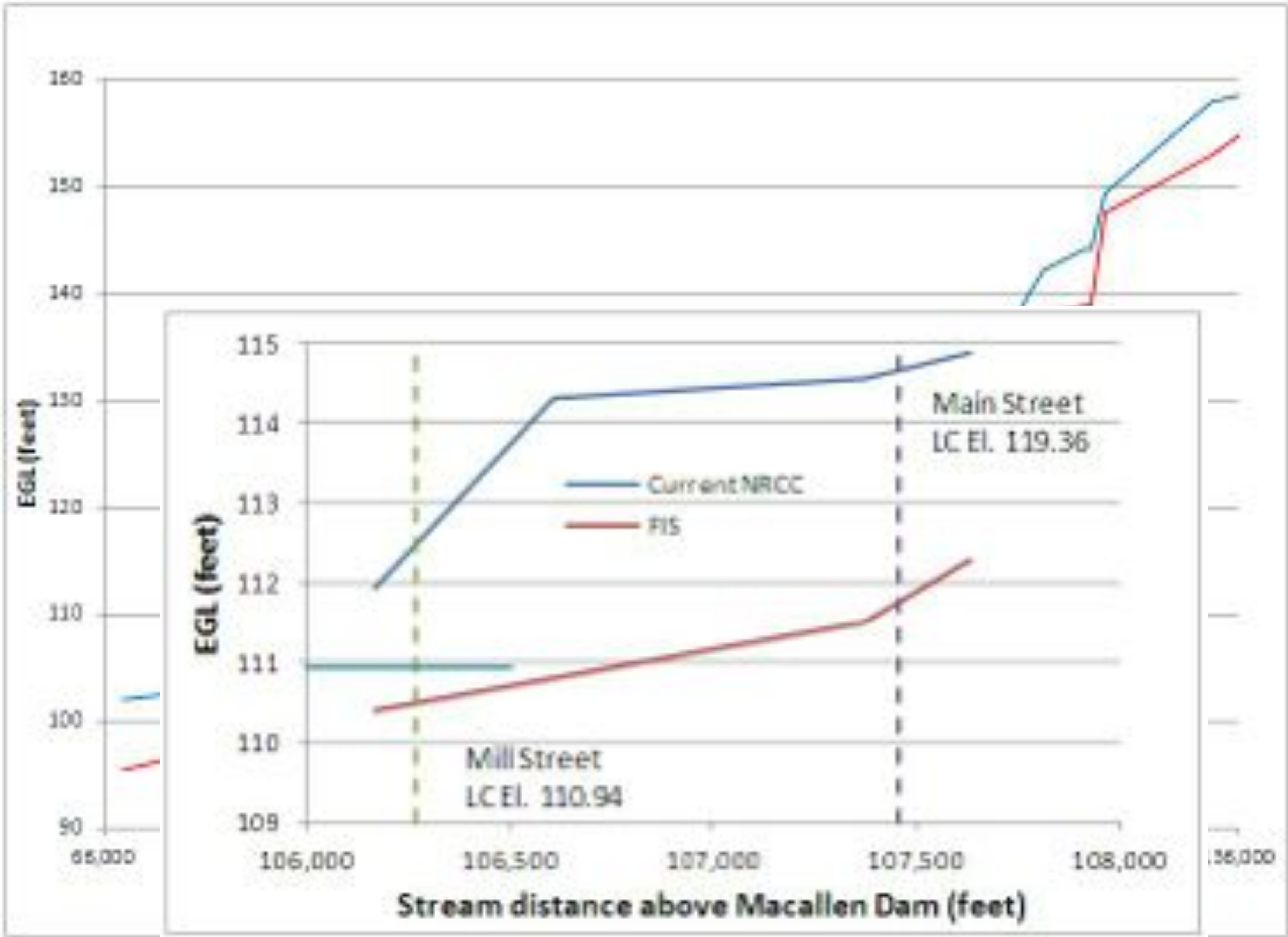
SCS 'Q' = HMS 'R'
SCS 'q' = HMS 'Q'

Subwatershed	Moonlight Brook, Newmarket			Intermittent Stream, Epping			Intermittent Stream, Raymond		
Area (sq. mi.)	0.88			1.2			0.86		
Subwatershed values	CN	R (in)	Q (cfs)	CN	R (in)	Q (cfs)	CN	R (in)	Q (cfs)
Current 2005	66.8	4.5	655	70	4.9	1,031	65.8	4.4	508
2050 conventional build-out	78	5.9	852	81.7	6.3	1,320	79.0	6.0	696
2050 LID build-out	69.5	4.8	704	69.4	4.8	1,016	66.6	4.5	520

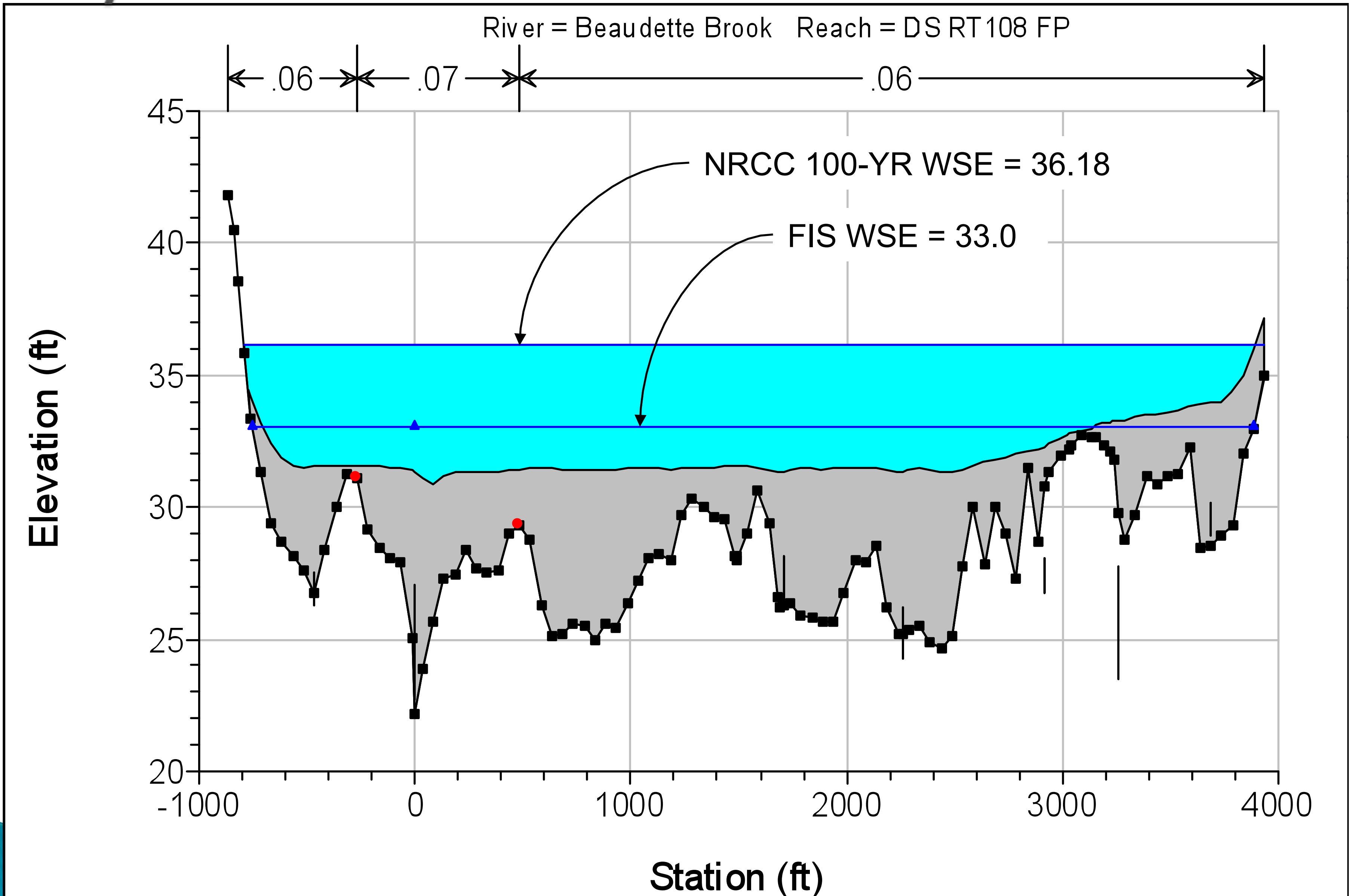
$$q_a = (q_{ua})(A)(Q_a) < q_b = (q_{ub})(A)(Q_b)$$

Hydraulic Results –

Energy Grade Line through Epping



Hydraulic Results – Route 108



Conclusions

- Hydrologic and hydraulic models provided updated conditions for the examination of land use changes
  - Meets FEMA guidance for redelineation

    75 yr record: 1935 – 2009 Q_{100} = 9,411 cfs

    $L_{0.01,0.68}$ = 6,886 cfs $H_{0.01,0.68}$ = 7,834 cfs
  - Significant increase in flood flows (FIS to current NRCC)

    USGS gage: 7,300 cfs to 10,649 cfs

    Hamil Brook: 1,300 cfs to 4,667 cfs

    Blake Road, Epping: 4,720 cfs to 6,708 cfs
  - Significant increase in BFE (FIS to current NRCC)

    Route 108: 33.0 feet to 36.18 feet
    - NRCC elevation almost two feet higher than April 2007 event

    3 feet average along length of Lamprey River profile

Conclusions

- Land use:
  - 90% increase of impervious cover since 1990 in Newfields, Deerfield, Fremont, Epping, and Brentwood
  - Newmarket and Epping exceed PREPs goal of < 10% IC
  - Expected land conversion by 2050 > 100% change
- Rainfall Rates
  - TP-40 Atlas 6.3 in/24 hr
  - NRCC Atlas 8.5 in/24 hr

❖Increasing IC and Rainfall rates have considerable effect on runoff

Conclusions

- Development Strategies:
  - Implement LID to reduce runoff curve number (CN)
    - Largest effect seen at urban scale (Current to Convention to LID)

Watercourse	Current	2050 Conv.	2050 LID
Moonlight Brook, Newmarket	66.8	78	69.5
Intermittent Stream, Epping	70	81.7	69.4
[illegible]tream,	65.8	79.0	66.6

Notes:
85% IC 0% EIC
WQV = 1"
Rooftop Infiltration
Porous asphalt for parking only
Bioretention for drive lanes of standard asphalt

Type	A	B	C	D
~~CN Predevelopment~~	~~38~~	~~55~~	~~70~~	~~77~~
CN Conventional	84	89	92	94
CN LID	64	73	80	83

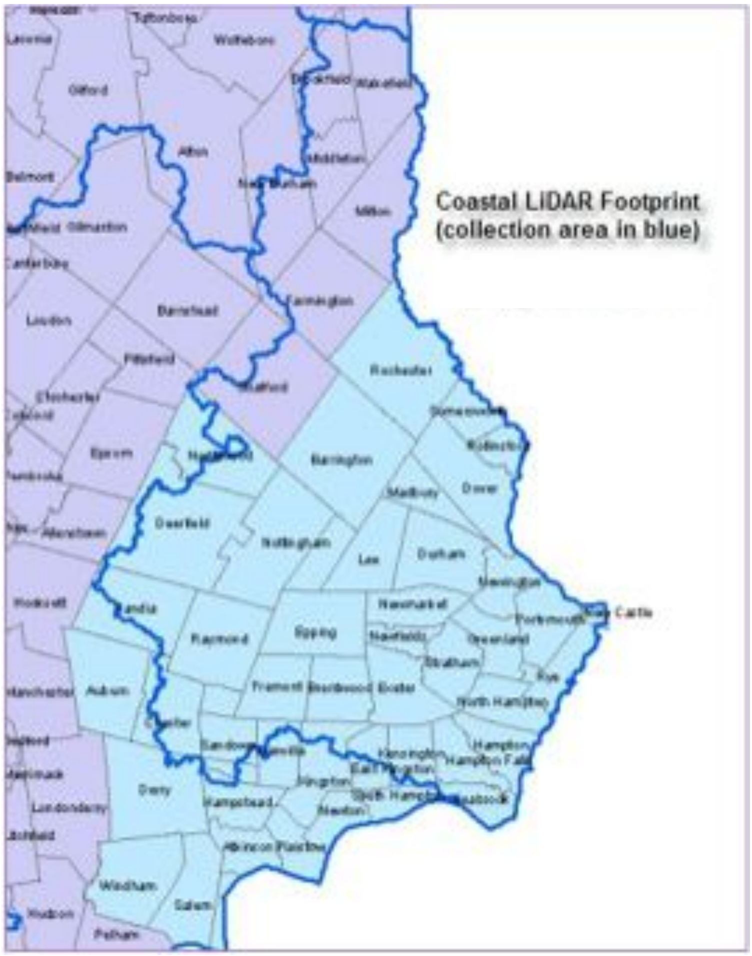
Conclusions

- Development Strategies:
  - Implement LID to reduce runoff (inches)
    - Largest effect seen at urban scale (Current to Convention to LID)

Watercourse	Current (in.)	2050 Conv. (in.)	2050 LID (in.)
Moonlight Brook, Newmarket	4.5	5.9	4.8
Intermittent Stream, Epping	4.9	6.3	4.8
Intermittent Stream, Raymond	4.4	6.0	4.5

$$q_a = (q_{ua})(A)(Q_a) < q_b = (q_{ub})(A)(Q_b)$$

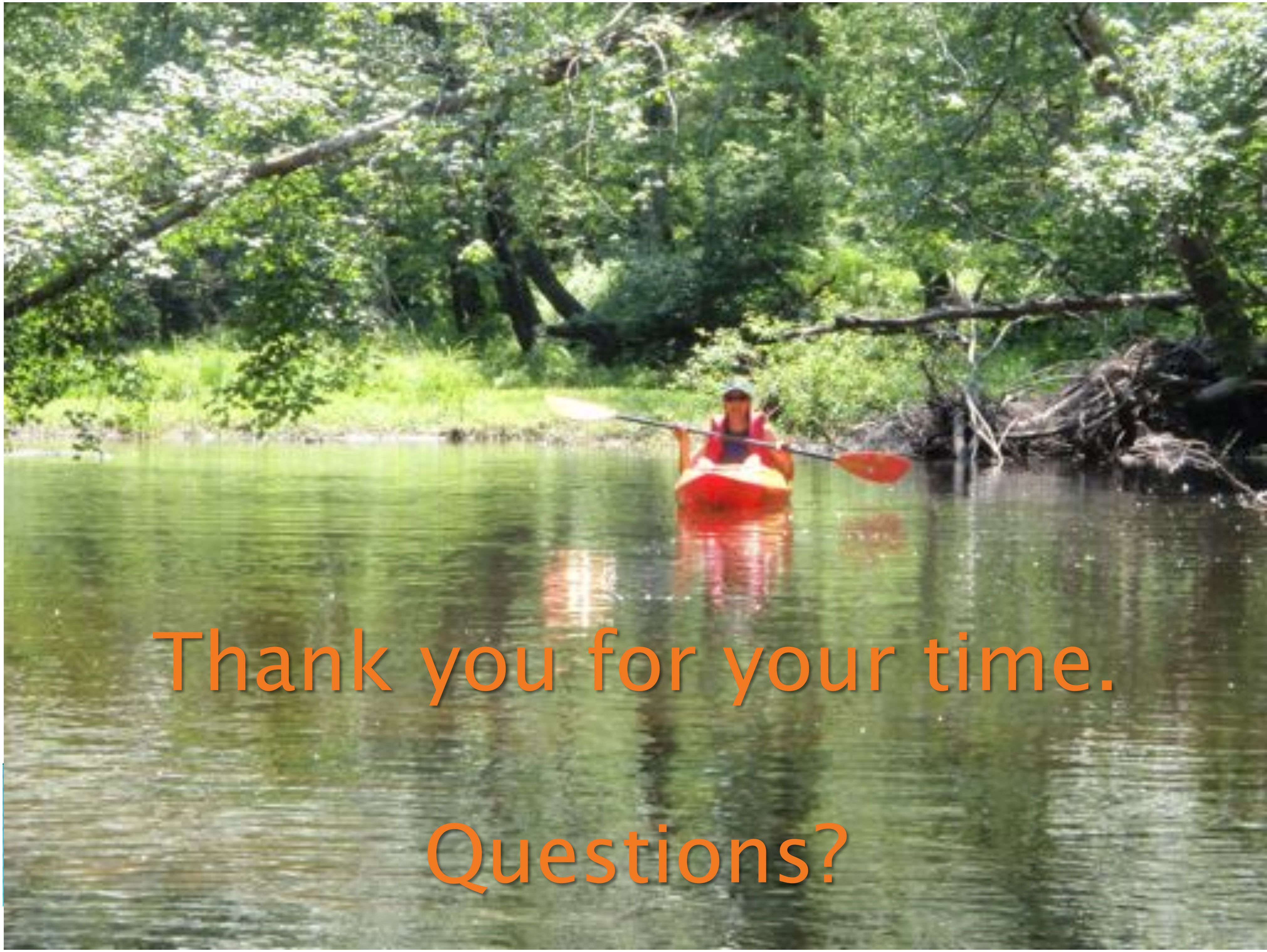
Future Effort



- Establish flood elevation based on datum NAVD88
- Generate cross sections at a spacing to avoid interpolation
- Include Piscassic and other tributaries in Zone A
- Include additional RT152, Lee as other bypass areas
- Calibrate results to additional USGS observations
- Extend study reach into Deerfield
- Widen the cross sections to generate the 500-year floodplain

New Flood Plain Maps and Questions of Legal Authority, Measures and Consequences
In Collaboration with Vermont Law School

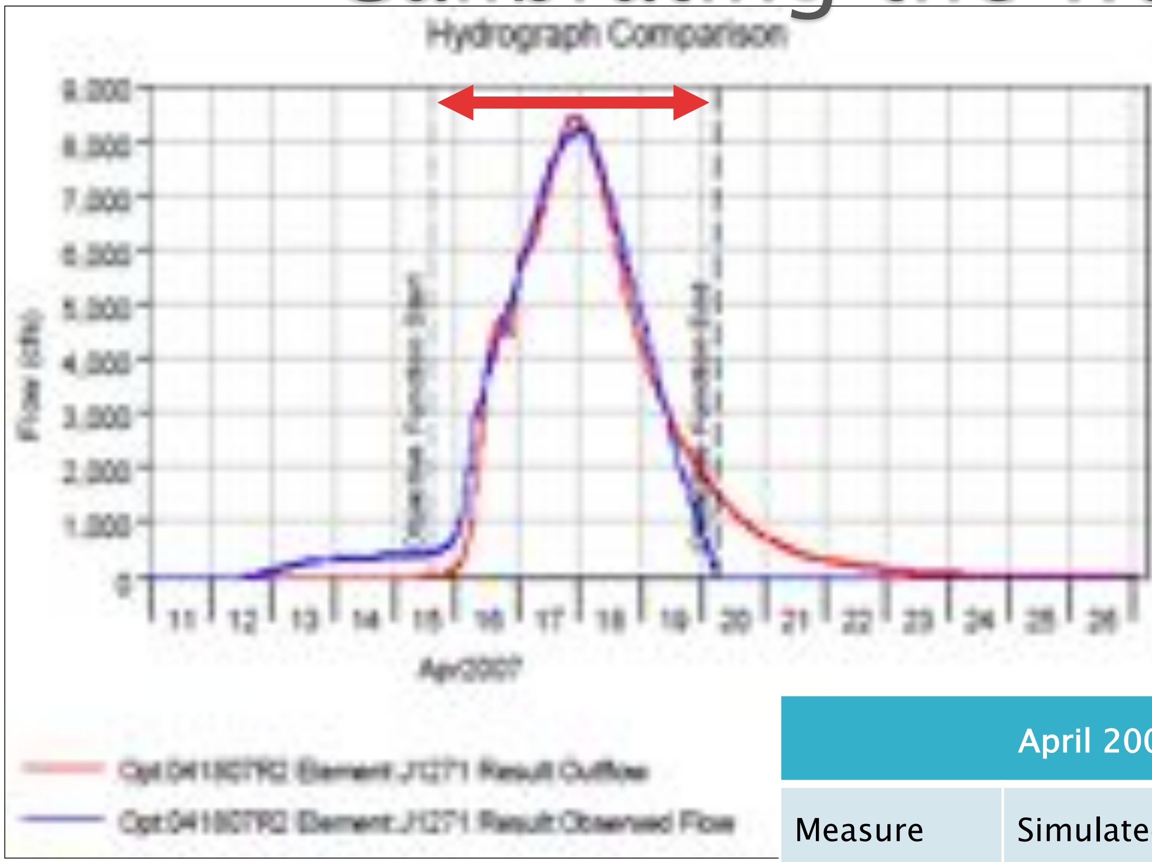
1. What is the potential liability of government if they fail to reduce vulnerability to the risk of flood based on UNH's information?
2. What legal and policy approaches may communities adopt to reduce flood risks in the expanded flood hazard?
3. Do New Hampshire communities have the legal authority to design and implement regulatory controls based on projected conditions (e.g., flooding levels)?
4. What legal standard of scientific and technical reliability must be met in order to support regulatory measures based on current/ future environmental conditions?
5. What is the potential regulatory takings exposure if communities impose regulatory controls that are designed to address anticipated future environmental conditions?



Thank you for your time.

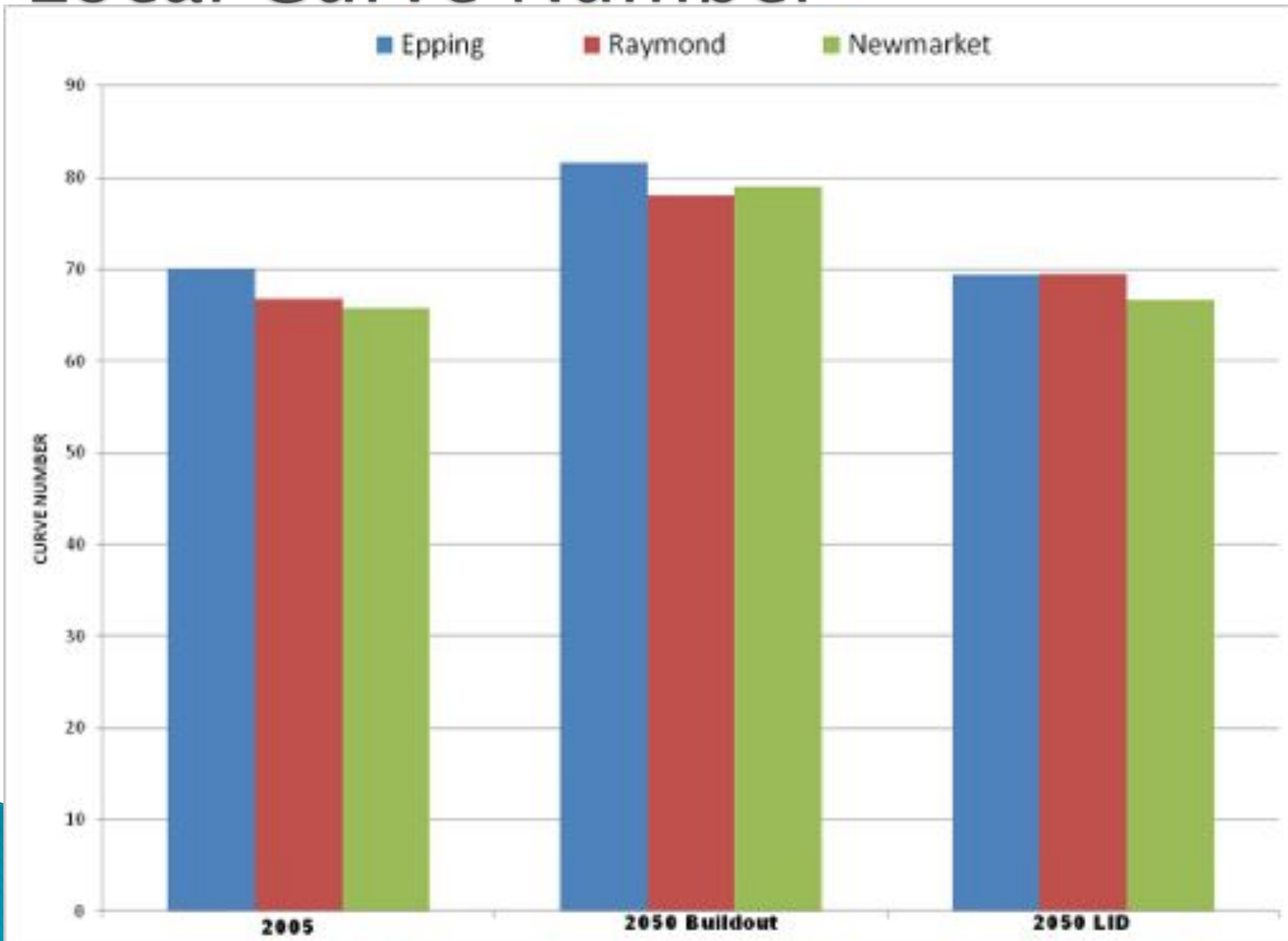
Questions?

Calibrating the Watershed



April 2007 gage discharge, less baseflow				
Measure	Simulated	Observed	Difference	% Difference
Runoff volume (IN)	4.36	4.29	0.07	1.63
Peak flow (CFS)	8332	8223	109	1.32
Time of Peak	17Apr2007, 23:02	18Apr2007, 01:45	2 hr 43 min	0.11
Time of Center of Mass	18Apr2007, 08:16	17Apr2007, 18:59	13 hr 15 min	0.52

Local Curve Number



Implementing LID

SCS graphical method:

$q_b = (q_{ub})(A)(Q_b)$

Where: q_b = before development peak discharge (cfs)

q_{ub} = unit peak discharge (csm/in)

A = drainage area (square mile)

Q_b = before development depth of runoff (inches)

$$CN^* = \frac{200}{\left[(P + 2Q + 2) - \sqrt{5PQ + 4Q^2}\right]}$$

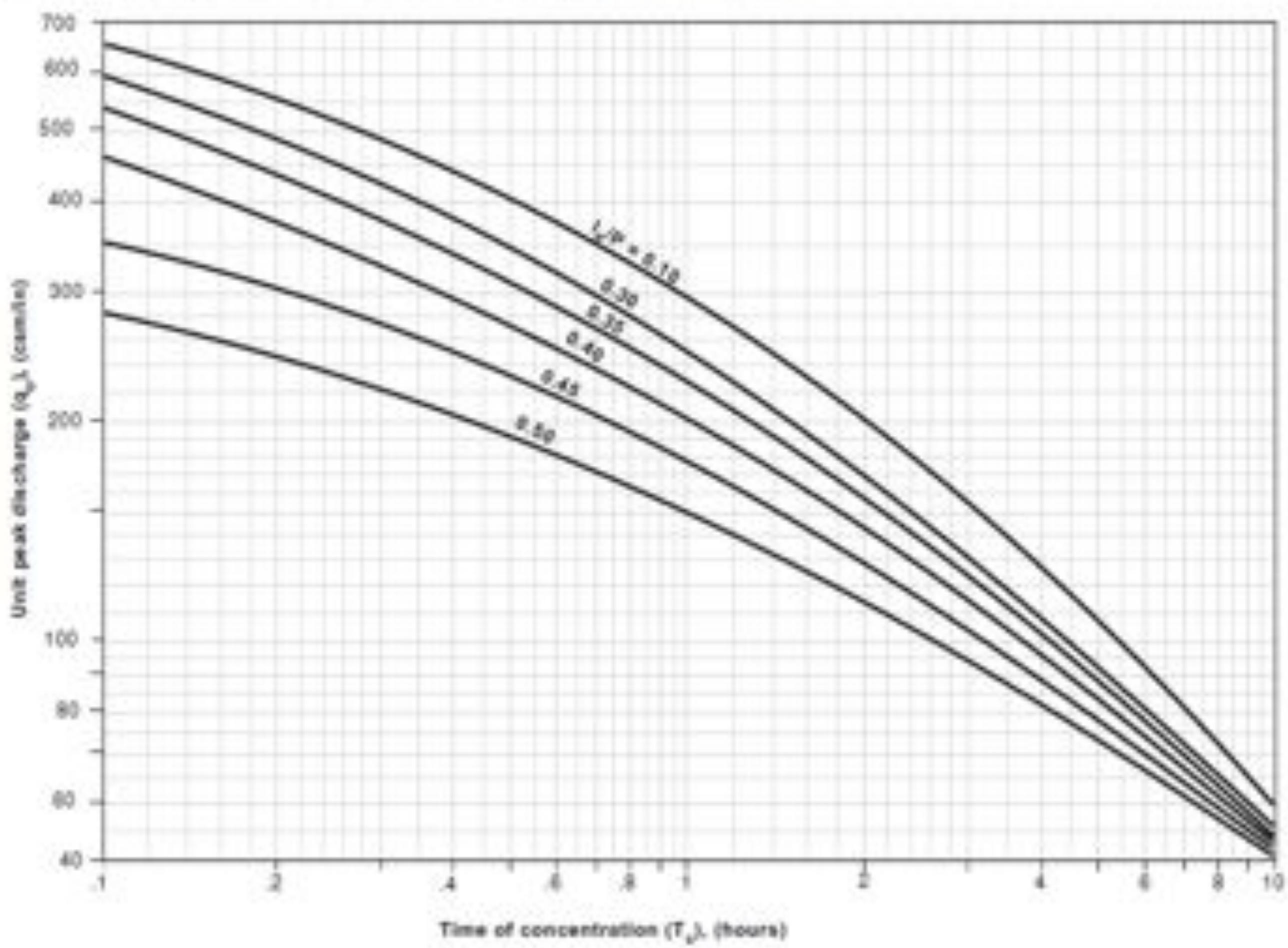
Where: CN* = Revised curve number

P = Design rainfall depth (inches)

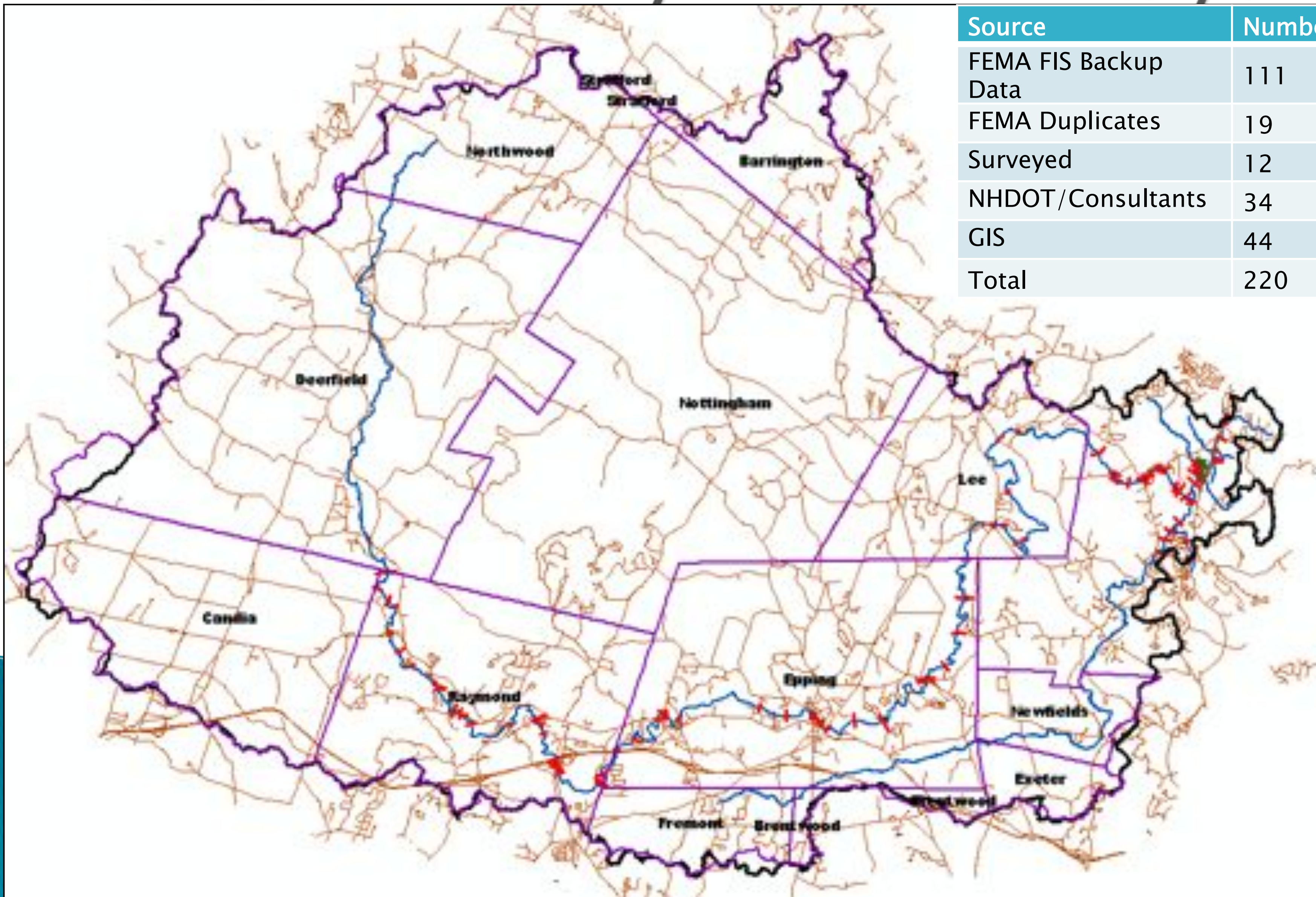
Q = After development runoff depth minus the runoff depth stored by infiltration practices (inches)

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-III Unit peak discharge (q_u) for NRCS (SCS) type III rainfall distribution



HEC-GeoRAS Hydraulic Analysis



Source	Number
FEMA FIS Backup Data	111
FEMA Duplicates	19
Surveyed	12
NHDOT/Consultants	34
GIS	44
Total	220