NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
NATIONAL OCEAN SERVICE

NOAA

Bacterial Contamination

in the context of

Land Use, Runoff and Climate

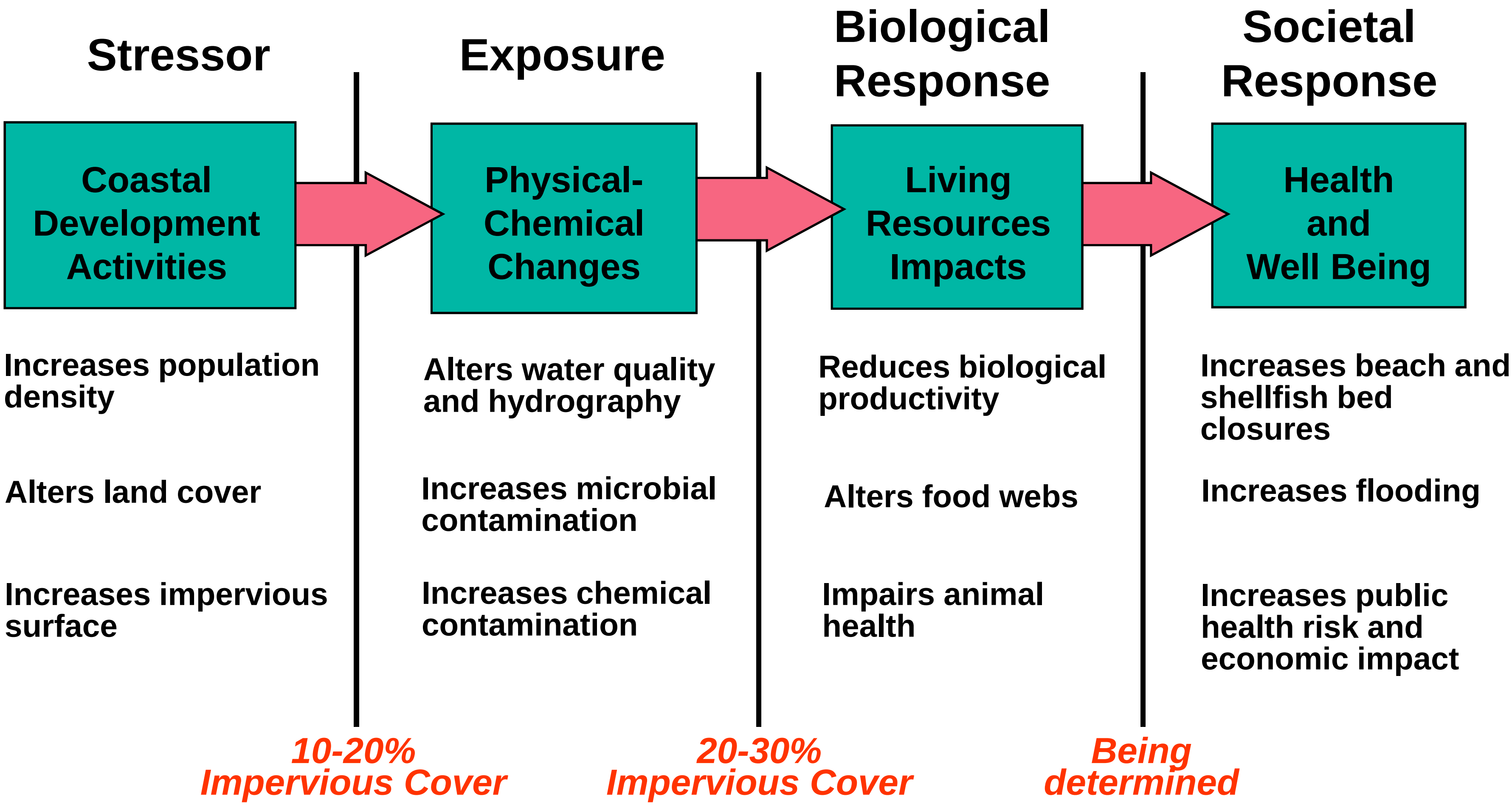
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · NOAA · U.S. DEPARTMENT OF COMMERCE

OCEANS & HUMAN HEALTH INITIATIVE

HOLLINGS MARINE LABORATORY
MUSC MEDICAL UNIVERSITY of SOUTH CAROLINA · COLLEGE of CHARLESTON · NIST

Center of Excellence for Oceans and Human Health at the Hollings Marine Laboratory

Conceptual Model of Creek Watershed Linkages

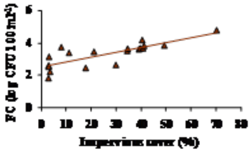


Center of Excellence for Oceans and Human Health at the Hollings Marine Laboratory

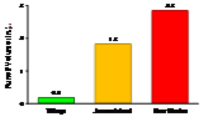
Presentation

Study design

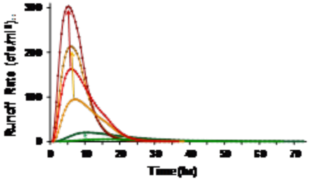
Pathogen indicator results

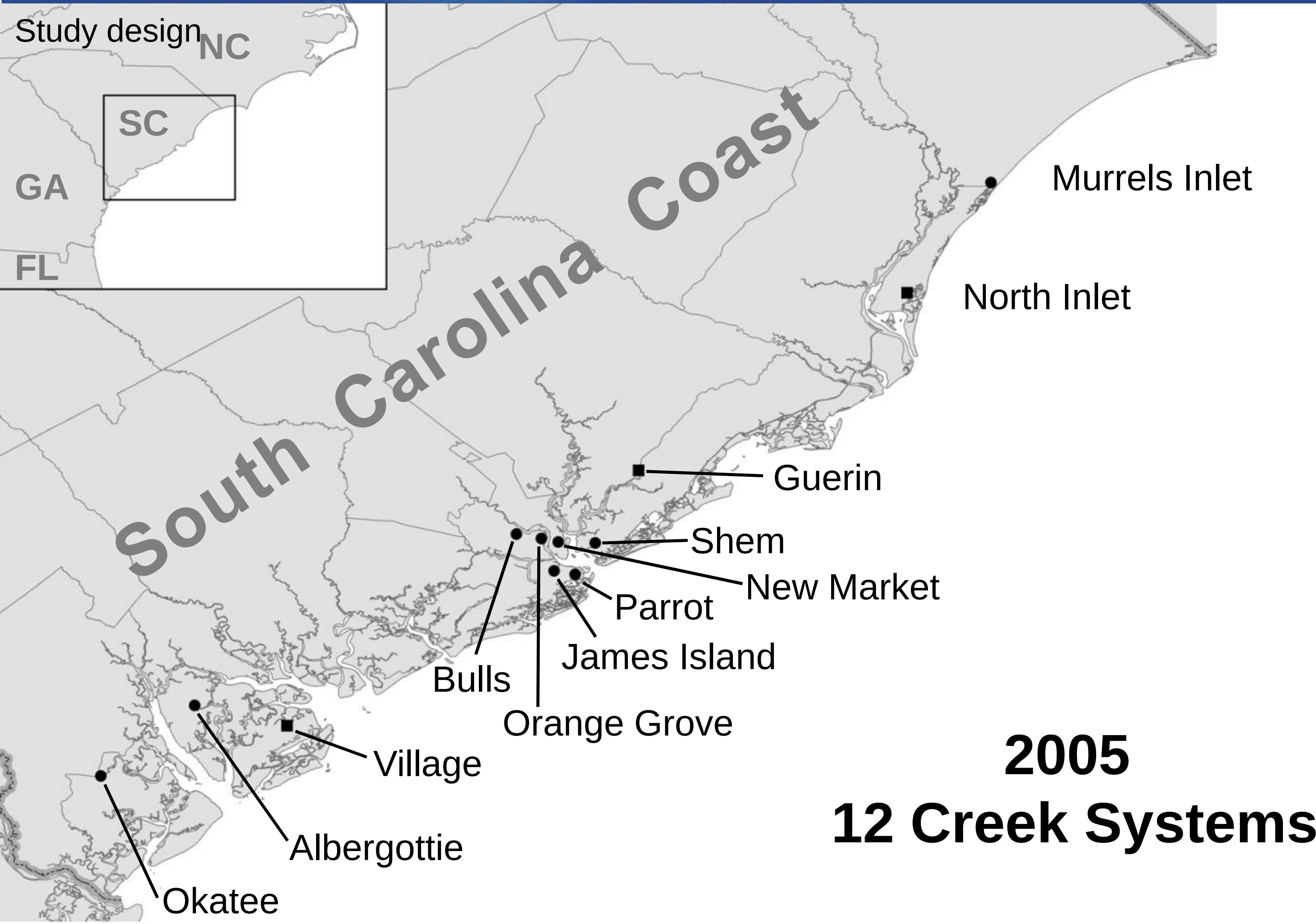


Stormwater runoff – modeled comparisons

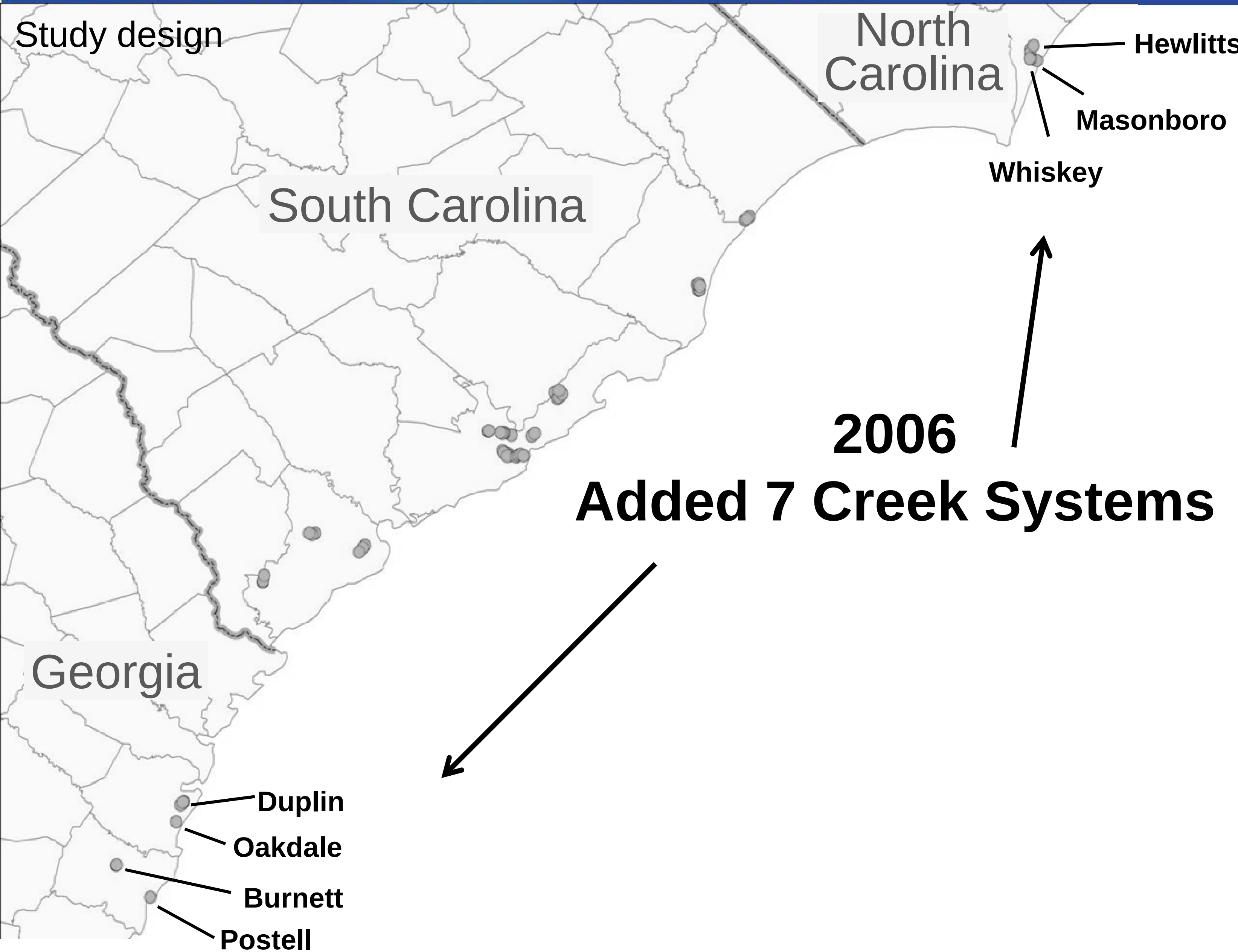


Projected climate impact on stormwater runoff




Study design
NC
SC
GA
FL
South Carolina Coast
Murrels Inlet
North Inlet
Guerin
Shem
New Market
Parrot
James Island
Bulls
Orange Grove
Village
Albergottie
Okatee
2005
12 Creek Systems

Study design



2006

Added 7 Creek Systems

Study design

Study watersheds are classified based on level of impervious surfaces that accompany coastal development

Undeveloped - Forested

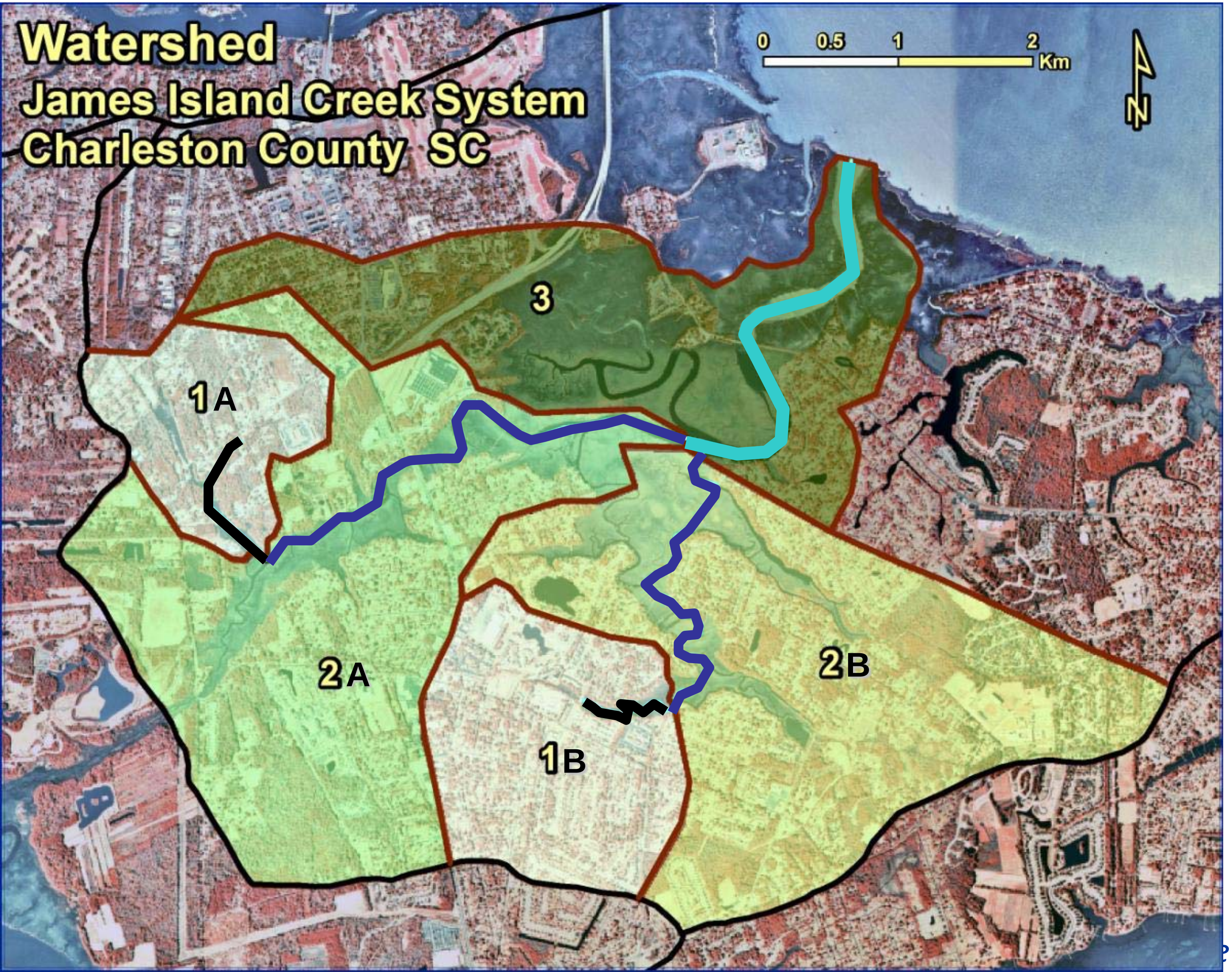
Holland / Steele

Developed - Suburban

Developed – Urban

Study design

Results here are from headwater creek watersheds (# 1)



Creek Lengths

1A – 850 m

1B – 850 m

2A – 6400 m

2B – 4600 m

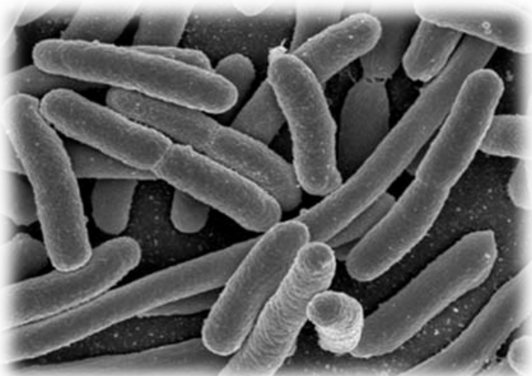
3 – 5800 m

Sampling in headwater tidal creeks – 2005 & 2006

Fecal coliform and **Enterococcus** are bacteria that have been used extensively as indicators of fecal pollution and enteric pathogens.

Coliphages are viruses that infect *Escherichia col*i and are being investigated to determine if they are a more appropriate indicator for water borne pathogens. F+ and F- are the two main types of coliphages.

Fecal coliform

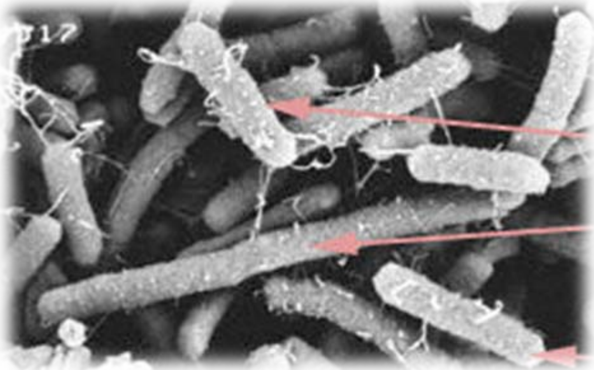


ttp://www.columbiariverkeeper.org/index.php/adopt_river/ecoli_monitoring

Enterococcus

http://microbewiki.kenyon.edu/images/b/bc/Wiki.png

Coliphages

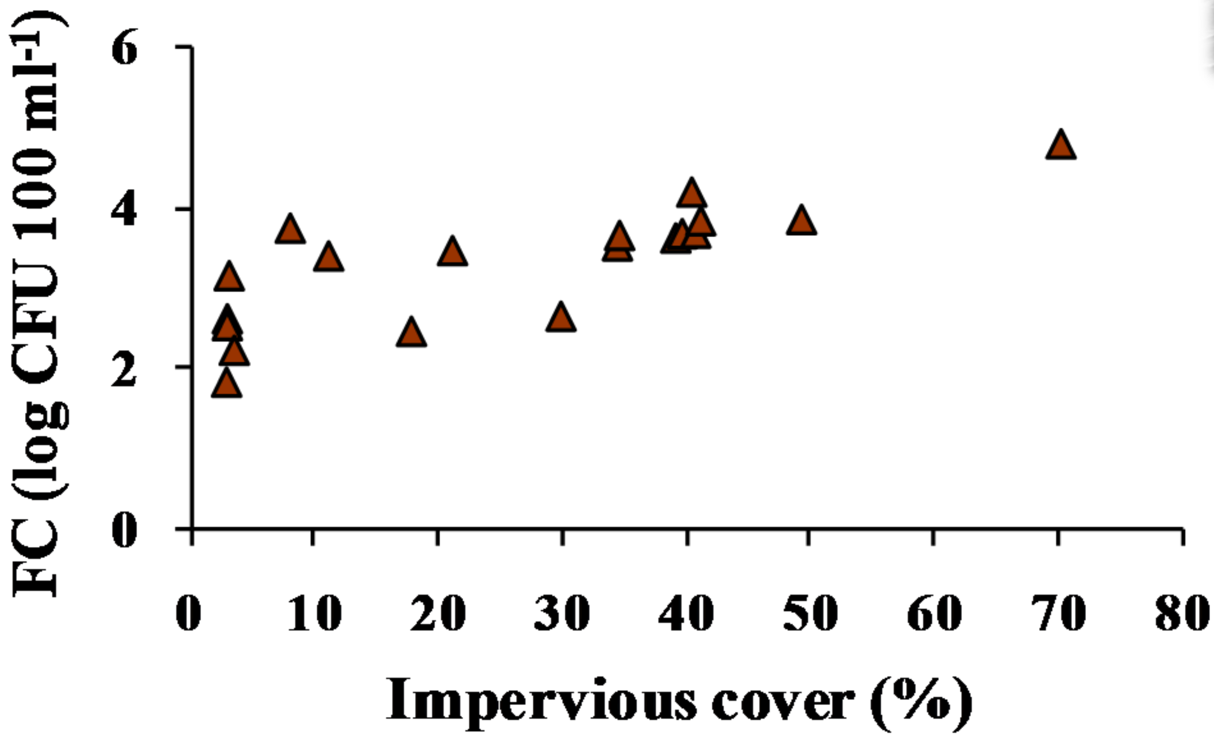


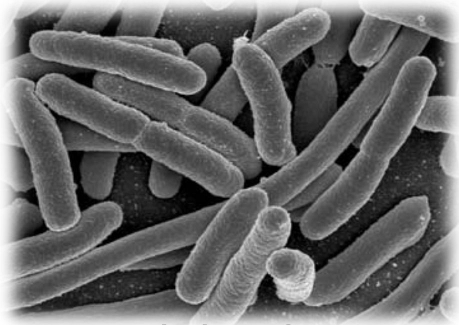
http://blass.com.au/definitions/coliphage

SEM shows *E. coli* cells with Phage particles attached

Collaborated with Center for Coastal Environmental Health and Biomolecular Research

Fecal coliform concentrations increase with development in headwater creek watersheds





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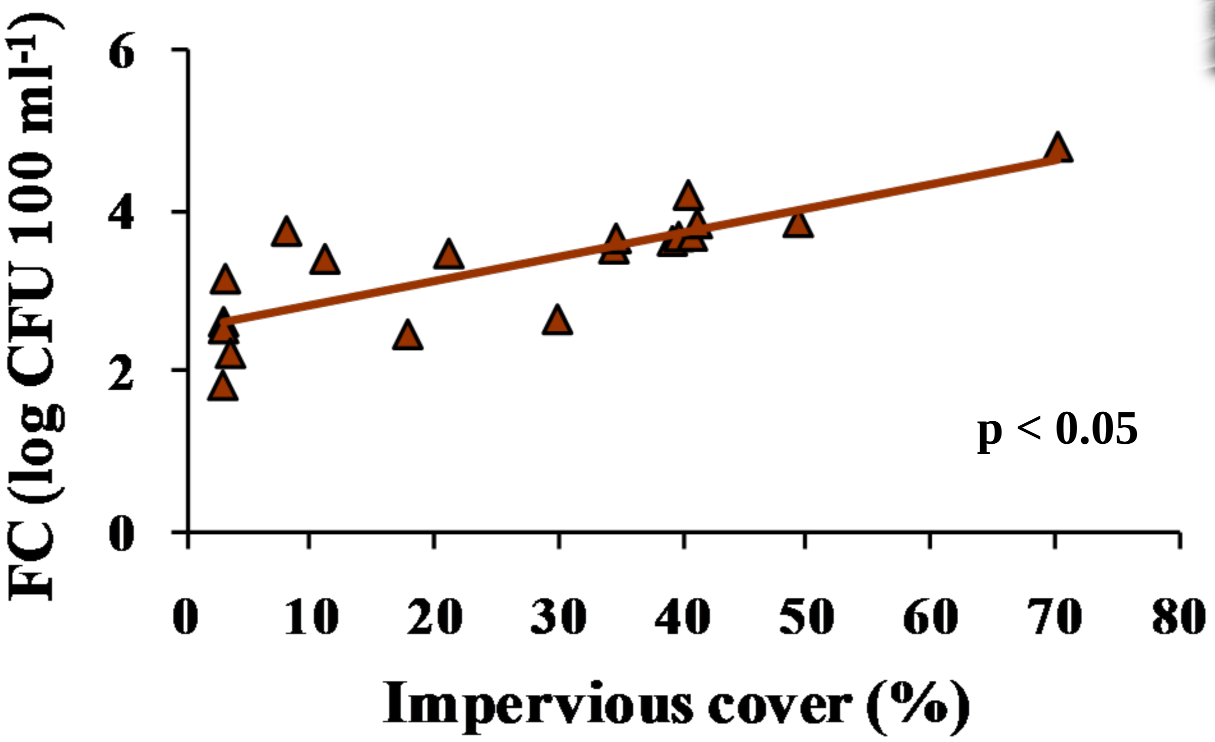
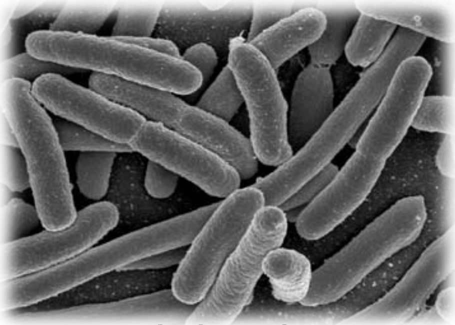
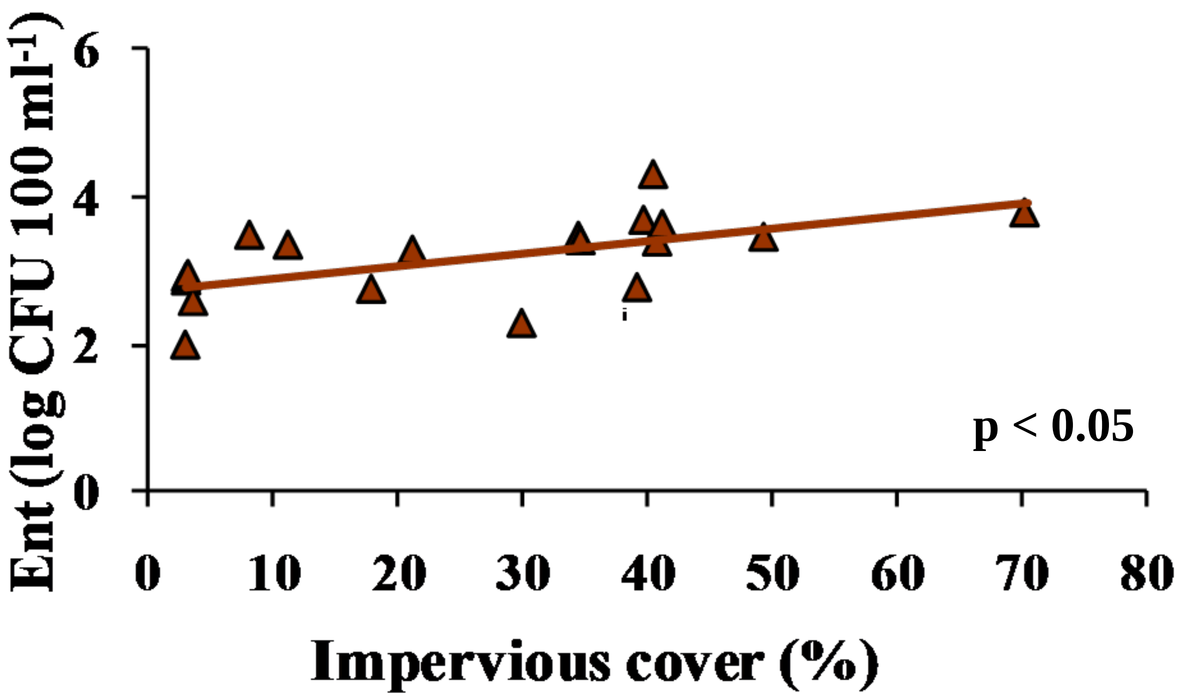
Fecal coliform concentrations increase with development in headwater creek watersheds





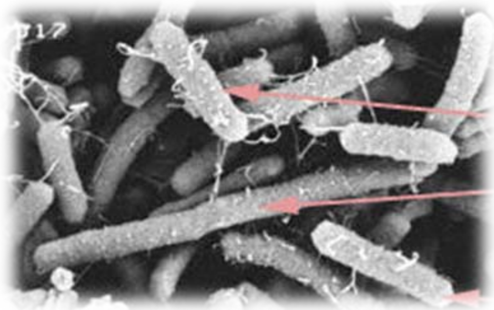
ttp://www.columbiariverkeeper.org/index.php/adopt_river/ecoli_monitoring

Enterococci concentrations increase with development in headwater creek watersheds



http://microbewiki.kenyon.edu/images/b/bc/Wiki.png

Coliphage concentrations increase with development in headwater creek watersheds



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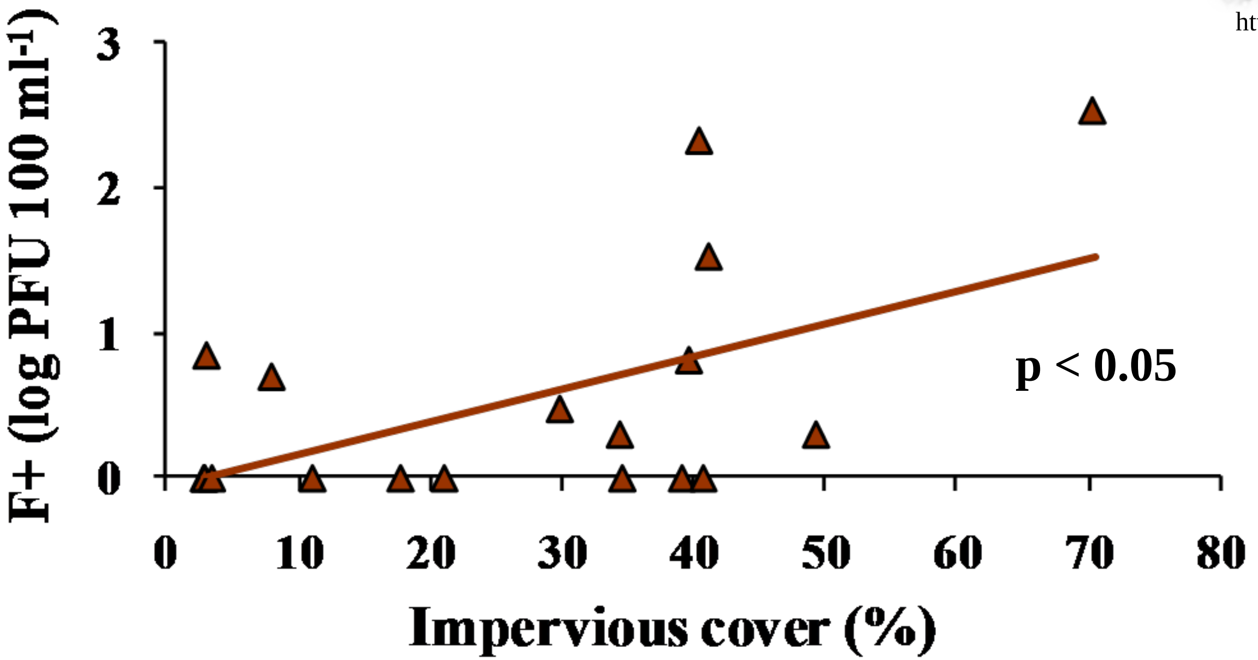
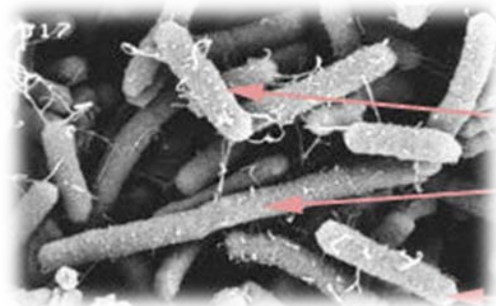


Coliphage concentrations increase with development in headwater creek watersheds



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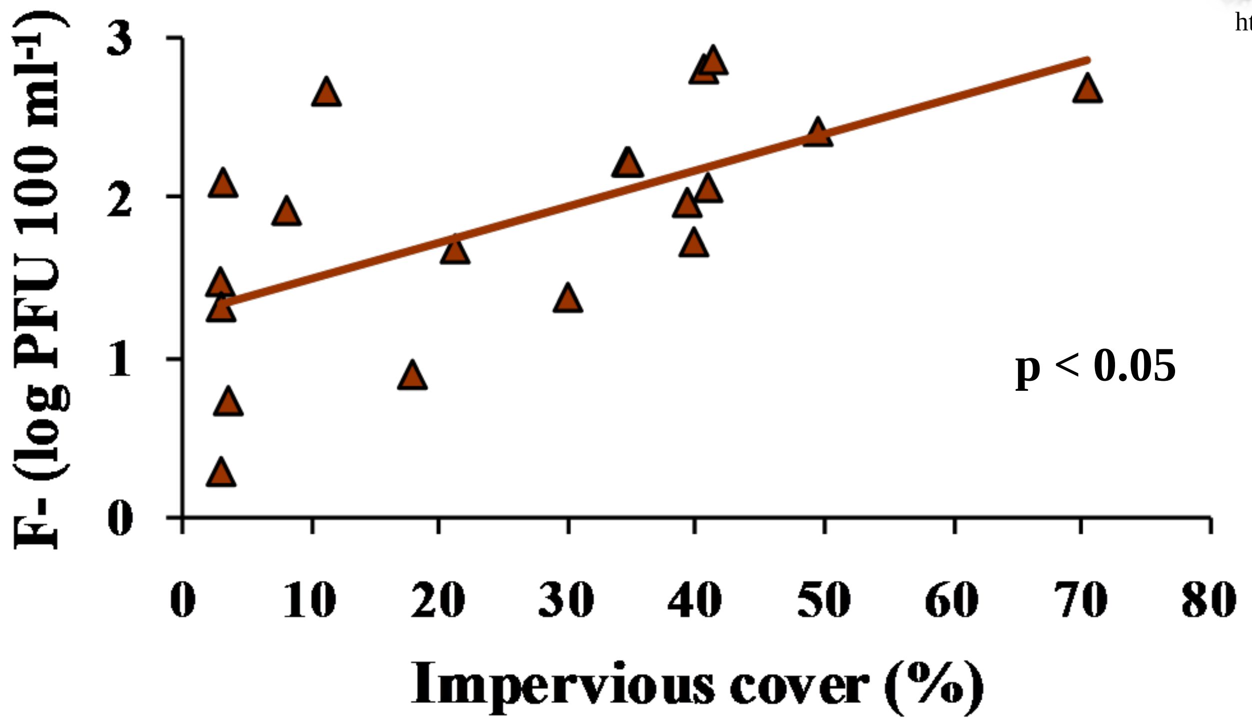


Modeling impact of land use on stormwater runoff

Stormwater runoff from developed watersheds is a leading cause of nonpoint source pollution

Stormwater Runoff, King & Huger Charleston SC Post & Courier December 2009

Stormwater Runoff – School Dismissal Savannah, Georgia Floodplain Management Department, March 2009

Stormwater Runoff, Crosstown, Charleston SC Post & Courier December 2009

Stormwater Runoff, King Street, Charleston SC Post & Courier June 2007

charlestoncity.info Accessed 5/13/2010

Modeling impact of land use on stormwater runoff

Runoff modeling is based upon the imperviousness of the watershed

Land use

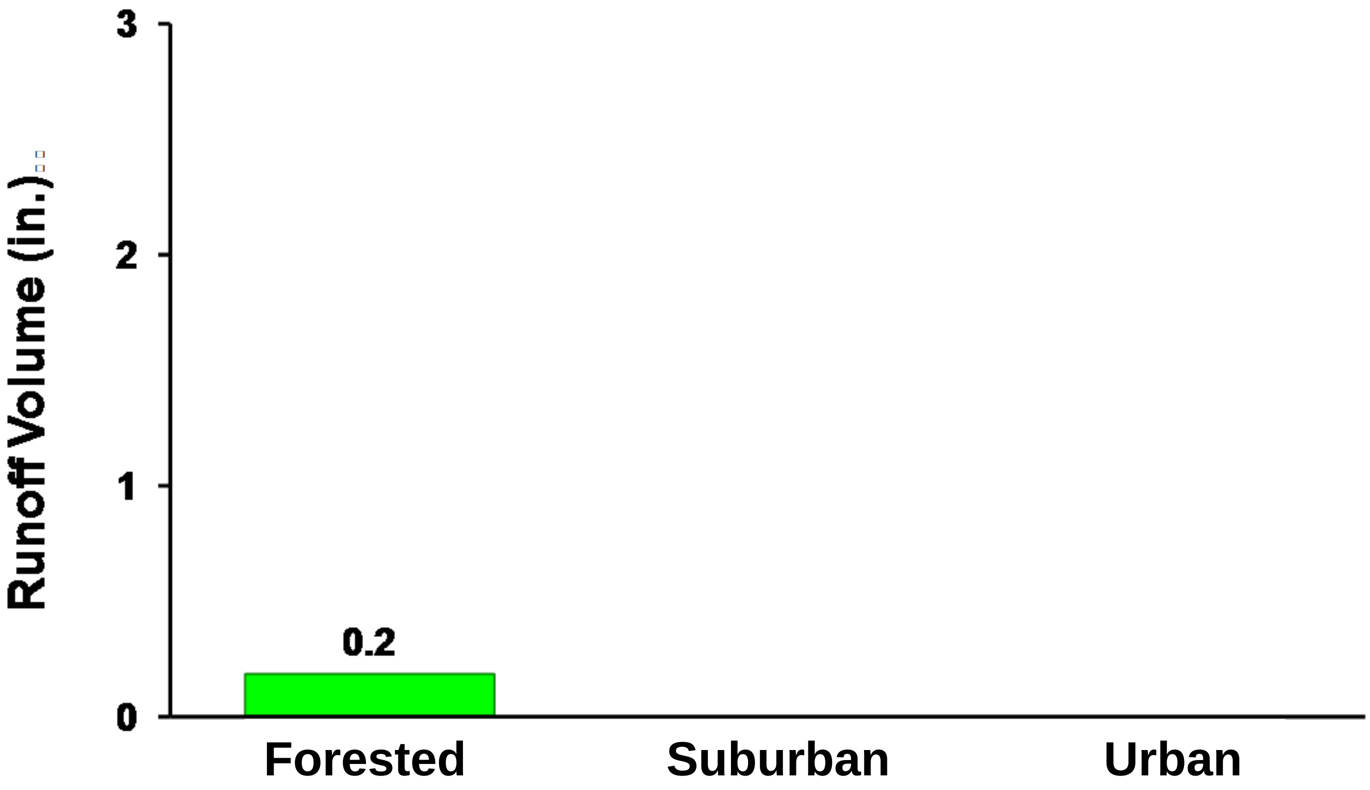
Undeveloped - Forested | **Developed - Suburban** | **Developed – Urban**

Holland / Steele

Most pervious → **Runoff increases with development** → Most impervious

Modeling impact of land use on stormwater runoff – among watersheds

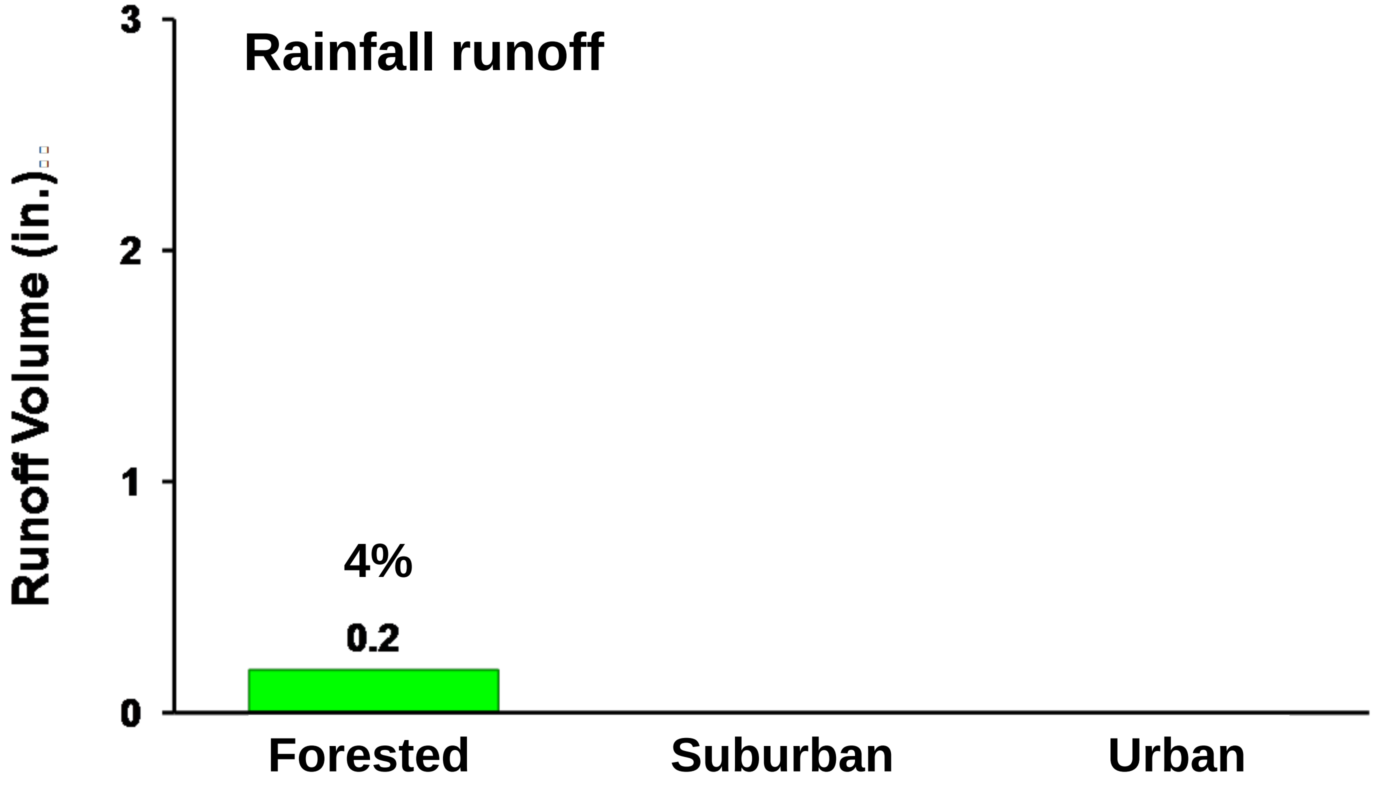
Amount of rainfall converted to stormwater runoff is low in an undeveloped forested watershed



4.5-in storm event

Modeling impact of land use on stormwater runoff – among watersheds

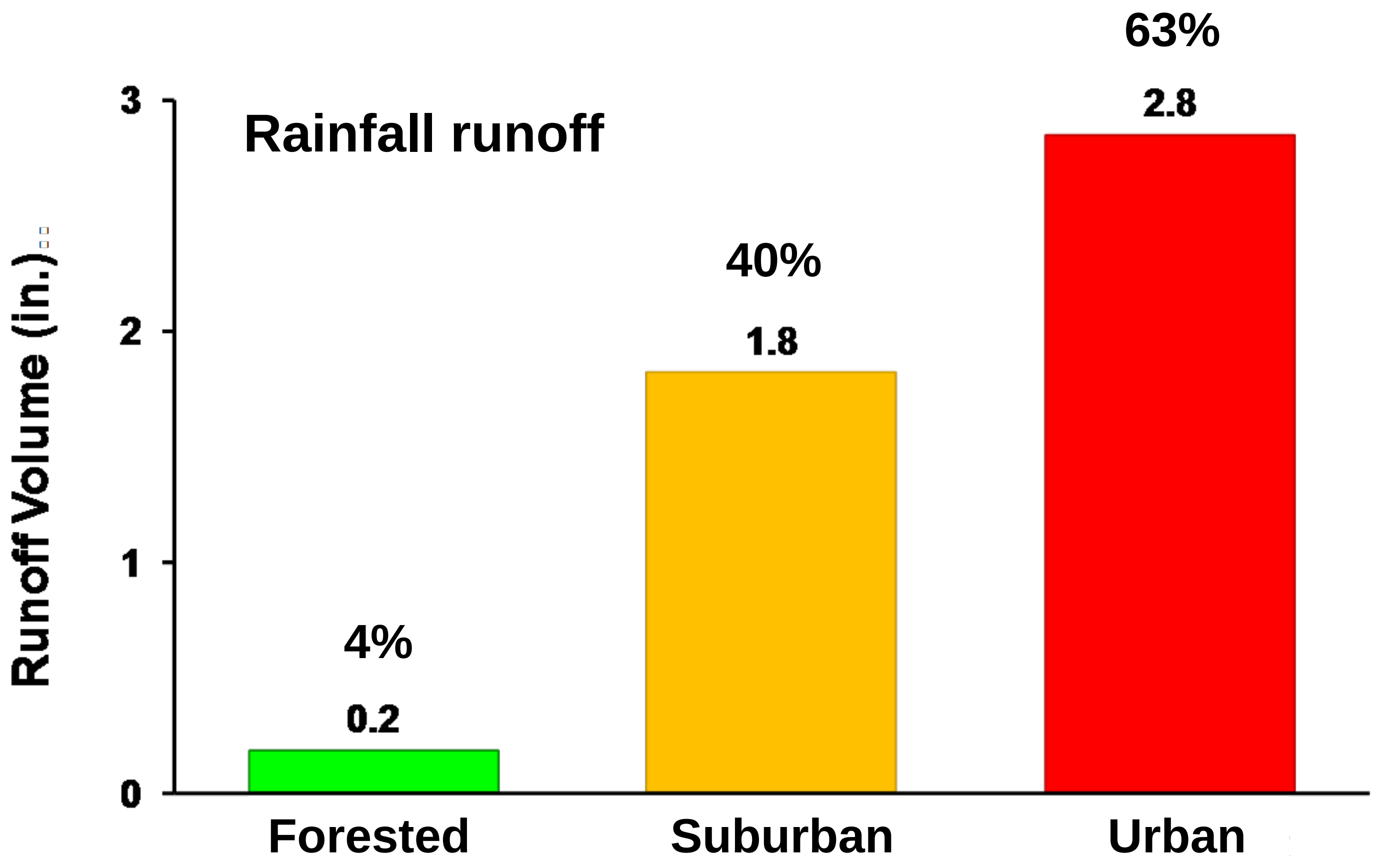
Amount of rainfall converted to stormwater runoff is low in an undeveloped forested watershed



4.5-in storm event

Modeling impact of land use on stormwater runoff – among watersheds

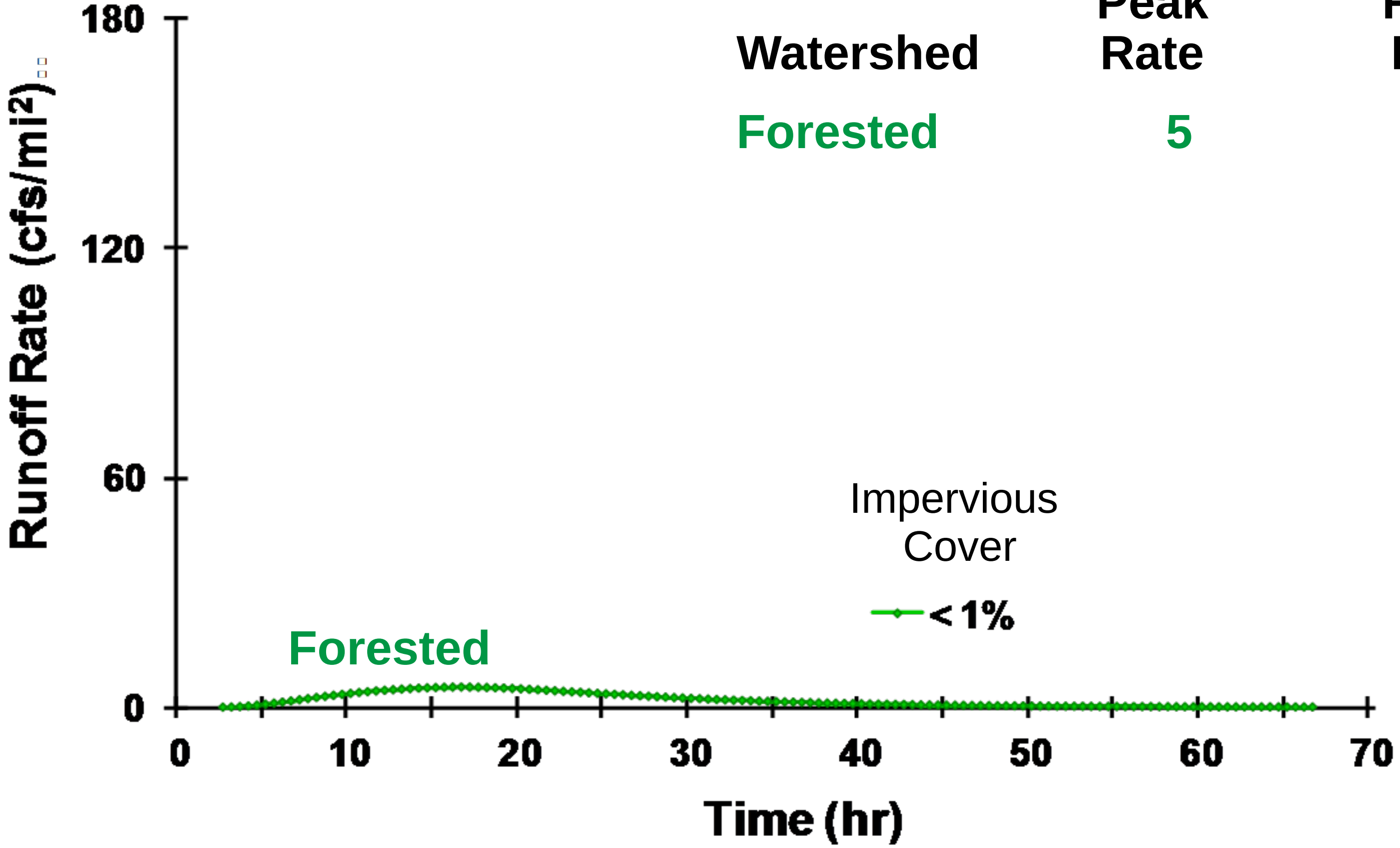
Stormwater runoff in developed areas is strikingly greater than in undeveloped areas



4.5-in storm event

Modeling impact of land use on stormwater runoff – among watersheds

Stormwater runoff rate and time can be shown using hydrographs



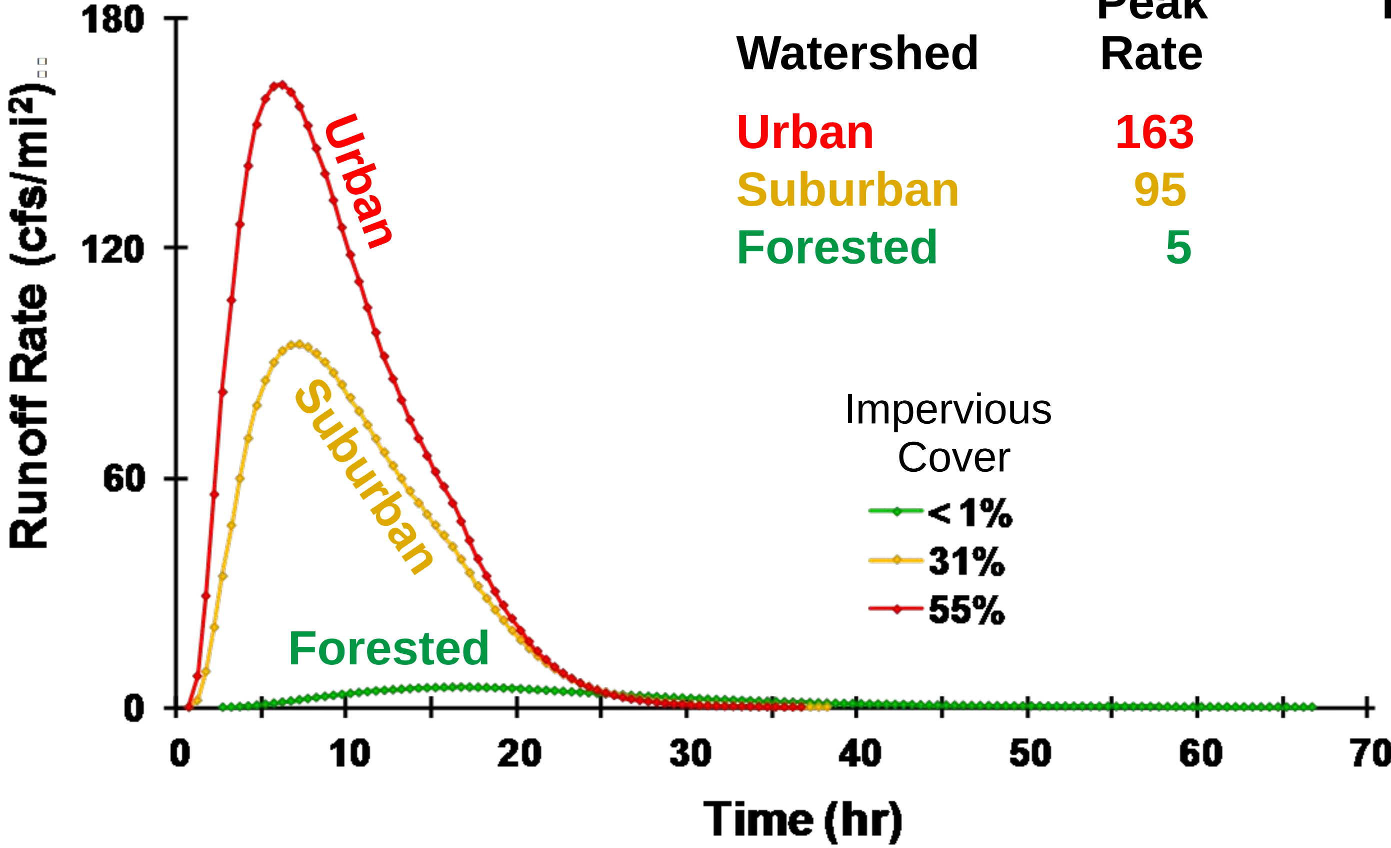
Watershed	Peak Rate	Rainfall Runoff
Forested	5	4%

24-hr 4.5-in storm event, average runoff conditions

Modeling impact of land use on stormwater runoff – among watersheds

More stormwater runs off at faster rates over less time in developed watersheds

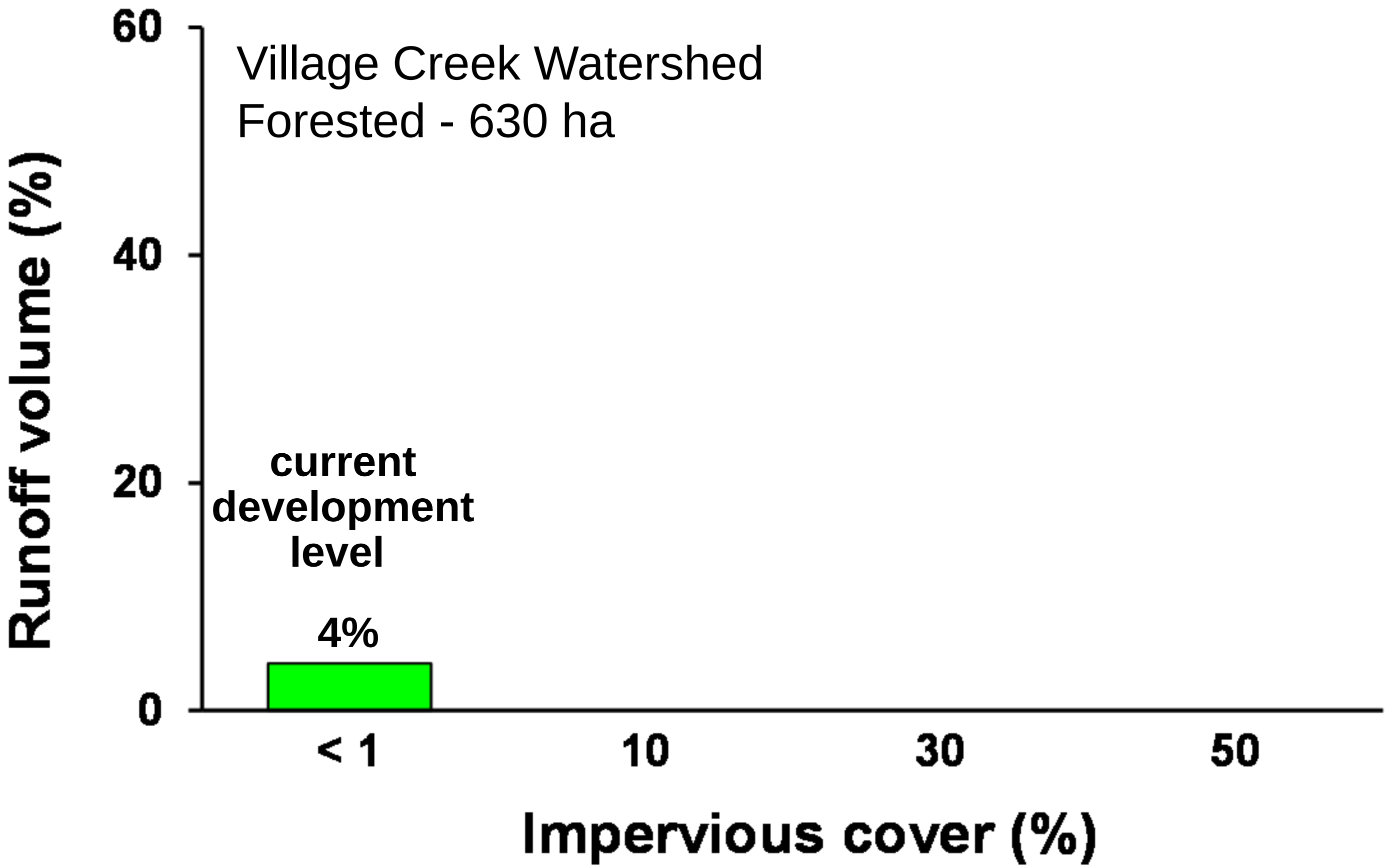
Watershed	Peak Rate	Rainfall Runoff
Urban	163	63%
Suburban	95	40%
Forested	5	4%



24-hr 4.5-in storm event, average runoff conditions

Modeling impact of land use on stormwater runoff – within an undeveloped watershed

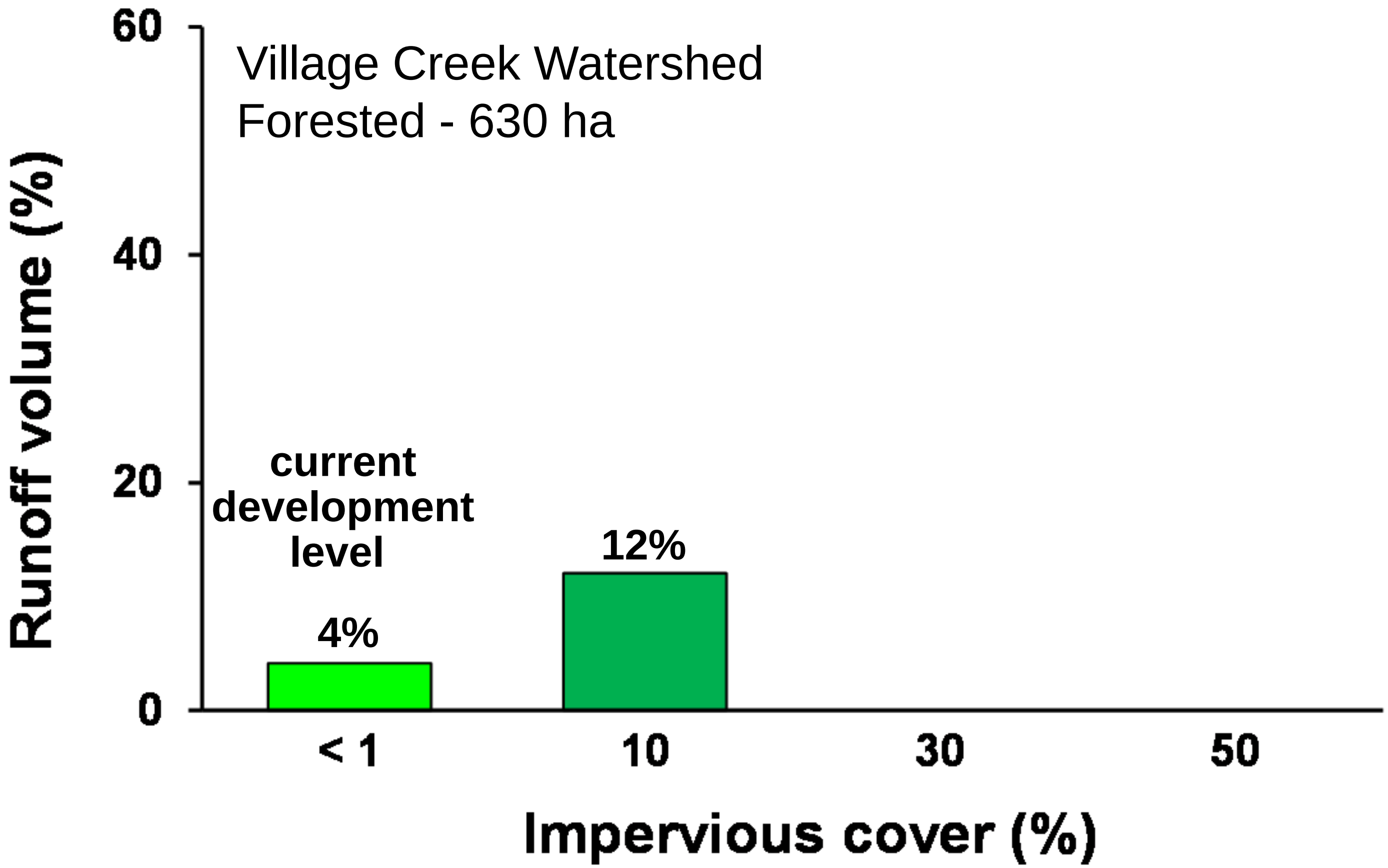
Amount of rainfall converted to stormwater runoff is low in an undeveloped watershed



4.5-in storm event

Modeling impact of land use on stormwater runoff – within an undeveloped watershed

Projected runoff as an undeveloped watershed is urbanized shows dramatic increase at each development stage



Modeling impact of land use on stormwater runoff – within an undeveloped watershed

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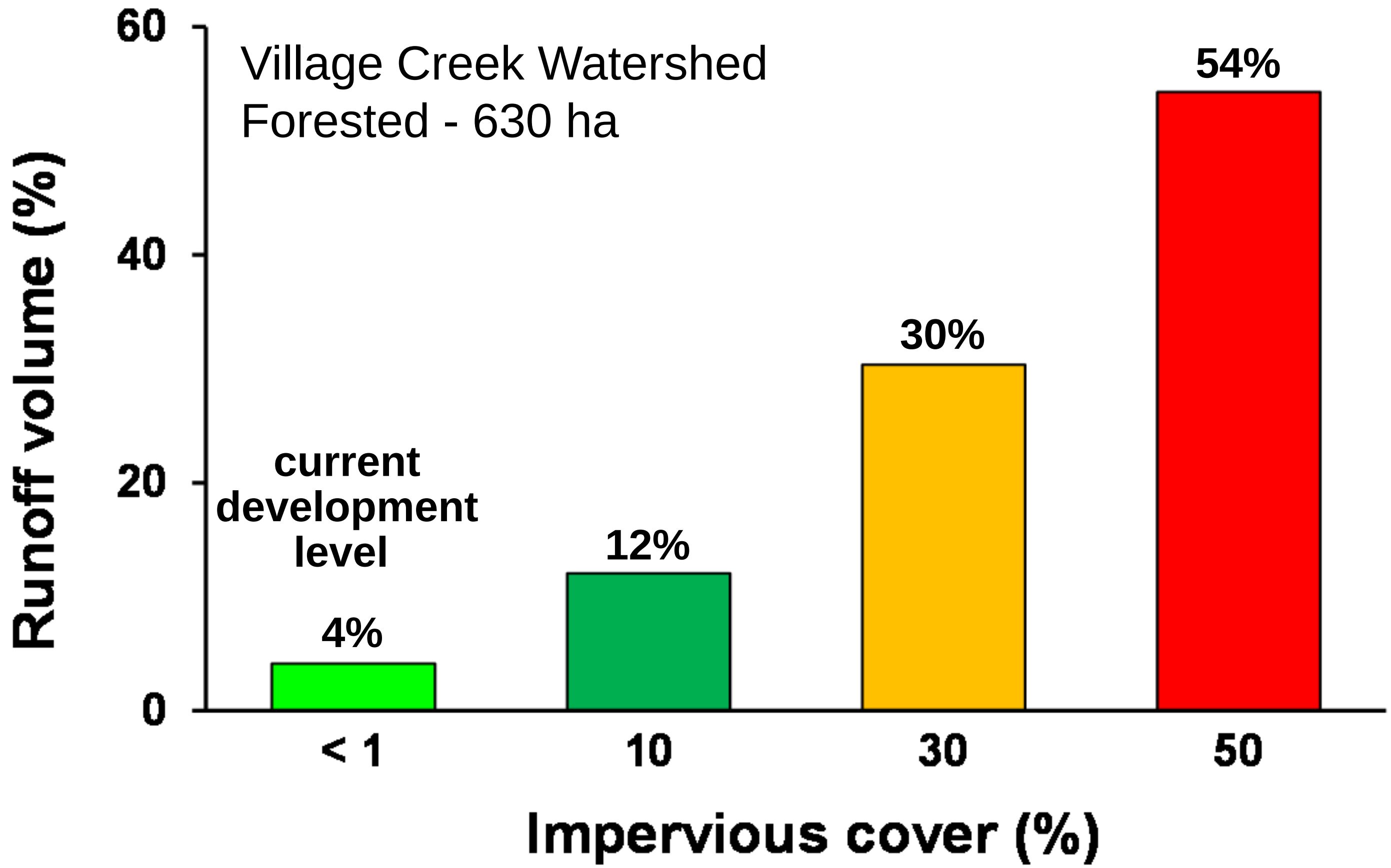
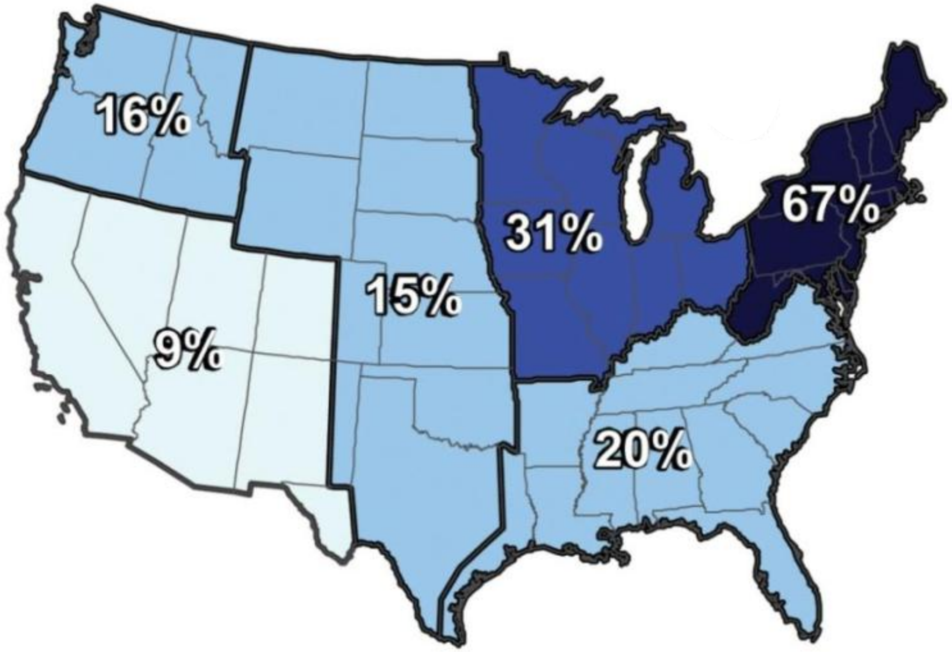


4.5-in storm event

Modeling impact of climate variability and change on runoff

Climate change models predict increases in **frequency** and **intensity** of heavy precipitation events (Bates et al. 2008, Karl et al. 2008)

Increase in very heavy precipitation (heaviest 1%)
1958 to 2007



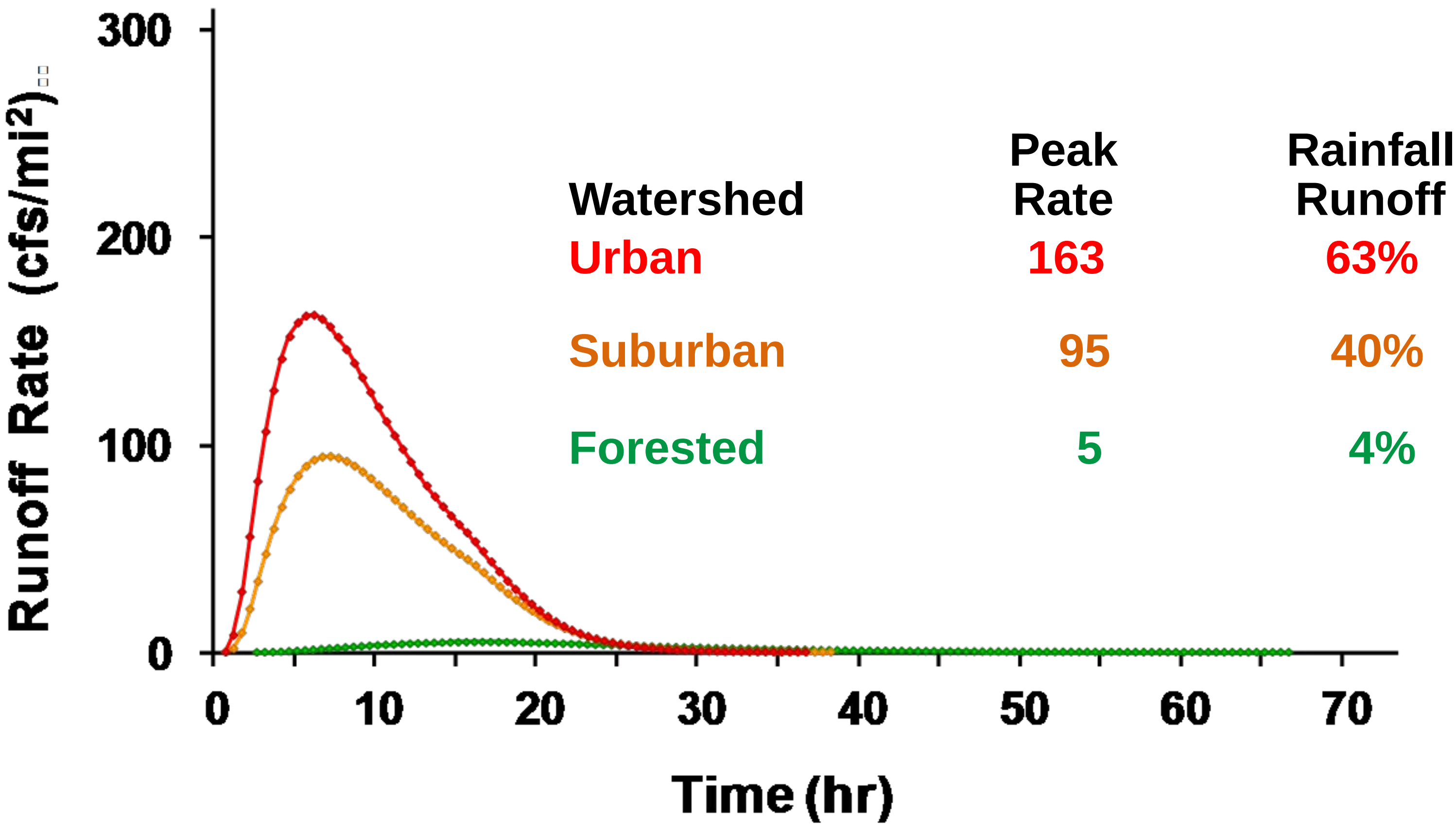
http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report/national-climate-change
Accessed 5/24/2010

Modeled climate scenario

- Increase rainfall amount by 15%
- Decrease rainfall period by 50%
- Change runoff condition to semi-saturated

Projecting impact of climate change

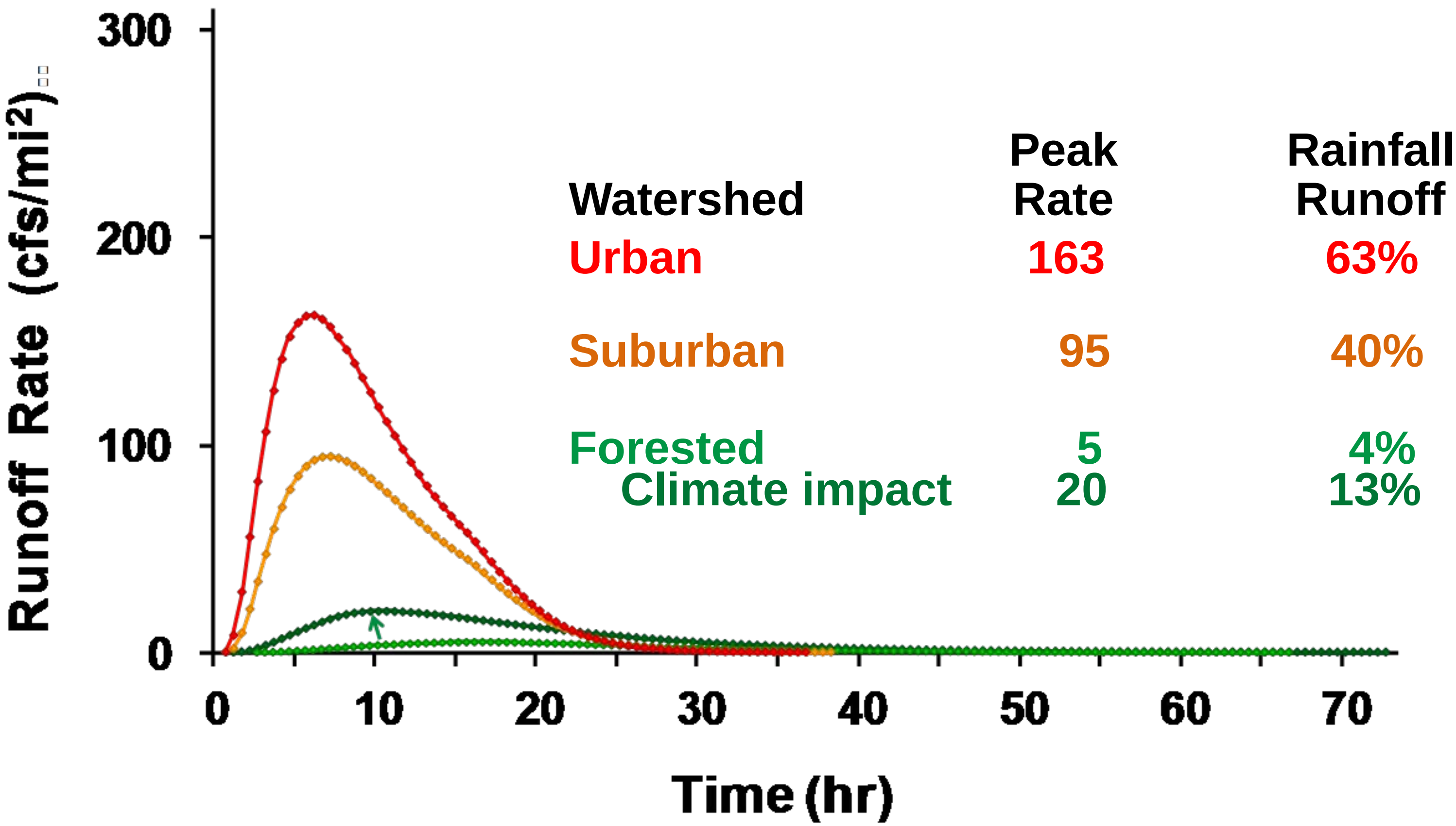
More stormwater runs off at faster rates over less time in developed watersheds



24-hr 4.5-in storm event, average runoff conditions

Projecting impact of climate change

Modeled climate scenario for an undeveloped watershed more than triples runoff rate and volume yet remains far below urbanized levels



24-hr 4.5-in storm event, average runoff conditions

Climate impact – 12-hr 5.2-in storm event, semi-saturated runoff conditions

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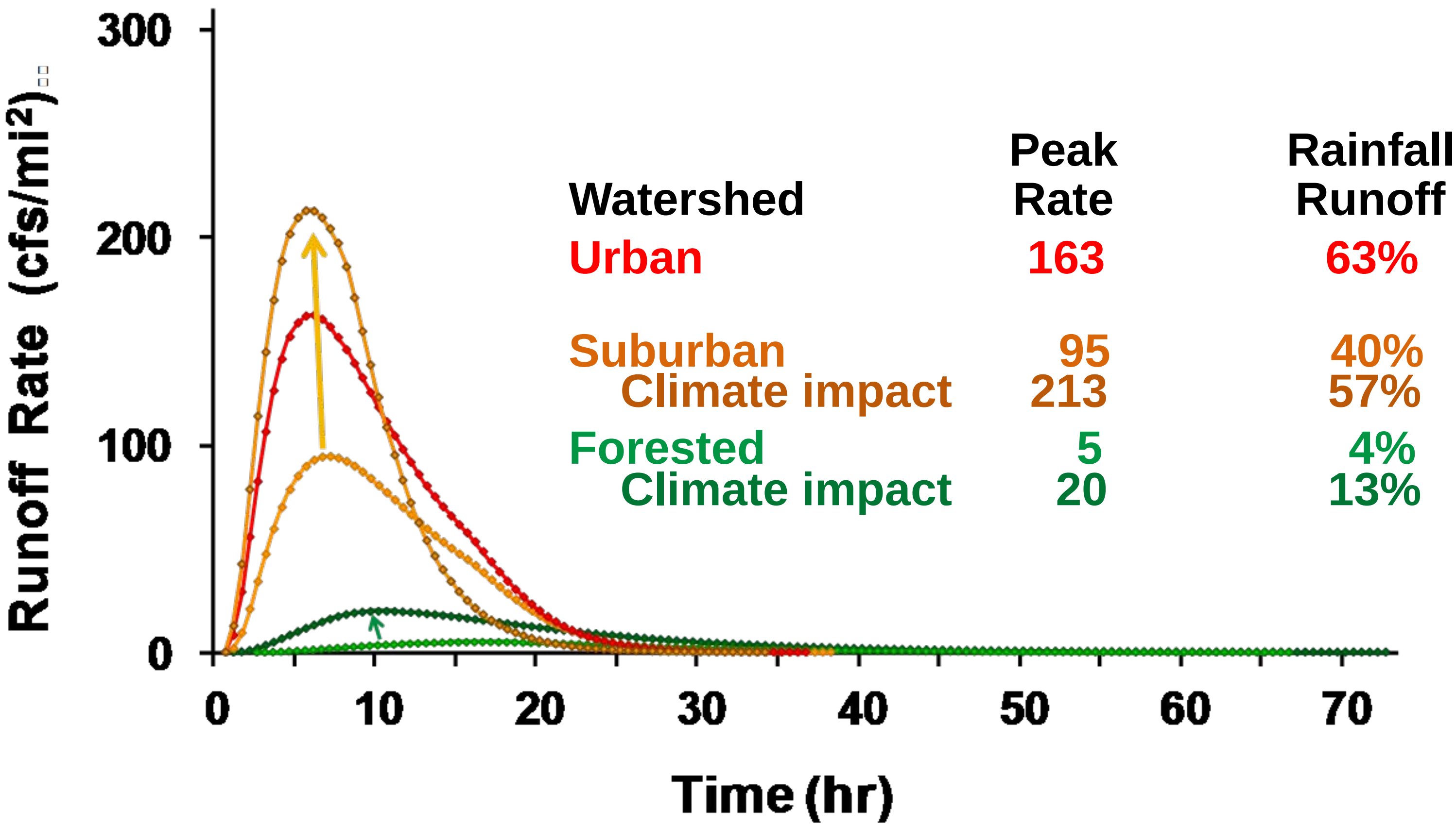
Projecting impact of climate change

Modeled climate scenario for a suburban watershed produces runoff that surpasses urban runoff at present scenario



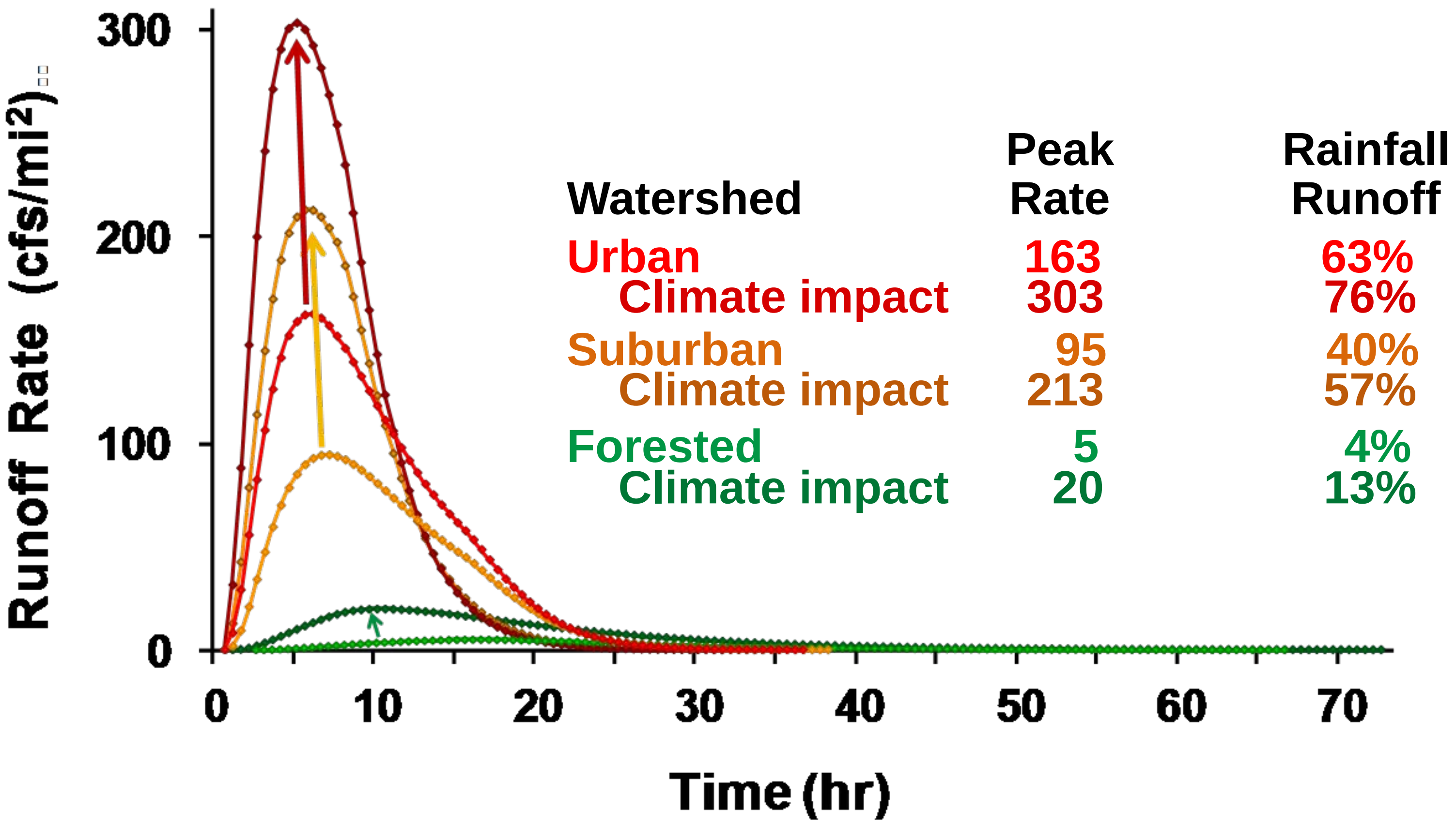
24-hr 4.5-in storm event, average runoff conditions

Climate impact – 12-hr 5.2-in storm event, semi-saturated runoff conditions

Center of Excellence for Oceans and Human Health at the Hollings Marine Laboratory

Projecting impact of climate change

Modeled climate scenario for developed watersheds dramatically amplifies impact of urbanization



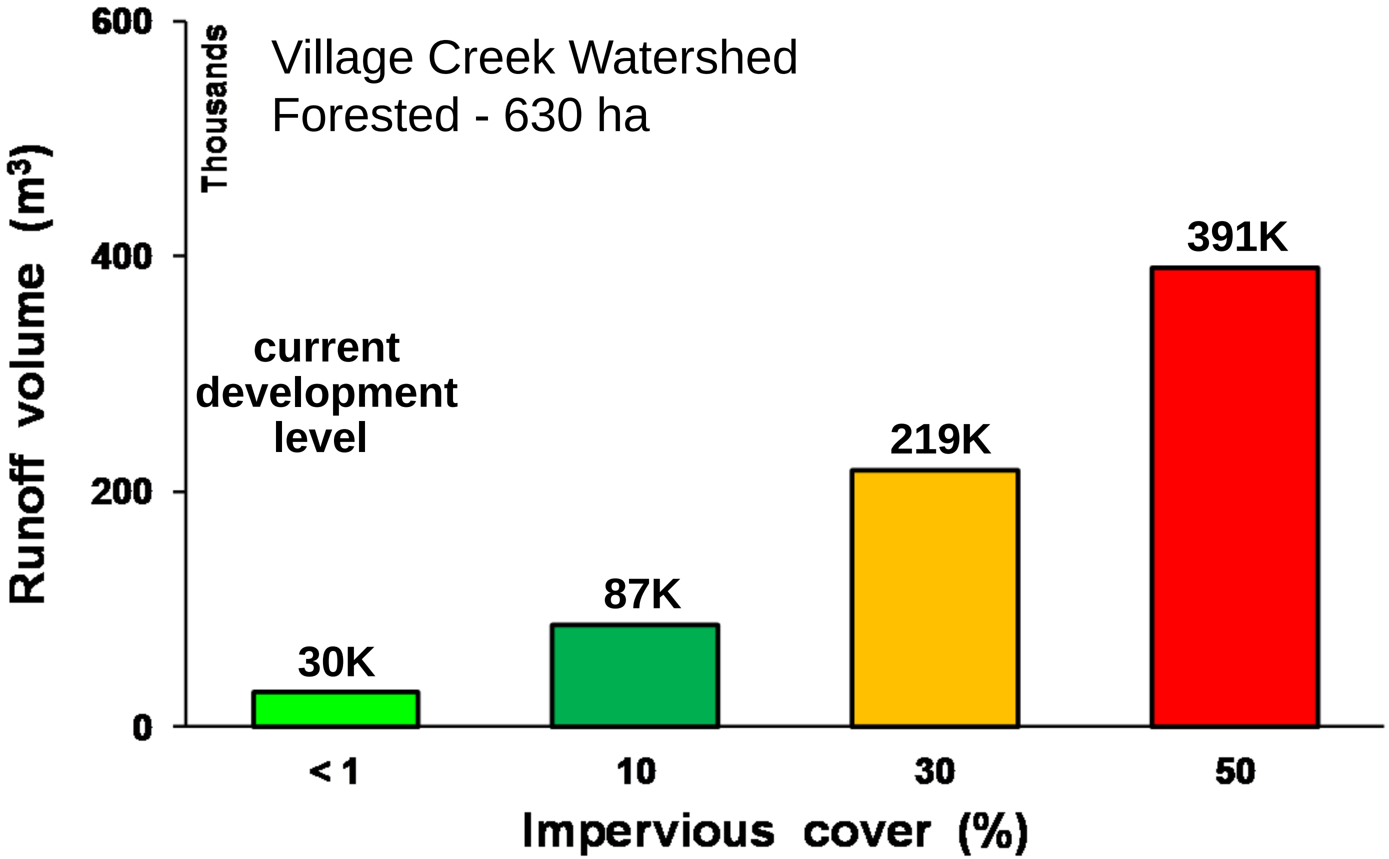
24-hr 4.5-in storm event, average runoff conditions

Climate impact – 12-hr 5.2-in storm event, semi-saturated runoff conditions

Center of Excellence for Oceans and Human Health at the Hollings Marine Laboratory

Projecting impact of climate change

Projected runoff as an undeveloped watershed is urbanized shows dramatic increase at each development stage



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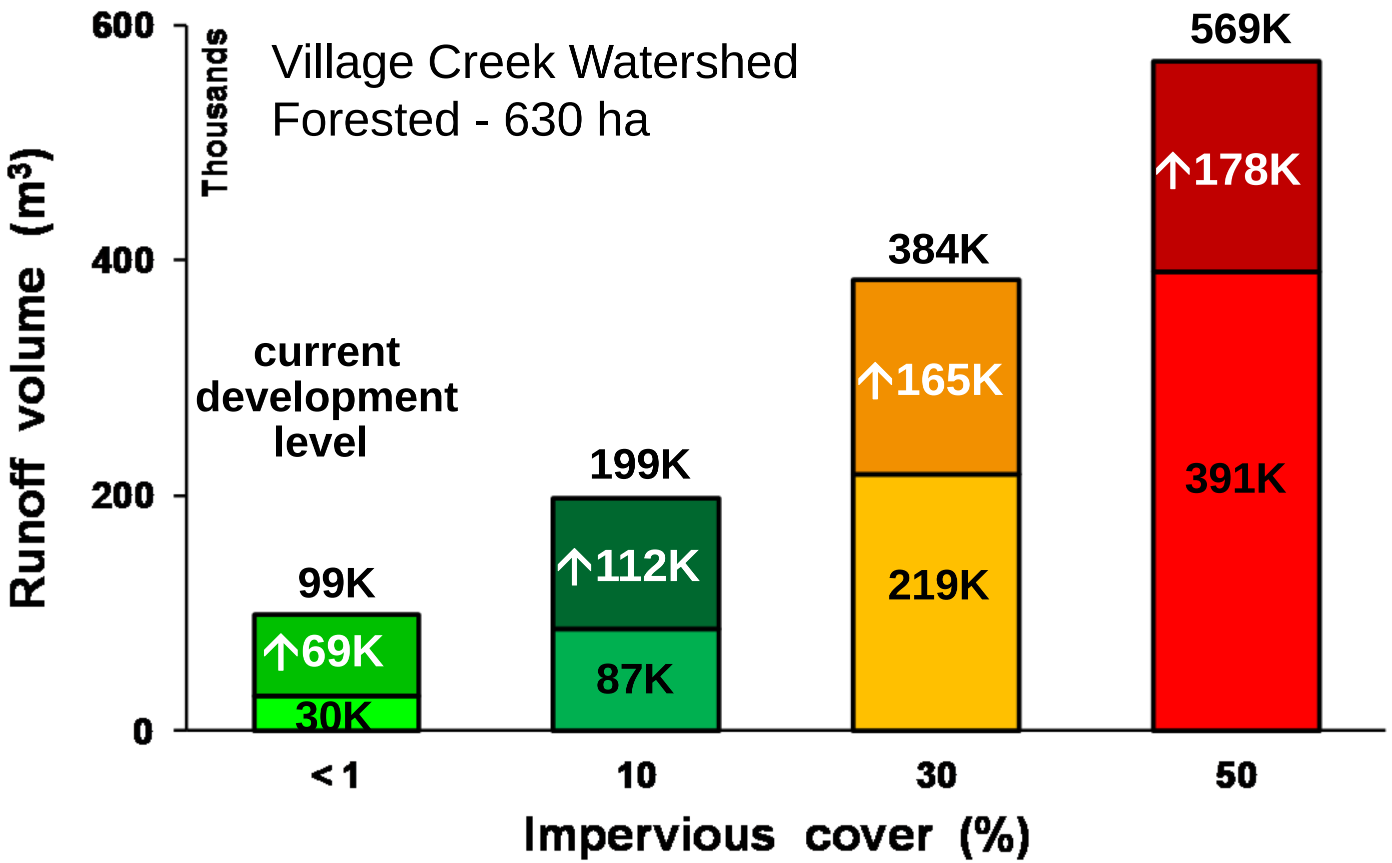
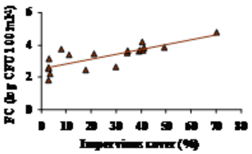


4.5-in storm event, average runoff conditions

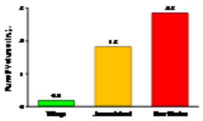
Climate impact – 5.2-in storm event, semi-saturated runoff conditions

Summary

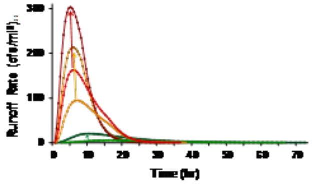
Pathogen indicator concentrations increase with impervious surfaces that accompany coastal development.



Stormwater runoff increases with coastal development and associated impervious surfaces.



Increased frequency and intensity of heavy storms will amplify impacts of coastal development.



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Thanks for listening

Questions?

Blair, A., D. Sanger, A.F. Holland, D. White, L. Vandiver, S. White. 2010. Stormwater Runoff – Modeling Impacts of Urbanization and Climate Change. Conference Paper in Proceedings of the 2010 South Carolina Water Resources Conference, Columbia, SC.

Holland, F. and D. Sanger. 2008. Tidal Creek Habitats: Sentinels of Coastal Health. Booklet prepared to highlight research outcomes and recommendations to local land use planners and the general public.

Sanger, D., A. Blair, G. DiDonato, T. Washburn, S. Jones, R. Chapman, D. Bergquist, G. Riekerk, E. Wirth, J. Stewart, D. White, L. Vandiver, S. White, and D. Whitall. 2008. Support for Integrated Ecosystem Assessments of NOAA's National Estuarine Research Reserves System (NERRS), Volume I: The Impacts of Coastal Development on the Ecology and Human Well-being of Tidal Creek Ecosystems of the US Southeast. NOAA Technical Memorandum NOS NCCOS 82. 76 pp. http://www.hml.noaa.gov/pdf/Tidal_Creek_Assessment_SE_NCCOS_Tech_Memo82.pdf

Tidal Creek Habitats Tool (web-based interactive map and tables providing public access to sentinel habitats data) http://www.hml.noaa.gov/tidalcreek/Default.aspx

				Geom Mean					Geom Mean	
f	Duplin Creek	ENT	733	7	f	Duplin Creek	FC	400	7	
f	Guerin Upland Cree	ENT	767	457	f	Guerin Upland (	FC	233	245	
f	Guerin Upland Cree	ENT	871		f	Guerin Upland (	FC	425		
f	North Inlet, Crab Ha	ENT	96		f	North Inlet, Crab	FC	65		
f	Oakdale	ENT	900		f	Oakdale	FC	1367		
f	Village Creek	ENT	164		f	Village Creek	FC	56		
f	Village Creek	ENT	600		f	Village Creek	FC	269		
s	Albergottie Upland	ENT	3100	10	s	Albergottie Upla	FC	5300	10	
s	Cross Creek	ENT	191	1636	s	Cross Creek	FC	430	2681	
s	Hewlitts Creek	ENT	2500		s	Hewlitts Creek	FC	3200		
s	Hewlitts Creek	ENT	3000		s	Hewlitts Creek	FC	4600		
s	James Island Scho	ENT	3600		s	James Island S	FC	5900		
s	James Island Scho	ENT	5100		s	James Island S	FC	7200		
s	Okatee River	ENT	564		s	Okatee River	FC	280		
s	Orangegrove Uplai	ENT	593		s	Orangegrove U	FC	4000		
s	Parrot Upland Cree	ENT	1933		s	Parrot Upland (	FC	2800		
s	Whiskey Creek	ENT	2600		s	Whiskey Creek	FC	4300		
u	Bulls Creek	ENT	21000	6	u	Bulls Creek	FC	14818	6	5
u	Burnett Creek	ENT	2268	5086	u	Burnett Creek	FC	2400	10684	6961
u	New Market Creek	ENT	6000		u	New Market Cre	FC	26000		
u	New Market Creek	ENT	6524		u	New Market Cre	FC	91000		
u	Postell	ENT	3200		u	Postell	FC	2600		
u	Shem Creek	ENT	2900		u	Shem Creek	FC	6800		

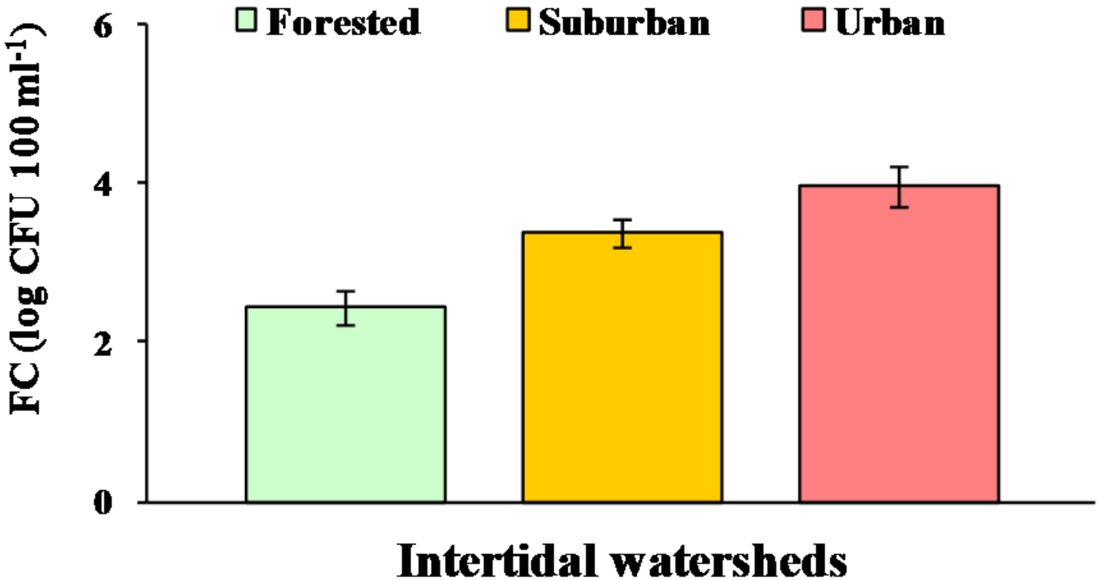
Hewlitts Creek	F+colipha	0		Hewlitts Creek	F-coliphag	114
Hewlitts Creek	F+colipha	1		Hewlitts Creek	F-coliphag	165
Whiskey Creek	F+colipha	0		Whiskey Creek	F-coliphag	165
Albergottie Upland Creek	F+colipha	4		Albergottie Upland Cre	F-coliphag	82
Bulls Creek	F+colipha	209		Bulls Creek	F-coliphag	624
Cross Creek	F+colipha	2		Cross Creek	F-coliphag	23
Guerin Upland Creek	F+colipha	0		Guerin Upland Creek	F-coliphag	40
Guerin Upland Creek	F+colipha	0		Guerin Upland Creek	F-coliphag	0
James Island School	F+colipha	26		James Island School	F-coliphag	201
James Island School	F+colipha	39		James Island School	F-coliphag	1224
New Market Creek	F+colipha	453		New Market Creek	F-coliphag	767
New Market Creek	F+colipha	221		New Market Creek	F-coliphag	190
North Inlet, Crab Haul	F+colipha	0		North Inlet, Crab Haul	F-coliphag	29
Okatee River	F+colipha	0		Okatee River	F-coliphag	7
Orangegrove Upland Creel	F+colipha	0		Orangegrove Upland (	F-coliphag	92
Parrot Upland Creek	F+colipha	0		Parrot Upland Creek	F-coliphag	47
Shem Creek	F+colipha	1		Shem Creek	F-coliphag	255
Village Creek	F+colipha	0		Village Creek	F-coliphag	7
Village Creek	F+colipha	0		Village Creek	F-coliphag	2
Burnett Creek	F+colipha	0		Burnett Creek	F-coliphag	454
Duplin Creek	F+colipha	0		Duplin Creek	F-coliphag	1
Oakdale	F+colipha	6		Oakdale	F-coliphag	123
Postell	F+colipha	5		Postell	F-coliphag	73

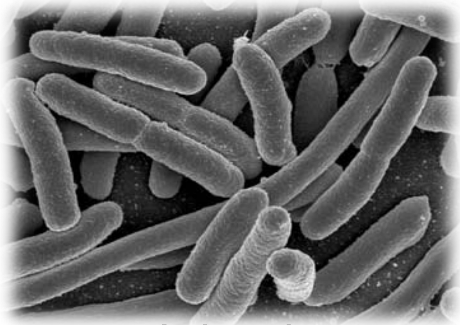
Male-specific coliphages isolated during this study will be further characterized to distinguish between F+RNA coliphages and F+DNA coliphages. Confirmed F+RNA coliphages will be genetically typed into one of four subgroups to aid source identifications (Stewart et al. 2006). Based on ecology studies, groups II and III are typically associated with human feces and wastewaters, while groups I and IV are typically associated with animal feces and wastewaters. These associations appear to be statistically significant (Schaper et al. 2002) and studies within the United States have concluded that the approach is useful, although not absolute, for distinguishing human from nonhuman sources of pollution (Stewart et al. 2006).

Fecal coliform concentrations increase with development

Geometric Mean (CFU / 100 ml)

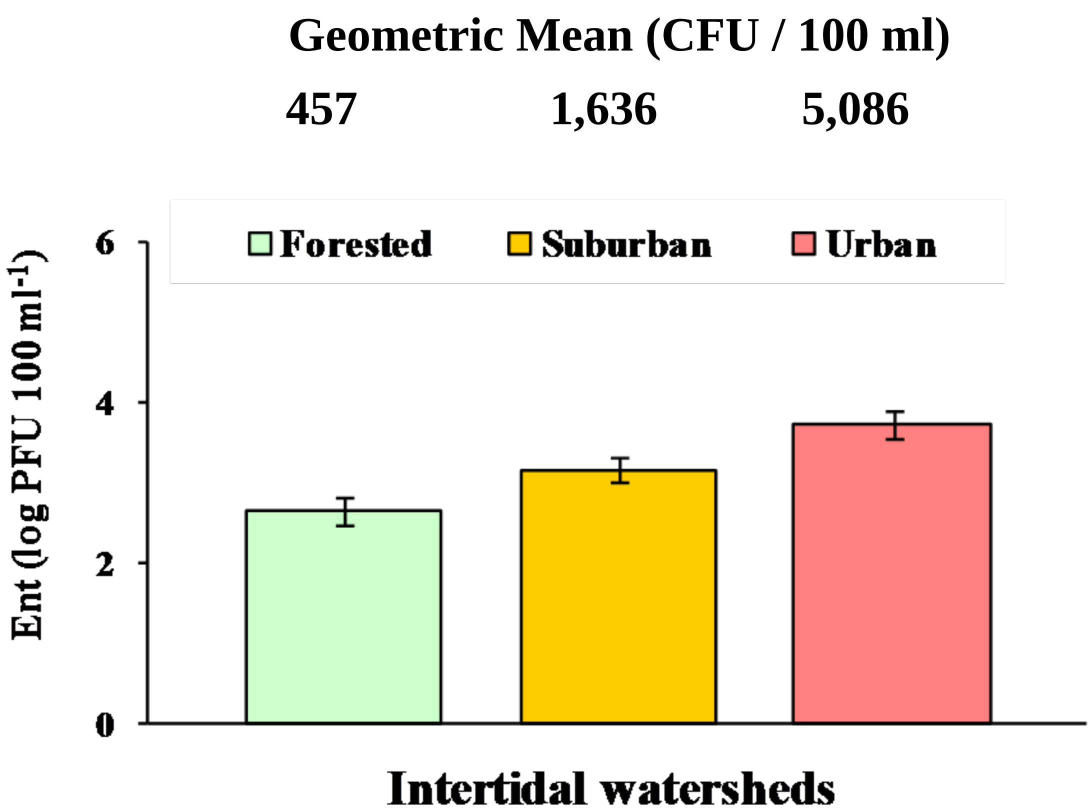
245	**2,681**	**10,684**





ttp://www.columbiariverkeeper.org/index.php/adopt_river/ecoli_monitoring

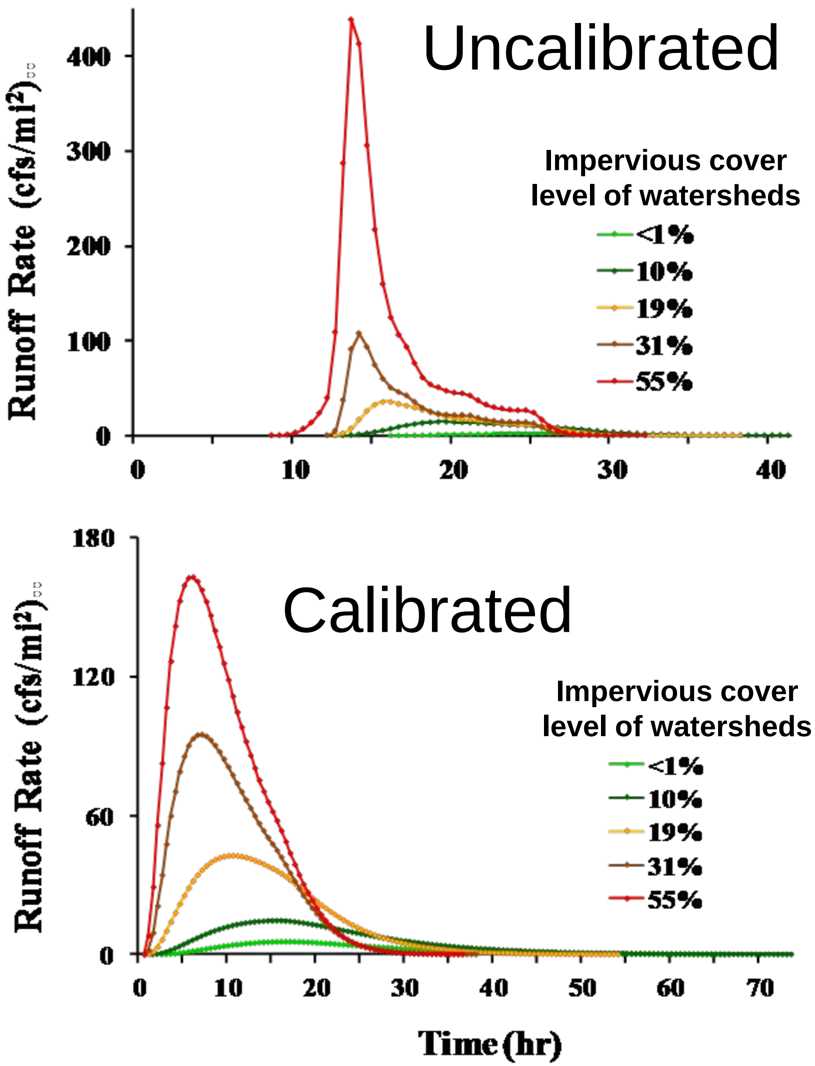
Enterococcus concentrations increase with development



http://microbewiki.kenyon.edu/images/b/bc/Wiki.png

Calibration

Stormwater runoff model was calibrated



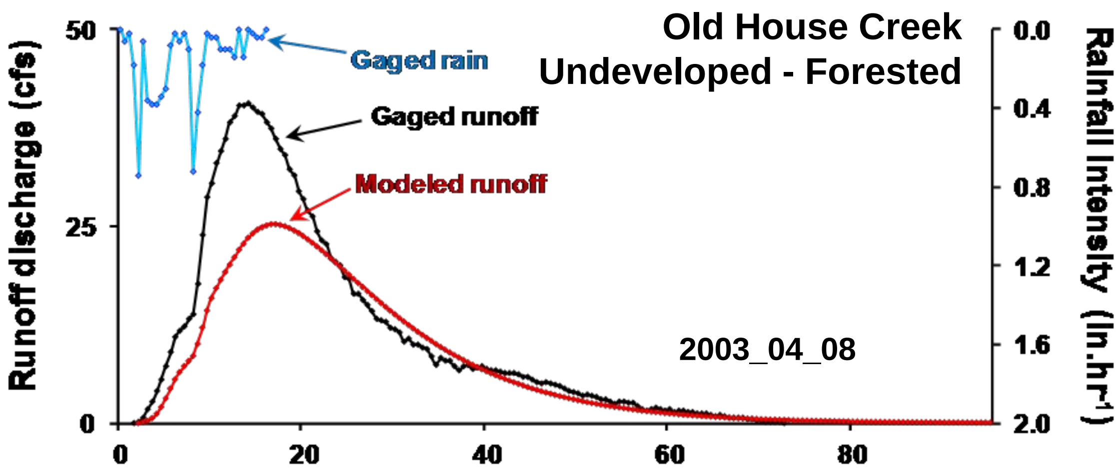
CALIBRATION

- Temporal rain distribution
- Peak rate factor
- Soil class change
- Sheet flow equation
- Ia : S ratio

24-hr 4.5-in storm event, average runoff conditions

Validation

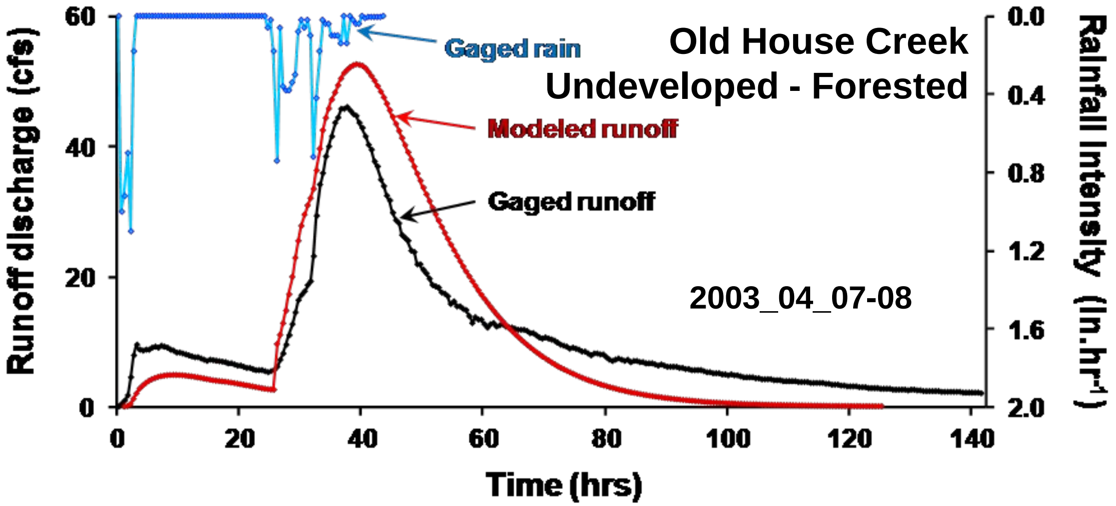
Model validation used USGS gaged rain and discharge data.



2.6 – Rainfall (inches)

Runoff (inches
1.17 – Gaged
0.92 – Modeled

0.93 - Curve r^2



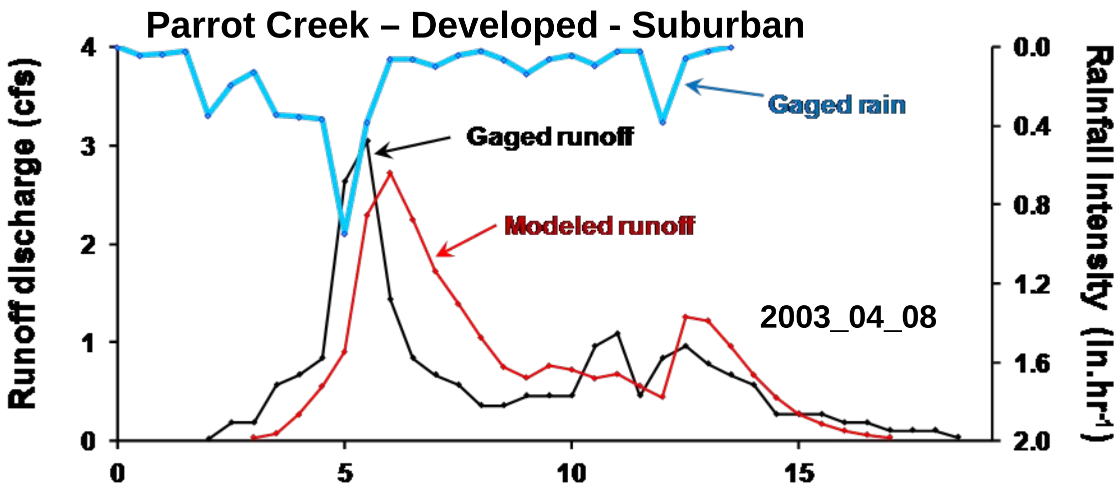
4.6 – Rainfall (inches)

Runoff (inches
2.20 – Gaged
2.14 – Modeled

0.97 - Curve r^2

Validation

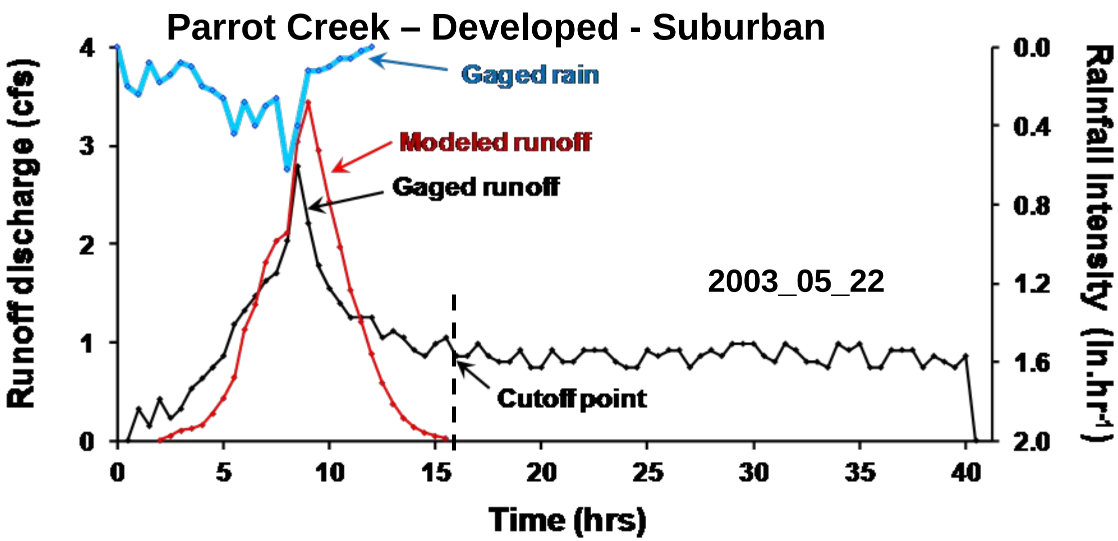
Model validation used USGS gaged rain and discharge data.



2.2 – Rainfall (inches)

Runoff (inches)
0.57 – Gaged
0.62 – Modeled

0.41 - Curve r^2



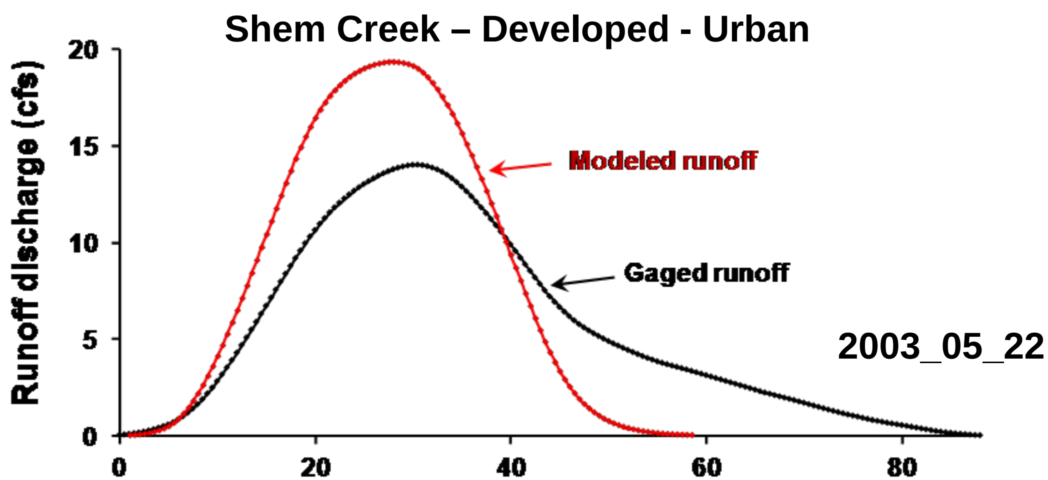
2.4 – Rainfall (inches)

Runoff (inches)
0.90 – Gaged
0.77 – Modeled

0.81 - Curve r^2

Validation

Model validation used USGS gaged rain and discharge data.

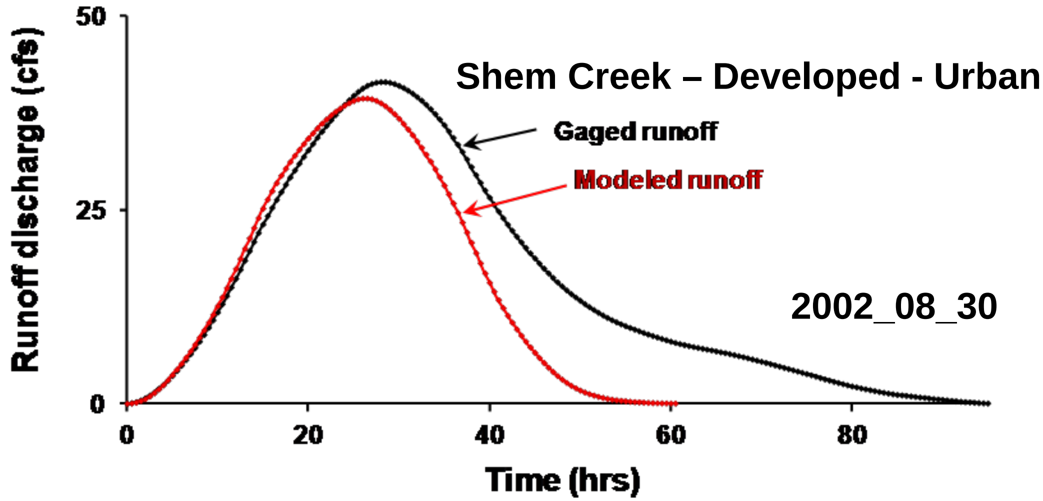


2.6 – Rainfall (inches)

Runoff (inches
1.17 – Gaged
0.92 – Modeled

0.88 - Curve r^2

Palmetto Filter (USGS-Conrads)



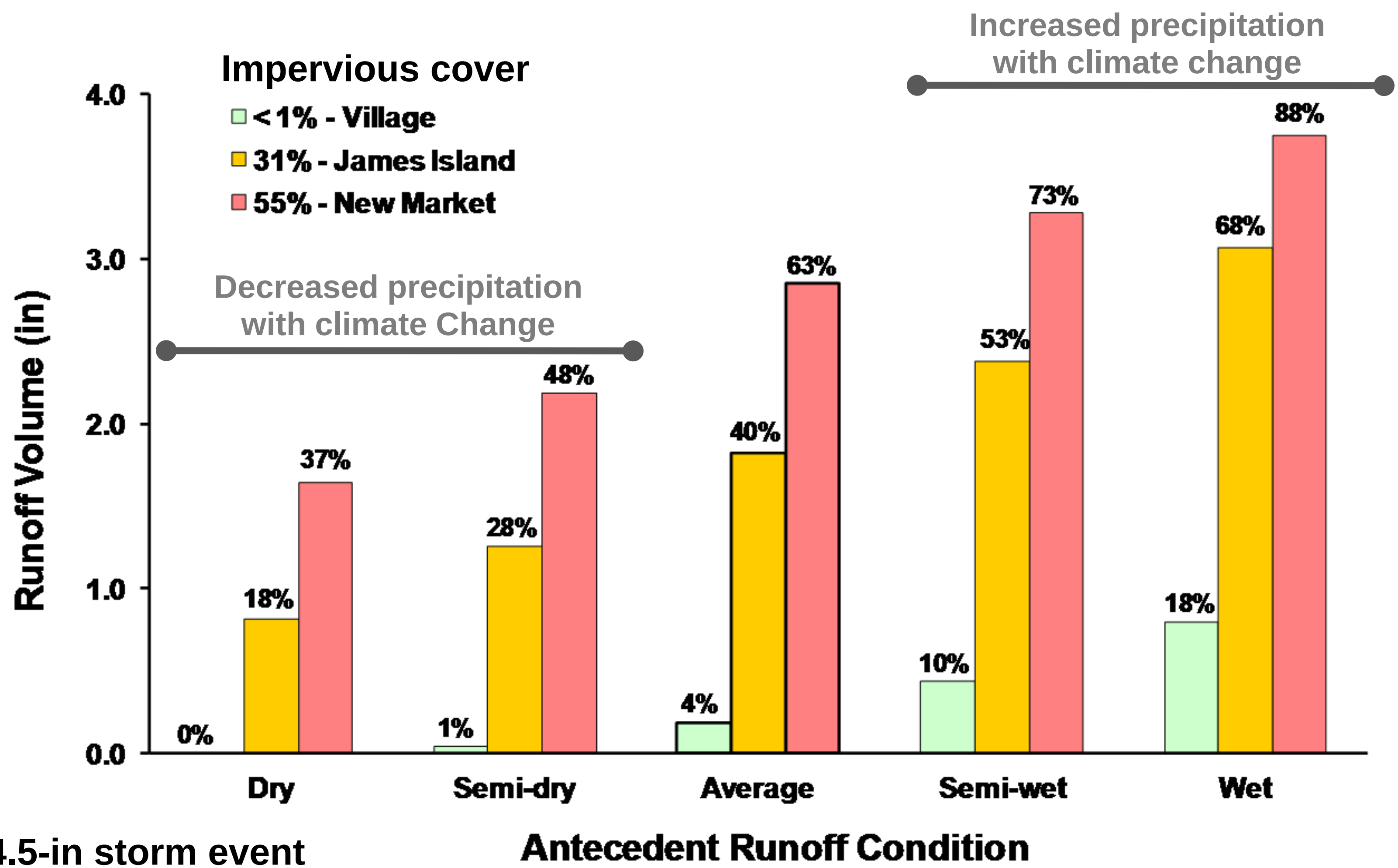
4.4 – Rainfall (inches)

Runoff (inches
3.50 – Gaged
2.51 – Modeled

0.88 - Curve r^2

Projecting impact of climate change

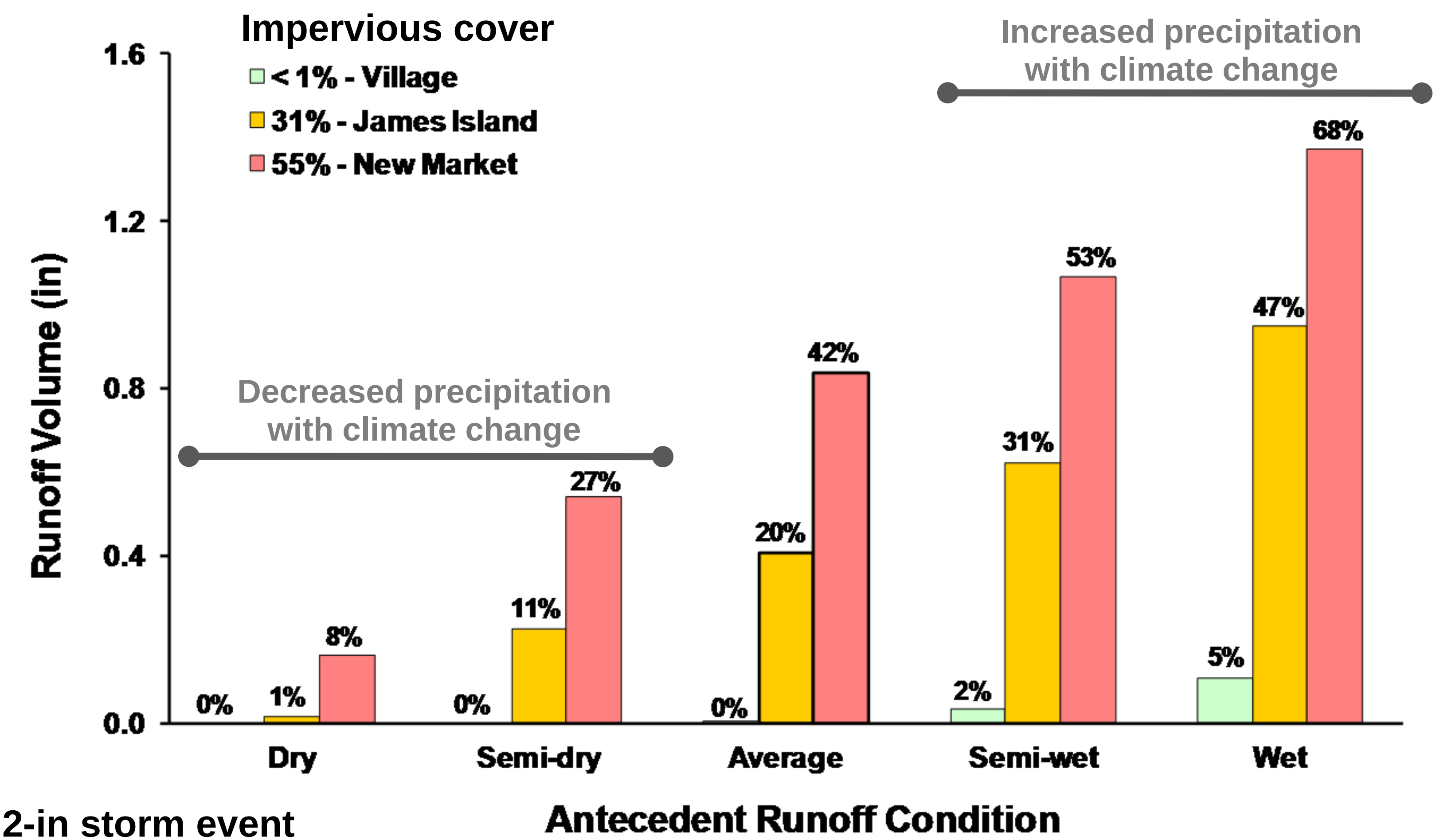
Precipitation – wet periods will be wetter and dry periods dryer



4.5-in storm event

Projecting impact of climate change

Precipitation – wet periods will be wetter and dry periods dryer



2-in storm event