Which Competing Hydraulic Design Model is Right for Your Municipality?

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Background

Charlotte-Mecklenburg
STORM
WATER
Services

UNC CHARLOTTE

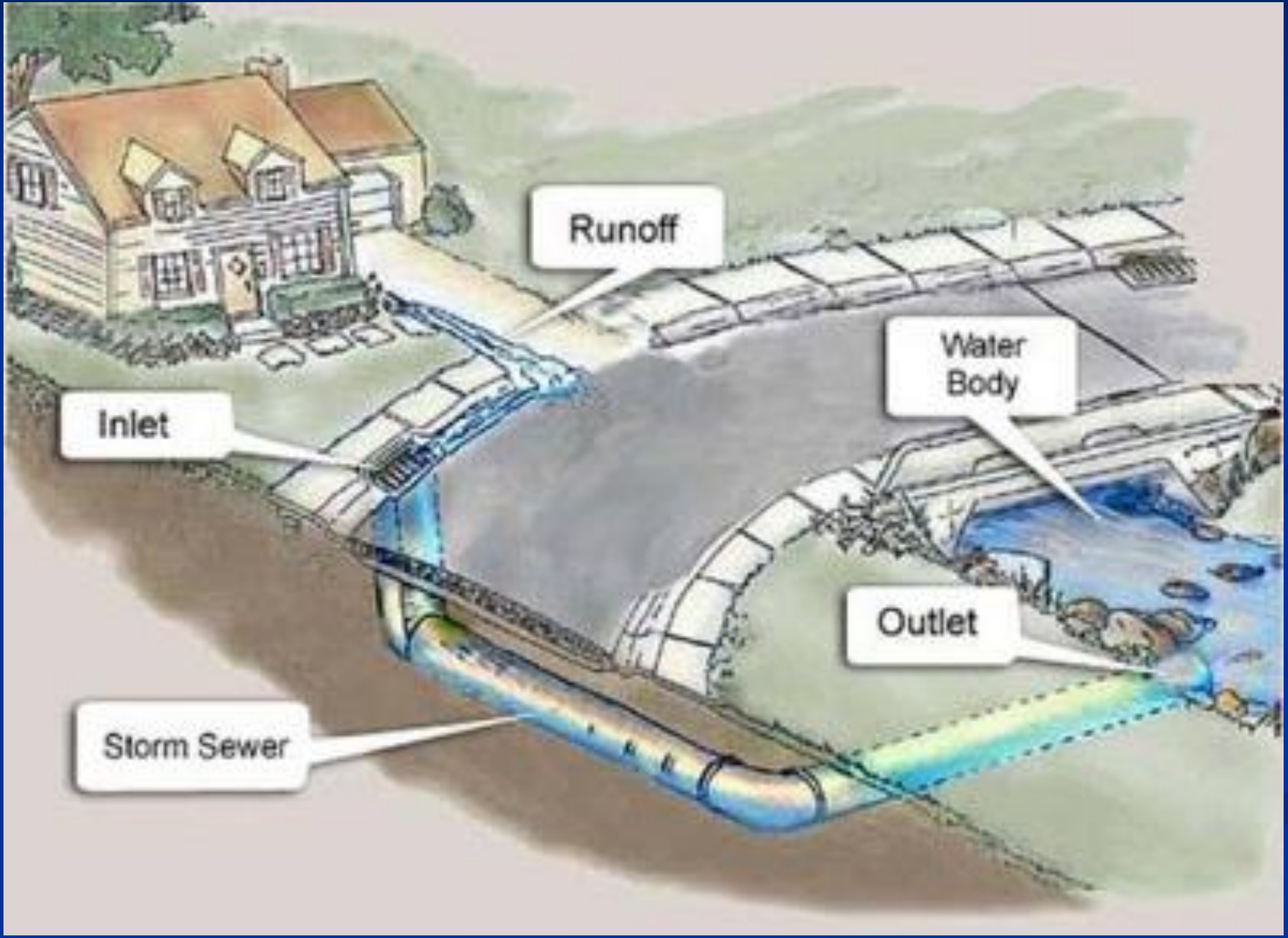
The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

SWMM

- Storm Water Management Model
- Developed by EPA
- Planning, analysis and design for stormwater

Charlotte – Careful Review of Hydraulic Models

Urban Watersheds



Illustrating Property Impacts

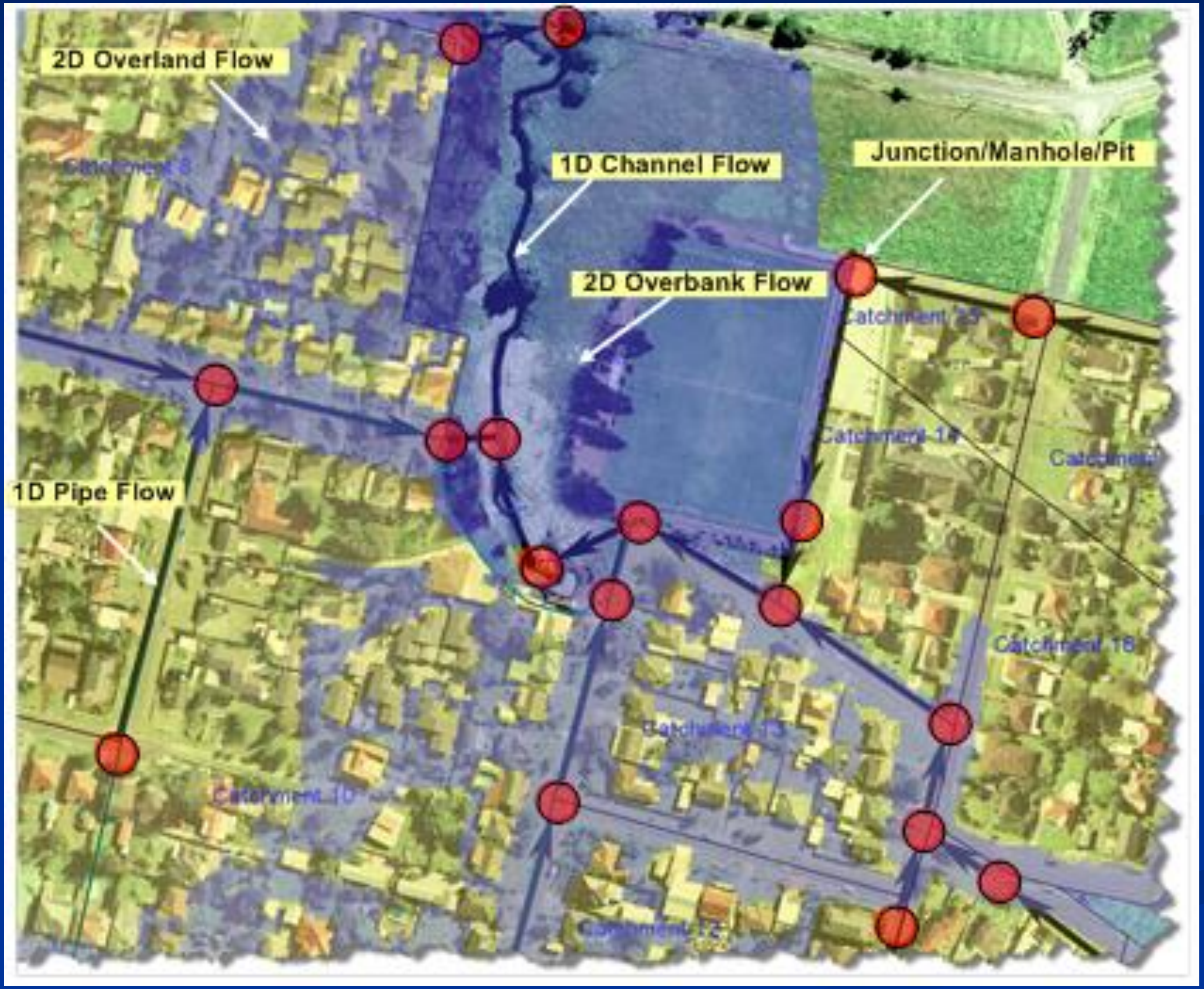


Image source: xpsolutions Tutorial 17: 2D Urban Flooding

Multiple Hydraulic Modeling Software Options

FLO-2D SOFTWARE

InfoWorks® ICM

XP SWMM

Bentley Sustaining Infrastructure

StormCAD®
Storm Sewer Design and Modeling

Autodesk® Storm & Sanitary Analysis

icpr®

Hydrologic Engineering Center

US Army Corps of Engineers

Wave Models

- Dynamic Wave (St. Venant's Equation)
- Kinematic Wave (Simplification)

Dynamic Wave Equation

Image Source: www.redbubble.com

Full Dynamic Wave (Saint Venant)

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - fv = -g\frac{\partial h}{\partial x} - bu,$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu = -g\frac{\partial h}{\partial y} - bv,$$

$$\frac{\partial h}{\partial t} = -\frac{\partial}{\partial x}\Big(u\,(H+h)\Big) - \frac{\partial}{\partial y}\Big(v\,(H+h)\Big)$$

- Complete representation of momentum and changes in downstream and side-to-side movement, as well as conservation of mass with flow and cross-section.

Kinematic Wave

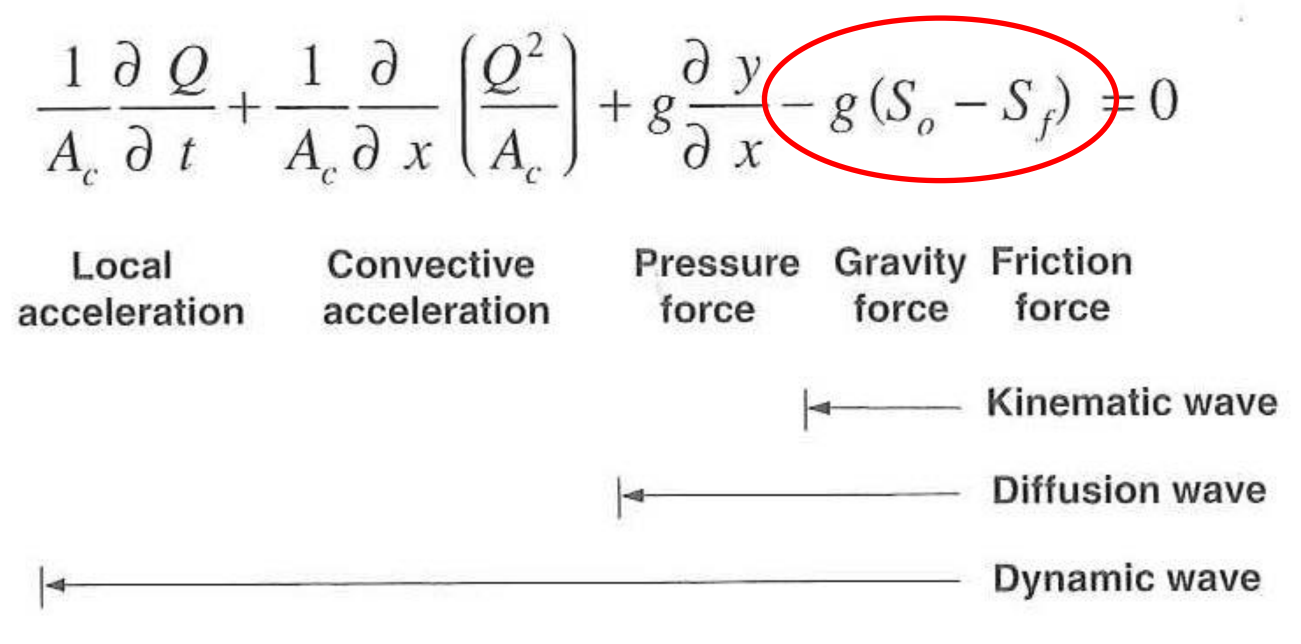


FIGURE 14.7
The St. Venant equation for momentum can be simplified by dropping terms as shown (redrawn from Chow et al. 1988).

Image Source: Chapra "Surface Water-Quality Modeling" 1997

- Simplified dynamic wave – gravitational momentum versus friction force.

Criterion For Accurate Kinematic Model

Ponce et al. (1978) criterion for kinematic:

- $\tau^* = T\, S_0\, F_n\, (g/y_0)^{1/2} > 171$
- Variables:
  - T = the wave period of the sinusoidal perturbation to the steady uniform flow
  - S_0 = the channel bottom slope
  - F_n = the steady uniform Froude number
  - y_0 = the uniform flow depth

Test Kinematic Criterion on Typical Charlotte Urban Watershed

Test Kinematic Criterion on Typical Charlotte Urban Watershed

Project name	Channel slope at outfall (first 500 feet)	10-yr storm peak flow (cfs)	T(c) (hrs)	Length of system (ft)	Froude
Parkwood	0.008	1424	3.23	6800	0.09
Lyon Court	0.0077	922	3.25	6500	0.03
Water Oak	0.009	224.5	3.66	4500	0.3
Cutchin	0.0254	472.6	3.52	4500	0.64
Averages	0.0125	761	3.42	5575	0.27

Ponce et al. (1978) criterion for kinematic:

- $\tau^* = T\, S_0\, F_n\, (g/y_0)^{1/2} = 1{,}990 > 171$

Difference in Practice?

Image Source: Public Domain/R.R. Cratty

Coastal Communities Using Dynamic Wave?

Hilton Head Island, SC

Thanks to Jeff Buckalew, PE, Town Engineer, and Brian McIlwee, PE, Stormwater Administrator

Wilmington, NC

Thanks to Robert Gordon, PE, Plan Review Engineer

Virginia Beach, VA

Thanks to Greg Johnson, PE, Stormwater Technical Services Engineer

Rocky Mount, NC

CITY OF
ROCKY
MOUNT
NORTH CAROLINA

Thanks to Donald Perry, PE, Stormwater Engineer

Asheville, NC

Asheville
NORTH CAROLINA
"Quality of Service, Quality of Life"

Thanks to McCray Coates, PE, Stormwater Services Manager, and
Marcus Barksdale, PE, Stormwater Services Coordinator

Key Points

- Dynamic wave equation-based hydraulic models are important to specify when:
  - Slopes are less than 0.5%
  - There are potentially significant backwater effects such as tidal forces
  - If 2D analysis of overland flow is needed
- For channel analysis, most engineers are using software that uses the dynamic wave equation

What Should Municipalities Ask?

Image Source: www.thepajamacompany.com

Questions

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