CI1550 Hydraulics and Hydrology: The Water Resource Tools Available in Autodesk® Infrastructure Design Suite

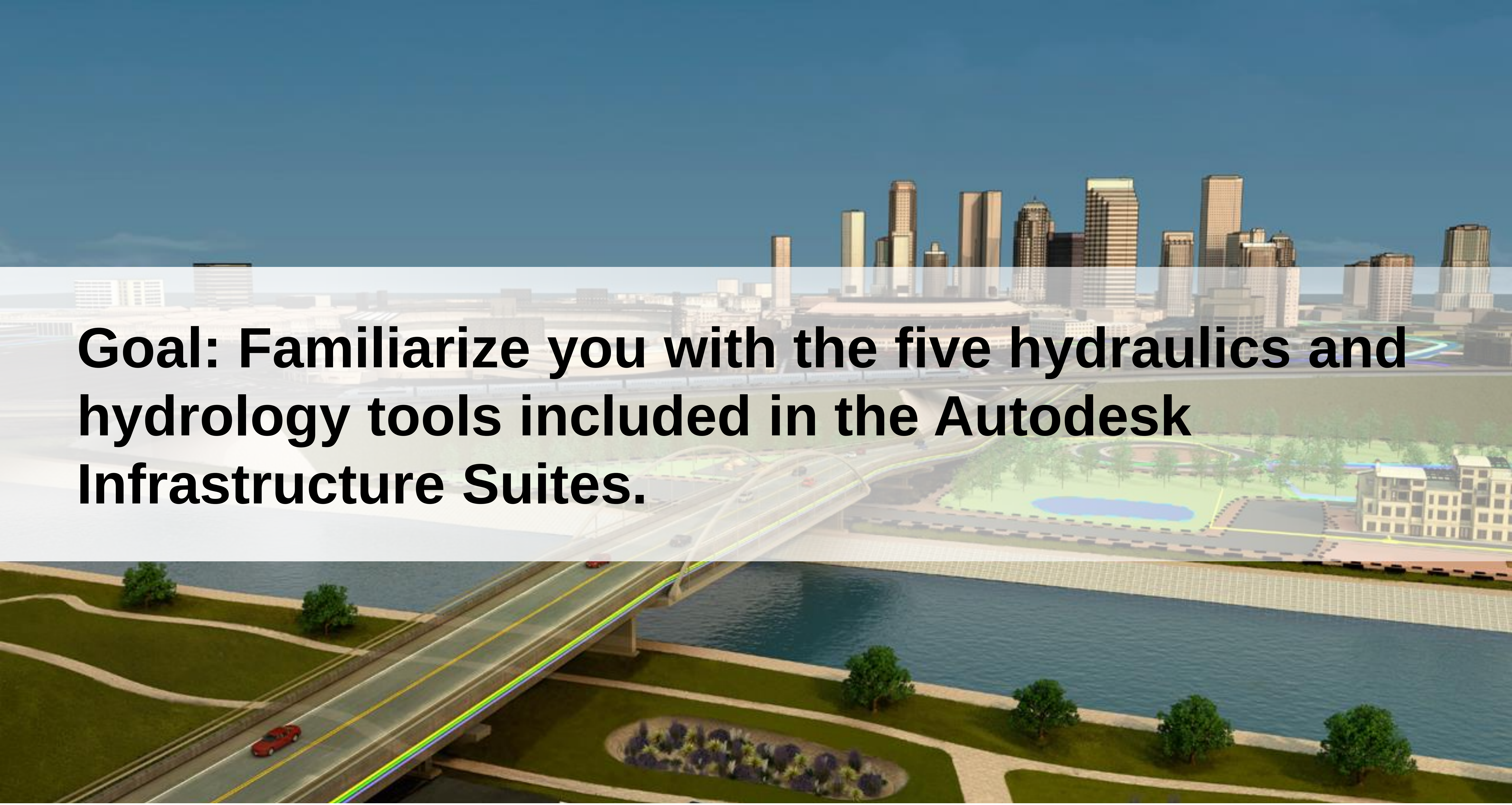
Dino Lustri, P.E., P.S., ACI

Consulting Civil Engineer, Surveyor and Mapper

Water Resources

Class summary

- Autodesk has given us a variety of water resource tools in Autodesk Infrastructure Design Suite. If you are a manager or a designer, you need to know if you can stop paying maintenance on competing software and move your organization forward with a single suite of tools. You want to know what is in the suite from someone who does what you do and if it can do the things you need it to do. In this class, you get a better understanding of what equations are being used in which applications and how to find the right fit for the project requirements that are being passed on down to you. We review Storm Sewers, Hydrographs, Express Tools, SSA, and River Analysis. You also learn some tips and tricks that those who already are familiar with these tools can use.



Goal: Familiarize you with the five hydraulics and hydrology tools included in the Autodesk Infrastructure Suites.

Key learning objectives

At the end of this class, you will be able to:

- Describe which H&H tools are available to you in the suites.
- Determine which H&H tool will best suit the requirements being asked of you.
- Decide if you can terminate competitive H&H products and save money.
- Use some tips and tricks for general H&H efforts.

Express Tools

Autodesk

Hydraflow Express Extension

AutoCAD®

Culverts

Civil 3D® 2014

Culverts | Channels | Inlets | Hydrology | Weirs

Uses Bernoulli's energy equation Standard Step method when computing the hydraulic profile for outlet control.
It uses Manning's equation to determine head losses due to pipe friction.

Hydraflow Express Extension uses the following equation:

$$\frac{V_1^2}{2g} + Z_1 + Y_1 = \frac{V^2}{2g} + Z_2 + Y_2 + HL$$

Hydraflow Express Extension

AutoCAD®

Channels

Civil 3D® 2014

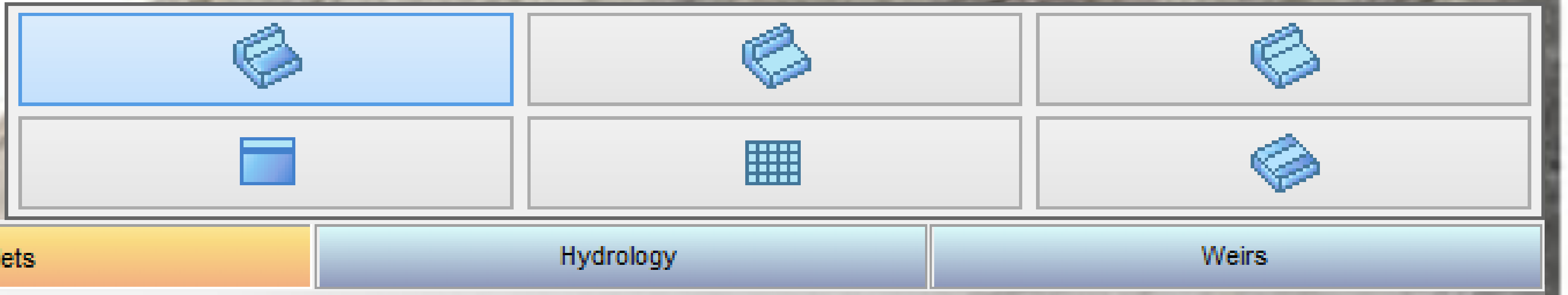
Uses Manning's equation to compute Qs at varying depths of flow. When a known Q is specified, it solves for the depth using an iterative procedure.

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S}$$

Hydraflow Express Extension

AutoCAD® Civil 3D® 2014

Inlets



Follows the basic methodology of FHWA HEC-22 for inlet interception capacity calculations. Clogging factors are not used in this program.

ON SAG:

Curb inlet $Q = C_w(L + 1.8W)d^{1.5}$

Grate inlet $Q = C_o A_g \sqrt{2gd}$

Slotted inlet $Q = C_w L D^{1.5}$

ON GRADE:

Curb inlet $L_T = K_T Q^{0.42} S_L^{0.3} \left(\frac{1}{n S_e}\right)^{0.6}$

Grate inlet $E = R_f E_o + R_s(1 - E_o)$

Slotted inlet $L_r = \frac{0.706\, Q^{0.442} S^{E} Z^{0.849}}{n^{0.384}}$

Q < 5.5 cfs, Slope < 0.09

Hydraflow Express Extension

AutoCAD® Civil 3D® 2014

Hydrology

Culverts	Channels	Inlets	Hydrology	Weirs

Uses the Unit Hydrograph Method for calculating runoff hydrographs. More specifically, it uses the triangular D-hour Unit Hydrograph approach.

$$Qp = \frac{484AQ}{Tp}$$

$$Tp = \frac{Tc + D}{1.7}$$

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

Hydraflow Express Extension

AutoCAD®

Weirs

Civil 3D® 2014

Culverts | Channels | Inlets | Hydrology | Weirs

Uses a variety of forms of the fundamental weir equation to compute flow rates at varying depths of flow. Sources for these equations include HEC-22 and "Open Channel Hydraulics", Richard French.

$$Q = CwL\,H^{1.5}$$

$$Q = CwA\sqrt{H}$$

$$Q = Cw\,H^{2.5}$$

$$Q = 3.1[B + .8Hz]\,H^{1.5}$$

$$Q = 4.96\sqrt{a}B(H - a/3)$$

Hydraflow Express Extension

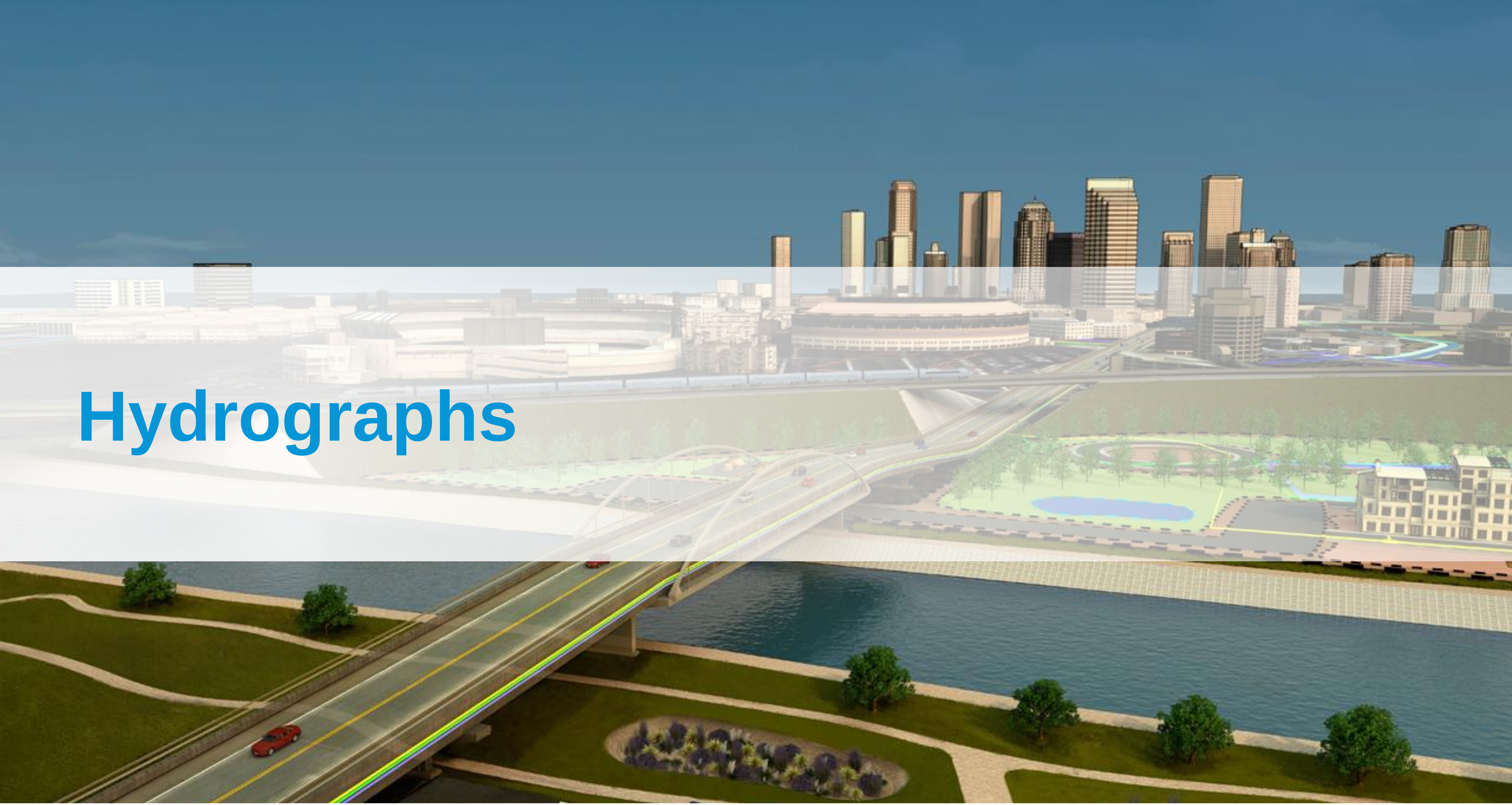
AutoCAD®

TIP

Civil 3D® 2014

Uses fixed values for the design velocity, min. and max. pipe sizes, min. slope, and so on.
You can modify these values by editing Express.ini located in…

C:\Users\dlustri\AppData\Local\Autodesk\C3D 2014\enu\HHApps\Express



Hydrographs

Hydraflow Hydrographs Extension

Uses the HEC-22, NRCS, and the Rational methods for most hydrologic calculations.

- NEH-4: Hydrology; Section 4, National Engineering Handbook
- TR-20: Computer Program Manual, 1992
- TR-55: Urban Hydrology For Small Watersheds
- A Guide To Hydrologic Analysis Using SCS Methods, Richard McCuen
- HEC No. 12: FHA, Drainage of Highway Pavements
- HEC No. 22: FHA, Urban Drainage Design Manual
- Hydrology for Engineers; Linsley, Kohler & Paulhus
- Urban Storm Drainage Management; Sheaffer, Wright, Taggart & Wright
- Handbook of Hydraulics; Brater, King, Lindell, Wei

Hydraflow Hydrographs Extension

Hydrographs

Uses the unit hydrograph method for calculating runoff hydrographs. It uses the triangular D-hour unit hydrograph approach as used in TR-20. The unit hydrograph represents a 1-inch rainfall over one time interval.

$$Qp = \frac{484AQ}{Tp}$$

Mountainous (600) > 484 > Swampy (300)

Storm Sewers

Hydraflow Storm Sewers Extension

AutoCAD®

Storm Sewers

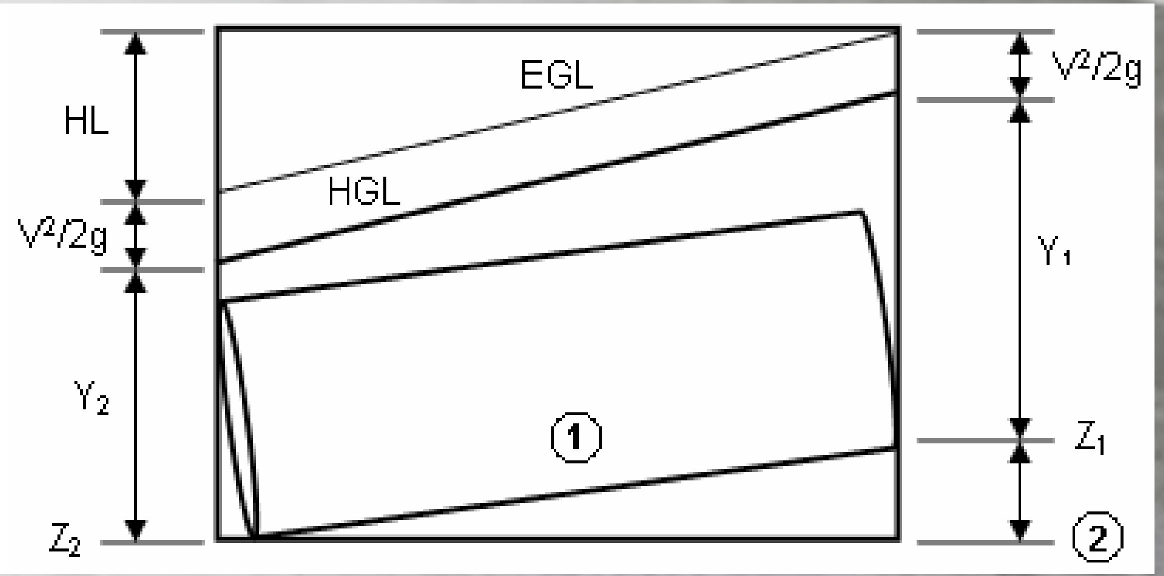
Civil 3D® 2014

Uses the Bernoulli Energy-based Standard Step method to compute the hydraulic profile.
It uses Manning's Equation to determine head losses due to pipe friction.

$$\frac{V_1^2}{2g}+Z_1+Y_1=\frac{V^2}{2g}+Z_2+Y_2+HL$$

$$HL=\frac{(hf_1+hf_2)}{2}$$

$$hf=\left(\frac{Qn}{K_m A R^{.667}}\right)^2\times LineLength$$



Hydraflow Storm Sewers Extension

AutoCAD®

Storm Sewers

Civil 3D® 2014

It uses Manning's Equation to determine head losses due to pipe friction.

- Calculates pipes flowing full

- (S) Slope of the invert refers to Energy Line Slope

$$D = \left(\frac{KdnQ}{\sqrt{S}} \right)^{0.375}$$

Where: D = Pipe diameter in ft (m)

n = Manning's n-value

Q = Line discharge in cfs (cms) or velocity x pipe area

S = Slope of the invert in ft/ft (m/m)

Kd = 2.16 (3.20)

Hydraflow Storm Sewers Extension

AutoCAD®

TIP

Civil 3D® 2014

When the real velocity is different from the assumed velocity, the computed Tc is incorrect and thus the computed Q and resulting HGL are incorrect. The EMS solves this problem by re-computing the HGL based on actual flow rates and actual Tc. To do this Hydraflow Storm Sewers Extension must compute three system iterations so that the computed Tc match those that were assumed with reasonable accuracy.

Hydraflow Storm Sewers Extension first computes the HGL using Tc based on the design velocity. It then computes the system a second time using Tc based on actual velocities. These new velocities are still incorrect because they are based on the original HGL calculation, however they are more accurate than those used on the first trial. As one would expect, several system iterations would cause the Q, Tc, and resulting HGL to converge to correct values. After extensive testing, it has been concluded that three iterations is the most practical balance between accuracy and time required to produce the results.

SSA: Storm and Sanitary Analysis

Storm and Sanitary Analysis

Hydrology Modeling Capabilities

- USEPA SWMM 5.0 (also imports and exports XPSWMM models)
- NRCS (SCS) TR-55
- NRCS (SCS) TR-20
- US Army Corps HEC-1
- Rational Method
- Modified Rational Method
- UK Modified Rational (Wallingford Procedure)
- DeKalb Rational Method
- Santa Barbara Unit Hydrograph
- Delmarva Unit Hydrograph
- Long-Term Continuous Simulation
- Maricopa & Pima Counties (Arizona) Papadakis-Kazan methodology
- Harris County (Texas) Method

Storm and Sanitary Analysis

Hydraulic Modeling Capabilities

1) Kinematic Wave (default)
2) Steady Flow
3) Hydrodynamic (i.e., Saint Venant equations)

- Storm sewers, sanitary sewers, and combined sewers
- Open channels
- Streams
- Bridges and culverts
- Curb and gutter storm drain inlets
- Detention ponds and outlet structures
- Force mains (using either Hazen-Williams or Darcy-Weisbach equations)
- Flood overflow routing

AUTODESK® AUTOCAD® STORM AND SANITARY ANALYSIS 2014

Storm and Sanitary Analysis

Kinematic Wave & Steady Flow

Cannot model backwater. Similar to Storm Sewers. HGL Spikes.

Hydrodynamic

Can model…

- backwater effects
- flow reversal
- surcharging
- looped connections
- pressure flow
- tidal outfalls
- interconnected ponds

Storm and Sanitary Analysis

In SSA, the equations used are…

For open channel and partially filled conduit, Mannings.

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

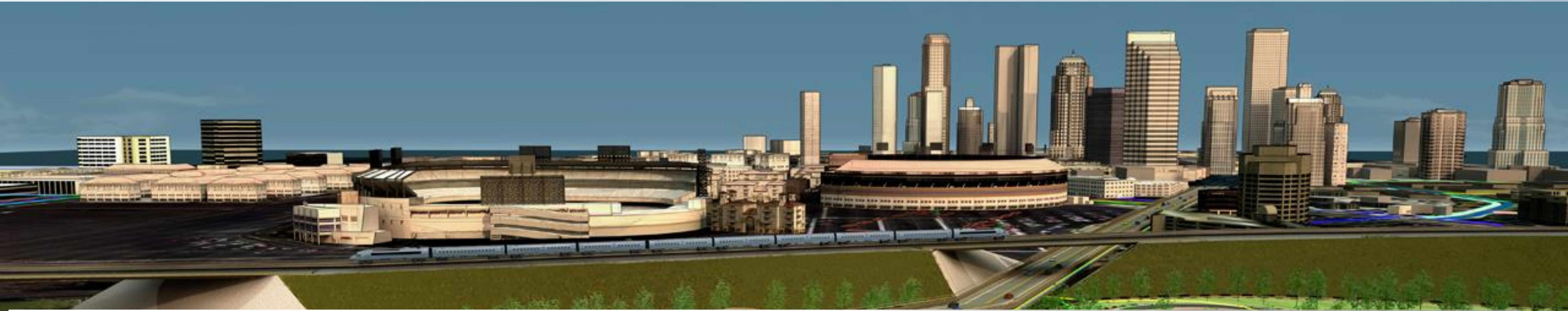
For Steady Flow and Kinematic Wave, the slope is the pipe slope.
For Hydrodynamic, it is the friction slope.

For pressurized systems, Hazen-Williams or Darcy-Weisbach replace Mannings.

$$Q = 1.318 C A R^{2/3} S^{1/2}$$

$$Q = \sqrt{\frac{8g}{f}} A R^{1/2} S^{1/2}$$

SSA vs. Storm Sewers vs. Hydrographs



So why use the other packages? Why don't we only use SSA?

1) Overkill
2) Time to enter data
3) Interactive peak flow design is better in Hydrographs and Storm Sewers

It depends on what you are being asked to do.

River Analysis

River Analysis

HEC-RAS with benefits

- Takes advantage of all your terrain tools in Civil 3D.

Benefits:

- Extract large amounts of data, rapidly,
- Taking advantage of your Civil 3D dynamic environment.

Let’s take a brief look at the suite…

…

SUMMARY

What software can you replace?

Which Suites have which tools?

MAP has the maintenance work space to facilitate the gathering of data.

Civil 3D Water Resource CAD tools:

- Stage Storage
- Water Drop
- Catchment
- Watershed Style
- Undocumented Commands…

Find your comfort level…calibrate….compare….verify

http://www.peanuts.com/characters/

AUTODESK®