Agenda

- Hydraulic Consultant Precertifications
- Introduction to 2D Hydraulic Analysis
- Subsurface Utility Design and Analysis (SUDA), Bentley Software Update
Hydraulic Design & Analysis Precertification Categories

- 10.1.1 Hydrologic Studies
- 10.2.1 Basic Hydraulic Studies
- 10.3.1 Complex Hydraulic Design
- 10.4.1 Pump Stations–Hydraulics
- 10.4.2 Pump Stations–Electrical
- 10.4.3 Pump Stations–Structures
- 10.5.1 Bridge Scour Evaluations and Analysis
Basic Requirements

- Licensed P.E.
- At least 2 years experience
- Demonstrate how you meet the minimum requirement for the category
Hydraulic Design & Analysis

- **Includes:**
  - Design of Hydraulic Structures
  - Analysis using hydrologic/hydraulic models

- **Does not include:**
  - Checking/reviewing hydraulics
  - Managing/overseeing a hydraulics project
  - Organizing/drawing the hydraulic sheets
<table>
<thead>
<tr>
<th>Category of Work</th>
<th>Description of Work Completed in This Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1.1 HYDROLOGIC STUDIES</td>
<td>PROVIDED RAINFALL AND RUNOFF DETERMINATION AND CHANNEL ROUTING IN THE HYDROLOGIC ANALYSIS OF COMPLEX DRAINAGE AREAS FOR BRIDGE CLASS CULVERT CROSSINGS AT TRIBUTARY WF-9 AND I-820</td>
</tr>
<tr>
<td>10.2.1 BASIC HYDRAULIC DESIGN</td>
<td>PROVIDED HYDRAULIC ANALYSIS USING HEC-RAS OF CULVERT CROSSINGS ALONG SR 121 AT WF-9 AND WF-9 TRIB</td>
</tr>
<tr>
<td>10.3.1 COMPLEX HYDRAULIC DESIGN</td>
<td>PROVIDED HYDRAULIC DESIGN USING HEC-RAS &amp; HYDRAULIC ANALYSIS FOR MULT OPENING BRIDGES OVER FLOODPLAIN W/ CHANNEL MOD</td>
</tr>
</tbody>
</table>
Common Problems & Application Tips

- Insufficient detail of work shown
  - Be descriptive
  - Include Methodology
    - Software/equations (method) used
    - Hand calculations/Spreadsheets

- Work described is not in the correct category
Common Problems & Application Tips

- Insufficient years of experience shown

- Only describes work in “PROJECT GENERAL DESCRIPTION”
  - Should describe work in “DESCRIPTION OF WORK” for each individual category
Common Problems & Application Tips

- Too much abbreviation
  - Can abbreviate but reasonably

- Reviewed/managed hydraulic design/analysis done by someone else
  - Only describe work personally done by applicant
  - Use words like designed, analyzed, modeled, computed, etc.
<table>
<thead>
<tr>
<th>Category(s) Of Work Covered In This Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

### Project Selection Menu

- [PROJECT 1](#)

<table>
<thead>
<tr>
<th>Project Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td></td>
</tr>
<tr>
<td>Date Began:</td>
<td>02 / 02 / 2010</td>
</tr>
<tr>
<td>Date Completed:</td>
<td>06 / 01 / 2011</td>
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<tr>
<td>Total Project Duration Represented In Days:</td>
<td>486</td>
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<tr>
<td>Total Project Duration Represented In Months:</td>
<td>15.68</td>
</tr>
<tr>
<td>Total Project Duration Represented In Years:</td>
<td>1.31</td>
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</table>

**Project General Description**

MIXED USE DEVELOPMENT ADJACENT TO US 281, INCLUDED THE DEVELOPMENT OF HYDROLOGIC FLOWS, STREET DESIGN, & DESIGN & CONSTRUCTION OF STORM SEWER SYSTEM W/ DISCHARGE INTO THE SA RIVER. THE PROJECT ALSO FEATURED COORDINATION ISSUES WITH TxDOT ALONG US 281 ROW.

<table>
<thead>
<tr>
<th>Contract Number:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager Name:</td>
<td></td>
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<tr>
<td>Client Name:</td>
<td></td>
</tr>
<tr>
<td>Client Phone Number:</td>
<td></td>
</tr>
<tr>
<td>Client Contact Name:</td>
<td></td>
</tr>
<tr>
<td>Estimated Construction Cost:</td>
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<tr>
<td>Estimated Project Fees:</td>
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</table>

<table>
<thead>
<tr>
<th>Category of Work</th>
<th>Description of Work Completed In This Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1.1 HYDROLOGIC STUDIES</td>
<td>OVERSAW DEVELOP. OF CATCHMENT AREAS FOR URBAN AREA R7.8AC. FLOWS DEVELOP. USING RATIONAL METHODS FOR INTERNAL...</td>
</tr>
<tr>
<td>10.1.1 HYDROLOGIC STUDIES</td>
<td>ROADWAY CATCHMENTS &amp; USED TO SIZE CURB INLETS FOR 82,000 FEET OF NEW STORMWATER SYSTEM.</td>
</tr>
<tr>
<td>10.2.1 BASIC HYDRAULIC DESIGN</td>
<td>DEVELOP. OF 82,000 OF NEW STORM SEWER &amp; CURB INLETS. STORM SEWER MODELED IN AUTODESK SSA TO EVALUATE PERFORMANCE...</td>
</tr>
<tr>
<td>10.2.1 BASIC HYDRAULIC DESIGN</td>
<td>OF PROPOSED SYSTEM DURING VARIOUS RAINFALL EVENTS. ALSO REQUIRED DUE TO OUTFALL BEING EXISTING CATCH BASIN ALONG...</td>
</tr>
<tr>
<td>10.2.1 BASIC HYDRAULIC DESIGN</td>
<td>SAN ANTONIO RIVER. ANALYSIS EVALUATED THE BACKWATER EFFECTS OF THE SA RIVER DURING LARGE RAINFALL EVENT.</td>
</tr>
</tbody>
</table>
10.1.1 Hydrologic Studies

<table>
<thead>
<tr>
<th>Category Description</th>
<th>Certification Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>This category includes rainfall, runoff determination, reservoir routing, and channel routing</td>
<td>The Firm must employ one professional engineer with a minimum of 2 years experience in analysis of complex watersheds</td>
</tr>
</tbody>
</table>

- Delineated 15 drainage areas and calculated peak flows using rational method for 5 culverts and 10 ditches.
- Developed HEC–HMS models using NRCS, computed curve numbers & Tc’s for 2 bridges and 4 culverts.
- Modeled and designed 3 detention ponds in HEC–HMS to mitigate proposed flows using stage storage routing.
10.2.1 Basic Hydraulic Design

<table>
<thead>
<tr>
<th>Category Description</th>
<th>Certification Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>This category includes storm drain systems, culverts, sedimentation filtration systems, and detention/retention ponds</td>
<td>The Firm must employ one professional engineer with a minimum of 2 years experience in hydrologic analysis, hydraulic design and storm water quality evaluation.</td>
</tr>
</tbody>
</table>

- Used HY–8 to analyze adequacy of 7 culvert designs.
- Calc. channel capacity using HEC–RAS to model 1800’ of proposed roadside channel.
- Performed storm drain design using Geopak Drainage for locating and sizing 6 inlets and 1400’ of storm drain.
10.3.1 Complex Hydraulic Design

<table>
<thead>
<tr>
<th>Category Description</th>
<th>Certification Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>This category includes hydraulic design of bridges over waterways, flood plain analysis and channel modifications.</td>
<td>The Firm must employ one professional engineer with a minimum of 2 years experience in river geomorphology, sediment transport and scour analysis, floodplain analysis, river, training techniques, and federal and state regulations and permit compliance.</td>
</tr>
</tbody>
</table>

- Used HEC–RAS to model impact for 3 off-system bridge replacements.
- Modeled floodplain impact from 2000ft of prop. rdwy. fill encroaching on floodplain using HEC–RAS.
- Used XP–SWMM for 2D modeling to assess effect of a 40ft rdwy widening along 1.5mi in an urban area.
## Examples

### 10.4.1 Pump Stations–Hydraulics

<table>
<thead>
<tr>
<th>Category Description</th>
<th>Certification Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>This category includes the design of pump stations for conveyance of storm waters</td>
<td>The Firm must employ one professional engineer with a minimum of 2 years experience in hydrologic analysis and storm drain and pump station design.</td>
</tr>
</tbody>
</table>

- Sized a pump station for a rdwy underpass using HEC-RAS
- Evaluated performance of 2 area pump stations to determine flood risk of roadway using NRCS with InfoWorks
Precertification Update

- TxDOT is in the process of updating all of the precertification work categories
  - Additional hydraulic categories are proposed to be added based on some of the common Non–Listed Categories (NLC)
Introduction to 2D Hydraulic Analysis

What is 1D and 2D Analysis?
- Hydraulic modeling to compute Water Surface Elevations (flood levels)

When is 2D used?
- Complex Riverine/Channel
- Urban Shallow Flooding
1D Vs 2D Flow

1D flow: Typically gradually varied and laminar

2D flow: Flow Mixes, Streamlines are not parallel

Streamlines do not cross
No mixing between layers
Channel walls
1D vs 2D Applications

1D
- Uniform Channels
- Flows contained in banks
- Narrow floodplains
- Single and Constant: WSEL applies across each cross section
- Velocity is constant in calculation of WSEL

2D
- Flows paths not well defined
- WSEL not constant at cross-section
- Velocity changes horizontally
- Split/Diverted Flow
- Alluvial Fans
- Floodplain Analysis (Wide Floodplains)
<table>
<thead>
<tr>
<th>Bridge Hydraulic Condition</th>
<th>Hydraulic Analysis Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One-Dimensional</td>
</tr>
<tr>
<td>Small streams</td>
<td>○</td>
</tr>
<tr>
<td>In-channel flows</td>
<td>●</td>
</tr>
<tr>
<td>Narrow to moderate-width floodplains</td>
<td>○</td>
</tr>
<tr>
<td>Wide floodplains</td>
<td>●</td>
</tr>
<tr>
<td>Minor floodplain constriction</td>
<td>○</td>
</tr>
<tr>
<td>Highly variable floodplain roughness</td>
<td>●</td>
</tr>
<tr>
<td>Highly sinuous channels</td>
<td>○</td>
</tr>
<tr>
<td>Multiple embankment openings</td>
<td>○/●</td>
</tr>
<tr>
<td>Unmatched multiple openings in series</td>
<td>○/●</td>
</tr>
<tr>
<td>Low skew roadway alignment (&lt;20°)</td>
<td>○</td>
</tr>
<tr>
<td>Moderately skewed roadway alignment (&gt;20° and &lt;30°)</td>
<td>●</td>
</tr>
<tr>
<td>Highly skewed roadway alignment (&gt;30°)</td>
<td>○</td>
</tr>
<tr>
<td>Detailed analysis of bends, confluences and angle of attack</td>
<td>○</td>
</tr>
<tr>
<td>Multiple channels</td>
<td>●</td>
</tr>
<tr>
<td>Small tidal streams and rivers</td>
<td>○</td>
</tr>
<tr>
<td>Large tidal waterways and wind-influenced conditions</td>
<td>○</td>
</tr>
<tr>
<td>Detailed flow distribution at bridges</td>
<td>●</td>
</tr>
<tr>
<td>Significant roadway overtopping</td>
<td>○</td>
</tr>
<tr>
<td>Upstream controls</td>
<td>○</td>
</tr>
<tr>
<td>Countermeasure design</td>
<td>○</td>
</tr>
</tbody>
</table>

- ○ well suited or primary use
- ● possible application or secondary use
- ○ unsuitable or rarely used
- ○/● possibly unsuitable depending on application

Source: FHWA HDS #7
Typical 1D cross section with 2D water surface overlaid
1D or 2D Flow?
1D or 2D Flow?
1D Analysis Approach

- Representative cross-section and reach lengths define channel
- Velocity and depth computed at each cross-section
- Starts with known condition and solves for unknown conditions at the next cross-section
2D Analysis Approach
Geometry is defined by a network of elements or nodes (mesh).

Each element in the mesh is a horizontal area with 3 or 4 sides.

Velocity varies horizontally and is depth averaged at a point (vertically).

2D modeling lays a mesh over the terrain and the 2D hydraulic computations determine where the water goes directionally.
Disadvantages

- Difficult to lay cross-sections (cross-sections must not cross)
- Does not capture complex flow (diverted/split)
- Possibly overestimates depth and velocity due to assumptions (most important outputs)
- Must estimate ineffective areas

Advantages

- Geometric input simplified with cross-sections and reach lengths (easier to make adjustments)
- Faster computational time
- Computes hydraulics through structures (bridges and culverts)
- Easier to troubleshoot
2D

Disadvantages

• More data intensive
  • Best with reliable and accurate topo/LiDAR
• Longer Computational Time
• Hydraulic structure computations limited (not very good at computing hydraulics through structures)
• Less User Experience

Advantages

• Models in 2 directions – dispersive flows. Good for split and diverted flows.
• Calculates ineffective flow areas (no estimating)
• No cross-section placement (no guess work)
• More informative – better defined flow patterns
• Dynamic mapping
TxDOT Applications for 2D

- Split flow or flow diverted to adjacent basin (adjacent cross-culvert)
- Wide floodplains where velocity and depth vary
- Urban areas with complex flow patterns created by numerous cross streets
- Inform 1D model – Define ineffective flow areas, contraction and expansion coefficients
  - Quick 2D by applying rain to mesh to diagnose problem, establish flow patterns
Split/Diverted Flow along Highway
Rain on Terrain (Mesh) Examples
Available Software

- Software (User Experience, widely used – Errors, bugs, issues can be vetted and corrected)
  - InfoWorks (Riverine and Storm sewer)
  - XPSWMM (Riverine and Storm sewer)
  - HEC-RAS (Riverine)
  - SRH-2D (Riverine)
Currently, no formal TxDOT policy/guidelines to develop a 2D Model or review a 2D Model. Contact Design Division, Hydraulics Branch for Guidance.

- FHWA, HDS 7, *Hydraulic Design of Safe Bridges*
- FEMA, *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix C: Guidance for Riverine Flooding Analyses and Mapping*
Subsurface Utility Design and Analysis (SUDA), Bentley Software
SUDA

Two components

- Utility Conflict Detection
- Hydraulic Design and Analysis
  - Stormsewer Network Design and Analysis
  - Culverts
Utility Conflict Detection

Gas Lines

Water lines
SUDA Storm Sewer Design Cell Library

- TxDOT developing Cell Library
- Approximately 50 TxDOT Drainage Structure Standards
- Approximately 4500 Cells generated from Standards
- Target date for completion of Cell Library – Summer 2018
SUDA Storm Sewer Design

- Replaces Geopak Drainage in ± 3 years
- StormCAD is the hydraulic engine (can be used stand-alone)
- Versatile Project Management Tools – Can analyze multiple rainfall events (design frequencies), multiple alternatives and compare results
- Currently does not generate sheets. Sheet generation in SUDA being developed for next update (Tentatively early 2018).
Questions?

- Hydraulics Branch Team
  - Saul Nuccitelli, PE, CFM  512-416-2219
    - Chief Hydraulics Engineer
  - Lucinda Soto, PE, CFM  512-416-2949
  - Ab Maamar-Tayeb, PE, CFM  512-416-2328
  - Kamal Uddin, EIT  512-416-2679
  - Hiruy Berhe, EIT  512-416-2346