Urban Drainage and Flood Control District

Annual Seminar

April 10, 2012

Trends and Developments in Stormwater & Floodplain Management

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

Paul A. Hindman, Executive Director
2480 W. 26th Avenue, Suite 156B
Denver, CO 80211-5304

Telephone 303-455-6277
Fax 303-455-7880
www.udfcd.org

UDFCD 2012 ANNUAL SEMINAR PROGRAM

STARTS	ENDS	TOPICS and PRESENTERS
7:15 AM	8:00 AM	Check-In / Continental Breakfast
8:00 AM	8:15 AM	Welcome & Opening Remarks by Paul A Hindman, PE, Executive Director (UDFCD)
8:15 AM	8:55 AM	Technical Session 1: New Rainfall Depth Reduction Factors for the UDFCD Region Ben R. Urbonas, PE, D.WRE (Urban Watersheds, LLC.)
8:55 AM	9:35 AM	Technical Session 2: Temporary Diversion Sizing When Working In Waterways Dave Bennetts, PE (UDFCD) and Shannon Tillack, EIT (Wright Water Engineers)
9:35 AM	9:55 AM	Morning Break
9:55 AM	10:30 AM	Technical Session 3: UDFCD Storm Drainage Criteria Manual: An Update on the Update Holly Piza, PE (UDFCD)
10:30 AM	11:05 AM	Technical Session 4: Floodplain Delineation Modeling: 2D or not 2D? Shea Thomas, PE (UDFCD) and Alan Turner, PE (CH2M Hill)
11:05 AM	11:45 AM	Technical Session 5: UDFCD-CDOT Physical Modeling of Median Inlets James Guo, PE, PhD, University of Colorado, and Amanullah Mommandi, PE, CDOT
11:45 AM	12:50 PM	Lunch
12:50 PM	1:20 PM	Technical Session 6: New Detention Sizing Methods Ken MacKenzie, PE (UDFCD), Ryan Taylor (UDFCD), and Jim Wulliman, PE (Muller Engineering)
1:20 PM	1:50 PM	Technical Session 7: Floodplain Management Program Update Bill DeGroot, PE (UDFCD) and David Mallory, PE (UDFCD)
1:50 PM	2:20 PM	Technical Session 8: The 2010 Fourmile Canyon Fire—One Year and One Flood Later Kevin Stewart, PE (UDFCD)
2:20 PM	2:40 PM	Afternoon Break
2:40 PM	3:00 PM	Technical Session 9: UDFCD Revised and Updated Construction Specifications Dave Bennetts, PE (UDFCD)
2:40 PM	4:15 PM	Technical Session 10: A 360 Degree Discussion of Erosion and Sediment Control in Drainageway Construction. By Laura Kroeger, PE (UDFCD), Jerry Naranjo (Naranjo Civil Constructors), Erik Nelson and Ryan Adrian (Douglas County)
4:15 PM	4:30 PM	Closing Remarks by Paul A Hindman, PE, Executive Director, UDFCD

Technical Session 1:
Developing New Depth Area Reduction Factors for the Urban Drainage & Flood Control District

Ben Urbonas, Urban Watersheds, LLC, part of Wright Water Engineers, Inc. Team

ABSTRACT:

Currently the Urban Drainage and Flood Control District (UDFCD) uses and recommends Depth Area Reduction Factors (DARFs) based on NWS TP40 report (also NOAA Atlas). NWS DARFs are geographically-based reduction factors for storm durations of 30-, 60, 120-, 360-, and 720-minutes. UDFCD extrapolated and developed a 15-minute DARF using this NWS information and published them in its Urban Storm Drainage Criteria Manual (USDCM) in 1984.

In 2011, Carlton Engineering, Inc. completed a report for the City of Colorado Springs on rainfall characteristic of the City and El Paso County (Carlton, 2011; Fountain Creek Watershed Rainfall Characterization). The study supporting this report included the development of local cell-centered (as opposed to geographically-based) DARFs based on radar images of rainstorms in Eastern Colorado and El Paso County. Dan Bare, P.E., Senior Civil Engineer with the City of Colorado Springs Engineering Department, generously gave UDFCD permission to use the information in this report to see if it could be applied to the UDFCD region.

Wright Water Engineers, Inc. (WWE) was asked by UDFCD to analyze the findings of Carlton's team to assess applicability to the UDFCD region engaged Ben Urbonas, P.E. of Urban Watersheds, LLC, as a sub-consultant to perform this assessment. This presentation reports on the findings of the investigation of how to apply Carlton's findings, how they were used to develop recommended new DARFs for use within the UDFCD region and the application of them to 5-year and smaller design storms for inclusion in the ongoing update to Volumes 1 & 2 of the USDCM.

Technical Session 2:
Temporary Diversion Sizing When Working in Waterways

David Bennetts, UDFCD
Shannon Tillack, Wright Water Engineers

ABSTRACT:

The Urban Storm Drainage Criteria Manual (USDCM) Volume 3 provides guidance on temporary diversion channel sizing criteria when working in or around a waterway. The current temporary diversion channel sizing criteria suggest using a curve that estimates the 2-year peak flow rates based on watershed imperviousness for small waterways (< 12 square miles). This 2-year peak flow rate temporary diversion channel sizing criteria is adopted by reference to Volume 3 in many Front Range MS4 permits and has been applied to projects, regardless of size, duration and other factors that affect costs, benefits and risks of temporary diversions. Requiring complete diversion of the 2-year peak flow rate for all projects requiring diversions is too general and does not address important factors including the temporal length of the project, the time of year for construction, current condition of the stream channel, and the different types of work (bank stabilization, roadway crossings, below-stream utility placement, etc.) that have different corresponding diversion needs, and other factors.

The U.S. Geological Survey (USGS) has been collecting Crest Stage Indicator (CSI) data for the Urban Drainage and Flood Control District (UDFCD) for over 30 years at approximately 29 sites in the metropolitan area. A flood-flow-frequency analysis and probability distribution analysis was performed for all monthly data for each month for which data were available. This analysis was conducted for both base flows and monthly peak flows. For projects that are not likely to exceed several weeks in duration in times of the year when wet weather is not generally anticipated, a linear regression equation with a seasonal safety factor coefficient can be used to determine the revised temporary diversion channel sizing criteria, based on project-specific characteristics.

Technical Session 3:
Updating Volumes 1 and 2 of the Urban Strom Drainage Criteria Manual (USDCM)

Holly Piza, UDFCD

ABSTRACT:

Volumes 1 and 2 of the Urban Storm Drainage Criteria Manual (USDCM) were last updated in 2001. These volumes are currently undergoing another update in order to capture experience gained and incorporate relevant research conducted over the past decade. This presentation will highlight significant changes, many of which are tied to the following goals for this project:

- ✓ Expand guidance on drop structure selection and design.
- ✓ Provide more guidance for full spectrum detention and EURV.
- ✓ Incorporate inlet research from the CSU hydraulics lab.
- ✓ Provide better guidance for bioengineering.
- ✓ Update the current details with the most current recommendations.
- ✓ Provide guidance on trail design next to streams.

The update process is guided by two committees – the stakeholder's group and the technical advisory committee. The technical advisory committee is further divided into the following core workgroups:

- ✓ Major Drainage
- ✓ Hydraulic Structures
- ✓ Streets-Inlets-Storm
- ✓ Storage
- ✓ Revegetation
- ✓ Trail Criteria

All interested parties will have the opportunity to review and comment on the manual as it develops. To find out more, please visit: www.udfcd.org to stay current on this project.

Technical Session 4:
Floodplain Delineation Modeling: 2D or not 2D?

Shea Thomas, UDFCD & Alan Turner, CH2M HILL

ABSTRACT:

Riverine hydraulic modeling within the United States has been largely dominated by the use of one-dimensional (1-D) analysis programs, such as the U.S. Army Corps of Engineers (USACE) HEC-RAS River Analysis System software or the Environmental Protection Agencies (EPA) Storm Water Management Model (SWMM). With the advancement in remote sensing technology that provides detailed and accurate terrain models, hydraulic analyses and floodplain delineations have become more accurate. With improved topographic mapping and the increased accuracy of hydraulic modeling, complex flow splits with multiple flow directions are more easily identified. A 1-D model is limited in accurately analyzing these complex situations due to the fundamental assumption that flow is in a single direction.

With increased computational power that is now available, the use of two-dimensional (2-D) hydraulic models can be quickly created and run to represent complex flow situations. Current regulations for floodplain modeling are generally geared toward 1-D modeling with kinematic wave routing assumptions. Many flooding scenarios are better represented by 2-D models than 1-D models; in particular areas of split flows caused by hydraulic structures, urban flooding areas, and alluvial fan analysis.

The purpose of this presentation is to provide guidance on when 2-D models should be utilized and how to correctly develop a 2-D model for riverine systems. In addition, in light of the current regulatory environment where most legacy models are 1-D and many regulations are geared toward 1-D modeling results, this presentation will offer guidelines on how the results of a 2-D hydraulic model can be used to quickly and efficiently develop 1-D models acceptable to regulatory agencies and municipalities for riverine systems.

Technical Session 5:
Hydraulic Efficiency of CDOT Type C and D Inlets

James C.Y. Guo, PhD, Professor and P.E. U of Colorado Denver
Amanullah Mommandi, Hydraulic Engineer, CDOT

ABSTRACT:

This presentation summarizes the theoretical derivation, laboratory data collection, modeling calibration, and design application developed for designs of CDOT Type C and D inlets.

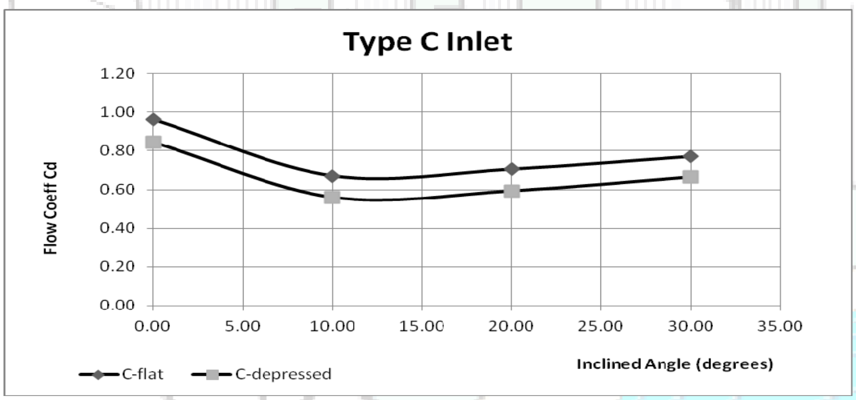
Type C and D inlets (TY C, TY D) are often installed at a low point for runoff collection from a large depressed area or in a highway median. According to the Hydraulic Design Manual issued by the Colorado Department of Transportation (CDOT), a TY C has a standard frame size of 3-ft by 3-ft with I-beam bars to support the loadings on its top. A TY D inlet is formed by two TY C inlets lined in series or in parallel with a standard dimension of 3-ft by 6-ft. A TY C or D inlet is often operated with a headwater ranging from 0.5 to 3 feet to increase its flow interception capacity. A depressed TY C or D inlet often entrains highway debris carried in the runoff flows. The flow eddies and swirls circulate twigs and leaves between the I-beam bars. The accumulated debris tends to clog the grate surface. As a result, an inclined Type D is preferred to reduce the clogging potential.

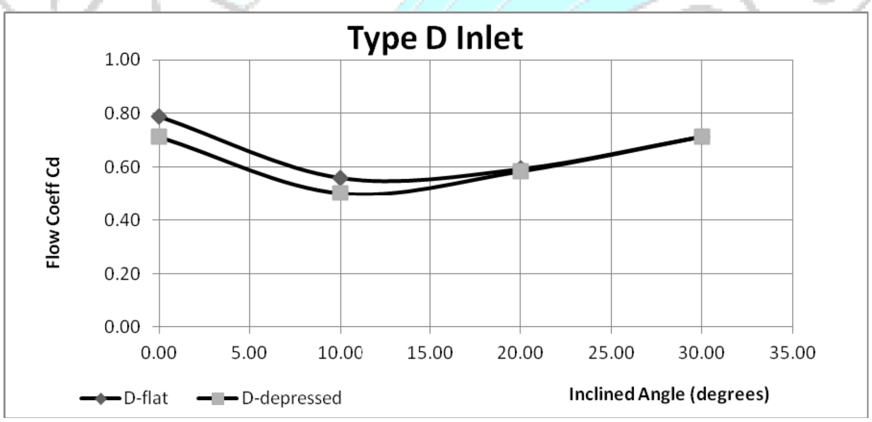
Laboratory Model for Inclined Type D Inlet

Laboratory Model for Flat Type D Inlet

In this study, a set of new formulas was derived to design Type C and D inlets. The values of flow coefficient, C_d, orifice coefficient, C_o, and weir coefficient, C_w, were derived from 92 sets of laboratory data. In comparison, a flat Type C inlet has the highest flow interception capacity compared to the inclined. The laboratory data indicate that there is a tradeoff between the reduction on clogging coefficient and the decrease in flow interception. With the recommended coefficients, the engineer can select the design parameters based on the optimal performance of the inlet under the specified condition in the field.

Flow Type	Flow Overtopping Two Sides of Inclined Grate	Flow overtopping the Lower Base Width	Condition
Orifice	$Q_o = nC_o BHCot\theta\sqrt{2gH} = nC_o BXCos\theta\sqrt{2gH}$ Subject to: $X = \frac{H}{Sin\theta} < L$		$H<H_b$ Un-submerged
Weir	$Q_{WS} = n\,C_w Cot\theta\, H^{\frac{5}{2}} = n\,C_w XCos\theta\, H^{\frac{3}{2}}$ subject to: $X = \frac{H}{Sin\theta} < L$ $Q_W = 2Q_{WS} + Q_{WB}$	$Q_{WB} = nC_w BH^{3/2}$	$H<H_b$ Un-submerged
Orifice	$Q_o = nC_o BLCos\theta\sqrt{2gH}\,[\frac{H^{\frac{3}{2}}}{H_b\sqrt{H}} - \frac{(H-H_b)^{\frac{3}{2}}}{H_b\sqrt{H}}]$ In case of θ=0 and Hb=0, then $Q_o = nC_o BL\sqrt{2gH}\ \ if\ \ \theta = 0$		$H \geq H_b$ Submerged
Weir	$Q_{WS} = nC_w LCos\theta\, H^{\frac{3}{2}}[\frac{H^{\frac{5}{2}}}{H^{\frac{3}{2}}H_b} - \frac{(H-H_b)^{\frac{5}{2}}}{H^{\frac{3}{2}}H_b}]$ In case of θ=0 and Hb=0, then $Q_{WS} = nC_w LH^{\frac{3}{2}}$ $Q_W = 2Q_{WS} + Q_{WB}$	$Q_{WB} = nC_w BH^{3/2}$	$H \geq H_b$ Submerged





Technical Session 6:
New Detention Sizing Methods

Ken MacKenzie & Ryan Taylor, UDFCD
Jim Wulliman, Muller Engineering Company

ABSTRACT:

As part of the Urban Storm Drainage Criteria Manual (USDCM) update, we have been re-evaluating our detention sizing and design methods. The Storage Chapter Technical Advisory Committee has provided valuable insight and guidance through this process and we are excited about some new developments. After providing a brief background on the issues and developments associated with detention practices, this presentation will go through our newly-proposed design criteria, including:

- ✓ New assumptions for historic peak unit runoff rates based on the one-hour point precipitation and hydrologic soil group including the derivation of new general equations to estimate these runoff rates.
- ✓ A new, simplified equation to estimate the required storage volume to safely and efficiently manage runoff events up to and including the 100-year storm in a full spectrum detention basin.
- ✓ An evaluation of alternative configurations for water quality outlet structures, including an option referred to as an elliptical slot weir.
- ✓ A new Microsoft Excel program to size and analyze full spectrum detention basins by utilizing the modified-puls routing method. The embedded design storm hydrographs resulted from rainfall depths ranging from 0.6 inches to 2.6 inches.
- ✓ An evaluation of inclined overflow grates associated with extended detention basins resulting from computational fluid dynamics models analyzed by ARCADIS.

Technical Session 7:
Floodplain Management Program Update

Bill DeGroot & David Mallory, UDFCD

ABSTRACT:

The Floodplain Management Program was established in 1974 to prevent new flood damage potential from being introduced into the especially hazardous area of the floodplain (aka 100-year floodplain) while encouraging the utilization of non-structural methods of flood damage mitigation. One major area of activity is overseeing the District's Maintenance Eligibility Program (MEP).

In 1980, the District's Board of Directors adopted the Maintenance Eligibility Policy: "Facilities constructed by, or approved for construction by, a local public body after March 1, 1980, must be approved by the District in order for these facilities to be eligible for District maintenance assistance." We have periodically issued MEP Guidelines in order to help folks through the program and gain eligibility for their projects. The guidelines were last updated in 2006, so we thought it appropriate to issue a new version.

This presentation will focus on major changes in the guidelines as well as tips for gracefully getting through the design review, construction and final acceptance phases. The role of sustainable natural systems in resilient communities is becoming widely recognized. There is mounting evidence that good stewardship of the natural environment provides a level of protection against the extremes of nature. We will discuss how the MEP leverages good floodplain management techniques and the legitimate profit motive of community builders that results in safe and proper development in and adjacent to floodplains.

Technical Session 8:
The 2010 Fourmile Canyon Fire—One Year and One Flood Later

Kevin Stewart, UDFCD

ABSTRACT:

The 2010 Labor Day Fourmile Canyon Fire in Boulder County has been labeled Colorado's most destructive wildfire, not because the burn area was so large, but because such a large number of homes were destroyed. As bad as this fire was for those homeowners, the increased flood threat may prove be the fire's most serious consequence.

This presentation will share some personal and professional insights beginning with a highly debated flood risk assessment and the implementation of two real-time hydrologic models that lacked supporting rainfall/runoff data for calibration. Adding to the debate was the fact that the largest flood on Fourmile Creek in the past 75 years did not likely exceed 500 cfs. Convincing residents that a life-threatening flash flood was likely in the next few years was not an easy task and there were many non-believers at the beginning of the 2011 flood season. In adjusting to the increased flood threat, decision-makers increasingly relied on real-time radar, rainfall measurements and stream level data to develop a common operating picture. Team building and developing relationships were of vital importance including interactions with the meteorologists and hydrologists from the National Weather Service, the Urban Drainage and Flood Control District and local government engineers. Enhancement of early notification and emergency response procedures combined with a well-targeted public education effort ultimately paid dividends when the system was tested by a dangerous flash flood resulting from a relatively small rainstorm on July 13, 2011. With the increased flood threat expected to continue unabated for a number of years to come, subsequent planning activities remain underway to further improve services and maintain high levels of trust among all parties concerned.

Technical Session 9:
UDFCD Revised and Updated Construction Specifications

David Bennetts, UDFCD

ABSTRACT:

The Design, Construction, and Maintenance (DCM) program recently completed an update to our standard specifications. These specifications are used for all construction projects the District builds, as well as by others both inside and outside of the District. The specifications cover standard construction activities, products, and installation for work in drainageways.

Revisions and updates to the standard specifications included:

- Complete review by District Staff
- Update to the revised CIS format
- Specifications for new construction techniques or materials
- Legal references and insurance limits
- Updated Criteria Manuel references
- Changes to better facilitate a 'paperless process'

The revised specifications have been reviewed by several outside consulting firms, legal council, several drainageway contractors, and major suppliers of material such as rock and pipe; and comments received were included in the revisions.

The new specifications will be posted on the District's website for all to use. This will eliminate the need to develop a full set of specifications for each individual project, and better facilitate the revised bidding process the District has been using.

Technical Session 10:
A 360 Degree Discussion of Erosion and Sediment Control in Drainageway Construction

Laura Kroeger & Barbara Chongtoua, UDFCD
Erik Nelson & Ryan Adrian, Douglas County
Jerry Naranjo, Naranjo Civil Constructors

ABSTRACT:

At last year's UDFCD annual seminar one of the topics presented was on how stream stabilization projects are actually (and should be considered) permanent best management practices (BMPs). With the approach that a BMP is a technique, process, activity, or structure used to reduce pollutant discharges in storm water (as defined in the USDCM Volume 3), stabilizing or repairing streams with active erosion significantly reduces the pollutant discharge.

The previous presentation suggested that we need to come into a better balance with implementing MS4 permits, when it applies to an eroding drainageway. The imbalance stems from well-meant but costly erosion and sediment control permit processes that divert money from construction of stream stabilization as a permanent BMP in order to spend more on temporary construction BMPs that are sometimes of dubious merit. The argument can be made that for actively eroding channels, the temporary impacts of construction may not cause pollution in a manner worse than the pre-construction condition. With that said, all parties agree that temporary construction BMPs are necessary, but more flexibility and a streamlined process would help reduce costs that, in return, would leave more money to go toward building the ultimate permanent solution.

The purpose of this panel discussion is:

1. A follow up on how the District has been working with MS4 permit holders to streamline the erosion and sediment control permit process, and

2. A look at future opportunities to focus more tax dollars on stream stabilization as the permanent BMP.

Hear from a local permit holder, a storm water inspector, a contractor, and a UDFCD project engineer on how we can all continue to strive for a better balance to meet permit requirements in a very cost effective manner.

2012 UDFCD Annual Seminar

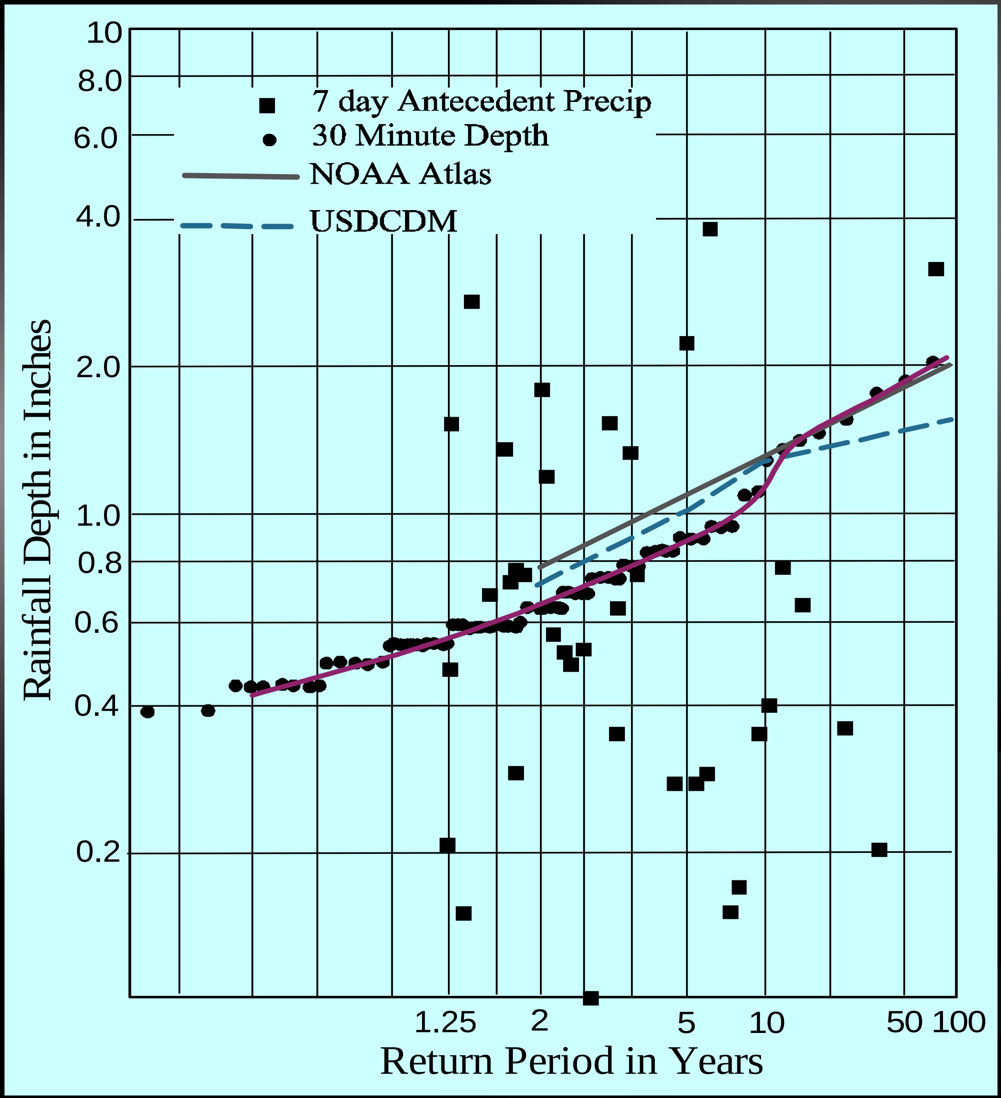
Developing New DARFs for UDFCD

Presentation by Ben Urbonas,
Urban Watersheds, LLC
and
Wright Water Engineers, Inc.

History of UDFCD Hydrology

- 1969 UDFCD contracted with the USGS to collect rainfall/runoff data from urban catchments.
- 1977 UDFCD started to analyze this data. Goal:
  - Develop more reliable urban runoff simulation techniques for UDFCD region
- Design storms were also analyzed
  - USGS obtained hourly rainfall data from NWS
  - 73 years of continuous hourly data
  - 5-minute data for 3 largest storms for each of the 73 years

1979 Comparison of 30 minute Depths
73 years of Data, NOAA Atlas, UDFCD Manual



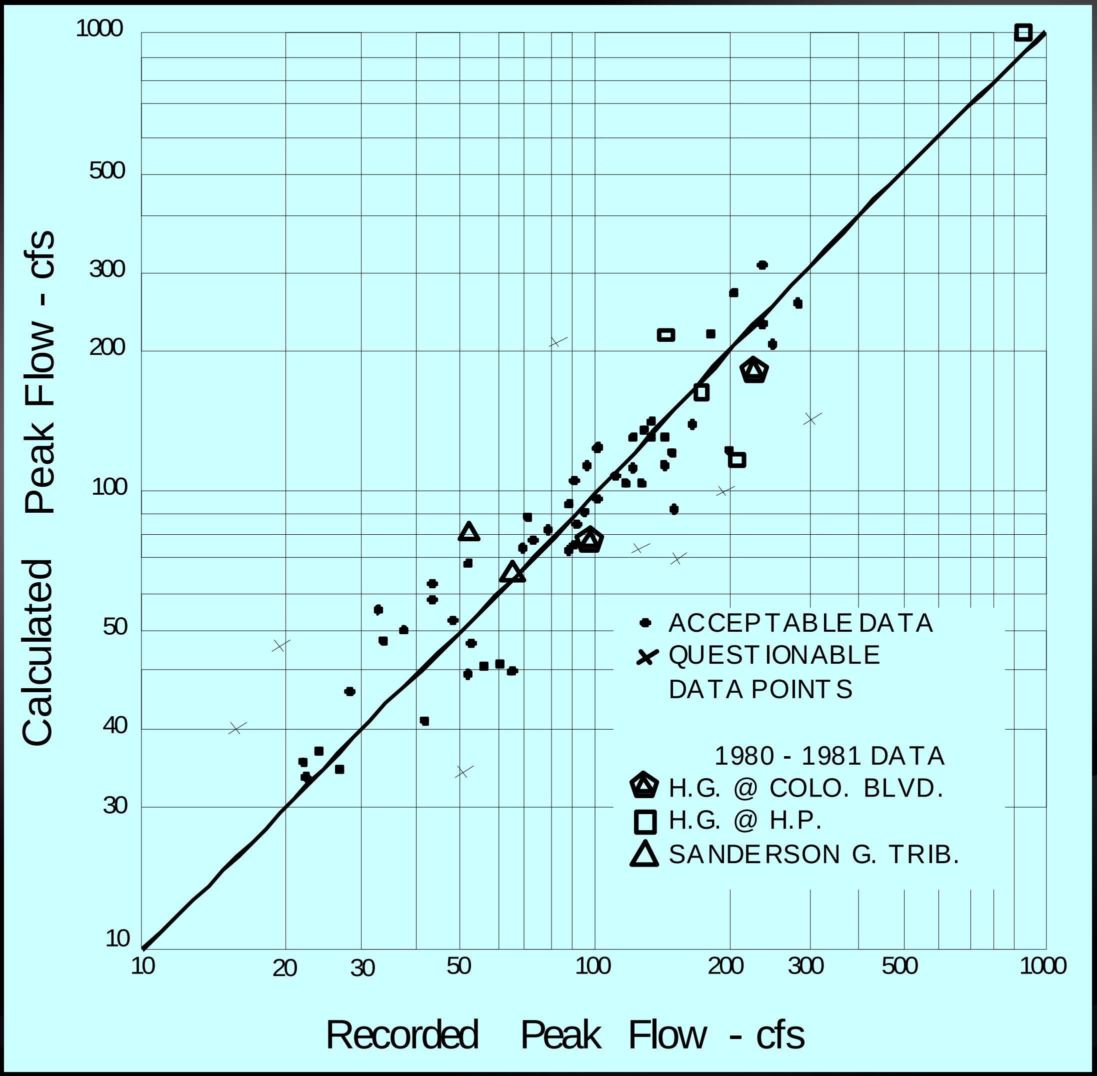
Original Pre-1979 Design Storm Procedure

1. User picked off 5-minute through 2-hour rainfall depths from isopluvial maps in USDCM
2. Plot a depth-duration curve
3. Segregated the values into 5-minute depths
4. Rearrange the 5-minute incremental depths into a “logical” temporal arrangement by placing the highest depth increment at 30 or 35 minutes from start of storm (depending on return period).

UDFCD Design Storm Analysis for 1979 Update

1. Calibrated CUHP model using recorded simultaneous rainfall/runoff data for a variety of land uses
2. Used the calibrated CUHP to process three larges storms with 5-minute data for 73 years of data
3. Picked off the largest 73 runoff peaks and volumes
4. Performed Log-Pearson Type III frequency analysis
5. Results became the basis for comparing peaks and volumes form existing and new design storms

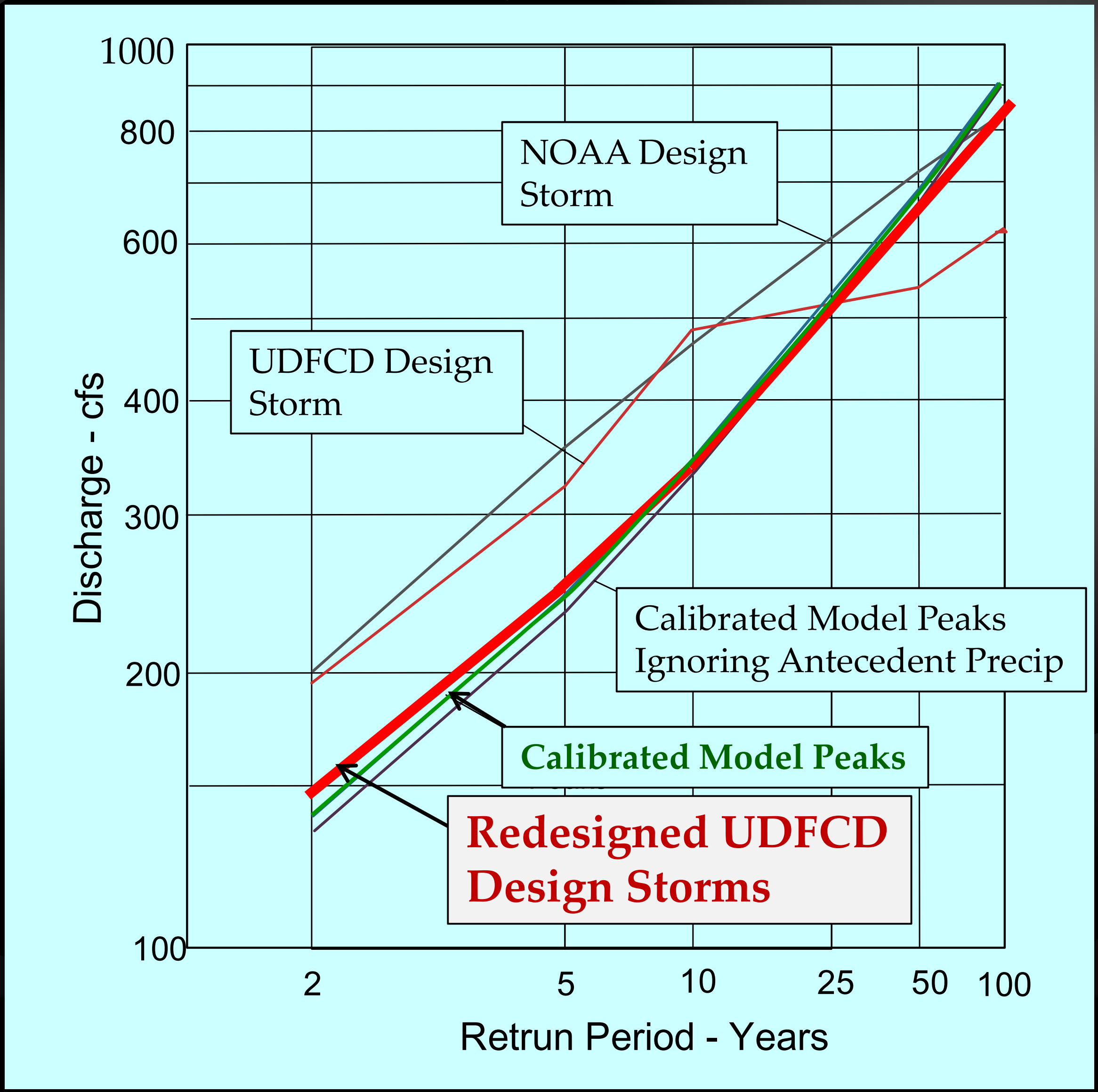
1978 Calibrated CUHP
Recorded vs. Calculated Peak Flows



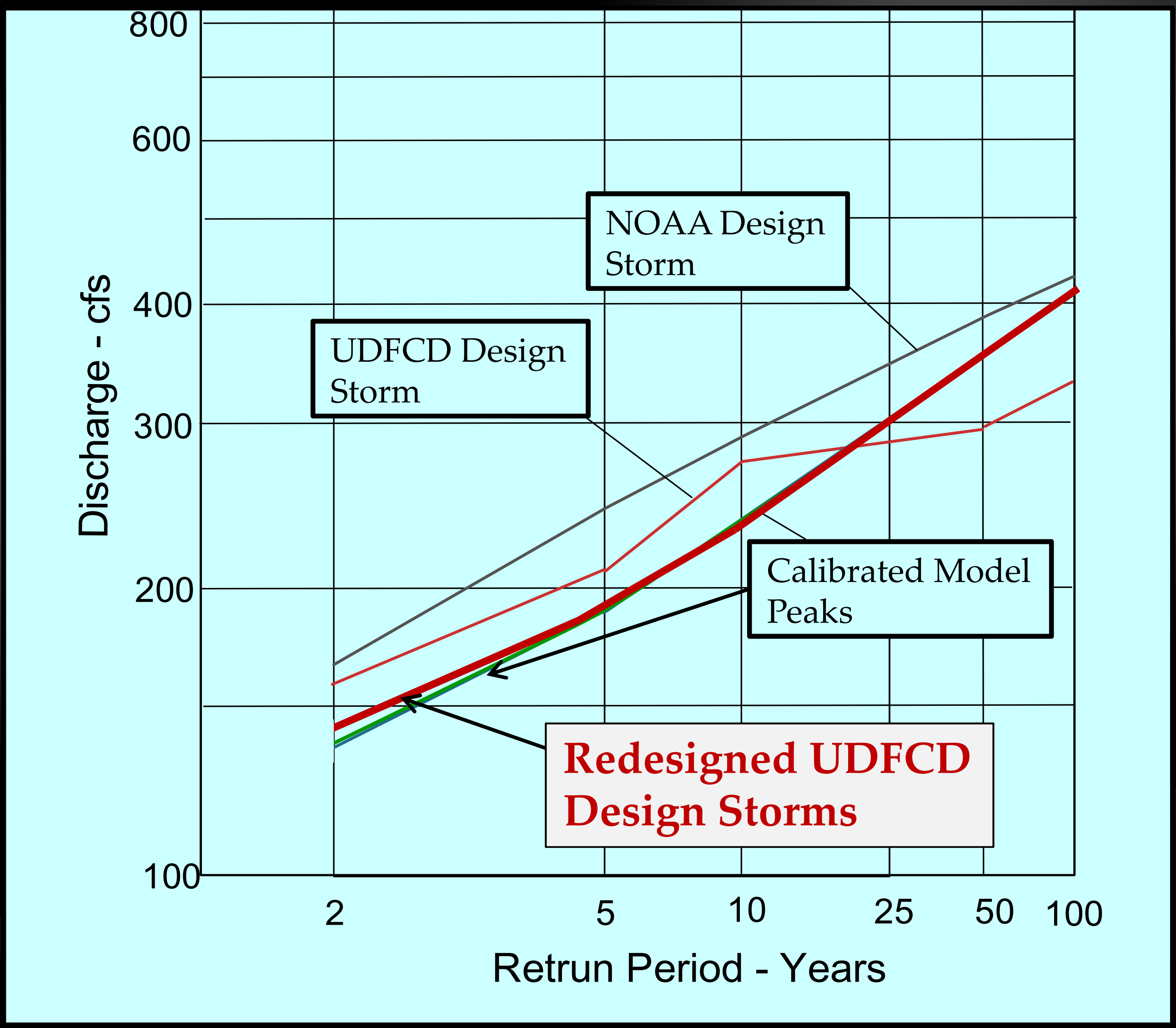
Post 1979
UDFCD Design Storms

1. **Developed using 73 years of rainfall to model runoff peaks using calibrated unit hydrograph model**
2. **2-hour duration front-loaded design storm pattern was selected after studying 73 years of storm patterns**
   - 3- and 6-hour durations were developed for large catchments
3. **Design storm distributions were adjusted to produce runoff peaks that best match runoff peaks at all return periods**

Redesigned Design Storm Peaks vs. Runoff Peak Statistics (250 ac & 40% Imp.)



Redesigned Design Storm Peaks vs. Runoff Peak Statistics (90 ac & 97% Imp.)



UDFCD Depth Area Reduction Factors (DARFs) in Use Today

1. **Current UDFCD DARFs are based on NOAA Atlas and are geographically-based types**
   - 30-, 60, 120-, 360-, and 720-minute DARFs from NOAA
   - UDFCD extrapolated 15-minute DARF
2. **Applied each duration DARF to internal durations of UDFCD design storms**
3. **Protocols for doing this are published in USDCM and are a part of UDFCD's USDCM spreadsheets**

New DARFs Recommended for UDFCD Region

for

10-year and smaller design storms

New DARFs for UDFCDs
10-year and Smaller Storms

Wright Water Engineers, Inc. (WWE) was asked by UDFCD to review the report prepared by Carlton Engineering, Inc. team for the City of Colorado Springs on the rainfall characteristics of El Paso County.

Carlton (2011). *Fountain Creek Watershed Rainfall Characterization*

WWE subcontract with me to help with this work.

Acknowledgements

1. UDFCD and WWE team wish to acknowledge Dan Bare of the City of Colorado Springs for sharing Carlton (2011) report with UDFCD and permitting UDFCD and the WWE team to use it for assessing the UDFCD DARFs and how to update them.
2. Also, we acknowledge the work by Carlton Engineering, Inc. and its principal subcontractors:
   a) OneRain, Inc.
   b) HydMet, Inc.

This analysis and development of recommended DARFs for the UDFCD Region would not have been possible without these contributions and work

DISCLAIMER

The recommendations and findings are those of the WWE team and do not necessarily reflect the conclusions and assessments reached by City of Colorado Springs and how it may apply the DARFs recommended in the Carlton to adjust City of Colorado Springs' design storms

Scope of the UDFCD Project

1. Conduct a detailed review of the Carlton Report and related materials developed for Colorado.
2. Determine if “Eastern Colorado” or the “El Paso County” findings are more appropriate to use for UDFCD region
3. Work with UDFCD to determine how to most economically transform the cell-centered DARFs in Carlton Report to geometrically-fixed DARFs
4. Develop recommendations for updated DARFs for use to adjust 10-year and smaller design storms for the UDFCD Region

Key Findings of Carlton Study

1. **Cell-Centered DARFs in Colorado Springs and El Paso County significantly differ from National Weather Service (NWS) DARFs.**

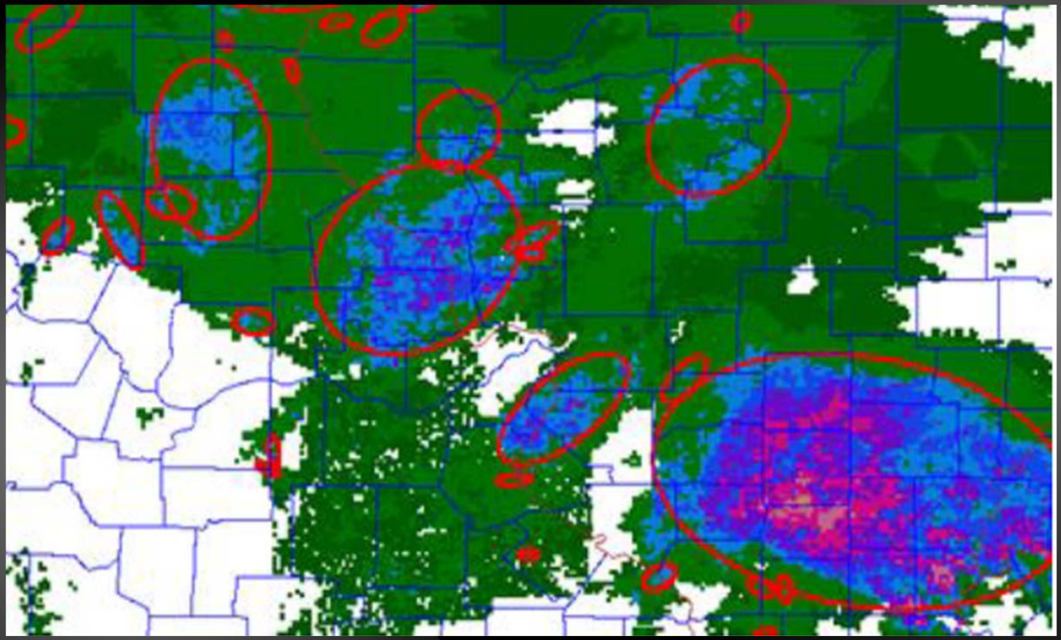
2. **DARFs developed by Carlton Team were Cell-Centered ones**

3. **DARFs were found to <u>vary with recurrence interval and location</u>.**

4. **Geographically-fixed and Storm-centered methods of computed DARFs <u>produce different results</u>.**

Geographically-fixed DARFs <u>decrease less rapidly with increasing area than</u> Storm-centered DARFs.

Example Radar Cell Images Enclosed by Fitter Ellipses



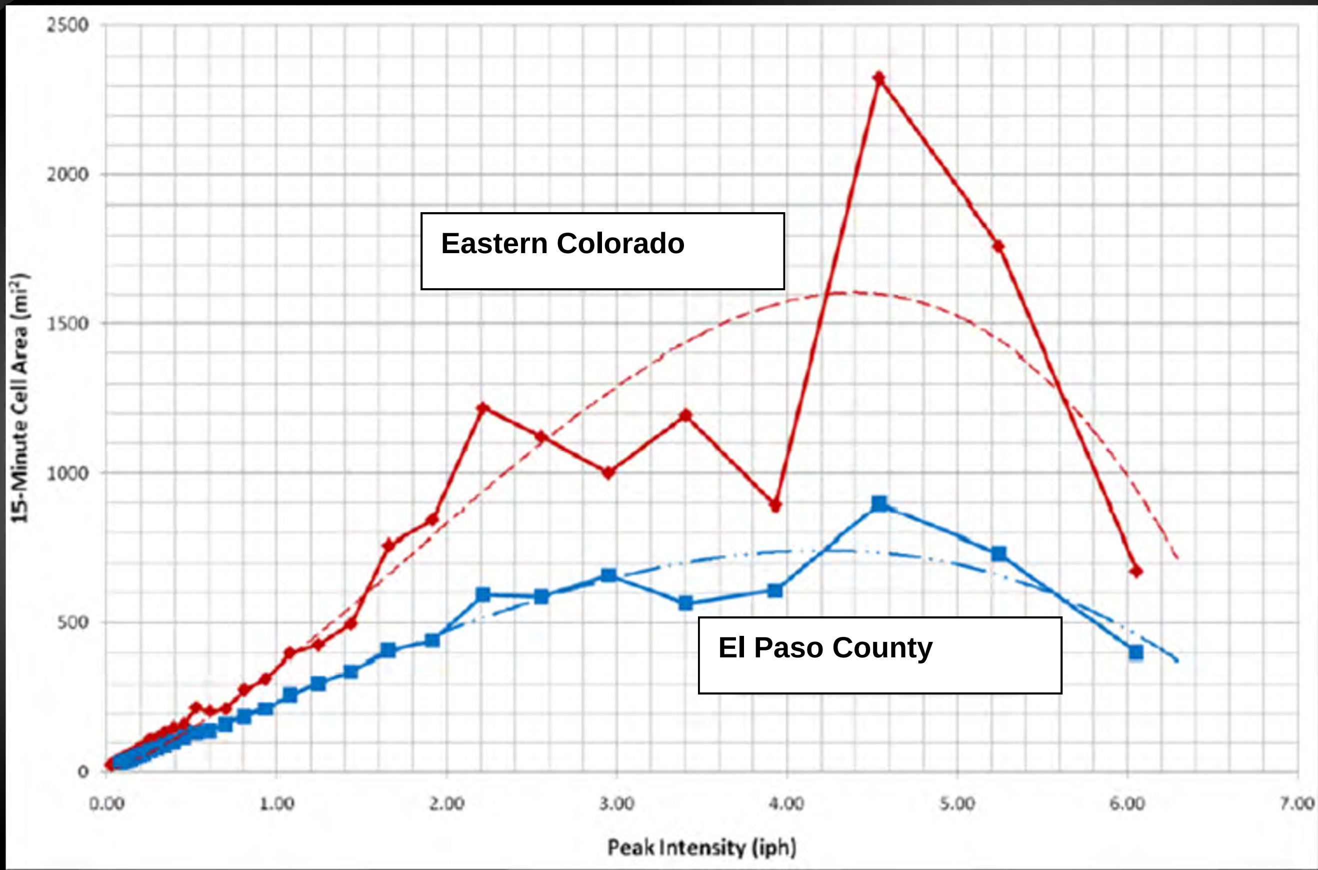
(Ref.: Carlton 2011)

- **Storm-centered** **DARF development** **<u>follows the cell</u>** **and computes average depths of** **<u>expanding area of the cell</u>**.
- **Geographically-fixed** **DARF development** **<u>looks at fixed areas on the ground</u>** **and computes storm averages depths within fixed areas.**

Carlton Study Data

1. Included 14 years of radar data from
    - June, 1994 to Sept, 2008
2. Entire data set was screened
3. Select 24 months of rainstorm data
    - Ones with greatest amount of rainfall
    - Approximately 300,000 individual storm cells analyzed

15-Minute Peak Intensity vs. 15-Minute Cell Size



Observation: El Paso County cell sizes are more compact than Eastern Plain cells for short duration rainfall storms. That is not the case for longer duration storms.

Comparison of DARFs for 2-year intensities
Eastern Colorado and El Paso County

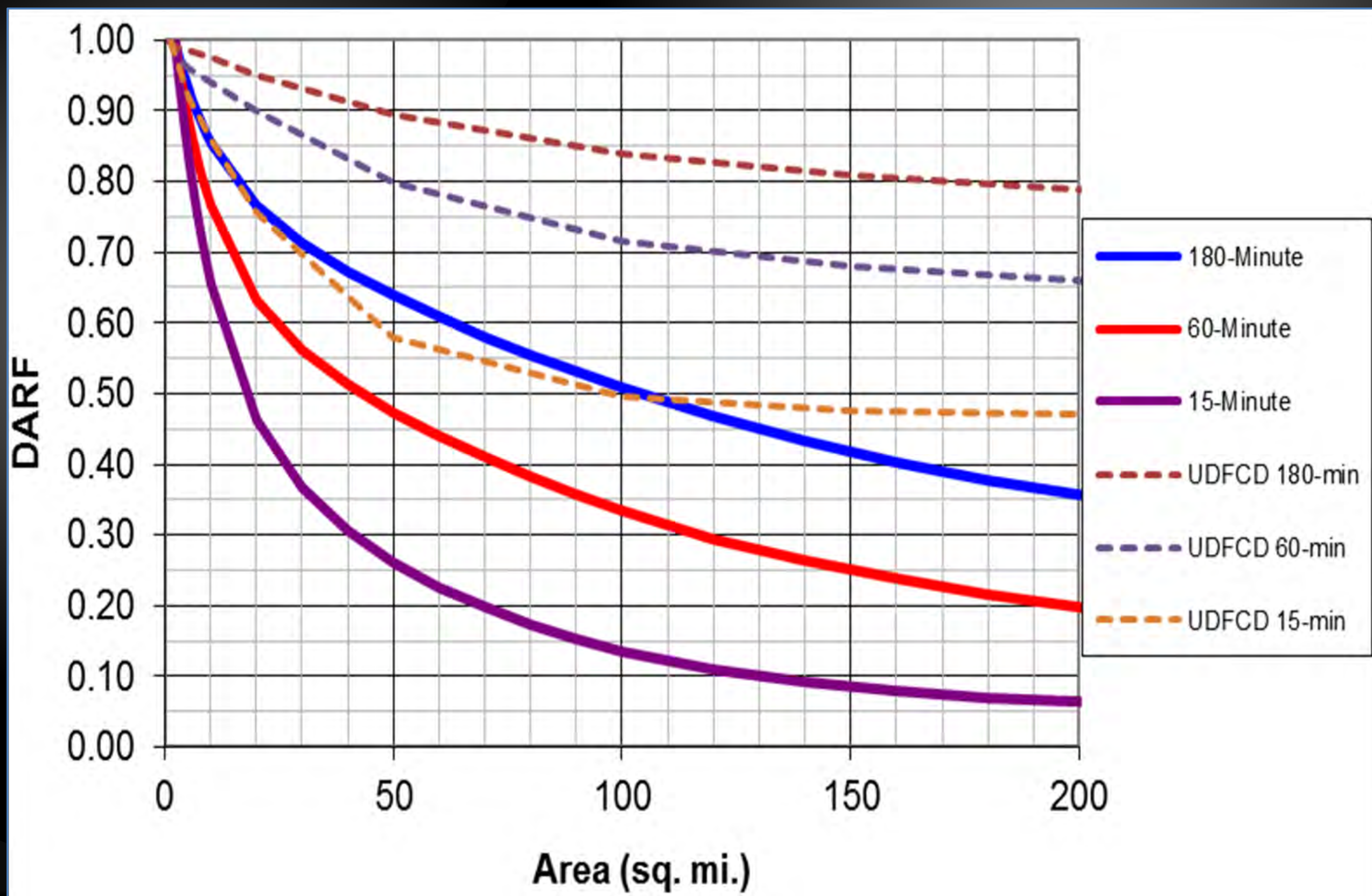
Ref.: Carlton (2011)

Area	DARF Eastern Plains		DARF El Paso County		% Differences	
Sq. Mi.	15- min	3-hr	15- min	3-hr	15- min	3-hr
20	0.84	0.67	0.71	0.69	15.5%	-3.0%
60	0.70	0.51	0.49	0.52	30.0%	-2.0%
120	0.46	0.40	0.32	0.40	30.4%	0.0%

Observations: Differences in DARFs are:

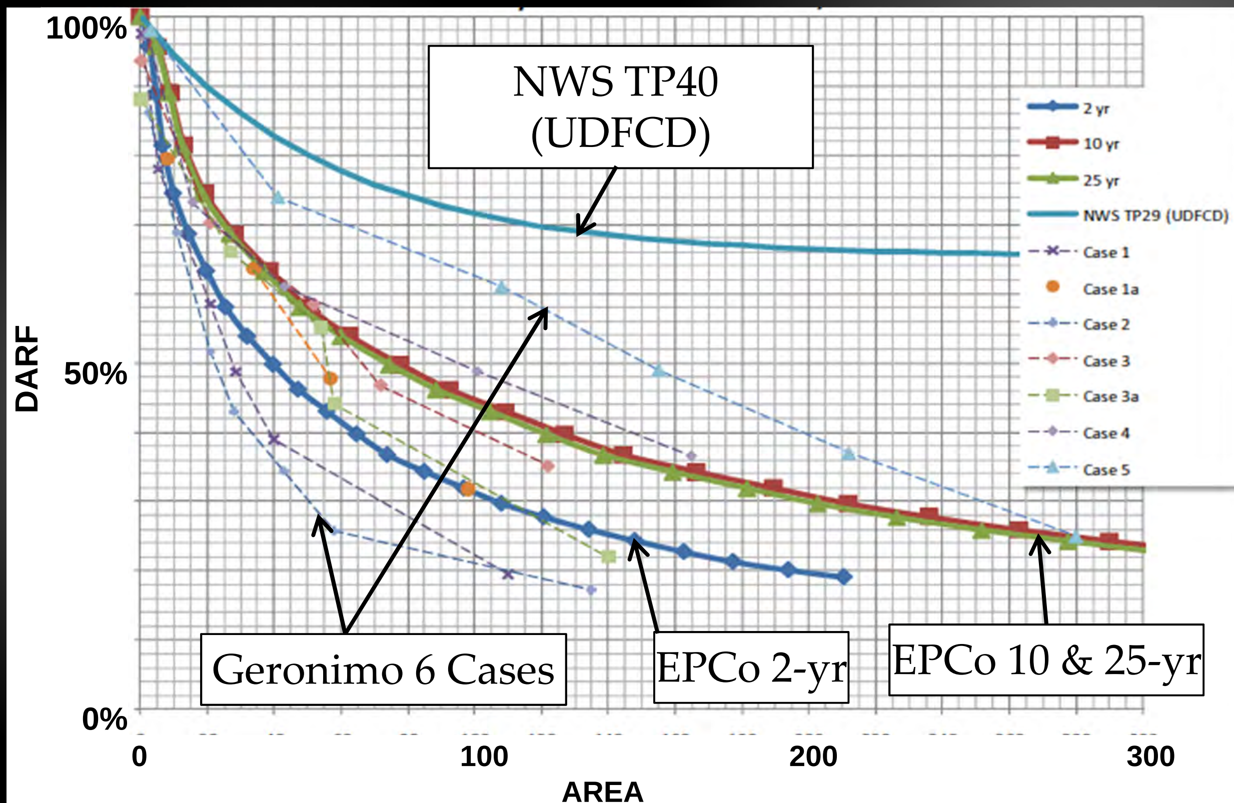
1. Significant for short duration rainstorms
2. Insignificant for longer duration storms
3. Use El Paso Co findings instead of Eastern CO.

Comparing
El Paso County Cell-Centered and Current UDFCD
2-year Storm Duration DARFs



Comparing 1-Hour DARFs for El Paso County with Geronimo (2004) Denver DARFs

Ref.: (Carlton, 2011)



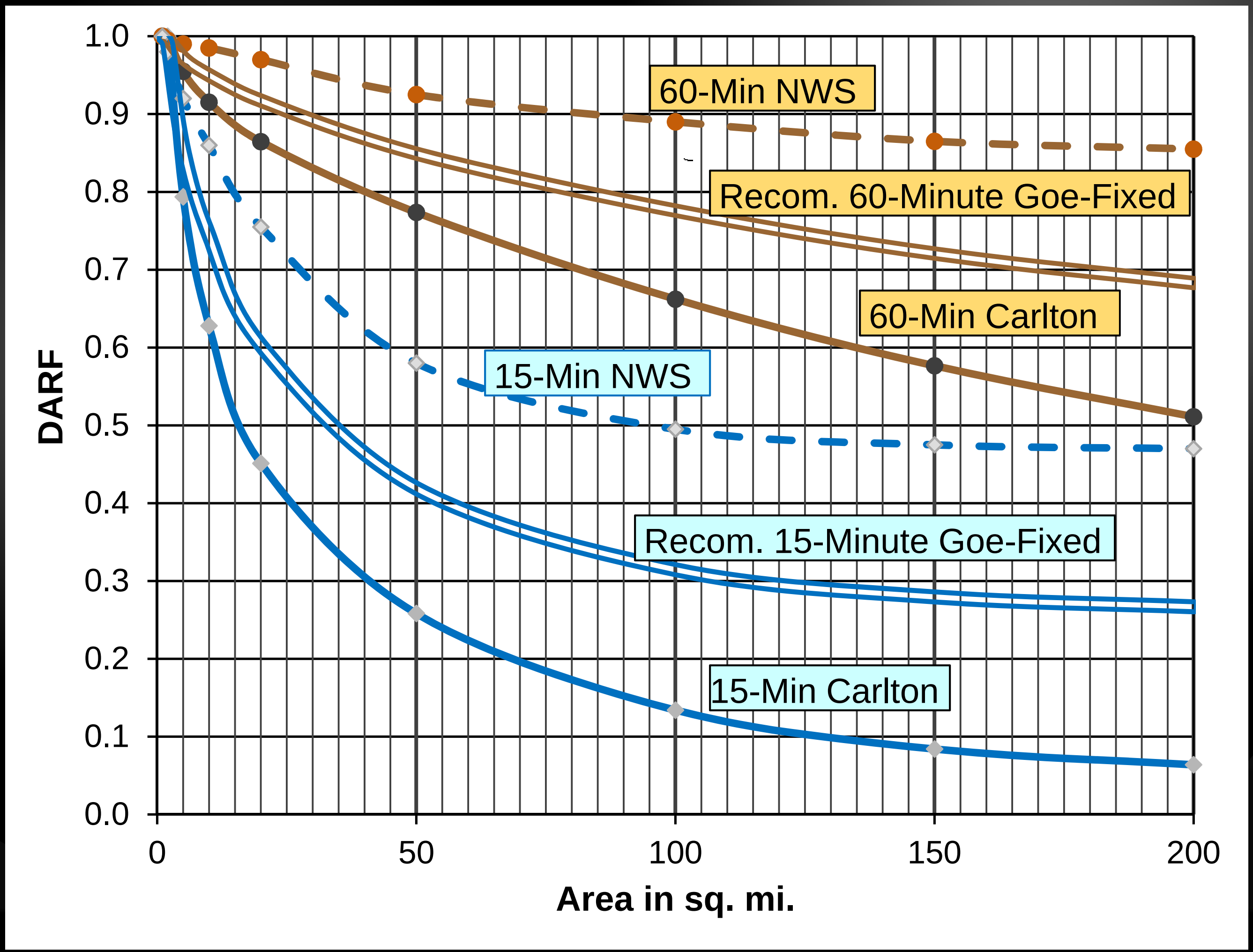
Observation: Use El Paso Co findings appear to be applicable for the UDFCD Region

Cell-Centered vs. Geographically-Fixed DARFs for UDFCD

1. Cell-Centered DARFs do not represent what is happening on the ground
2. Geographically-Fixed DARFs decay slower
3. Literature search did not provide guidance of converting one to the other type
4. Options were examined, including costs
5. UDFCD staff & WWE agreed to a pragmatic approach to develop Geographically-Fixed DARFs

   i.e., Use curves ½ way between NWS Geographically-Fixed and El Paso Co Cell-Centered DARFs

Adjusting Cell-Centered to Geographically-Fixed DARFS



Recommended DARFs for UDFCDs

10-year and Smaller Design Storms

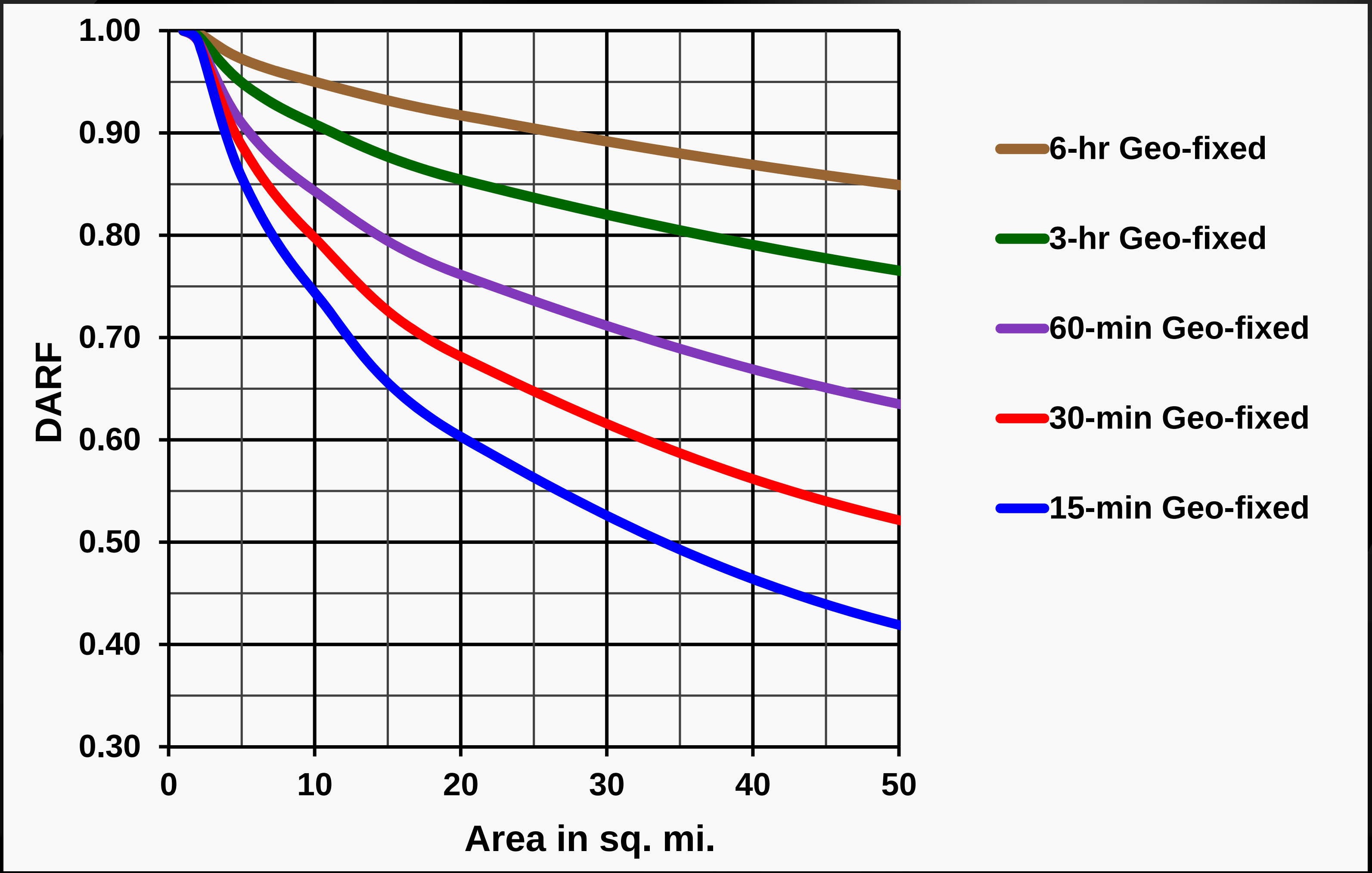


Table Values of Recommended DARFs for UDFCDs 5-yr and Smaller Design Storms

	Duration, minutes					
Area sq.mi.	15	30	60	120	180	360
1	1	1	1	1	1	1
2	1	1	1	1	1	1
5	0.857	0.888	0.910	0.935	0.949	0.972
10	0.744	0.798	0.843	0.885	0.908	0.950
15	0.674	0.739	0.802	0.853	0.881	0.934
20	0.603	0.681	0.762	0.821	0.854	0.917
30	0.542	0.628	0.719	0.785	0.825	0.895
40	0.480	0.575	0.677	0.750	0.795	0.872
50	0.419	0.521	0.635	0.715	0.765	0.849

Applying the Recommended DARFs to UDFCDs

10-year, and Smaller,

Design Storms

Example of Developing correction factors
2-hour design storm & 10-sq. mi. area

	Existing Design Storm		DARF Adjusted Storm		DARF Values for Each Duration	
Time	Depth Factor	Sub-Total	Corrected Factor	Sub-Totals	Calculated DARF Value	Expected DARF Value
0:05	0.02		0.020			
0:10	0.04		0.040			
0:15	0.084		0.080			
0:20	0.16		0.119			
0:25	0.25		0.186			
0:30	0.14	**0.55**	0.104	**0.409**	**0.744**	**0.744**
0:35	0.063		0.060			
0:40	0.05	**0.747**	0.047	**0.596**	**0.798**	**0.798**
0:45	0.03		0.032			
0:50	0.03		0.032			
0:55	0.03		0.032			
1:00	0.03	**0.927**	0.030	**0.781**	**0.842**	**0.843**
1:05	0.03		0.030			
1:10	0.02		0.020			
1:15	0.02		0.020			
1:20	0.02		0.020			
1:25	0.02		0.020			
1:30	0.02		0.020			
1:35	0.02		0.020			
1:40	0.02		0.020			
1:45	0.02		0.020			
1:50	0.02		0.020			
1:55	0.01		0.018			
2:00	0.01	**1.157**	0.015	**1.024**	**0.885**	**0.885**

10-year and Smaller Design Storms

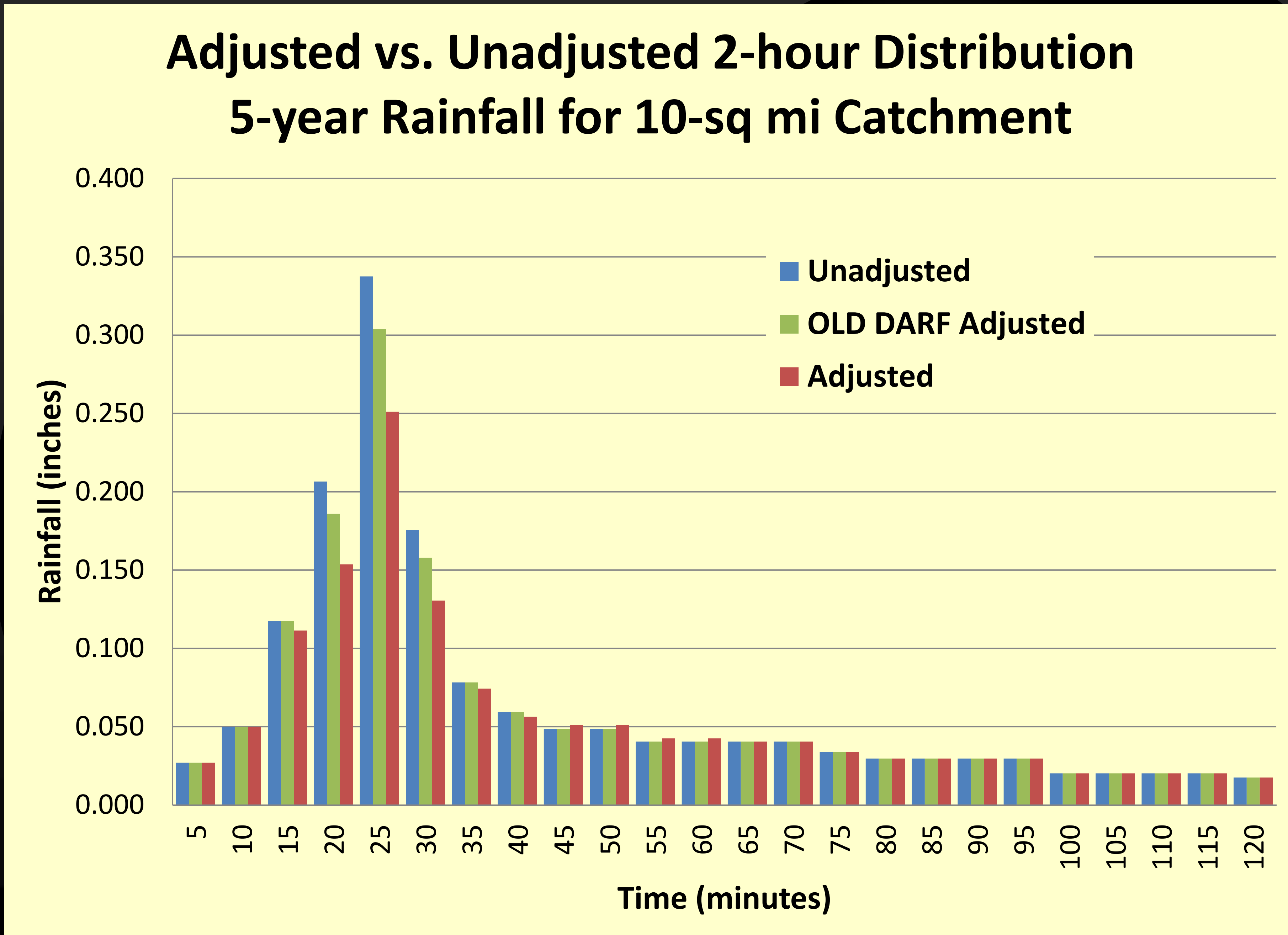
	Correction Factor by Watershed Area in Square Miles						
Time	5	10	15	20	30	40	50
0:05	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0:10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0:15	0.986	0.949	0.924	0.9	0.854	0.8	0.793
0:20	0.857	0.744	0.67	0.65	0.615	0.58	0.57
0:25	0.857	0.744	0.674	0.603	0.542	0.48	0.419
0:30	0.857	0.744	0.674	0.603	0.542	0.48	0.45
0:35	0.977	0.949	0.924	0.9	0.854	0.825	0.793
0:40	0.977	0.949	0.924	0.9	0.854	0.825	0.8
0:45	1.00	1.05	1.10	1.10	1.05	1.00	1.00
0:50	1.00	1.05	1.10	1.10	1.05	1.00	1.00
0:55	1.00	1.05	1.10	1.00	1.00	1.00	1.00
1:00	1.00	1.05	1.10	1.00	1.00	1.00	1.00
1:05	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:15	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:25	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:30	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:35	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:40	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:45	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1:55	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2:00	1.00	1.00	1.00	1.00	1.00	1.10	1.10
2:05-3:00	N/A	N/A	0.88	0.94	0.95	0.95	0.96
3:05-6:00	N/A	N/A	N/A	1.01	1.03	1.05	1.06

Completing Previous Table

1. Developed all correction factors for the UDFCD design storms for areas ranging from 5 to 50 sq. miles
   - covers most watershed sizes in UDFCD
   - these DARFs are for 10-year and smaller storms only affecting only pipes and low-flow channels
2. Discovered minor inconsistencies in 50 to 60 min. duration storm depths
   - Graphically smoothed our the initial correction factors to arrive at final recommendations

How to Apply the Resultant Design Storms in Large Catchment?

1. Run rainfall/runoff model (CUHP, SWMM, other) without corrections. Use results for catchments of 2 sq. mi. or smaller
2. Run model with 5 sq. mi. correction. Use results to waterways between 2 and 5 sq. mi. limits
3. Repeat step 2 for 10, 20, 30 and 50 sq. mi. corrections and apply each to the waterways serving intervening catchment areas.
4. These will provide peak flow information to develop peak flow profiles along the waterways that my be used on planning and design.



Adjusted vs. Unadjusted 2-hour Distribution
5-year Rainfall for 10-sq mi Catchment
Rainfall (inches)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Unadjusted
OLD DARF Adjusted
Adjusted
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
Time (minutes)

???

QUESTIONS?

???

Temporary Diversion Sizing When Working in Waterways

DAVID BENNETTS
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

SHANNON TILLACK
WRIGHT WATER ENGINEERS

Evolution of Temporary Diversion Sizing Methods

Contractor's Judgment

Contractor developed diversions based on a number of factors:

- Time of Year
- Duration of project
- Base flow of drainageway
- Area of Project site
- What they were building and how
- General concurrence of owner
- Amount of risk they were willing to assume

Evolution of Temporary Diversion Sizing Methods

Examples

Evolution of Temporary Diversion Sizing Methods

Examples

Evolution of Temporary Diversion Sizing Methods

Changes in Construction Stormwater Management

MS4 Permits

- Erosion

Evolution of Temporary Diversion Sizing Methods

Changes in Construction Stormwater Management

Construction BMP's

- District developed guidance on construction BMP's in Volume 3 of Criteria Manual
- Guidance in sizing temporary diversions

Evolution of Temporary Diversion Sizing Methods

District Volume 3 Criteria Manual

TDC Fact Sheet – SM8

Consider a number of options when sizing a temporary diversion

- Time of Year
- Duration of project
- Base flow of drainageway
- Site disturbance
- Type of work being done
- TDC sizing procedure using Nomograph

Evolution of Temporary Diversion Sizing Methods

MS4 Permits

2 year diversion requirement

Requirement to size all TCD using 2-year peak flows

- Disturbance to site
- Additional Costs
- One size does not fit all

Evolution of Temporary Diversion Sizing Methods

Examples

Evolution of Temporary Diversion Sizing Methods

Examples

Evolution of Temporary Diversion Sizing Methods

Examples

Design Process

Step 1:
Determine if diversion is appropriate

Step 2:
Determine project duration

Step 3:
Determine time of year of construction

Step 4:
Gather diversion sizing parameters

Step 5:
Perform sizing calculations & use engineering judgment

Step 6:
Determine appropriate method of diversion

Step 1: Determine If Diversion Is Appropriate

Factors to Consider…

1. Cause greater environmental impacts than without diversion
2. Consequences of exceeding diversion capacity
3. Cost to construct diversion
4. Availability of space/limited ROW
5. Permitting requirements

Step 2: Determine Project Duration

Short Duration Projects

- Completed within one month or less

Long Duration Projects

- Lasts longer than three months

Interim Duration Projects

Step 3: Determine Time of Year of Construction

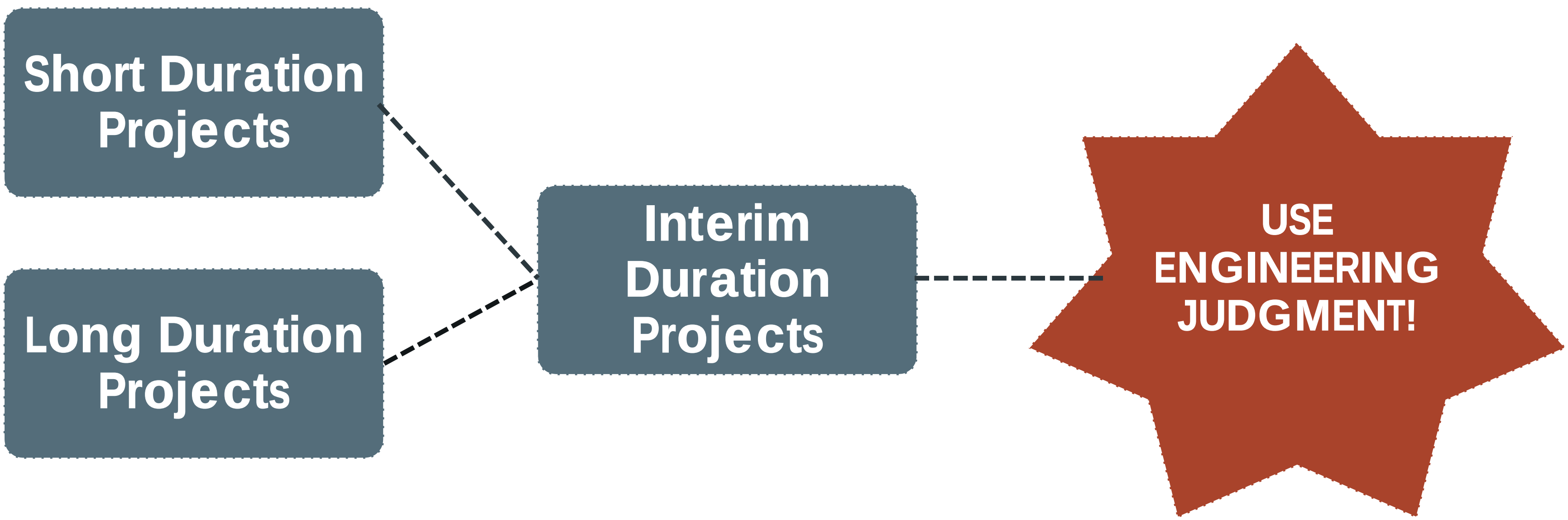
November – March: Lower risk of rainfall/runoff events

April – October: Higher risk of rainfall/runoff events

Step 4: Gather Sizing Parameters

1. Tributary area
2. Imperviousness
3. Project duration safety factor
4. Seasonal sizing coefficient

Step 5: Perform Sizing Calculations



Basis of Sizing Criteria

Crest Stage Indicator (CSI) Data:

- 30 years, 21 gages in metropolitan area
- Estimate of peak flow for each month from April through September
- Observation of the conditions at the site
- Estimation of baseflow at time of visit

Sizing Methodology: Short Duration Projects

- Tributary Area, A
- Safety Factor, C
- Sizing Coefficient, K

Time of Year	Project Duration	Safety Factor, C	Sizing Coefficient, K
November - March	< 2 weeks	1.0	0.2
November - March	2 weeks – 1 month	1.5	0.2
April - October	< 2 weeks (during dry weather conditions)	1.0	0.5
April - October	2 weeks – 1 month	1.5	0.5

Calculated Diversion Design Flow (cfs):

$$Q = C \cdot K \cdot A$$

Example:
Short Duration Project

Example: Goldsmith Gulch Bank Stabilization

- 0.12 acres of disturbance
- Completed within 2 weeks during Nov – March time period
- Tributary Area = 6.2 mi^2

Factors for Short Duration Projects

Time of Year	Project Duration	Safety Factor, C	Sizing Coefficient, K
Nov - March	< 2 weeks	1.0	0.2

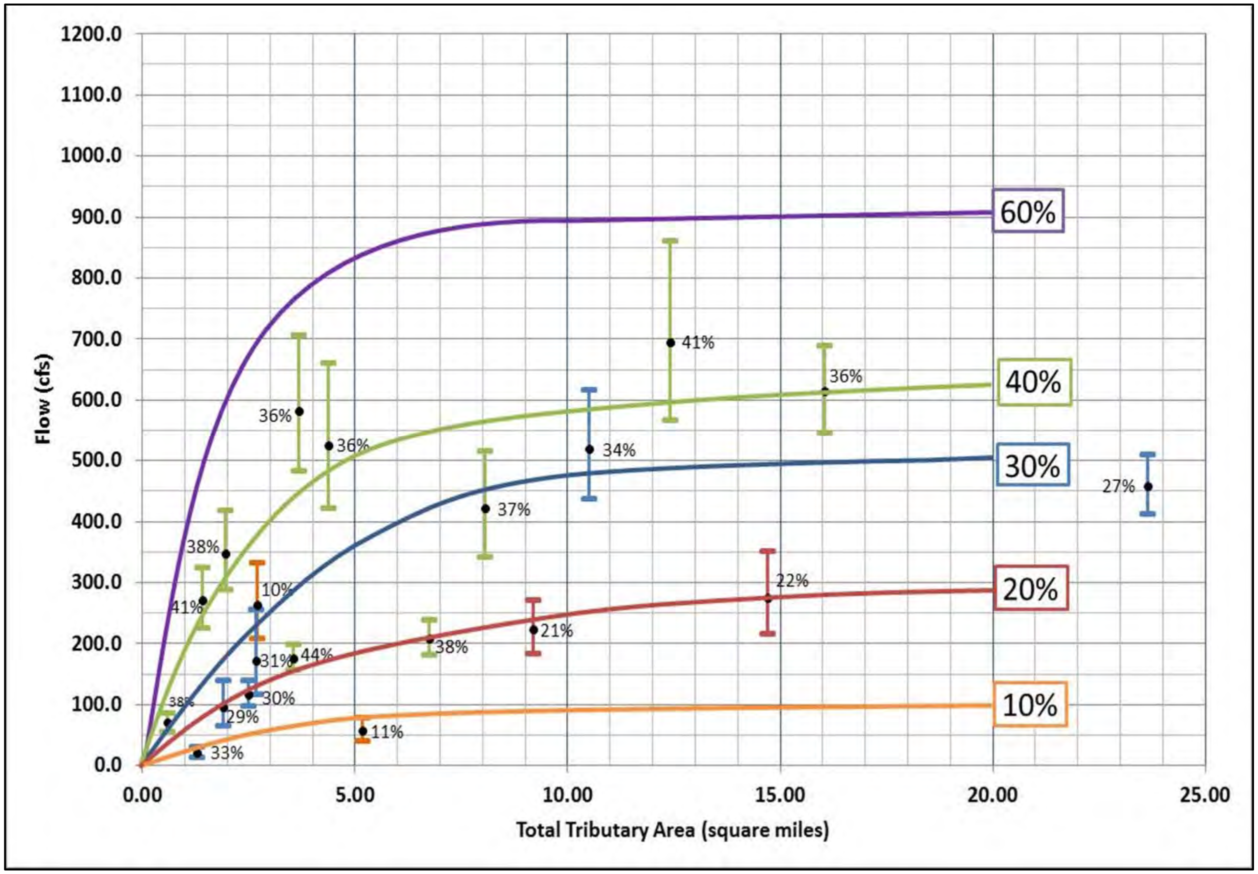
$$Q = C \cdot K \cdot A$$

$$Q = 1.0 \cdot 0.2 \cdot 6.2\ mi^2$$

$$\mathbf{Q = 1.3\ cfs}$$

Sizing Methodology: Long Duration Projects

In-Progress



Temporary Diversion Method Sizing Nomograph for Long Duration Projects Based on 2-Year Peak Flows

Lakewood Gulch

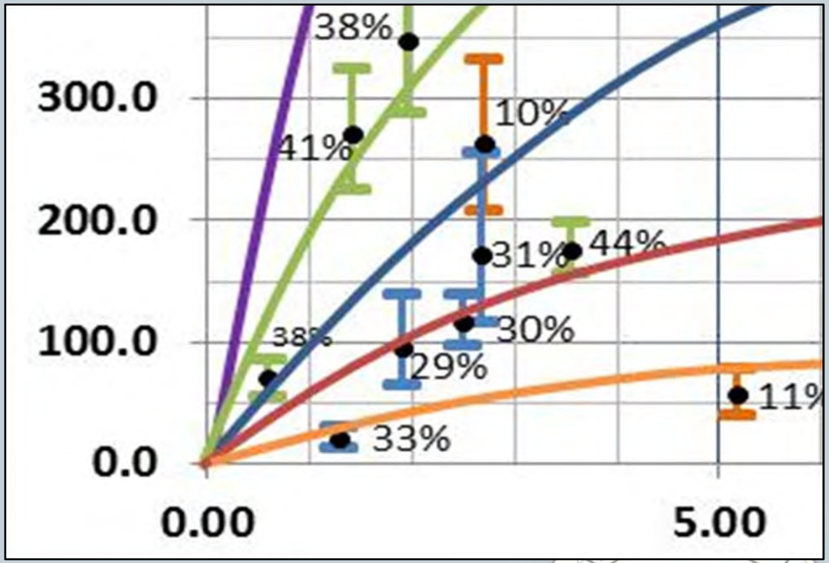
Example:

Long Duration Project

Example: Rock Creek at Rock Creek Farm

- Tributary Area = 3 mi^2
- Watershed Imperviousness = 10%

Factors for Long Duration Projects



Q = 50 cfs

Sizing Methodology: Interim Duration Projects

- Combination of sizing methods
- Weigh flow rates in combination with site-specific factors
- Apply engineering judgment

Step 6: Determine Method of Diversion

1. Temporary Diversion Channel
2. Coffer Dam or Berm

Step 6: Determine Method of Diversion

3. Piped Diversion

4. Pumped Diversion

REVISED FACT SHEET

Available in

Summer 2012

Description

Photograph TDC-1. Use of a temporary diversion channel (right side) to enable installation of a grade control structure (left side). Photo courtesy of WWE.

A temporary diversion channel diverts water from a stream to allow for construction activities to take place underneath or in the stream. Diversion channels are often required during the construction of detention ponds, dams, in-stream grade control structures, utility installation and other activities that require working in waterways.

Appropriate Uses

Temporary diversion channels vary with the size of the waterway that is being diverted. For large streams, a temporary diversion may consist of berms or coffer dams constructed in the stream to confine flow to one side of the stream while work progresses on the dry side of the berm. For smaller streams and often for construction of dams and detention basins, a temporary diversion channel may divert the entire waterway, as illustrated in Figure TDC-1. For very short duration projects (typically less than 4 weeks) during dry periods with low base flows, a pump and bypass pipe may serve as a temporary diversion. Whenever a temporary diversion is used, construction should be scheduled during drier times of the year if possible, and construction in the waterway should progress as quickly as possible to reduce the risk of exceeding the temporary diversion channel capacity.

Some construction activities within a waterway are very short lived, namely a few hours or days in duration, and are minor in nature. These are typically associated with maintenance of utilities and stream crossings and minor repairs to outfalls and eroded banks. In these cases, construction of temporary diversion channels can often cause more soil disturbance and sediment movement than the maintenance activity itself. If it can be reasonably determined based on area and duration of disturbance that channel work will result in less disturbance and movement of sediment than would be done through installation of a temporary diversion channel, it is reasonable to exempt these activities from the requirement to construct a temporary diversion.

Design and Installation

Temporary Diversion Channel sizing procedures typically include the following steps:

- Using the tributary area, A (in acres), determine the design peak flow rate according to Figure DC-2. Note: For long duration projects, or where the consequences of diversion failure warrant, a larger design flow may be necessary.
- Determine depth of flow, 1-foot maximum for flows less than 20 cfs and 3 feet maximum for flows less than 100 cfs. (Flows in excess of 100 cfs should be designed in accordance with the *Major Drainage* chapter in Volume 1).

Temporary Diversion Channel	
Functions	
Erosion Control	Yes
Sediment Control	No
Site/Material Management	No

QUESTIONS?

Dave Bennetts: dbennetts@udfcd.org

Shannon Tillack: stillack@wrightwater.com

USDCM Volume 1 and 2 Updates

UPDATE ON THE UPDATE!

Update on the Update!

- What are criteria?
- Survey results
- Importance of Safety
- Additions to the criteria
- Trails adjacent to streams criteria

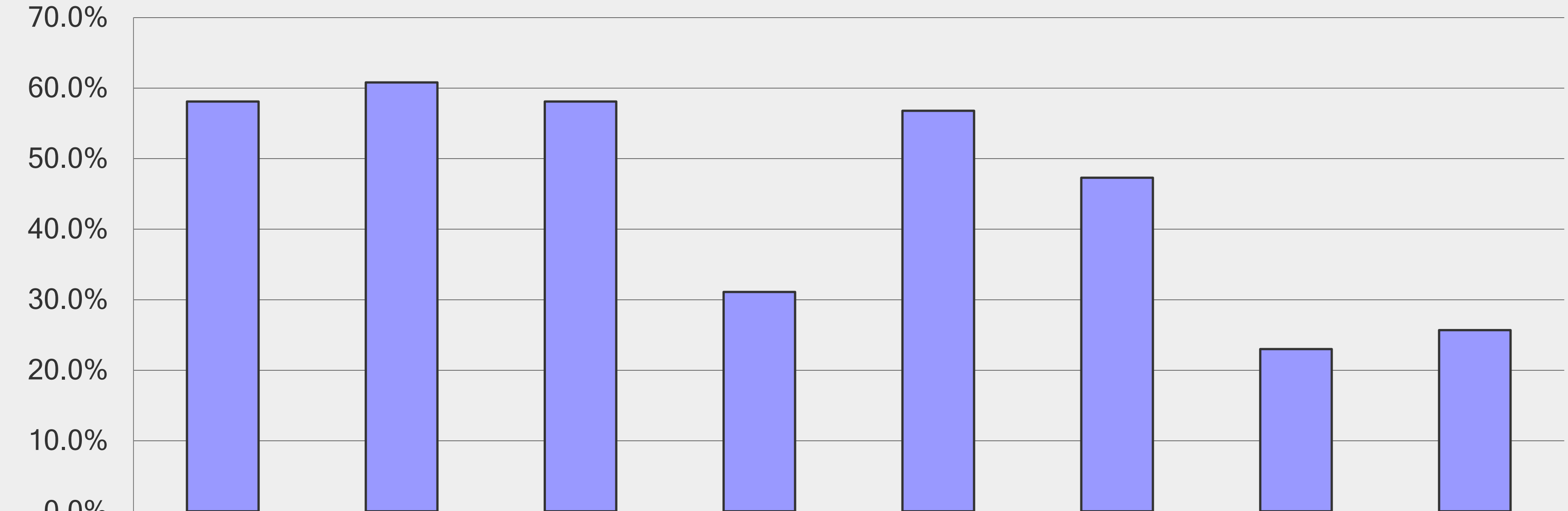
What are "criteria"?

- Provides design standards and guidance
- Identifies additional resources
- Based on detailed analysis using a range of values
- Based on published work by others
- Based on standard practice
- Based on experience
- Based on judgment
- Requires additional analysis and good engineering judgment by the user

What are "criteria"?

- When USDCM criteria is followed does it make a project eligible for UDFCD maintenance?
- Do UDFCD projects always follow USDCM criteria?

Which of the following areas do you believe would benefit from more guidance?



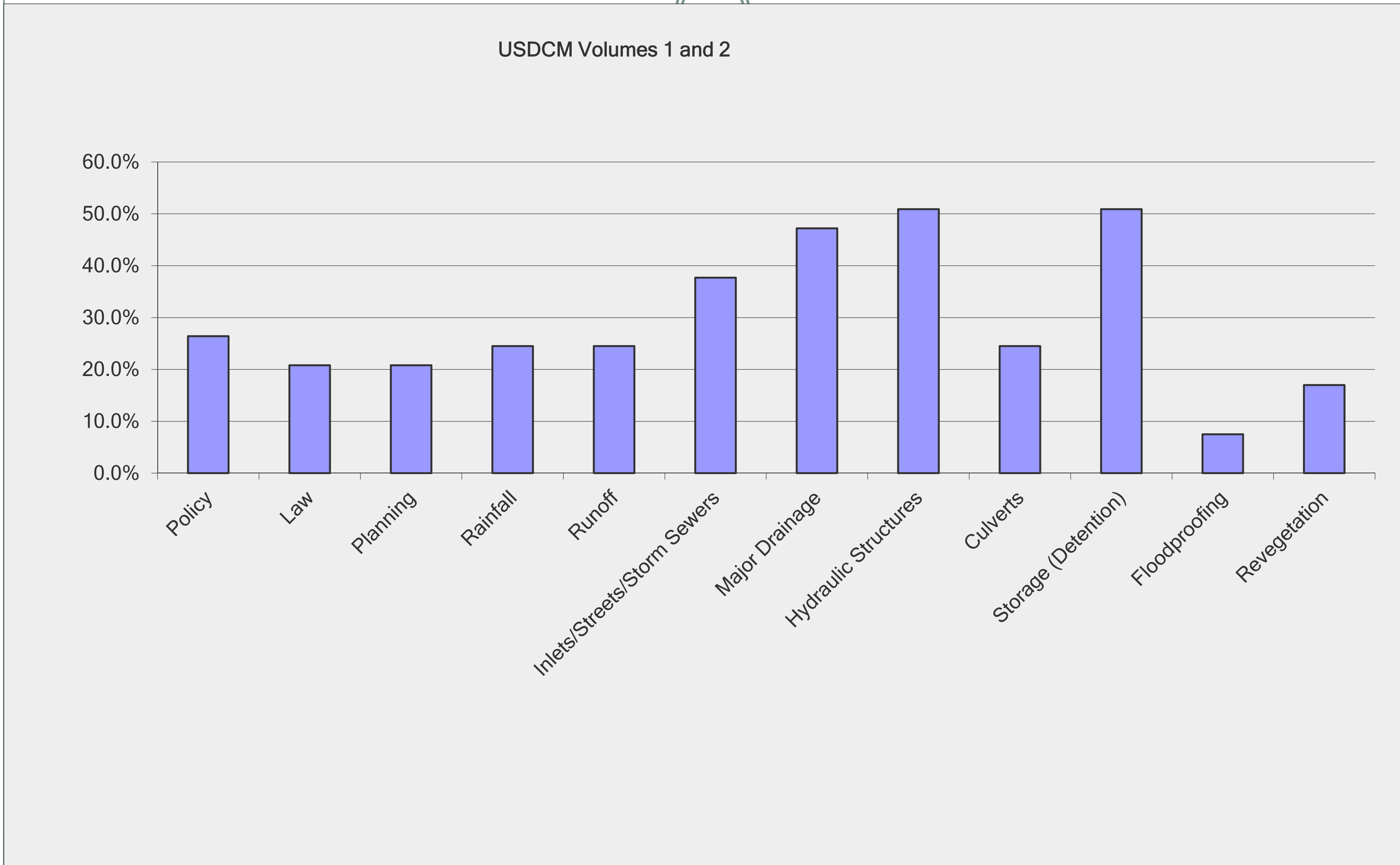
	Early planning for site designs integrating water quantity and quality; holistic design principles	Full spectrum detention / EURV	Use of green infrastructur e approaches with streets/inlets /storm sewers	Integrating water conservation principles with revegetation guidance	Transportati on-related drainage projects	Maintenance	Safety	No adverse impact and other floodplain issues
Series1	58.1%	60.8%	58.1%	31.1%	56.8%	47.3%	23.0%	25.7%


PUBLIC WORKS
Protecting the Present &
Building the Future
COMMITMENT TO SERVICE
ACCOUNTABILITY
INNOVATION
EMPOWERMENT
PERFORMANCE
INTEGRITY
DIVERSITY
TEAMWORK
RESPECT
EXCELLENCE
SAFETY

Safety

- Hydraulic Structures
  - Trash Racks
  - Drops
  - Walls
- Ponds
- Trails

Which of the following chapters do you believe need major, substantive revisions?



Additions to Criteria

- Revised DARF for the events up to the 10-year
- Improved Simplified Equation for sizing basins
- Sculpted Concrete Drop Structures
- Incorporate CSU Inlet Study
- Void-filled riprap for channel lining
- Expanded outfall details and guidance
- Trails adjacent to streams

Trails Adjacent to Streams Criteria

April 10, 2012

Frequency of Inundation

Trail type	Minimum Trail Surface Elevation (when practicable) (WSE)	Minimum Trail Surface Elevation (WSE)	Other Considerations
Shared Use (New)	10-year	5-year	Elevating the trail to the 10-year WSE is preferred.
Shared Use (Retrofit)	10-year	2-year	Where possible also elevate the trail two feet above the baseflow.
Stream Crossings	2 to 5-year	2-year	
Bridge Underpass	5-year	2-year	
Culvert Underpasses less than 100 feet in length	5-year	2-year	The user should be able to see then water is rising and climb to safety.
Culvert Underpasses greater than 100 feet in length	10-year	5-year	The culvert should be straight. The user should be able to see then water is rising and climb to safety.

Edge Treatment Criteria

Photo Courtesy Muller

Edge Treatment Criteria

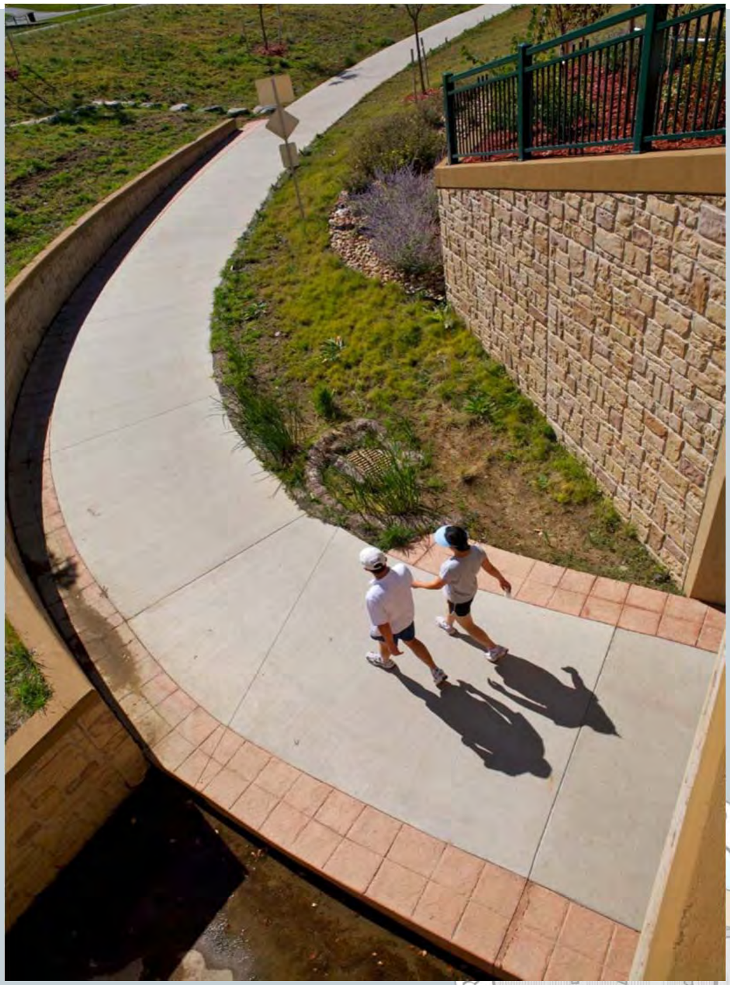


Photo Courtesy Architerra Group

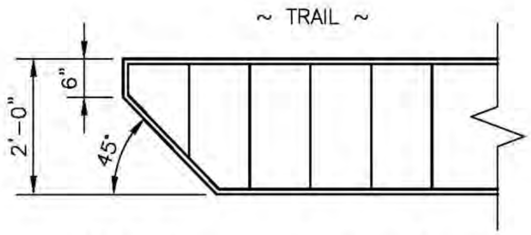
Rails, Curb Rails, and Rumble Strips

	Difference in elevation from trail surface to adjacent grade (Design[1])	Edge Treatment
Trails perpendicular to stream or in an underpass	Up to 3'-0" inches	Rumble strip or curb rail
	up to 4'-6" inches	curb rail
	Greater than 4'-6" inches	Full rail[2] (typically 3'-6" inches for shared use and 4'-6" for equestrian)
Trails parallel to stream and not in an underpass	Up to 3'-0" inches	Rumble strip
	Greater than 3'-0" inches or adjacent slope steeper than 3:1[3]	Full rail[2] (typically 3'-6" inches for shared use and 4'-6" for equestrian)

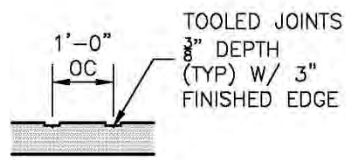
1 Values provided assume that differences in elevation following construction may potentially increase in some areas by up to 20% due to stream degradation.

2 Span 100-year floodplain (preferred) or model flooding effects with rail fully clogged.

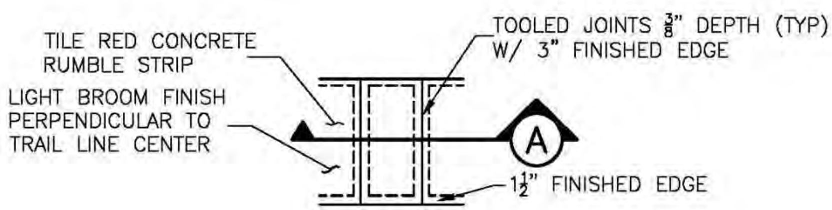
3 Adjacent slope refers to slope adjacent to the 2-foot bench.



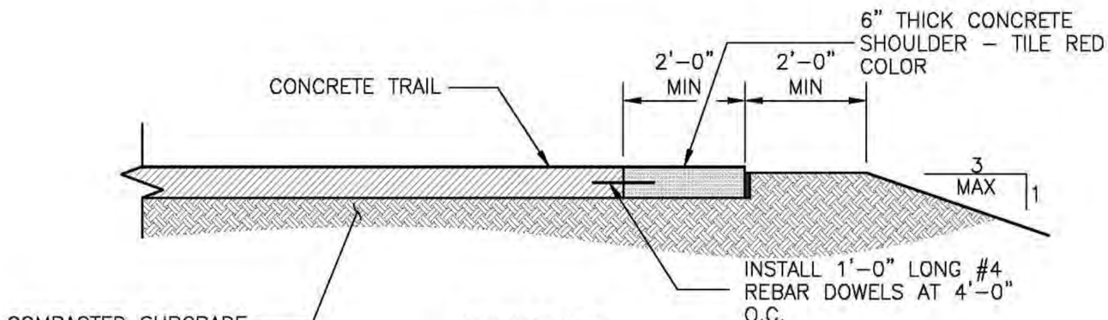
TYPICAL RETURN PLAN



SECTION A



TYPICAL SCORING PLAN



SECTION

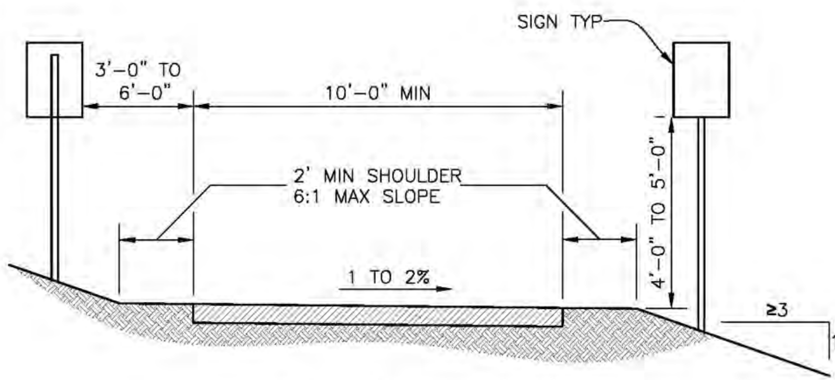
April 10, 2012

Rail Design

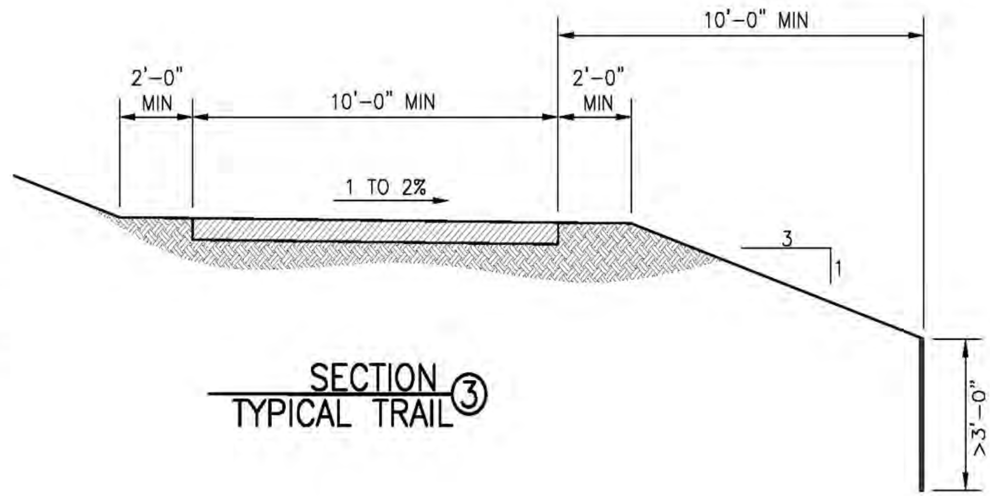
Typical Trail Width and Material

Trail Type	Width (feet)	Width for High Use or Conflict areas (feet)	Minimum Vertical Clearance for Consideration[1] (feet)	Typical Minimum Vertical Clearance[2,4] (feet)	Preferred Vertical Clearence[4] (feet)	Typical Materials[5]
Maintenance Only	10	12[3]	8	8	10	Stabilized Rock, Concrete, Reinforced Grass
Shared-Use with Bicyclists	10	12 to 14	8	8 to 9	10	Concrete or Proprietary
Equestrian	1.5 to 2.5	8	10	10	12 to 13	Grass or Compacted Soil

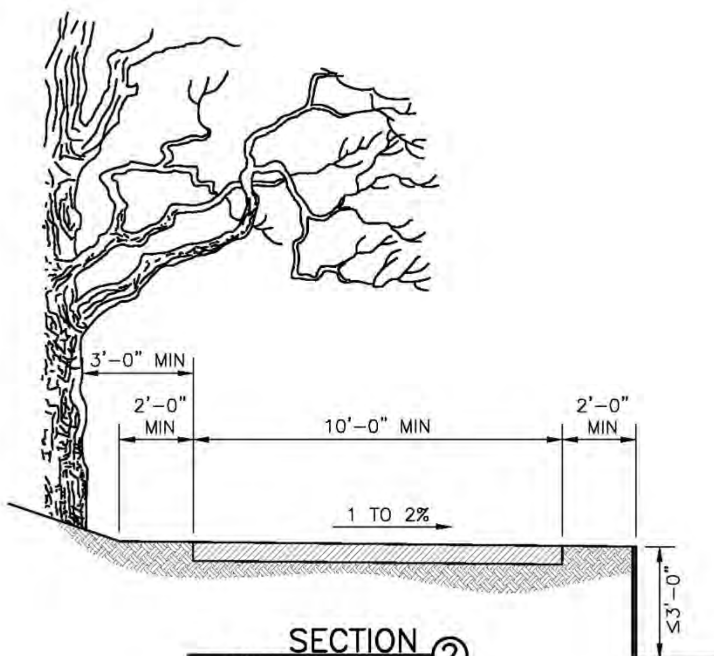
1 Represents the minimum clearance that should be considered.
2 Represents typical minimum criteria common to reviewing agencies and owners.
3 Also recommended where a rail or wall is placed on both sides of the trail.
4 Based on review of trail criteria for several agencies in various parts of the United States. Values will vary based on community.
5 Not intended to be limiting



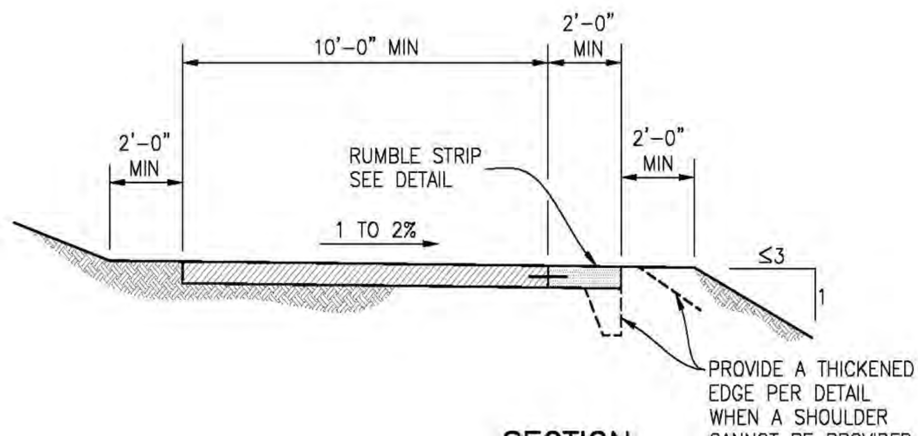
SECTION ①
TYPICAL TRAIL



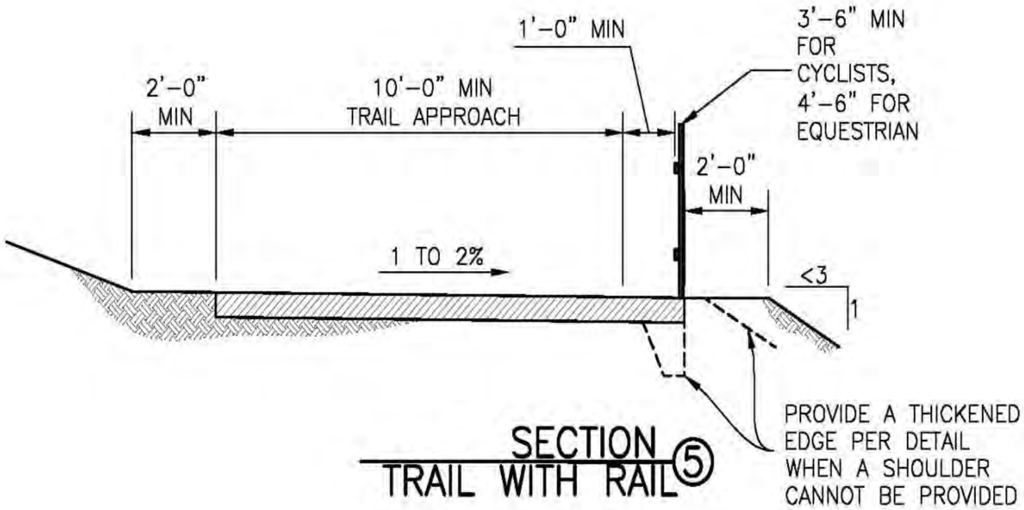
SECTION ③
TYPICAL TRAIL

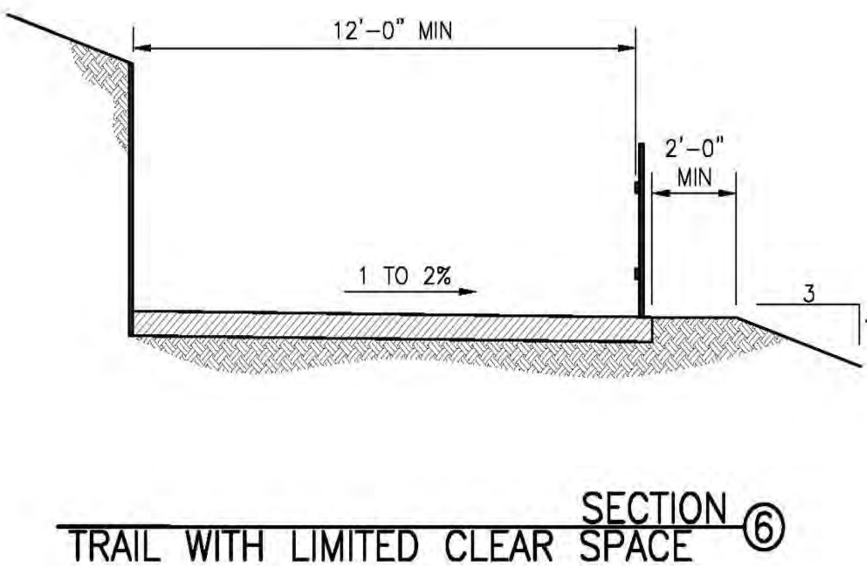


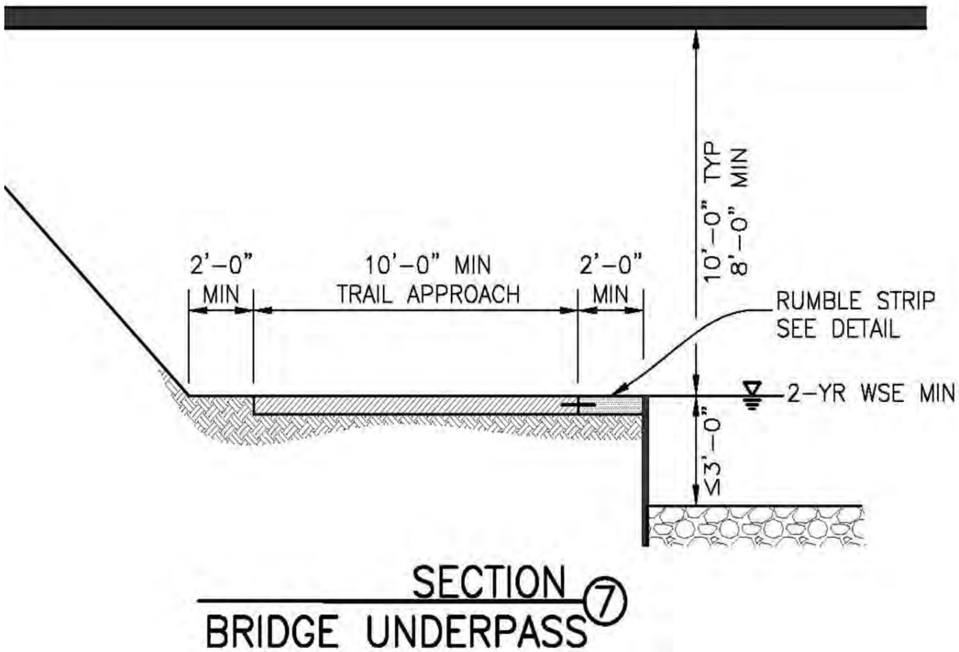
SECTION ②
TYPICAL TRAIL



SECTION ④
TRAIL SECTION WITH RUMBLE STRIP


1'-0" MIN
3'-6" MIN FOR CYCLISTS, 4'-6" FOR EQUESTRIAN
2'-0" MIN
10'-0" MIN TRAIL APPROACH
2'-0" MIN
1 TO 2%
<3
1
PROVIDE A THICKENED EDGE PER DETAIL WHEN A SHOULDER CANNOT BE PROVIDED
SECTION 5
TRAIL WITH RAIL


12'-0" MIN
2'-0" MIN
1 TO 2%
3
1
SECTION 6
TRAIL WITH LIMITED CLEAR SPACE


2'–0"
MIN
10'–0" MIN
TRAIL APPROACH
2'–0"
MIN
10'–0" TYP
8'–0" MIN
RUMBLE STRIP
SEE DETAIL
2–YR WSE MIN
≤3'–0"
SECTION 7
BRIDGE UNDERPASS

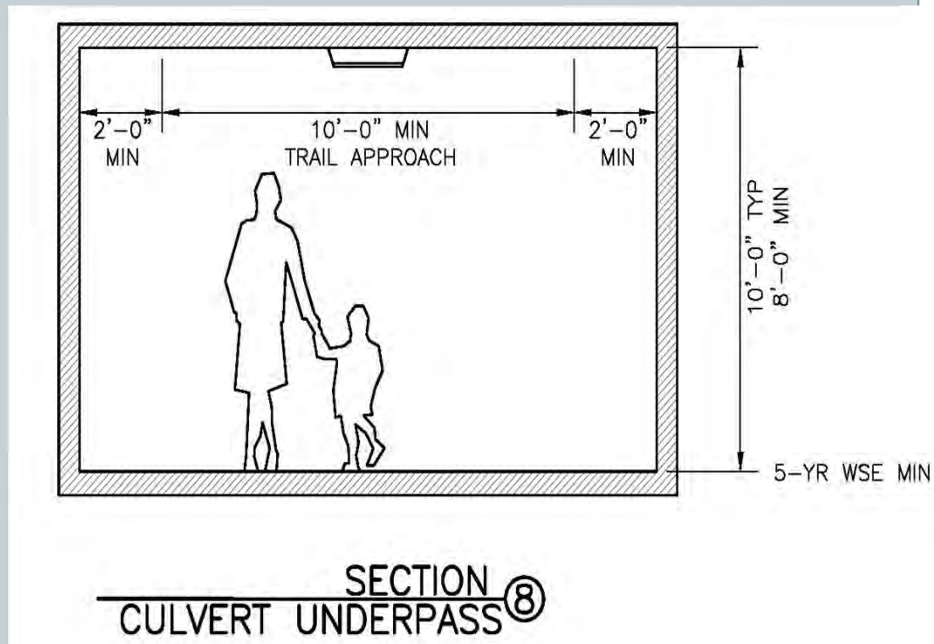
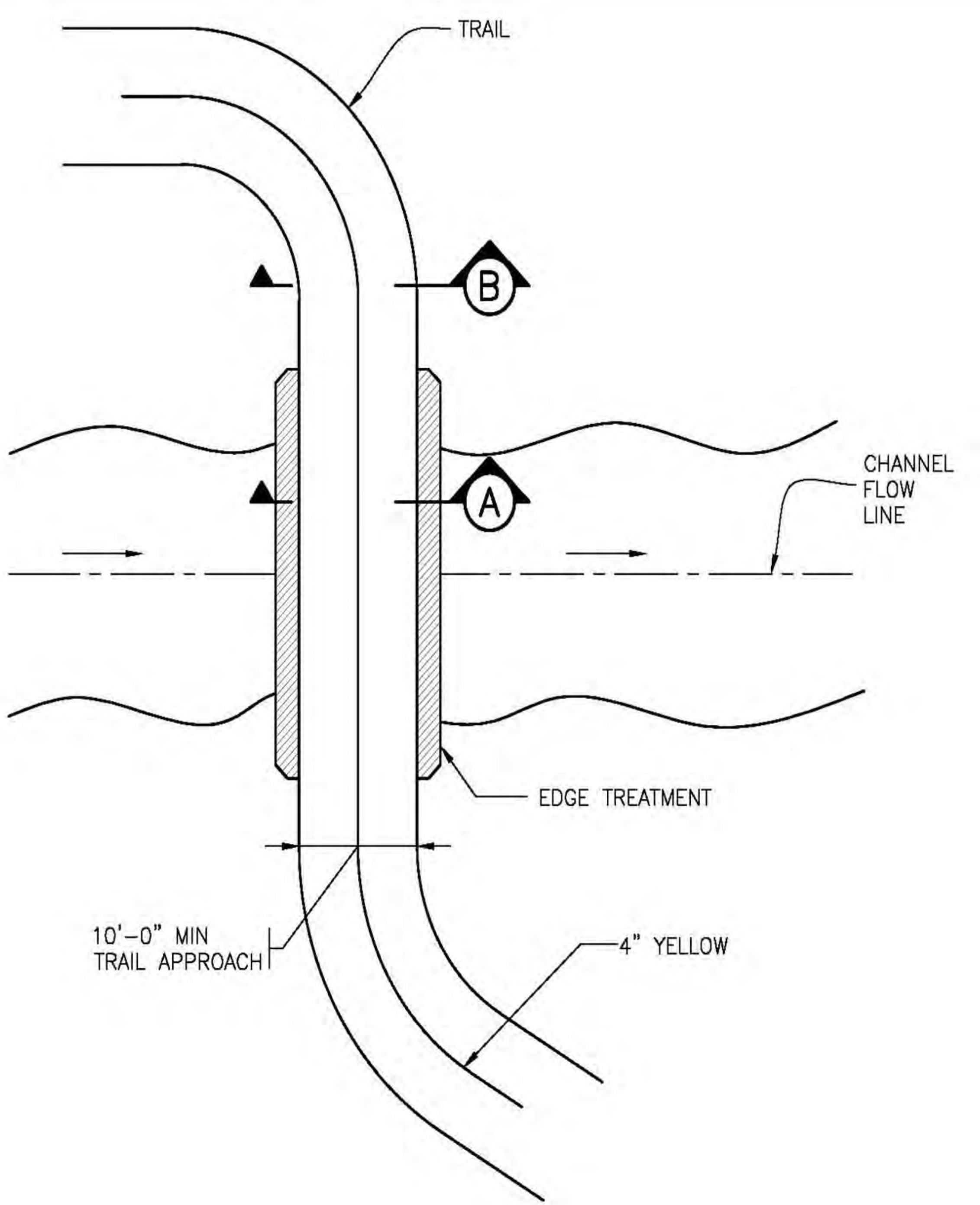
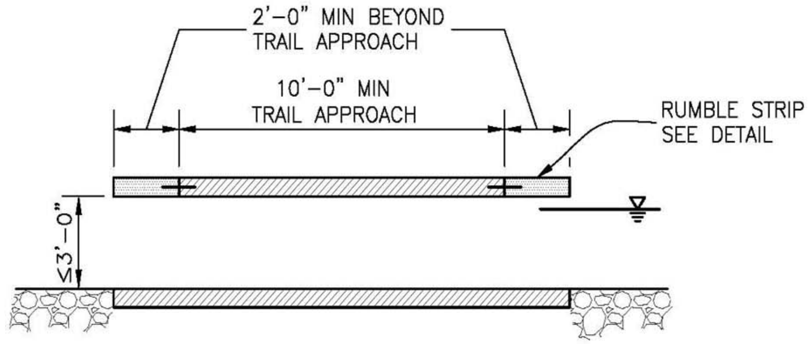
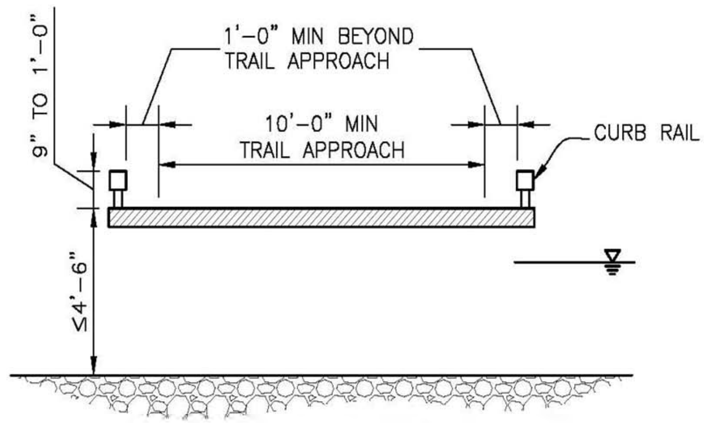

2'–0"
MIN
10'–0" MIN
TRAIL APPROACH
2'–0"
MIN
10'–0" TYP
8'–0" MIN
5–YR WSE MIN
SECTION 8
CULVERT UNDERPASS

Photo Courtesy Architerra Group

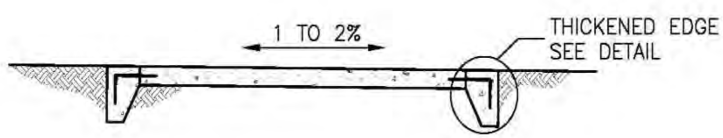

TRAIL
B
A
CHANNEL
FLOW
LINE
EDGE TREATMENT
10'–0" MIN
TRAIL APPROACH
4" YELLOW



SECTION (A)
CROSSING WITH RUMBLE STRIP

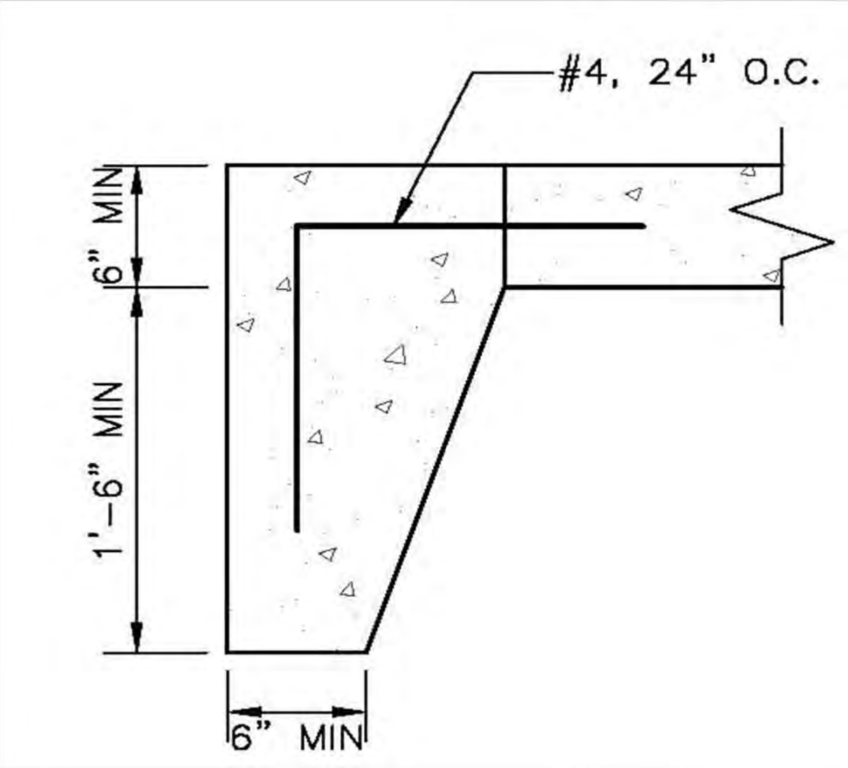


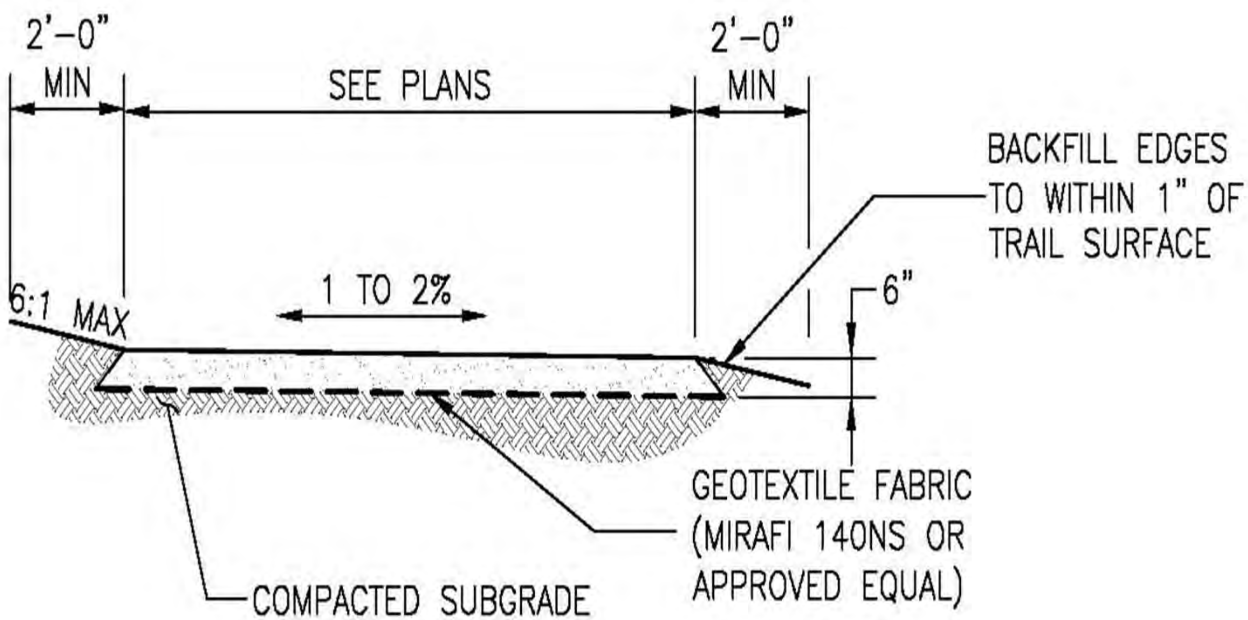
SECTION (A)
CROSSING WITH CURB RAIL



SECTION (B)
OVERTOPPING PROTECTION

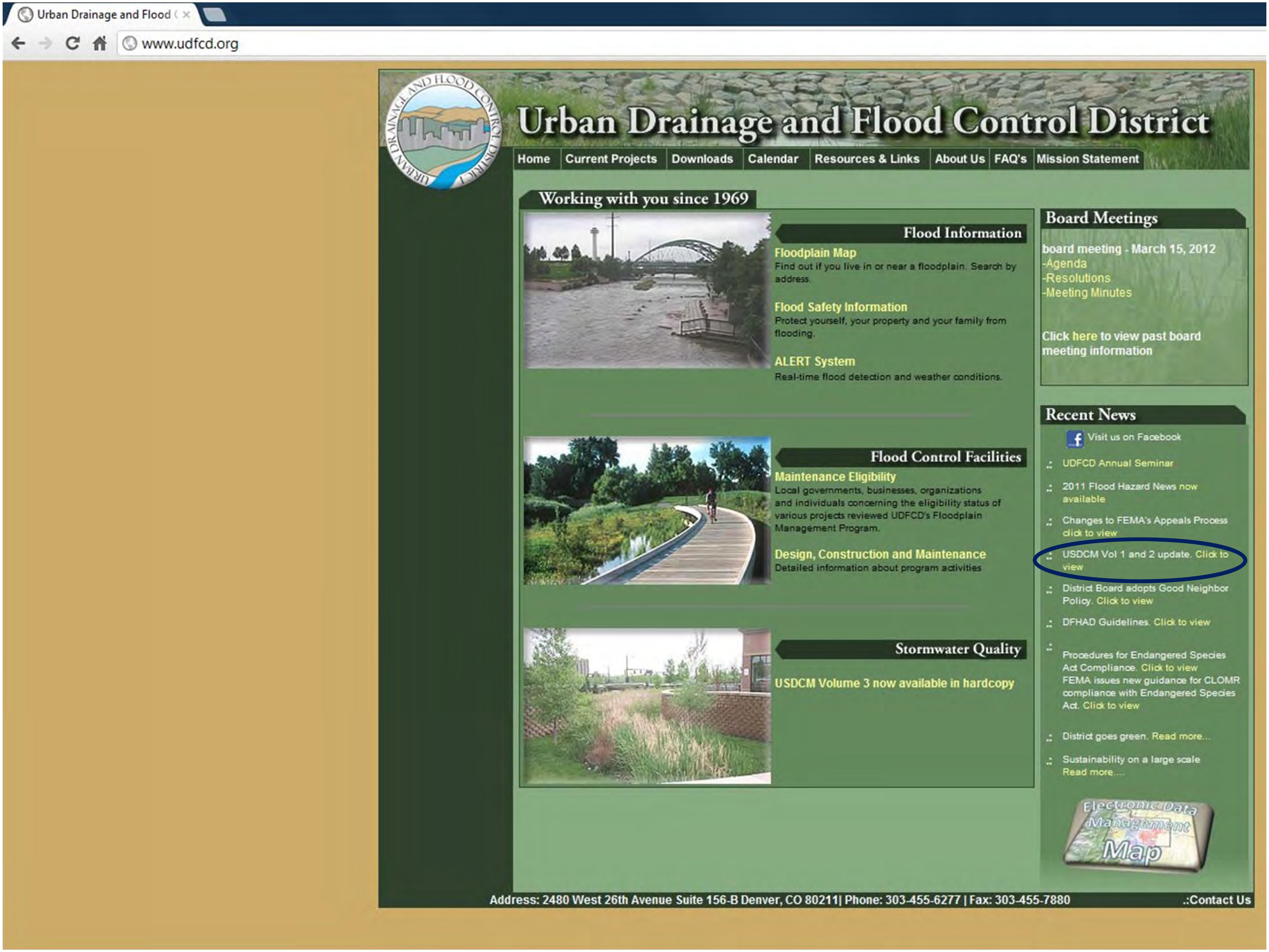
Overtopping Protection




2'–0"
MIN
SEE PLANS
2'–0"
MIN
BACKFILL EDGES
TO WITHIN 1" OF
TRAIL SURFACE
6:1 MAX
1 TO 2%
6"
GEOTEXTILE FABRIC
(MIRAFI 140NS OR
APPROVED EQUAL)
COMPACTED SUBGRADE

Proprietary Surfaces

- The surface should provide a structurally sound, maintainable surface allowing for frequent inundation without requiring repair.



Urban Drainage and Flood
www.udfcd.org
Urban Drainage and Flood Control District
Home
Current Projects
Downloads
Calendar
Resources & Links
About Us
FAQ's
Mission Statement
Working with you since 1969
Flood Information
Floodplain Map
Find out if you live in or near a floodplain. Search by address.
Flood Safety Information
Protect yourself, your property and your family from flooding.
ALERT System
Real-time flood detection and weather conditions.
Flood Control Facilities
Maintenance Eligibility
Local governments, businesses, organizations and individuals concerning the eligibility status of various projects reviewed UDFCD's Floodplain Management Program.
Design, Construction and Maintenance
Detailed information about program activities
Stormwater Quality
USDCM Volume 3 now available in hardcopy
Board Meetings
board meeting - March 15, 2012
-Agenda
-Resolutions
-Meeting Minutes
Click here to view past board meeting information
Recent News
Visit us on Facebook
UDFCD Annual Seminar
2011 Flood Hazard News now available
Changes to FEMA's Appeals Process click to view
USDCM Vol 1 and 2 update. Click to view
District Board adopts Good Neighbor Policy. Click to view
DFHAD Guidelines. Click to view
Procedures for Endangered Species Act Compliance. Click to view
FEMA issues new guidance for CLOMR compliance with Endangered Species Act. Click to view
District goes green. Read more...
Sustainability on a large scale Read more....
Electronic Data Management Map
Address: 2480 West 26th Avenue Suite 156-B Denver, CO 80211| Phone: 303-455-6277 | Fax: 303-455-7880
.:Contact Us

UDFCD Criteria Manual

- Home
  - Hydraulic Structures Core Group Meeting Minutes
  - Revegetation Core Group Meetings
- All Stakeholder Meeting Minutes
- Draft Trail Criteria
- Storage Chapter Core Group Meeting Minutes
- Trail Criteria Comments and Responses
- Trail Criteria Core Group Meeting Minutes
- Update Survey Results
- Sitemap

Use of Documents

All documents posted are in **draft form** and are subject to change without notice. These documents are not intended for design use. Please feel free to comment on these documents Email comments to hpiza@udfcd.org.

Home

We are currently in the early stages of updating Volumes 1 and 2 of the USDCM. Contact Holly Piza at hpiza@udfcd.org to see how you can get involved.

General Information Regarding the Update:

- Results from our survey
- Stakeholder meeting minutes from the first stakeholder meeting

Update Progress:

Trail Criteria: This is a new section that will be incorporated into the Major Drainage Chapter

- Trail Criteria - Core group meeting minutes
- Trail Criteria Draft Criteria (Second Draft made available Jan 23, 2012)
- Comments and UDFCD response to first draft dated Oct 2011

Storage Chapter:

- Storage Chapter - Core group meeting minutes
- Storage chapter draft (coming in April)

Revegetation Chapter:

- Revegetation - Core group meeting minutes **(New)**

Hydraulic Structures Chapter:

- Hydraulic Structures - Core group meeting minutes **(New)**

Questions

Holly Piza
hpiza@udfcd.org

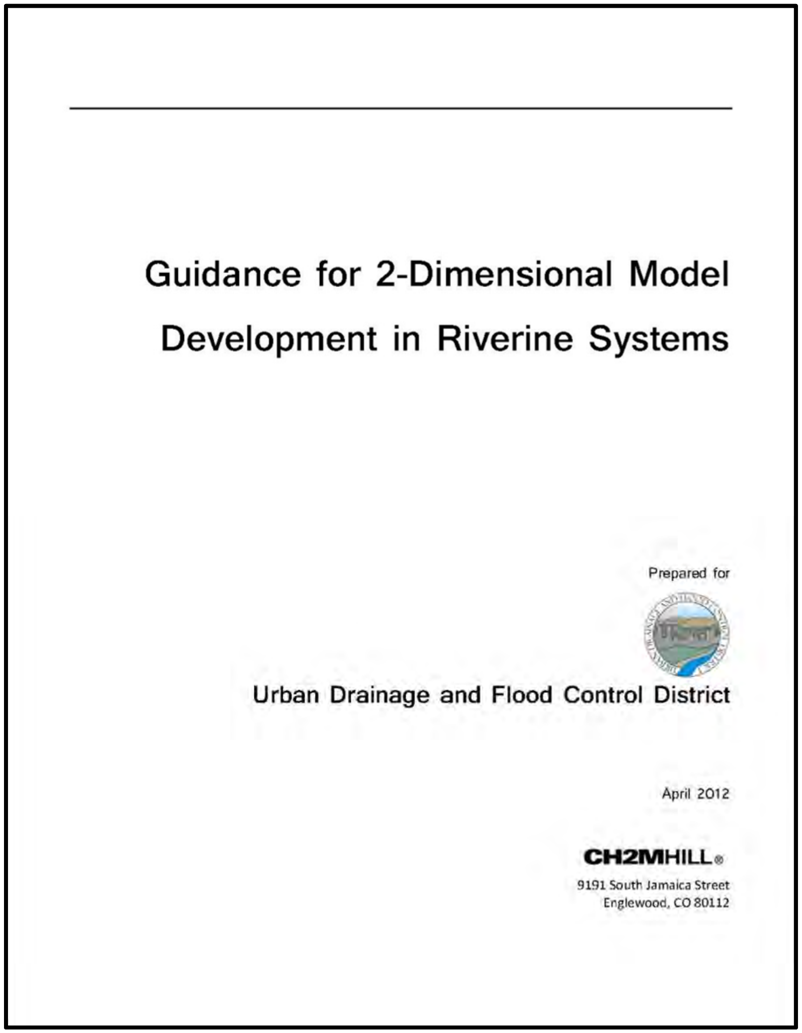
2D or Not 2D?

Guidance for 2-Dimensional Floodplain Modeling

PRESENTED BY:

SHEA THOMAS – UDFCD
ALAN TURNER – CH2M HILL

Outline



Guidance for 2-Dimensional Model Development in Riverine Systems

Prepared for

Urban Drainage and Flood Control District

April 2012

CH2MHILL®

9191 South Jamaica Street
Englewood, CO 80112

- Purpose
- Case Studies
- 2D modeling basics
- Keys to Success
- Using 2D before 1D
- 2D in UDFCD studies

Purpose for study

- 2D emerging locally in industry – 2 use or not 2 use?
- What is the difference in results between 1D and 2D models?
- When should a 2D model be used in a floodplain study?
- What are some tips for setting up a 2D model for floodplain analysis?

Ultimate goal:

Provide guidance for using 2D results to enhance a 1D model

Willow Creek

Area = 6,047 acres

Average slope = 0.8%

Stream length = 5 mi.

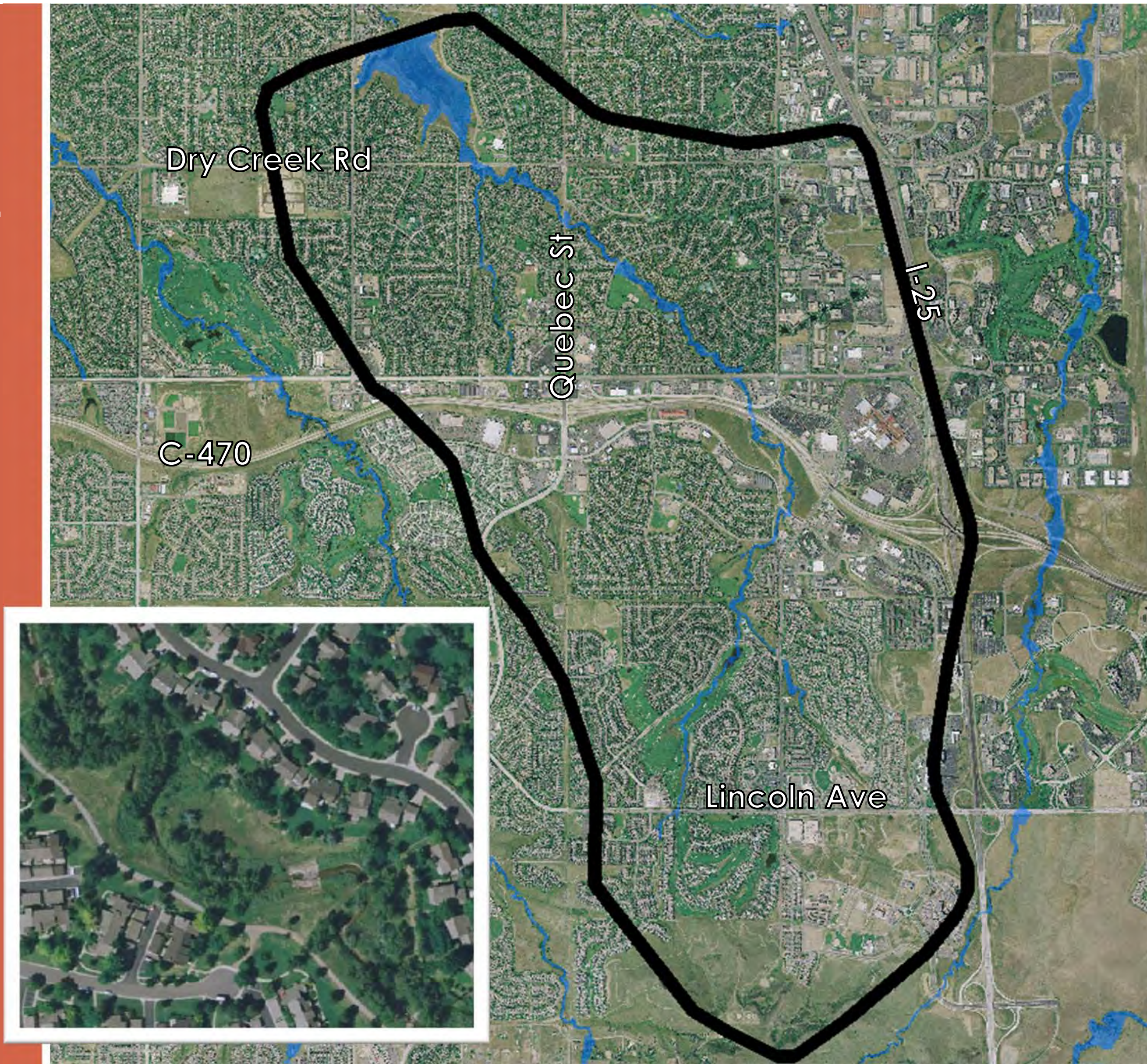
Peak Q = 9,000 cfs

Watershed:

Nearly full buildout, residential and commercial

Floodplain:

Mostly confined within channel



Coal Creek

Area = 16,835 acres

Average slope = 1.2%

Stream length = 1 mi.

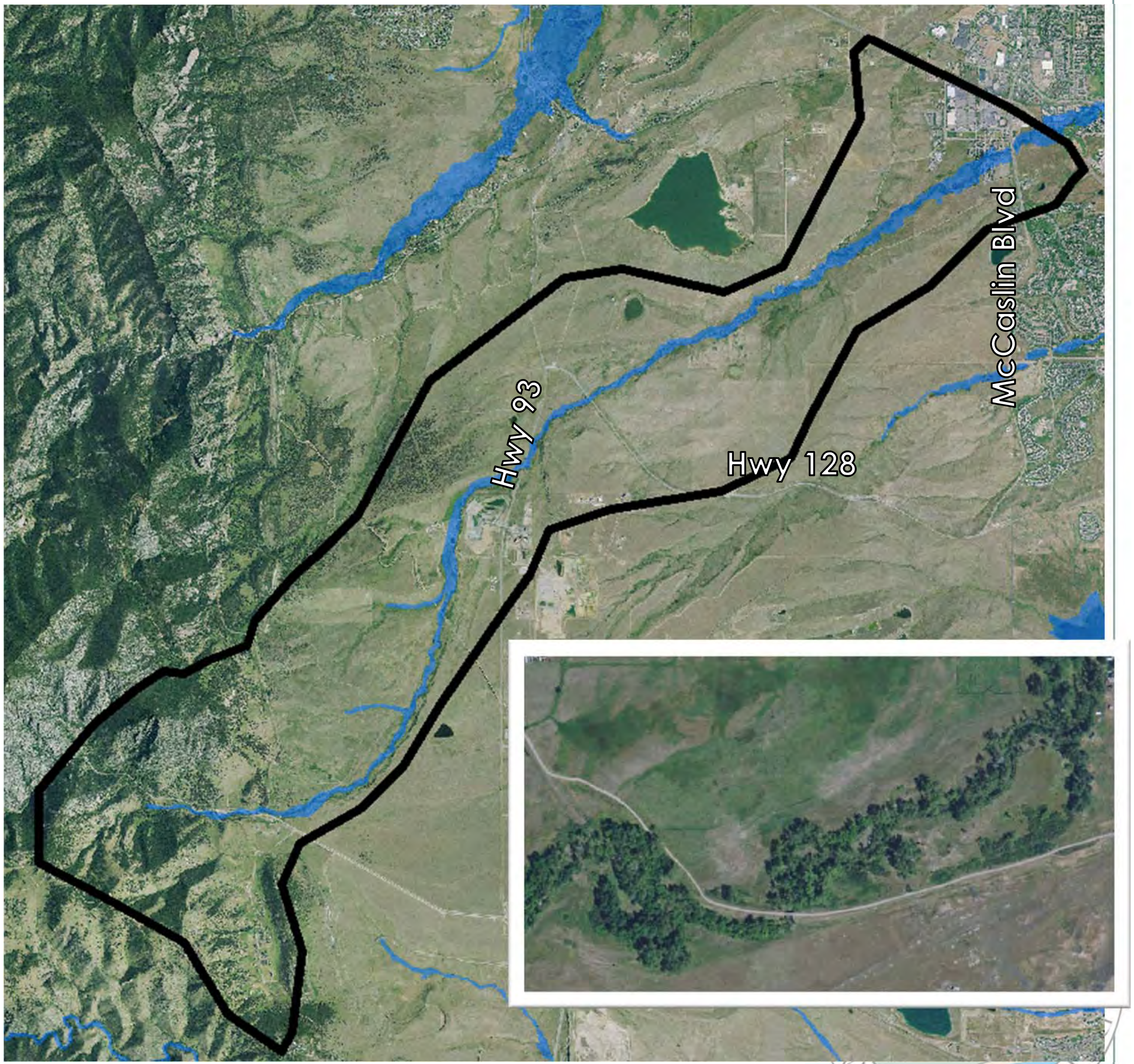
Peak Q = 3,770 cfs

Watershed:

Undeveloped upper; low density residential lower

Floodplain:

Split flows outside channel banks



Little Dry Creek

Dam breach analysis

Average slope = 0.6%

Stream length = 9 mi.

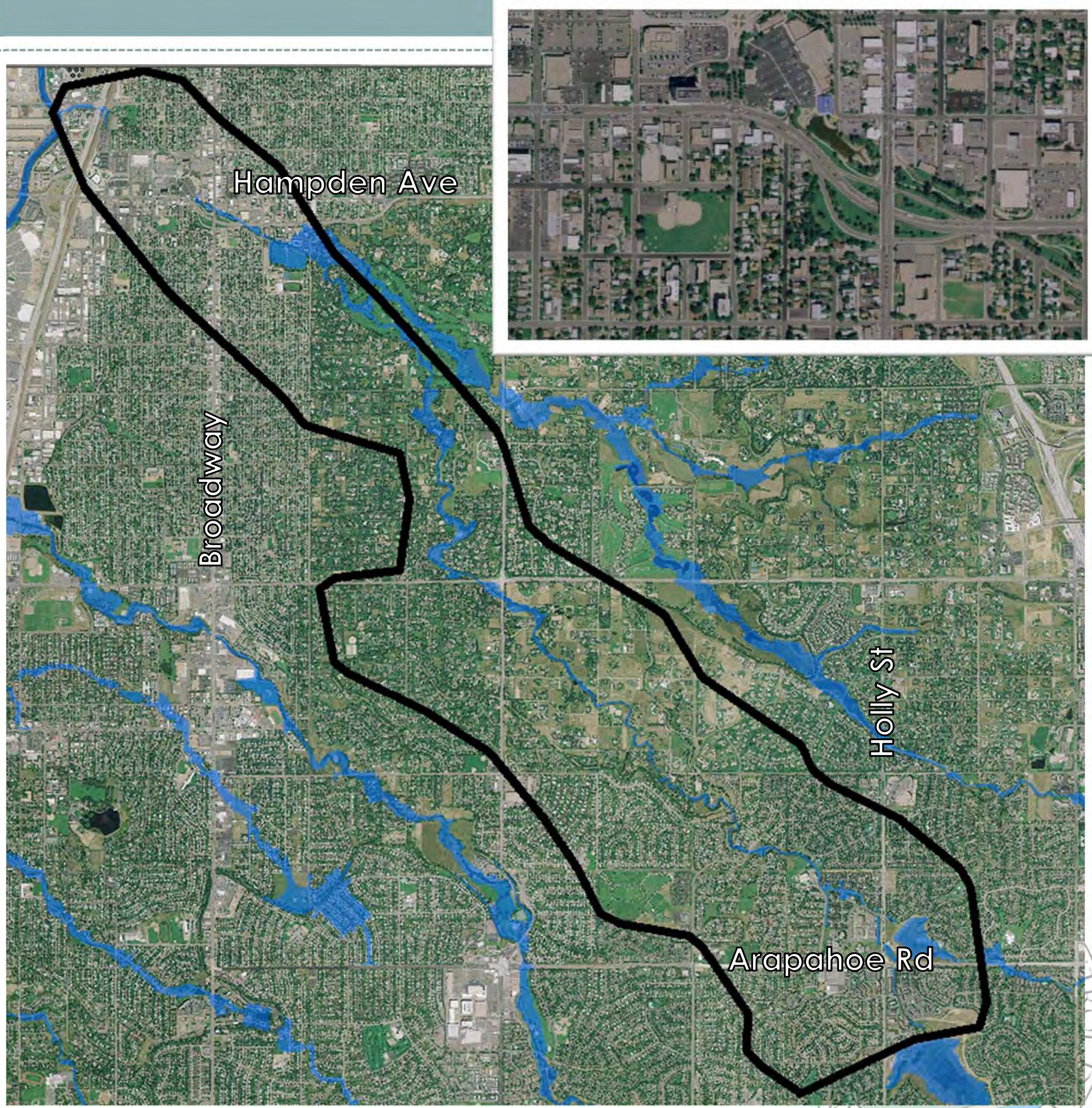
Peak Q = 100,000 cfs

Watershed:

Fully developed, residential, commercial and industrial

Floodplain:

Urban flow beyond channel



Kinematic vs. Dynamic Wave

<u>Kinematic:</u>
Passage of flood wave appears as a uniform rise and fall in the water surface over a relatively long period of time
Froude number < 2

<u>Dynamic</u>:
Higher velocities and quicker attenuation
Example – large flood wave in a wide river

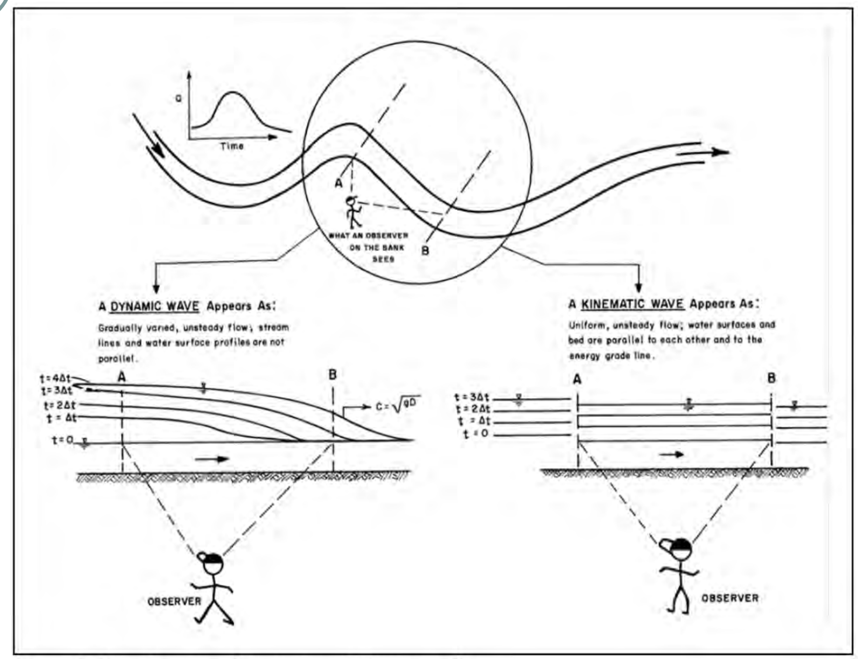


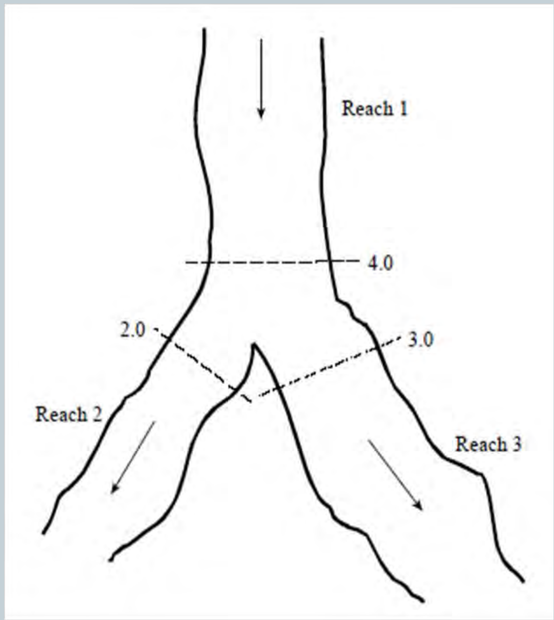
Figure 1 Visualization of Dynamic and Kinematic Waves

USACE TD-10

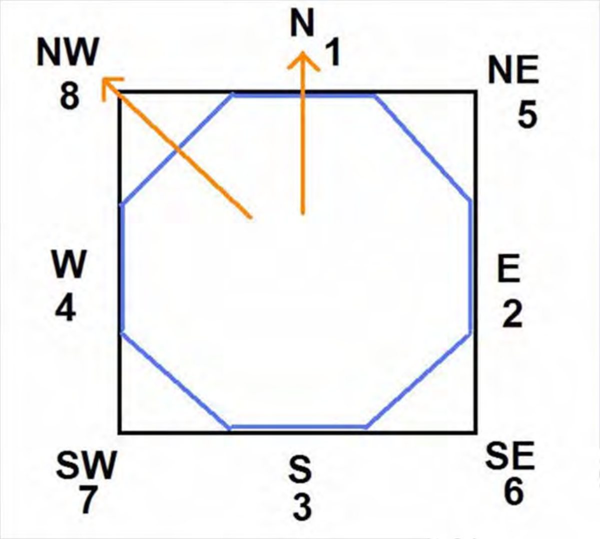
Flood flows for smaller watersheds are generally dominated by kinematic waves

Model basics

Flow in 1D models

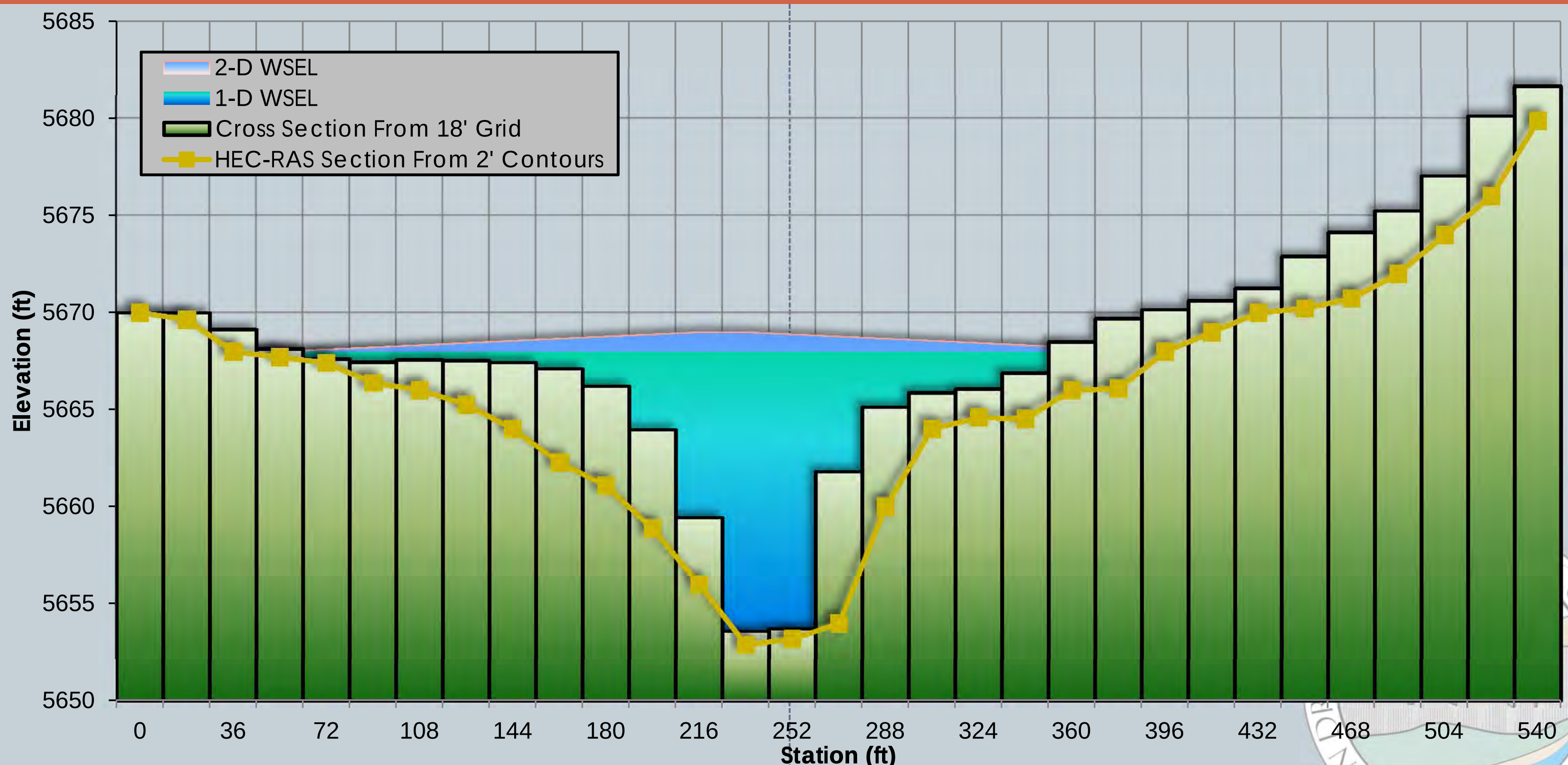


Flow in 2D models



Model basics

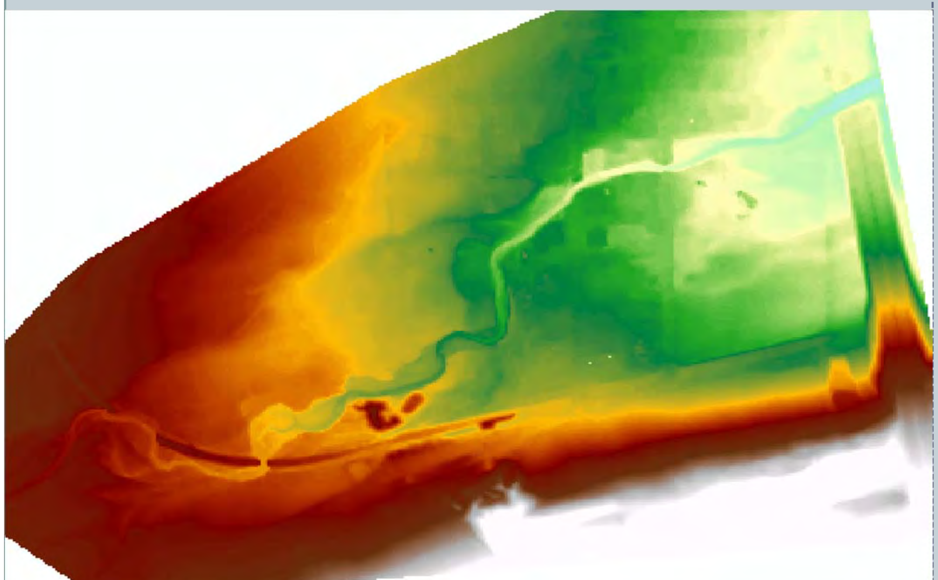
Differences in terrain and water surface representation



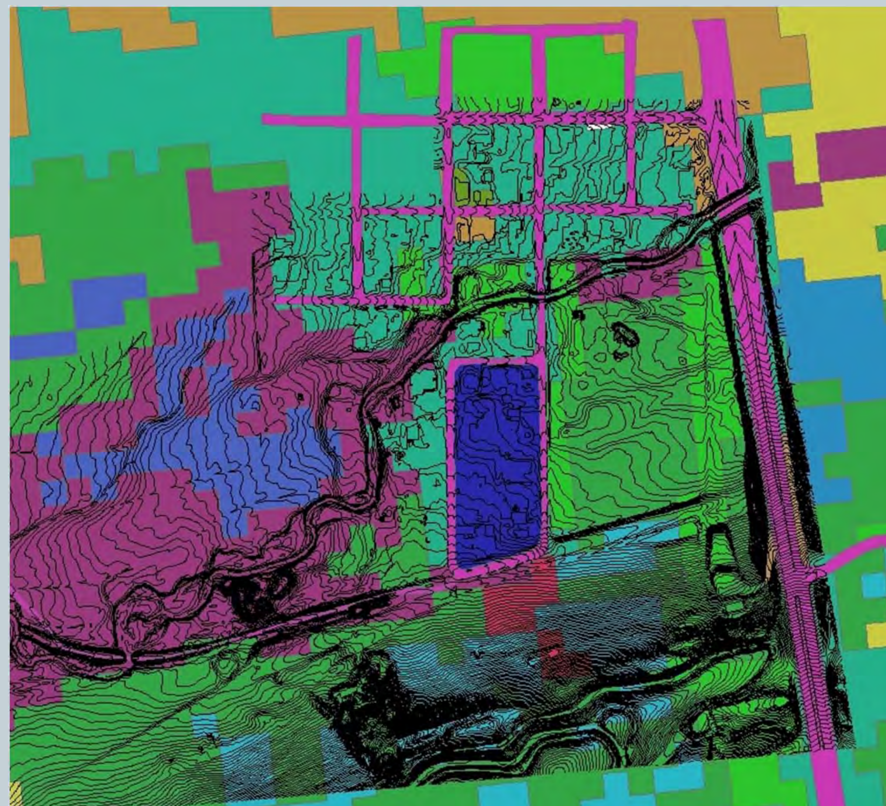
Model basics

Additional 2D data requirements

Bathymetric terrain data



Land use data

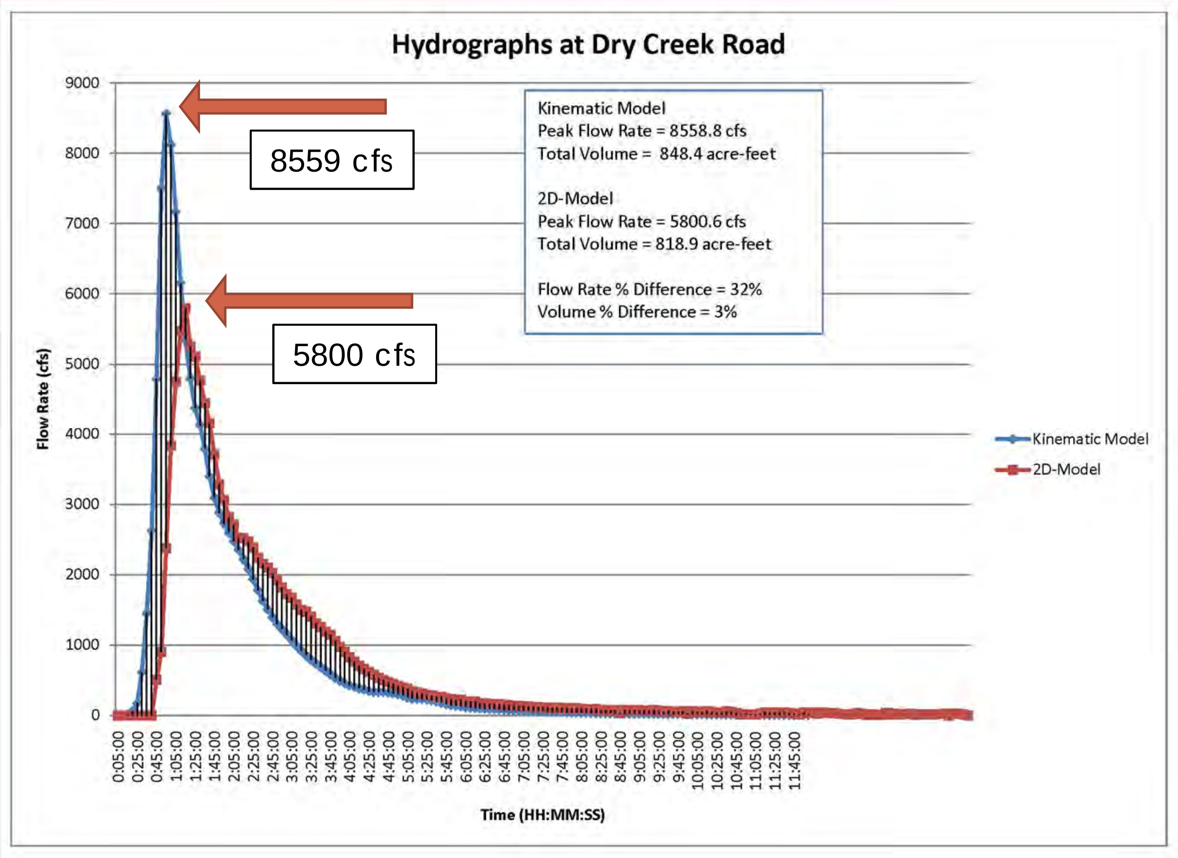


Model basics

Traditional routing	2-Dimensional routing
• Use CUHP and SWMM • Calibrated to published results • Kinematic routing	• Hydrograph from CUHP or SWMM place at 1 or more grid cells • Model can develop hydrology • Dynamic wave routing

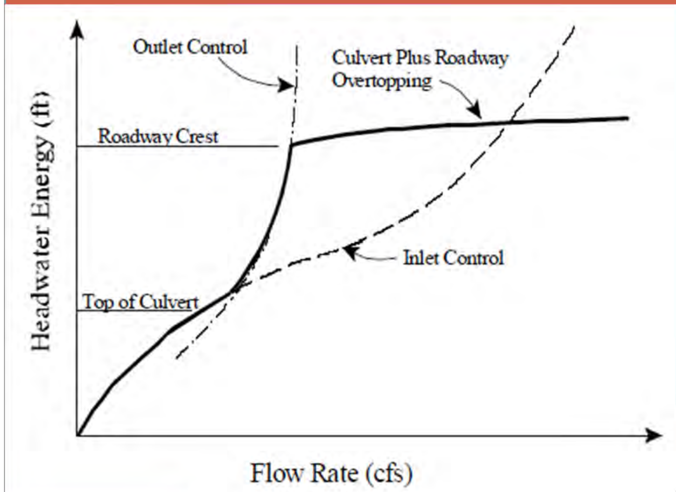
Model basics

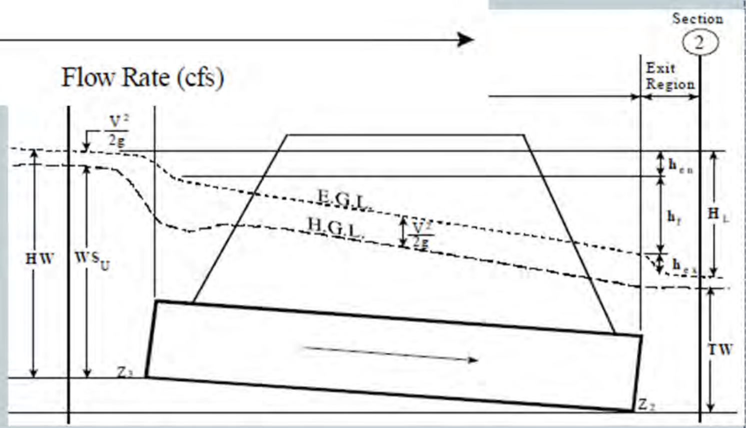
Routed hydrograph



Model basics

Modeling hydraulic structures



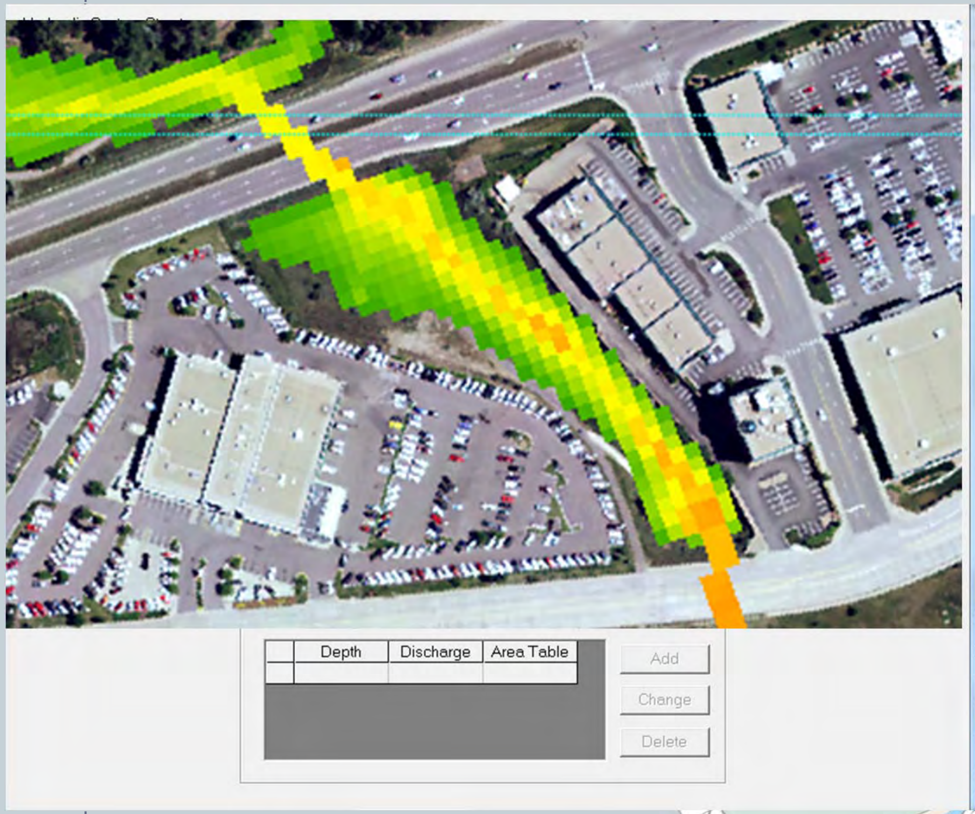


- 1-D Models
  - Internal Hydraulic Culvert and Bridge Routines
  - Account for Headwater and Tailwater Conditions

Model basics

Modeling hydraulic structures

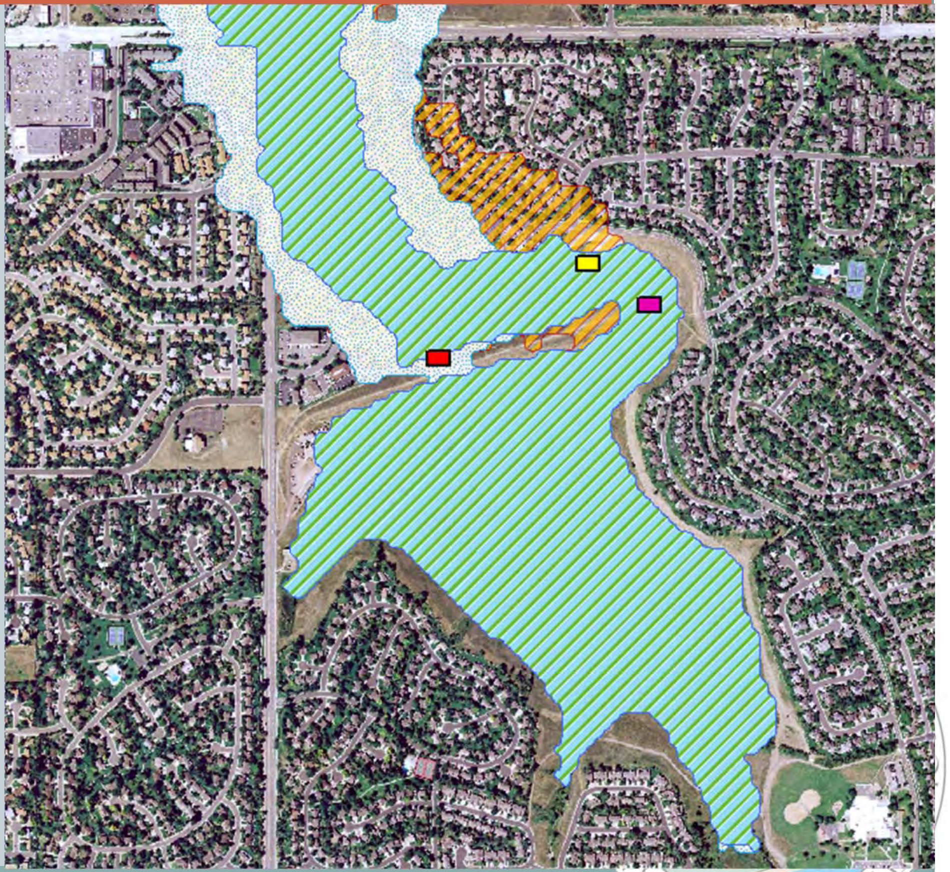
- 2-D Models
  - Computed with Rating Curves
  - Coupled with 1-D Channels
  - “Burned” Into Terrain



Keys to Success

Hydrograph loading

- Hydrograph Loading is associated with a grid cell
- Placement can affect floodplain
- Loading points need to represent hydraulic conditions



Keys to Success

Manning's *n* value selection

- Each grid cell is assigned an *n* value
- Urban areas and streets can impact flow paths

Table 1
Effective Resistance Parameters for Overland Flow

Surface	N value	Source
Asphalt/Concrete*	0.05 - 0.15	a
Bare Packed Soil Free of Stone	0.10	c
Fallow – No Residue	0.008 - 0.012	b
Convential Tillage – No Residue	0.06 - 0.12	b
Convential Tillage – With Residue	0.16 - 0.22	b
Chisel Plow – No Residue	0.06 - 0.12	b
Chisel Plow – With Residue	0.10 - 0.16	b
Fall Disking – With Residue	0.30 - 0.50	b
No Till – No Residue	0.04 - 0.10	b
No Till (20-40 percent residue cover)	0.07 - 0.17	b
No Till (60-100 percent residue cover)	0.17 - 0.47	b
Sparse Rangeland with Debris:		
0 Percent Cover	0.09 - 0.34	b
20 Percent Cover	0.05 - 0.25	b
Sparse Vegetation	0.053 - 0.13	f
Short Grass Prarie	0.10 - 0.20	f
Poor Grass Cover on Moderately Rough	0.30	c
Bare Surface		
Light Turf	0.20	a
Average Grass Cover	0.4	c
Dense Turf	0.17 - 0.80	a,c,e,f
Dense Grass	0.17 - 0.30	d
Bermuda Grass	0.30 - 0.48	d
Dense Shrubbery and Forest Litter	0.4	a

Legend: a) Harley (1975), b) Engman (1986), c) Hathaway (1945), d) Palmer (1946), e) Ragan and Duru (1972), f) Woolhiser (1975). [Hjemfelt, 1986]

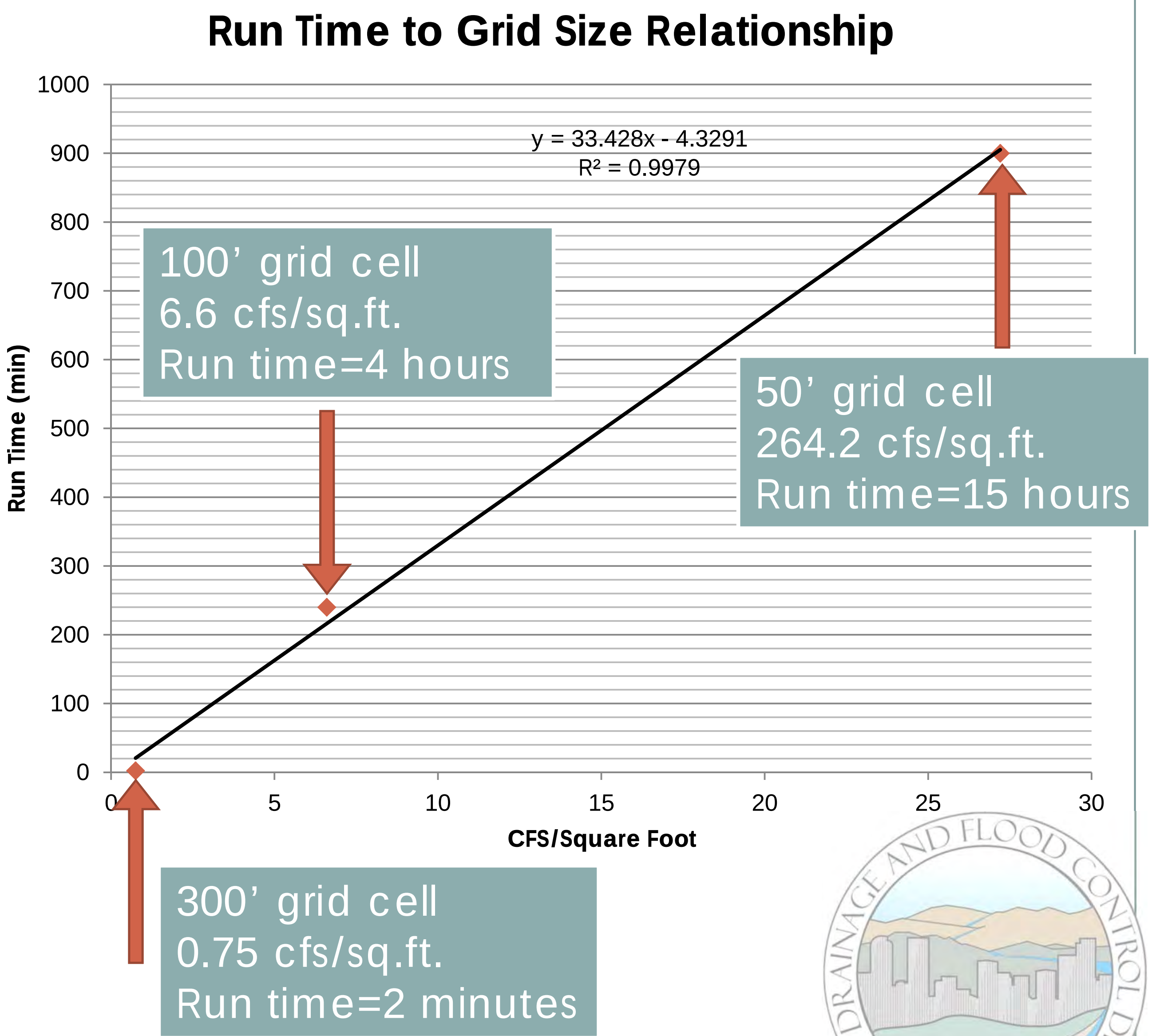
Run time

Manual recommends 0.1 to 1 cfs / sq. ft.

i.e. for Q = 100 cfs
use 10’ x 10’ grid

Little Dry Creek example:

Q = 68,000 cfs → 250’ grid (recommended)

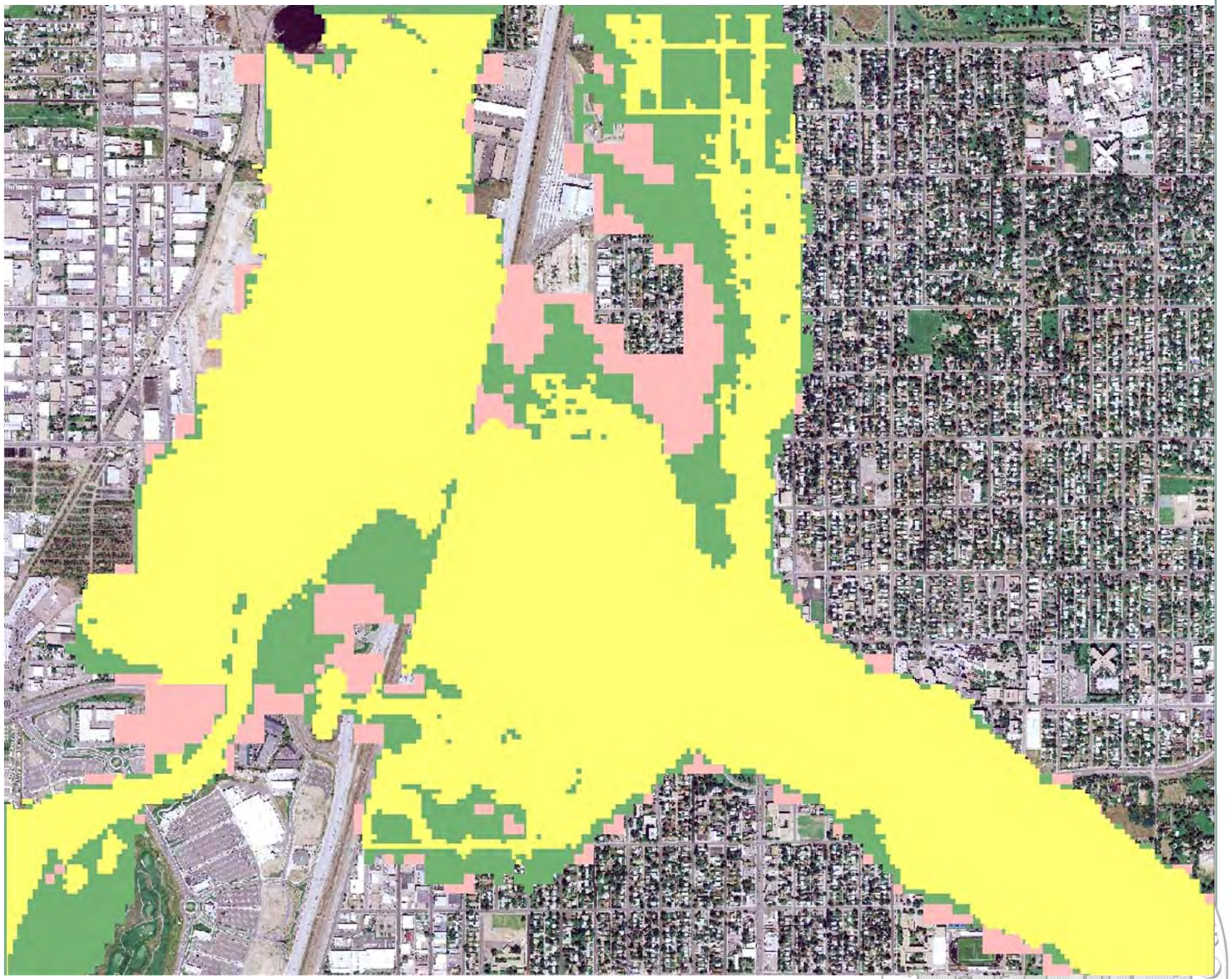


Resolution

300’ grid

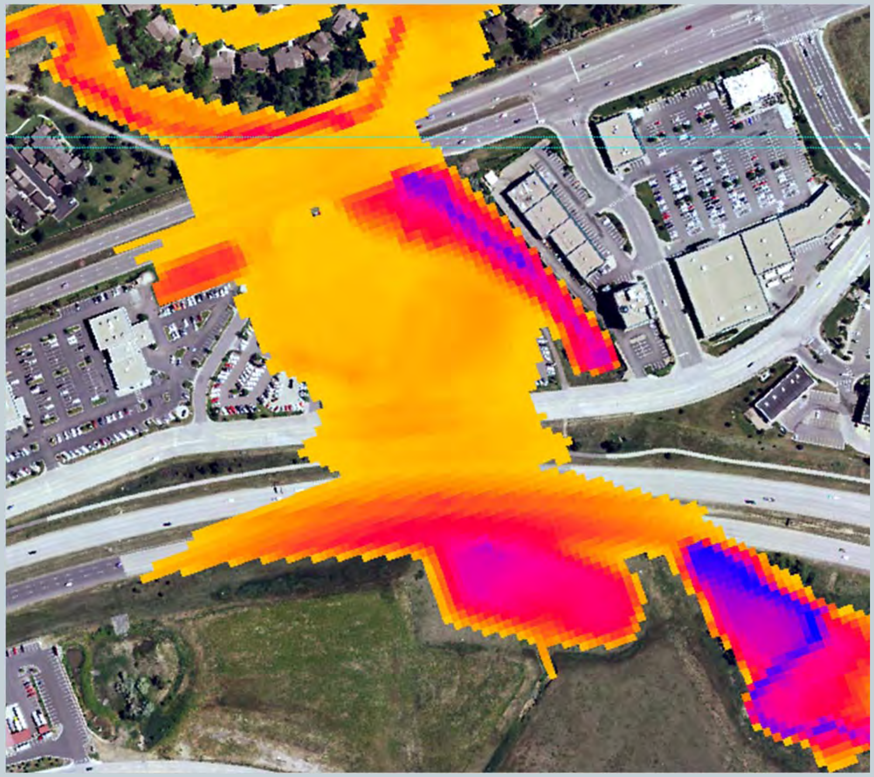
100’ grid

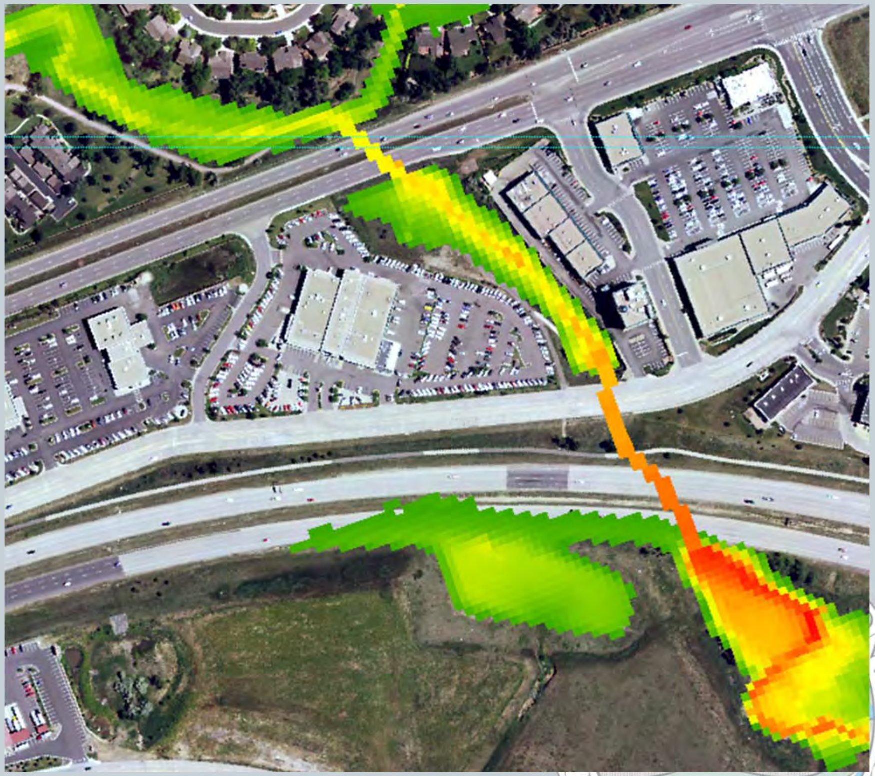
50’ grid



Keys to Success

Approach to modeling structures





Case Study Summary

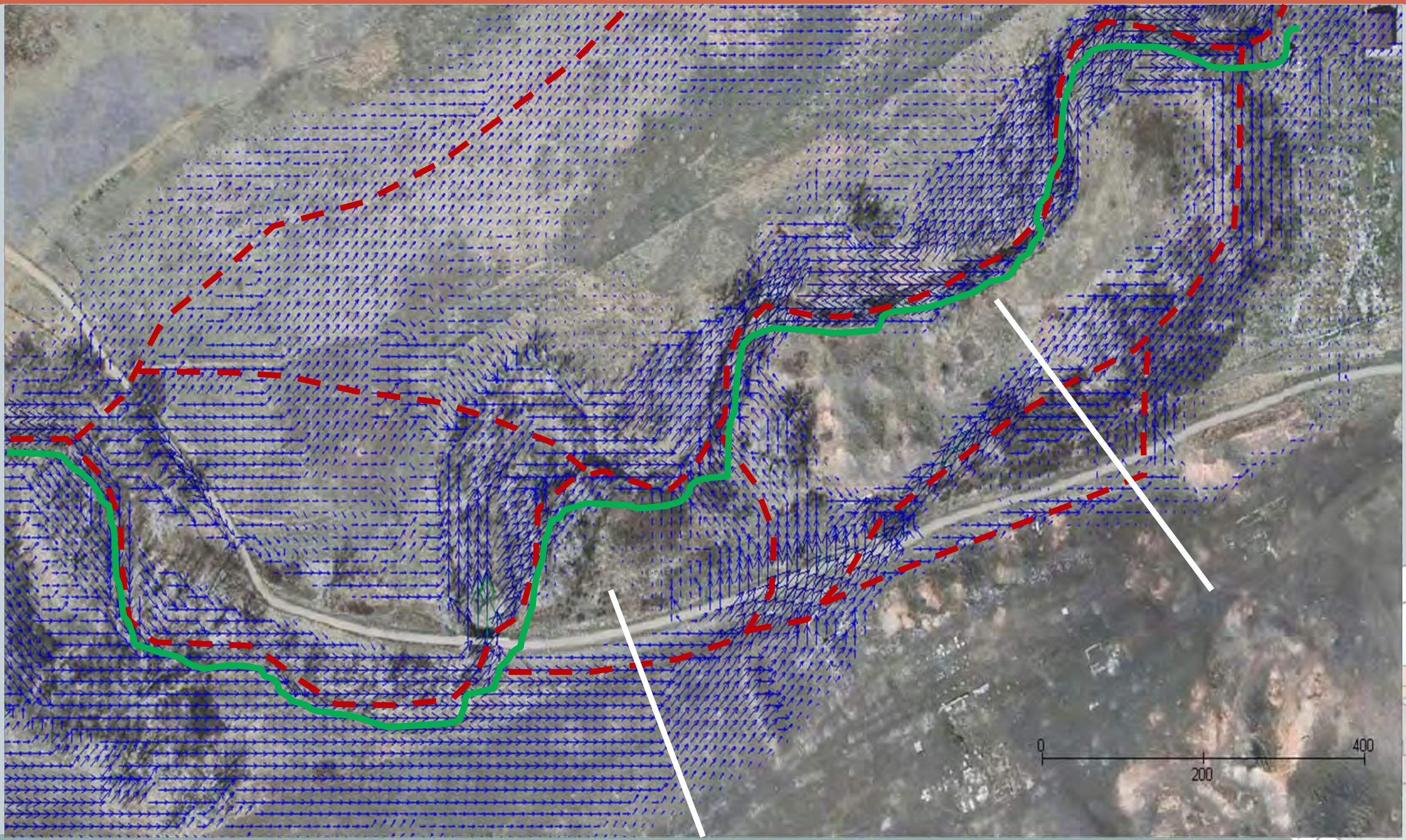
	Willow Creek	Coal Creek	Little Dry Creek
Watershed Area	6,047 acres	16,835 acres	Dam breach
Grid Size	18 ft	14 ft	50 ft
# of Cells	169,000	43,000	191,000
Structures	10	0	0
Model Run Time	14 hours	7 hours	15 hours
Effort to develop model	Extensive	Minimal	Minimal

Using 2D before 1D

Flow path and cross sections

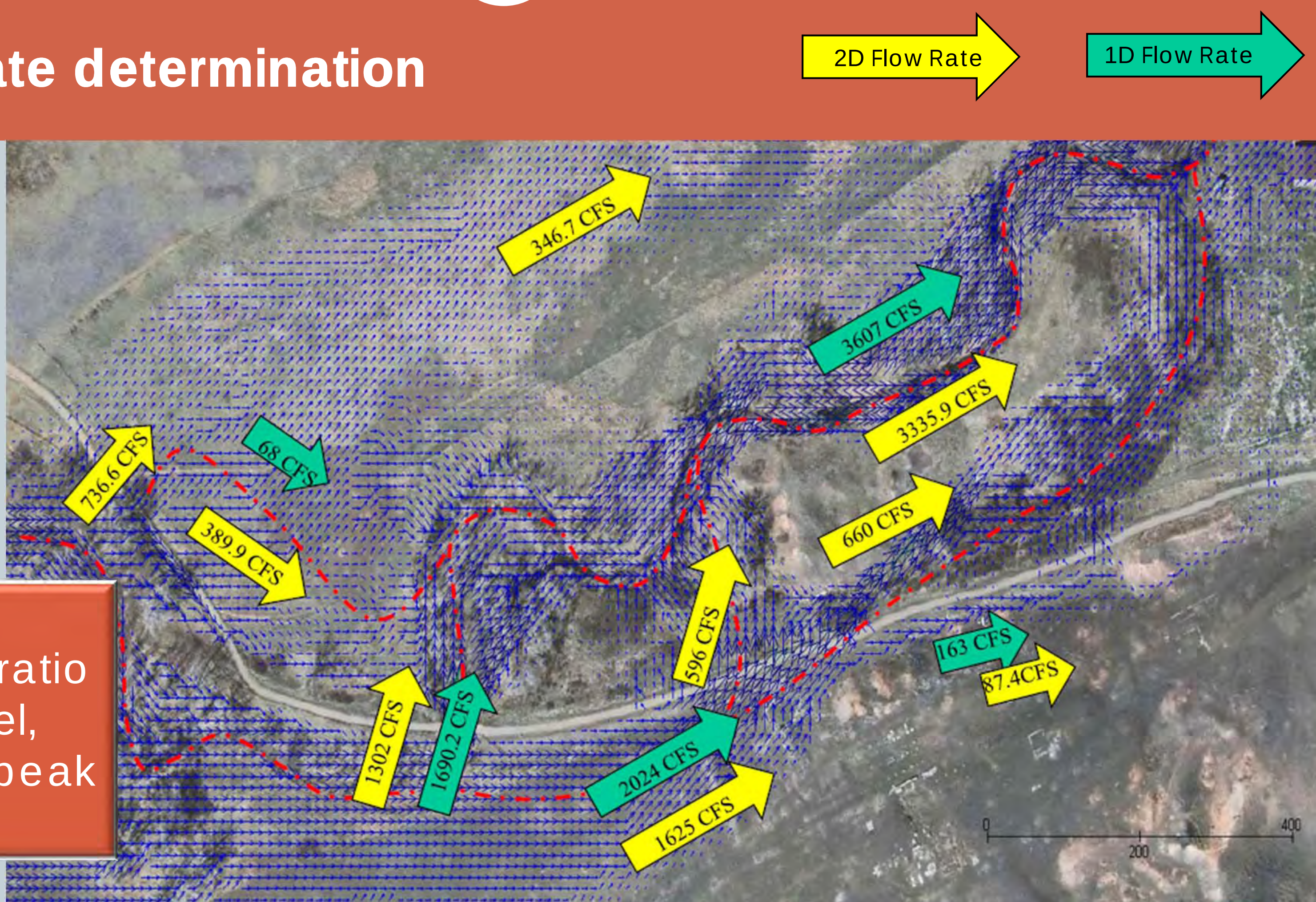
FEMA Centerline

Refined Centerline



Using 2D before 1D

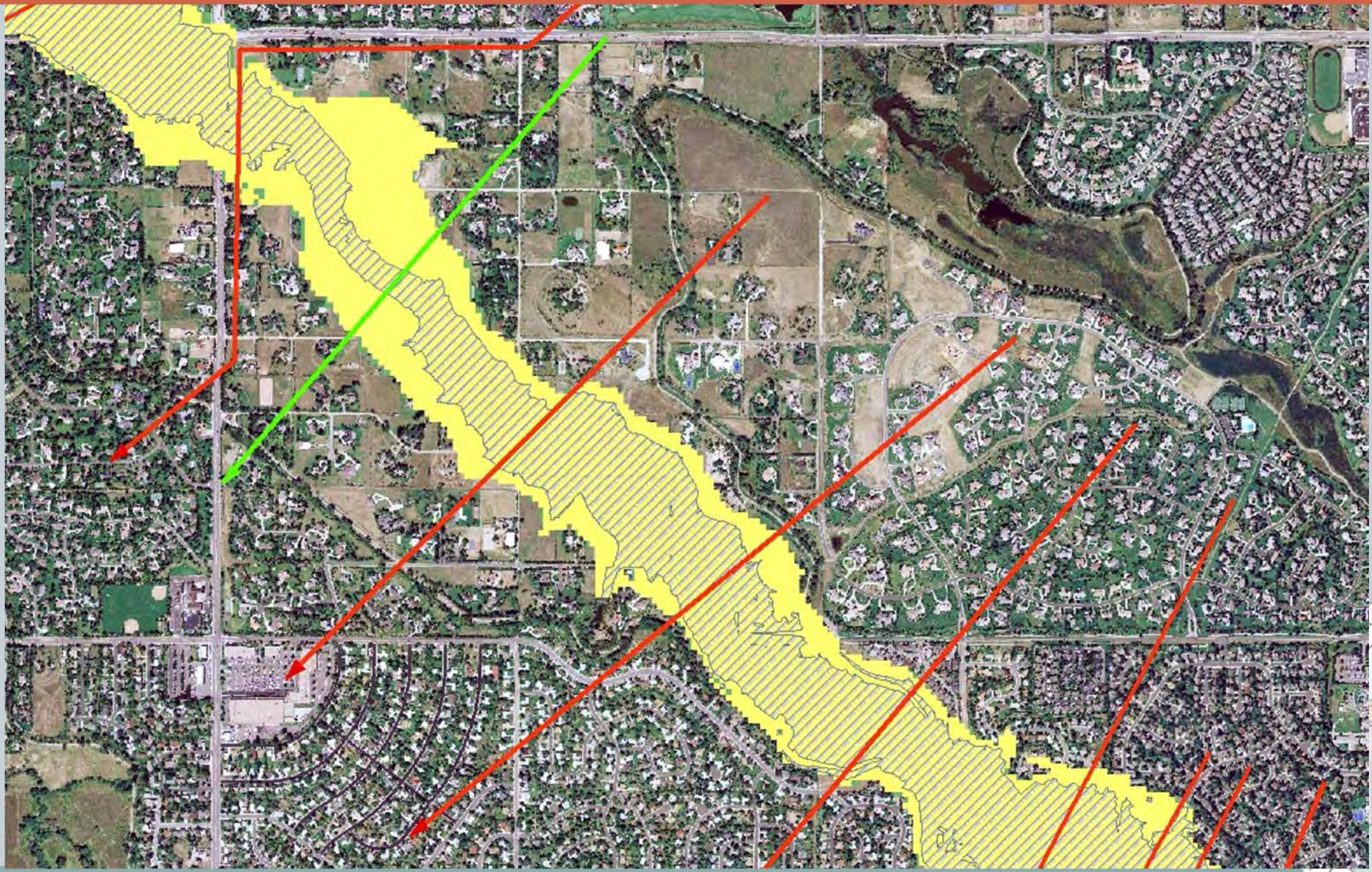
Split flow rate determination



Use Qsplit/Qtotal ratio from 2D model, *not* resultant peak flow value

Using 2D before 1D

Additional cross sections

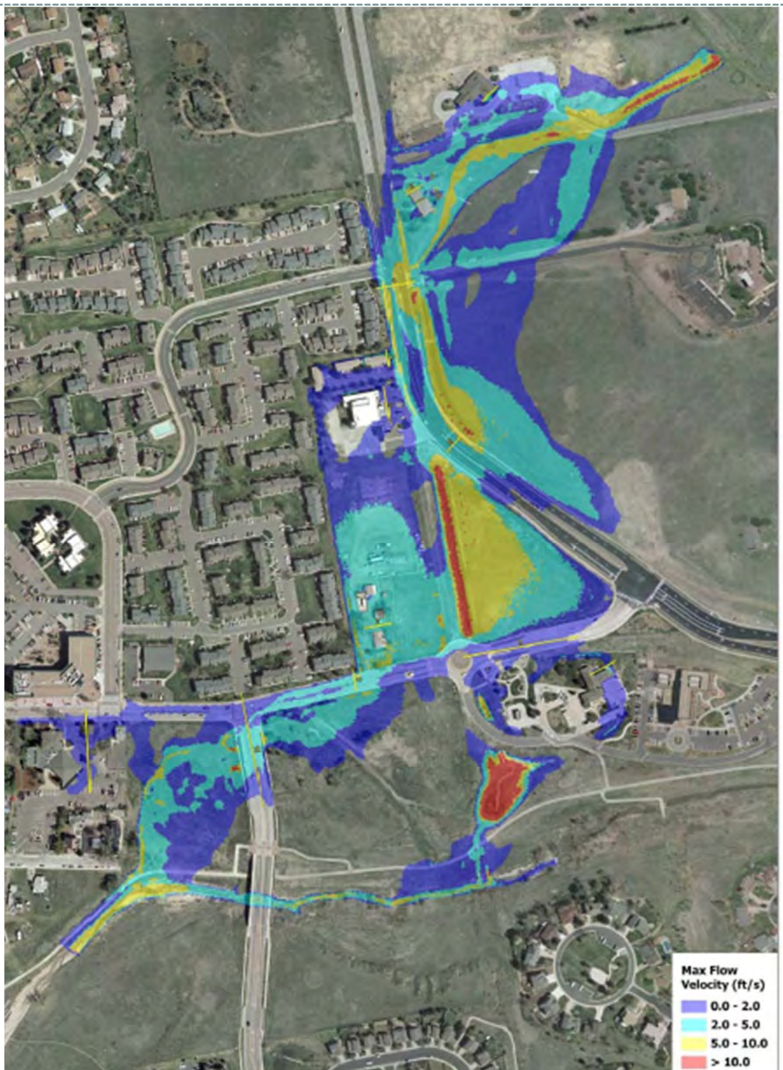


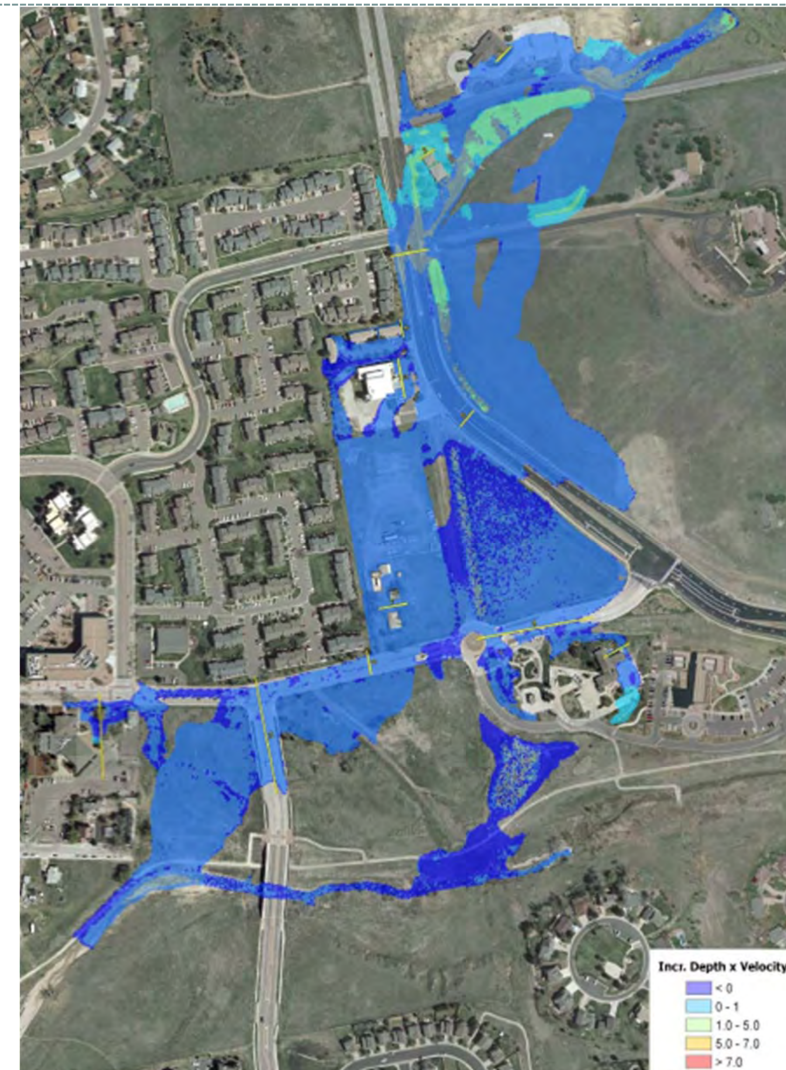
UDFCD studies using 2D

- Pine Gulch Dam Emergency Action Plan
- Park Hill Outfall Systems Plan
- Globeville-Utah Junction Outfall Systems Plan
- South Boulder Creek Mitigation Plan
- Twomile Canyon Creek Floodplain Mapping*

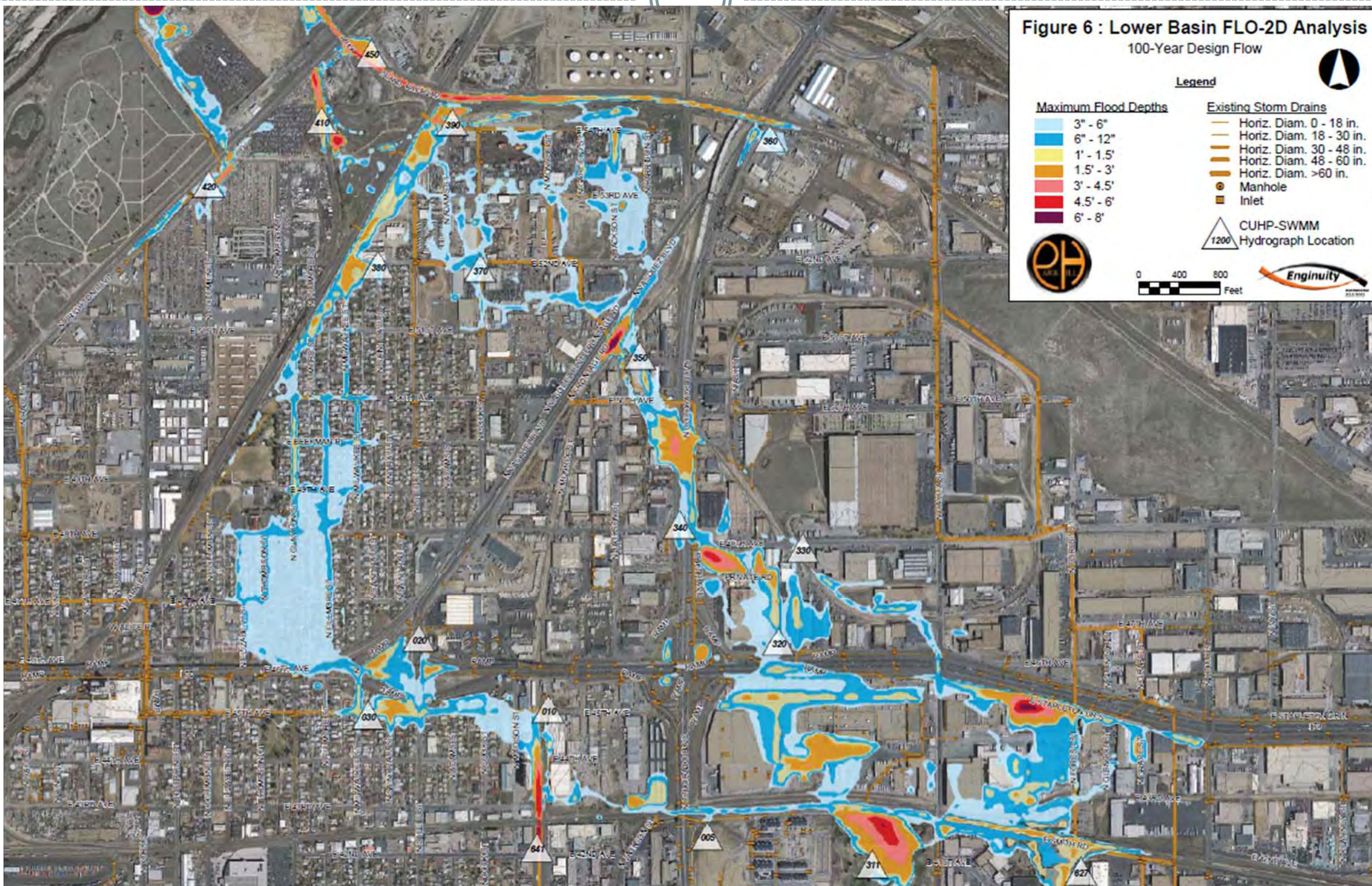
*regulatory model will be HEC-RAS

Pine Gulch Dam EAP

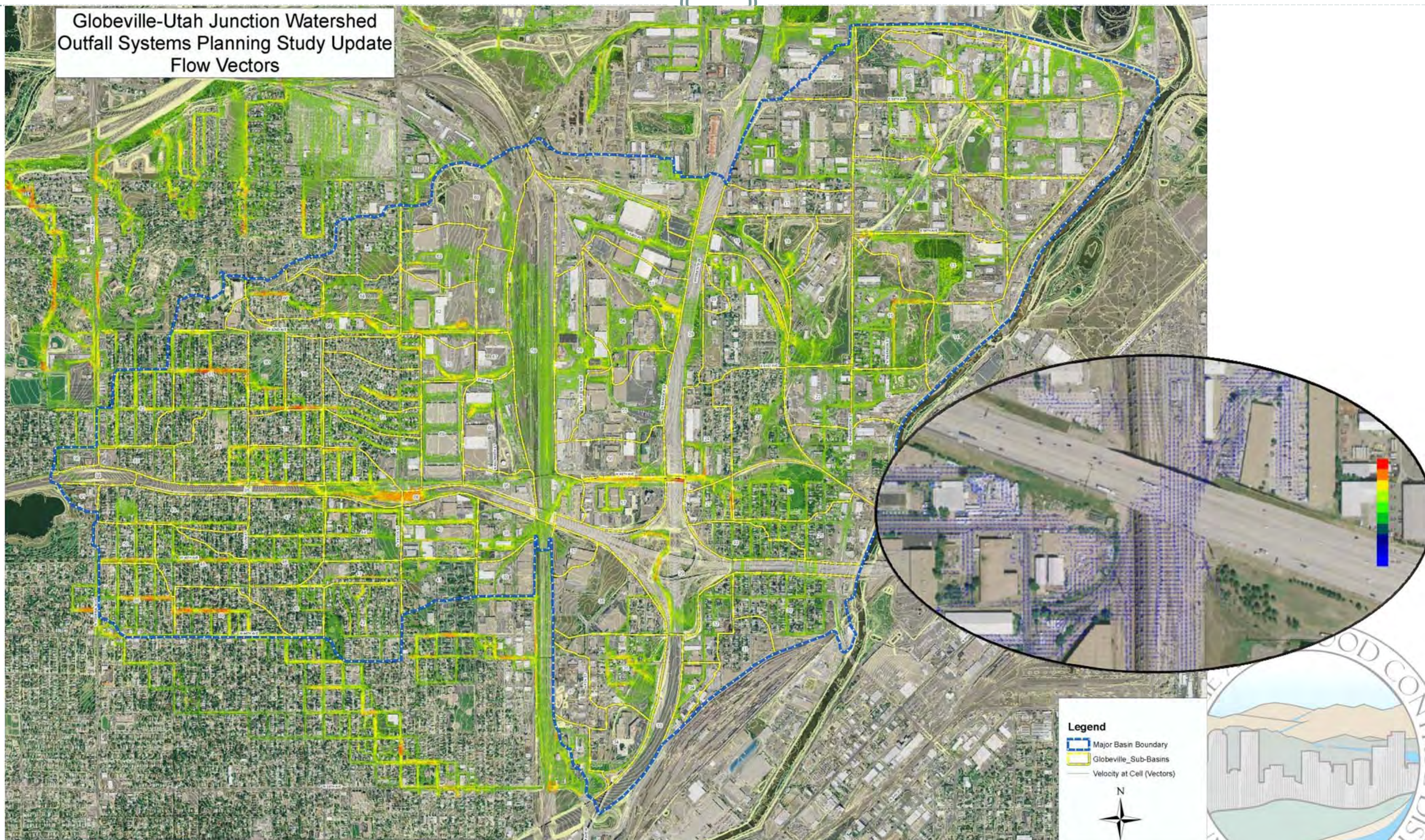




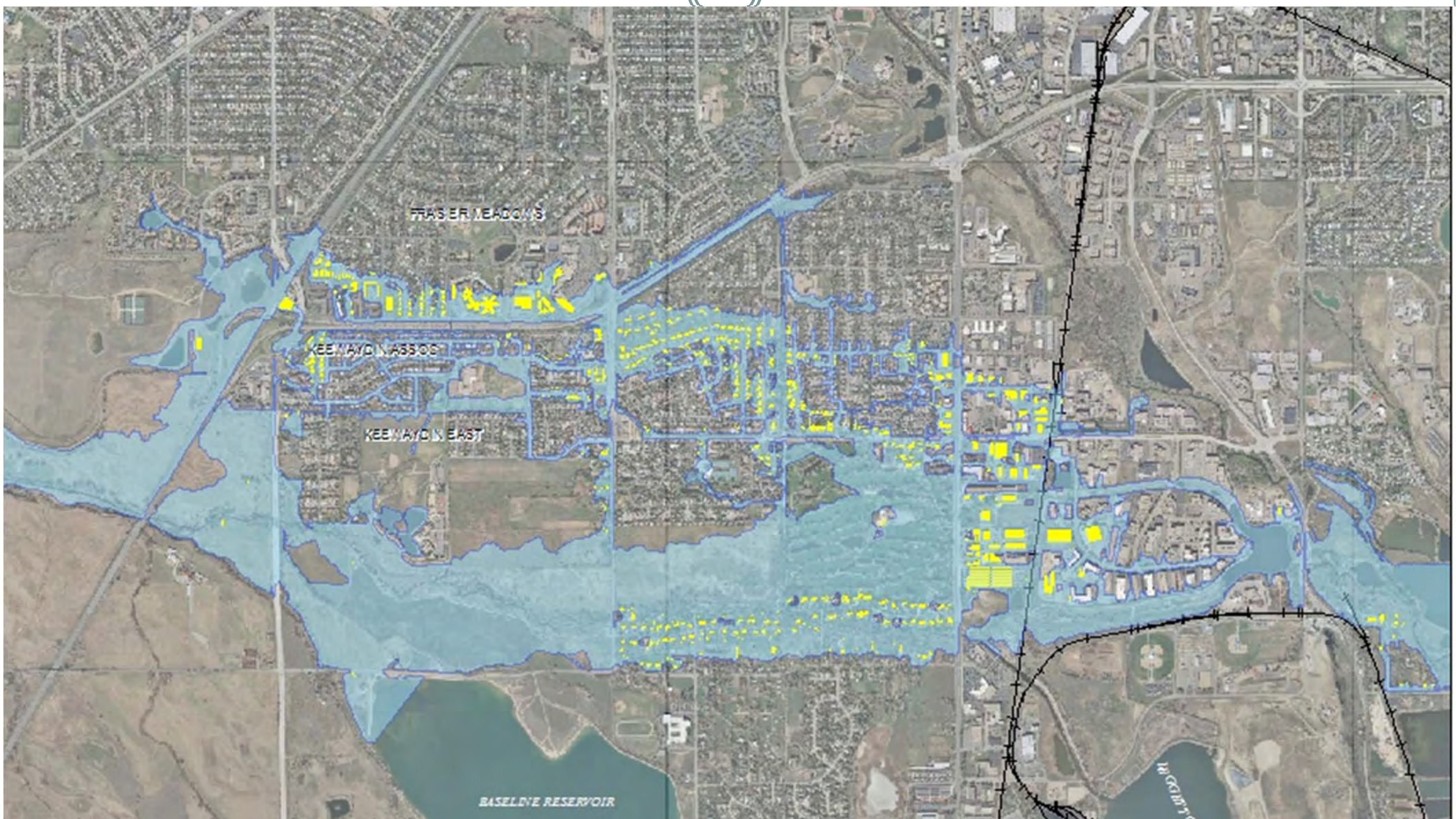
Park Hill OSP



Globeville - Utah Junction OSP



South Boulder Creek Mitigation Plan



Conclusions

For riverine systems, 2 Dimensional models:

- Do help reduce 1D model development time for complex systems by eliminating guesswork and assumptions
- Do provide information to develop more accurate 1D models

- Don't produce the same hydrology as other accepted models which may result in smaller infrastructure
- Don't model crossing structures well
- Don't ensure accurate results (easily manipulated)

Questions?

Shea Thomas, PE
Urban Drainage and Flood Control District
sthomas@udfcd.org

Alan Turner, PE
CH2M Hill
alan.turner@ch2m.com

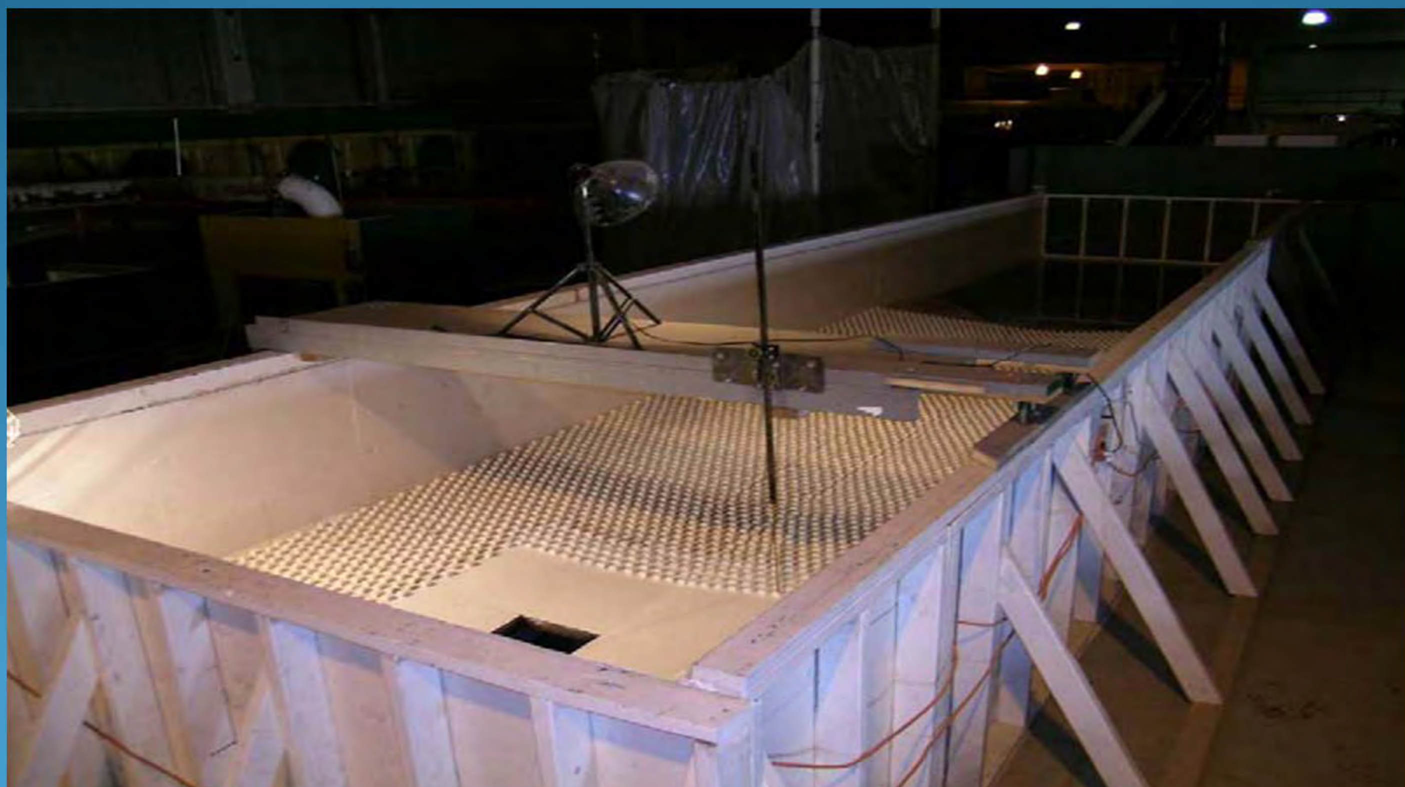
"Guidance for 2-Dimensional Model Development in Riverine Systems"
www.udfcd.org

Hydraulic Capacity for Type C and D Inlets

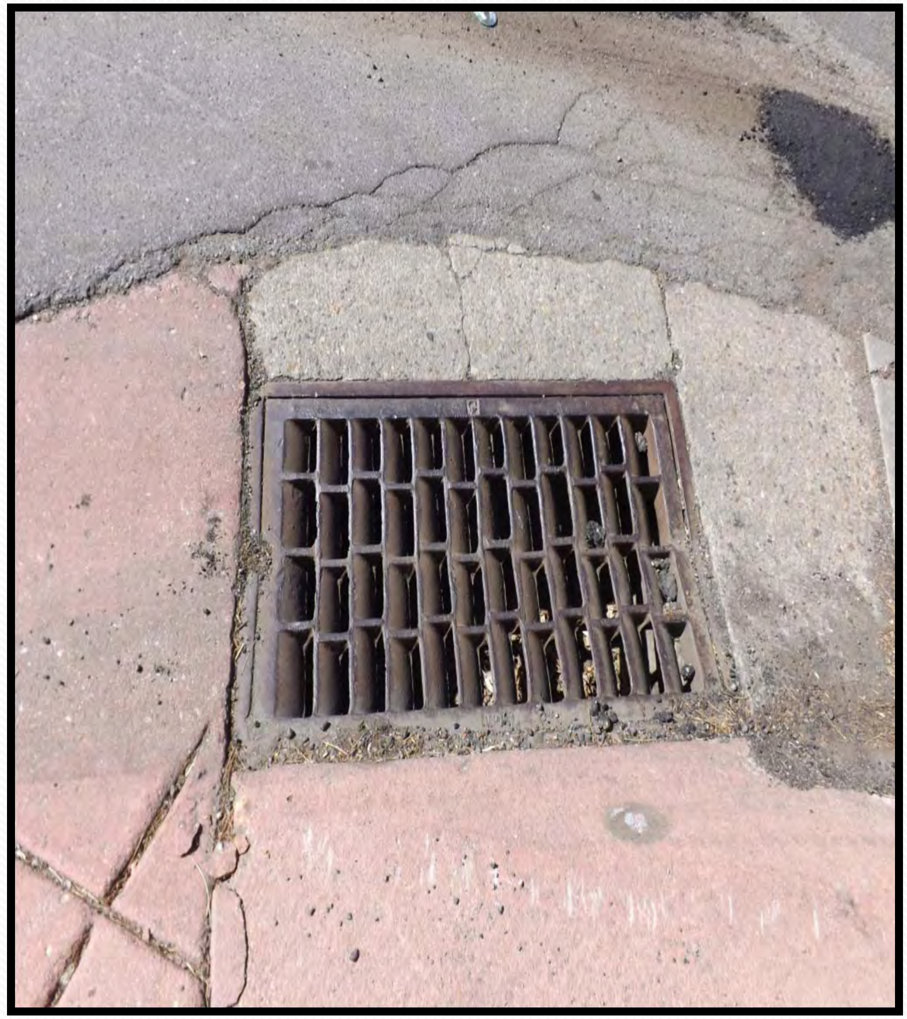
presented

by

James C.Y. Guo, Professor and Director, UC-Denver
Ken MacKenzie, Project Manager, UDFCD
Amanullah Mommandi, Hydraulic Program Manager, CDOT



Inlets - Type 13 and Type 16 (van grate)

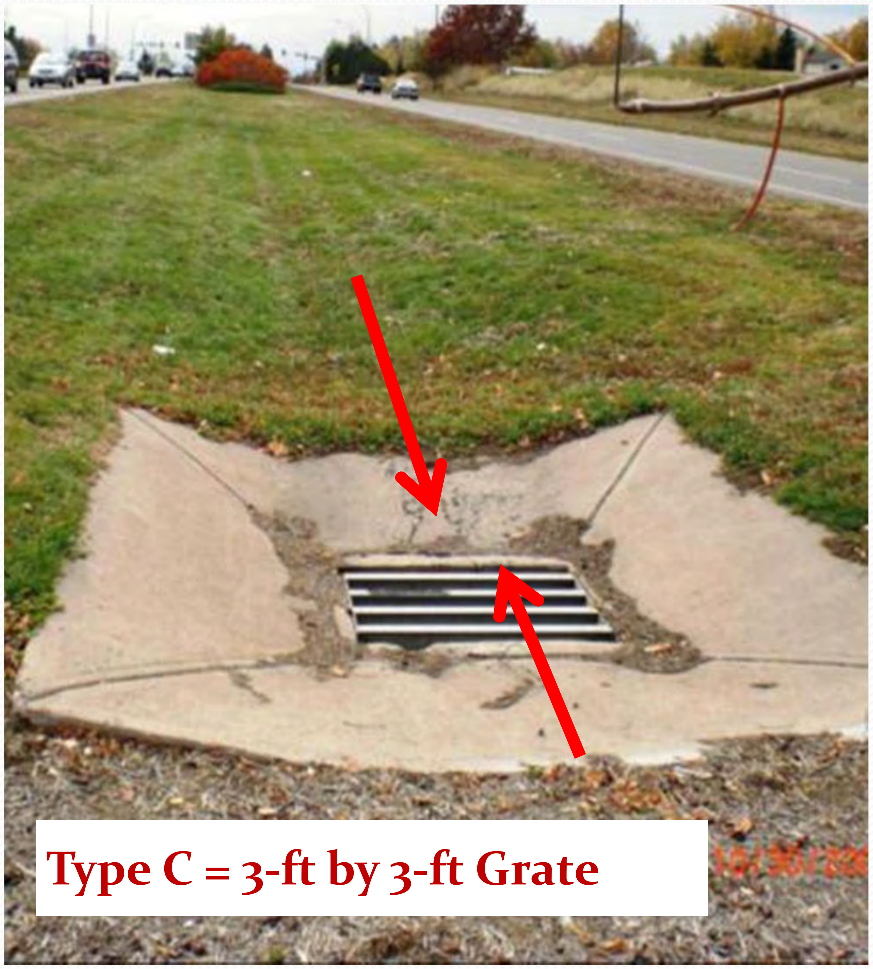


Combination Inlets

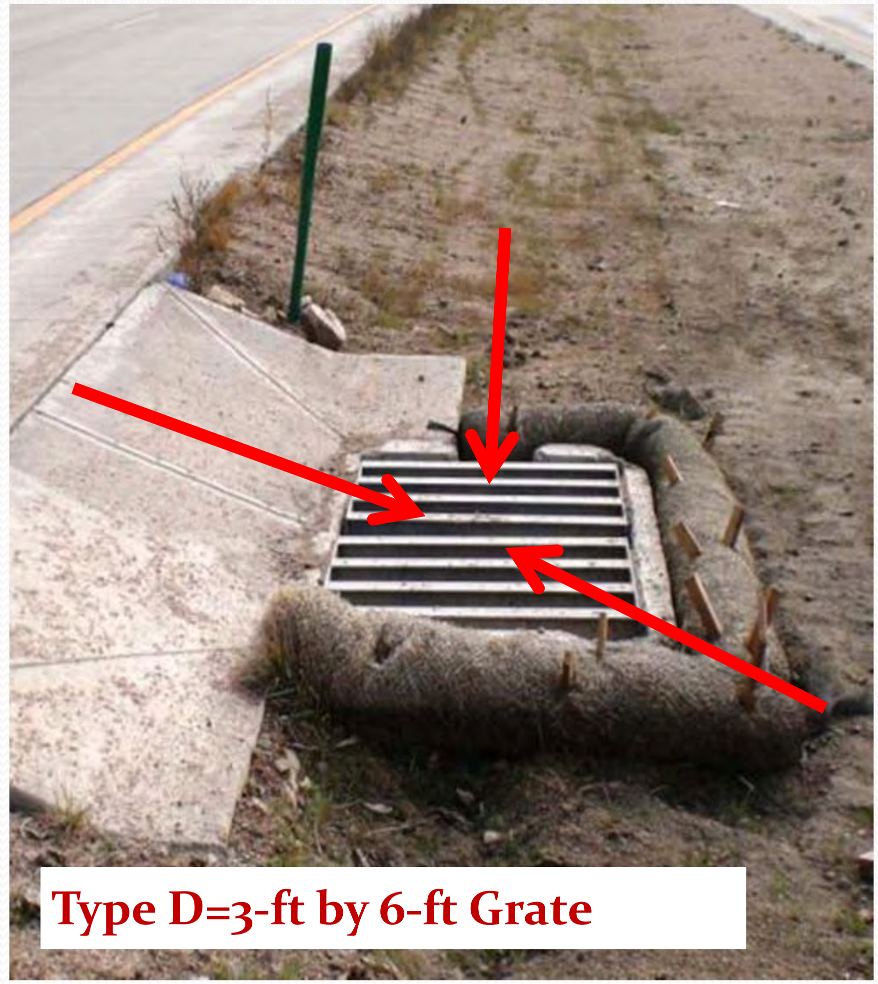
ONE and TWO grates

Inlet Type – R
5 and 10 ft.

Type C and D Inlets



Type C = 3-ft by 3-ft Grate

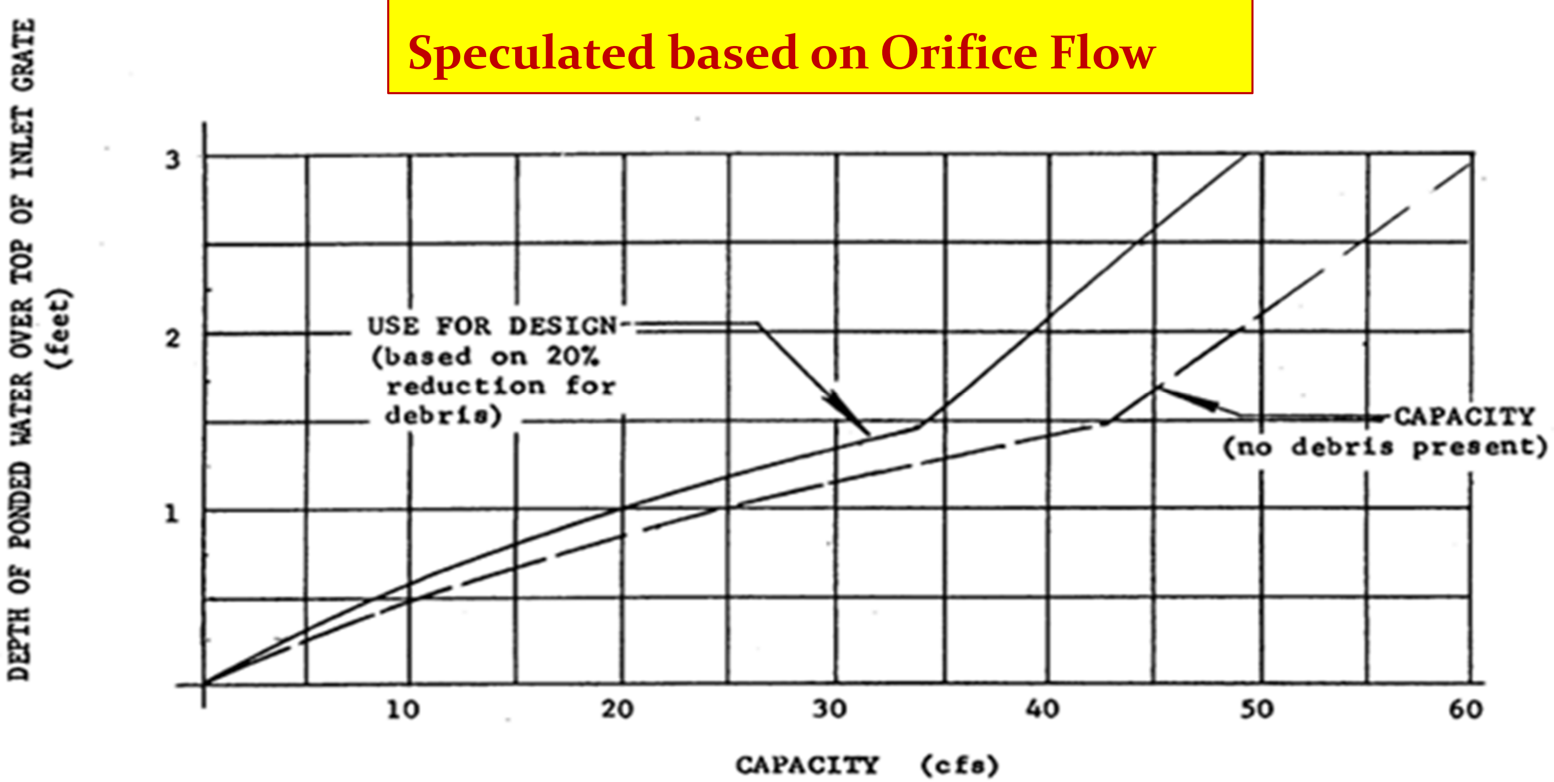


Type D=3-ft by 6-ft Grate

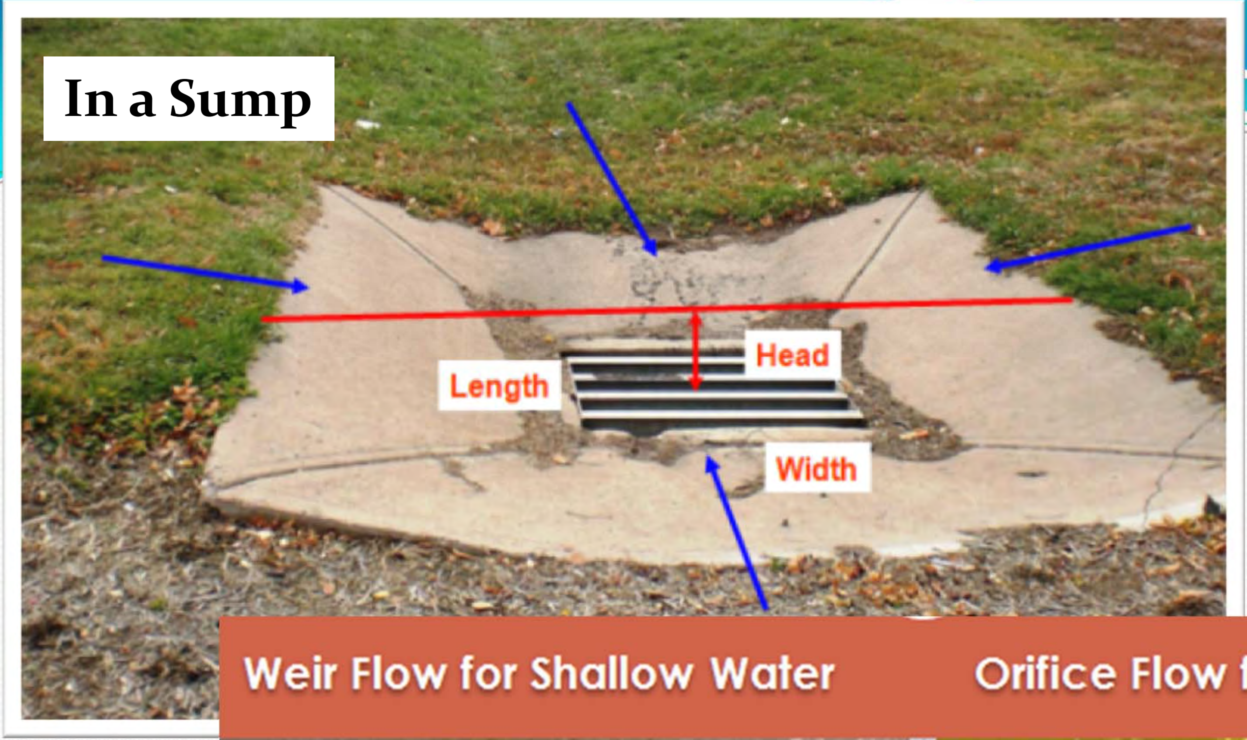
CURRENT CDOT DEISGN PRACTICE for Type C and Type D Inlets

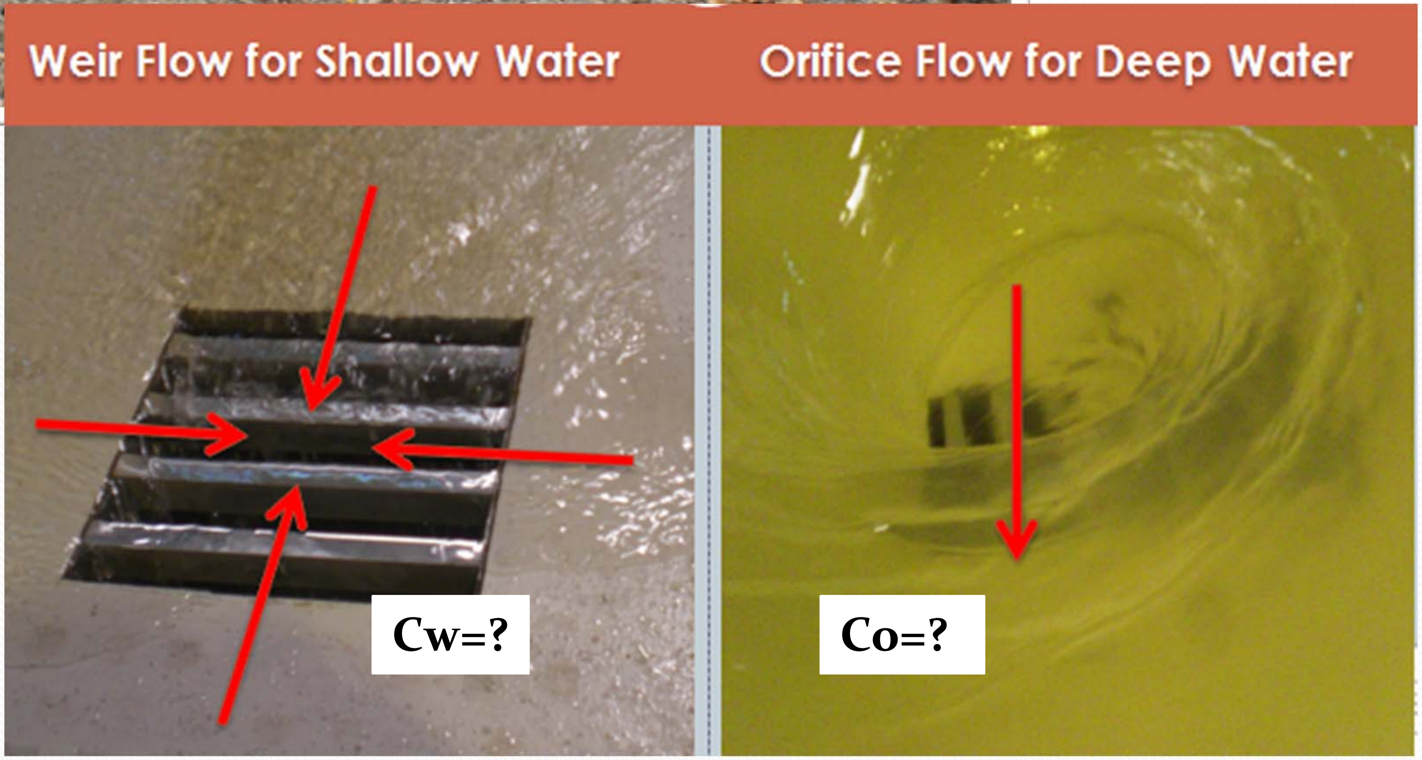
Two Type C 's = 1.8 x Single Type C
Three Type C's = 2.5 x Single Type C

Speculated based on Orifice Flow

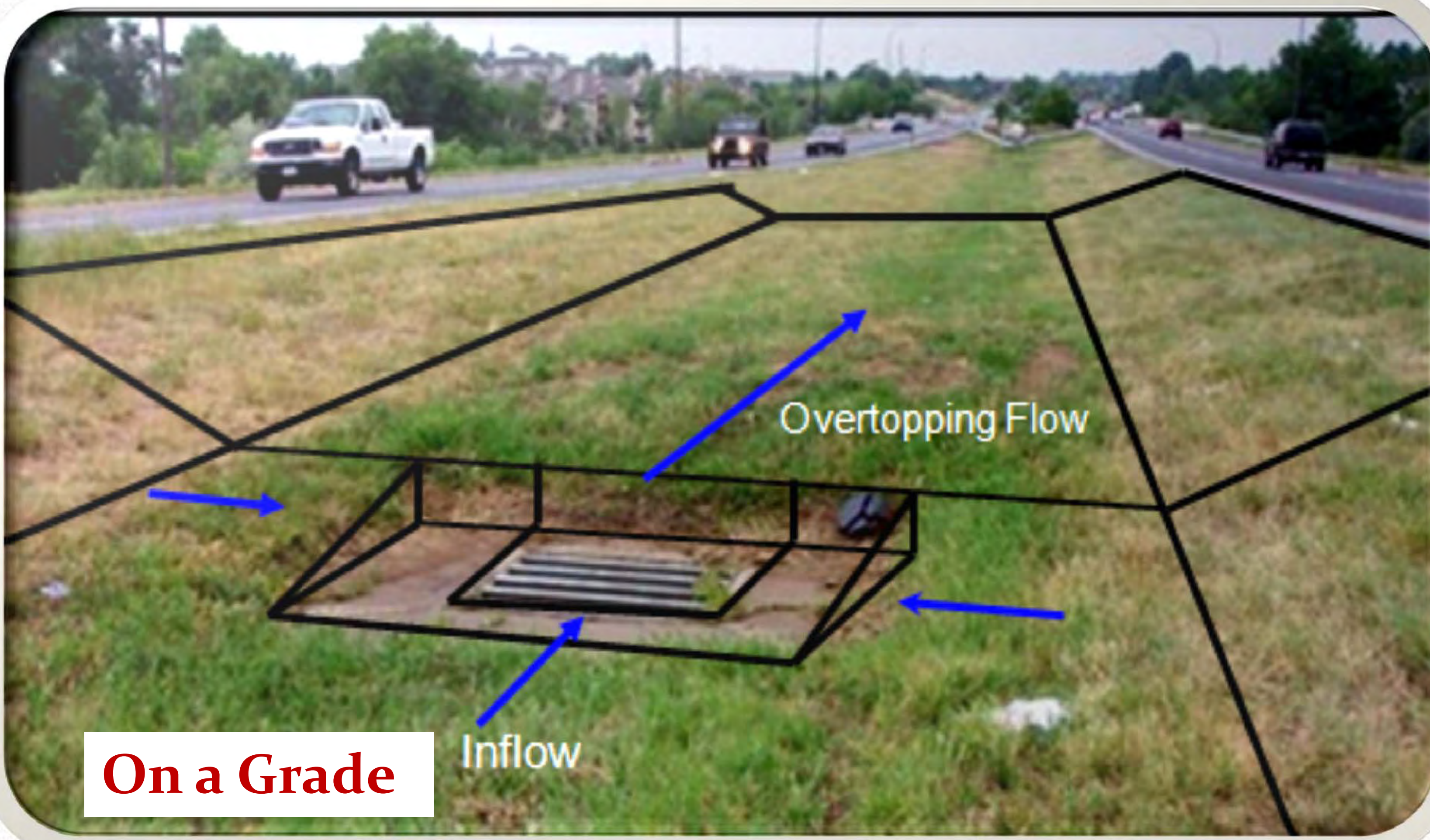


Hydraulics Flat Type C

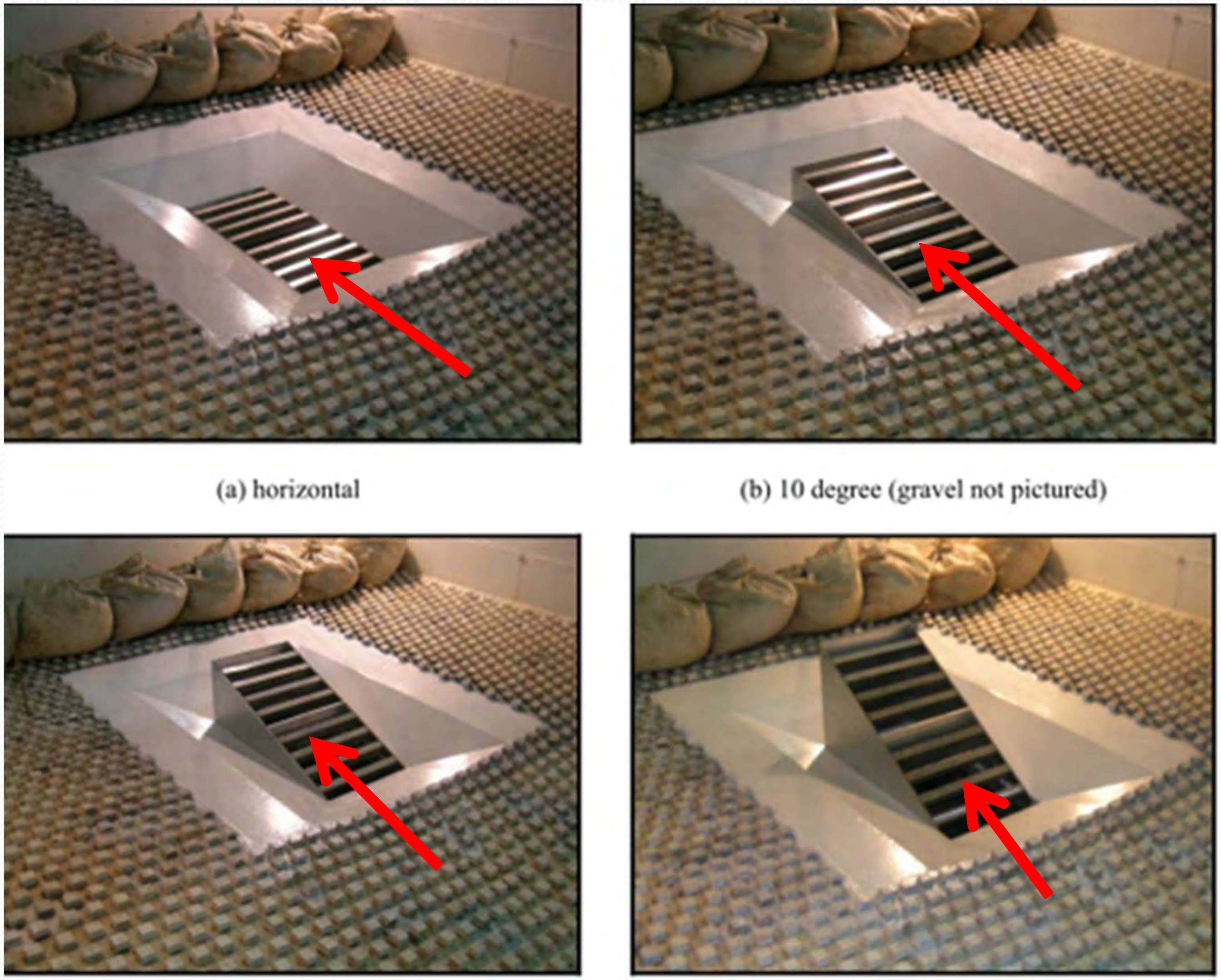




Type C on a Grade with an Inclined Angle



Type D Model Inlets laid in Series



(a) horizontal

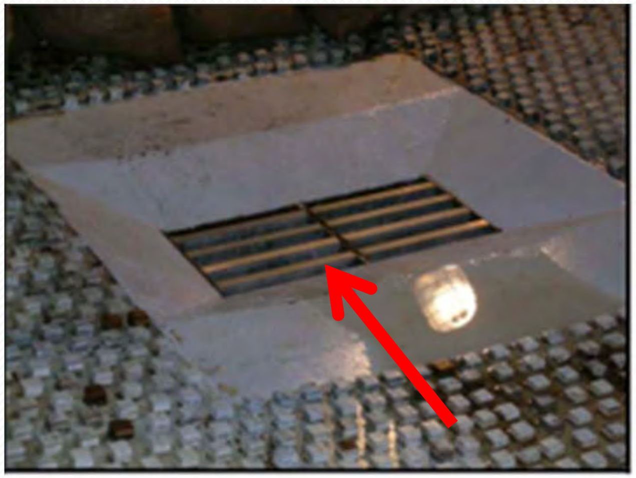
(b) 10 degree (gravel not pictured)

(c) 20 degree (gravel not pictured)

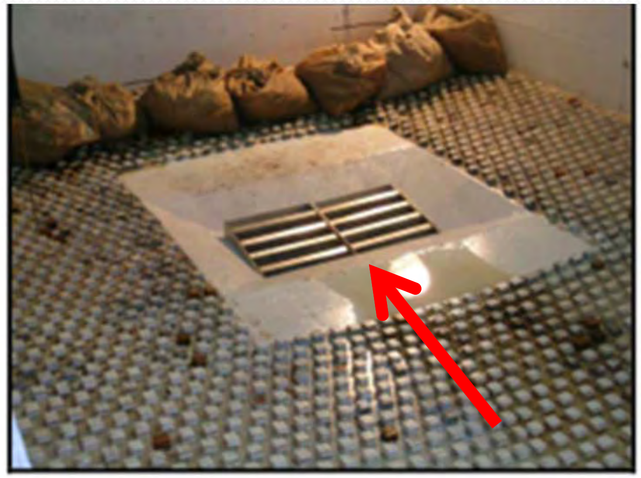
(d) 30 degree (gravel not pictured)

Flow Direction

Type D Model Inlets laid in Parallel (Rotated)

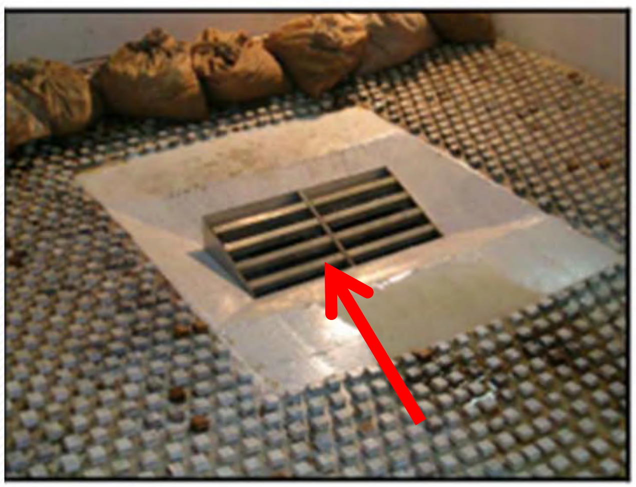


(a) horizontal

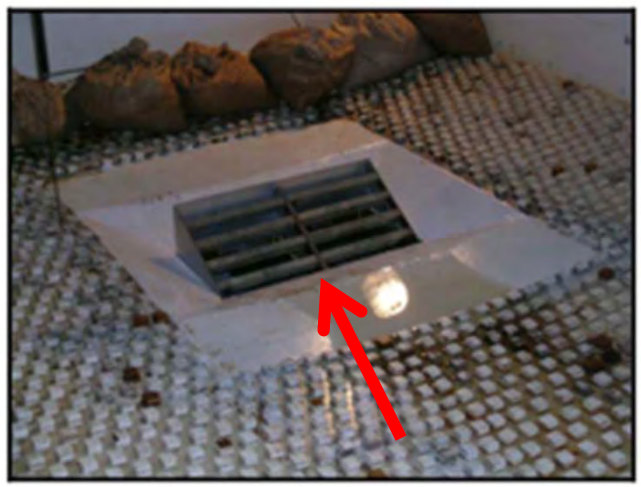


(b) 10 degree (gravel not pictured)

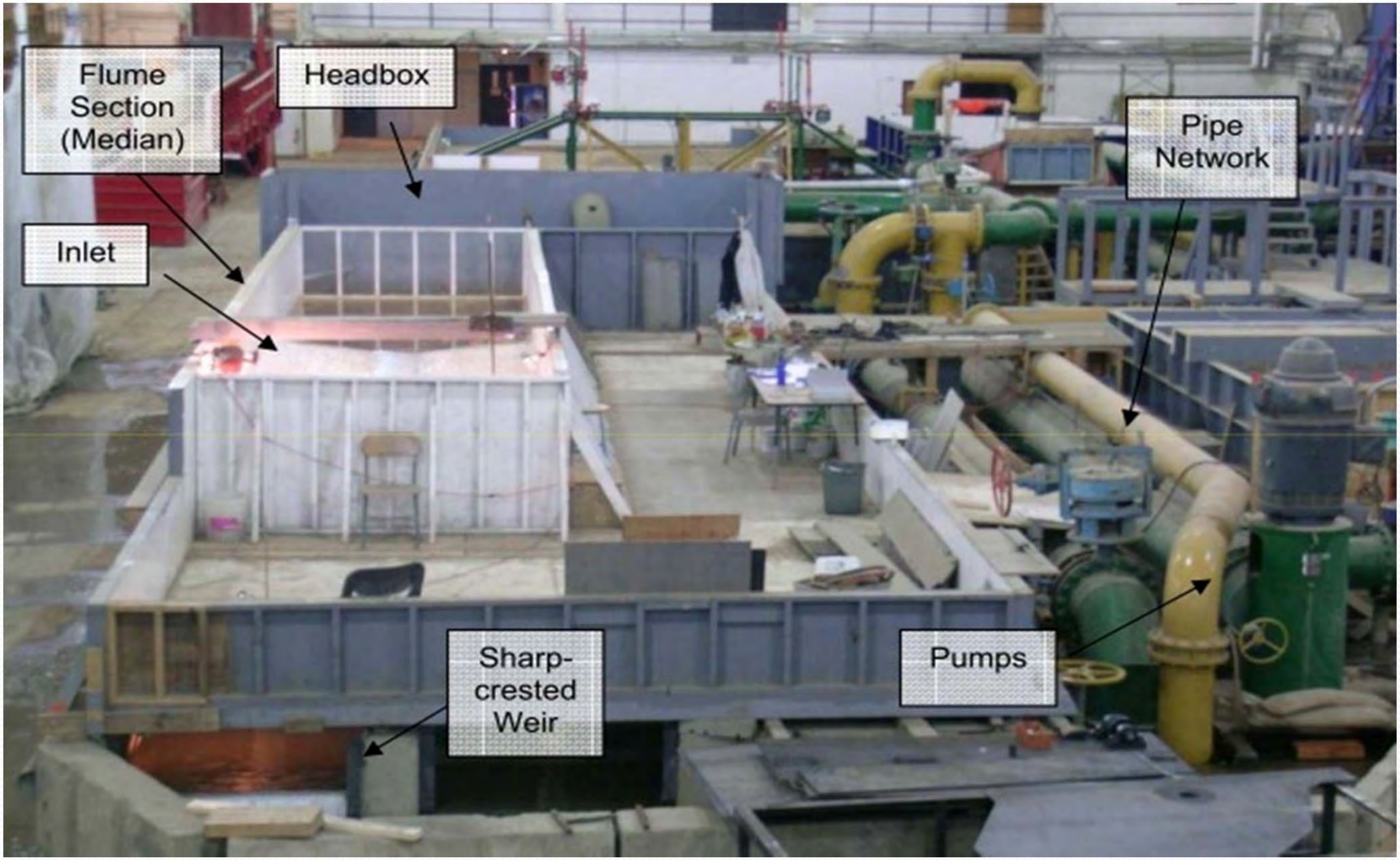
Flow Direction



(c) 20 degree (gravel not pictured)



(d) 30 degree (gravel not pictured)


Flume Section (Median)
Headbox
Inlet
Pipe Network
Sharp-crested Weir
Pumps

How to Collect Flow Data

Working
With Hands-in

Fishing
With Hands-out

Summary of Data Collections

Model Scale = 1/3 using Froude Number Similarity

Matrix of Inlet Parameters

Inlets = Type C or Type D

Depression Depth = 0 or 1 foot.

Inclined angles= 0, 10, 20, and 30 degrees

Orientation = In-series or In-parallel (Rotated)

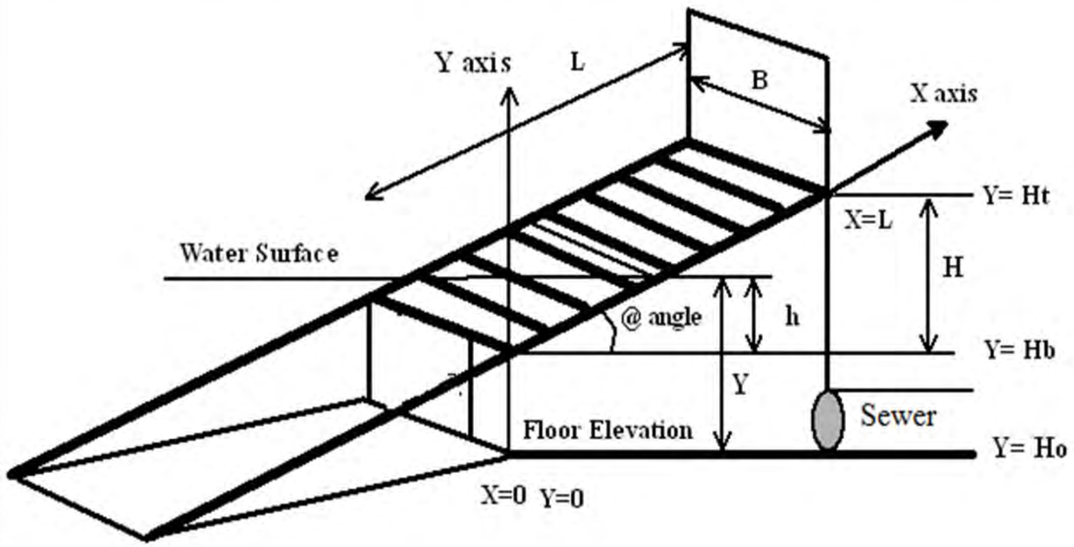
A total of 96 data sets was collected, and each data set includes:

(1) flow intercepted by the model inlet and

(2) flow depth at the front of the model inlet.

	Flow	Depth	Discharge	Intercepted
	Min	Max	Min	Max
	feet	feet	cfs	cfs
Model	0.32	1.38	1.11	17.29
Prototye	0.96	4.14	7.93	123.55

Theoretical Capacity –
Type C = Inclined Outlet Box for Detention



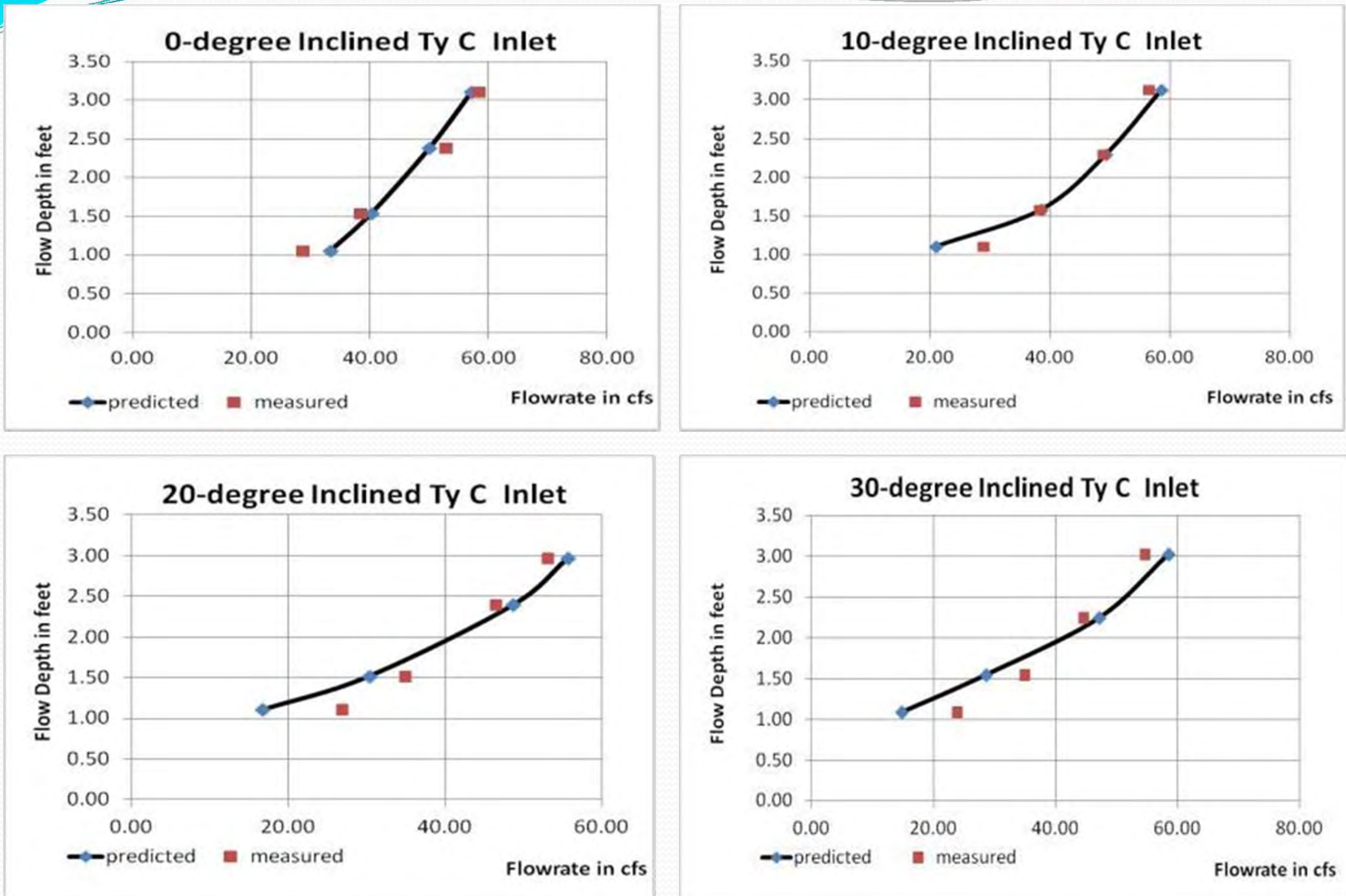
When water depth <Ht (submerged) or >Ht (un-submerged)

Qsw = weir flow on two submerged sides
Qbw = weir flow on the submerged base width
Qo = orifice flow for the submerged area

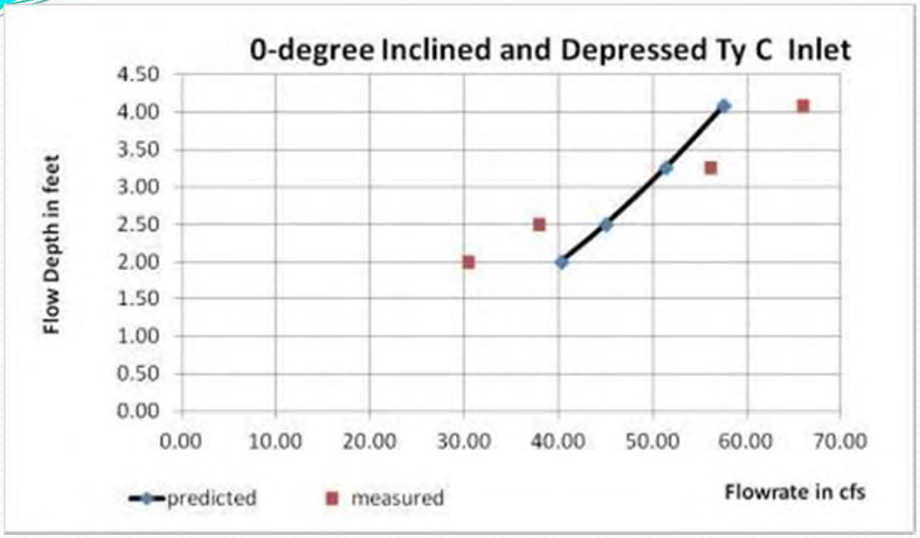
Design Q = min (2Qsw+Qbw, Qo)

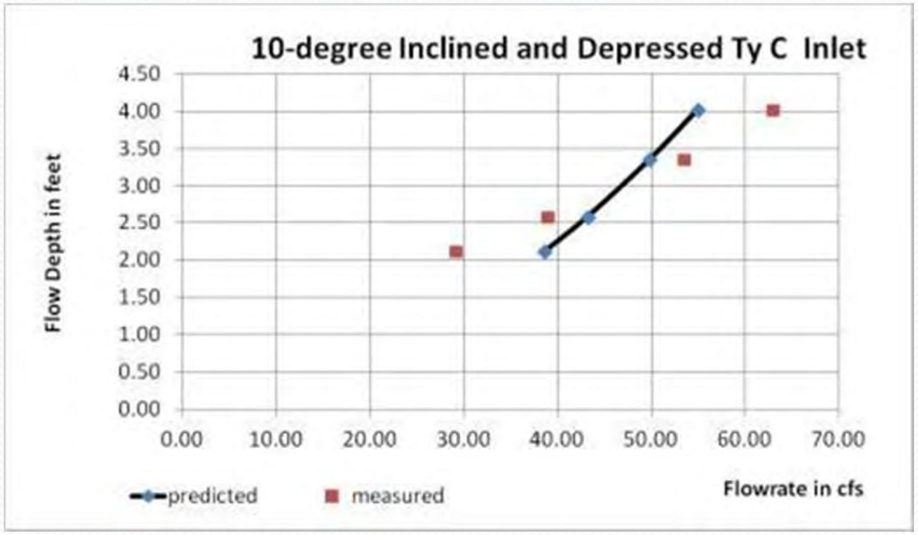
Flow Type	Flow Overtopping Two Sides of Inclined Grate	Flow overtopping the Lower Base Width	Condition
Orifice	$Q_o = \frac{2}{3} nC_d BHCot\,\theta\sqrt{2gH} = \frac{2}{3} nC_d BXCos\,\theta\sqrt{2gH}$ Subject to: $X = \frac{H}{Sin\theta} < L$		$H<H_b$ Un-submerged
Weir	$Q_{WS} = \frac{4}{15} nC_d\sqrt{2g}Cot\theta H^{\frac{5}{2}} = \frac{4}{15} nC_d XCos\theta\sqrt{2g}H^{\frac{3}{2}}$ subject to: $X = \frac{H}{Sin\theta} < L$ $Q_W = 2Q_{WS} + Q_{WB}$	$Q_{WB} = \frac{2}{3} nC_d\sqrt{2g}BH^{3/2}$	$H<H_b$ Un-submerged
Orifice	$Q_o = \frac{2}{3} nC_d BLCos\theta\sqrt{2gH}[\frac{H^{\frac{3}{2}}}{H_b\sqrt{H}} - \frac{(H-H_b)^{\frac{3}{2}}}{H_b\sqrt{H}}]$ In case of θ=0 and Hb=0, then $Q_o = \frac{2}{3} nC_d BL\sqrt{2gH}\ if\ \theta = 0$		$H \geq H_b$ Submerged
Weir	$Q_{WS} = \frac{4}{15} nC_d\sqrt{2g}LCos\theta H^{\frac{3}{2}}[\frac{H^{\frac{5}{2}}}{H^{\frac{3}{2}}H_b} - \frac{(H-H_b)^{\frac{5}{2}}}{H^{\frac{3}{2}}H_b}]$ In case of θ=0 and Hb=0, then $Q_{WS} = \frac{2}{3} nC_d L\sqrt{2g}H^{\frac{3}{2}}$ $Q_W = 2Q_{WS} + Q_{WB}$	$Q_{WB} = \frac{2}{3} nC_d\sqrt{2g}BH^{3/2}$	$H \geq H_b$ Submerged

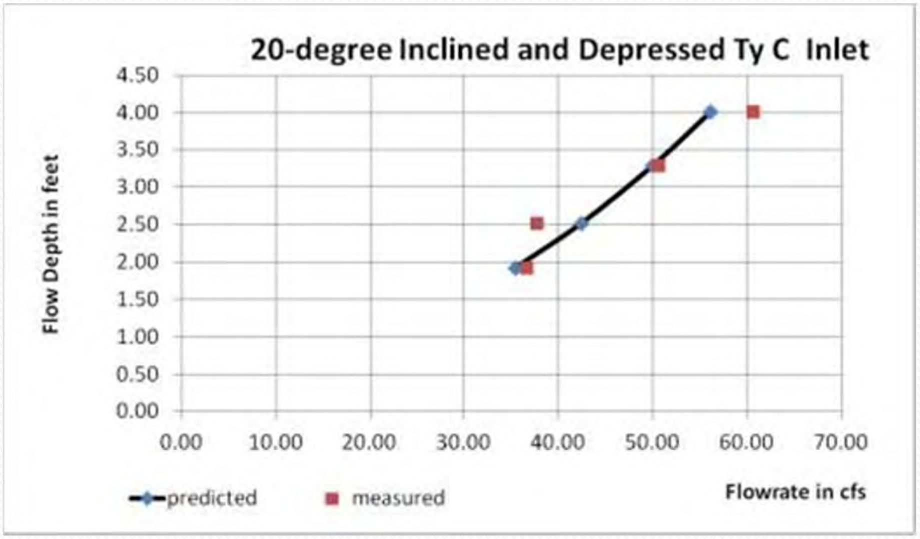
Data Analysis – Type C inlet – Flat W/O Depression

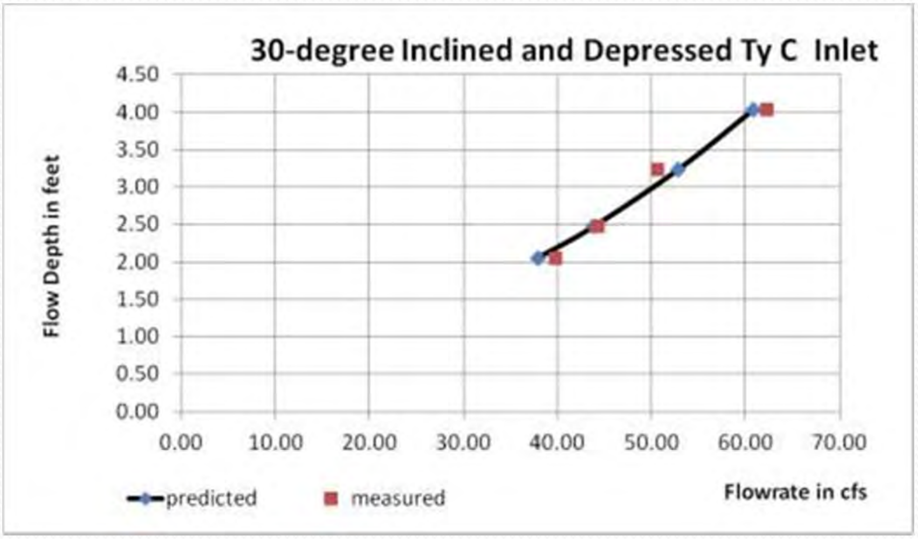


Data Analysis – Type C inlet – Flat W 1-ft Depression

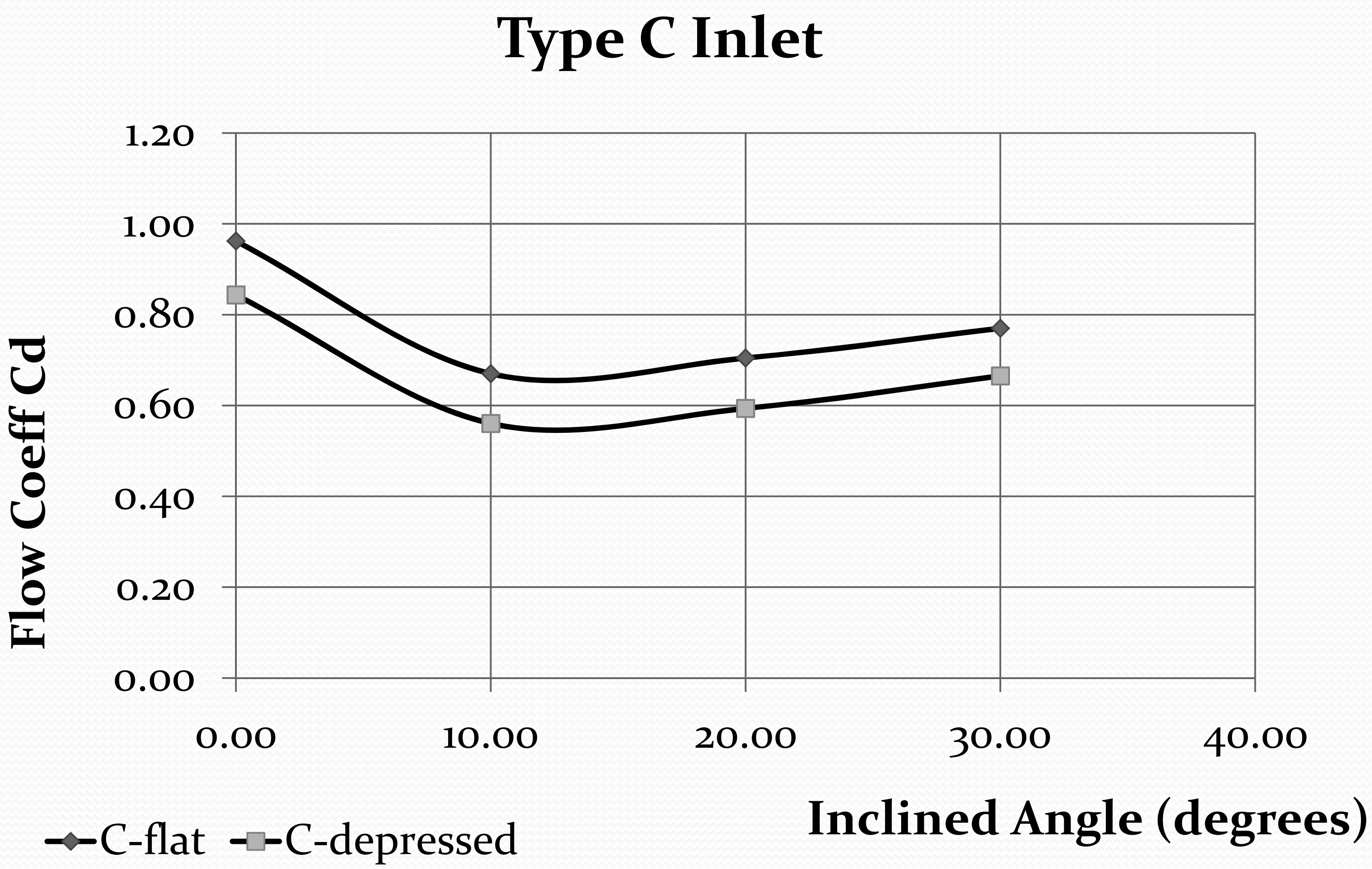




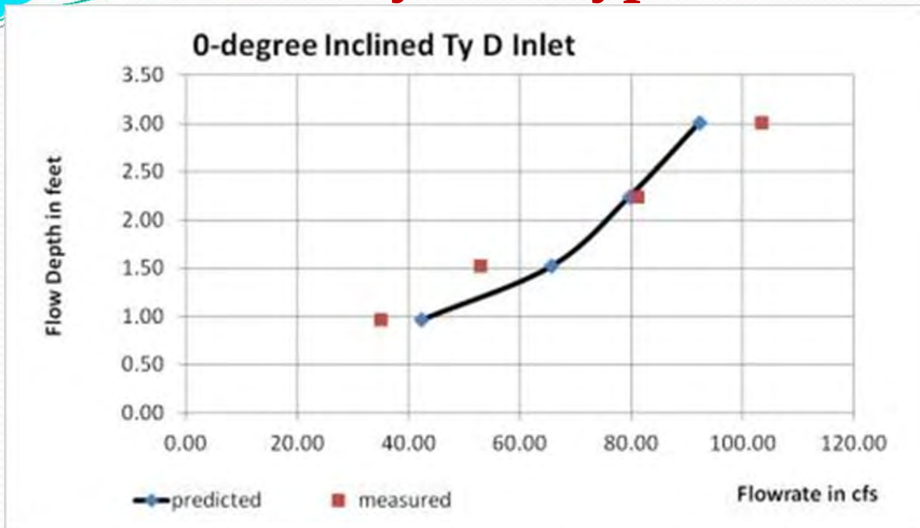


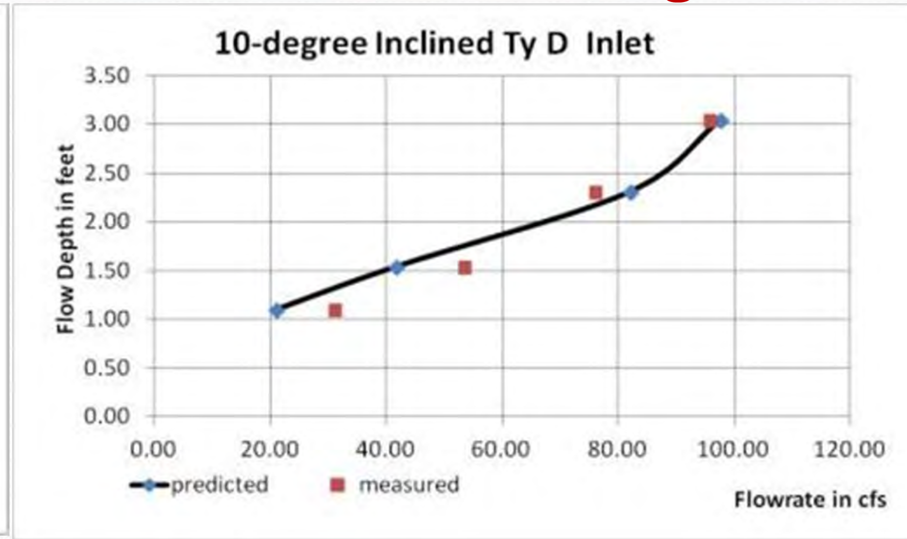


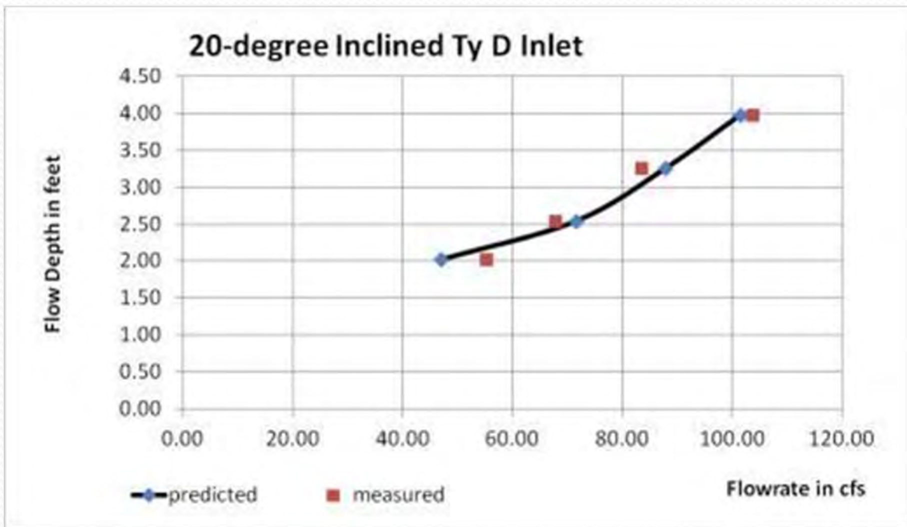
Flow Coefficients for Type C Inlet W and W/O One-ft Depression

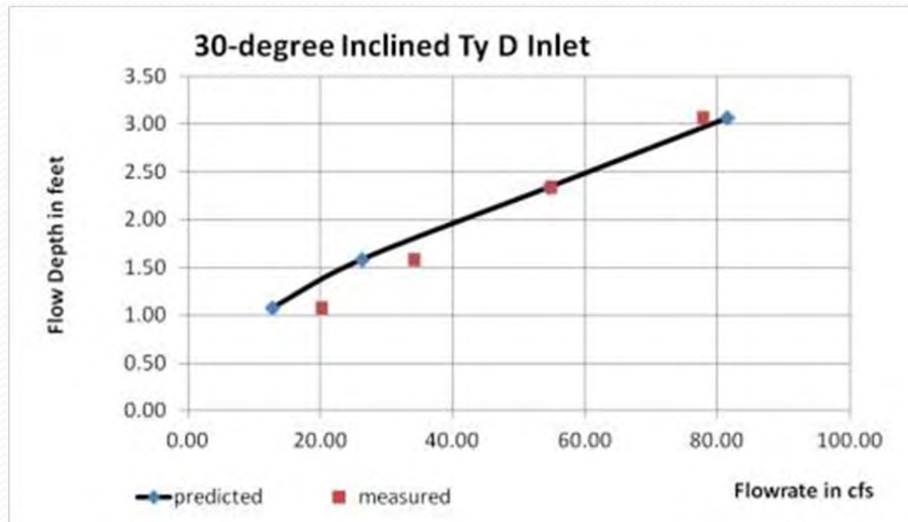


Data Analysis – Type D inlet with Various Inclined Angles

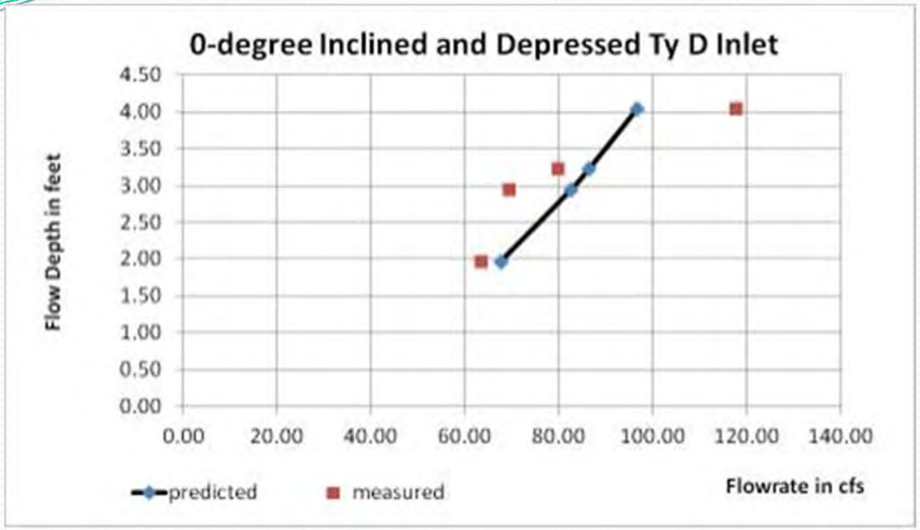


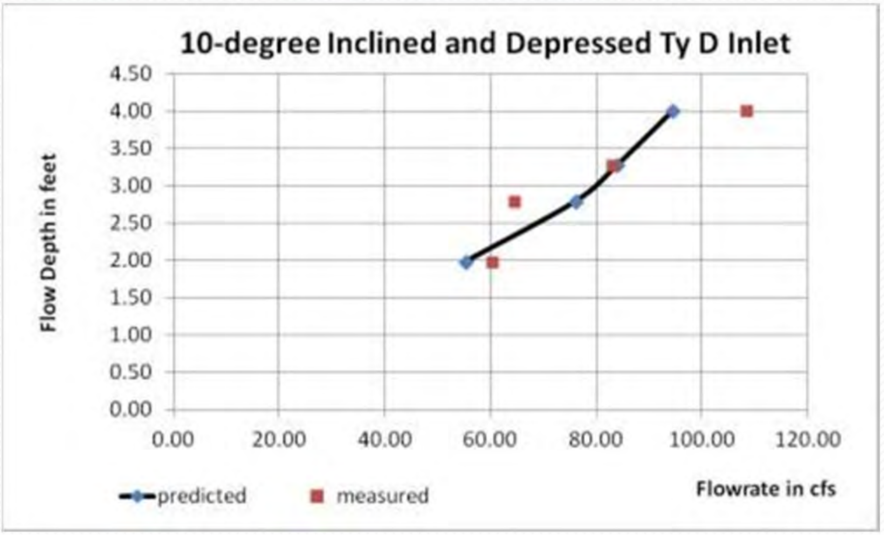


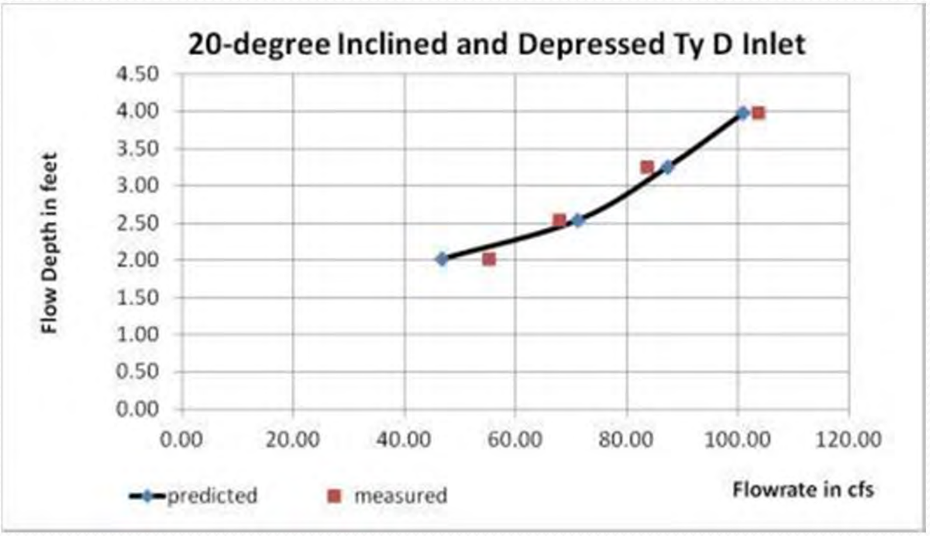


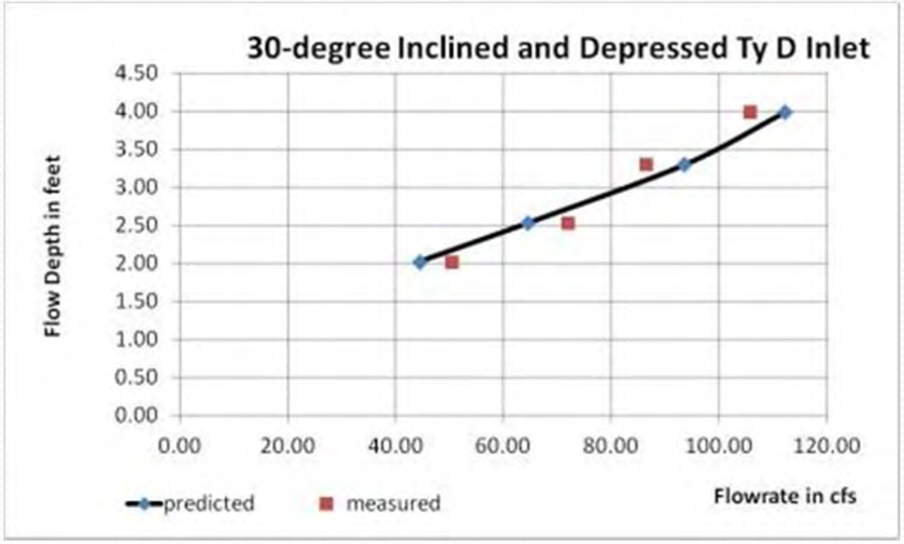


Data Analysis – Type D inlet – 1-ft Depression

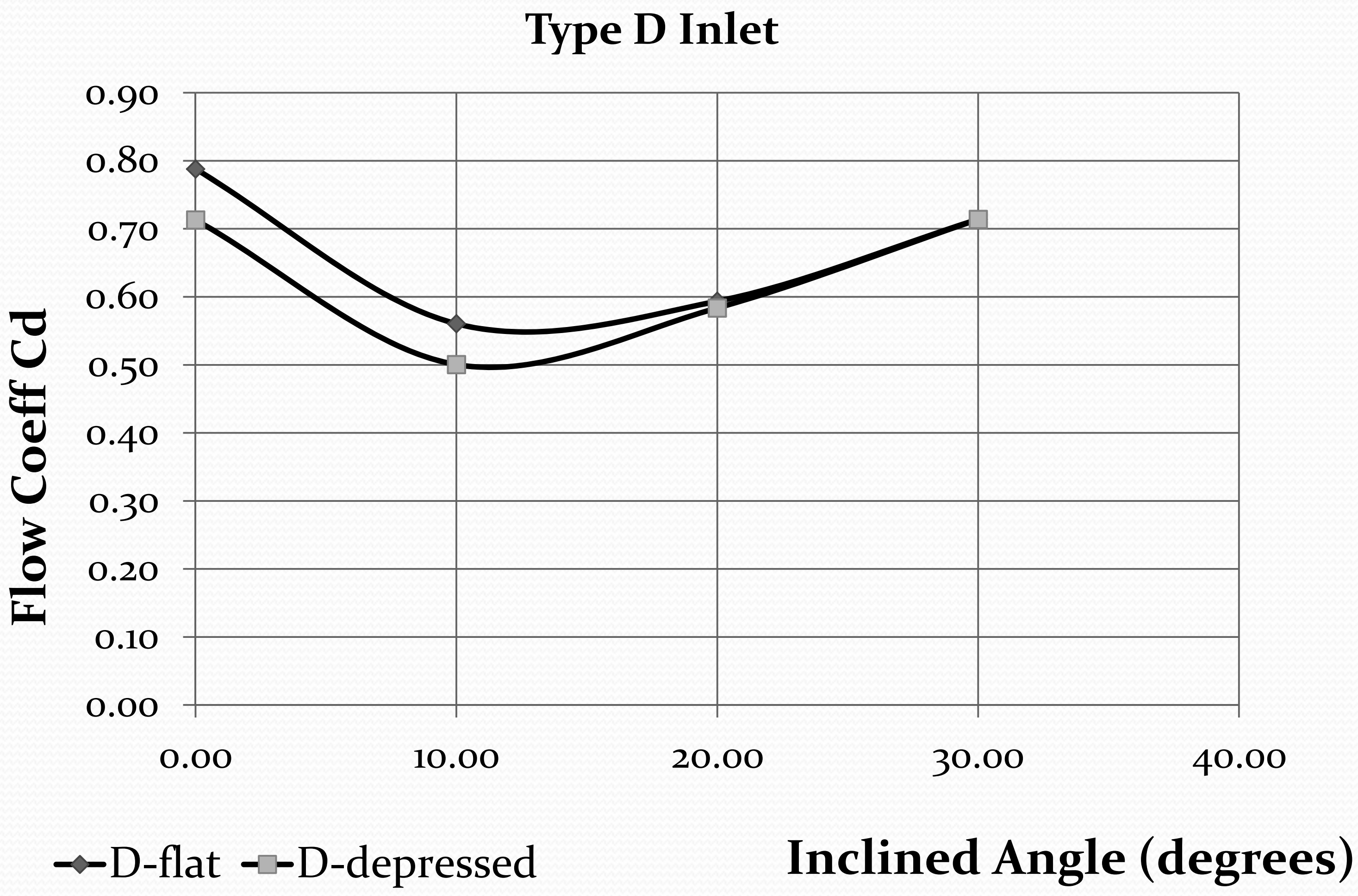




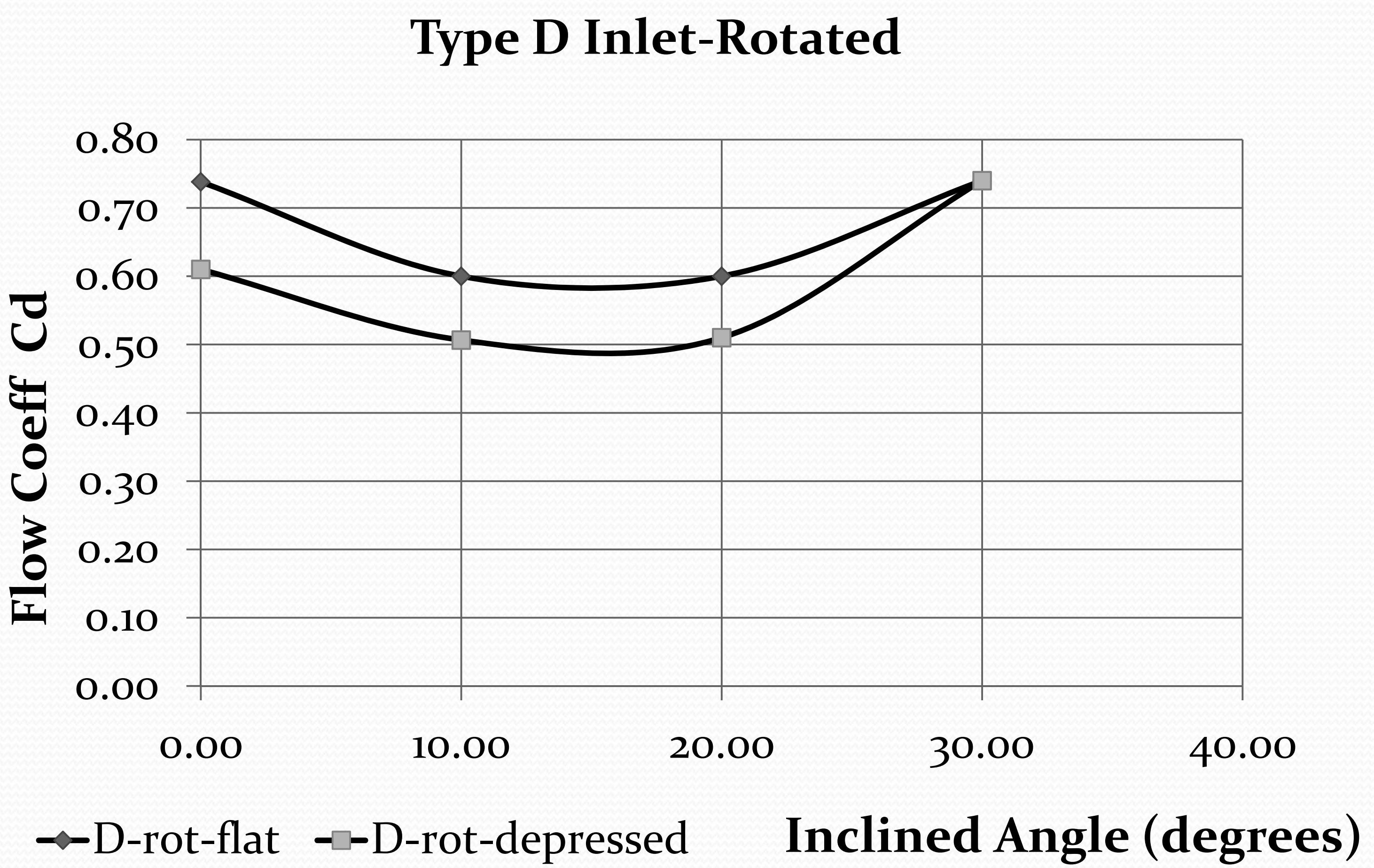




Flow Coefficients for Type D Inlet W and W/O One-ft Depression

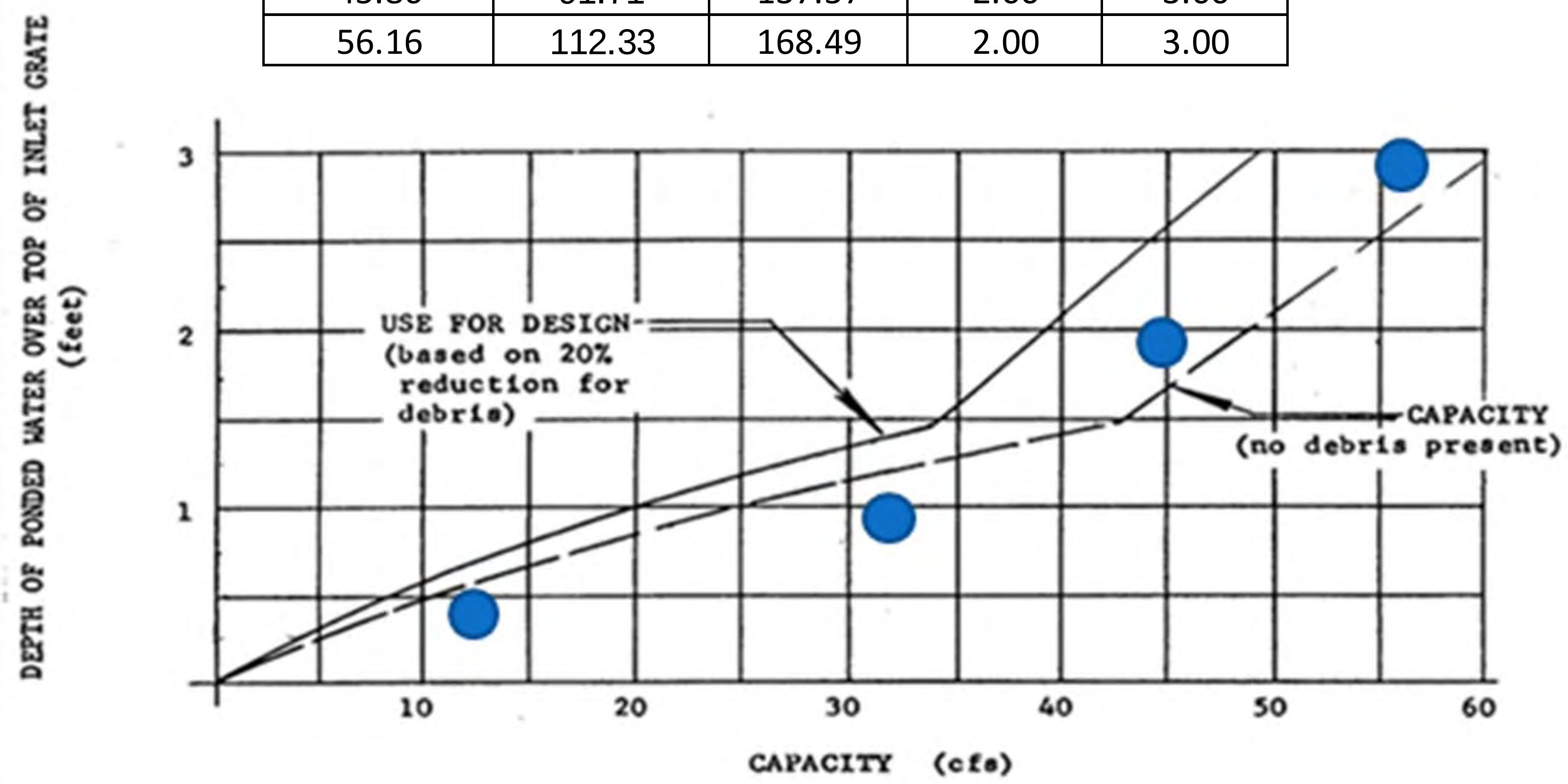


Flow Coefficients for Type D Rotated Inlet W and W/O One-ft Depression



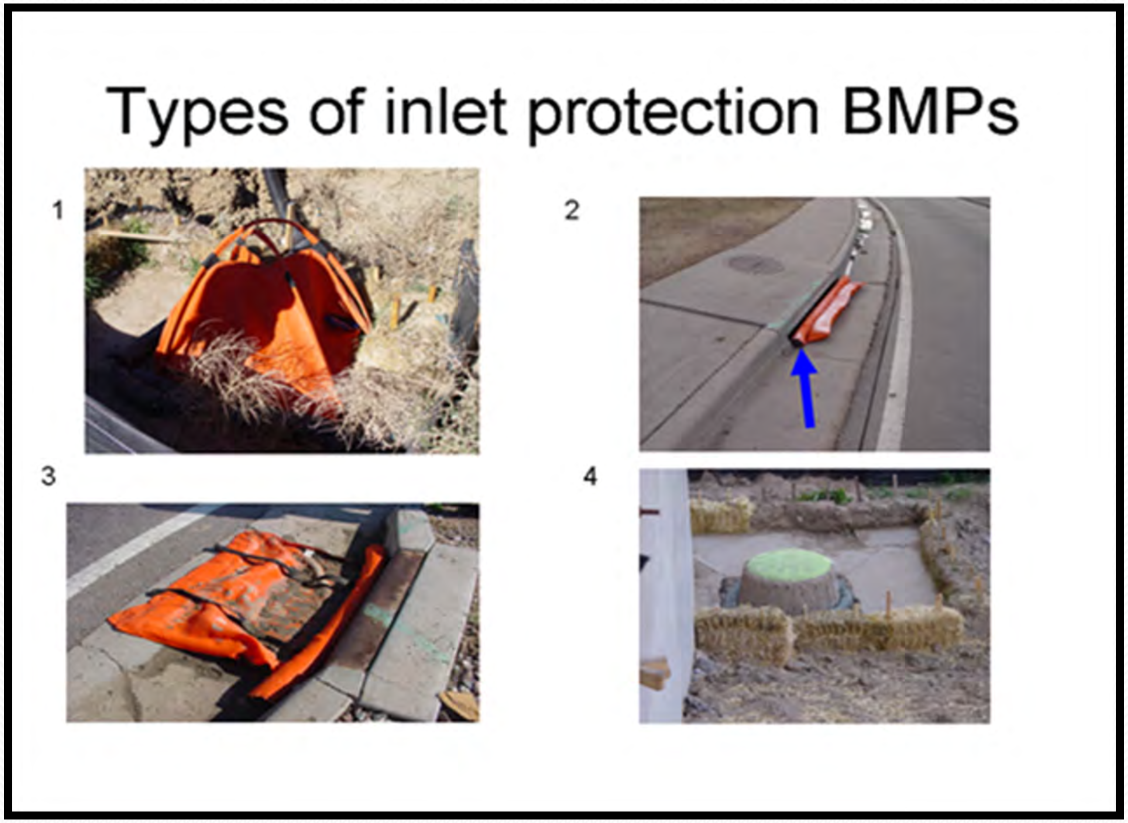
Comparison with current practice

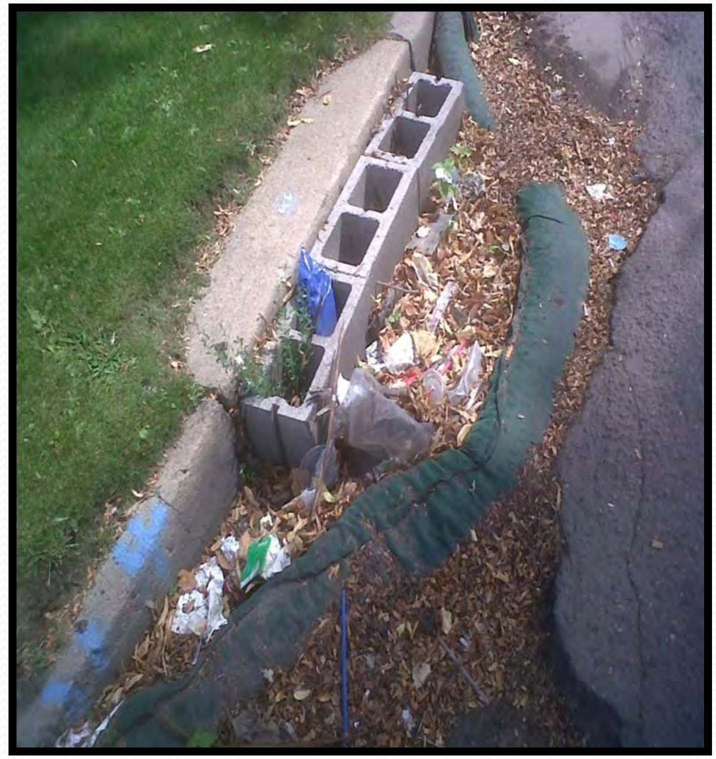
Single Type C	Double Type C	Triple Type C	Ratio 2 to 1	Ratio 3 to 1
cfs	cfs	cfs		
13.10	18.56	24.02	1.42	1.83
32.43	52.50	67.94	1.62	2.10
45.86	91.71	137.57	2.00	3.00
56.16	112.33	168.49	2.00	3.00



Debris Clogging --
Effective Orifice Area and Wetted Weir Length

From Theory to Practice





Flood during construction

Flood due to clogged drain

OVERLOADED SEDIEMNT FROM CONSTRUCTION SITE

Damage due to Bridge Deck Drains

Erosion due to Bridge Deck Drains

Project Sponsors: UDFCD+CDOT and Others
Model Design: Ken MacKenzie, UDFCD
Data Collection: Brendan C. Comport, Amanda L. Cox, CSU Hydraulic Laboratory
Theory & Data Analysis: James C.Y. Guo, UC-Denver
Project Reviewer: Amanullah Mommandi, CDOT

New Detention Sizing Methods

KEN A. MACKENZIE, P.E., CFM
UDFCD, DENVER, CO

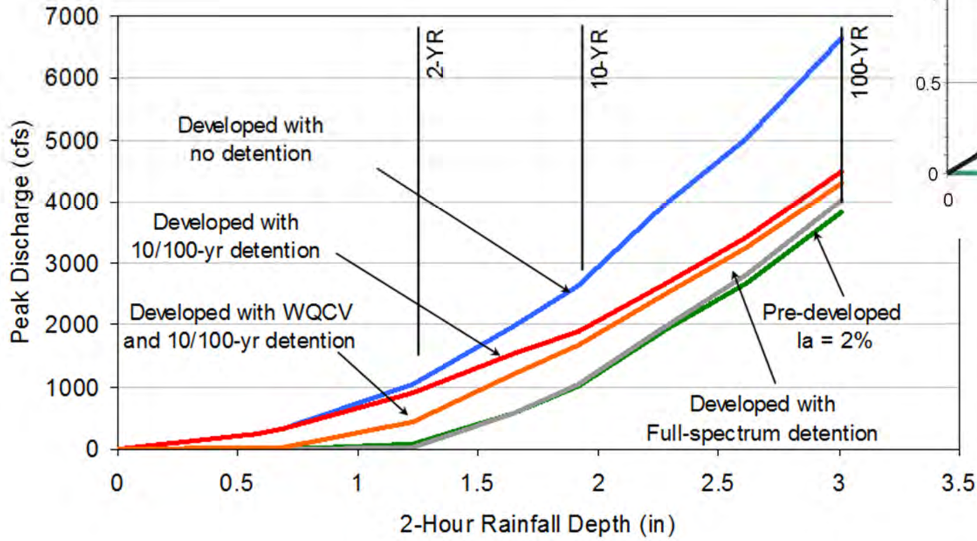
JIM WULLIMAN, P.E.
MULLER ENGINEERING COMPANY, LAKEWOOD, CO

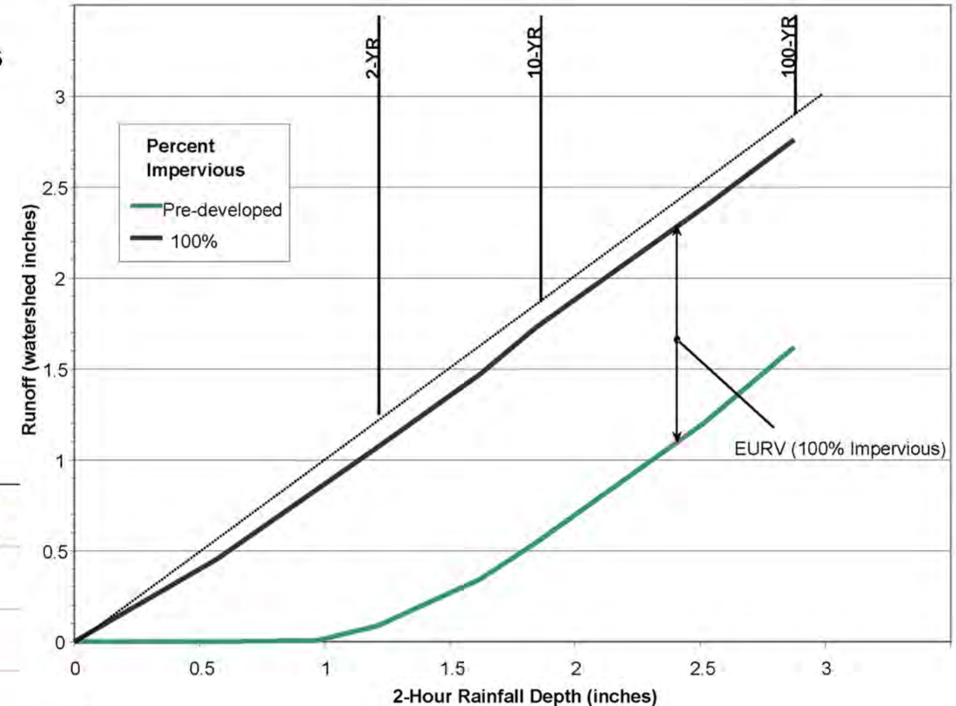
RYAN J. TAYLOR, E.I.T,
UDFCD, DENVER, CO

2004 - Initial Concept Development

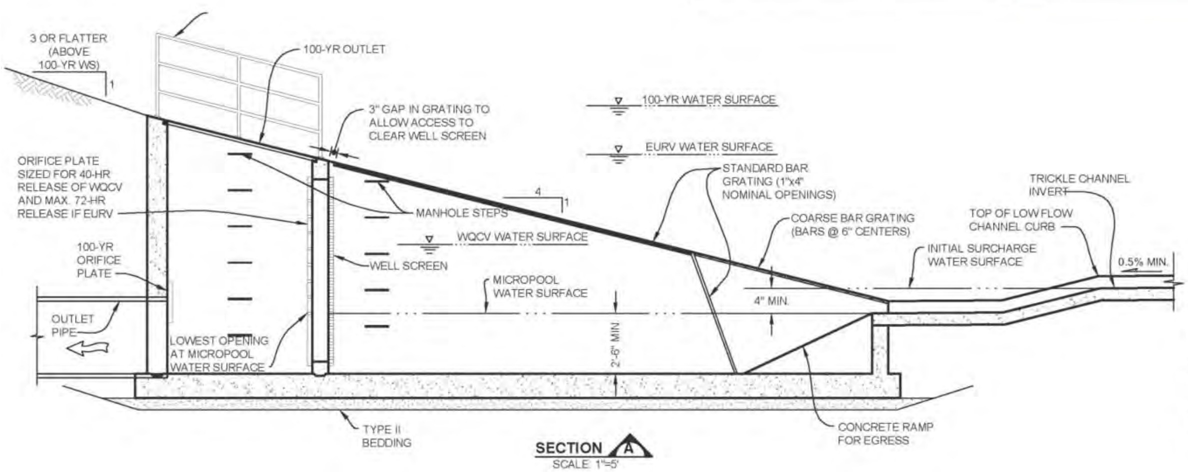
Peak Flow Control for Full Spectrum of Design Storms

Jim Wulliman, P.E., Muller Engineering Company, Lakewood, CO
Ben Urbonas, P.E., Urban Drainage & Flood Control District, Denver, CO





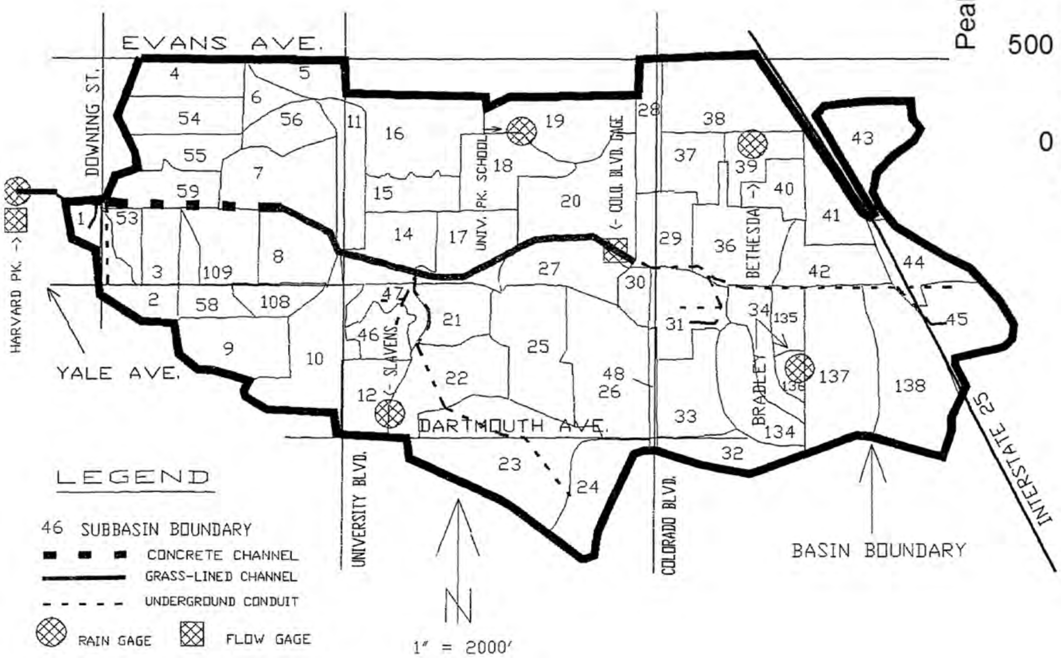
2006 – Design of First FSD Facilities

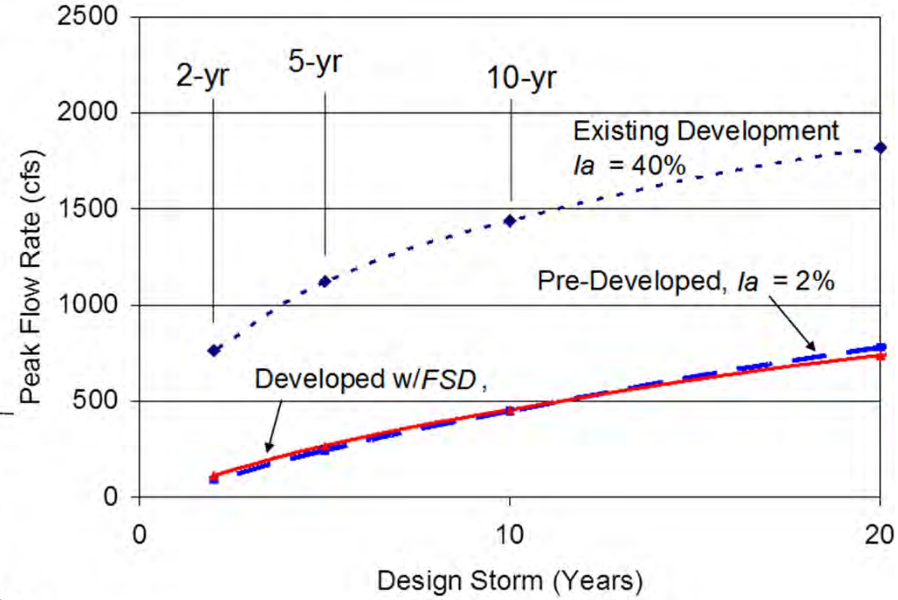


2007 – Continuous Simulation Study

Full Spectrum Detention to Control Stormwater Runoff

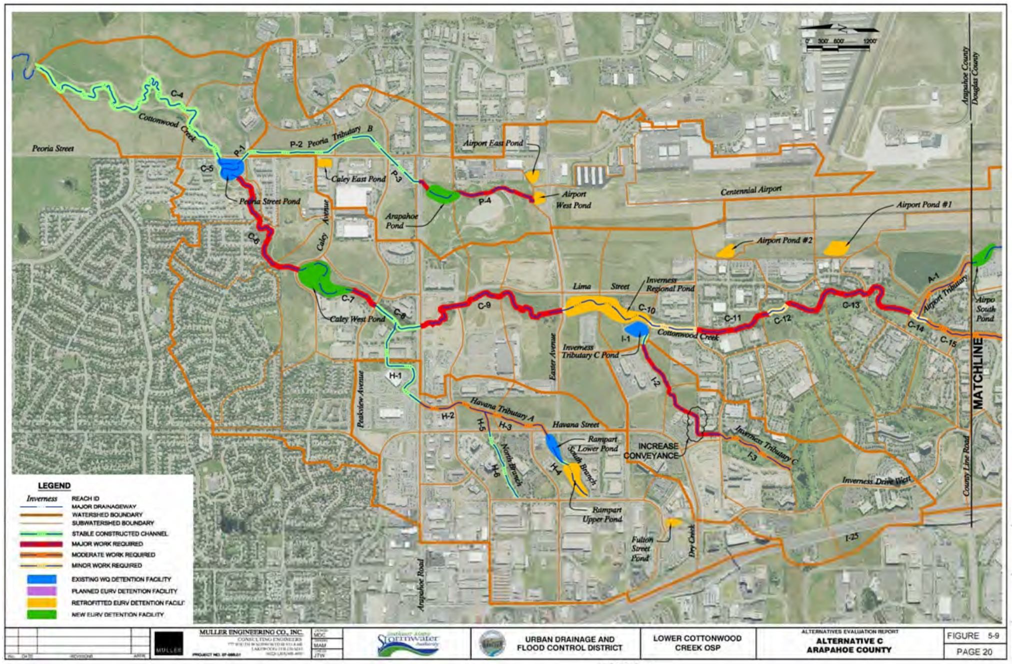
Ben Urbonas, PE, D.WRE, L.M.ASCE/EWRI, Urban Drainage and Flood Control District, Denver, Colorado
Jim Wulliman, PE, M.ASCE/EWRI, Muller Engineering Company, Lakewood, Colorado



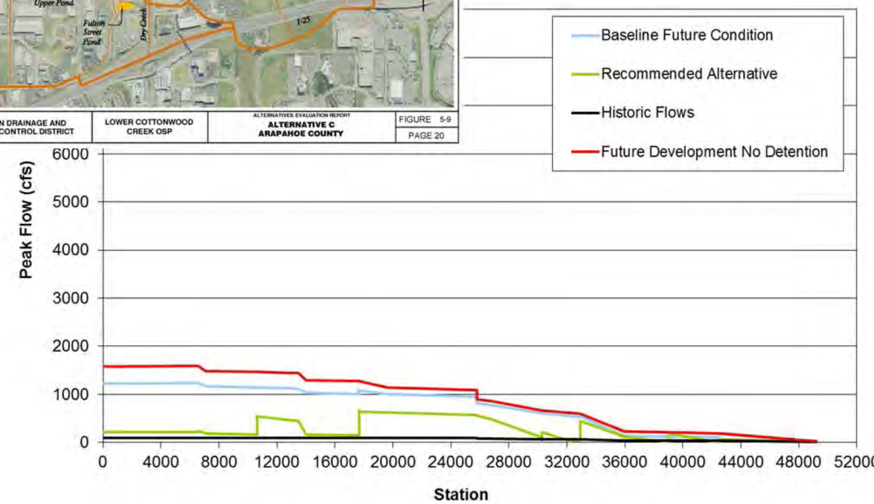


2010 – First Master Plan Based on FSD

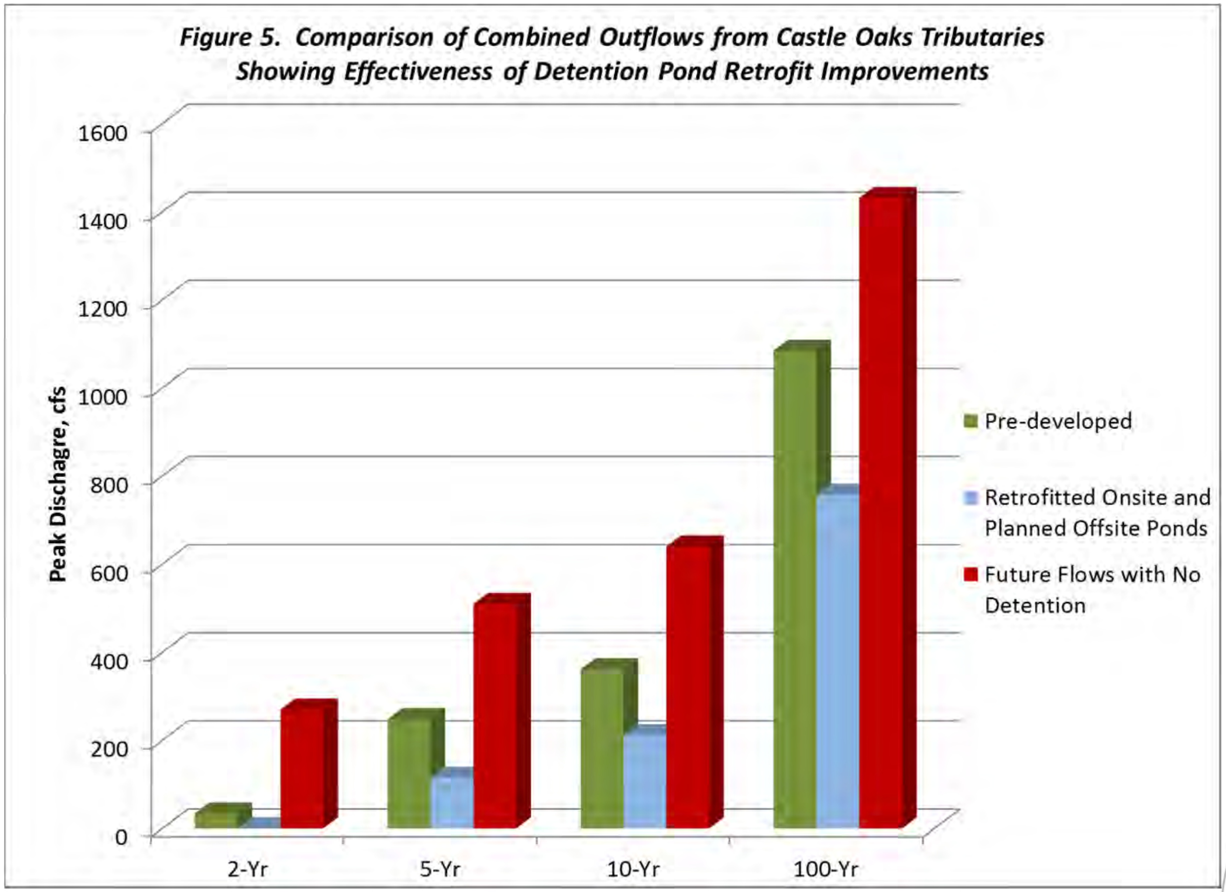
Lower Cottonwood Creek OSP



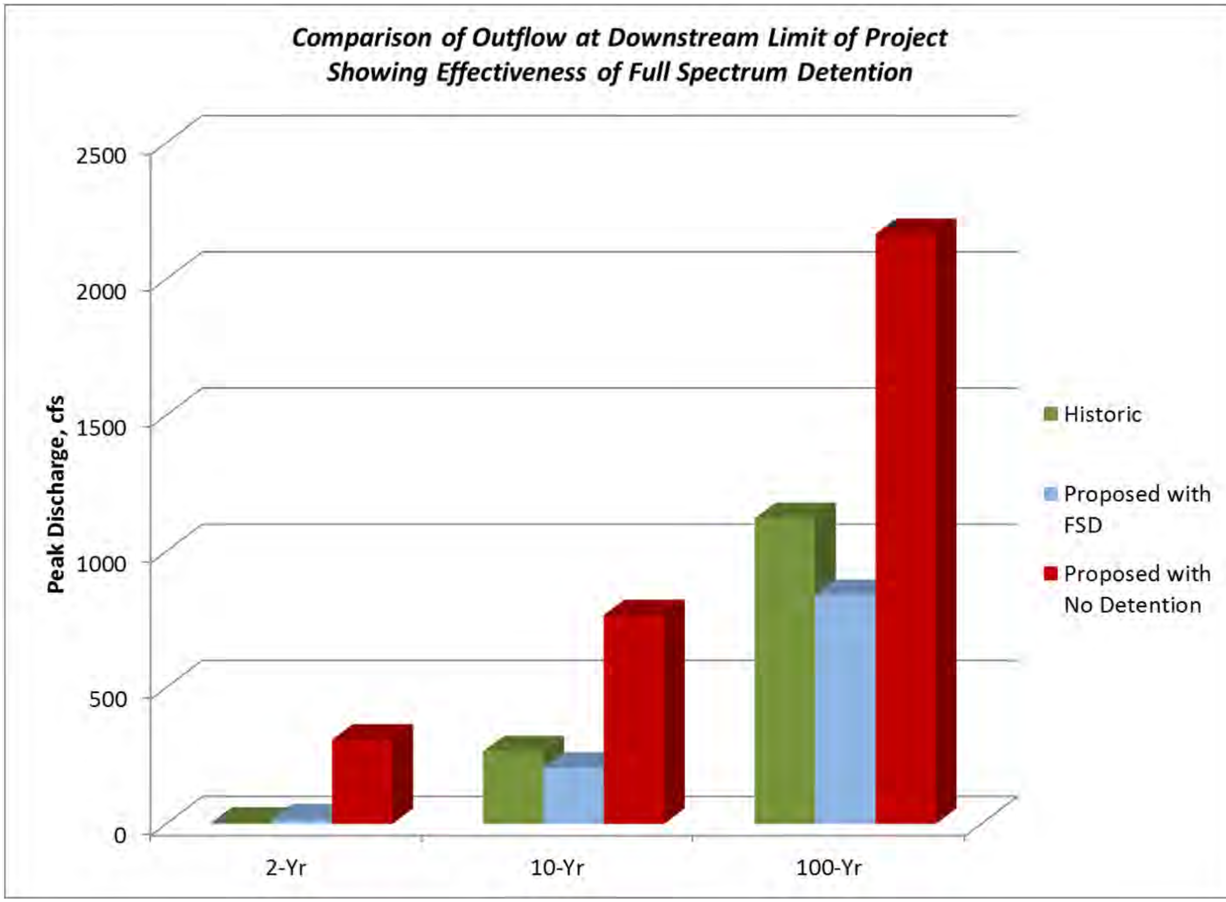
2-Year Peak Flows



2011 – McMurdo Gulch Study



2012 – East Toll Gate Creek Study



2012 – Historic Peak Unit Runoff Rates

General Equations based on point precipitation

Hydrologic Soil Group A:

$$q_A = (-0.0307 * P^2 + 0.0655 * P - 0.0346) * LN(A) + (0.4118 * P^2 - 0.8943 * P + 0.4789) \quad (1)$$

Hydrologic Soil Group B:

$$q_B = (-0.0739 * P + 0.069) * LN(A) + (1.1102 * P - 1.0377) \quad (2)$$

Hydrologic Soil Groups C & D:

$$q_{C/D} = (-0.0787 * P + 0.0733) * LN(A) + (1.1922 * P - 1.1116) \quad (3)$$

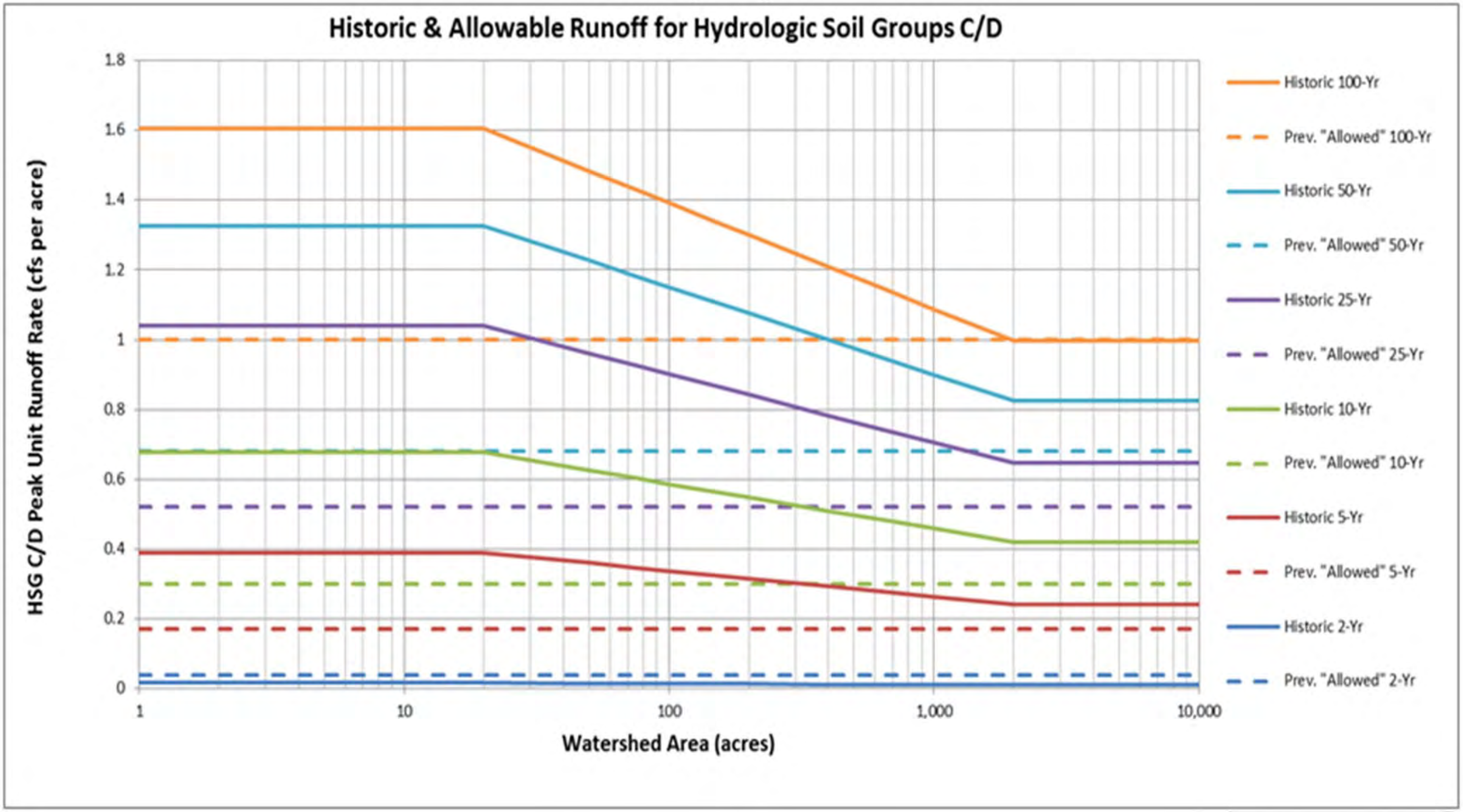
In which:

P = One-hour point precipitation, in inches

A = watershed area, in acres

*Only valid for one-hour rainfall depths of 0.94 – 2.72 inches

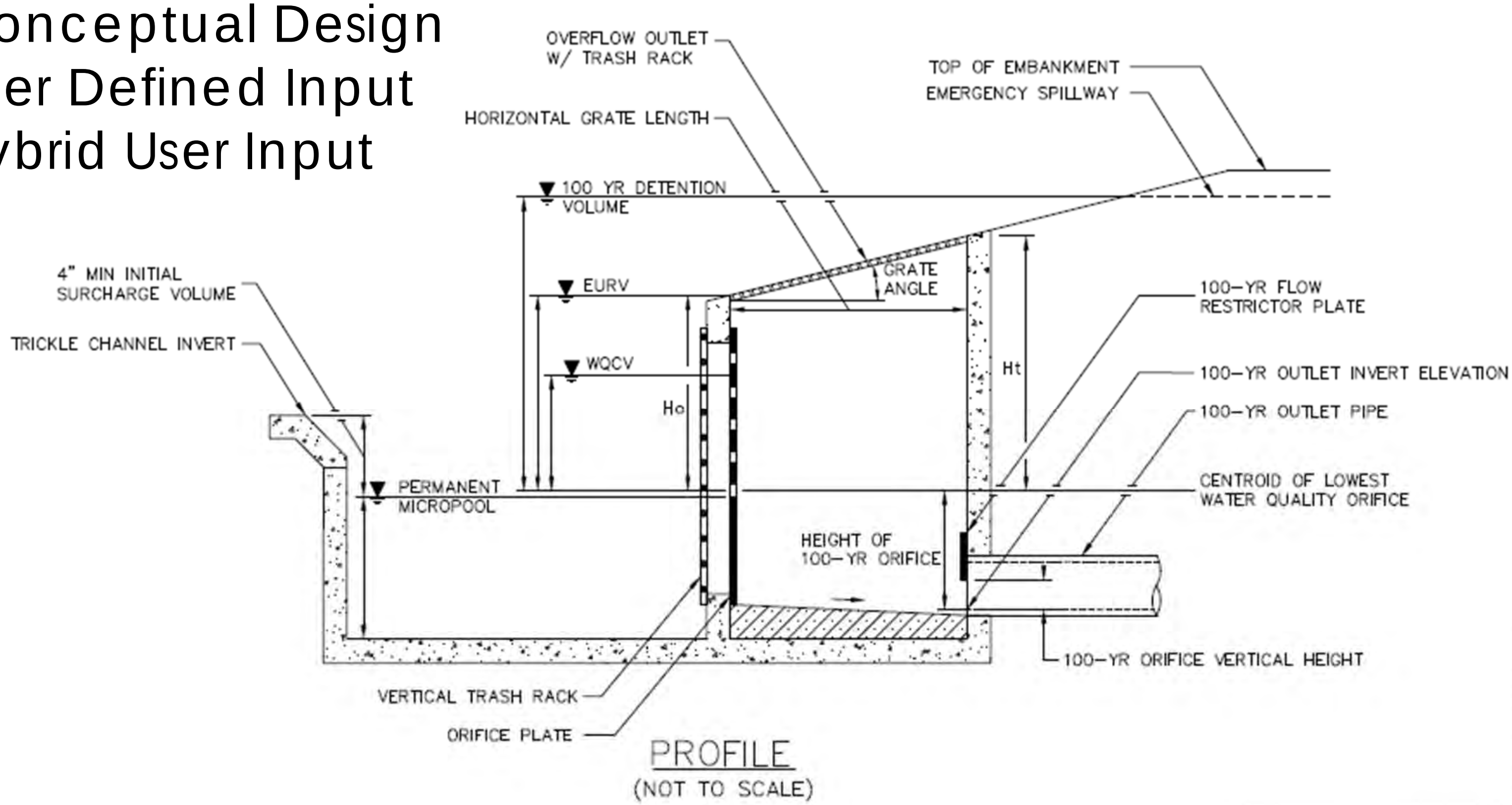
2012 – Historic Peak Unit Runoff Rates



2012 – UD-ResRoute

- Modified Puls Reservoir Routing for Full-Spectrum Detention

- 3 Methods
    1. Conceptual Design
    2. User Defined Input
    3. Hybrid User Input



UD-ResRoute - Conceptual Design Method

- Routes Multiple Storm Hydrographs From CUHP
- 16,000 Storm Hydrographs Embedded In Workbook

User (Input) Watershed Characteristics

Watershed Area =	20.00	acres
Watershed Imperviousness =	50.0%	percent
Percentage Hydrologic Soil Group A =		percent
Percentage Hydrologic Soil Group B =		percent
Percentage Hydrologic Soil Groups C/D =	100%	percent

Clear Input Parameters

Calculated Watershed Parameters

Required EURV =	40305	ft^3
Calculated EURV =	0.896	ac-ft
Calculated EURV =	39038	ft^3
Calc vs. Req Volume % Diff =	-3%	
Time to Drain EURV =	52.00	hrs

User (Input) Detention-Storage Parameters

Depth of Initial Surcharge Volume =	0.33	ft.
Trickle Channel Slope =	0.008	V:H
Detention Basin Length to Width Ratio =	3.00	L:W
Basin Side Slope (Above Basin Floor) =	4.00	H:V
Available EURV Ponding Depth =	3.00	ft. (relative to lowest WQ orifice)
Desired WQCV Drain Time =	40	hours
OPTIONAL Override EURV =		ac-ft

Calculated Detention-Storage Parameters

Depth Where Basin Floor Meets Side Slopes =	2.18	ft.
Surface Area of Initial Surcharge Volume =	366	ft^2

Clear User Defined Stage-Storage/Discharge Table

UD-ResRoute - Conceptual Design Method

User (Input) Outlet Discharge Parameters

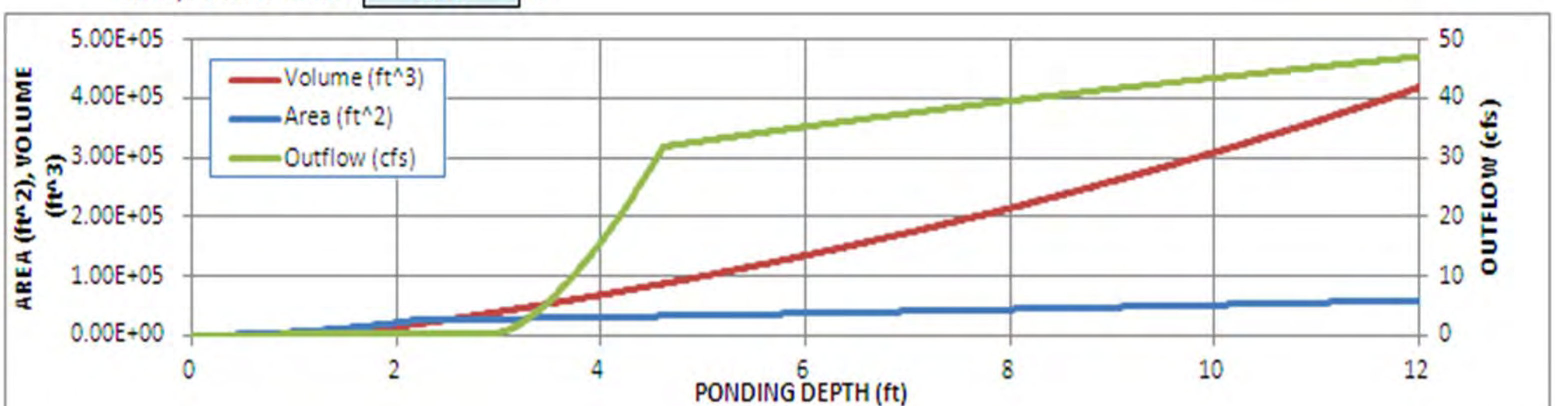
Height of Lower (Front) Edge H_o =	3.00	ft. (relative to lowest WQ orifice)
Lower Edge Weir Length =	5.00	ft.
Slope of Weir Sides =	0.00	H:V (enter zero for flat grate)
Horizontal Length of Weir Sides =	5.00	ft.
Opening Ratio of Grate, n =	0.30	(includes bars and clogging)
WQ Orifice Vertical Spacing =	4.0	inches
WQ Orifice Area per Row =	1.02	$inch^2$
100-year Orifice Invert =	-2.50	ft. (relative to lowest WQ orifice)
100-yr Orifice Vertical Height =		ft
100-yr Orifice Diameter =	1.84	ft
100-yr Orifice Area =	2.65	ft^2

☐ **Override Calculated Value**

Calculated Outlet Discharge Parameters

Grate Angle =	0.000	Radians
Grate Discharge Coeff, C_d =	0.63	
Height of Grate Upper Edge H_t =	3.00	ft.
Grate Open Area / 100-yr Orifice Area =	2.83	should be ≥ 4
WQ Orifice Area per Row =	7.056E-03	ft^2
Orifice Dia =	1.14	inch

Calculate 100-yr Orifice Area



UD-ResRoute - User Defined Input Method

User (Input) Watershed Characteristics

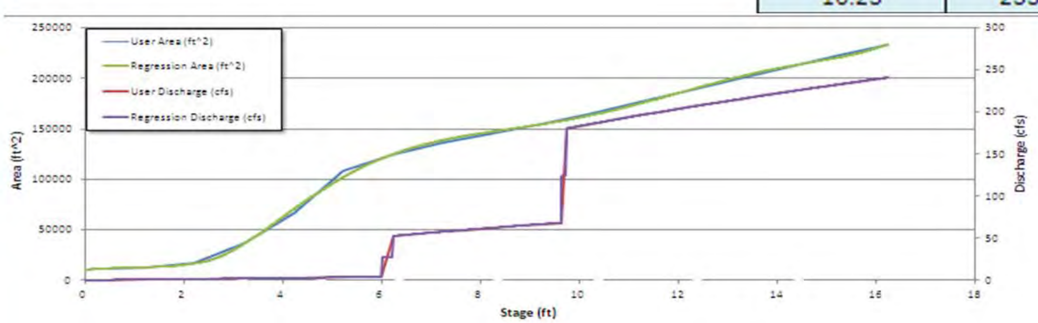
Watershed Area =	20.00	acres
Watershed Imperviousness =	40.0%	percent
Percentage Hydrologic Soil Group A =		percent
Percentage Hydrologic Soil Group B =		percent
Percentage Hydrologic Soil Groups C/D =	100%	percent
Depth of Initial Surcharge Volume =	0.33	ft.

Clear Input Parameters

Perform Regression Analysis

Clear User Defined Stage-Storage/Discharge Table

User Defined Stage (ft)	User Defined Area (ft^2)	User Defined Stage (ft)	User Defined Discharge (cfs)
0	10757	0.00	0.00
0.23	11153	0.29	0.36
1.23	13140	1.23	1.18
2.23	17088	2.23	1.72
3.23	36506	3.23	2.42
4.23	66852	4.23	3.09
5.23	107994	5.23	3.63
6.23	124677	6.00	3.99
7.23	136036	6.23	52.74
8.23	145415	6.73	55.33
9.23	154740	7.23	57.8
10.23	165206	7.73	60.17
11.23	176084	8.23	62.44
12.23	188163	8.73	64.64
13.23	199733	9.23	66.77
14.23	210853	9.63	68.42
15.23	222603	9.73	180.33
16.23	233120	10.23	185.69



- Analyze Previously Built EDBs
- Stage - Area
- Stage – Discharge
- Polynomial Regression Using Multiple Curves

UD-ResRoute - Hybrid User Input Method

- Stage – Area
- Polynomial Regression Using Multiple Curves
- Modified Puls Routing for Discharge Based on Hydraulic Structure

User (Input) Watershed Characteristics

Watershed Area =	20.00	acres
Watershed Imperviousness =	40.0%	percent
Percentage Hydrologic Soil Group A =		percent
Percentage Hydrologic Soil Group B =		percent
Percentage Hydrologic Soil Groups C/D =	100%	percent

Clear Input Parameters

Perform Regression Analysis

User (Input) Detention-Storage Parameters

Depth of Initial Surcharge Volume =	0.33	ft.
Trickle Channel Slope =	0.008	V:H
Available EURV Ponding Depth =	3.00	ft. (relative to lowest WQ orifice)
Desired WQCV Drain Time =	40	hours

Clear User Defined Stage-Storage/Discharge Table

User Stage (ft)	User Area (ft^2)
0	10757
0.23	11153
1.23	13140
2.23	17088
3.23	36506
4.23	66852
5.23	107994
6.23	124677
7.23	136036
8.23	145415
9.23	154740
10.23	165206
11.23	176084
12.23	188163
13.23	199733
14.23	210853
15.23	222603
16.23	233120

UD-ResRoute – Hybrid User Input Method

User (Input) Outlet Discharge Parameters

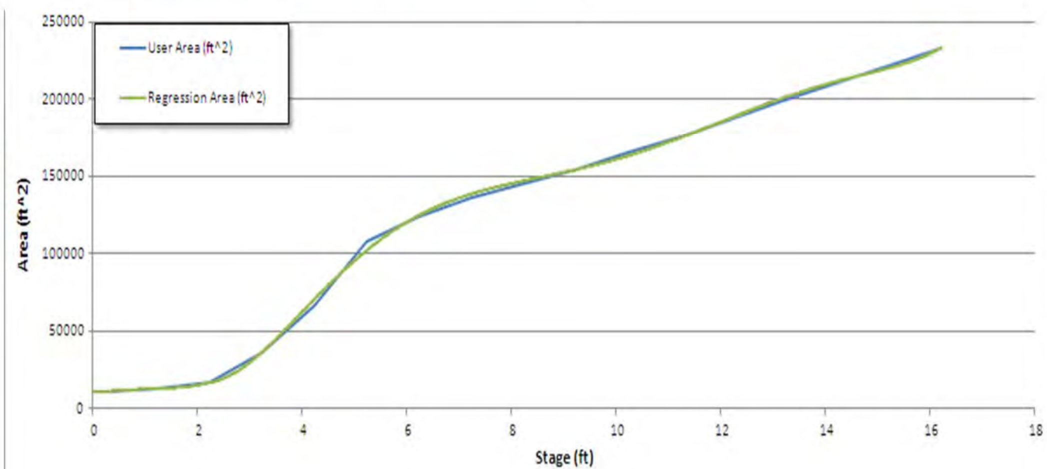
Height of Lower (Front) Edge H_o =	3.00	ft. (relative to lowest WQ orifice)
Lower Edge Weir Length =	1000.00	ft.
Slope of Weir Sides =	0.00	H:V (enter zero for flat grate)
Horizontal Length of Weir Sides =	5.00	ft.
Opening Ratio of Grate, n =	0.30	(includes bars and clogging)
WQ Orifice Vertical Spacing =	4.0	inches
WQ Orifice Area per Row =	1.02	$inch^2$
100-year Orifice Invert =	-2.50	ft. (relative to lowest WQ orifice)
100-yr Orifice Vertical Height =		ft
100-yr Orifice Diameter =	3.09	ft
100-yr Orifice Area =	7.51	ft^2

Hydraulic Structure Input

Calculate 100-yr Orifice Area

Calculated Outlet Discharge Parameters

Grate Angle =	0.000	Radians
Grate Discharge Coeff, C_d =	0.63	
Height of Grate Upper Edge H_t =	3.00	ft.
Grate Open Area / 100-yr Orifice Area =	199.65	should be ≥ 4
WQ Orifice Area per Row =	7.056E-03	ft^2
Orifice Dia =	1.14	inch



Polynomial Regression Matching

UD-ResRoute - Output

Routed Hydrograph Results For 3:1 Rectangular Basin with 0.0072 Ft / Ft Slope Trickle Channel

Design Storm Return Period =	WQCV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	
Calculated Runoff Volume =	0.410	0.879	1.266	1.605	2.115	2.482	2.875	acre-ft
OPTIONAL Override Runoff Volume =								acre-ft
Inflow Hydrograph Volume =	0.410	0.879	1.265	1.605	2.114	2.481	2.875	acre-ft
Ratio Peak Outflow to Historic Q =	N/A	1.67	0.08	0.28	0.72	0.88	1.00	Ratio
Structure Controlling Flow =	N/A	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	100yr Outlet	
Max Velocity at Grate =	0.00	0.00	0.00	0.07	0.33	0.52	0.73	fps
Time to Drain Detention Basin =	40.00	61.17	73.33	77.33	77.50	77.58	77.58	hours
Maximum Ponding Depth =	1.98	2.75	3.34	3.67	3.97	4.14	4.31	ft.
Maximum Volume Stored =	0.379	0.831	1.204	1.429	1.635	1.754	1.868	acre-ft
Historic Peak Flow Rate Per Acre (q) =	0.00	0.01	0.36	0.63	0.96	1.23	1.49	cfs/acre
Historic Peak Q =	0.00	0.20	5.40	9.41	14.46	18.47	22.34	cfs
Peak Inflow Q =	9.14	19.54	28.07	35.57	46.79	55.04	63.91	cfs
Peak Outflow Q =	0.20	0.33	0.42	2.67	10.37	16.16	22.32	cfs
One-Hour Rainfall Depth =	0.53	0.95	1.34	1.64	2.02	2.32	2.61	inches
Distributed Rainfall Depth (CUHP) =	0.609	1.104	1.553	1.892	2.339	2.677	3.016	inches

UD-ResRoute - Output

Routed Hydrograph Results For 3:1 Rectangular Basin with 0.0072 Ft / Ft Slope Trickle Channel

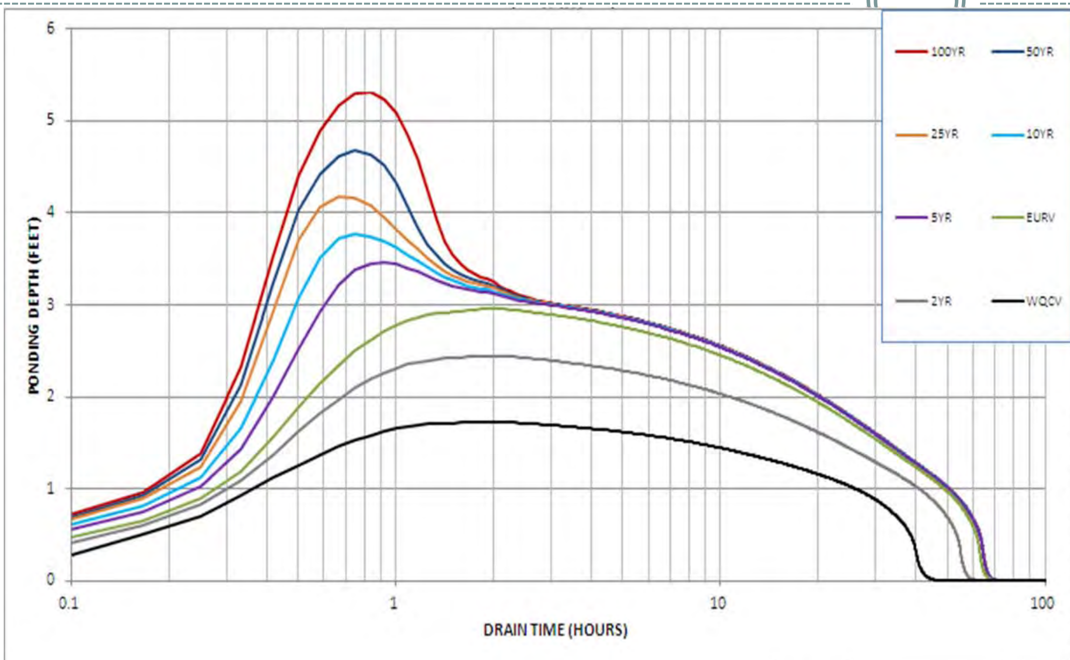
Design Storm Return Period =	WQCV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	
Calculated Runoff Volume =	0.410	0.879	1.266	1.605	2.115	2.482	2.875	acre-ft
OPTIONAL Override Runoff Volume =								acre-ft
Inflow Hydrograph Volume =	0.410	0.879	1.265	1.605	2.114	2.481	2.875	acre-ft
Ratio Peak Outflow to Historic Q =	N/A	1.67	0.08	0.28	0.72	0.88	1.00	Ratio
Structure Controlling Flow =	N/A	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	100yr Outlet	
Max Velocity at Grate =	0.00	0.00	0.00	0.07	0.33	0.52	0.73	fps
Time to Drain Detention Basin =	40.00	61.17	73.33	77.33	77.50	77.58	77.58	hours
Maximum Ponding Depth =	1.98	2.75	3.34	3.67	3.97	4.14	4.31	ft.
Maximum Volume Stored =	0.379	0.831	1.204	1.429	1.635	1.754	1.868	acre-ft
Historic Peak Flow Rate Per Acre (q) =	0.00	0.01	0.36	0.63	0.96	1.23	1.49	cfs/acre
Historic Peak Q =	0.00	0.20	5.40	9.41	14.46	18.47	22.34	cfs
Peak Inflow Q =	9.14	19.54	28.07	35.57	46.79	55.04	63.91	cfs
Peak Outflow Q =	0.20	0.33	0.42	2.67	10.37	16.16	22.32	cfs
One-Hour Rainfall Depth =	0.53	0.95	1.34	1.64	2.02	2.32	2.61	inches
Distributed Rainfall Depth (CUHP) =	0.609	1.104	1.553	1.892	2.339	2.677	3.016	inches

UD-ResRoute - Output

Routed Hydrograph Results For 3:1 Rectangular Basin with 0.0072 Ft / Ft Slope Trickle Channel

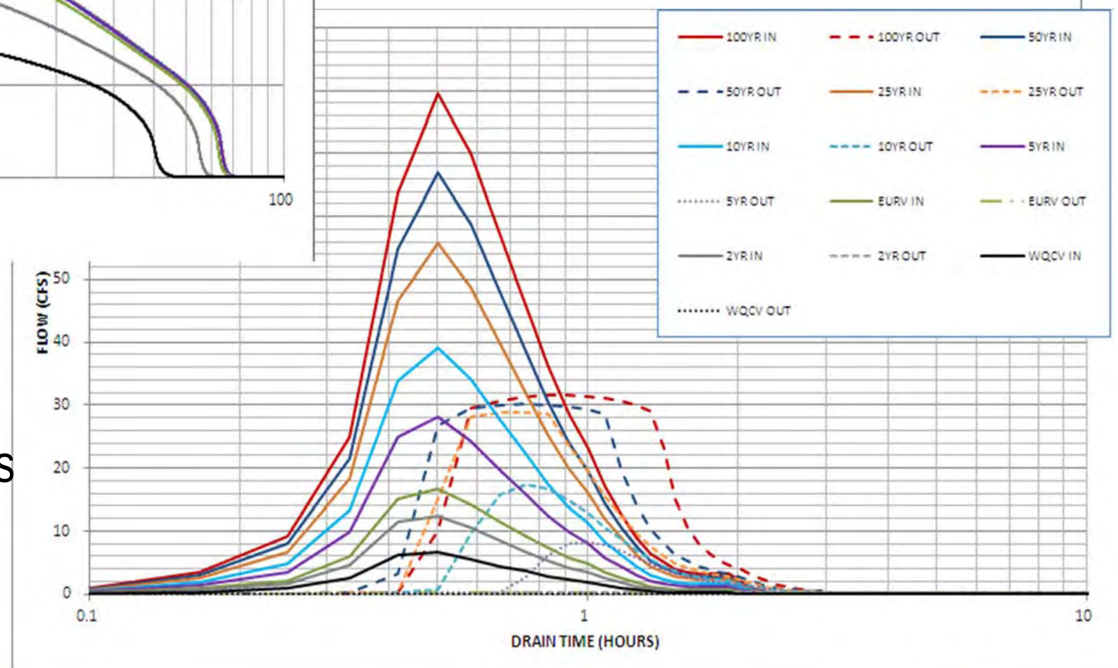
Design Storm Return Period =	WQCV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	
Calculated Runoff Volume =	0.410	0.879	1.266	1.605	2.115	2.482	2.875	acre-ft
OPTIONAL Override Runoff Volume =								acre-ft
Inflow Hydrograph Volume =	0.410	0.879	1.265	1.605	2.114	2.481	2.875	acre-ft
Ratio Peak Outflow to Historic Q =	N/A	1.67	0.08	0.28	0.72	0.88	1.00	Ratio
Structure Controlling Flow =	N/A	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	Grate/Plate	100yr Outlet	
Max Velocity at Grate =	0.00	0.00	0.00	0.07	0.33	0.52	0.73	fps
Time to Drain Detention Basin =	40.00	61.17	73.33	77.33	77.50	77.58	77.58	hours
Maximum Ponding Depth =	1.98	2.75	3.34	3.67	3.97	4.14	4.31	ft.
Maximum Volume Stored =	0.379	0.831	1.204	1.429	1.635	1.754	1.868	acre-ft
Historic Peak Flow Rate Per Acre (q) =	0.00	0.01	0.36	0.63	0.96	1.23	1.49	cfs/acre
Historic Peak Q =	0.00	0.20	5.40	9.41	14.46	18.47	22.34	cfs
Peak Inflow Q =	9.14	19.54	28.07	35.57	46.79	55.04	63.91	cfs
Peak Outflow Q =	0.20	0.33	0.42	2.67	10.37	16.16	22.32	cfs
One-Hour Rainfall Depth =	0.53	0.95	1.34	1.64	2.02	2.32	2.61	inches
Distributed Rainfall Depth (CUHP) =	0.609	1.104	1.553	1.892	2.339	2.677	3.016	inches

UD-ResRoute - Output

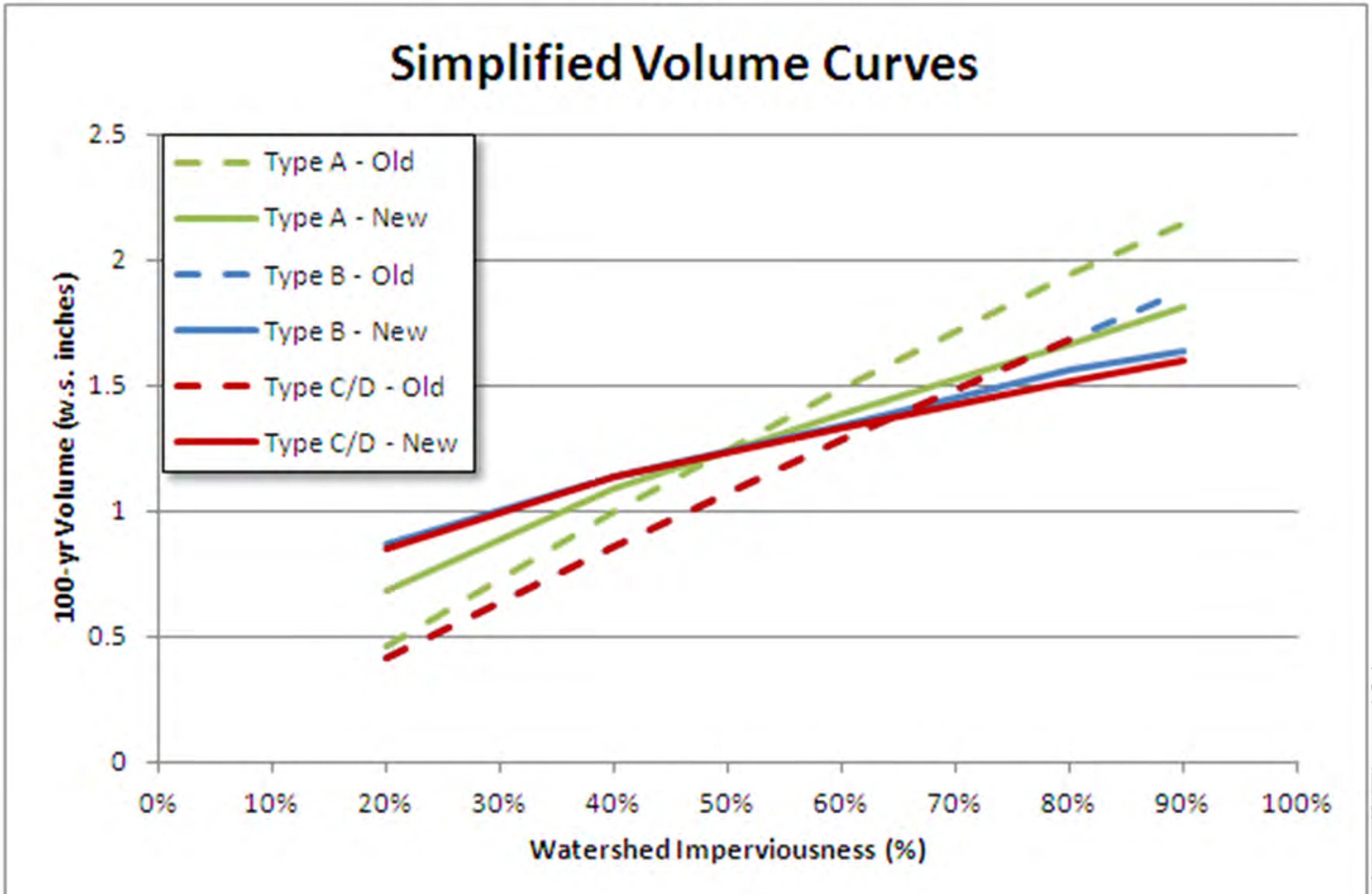


Drain Time vs Ponding Depth

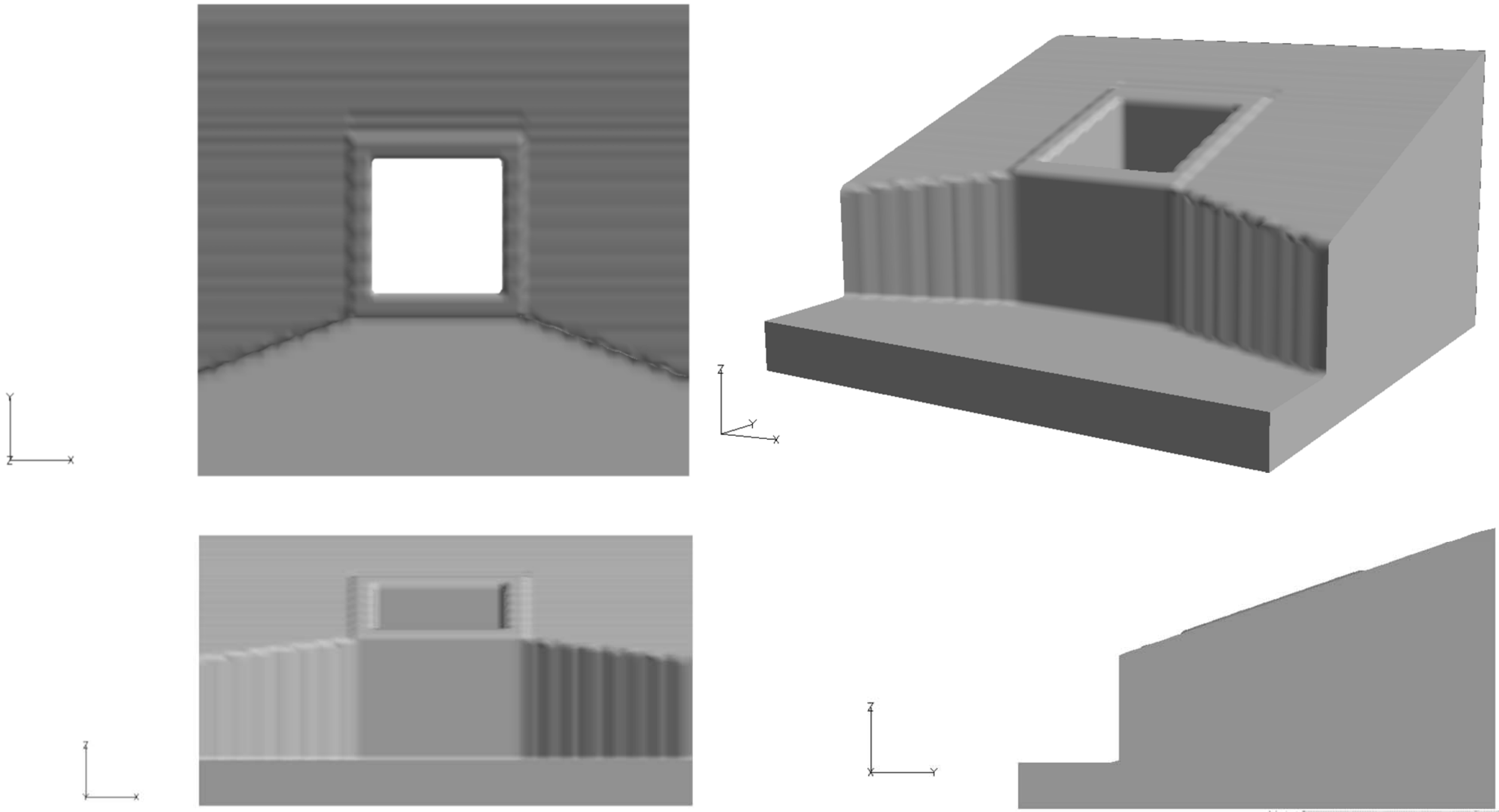
Inflow & Outflow Hydrographs



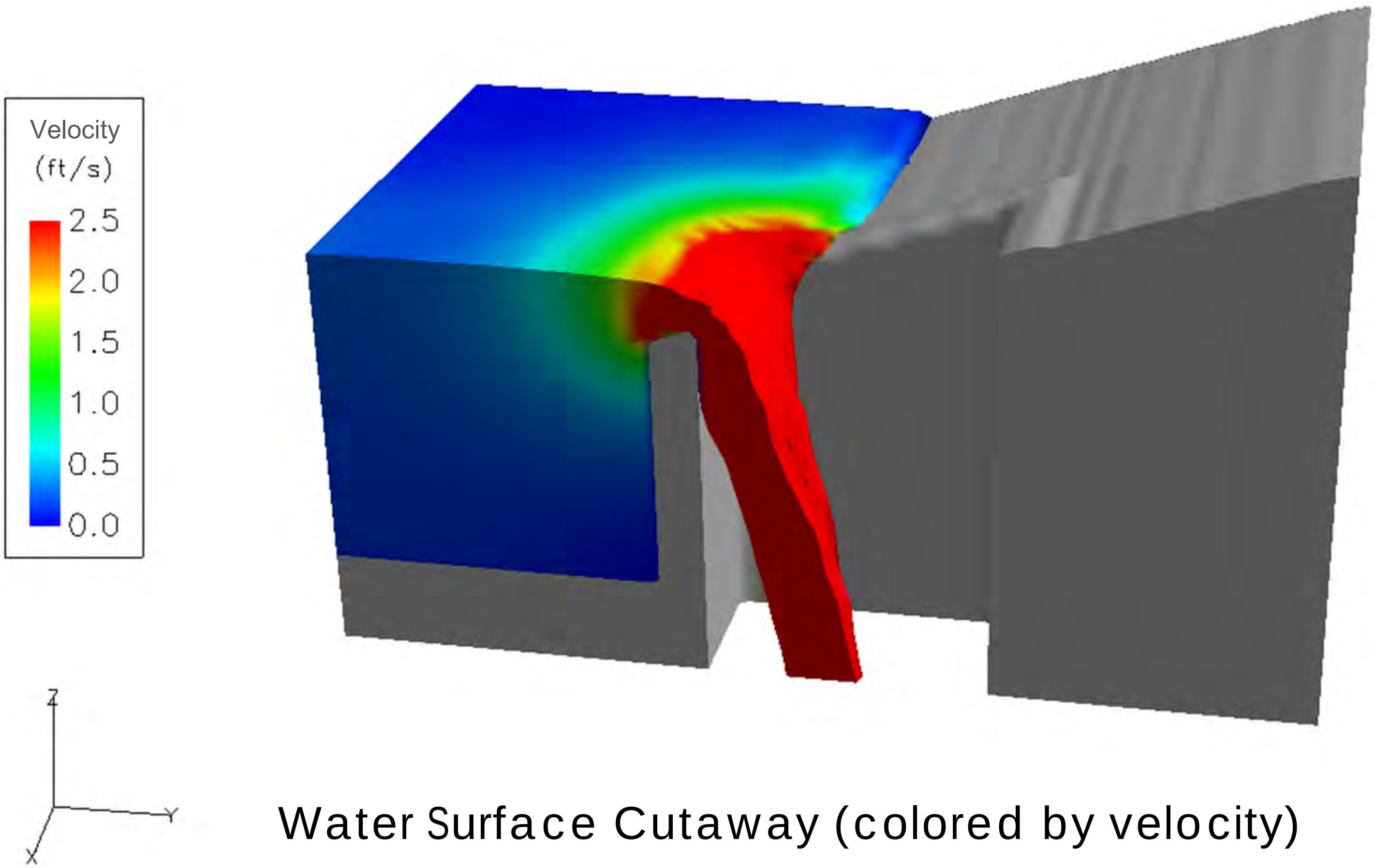
Simplified Volume Equations



ARCADIS Flow-3D CFD Model

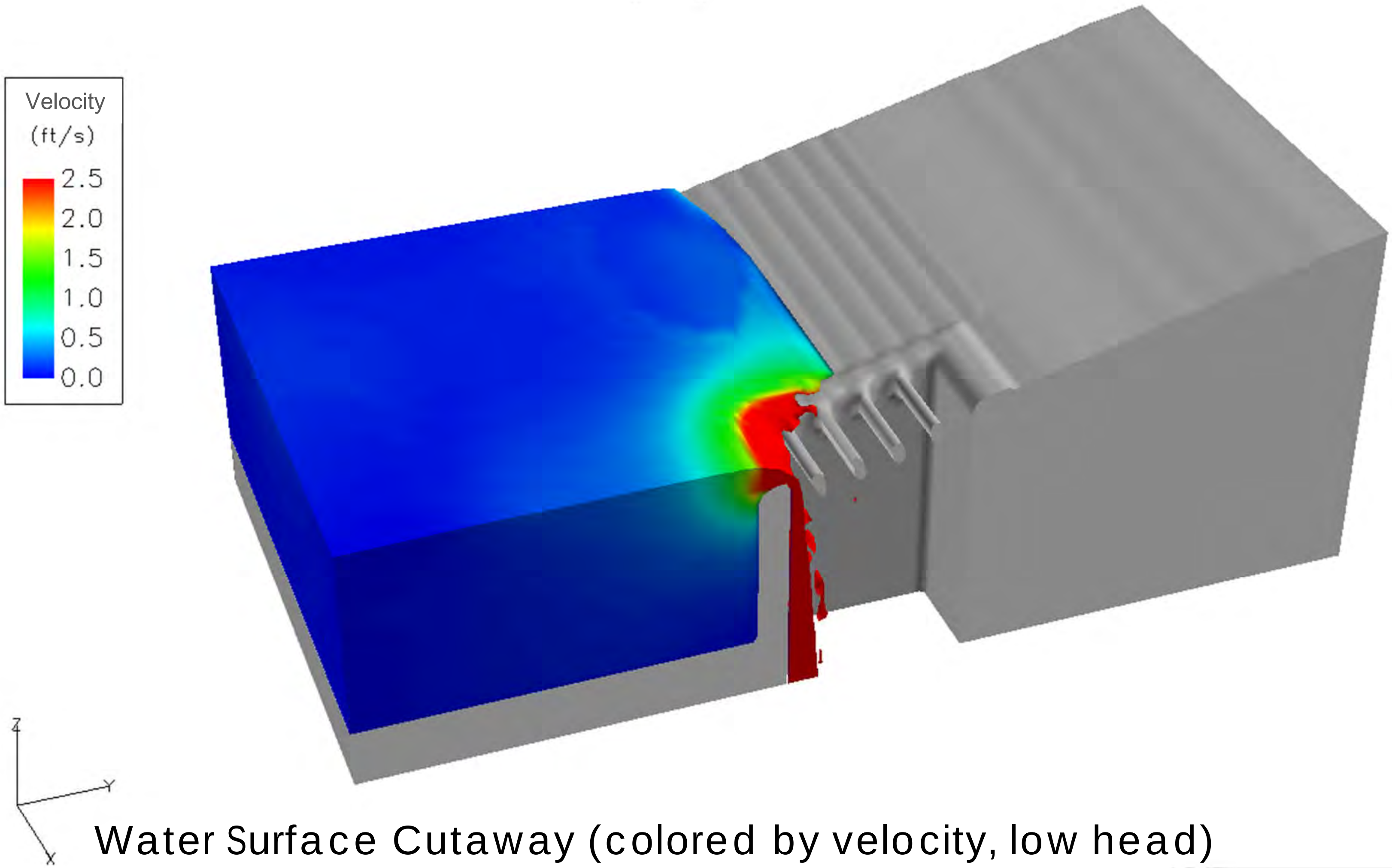


Flow-3D CFD Outlet Structure



Water Surface Cutaway (colored by velocity)

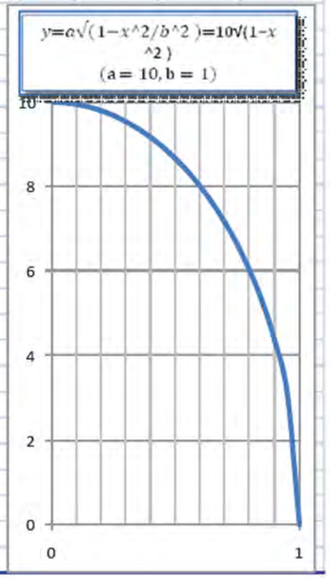
Flow-3D CFD Outlet Structure

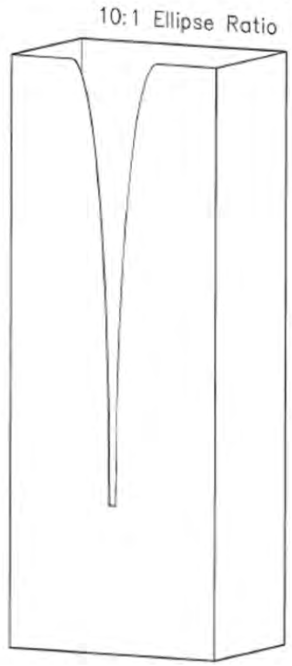


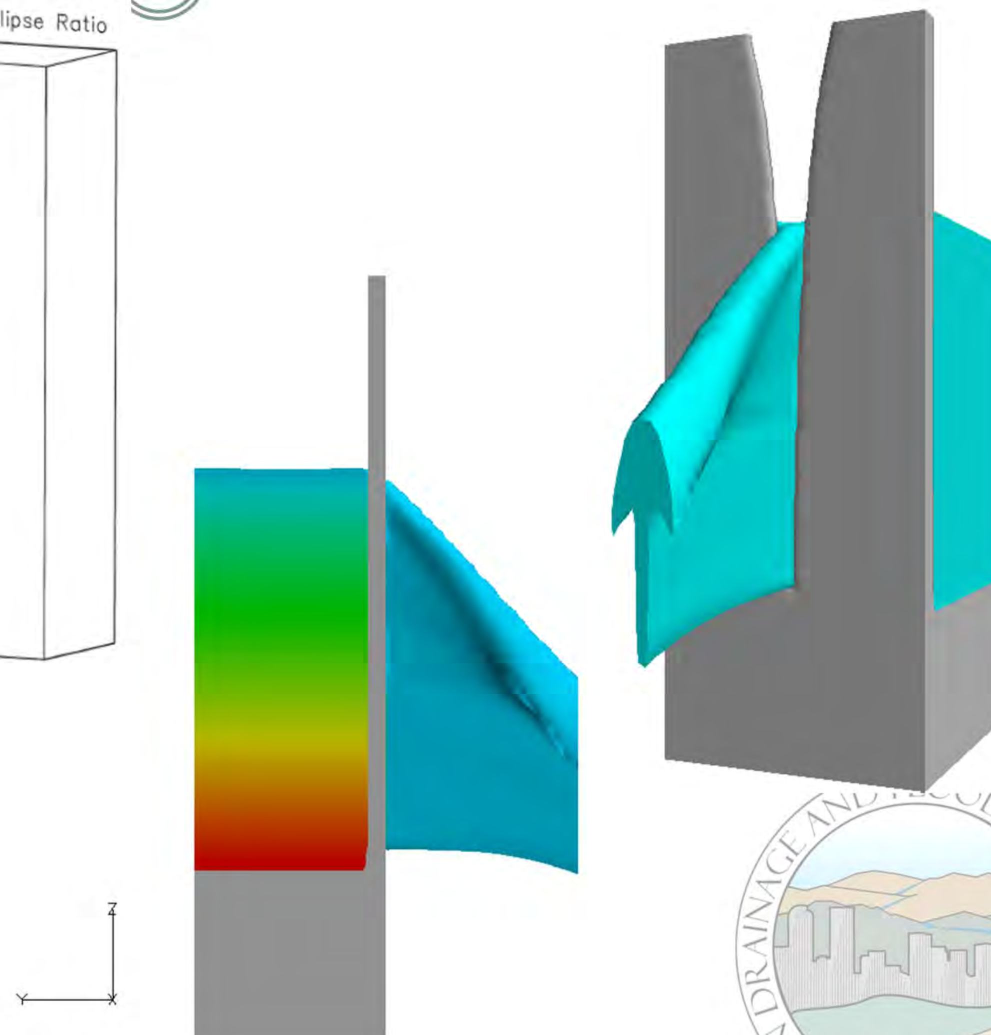
Water Surface Cutaway (colored by velocity, low head)

Elliptical Slot Weir

CURVE BASED ON ELLIPSE WHERE MAJOR AXIS RADIUS = 10 TIMES MINOR RADIUS AXIS	
a	b
10	1
x	y
0.00	10.0000
0.05	9.9875
0.10	9.9499
0.15	9.8869
0.20	9.7980
0.25	9.6825
0.30	9.5394
0.35	9.3675
0.40	9.1652
0.45	8.9303
0.50	8.6603
0.55	8.3516
0.60	8.0000
0.65	7.5993
0.70	7.1414
0.75	6.6144
0.80	6.0000
0.85	5.2678
0.90	4.3589
0.95	3.1225
1.00	0.0000



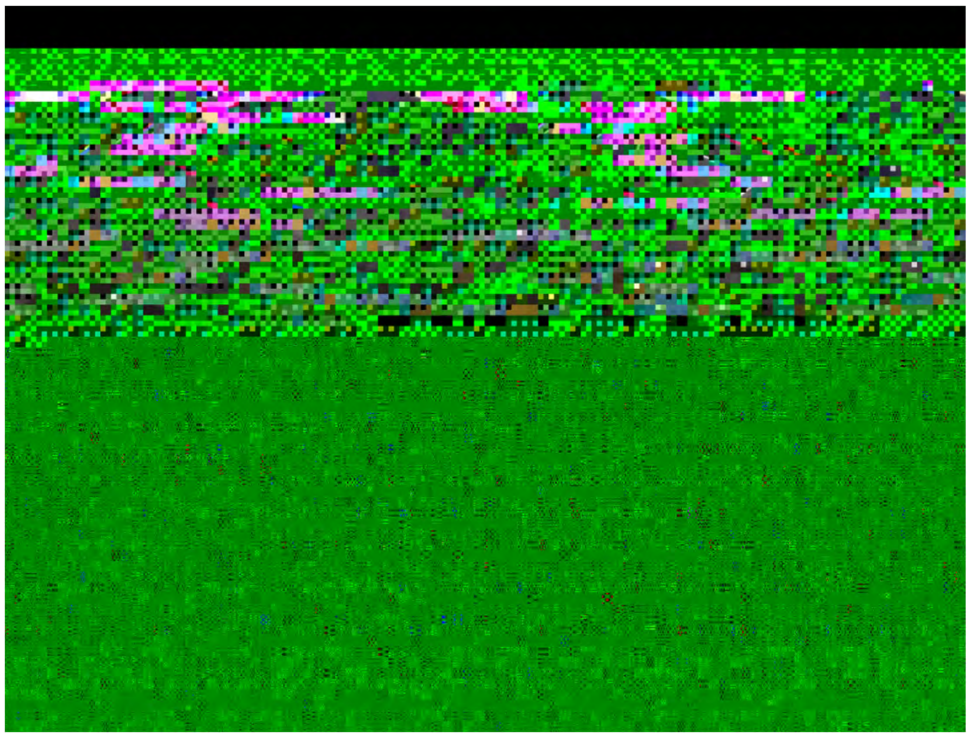




ARCADIS CFD Modeling

Elliptical Slot Weir

Video of Elliptical Weir During Testing



Thank You

Questions...

Floodplain Management Maintenance Eligibility Updates

WHAT YOU NEED TO KNOW
TO FIND ENLIGHTENMENT, TRUE HAPPINESS,
GREAT WEALTH AND THE RESPECT OF YOUR PEERS

BILL DEGROOT, PE
DAVID MALLORY, PE

Floodplain Management Updates

FLOOD HAZARD NEWS

FLOOD HAZARD INFORMATION BROCHURE

FLOOD HAZARD AREA DELINEATION STUDIES

DFIRM MAINTENANCE PROJECTS

LOMC REVIEWS

LOMC DATABASE

2011 *Flood Hazard News*

- Available on our website home page.

Flood Hazard News

An annual publication of the Urban Drainage and Flood Control District

Vol. 41, No. 1 December, 2011

Inside this issue

Piney Creek Stream Stabilization, Bridge and Storm Sewer Project

Colorado Association of Stormwater and Floodplain Managers Grand Award Winner for 2011

By
Richard Borchardt, Senior Project Engineer

Introduction

The Piney Creek Stream Stabilization, Bridge Crossing, and Storm Sewer Outfall project is located in the City of Centennial north of Arapahoe Road and west of Liverpool Street near the intersection of Caley Drive and Euclid Drive in the Piney Creek Ranches subdivision. The project improves the safety, reduces the loss of property, stabilizes the channel, and enhances water quality. The project won the Colorado Association of Stormwater and Floodplain Managers (CASFM) Grand Award for 2011.

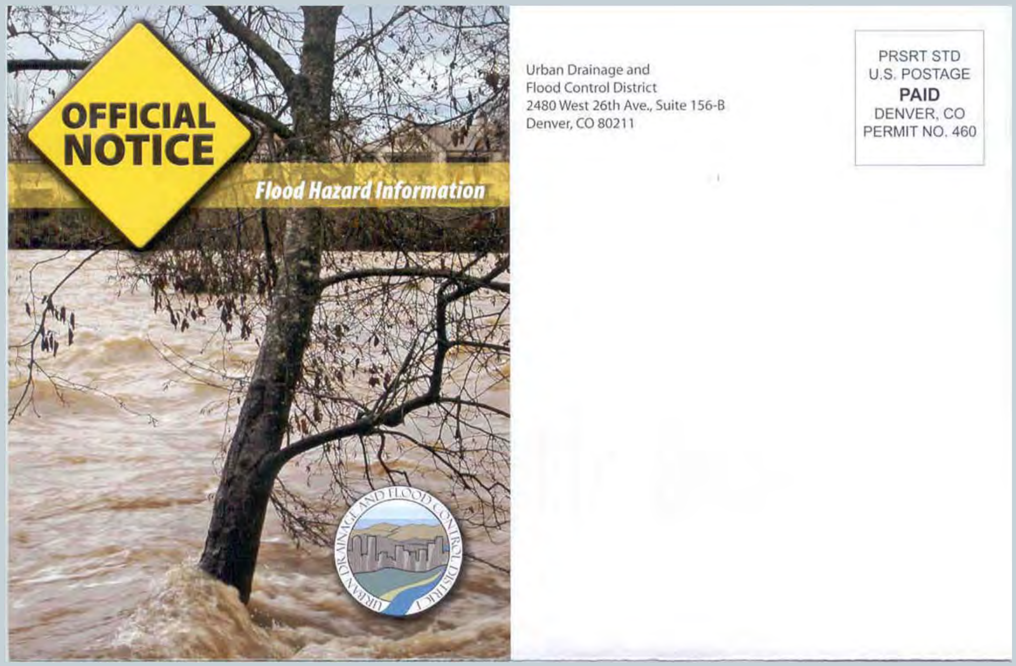
Piney Creek is a sand bed channel that is confined by residential development along the majority of its banks. The continuous development and loss of pervious area in the watershed keeps changing the nature of the stream. Piney Creek went from an ephemeral to a perennial stream. The result of these changes has caused an imbalance in sediment load, incising of the channel, and severe bank erosion. The residents were experiencing property loss, and adjacent structures were being threatened. An even more apparent problem in this area was the street crossing of Piney Creek to get into the residential area. This street-channel crossing was at-grade and became dangerous to cross even in more frequent rainfall and runoff events. When the creek rose from storms or iced over during the winter months it caused unsafe travel conditions.

In addition, a retention pond was located on the south side of Arapahoe Road that collected storm runoff from the Estancia development. There was a concern that the pond would overtop or breach and flow across Arapahoe Road in the next storm, since there was no drain or outfall.

Piney Creek and Caley Drive - Before

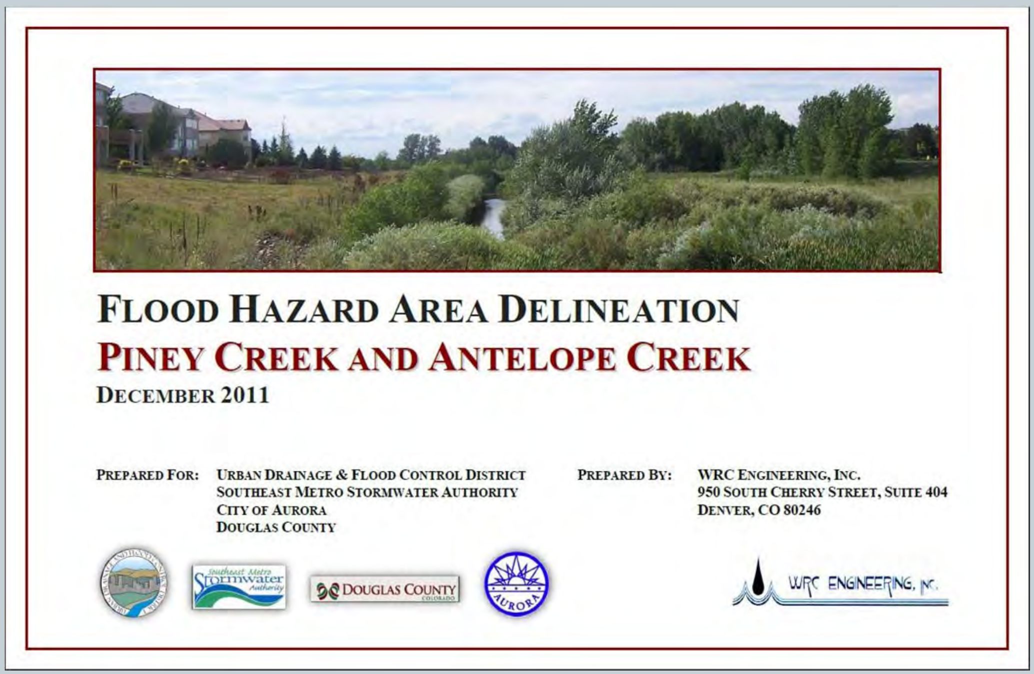
Flood Hazard Information Brochures

- 2012 versions going in the mail next week
- 58 different versions
- 22,000 total brochures being mailed



Flood Hazard Area Delineation studies (FHAD's)

- Piggyback on master plans
- In progress: 6
- Completed in last year: 6



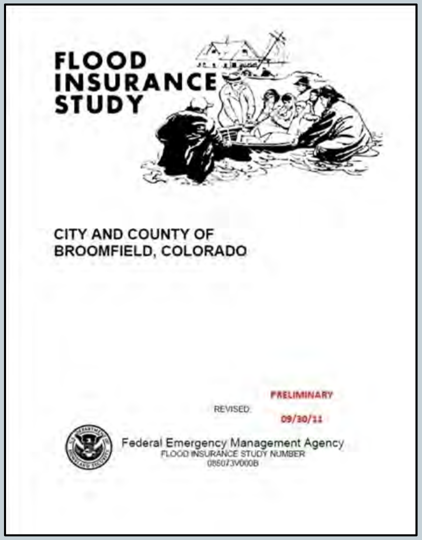
FLOOD HAZARD AREA DELINEATION
PINEY CREEK AND ANTELOPE CREEK
DECEMBER 2011

PREPARED FOR: URBAN DRAINAGE & FLOOD CONTROL DISTRICT
SOUTHEAST METRO STORMWATER AUTHORITY
CITY OF AURORA
DOUGLAS COUNTY

PREPARED BY: WRC ENGINEERING, INC.
950 SOUTH CHERRY STREET, SUITE 404
DENVER, CO 80246

Digital Flood Insurance Rate Map (DFIRM) Maintenance Projects

- Broomfield:
  - Advertising for 90-day appeal period to begin about May 1
- Denver:
  - In the middle of 30-day review of preliminary products
- Jefferson County
  - 30-day review should begin later this month
- Douglas County
  - Headed for a fall preliminary map


FLOOD INSURANCE STUDY

CITY AND COUNTY OF BROOMFIELD, COLORADO

PRELIMINARY

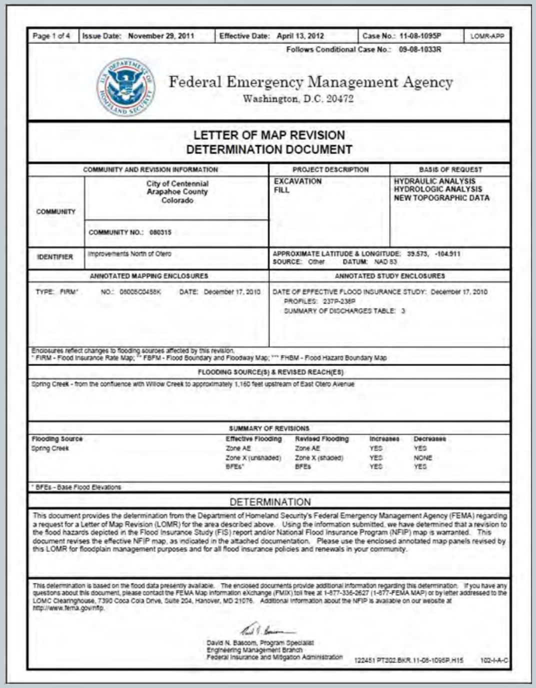
REVISED: 09/30/11

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER

Letter Of Map Change (LOMC) Reviews

- Started in 2001
- We have completed 387 cases in that time
- Opened 42 cases in the last year
- 17 open cases
- Digital LOMC Guidelines
  - Save trees
  - Save storage space



Page 1 of 4 | Issue Date: November 29, 2011 | Effective Date: April 13, 2012 | Case No.: 11-08-1095P | LOMR-APP

Follows Conditional Case No.: 09-08-1033R

Federal Emergency Management Agency
Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT

COMMUNITY AND REVISION INFORMATION		PROJECT DESCRIPTION	BASIS OF REQUEST
COMMUNITY	City of Centennial Arapahoe County Colorado COMMUNITY NO.: 080315	EXCAVATION FILL	HYDRAULIC ANALYSIS HYDROLOGIC ANALYSIS NEW TOPOGRAPHIC DATA
IDENTIFIER	Improvements North of Otero	APPROXIMATE LATITUDE & LONGITUDE: 39.573, -104.911 SOURCE: Other DATUM: NAD 83	

ANNOTATED MAPPING ENCLOSURES	ANNOTATED STUDY ENCLOSURES
TYPE: FIRM* NO.: 08005C0458K DATE: December 17, 2010	DATE OF EFFECTIVE FLOOD INSURANCE STUDY: December 17, 2010 PROFILES: 237P-238P SUMMARY OF DISCHARGES TABLE: 3

Enclosures reflect changes to flooding sources affected by this revision.
* FIRM - Flood Insurance Rate Map; ** FBFM - Flood Boundary and Floodway Map; *** FHBM - Flood Hazard Boundary Map

FLOODING SOURCE(S) & REVISED REACH(ES)

Spring Creek - from the confluence with Willow Creek to approximately 1,160 feet upstream of East Otero Avenue

SUMMARY OF REVISIONS

Flooding Source	Effective Flooding	Revised Flooding	Increases	Decreases
Spring Creek	Zone AE	Zone AE	YES	YES
	Zone X (unshaded)	Zone X (shaded)	YES	NONE
	BFEs*	BFEs	YES	YES

* BFEs - Base Flood Elevations

DETERMINATION

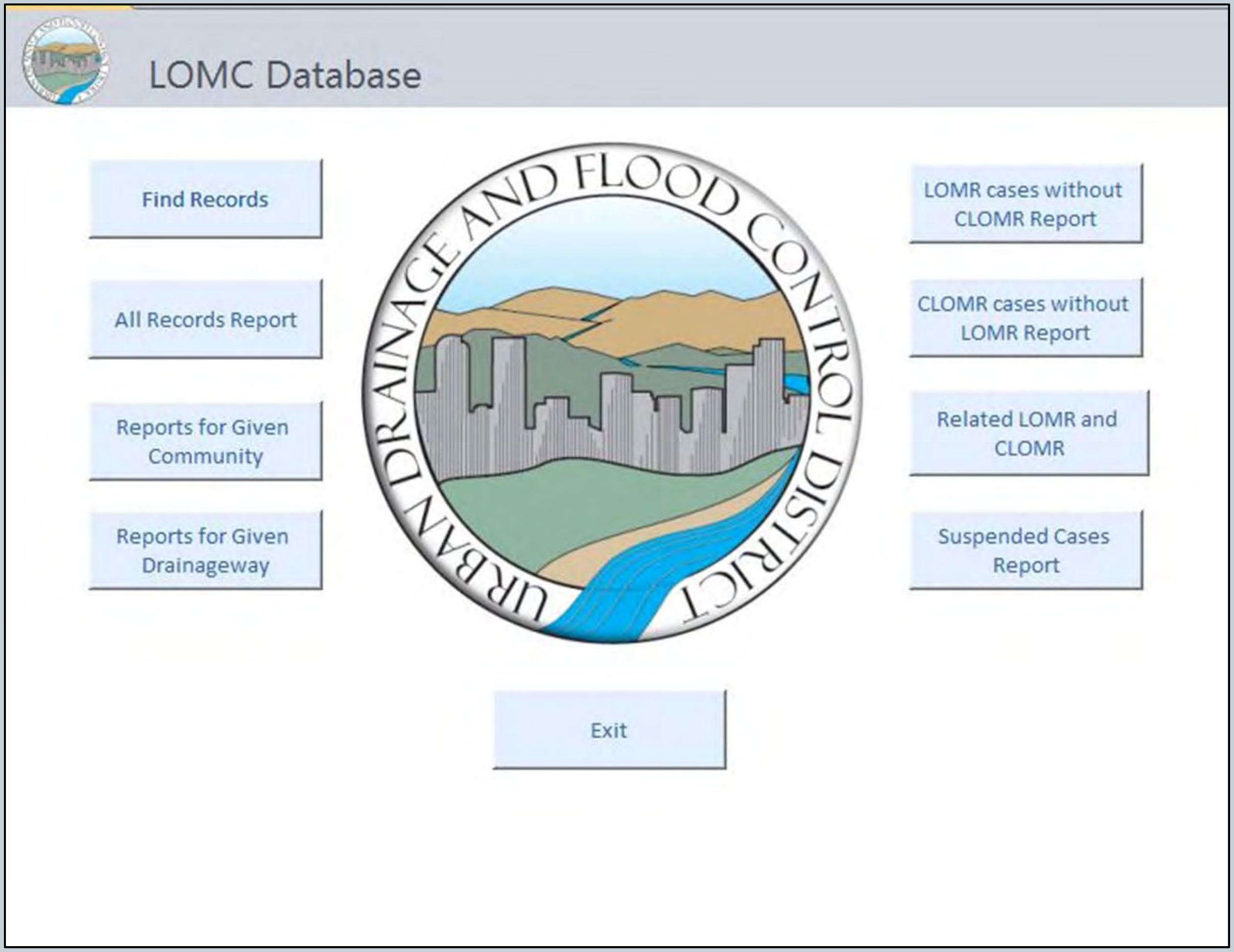
This document provides the determination from the Department of Homeland Security's Federal Emergency Management Agency (FEMA) regarding a request for a Letter of Map Revision (LOMR) for the area described above. Using the information submitted, we have determined that a revision to the flood hazards depicted in the Flood Insurance Study (FIS) report and/or National Flood Insurance Program (NFIP) map is warranted. This document revises the effective NFIP map, as indicated in the attached documentation. Please use the enclosed annotated map panels revised by this LOMR for floodplain management purposes and for all flood insurance policies and renewals in your community.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Map Information eXchange (FMIX) toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 7390 Coca Cola Drive, Suite 204, Hanover, MD 21076. Additional information about the NFIP is available on our website at http://www.fema.gov/nfip.

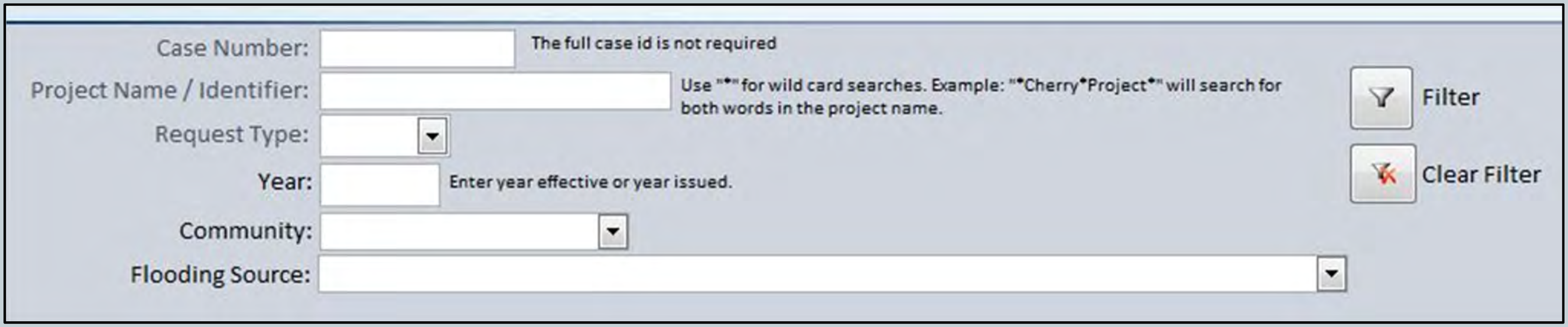
David N. Bascom, Program Specialist
Engineering Management Branch
Federal Insurance and Mitigation Administration

122451 PT202.BKR.11-08-1095P.H15 102-I-A-C

LOMC Database



LOMC Database



- Terri Fead, Project Engineer
- Joanna Czarnecka, Construction Engineer

- David Mallory, Senior Project Engineer

Maintenance Eligibility Program Updates

MAINTENANCE ELIGIBILITY GUIDELINES UPDATED MARCH 2012

THE EDM AND THE MEP

GOOD NEIGHBOR POLICY

FLOODPLAIN PRESERVATION BROCHURE

Maintenance Eligibility Program

- Originally established to offer communities assistance in maintaining major drainageways constructed after March 1, 1980 in order to minimize maintenance requirements and enhance maintenance access.
- Projects are submitted through local government referrals and reviewed for conformance with the USDCM.
- Construction must complete the approved design, and satisfactory maintenance access provided.

Goals of the MEP

- Promote and encourage good floodplain management practices. Protect property, save lives.
- Preserve and enhance natural stream corridors to the extent possible.
- Implement District sponsored drainageway master plans and supervise necessary revisions in order to accommodate development.
- Mentor the design and construction phases of major drainageway infrastructure development, funded by others.

Maintenance Eligibility Program Benefits

- Additional major drainageway plan review resources.
- Coordinated implementation of District sponsored master plans.
- Coordination with the FEMA review process for Letters of Map Change.
- Additional drainageway maintenance funding.

Section 404 Permit Considerations

- Projects being considered for maintenance eligibility may also require a permit under Section 404 CWA.
- Meeting District design criteria and Section 404 permit requirements are not mutually exclusive.
- The District and USACE have never failed to find consensus on major drainageway projects when ***early consultation*** was sought.

Final Plans and Construction Documents

- Visit the site.
- Assume the District's Master Plan will be Implemented.
- Use enlarged details.
- Provide hydrologic and hydraulic data.
- Plan & profile sheets needed even for floodplain preservation projects.
- Prudent use of computerized results.
- Generous use of report text and tables.

Colorado State Board of Registration
Rules of Conduct for Professional Engineers

3.1.1 – Primary Obligation of Licensees.

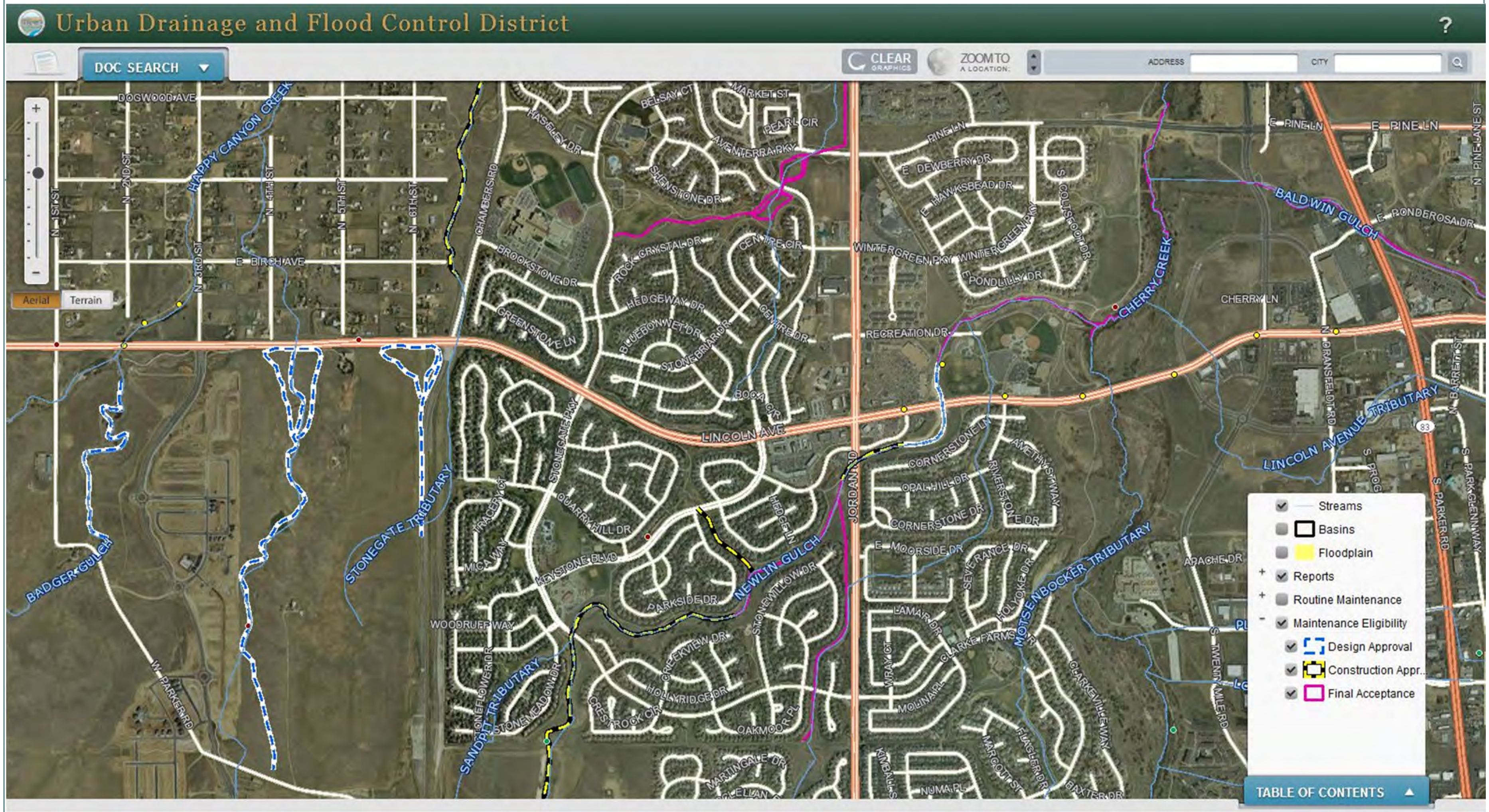
Licensees shall at all times recognize that their primary obligation is to protect the safety, health, property, and welfare of the public. If their professional judgment is overruled under circumstances where the safety, health, property, or welfare of the public is endangered, they shall notify their employer or client and/or such other authority as may be appropriate.

Post Approval Process

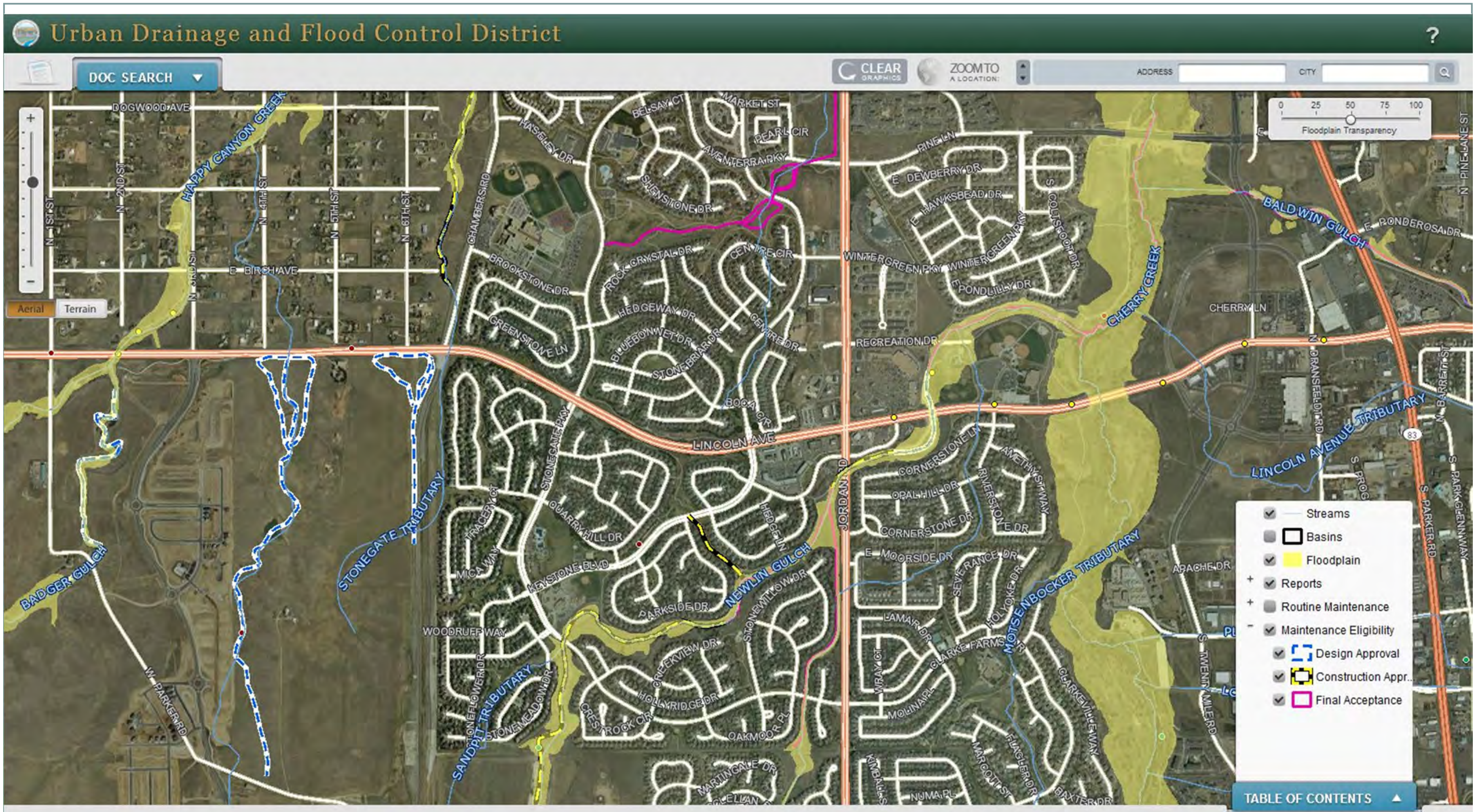
- Significant role of local government.
- Periodic construction site visits are made. These site visits are not a substitute for local government observation.
- Completion walk through & punch list developed.
- Construction accepted.
- Revegetation & maintenance access confirmed.
- Maintenance eligibility certified.

Common Construction Problems

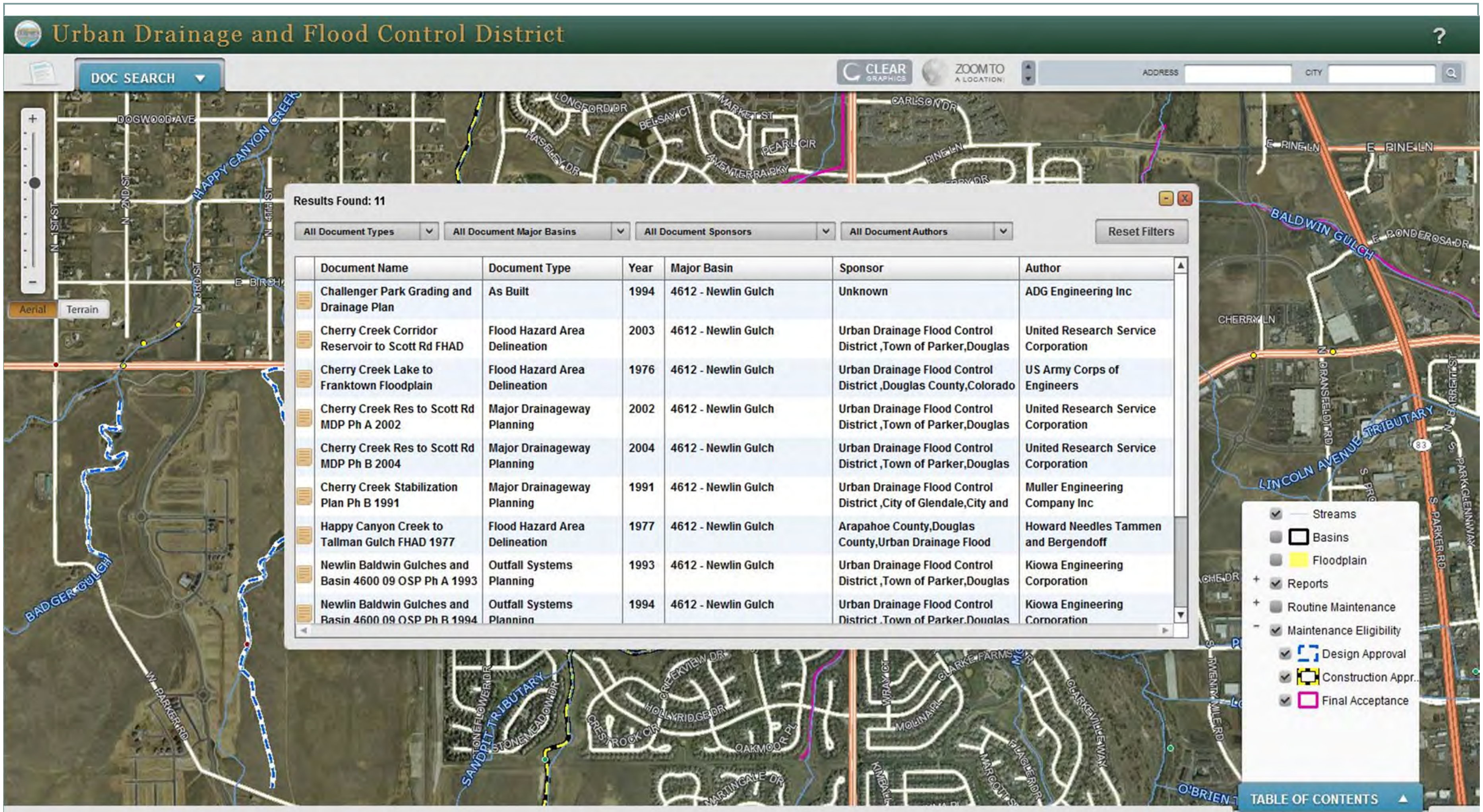
- Grade Control Structures.
- Pre-grout inspection for all grouted boulder installations.
- Soil riprap placement.
- Absent design consultant. We do not interpret or revise plans in the field.
- Completing a MEP project should not pre-qualify a contractor for public sector projects.



EDM with MEP Layer Enabled



EDM with MEP & Floodplain Layer Enabled



Document Name	Document Type	Year	Major Basin	Sponsor	Author
Challenger Park Grading and Drainage Plan	As Built	1994	4612 - Newlin Gulch	Unknown	ADG Engineering Inc
Cherry Creek Corridor Reservoir to Scott Rd FHAD	Flood Hazard Area Delineation	2003	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Town of Parker,Douglas	United Research Service Corporation
Cherry Creek Lake to Franktown Floodplain	Flood Hazard Area Delineation	1976	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Douglas County,Colorado	US Army Corps of Engineers
Cherry Creek Res to Scott Rd MDP Ph A 2002	Major Drainageway Planning	2002	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Town of Parker,Douglas	United Research Service Corporation
Cherry Creek Res to Scott Rd MDP Ph B 2004	Major Drainageway Planning	2004	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Town of Parker,Douglas	United Research Service Corporation
Cherry Creek Stabilization Plan Ph B 1991	Major Drainageway Planning	1991	4612 - Newlin Gulch	Urban Drainage Flood Control District ,City of Glendale,City and	Muller Engineering Company Inc
Happy Canyon Creek to Tallman Gulch FHAD 1977	Flood Hazard Area Delineation	1977	4612 - Newlin Gulch	Arapahoe County,Douglas County,Urban Drainage Flood	Howard Needles Tammen and Bergendoff
Newlin Baldwin Gulches and Basin 4600 09 OSP Ph A 1993	Outfall Systems Planning	1993	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Town of Parker,Douglas	Kiowa Engineering Corporation
Newlin Baldwin Gulches and Basin 4600 09 OSP Ph B 1994	Outfall Systems Planning	1994	4612 - Newlin Gulch	Urban Drainage Flood Control District ,Town of Parker,Douglas	Kiowa Engineering Corporation

Available Documents for Newlin Gulch

Good Neighbor Policy

Good Neighbor Policy

Adopted by the Board of Directors
Urban Drainage and Flood Control District
February 1, 2011

WHEREAS, the Urban Drainage and Flood Control District was established by the Colorado General Assembly in 1969 in order to assist local governments with multijurisdictional drainage and flood control problems, including the authority to levy property taxes for operations and planning; and

WHEREAS, the General Assembly has subsequently authorized the District to levy property taxes for design and construction of projects, for maintenance, and for the South Platte River; and

WHEREAS, the District has constructed approximately $180 million in drainage and flood control projects in partnership with local jurisdictions; and

WHEREAS, the District has contributed approximately $12 million to the acquisition and preservation of key floodplain areas in partnership with local jurisdictions and other partners; and

WHEREAS, many District projects are designed and constructed, by necessity, for rare events; and are therefore not utilized very frequently for their primary intended purpose; and

WHEREAS, the District staff has worked with local government partners to enhance the projects to make them more valuable to their constituents on a daily basis; and

WHEREAS, the Natural and Beneficial Functions (NBF) of drainageways and floodplains; including trail corridors, parks, recreation, wildlife habitat, flood storage, and groundwater recharge, can serve as amenities to adjacent neighborhoods and entire communities.

NOW, THEREFORE, BE IT RESOLVED THAT:

1. The Board of Directors of the Urban Drainage and Flood Control District adopts the following "Good Neighbor Policy":

2. The Master Planning Program will, during the preparation of storm drainage criteria, major drainage plans, outfall systems plans, and other master planning studies, identify and incorporate NBF and other opportunities.

3. The Floodplain Management Program will continue to map the 1% and 0.2% floodplains in undeveloped areas in order to identify areas that are hazardous to develop, and areas of significant NBF; and to work with local governments in the management of future development in or near these hazardous areas to minimize future flood risks and maximize preservation of the NBF.

4. The Design, Construction, and Maintenance Program (DCM) will, when feasible, include amenities in flood management projects that enhance neighborhoods and preserve NBF. As a result of including these amenities, the public will be drawn to the flood management projects; therefore, public safety is of paramount importance and will be included in all planning, design, construction, operation, and maintenance of these facilities.

5. The DCM Program will participate with local government partners and others such as Great Outdoors Colorado and the Trust for Public Land to acquire and preserve areas of significant NBF and/or flood hazards.

6. The Information Services and Flood Warning Program will continue adapting state-of-the-art information technologies to keep decision-makers, partners and other stakeholders informed concerning past, present and future flood threats; and will provide local governments, consultants, affiliates, and the general public with easy access to educational material, publications and other helpful information associated with District programs and activities.

2480 West 26th Ave. Suite 156-B Denver, CO 80211
303-455-6277
www.udfcd.org.

Good Neighbor Policy

- Major Drainageway projects are designed and constructed, by necessity for rare events.
- The District works with Local Governments to enhance projects to make them more valuable to constituents on a daily basis.
- NBF of drainageways and floodplains, including trails, parks, wildlife habitat, flood storage, and water quality enhancement, add value to the community.

Environmental Values of Naturally Functioning Floodplains

Ecosystem Services

"...floodplains were the second ranked ecosystem type, behind only estuaries, in terms of their per-hectare value to society. Despite representing <2% of Earth's terrestrial land surface area, floodplains provide approximately 25% of all terrestrial ecosystem service benefits."

Opperman, Jeffrey, Luster, Ryan, et.al. 2010. Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale. Journal of the American Water Resources Association 46(2): 211-226.

Good Neighbor Policy

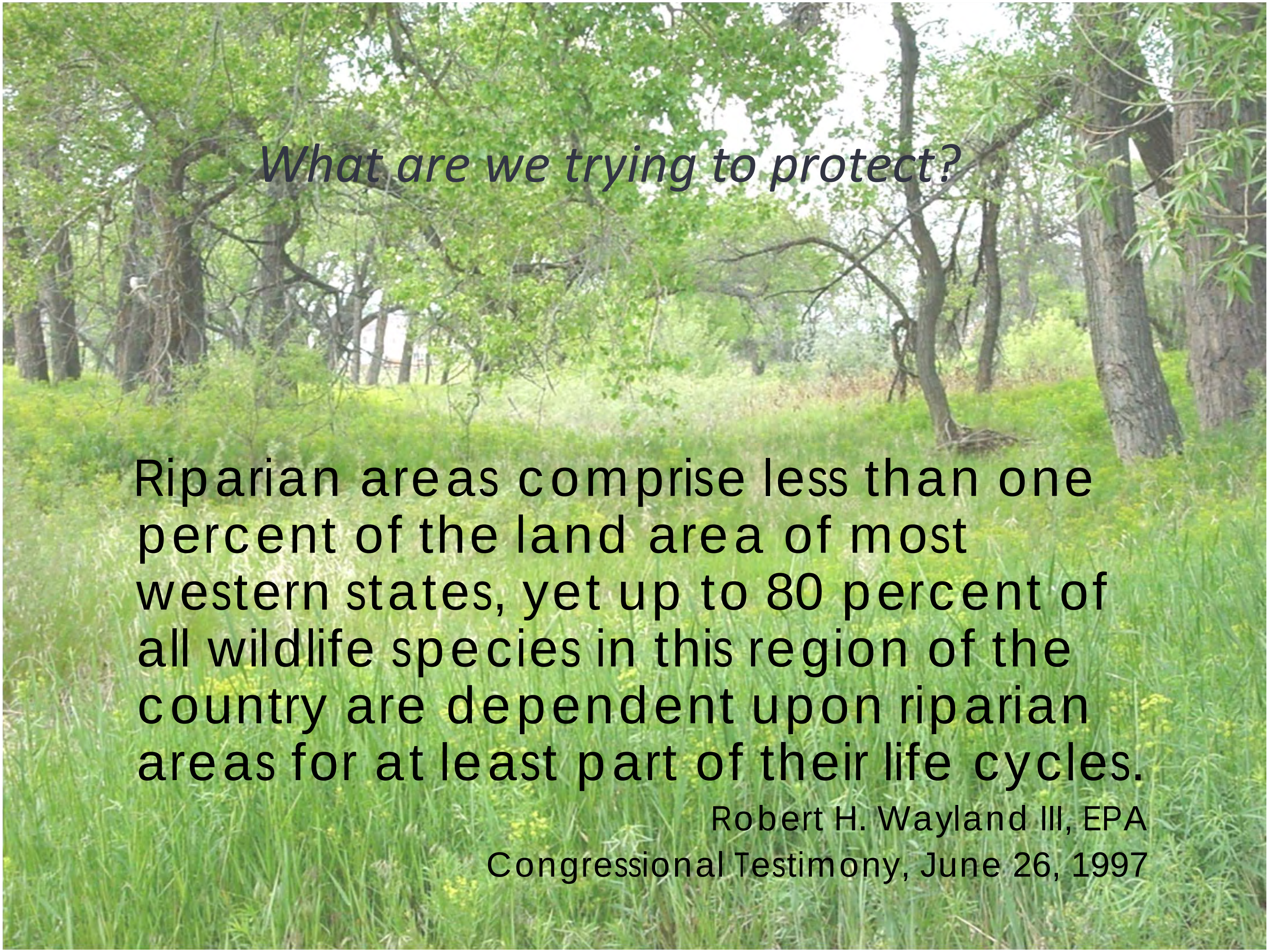
- Floodplain Management Program will continue to identify areas that are hazardous (1% and 0.2% floodplains) to development.
- Work with Local Governments to encourage safe and proper development, and
- Maximize the floodplain preservation and the natural and beneficial functions of the floodplain resource.

Urbanization Impacts Natural Drainageways

- Development projects are responsible for a significant portion of our Major Drainage Infrastructure.
- Increases watershed imperviousness, which increases drainageway runoff volumes.
- Decreases naturally occurring overbank storage.
- Dramatically accelerates the natural stream degradation process.

District Preference for Floodplain Preservation over Channelization

- More compatible with communities' open space and multi-use goals. Increases property values.
- Promotes flood attenuation, wildlife habitat, groundwater recharge, and water quality enhancement.
- Generally favored by federal permit programs (Section 404 CWA).
- Low flow stabilization (grade controls) and maintenance access are usually all that's required for maintenance eligibility.
- Channelization is a single purpose approach that usually destroys stream corridors.


What are we trying to protect?
Riparian areas comprise less than one percent of the land area of most western states, yet up to 80 percent of all wildlife species in this region of the country are dependent upon riparian areas for at least part of their life cycles.
Robert H. Wayland III, EPA
Congressional Testimony, June 26, 1997

Our Approach to the Private Sector

- Developers are in the business to make money.
- If there is money to be made developing in the floodplain, they will do it.
- So, we need to show them how to make money by preserving the floodplain instead of destroying it.

Public Sector Perspective

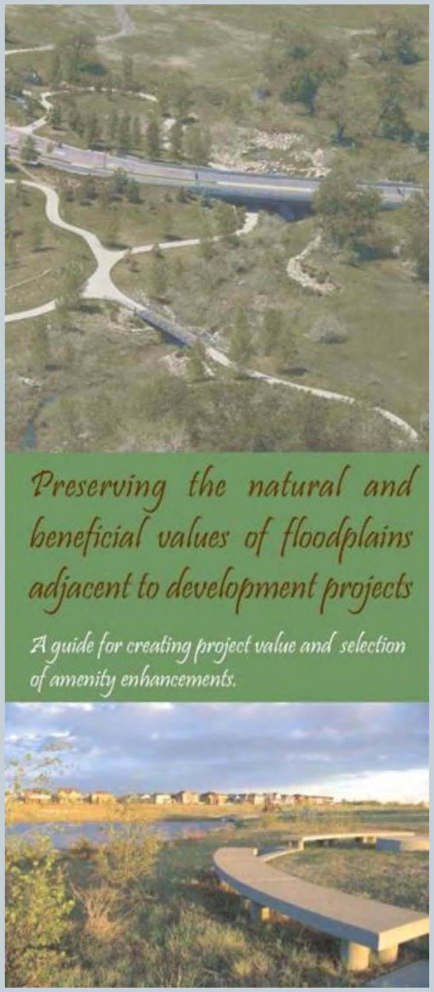
- Local governments depend on development to provide the tax revenues which sometimes leads to decisions that are damaging to the floodplain resource.
- So we need to show them how to have development that provides the tax revenue, but also develops floodplains into a community amenity and asset.

We Had Great Examples

And Then, Not So Much

In spite of our best efforts, many projects were still less than inspiring.

Early Influence of Entitlement Process



- We had a "good examples" page on our website, but it had limited success.
- We saw an opportunity to prepare a brochure which would market the floodplain as an asset to developers and communities.
- Distributed at the pre-application meeting.

Welcome
Bill DeGroot, UDFCD Floodplain Manager

Philosophy Why preserve the natural and beneficial values of floodplains

Library Links Resources

Regulatory 404 permitting
Land Development Approvals
UDFCD maintenance eligibility

Good Examples Projects that exemplify holistic planning offer amenities for livable communities

Business Cases Projects illustrating social, economic ,and environmental benefits

Trail Criteria, Underpass

- Using Draft Trail Criteria dated January, 2012
- Preference for Bridges at grade separations.

Trail Criteria, Underpass

- Next is Three-sided Arches or Box Structures.
- Single-barrel box culverts are less desirable, but still better than.....

Trail Criteria, Underpass

- Least desirable is the pedestrian/higher flow combo.
- Continual safety and maintenance problems.
- Arrangements that require floodwalls will not be eligible.

Grade Control Structures

- Preference for driven and capped sheet pile structures (PZ 22 min). Minimum cutoff depth is 10 feet.
- Where soils allow an open trench, concrete is acceptable. Minimum cutoff depth is 6 feet.

Grade Control Structures

- District does not endorse the use of concrete spread footings or stem walls.
- Intent is to minimize disturbance to the stream.

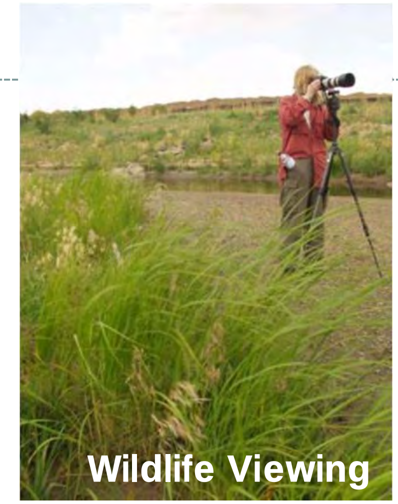
Grade Control Structures

- Check structures really work!
- Eight feet of down-cut into the bedrock zone.

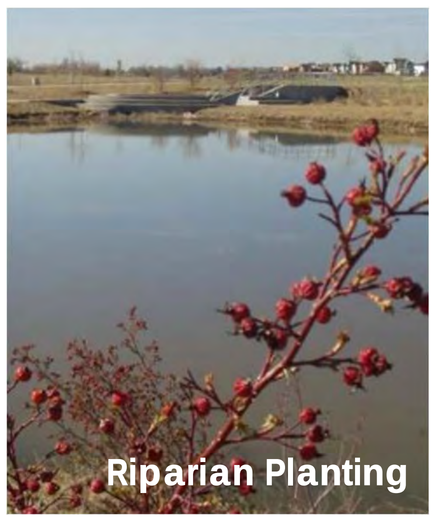
Thank You!


Contemplative Viewing Areas


Raccoon Tracks


Wildlife Viewing


Meadowlark


Riparian Planting


Boulder Jetties

Photos courtesy of Michelle Slovensky

The 2010 Fourmile Canyon Fire—
One Year and One Flood Later

UDFCD Annual Seminar

April 10, 2012

…a retrospective look at the 2011 flood season and the flash flood of July 13, 2011

Kevin Stewart, P.E.
Program Manager, Information Services & Flood Warning Program
Urban Drainage and Flood Control District

A Federal/Regional/Local Early Warning Partnership

Urban Drainage & Flood Control District Flood Warning Program

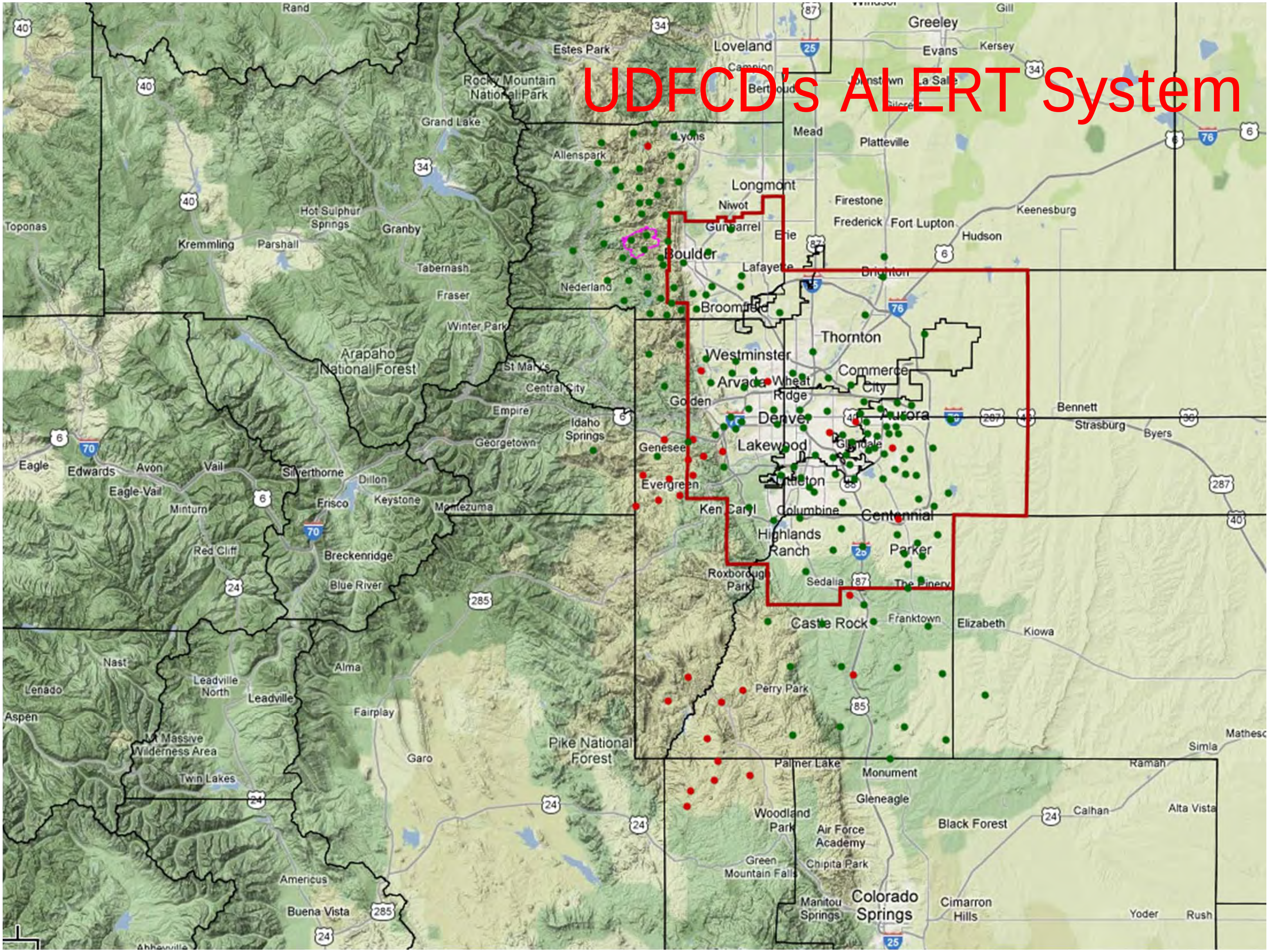
Serving the greater Denver/Boulder metropolitan area since 1979
in cooperation with NOAA's National Weather Service

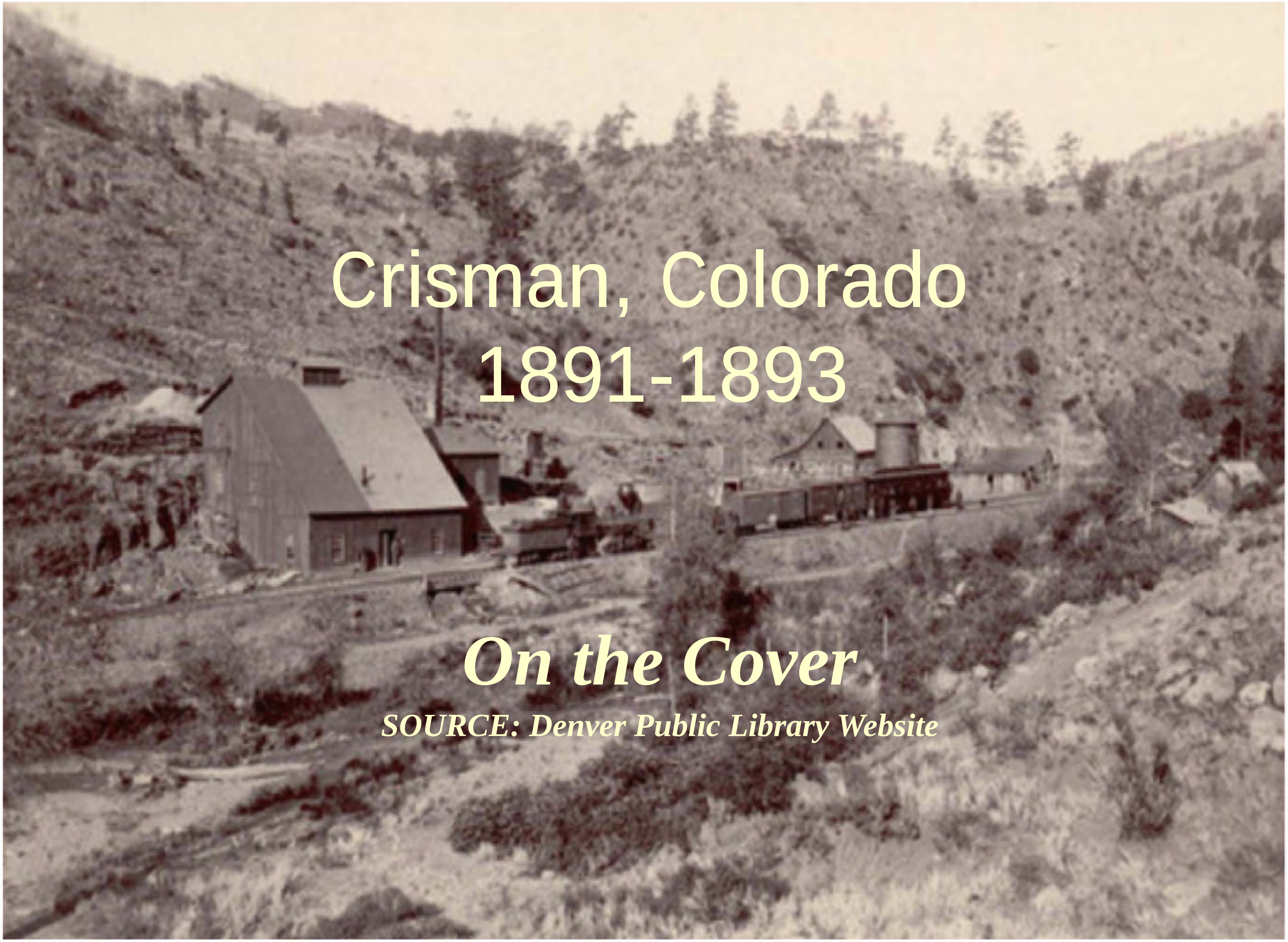
Flood Warning Program Primary Mission

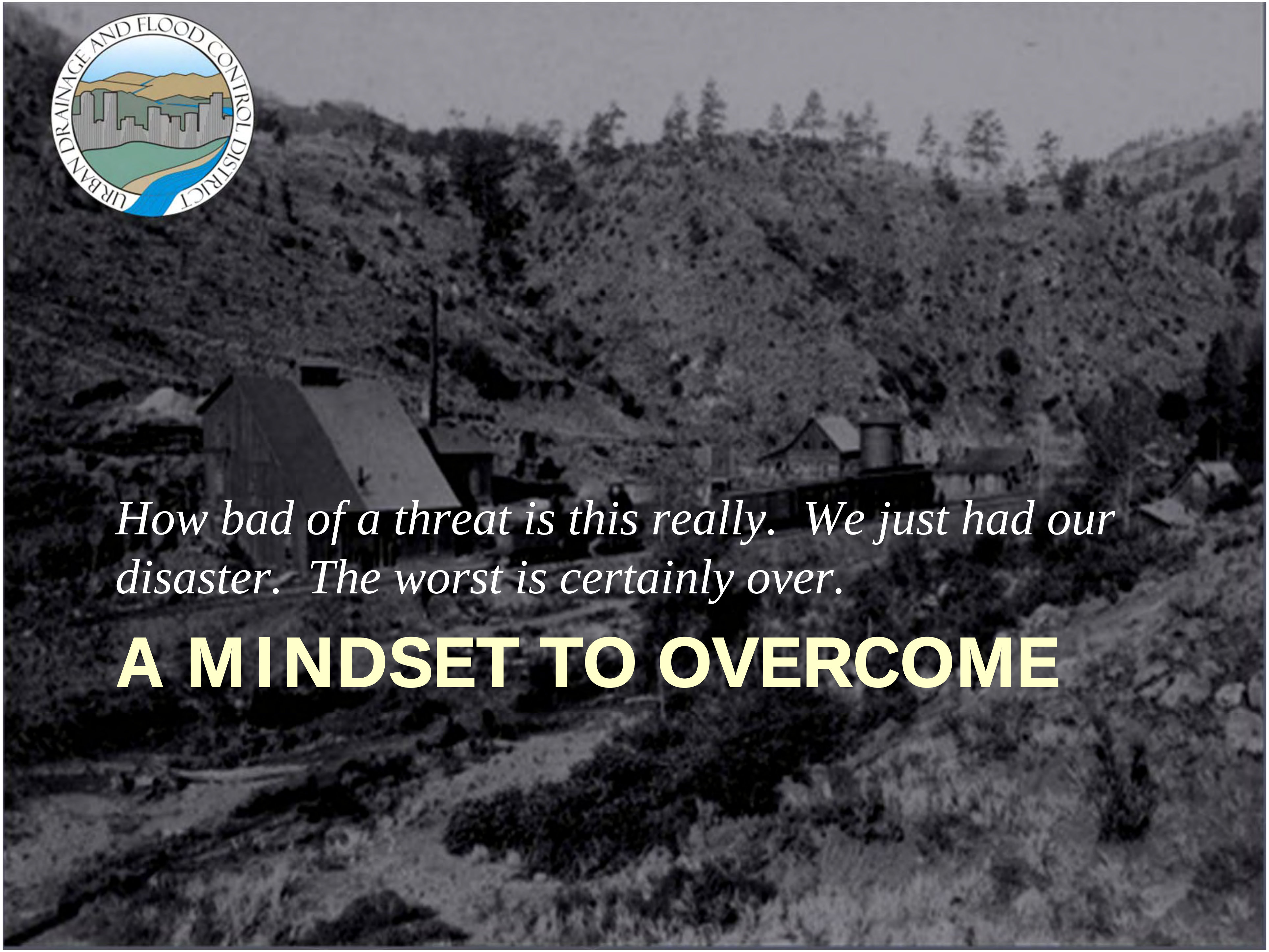
Provide local governments with early notifications of potential and imminent flood threats *(primarily flash flood threats)* in time to take appropriate defensive actions…

…to protect lives and property

UDFCD's ALERT System




Crisman, Colorado
1891-1893
On the Cover
SOURCE: Denver Public Library Website


URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
How bad of a threat is this really. We just had our disaster. The worst is certainly over.
A MINDSET TO OVERCOME

THE FIRE

Labor Day
September 6, 2010

The Initial Impact

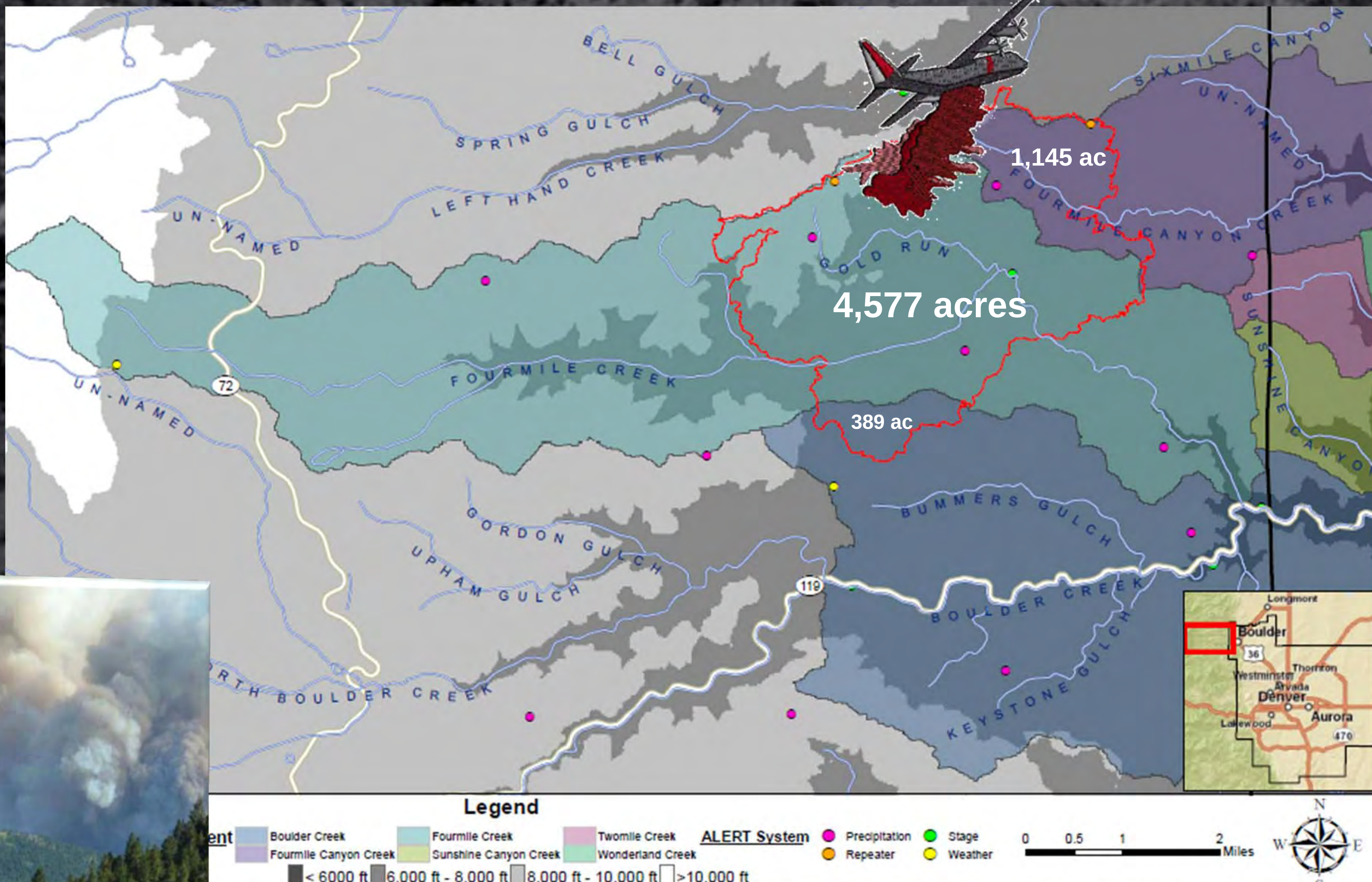
Acres burned:		
Total:	6,181	
First 14 hours:	~6,000	(~429 acres per hour)
Structures threatened:	500	
Structures lost:	169	
Structures damaged:	14	
People evacuated:	3000	
Cost:	$10,800,000	
Firefighter injuries:	7 (all minor)	
Fatalities:	0	

Memories of past floods fade quickly.

City of Boulder is rated Colorado's highest flash flood risk, but has experienced very few floods.

Year	*Date(s)*	*Brief Description*
1894	May 29 - June 2	**RECORD FLOOD** on Boulder Creek, 4.5" to 6" totals west of Boulder, many bridges lost, extensive property and agricultural damage, **one death**, slow onset, South Boulder, Left Hand, Four Mile Canyon and St. Vrain also impacted.
1896	August 19	Fourmile Creek **flash flood**, storm center near Magnolia, rain amount unknown, road and property damage at Salina.
1914	June 1-2	Snowpack 50% above normal; **heavy rain** in mountains; worst Boulder Creek flood since 1894; damage to bridges, farms and Boulder's water system.
1921	June 2-7	Record flow since 1916 at Orodell stream gage on Boulder Creek (June 6); 5-days of general rainfall over 520 sq. mi. of SPR basin, Longmont recorded **4.3" in 6 hours**.
1929	July 31	Storm center near Bummers Gulch, **heavy rain** also in Boulder, flooding on Boulder, S. Boulder, Four Mile Canyon and Gregory Creeks; 4.8" rain, damage to streets, lawns, bridges, RR and at 9th & Arapahoe
1938	September 2	**Record flood** on South Boulder Creek; extensive damage at Eldorado Springs; 6" rains reported west of town.
1969	May 7	Long duration storm (May 4-8); 7.6" to 9.3" rain totals; most notable flooding along South Boulder Creek and Thunderbird Lane (Foothills Parkway area)—also downstream.

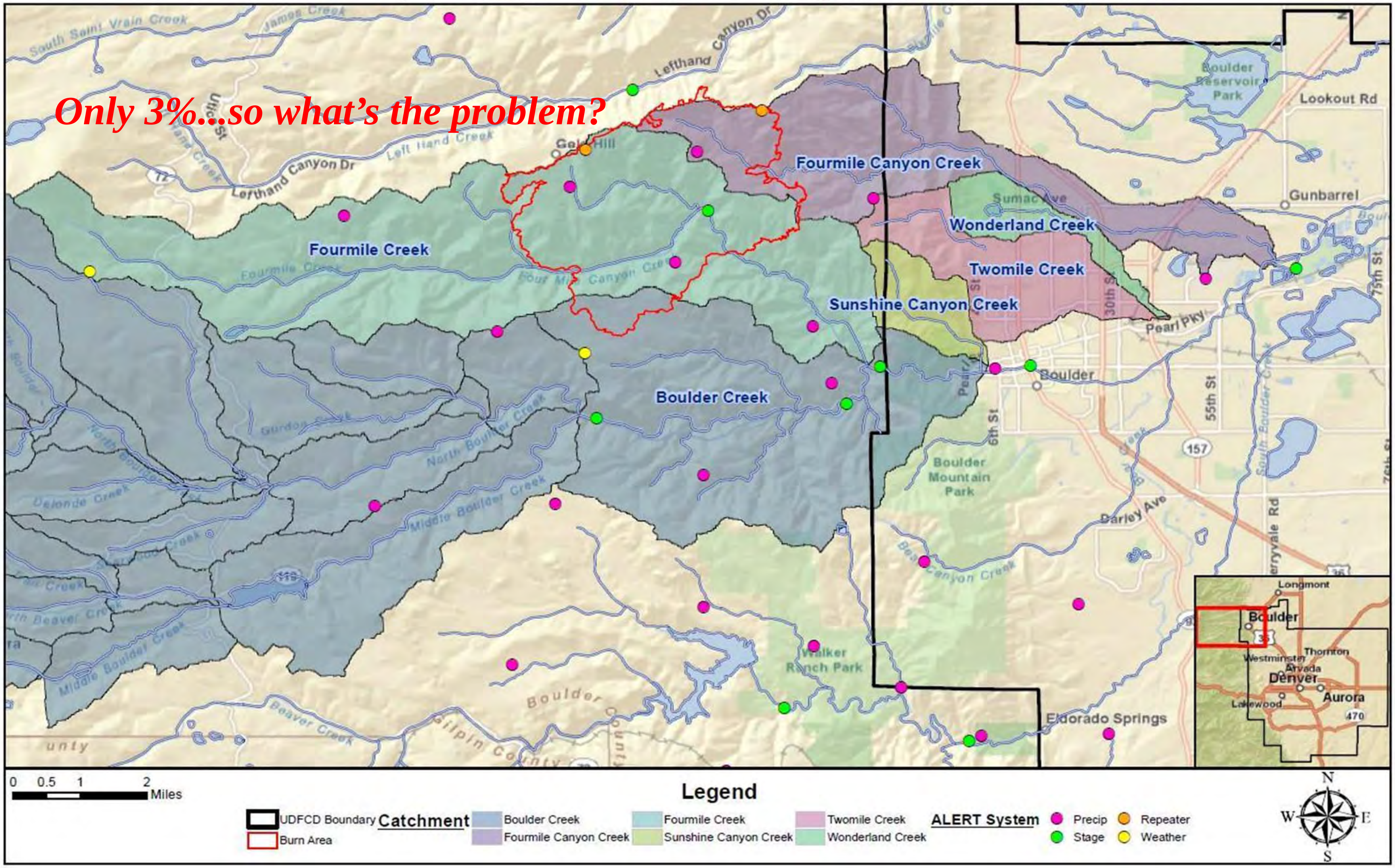
The Fourmile Burn Area & Affected Watersheds



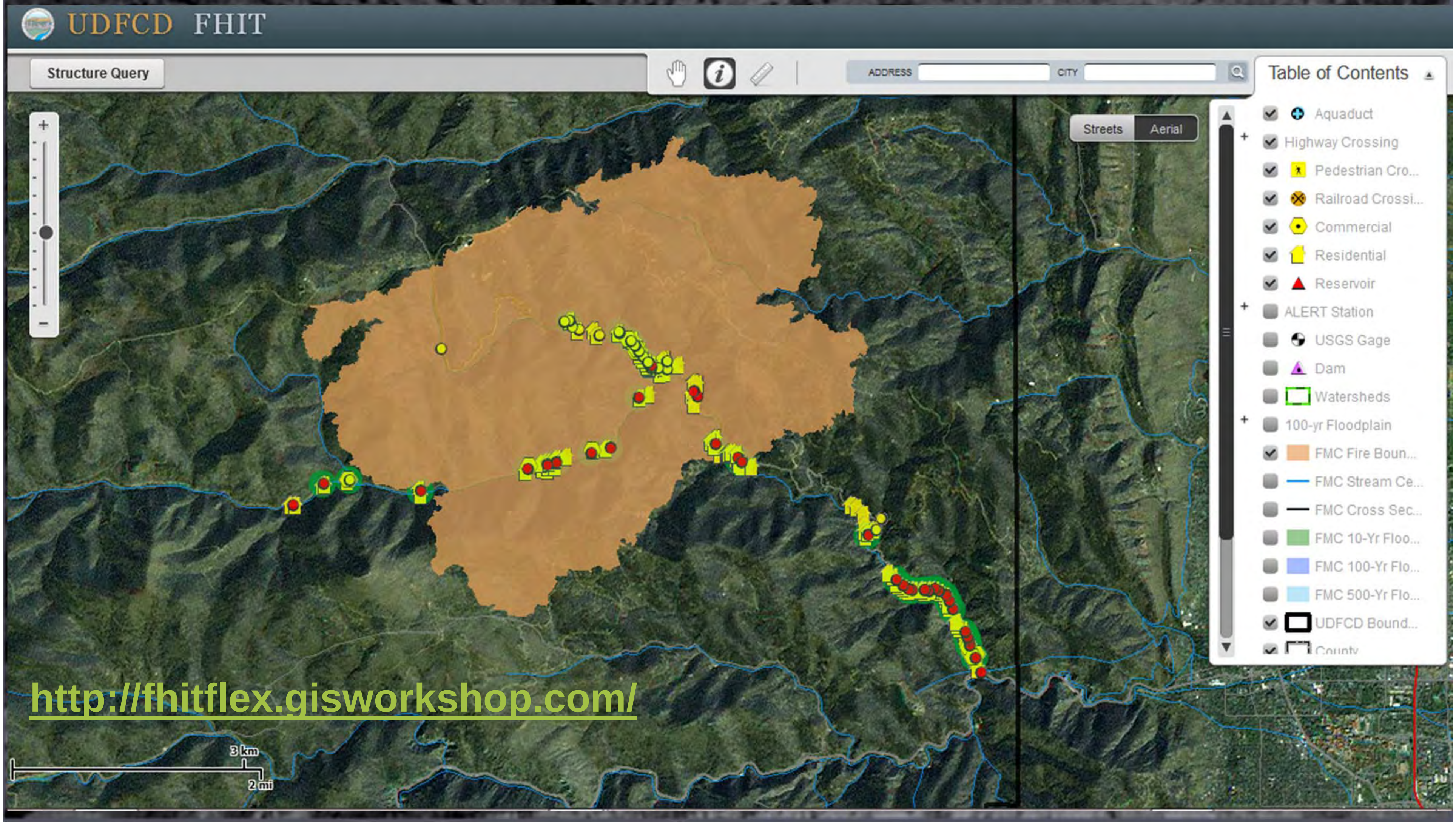
Urban Drainage and Flood Control District

Flood Warning Program

September 2010 Fourmile Canyon Wildfire Watersheds



A Flood Hazard Inventory



http://fhitflex.gisworkshop.com/

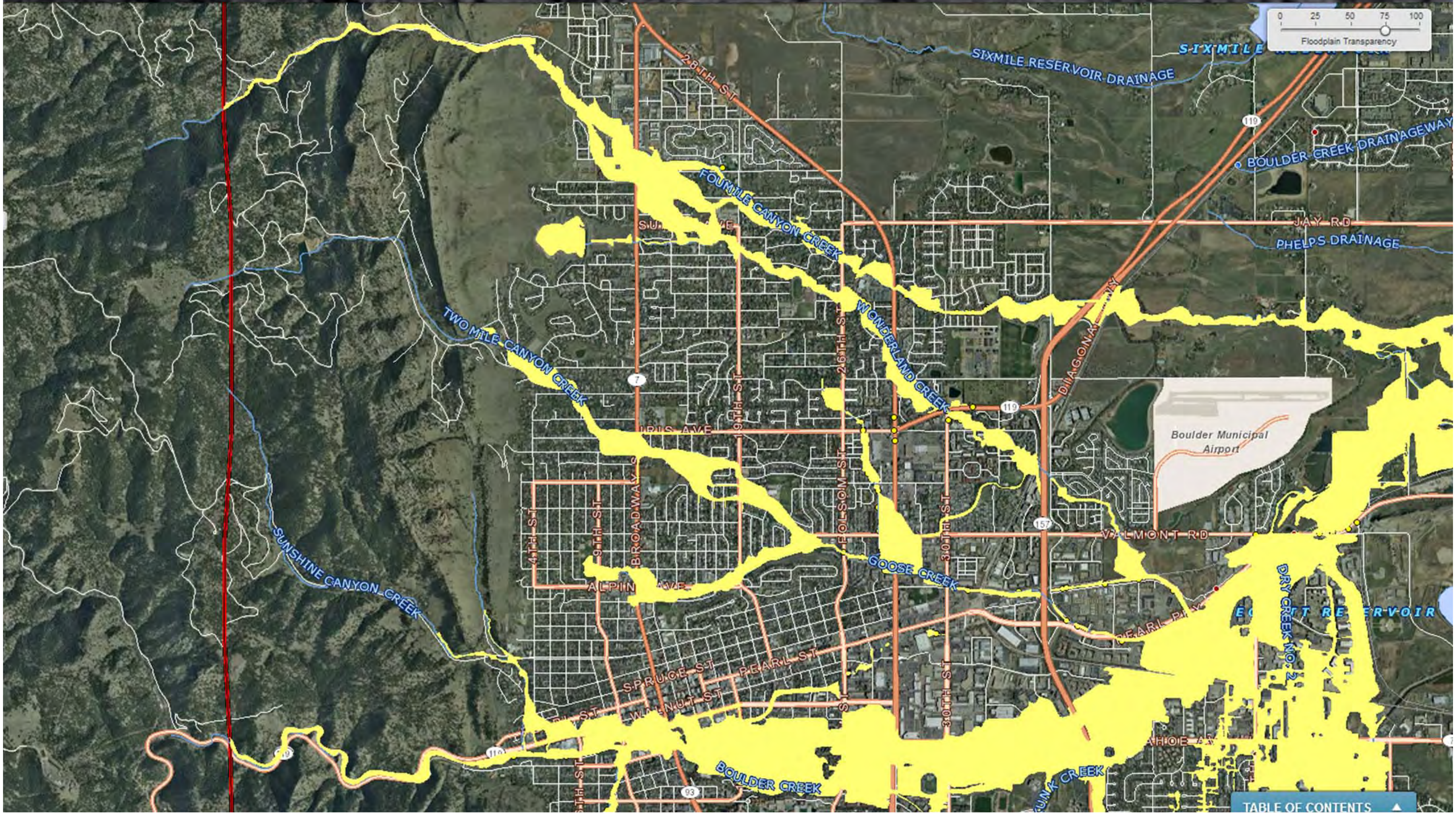
Three commercial properties along Fourmile Creek at risk from flood flows ranging from 500 to 6,000 cfs. The Boulder Mountain Lodge is the highest risk facility of the three.

A FLOOD RISK ASSESSMENT

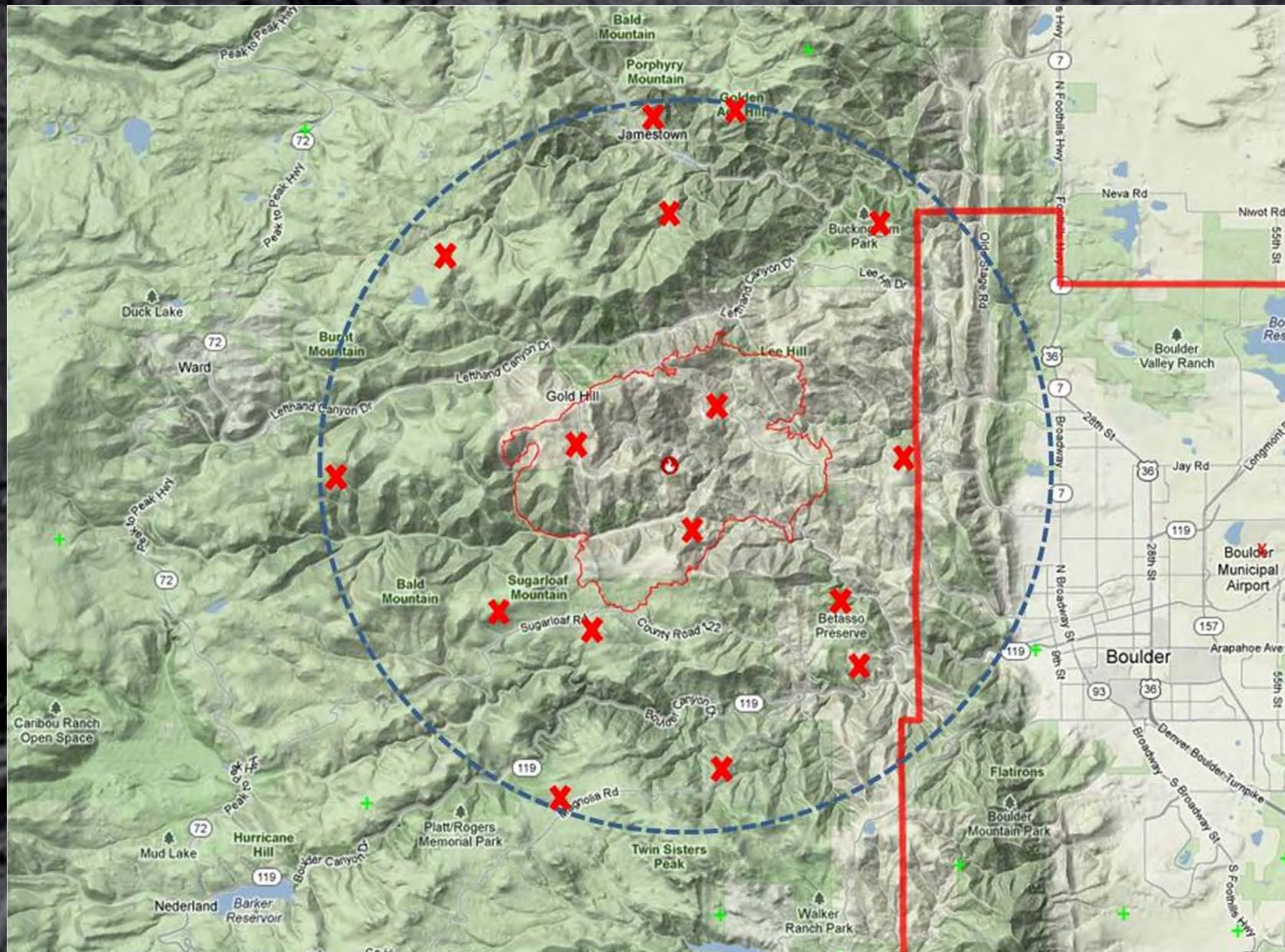
some facts & opinions

- One-hour rainfall measurements from the ALERT System exceeded 0.9” (2-year frequency, 50% annual probability) on 40 days in the past 22 years within a 5-mile radius of the FMBA.
- 1” to 1.5” in 1hour over the FMBA is capable of producing a flood peak on Fourmile Creek that could overtop SH 119 (Qcap ~2,000 CFS unobstructed)
- As little as 100 CFS will threaten existing private drive crossings along Fourmile Creek and is likely from 1-hour rainfalls exceeding 0.5”
- Many private homes (~80) and one 30-unit lodge are at risk from flooding in the FMBA and along Fourmile Creek downstream of the FMBA.
- The Boulder Mountain Lodge is located a short distance upstream of SH 119 where floodwaters can reach depths of 19-feet or more.
- Unsecured liquid propane tanks present serious concerns.
- The May 30, 1995 flood on Fourmile Creek (est. 400-500 CFS) was caused by a combination of general widespread rainfall and snowmelt. This was likely the largest event on Fourmile Creek and Fourmile Canyon Creek in at least the past 75 years according to the USGS. The July 13, 2011 flood was about twice that magnitude (~800 CFS).
- The May 15, 2003 storm produced a 100-year rainfall at Betasso (2.35” in 1hr) and a peak flow of only 400 cfs in Fourmile Creek at its Boulder Creek confluence. Today that much rain over the FMBA would be a disaster for the immediate area and the City of Boulder.

City of Boulder Floodplains



16 ALERT rain gages within 5-mile radius of the Fourmile Burn Area



One-Hour Rainfall >0.5” & < 0.9” within 5-mile radius of the FMBA

154 days between 1990 & 2011

15 days in April
18 days in May
30 days in June
33 days in July
34 days in August
24 days in September

YEAR	DATES	YEAR	DATES
1990	5-28,30 7-11,16,19,20 8-5,11,16 9-2,5,6	2001	4-11 7-8,11 8-5,7,8,11,15
1991	5-15,16,22 6-13 7-25,26 9-9,11	2002	5-24 8-5 9-10,12
1992	6-27 9-24,29	2003	4-24 6-17,19 7-27 8-30
1993	4-22 6-7,11,17 7-13 9-14,17	2004	4-4,5 5-1 6-8,9,27,29 7-19,23,28 9-19,30
1994	4-30 5-11 6-2,18,20,21 7-31 8-10,11,13 9-13	2005	4-11 6-3 8-10,22,23 9-14
1995	5-18,29 6-17 7-14 8-19,24 9-14	2006	4-26 7-2,25 8-13
1996	4-8, 5-23, 6-12,16,21 7-9 9-18	2007	5-5,6 6-12 7-7,27,30 8-15,17,24 9-5,24
1997	4-13,25 6-7,10,12,13 8-3,4,5 9-11	2008	8-6,9
1998	4-3,26 7-22,26,30 8-1,4	2009	4-19 5-23 6-24,26 7-27 9-8
1999	5-11,20,24 7-8,16,17,24,29 8-5,10 9-2,24,29	2010	4-21 5-14 6-23,26 7-7 8-6,9
2000	8-16	2011	6-19 7-14,17

One-Hour Rainfall > 0.9"
within 5-mile radius of the FMBA

40 days between 1990 & 2011

YEAR	DATES & TIMES
1990	Jul-4@1828, Aug-17@1300
1991	May-31@2101, Jun-1@1413, Jul-22@1358, Aug-3@1051
1996	Jul-28@1918, Sep-14@1834
1997	Jun-6@1548, Jul-30@1559
1998	Jul-8@2352, Jul-24@1915, Jul-25@1814
1999	Jul-19@1556, Jul-28@1738, Jul-30@1618, Jul-31@1536, Aug-4@1614, Aug-7@1531, Aug-27@1449
2000	Jul-16@2101
2001	Aug-9@1931, Aug-30@1912
2002	Jun-3@1954
2003	May-15@2047, Jun-18@2328, Jul-29@1352, Aug-29@2146
2004	Jul-16@1431, Aug-18@1617
2005	Jul-25@1708
2006	Jun-24@1841, Jul-20@1544, Aug-14@1510
2007	Jul-26@2316, Jul-29@1559
2010	Jul-4@2032
2011	Jul-7@1836, Jul-13@1856, Jul-19@1609

The May 30, 1995 flooding was caused by more general widespread rains with snowmelt runoff near record levels.

2 days in May
5 days in June
23 days in July
9 days in August
1 day in September

Opinions varied...
no absolute consensus

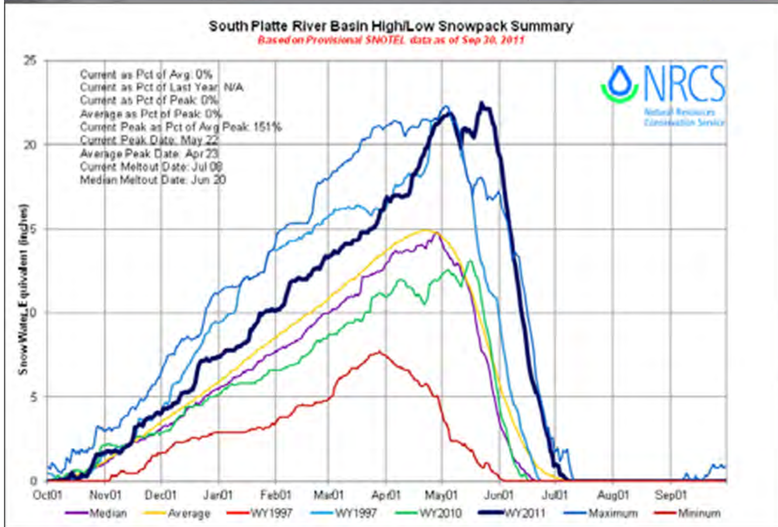
1-HR PCP	Vieux	LRE	WWE	UCD
0.5"	880	150	200	550
0.75"	1,600	460	470	900
1.0"	2,400	890	820	1,400
1.25"	3,300	1,400	1,200	1,800
1.5"	4,300	2,000	1,800	2,200
1.75"	5,300	2,600	2,800	2,700
2.0"	6,300	3,300	3,800	3,200
2.5"	8,400	4,600	5,900	4,300
3.0"	10,500	6,100	7,500	5,600

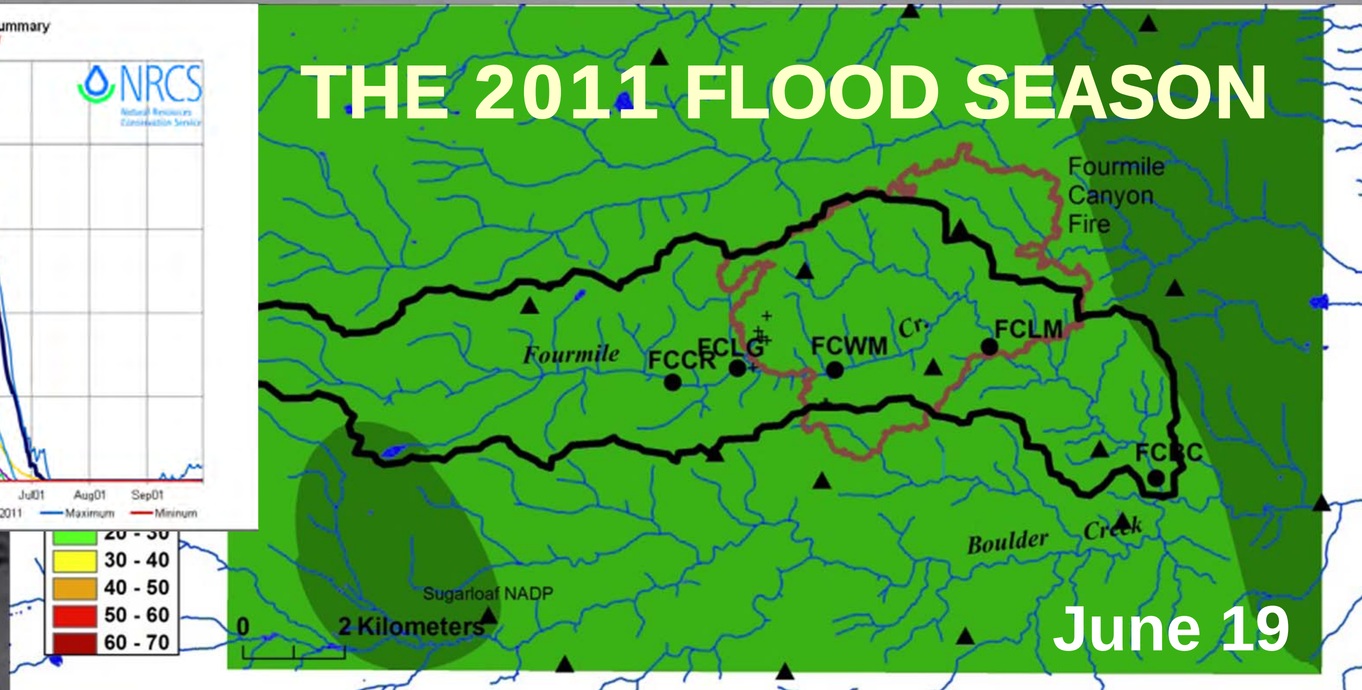
Peak discharge estimates in CFS from runoff models for the 4,577-acre burn area portion of the Fourmile Creek watershed.

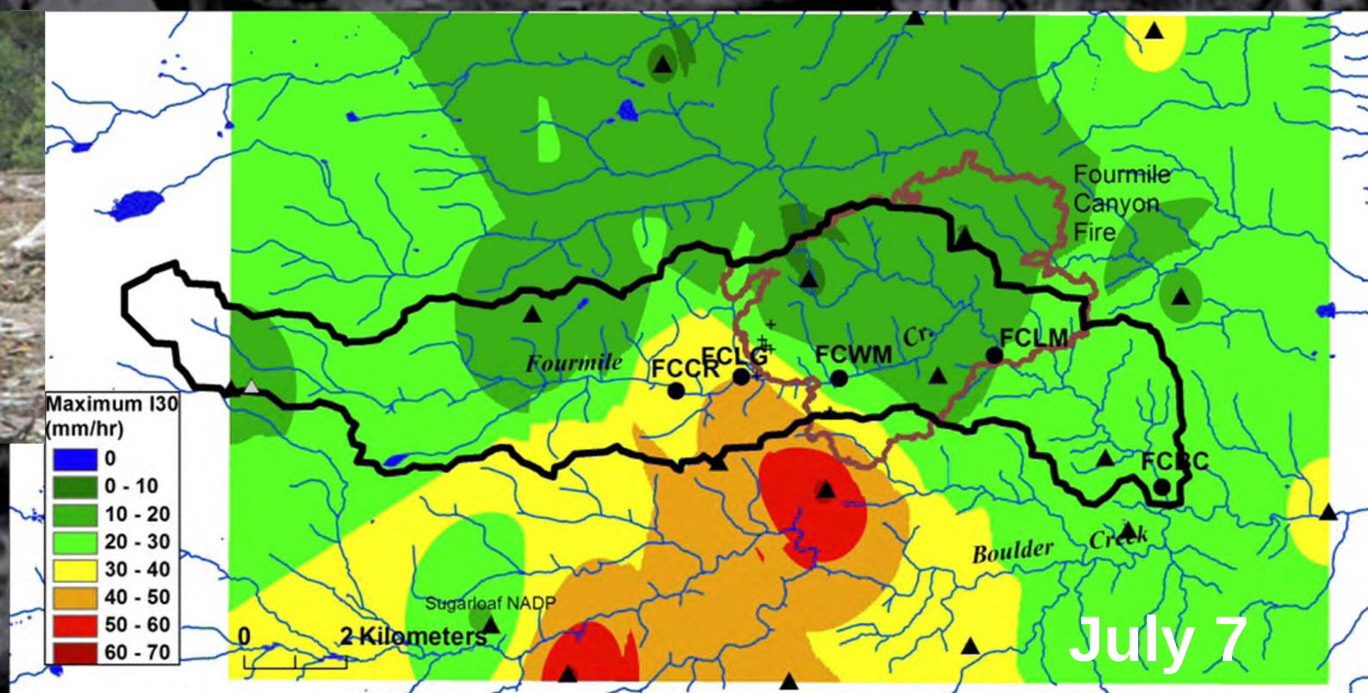
Houston, we have a problem!

A conclusion held by a few believers prior to the 2011 flood season.

THE 2011 FLOOD SEASON

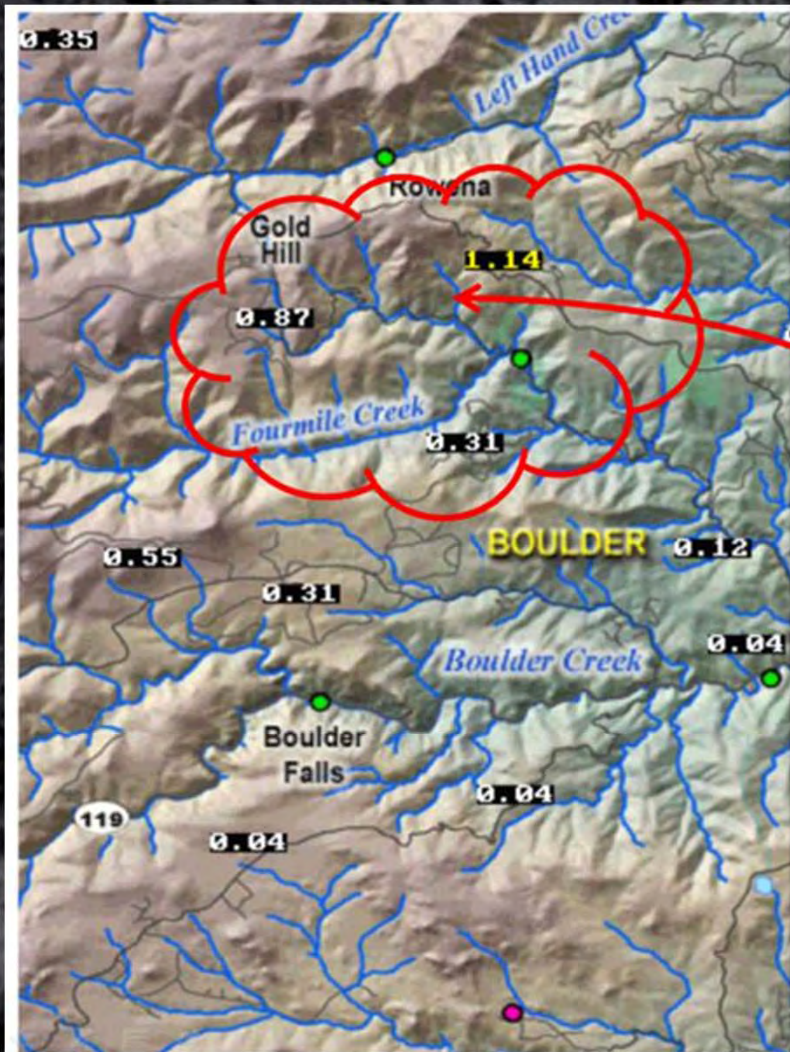


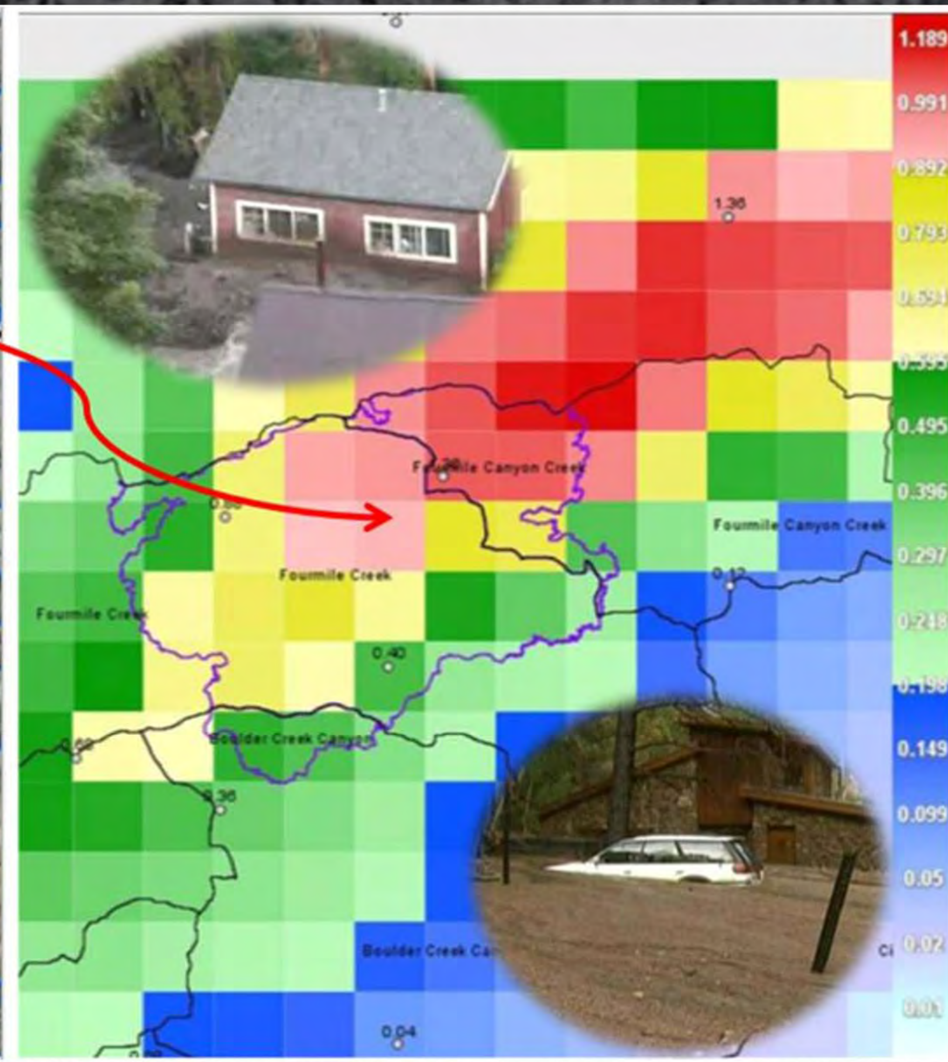


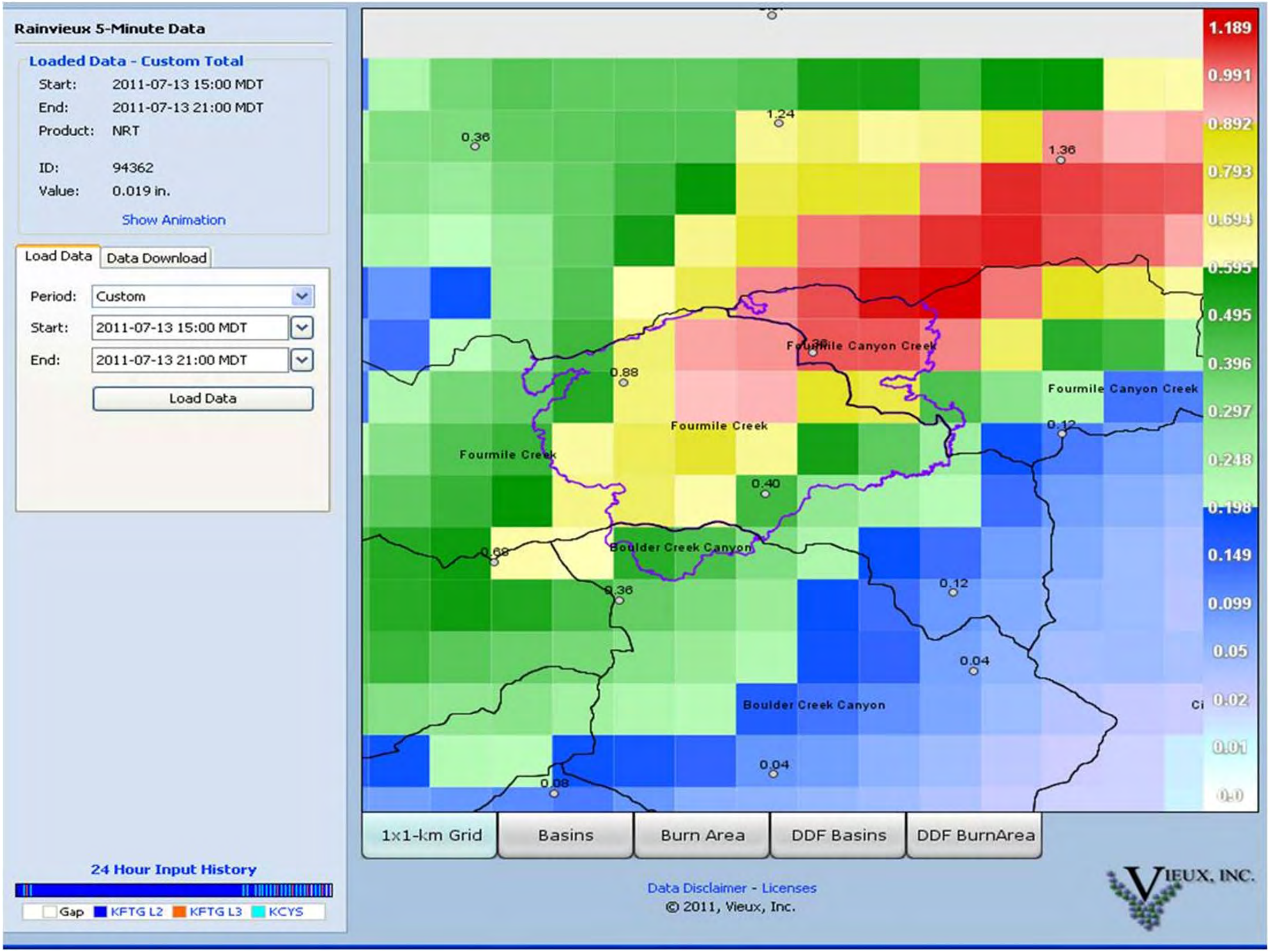


The July 13, 2011 Flash Flood

A relatively small event with serious impacts







Rainvieux 5-Minute Data
Loaded Data - Custom Total
Start: 2011-07-13 15:00 MDT
End: 2011-07-13 21:00 MDT
Product: NRT
ID: 94362
Value: 0.019 in.
Show Animation
Load Data
Data Download
Period: Custom
Start: 2011-07-13 15:00 MDT
End: 2011-07-13 21:00 MDT
Load Data
24 Hour Input History
Gap
KFTG L2
KFTG L3
KCYS
1.189
0.991
0.892
0.793
0.694
0.595
0.495
0.396
0.297
0.248
0.198
0.149
0.099
0.05
0.02
0.01
0.0
0.36
1.24
1.36
0.88
0.12
0.40
0.68
0.36
0.12
0.04
0.04
0.08
Fourmile Canyon Creek
Fourmile Canyon Creek
Fourmile Creek
Fourmile Creek
Boulder Creek Canyon
Boulder Creek Canyon
1x1-km Grid
Basins
Burn Area
DDF Basins
DDF BurnArea
Data Disclaimer - Licenses
© 2011, Vieux, Inc.
VIEUX, INC.

The Morning Forecast

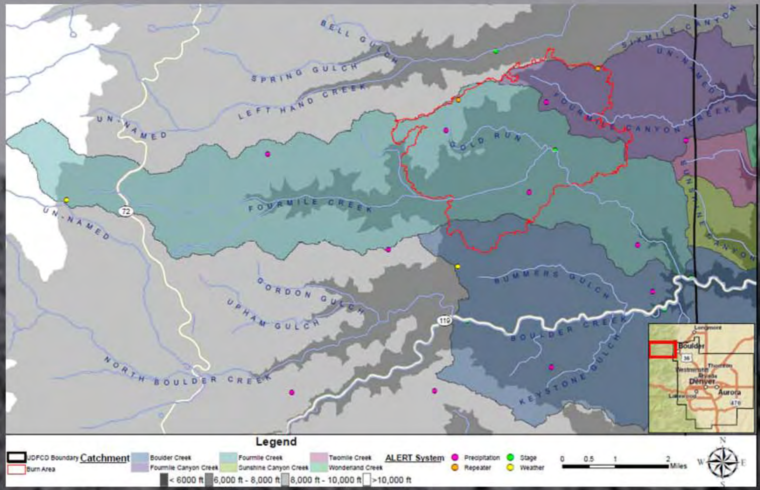
HPO Msg Potential HIGH: AFTERNOON/EVENING THUNDERSTORMS... MORE HEAVY RAINFALL POSSIBLE 07/13/11 911 AM

STORM RAINFALL POTENTIAL AND DURATION: Weak to moderate thunderstorms will produce 0.10-0.60" in 10-30 minutes. Strong thunderstorms will have the potential to produce 0.60-1.60" in 10-30 minutes.

WORST CASE SCENARIO: A slow moving thunderstorm complex or "training" thunderstorms may result in up to 2.50" in 45-60 minutes.

July 13 Timeline

5:24pm first message concerning FMBA heavy rain threat
5:53pm NWS issues small stream flood advisory for FMBA
6:06pm first ¼" rainfall rate alarm within 5 miles of FMBA
6:15pm first ¼" rain alarm in FMBA at Gold Hill
6:17pm NWS issues flash flood warning for FMBA
6:22pm ¼" rain alarm in FMBA at **Sunshine**
6:28pm first ½" rain alarm at Gold Hill
6:33pm ½" rain alarm at **Sunshine**
6:47pm first ¾" rain alarm at Gold Hill
6:50pm ¾" rain alarm at **Sunshine**
6:54pm Fourmile Creek at Salina gage detects small rise
6:55pm 1" rain alarm at **Sunshine**
7:05pm FM Creek at Logan Mill Road gage detects rise
7:20pm FM Creek at Logan Mill peaks showing 4' rise. Actual peak time was later estimated to have occurred at 7:17pm and 0.8' higher than the 7:20 pm measurement.

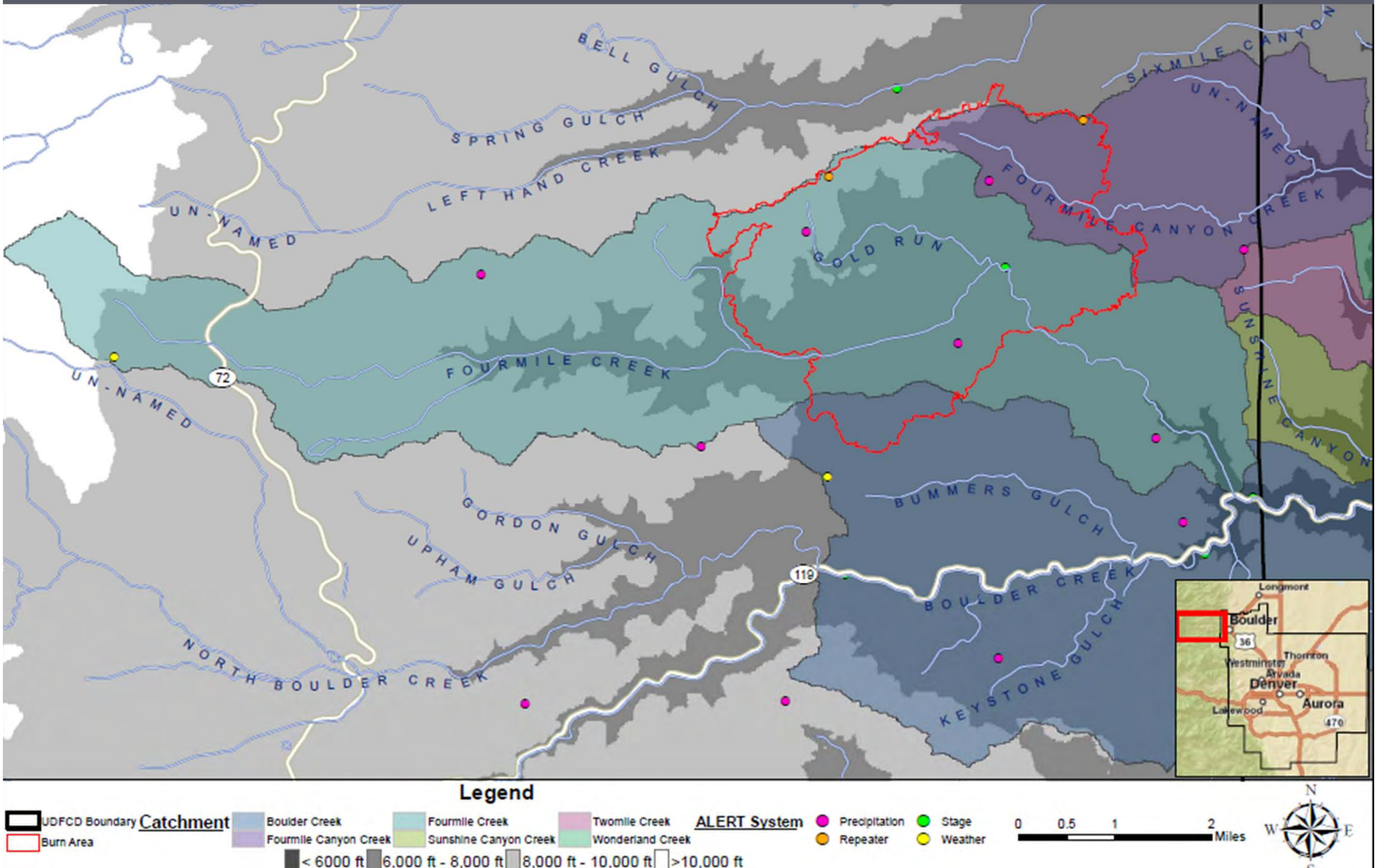


Hydro-modeling in Real-Time

Leonard Rice Engineers (Denver, CO)

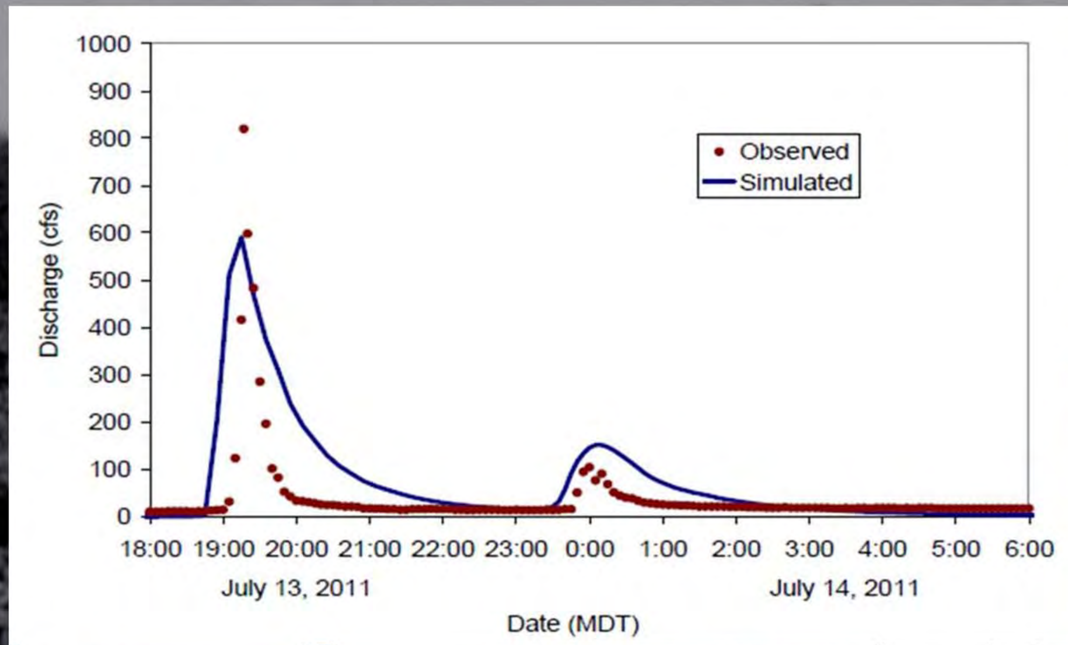
&

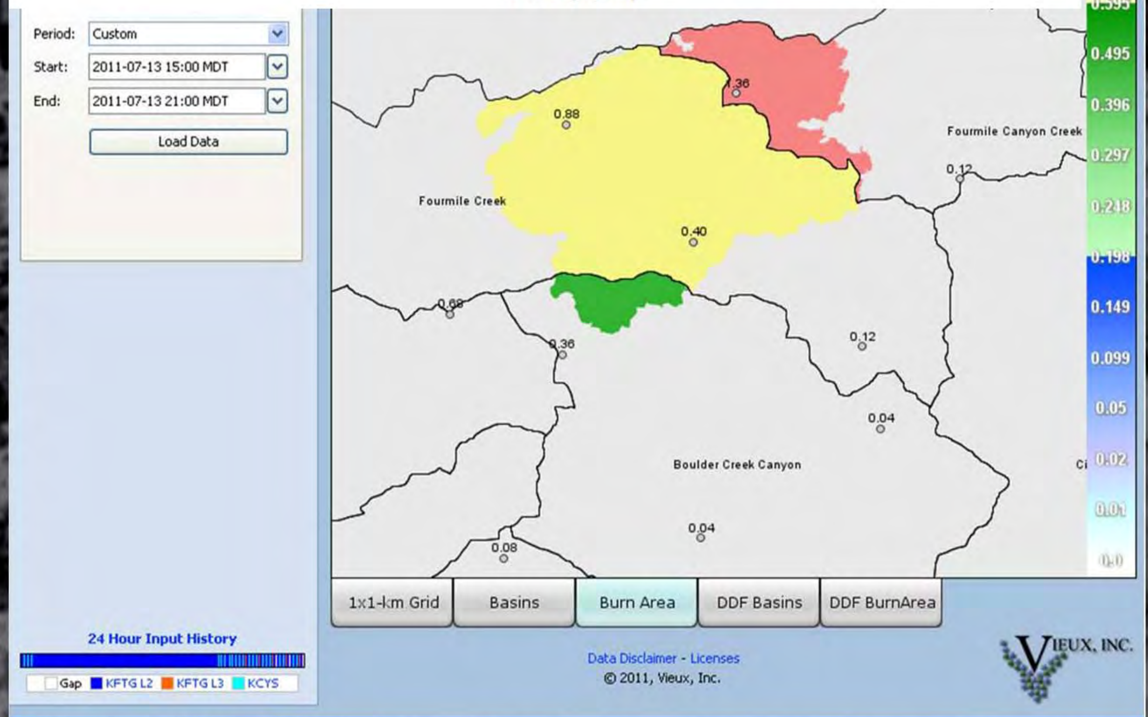
Vieux (Norman, OK)

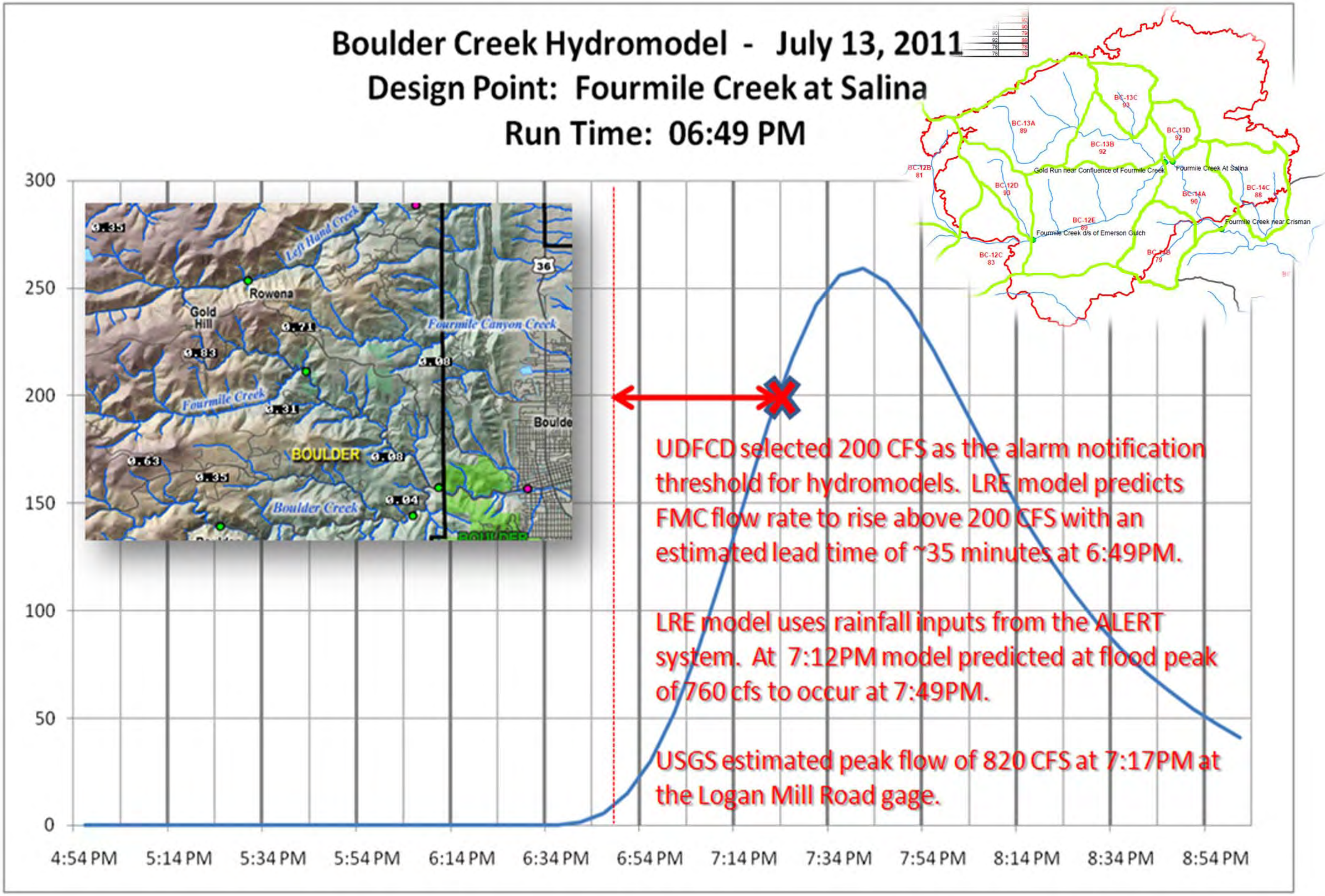


BELL GULCH
SPRING GULCH
LEFT HAND CREEK
SIXMILE CANYON
UN-NAMED
FOURMILE CANYON CREEK
GOLD RUN
FOURMILE CREEK
SUNSHINE CANYON
72
BUMMERS GULCH
GORDON GULCH
UPHAM GULCH
119
BOULDER CREEK
KEYSTONE GULCH
NORTH BOULDER CREEK
Longmont
Boulder
36
Westminster
Thornton
Arvada
Denver
Aurora
Lakewood
470
Legend
UDFCD Boundary
Burn Area
Catchment
Boulder Creek
Fourmile Canyon Creek
Fourmile Creek
Sunshine Canyon Creek
Twomile Creek
Wonderland Creek
ALERT System
Precipitation
Repeater
Stage
Weather
< 6000 ft
6,000 ft - 8,000 ft
8,000 ft - 10,000 ft
>10,000 ft
0 0.5 1 2
Miles
N
W
E
S

Can impacts like this be forecast with enough lead time for people to protect themselves and their loved ones?





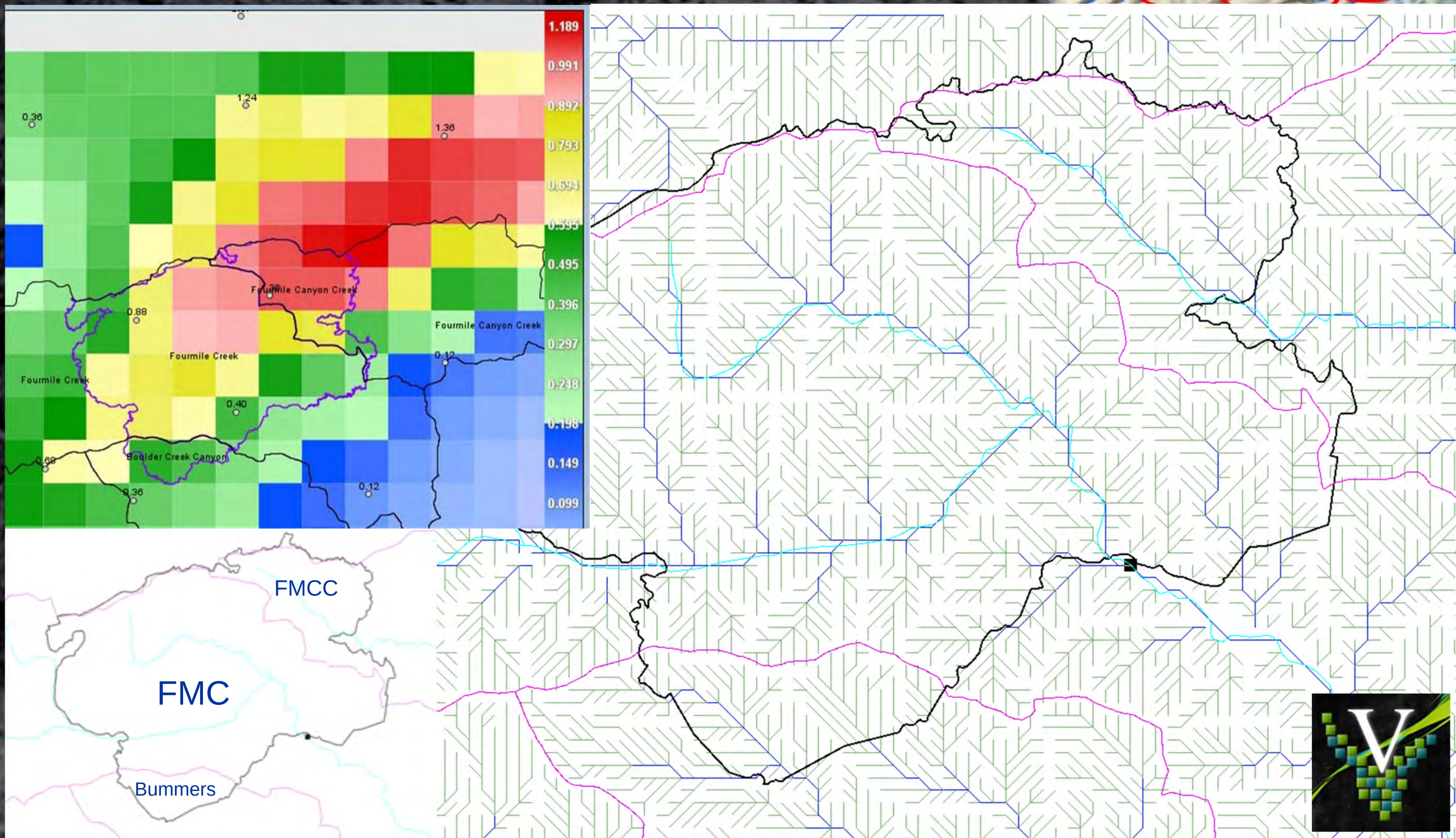


Vertical scale: discharge in CFS
1-hr rainfall ending at model run time

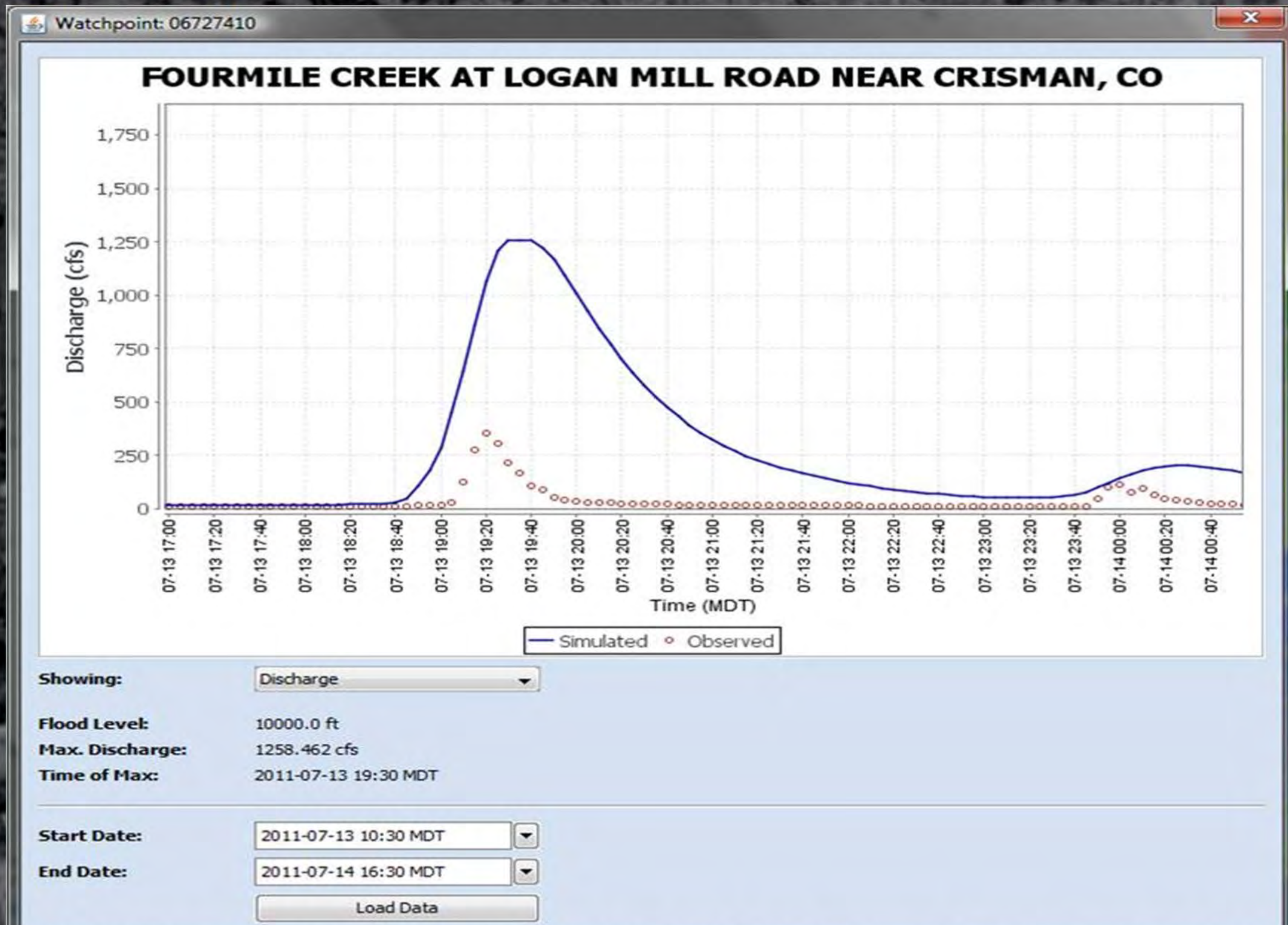
LEONARD RICE ENGINEERS, INC.

A Distributed Continuous Simulation Model

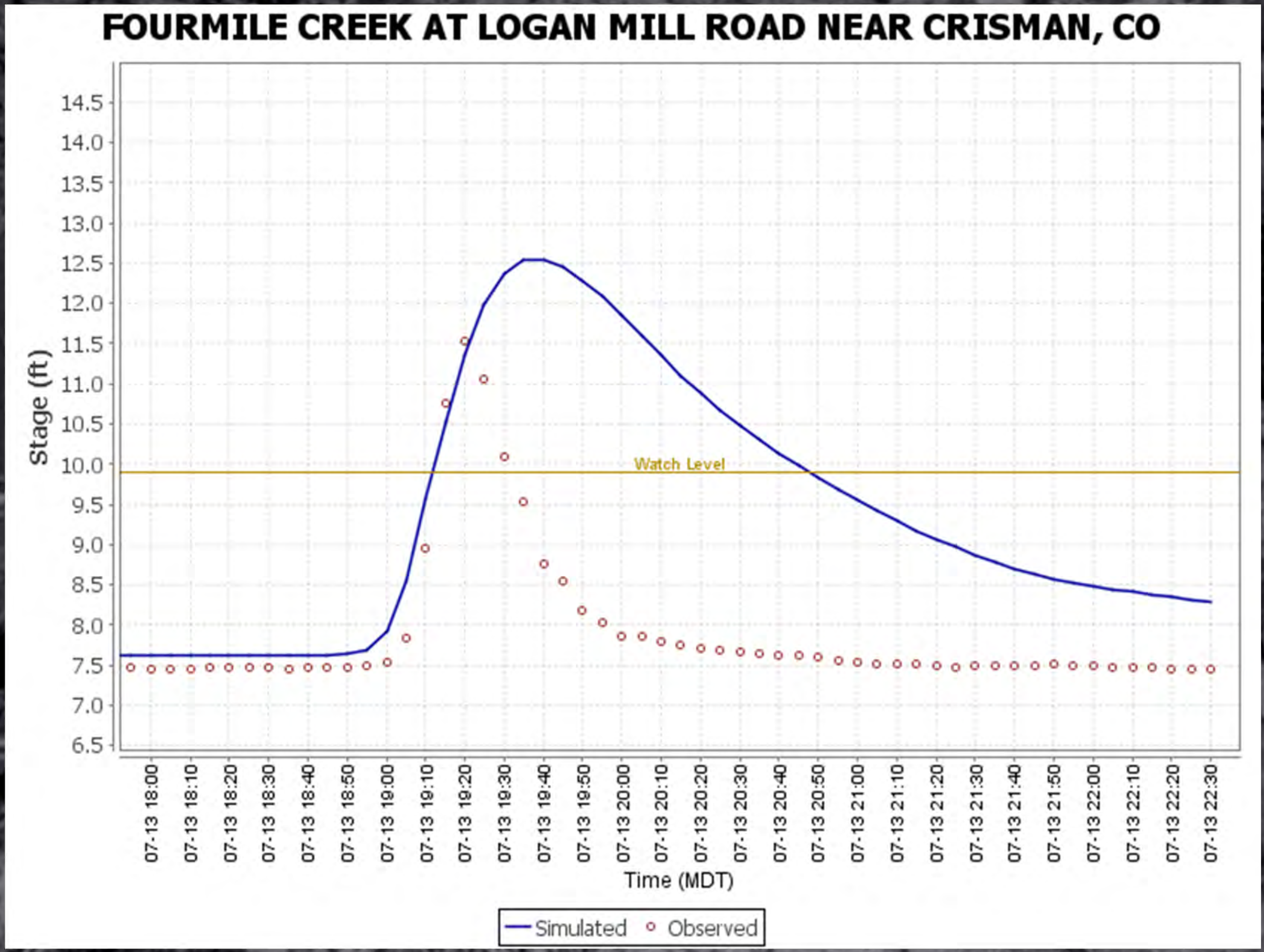
(Drainage network derived from 10m DEM)



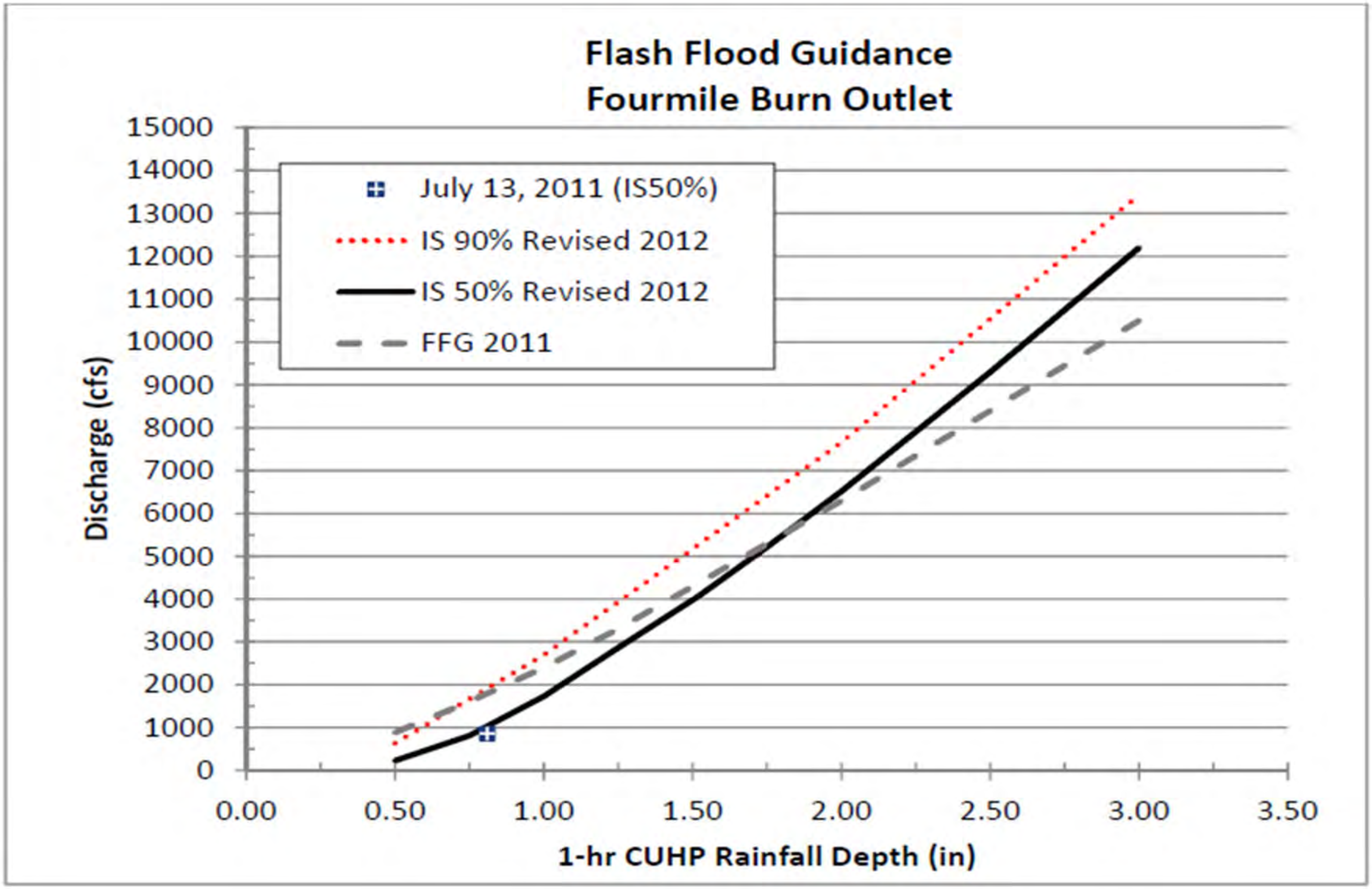
Vflo before 7/13 calibration



Vflo after 7/13 calibration



Vflo after 7/13 calibration



Lessons Learned in 2011

….from the technologies used and from the people affected.

Live Steaming Video

Eye-witness Reports
July 13, 2011

- 12 people stranded behind a washed out road were found safe.
- 4 people covered head-to-toe with mud treated for exposure and minor injuries at Gold Hill.
- Cars trapped by lots of debris, trees, mud and rock on roads.
- Bridges and roads washed out.
- Large debris easily conveyed downstream by Fourmile and Fourmile Canyon Creeks.
- At least 10 private homes sustained damage.
- Fire department vehicle in route to rescue was washing off Gold Run Road by raging floodwaters. Damages to vehicle totaled $1,500. No one was hurt.
- Surprisingly slow moving 6' to 10' high "walls of water" were reported by fire and sheriff's department officials at a number of locations. Ingram Gulch was one of those locations.

July 13 was not the most intense rainfall event of 2011 in Boulder County.

1 Hour Peak Intensities

Station	Date	Tips	Inches	
4570	7/7/11 6:14 PM	40	1.57	> 1"/hr
4730	7/7/11 6:53 PM	39	1.54	
4160	**7/13/11 7:05 PM**	**34**	**1.34**	
4200	7/13/11 7:16 PM	34	1.34	
4190	7/13/11 7:00 PM	31	1.22	
4130	7/7/11 6:57 PM	29	1.14	
4520	7/11/11 4:21 PM	26	1.02	
4080	7/7/11 6:36 PM	25	0.98	> 0.75"/hr
4080	7/19/11 4:09 PM	23	0.91	
4260	7/17/11 5:38 PM	23	0.91	
4150	**7/13/11 6:56 PM**	**22**	**0.87**	
4300	7/12/11 10:22 PM	22	0.87	
4340	7/7/11 6:52 PM	22	0.87	
4360	7/7/11 6:35 PM	22	0.87	
4750	7/9/11 5:54 PM	21	0.83	
4090	6/19/11 10:46 PM	20	0.79	
4090	7/7/11 6:30 PM	20	0.79	
4200	7/7/11 6:52 PM	20	0.79	
4220	7/17/11 4:44 PM	20	0.79	
4260	7/12/11 4:35 PM	20	0.79	
4490	7/11/11 4:05 PM	20	0.79	
4520	7/7/11 7:18 PM	20	0.79	

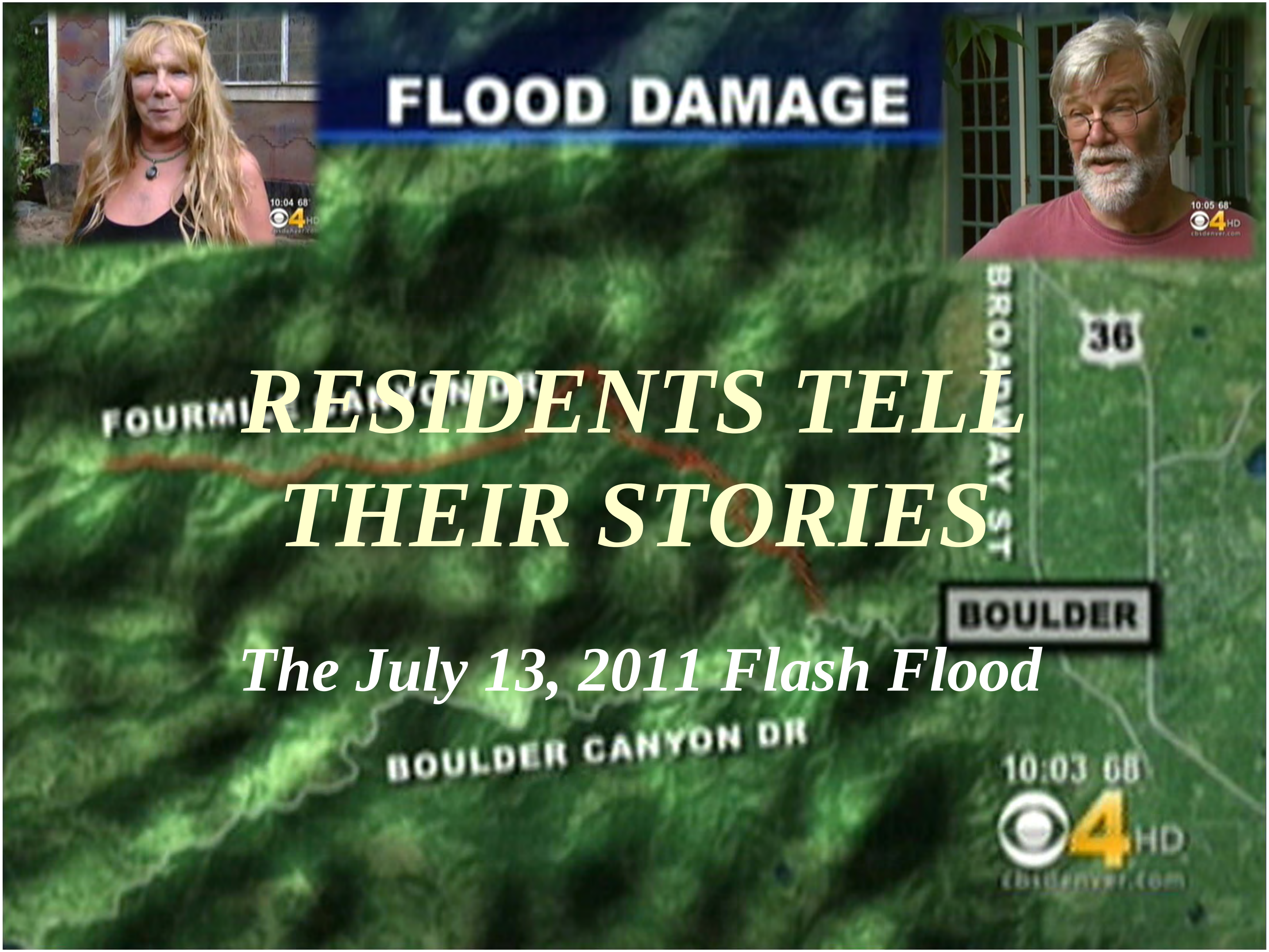
10 Minute Peak Intensities

Station	Date	Tips	Inches	in/hr
4730	7/7/11 6:12 PM	22	0.866	5.20
4130	7/7/11 6:08 PM	19	0.748	4.49
4570	7/7/11 6:00 PM	19	0.748	4.49
4520	7/11/11 3:44 PM	15	0.591	3.54
4190	7/13/11 6:37 PM	14	0.551	3.31
4260	7/17/11 5:36 PM	14	0.551	3.31
4860	7/12/11 10:19 PM	55	0.550	3.30
4080	7/19/11 3:48 PM	13	0.512	3.07
4090	6/19/11 10:44 PM	13	0.512	3.07
4090	7/14/11 5:03 PM	13	0.512	3.07
4200	7/13/11 7:06 PM	13	0.512	3.07
4340	7/7/11 6:48 PM	13	0.512	3.07
4350	7/10/11 7:24 PM	13	0.512	3.07
4750	7/9/11 5:38 PM	13	0.512	3.07
4300	7/12/11 10:02 PM	12	0.472	2.83
4520	7/7/11 6:30 PM	12	0.472	2.83
4030	8/19/11 5:12 PM	11	0.433	2.60
4200	7/7/11 6:29 PM	11	0.433	2.60
4220	7/12/11 10:04 PM	11	0.433	2.60
4220	7/17/11 4:28 PM	11	0.433	2.60
4260	7/12/11 3:52 PM	11	0.433	2.60
4710	7/12/11 9:51 PM	11	0.433	2.60
4070	7/7/11 5:49 PM	10	0.394	2.36
4110	7/7/11 6:24 PM	10	0.394	2.36
4160	**7/13/11 6:52 PM**	**10**	**0.394**	**2.36**


The EOC
Where critical decisions are made.
Message Center
Gaining situational awareness, a common operating picture, leaning forward & using plain language

RESIDENTS TELL THEIR STORIES

The July 13, 2011 Flash Flood



MORE BELIEVERS NOW

UDFCD Updated Specifications

DAVID BENNETTS

PROGRAM MANAGER

DESIGN, CONSTRUCTION, & MAINTENANCE PROGRAM

UDFCD Specifications Update

Need for Update

- Change in CSI Format
- Specifications Outdated
- Not Complete
- Changes in the Law
- Eliminate Misuse
- Move to Paperless Process
- Provide Specifications on Website
- Future Revisions & Updates

UDFCD Specifications Update

Review Process

- Update and Review by District Consultant (CH2M Hill)
- Review by District Staff
- Review for Criteria Compliance
- Legal Review
- Contractor Review
- Supplier Review

- All comments compiled into final set of specifications

UDFCD Specifications Update

Project Status

Completed to Date

- Divisions 2 – 33
- Includes 42 specifications

Still in development

- Revised Instructions for Use
- Division 0 - Boiler Plate
- Division 1

UDFCD Specifications Update

Division 1 Specifications

- 01 11 00 Summary of Work
- 01 13 00 Site Conditions
- 01 14 19 Use of Site
- 01 18 00 Project Utility Sources
- 01 25 00 Substitution Procedures
- 01 26 00 Contract Modification Procedures
- 01 29 00 Payment Procedures
- 01 31 19 Project Meetings
- 01 32 00 Construction Progress Documentation
- 01 32 13 Schedule of Work
- 01 33 00 Submittal Procedures
- 01 35 13 Special Project Procedures
- 01 42 19 Reference Standards
- 01 45 23 Inspection and Materials Testing
- 01 52 00 Owner Field Offices
- 01 55 26 Traffic Control
- 01 56 39 Temporary Tree and Planting Protection
- 01 57 19 Temporary Environmental Controls
- 01 58 00 Project Sign
- 01 66 00 Product Delivery, Storage, and Handling
- 01 71 13 Mobilization
- 01 71 23 Field Engineering and Surveying
- 01 77 00 Closeout Procedures

UDFCD Specifications Update

Questions?

Thanks!

dbennetts@udfcd.org

360° Discussion of Erosion and Sediment Control in Drainageway Construction

KEN MACKENZIE
LAURA KROEGER

- WHERE WE LEFT OFF LAST YEAR
- WHAT HAS HAPPENED
- WHAT IS GOING ON LOCALLY
- WHAT IS GOING ON WITH YOU
- FUTURE THOUGHTS

Bestest BMP

Stream Stabilization is a permanent BMP

Offers big bang for buck in water quality

Not recognized as a BMP in MS4 process

Implementation of permit process can impede maximizing permanent BMP

Moving forward, how to meet permit requirements while keeping the focus on the ultimate solution of stabilizing the stream

Confluence of South Platte River and Marcy Gulch
(no construction activity)

Nationally

NAFSMA Annual Meeting

Water Environment Research Foundation (WERF)

- RFP Issued research funding
- Michael Baker Jr., “Protocol and Guidance for BMP Credits for Stream Restoration”

Problem Statement

- It is widely recognized that urban streams contribute significant sediment and phosphorus to receiving waters. Several studies have shown that streambank sediments may have significant phosphorus components. Traditional approaches and regulations that focus stormwater management quality controls on impervious surfaces only may miss opportunities to address a primary source of sediments and nutrients.

- One size fits all mentality
  - *"Being effective is about doing the right things, while being efficient is about doing the rights things in the right manner."*
- MS4's forced to manage regulations not water quality
  - *Approval process*, Maintenance and inspection records
  - Missing big picture
- Maximum Extent Practicable morphed into "zero-risk" mentality
  - Zero risk means no thinking required
  - Even WQCV is probability based approach and not zero-risk.

Don’t Lose Site of the Big Picture

Grange Hall Creek

Seeking on District Stream Stabilization

Recognition we are different than other permit applicants

Streamline application process, especially for maintenance activities

Adopt a partnering philosophy so can utilize entire teams knowledge and experience

Flexibility to adapt in the field to conditions

Keep the most tax payer dollars in the permanent BMP solution

Coyote Gulch

360° Discussion

ERIK NELSON, DOUGLAS COUNTY
RYAN ADRIAN, DOUGLAS COUNTY
BARBARA CHONGTOUA, UDFCD
JERRY NARANJO, NARANJO CIVIL CONSTRUCTORS
YOU…

Future Engagements

Colorado Chapter International Erosion Control Association (IECA)

International Erosion Control Association

StormCon

- Case Study on Marcy Gulch
  - Stream erosion significant source of sediment and pollutants
  - Importance of restoring streams to the natural ecological and hydraulic function

StormCon denver 2012

Don’t Lose Site of the Big Picture

Big Dry Creek (Arapahoe)