Welcome to the Urban Drainage and Flood Control District's

2015 Annual Seminar

2015 UDFCD ANNUAL SEMINAR PROGRAM

April 7, 2015 at the OMNI Hotel in Broomfield

500 Interlocken Blvd | Broomfield CO 80021

7:45 AM	8:30 AM	Registration and Continental Breakfast	
8:30 AM	9:10 AM	Paul Hindman	Welcome & Opening Remarks Stormwater Management vs. Water Rights
9:10 AM	9:50 AM	David Bennetts, Andrew Earles	Planning for Uncertainty: Climate Change and the UDFCD Urban Drainage System
9:50 AM	10:10 AM	Morning Networking Break	
10:10 AM	10:50 AM	Kevin Stewart	Beyond ALERT: Hydro Models, Risk Assessment & Gauge Adjusted Radar Rainfall
10:50 AM	11:30 AM	David Mallory, Teresa Patterson, Joanna Czarnecka	New Initiatives in Flood Risk Communication
11:30 AM	12:10 PM	Barbara Chongtoua	The Next Generation of Maintenance: Adaptive Vegetation Management
12:10 PM	1:10 PM	Lunch Buffet & ***Friend of UDFCD*** *AWARD* Presentation	
1:10 PM	1:50 PM	Holly Piza	Rainwater Harvesting and Cloud-Based Infrastructure
1:50 PM	2:30 PM	Shea Thomas, Gerald Blackler	**C**hallenging **U**ncertainty in **H**ydrologic **P**aradigms
2:30 PM	2:50 PM	Afternoon Networking Break	
2:50 PM	3:30 PM	Ken MacKenzie, Jesse Nolle	Repurposing the High Line Canal for Stormwater Treatment and Runoff Reduction
3:30 PM	4:00 PM	Holly Piza, Sarah Anderson, Jesse Clark, Jim Wulliman	Developments in Ultra-Urban Green Infrastructure
4:00 PM	4:10 PM	Paul Hindman	Closing Remarks

SESSION 1

Stormwater Management versus Water Rights

By Paul Hindman, UDFCD

ABSTRACT:

For years local governments in the State of Colorado have been managing stormwater effectively using regional detention basins as one of their big tools in their limited toolbox. Recently the State Engineer rendered a decision that would require regional stormwater basins to have a water right, or augmentation plan to account for the losses due to infiltration and timing. It's the District's opinion, which is shared by almost all local governments that this decision would be costly and may even be unattainable for future detention basins. This requirement is unnecessary because the developments, with the increase in impervious area, allows more water to runoff and therefore increase the available water downstream. Therefore the so called injury is to water that was never in the receiving stream.

The District decided to introduce legislation to rectify this situation by stating that regional detention basins do not injure water rights. This presentation will explain in detail the nuances of this issue as well as describe the process of SB 15-212 in the 2015 Colorado General Assembly.

SESSION 2

Planning for Variability & Uncertainty: Climate Change and the UDFCD Urban Drainage System

By David Bennetts, P.E.; Dr. Andrew Earles, P.E., D.WRE; and Julia Traylor, EIT.

ABSTRACT:

Climate change is a topic that we hear about almost daily in the news, and it is a topic that has been the subject of extensive Federal research for more than a decade. With the potential for climate change to affect temperature, rainfall, runoff, evapotranspiration and other hydrologic variables, it is reasonable to ask how these changes may affect the urban drainage system. Increasingly, this question has been posed to Urban Drainage and Flood Control District (UDFCD). To address this question, UDFCD and Wright Water Engineers, Inc. (WWE) have reviewed climate change projections for Colorado and the Front Range to identify potential vulnerabilities of the urban drainage system and to inventory and assess UDFCD policies, criteria and programs that provide resiliency for future climate and hydrologic variability.

While global and regional climate models are generally consistent in projections of future increases in average temperatures, hydrologic effects of climate change are far less certain and range from decreases to increases in annual and seasonal precipitation. The natural variability of hydrology and the short period of record of available data make it very difficult to detect trends (if any) in long-term precipitation due to changes in climate. Given the high level of uncertainty in hydrologic projections and natural variability in hydrologic processes, it is not possible to say that precipitation, runoff, flooding or other variables will increase or decrease in the future. However, based on climate model projections, it is likely the variability will increase, resulting in both wetter-than-normal and drought years. Therefore, evaluating implications of increased and decreased precipitation is prudent.

Although increases in average temperatures and increased variability in hydrology are widely projected by climate change experts, the effects of these changes in the urban drainage system cannot be forecast with a high degree of certainty. Existing programs, policies and criteria of UDFCD have been developed over a period of more than 40 years with an understanding and respect for the natural variability of hydrology. As a result, the urban drainage system in the metropolitan Denver area already has a high degree of resilience to potential future hydrologic changes associated with climate. In addition, UDFCD programs have a long history of adaptive management, and this approach will serve UDFCD well in addressing future changes in climate whether these changes include increases or decreases in precipitation and runoff or both.

SESSION 3

Beyond ALERT: Hydro Models, Risk Assessment & Gauge Adjusted Radar Rainfall

By Kevin Stewart, P.E., UDFCD

ABSTRACT:

The first ALERT rain and stream gages in the UDFCD region were installed in 1979 for the Boulder Creek watershed upstream of Boulder. This project greatly enhanced the ability to detect developing flood threats, providing valuable warning lead-time for people to take appropriate defensive measures. The “September-To-Remember” floods of 2013 clearly validated that this decades-old idea of instituting community-based flood warning systems was a good one. Today the automated gaging network continues to be a critical decision-support cog in a toolbox full of assets.

The “Beyond ALERT” presentation will focus on some of the newer automated aspects of early flood detection and warning including integration of real-time hydrologic models; open source management of and access to flood risk information; increased coverage and uses for real-time and archived radar-derived precipitation estimates; and other new developments for recognizing flood threats.

SESSION 4

The new UDFCD CRS Assistance Program

By David Mallory, P.E., Teresa Patterson, P.E., and Joanna Czarnecka, EIT

ABSTRACT:

With the recent congressional initiatives to reform the National Flood Insurance Program (NFIP), flood insurance premiums will increase tenfold over the course of a few years to reflect the true risk of living in high-flood areas. The NFIP Community Rating System (CRS) is a voluntary incentive program that reduces flood insurance premiums for communities that surpass the minimum NFIP requirements. With the reform, there has been a heightened interest in the CRS program and we have intensified our efforts to proactively support communities participating in the CRS.

The new UDFCD CRS Assistance Program explores UDFCD activities that can be credited toward CRS scores, promotes opportunities to increase CRS credits, and provides a UDFCD point of contact. As part of this program we are researching and publishing a report that cross references current UDFCD activities to the CRS scoring system. We are also facilitating a multi-jurisdictional Program for Public Information (PPI) committee, a CRS incentive for developing a public outreach plan. Additionally, we are overhauling the annual Flood Hazard Information Brochure that is mailed to properties near high flood risk areas to improve the brochure's content and maximize CRS credits.

SESSION 5

The Next Generation of Routine Maintenance: Adaptive Stream Management

By Barbara Chongtoua, P.E., UDFCD

ABSTRACT:

Stream systems are an important asset to communities for open space, recreation, and floodplain management. Beginning this past spring in 2014, the next generation of routine maintenance for streams was implemented in the City and County of Denver. We will discuss why we evolved from routine maintenance to adaptive stream management and explore the following topics in more detail:

- What are the characteristics of a healthy stream?
- Why is health essential for function?
- Why is managing the vegetation communities required for stream stability?
- What does the adaptive stream management approach look like?

In summary, streams are a type of public infrastructure serving a valuable function similar to roads and pipes, and as such, managing their health is essential for performance. Implementing an Adaptive Stream Management approach will assist us to improve the health of streams and as a result, to sustain their utilitarian function for floodplain management.

SESSION 6

2015 Friend of UDFCD Award: Mark Glidden

Presented by David Bennetts and Paul Hindman, UDFCD

ABSTRACT:

UDFCD honors Mark Glidden for 38 years of integrity, commitment, and dedication to the craft of stormwater management. Mark received his B.S. and M.S. degrees in civil engineering from the University of Colorado in 1977 and 1981 respectively, where his master's thesis studied the potential effectiveness of detention policies; setting the stage for modern full spectrum detention as a design standard by concluding among other things that:

> ***Extended detention that is designed to capture very small storms has the potential of reducing flow energy in small waterways, thereby reducing erosion.***

He has worked with UDFCD in many roles and for several of the top water resources engineering firms in the UDFCD region, including CH2M HILL (2003-2015); HDR Engineering (1997-2003); Merrick & Company (1977-1984 & 1993-1997); Boyle Engineering (1986-1993), and Wright Water Engineers (1984-1986).

Among his many accomplishments, Mark has served on the following:

- University of Colorado at Denver, College of Engineering – Engineering Advisory Council
- American Society of Civil Engineers Environmental and Water Resource Institute – Knowledge Management Committee
- American Society of Civil Engineers – Committee on Continuing Education (Former Chair)
- American Society of Civil Engineers Environmental and Water Resource Institute – Continuing Education Council (Former Chair)
- Instructor for ASCE Class on Manual of Practice for Urban Stormwater Management Systems (MOP 77)
- Urban Hydrology Chapter Author for ASCE Hydrology Handbook
- Construction Methods Chapter Author for ASCE Manual of Practice No. 77
- Colorado Association of Stormwater and Floodplain Managers (Former Chair)
- American Public Works Association – Institute of Water Resources (Former Chair)
- City of Aurora Drainage Board
- Denver Regional Council of Governments – Environmental Policy Committee

PLEASE JOIN US IN HONORING MARK GLIDDEN AS A TRUE FRIEND OF UDFCD.

Rainwater Harvesting Cloud-Based Infrastructure

By Holly Piza, P.E., UDFCD

ABSTRACT:

Although rainwater harvesting systems are designed to capture and use stormwater, use of this practice as a stormwater control measure (SCM) in Colorado is rarely seen as a viable alternative. First, the practice doesn't typically provide the volume required to capture the water quality capture volume (WQCV) when it rains because the tank may already be full. Second, western water law dictates that diverting and using rainwater for beneficial use is illegal without a water right.
In 2012, Urban Drainage and Flood Control District (UDFCD) applied for a permit from the State which allowed for the construction of a 3000 gallon, above ground rainwater harvesting system on a new school building owned by Denver Public Schools (DPS). Per water law in Colorado, this system requires detailed accounting on water use as well as augmentation.

The project is part of a Water Environment Research Foundation (WERF) study on high-performance SCMs that utilize cloud-based infrastructure. At this site, a 3,000-gallon cistern collects rainwater from the roof of a school building and uses it for irrigation of the adjacent landscape areas. When available, the cistern will capture a rainfall depth of approximately 0.7 inches, slightly larger than the WQCV in the Denver area. The part of this design that makes it both unique and specifically designed for treatment of stormwater is that the system has a connection to NOAA weather forecasting and it will drain prior to an event, commensurate with the forecast so that the volume is available for stormwater capture. The controls for this system are fully automated and can also be controlled remotely. The equipment assembly used to release and measure water evacuated from the system, as well as the software utilized for this purpose, was developed by Geosyntec Consultants.

This type of automated system can be used to address stormwater treatment using a smaller footprint than would be required for conventional methods because it better utilizes the volume of SCMs in series. Additionally, communities with combined sewer overflows (CSOs) can use this type of system to "beat the peak" and reduce the volume of untreated wastewater entering the receiving water. UDFCD is using these data to determine if this type of configuration, utilizing automated controls at the outlet, is an effective tool in managing stormwater, and if this in combination with rainwater harvesting provides a more effective control measure than rainwater harvesting alone. The paper also includes to what extent this practice helps sustain a landscape in a semi-arid climate. Three years of data have been collected and analyzed.

SESSION 8

Challenging Uncertainty in Hydrologic Paradigms

By Shea Thomas, P.E., and Gerald Blackler, P.E., PhD

ABSTRACT:

The Urban Drainage and Flood Control District, in partnership with the communities we serve and with selected regional experts, is proposing to re-examine the regional calibration of the Colorado Urban Hydrograph Procedure (CUHP). CUHP is the regional hydrologic model and, used in conjunction with the EPA's Storm Water Management Model (SWMM), is the standard of practice for determining peak flow rates, volumes of runoff, flooding depths and floodplain extents. It is one of only a few truly calibrated hydrologic models in existence. While we believe CUHP generally provides reasonable results and is certainly much better than any uncalibrated model, we also believe a recalibration is in order at this time for the following reasons:

1. It's been 30+ years since the last major calibration effort.
2. A great deal of rainfall and runoff data has been collected since the last calibration effort.
3. This model is the basis for every master plan we publish. These plans each entail tens to hundreds of millions of dollars in planned improvements, all based on the accuracy of this model.

Any modification of a widely accepted regional hydrologic model, whether to the modeling protocols, to the code, or to the design storm distributions, will likely have a ripple effect on master planning activities, capital improvement projects and floodplain delineations. Therefore those modifications need to be thoroughly justified and backed by sound technical practices.

This presentation will discuss the hydrology developed in recent master plan updates including the process of calibrating a watershed model to the results produced in the previous study and will compare those results to predicted peak flows determined from stream gauge data statistical analysis. Preliminary analyses performed to date that will set the stage for the more in-depth study will be explained. Initial data gathering tasks, potential outcomes, stakeholder involvement process and a tentative schedule will also be presented.

OUR PLAN TO REPURPOSE THE DENVER HIGH LINE CANAL FOR STORMWATER QUALITY AND RUNOFF REDUCTION

By Jessica Nolle, P.E., and Ken A MacKenzie, P.E.

ABSTRACT:

The Denver High Line Canal is a 130-year-old major irrigation ditch that snakes along a 66-mile-long path through the Denver urbanized region. While it once served to bring thousands of acres of semi-arid, high plains prairie into agricultural production, nearly all of that land has now urbanized, rendering much of the canal obsolete. With urbanization, the canal has become a treasured recreational trail, due in part to the impressive gallery of giant cottonwoods that have grown up along its banks over the past 90 years, providing a full canopy of shade in many areas. The canal is extremely inefficient at delivering water due to seepage, infiltration, evaporation, and evapotranspiration via the thirsty cottonwoods. Reasonably, these same things that make it bad for water delivery make it good for stormwater pollutant reduction and runoff reduction.

In 2014, the Urban Drainage and Flood Control District, Denver Water, and four local governments completed a feasibility study that confirmed the practicability of retrofitting the High Line Canal to provide stormwater quality enhancement and runoff reduction. Specific project outcomes included characterization of all watersheds which cross the canal; determination of the canal's treatment capacity; determination of infrastructure needed; estimation of the annual stormwater volume available for infiltration, evaporative and vegetative water losses; estimation of capital, operational, and maintenance costs; evaluation of a framework for operating within the Colorado water rights administration system; conceptual design of a pilot project to further confirm the project feasibility, and identification of future steps for project implementation.

SESSION 10

Developments in Ultra-Urban Green Infrastructure

By Sarah Anderson, Holly Piza, Paul Thomas, and Jim Wulliman

ABSTRACT:

Permit compliance associated with stormwater quality, especially for redevelopment of high density areas, typically necessitates a variety of options available to a municipality and developers within the municipality. Options can include a centralized water quality facility for a single development, multiple facilities dispersed throughout a single development, a sub-regional centralized facility that treats more than one development, and stormwater banking via a centralized sub-regional water quality facility in a different watershed than the development. Guidance and criteria for design, construction, and maintenance of Best Management practices (BMPs) for centralized water quality facilities is provided in the USDCM Volume 3. However, specific guidance for dispersed facilities has not been developed specific to the UDFCD region.

The City and County of Denver (CCD), with UDFCD, is developing a new manual for post construction BMPs. This manual will build off of concepts of bioretention and permeable pavements found in the USDCM Volume 3 and will focus on installations in the right-of-way and in high density urban areas where dispersed BMPS are desired. The manual will include Streetside Stormwater Planters, Streetside Bumpout Planters, Green Gutters, Tree Trenches, and Green Alleys.

Due to the number of facilities required when BMPs are dispersed, planning and budgeting for maintenance and operation can be complex. CCD is developing policy related to potential public-private partnerships for when these facilities are located in public right-of-way and is also exploring how best to address maintenance of these facilities.

This presentation will provide a preview to the BMPs included in this manual and explore the steps required for implementation of these new criteria.

Stormwater Management versus Water Rights

Paul A. Hindman, Executive Director

2015 UDFCD Annual Seminar April 7,2015

Detention Quiz

In the following slides, which stormwater detention basin is required under current Colorado State Law to have a water right/augmentation plan?

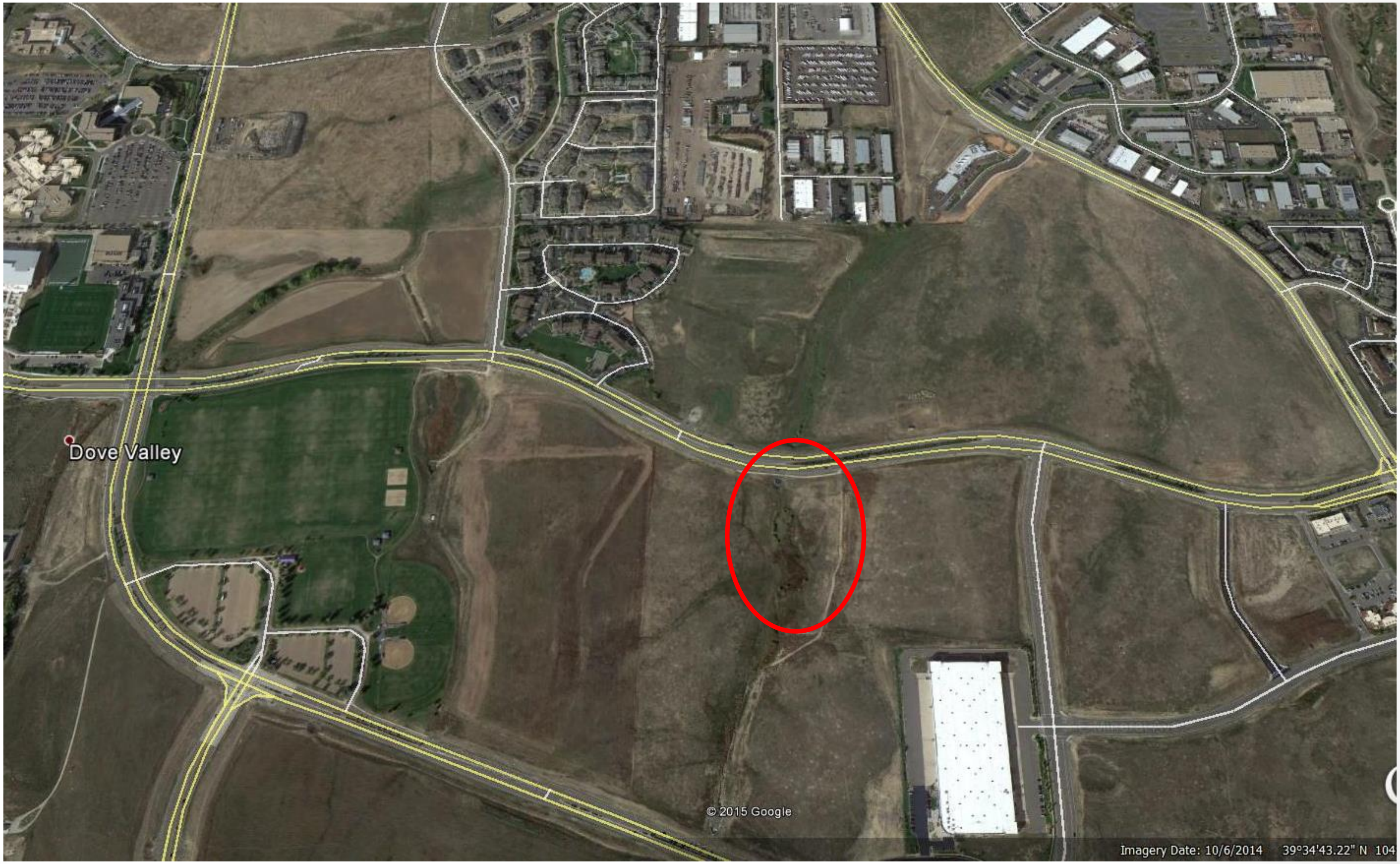
#1


3000 S Holly Pl
Exit Street View
Google earth
© 2015 Google
© 2015 Google
39°39'52.31" N 104°55'10.33" W elev 5483 ft eye alt 5498 ft

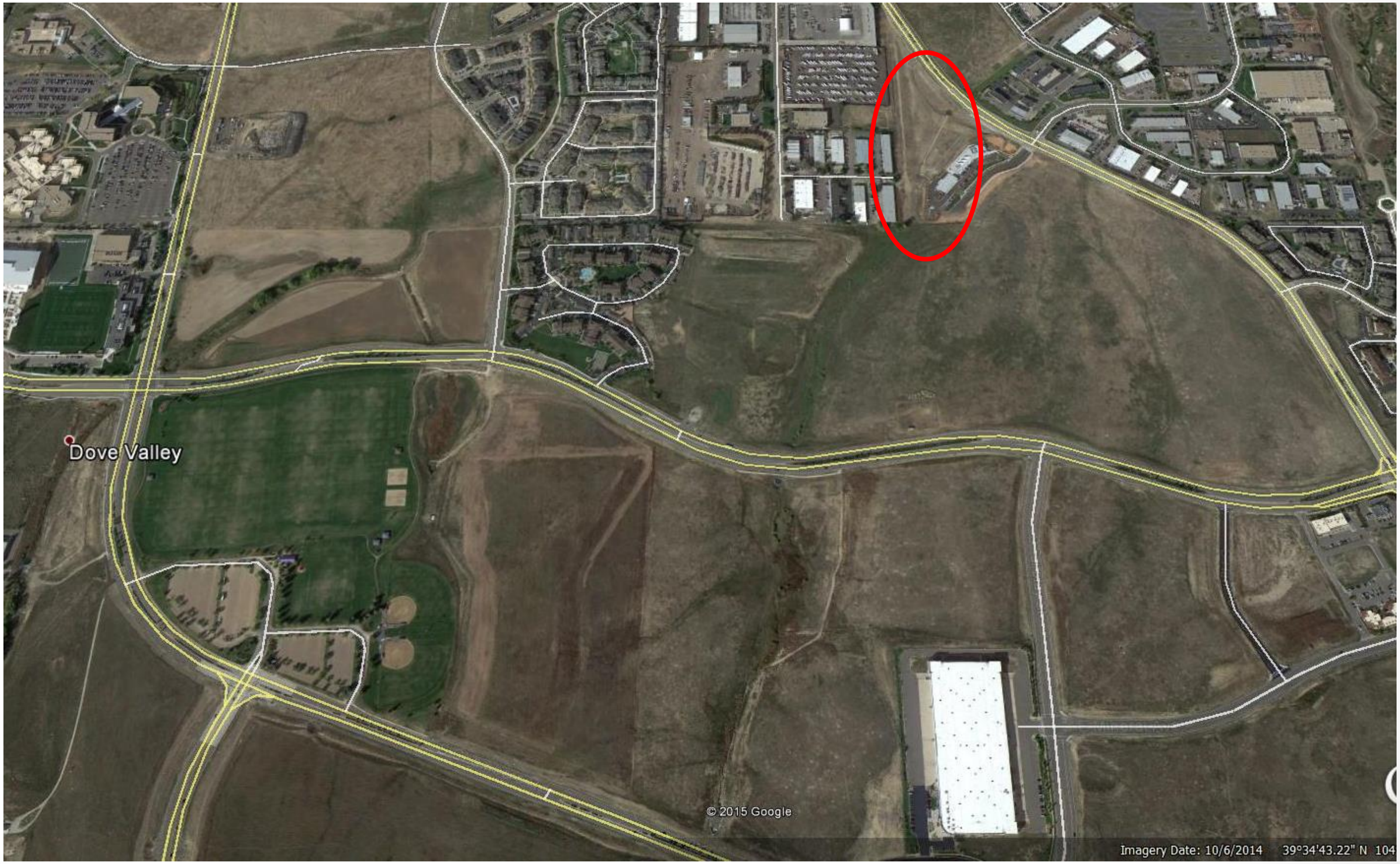
#2


6674 E Iliff Ave
Exit Street View
© 2015 Google
© 2015 Google
Google earth
39°40'28.58" N 104°54'44.29" W elev 5459 ft eye alt 5453 ft

#3


Dove Valley
© 2015 Google
Imagery Date: 10/6/2014 39°34'43.22" N 104

#4


Dove Valley
© 2015 Google
Imagery Date: 10/6/2014 39°34'43.22" N 104

#5

Ventana St
Exit Street View
© 2015 Google
© 2015 Google
Google earth
39°29'12.96" N 104°46'50.02" W elev 5970 ft eye alt 5960 ft

#6


10608 Longs Way
Exit Street View
Google earth
© 2015 Google
© 2015 Google
39°31'28.80" N 104°45'53.42" W elev 5876 ft eye alt 5884 ft

#7


S Twenty Mile Rd
Exit Street View
Google earth
© 2015 Google
© 2015 Google
Report a problem
39°31'24.01" N 104°46'37.25" W elev 5818 ft eye alt 5827 ft

#8


S Buckley Rd
Exit Street View
Google earth
© 2015 Google
© 2015 Google
Report a problem
39°36'32.99" N 104°47'28.50" W elev 5701 ft eye alt 5712 ft

Answers

Needs Water Right (yes)	Exempt (no)
1	3
2	5
4	8
6	
7	

How did we get here?

- 1970’s (probably earlier)
- 1990’s
- 2010’s
- 2015!

1970's

- September 1, 1972
  - C.R.S. 30-28-133; Counties adopt regulations to detain to 100-yr
- September 14, 1972-District and APWA Seminar
  - "discussed … legislation … for on-site detention"
  - "approach which might be used for implementing a regional stormwater detention plan."
  - "water rights are an important consideration."
- 1973-Englewood Dam
  - 1st regional Dam improved by District-Englewood Dam

1990's

- November 16, 1990
  - Phase 1, NPDES regulations go live
  - Water Quality Basin key for MS4 permits
- December, 1999
  - Phase 2, NPDES regulations
  - Water Quality Basin continue to be critical component of permits
    - EDB's (Extended Detention Basins) refined

2010 to 2013

- Fountain Creek – Pueblo
  - Proposed basin-challenged
  - Matrix contacts District – What's Up?

- Aspen
  - WQ Basin-meeting
  - What's Up?

2011-2012

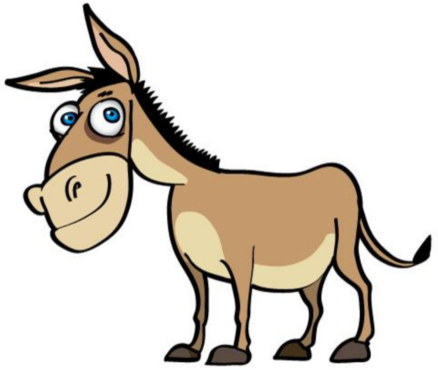
- May 21, 2011-SEO Administrative Approach for Storm Water Management
  - Individual Site release in 72 hours-Okay!
- 2012-Famous Quote to Aspen-Ken MacKenzie

"I'll take care of it."

2014

- April 28-SEO letter to UDFCD.
  - Regional detention basins need water right
  - In time and quantity
- October 29-Letter from SEO to Colorado Springs. Stop it!
  - Deadline April 1, 2015 (not an April Fools joke).

ASSUME=<u>ASS</u> (out of) <u>U</u> (and) <u>ME</u>!



2014

- July-Formed a small task force
  - Colorado Stormwater Council members
  - Best option is legislation
- August-UDFCD hires Bennett Raley
  - Draft conceptual legislation
  - Start conversation with water users
- September-Meet with Colorado Springs
  - Pursue joint legislation to include fire debris basins

2014-15

- December, 2014 District Board passes resolution supporting legislation
- February 22, 2015 The Pueblo Chieftain chieftain.com

  "Farmers … want to ensure junior water rights are not damaged in the process"

- April 1, 2015- The Gazette gazette.com

  "water basins that hold back flood debris … caught up in an unforeseen battle over water rights…"

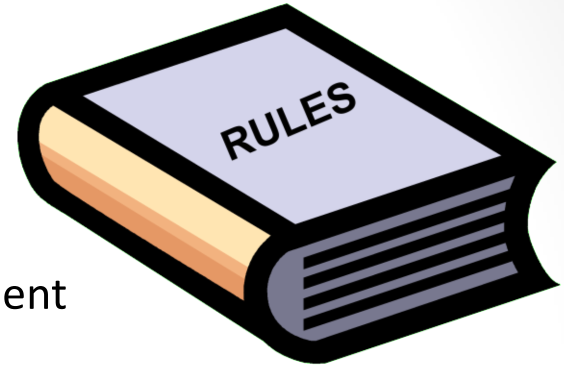
- April 2, 2015

  "We're still trying to find a compromise. I don't know whether we are going to get there or not," Sonnenberg said

Current Status

- Individual Site Stormwater Detention Basins
  - Exempt
- Regional Stormwater Detention Basins
  - Water right for losses in Quantity and Time
  - Only one case-SEO Fountain Creek
- Fire Debris Basin
  - Water right for losses in Quantity and Time
  - Only one case-SEO Fountain Creek

Proposed Legislation



- Regional Stormwater Detention Basin
  - Current basins grandfathered
    - Owned, operated or oversight by government
    - 97% of 5-yr drain in 72 hours
    - 99% of all water in 120 hours
    - Must be passive
  - New
    - Same as above
    - Inform water users – SEO Substitute Water Supply list (Stormwater only)
  - Not injurious - rebuttable presumption
    - Hydrologic condition before development

Proposed Legislation (cont.)

- Fire Debris Basin
  - Non permanent
  - On or adjacent to Non-perennial
  - No notification requirement
- Not injurious - rebuttable presumption
  - Hydrologic condition before fire

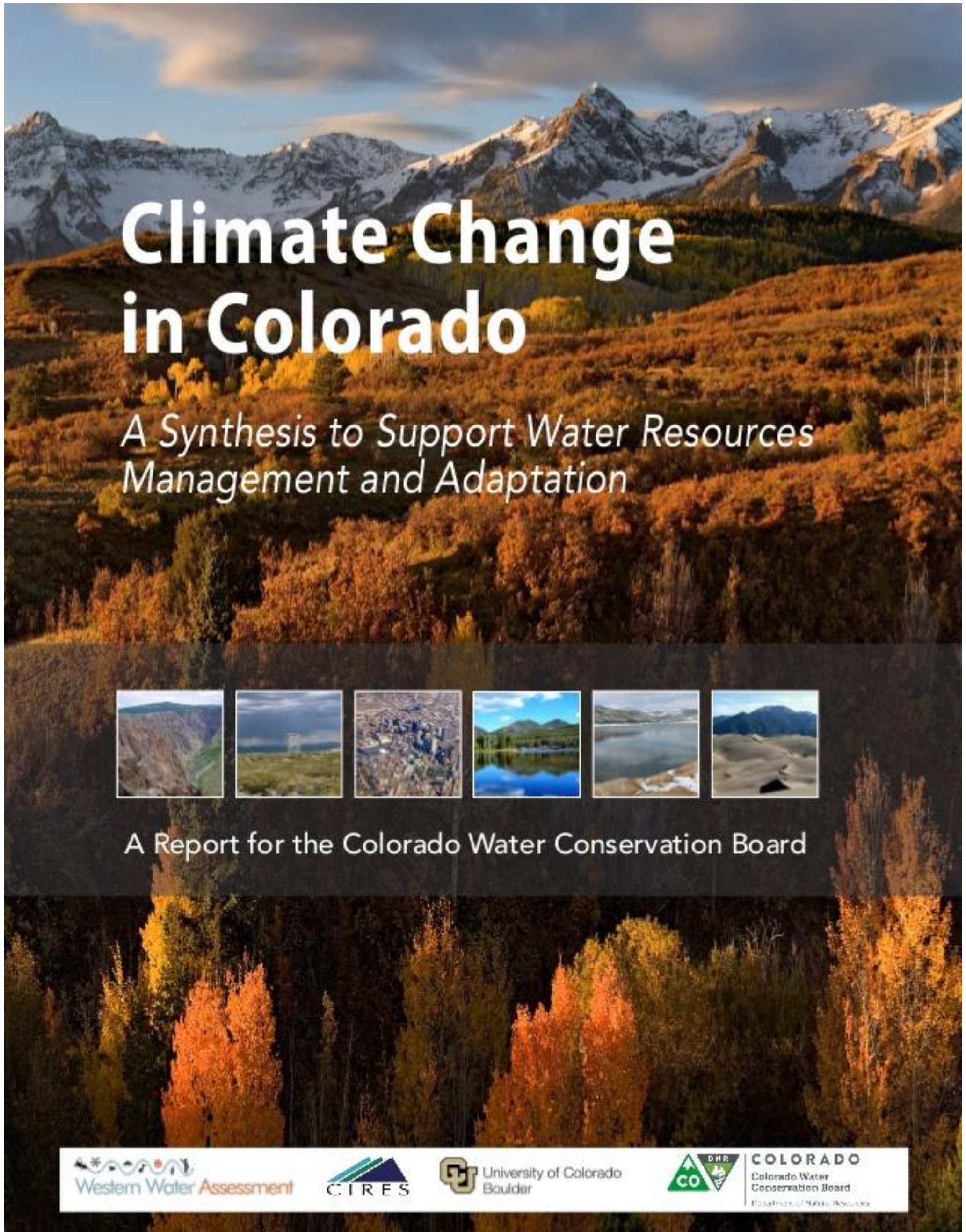
Time Frame

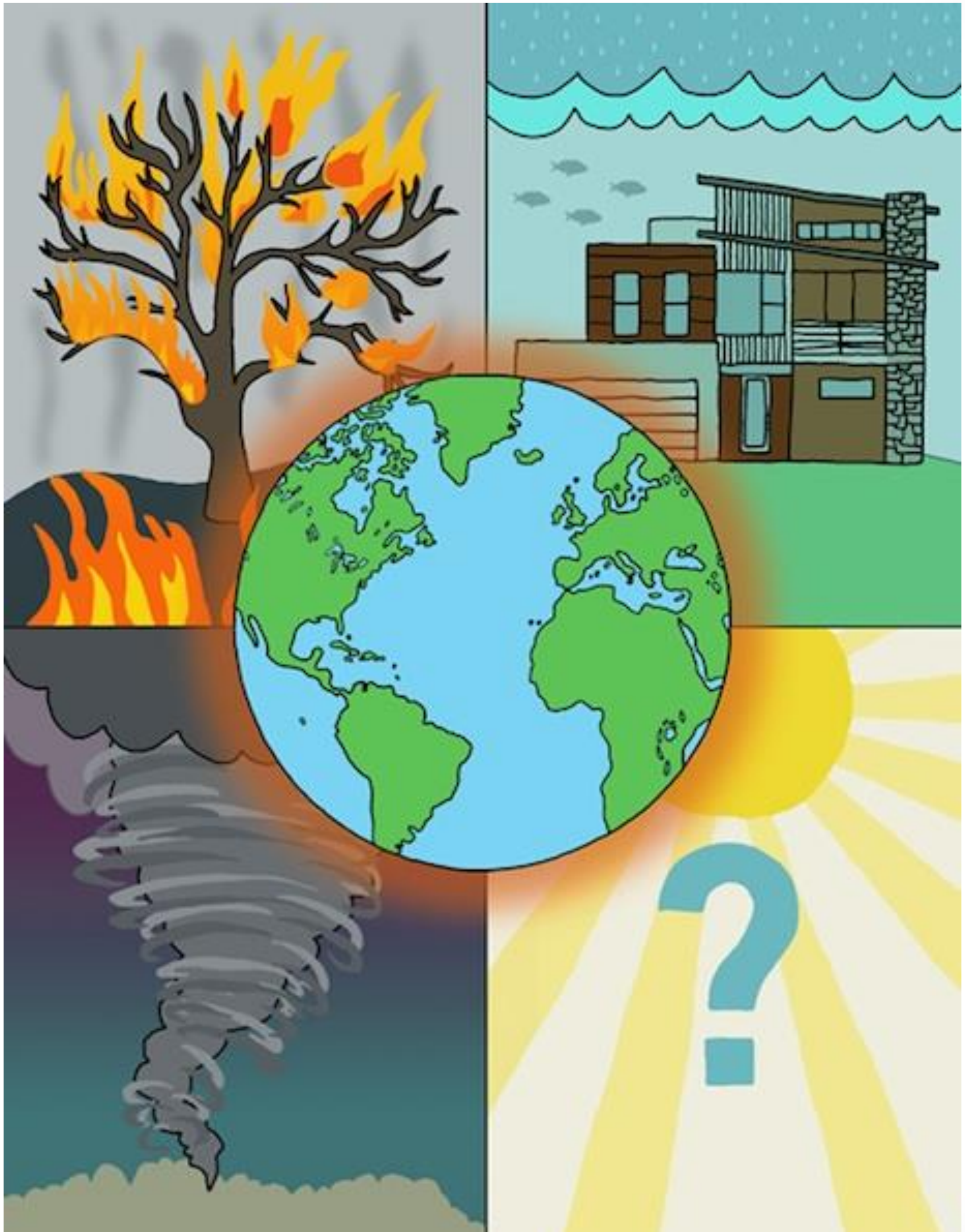
- March 12, 2015
  - SB 15-212 introduced by Senator Sonnenberg
    - Rep. Winter as House sponsor
- April 16, 2015
  - Senate Agricultural Committee
    - Testimony

Planning for Variability & Uncertainty: Climate Change and the UDFCD Urban Drainage System

David Bennetts, P.E.
Manager of Design, Construction, and Maintenance Programs, UDFCD

Dr. Andrew Earles, P.E., D. WRE
Wright Water Engineers, Inc.


Climate Change in Colorado
A Synthesis to Support Water Resources Management and Adaptation
A Report for the Colorado Water Conservation Board
Western Water Assessment
CIRES
University of Colorado Boulder
COLORADO
Colorado Water Conservation Board

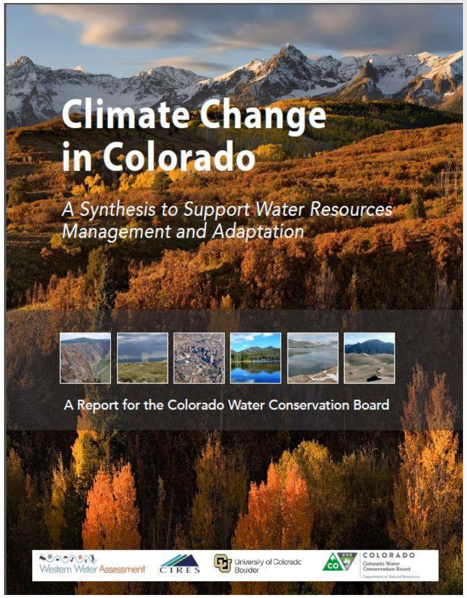



URBAN
STORM
DRAINAGE
CRITERIA MANUAL
Volume 1
Urban Drainage and Flood Control District
Denver, Colorado June 2001
URBAN
STORM
DRAINAGE
CRITERIA MANUAL
Volume 2
Urban Drainage and Flood Control District
Denver, Colorado June 2001
URBAN
STORM
DRAINAGE
CRITERIA MANUAL
volume 3 - best management practices
Urban Drainage and Flood Control District
Denver, Colorado September, 1999

Overview

- What are the climate experts telling us?
  - Temperature
  - Precipitation
  - Stream Flow
  - Drought & Wildfire
- What are potential vulnerabilities of urban drainage systems?
- Adaptive Management for resilience

Major Sources of Climate Information

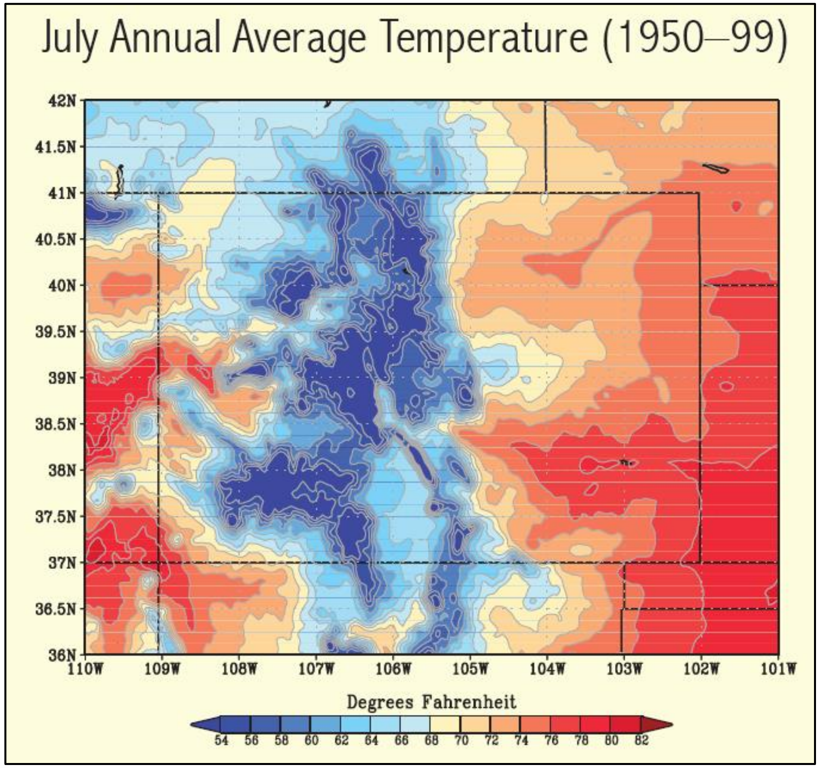


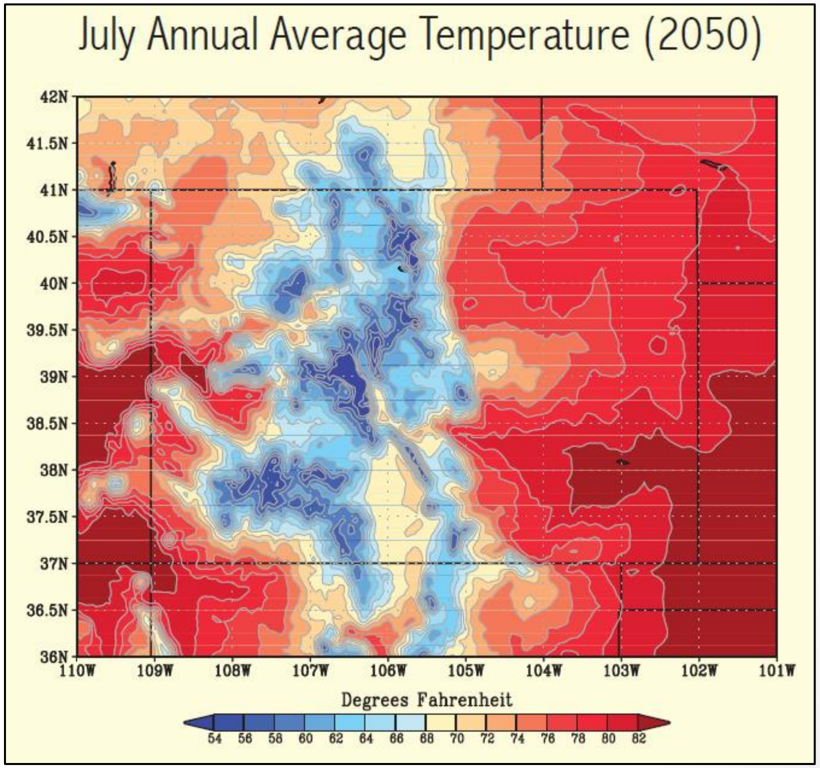
Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.

Contributors:

- Colorado Water Conservation Board
- U.S. Army Corps of Engineers
- CIRES Western Water Assessment
- Colorado Springs Utilities
- Bureau of Reclamation
- U.S. Geological Survey
- Riverside Technology
- Colorado Natural Heritage Program
- Rocky Mountain Climate Organization
- AMEC Environment & Infrastructure
- NOAA ESRL Physical Science Division
- Colorado Parks & Wildlife
- Denver Water
- Colorado River District
- Northern Water
- NOAA NWS Colorado Basin River Forecast Center
- National Center for Atmospheric Research
- City of Thornton
- Colorado State University
- The Nature Conservancy
- Stratus Consulting
- Western Resources Advocates
- Cooperative Institute for Research in Environmental Sciences (CIRES)
- University of Colorado Boulder
- Colorado Climate Center
- NOAA Climate Program

WHAT ARE THE CLIMATE EXPERTS TELLING US?

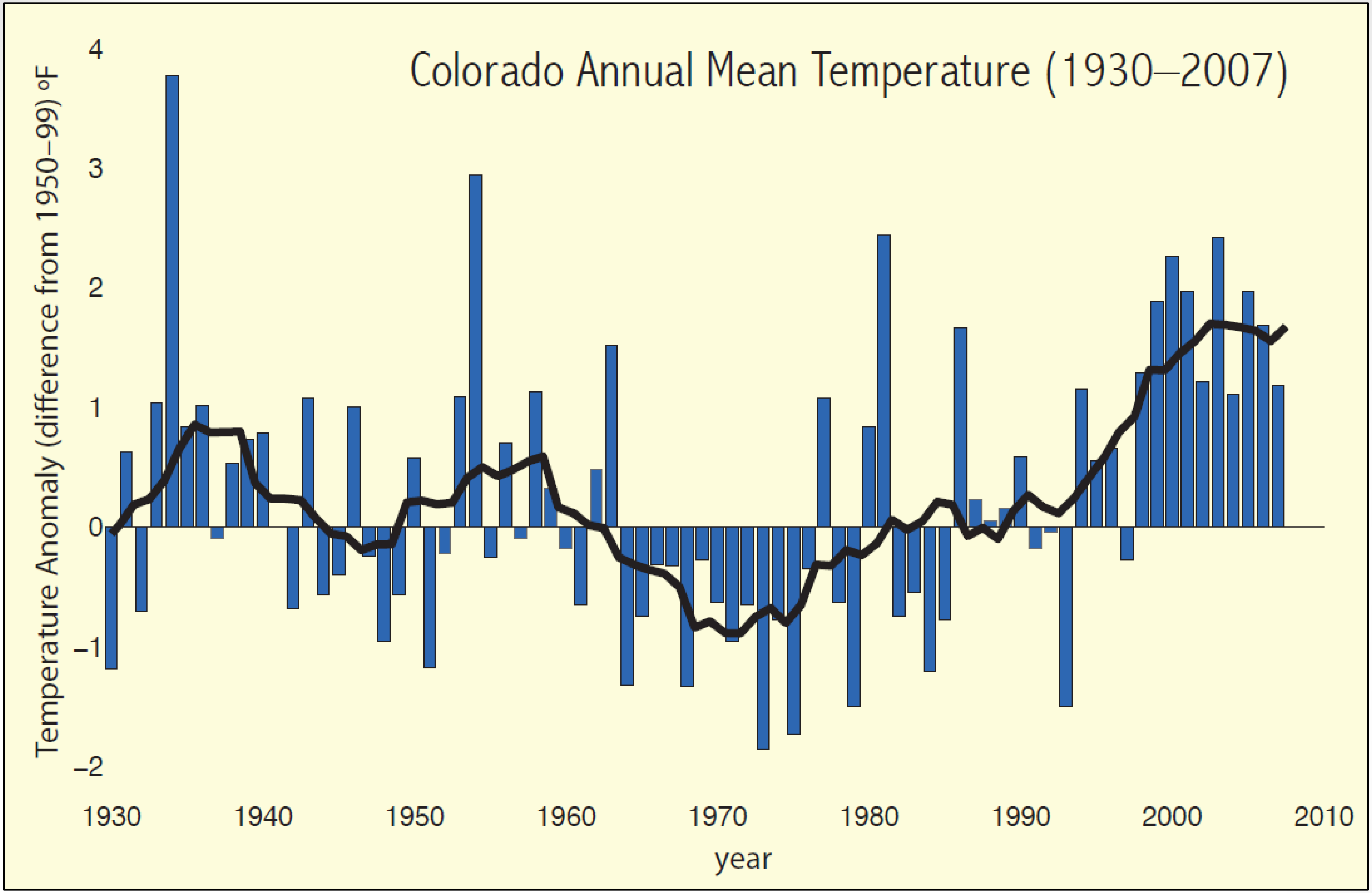




Source: Colorado Water Conservation Board. (2014). Fact Sheet. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

TEMPERATURE

- Mid-21st century summer temperatures for Front Range similar to Eastern Plains today.
- Climate models project Colorado will warm by 2.5°F by 2025 and 4°F by 2050, relative to 1950-99 baseline.
- Summers projected to warm more than winters. Typical summer monthly temperatures expected to be as warm or warmer than hottest 10% of summers from 1950-99.
- By 2050, 54 General Circulation Models predict increases in monthly average temperatures. None predict lower temperatures.

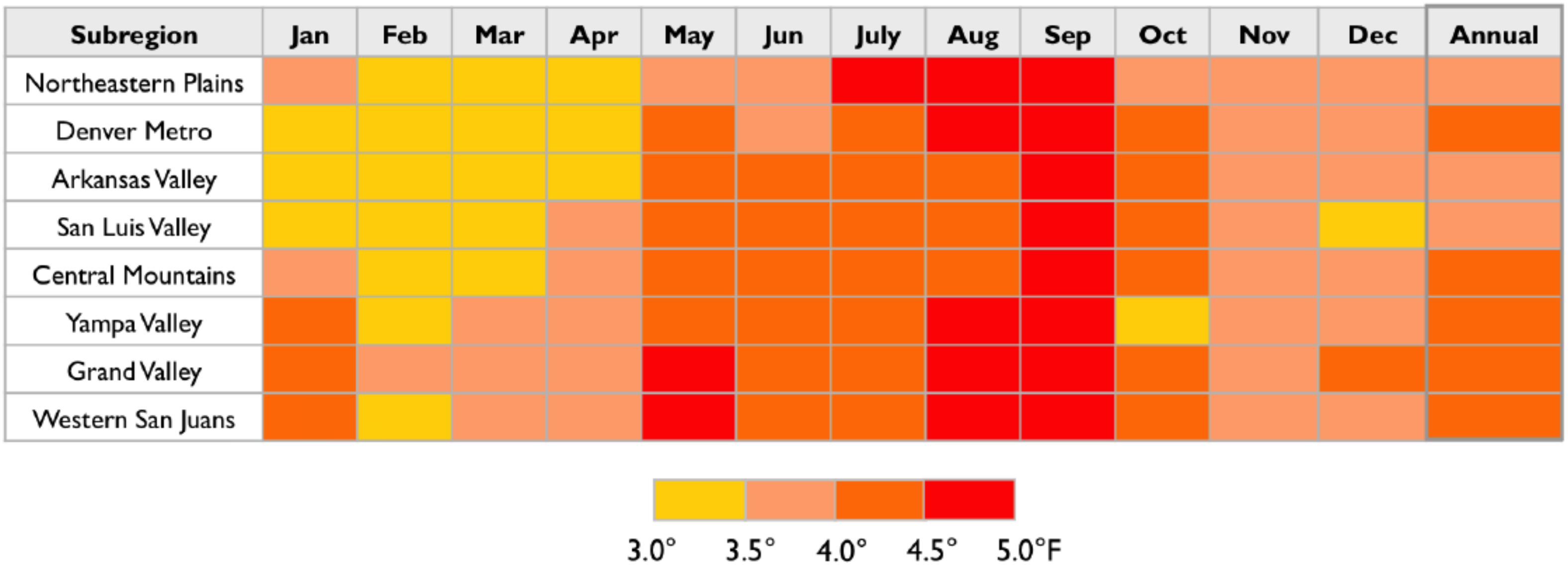


Source: Colorado Water Conservation Board. (2014). Fact Sheet. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

Based on IPCC & UK climate model projections, Colorado temperatures could increase by 3-4°F in spring/fall (range of 1-8°F) and 5-6°F in summer/winter (range of 2-12°F) by 2100.

Seasonal Differences in Warming

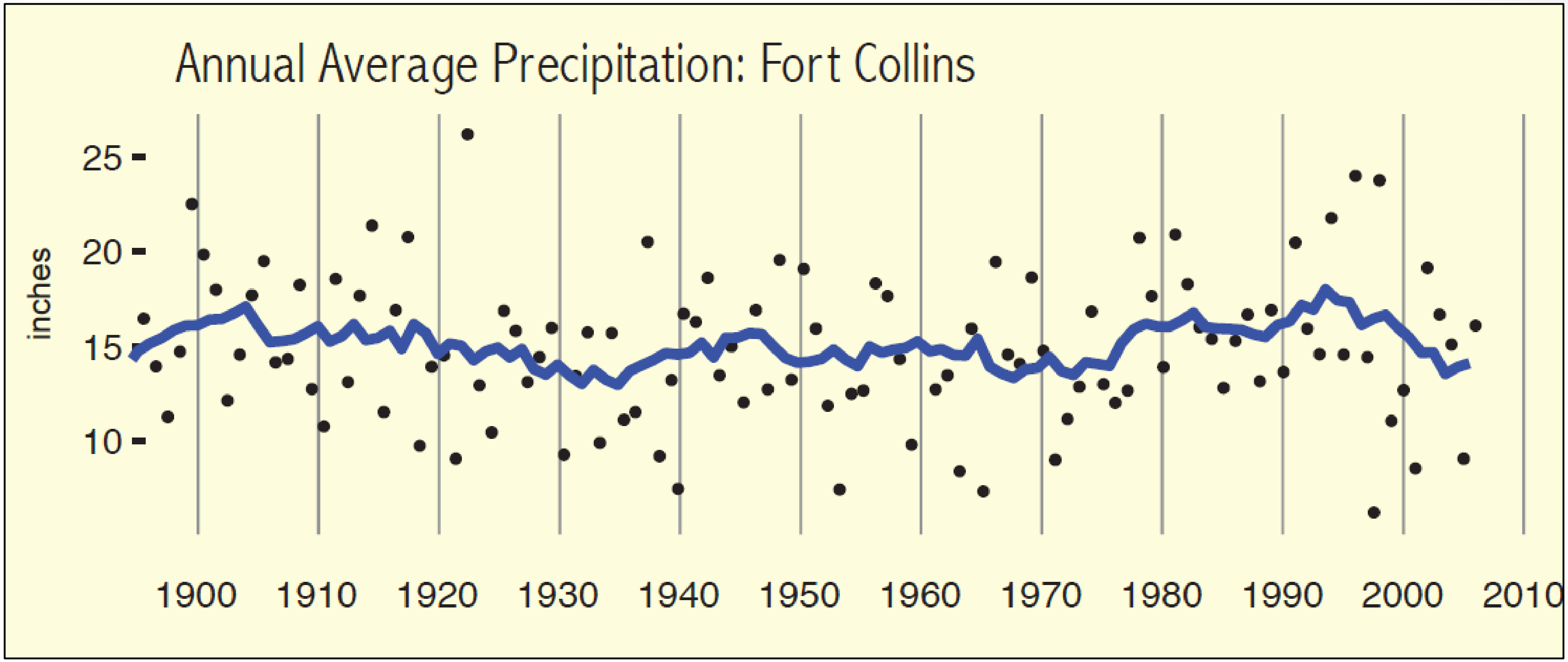
TABLE 5-1. Projected monthly temperature change for eight subregions under RCP 4.5 for 2035–2064



Source: Colorado Water Conservation Board. (2014). Projections of Colorado's Future Climate and Implications for Water Resources. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

- Less relative warming in the winter and early spring
- Most warming in the late summer and early fall

PRECIPITATION



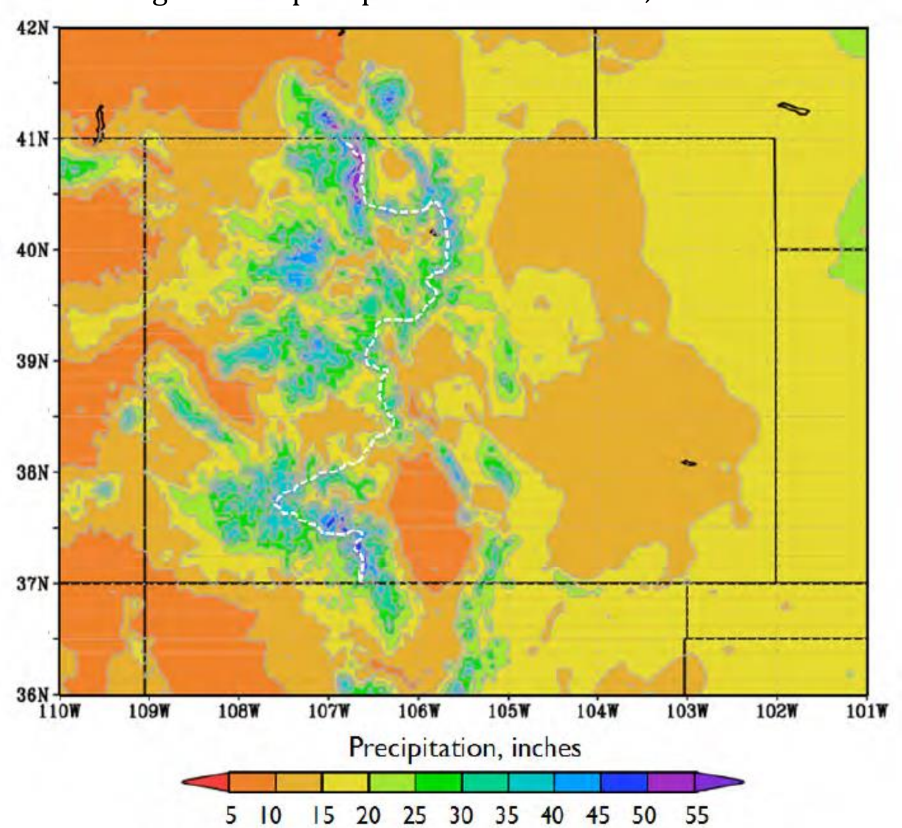
Source: Colorado Water Conservation Board. (2014). Fact Sheet. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

- No consistent long-term trends detected. Variability is high.
- Precipitation more variable than temperature.
- GCM projections: +2.0 inches in rainy months to -1.5 inches (deficit) by 2050, compared to historic data.

PRECIPITATION

- Climate model projections show less agreement regarding future precipitation change for Colorado (especially metro area).
- Individual model projections of change by 2050 in statewide annual precipitation under medium-low emissions scenario range from -5% to +6%.

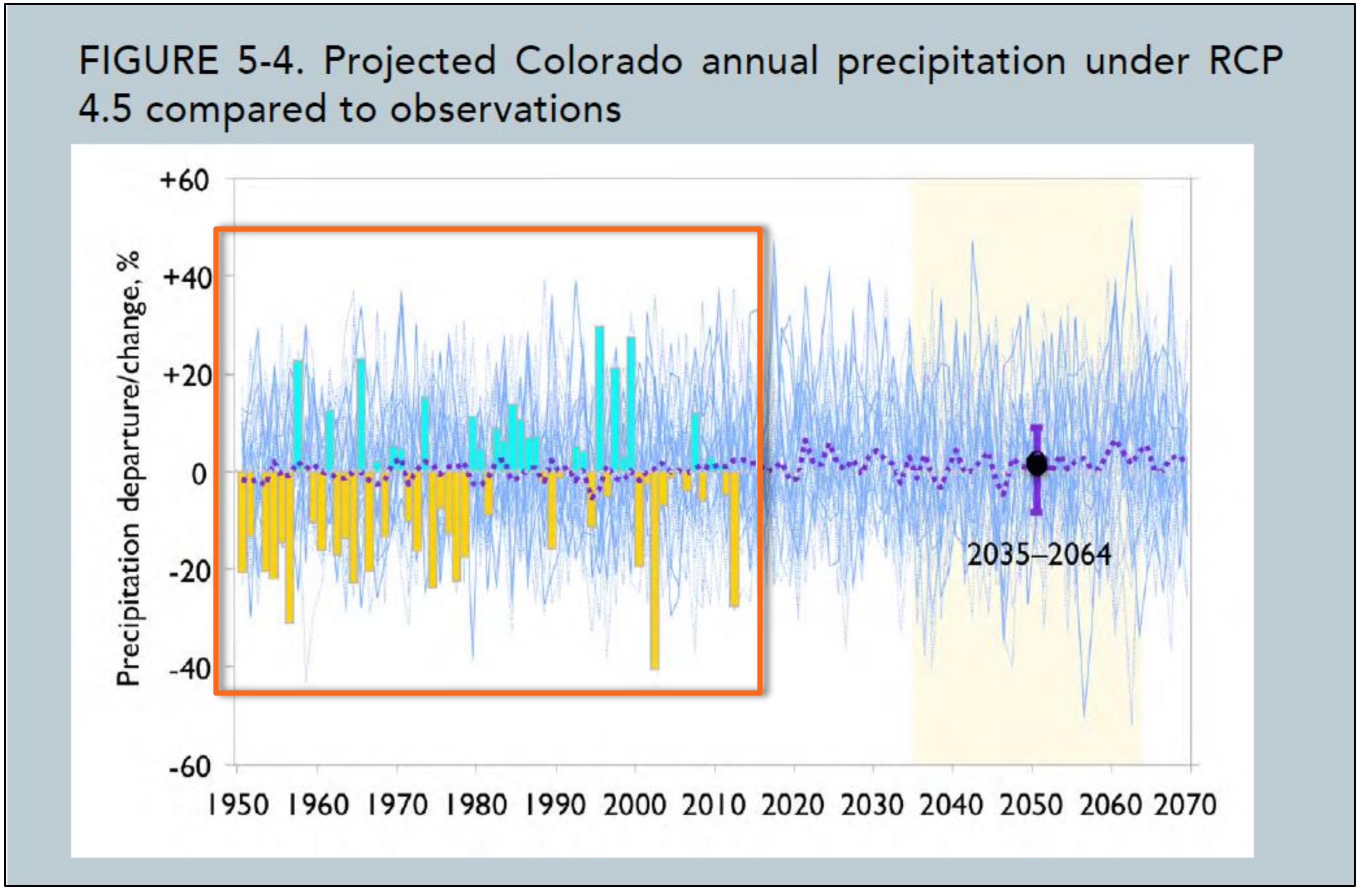
Average annual precipitation for Colorado, 1950-1999



- Projections under a high emissions scenario show a similar range (-3% to +8%).

Source: Colorado Water Conservation Board. (2014). Projections of Colorado's Future Climate and Implications for Water Resources. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

PRECIPITATION



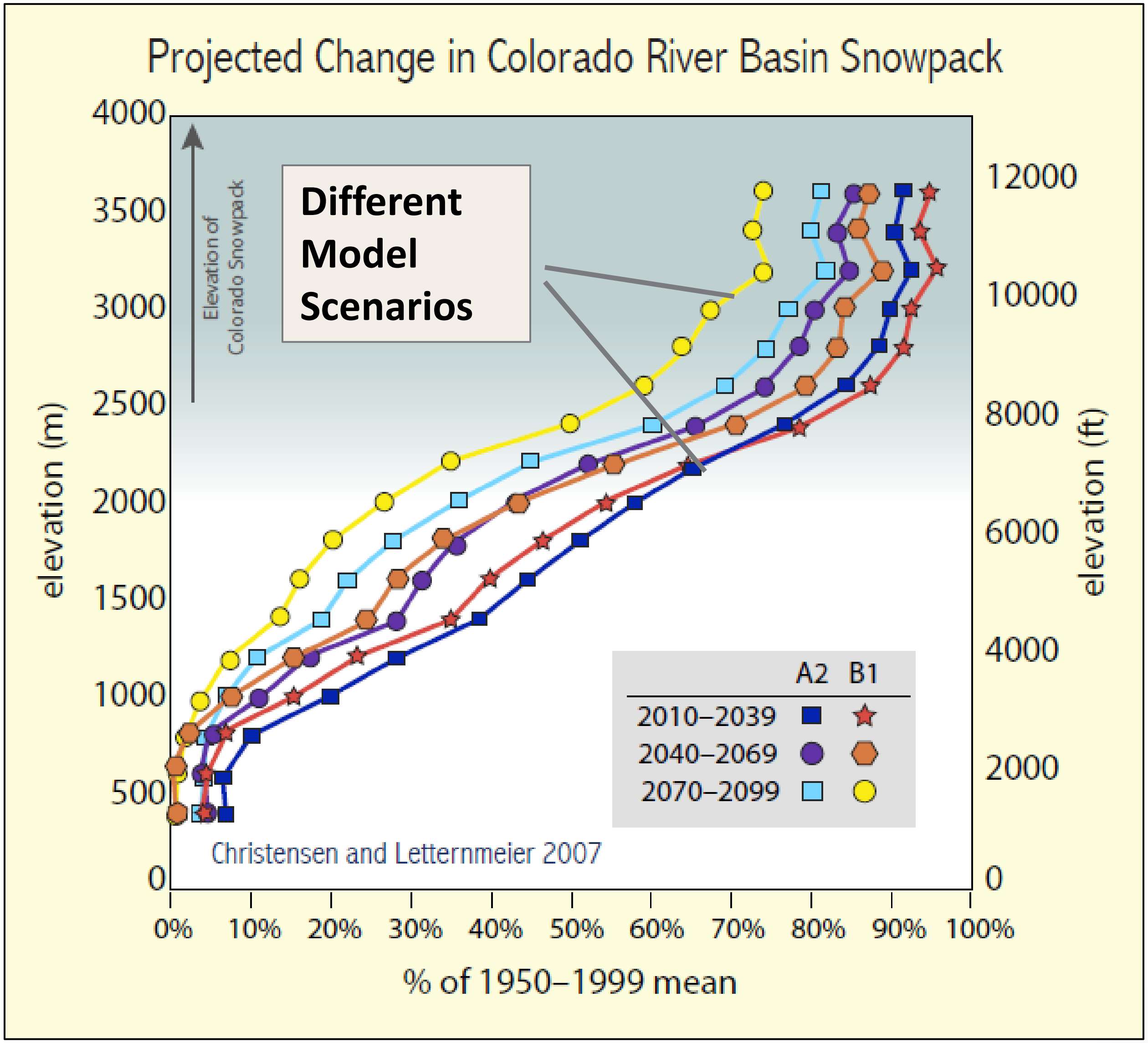
Source: Colorado Water Conservation Board. (2014). Projections of Colorado's Future Climate and Implications for Water Resources. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

Nearly all projections indicate increasing winter precipitation by 2050. Weaker consensus among the projections in the other seasons.

PRECIPITATION

- Difference in temperature between sub-regions greatest in winter and early spring - western slope is projected to warm more than the eastern slope.
- Precipitation totals projected to change little in summer - potential increase in summer thunderstorms frequency with moisture from Gulf of Mexico.
- Spring and fall - precipitation estimated to increase by 10%,
- Winter precipitation could have increases of 20% or more.
- Changes in temperatures may increase evaporation, and in turn precipitation, so the hydrological cycle may also be affected, resulting in more intensive convective storm activity.

SNOWPACK



Source: Colorado Water Conservation Board. (2014). Fact Sheet. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

RUNOFF

- Timing of runoff projected to shift earlier in the spring.

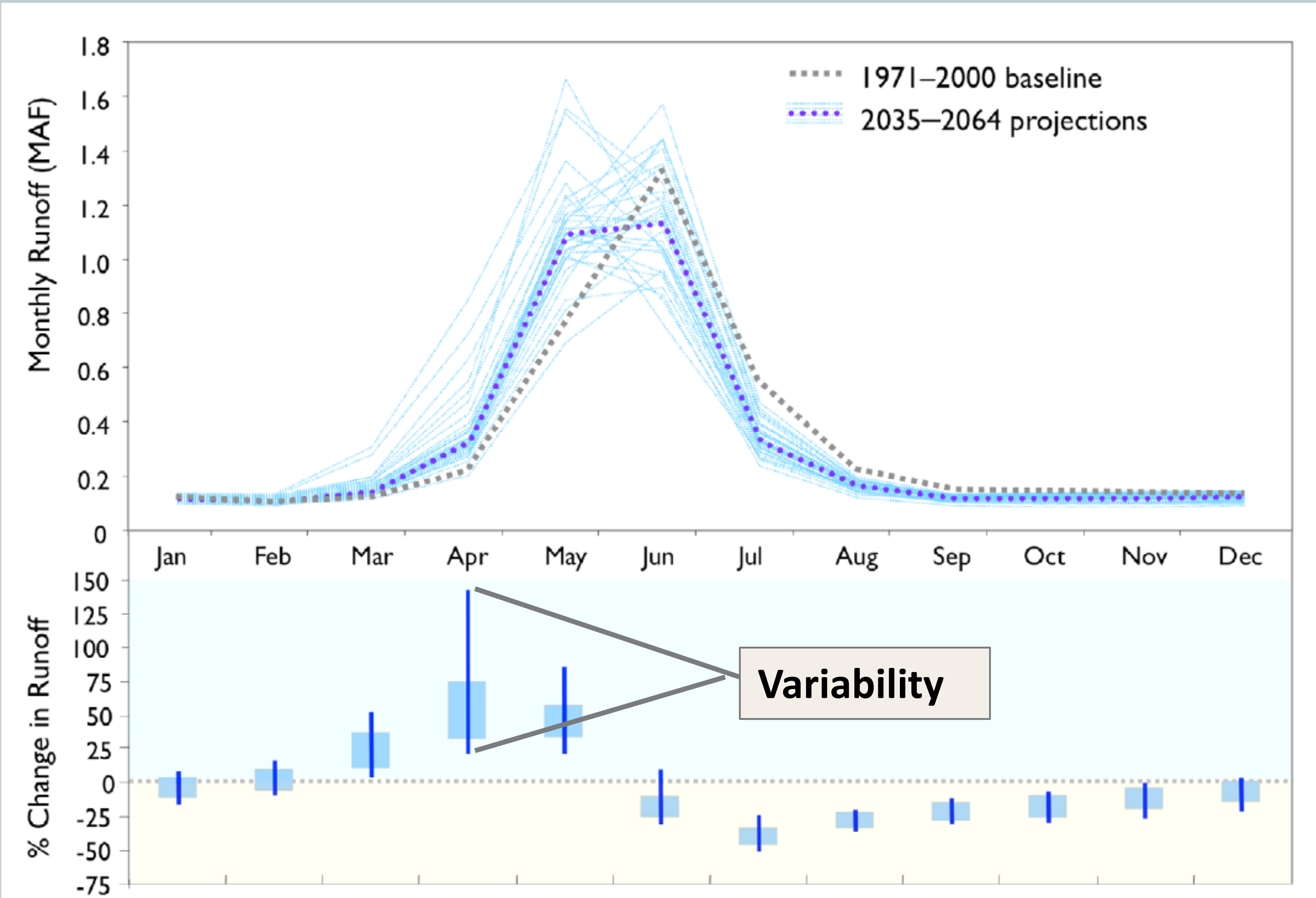
- Late-summer flows may be reduced.

- Recent hydrology projections of declining runoff for most of Colorado's river basins in the 21st century.

- For Upper Colorado River Basin, projections suggest decreases in runoff ranging from 6% to 20% by 2050 compared to the 20th century average.

RUNOFF

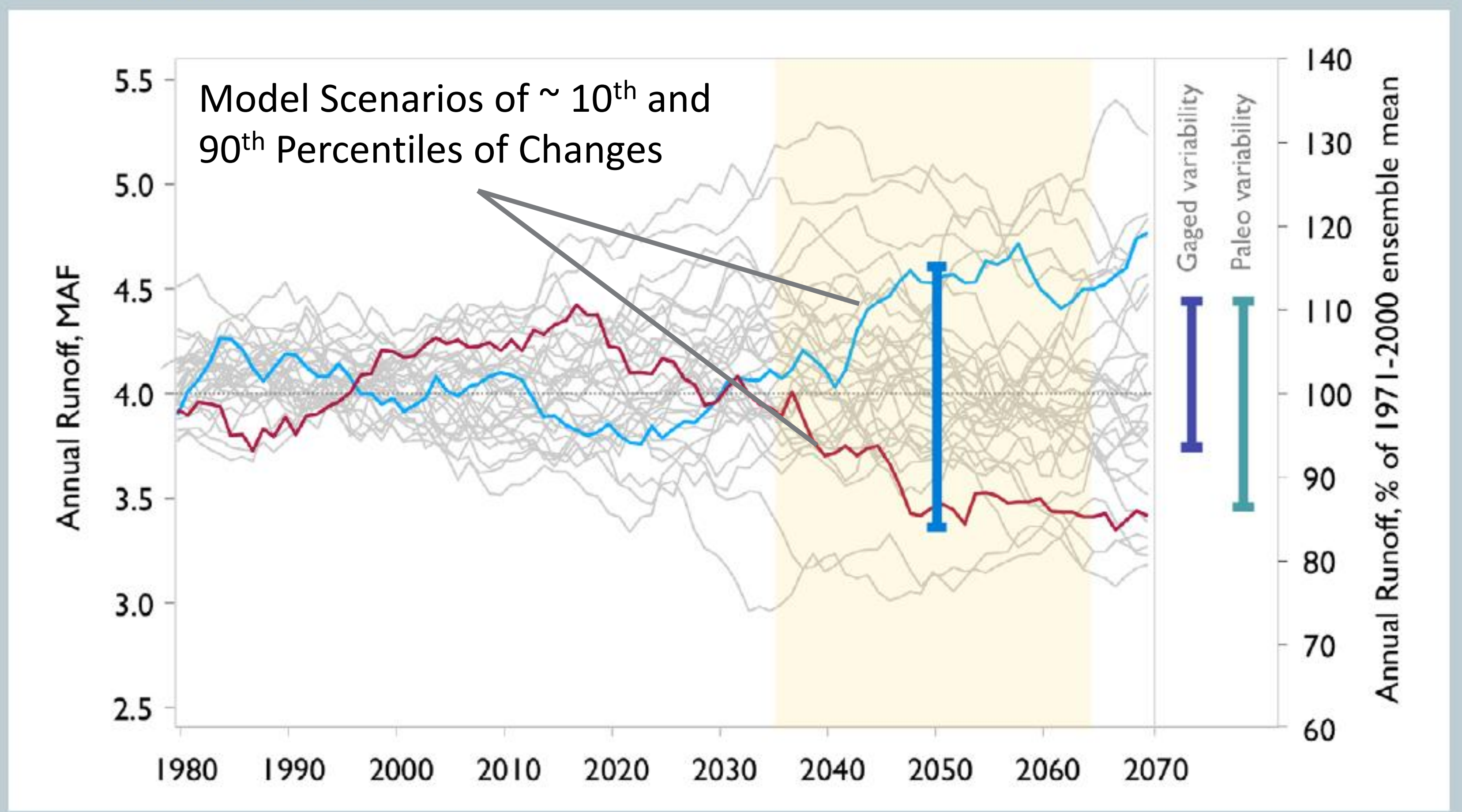
FIGURE 5-16. Projected change in monthly runoff for the Colorado River headwaters



Source: Colorado Water Conservation Board. (2014). Projections of Colorado's Future Climate and Implications for Water Resources. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

RUNOFF

FIGURE 5-15. Projected annual runoff for the Colorado River from 1980–2070 under RCP 4.5



Source: Colorado Water Conservation Board. (2014). Projections of Colorado's Future Climate and Implications for Water Resources. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*.

FLOODING

- Projections for low-frequency events (e.g. 100-year flood) cannot be made with certainty and range from no change to a modest shift to higher frequency.
- Projections for more frequent flood events are also uncertain but indicate possible shifts in frequency.
- Current 10-year → Future 5-year.
- Current 25-year → Future 10-year.

Source: Urban Drainage and Flood Control District, & Wright Water Engineers, Inc. (2014). *A September to Remember: The 2013 Colorado Flood Within the Urban Drainage and Flood Control District*.

DROUGHT

- Most climate projections indicate that heat waves, droughts and wildfires will increase in frequency and severity in Colorado by the mid-21st century.
- Measures of agricultural drought such as soil moisture and Palmer Drought Severity Index (PDSI) are also expected to generally intensify due to warming.

WILDFIRES

- Along Front Range, drier conditions would reduce range and health of ponderosa and lodge pole forests, and increase their susceptibility to fire.

- Milder winters may increase likelihood of insect outbreaks and subsequent wildfires from the dead fuel.

WETLANDS

- Changes in timing, aerial distribution, intensity or form of precipitation (rain, snow, hail, etc.) and increased evaporation/transpiration rates, have potential to affect wetlands.

Urban Drainage and Flood Control District, & Wright Water Engineers, Inc. (2014). *A September to Remember: The 2013 Colorado Flood Within the Urban Drainage and Flood Control District.*

POTENTIAL VULNERABILITIES

Elements of Urban Drainage System

Minor system

- Streets, inlets and storm drains
- On-site detention and water quality facilities
- LID/ Green Infrastructure

Watersheds

- Urban
- Mountain

Major system

- Channels/streams – hydrology
- Channels/streams – water quality
- Floodplains
- Wetlands
- Trails
- Riparian and aquatic ecosystems
- Regional water quality & detention facilities

Vulnerabilities - Streets, Inlets and Storm Drains

Precipitation

- Runoff frequency & magnitude (minor events)
- More precipitation in winter months/ icing
- Maintenance
- Pipes versus open channels

On Site Detention Ponds/Water Quality Ponds

Temperature

- Heat stress on vegetation
- Greater evaporation/ET

Precipitation

- More frequent summer runoff/inter-event time
- Increased winter runoff/pollutant stress on vegetation
- Maintenance

LID and Green Infrastructure

Temperature

- Potential plant "palette" changes
- Runoff temperature moderation effects
- Temperature affects kinetics of biological, chemical and physical processes

Precipitation

- Increased frequency of inundation/vegetation stress
- Maintenance
- Winter pollutant (sand, chloride) loads may increase and affect vegetation and maintenance

Channels/Streams Hydrology

Temperature

- Earlier runoff, lower stream flow in summer/fall

Stream Flow

- Lower baseflows and earlier runoff from major urban streams

Precipitation

- More frequent stormwater flows → increased erosion potential
- Lower flows and/or dry channels in late summer/fall
- Potentially more “flashy” hydrology
- More frequent flooding in areas with undersized major drainageways

Channels/Streams Water Quality

Temperature

- Increased water temperature decreases dissolved oxygen and affects other parameters
- Increased stream temperatures and lower flows may affect aquatic ecosystems

Precipitation

- More frequent runoff/pollutant loading with increased runoff temperatures in summer
- More winter precipitation snow/ice/rain or mix and use of sand and deicers/chlorides

Stream Flow

- Lower flows/ earlier runoff would increase water temperatures
- More streams may be intermittent
- Stormwater runoff may have more pronounced impact on stream water quality with lower flows

Floodplains

Temperature

- Characteristics of vegetation may change with stresses of temperature and drought

Stream Flow

- No significant direct impacts, aside from water availability for vegetation

Precipitation

- More frequent flooding in areas with local drainage problems/undersized systems
- Floodplains preserved with allowance for freeboard should still provide similar level of protection
- Frequency of out of bank flows may increase

Urban Drainage and Flood Control District, & Wright Water Engineers, Inc. (2014). *A September to Remember: The 2013 Colorado Flood Within the Urban Drainage and Flood Control District.*

Wetlands

Temperature

- Increased evapotranspiration – more water required
- Transition of some wetland areas to transitional areas and some transitional areas to uplands

Precipitation

- Greater pollutant loading from sand and deicers/chlorides associated with increased winter precipitation

Stream Flow

- Decreased availability of water to sustain wetlands
- If water levels (surface or groundwater) decline, wetland vegetation may be displaced

Trails

Precipitation/Runoff Frequency

- More frequent trail inundation
- Increased maintenance frequency

Riparian Corridor Ecosystems

Temperature

- Increased temperatures may shift make up of aquatic ecosystems
- Types of vegetation successful along riparian corridors may shift (drought and flood tolerance)

Stream Flow

- Decreased water availability & increased temperatures may alter character of vegetation

Precipitation

- Systems likely to experience greater fluctuations of drought and flooding
- Declines in stream flow would make less water available, especially in late summer and fall
- May increase maintenance requirements

Detention Storage & Water Quality Facilities

Temperature

- Heat stress on vegetation
- Greater evaporation/ET from ponds with permanent water surface or wetland ponds
- Increasingly greater difficulties in water rights for BMPs that have permanent water features

Precipitation

- More frequent operation at minor event stages as well as more frequent floods in the 10- to 50-year range
- Potentially more frequent operation at major event stage, but models are highly uncertain
- Increased maintenance requirements

Stream Flow

- Facilities with permanent pools or wetlands may be more likely to dry out if there is decreased water availability

Vegetation/Erosion

Temperature

- Increased wildfire risk/ debris flow and flooding problems
- Changes in vegetation (native and urban) due to higher ET, greater water conservation, etc. affect erosion potential

Precipitation

- Lack of precipitation in late-summer and early fall & warmer temperatures may stress some types of vegetation
- Increased erosion from more frequent intense rainfall in areas with poor quality vegetative cover

Stream Flow

- Indirect impacts - increases in water conservation, decreases in irrigated areas, etc. may affect runoff and erosion characteristics in watersheds

Runoff

Temperature

- Increased runoff temperatures runoff
- Less spring runoff, earlier in season

Precipitation

- Increased frequency of runoff from small events, increase in frequency of flows exceeding minor system capacity
- Increased load of pollutants associated with winter runoff

Stream Flow

- Indirect impacts - increases in water conservation, decreases in irrigated areas, etc. may affect runoff and erosion characteristics in watersheds

Pollutant Loading

Temperature

- Potential increases in erosion from decreased vegetative cover
- Increased runoff temperatures in streams

Precipitation

- More frequent runoff/pollutant loading in summer with increased runoff temperatures, often in times of low stream flow
- More winter precipitation snow/ice/rain or mix may increase loads of sand and deicers/chlorides

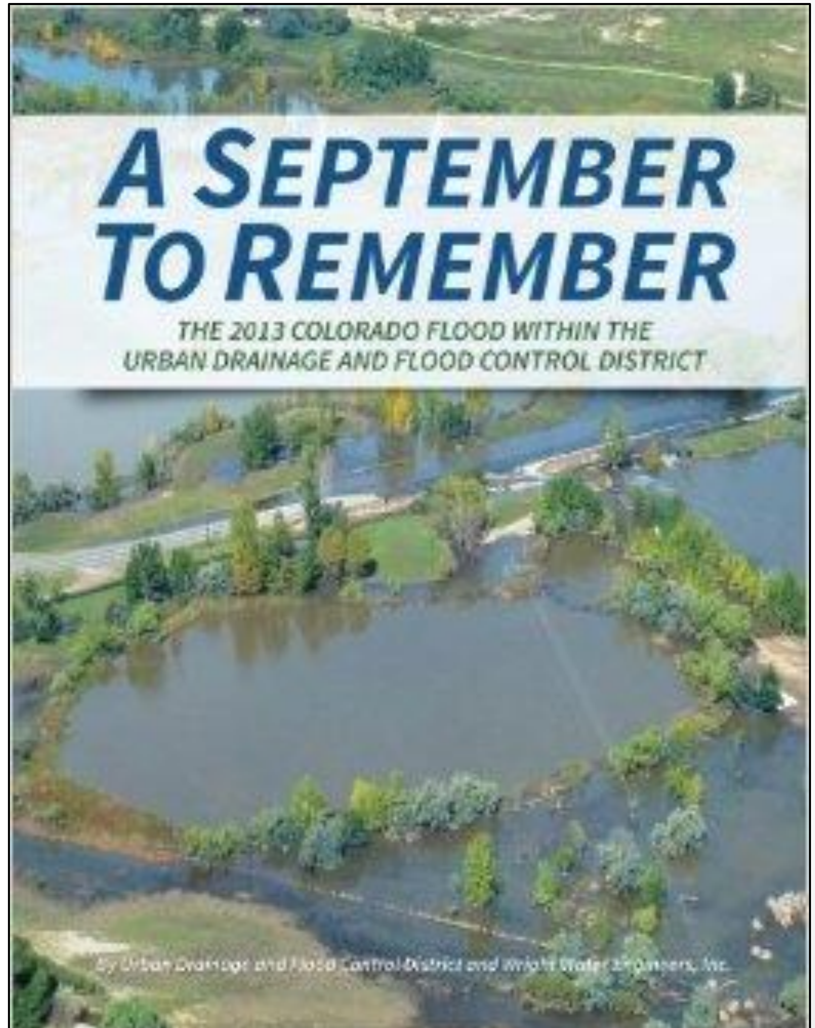
Stream Flow

- Indirect impact of lower stream flow may lead to increases in water conservation, decreases in irrigated areas, etc. that could affect runoff and erosion characteristics in watersheds

RESILIENCE

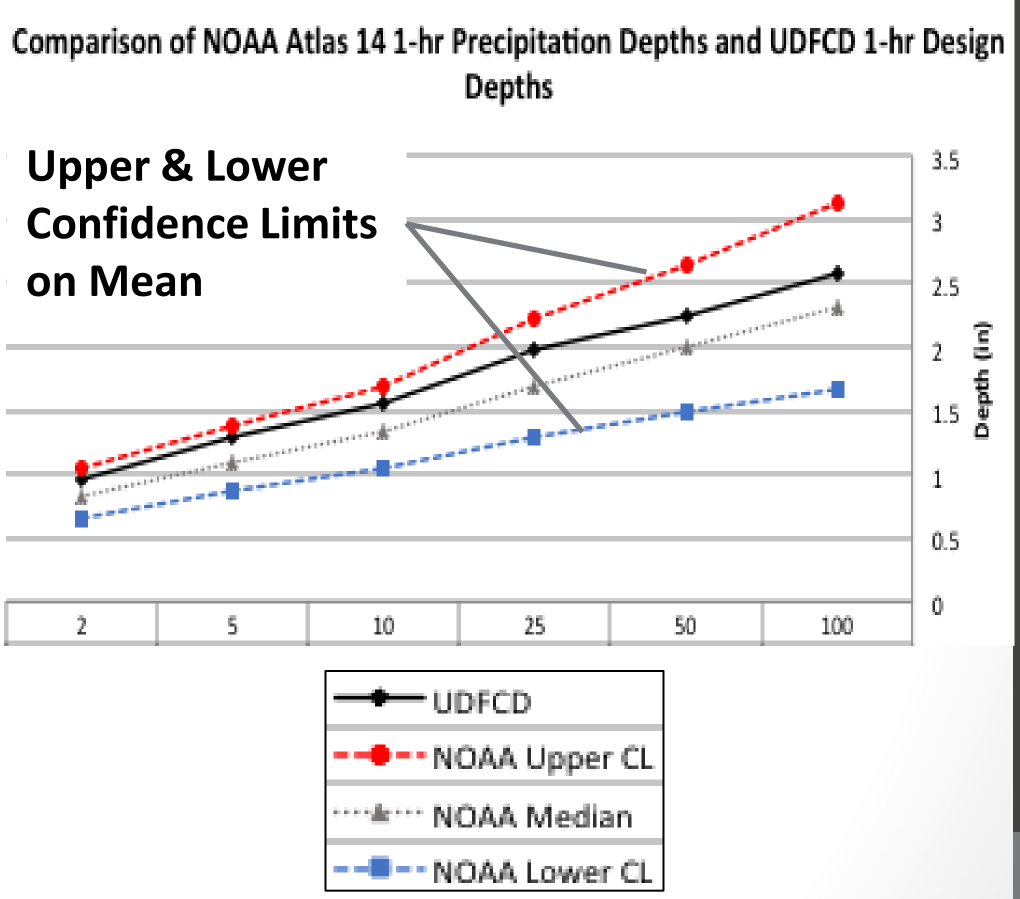
UDFCD Programs & Policies

- Master Planning
  - Urban Storm Drainage Criteria Manual
- Floodplain Management
- Design Construction & Maintenance
- Information Services and Flood Warning
- Institutional



Master Planning & Criteria

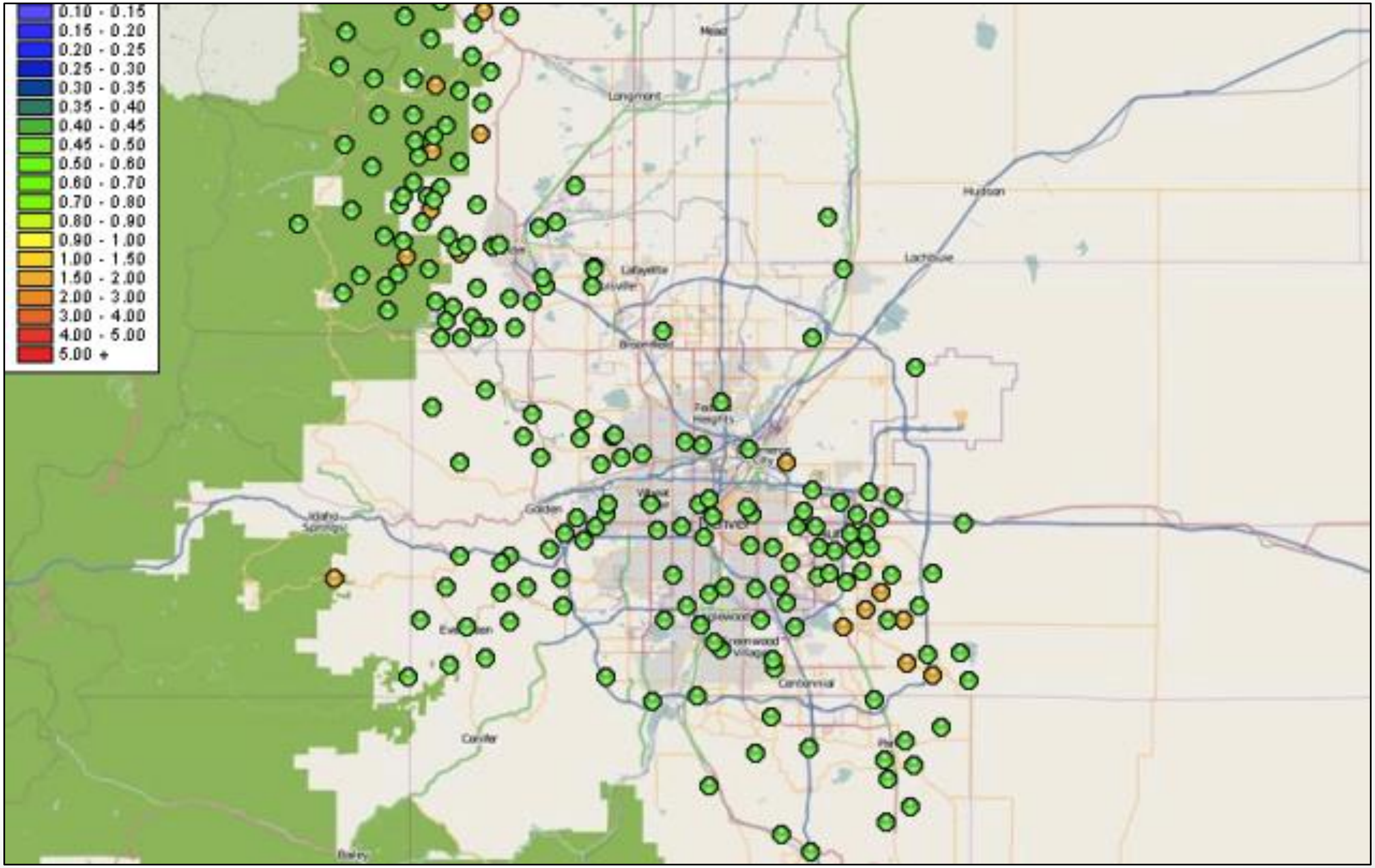
- Effective Master Planning process with updates over time as conditions and state-of-practice evolve
- Rainfall (UDFCD/NOAA Atlas 2 versus NOAA Atlas 14)
- Runoff
  - Fully developed conditions
  - Inadvertent storage/on site detention
  - Conservative modeling assumptions
  - Open channels versus pipes



Floodplain Management

- UDFCD Floodplain Preservation & Good Neighbor Policies
  - Natural and beneficial functions and uses of floodplains
- FEMA Cooperating Technical Partner
- Freeboard Criteria
- Conservative Floodplain/Floodway Modeling Practices
- Public Information

Flood Warning & Information Services



Design Construction & Maintenance

- Reduce flood risks by promoting healthy streams that provide an effective urban drainage system
- UDFCD has constructed and maintained improvements for the past 4 decades
- Despite progress, there are many areas where improvements remain to be implemented
- Collaborative design and construction approach focused on natural beneficial functions

Adaptive Management

Items with Cost Considerations

- Erosion Potential
- Increased Maintenance

  (Stream Management)
- Adapting Vegetation

Planning for Variability and Uncertainty: Climate Change and the UDFCD Urban Drainage System

Adaptive Management

Acknowledgements

- UDFCD & WWE staff involved in developing and refining white paper – Ken MacKenzie, Kevin Stewart, Laura Kroeger, Holly Piza, Shea Thomas, Dave Skuodas, Julia Traylor, Shannon Tillack, Jonathan Jones and others.

- Peer reviewers:
  - Ben Urbonas, P.E., former Manager of Master Planning at UDFCD
  - Bill DeGroot, P.E., former Manager of Floodplain Management at UDFCD
  - Dr. Balaji Rajagopalan, University of Colorado, Boulder
  - Nolan Doeskin, Colorado State Climatologist

Thank You


THIS IS THE SOLUTION WE'VE DEVISED FOR DEALING WITH THE FLOODING CAUSED BY CLIMATE CHANGE.
Chris Madden

Beyond ALERT: Hydro Models, Risk Assessment & GARR…

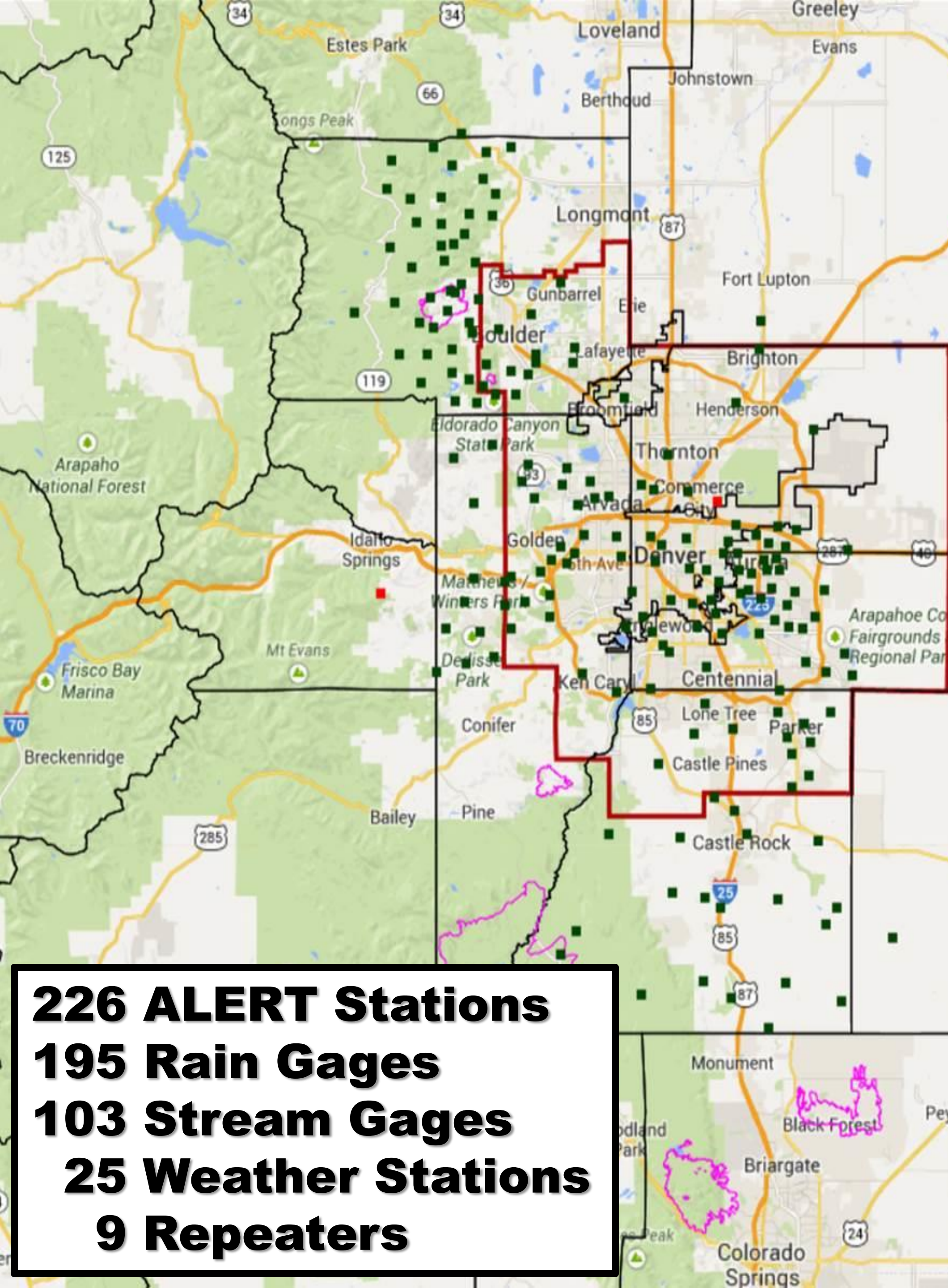
Gauge Adjusted Radar Rainfall

Kevin Stewart, P.E., Manager
Information Services & Flood Warning Program

The ALERT System

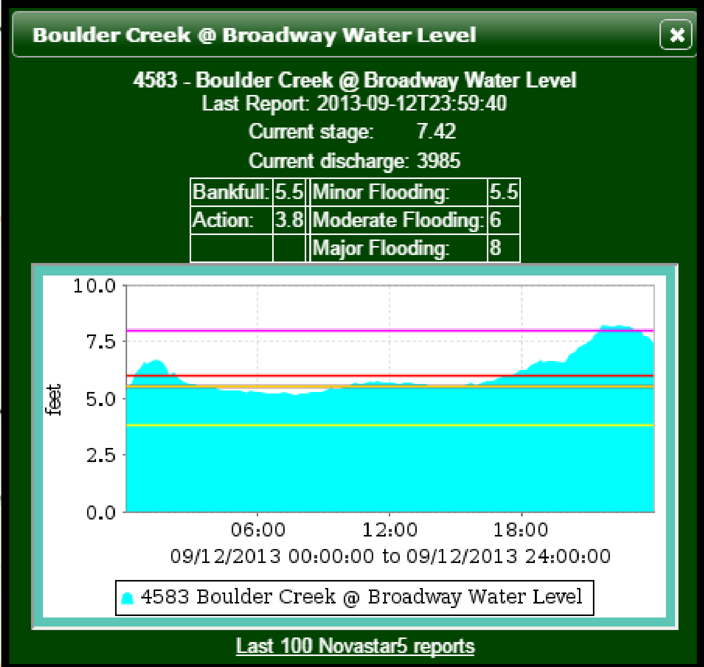
"Automated Local Evaluation in Real-Time"

BEYOND WHAT?



The ALERT System

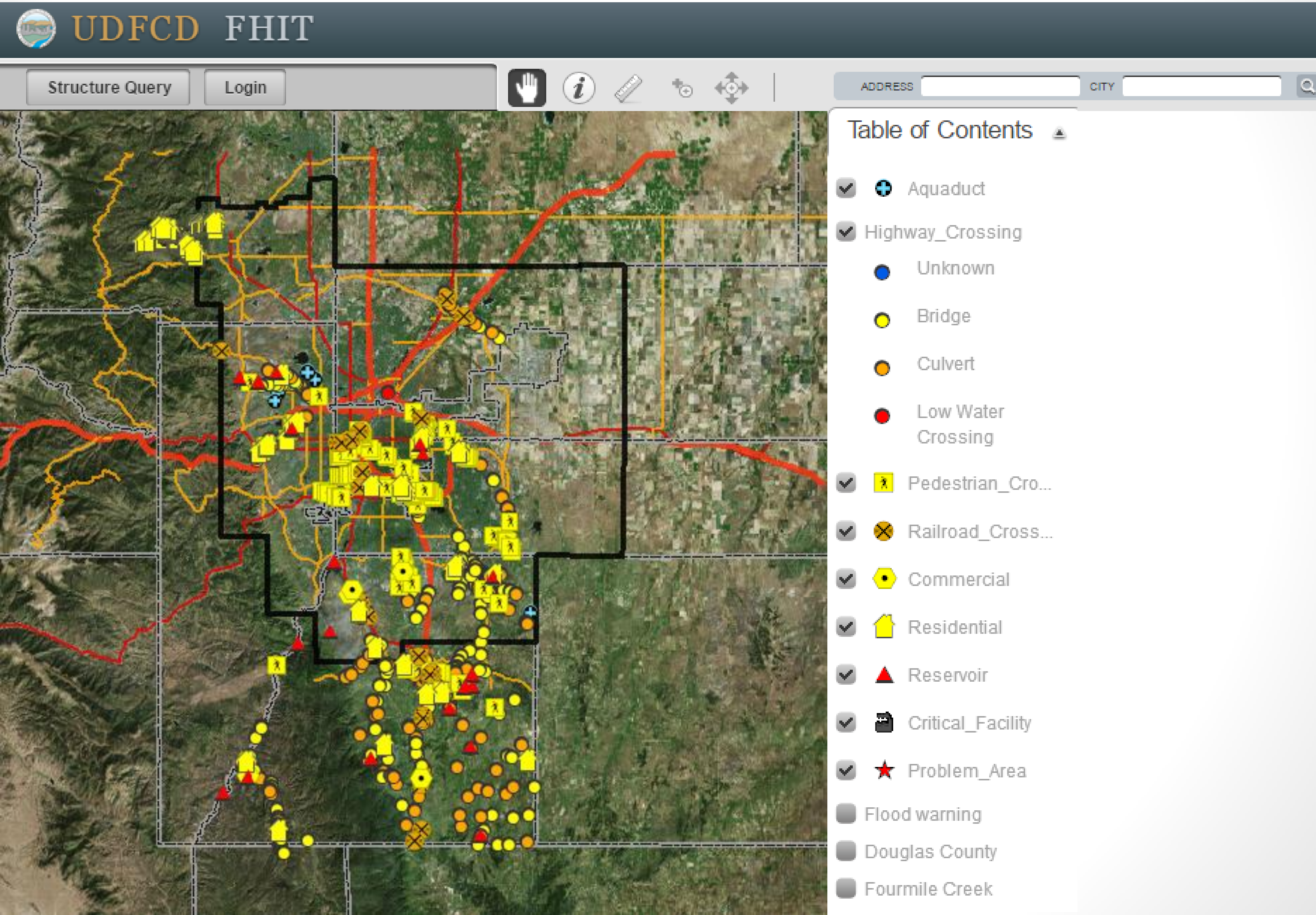
226 ALERT Stations
195 Rain Gages
103 Stream Gages
25 Weather Stations
9 Repeaters



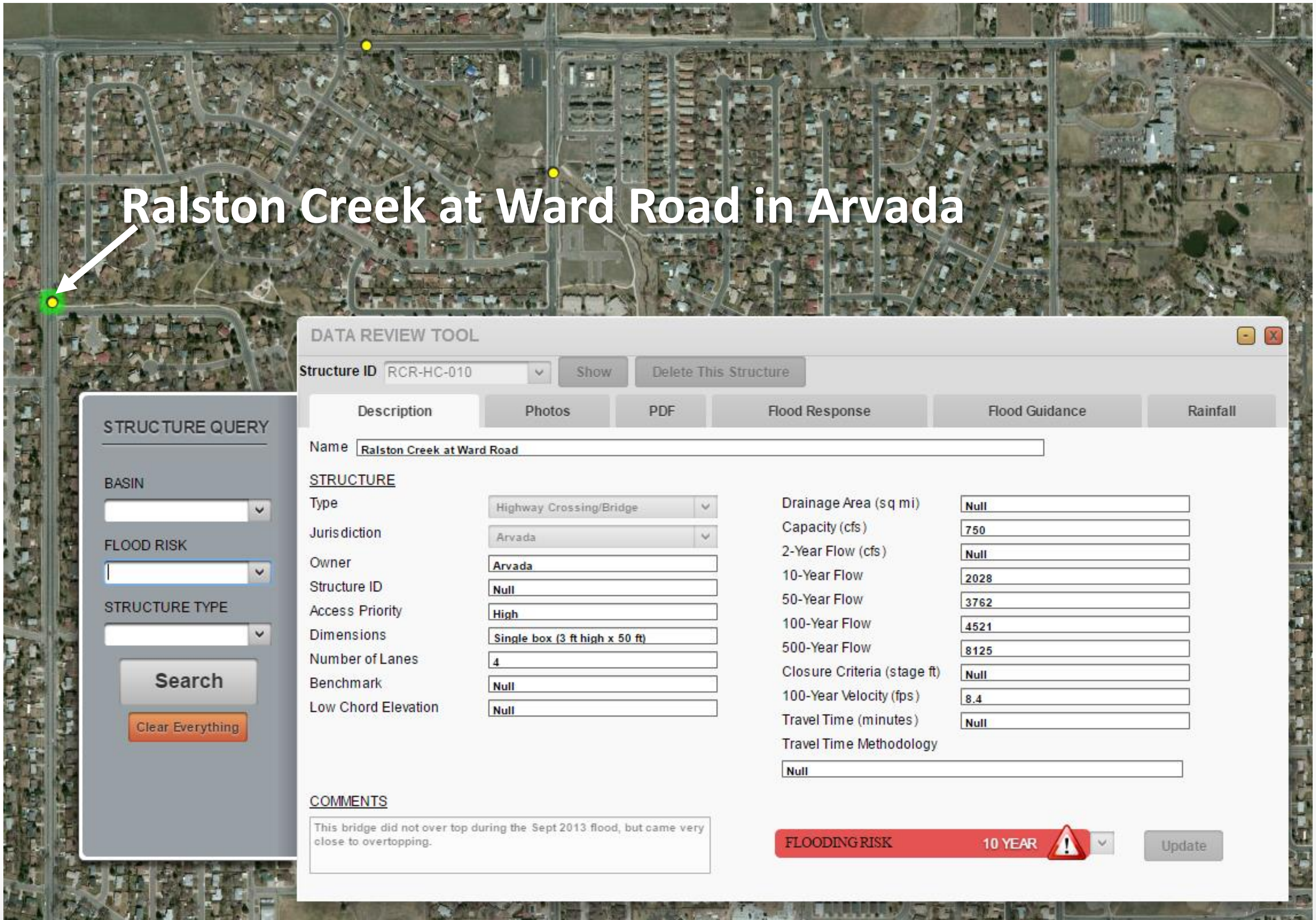
Flood Risk Assessment…*understanding the risks, having a plan, knowing what to do & practicing what to do.*

THE BASICS

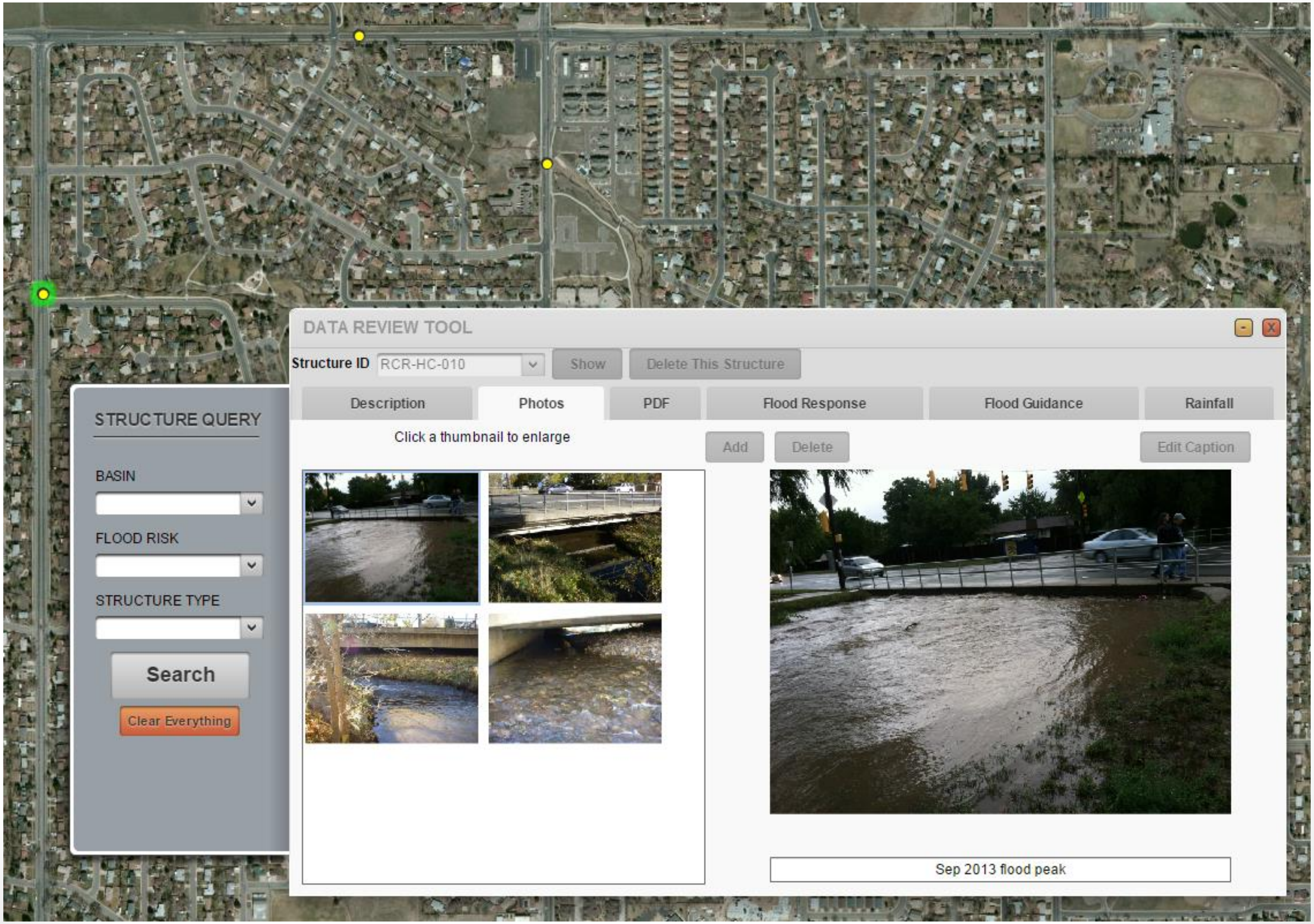
Flood Hazard Information Tool



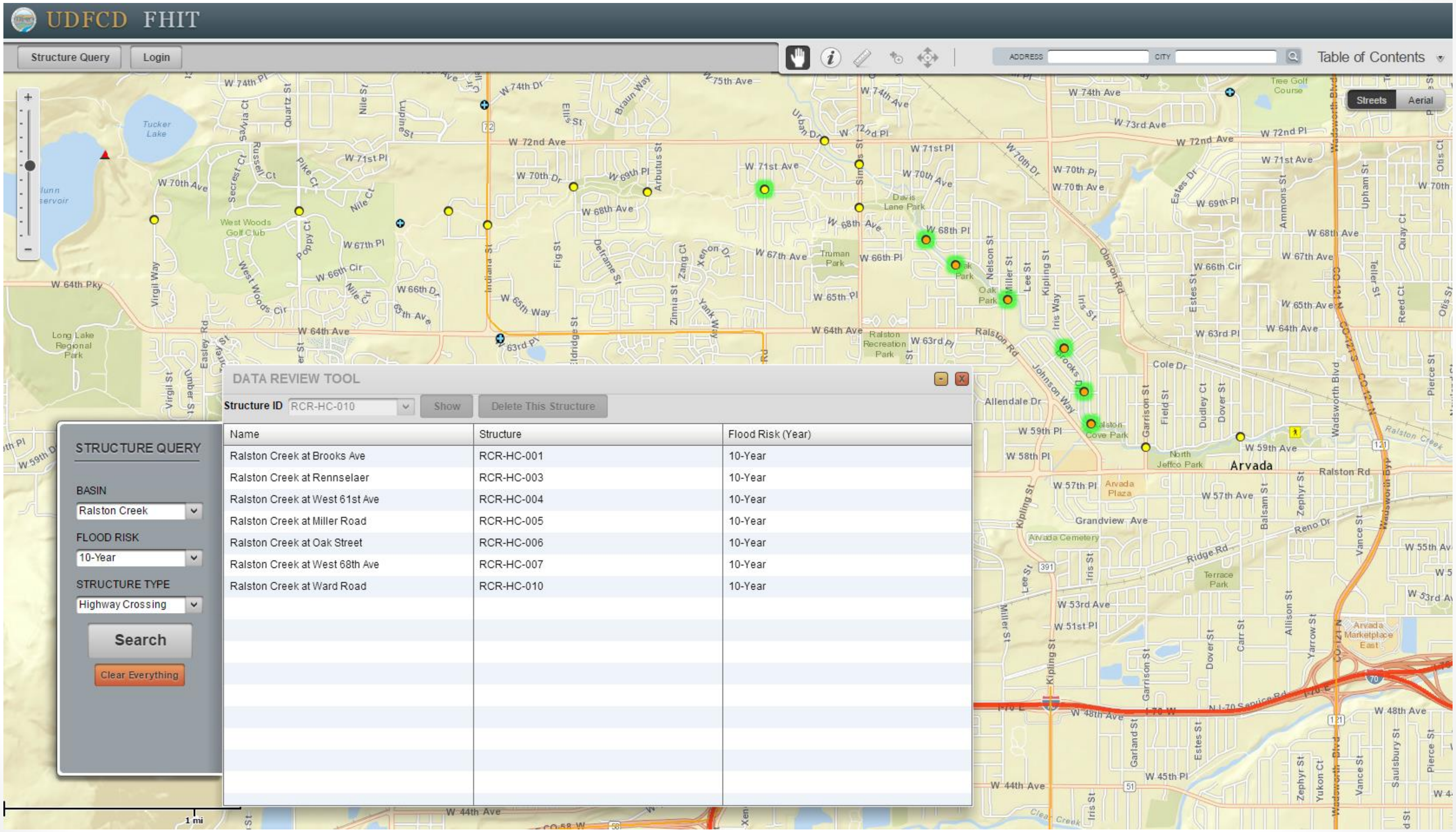
Document capacities



Photographs & more



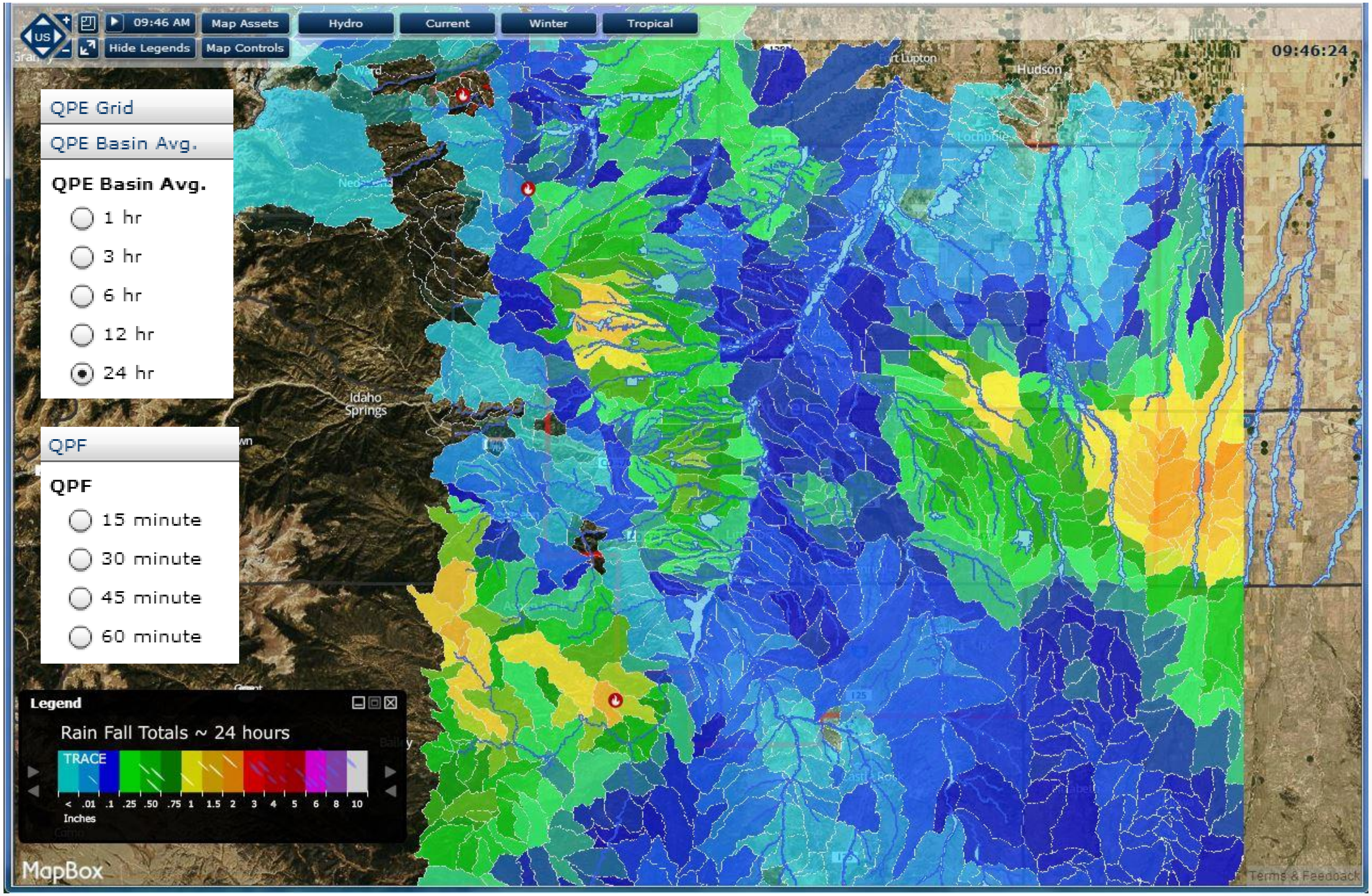
Locating higher risk facilities



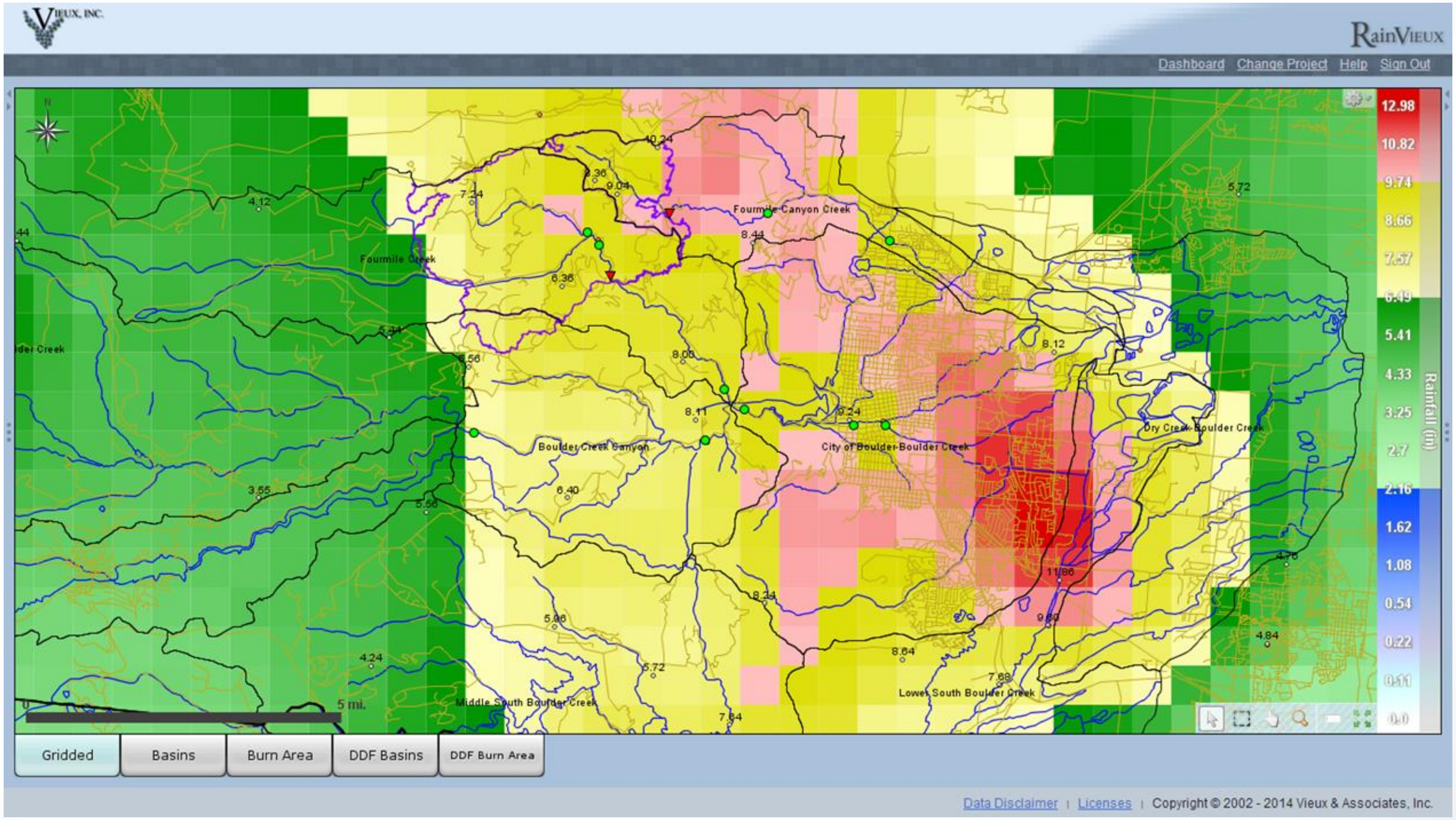
A better picture of heavy rainfall extents & potential impacts?

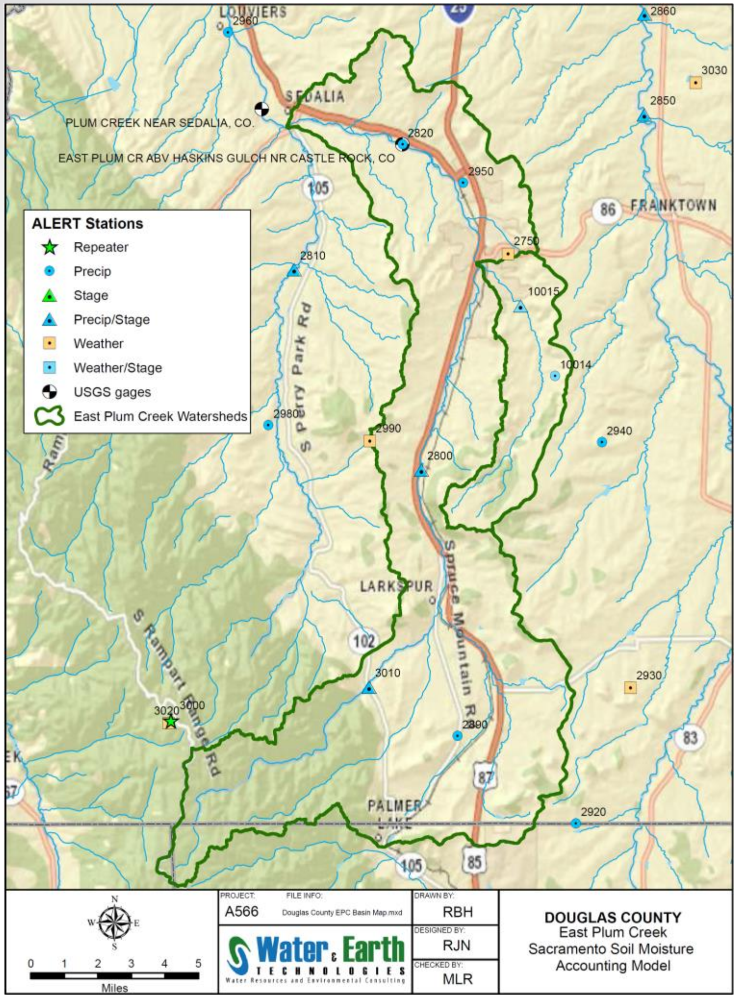
GARR – ESTIMATING RAINFALL USING NWS RADAR (*RT-QPE & FUTURE-QPF*)

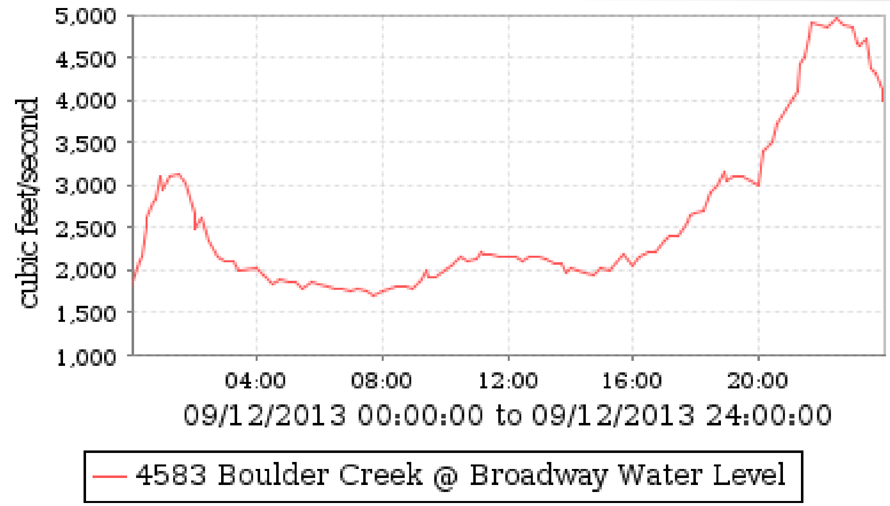
GARR mapped to watersheds

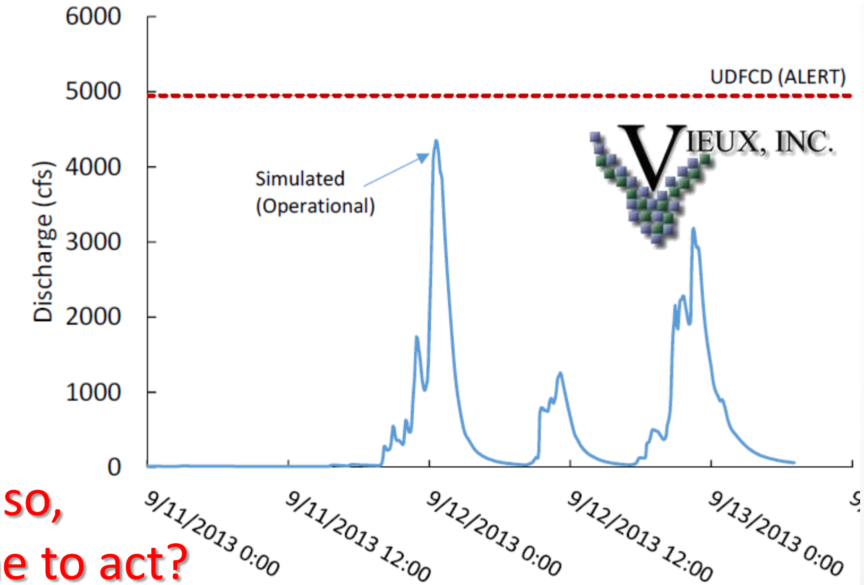


GARR mapped to 1km grids









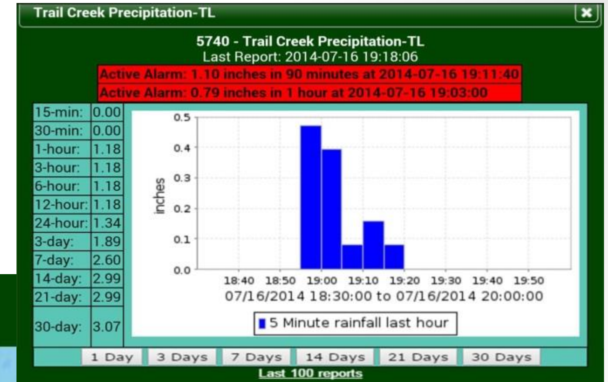
Can these tools be trusted and if so,
will the threat be detected in time to act?

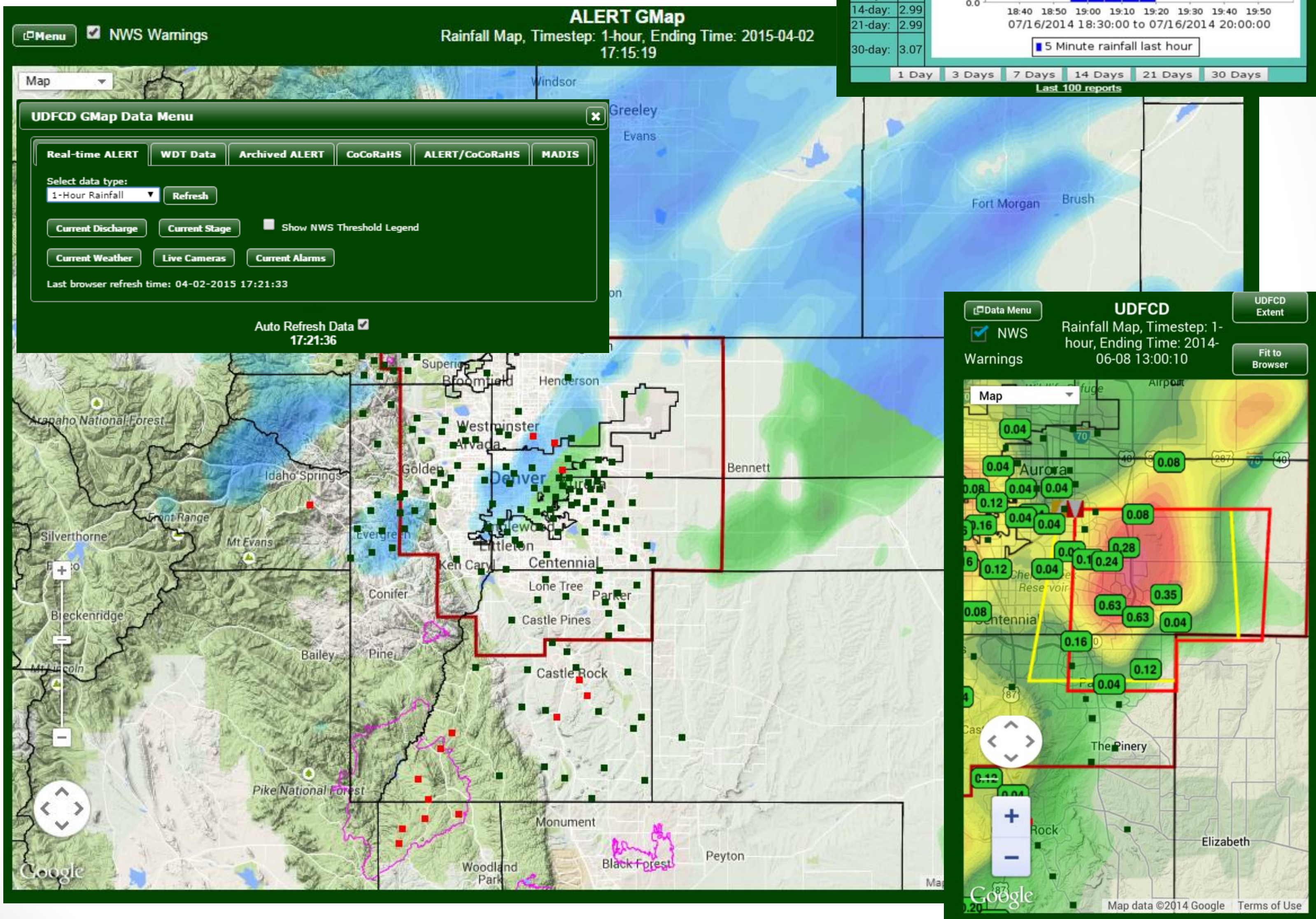
REAL-TIME HYDRO MODELS

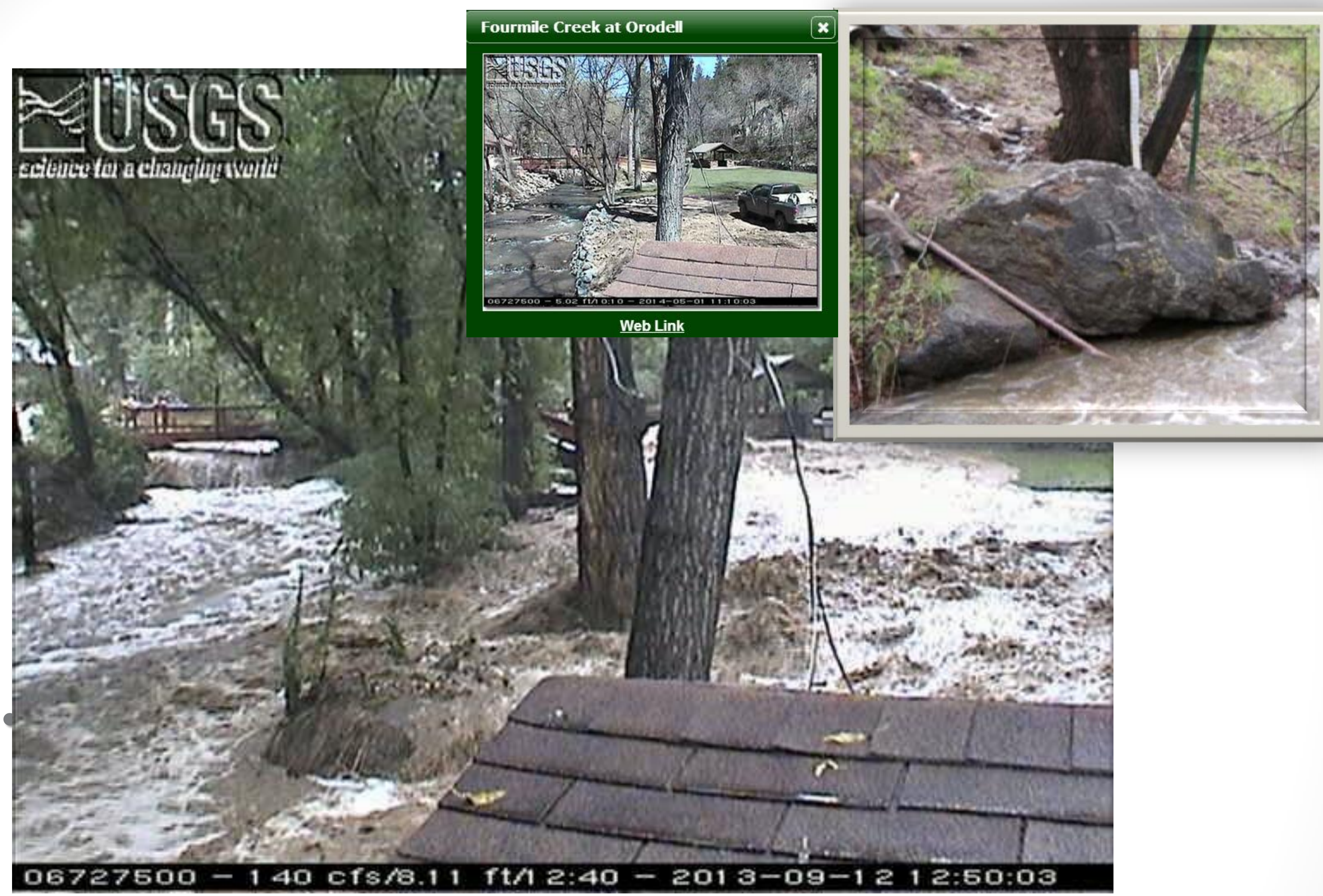
If only we had more time!

THERE IS MORE BEYOND ALERT…

Many RT data sources, map options & plots







USGS STREAMGAGE WITH LIVE VIDEO WEBCAM — SEPT. 12, 2013

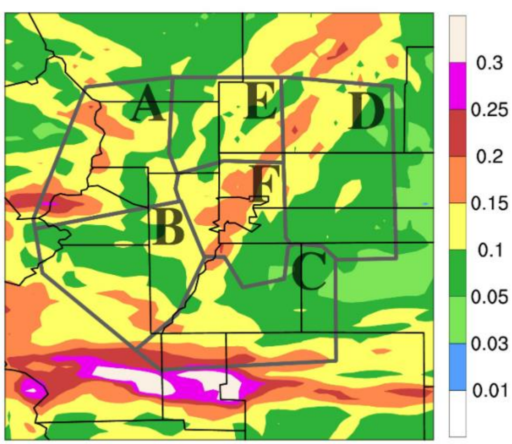
Dewberry

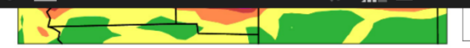
New for 2015

High resolution gridded rain forecasts

Zone	Threat	Primetime
A	VERY HIGH	13-6Mon
B	VERY HIGH	14-6Mon
C	VERY HIGH	15-2Mon
D	VERY HIGH	13-6Mon
E	VERY HIGH	14-6Mon
F	VERY HIGH	15-6Mon

Maximum 1-hour rainfall

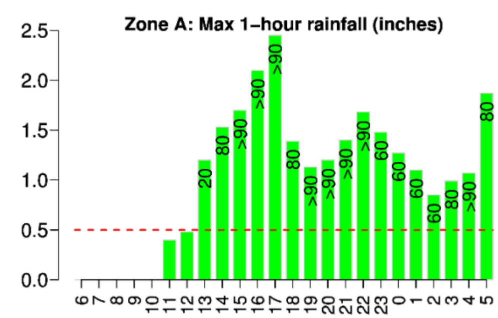




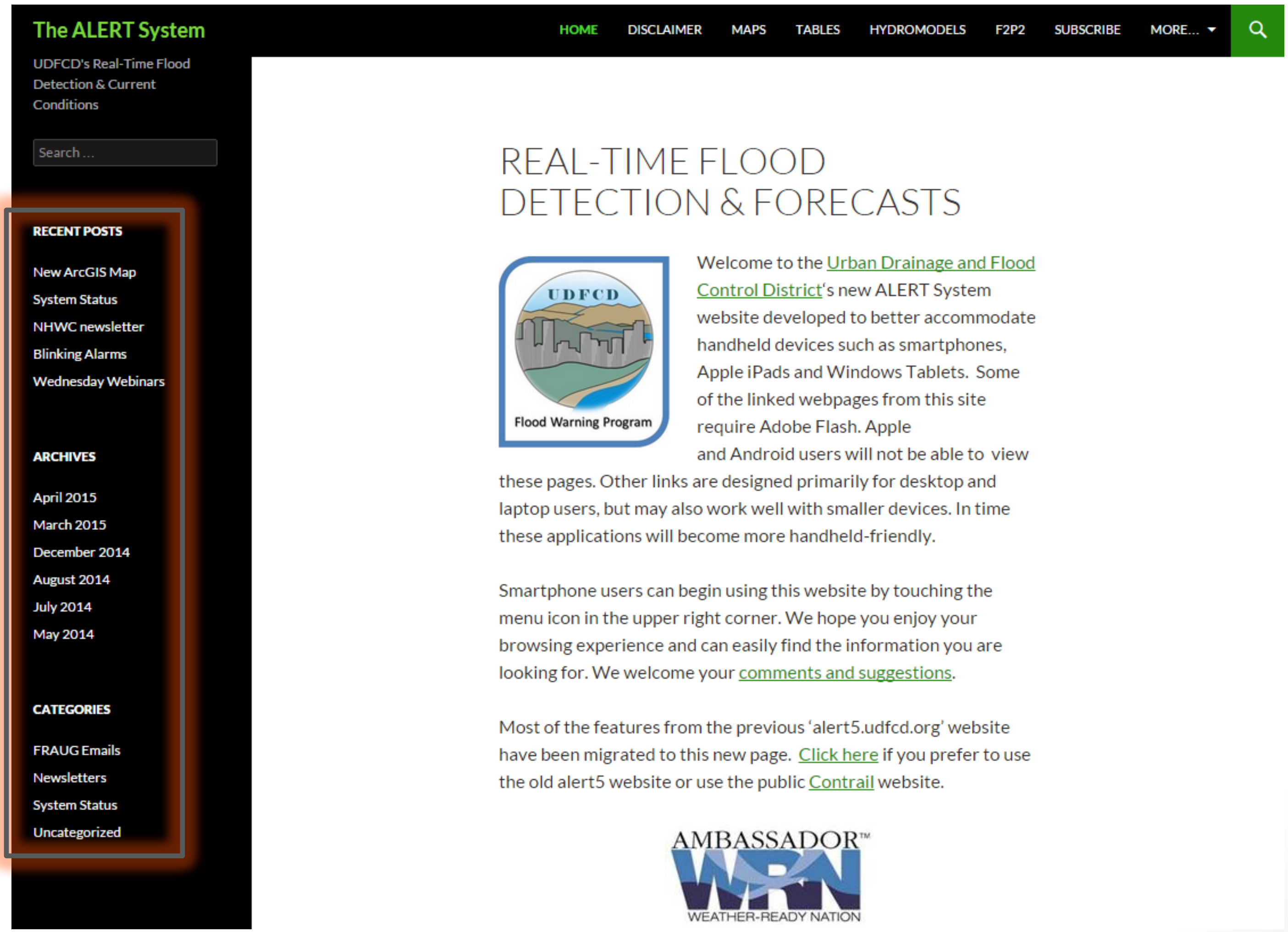
Zone-specific Forecasts

Zone A: Northern Foothills

ZONE A: Overall Threat	VERY HIGH
% exceeding 0.5 in 1hr	>90%
% exceeding 2.5 in 3hr	>90%
% exceeding 5 in 6hr	20%
% exceeding 5 in 24hr	>90%
Primetime	13-6Mon



http://alert5.udfcd.org



We hope you will accept our invitation. You will not be disappointed but if you are, simply click 'unsubscribe' and have a nice day. Thanks for listening.

SUBSCRIBE

Join the Front Range ALERT Users Group (FRAUG) subscription email list to receive information about system updates and new webpage features. Just click on the above link and send your request. After your request is approved you will begin receiving periodic information about the ALERT System. Subscribers may also send emails to the list. Please do not use 'Reply All' unless you intend everyone on the list to read your reply. An archive of the emails are posted to the Blog that is available to all users of this website (*see topics listed under RECENT POSTS*).

Notifications ←*Click here to sign up for ALERT rainfall and water level alarms; NWS warnings from EMWIN-Denver; and F2P2 flood threat messages and forecast products.*

New Initiatives in Flood Risk Communication

David Mallory, P.E., CFM, Manager, Floodplain Management Program
Teresa Patterson, P.E., CFM, Project Manager
Joanna Czarnecka, E.I., CFM, Senior Construction Manager

2015 UDFCD Annual Seminar April 7,2015

INTRODUCTION

- Floodplain Management Staff
- Recent Changes in Flood Insurance
- Community Rating System (CRS)
- UDFCD CRS Assistance to Communities
- Program for Public Information (PPI)
- Flood Hazard Information Brochure

FLOOD INSURANCE REFORM

- Biggert Waters Flood Insurance Reform Act of 2012
- Homeowners Flood Insurance Affordability Act of 2014
- Technical Mapping Advisory Council

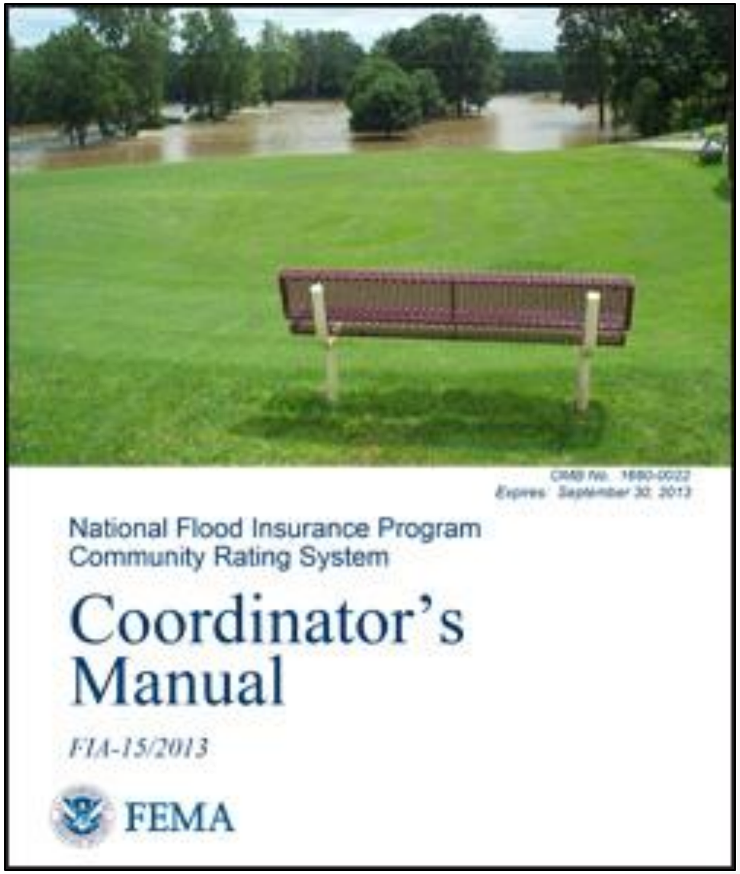
SO WHAT DOES THIS MEAN?

- How do we adapt to this new reality?
- Risk communication is now really important
- So is anything that reduces the pain, like the Community Rating System
- Who should pay attention?

It’s everybody’s job!

COMMUNITY RATING SYSTEM

- Voluntary Incentive Program
- Part of National Flood Insurance Program (NFIP)
- Reduced flood insurance premiums for better floodplain management



3 GOALS

- Reduce and avoid flood damage to insurable property
- Strengthen and support insurance aspects of the NFIP
- Foster comprehensive floodplain management

ACTIVITIES

Public Information

Mapping & Regulations

CRS

Flood Damage Reduction

Flood Preparedness

CRS RATING

CRS Points

4,500+ points = Class 1

<500 points = Class 10

Insurance Rates

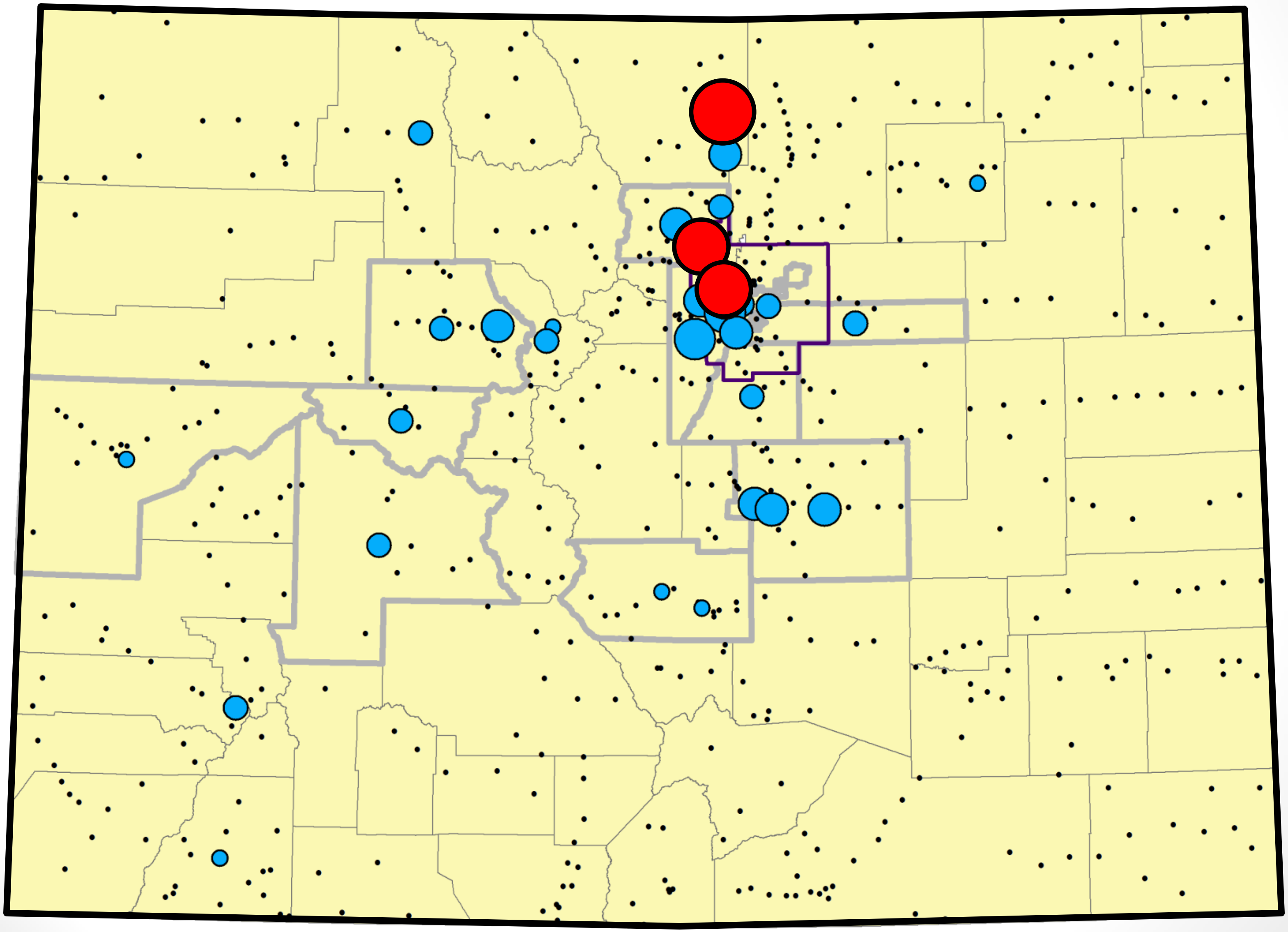
0% Reduction = Class 10

45% Reduction = Class 1

AUDIENCE PARTICIPATION

"You're not allowed to use the sprinkler system to keep your audience awake."

COLORADO CRS COMMUNITIES



COLORADO CRS SAVINGS

POLICIES	PREMIUM	CRS SAVINGS
15,000	$11.5 million	$1.5 million

OTHER REWARDS

- Raise risk awareness
- Increase public safety
- Reduced damages
- Evaluate floodplain program

INFORMATION

INFORMATION

- **CRS Resources**
  - CRS Manual
  - Webinars

- **Emergency Management Institute**
  4-Day CRS class – **FREE** to government
- **CASFM**

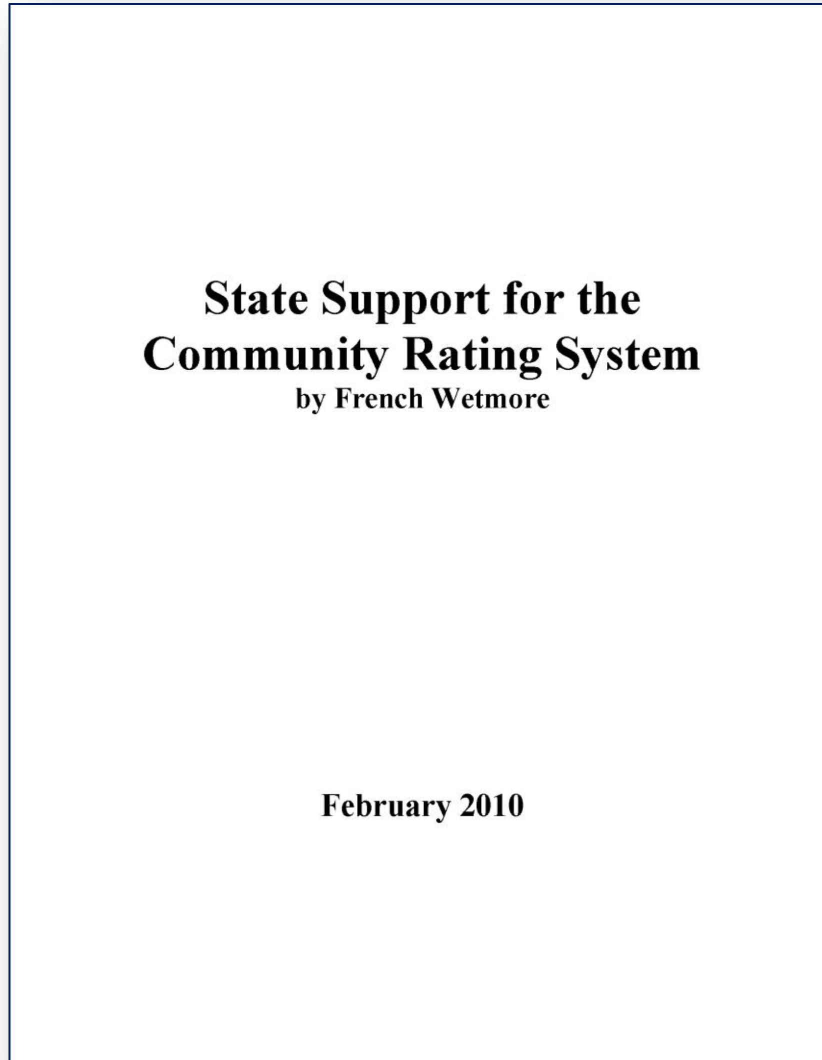
CRS reduces Flood Insurance Premiums and builds Flood Resilient Communities

CRS ASSISTANCE PROGRAM

- UDFCD Adapting to Flood Insurance Changes
- CRS credits for UDFCD Activities
- Point of contact: Floodplain Management Program

CREDIT FOR UDFCD ACTIVITIES

Update will be posted on www.udfcd.org



State Support for the Community Rating System
by French Wetmore

February 2010

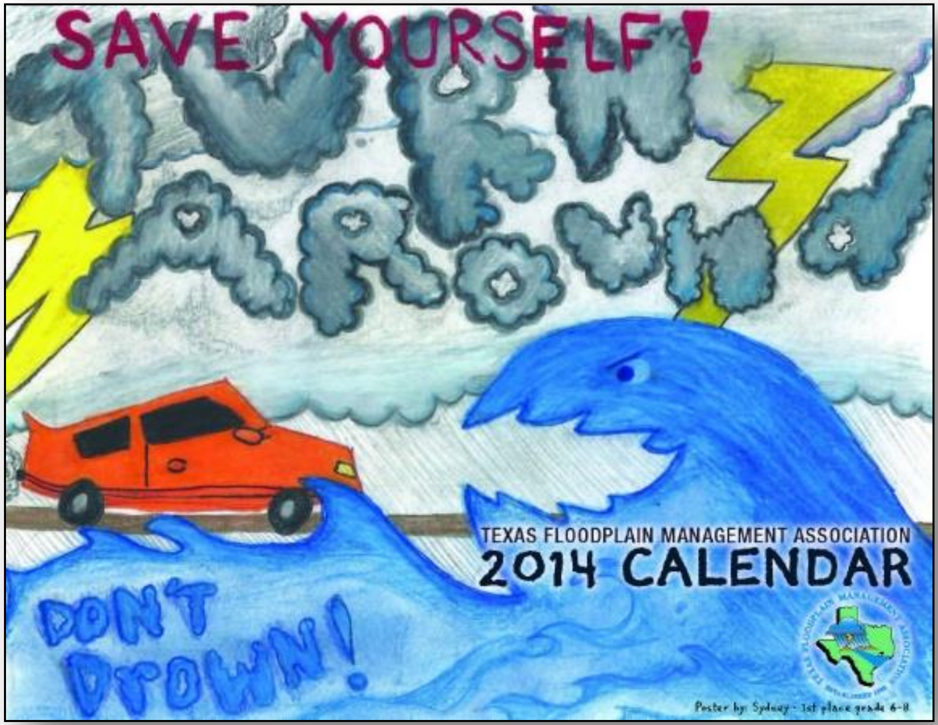
CRS Assistance-
Get credit for what we are already doing

PROGRAM FOR PUBLIC INFORMATION (PPI)

- Public Outreach Plan
- Defined Messaging

PROGRAM FOR PUBLIC INFORMATION (PPI)

- Community Rating System (CRS) Activity 330
- CRS Extra Credit! – Outreach & Flood Response



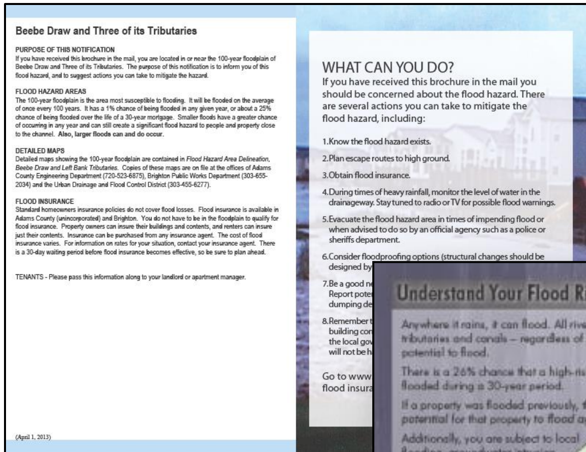
DENVER METRO PPI

- Multijurisdictional within UDFCD
- 6-7 communities

APRIL 2, 2015

Denver Metro PPI- Cooperative effort to reach a broader audience

ANNUAL FLOOD BROCHURE



Beebe Draw and Three of its Tributaries

PURPOSE OF THIS NOTIFICATION
If you have received this brochure in the mail, you are located in or near the 100-year floodplain of Beebe Draw and Three of its Tributaries. The purpose of this notification is to inform you of this flood hazard, and to suggest actions you can take to mitigate the hazard.

FLOOD HAZARD AREAS
The 100-year floodplain is the area most susceptible to flooding. It will be flooded on the average of once every 100 years. It has a 1% chance of being flooded in any given year, or about a 25% chance of being flooded over the life of a 30-year mortgage. Smaller floods have a greater chance of occurring in any year and can still create a significant flood hazard to people and property close to the channel. **Also, larger floods can and do occur.**

DETAILED MAPS
Detailed maps showing the 100-year floodplain are contained in *Flood Hazard Area Delineation, Beebe Draw and Left Bank Tributaries*. Copies of these maps are on file at the offices of Adams County Engineering Department (720-523-6875), Brighton Public Works Department (303-655-2034) and the Urban Drainage and Flood Control District (303-455-6277).

FLOOD INSURANCE
Standard homeowners insurance policies do not cover flood losses. Flood insurance is available in Adams County (unincorporated) and Brighton. You do not have to be in the floodplain to qualify for flood insurance. Property owners can insure their buildings and contents, and renters can insure just their contents. Insurance can be purchased from any insurance agent. The cost of flood insurance varies. For information on rates for your situation, contact your insurance agent. There is a 30-day waiting period before flood insurance becomes effective, so be sure to plan ahead.

TENANTS - Please pass this information along to your landlord or apartment manager.

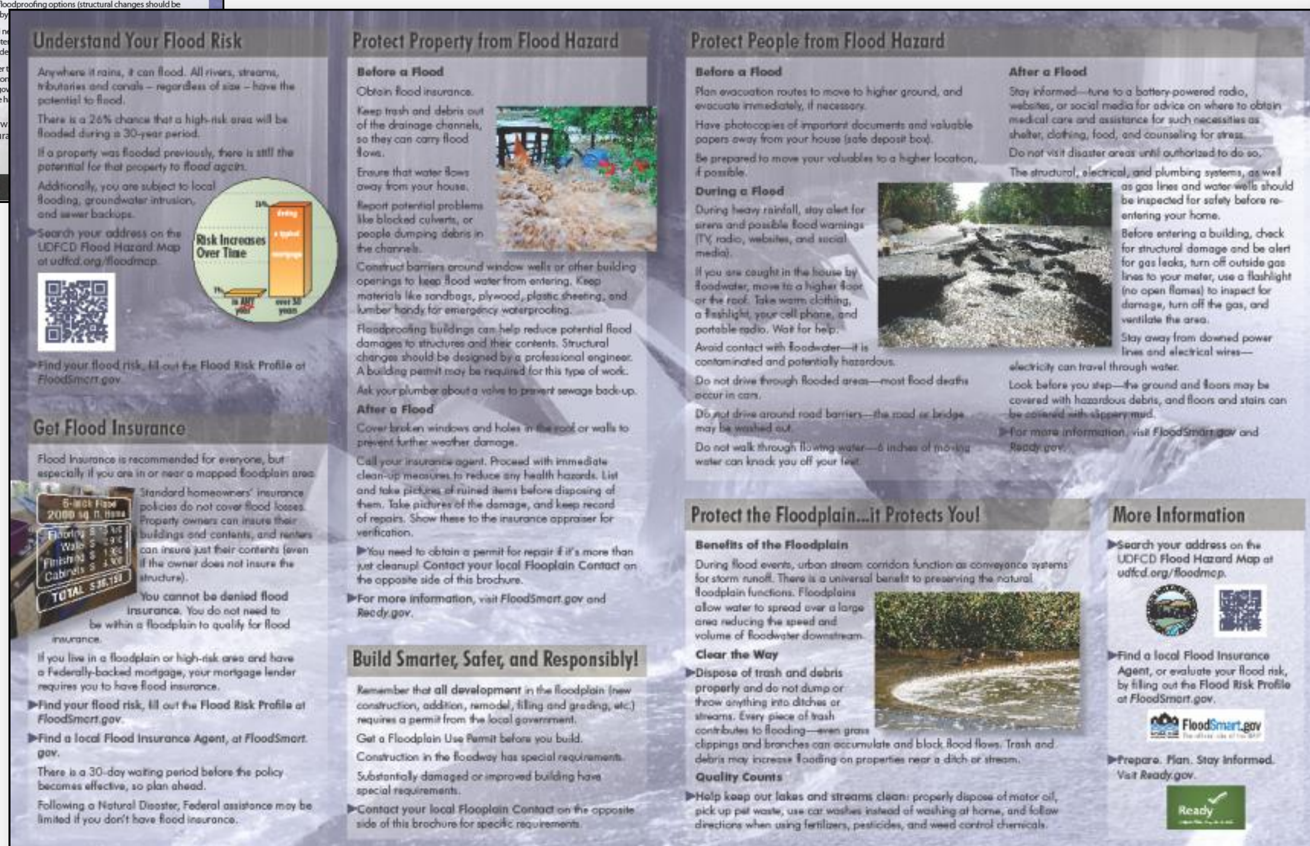
(April 1, 2013)

WHAT CAN YOU DO?

If you have received this brochure in the mail you should be concerned about the flood hazard. There are several actions you can take to mitigate the flood hazard, including:

1. Know the flood hazard exists.
2. Plan escape routes to high ground.
3. Obtain flood insurance.
4. During times of heavy rainfall, monitor the level of water in the drainageway. Stay tuned to radio or TV for possible flood warnings.
5. Evacuate the flood hazard area in times of impending flood or when advised to do so by an official agency such as a police or sheriffs department.
6. Consider floodproofing options (structural changes should be designed by
7. Be a good ne
Report pote
dumping de
8. Remember t
building con
the local gov
will not be h

Go to www
flood insura



Understand Your Flood Risk

Anywhere it rains, it can flood. All rivers, streams, tributaries and canals – regardless of size – have the potential to flood.

There is a 26% chance that a high-risk area will be flooded during a 30-year period.

If a property was flooded previously, there is still the potential for that property to flood again.

Additionally, you are subject to local flooding, groundwater intrusion, and sewer backups.

▶Search your address on the UDFCD Flood Hazard Map at udfcd.org/floodmap.

▶Find your flood risk, fill out the Flood Risk Profile at FloodSmart.gov

Get Flood Insurance

Flood Insurance is recommended for everyone, but especially if you are in or near a mapped floodplain area.

Standard homeowners' insurance policies do not cover flood losses. Property owners can insure their buildings and contents, and renters can insure just their contents (even if the owner does not insure the structure).

You cannot be denied flood insurance. You do not need to be within a floodplain to qualify for flood insurance.

If you live in a floodplain or high-risk area and have a Federally-backed mortgage, your mortgage lender requires you to have flood insurance.

▶**Find your flood risk, fill out the Flood Risk Profile at *FloodSmart.gov*.**

▶**Find a local Flood Insurance Agent, at *FloodSmart.gov*.**

There is a 30-day waiting period before the policy becomes effective, so plan ahead.

Following a Natural Disaster, Federal assistance may be limited if you don't have flood insurance.

Protect Property from Flood Hazard

Before a Flood

Obtain flood insurance.

Keep trash and debris out of the drainage channels, so they can carry flood flows.

Ensure that water flows away from your house.

Report potential problems like blocked culverts, or people dumping debris in the channels.

Construct barriers around window wells or other building openings to keep flood water from entering. Keep materials like sandbags, plywood, plastic sheeting, and lumber handy for emergency waterproofing.

Floodproofing buildings can help reduce potential flood damages to structures and their contents. Structural changes should be designed by a professional engineer. A building permit may be required for this type of work.

Ask your plumber about a valve to prevent sewage back-up.

After a Flood

Cover broken windows and holes in the roof or walls to prevent further weather damage.

Call your insurance agent. Proceed with immediate clean-up measures to reduce any health hazards. List and take pictures of ruined items before disposing of them. Take pictures of the damage, and keep record of repairs. Show these to the insurance appraiser for verification.

▶You need to obtain a permit for repair if it's more than just cleanup! **Contact your local Flooplain Contact** on the opposite side of this brochure.

▶**For more information,** visit *FloodSmart.gov* and *Ready.gov*.

Build Smarter, Safer, and Responsibly!

Remember that **all development** in the floodplain (new construction, addition, remodel, filling and grading, etc.) requires a permit from the local government.

Get a Floodplain Use Permit before you build.

Construction in the floodway has special requirements.

Substantially damaged or improved building have special requirements.

▶**Contact your local Flooplain Contact** on the opposite side of this brochure for specific requirements.

Protect People from Flood Hazard

Before a Flood

Plan evacuation routes to move to higher ground, and evacuate immediately, if necessary.

Have photocopies of important documents and valuable papers away from your house (safe deposit box).

Be prepared to move your valuables to a higher location, if possible.

During a Flood

During heavy rainfall, stay alert for sirens and possible flood warnings (TV, radio, websites, and social media).

If you are caught in the house by floodwater, move to a higher floor or the roof. Take warm clothing, a flashlight, your cell phone, and portable radio. Wait for help.

Avoid contact with floodwater—it is contaminated and potentially hazardous.

Do not drive through flooded areas—most flood deaths occur in cars.

Do not drive around road barriers—the road or bridge may be washed out.

Do not walk through flowing water—6 inches of moving water can knock you off your feet.

After a Flood

Stay informed—tune to a battery-powered radio, websites, or social media for advice on where to obtain medical care and assistance for such necessities as shelter, clothing, food, and counseling for stress.

Do not visit disaster areas until authorized to do so.

The structural, electrical, and plumbing systems, as well as gas lines and water wells should be inspected for safety before re-entering your home.

Before entering a building, check for structural damage and be alert for gas leaks, turn off outside gas lines to your meter, use a flashlight (no open flames) to inspect for damage, turn off the gas, and ventilate the area.

Stay away from downed power lines and electrical wires—electricity can travel through water.

Look before you step—the ground and floors may be covered with hazardous debris, and floors and stairs can be covered with slippery mud.

▶For more information, visit *FloodSmart.gov* and *Ready.gov*.

Protect the Floodplain...it Protects You!

Benefits of the Floodplain

During flood events, urban stream corridors function as conveyance systems for storm runoff. There is a universal benefit to preserving the natural floodplain functions. Floodplains allow water to spread over a large area reducing the speed and volume of floodwater downstream.

Clear the Way

▶**Dispose of trash and debris properly** and do not dump or throw anything into ditches or streams. Every piece of trash contributes to flooding—even grass clippings and branches can accumulate and block flood flows. Trash and debris may increase flooding on properties near a ditch or stream.

Quality Counts

▶**Help keep our lakes and streams clean:** properly dispose of motor oil, pick up pet waste, use car washes instead of washing at home, and follow directions when using fertilizers, pesticides, and weed control chemicals.

More Information

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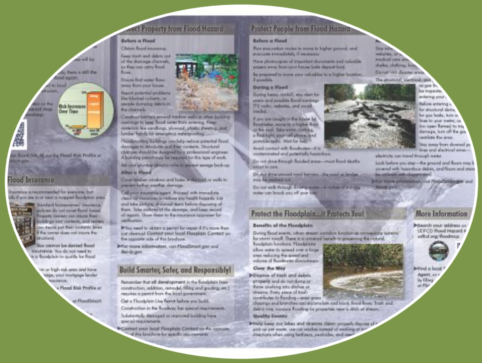
ANNUAL FLOOD BROCHURE

Old

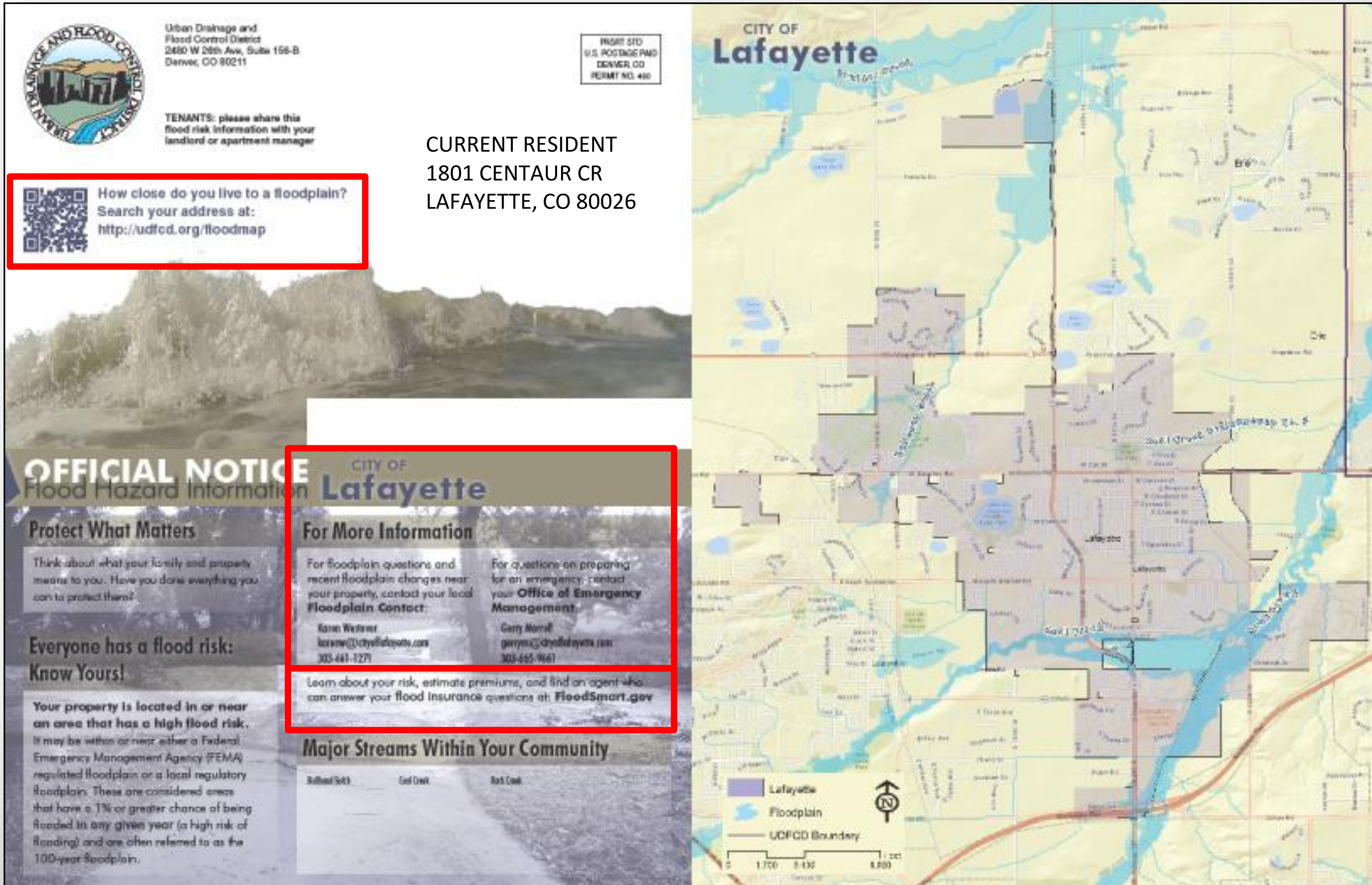
- Watershed-Based
- Manual Addressing
- 22,000
- 8.5”x11”



New

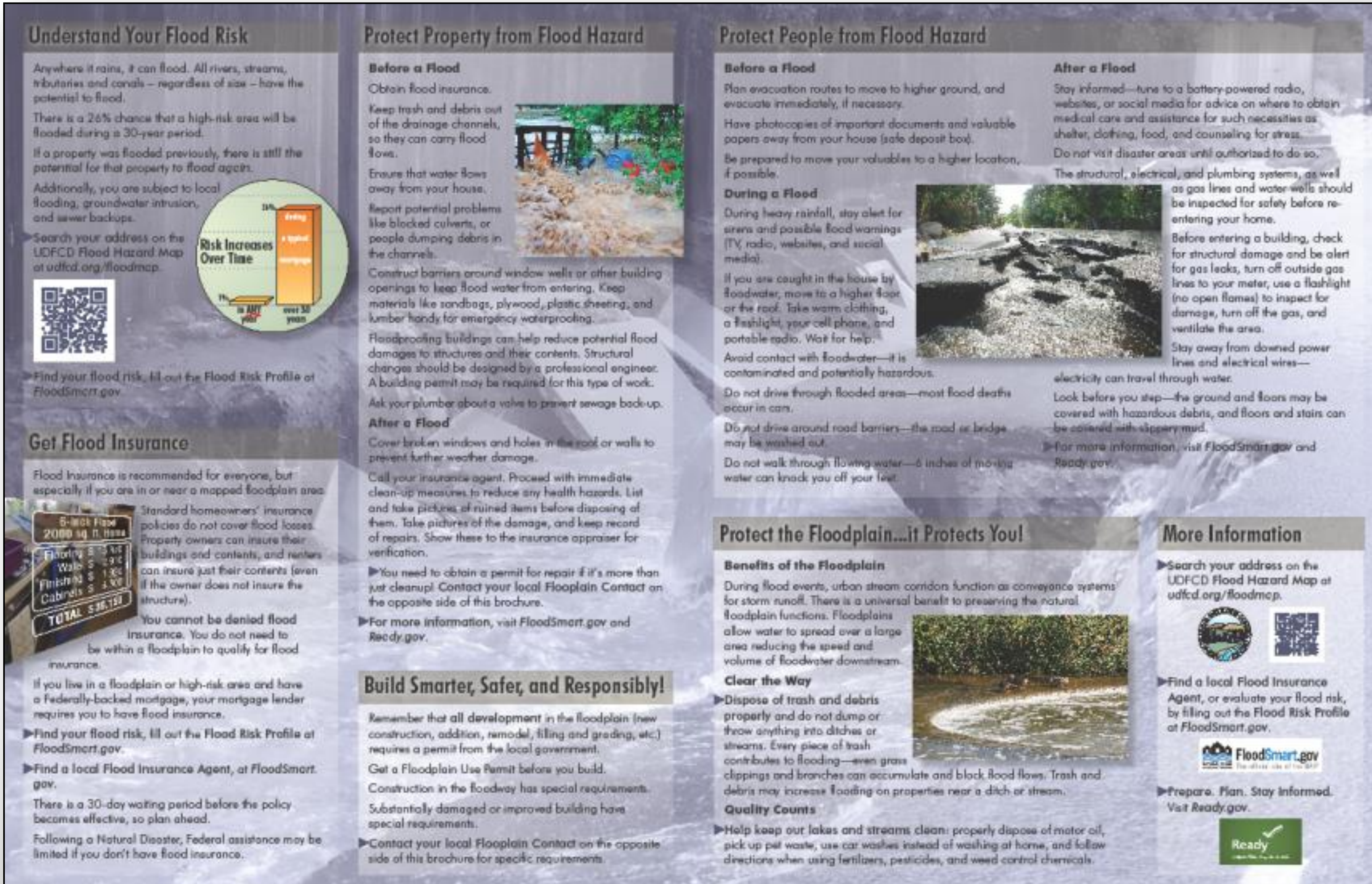
- Community-Based
- GIS Addressing
- 35,000
- 11”x17”
- Future Updates Easier

COMMUNITY SIDE



2015 UDFCD Annual Seminar April 7,2015

MESSAGING



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Flood Brochure - Reaching more people with stronger message and updated graphics

SUMMARY

- Risk communication is more important
- CRS communities benefit from enhanced floodplain management
- UDFCD taking on more active role in providing CRS support

QUESTIONS???

CRS RESOURCES

- **CRSResources.org**
  - CRS Manual
  - Webinars

- Emergency Management Institute **training.fema.gov/emicourses/**
  - 4-Day CRS class – FREE to gov't

- **CASFM.org**
  - CRS Committee

Next Generation of Routine Maintenance: ADAPTIVE Stream Management

UDFCD Annual Seminar

April 2015

Public Works Infrastructure

Interiors of Storm Pipes

Photos Courtesy of Denver

Babi Yar Tributary, Denver

How is Your Health?

Preventative Maintenance

Free of obstructions

Healthy?

Free of obstructions

Photos Courtesy of Denver

Minimal Structural Issues

Photos Courtesy of Denver

Stream Health

Mow for Weed Control

Trash and Debris Removal

Minimal Structural Issues

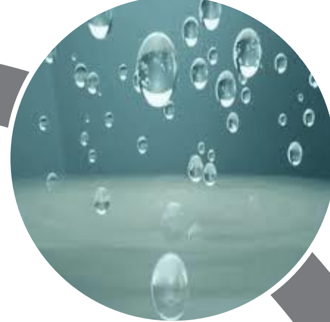
Cherry Creek at Quebec, Denver

Perpetual Costs

In Denver, the UDFCD expends $200k to $500k annually.

Lakewood Gulch at Tennyson Street, July 2013

What is stream health?



Natural hydrologic regime.

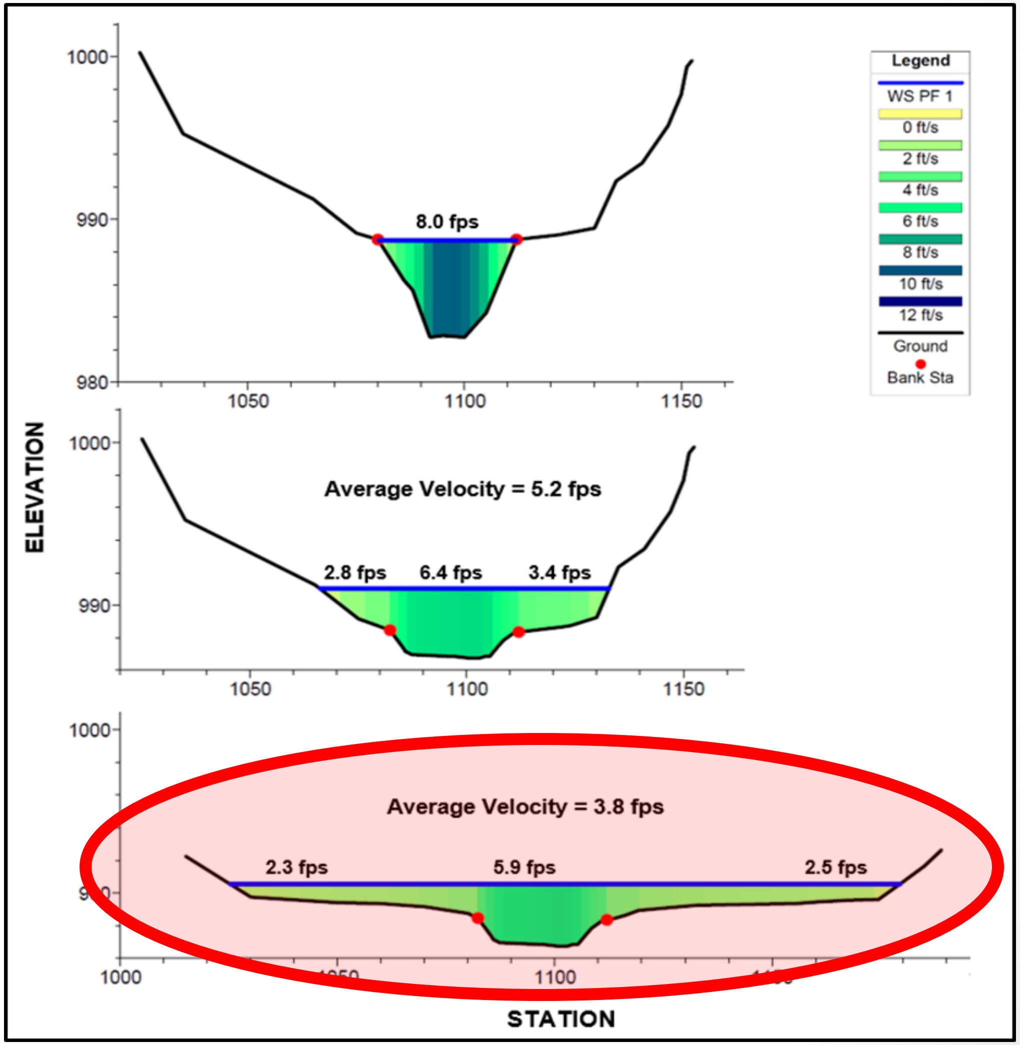
Hydraulically stable energy processes**.**

Geomorphically stable plan, profile, cross section.

Physical assembly of living and non-living parts on the trajectory to sustain other ecologic functions.

Hydraulic Stability?

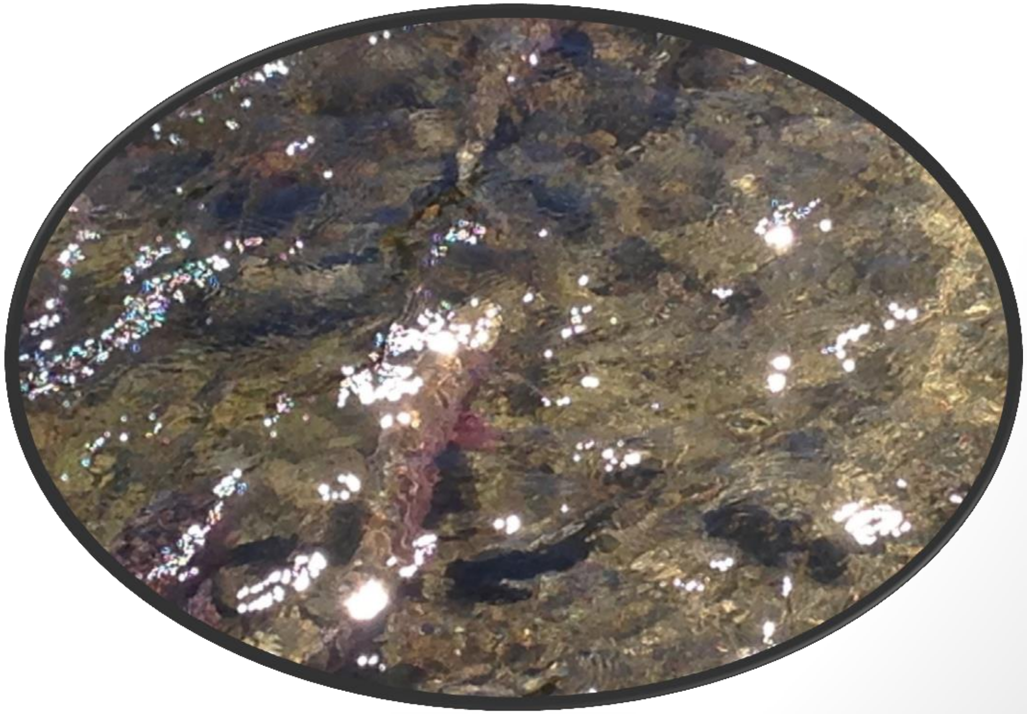
- Stable velocity / shear stress
- Floodplain Connectivity
- Surface /Groundwater Exchange



Graphic Courtesy of Muller

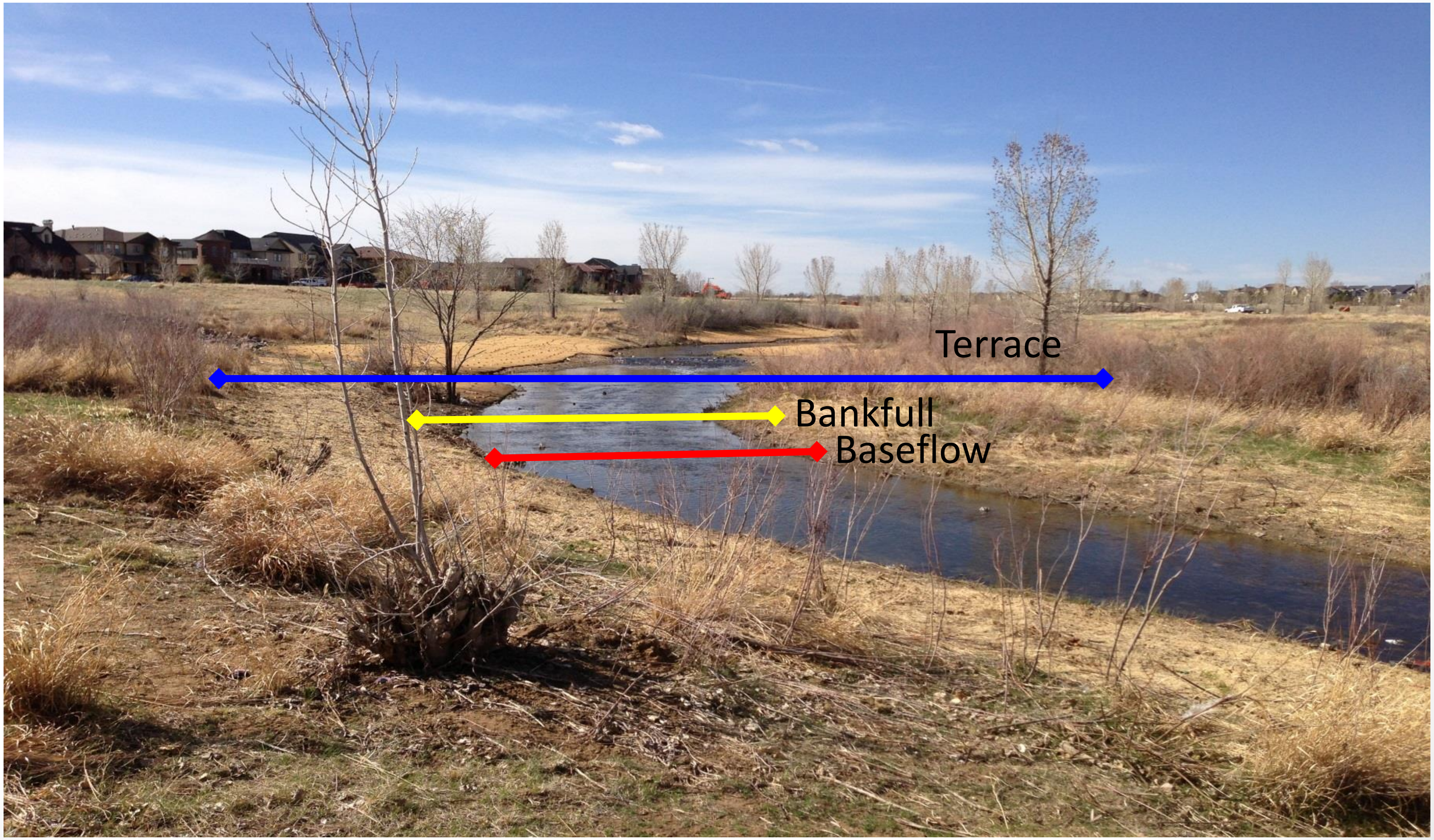
What is geomorphic stability?

- Sediment influences
  - Cross Section
  - Planform
  - Profile



What is geomorphic stability?

- Multi-stage cross section connecting bank full channel to the floodplain



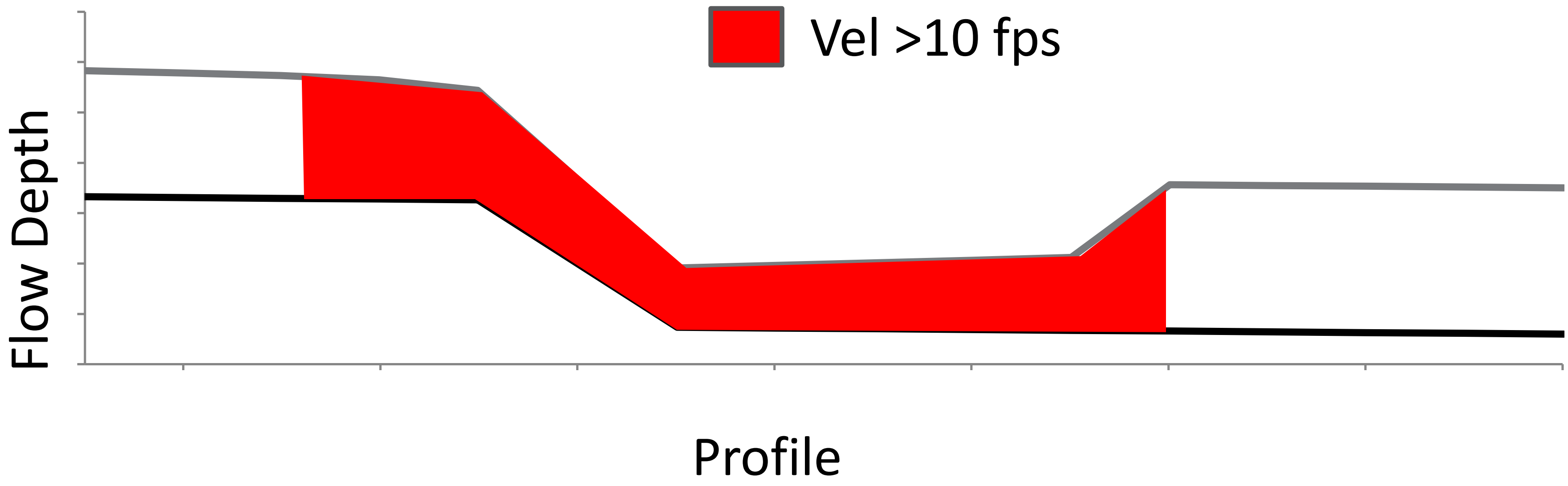
What is geomorphic stability?

- Meandering planform

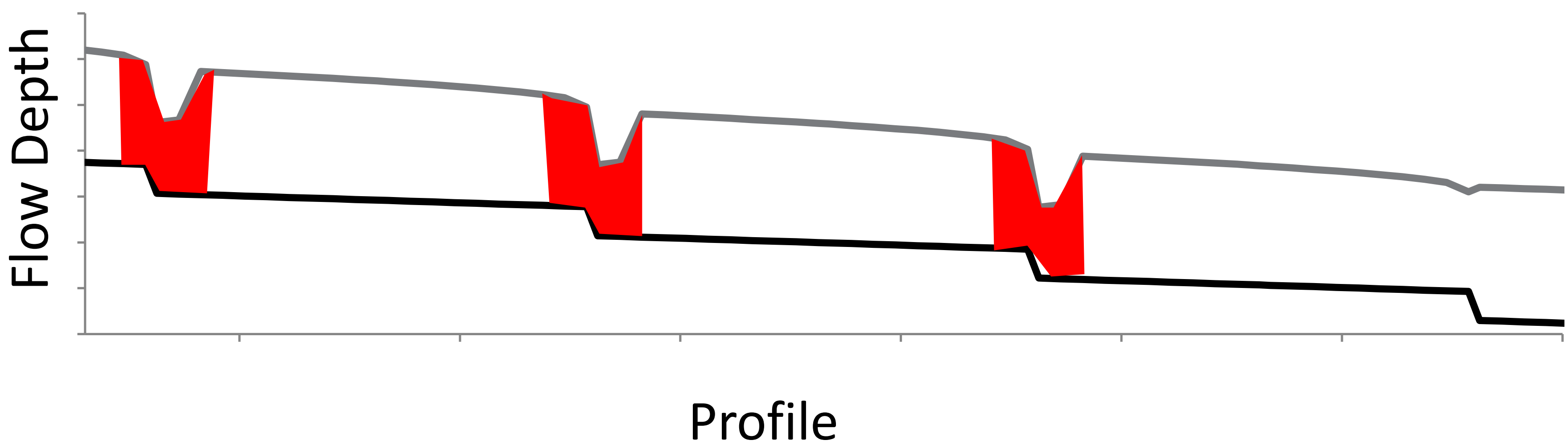
What is geomorphic stability?

- And profile promotes uniform energy dissipation

1 Large Drop Structure



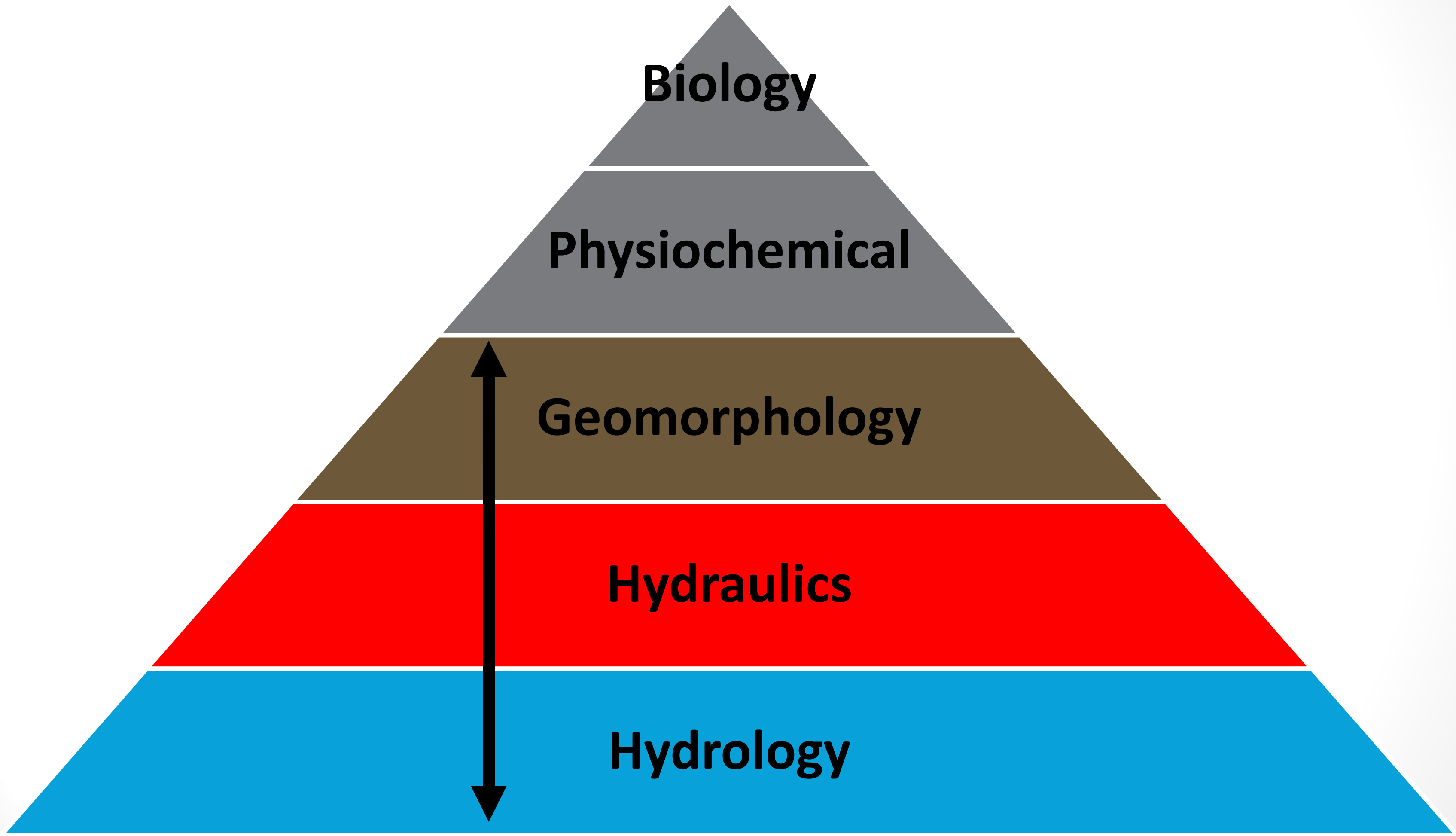
Four Small Drop Structures



Physical Assembly of What?

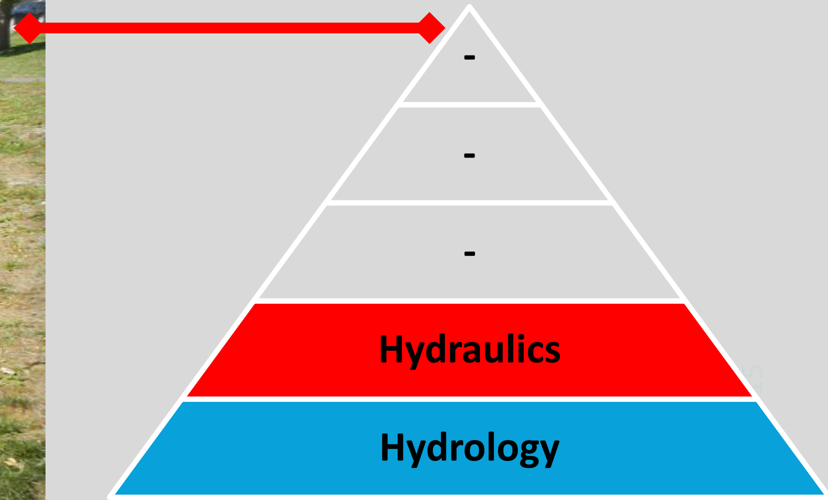
- Assembly of living / non-living elements on trajectory to sustain other ecologic functions

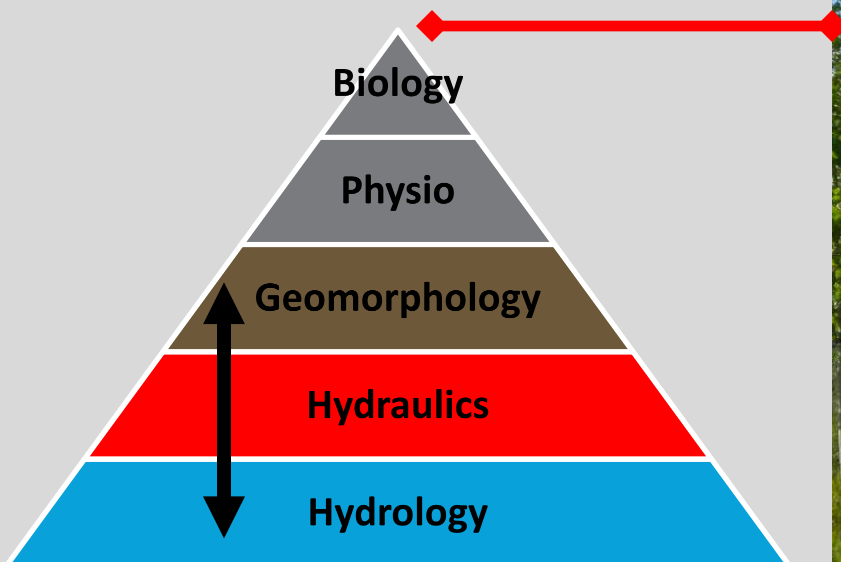
Stream Functions Pyramid



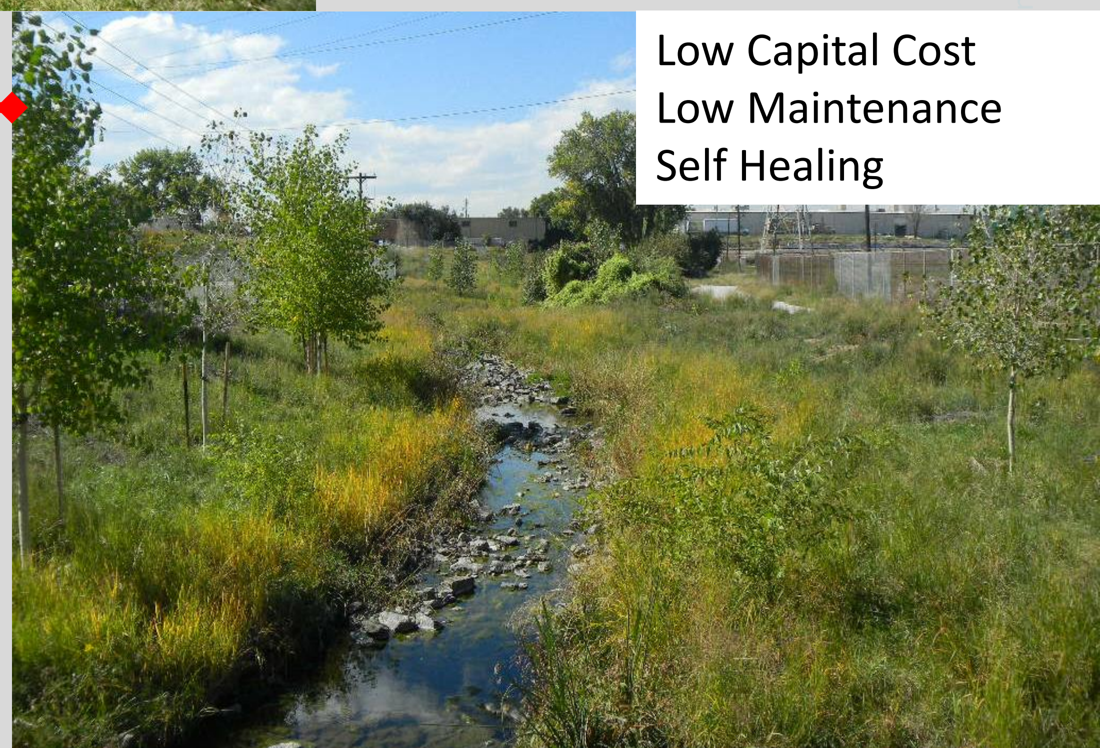
*A Function Based Framework, EPA et als, May 2012

High Capital Cost
High Maintenance
People Dependent

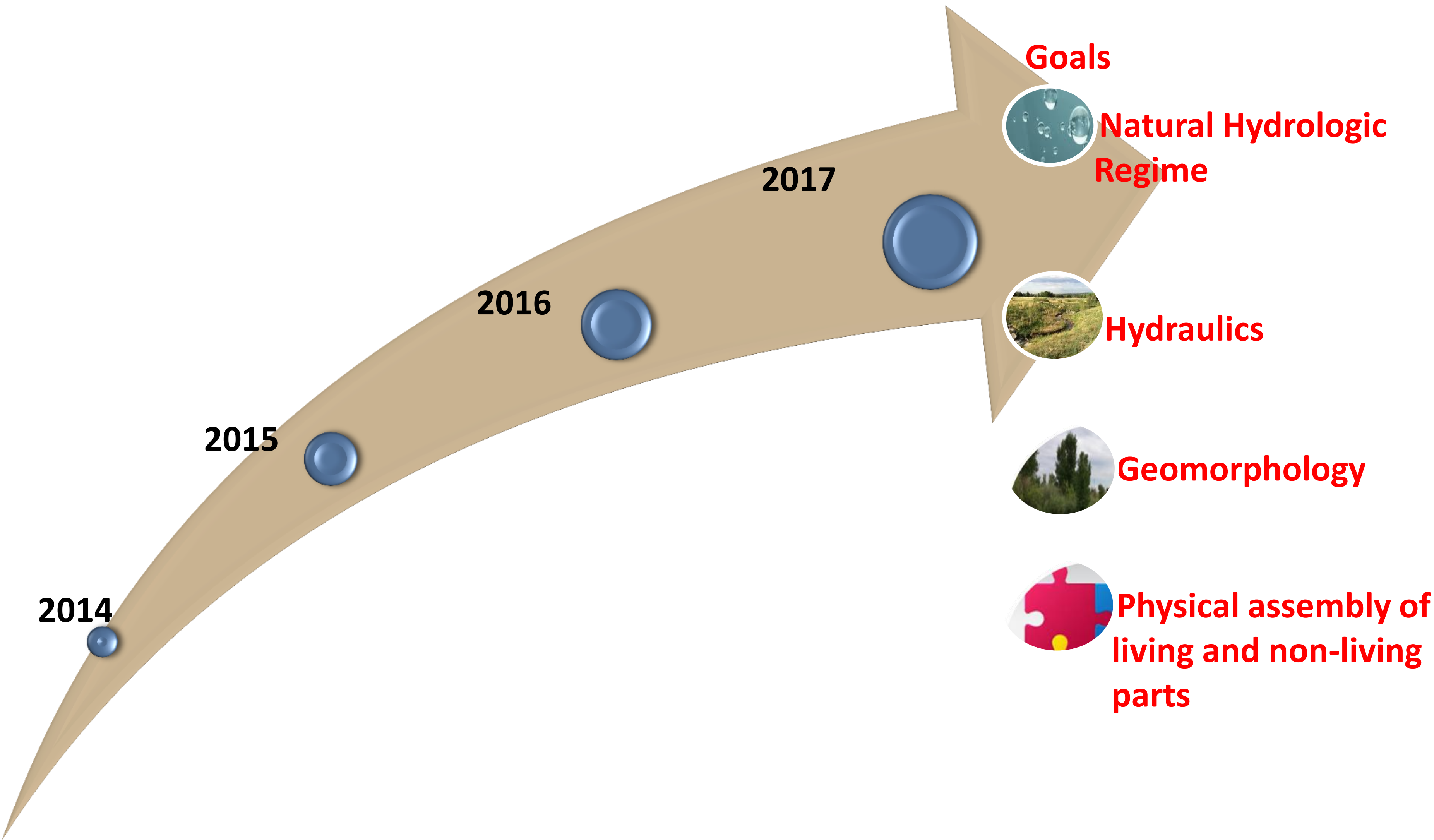




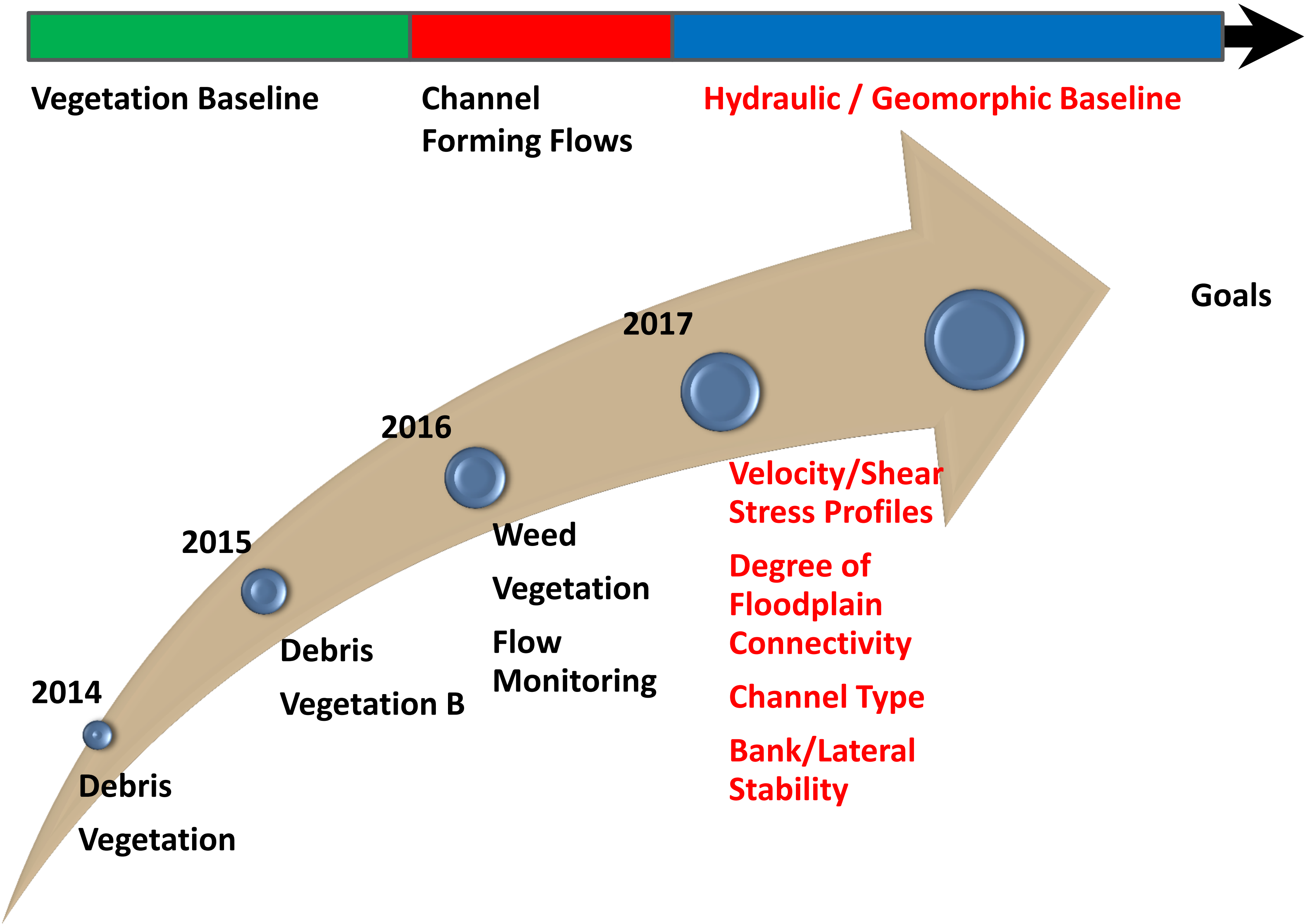
Low Capital Cost
Low Maintenance
Self Healing



Next Generation of Routine: Adaptive Stream Management



Next Generation of Routine: Adaptive Stream Management



Adaptive Stream Management

Pilot Project in Denver

Adaptive management
of stream function.

Measurable Objectives

- Grass types that constitutes the armoring layer?
- Benefits to removing broad scale mowing?
- Fractures in the armoring layer?

Stream Type

- Natural Stream
- Naturalized Stream
- Concrete Channel
- Pipe
- Swale


Photos Courtesy of Muller

Stream Type

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Photos Courtesy of ERO

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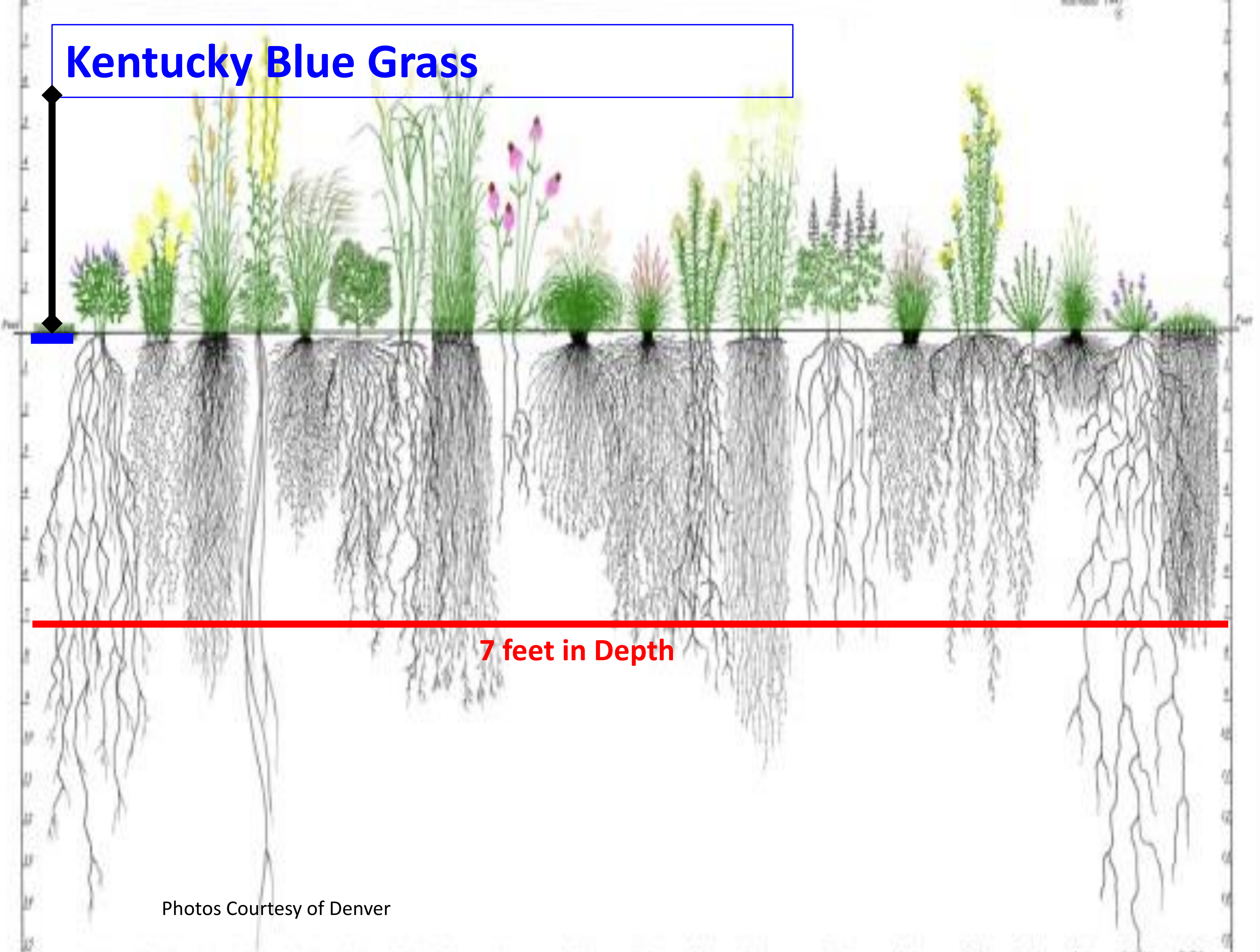
Photos Courtesy of Muller

Vegetation Communities

- Bluegrass
- Uplands
- Riparian
- Wetlands

Kentucky Blue Grass



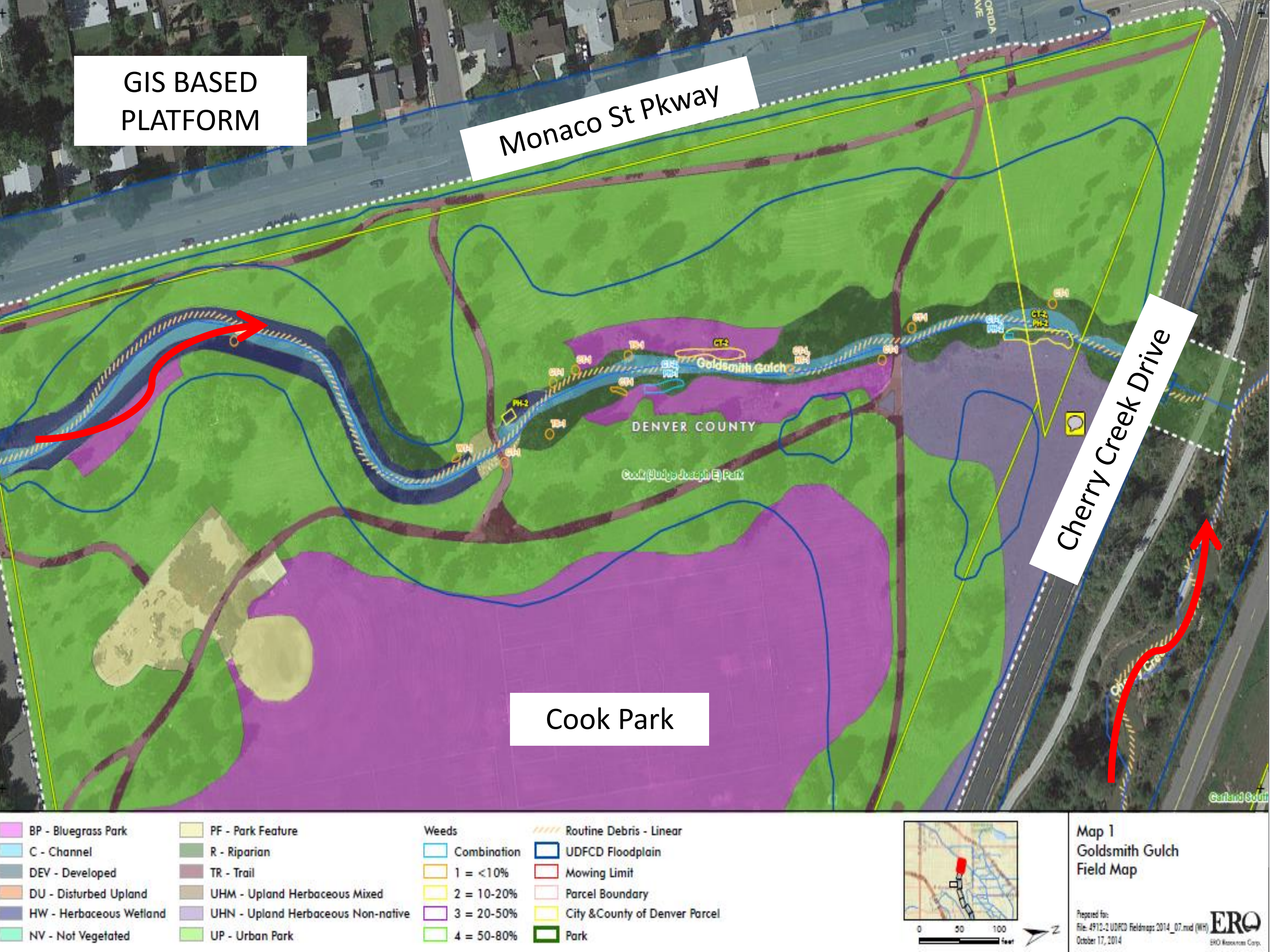
Photos Courtesy of Denver

Fractures in the armoring layer?

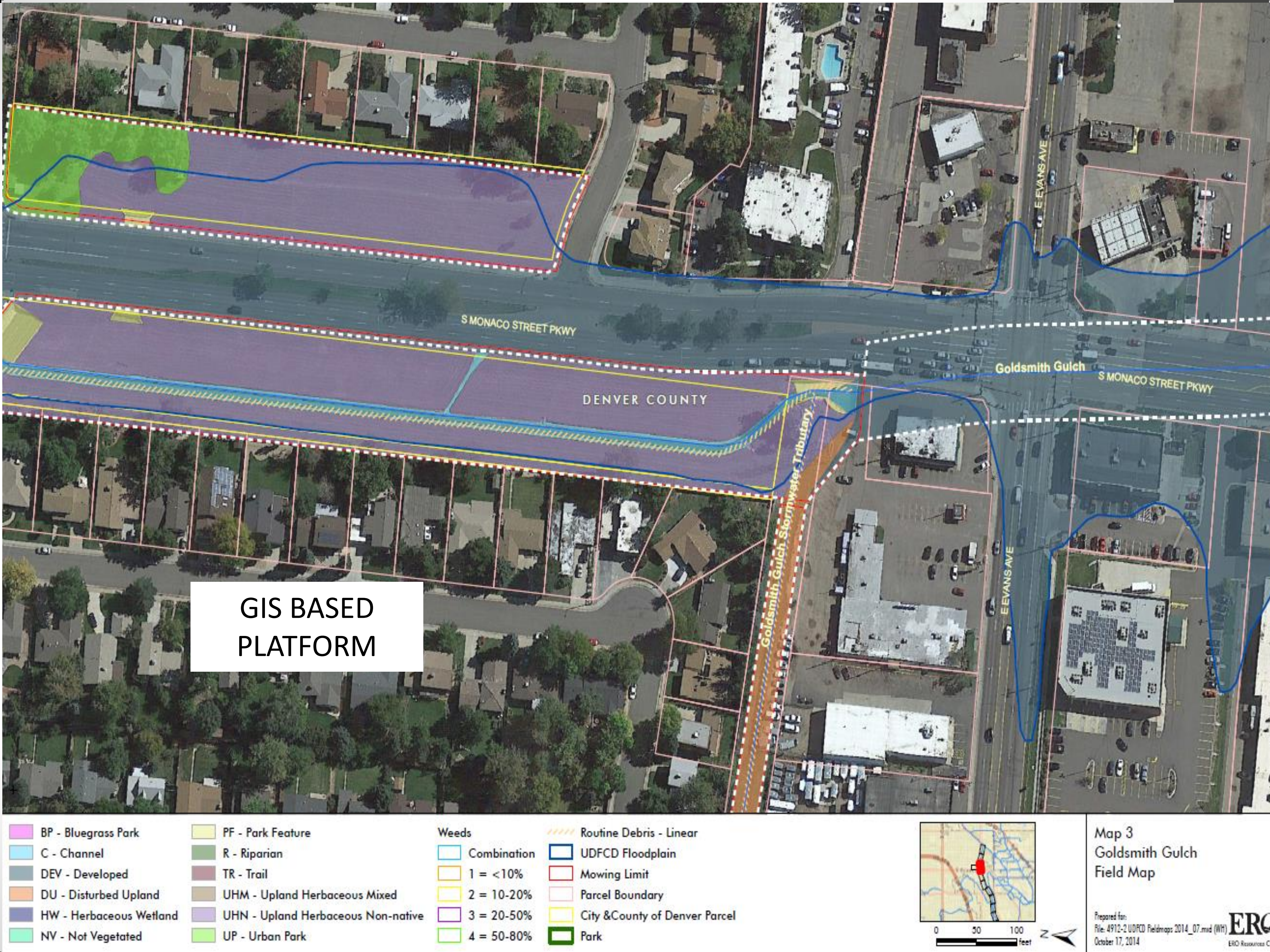
WEEDS


Baseline Survey Summary
Goldsmith Gulch


Cherry Creek
Monaco
Goldsmith Gulch
I-225
I-25



GIS BASED PLATFORM
Monaco St Pkway
Cherry Creek Drive
Cook Park
DENVER COUNTY
Goldsmith Gulch
Cook (Judge Joseph E) Park
BP - Bluegrass Park
C - Channel
DEV - Developed
DU - Disturbed Upland
HW - Herbaceous Wetland
NV - Not Vegetated
PF - Park Feature
R - Riparian
TR - Trail
UHM - Upland Herbaceous Mixed
UHN - Upland Herbaceous Non-native
UP - Urban Park
Weeds
Combination
1 = <10%
2 = 10-20%
3 = 20-50%
4 = 50-80%
Routine Debris - Linear
UDFCD Floodplain
Mowing Limit
Parcel Boundary
City &County of Denver Parcel
Park
0 50 100 feet
Map 1
Goldsmith Gulch
Field Map
ERO


GIS BASED
PLATFORM
S MONACO STREET PKWY
DENVER COUNTY
Goldsmith Gulch
S MONACO STREET PKWY
E EVANS AVE
E EVANS AVE
Goldsmith Gulch Stormwater Tributary
BP - Bluegrass Park
C - Channel
DEV - Developed
DU - Disturbed Upland
HW - Herbaceous Wetland
NV - Not Vegetated
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TR - Trail
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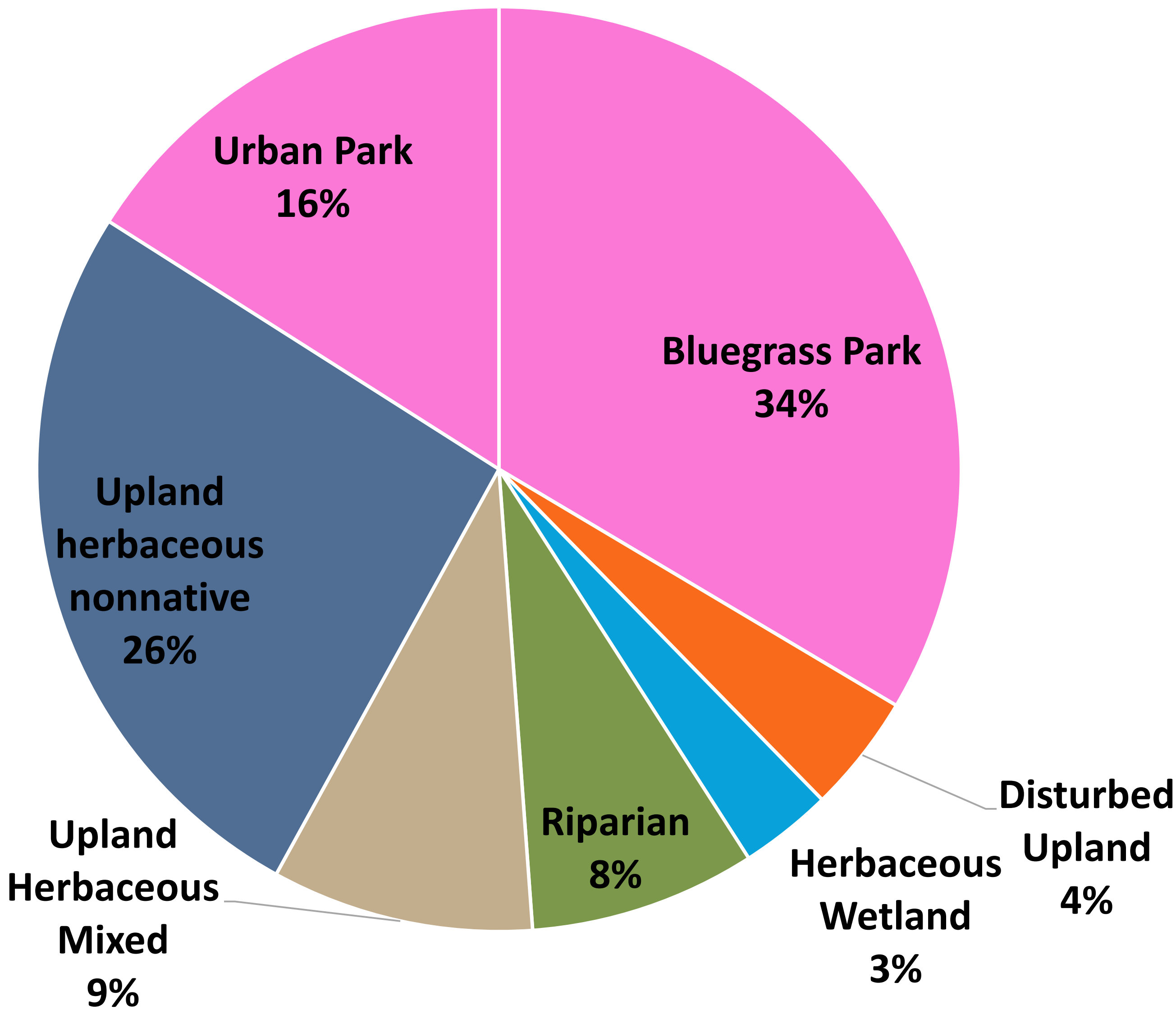
UHN - Upland Herbaceous Non-native
UP - Urban Park
Weeds
Combination
1 = <10%
2 = 10-20%
3 = 20-50%
4 = 50-80%
Routine Debris - Linear
UDFCD Floodplain
Mowing Limit
Parcel Boundary
City &County of Denver Parcel
Park
0 50 100
feet
Map 3
Goldsmith Gulch
Field Map
Prepared for:
File: 4912-2 UDFCD Fieldmaps 2014_07.mxd (WH)
October 17, 2014

Vegetation Communities, All Streams in Denver



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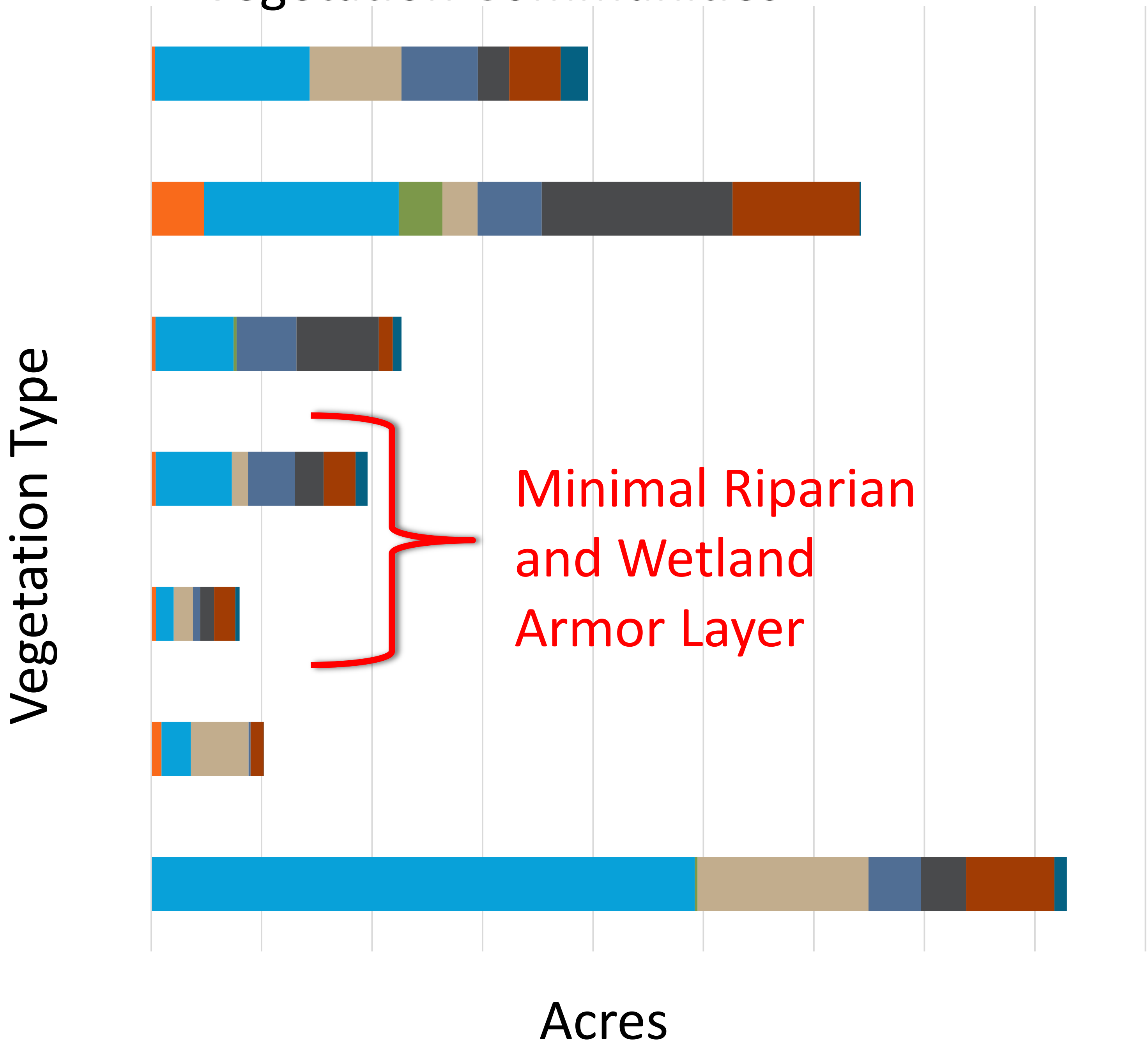
Vegetation Communities




Goldsmith Gulch, July 2014

Progression of Vegetation Health at Cherry Creek

June 2013

Avg. Daily High Temperature: 88˚F
Prev. 3-Month Precipitation: 2.64 inches

June 2014

Avg. Daily High Temperature: 83˚F
Prev. 3-Month Precipitation: 3.43 inches

Progression of Vegetation Health at Goldsmith Gulch

Monaco Detention (above), and Tamarac Drive (below)

June 2012

Avg. Daily High Temperature: 92˚F
Prev. 3-Month Precipitation: 2.79 inches

June 2013

Avg. Daily High Temperature: 88˚F
Prev. 3-Month Precipitation: 4.02 inches

June 2014

Avg. Daily High Temperature: 83˚F
Prev. 3-Month Precipitation: 4.69 inches

Progression of Vegetation Health at Goldsmith Gulch

Monaco Detention (above), and Tamarac Drive (below)

July 2012

Avg. Daily High Temperature: 94˚F
Prev. 3-Month Precipitation: 3.16 inches

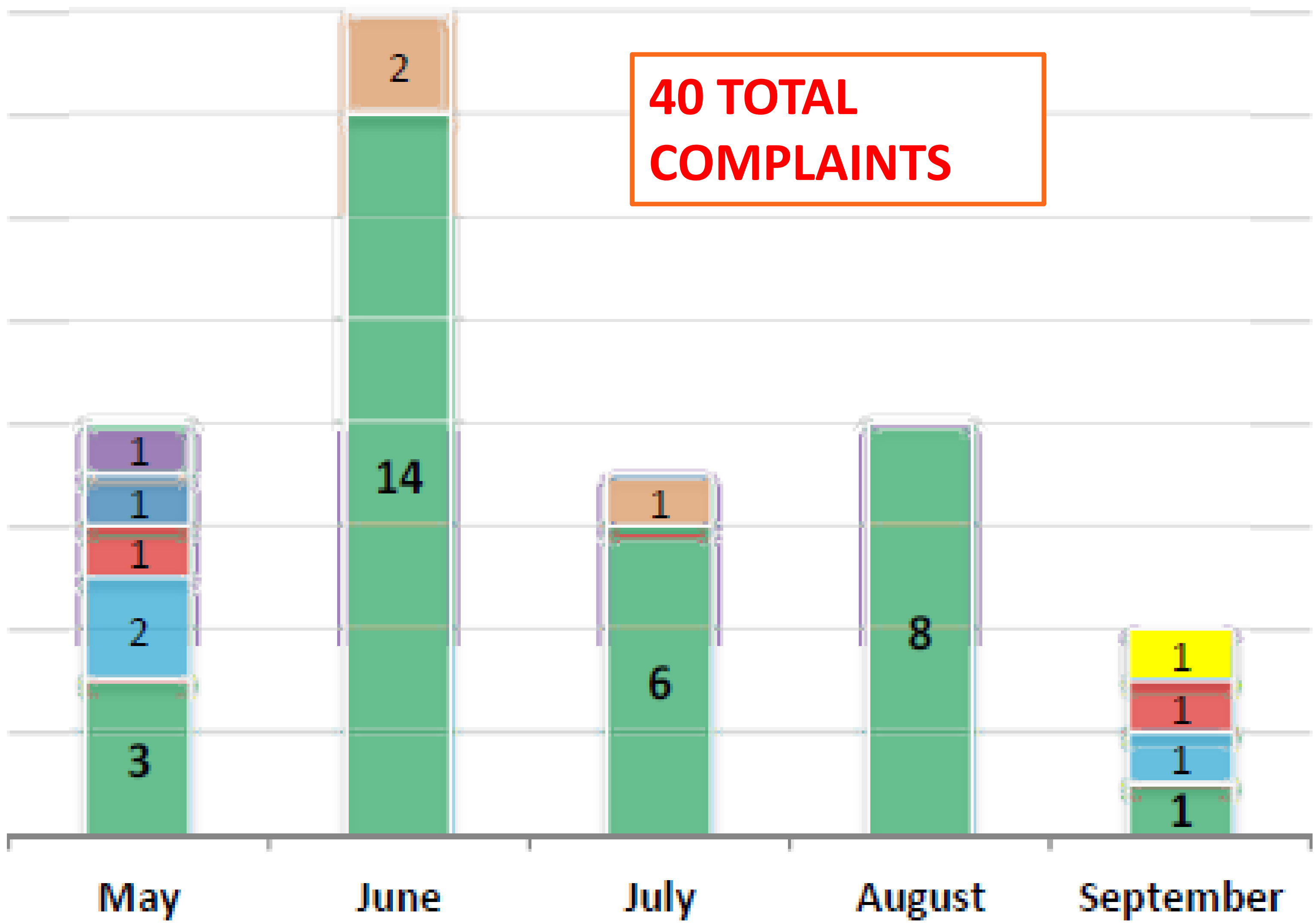
July 2013

Avg. Daily High Temperature: 88˚F
Prev. 3-Month Precipitation: 4.85 inches

July 2014

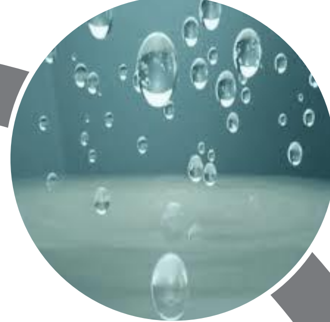
Avg. Daily High Temperature: 88˚F
Prev. 3-Month Precipitation: 6.54 inches

Season 2014


2
40 TOTAL COMPLAINTS
1
1
1
2
3
14
1
6
8
1
1
1
1
May
June
July
August
September


Take
Away

What is stream health?



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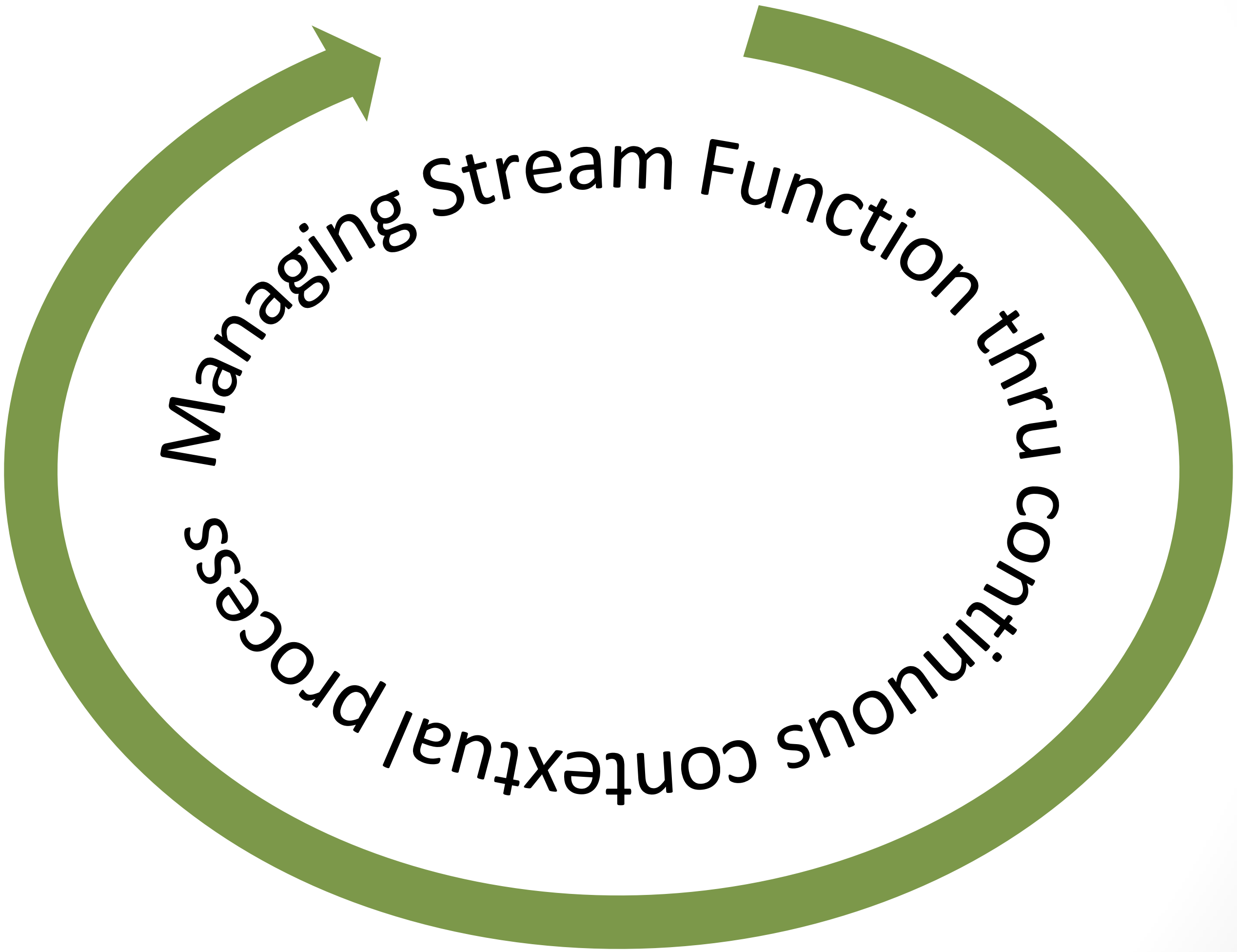


Pilot Project

- Dominant blue grass and **minimal riparian and wetlands** armoring layer.
- Eliminating broad scale mowing has been **beneficial**.

Friend of the District Award

Mark Glidden

Accomplishments

- ASCE Environmental and Water Resource Institute – Knowledge Management Committee
- ASCE – Committee on Continuing Education (Former Chair)
- ASCE Environmental and Water Resource Institute – Continuing Education Council (Former Chair)
- Instructor for ASCE Class on Manual of Practice for Urban Stormwater Management Systems (MOP 77)
- Urban Hydrology Chapter Author for ASCE Hydrology Handbook
- Construction Methods Chapter Author for ASCE Manual of Practice No. 77

Accomplishments

- University of Colorado at Denver, College of Engineering – Engineering Advisory Council
- Colorado Association of Stormwater and Floodplain Managers (Former Chair)
- American Public Works Association – Institute of Water Resources (Former Chair)
- City of Aurora Drainage Board
- Denver Regional Council of Governments – Environmental Policy Committee

2015 Friend of UDFCD Award

Mark W. Glidden, P.E.

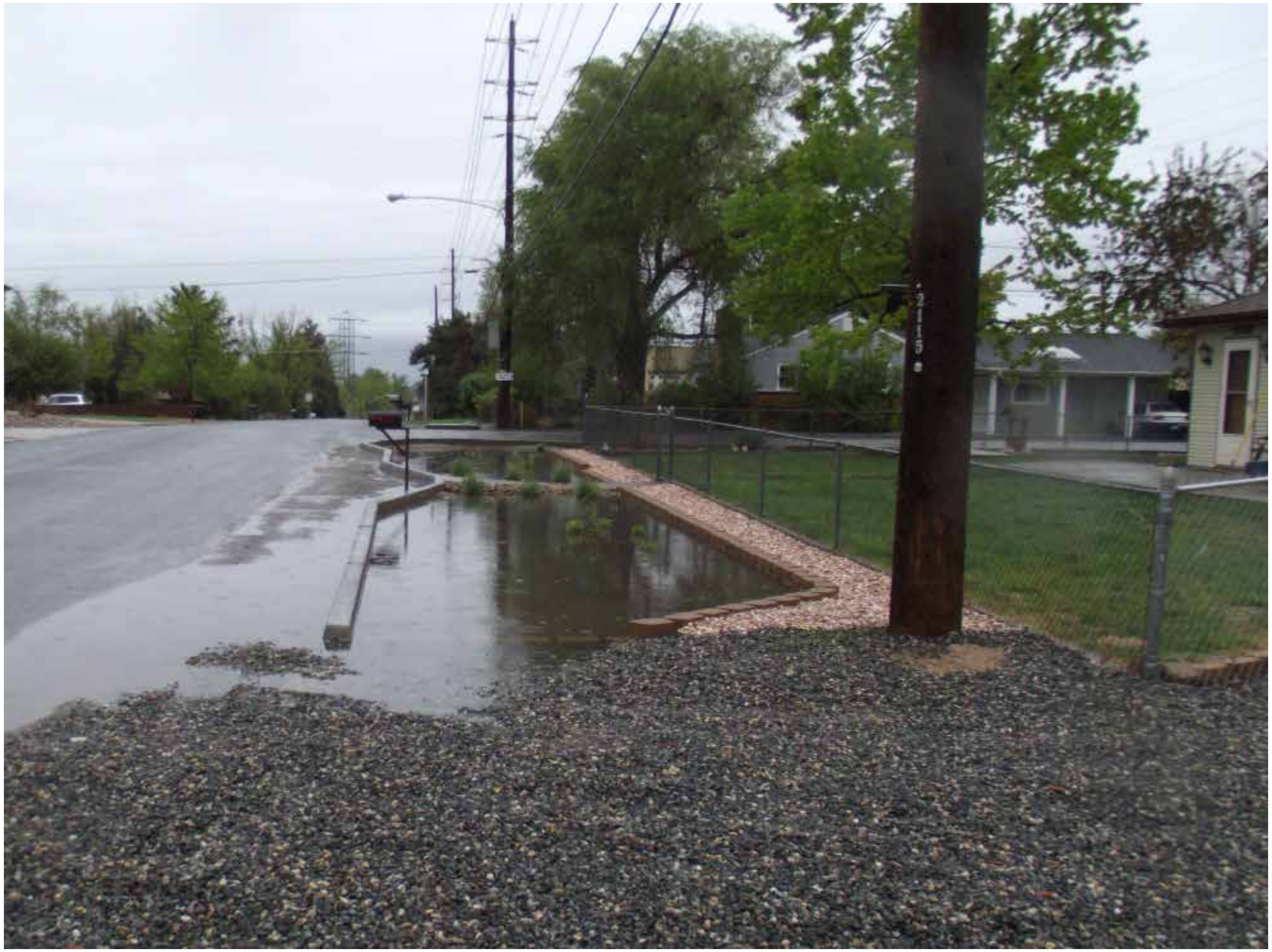
For His Contributions to
The State of the Practice
In Stormwater Management

Rainwater Harvesting with Cloud-based Infrastructure

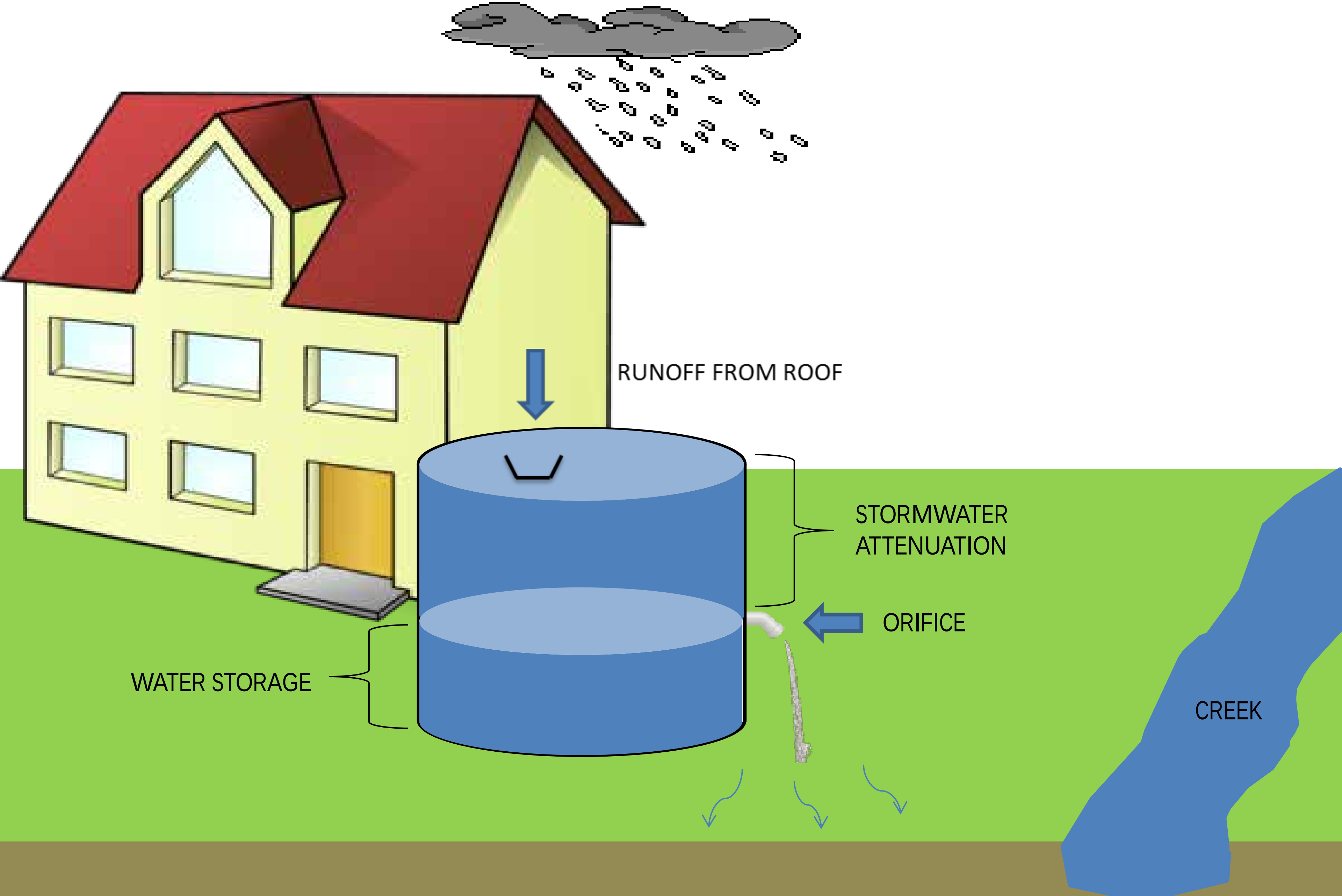
Holly Piza, PE
Project Manager, Master Planning Program

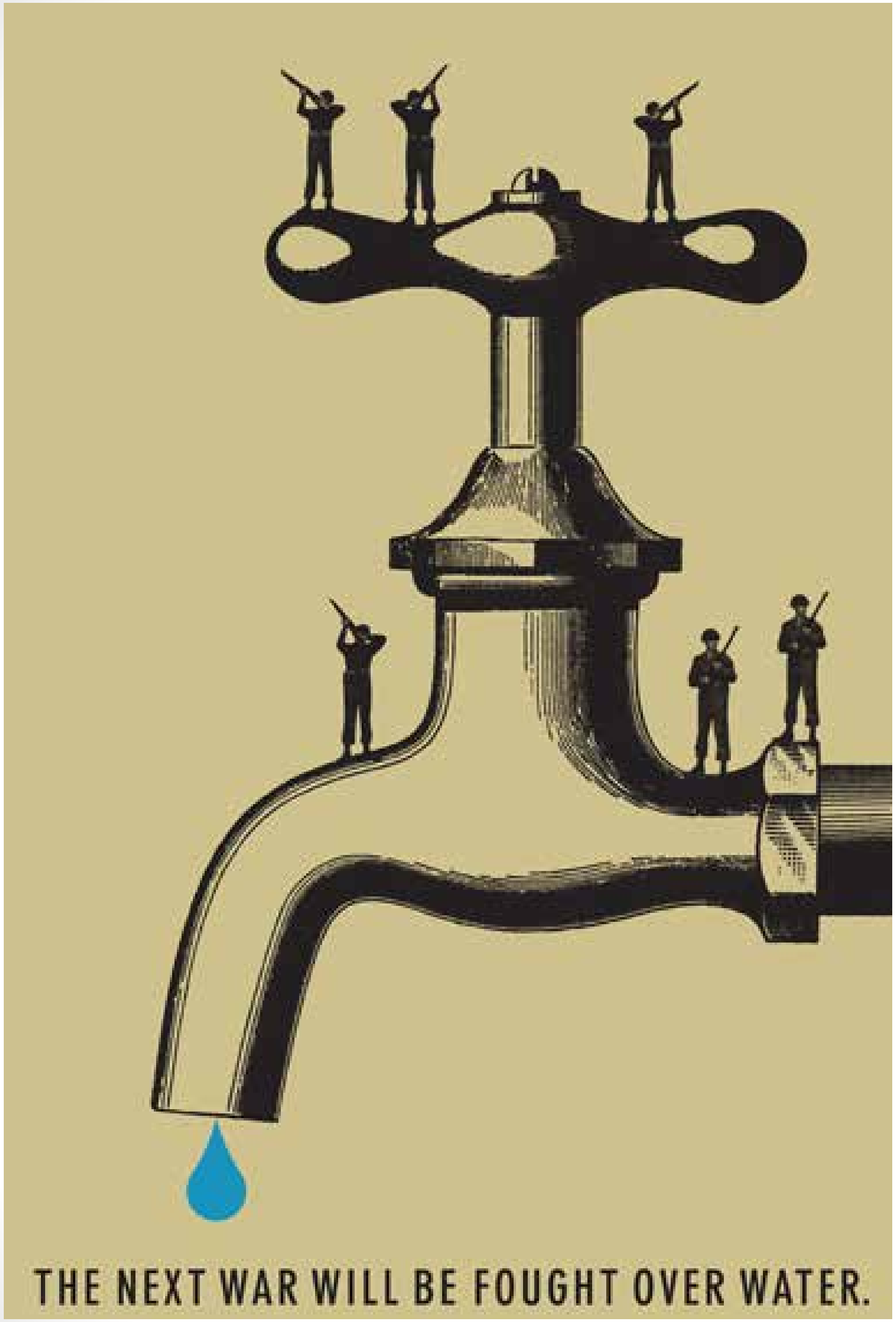
2015 UDFCD Annual Seminar April 7,2015

The Problem with Rainwater Harvesting



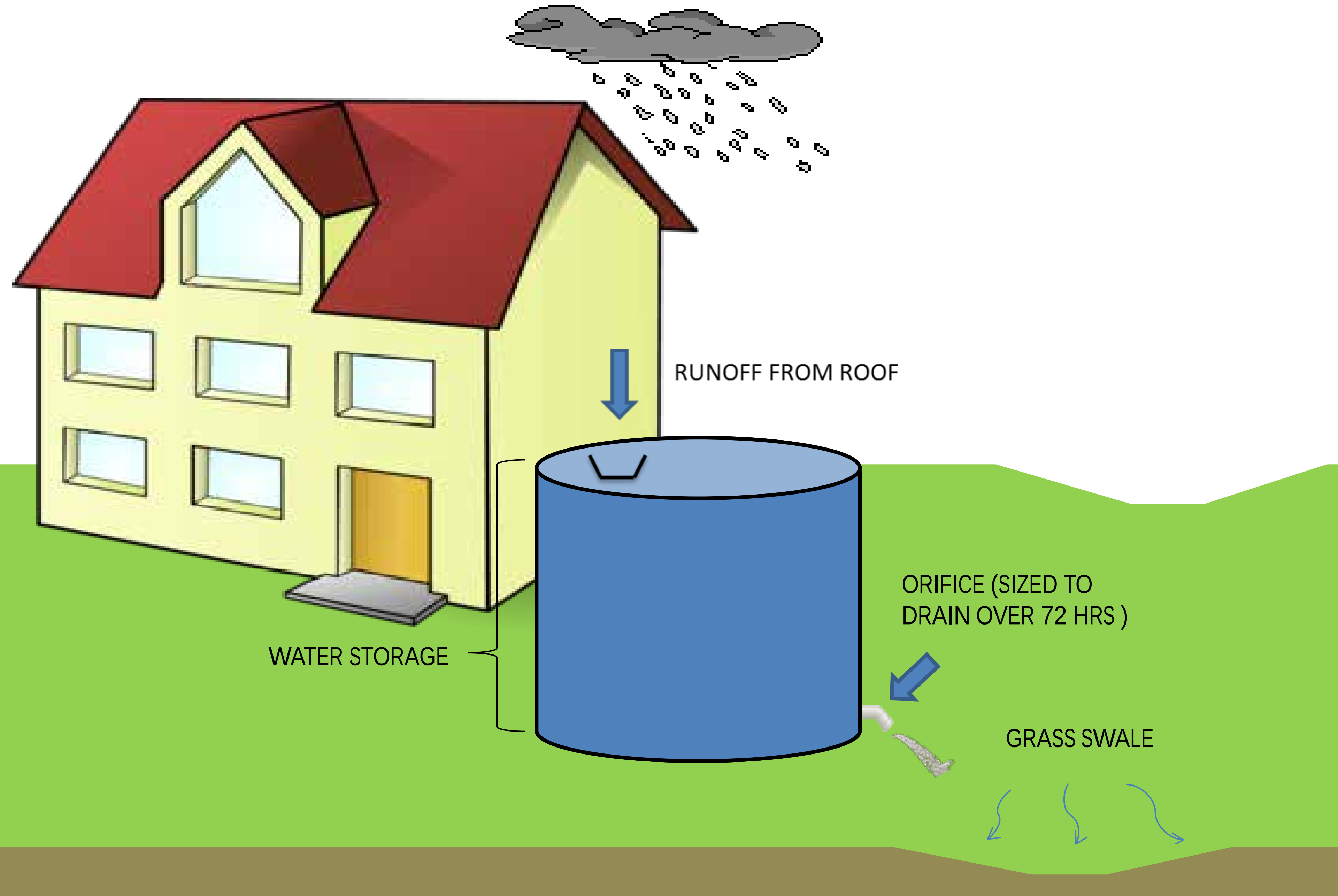
North Carolina Cistern (Passive Control)



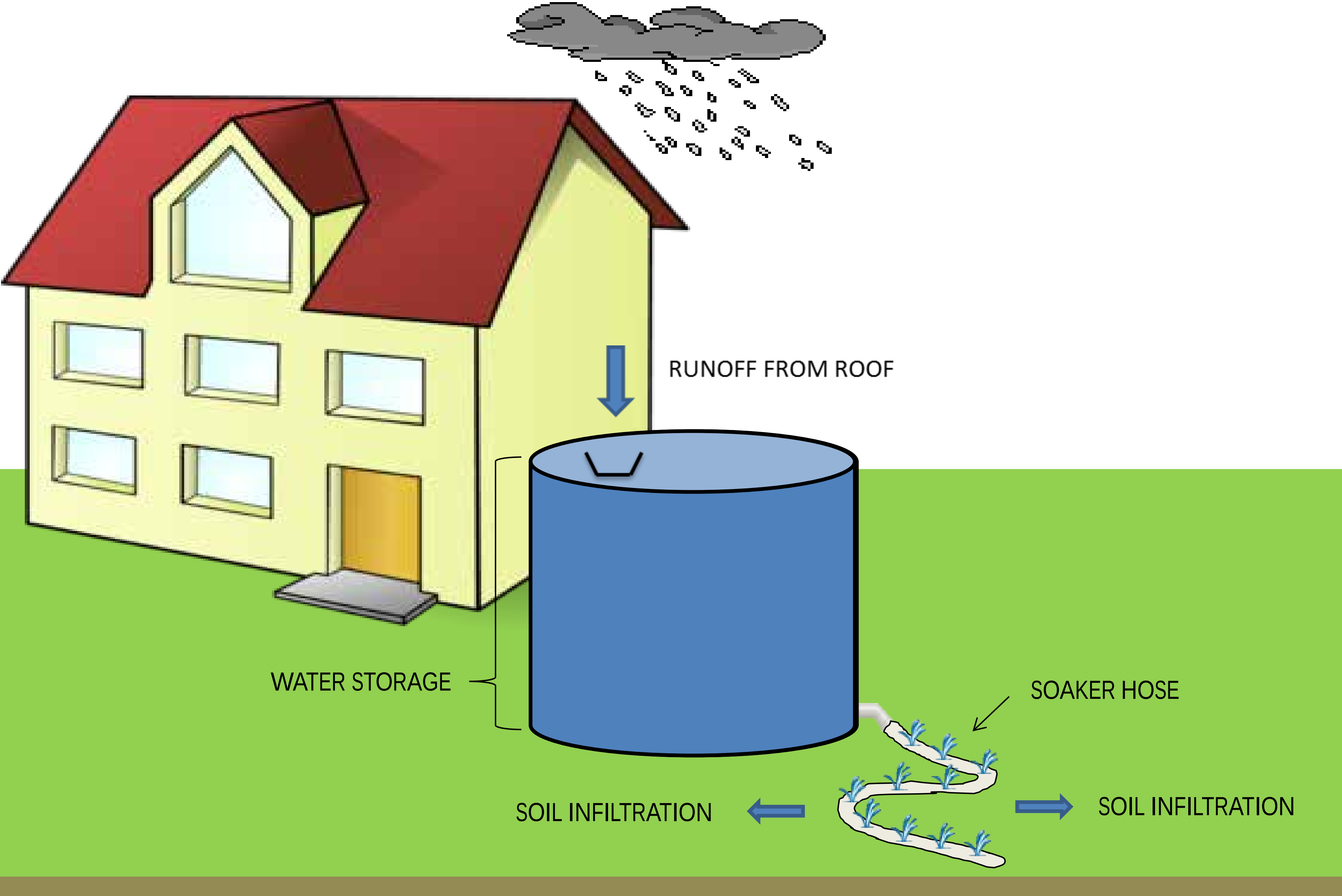


Credit: Scorsone/Drueding

Colorado Cistern (Passive Control)



Colorado Cistern (Passive Control)

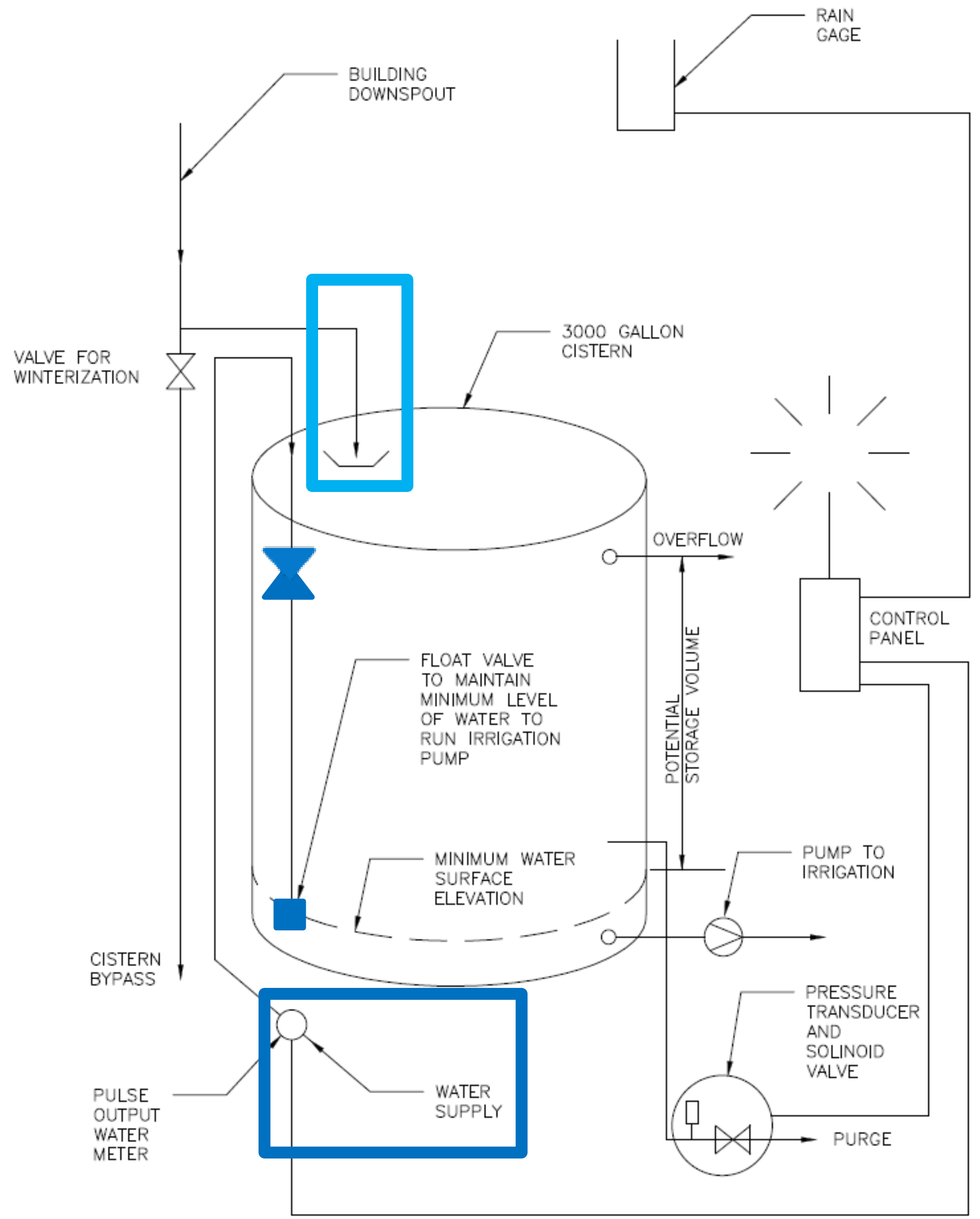


Denver Green School Cistern

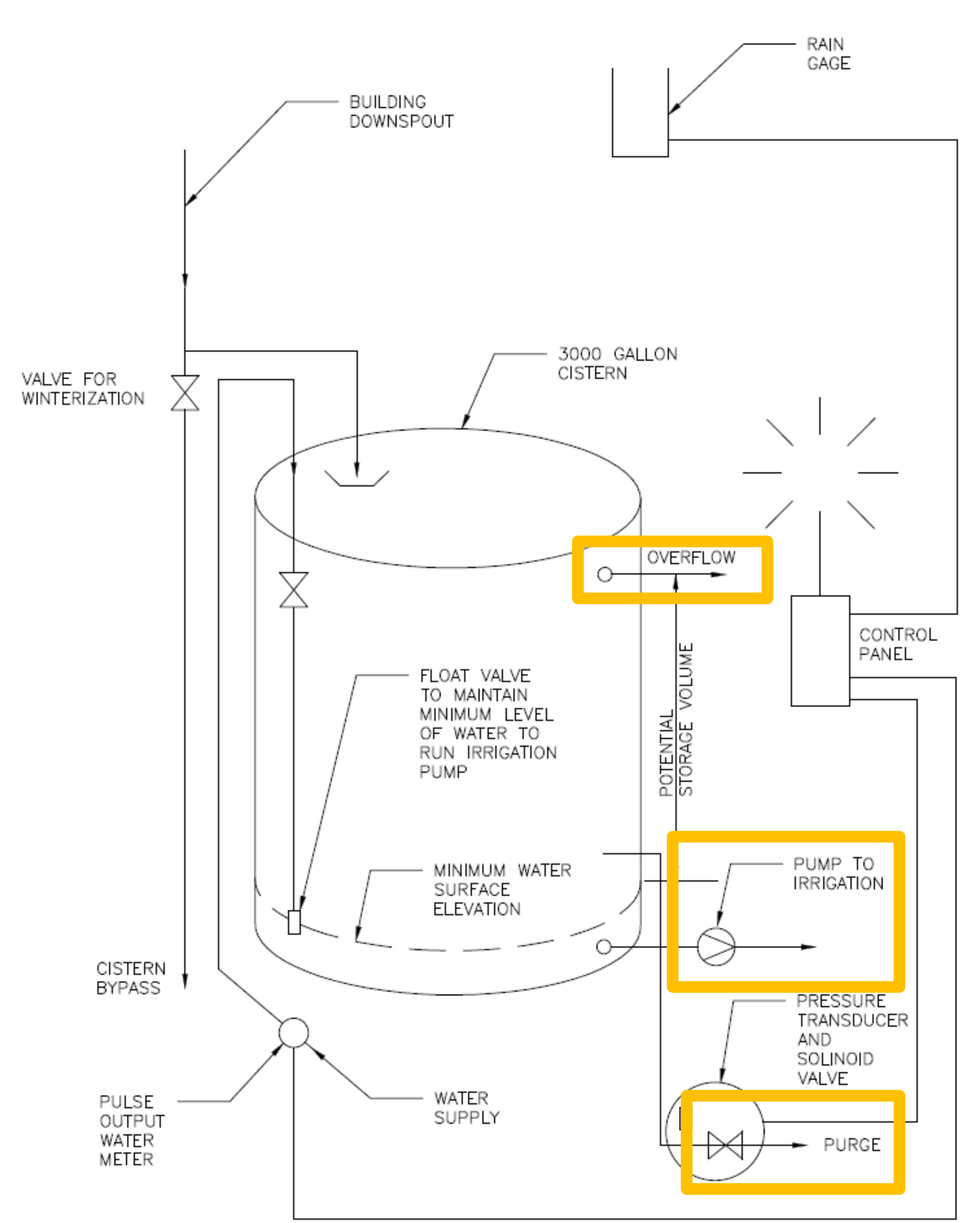
- New Building
- 7300 Square-feet – one downspout!
- Project Based Learning

Denver Green School
Denver Public Schools

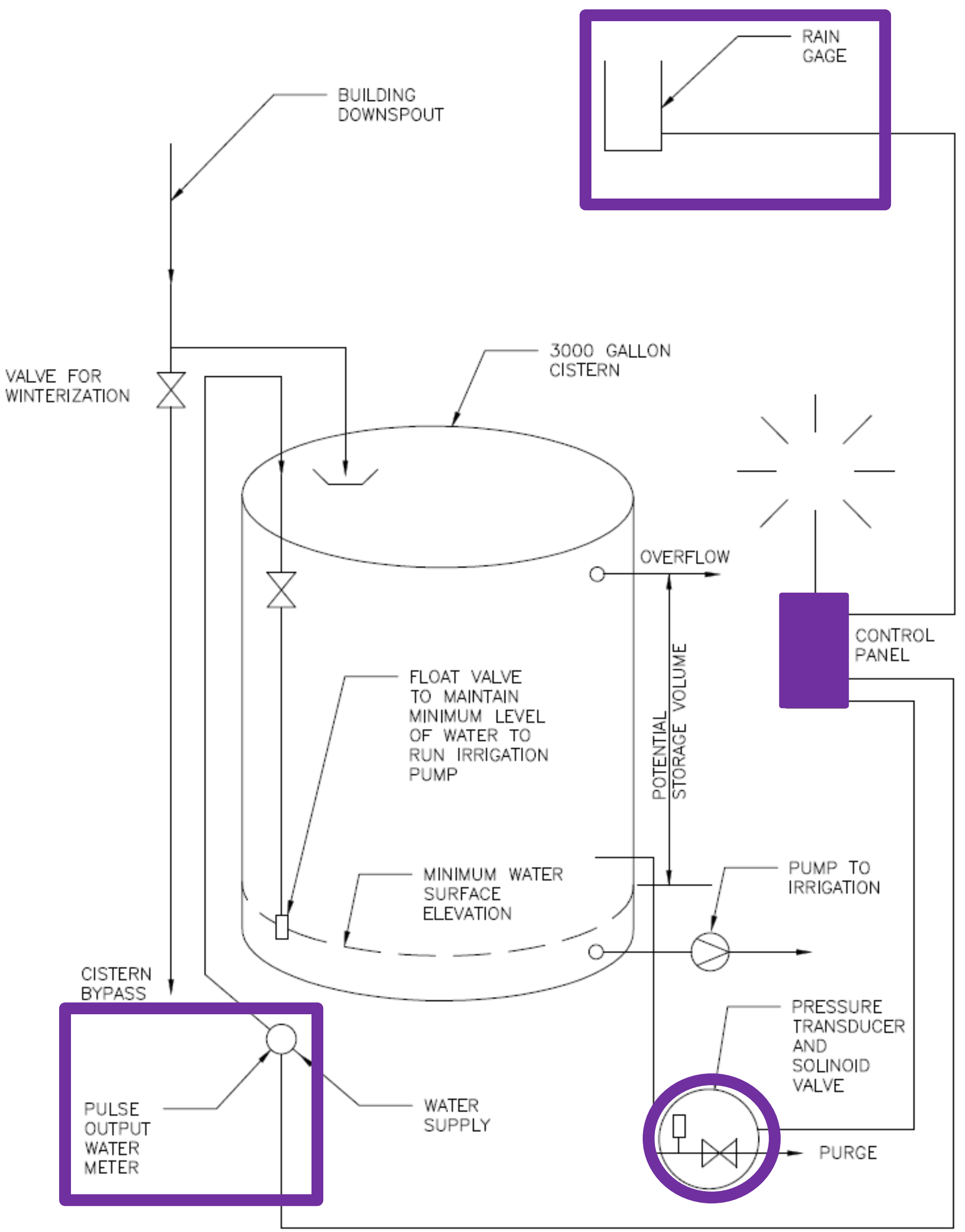
Active Control



Active Control



Active Control

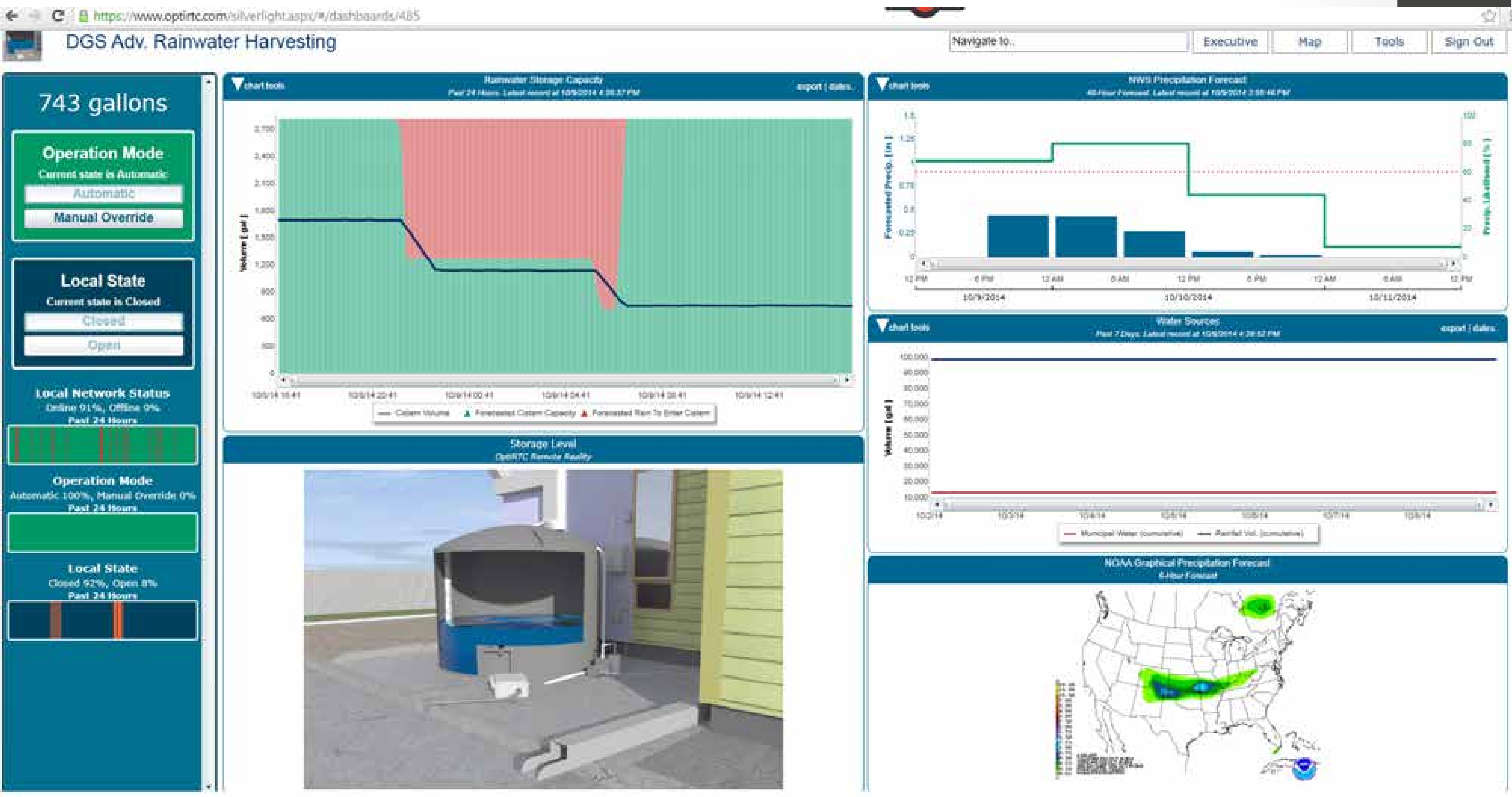


Sizing for Stormwater Capture

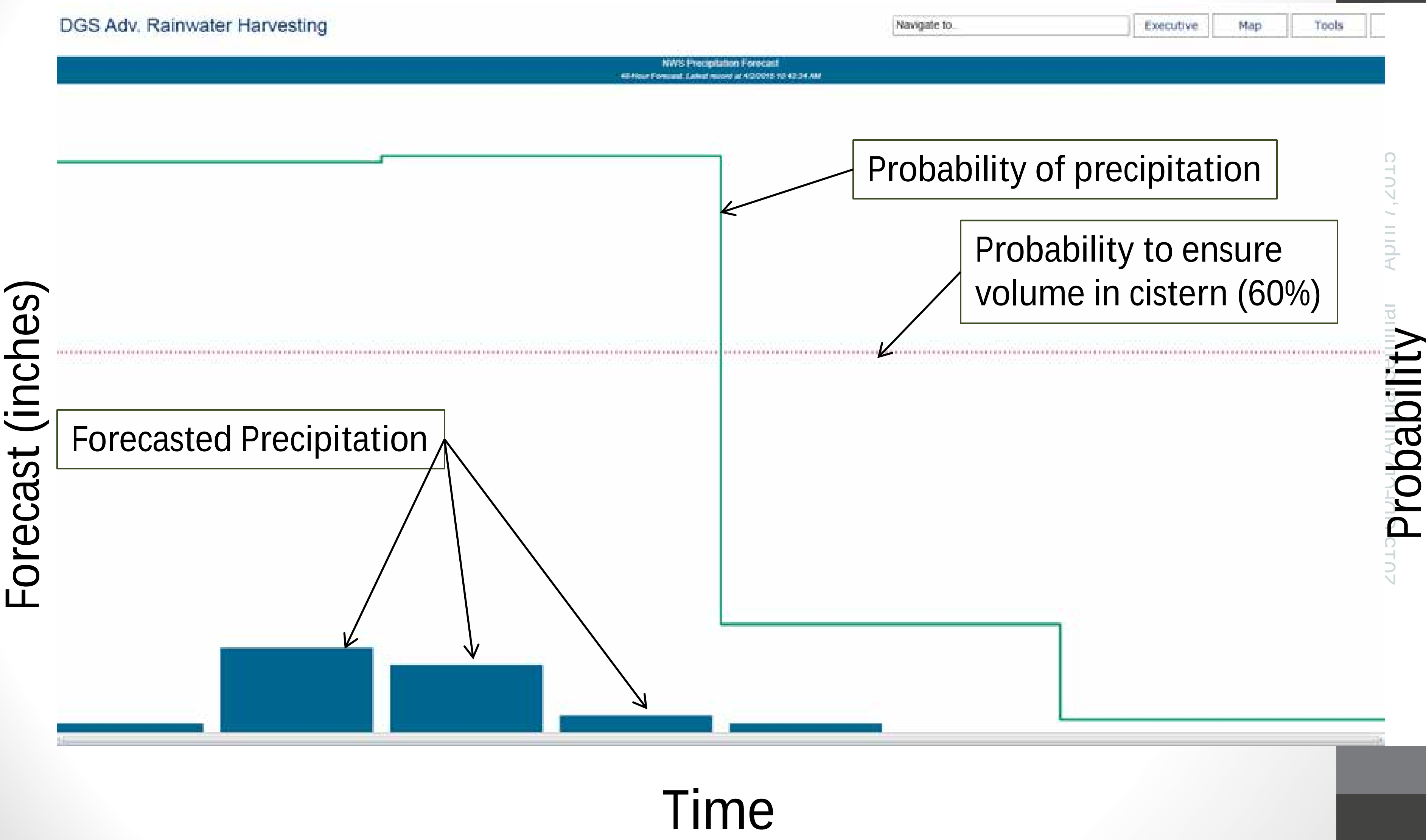
- WQCV Event = 0.6 inches
- Annual Rainfall = 15 inches
  - April through September --1 to 2 inches per month)

- 3000 gallon cistern
- 7,300 SF roof
- Appox. 0.7” event

Purge Event (Screenshot)



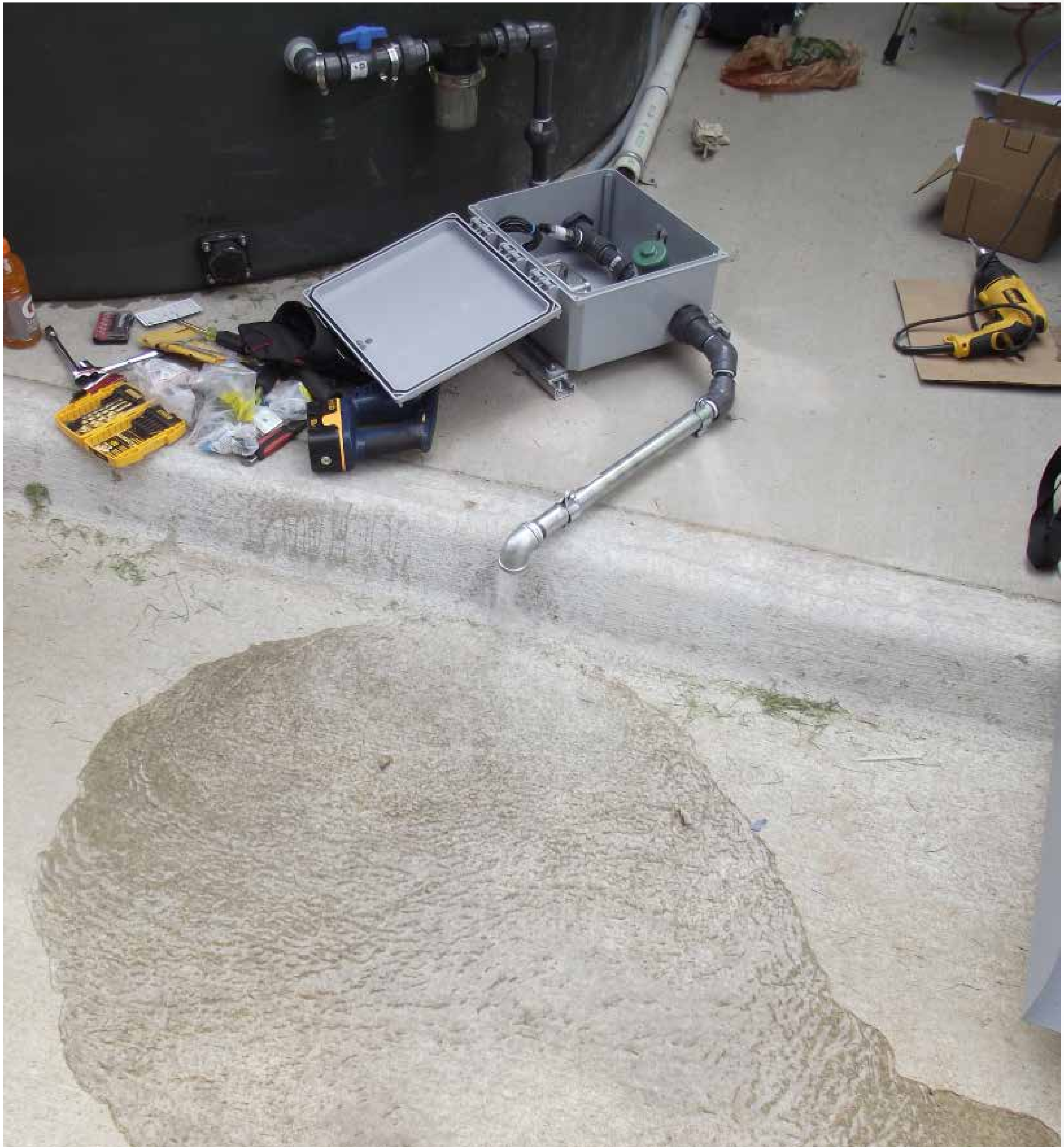
NWS Forecast



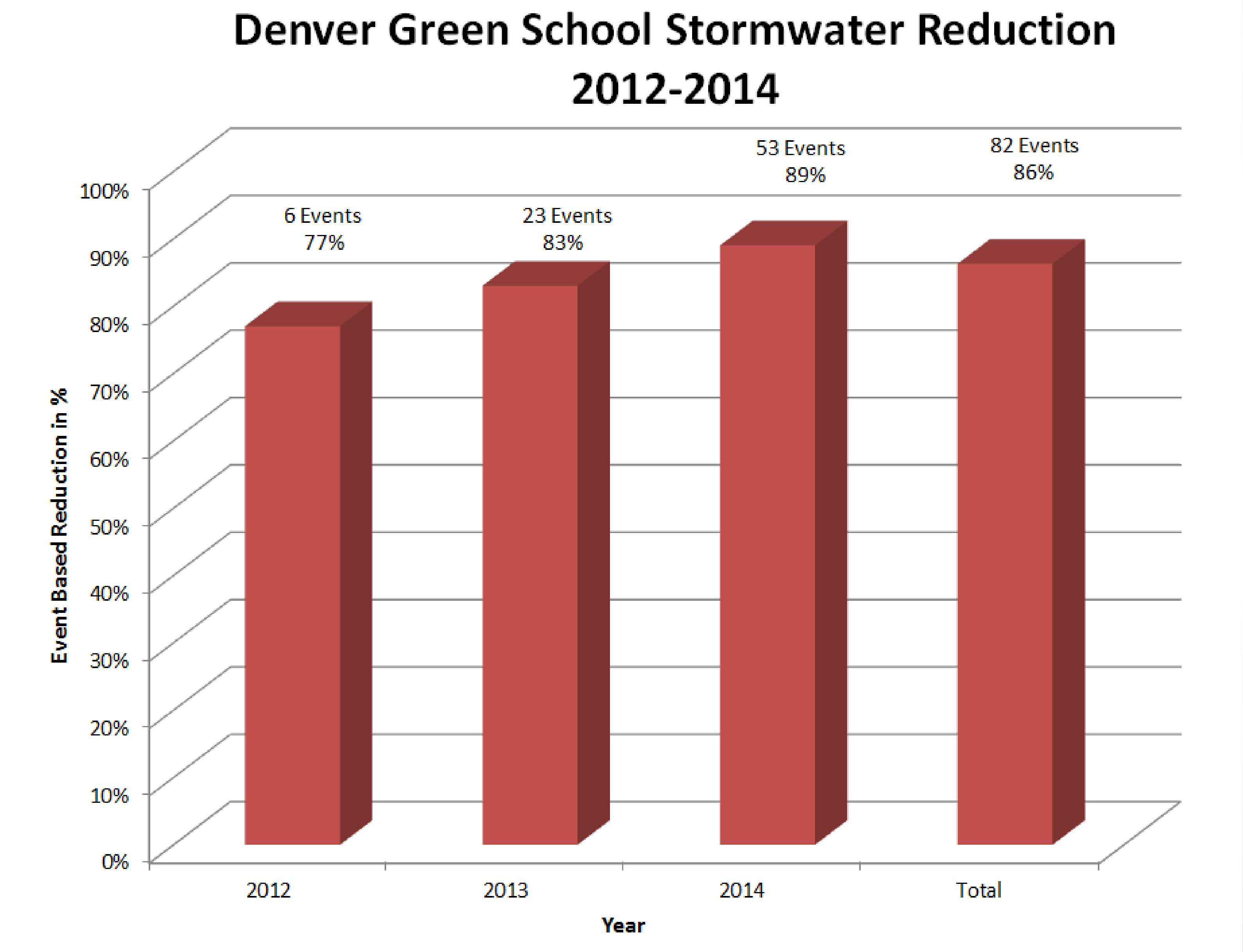
Purge followed by rain

Volume

Time (5 days total)



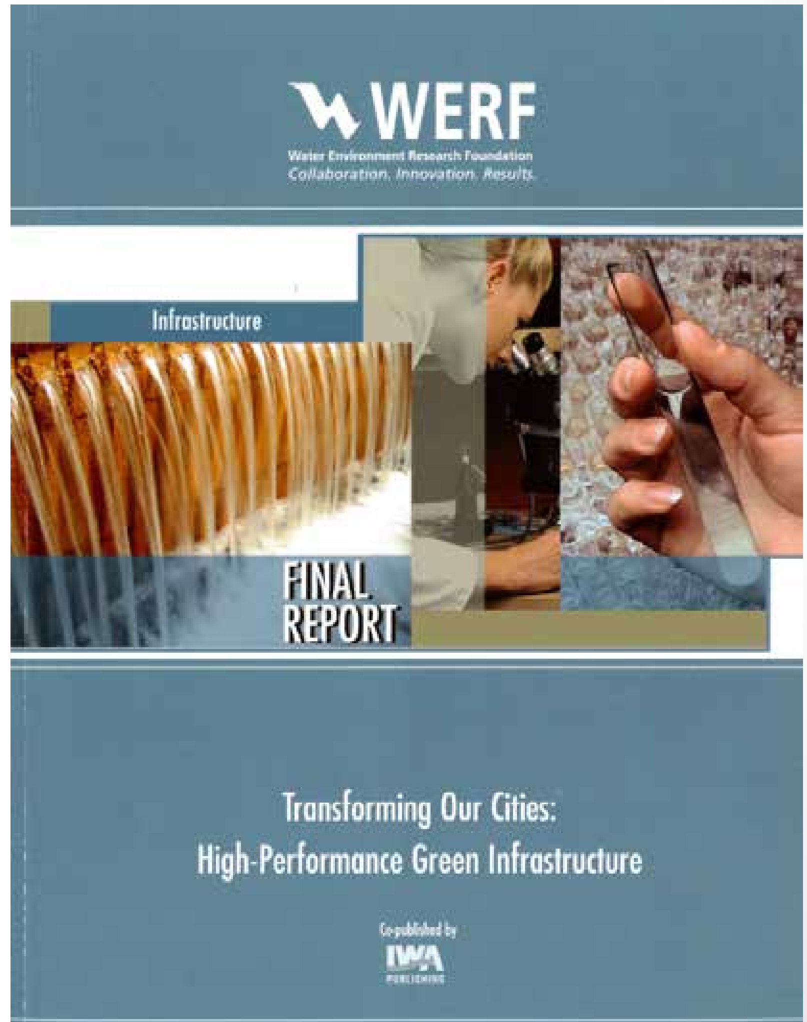
Conclusions



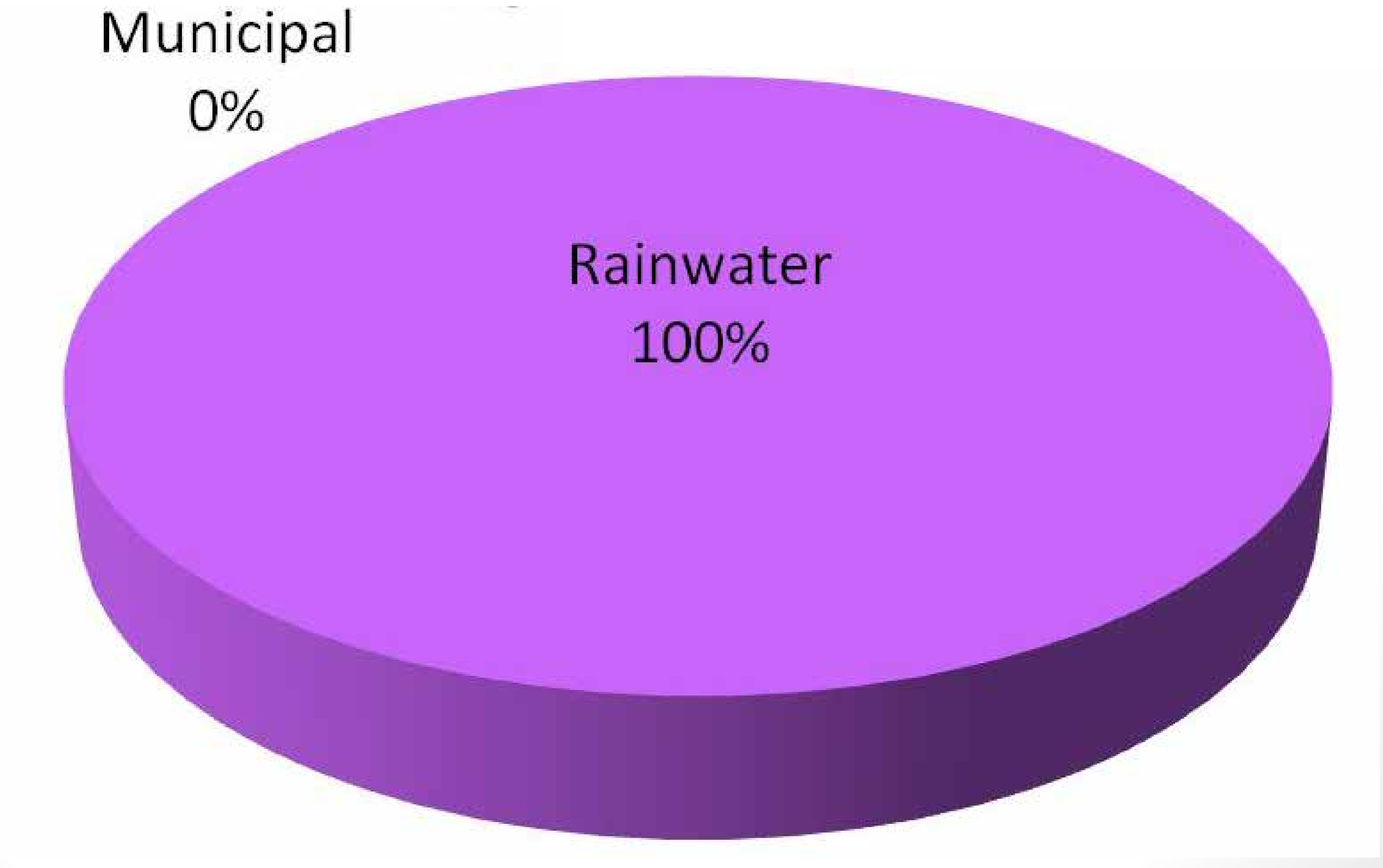
Cloud-based Infrastructure

- 99% Decrease in Wet-weather Discharge
- 95% Reduction in Water Lost to Bypass
- 2x Increase in Residence time
- 50% Decrease in Required Storage Volume

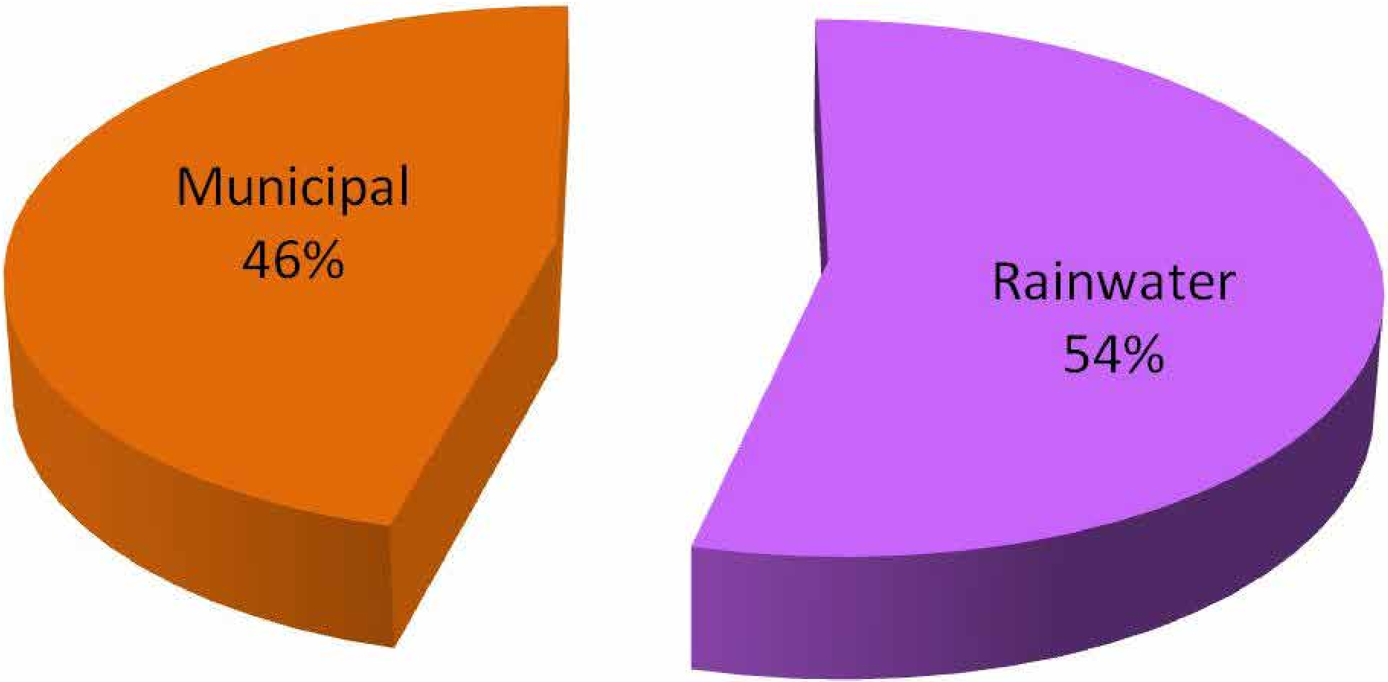
OptiRTC



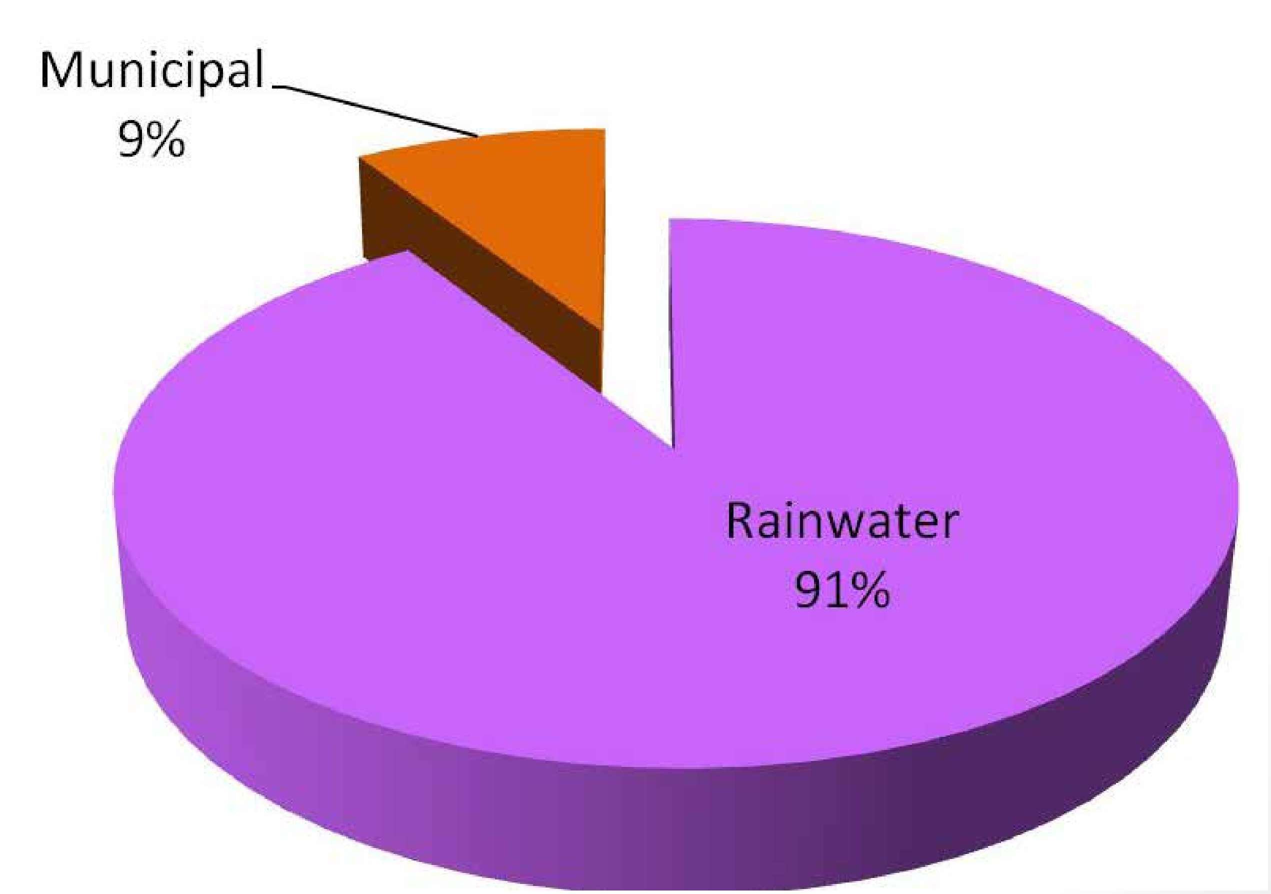
2012 Irrigation Supply



2013 Irrigation Supply

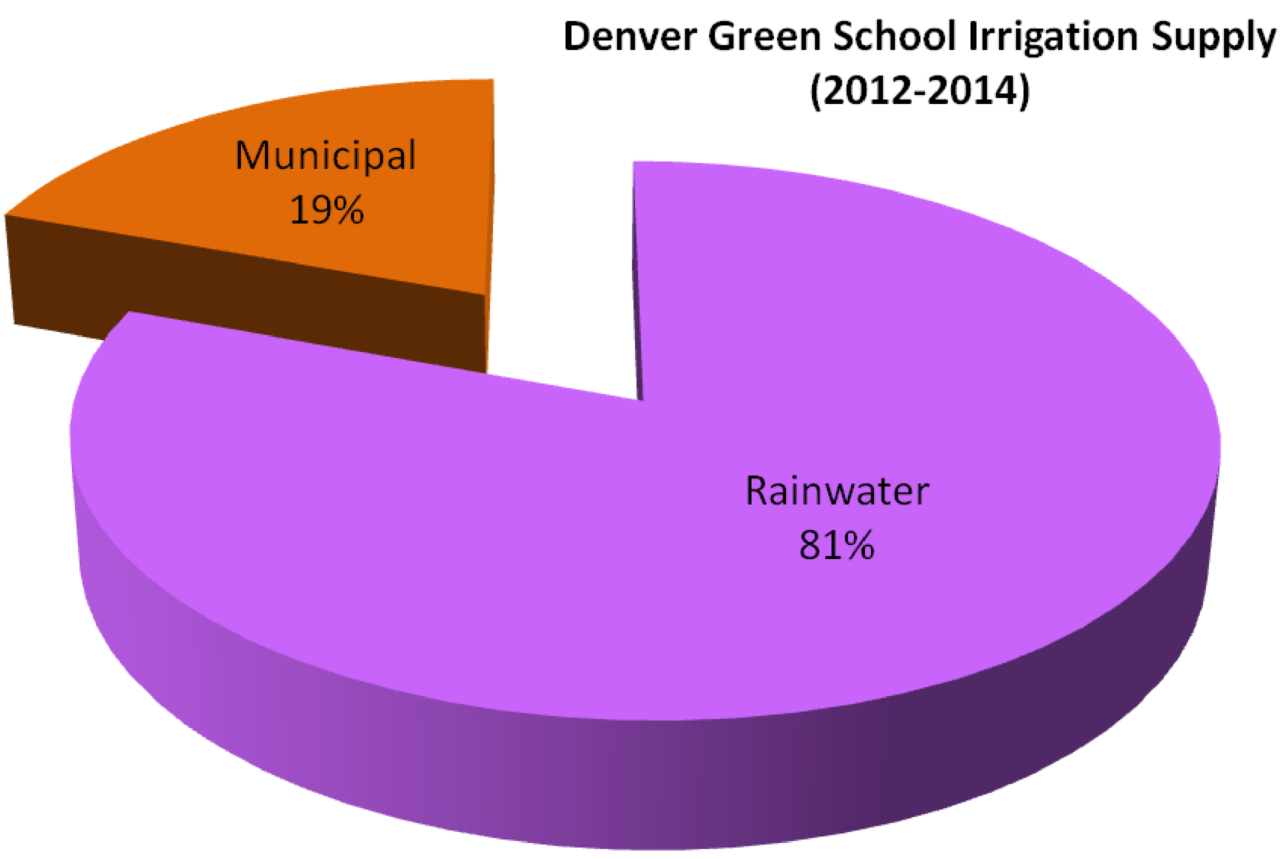


2014 Irrigation Supply



Conclusions

- Sizing for WQCV + 15% was about right.



Costs

Pump and Cistern	$3800	
Downspout	$902	
Smart Technology	$15,000	(UDFCD share)
Water Augmentation and Filing	$2000	For 5 years
Total:	**$21,702**	

Cost saved in irrigation water = $33

Cost difference between a 0.75” tap and a 1” tap > $11,000

Thank You

- WERF
- Geosyntec
- Urban Watersheds Research Institute
- Trevor Toms
- Denver Botanic Gardens
- Welby Farms
- Denver Public Schools
- Denver Water

Challenging Uncertainty in Hydrologic Paradigms

Shea Thomas, Project Manager
Gerald Blackler, Enginuity Engineering Solutions

2015 UDFCD Annual Seminar April 7, 2015

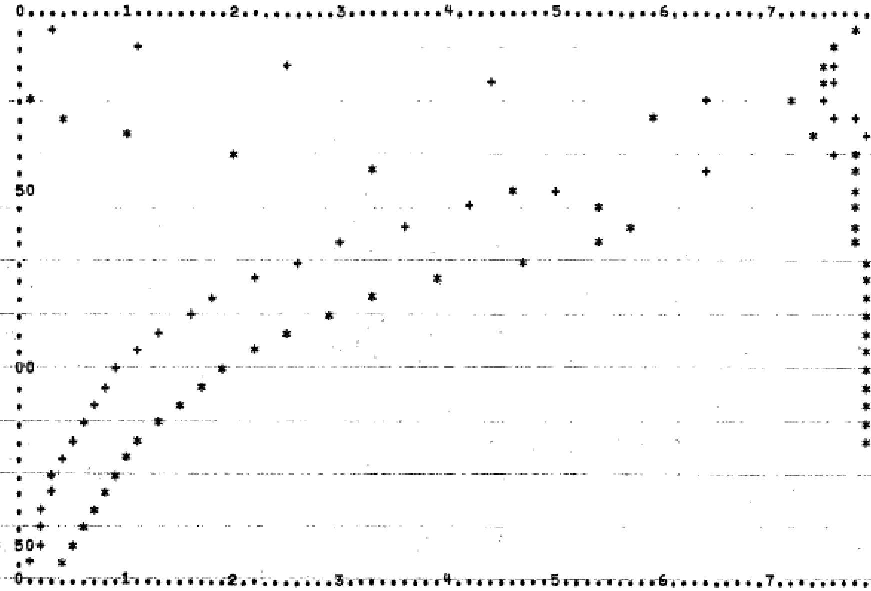
“Hydrology is more of an art than a science.”

- Everyone

Colorado Urban Hydrograph Procedure

BASIN J-3   10 YR STORM, FUTURE CONDITION

FLOWS IN CFS   RAIN AND RUNOFF



TIME	U-HYD	S-HYD	HY-IN	H-OUT	RNOFF	RAIN
5	9	0	0	0	0,000	0,060
10	35	0	0	0	0,009	0,100
15	79	0	0	0	0,019	0,120
20	140	2	0	0	0,021	0,130
25	205	4	0	0	0,082	0,200
30	244	13	0	0	0,474	0,520
35	257	33	0	0	0,117	0,160
40	244	64	0	0	0,008	0,050
45	205	105	0	0	0,006	0,040
50	161	147	0	0	0,006	0,040
55	136	173	0	0	0,006	0,040
60	115	183	0	0	0,006	0,040
65	97	175	0	0	0,006	0,040
70	82	152	0	0	0,005	0,030
75	70	125	0	0	0,005	0,030
80	59	106	0	0	0,005	0,030
85	50	92	0	0	0,005	0,030
90	42	80	0	0	0,005	0,030
95	36	70	0	0	0,005	0,030
100	30	61	0	0	0,005	0,030
105	26	53	0	0	0,003	0,020
110	22	47	0	0	0,003	0,020
115	18	41	0	0	0,003	0,020
120	16	37	0	0	0,003	0,020
125	13	32	0	0	0,000	0,000
130	11	29	0	0	0,000	0,000
135	9	25	0	0	0,000	0,000
140	8	22	0	0	0,000	0,000
145	7	19	0	0	0,000	0,000
150	6	16	0	0	0,000	0,000
155	5	14	0	0	0,000	0,000
VOLUMES AND TOTALS	16,3	13,2	0,0	13,2	0,810	1,830

(+)=QU   (*)=QS   (,)=QIN   (X)=QOUT

****HYDROGRAPH STORED IN LOCATION 133 FILE 3****

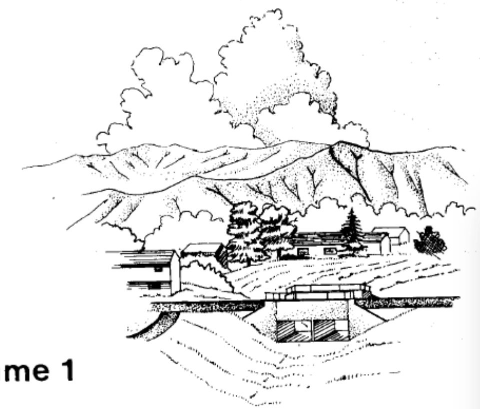
DeGROOT

1972

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

City of Denver   Jefferson County   City of Lakewood

MAJOR DRAINAGEWAY PLANNING SANDERSON GULCH / WEIR GULCH



Volume 1

FRASIER & GINGERY , INC.
Consulting Engineers
Denver , Colorado
AUGUST 1972

SANDERSON GULCH

MAJOR DRAINAGEWAY PLAN

SEPTEMBER 2013

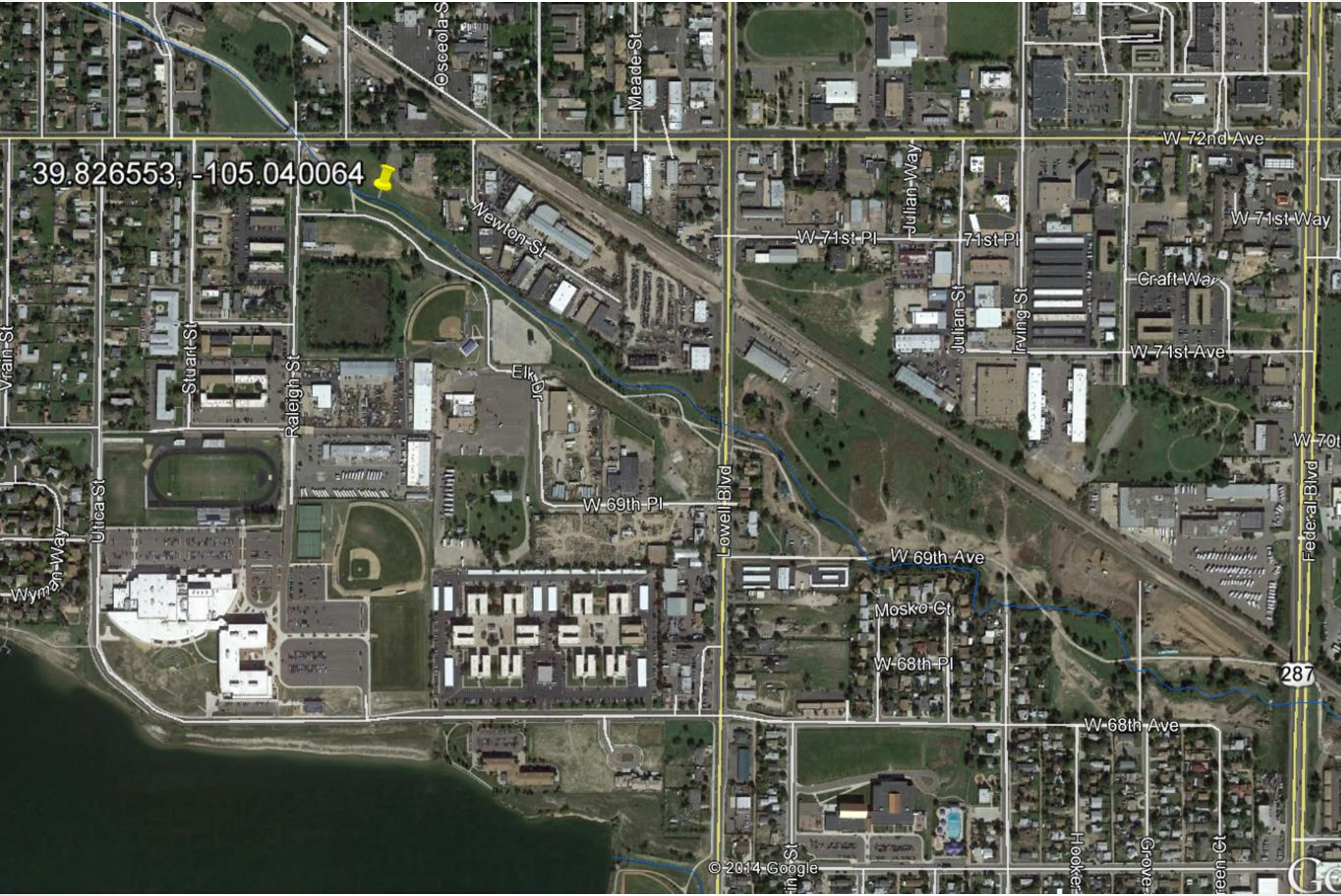
DENVER THE MILE HIGH CITY
City of Lakewood COLORADO

Sponsored by:
Urban Drainage and Flood Control District
City and County of Denver
City of Lakewood

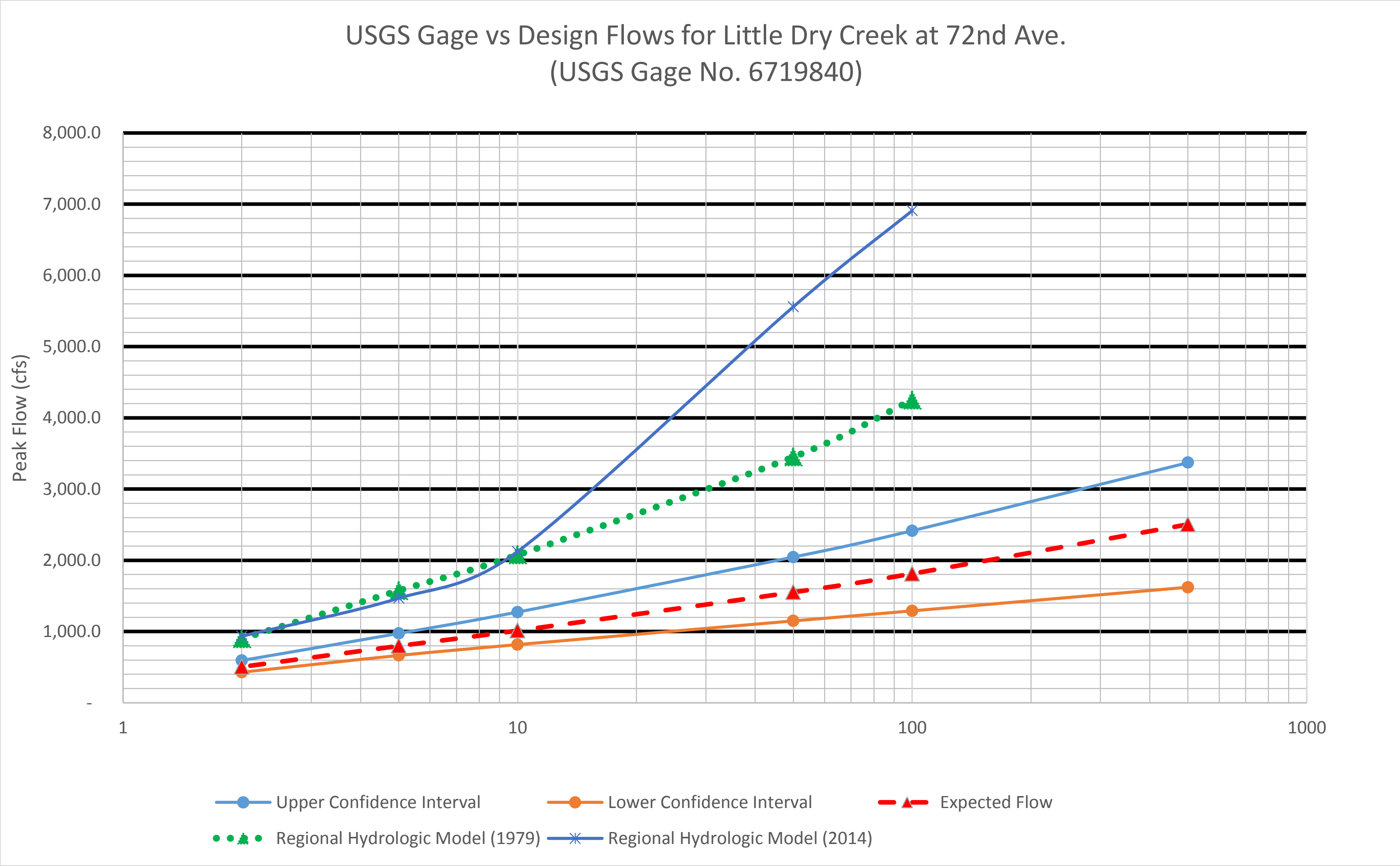
Prepared by:
Matrix DESIGN GROUP
1601 Blake Street, Suite 200 | Denver, Colorado 80202 | 303.573.0200

2013

Little Dry Creek



A word about gages…



1979 FHAD	
2-yr	875
5-yr	1550
10-yr	2100
25-yr	2820
50-yr	3450
100-yr	4250

Little Dry Creek

Raw Gage Data			
Date	Flow (cfs)	Date	Flow (cfs)
6/1/1991	1280.0	5/29/1990	518.0
8/24/1992	1280.0	4/25/1994	494.0
7/31/1997	1040.0	11/30/1984	464.0
11/30/1981	954.0	6/12/2010	463.0
11/30/1983	954.0	8/9/1999	431.0
7/8/2011	893.0	11/30/1982	420.0
11/30/1986	762.0	11/30/1985	368.0
5/17/1995	759.0	8/18/2004	347.0
7/20/2009	676.0	8/24/2007	286.0
6/9/1989	659.0	8/13/2006	278.0
8/17/2000	646.0	7/7/2012	270.0
9/17/1996	632.0	6/10/1988	255.0
6/28/2013	600.0	8/4/2005	230.0
6/17/1993	560.0	4/19/2003	207.0
8/1/2001	547.0	7/6/2002	191.0

Probability of 100-yr Event in 30 years

1979 FHAD	
2-yr	875
5-yr	1550
10-yr	2100
25-yr	2820
50-yr	3450
100-yr	4250

Raw Gage Data			
Date	Flow (cfs)	Date	Flow (cfs)
6/1/1991	1280.0	5/29/1990	518.0
8/24/1992	1280.0	4/25/1994	494.0
7/31/1997	1040.0	11/30/1984	464.0
11/30/1981	954.0	6/12/2010	463.0
11/30/1983	954.0	8/9/1999	431.0
7/8/2011	893.0	11/30/1982	420.0
11/30/1986	762.0	11/30/1985	368.0
5/17/1995	759.0	8/18/2004	347.0
7/20/2009	676.0	8/24/2007	286.0
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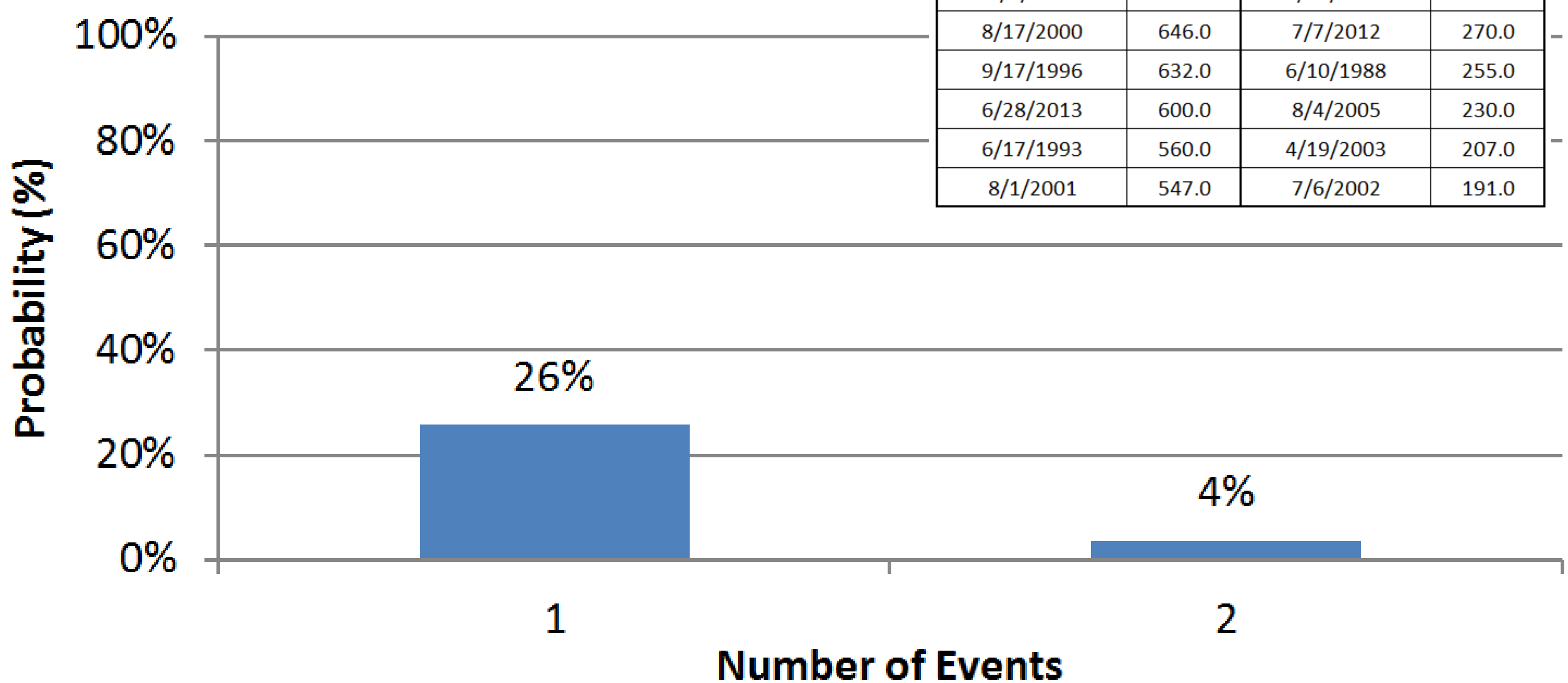
9/17/1996	632.0	6/10/1988	255.0
6/28/2013	600.0	8/4/2005	230.0
6/17/1993	560.0	4/19/2003	207.0
8/1/2001	547.0	7/6/2002	191.0



Probability of 10-yr Event in 30 years

1979 FHAD	
2-yr	875
5-yr	1550
10-yr	2100
25-yr	2820
50-yr	3450
100-yr	4250

Raw Gage Data			
Date	Flow (cfs)	Date	Flow (cfs)
6/1/1991	1280.0	5/29/1990	518.0
8/24/1992	1280.0	4/25/1994	494.0
7/31/1997	1040.0	11/30/1984	464.0
11/30/1981	954.0	6/12/2010	463.0
11/30/1983	954.0	8/9/1999	431.0
7/8/2011	893.0	11/30/1982	420.0
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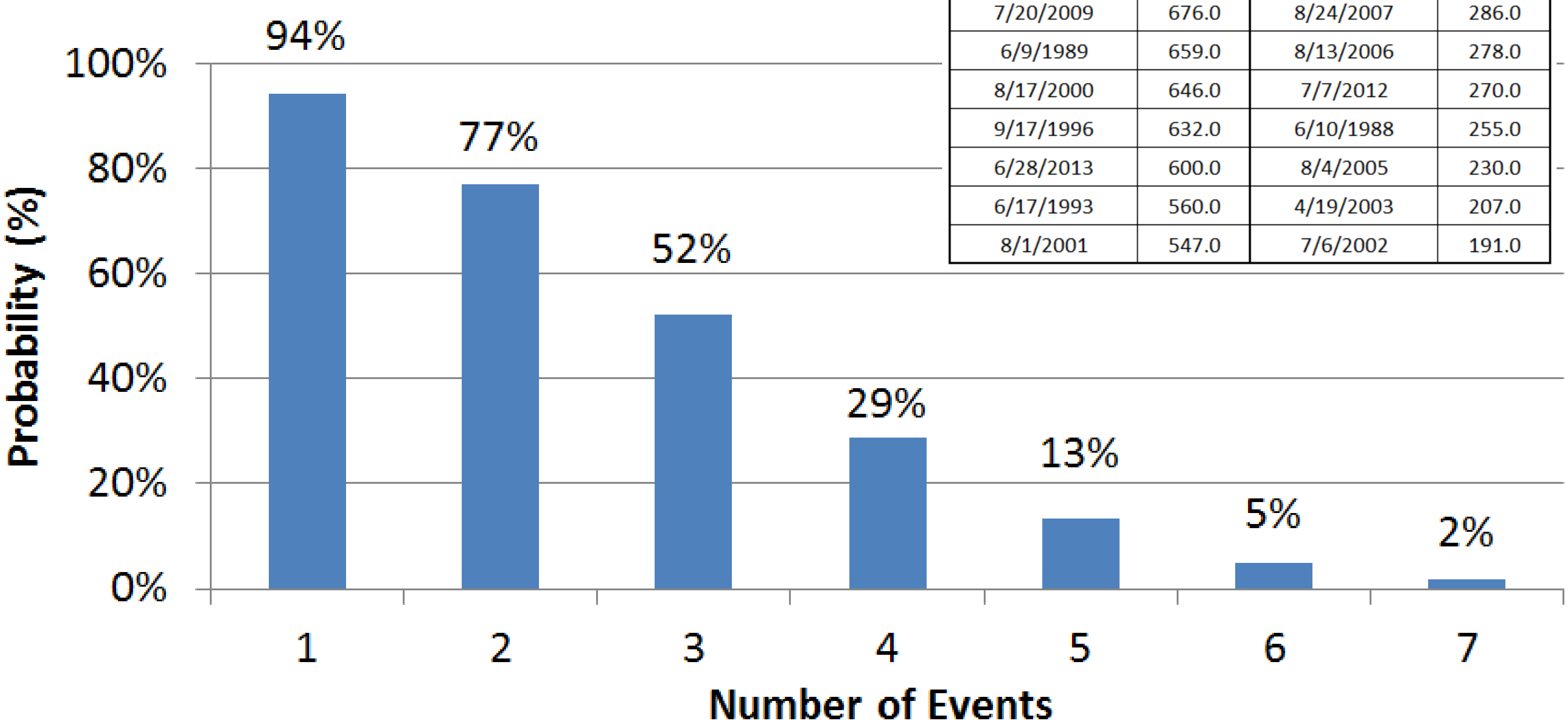
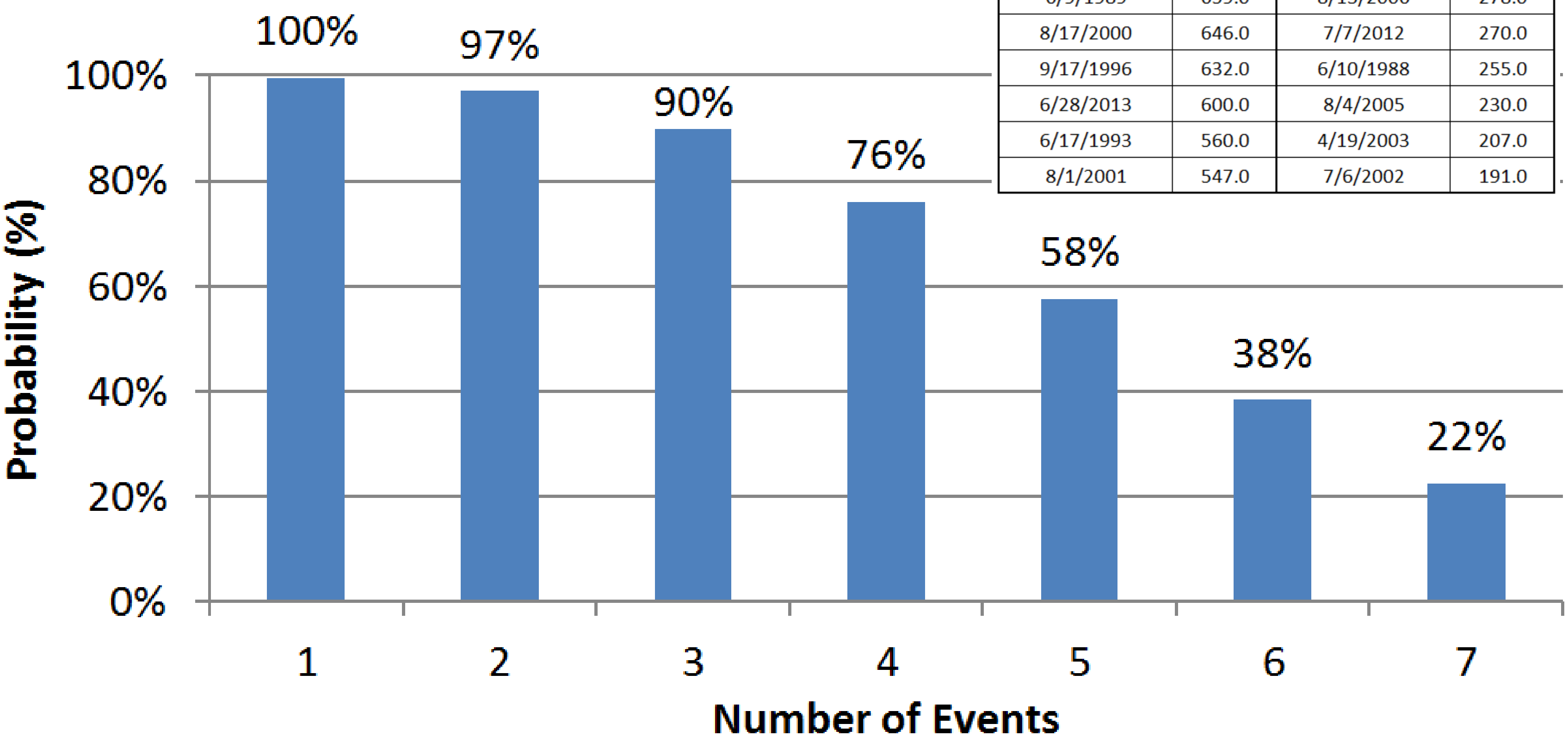
9/17/1996	632.0	6/10/1988	255.0
6/28/2013	600.0	8/4/2005	230.0
6/17/1993	560.0	4/19/2003	207.0
8/1/2001	547.0	7/6/2002	191.0



Probability of 5-yr Event in 30 years

1979 FHAD	
2-yr	875
5-yr	1550
10-yr	2100
25-yr	2820
50-yr	3450
100-yr	4250

Raw Gage Data			
Date	Flow (cfs)	Date	Flow (cfs)
6/1/1991	1280.0	5/29/1990	518.0
8/24/1992	1280.0	4/25/1994	494.0
7/31/1997	1040.0	11/30/1984	464.0
11/30/1981	954.0	6/12/2010	463.0
11/30/1983	954.0	8/9/1999	431.0
7/8/2011	893.0	11/30/1982	420.0
11/30/1986	762.0	11/30/1985	368.0
5/17/1995	759.0	8/18/2004	347.0
7/20/2009	676.0	8/24/2007	286.0
6/9/1989	659.0	8/13/2006	278.0
8/17/2000	646.0	7/7/2012	270.0
9/17/1996	632.0	6/10/1988	255.0
6/28/2013	600.0	8/4/2005	230.0
6/17/1993	560.0	4/19/2003	207.0
8/1/2001	547.0	7/6/2002	191.0



Probability of 2-yr Event in 30 years

1979 FHAD	
2-yr	875
5-yr	1550
10-yr	2100
25-yr	2820
50-yr	3450
100-yr	4250

Raw Gage Data			
Date	Flow (cfs)	Date	Flow (cfs)
6/1/1991	1280.0	5/29/1990	518.0
8/24/1992	1280.0	4/25/1994	494.0
7/31/1997	1040.0	11/30/1984	464.0
11/30/1981	954.0	6/12/2010	463.0
11/30/1983	954.0	8/9/1999	431.0
7/8/2011	893.0	11/30/1982	420.0
11/30/1986	762.0	11/30/1985	368.0
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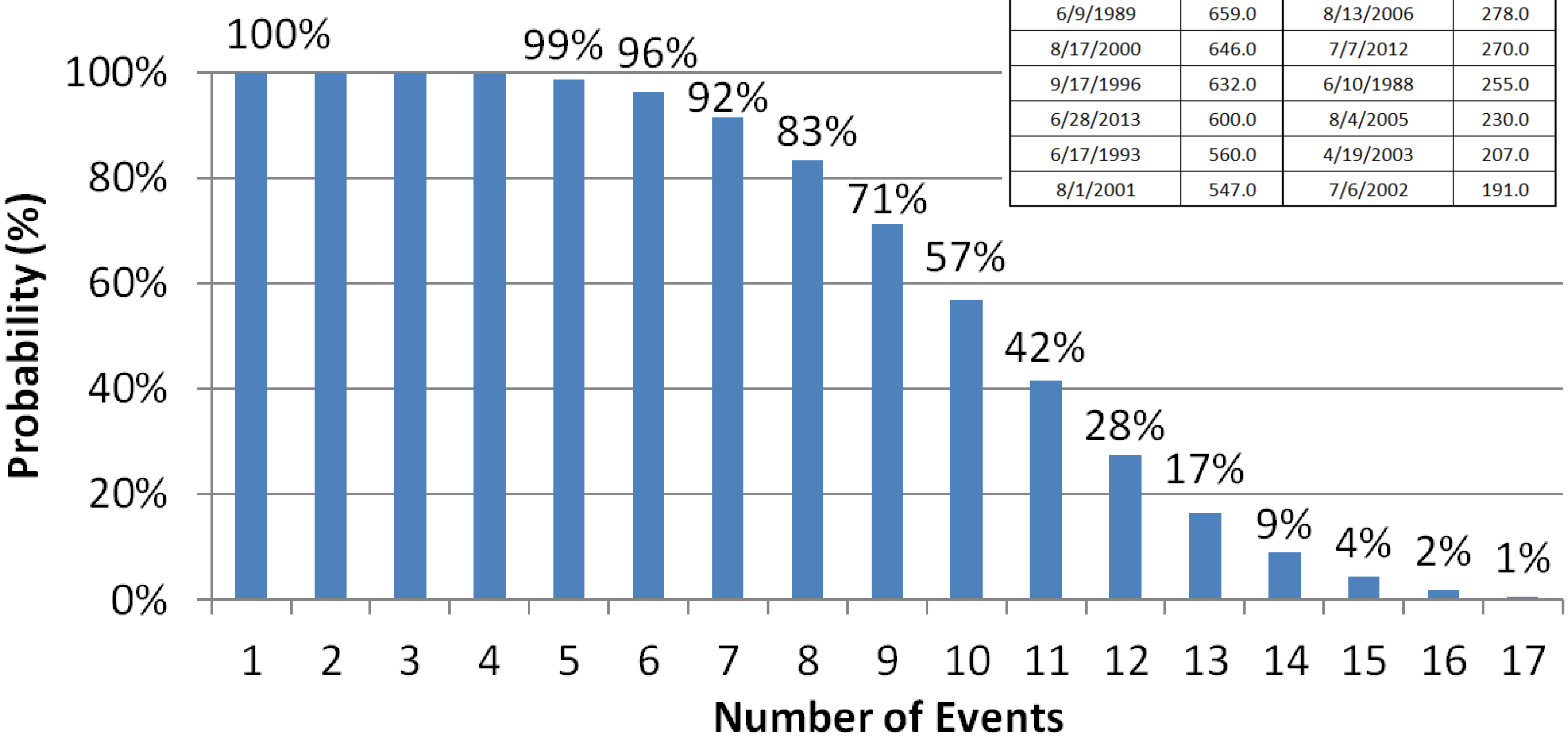
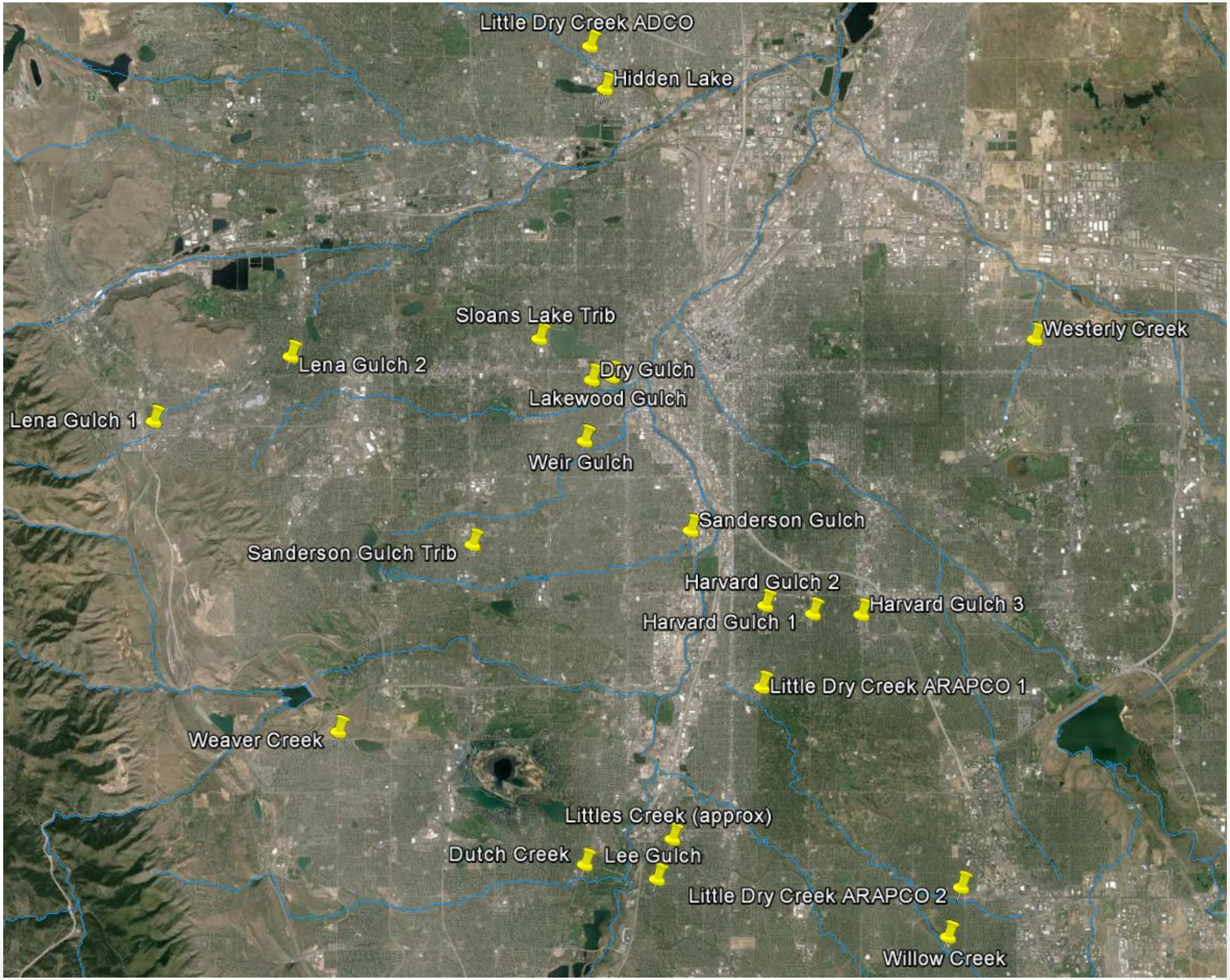
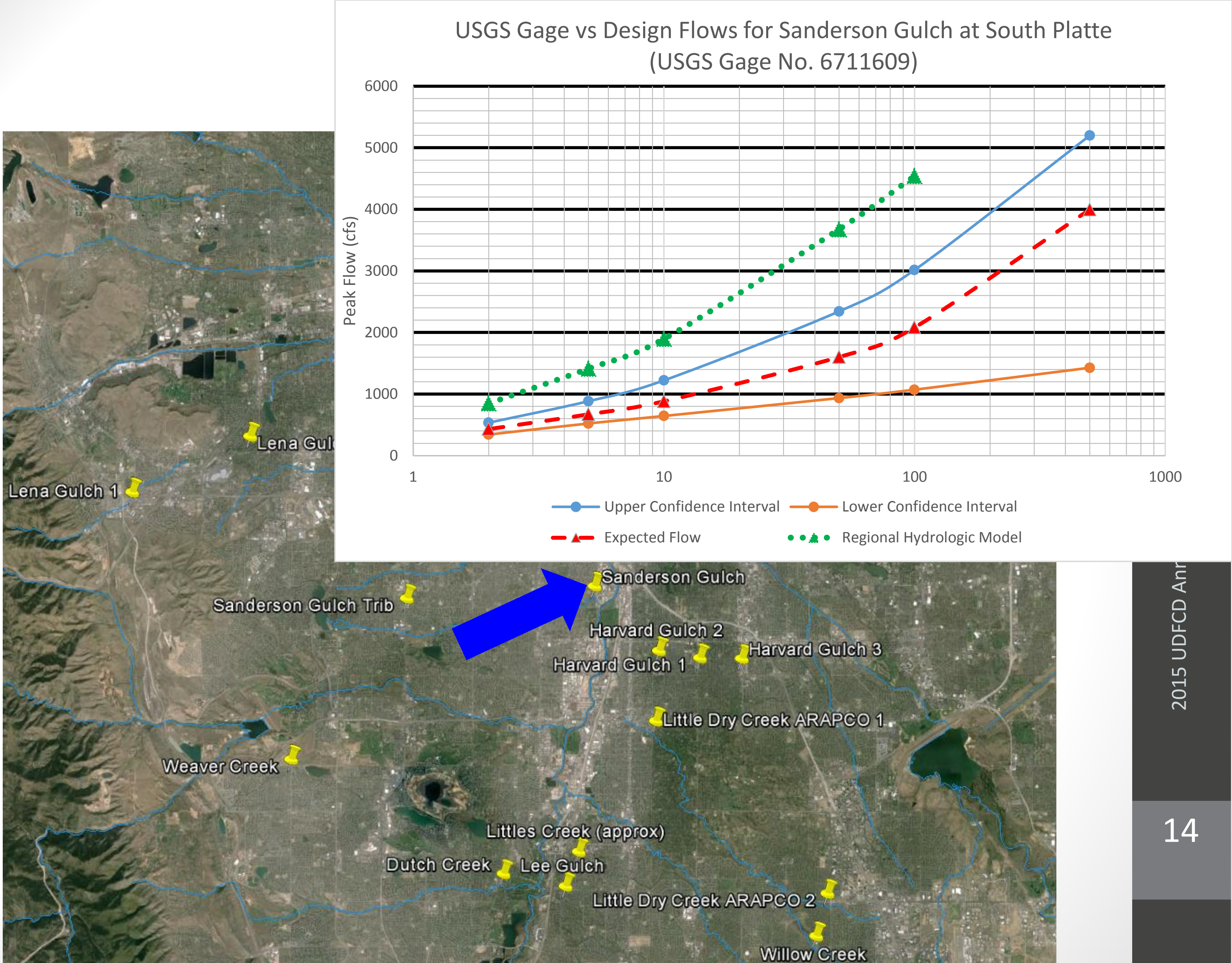
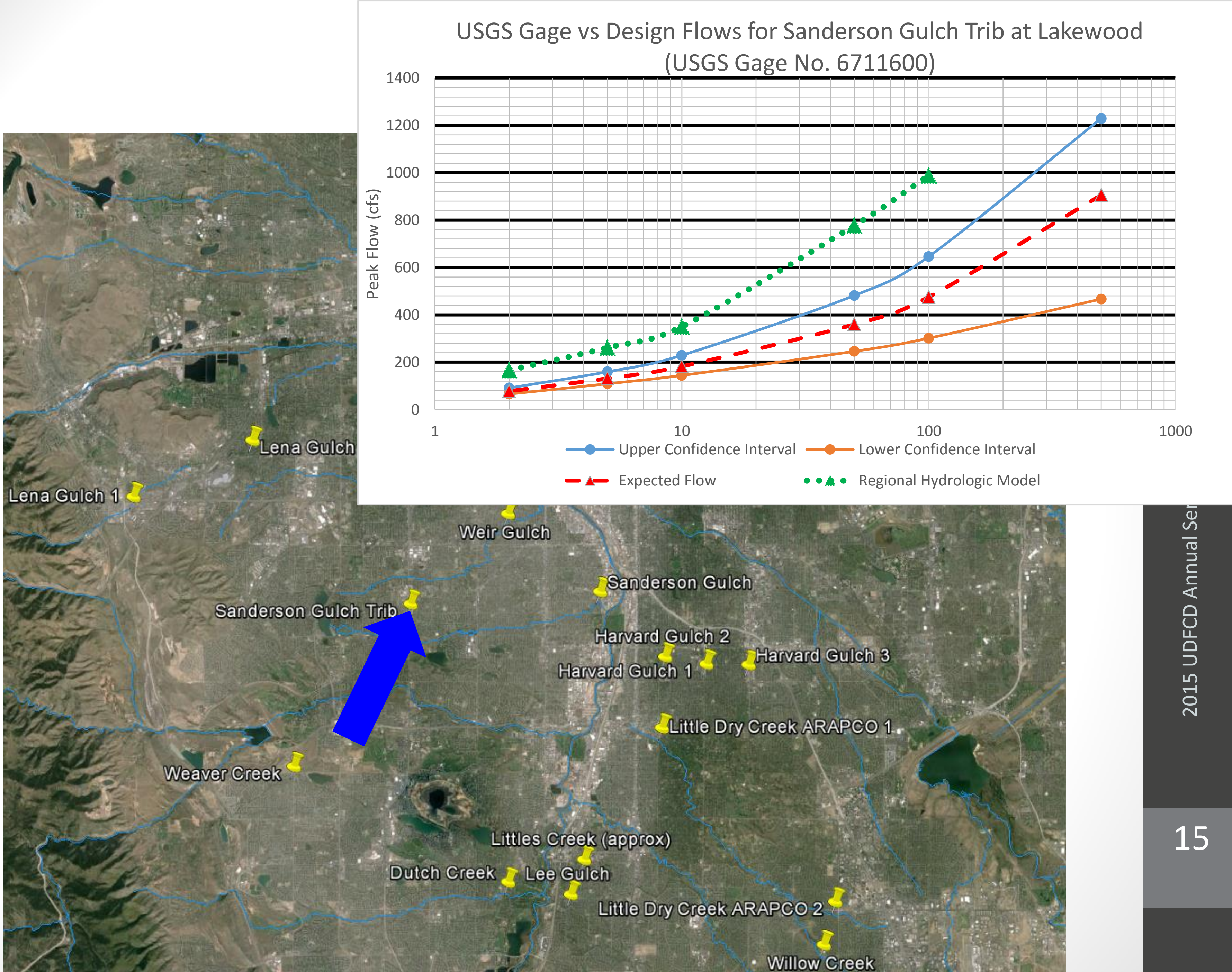
7/20/2009	676.0	8/24/2007	286.0
6/9/1989	659.0	8/13/2006	278.0
8/17/2000	646.0	7/7/2012	270.0
9/17/1996	632.0	6/10/1988	255.0
6/28/2013	600.0	8/4/2005	230.0
6/17/1993	560.0	4/19/2003	207.0
8/1/2001	547.0	7/6/2002	191.0

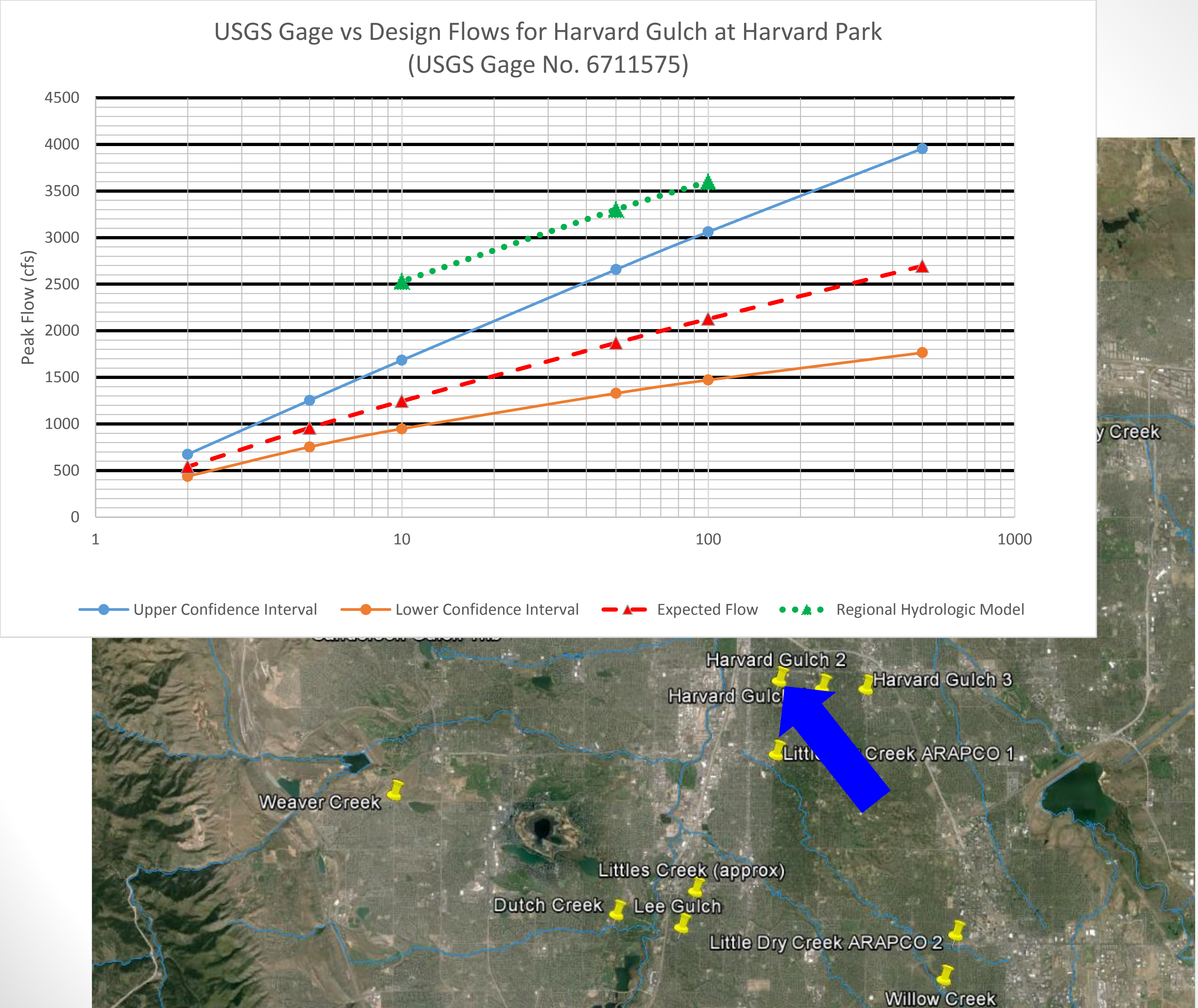


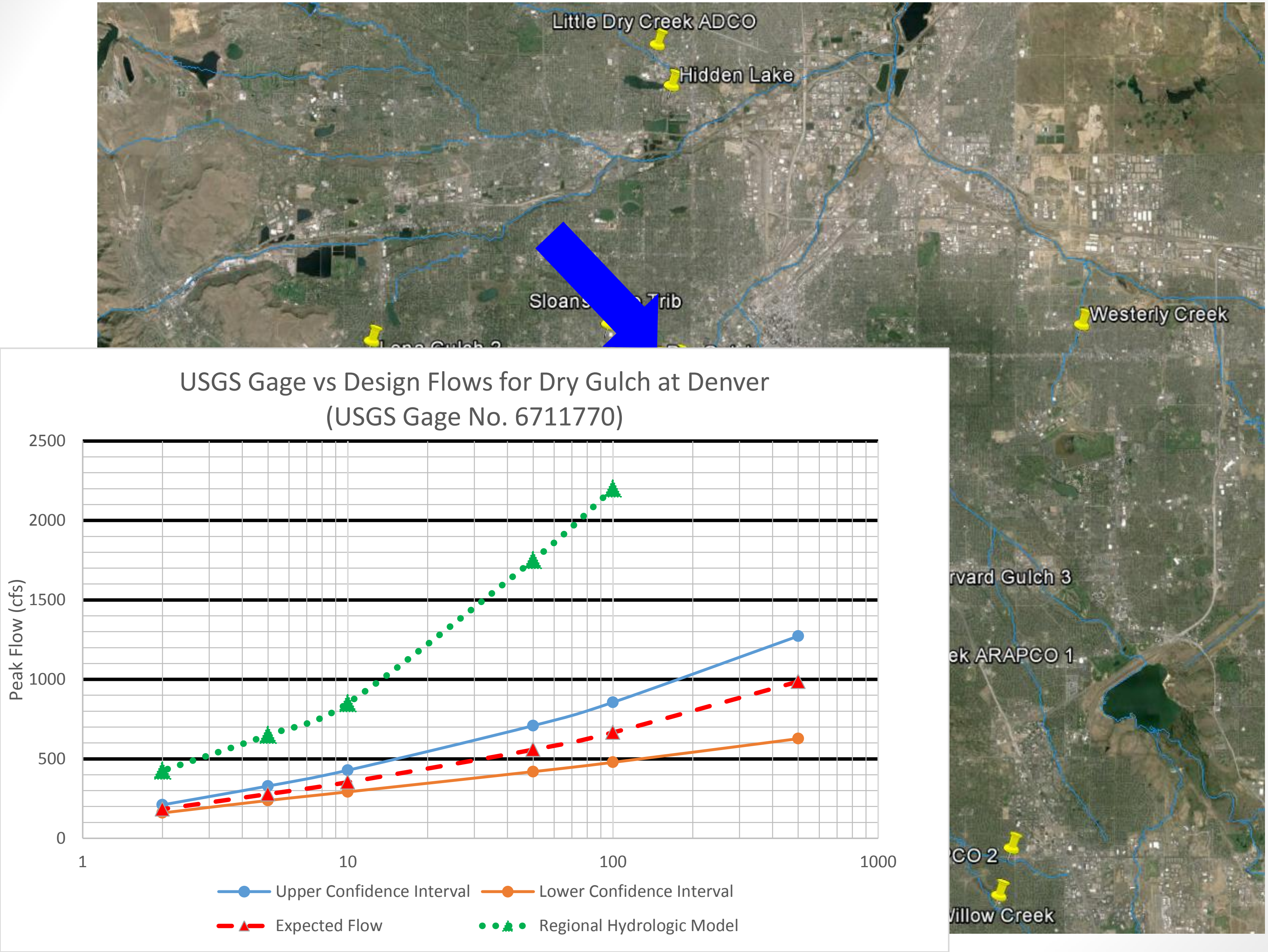
USGS Stream Gages



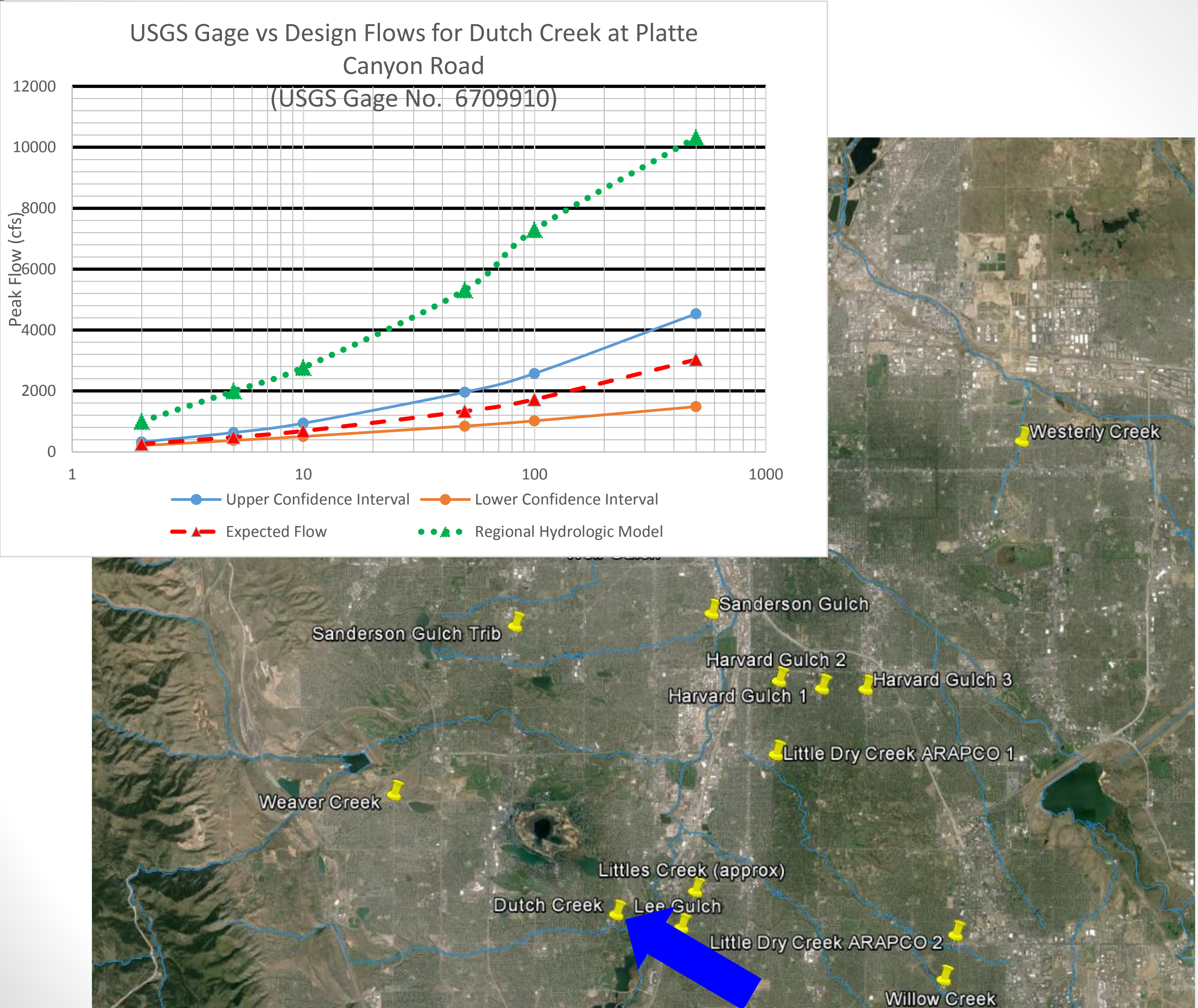

USGS Gage vs Design Flows for Sanderson Gulch at South Platte
(USGS Gage No. 6711609)
Peak Flow (cfs)
6000
5000
4000
3000
2000
1000
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model
Lena Gul
Lena Gulch 1
Sanderson Gulch
Sanderson Gulch Trib
Harvard Gulch 2
Harvard Gulch 3
Harvard Gulch 1
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek

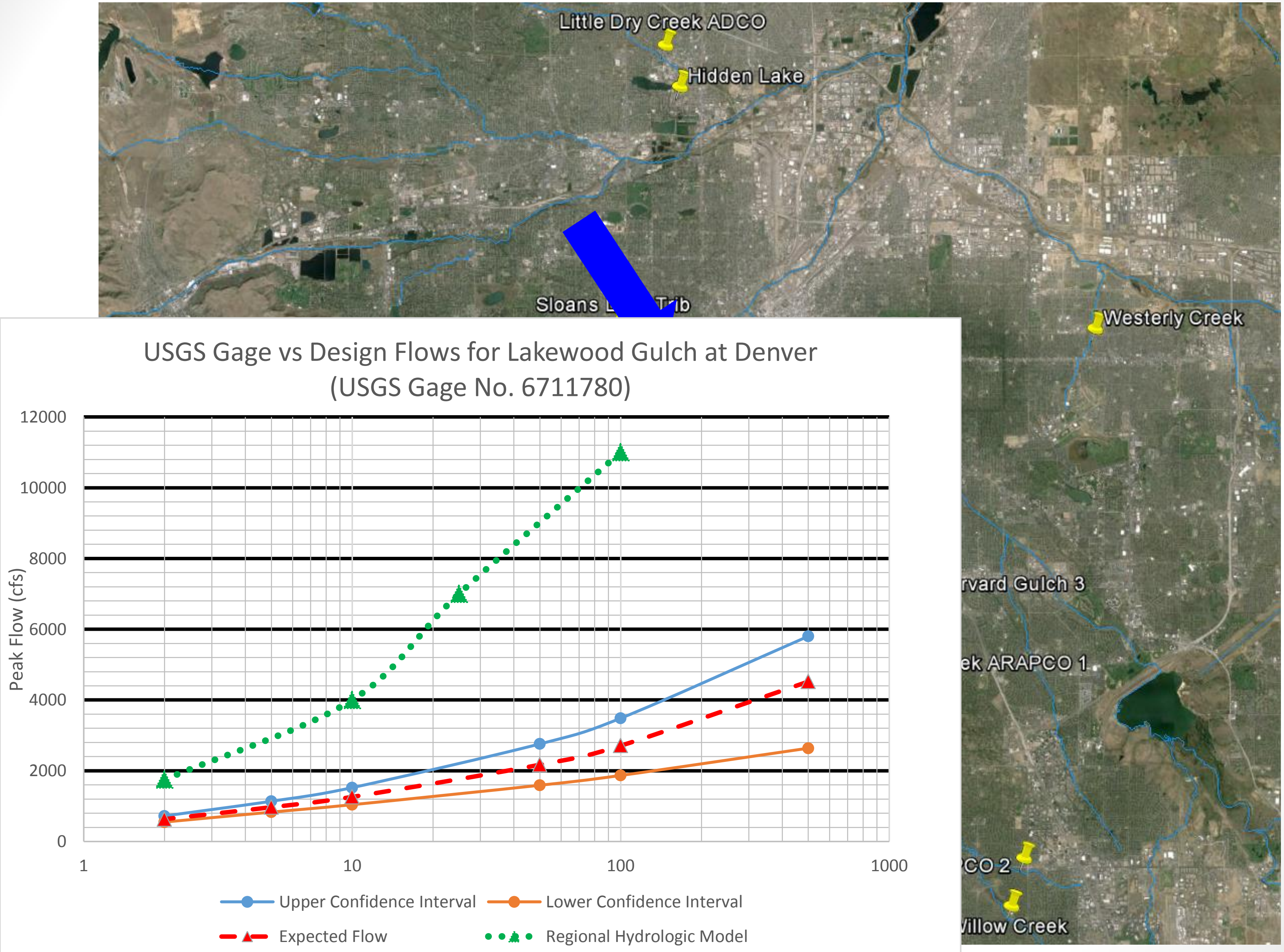

Lena Gulch
Lena Gulch 1
Weir Gulch
Sanderson Gulch
Sanderson Gulch Trib
Harvard Gulch 2
Harvard Gulch 3
Harvard Gulch 1
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek
USGS Gage vs Design Flows for Sanderson Gulch Trib at Lakewood
(USGS Gage No. 6711600)
Peak Flow (cfs)
1400
1200
1000
800
600
400
200
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model

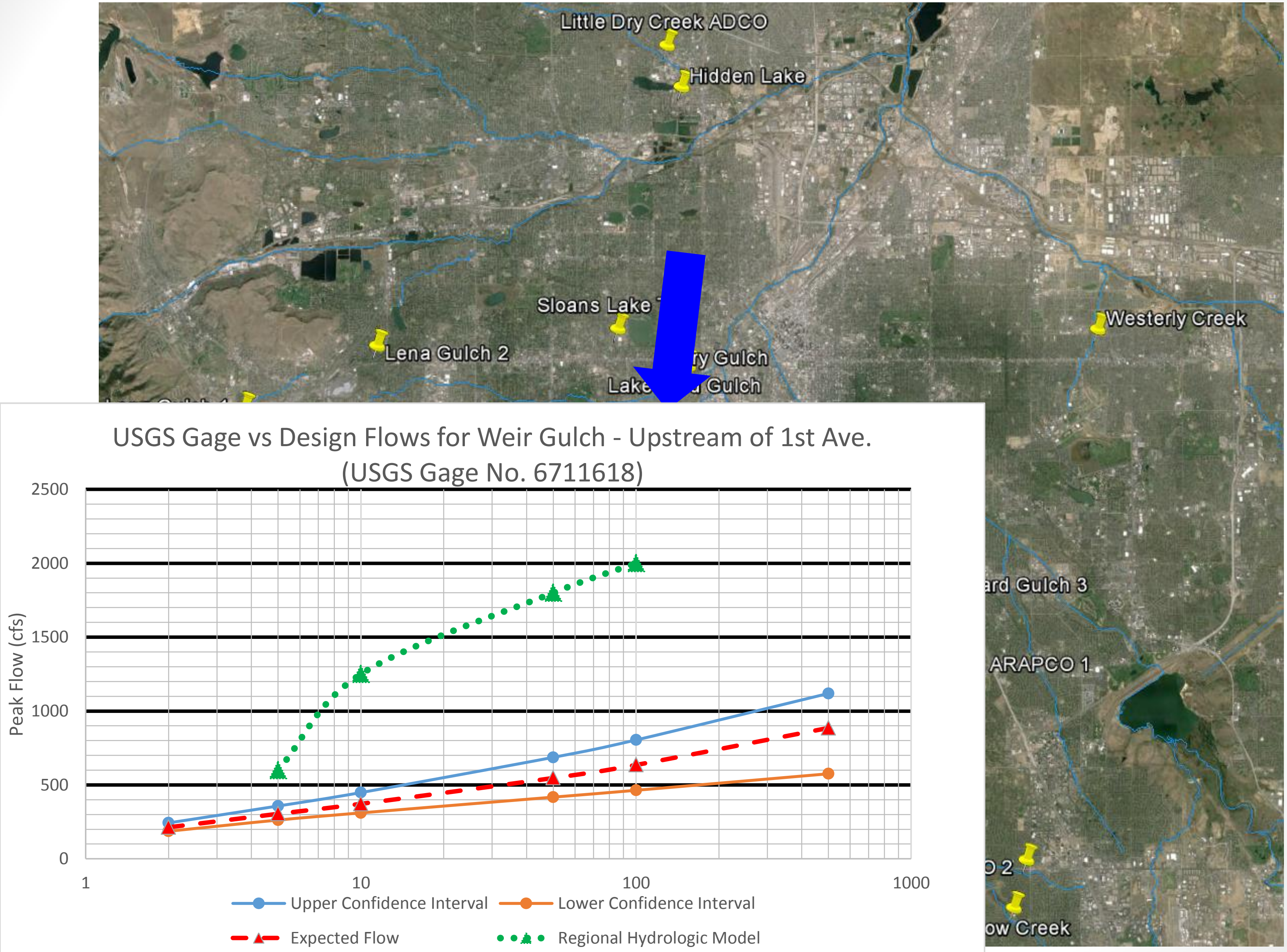

USGS Gage vs Design Flows for Harvard Gulch at Harvard Park
(USGS Gage No. 6711575)
Peak Flow (cfs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model
Harvard Gulch 2
Harvard Gulch 3
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek

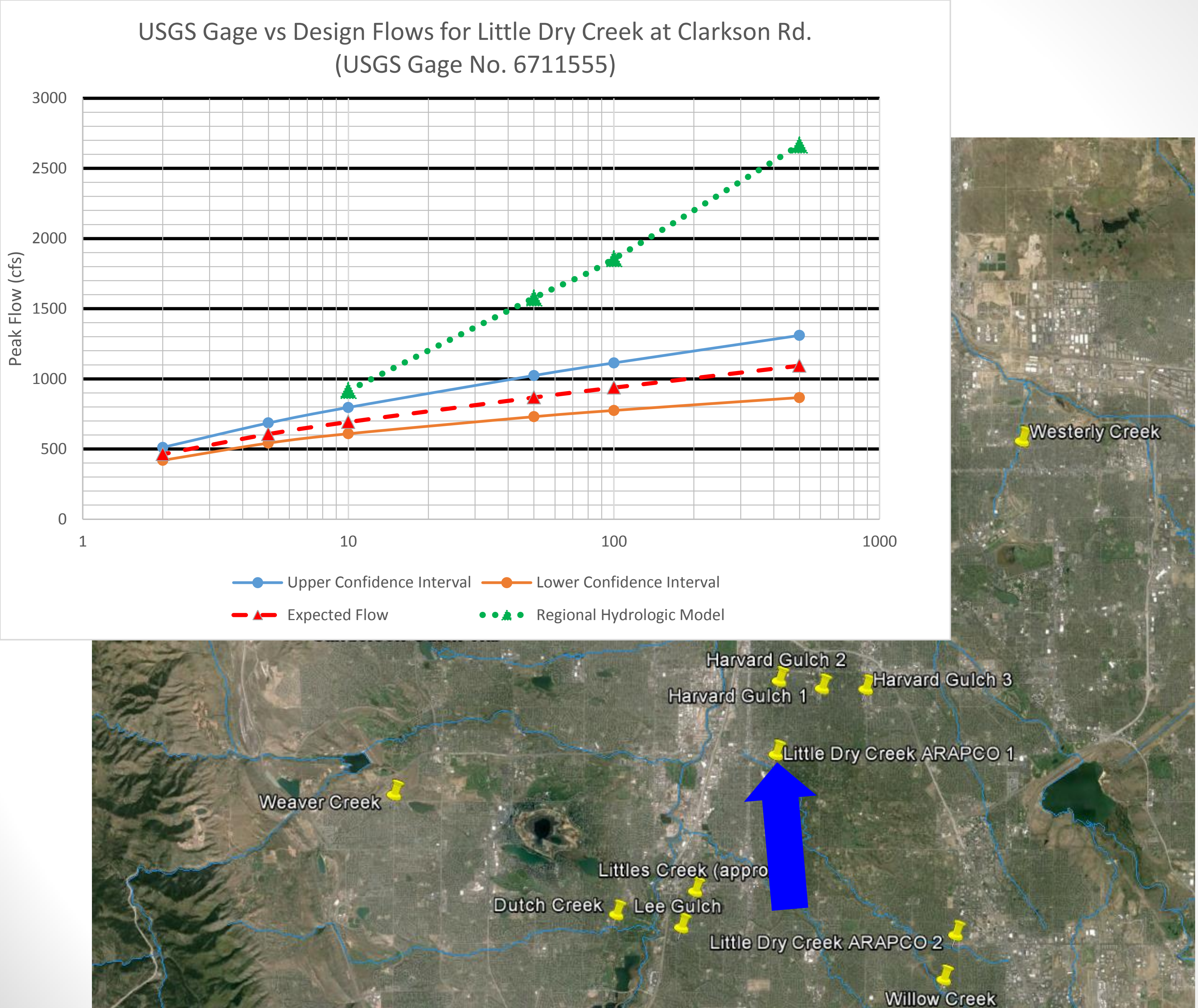


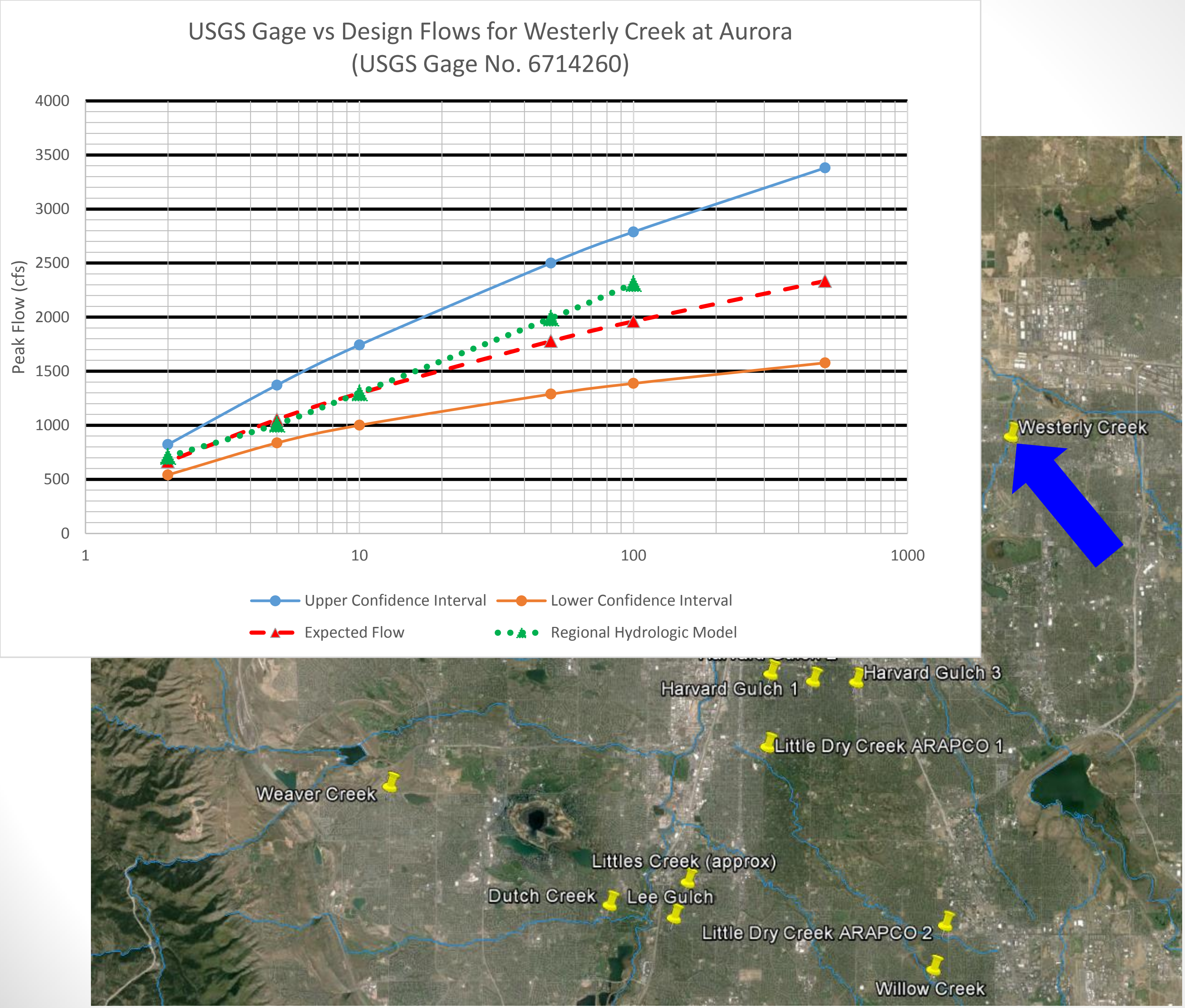
Little Dry Creek ADCO
Hidden Lake
Westerly Creek
USGS Gage vs Design Flows for Dry Gulch at Denver
(USGS Gage No. 6711770)
Peak Flow (cfs)
2500
2000
1500
1000
500
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model

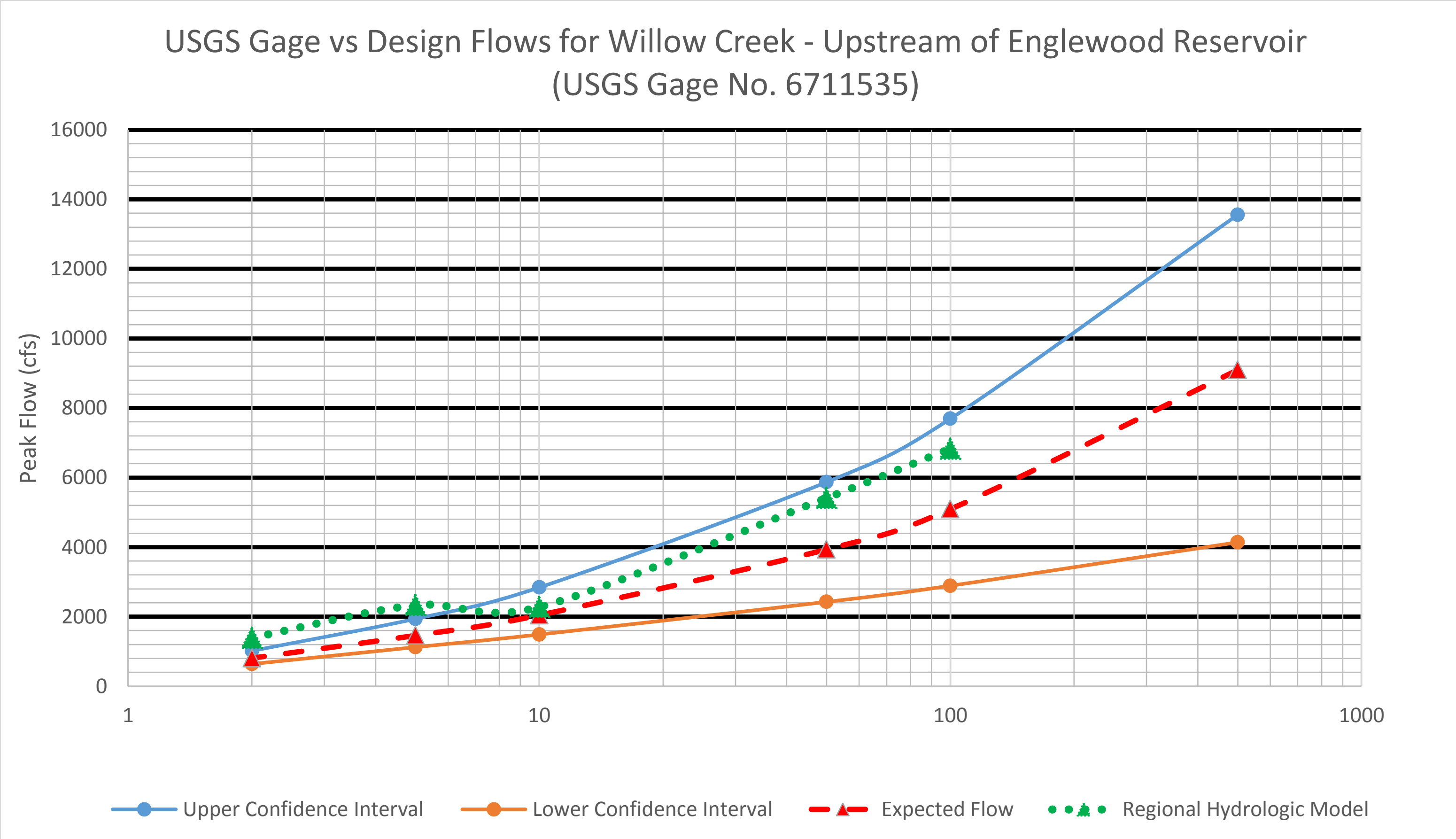

USGS Gage vs Design Flows for Dutch Creek at Platte Canyon Road
(USGS Gage No. 6709910)
Peak Flow (cfs)
12000
10000
8000
6000
4000
2000
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model
Westerly Creek
Sanderson Gulch
Sanderson Gulch Trib
Harvard Gulch 2
Harvard Gulch 3
Harvard Gulch 1
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek


Little Dry Creek ADCO
Hidden Lake
Westerly Creek
USGS Gage vs Design Flows for Lakewood Gulch at Denver
(USGS Gage No. 6711780)
Peak Flow (cfs)
12000
10000
8000
6000
4000
2000
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model

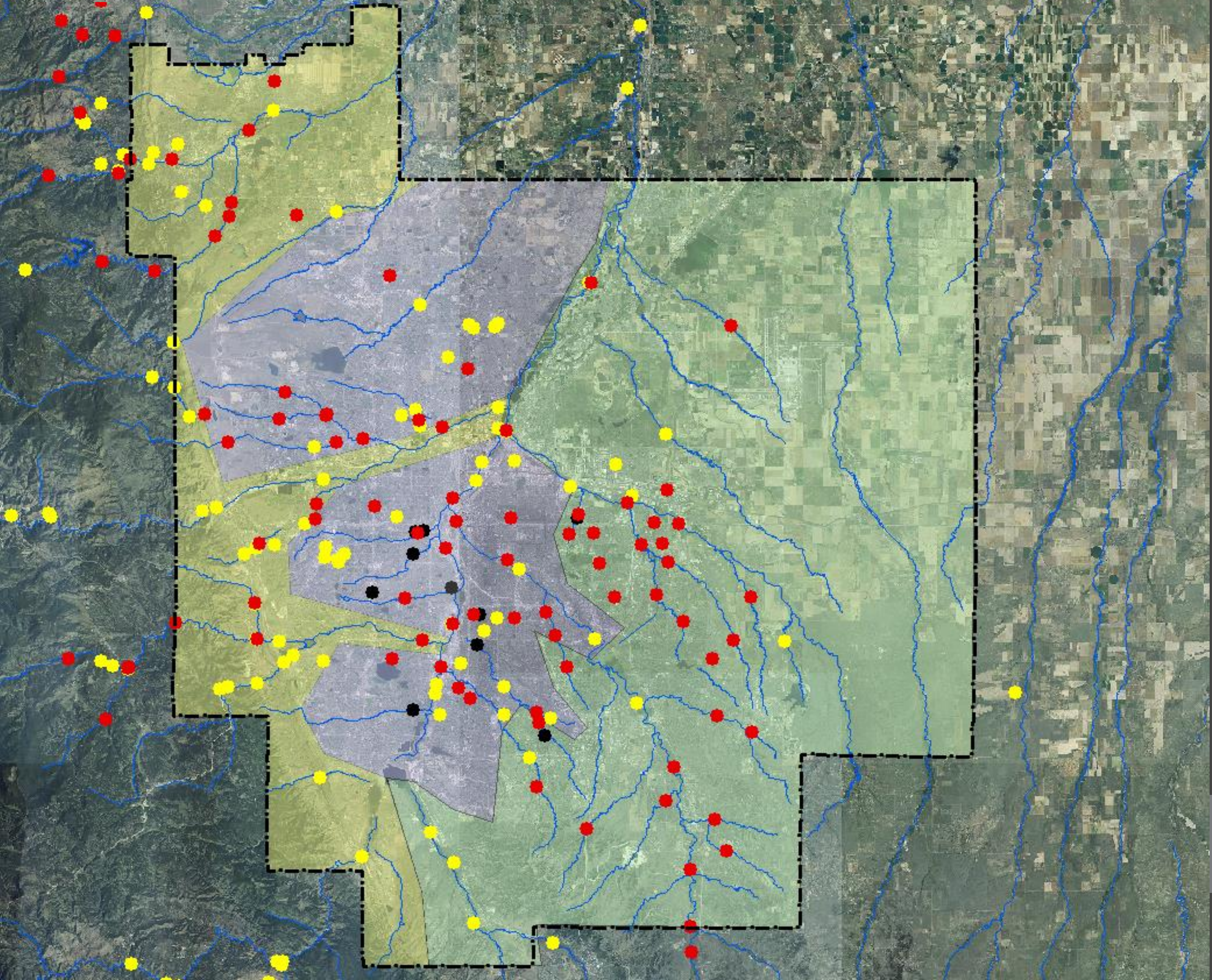

Little Dry Creek ADCO
Hidden Lake
Sloans Lake
Lena Gulch 2
Westerly Creek
ARAPCO 1
USGS Gage vs Design Flows for Weir Gulch - Upstream of 1st Ave.
(USGS Gage No. 6711618)
Peak Flow (cfs)
2500
2000
1500
1000
500
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model


USGS Gage vs Design Flows for Little Dry Creek at Clarkson Rd.
(USGS Gage No. 6711555)
Peak Flow (cfs)
3000
2500
2000
1500
1000
500
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model
Westerly Creek
Harvard Gulch 2
Harvard Gulch 3
Harvard Gulch 1
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (appro
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek


USGS Gage vs Design Flows for Westerly Creek at Aurora
(USGS Gage No. 6714260)
Peak Flow (cfs)
4000
3500
3000
2500
2000
1500
1000
500
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model
Westerly Creek
Harvard Gulch 1
Harvard Gulch 3
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek


USGS Gage vs Design Flows for Willow Creek - Upstream of Englewood Reservoir
(USGS Gage No. 6711535)
Peak Flow (cfs)
16000
14000
12000
10000
8000
6000
4000
2000
0
1
10
100
1000
Upper Confidence Interval
Lower Confidence Interval
Expected Flow
Regional Hydrologic Model


Harvard Gulch 2
Harvard Gulch 3
Harvard Gulch 1
Little Dry Creek ARAPCO 1
Weaver Creek
Littles Creek (approx)
Dutch Creek
Lee Gulch
Little Dry Creek ARAPCO 2
Willow Creek



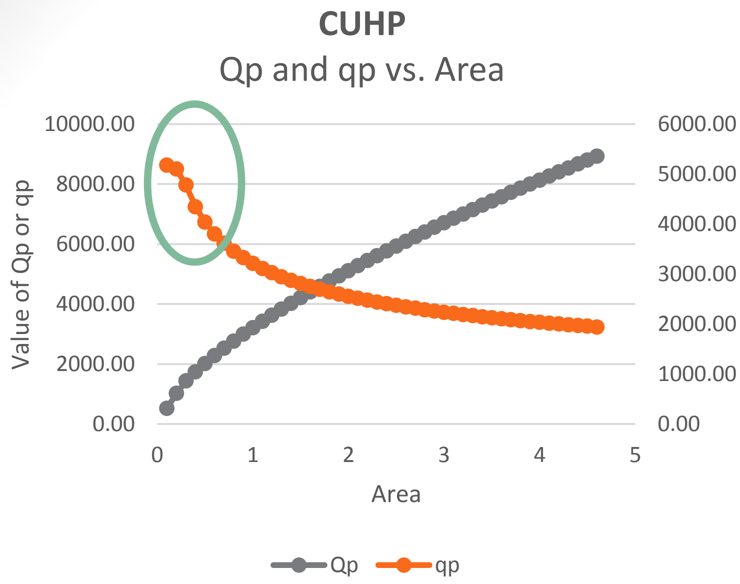
Let's Back up…

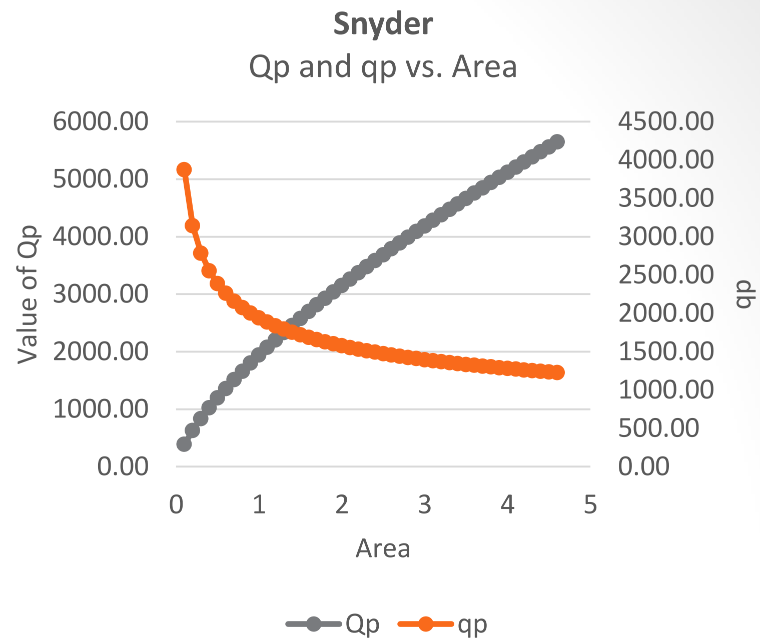
- What is CUHP?
  - Unit Hydrograph Procedure (Snyder)
  - Many features unique to CUHP:
    - Rainfall Excess from four planes
    - DCIA Levels (D and R Curves)
    - Calibrated to Denver Metro Area
- What do we use it for?
  - Everything..
    - Yes, everything.

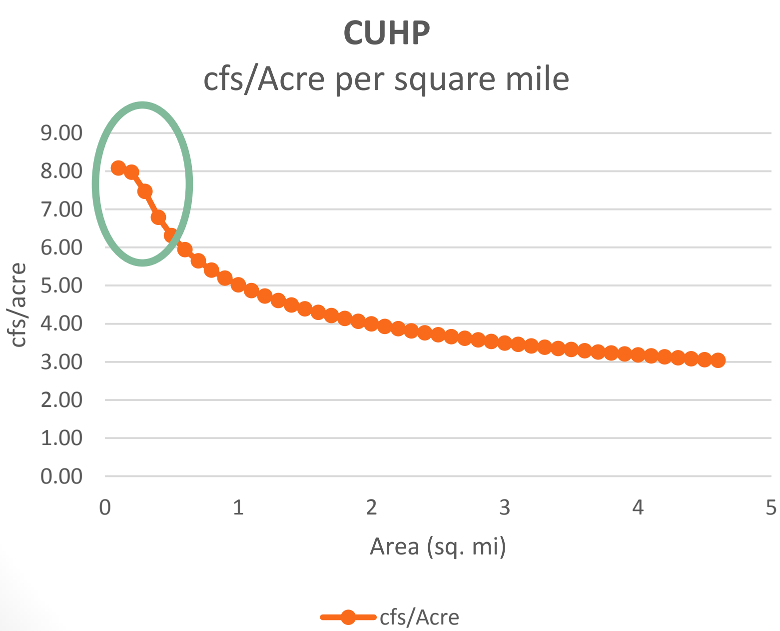
History of CUHP

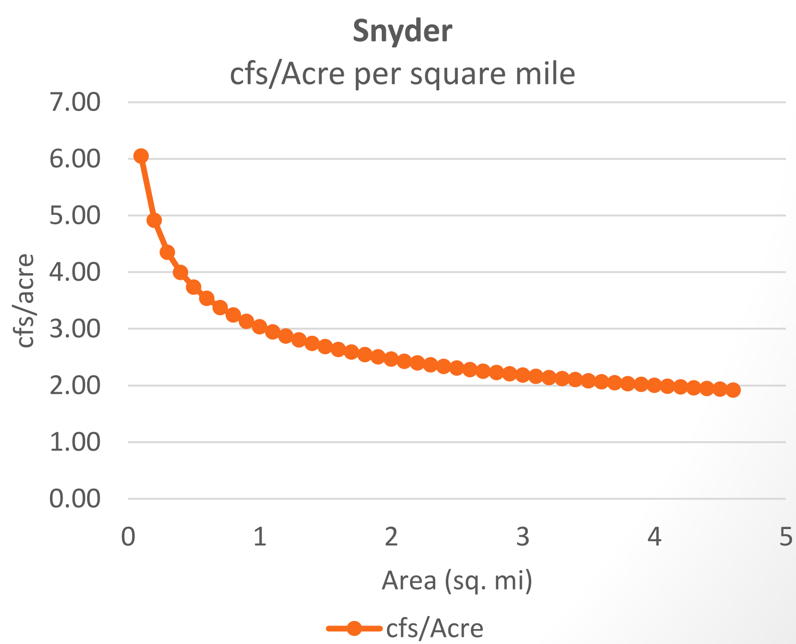
1971	• CUHP Developed based on 8 watersheds in District
1995	• UIA and DCIA Added
2007	• Corrected Rainfall
2008	• Corrected *tc* and modified *Cp* and *Ct*
2009	• Rainfall Excess, D and R Equations
2013	• Automatic checks, multiple runs, calls for recommended values, C to VBA, runs in Excel

What hasn't been done in over 40 years?


CUHP
Qp and qp vs. Area
Value of Qp or qp
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
0
1
2
3
4
5
Area
Qp
qp

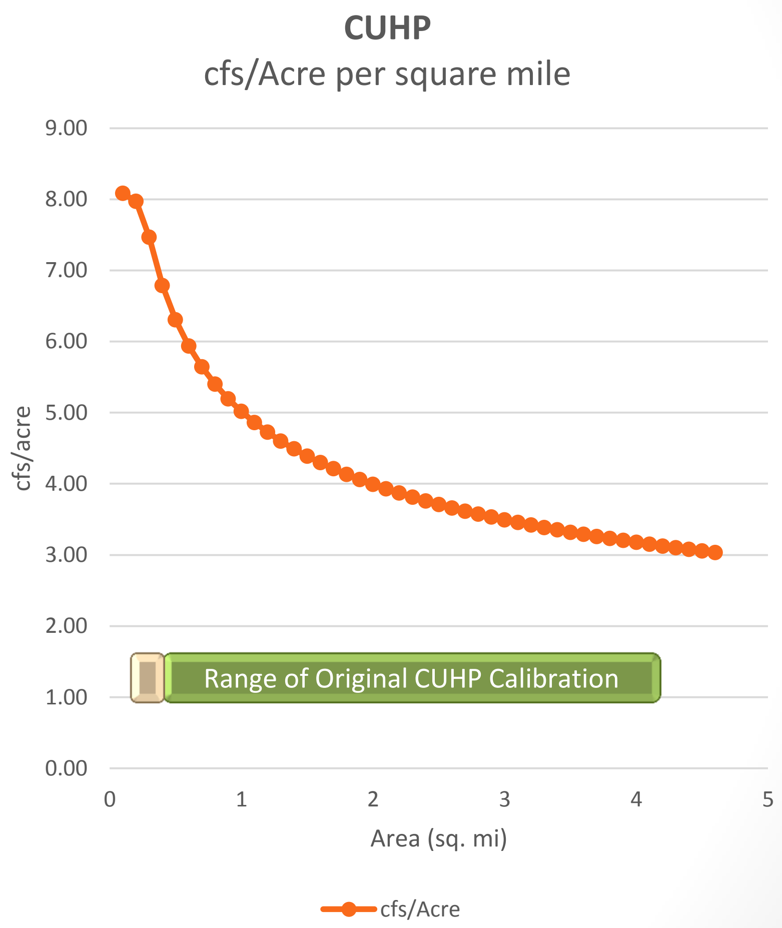

Snyder
Qp and qp vs. Area
Value of Qp
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
qp
0
1
2
3
4
5
Area
Qp
qp


CUHP
cfs/Acre per square mile
cfs/acre
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
1
2
3
4
5
Area (sq. mi)
cfs/Acre


Snyder
cfs/Acre per square mile
cfs/acre
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
1
2
3
4
5
Area (sq. mi)
cfs/Acre

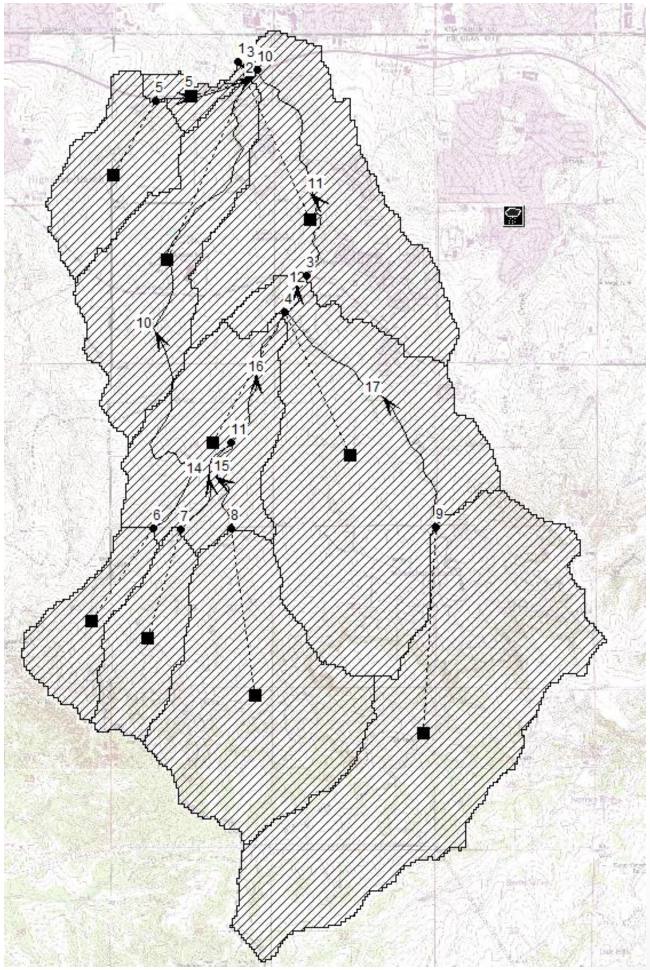
Basis of CUHP

- What are the range of drainage areas CUHP was originally calibrated with?
- What range do we typically apply CUHP in our studies?



Are there other models?

- SWMM5
- HEC-HMS
- Rain-on-Grid
  - GSSHA (US Army Corps)
  - Flo-2D
- None are calibrated to UDFCD, like CUHP.



Starting over?

Infiltration Editor

Infiltration Method: HORTON

Property	Value
Max. Infil. Rate	
Min. Infil. Rate	
Decay Constant	
Drying Time	7
Max. Volume	0

Decay constant for the Horton infiltration curve (1/hr)

OK | Cancel | Help

Subcatchment 5B

Property	Value
Name	5B
X-Coordinate	1664549.472
Y-Coordinate	14354942.666
Description	
Tag	
Rain Gage	1
Outlet	4
Area	1477.55
Width	
% Slope	0.013574
% Imperv	64.3
N-Imperv	.20
N-Perv	.5
Dstore-Imperv	0
Dstore-Perv	0
%Zero-Imperv	
Subarea Routing	
Percent Routed	
Infiltration	HORTON
Groundwater	NO
Snow Pack	

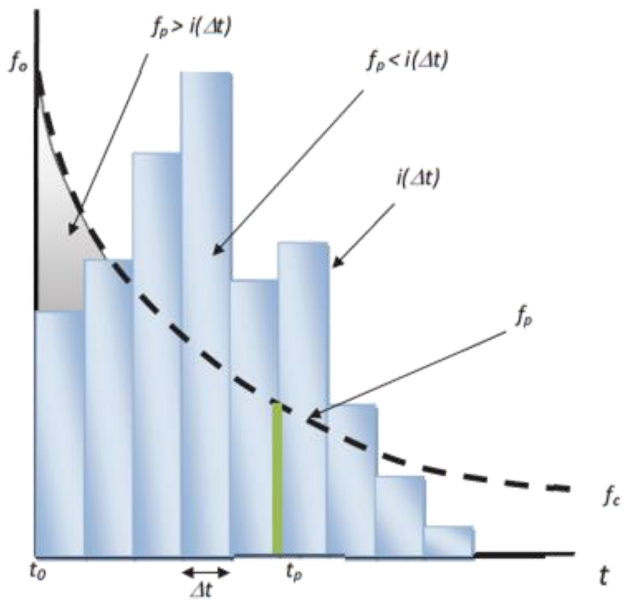
Infiltration parameters (click to edit)

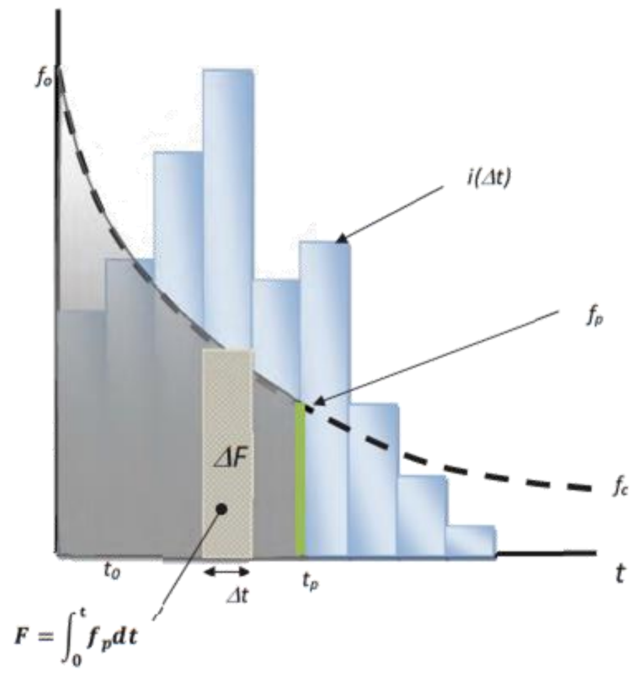
Quiz on new models

What value for initial and final infiltration should be used with Horton's Equation in SWMM5? (Assume C and D Soils)

Infiltration

Applying Infiltration Values for CUHP are **NOT** Applicable in SWMM5 even though they use the same equation (Horton).





Quiz on new models

True or False?

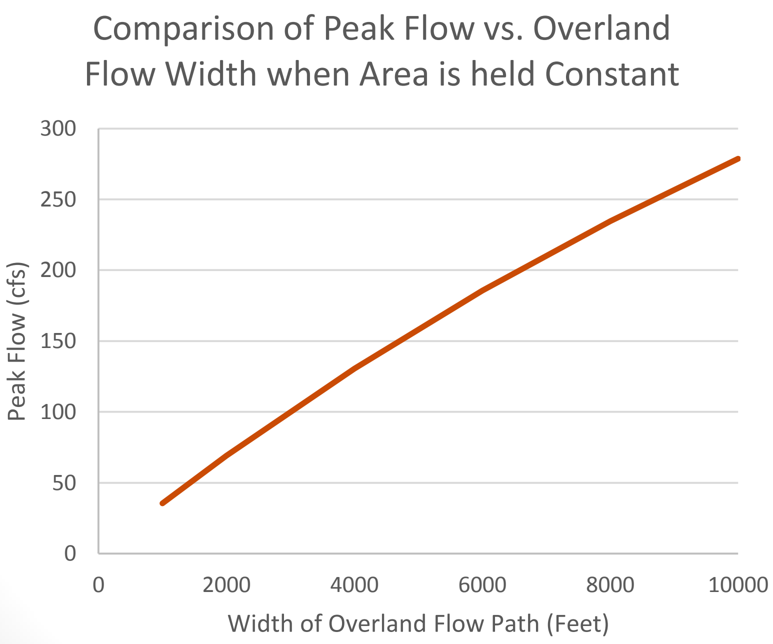
- When the width gets larger the peak flow will decrease

Width of Overland Flow Path

Think of the basin shape, a high value of *w* makes a wide and short basin.

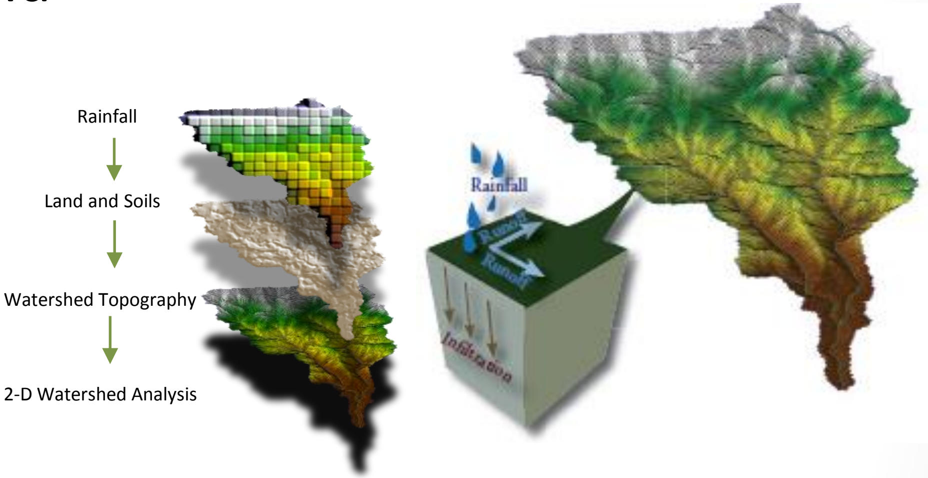
$$Q_{out} = \frac{1.49}{n} w (d - dp)^{5/3} \sqrt{S}$$

$$\frac{d_2 - d_1}{\Delta t} = i_E - \frac{1.49 * w}{A * n} \left(d_1 + \frac{1}{2}(d_2 - d_1) - dp \right)^{5/3}$$

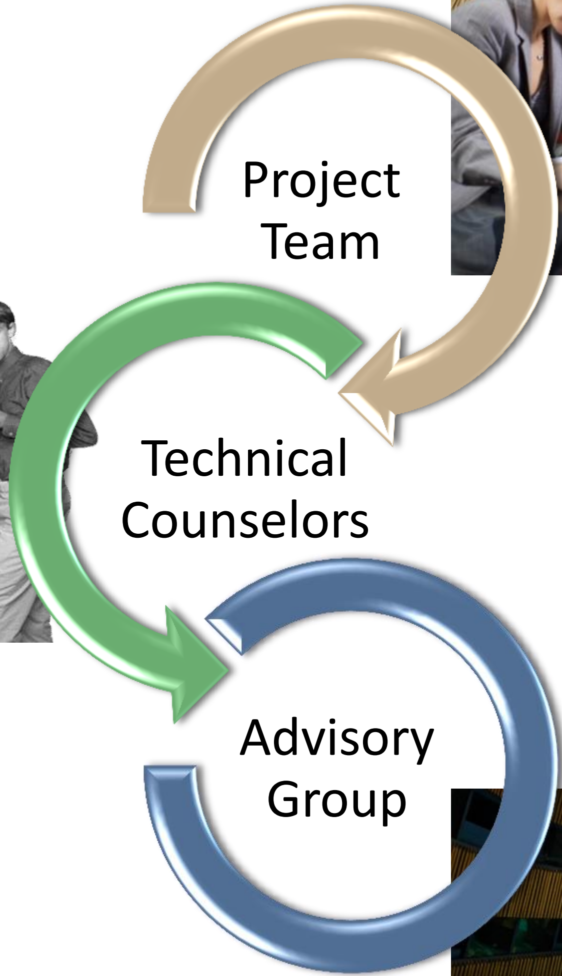


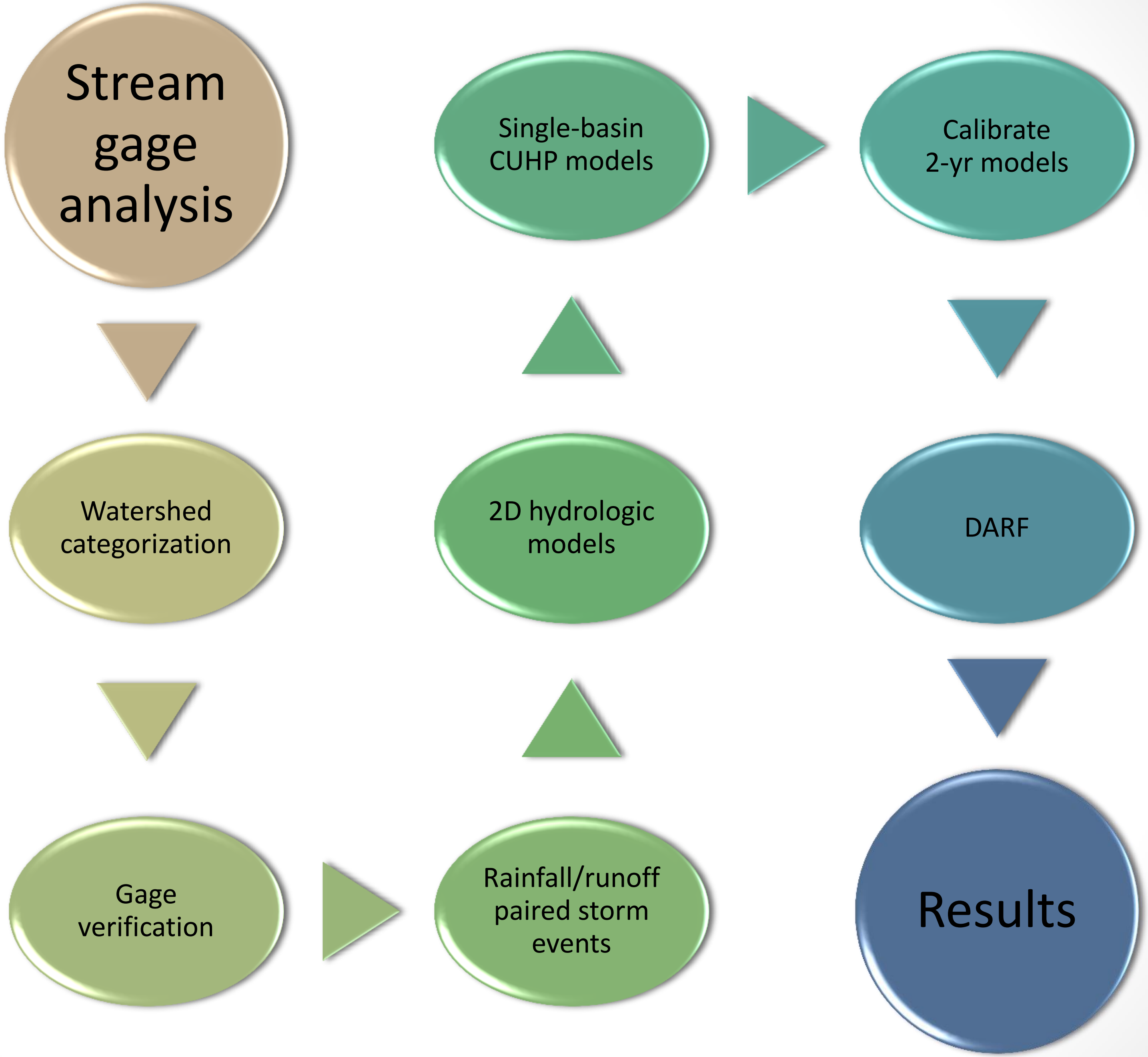
New Models – Rain On Grid?

- Physically Based
  - Capture Intentional and Unintentional Storage Areas
- Radar and Gridded Rainfall
- Initial Studies Show Promise
- Still may be too soon…

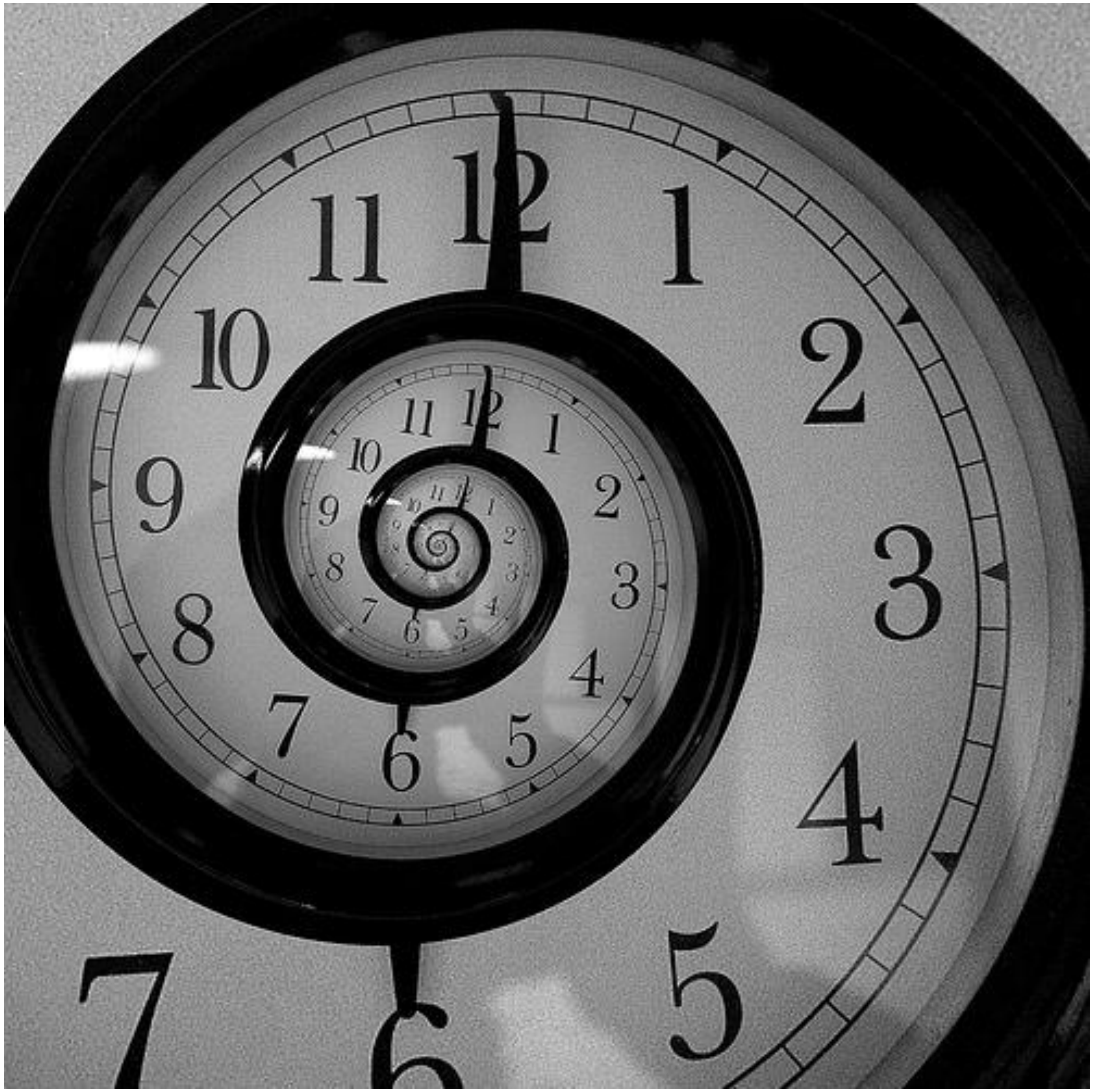


For now, more Questions than Answers…


Project Team
Technical Counselors
Advisory Group


Stream gage analysis
Watershed categorization
Gage verification
Rainfall/runoff paired storm events
2D hydrologic models
Single-basin CUHP models
Calibrate 2-yr models
DARF
Results


????
Change in policy
Different model
Storm zones
Revised DARF
New design storm
Revise modeling process
Do nothing
Re-write of CUHP



Questions?

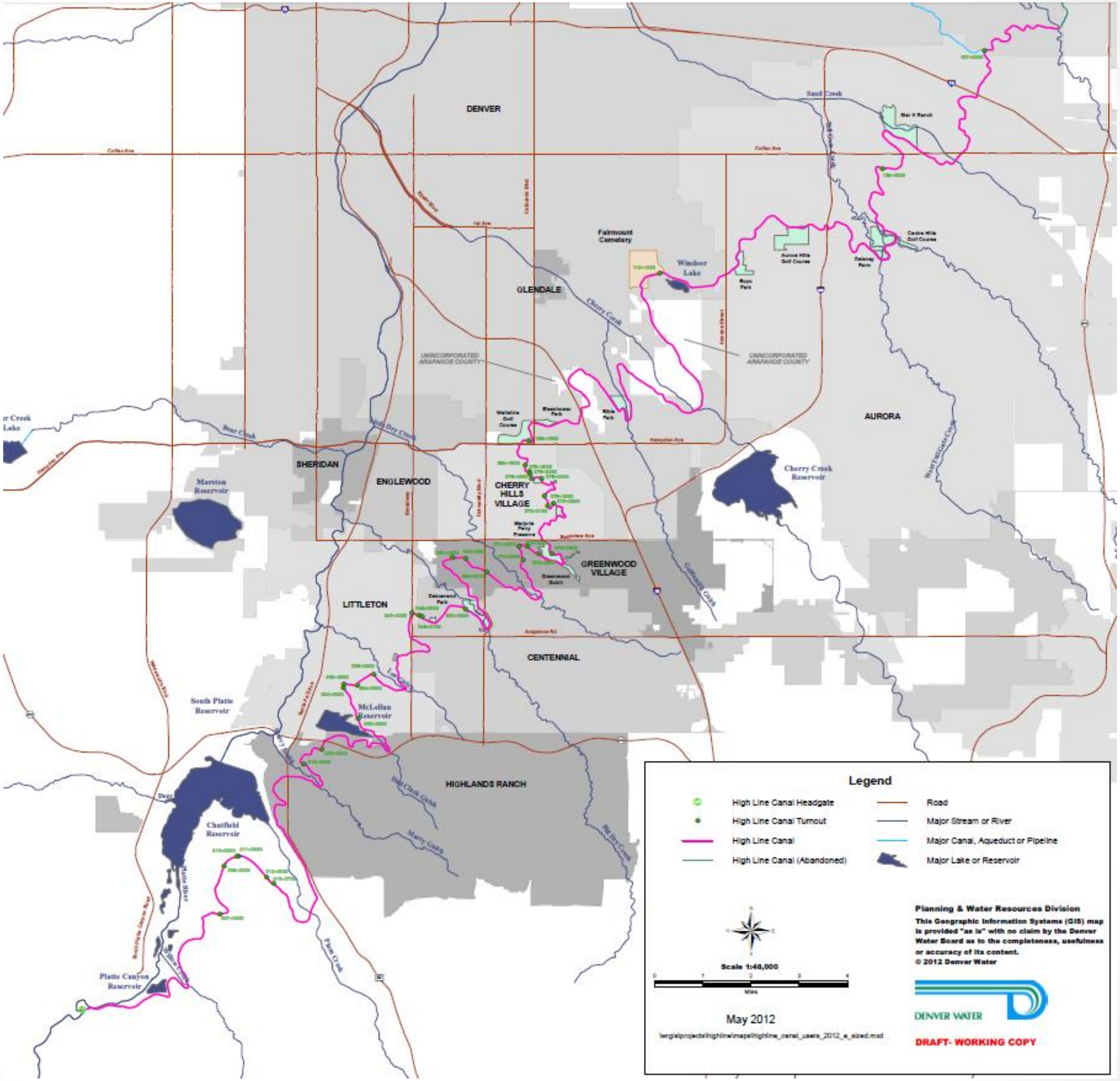
sthomas@udfcd.org
gblackler@enginuity-es.com

Our Plan to Repurpose the DENVER HIGH LINE CANAL

For Stormwater Quality and Runoff Reduction

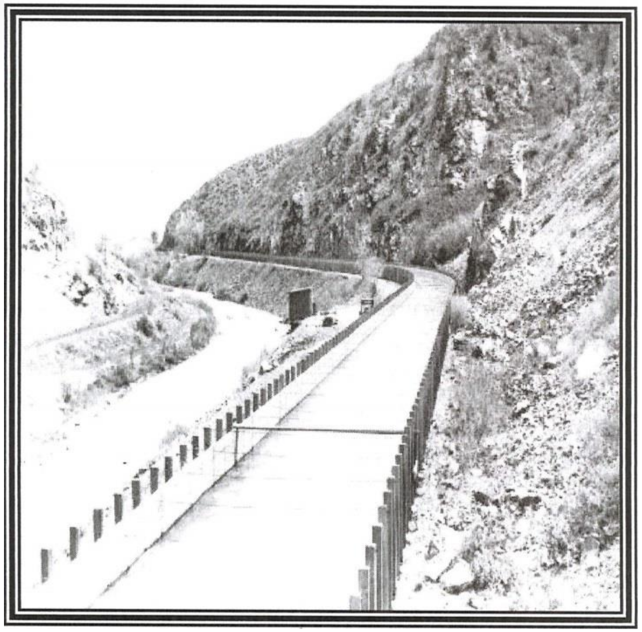
Jessie Nolle, P.E., RESPEC Consulting & Services

Ken A MacKenzie, P.E., Urban Drainage and Flood Control District



DENVER
GLENDALE
Fairmount Cemetery
Windsor Lake
AURORA
Cherry Creek Reservoir
UNINCORPORATED ARAPAHOE COUNTY
UNINCORPORATED ARAPAHOE COUNTY
Sand Creek
Cherry Creek
Bear Creek
SHERIDAN
ENGLEWOOD
CHERRY HILLS VILLAGE
GREENWOOD VILLAGE
LITTLETON
CENTENNIAL
HIGHLANDS RANCH
Marston Reservoir
South Platte Reservoir
McLellan Reservoir
Chatfield Reservoir
Platte Canyon Reservoir
Legend
High Line Canal Headgate
High Line Canal Turnout
High Line Canal
High Line Canal (Abandoned)
Road
Major Stream or River
Major Canal, Aqueduct or Pipeline
Major Lake or Reservoir
Scale 1:48,000
Miles
May 2012
Planning & Water Resources Division
This Geographic Information Systems (GIS) map is provided "as is" with no claim by the Denver Water Board as to the completeness, usefulness or accuracy of its content.
© 2012 Denver Water
DENVER WATER
DRAFT- WORKING COPY

HISTORY



- First large irrigation canal built in Colorado for transporting and selling water to landowners who had purchased water deeds

- Investment scheme by wealthy Englishmen

- Construction began in 1880 and was completed in 1883

- Total cost was $650,000

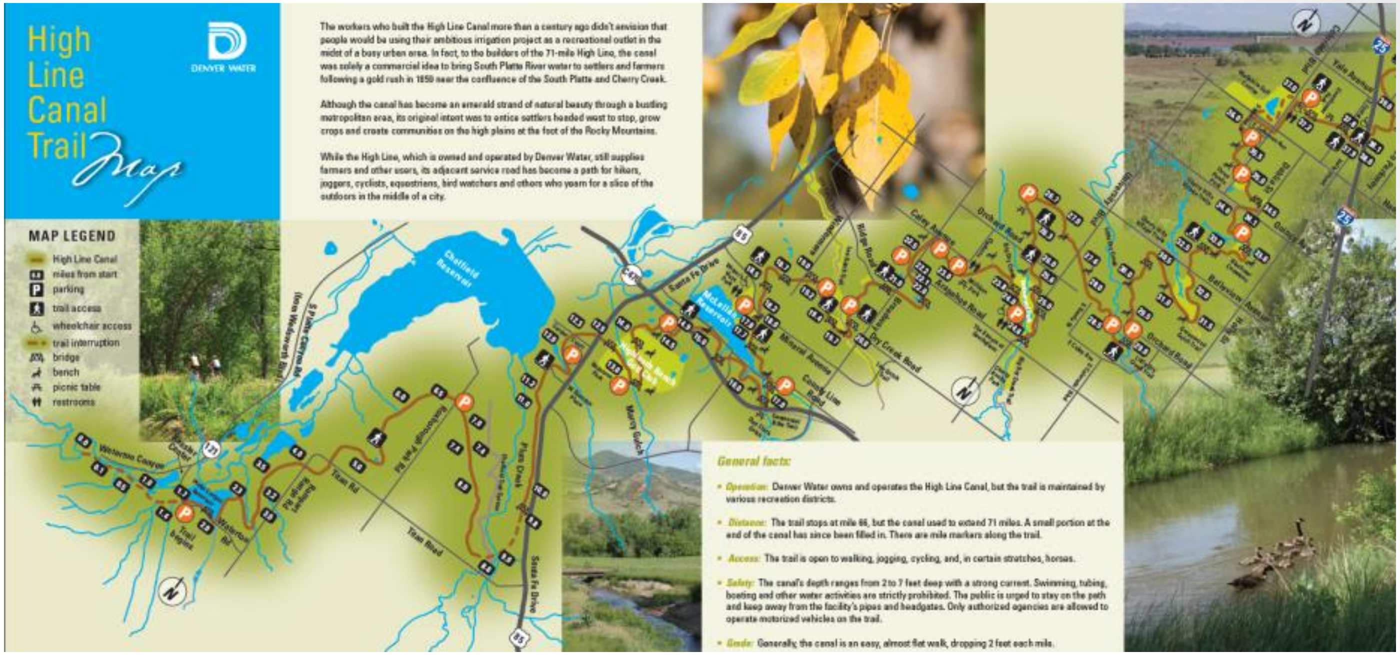
- Ditch Diggers were paid $1 per day

STATUS

- Owned and operated by Denver Water
- 80 current customers
- Recreational use agreements with seven agencies
- Length: 66.5 miles
- Maximum capacity is 600 cfs
- On average, flows about 2’ deep
- Drops ~132 feet over 66 miles = 2 ft/mile or slope of 0.04%.
- Loses 70% - 90% of all water

VALUE

VALUE

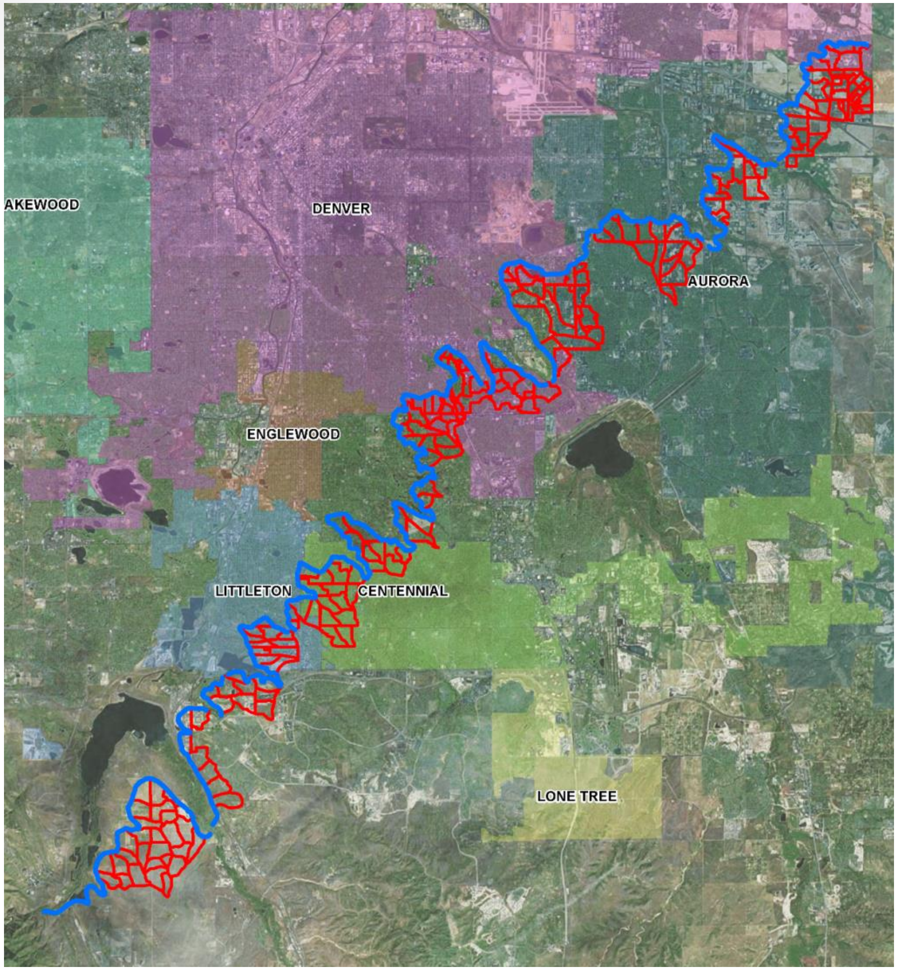

High Line Canal Trail Map
DENVER WATER
The workers who built the High Line Canal more than a century ago didn't envision that people would be using their ambitious irrigation project as a recreational outlet in the midst of a busy urban area. In fact, to the builders of the 71-mile High Line, the canal was solely a commercial idea to bring South Platte River water to settlers and farmers following a gold rush in 1859 near the confluence of the South Platte and Cherry Creek.
Although the canal has become an emerald strand of natural beauty through a bustling metropolitan area, its original intent was to entice settlers headed west to stop, grow crops and create communities on the high plains at the foot of the Rocky Mountains.
While the High Line, which is owned and operated by Denver Water, still supplies farmers and other users, its adjacent service road has become a path for hikers, joggers, cyclists, equestrians, bird watchers and others who yearn for a slice of the outdoors in the middle of a city.
MAP LEGEND
High Line Canal
miles from start
parking
trail access
wheelchair access
trail interruption
bridge
bench
picnic table
restrooms
Chatfield Reservoir
Santa Fe Drive
General facts:
Operation: Denver Water owns and operates the High Line Canal, but the trail is maintained by various recreation districts.
Distance: The trail stops at mile 66, but the canal used to extend 71 miles. A small portion at the end of the canal has since been filled in. There are mile markers along the trail.
Access: The trail is open to walking, jogging, cycling, and, in certain stretches, horses.
Safety: The canal's depth ranges from 2 to 7 feet deep with a strong current. Swimming, tubing, boating and other water activities are strictly prohibited. The public is urged to stay on the path and keep away from the facility's pipes and headgates. Only authorized agencies are allowed to operate motorized vehicles on the trail.
Grade: Generally, the canal is an easy, almost flat walk, dropping 2 feet each mile.


MAP LEGEND
High Line Canal
miles from start
parking
trail access
wheelchair access
trail interruption
bridge
bench
picnic table
restrooms
© 2011 Denver Water
Published by Denver Water, 2011
Editors:
Denver Water Community Relations
Photography:
Denver Water Community Relations
Tim O'Hara Photography
Graphic Design:
TaCito Design, Inc.
Maps:
Denver Water GIS & Recreation
TaCito Design, Inc.

Goals of this Feasibility Study

- Identify watersheds which do or could flow into the HLC.
- Determine HLC's capacity.
- Determine required infrastructure.
- Estimate annual volume of stormwater available for infiltration.
- Quantify anticipated benefits including water quality treatment, preservation of trees, and enhancement of the recreational experience.
- Estimate capital improvement and O&M costs.
- Evaluate framework for operating within the Colorado water rights administration system.
- Conceptual design of a pilot project.

Water Quality Hydrology

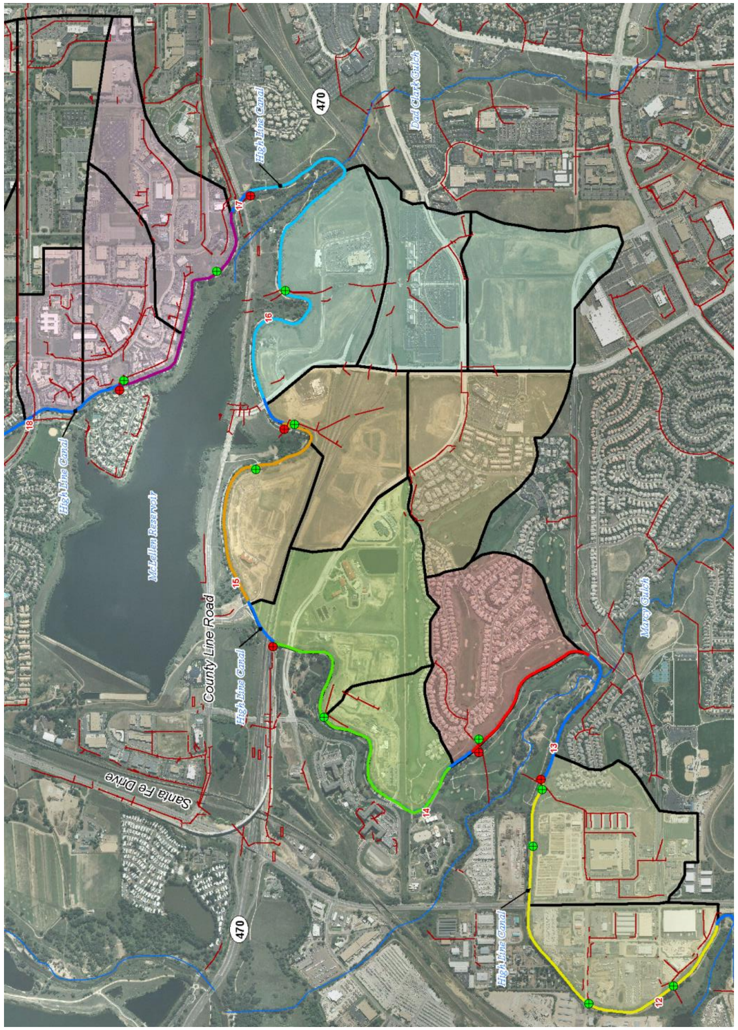


Watersheds which currently or could drain into the HLC were evaluated based upon the following:

- Physical ability to drain to HLC
- Flow from storm sewer systems and streets
- Capacity of HLC
- Diversions from natural channels are not feasible without obtaining a diversion water right

- About 240 watersheds were selected for consideration to drain to the HLC for a total of about 26 square miles.

Information Management



A GIS base map was prepared including:

- Tributary watersheds
- HLC stationing
- Storm drain systems crossing the canal
- Potential stormwater outflow points out of the canal
- Stormwater inflow points into the canal
- Denver Water head gates
- Jurisdictional boundaries
- Canal reaches and segments

Data was then exported into Google Earth for review and comment by project stakeholders

Water Quality BMP Design Concepts

Bioretention (Rain Garden)

- 12-hour drain time
- Filter media may be required for infiltration capacity
- 2-foot depth of growing and filter media for underdrain

Extended Detention Basin

- 40-hour drain time
- 20% to 25% increase in required WQCV
- Usually includes a micropool
- Release structure used to control drain time

Hybrid Option

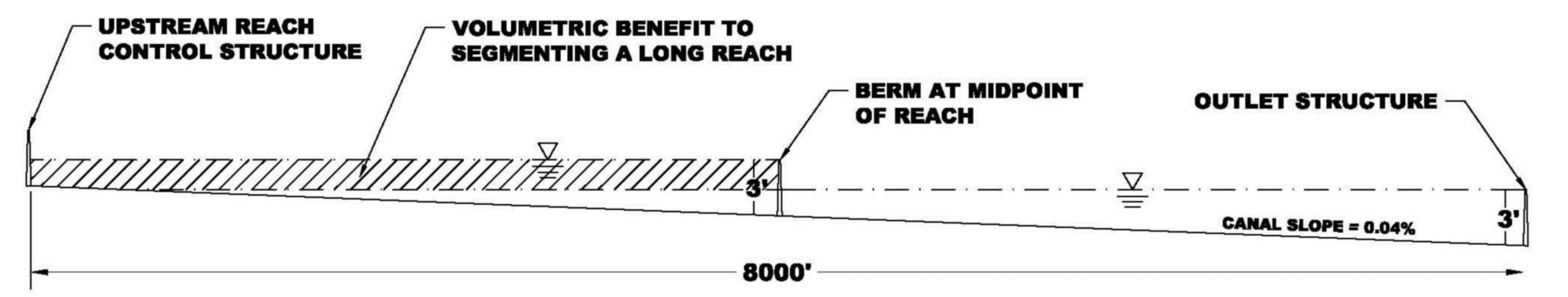
- 24-hour drain time to calculate WQCV
- Passive release structure to release excess WQCV

Water Quality BMP Design Considerations

- Maximize available canal volume at 3 feet deep
- 72-hour drain time (max allowed) to best support vegetation
- Segmented design concept allowed for more volume and infiltration at same average depth

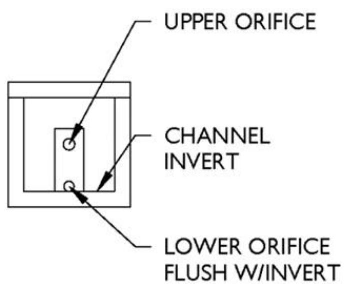
Based upon these criteria the canal was initially divided into 52 reaches. Each reach was later divided into two segments.

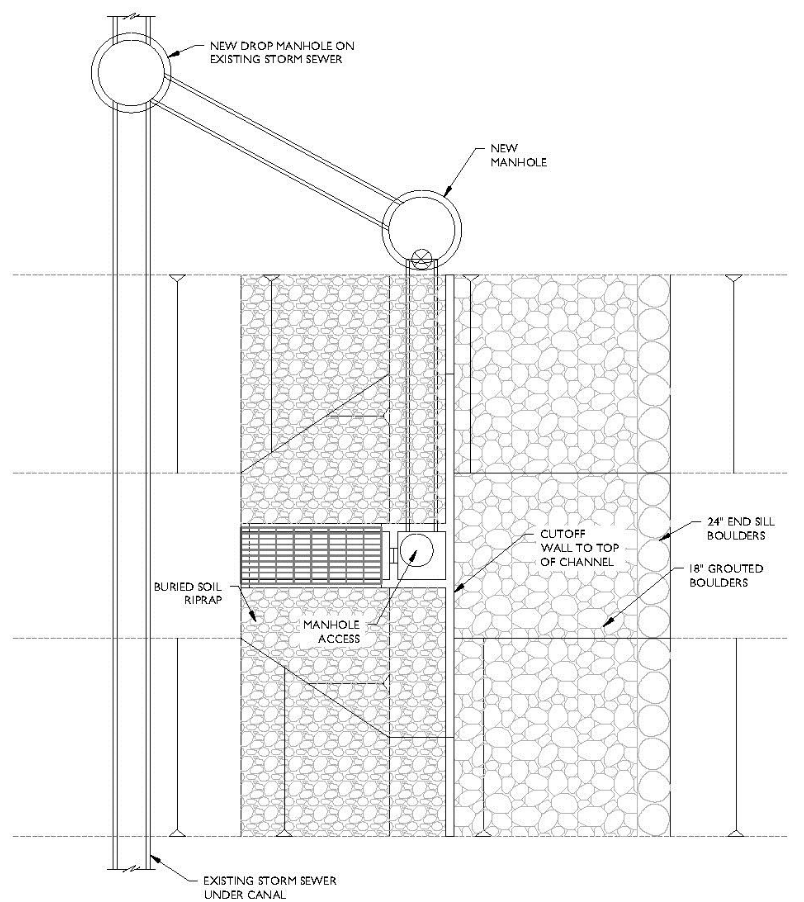
- Reach lengths vary between 2432' and 9598' and average 6293'.
- 36 of 52 reaches are greater than 1.0 mile in length.



Water Quality BMP Design

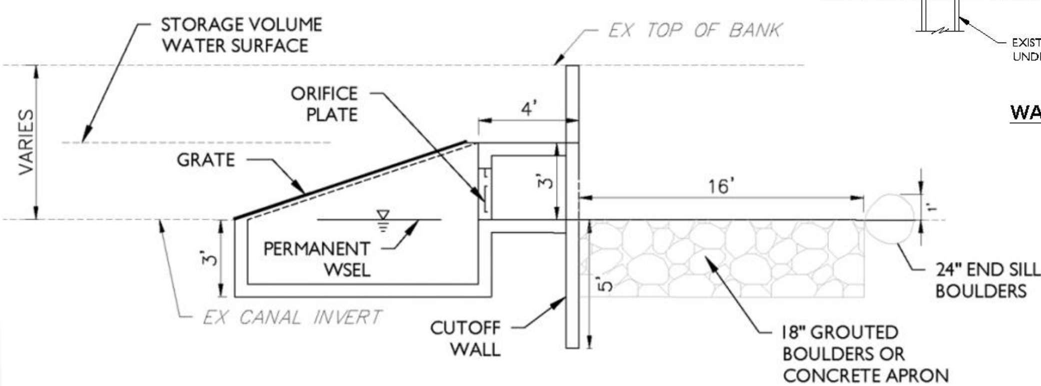
Must have defined outflow location to avoid trans-basin diversions



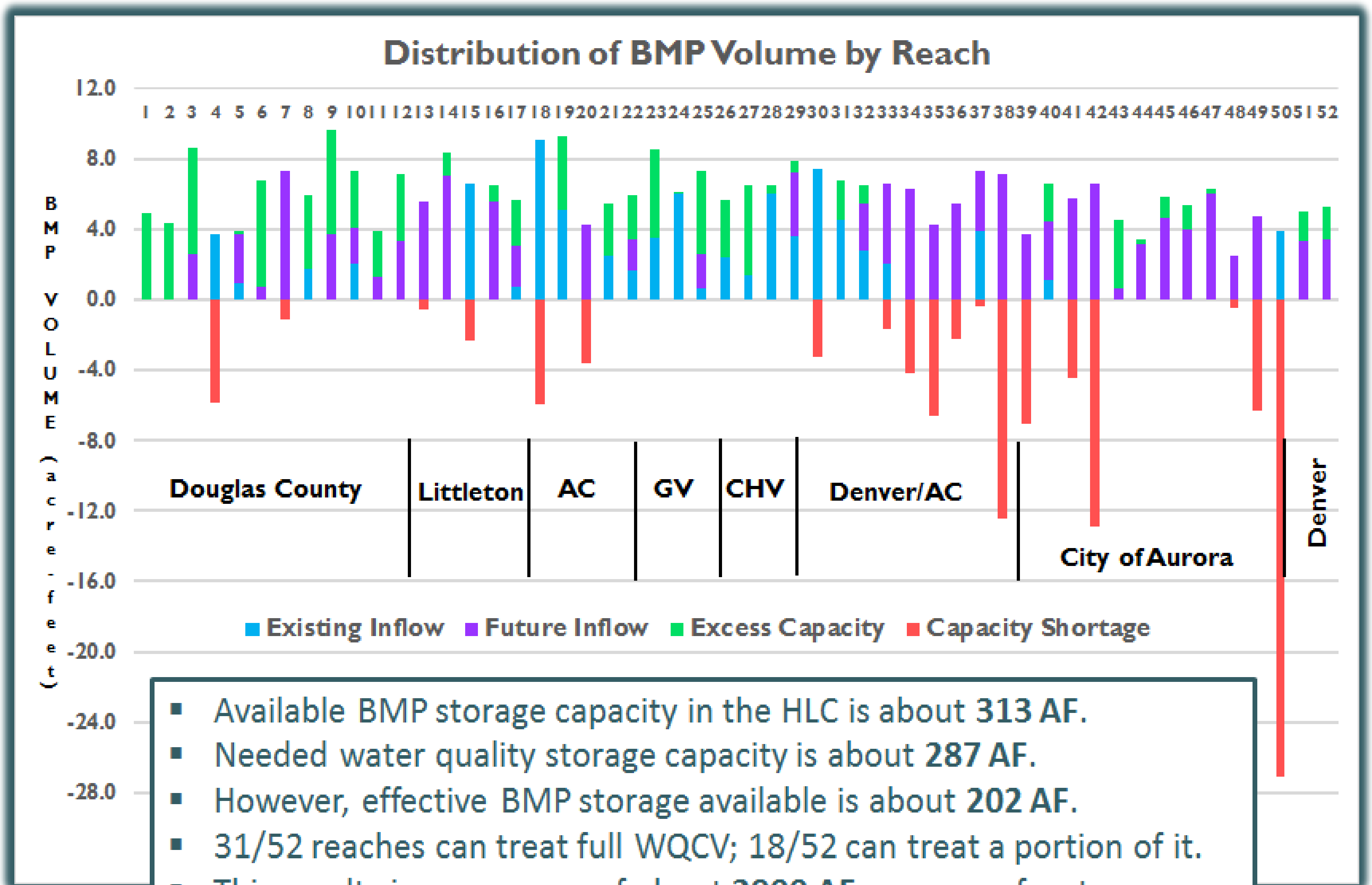


WATER QUALITY OUTFALL STRUCTURE

N.T.S.



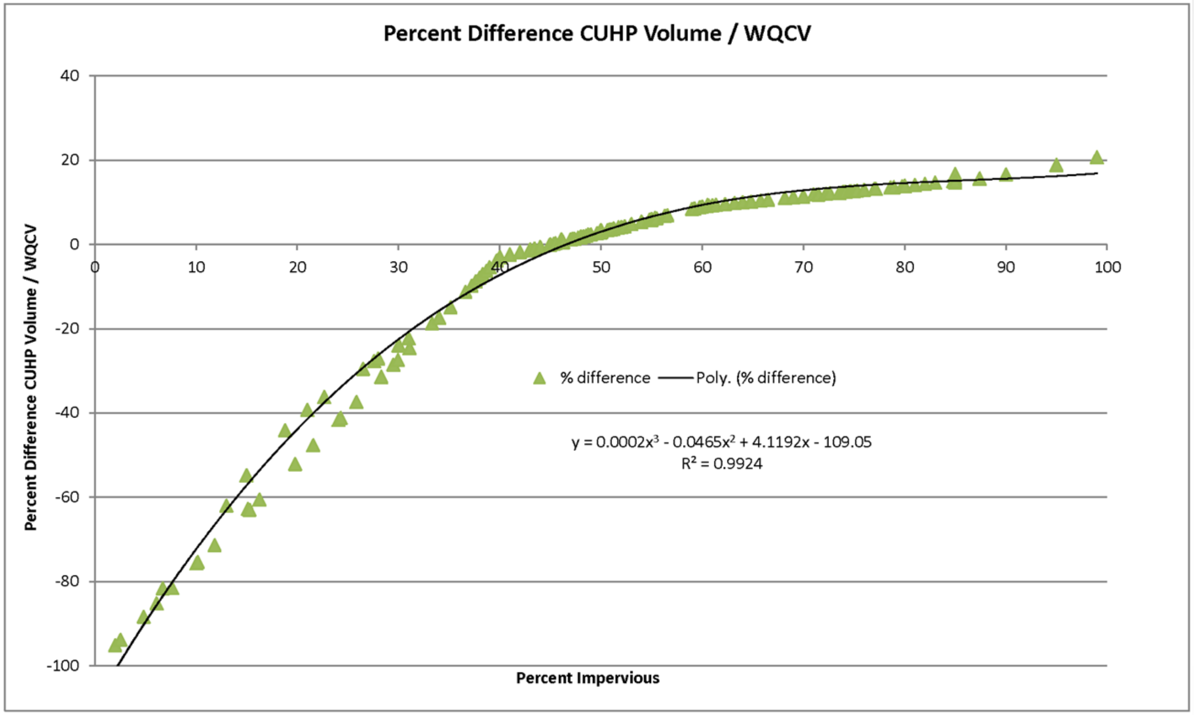
Canal Potential by Reach



- Available BMP storage capacity in the HLC is about **313 AF**.
- Needed water quality storage capacity is about **287 AF**.
- However, effective BMP storage available is about **202 AF**.
- 31/52 reaches can treat full WQCV; 18/52 can treat a portion of it.
- This results in an average of about **2900 AF** per year of water temporarily stored by the BMP.

What about Inflow Rates?

- The WQ event is a 0.53” 1-hour rainfall distributed as a 0.61” 2-hour rainfall.
- Existing storm sewers can be diverted but how much flow can we take?



- The WQCV does not equal CUHP excess precipitation for a WQ event.
- A correlation was developed between basin imperviousness, CUHP excess precipitation, and the WQCV for each of the basins within the project area.
- The percent difference for each basin can be used to adjust the peak runoff calculated by the SWMM model for each design reach that has the capacity to store the calculated WQCV.

Precipitation, Treatment & Benefit

- Average annual precipitation about 15-16 inches in 40-50 storm events
- Goal is to capture 80% of total annual runoff or 90% of all precipitation events
- 5-6 inches of runoff a year yields about 4000 AF of runoff with 2900 AF able to be treated
- 72-hour drain time provides about 100 additional days that the canal bottom will be wet -> up to 1000 AFY in infiltration, ideal for trees
- 80% to 90% of annual TSS load will be removed in reaches able to handle the full WQCV

Cost Alternatives

- $36 million to retrofit the entire Canal with ~$1 million in O&M

- $75 million to develop alternative water quality treatment facilities for tributary watersheds

- $31 million to buy water rights equivalent to what the HLC would provide to trees with a retrofit design.

Challenges

Algae / Odors

Aesthetics / Trash

Bacteria

Mosquitos / West Nile Virus

Waters of the State of Colorado

Waters of the U.S.

Existing Water Customers

Water rights

Ownership / Management

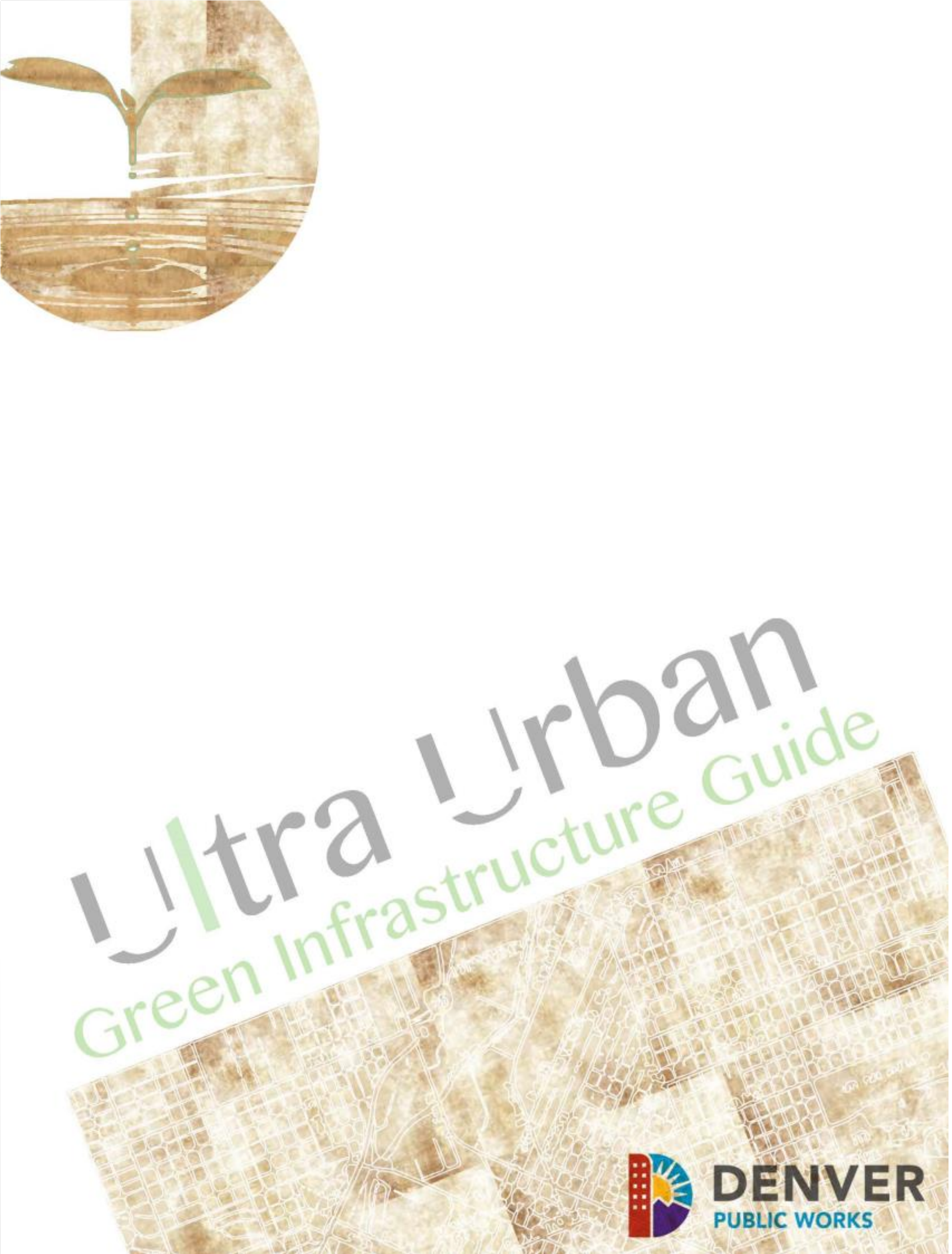
Property damage from flooding and seepage

The Vision…

Developments in Ultra-Urban Green Infrastructure

Sarah Anderson - City and County of Denver
Jim Wulliman, PE - Muller Engineering Co.
Paul Thomas, RLA – Stream Design
Holly Piza, PE – Urban Drainage and Flood Control District

2015 UDFCD Annual Seminar April 7,2015



Timely for Denver:

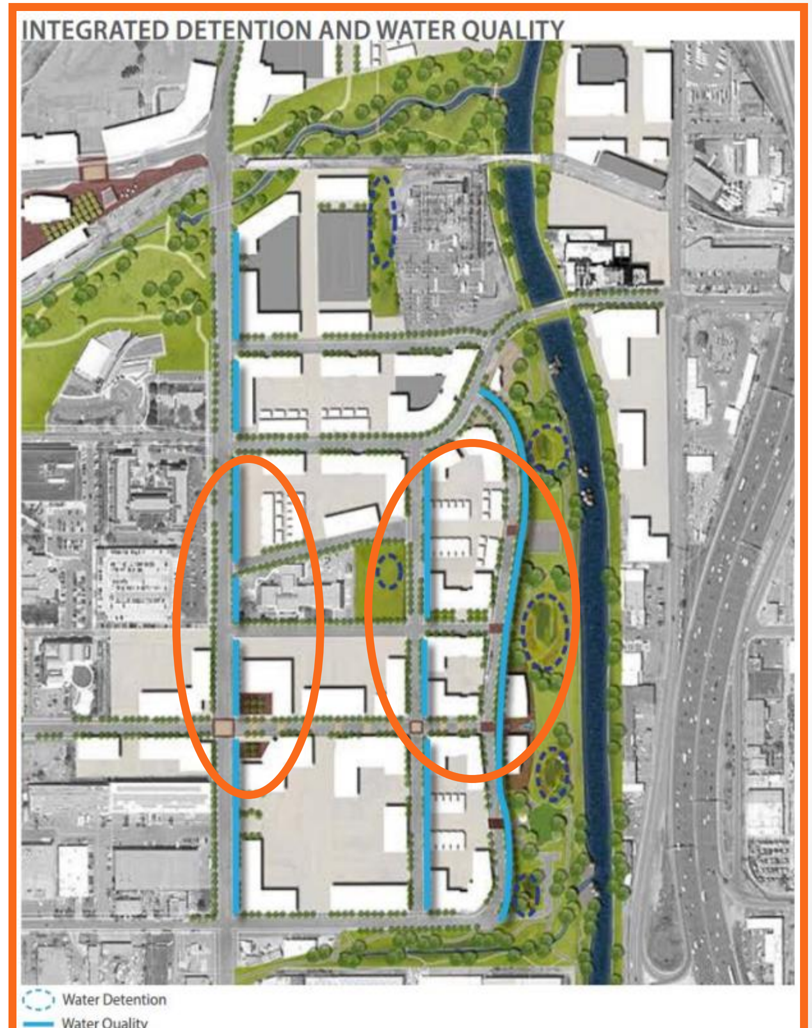
1. Pilot Program with CDPHE

In design:
Brighton Blvd (26th-44th)

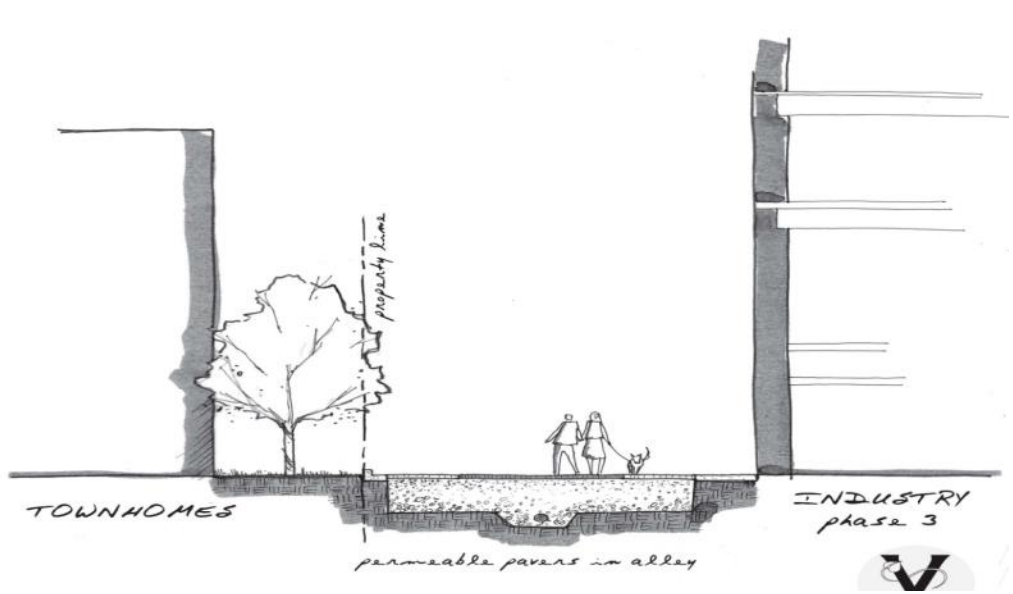
21st Street/Festival Street
Benedict Park to the Ballpark

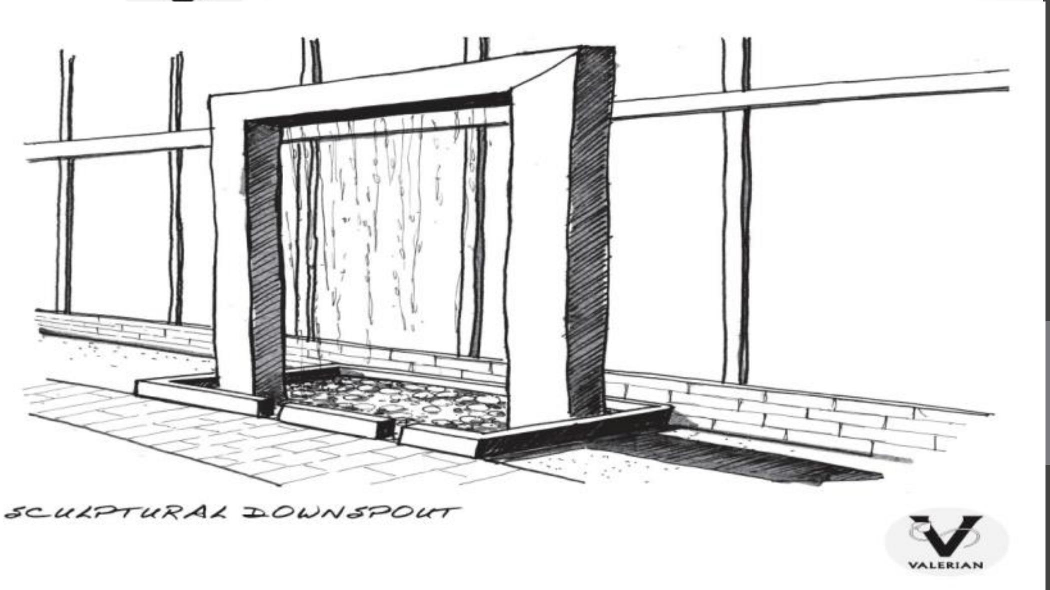
2. Future Plans & "Green Streets"

(Master Plans, Station Area Plans, Neighborhood Plans, etc)



3. Private Development





Next Steps

- Update the CCD Storm Drainage Design & Technical Criteria Manual
- Formalize policy for using the right-of-way
- Identify opportunities for P3's
- Develop maintenance protocols for BIDs/MIDs
- Establish (funded) maintenance program

Green Infrastructure Works!


(Flickr Hive Mind. Net)

Green Infrastructure Works!

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. (USEPA)

(Flickr Hive Mind. Net)

Green Infrastructure Works!

(in rural settings)

Green Infrastructure Works!

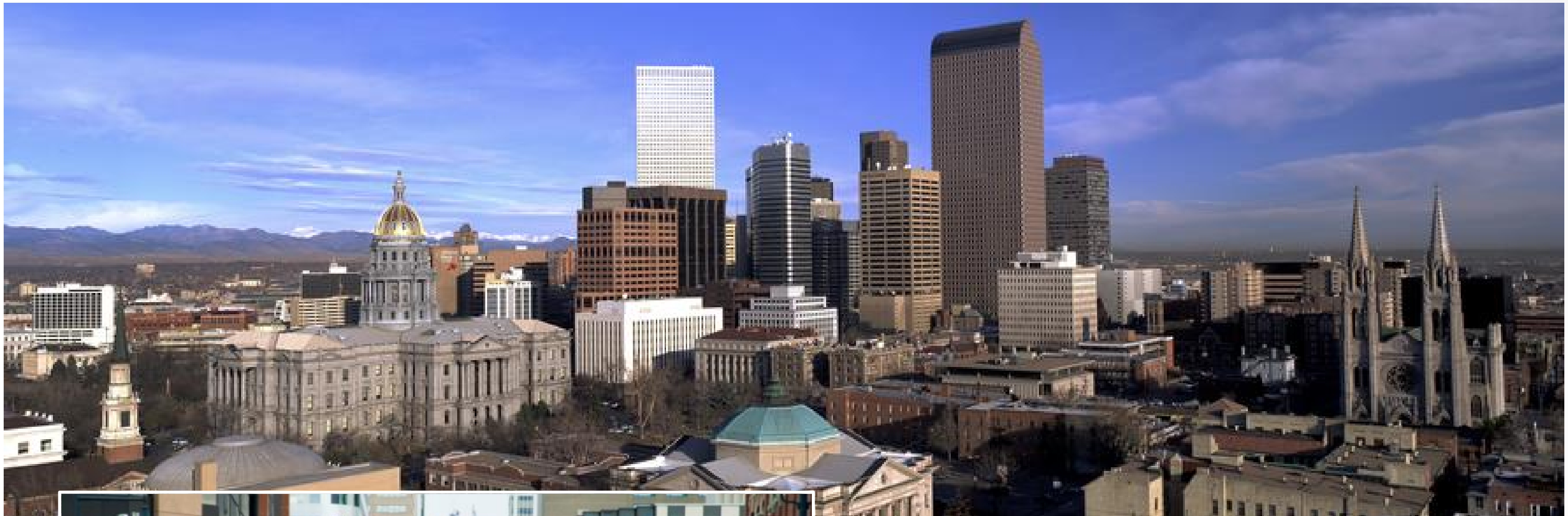
(in parks)

Green Infrastructure Works!

(in suburban environment)

Green Infrastructure Works!

(in ultra-urban setting)



Green Infrastructure Works!

(in ultra-urban setting)

- Design issues are worked out
- Inter-departmental approval is attained
- Plan for maintenance is developed

Our Approach

Identify typical urban landscape forms

Convert to Stormwater Management BMPs

Streetside Planter

Bumpout Planter

Tree Plantings

Median Barrier

Alley

Convert to Stormwater Management BMPs

Streetside Stormwater Planter

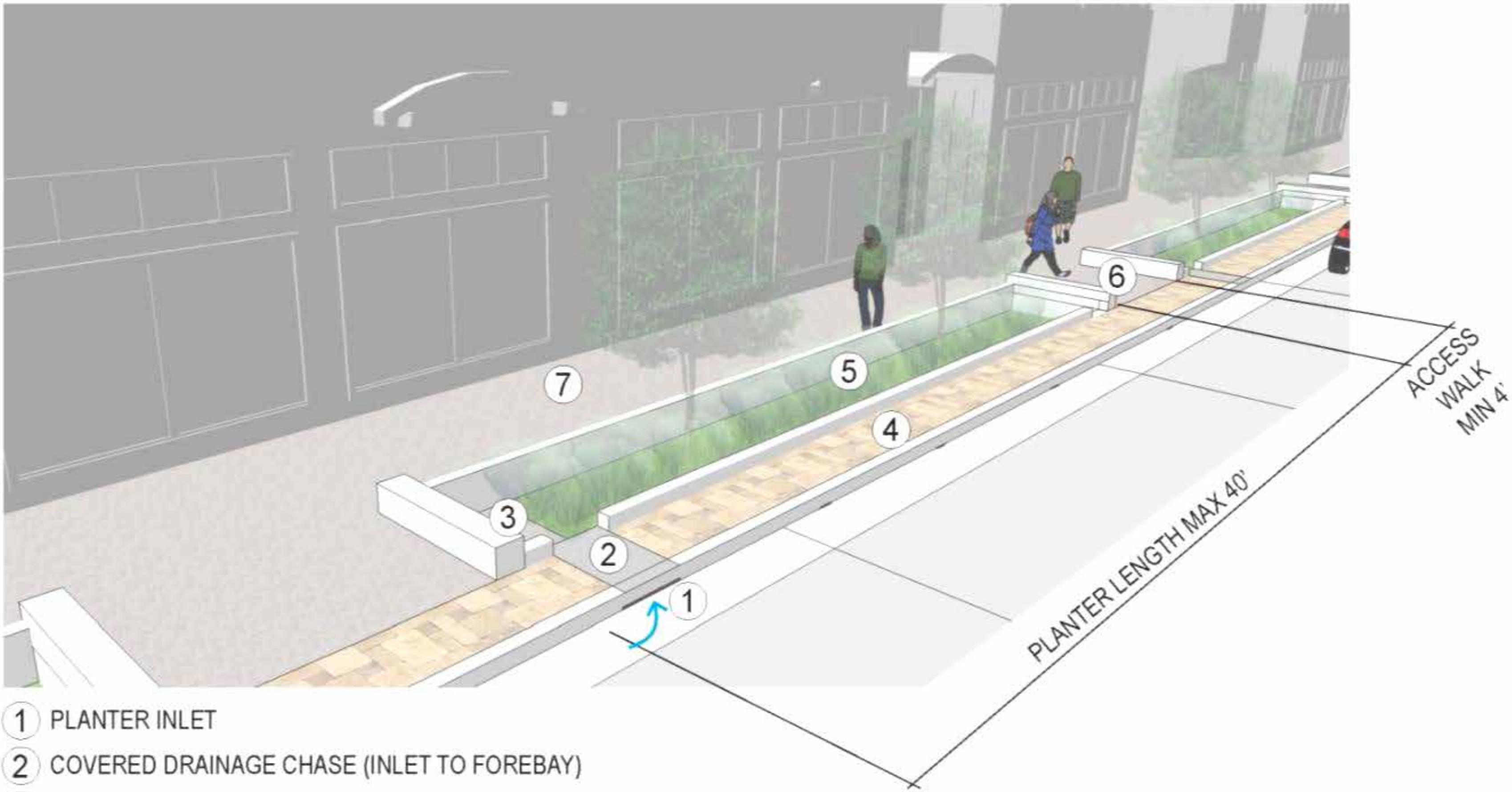
Bumpout Stormwater Planter

Tree Pit / Tree Trench

Green Gutter

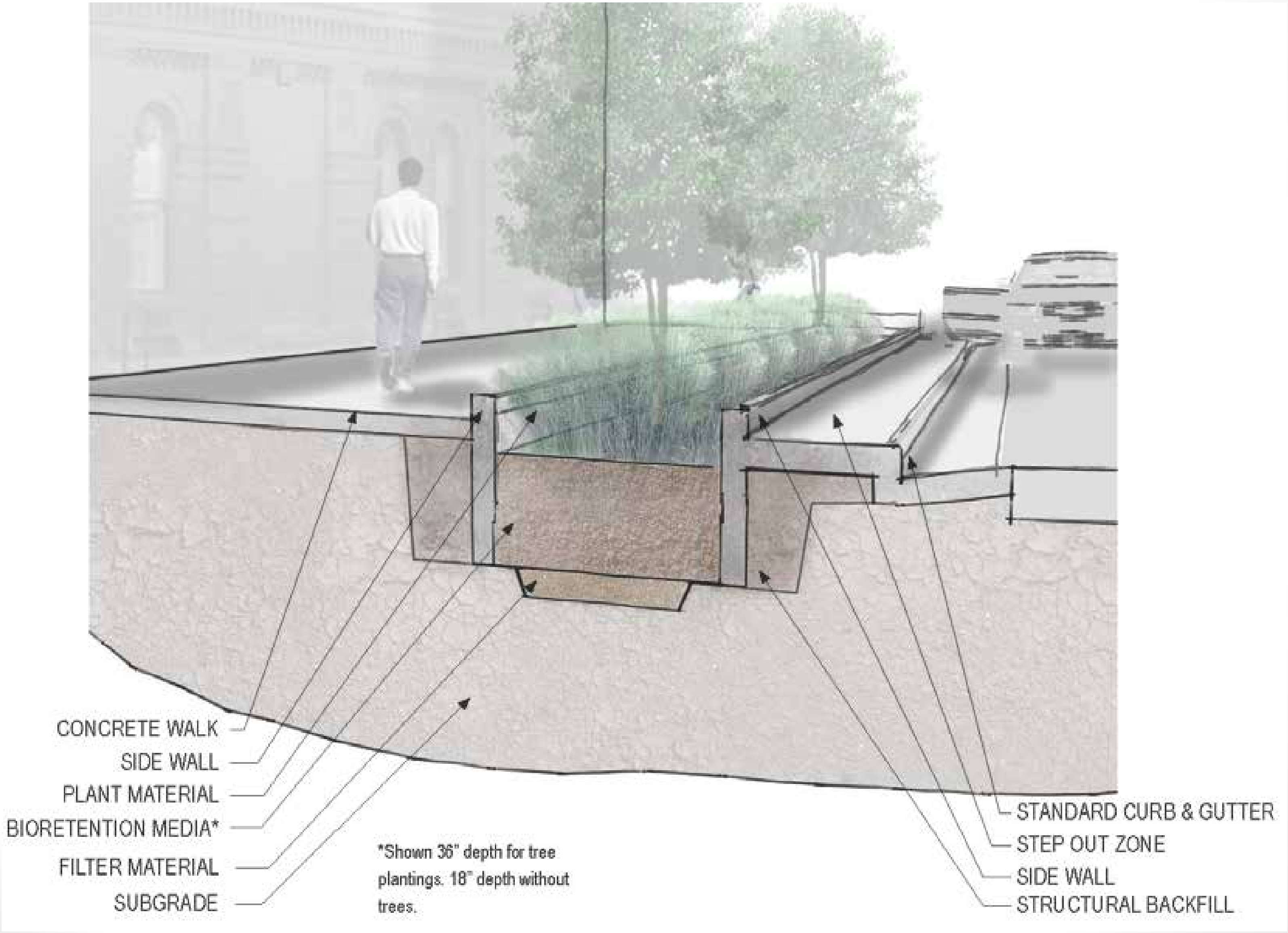
Green Alley

Streetside Stormwater Planter

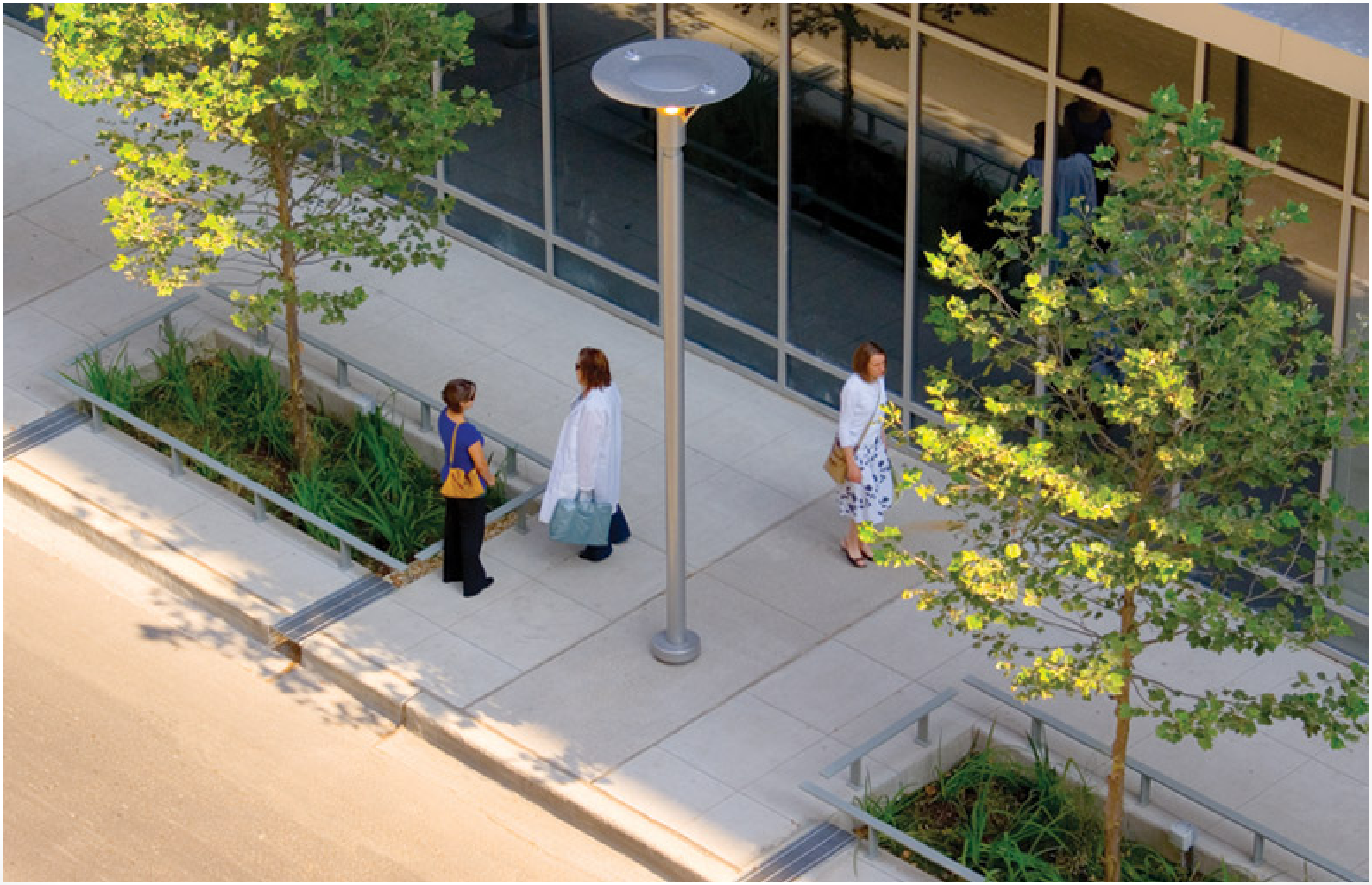


1 PLANTER INLET
2 COVERED DRAINAGE CHASE (INLET TO FOREBAY)
3 FOREBAY (SEDIMENT COLLECTION)
4 STEP-OUT ZONE
5 PLANTING AREA (IRRIGATED)
6 ACCESS WALK
7 PEDESTRIAN SIDEWALK

Streetside Stormwater Planter

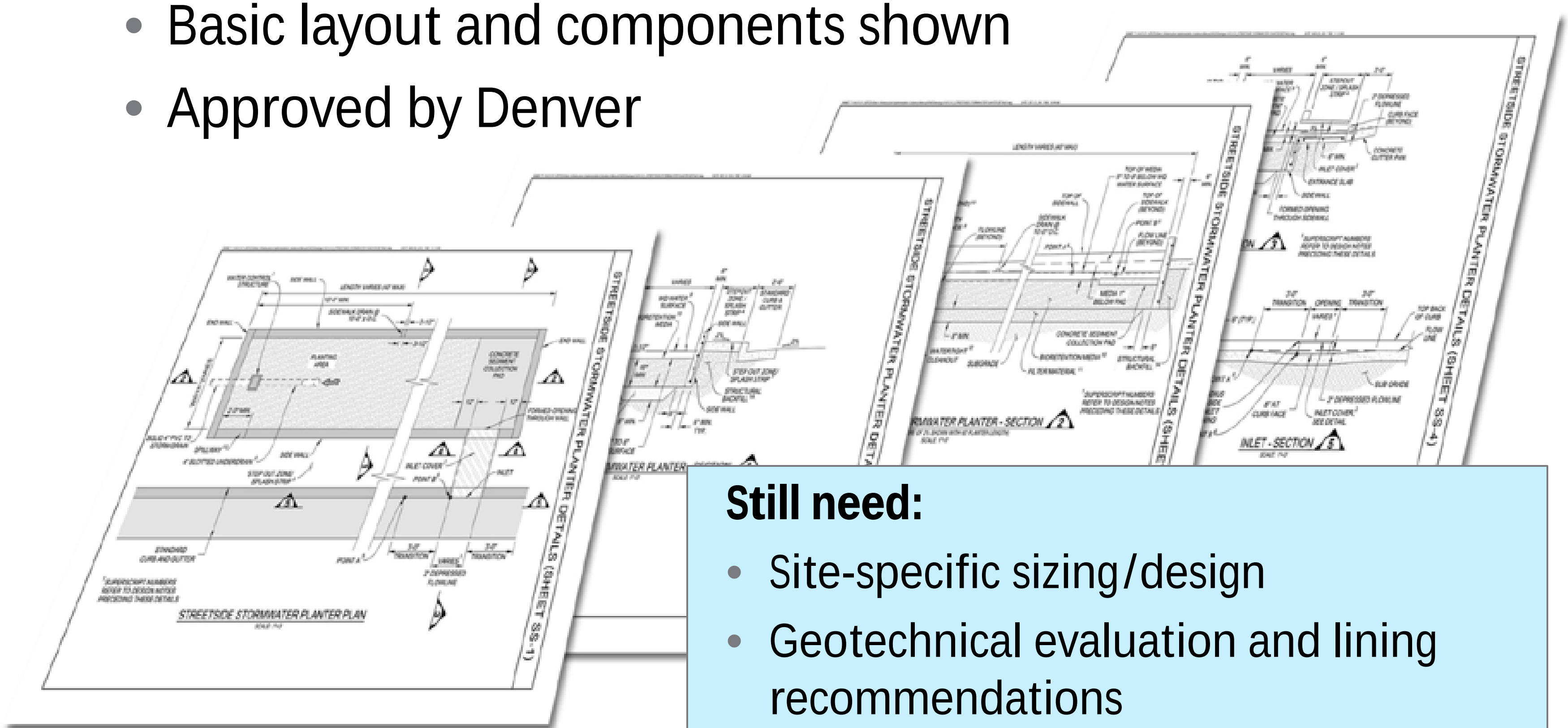


Streetside Stormwater Planter



Design Details

- Basic layout and components shown
- Approved by Denver

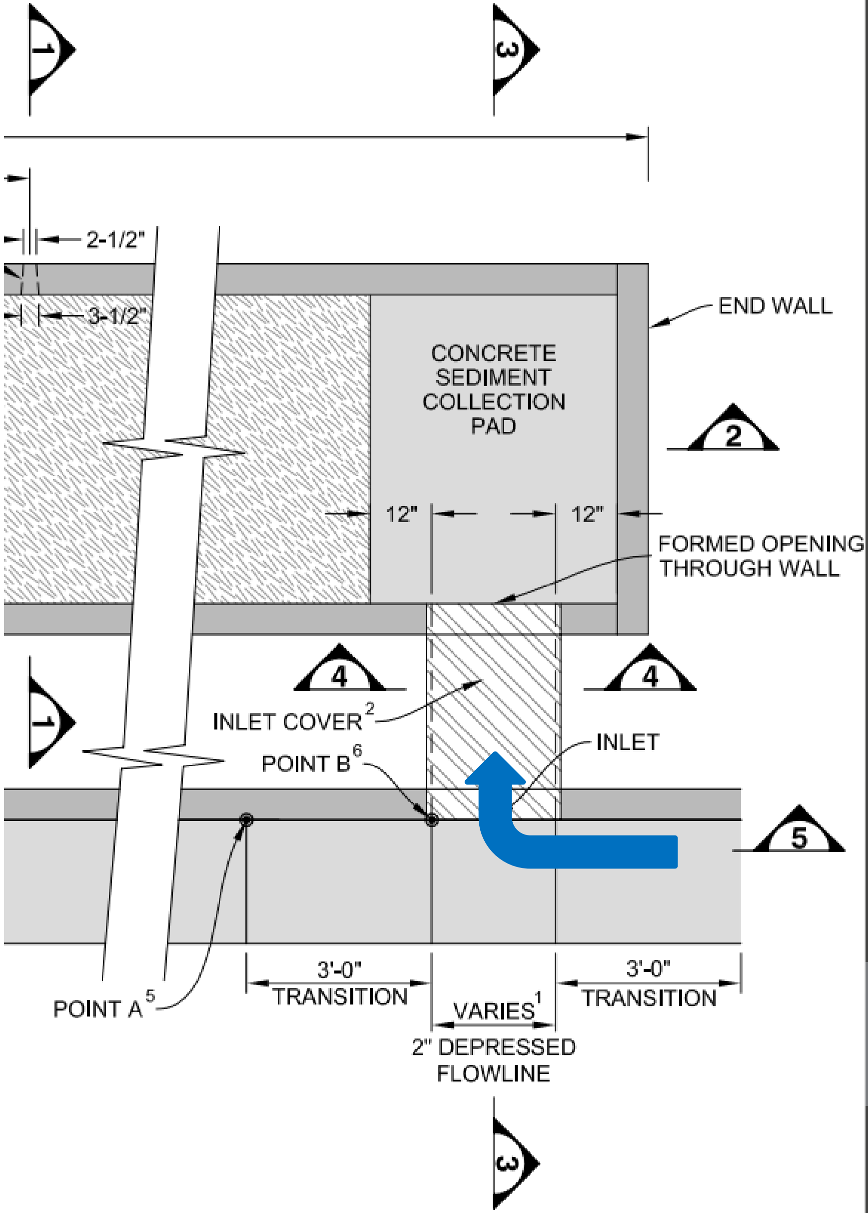


Still need:

- Site-specific sizing/design
- Geotechnical evaluation and lining recommendations
- Wall structural/reinforcing design
- Address utility conflicts
- Underdrain connection
- Irrigation

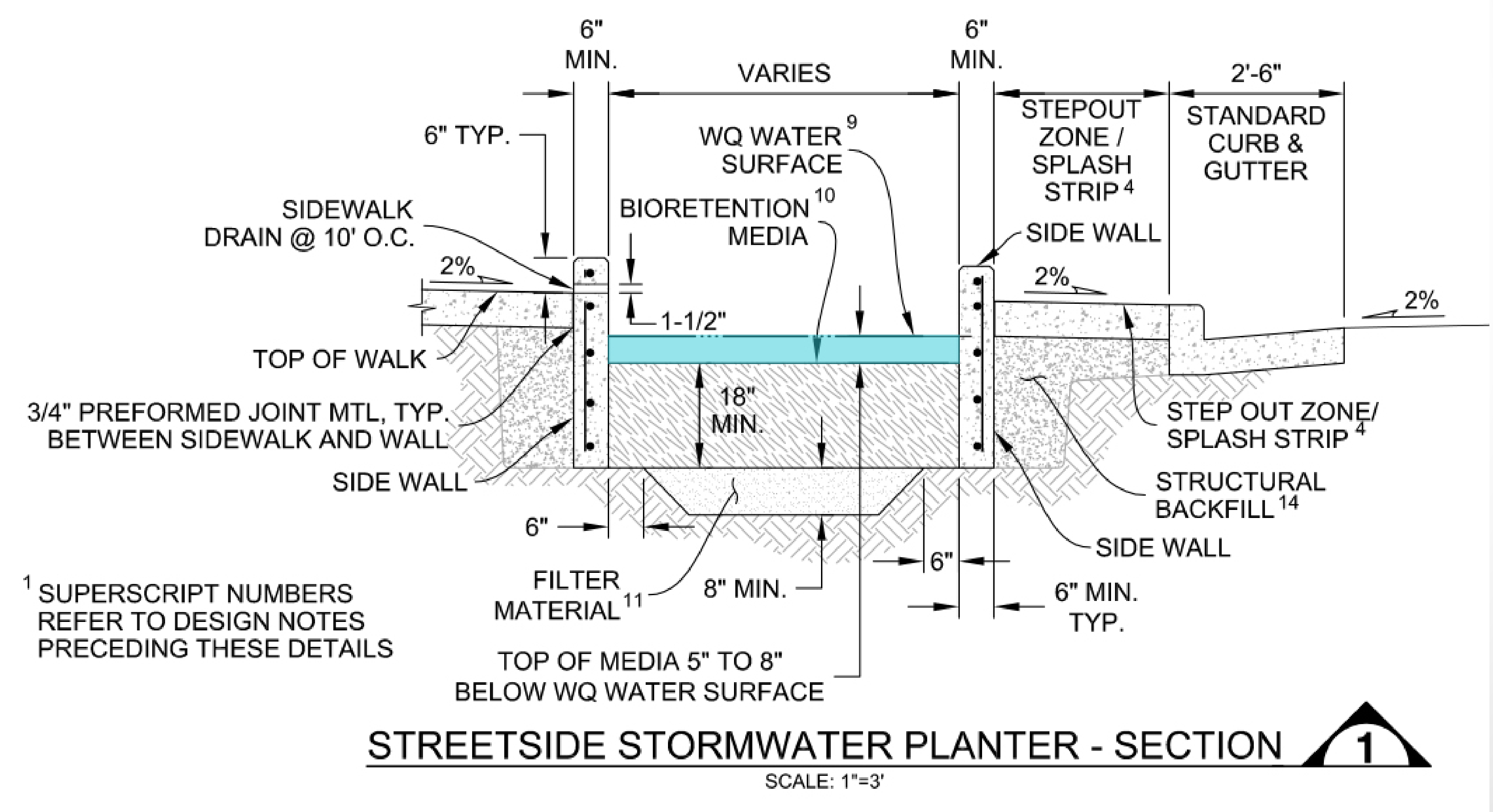
Inlet Design

- Emulates curb-opening inlet
- Based on WQ peak flow rate
  - I = 2.04 iph
  - C = 0.84
- 2' to 3' open width
- HS-20 loading for cover
- Sediment collection pad



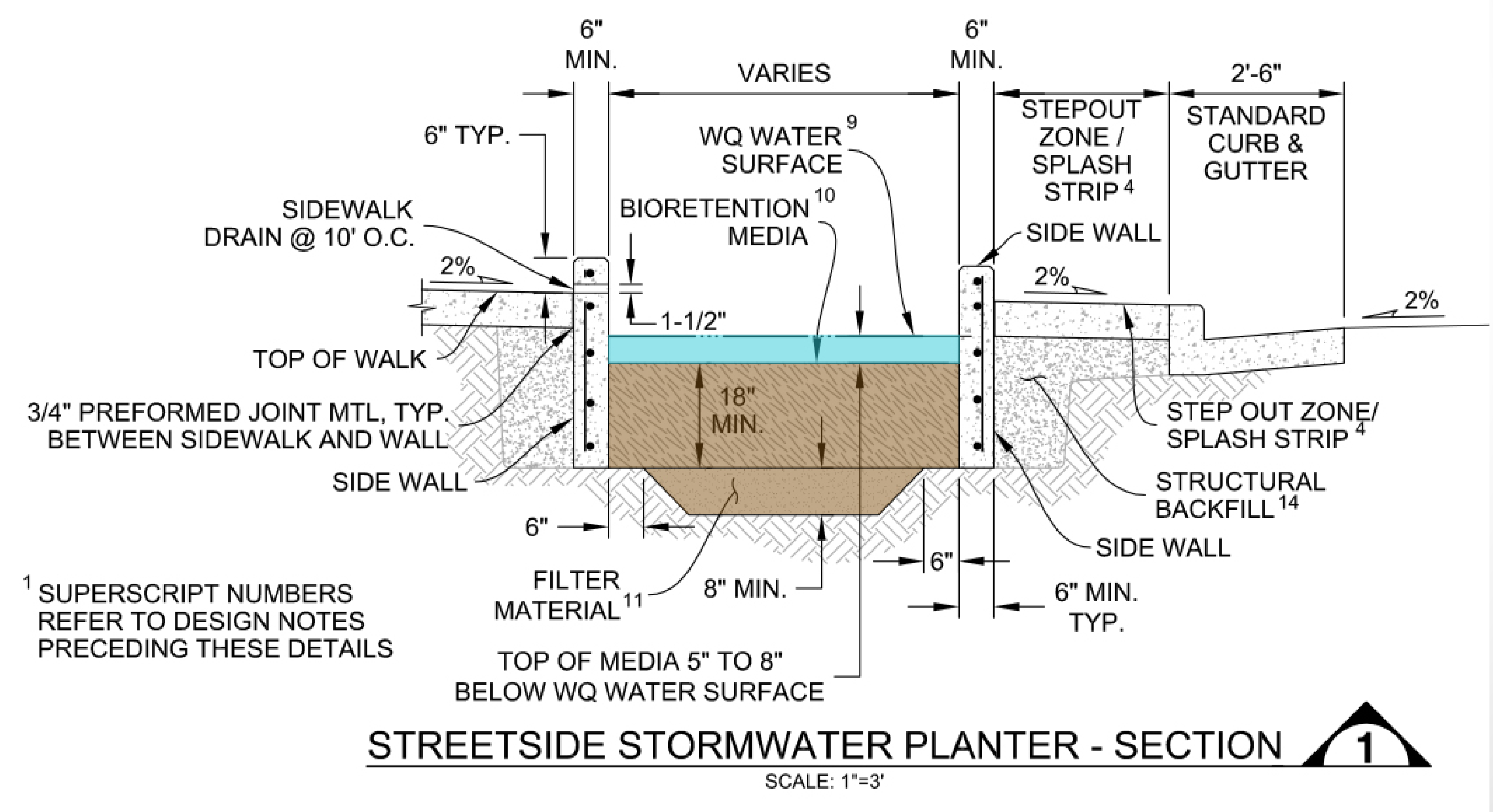
WQCV Design

- Top of WQCV = flowline elevation



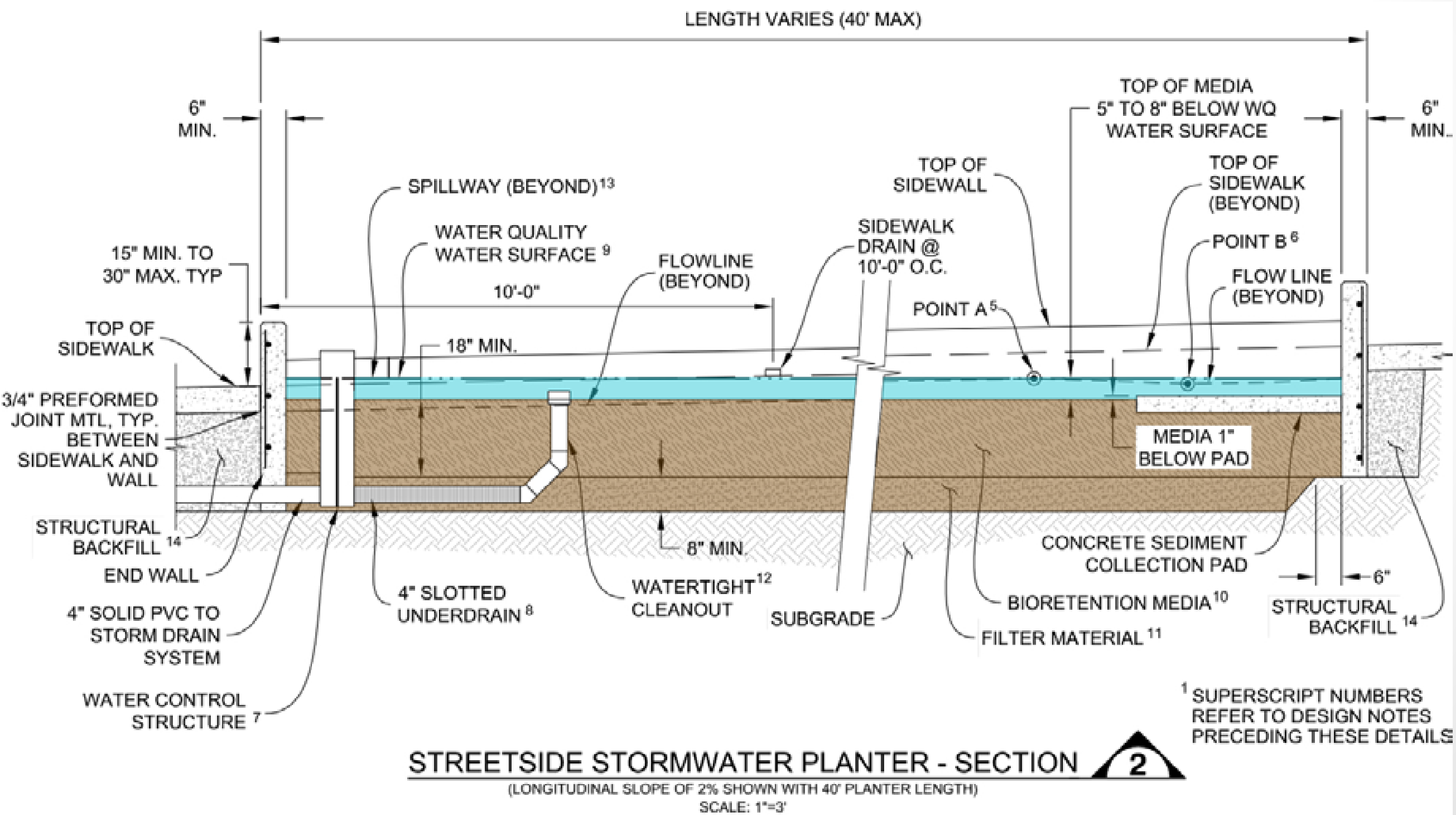
WQCV Design

- Top of WQCV = flowline elevation
- Keep top of media as high as possible
- Can account for pore space volume @ 14% porosity



WQCV Design

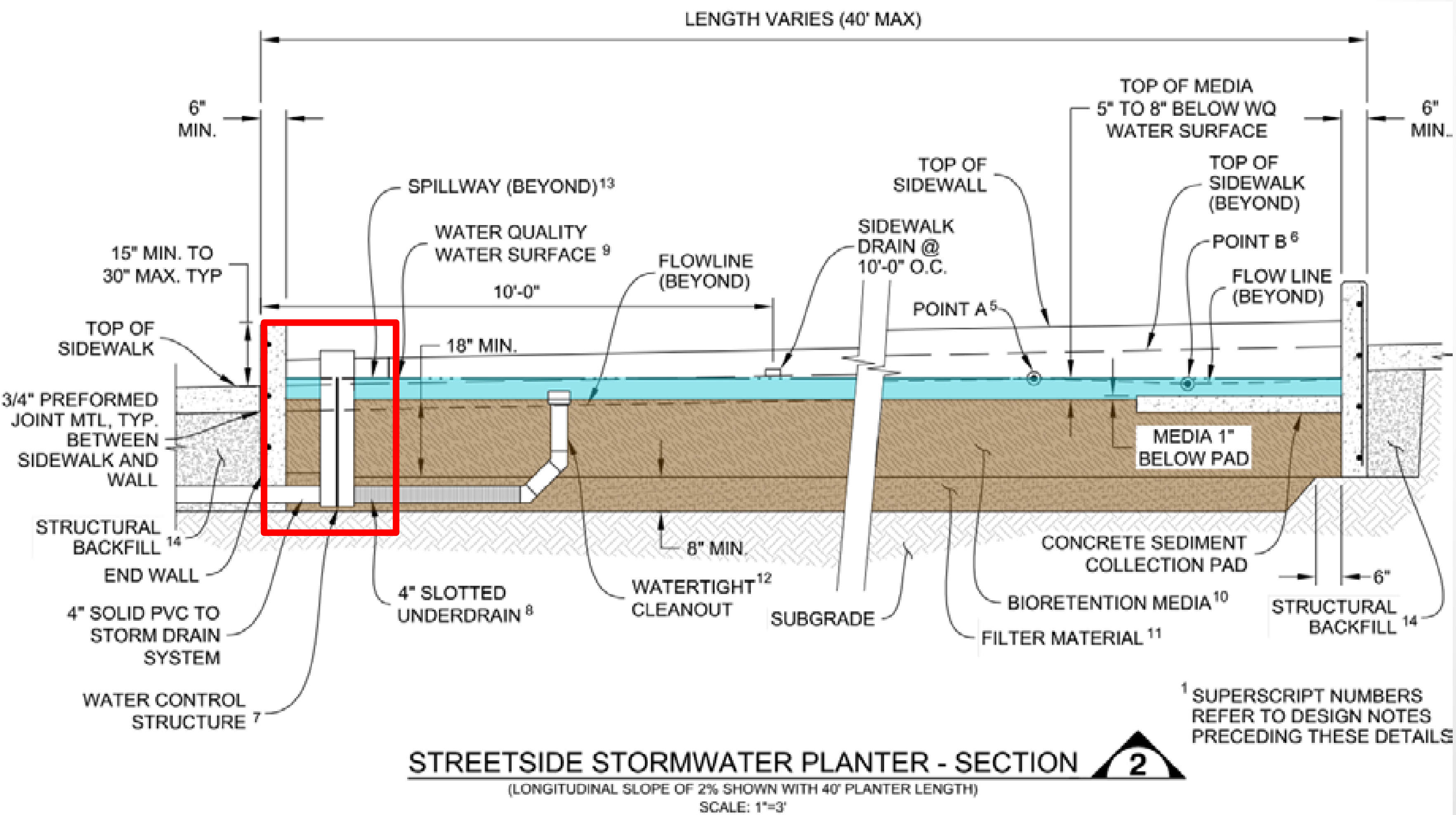
- Top of media stays horizontal
- Depth to media "rises" relative to sloping sidewalk



April 7,2015 2015 UDFCD Annual Seminar

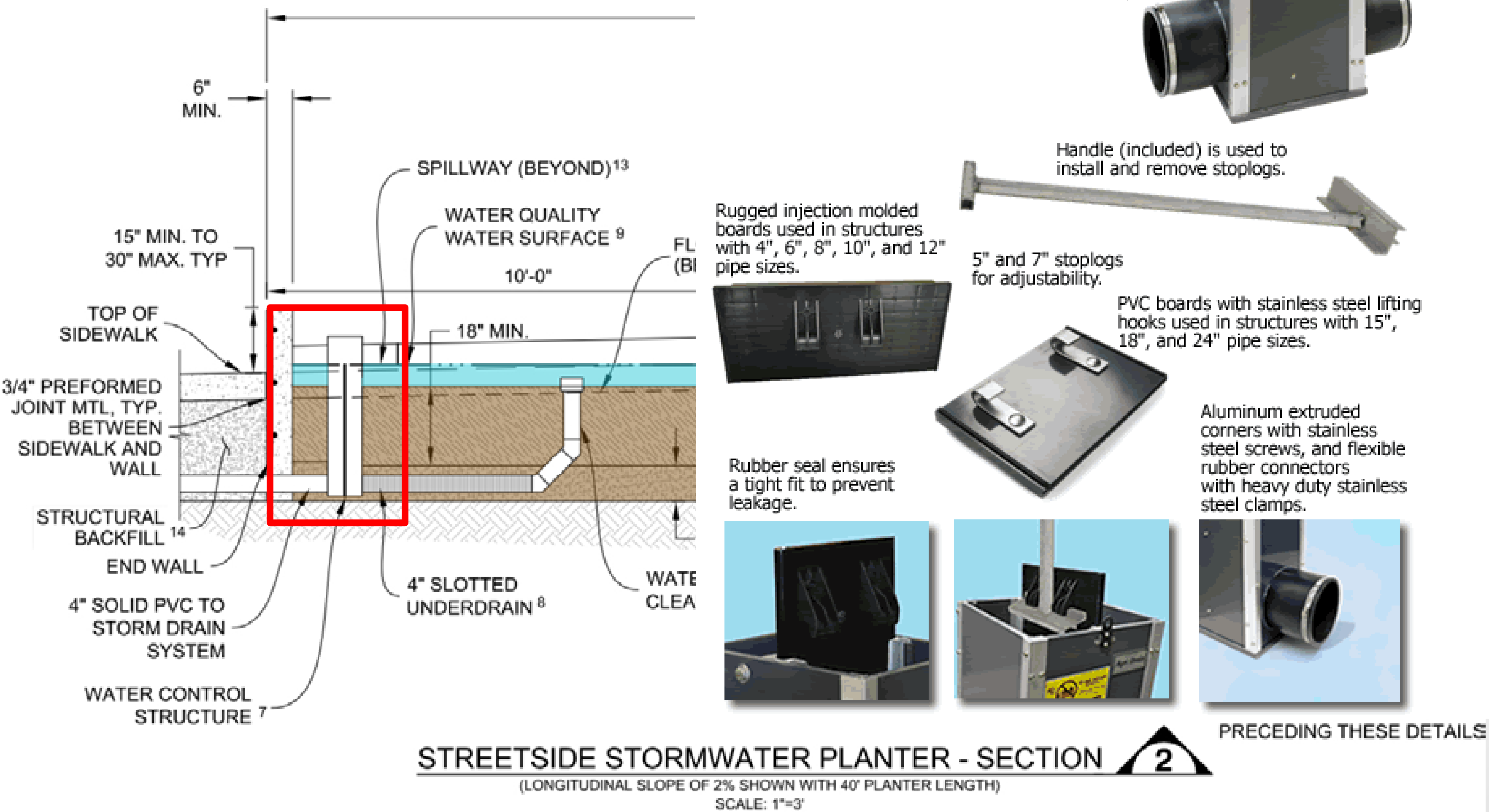
WQCV Design

- Weir and orifice controls WS and drain time



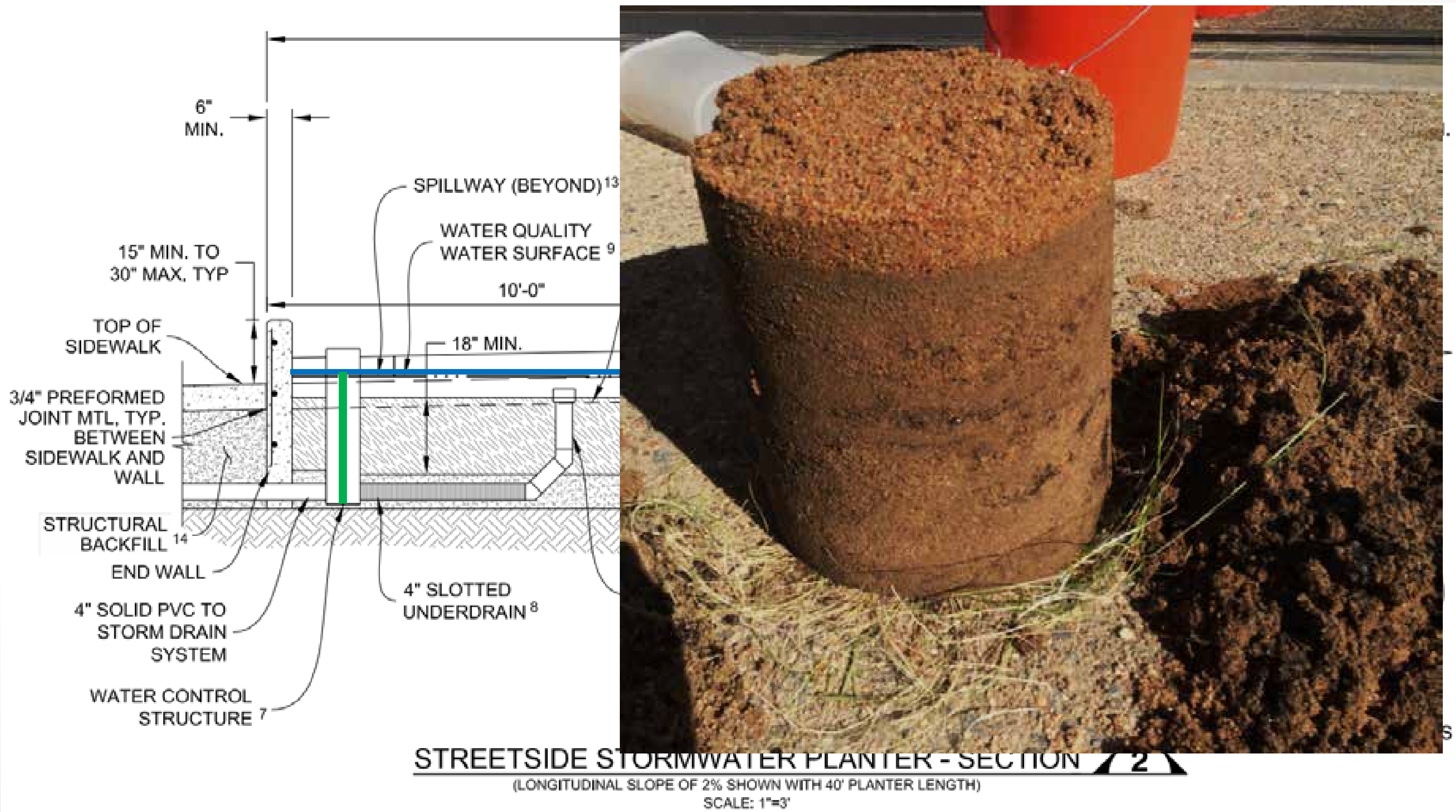
WQCV Design

- Weir and orifice controls WS and drain time



Media

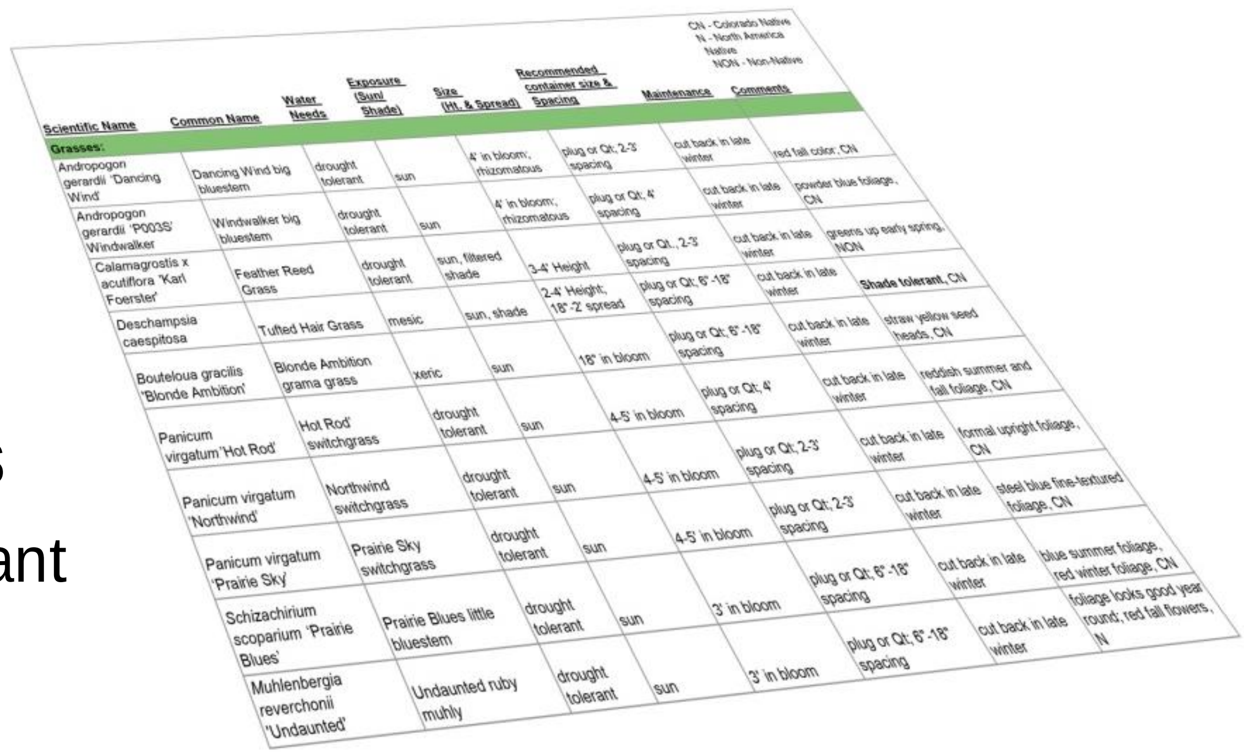
- Biologically healthy sandy loam topsoil
- Tight UDFCD specification



Planting Recommendations

Plant Types:

- Grasses
- Perennials
- Shrubs
- Trees



CN - Colorado Native
N - North America Native
NON - Non-Native

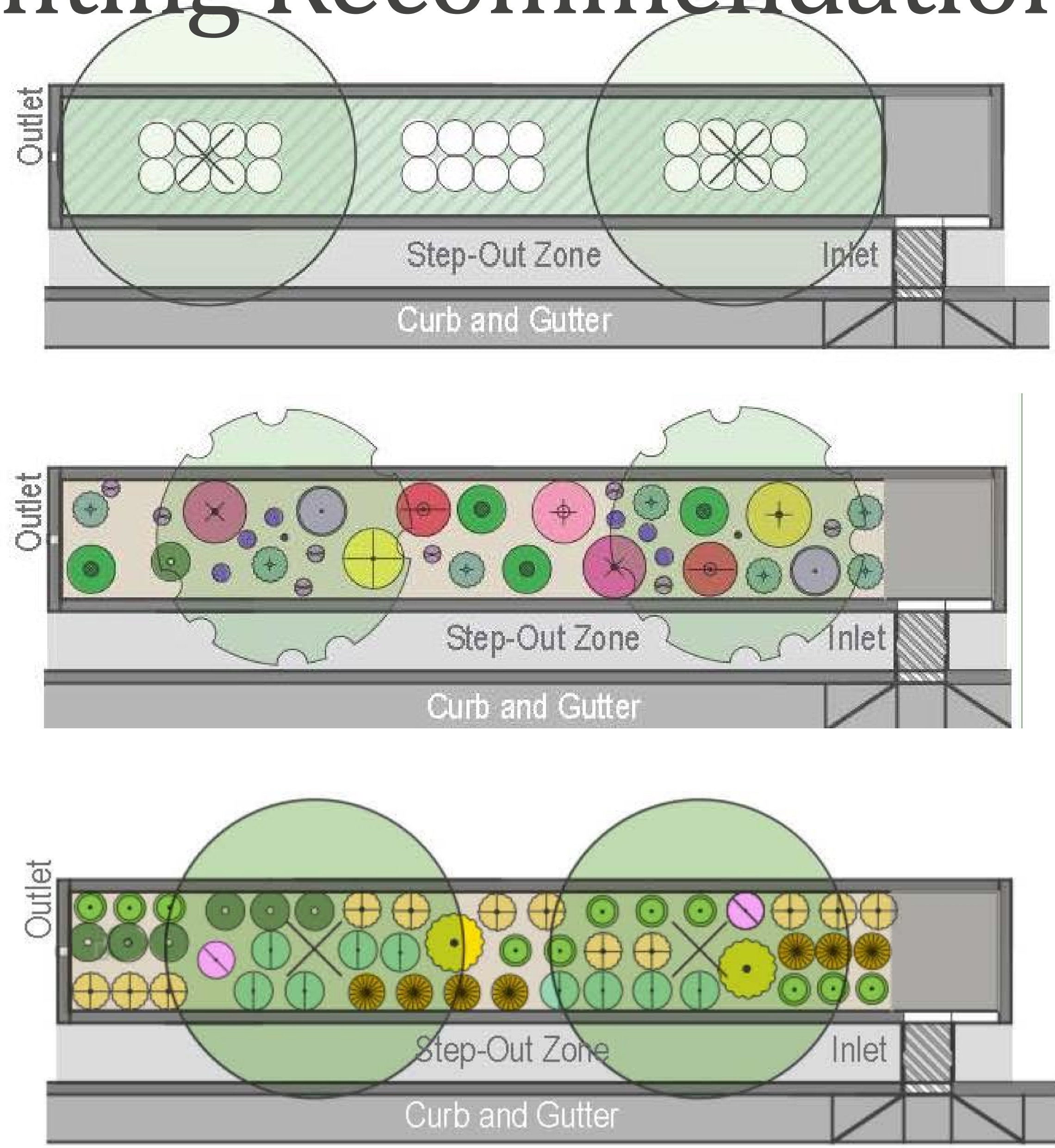
Scientific Name	Common Name	Water Needs	Exposure (Sun/ Shade)	Size (Ht. & Spread)	Recommended container size & Spacing	Maintenance	Comments
Grasses:							
Andropogon gerardii 'Dancing Wind'	Dancing Wind big bluestem	drought tolerant	sun	4' in bloom; rhizomatous	plug or Qt; 2-3' spacing	cut back in late winter	red fall color, CN
Andropogon gerardii 'P003S' Windwalker	Windwalker big bluestem	drought tolerant	sun	4' in bloom; rhizomatous	plug or Qt; 4' spacing	cut back in late winter	powder blue foliage, CN
Calamagrostis x acutiflora 'Karl Foerster'	Feather Reed Grass	drought tolerant	sun, filtered shade	3-4' Height	plug or Qt., 2-3' spacing	cut back in late winter	greens up early spring, NON
Deschampsia caespitosa	Tufted Hair Grass	mesic	sun, shade	2-4' Height; 18"-2' spread	plug or Qt; 6"-18" spacing	cut back in late winter	**Shade tolerant**, CN
Bouteloua gracilis 'Blonde Ambition'	Blonde Ambition grama grass	xeric	sun	18" in bloom	plug or Qt; 6"-18" spacing	cut back in late winter	straw yellow seed heads, CN
Panicum virgatum 'Hot Rod'	Hot Rod' switchgrass	drought tolerant	sun	4-5' in bloom	plug or Qt; 4' spacing	cut back in late winter	reddish summer and fall foliage, CN
Panicum virgatum 'Northwind'	Northwind switchgrass	drought tolerant	sun	4-5' in bloom	plug or Qt; 2-3' spacing	cut back in late winter	formal upright foliage, CN
Panicum virgatum 'Prairie Sky'	Prairie Sky switchgrass	drought tolerant	sun	4-5' in bloom	plug or Qt; 2-3' spacing	cut back in late winter	steel blue fine-textured foliage, CN
Schizachirium scoparium 'Prairie Blues'	Prairie Blues little bluestem	drought tolerant	sun	3' in bloom	plug or Qt; 6"-18" spacing	cut back in late winter	blue summer foliage, red winter foliage, CN
Muhlenbergia reverchonii 'Undaunted'	Undaunted ruby muhly	drought tolerant	sun	3' in bloom	plug or Qt; 6"-18" spacing	cut back in late winter	foliage looks good year round; red fall flowers, N

Requirements

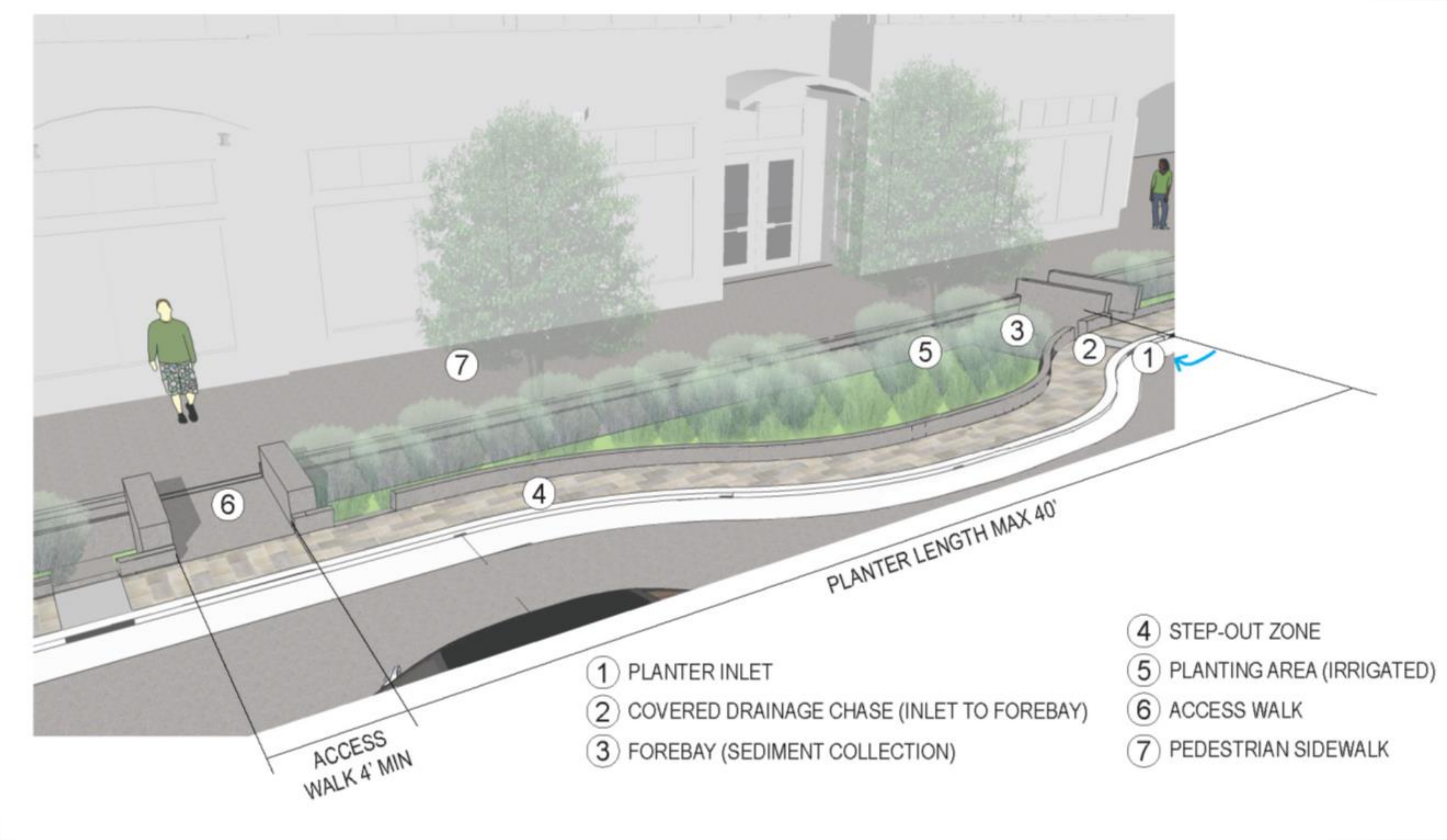
- Drought Tolerant
- Flood Tolerant
- Non-invasive
- Height 18" min. to 4' max.

Planting Recommendations

Maintenance ↓



Bumpout Stormwater Planter



Bumpout Stormwater Planter

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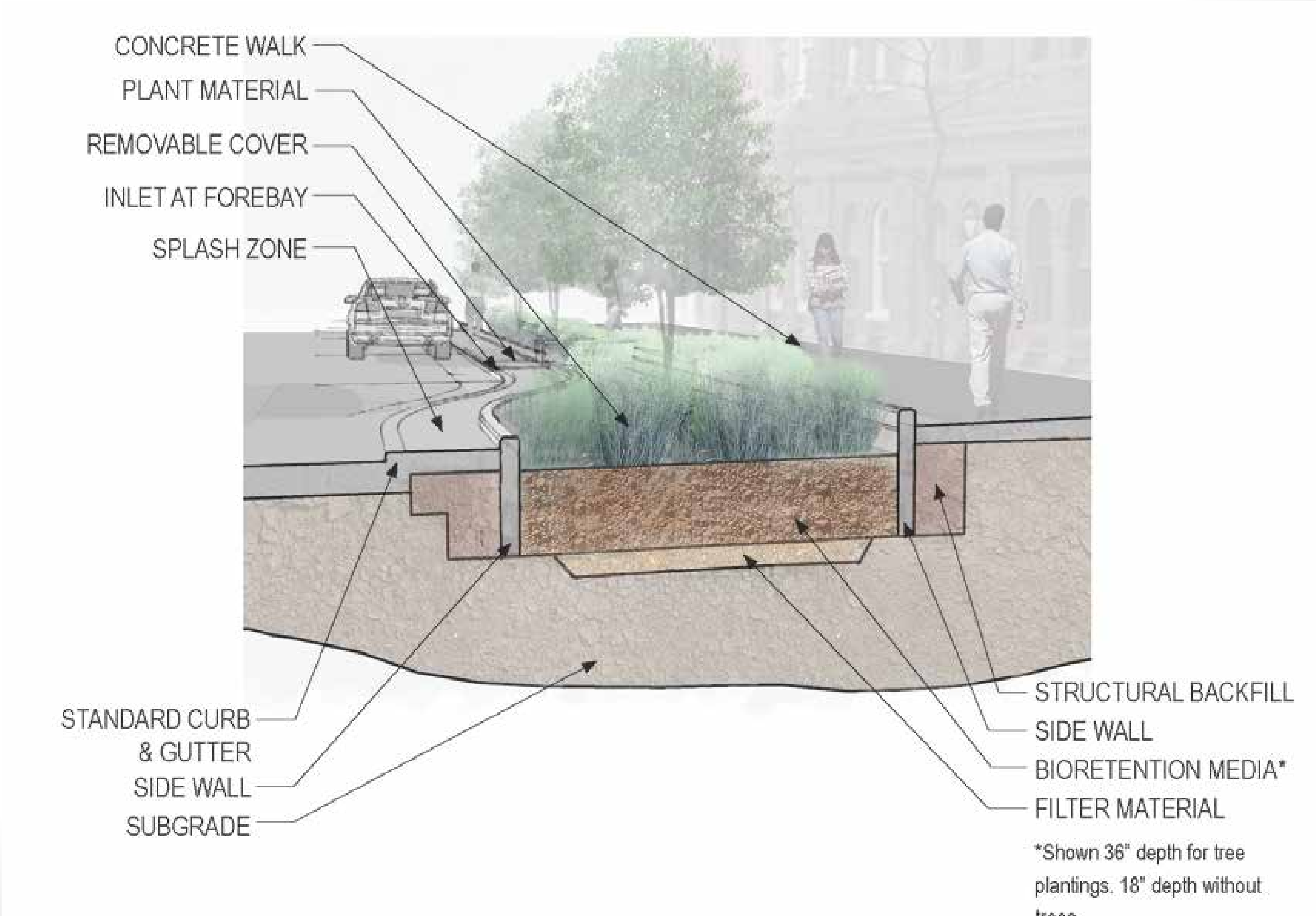
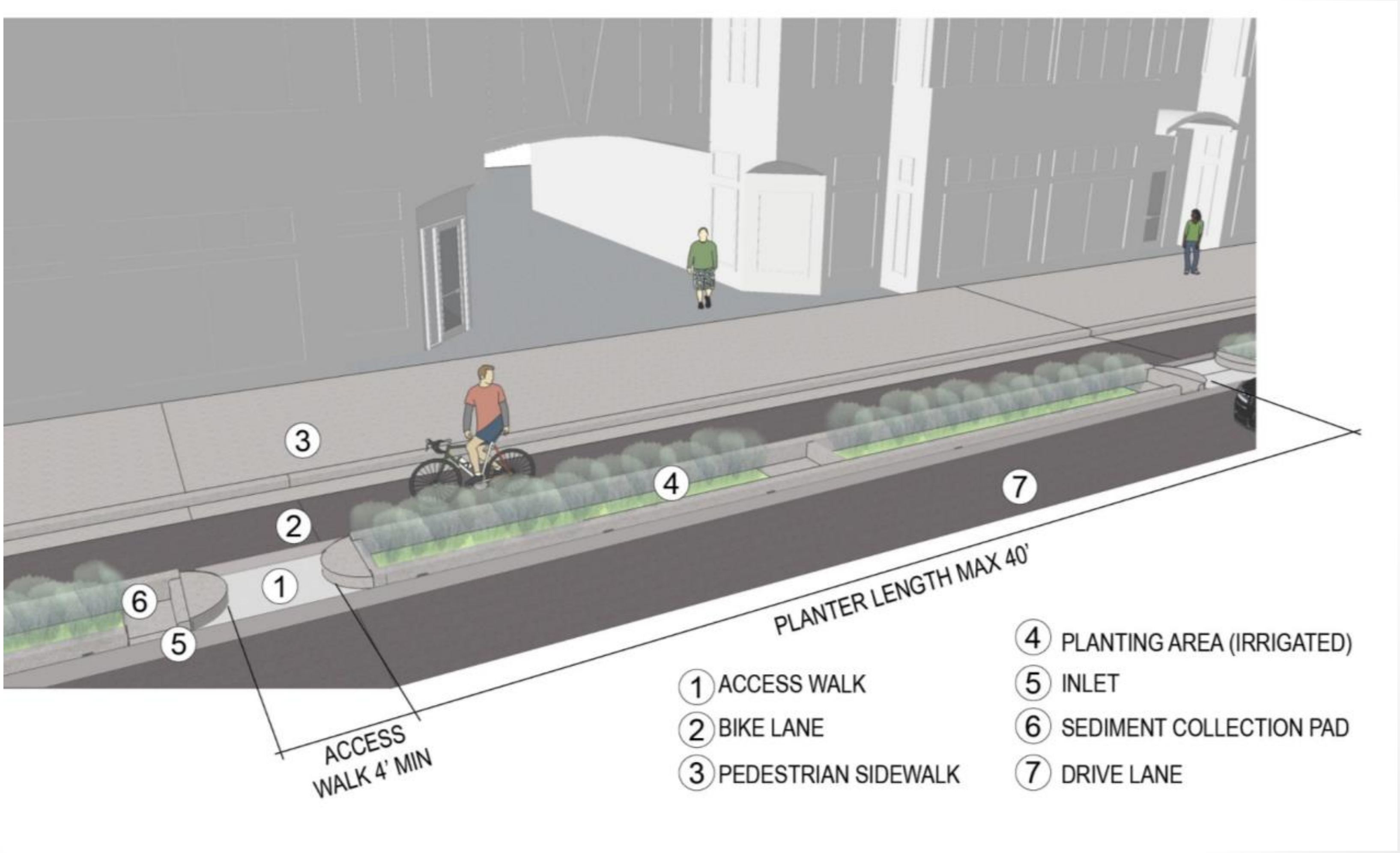


Green Gutter

Green Gutter



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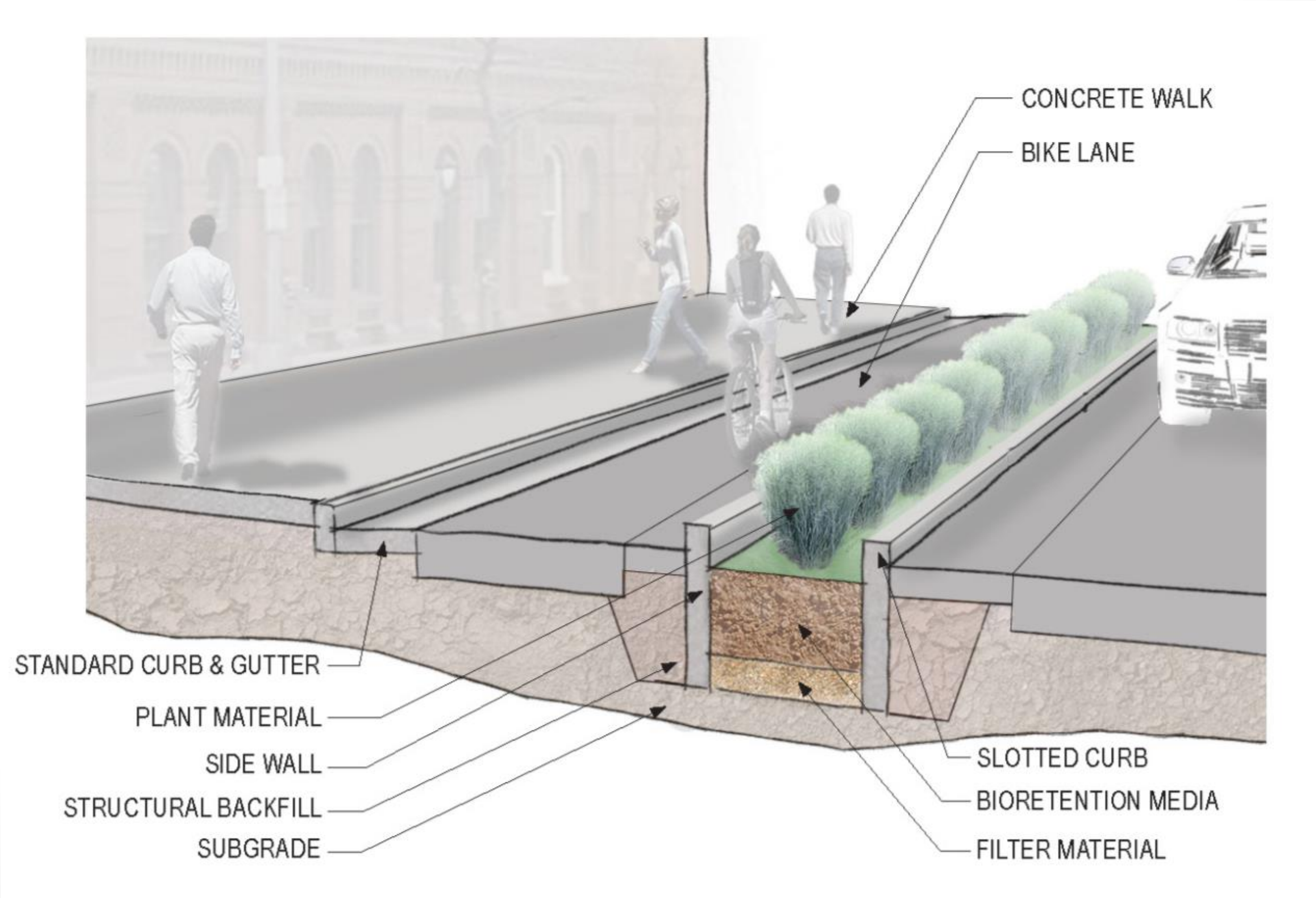
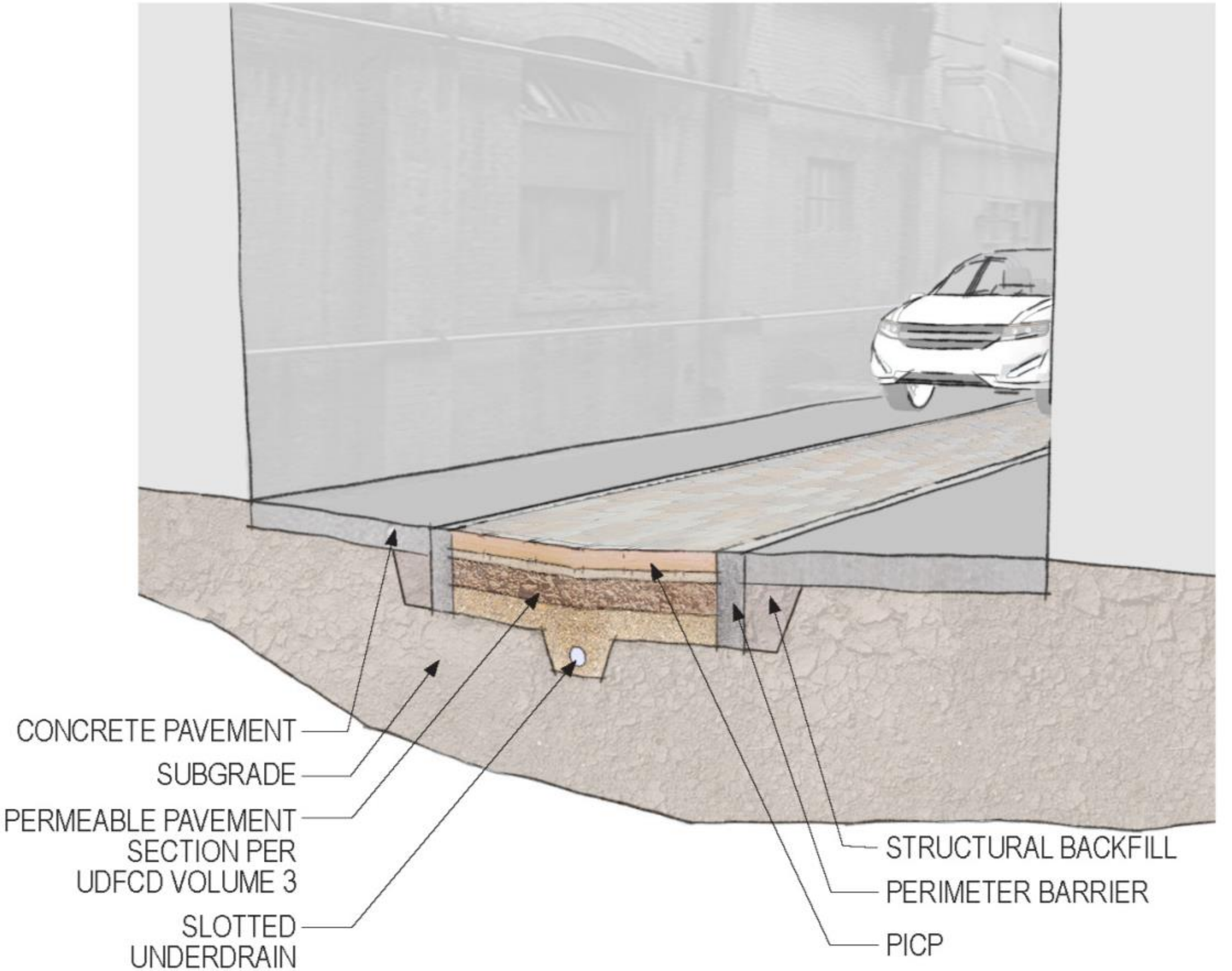
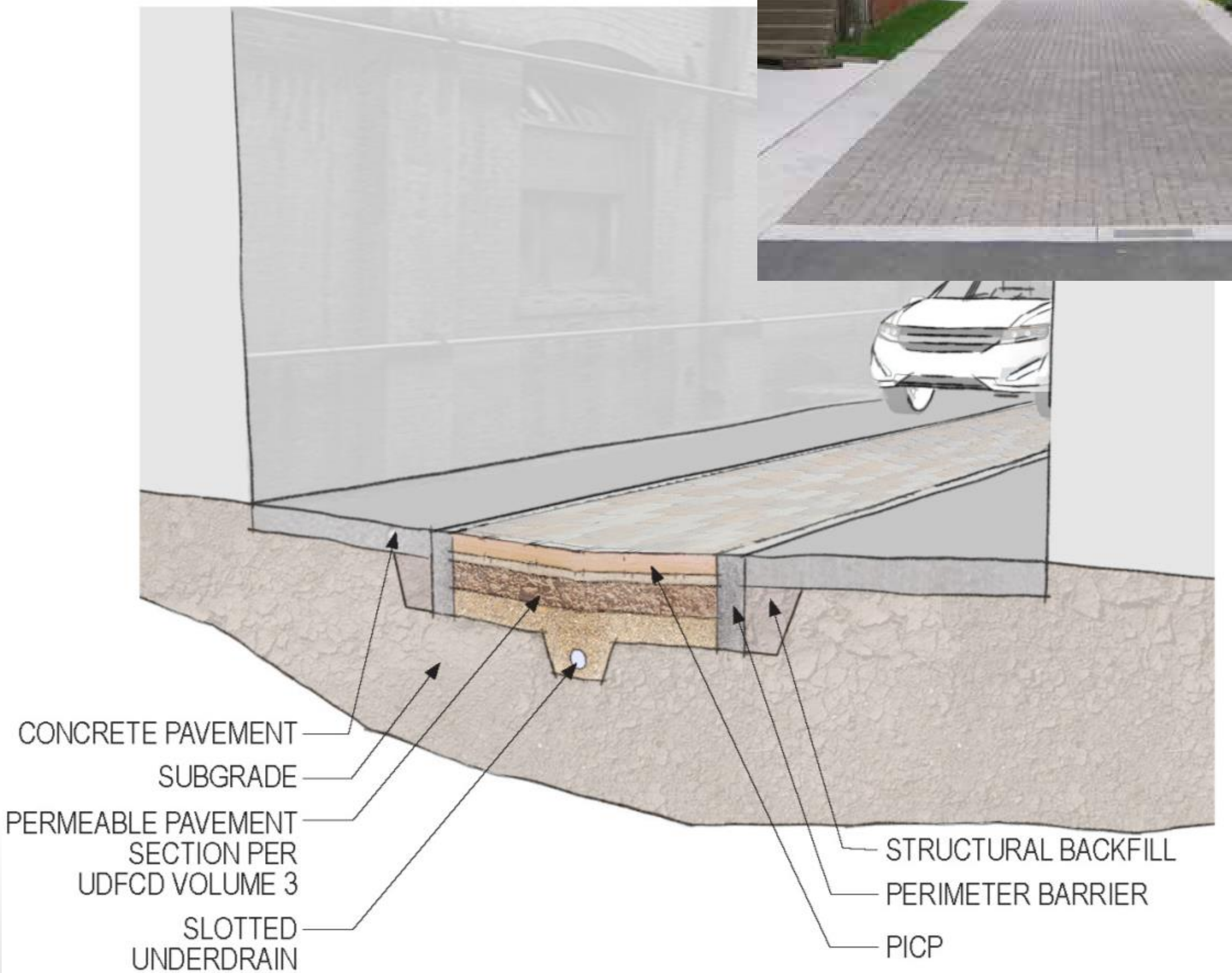


Green Alley


CONCRETE PAVEMENT
SUBGRADE
PERMEABLE PAVEMENT SECTION PER UDFCD VOLUME 3
SLOTTED UNDERDRAIN
STRUCTURAL BACKFILL
PERIMETER BARRIER
PICP

Green Alley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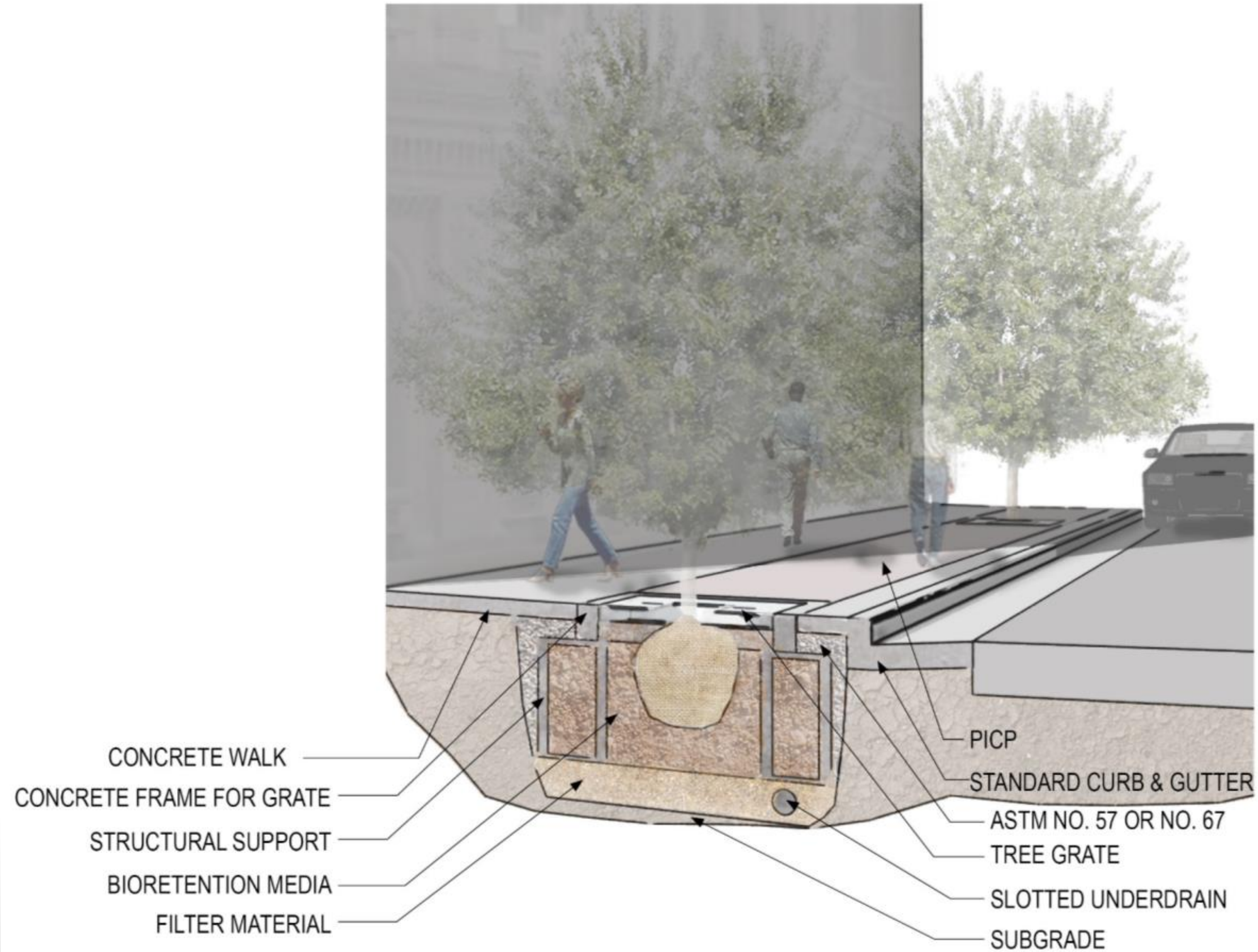
Tree Trench

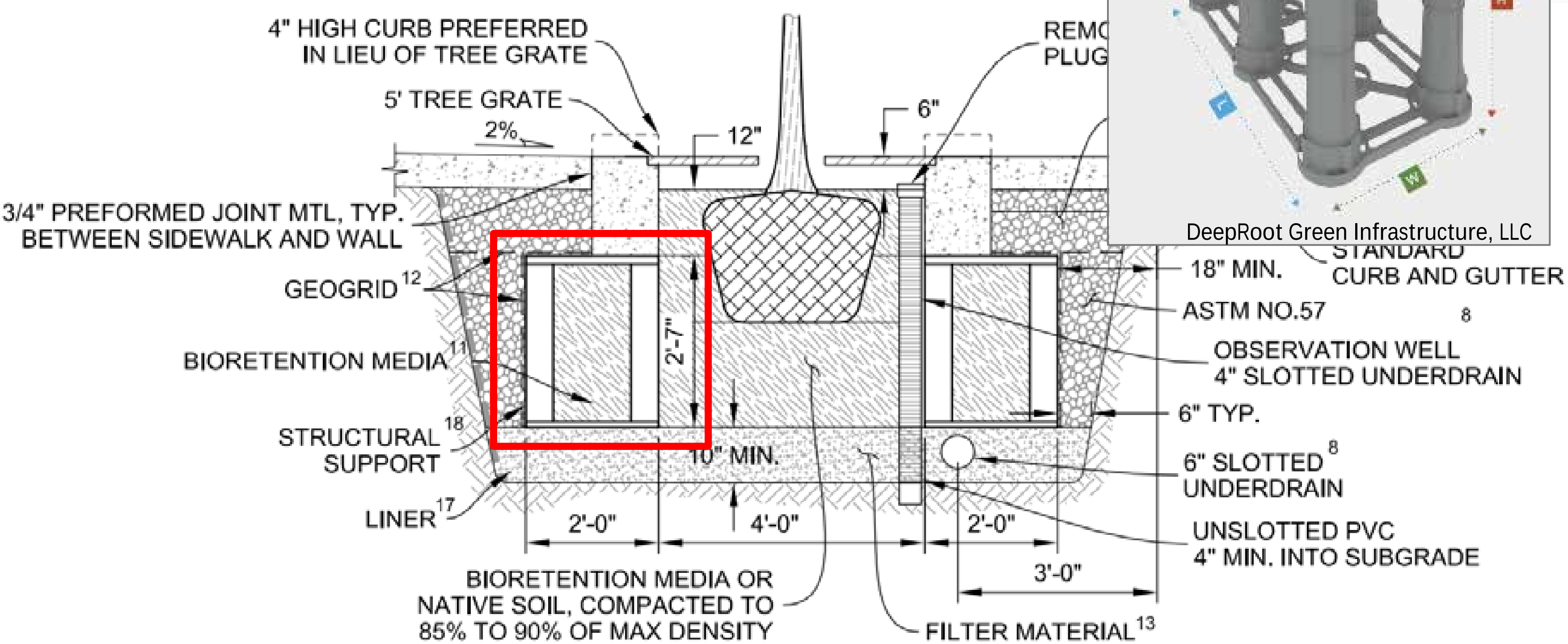
Tree Trench


CONCRETE WALK
CONCRETE FRAME FOR GRATE
STRUCTURAL SUPPORT
BIORETENTION MEDIA
FILTER MATERIAL
PICP
STANDARD CURB & GUTTER
ASTM NO. 57 OR NO. 67
TREE GRATE
SLOTTED UNDERDRAIN
SUBGRADE

Tree Trench

- HS-20 loading applies to features in ROW
- Structural supports provide load bearing whi
  reducing compaction in media

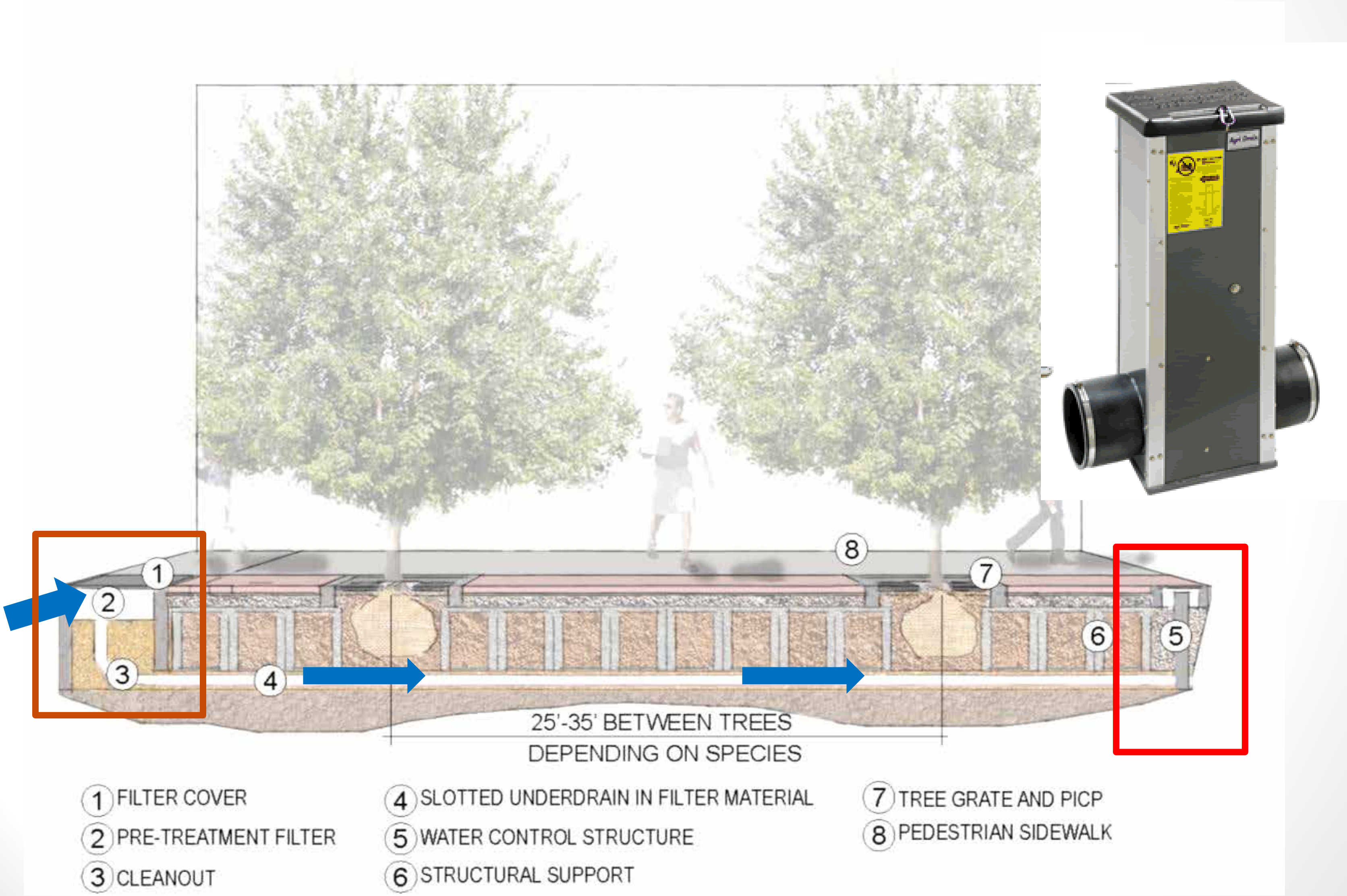
DeepRoot Green Infrastructure, LLC



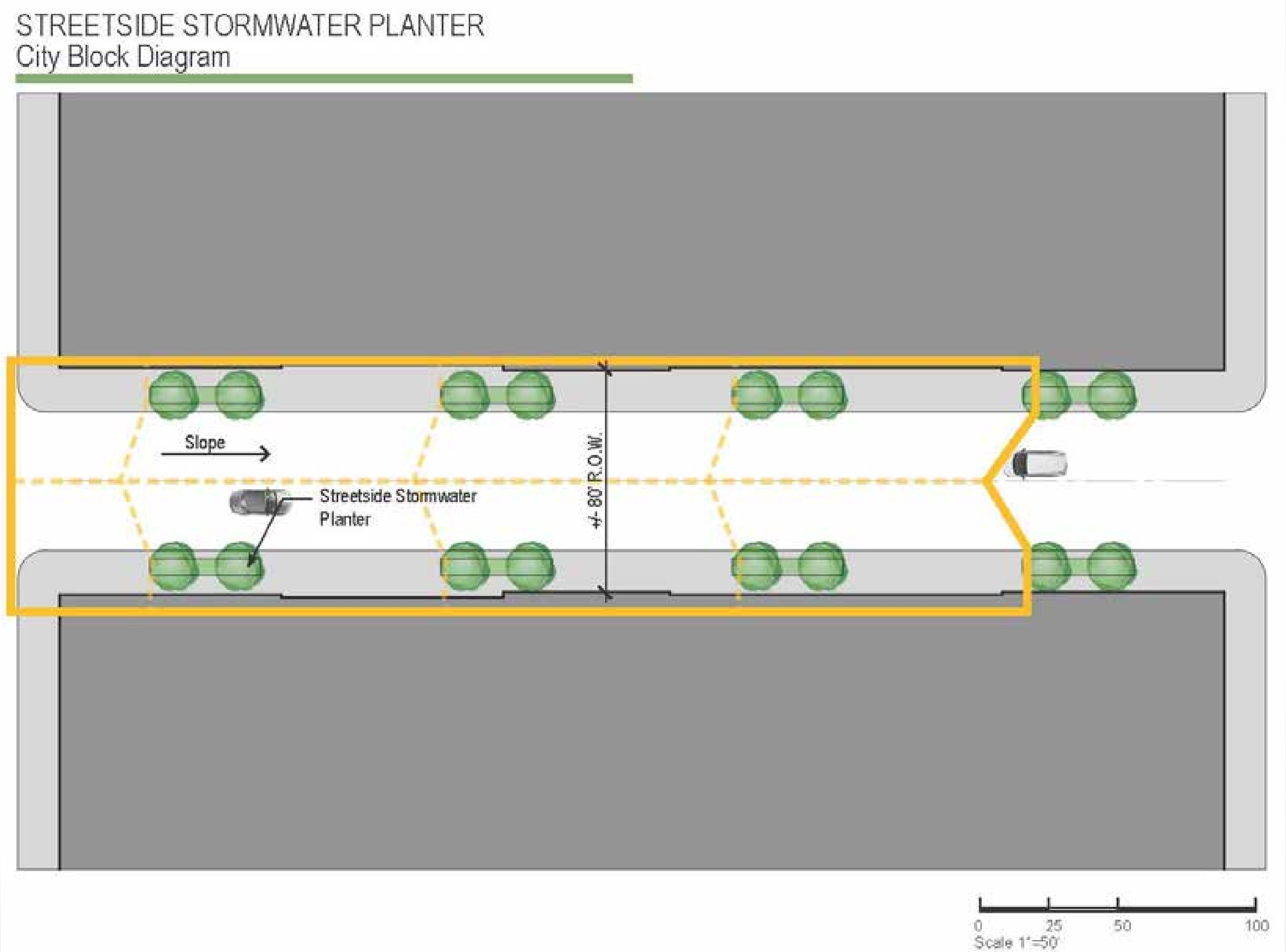
TREE TRENCH / PIT - SECTION 1

SCALE: 1"=3'

Tree Trench


1
2
3
4
5
6
7
8
25'-35' BETWEEN TREES
DEPENDING ON SPECIES
1 FILTER COVER
2 PRE-TREATMENT FILTER
3 CLEANOUT
4 SLOTTED UNDERDRAIN IN FILTER MATERIAL
5 WATER CONTROL STRUCTURE
6 STRUCTURAL SUPPORT
7 TREE GRATE AND PICP
8 PEDESTRIAN SIDEWALK

Block Layouts



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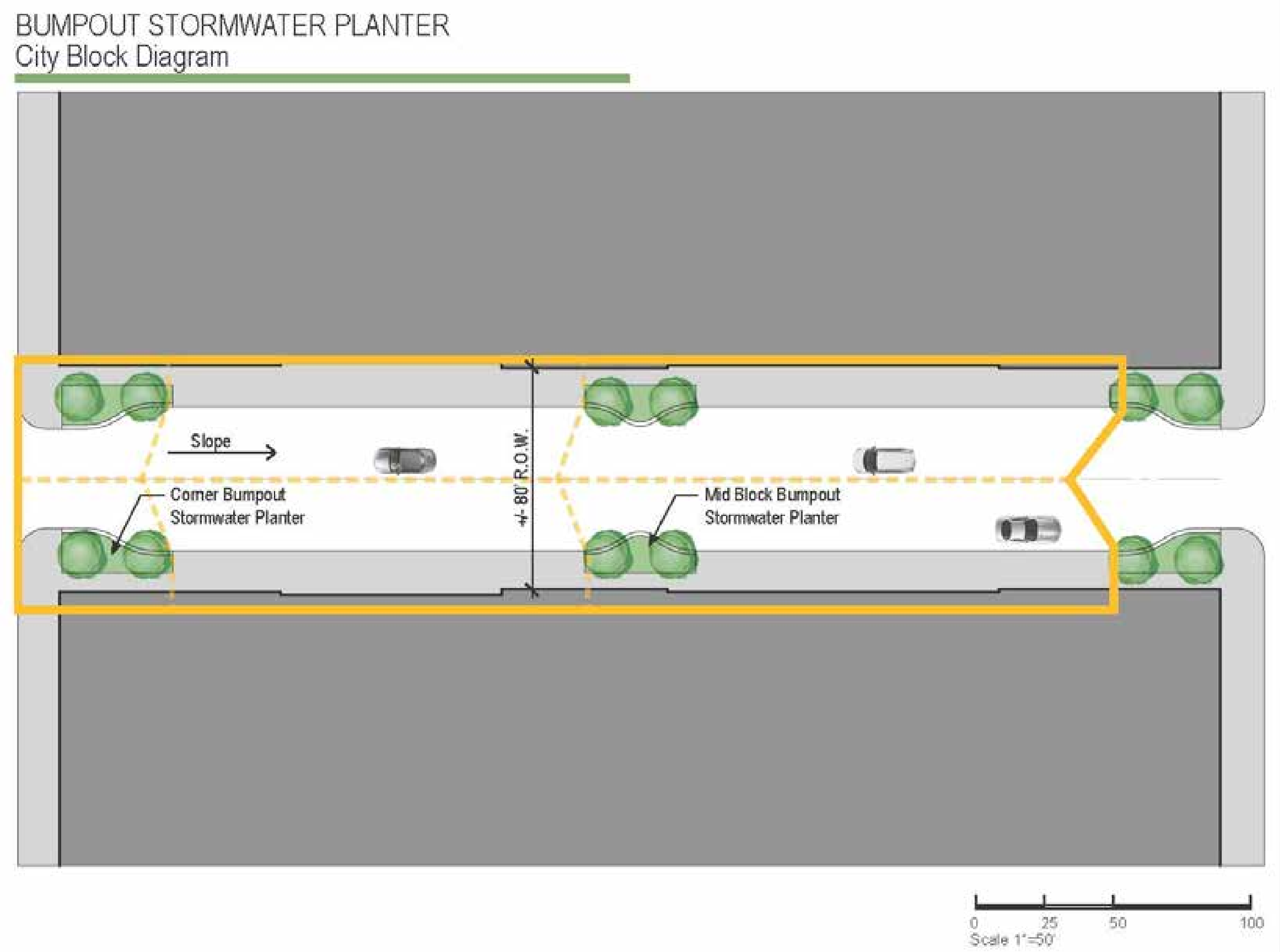

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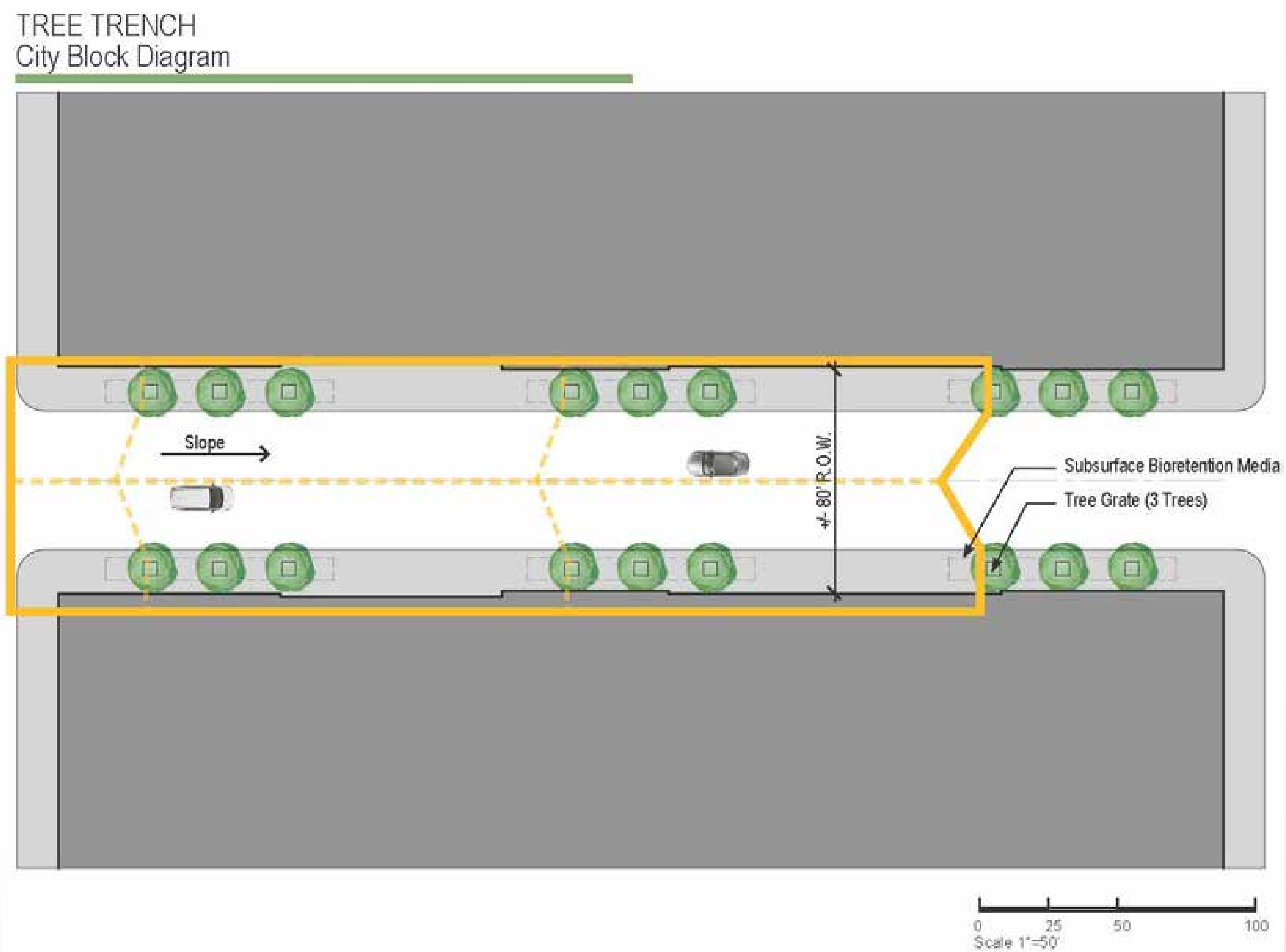
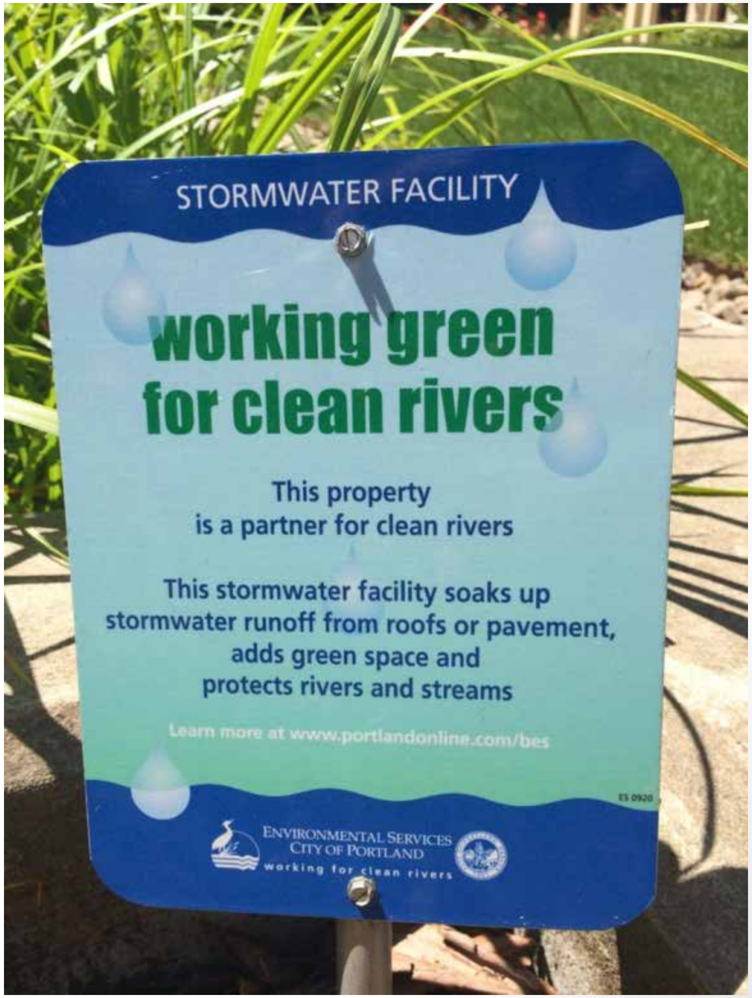



YES YOU CAN!

Upcoming Efforts

- Planning
- Policy
- Public Process



UDFCD Efforts

- Monitoring
- Inspection tools
- Maintenance tools

Questions