Hot ‘n Cold Flooding

“Cool” Flood Products that Communities Actually Want

Griffin Cullen
Geoff Uhlemann
CASFM – 9/25/19
Crested Butte

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

AECOM

About the Author

ISAAC ALLEN

Discovery

- August 2016 (post Gold King release)
- Discussed hazard mitigation with communities in the Animas Watershed
  - San Juan County and the Town of Silverton
  - La Plata County and the City of Durango
  - Southern Ute Indian Tribe

Discovery Report

Animas Watershed, Colorado and New Mexico
HUC-8 No. 14080104

Colorado: La Plata and San Juan Counties; City of Durango and Town of Silverton; Southern Ute Indian Tribe

New Mexico: San Juan County; Cities of Aztec and Farmington

October 12, 2016

COLORADO Colorado Water Conservation Board Department of Natural Resources AECOM FEMA EDAC EARTH DATA ANALYSIS CENTER

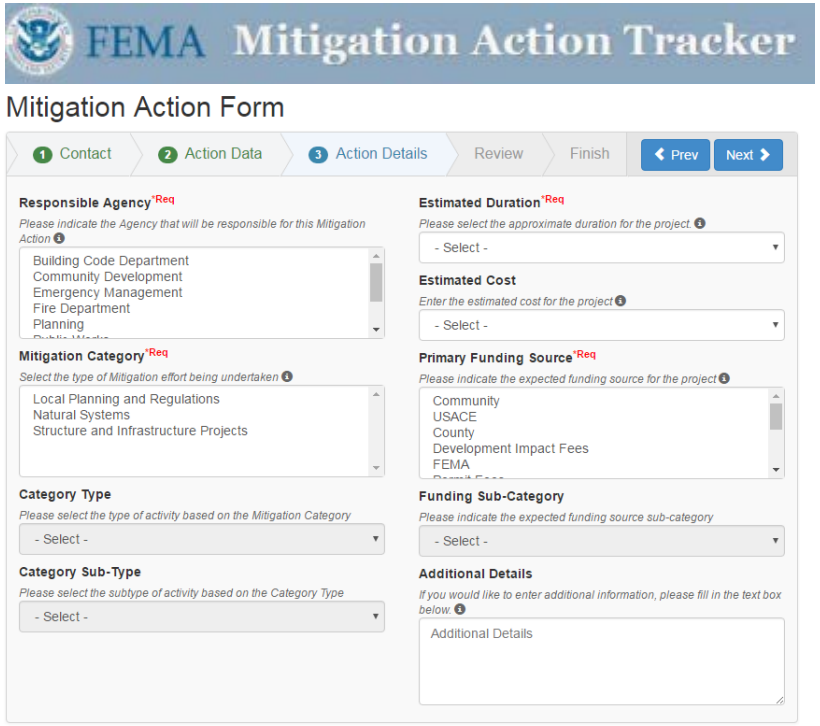
Non-Std NRPs

Hot ‘n Cold Flooding

- Post-Fire Flooding
- Ice Jamming
- Snowmelt
- Travel Time Estimator
- Questions

Table 16: LPC Mitigation Actions

Hazard Type	Mitigation Action	Action By	Potential Funding Source or Support
Flood Hazard or Debris Flow	Analyze post-fire flooding and debris flows to increase resiliency.	Floodplain Administrator	State/FEMA, CSFS, CGS
Flood	Animas restudy/PMR based on considerable number of LOMRs in LPC.	Floodplain Administrator	State/FEMA
Flood	Update floodplain mapping along Animas River and potentially other areas within county using updated topographic data.	Floodplain Administrator	State/FEMA

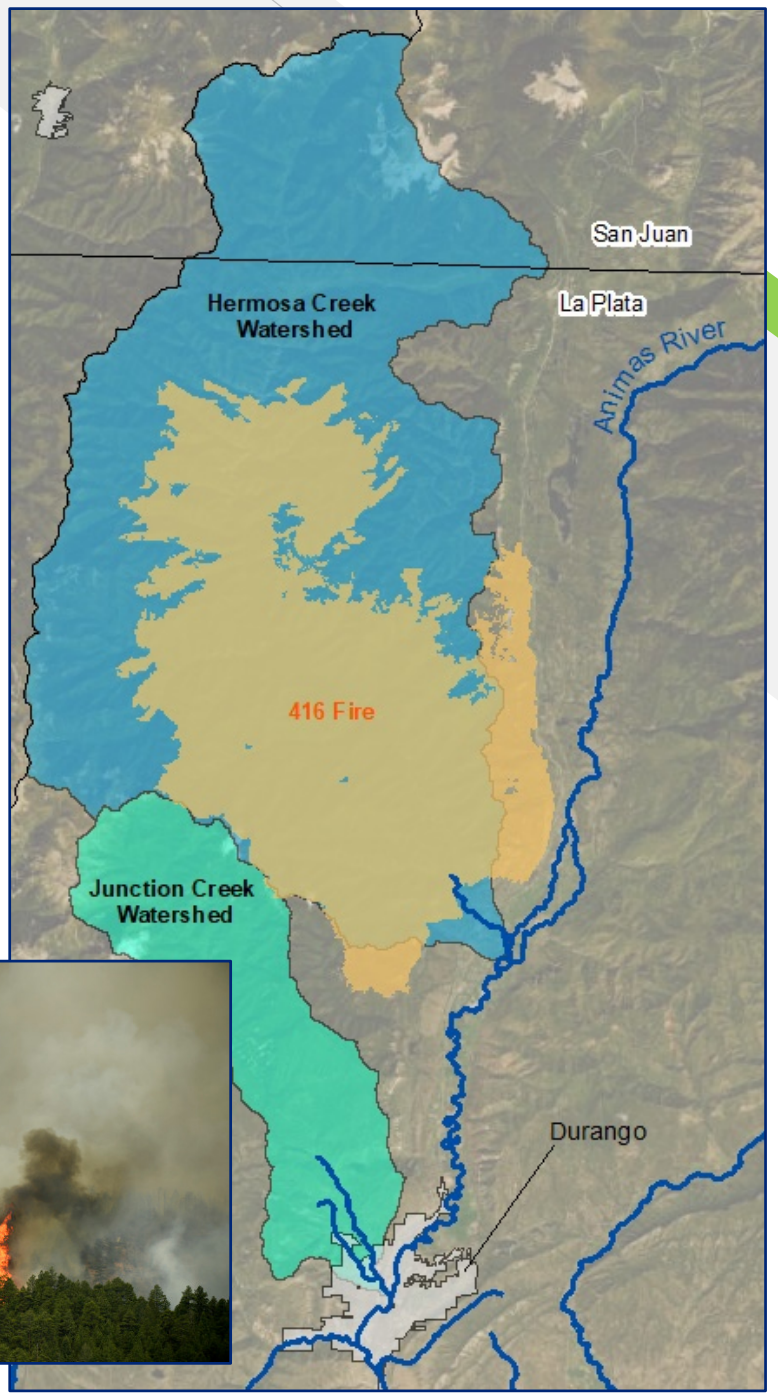


Post- Fire Flooding

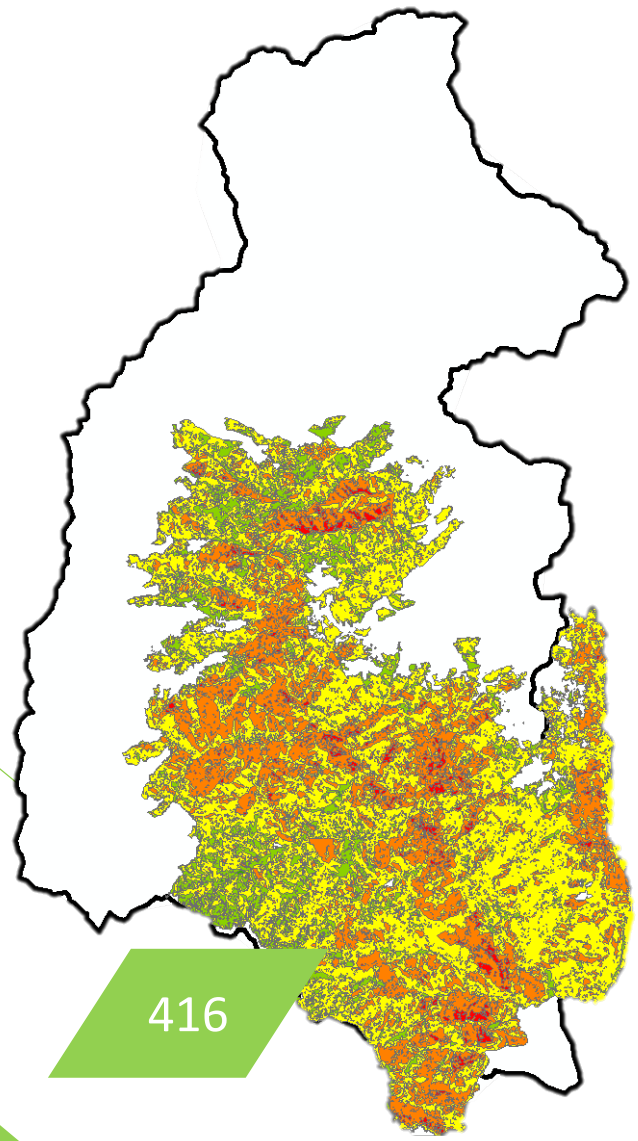
Hermosa Creek and Junction Creek

Fire and Flood Risk

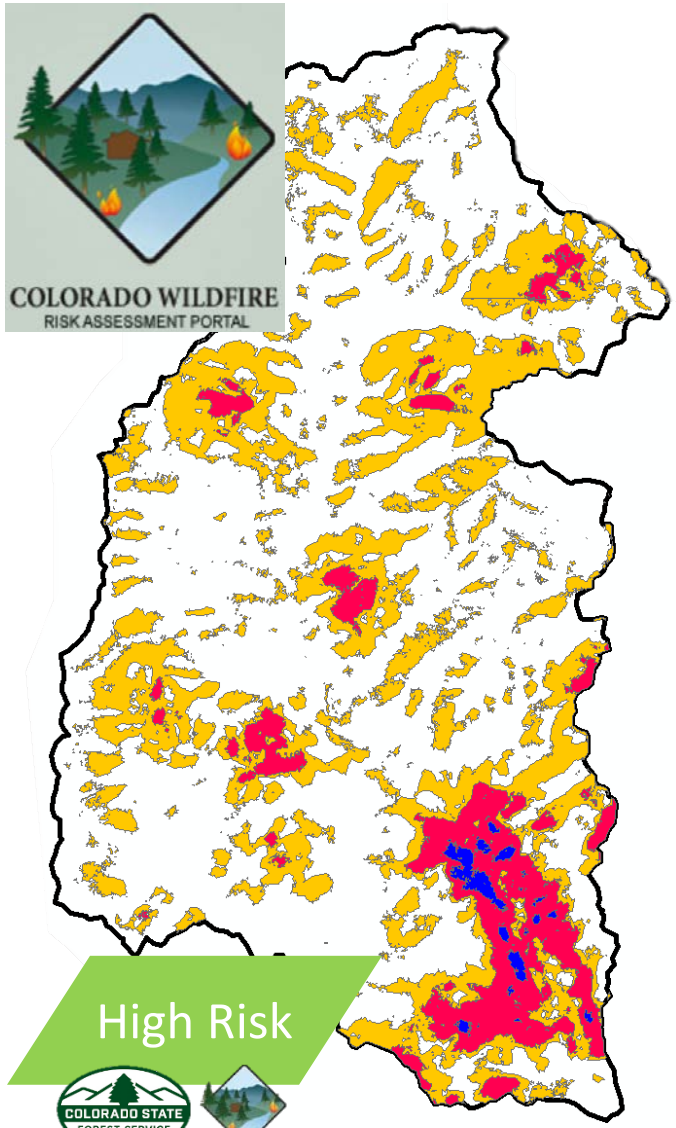
- La Plata County and City of Durango requested post fire flooding analysis to increase resilience.
  - **Junction Creek Watershed** – heavily forested with significant development at downstream end
  - **Hermosa Creek Watershed** - added after 416 Fire
- 416 Fire
  - June 1 – July 31, 2018
  - 57,000 Acres (largely in Hermosa)
- Wildfire risk may become increasingly important as bettle kill continues to move from the south.



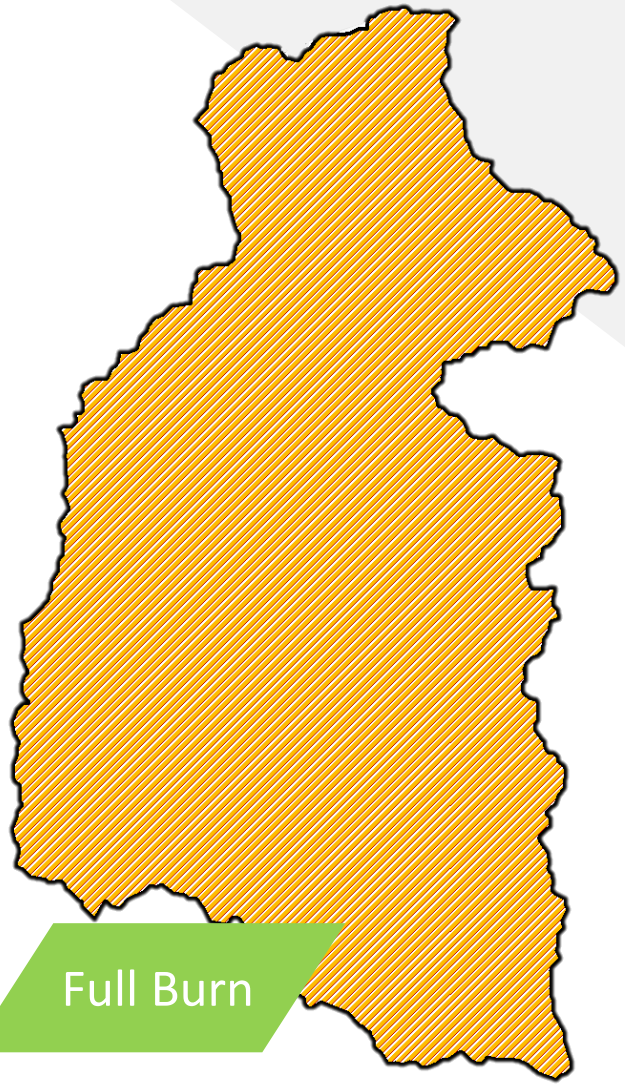
Scenarios



416



High Risk



Full Burn

Base - Hydrology

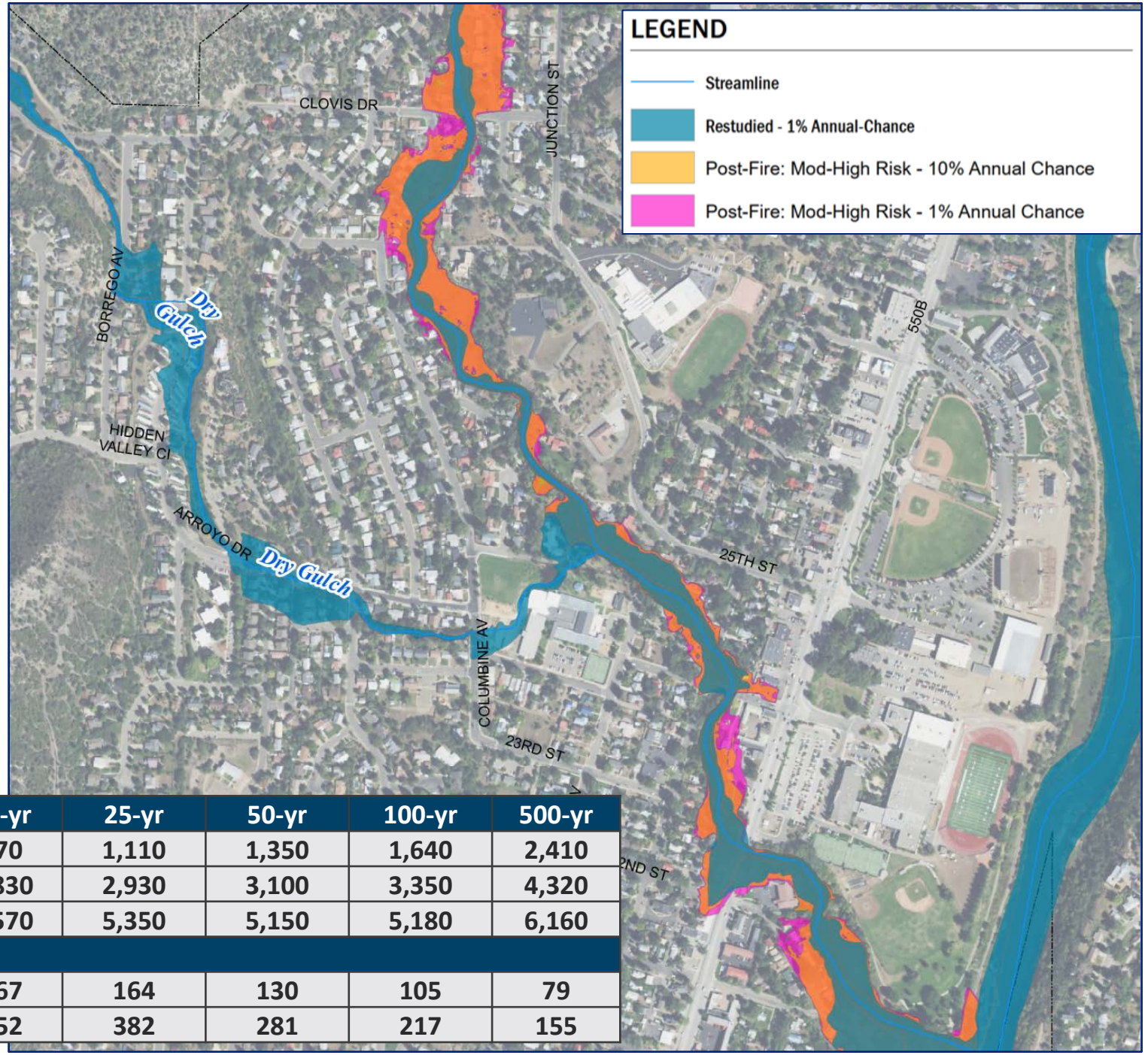
- Gage analysis results from Risk MAP
  - USGS Gage Hermosa Creek Near Hermosa, CO
- Existing conditions HEC-HMS model setup to match gage
  - CN Calibration

Post-Fire Hydrology

- Post-fire CN adjustments
  - Spatial identification of fire footprint
  - CN modification based on USDA examples. Factors:
    - Burn severity
    - Initial landcover type
    - Pre-burn soil condition
  - New basin composite CN values
- Sediment bulking factor applied based on empirical estimates (1.09 – 1.12)
  - Bulking factor of 1.25 transitions to debris flow

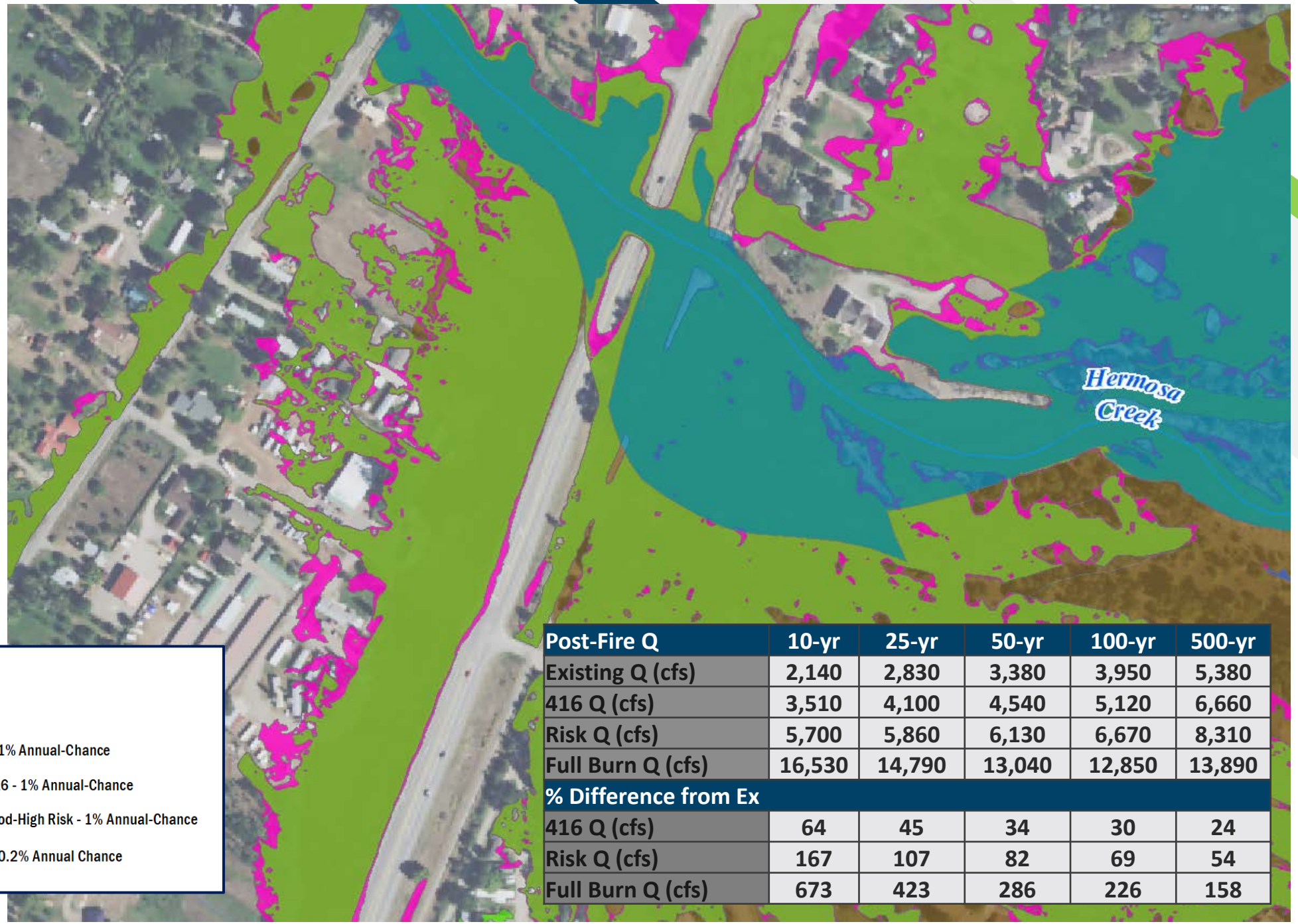
Hydraulics and Mapping

- Hermosa and Junction Creek Models
- Minor revisions to the ineffective flows as necessary
- 10 year and 100 year outputs
  - Minimal extents, larger changes in depth.



Post-Fire Q	10-yr	25-yr	50-yr	100-yr	500-yr
Existing Q (cfs)	770	1,110	1,350	1,640	2,410
Risk Q (cfs)	2,830	2,930	3,100	3,350	4,320
Full Burn Q (cfs)	6,570	5,350	5,150	5,180	6,160
% Difference from Ex					
Risk Q (cfs)	267	164	130	105	79
Full Burn Q (cfs)	752	382	281	217	155

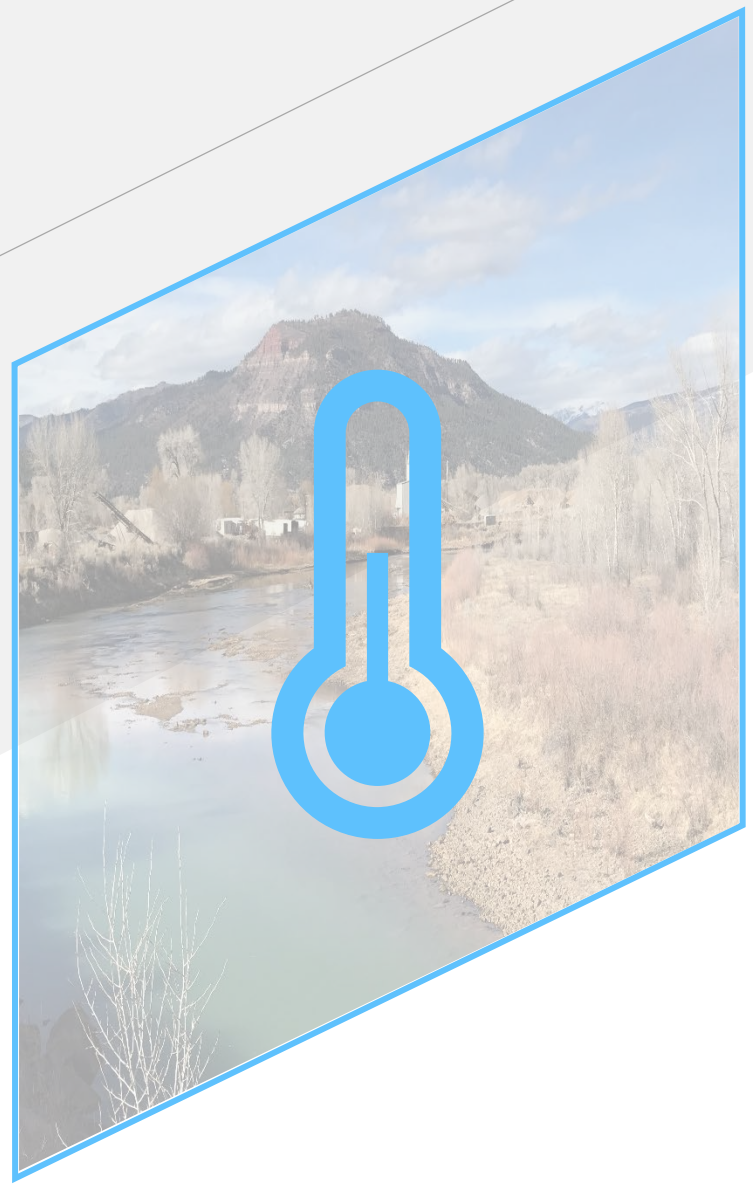
Hermosa Creek



LEGEND

- Streamline
- Restudied - 1% Annual-Chance
- Post-Fire: 416 - 1% Annual-Chance
- Post-Fire: Mod-High Risk - 1% Annual-Chance
- Restudied - 0.2% Annual Chance

Post-Fire Q	10-yr	25-yr	50-yr	100-yr	500-yr
Existing Q (cfs)	2,140	2,830	3,380	3,950	5,380
416 Q (cfs)	3,510	4,100	4,540	5,120	6,660
Risk Q (cfs)	5,700	5,860	6,130	6,670	8,310
Full Burn Q (cfs)	16,530	14,790	13,040	12,850	13,890
% Difference from Ex					
416 Q (cfs)	64	45	34	30	24
Risk Q (cfs)	167	107	82	69	54
Full Burn Q (cfs)	673	423	286	226	158

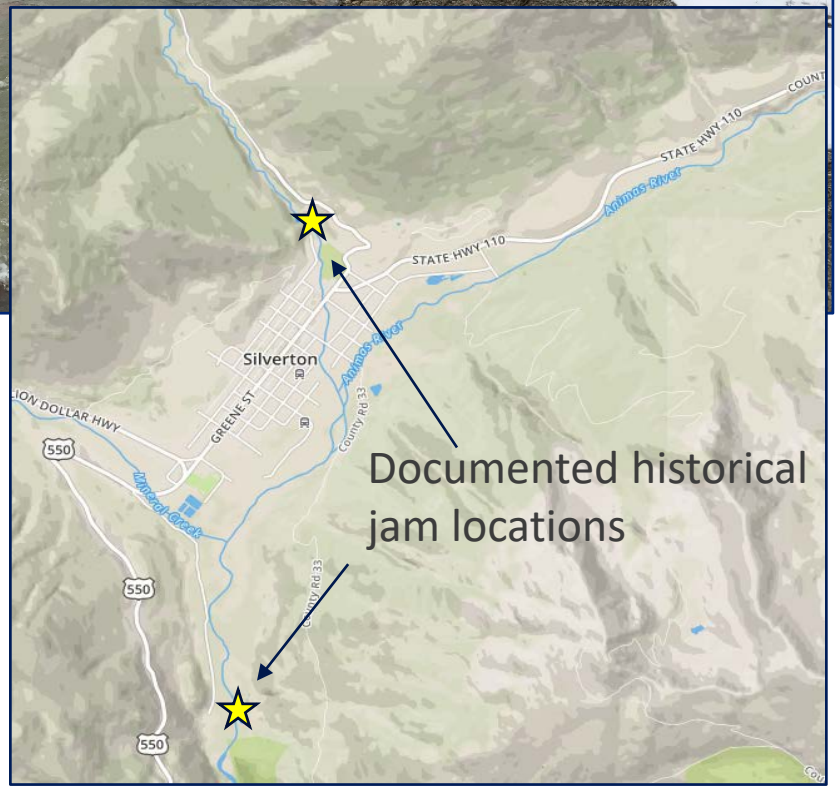


Ice Jamming

Animas River & Cement Creek

Ice Jamming Background

- The Town of Silverton noted ice jamming as a historic issue.
- Also documented by the US Army Corps of Engineers CRREL ice jam database.

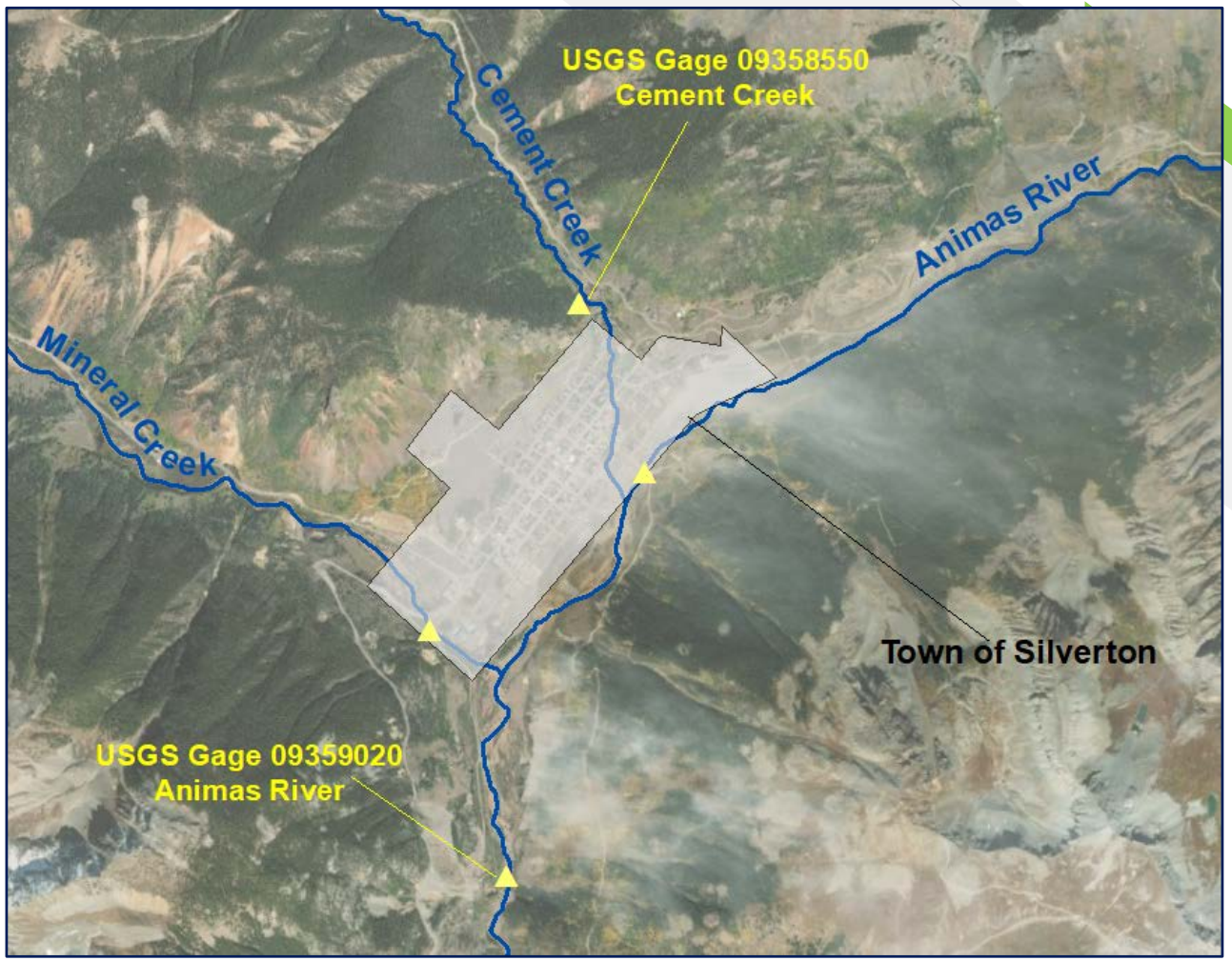


Method

1. Separate gage records into snowmelt only events– FFA using 17C
2. Determine average ice thickness (t_i) based on:
    1. Temperature record
    2. Accumulated Freezing Degree Days calculation (AFDD)
    3. Stefan Equation (C – coefficient)

$$t_i = C(AFDD)^{0.5}$$

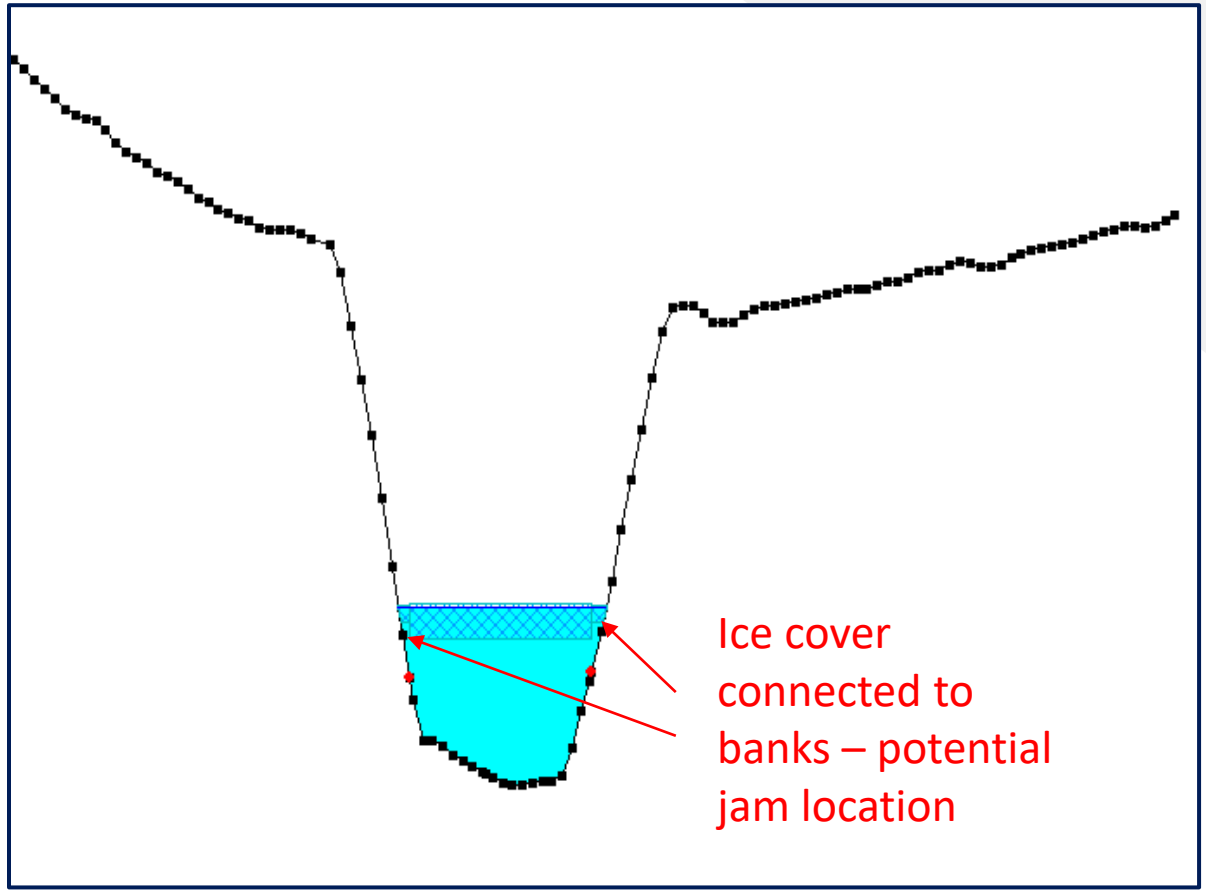
3. Determine ice forming flow and run in HEC-RAS to estimate ice cover thickness and width



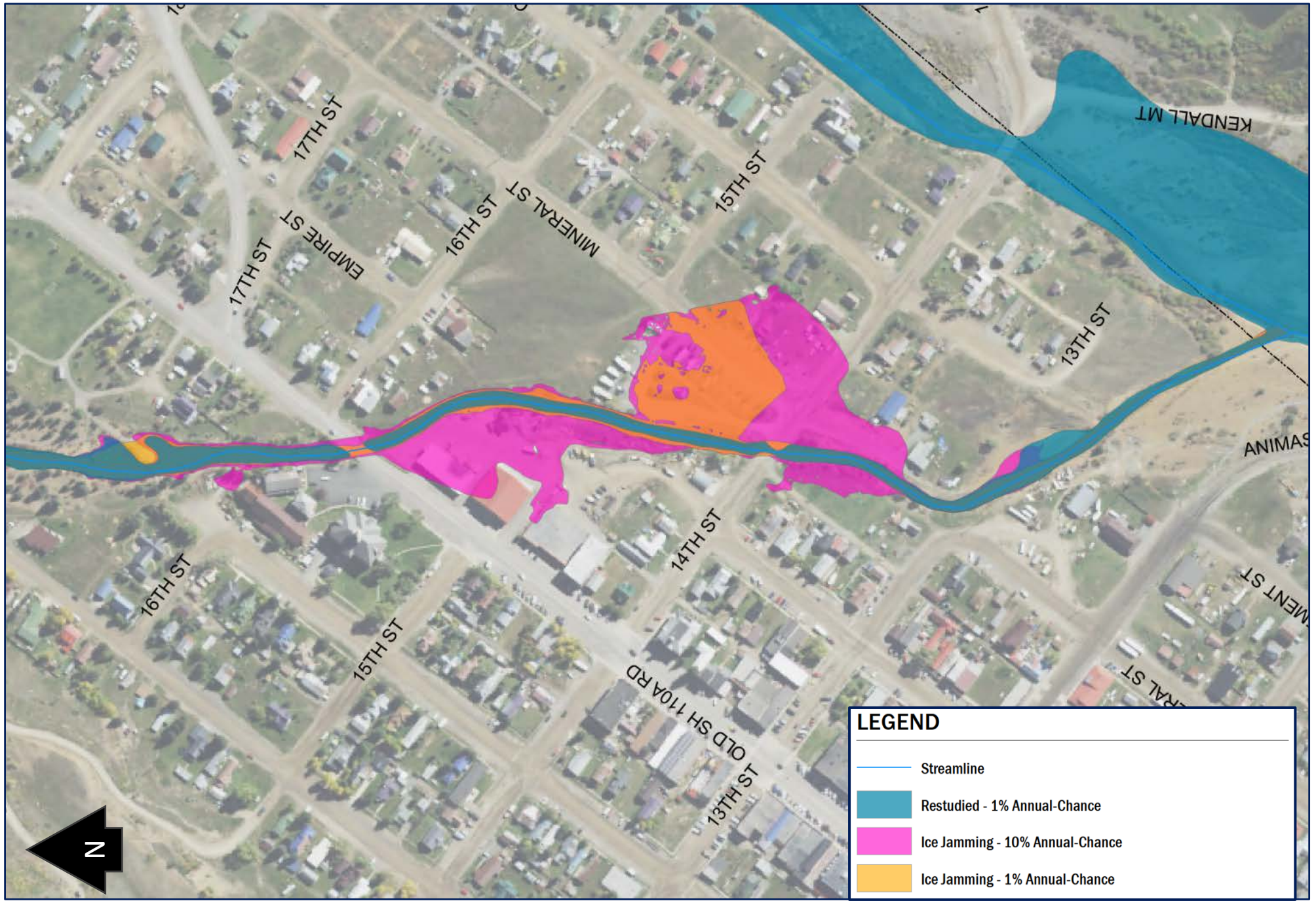
Method (cont'd)

4. Identify locations where jamming is possible
5. Set jam parameters and possible jam locations – run HEC-RAS to identify ice effected WSELs

- Combined probability analysis using open-water vs. snowmelt WSEL results can be used to generate updated profiles
  - For non-regulatory products, only looked at mapping

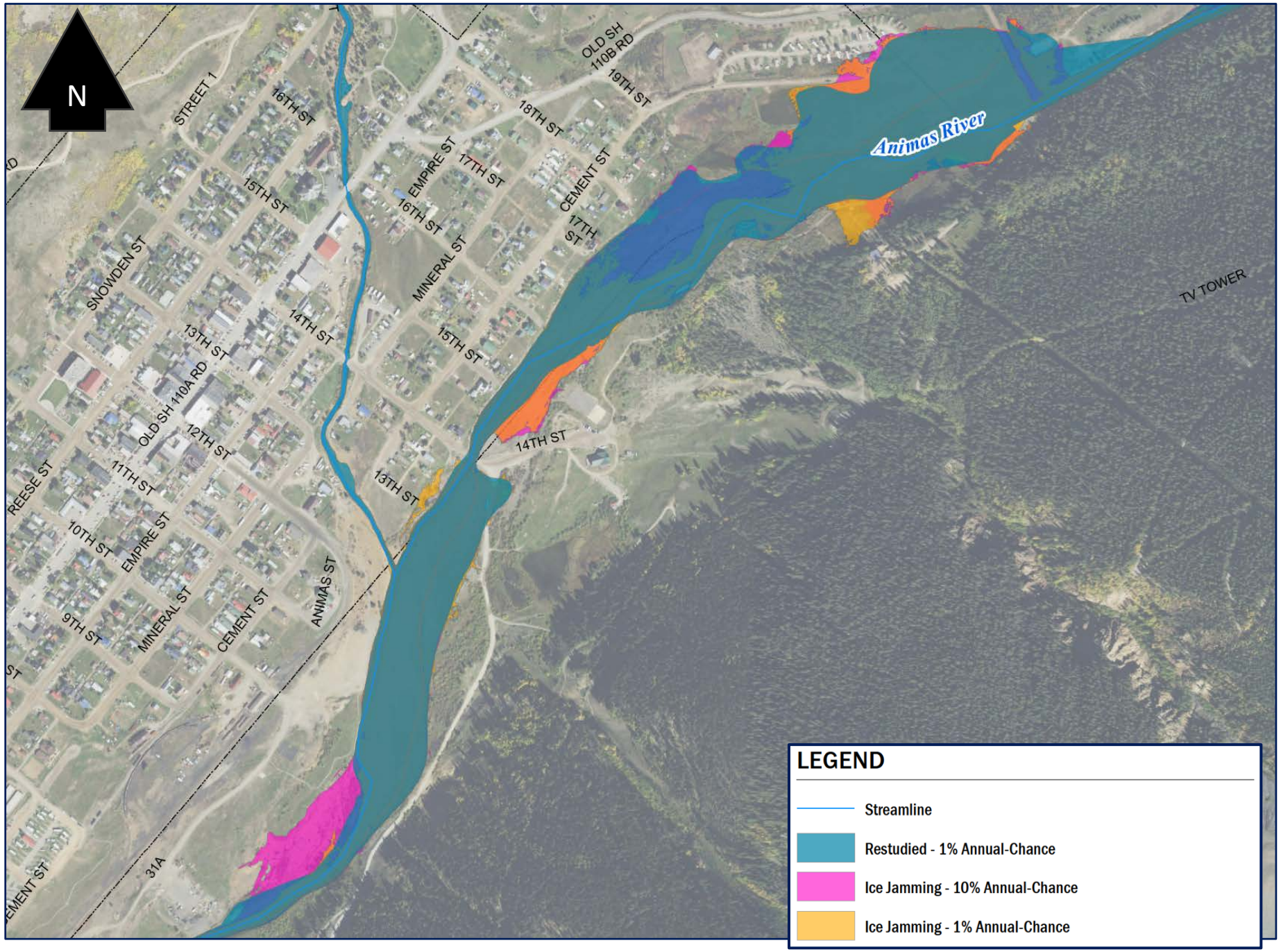


Cement Creek



Animas River

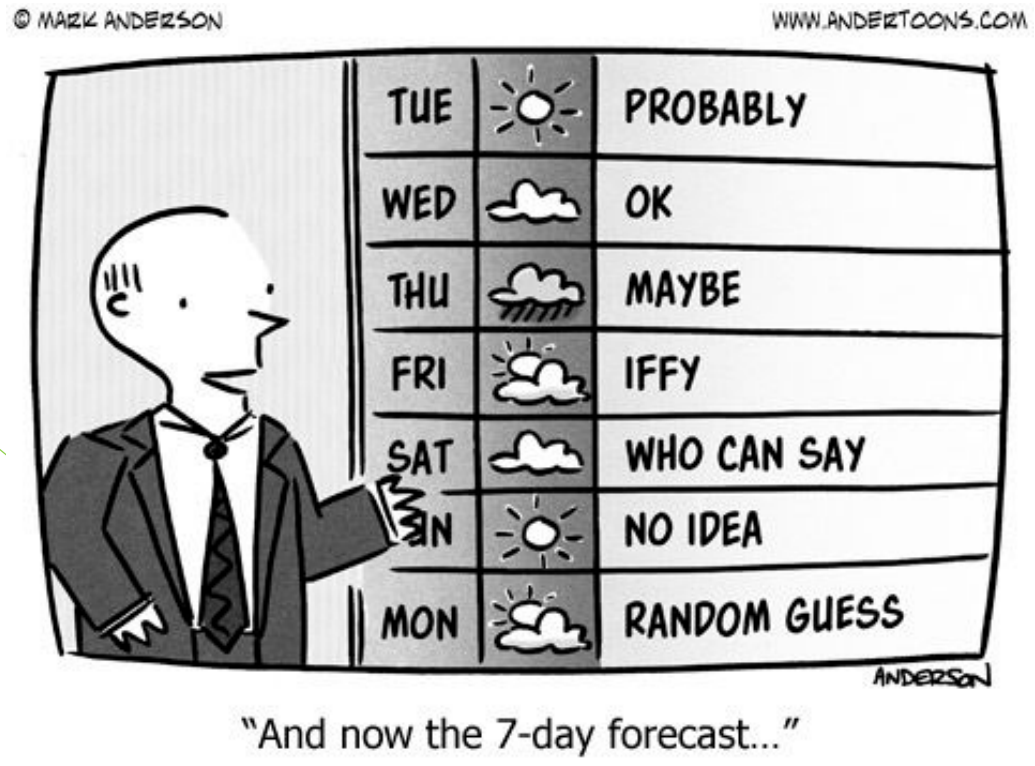
- No WSEL calibration data available
- Hypothetical jam scenarios
- Conservative results



Snowmelt

Hermosa Basin & Silverton

Near-future Snowmelt Forecast



"And now the 7-day forecast..."

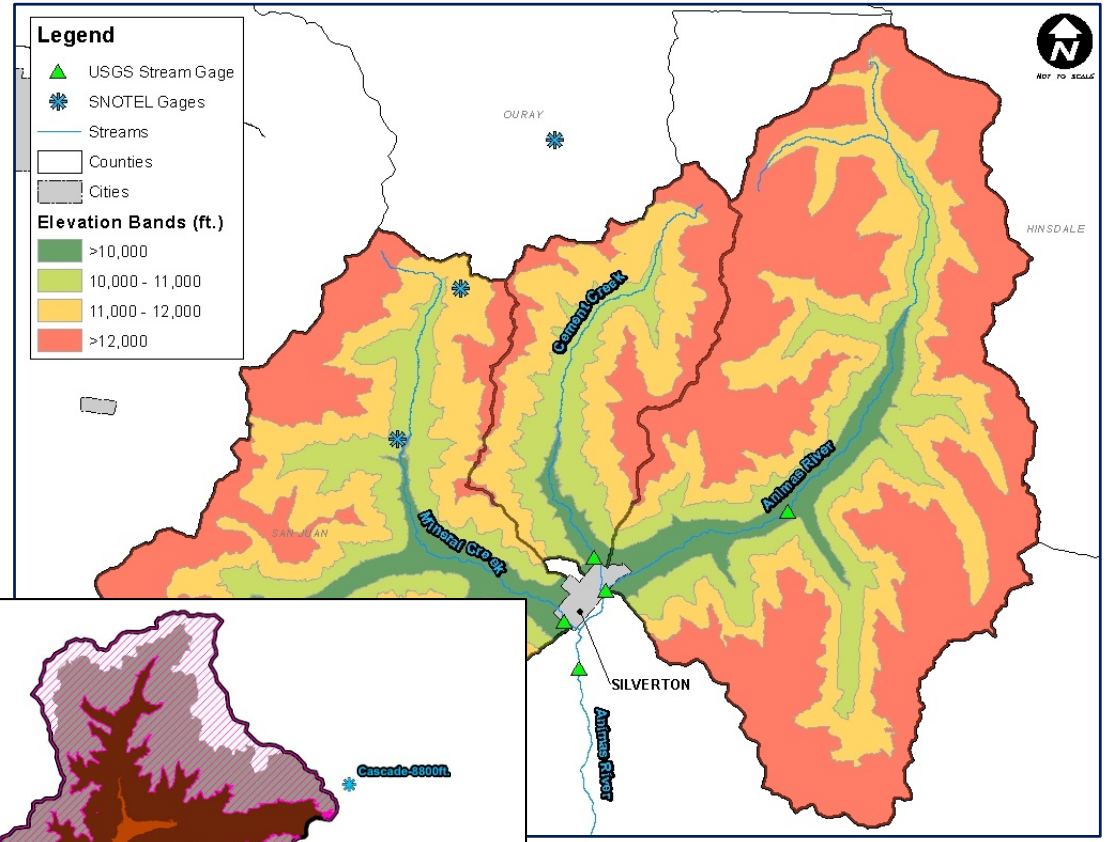
SNODAS

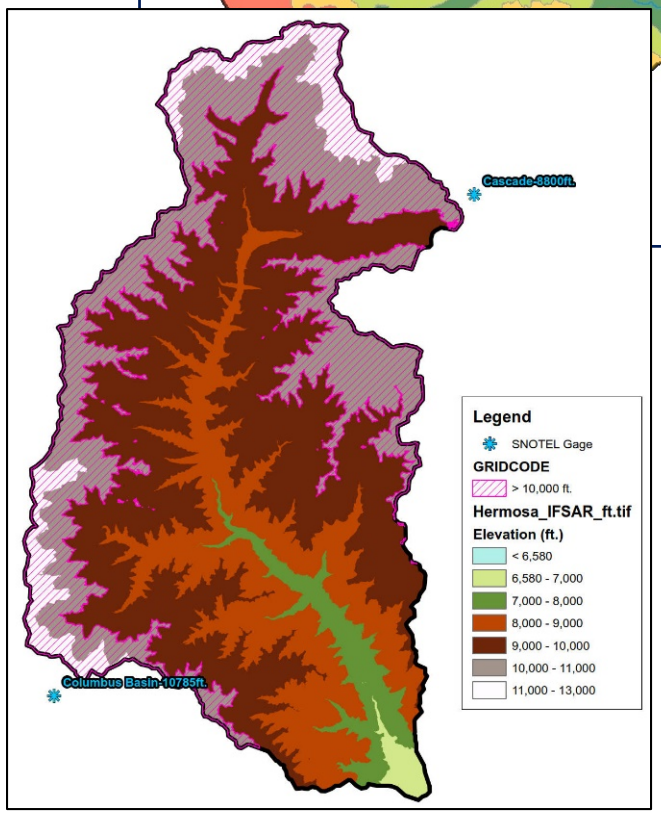
Flood Annual Chance

NOAA Atlas

Overview

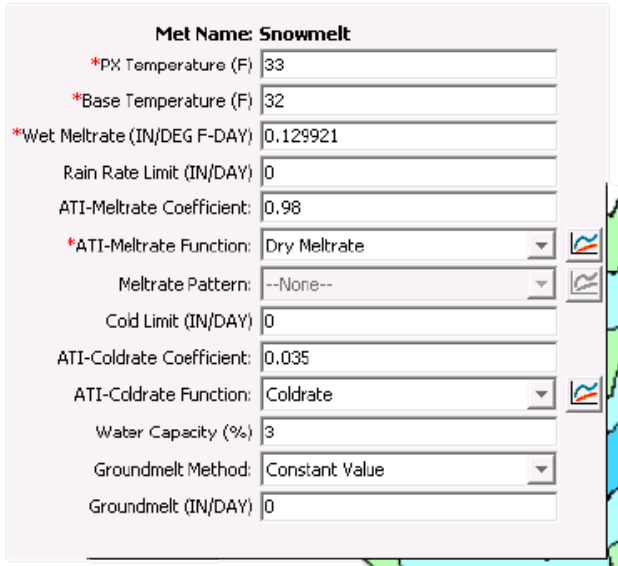
- 2019 high snowpack year
- Data available for early warning on potential snowmelt flooding
- Project areas
  - Hermosa
  - Silverton
- On June 15, 2019:
  - Mineral Creek basin:
    - Red Mountain Pass SNOTEL gage:– 17.7 in. SWE (970% of 1981-2010 average)
  - Hermosa Creek basin:
    - Columbus Basin SNOTEL gage: 25.7 in. SWE (1,078% of 1981-2010 average)

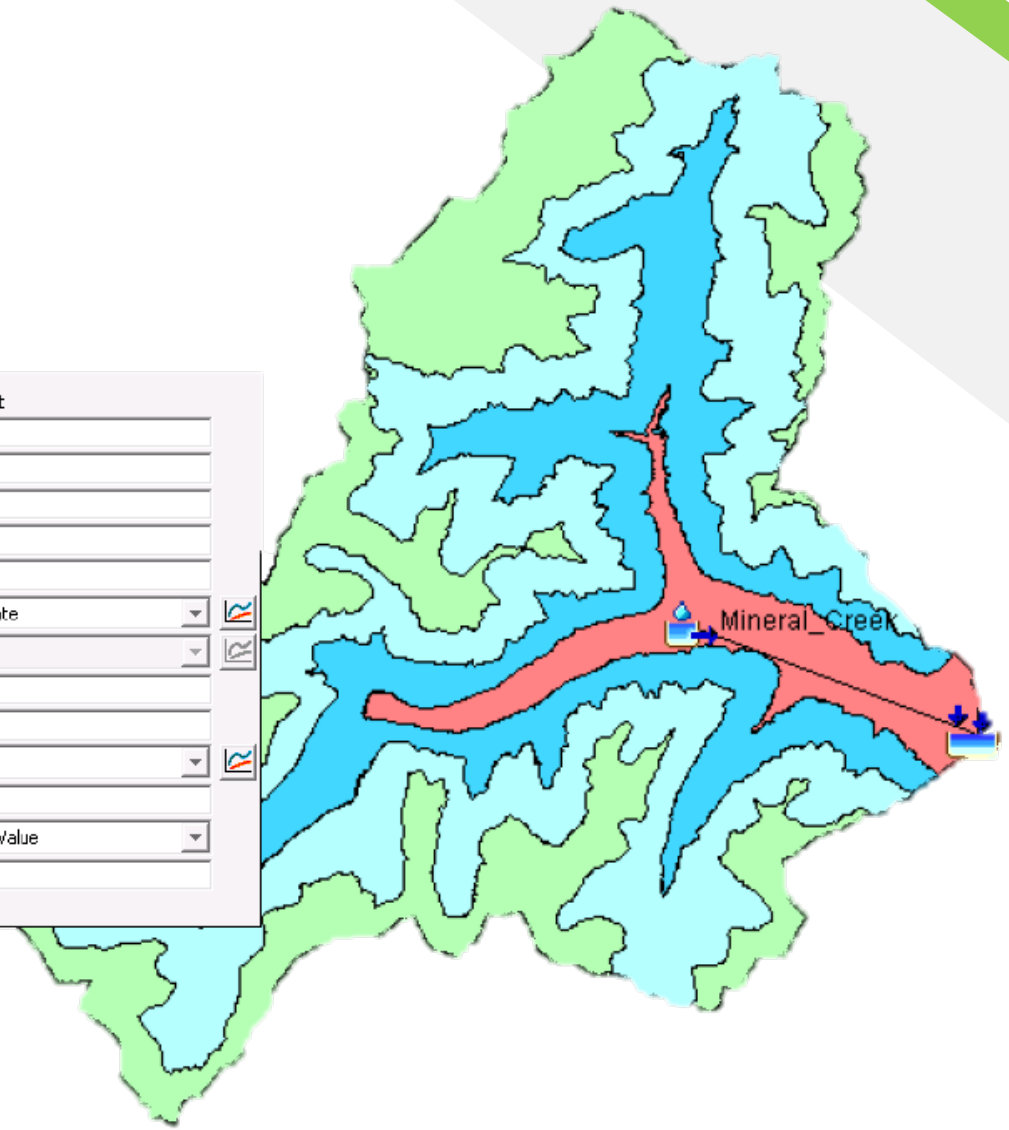




Methods – Similarities

- Accumulated Fahrenheit Degree Day (AFDD) Methodology - Temperature Index Modeling in HEC-HMS
- Simple basin schematic
- Only modeled snowpack decay – assumed no snow or rain events
- Calibrated and validated HEC-HMS model using historical records





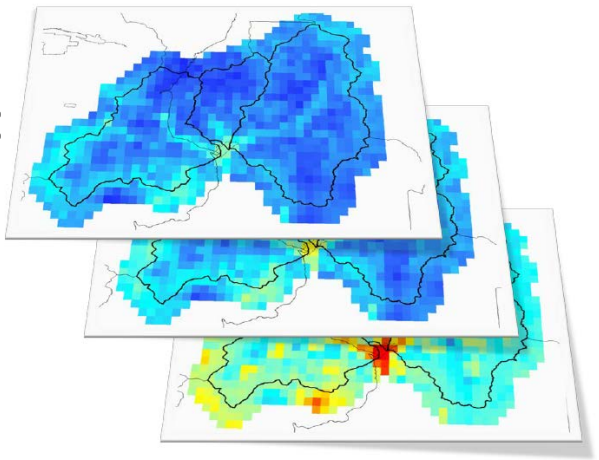
Methods – Differences

Hermosa

- SNOTEL data – assumed depth and area of snow coverage
  2 gages (10.8k vs 8.8k ftmsl)
- 24-hr model time-step
- No overlap between stream gage and snowpack record – calibration only based on snowpack

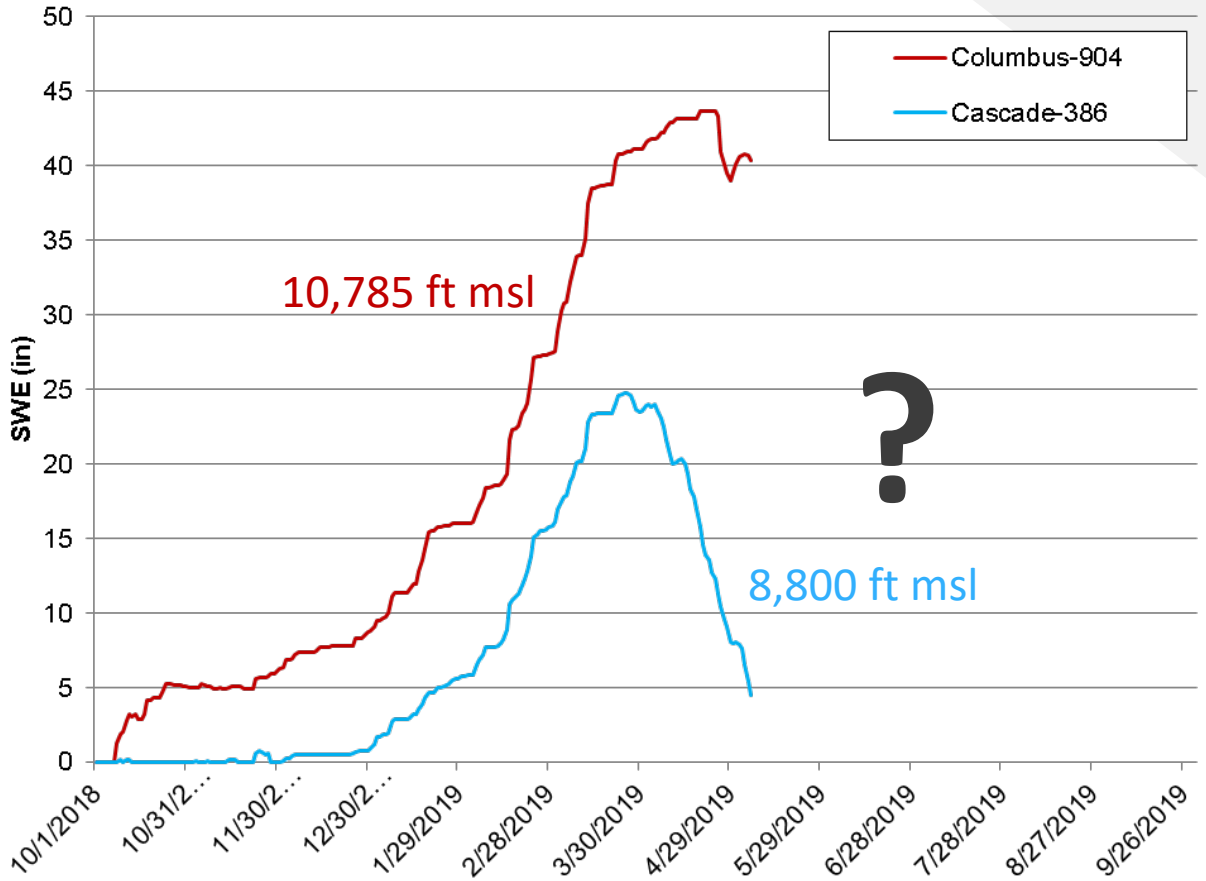
Silverton

- SNODAS data – modeled forcast of SWE from National Snow & Ice Data Center
  (no SNOTEL gage)
- 6-hr model time step
- Models calibrated to:
  - snowpack
  - streamflow



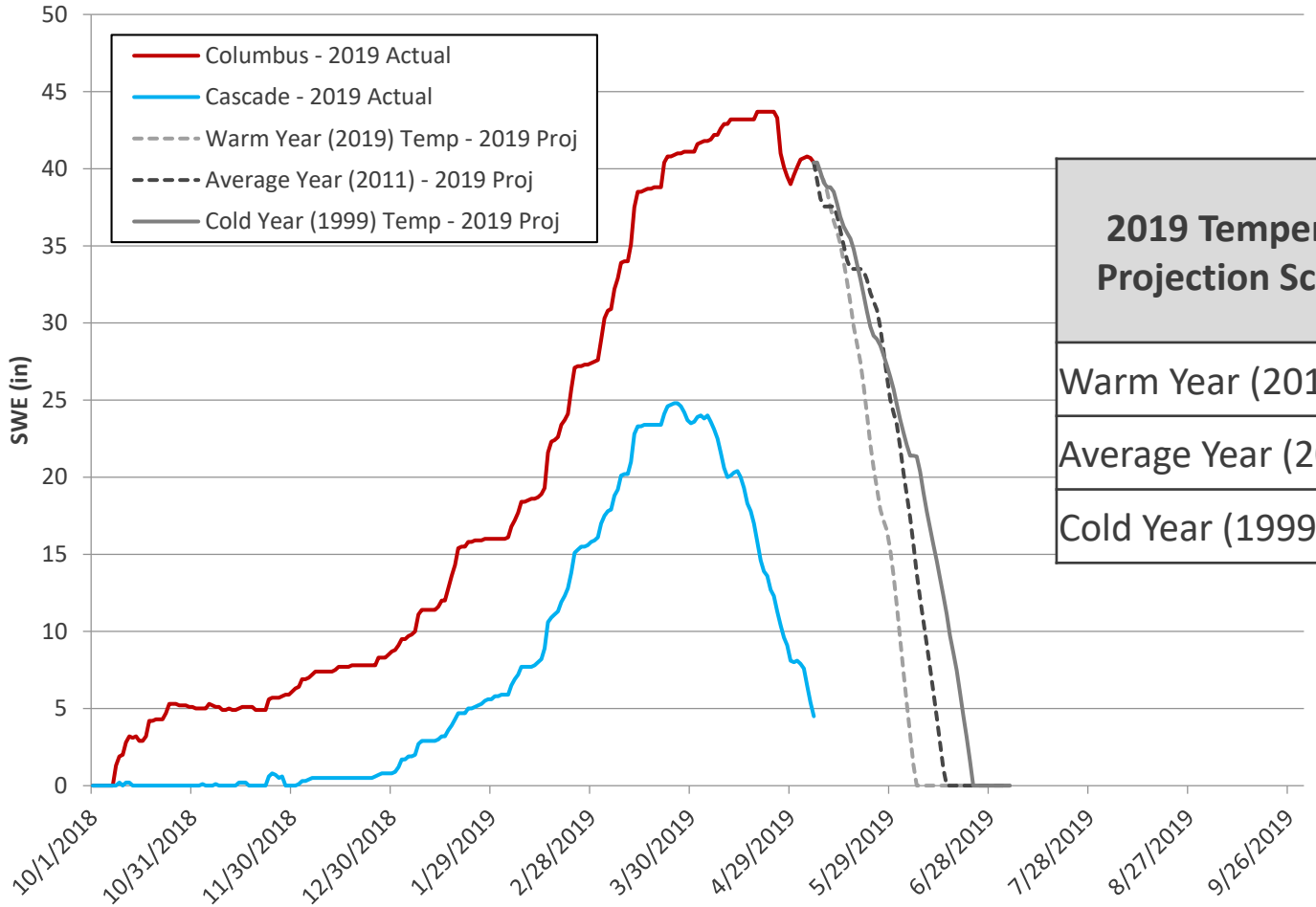
2019 Predictions & Outreach

- Assumed peak snowpack
- Evaluated 3 temperature scenarios including:
  - Warm Year (Actual)
  - Average Year (Actual)
  - Cold Year (Actual)
- Generated predictions in spring – outreach with communities
  - Shared predicted range of flows
  - Shared draft floodplains for corresponding recurrence intervals



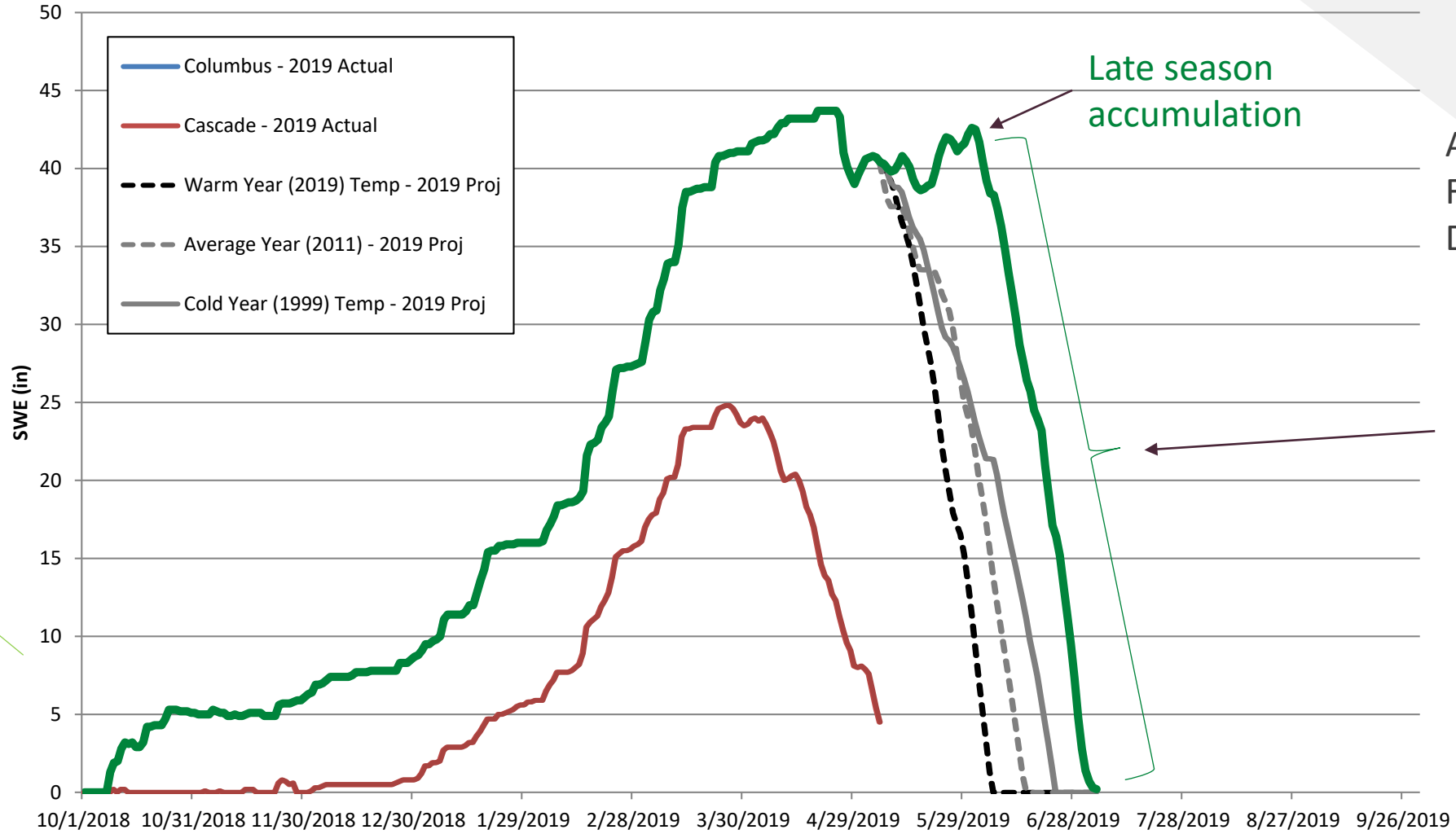
Outreach Sample

Timing & Rates



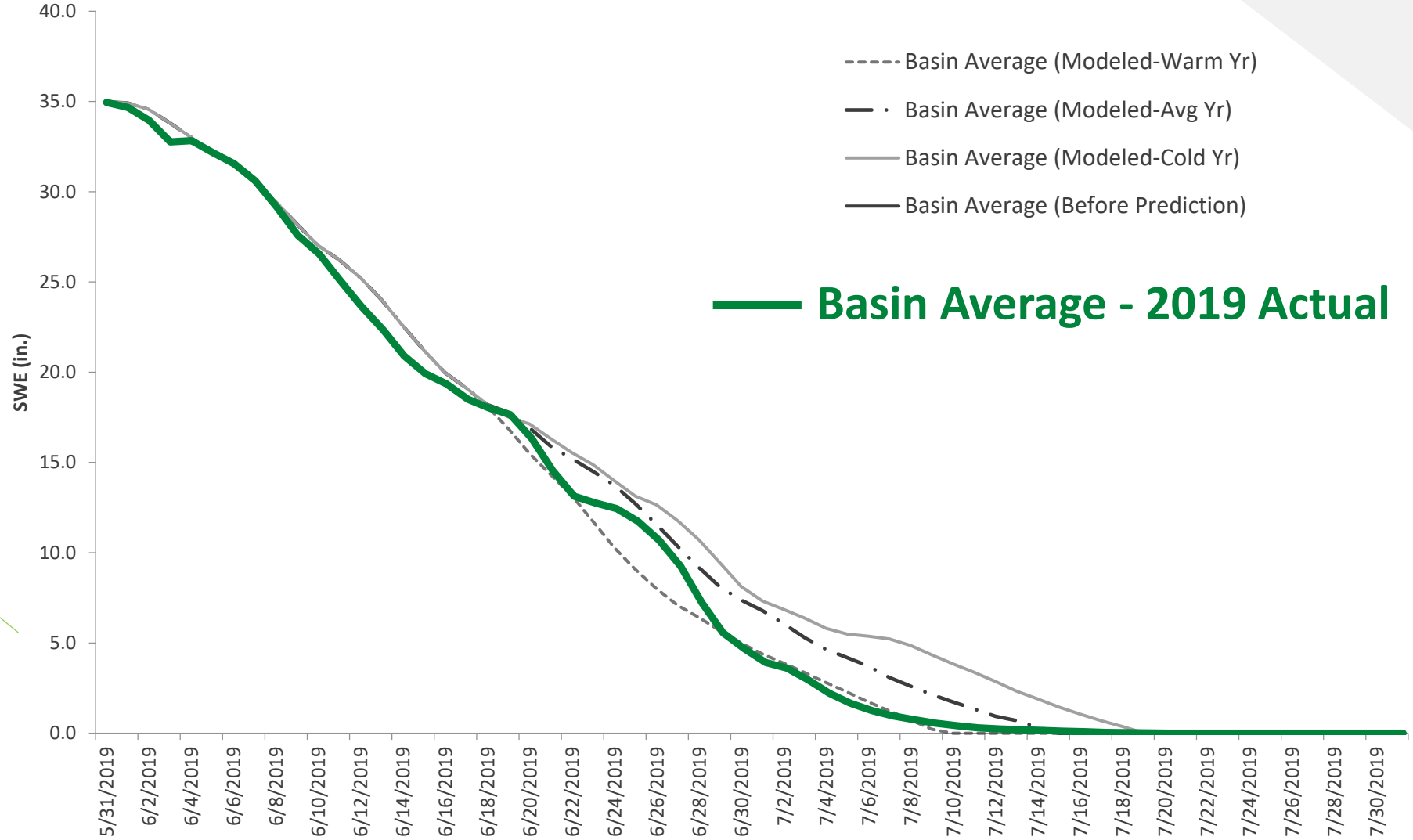
2019 Temperature Projection Scenario	Q Peak (cfs)	Peak Date	*Estimated Recurrence Interval
Warm Year (2012)	3,250	6/3/2019	25-50 Year
Average Year (2011)	2,730	6/7/2019	10-25 Year
Cold Year (1999)	2,390	6/24/2019	10-25 Year

Results: Hermosa

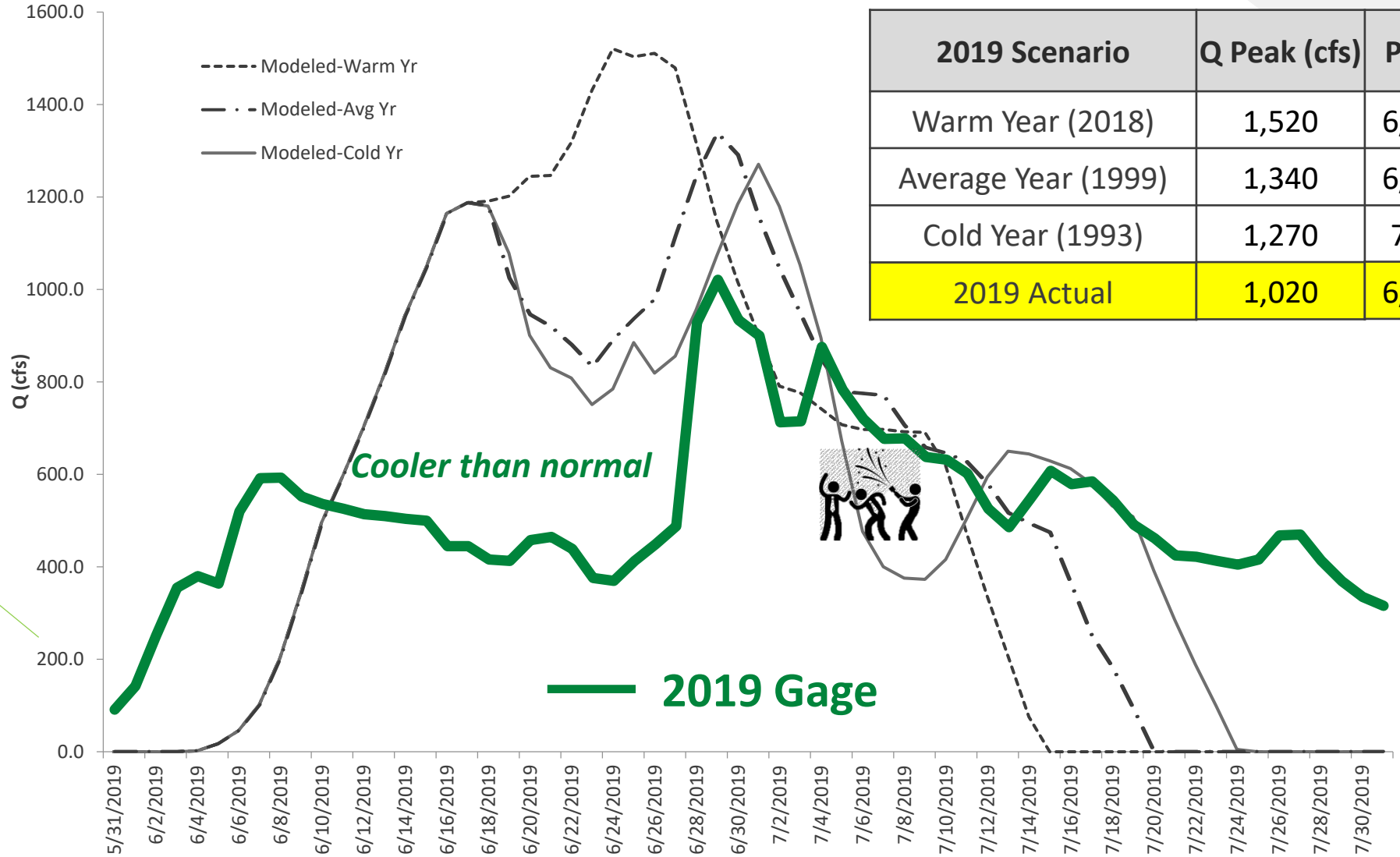


Columbus: 2019 Actual (Post-Prediction)

Results: Mineral Creek (SWE)

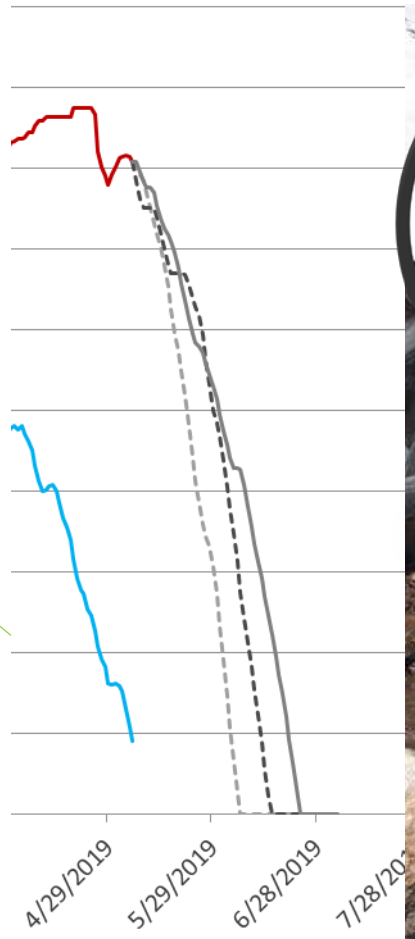


Results: Mineral Creek (Q)



2019 Scenario	Q Peak (cfs)	Peak Date	Recurrence Interval
Warm Year (2018)	1,520	6/24/2019	~ 25 Year
Average Year (1999)	1,340	6/29/2019	~ 10 Year
Cold Year (1993)	1,270	7/1/2019	< 10 Year
2019 Actual	1,020	6/29/2019	< 10 Year

Main Points



Temperature driven, means elevation-band based

Peak flow is based on slope (melt rate) not snowpack

Larger snowpack = later melt/
season = larger rate

Travel Time Estimator

Purpose

- Gold King spill
- Use model depth and velocity grids to estimate travel times from any point in the watershed
- Early warning system
- T=d/v
- Webtool that can toggle varied flows and locations

Questions or Compliments?

AECOM

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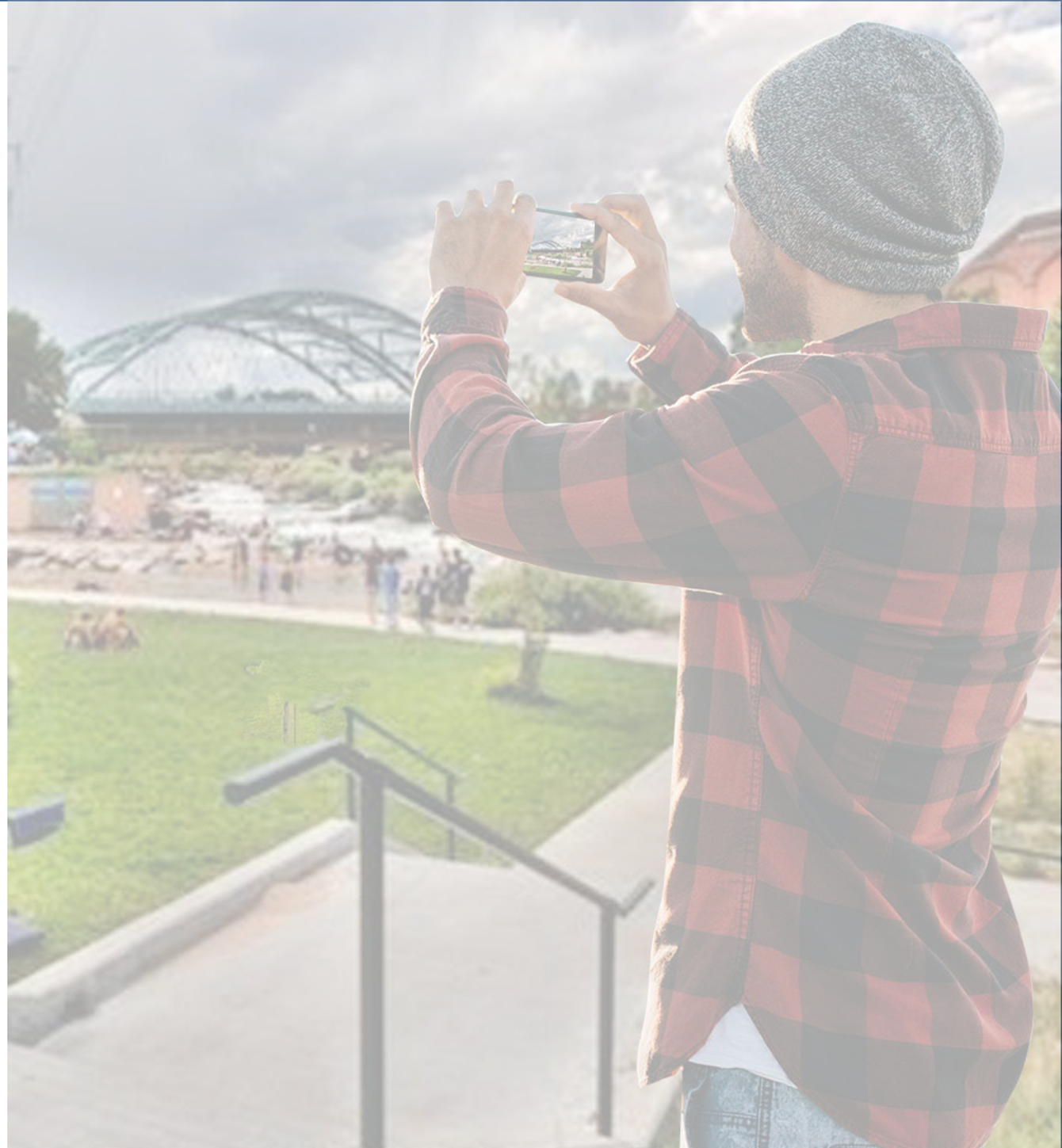
Augmented Reality Flood Walk

Colorado Association of Stormwater and Floodplain Managers Conference
September – 2019



Why Communicate Flood Risk?

Know Your Risk

- Building a culture of resilience
- Mitigation of Hazards & Risks
- Risk Analysis Branch
- Risk MAP Program
- Risk Communication

Innovative Communication

Get the Flood Facts

Creative & Innovative Ideas

- Youth Engagement
- Social Media
- Risk Visualization
- Immersed – Virtual Reality
- Exploring Other New Options

IMMERSED

A VR EXPERIENCE ABOUT FLOOD & RESILIENCE

How Do We Innovate?

Q: How can we portray flood risk to raise awareness of pre-disaster hazard mitigation and enhance public safety in a compelling way?

Telling A Compelling Story

"We came to the shallow, yellow, muddy South Platte, with its low banks and its scattering of flat sand-bars and pigmy islands — a melancholy stream straggling through the centre of the enormous flat plain, and only saved from being impossible to find with the naked eye by its sentinel rank of scattering trees standing on either bank"

-Mark Twain
Roughing It

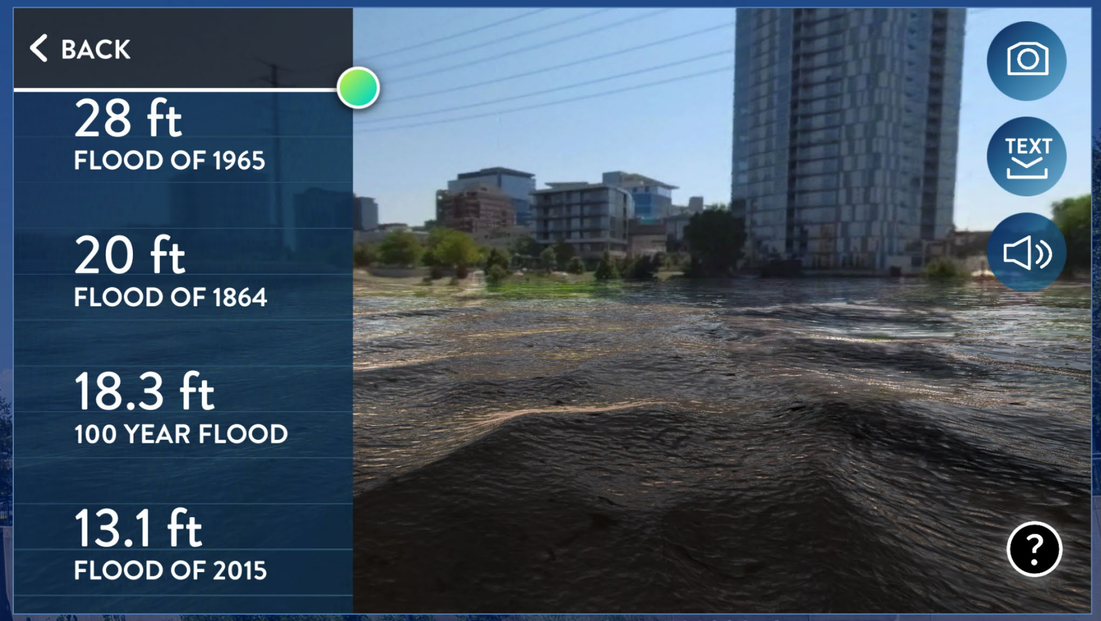
Storytelling

- Compelling Stories
  - Emotional Connections
- Storytelling vs. Fact Sharing
- Finding The River's Story
- Partners
  - City of Denver
  - The Greenway Foundation
  - Denver Parks & Recreation
  - Mile High Flood District

Flood Walk: An Augmented Reality Experience

Flood Walk

- Immersive experience
- On and off-site functionality
- Storytelling capabilities
  - ➢ Past, Present, and Future
- Social sharing features



Flood Walk Experiences

How Does it Work?

QUICKSTART

OFF-SITE

No matter where you are, you can experience Floodwalk. Using this app, you can explore various experiences from each location without needing to be there.

Off-site demo

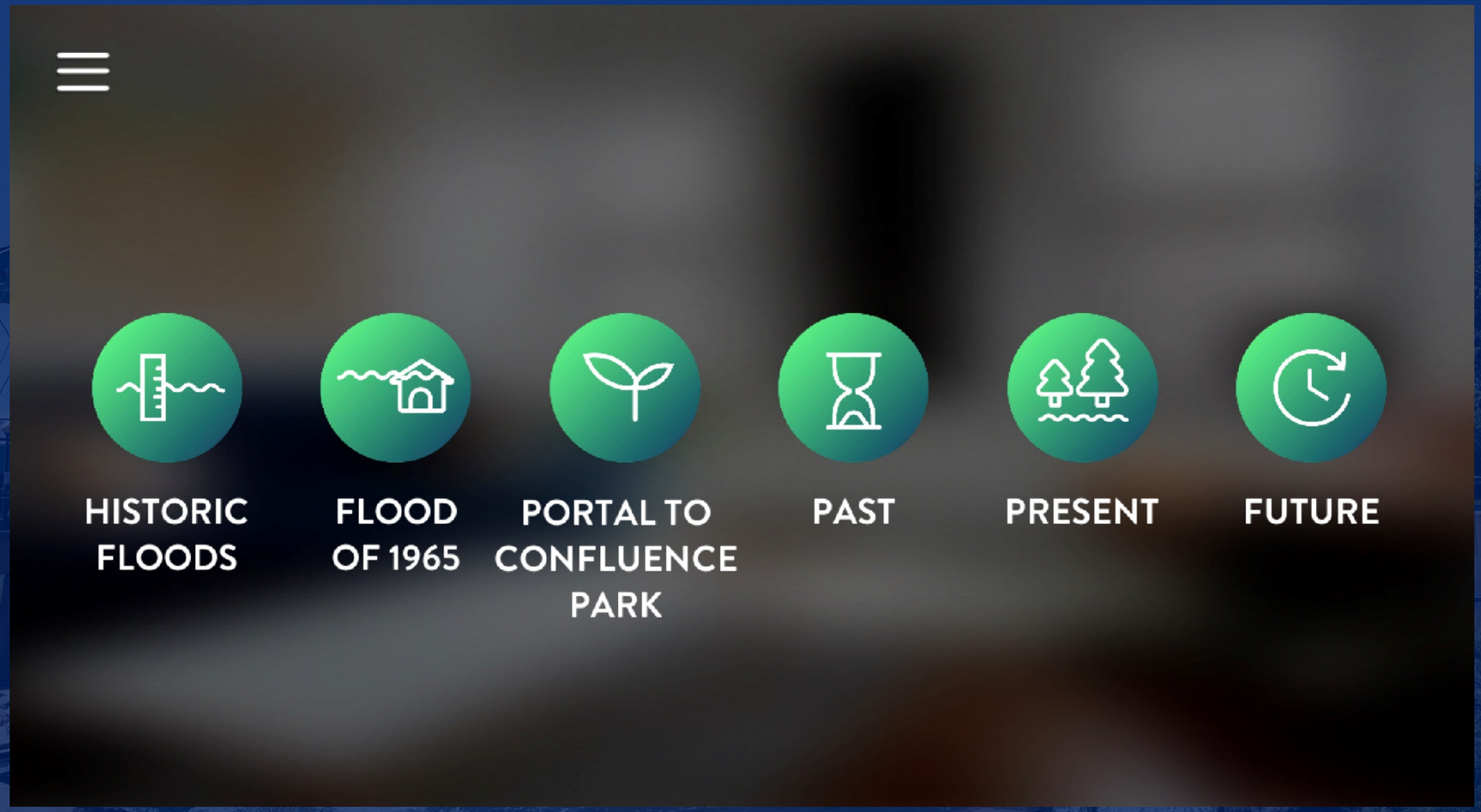
QUICKSTART

ON-SITE

Using the map, navigate to different experiences throughout your current location.

On-site demo

Markers


HISTORIC FLOODS
FLOOD OF 1965
PORTAL TO CONFLUENCE PARK
PAST
PRESENT
FUTURE

Flood of 1965

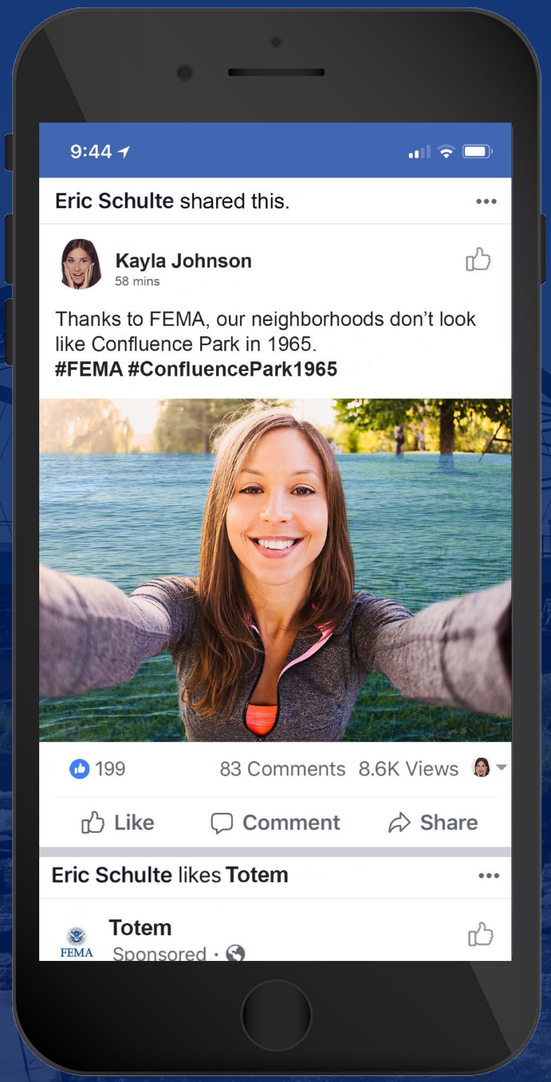
Past and Present

Past and Present

Release and Downloads

Citizens for the River Festival – June 22, 2019
Download Totals: 650
    Apple: 544
    Android: 106
Impression Totals: 3,796
    Apple: 3,292
    Android: 504

Social Media Sharing



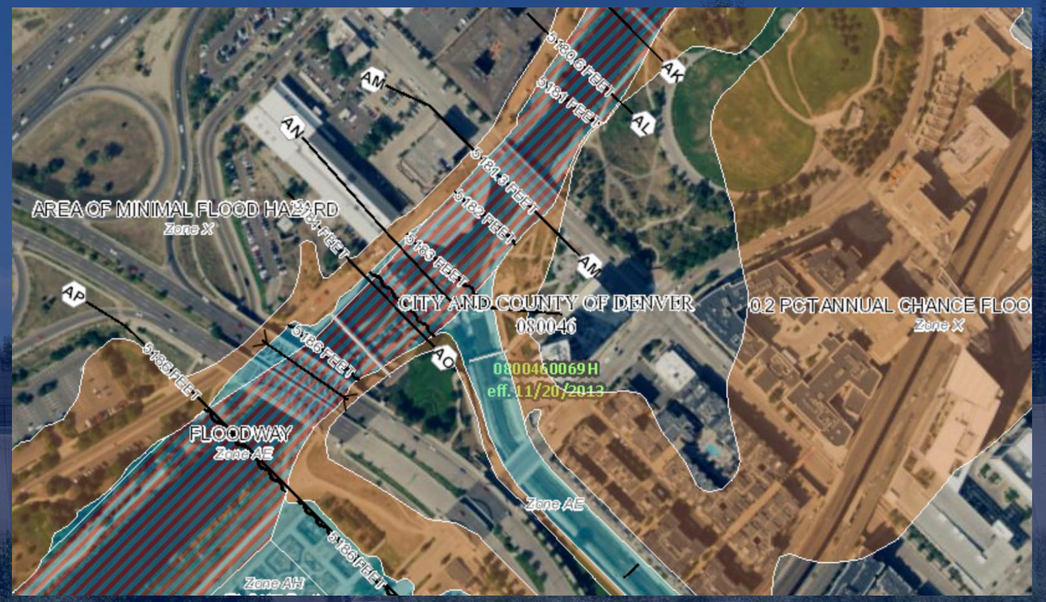
SOCIAL SHARING

ADA COMPLIANT

Innovation and Creativity Is Not Easy

Overcoming Challenges

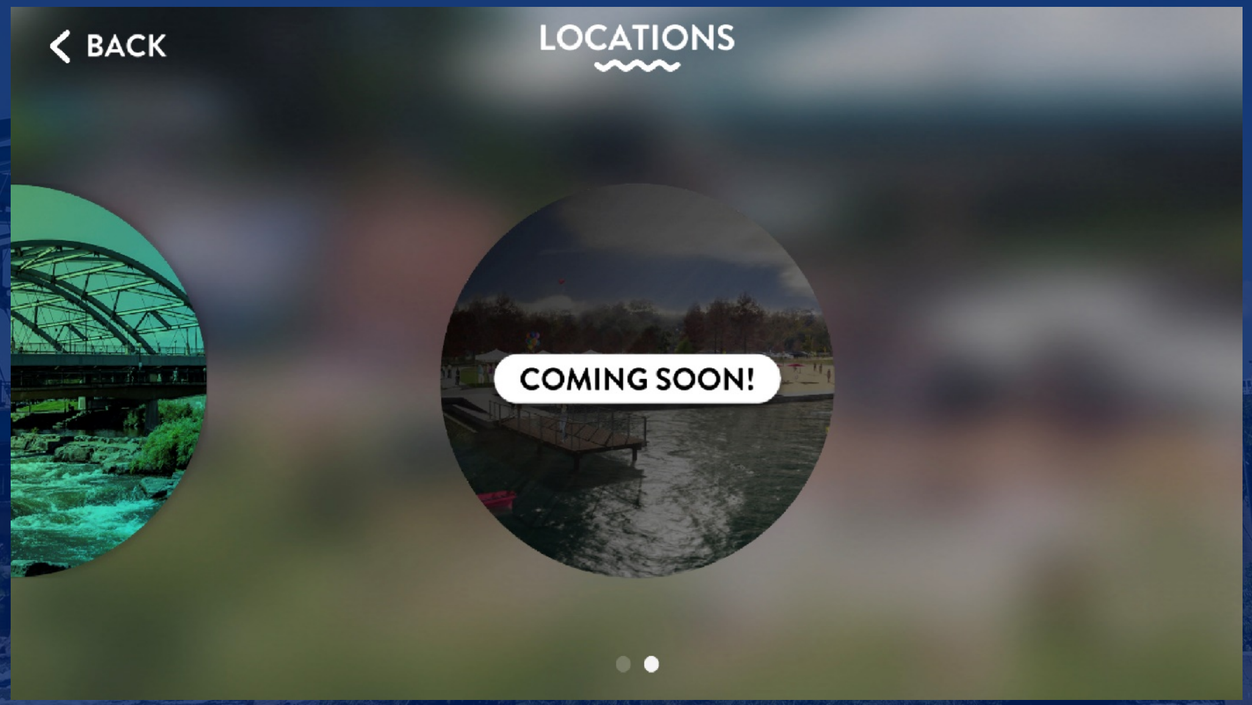
- Measuring Success
- Scalability into other cities
- User Privacy Concerns
- Android Downloads
- Data Usage
- IT and Cyber Security
- Ongoing Maintenance



More Challenges….

- HQ
- Legal
- External Affairs
- IT
- Contracting
- Programs

What’s next?



Questions?

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Working Together to Reduce Flood Risk:

Silver Jackets Interagency Program and Projects in Colorado

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Omaha District

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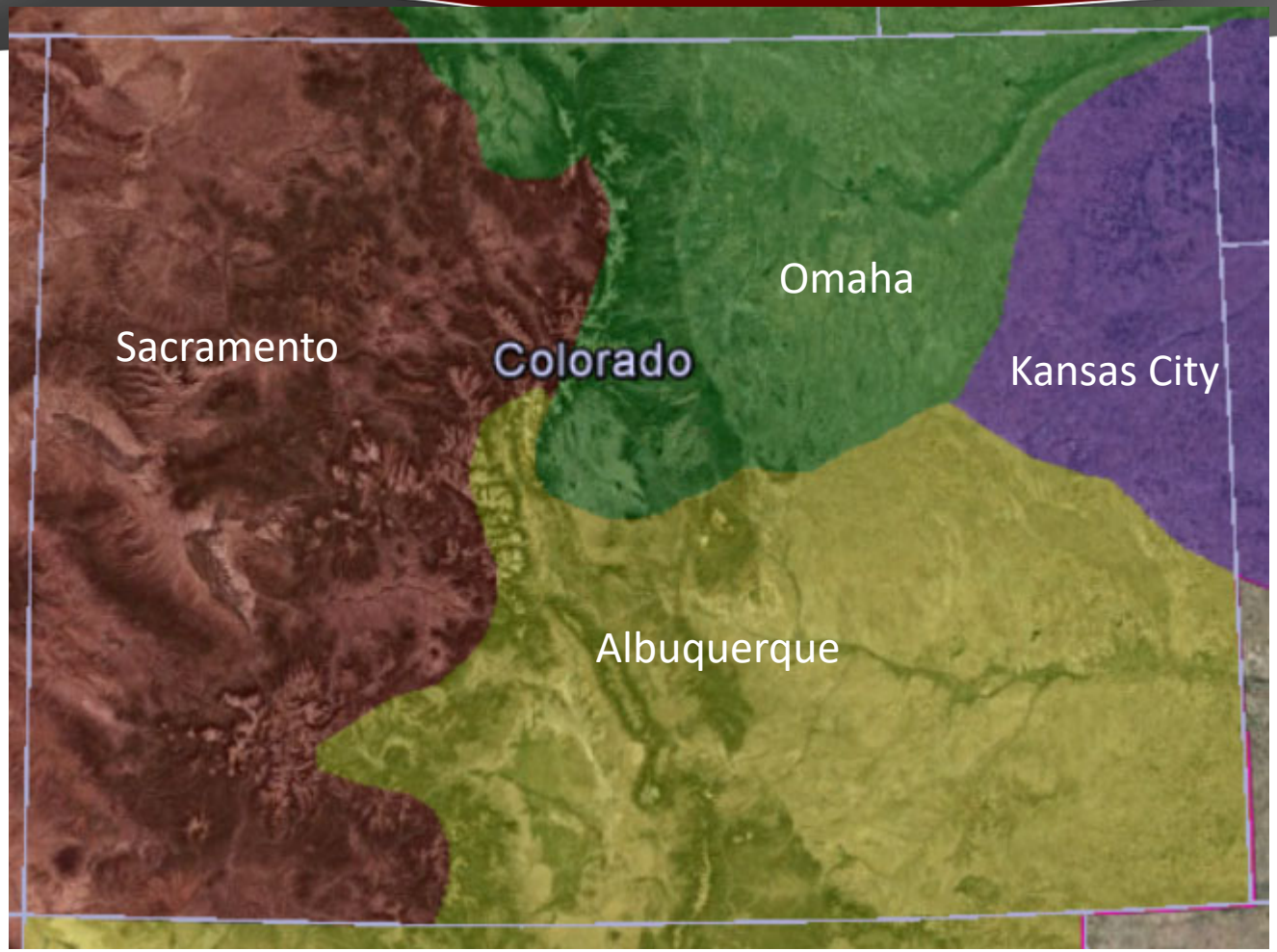
Plan Formulator/Project Manager
Omaha District

US Army Corps of Engineers

- Flood Risk Management
- Water Supply
- Water Quality
- Ecosystem Restoration
- Emergency Response
- Cultural Resource Protection

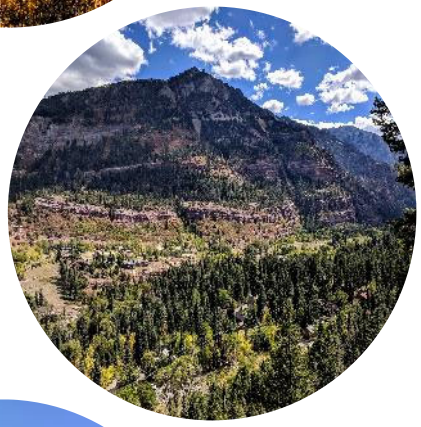
US Army Corps of Engineers
Sacramento District

USACE District Boundaries



US Army Corps of Engineers
Sacramento District

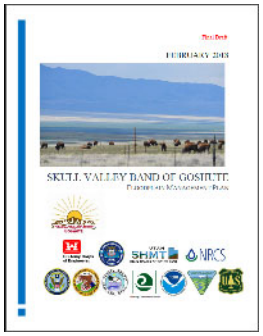
Planning and Technical Services

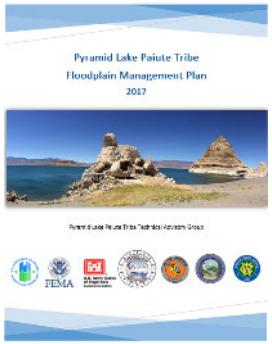


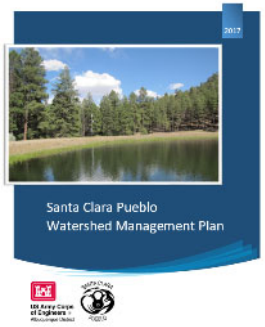
- Tribal Partnership Program
- Planning Assistance to States Program
- Floodplain Management Services
- Silver Jackets

Silver Jackets

- Interagency Program to Reduce Flood Risk
- State Led Teams
- Competitive Project Proposals
- 12-18 month Projects







Preparation and Training

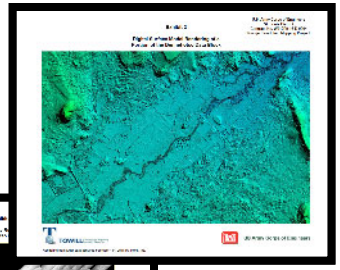
Flood Event

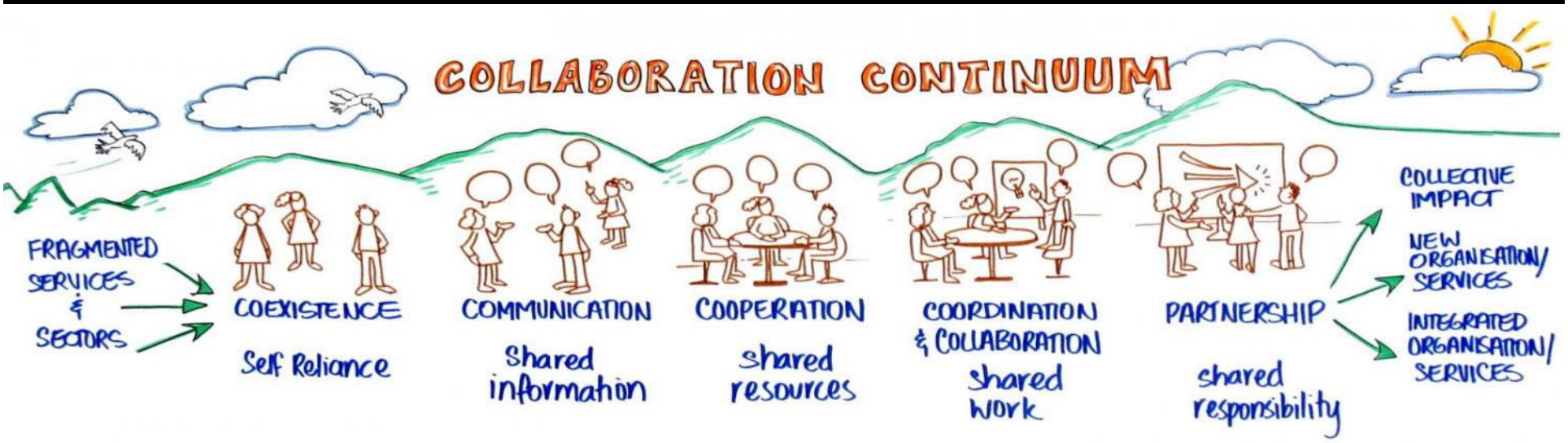
Response

Recovery

Mitigation

Flood Risk Management Life Cycle



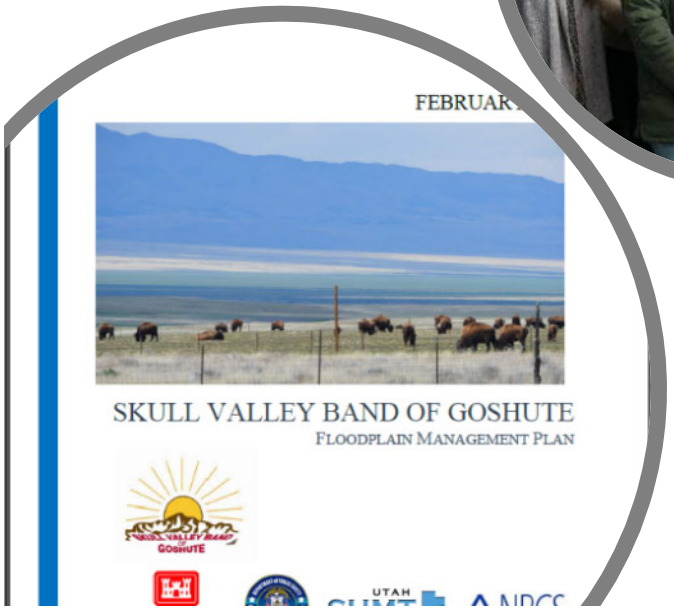


Project 1 → Project 2 → Project 3

Developing Partnerships:
From Coexistence to Communication

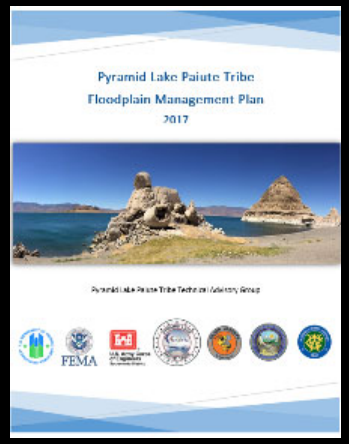
- Fire in the Upper Watershed
- Debris Flows and Flooding
- Support from BIA and NRCS

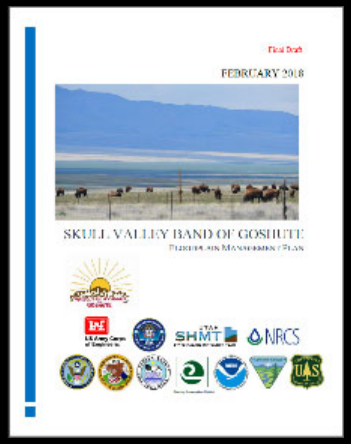
Developing Partnerships: *From Communication to Cooperation and Collaboration*

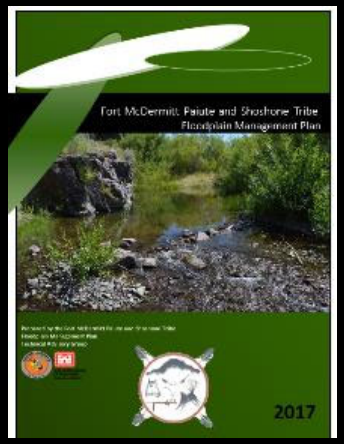


- Developed Silver Jackets Proposal to Develop a Floodplain Management Plan
- Interagency Project Brought Together New Resources

Floodplain Management Plans
Collaboration. Planning. Outreach







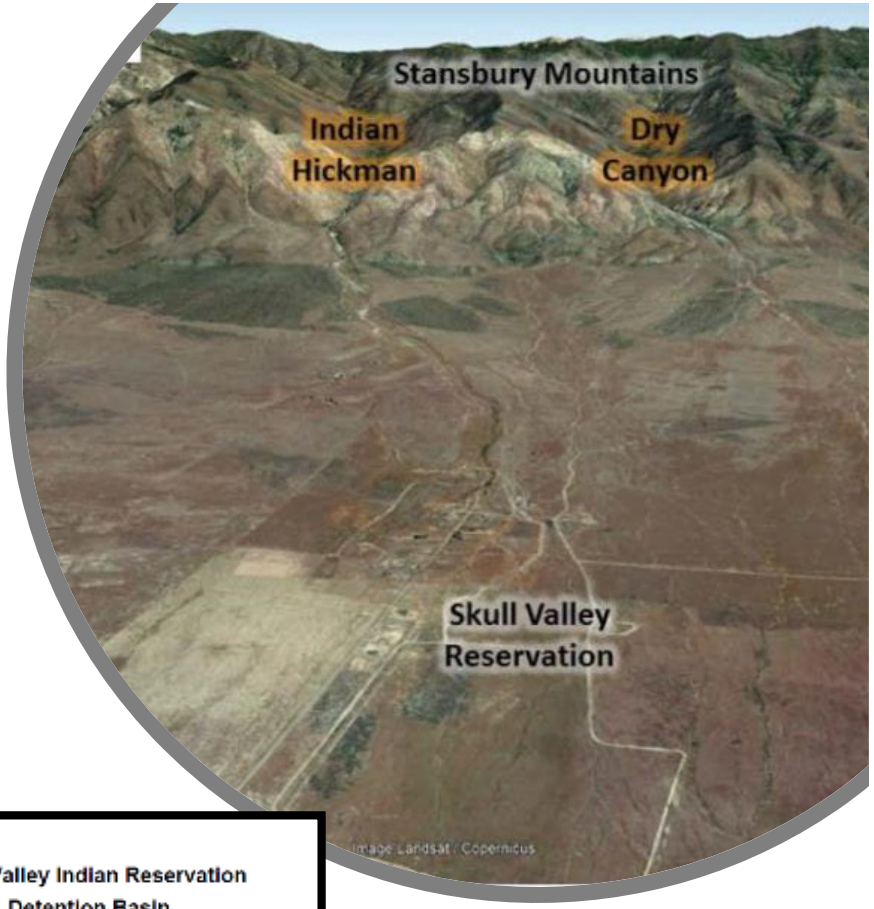
Goals
What long-term outcomes do you want to achieve?

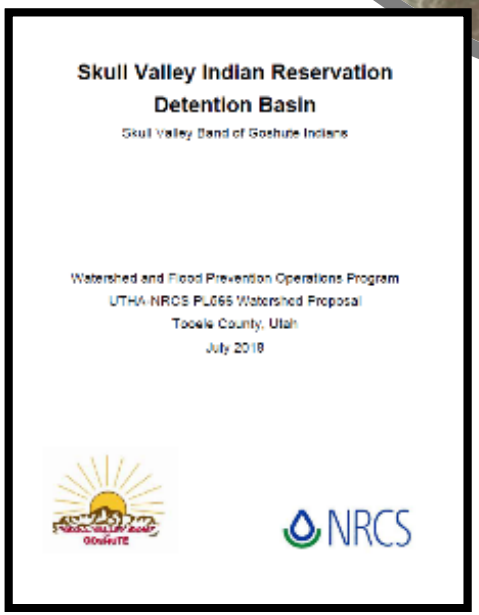
Actions
What specific actions will the Tribe take to reduce flood risk?

Action Plan
How will the actions be prioritized and implemented?

Developing Partnerships:
Ongoing Partnerships

- Floodplain Mapping
- Tribal Mitigation Plan
- Flood Risk Mitigation Measures




Skull Valley Indian Reservation
Detention Basin
Skull Valley Band of Goshute Indians

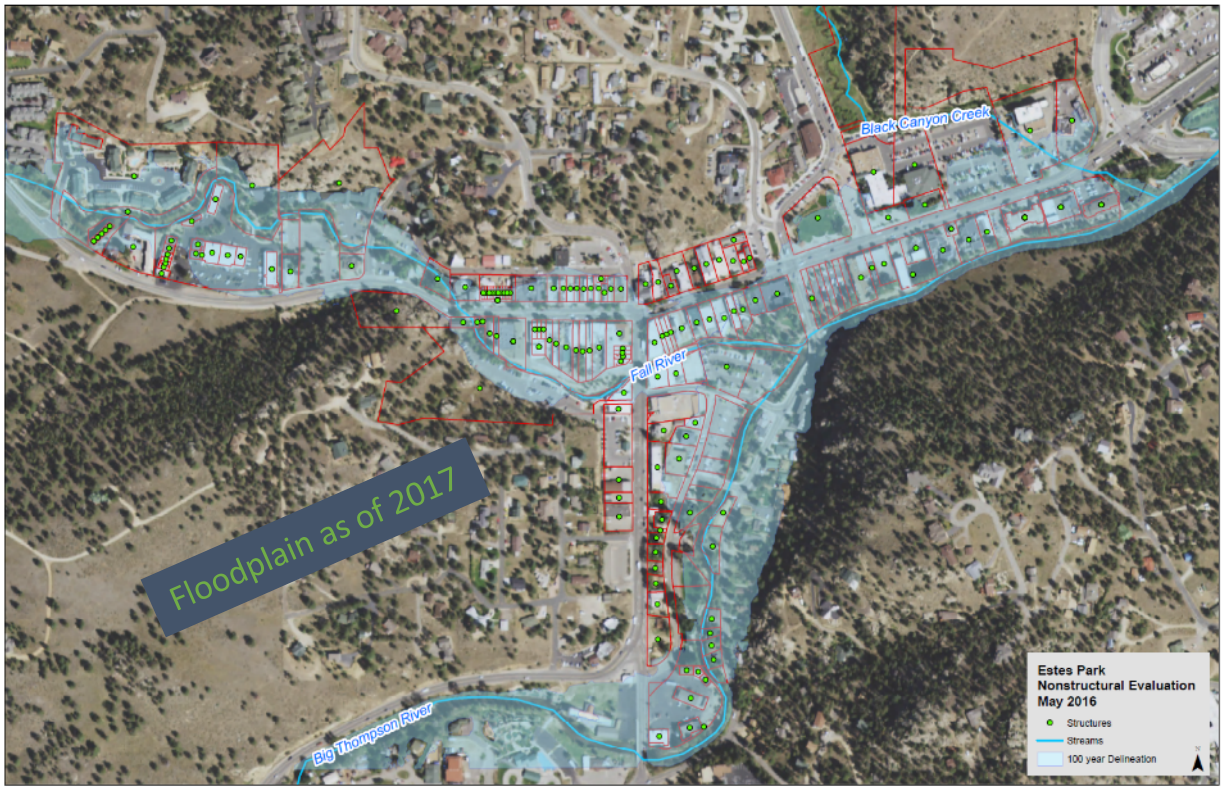
Watershed and Flood Prevention Operations Program
UTHA-NRCS PL566 Watershed Proposal
Tooele County, Utah
July 2018

NRCS

Colorado Silver Jackets Projects

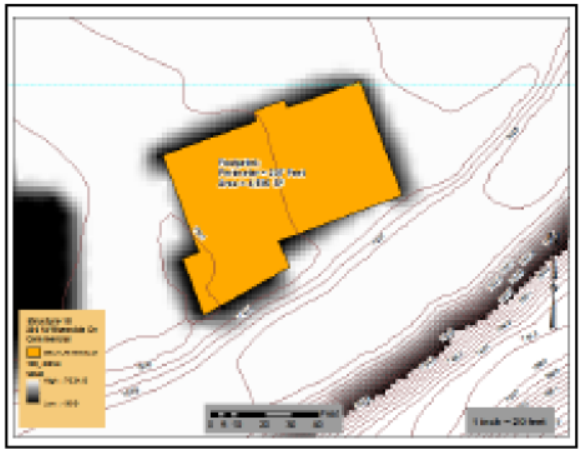
- Nonstructural Floodproofing Workshops – 2015
- Estes Park Nonstructural Assessment - 2016
- Ice Jam Workshops – 2017
- Brush and Sterling Nonstructural Assessment – 2018
- Advanced Floodplain Management Workshops – 2019/2020
- Post-Wildfire Flood Resource Guide – 2020
- Grand Lake Floodplain Mapping – 2020/2021
- Third Creek Flood Risk Assessment – 2020/2021

Estes Park Nonstructural Assessment



Example Structure

Structure Information/Data:		Structure/Flood Elevations:	
Name/Description	Microbrew and Salon	First Floor Elevation (FF)	7541
Address	386 W Riverside Dr 5	Lowest Adjacent Grade Front (LGF)	7540
Occupancy type	Commercial	Lowest Adjacent Grade Back (LGB)	7540
Number of Stories	2	Base Flood Elevation Front (BFEF)	7541.1
Building Construction	CMU	Base Flood Elevation Back (BFEB)	7542.4
Foundation Wall	Masonry	FF minus BFE	-1.4
Slab/Crawlspace/Basement	Slab/Crawlspace	FF minus LG	1
Condition (Good/Fair/Poor)	Good	Depth of Flooding Front (BFEF-LGF)	1.1
1st Floor Window Count	2	Depth of Flooding Back (BFEB-LGB)	2.4
1st Floor Door Count	2	Max Velocity Front	2.3
Basement/Crawlspace Elevation (B)	7539.5	Max Velocity Back	7



Building Footprint

Side View

Floodproofing Recommendations

Structure Information/Data:		Structure/Flood Elevations:	
Name/Description	Microbrew and Salon	First Floor Elevation (FF)	7541
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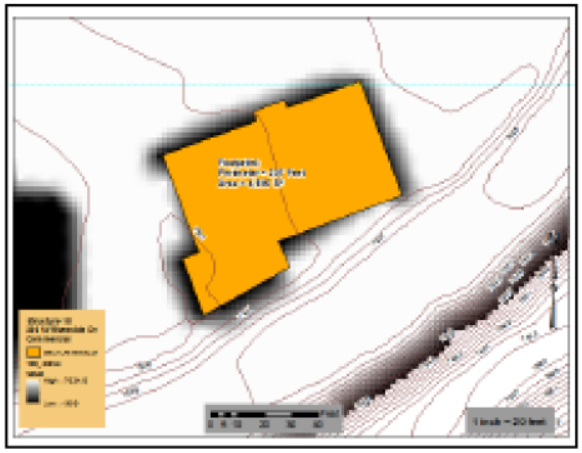
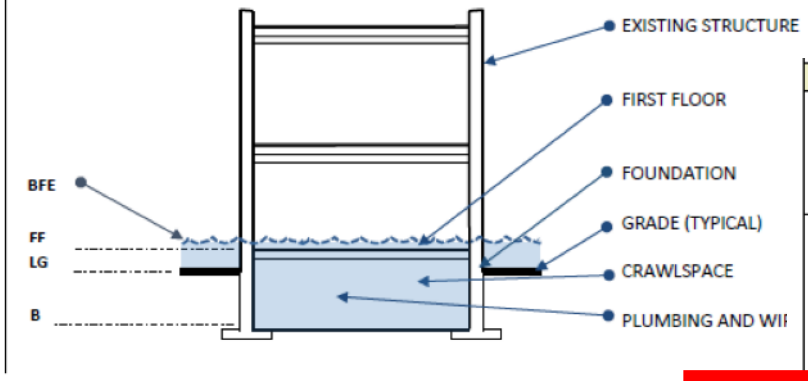


Building Footprint

Side View

Floodproofing Recommendations

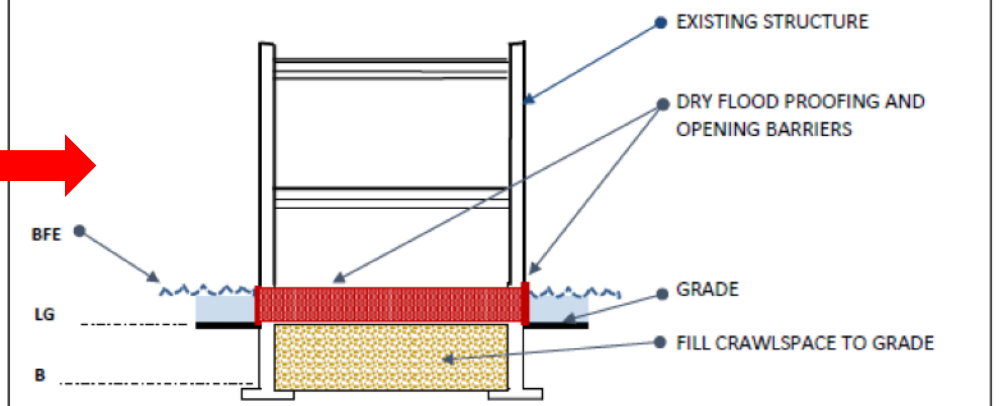
Existing Structure / Flood Elevation Data and Graphics							
FF	B	LG	FF-LG	BFEB	FF-BFE	B-BFE	LG-BFE
7541.0	7539.5	7540	1.0	7542.4	-1.4	-2.9	-2.4



DIAGRAMATIC BUILDING SECTION (EXISTING)
NOT TO SCALE

Proposed Mitigation Measures

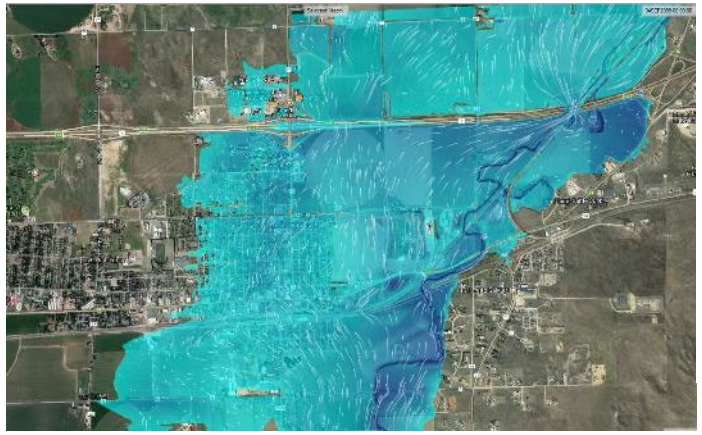
1. Dry flood proof exterior walls to 1.4 + freeboard above first floor elevation.
2. Dry flood proof party (common) walls if adjacent businesses do not implement exterior dry flood proofing.
3. Incorporate certified flood barriers for all openings, with sump pump and emergency power.
4. Fill crawlspace with uniform material and evacuate utilities and stored items.
5. Incorporate anti-backflow valve into sewer line.

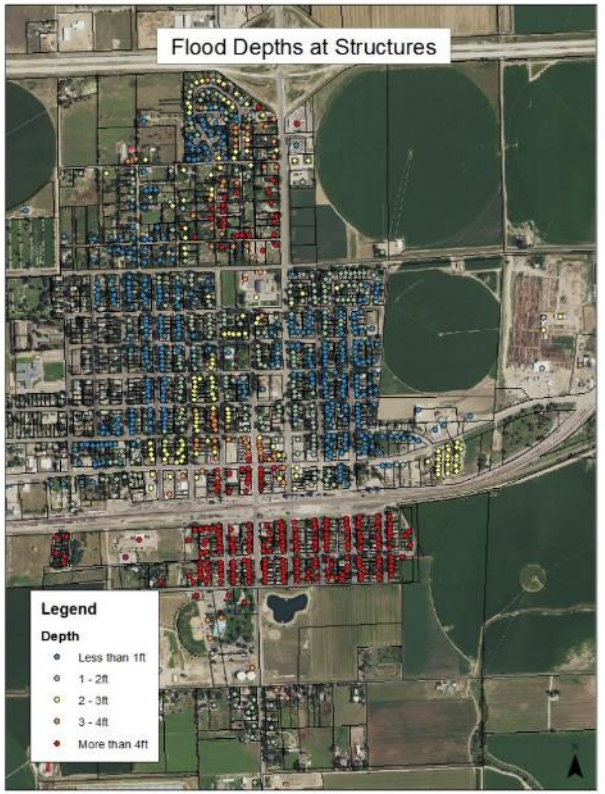


DIAGRAMATIC BUILDING SECTION (PROPOSED)
NOT TO SCALE

Brush & Sterling Nonstructural Assessment

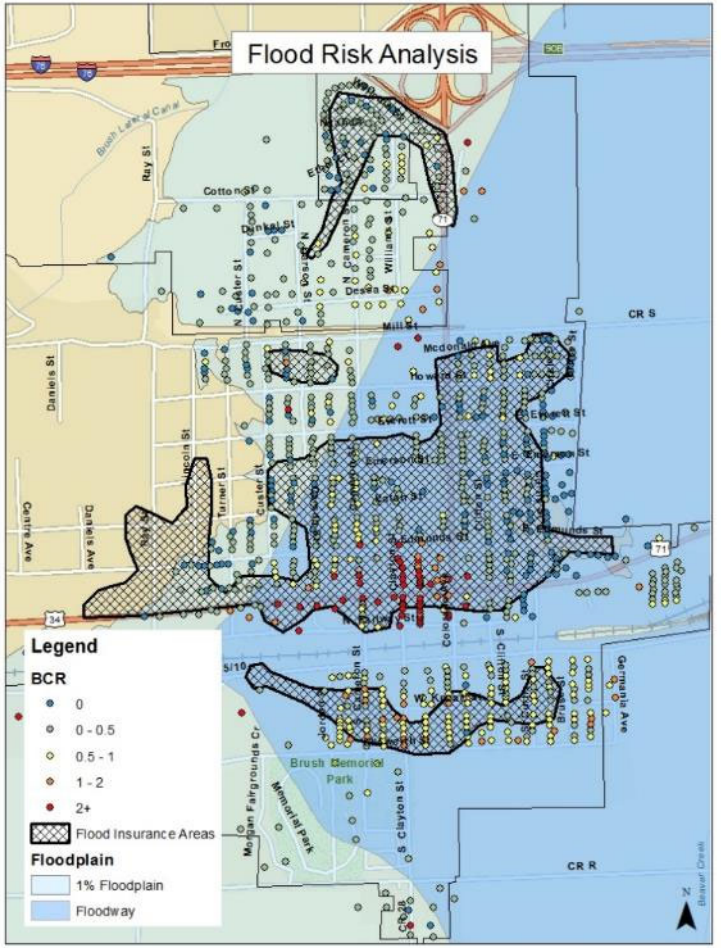
- Study components
  - Flood data
  - Structure characteristics
  - Flood Insurance
  - Floodproofing recommendations
  - Benefit-cost analysis





Assessment Results

Structure	Address	Building Type	Floodproofing Method Recommended	Benefits	Cost	BCR
1	0945 N CAMERON ST	R	Elevation	19,184	72,072	0.27
2	416 DESSA ST	R	Elevation	41,744	54,511	0.77
3	6 CIRCLE DR	R	Elevation	41,595	102,628	0.41
4	5 CIRCLE DR	R	Elevation	65,730	136,765	0.48
5	602 ELLSWORTH ST	C	Wet floodproofing	33,859	138,436	0.24
7	602 ELLSWORTH ST	C	Wet floodproofing	1,742	36,693	0.05
9	602 ELLSWORTH ST	C	Wet floodproofing	1,242	24,472	0.05
11	5 ETHEL CT	R	-	0	0	0.00
12	411 CUSTER ST	R		0	0	0.00
14	1300 S RAILWAY ST	C	Dry floodproofing	258,806	113,154	2.29
15	719 EVERETT ST	R	Fill Basement	3,015	11,896	0.25
16	718 CARSON ST	R	Fill Basement	2,804	19,582	0.14
17	1049 WILLIAMS ST	R	Elevation	5,211	103,063	0.05
18	36 MCDONALD AVE	R	Elevation	79,765	123,907	0.64
19	1038 WILLIAMS ST	R	Elevation	14,518	98,037	0.15
20	720 CAMERON ST	R	Elevation	64,477	103,940	0.62
21	520 CARSON ST	R	Elevation	21,790	85,405	0.26
22	514 CAMERON ST	R	Elevation	6,291	72,446	0.09



FPMS Ouray Colorado

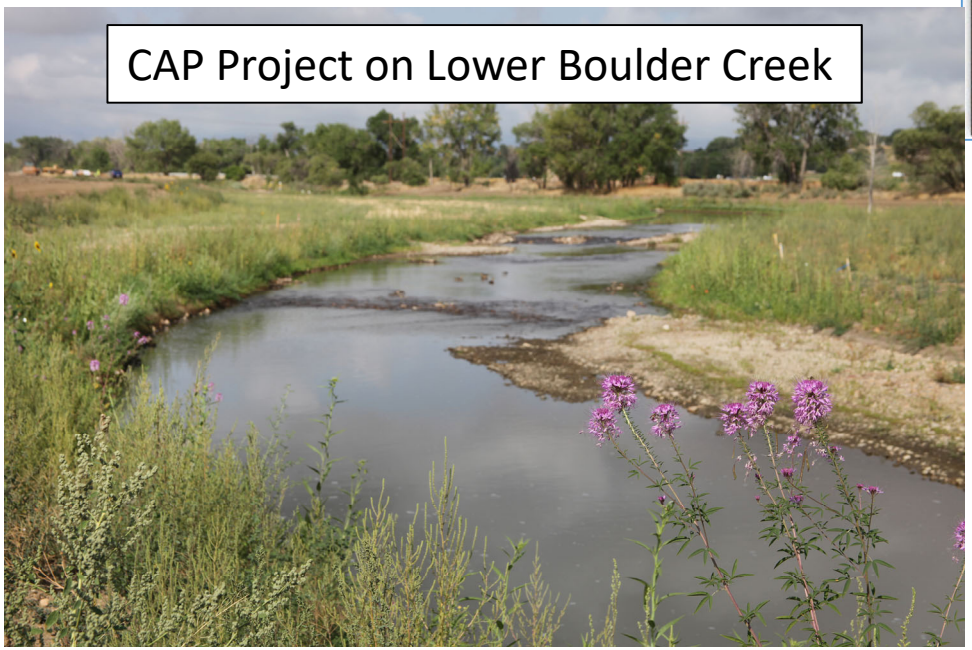
- Floodplain Management Services Study
- Corbett Creek, Ouray, CO
- CR 17, Secondary Evacuation Route
- Engineering Research and Development Center (ERDC) Support

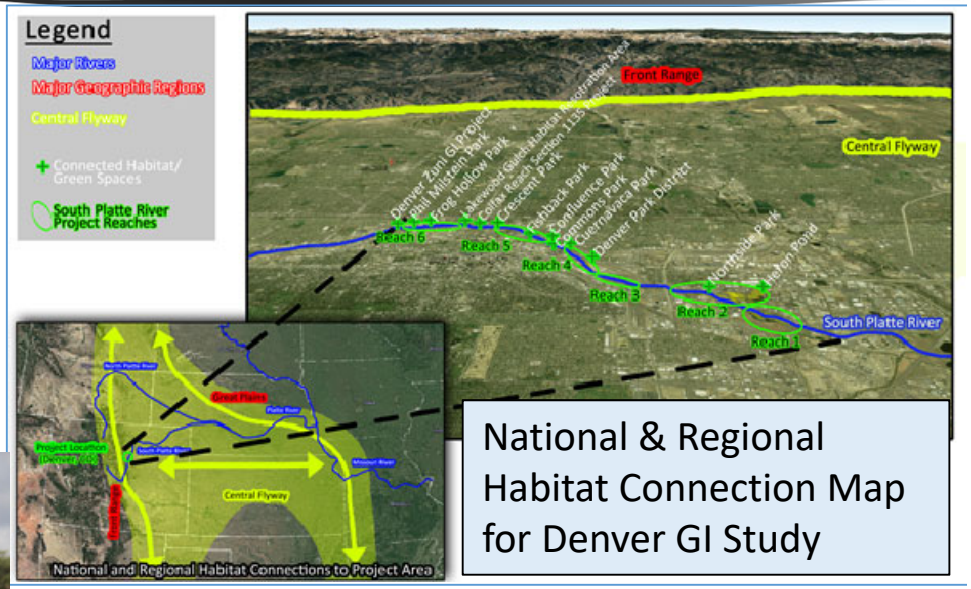
USACE Civil Works Construction Authorities

Continuing Authorities Program (CAP)

Shorter-term ➔ Streamlined Construction

- Feasibility Study & Integrated NEPA (typ. EA)
- Delegated Approval & Pre-authorized for Construction





National & Regional Habitat Connection Map for Denver GI Study

Specifically Authorized

Longer-term ➔ Requires Authorization

- Feasibility Study & Integrated NEPA
- Upon Approval Construction Authorized through WRDA

Streamlined Construction (CAP)

Pre-Authorized for Construction within Limits

Planning Phase

- Feasibility Study – 50 / 50 above $100K
- Delegated approval authority (NWD Commander)

Construction Phase

- Cost-share based on project type & program

Section 206 Project in Greeley, CO

Section	Authority	Purpose	Cost share % (Fed/non-Fed)	Federal Project limit	Program limit (competitive funds)
14	Emergency Streambank Protection	Small erosion risk reduction projects for public infrastructure and facilities	65/35	$5,000,000	$25,000,000 per FY
205	Flood Damage Protection	Small flood risk management projects	65/35	$10,000,000	$68,750,000 per FY
206	Aquatic Ecosystem Restoration	Restore degraded aquatic ecosystem in the public interest	65/35	$10,000,000	$62,500,000 per FY
1135	Modifications for Improvement of the Environment	Restore a degraded ecosystem that resulted from historic Corps projects	75/25	$10,000,000	$50,000,000 per FY
203	Tribal Partnership Program	Protect Tribal property and cultural resources, restore natural habitats	65/35	$12,500,000	n/a

CAP Projects in Colorado

Section 205 – Flood Risk Management

- St Vrain Creek, Longmont, CO
  - Feasibility Study scheduled to be complete in early 2020

Section 1135 – Ecosystem Restoration in Corps Project Areas

- South Platte River, Denver, CO (middle)
  - Design anticipated to start later this year

Section 206 – Ecosystem Restoration

- Lower Boulder Creek (left)
  - Construction Scheduled to be done by early 2020.
- Cache la Poudre River, Greeley, CO (right)
  - First phase of construction scheduled to be complete in 2020

Specifically Authorized

Congressionally Directed

Authorized by Phase

Study authority typically a Committee Resolution

Construction authority typically through WRDA

Appropriations are individual line items

Energy and Water Appropriations Acts

Limited discretion through workplan (if applicable)

Limited number of “New Starts” annually

Scope is not constrained

No maximum project cost limit

Allows for multi-purpose projects/watersheds

Approval Authority resides with ASA(CW)

Upon approval report is provided to Congress for consideration for authorization for construction (WRDA)

South Platte River Multi-purpose GI Study (above) & Bear Creek Water Reallocation Study (below)

Specifically Authorized Projects in Colorado

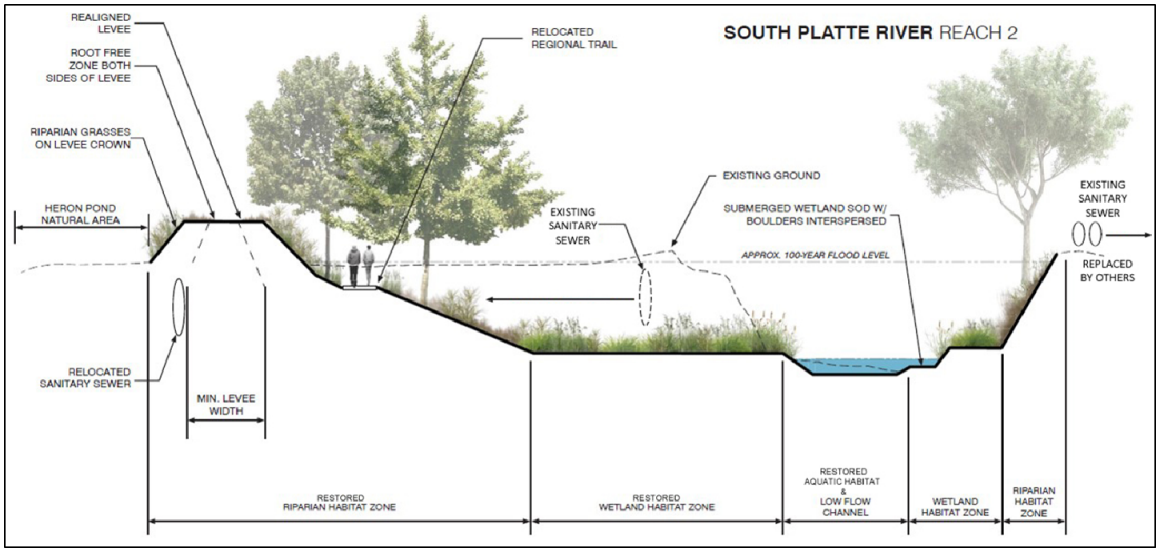
Chatfield Reallocation Project

- Project reallocating >20,000 acre-ft within the Chatfield Reservoir for Water Supply and Environmental Purposes.

Chatfield Storage Reallocation Project

Bear Creek Reallocation Project

- Project seeking to reallocate storage within the Bear Creek Reservoir for Water Supply
- Feasibility Study started in August 2019



Adams & Denver Counties, CO Project (left)

- Large scale (~$520M) Ecosystem Restoration & Flood Risk Management Project in Denver, CO.
- Chief's Report signed in July 2019 to finalized Feasibility Study

Questions?

https://silverjackets.nfrmp.us/State-Teams/Colorado

https://www.nwo.usace.army.mil/Missions/Civil-Works/Planning/

Contact Information

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Melissa.Weymiller@usace.army.mil
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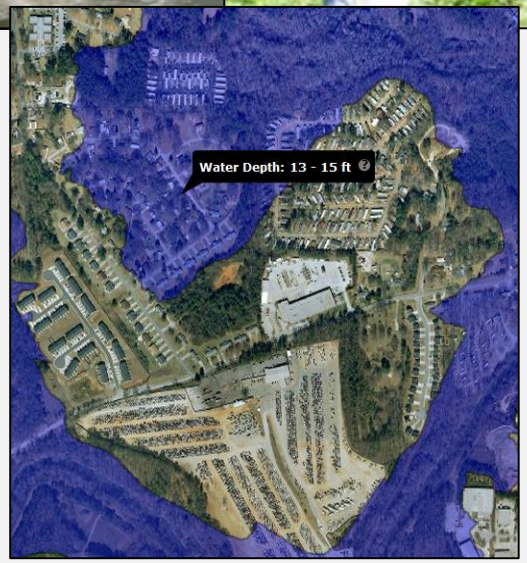
The USGS Flood Inundation Mapping Program: Using flood inundation maps and real-time streamgages with a case study from Fort Morgan, Colorado



Colorado Association of Stormwater and Floodplain Managers Annual Conference

September 25, 2019

Mike Kohn, P.E.
Civil Engineer
USGS Colorado Water Science Center
Denver, CO

Thuy Patton, CFM
Floodplain Mapping Coordinator
Colorado Water Conservation Board
Denver, CO

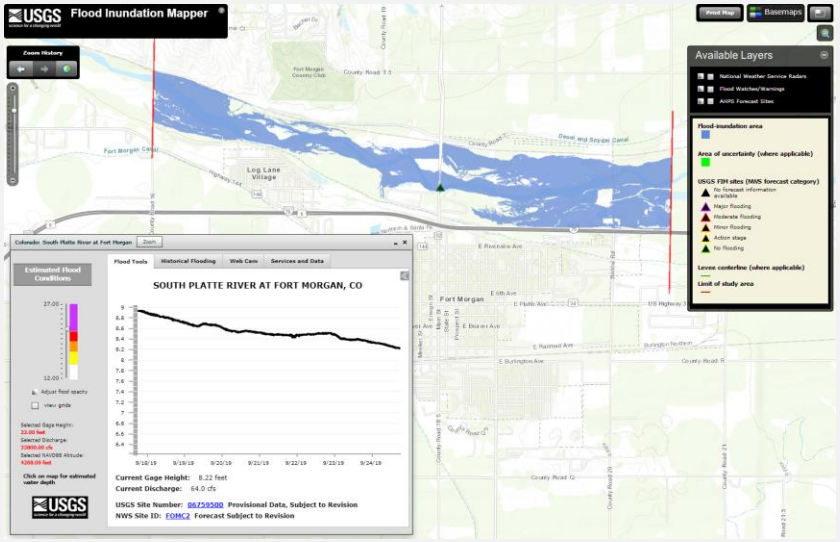
U.S. Department of the Interior
U.S. Geological Survey

Types of Flood Inundation Maps

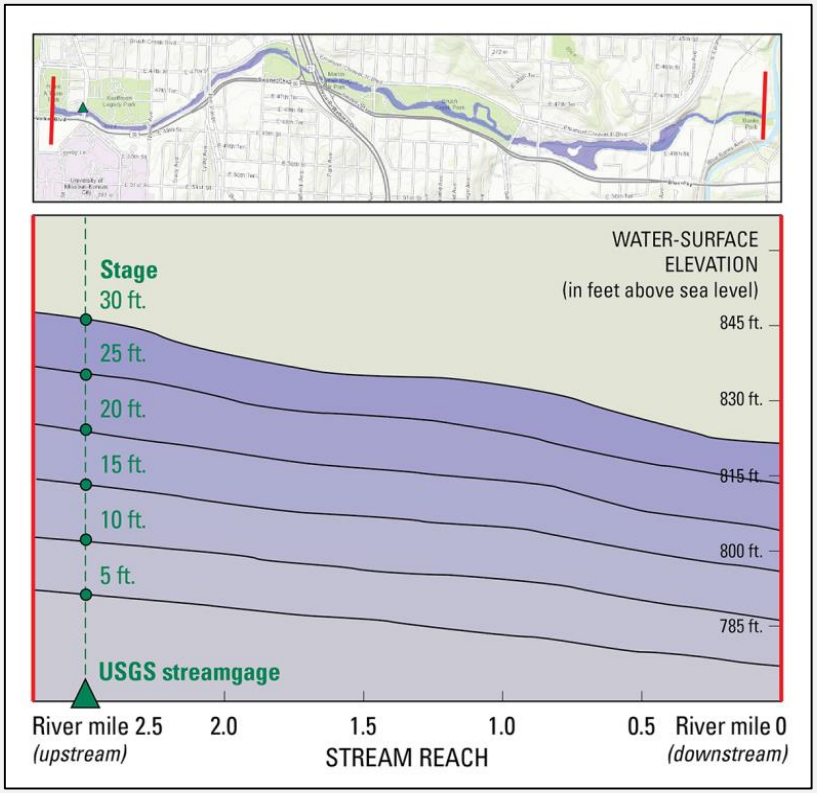
- **Modeled Flood Inundation Map Libraries**
  - **Probabilistic flows (i.e. 1% chance flood)**
    - **Most common examples are FEMA's Flood Insurance Rate Maps (FIRM)**
    - **Typically, several are created (20%, 10%, 4%, 1%, 0.2% Exceedance Probability Flows)**
  - **Scenario based**
    - **Dam break**
    - **Levee breach**
  - **Deterministic flows – USGS Flood Inundation Mapping Program**
    - **Stage Intervals**

    (i.e. every 2 feet in stage)
    - **Critical stages**

    (i.e. Moderate and Major flood stages)

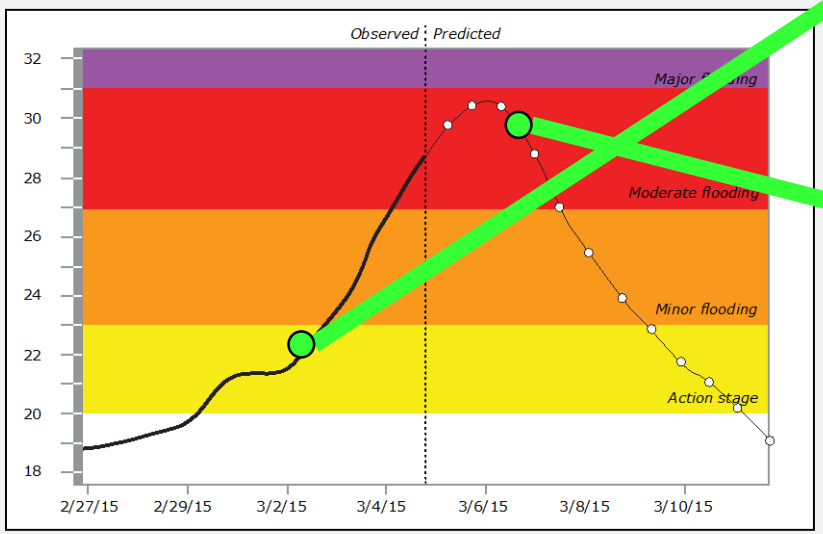


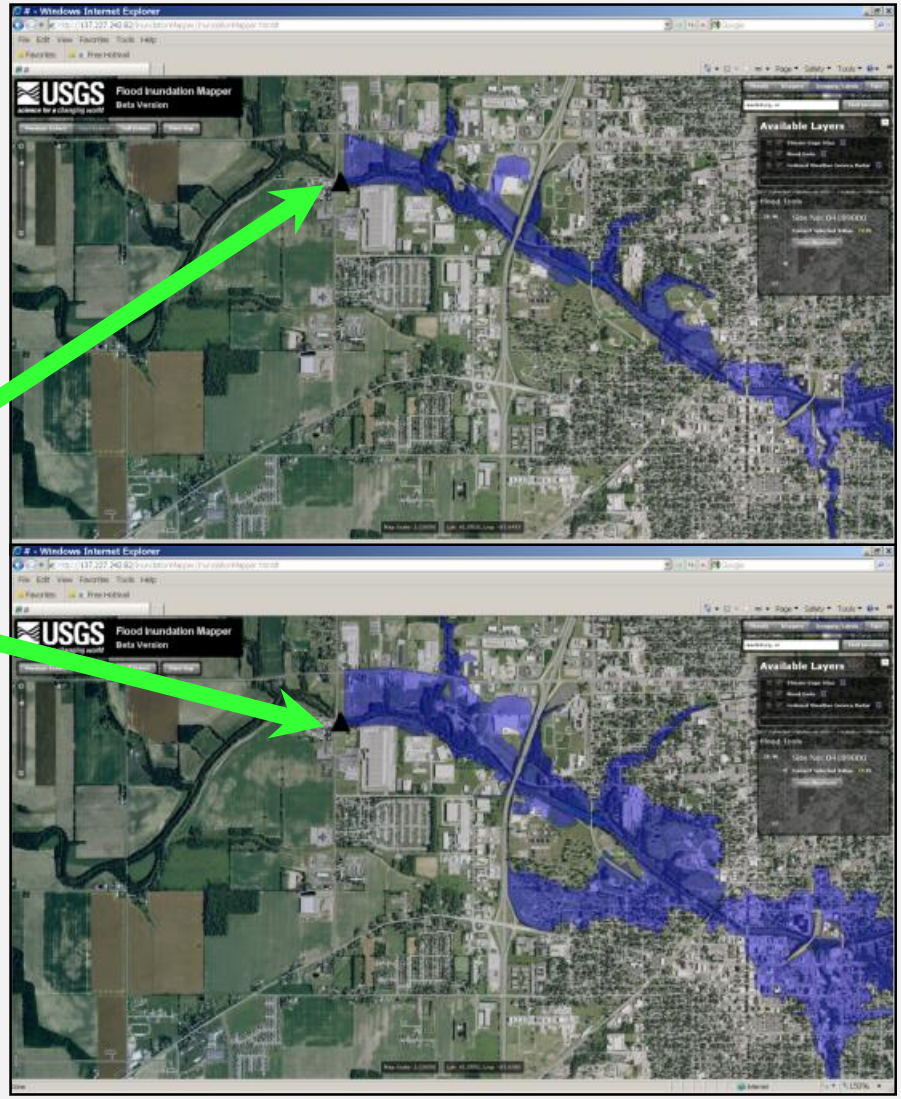
Deterministic Flood Inundation Map Libraries



- Based on even “slices” of stage or flow
- Any hydraulic model (calibrated to a USGS gage rating curve)
- Presents a full range of maps
  - Usually ~15 maps
  - From bankfull to peak of record
- Robust as long as base conditions don’t change

Flood inundation maps can translate a hydrograph into operational maps that communicate risk and consequences.





USGS

USGS and NWS Data Networks

Over 8,100 USGS Gages reporting current stream conditions in NWIS

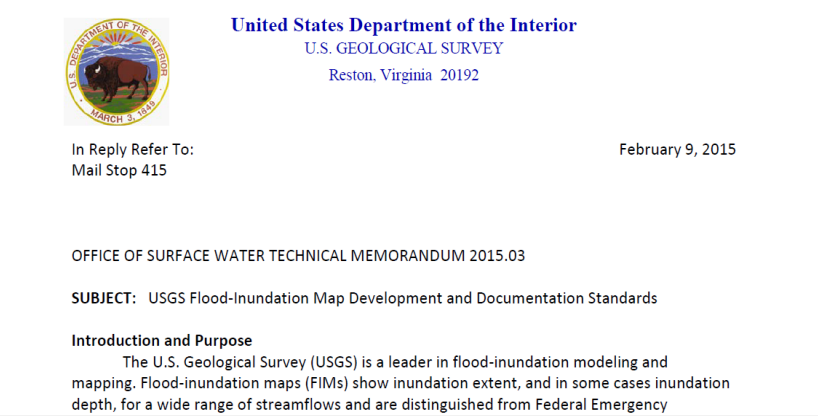
Over 4,000 NWS Flood Forecast/Warning locations in AHPS

USGS

Surface Water Tech Memorandum 2015.03

USGS Flood-Inundation Map Development and Documentation Standards

- At a USGS gage
- Starts with NWS guidelines but with 10 exceptions/additions
- Documentation
- Peer-review



United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

In Reply Refer To:
Mail Stop 415

February 9, 2015

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2015.03

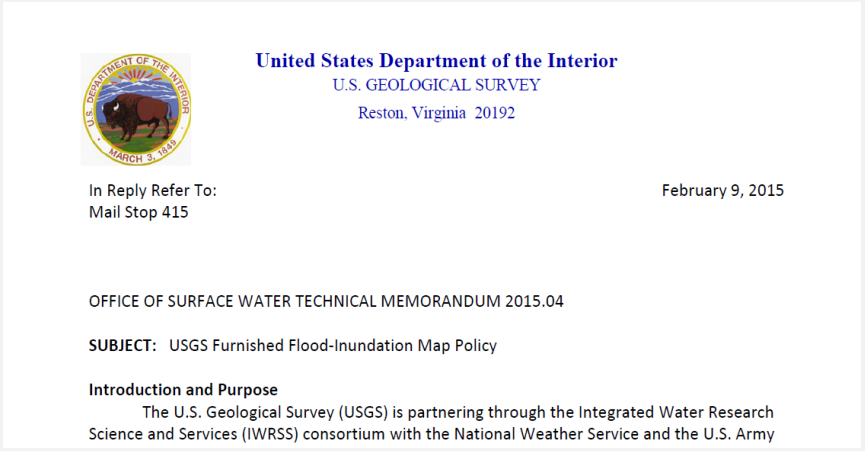
SUBJECT: USGS Flood-Inundation Map Development and Documentation Standards

Introduction and Purpose

The U.S. Geological Survey (USGS) is a leader in flood-inundation modeling and mapping. Flood-inundation maps (FIMs) show inundation extent, and in some cases inundation depth, for a wide range of streamflows and are distinguished from Federal Emergency

Surface Water Tech Memorandum 2015.04

- **USGS Furnished Flood-Inundation Map Policy**
- **First approved in Idaho, Dec, 2015**
- **At a USGS gage**
- **Meets USGS Requirements**
- **Work with local USGS Water Science Center**



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Reston, Virginia 20192

In Reply Refer To:
Mail Stop 415

February 9, 2015

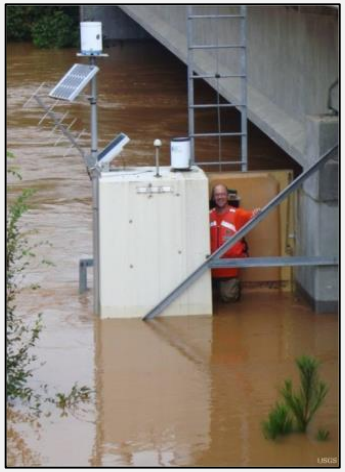
OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2015.04

SUBJECT: USGS Furnished Flood-Inundation Map Policy

Introduction and Purpose

The U.S. Geological Survey (USGS) is partnering through the Integrated Water Research Science and Services (IWRSS) consortium with the National Weather Service and the U.S. Army

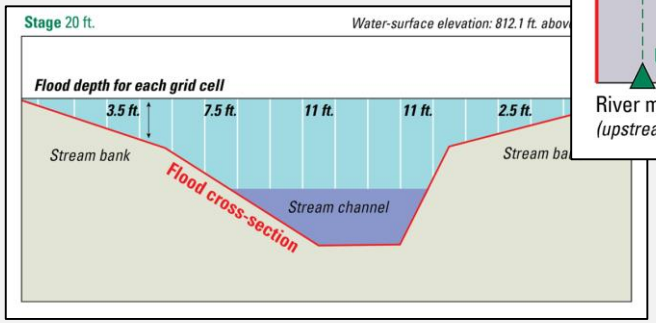
USGS FIM Program becomes a tool for flood…

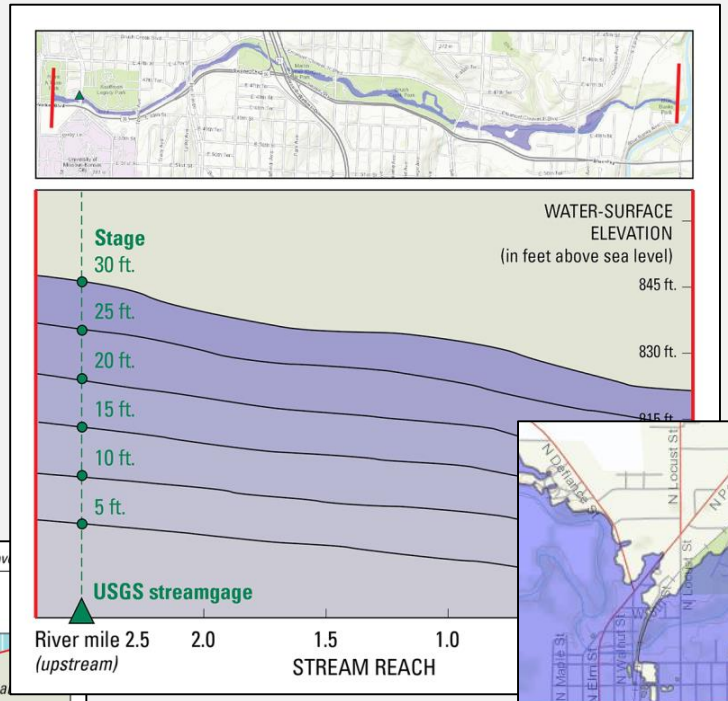


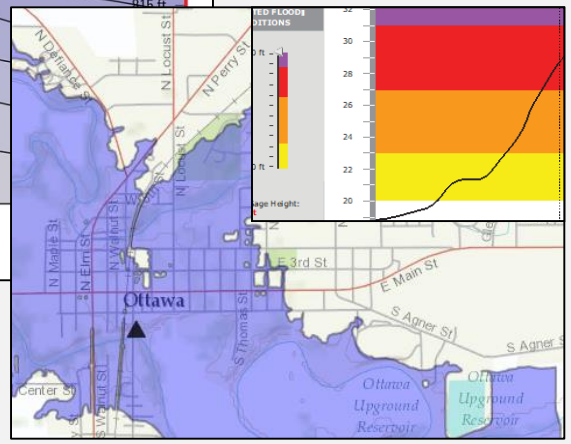
- Preparedness
  - "What-if" scenarios
- Response
  - Tied to gage & forecast data
- Recovery
  - Damage assessment
- Mitigation & planning
  - Flood risk analyses
- Environmental & ecological assessments

USGS Flood Inundation Map Libraries Workflow

1. Stream Selection
2. Gather Data
3. Model Flood Heights
4. Delineate Flood Extents
5. Compute Flood Depths
6. Process Map Library
7. Publication

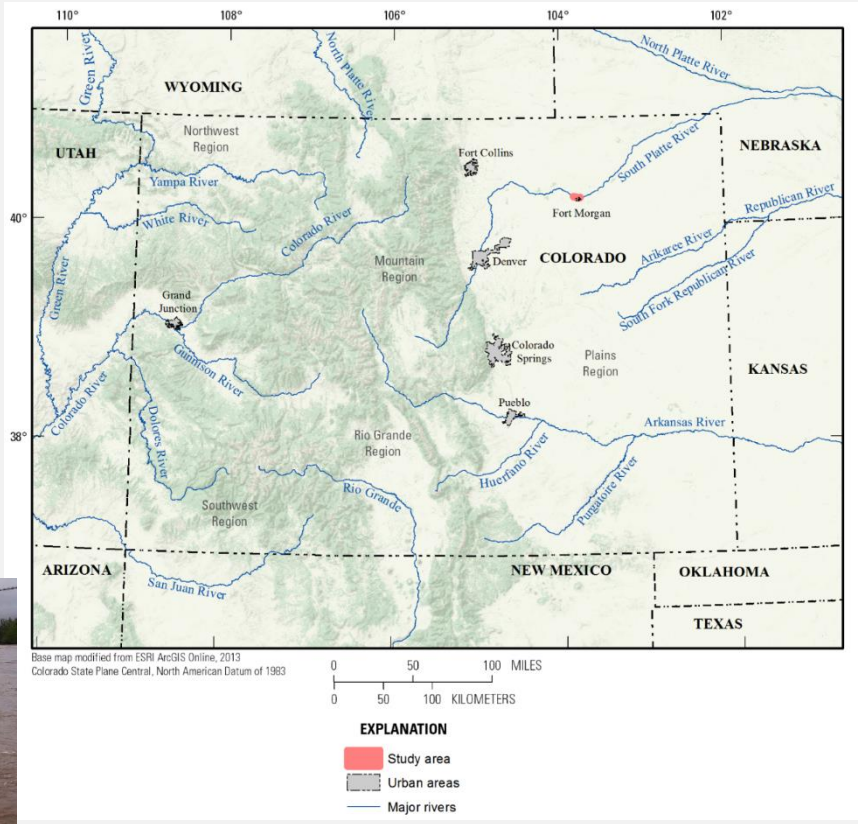






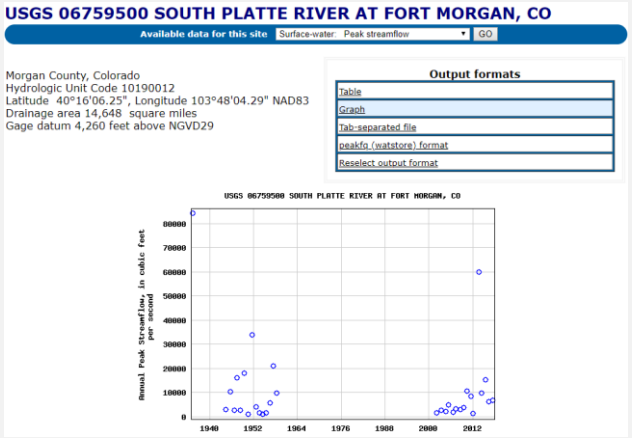
1. Stream Selection

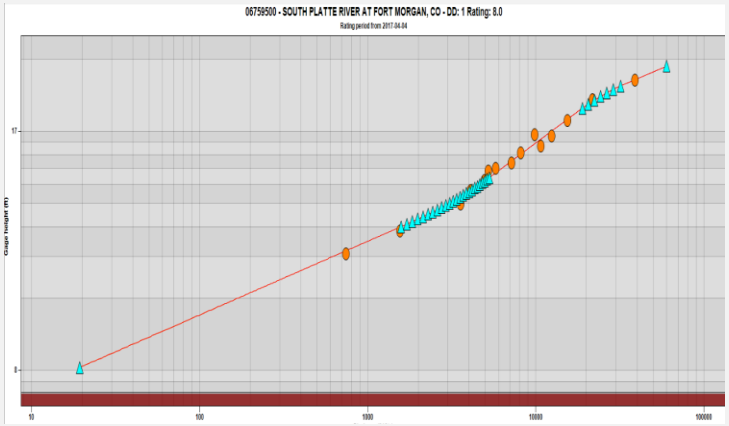
- Streamflow information
- Flood forecast information
- Elevation data availability
  - Topography
  - Bathymetry
  - Structural surveys
- Flood impact locations
  - Critical infrastructure
  - Populations



2. Gather Data

- **Real-time streamflow information from a gage within the selected reach**
  - **Historical flood levels at that gage**
  - **Current and historical rating curves at that gage**
  - **Additional flood stage data within the reach**

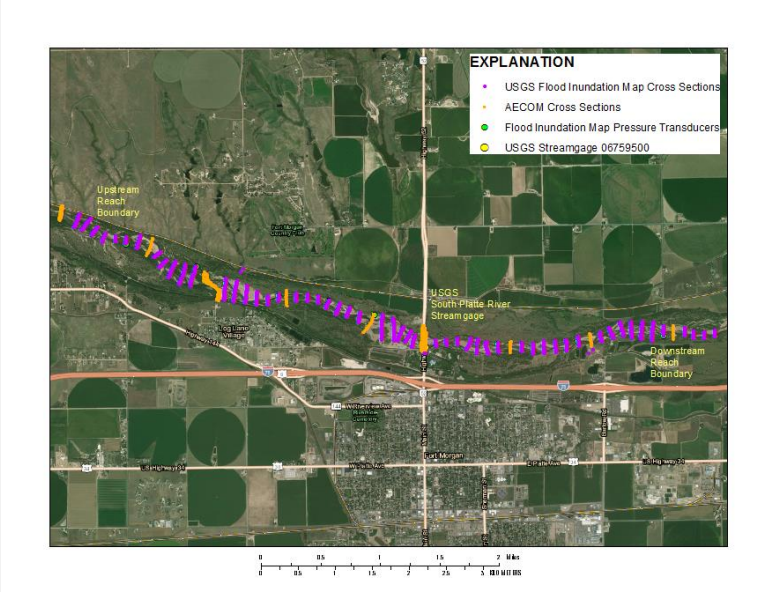


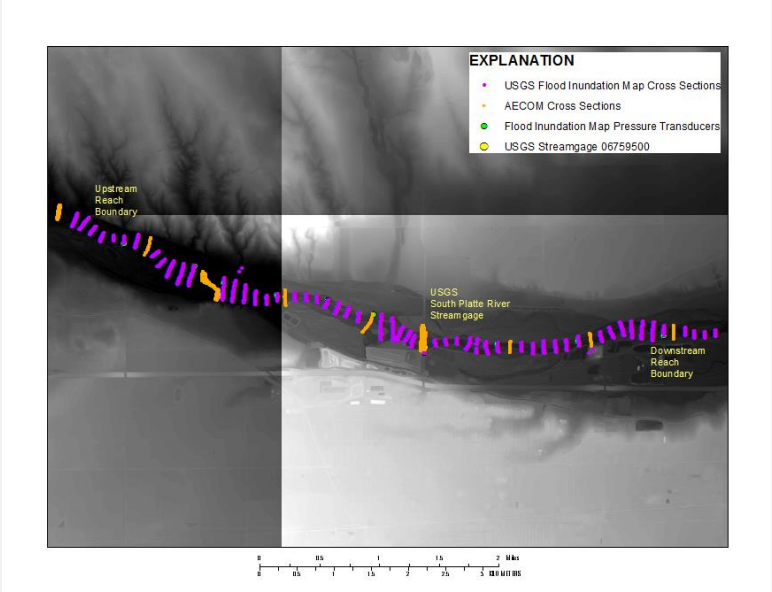


USGS

2. Gather Data

- **High-resolution elevation data (dictates the quality of the maps more than any other factor)**
- **Existing hydraulic models (if available and recent)**

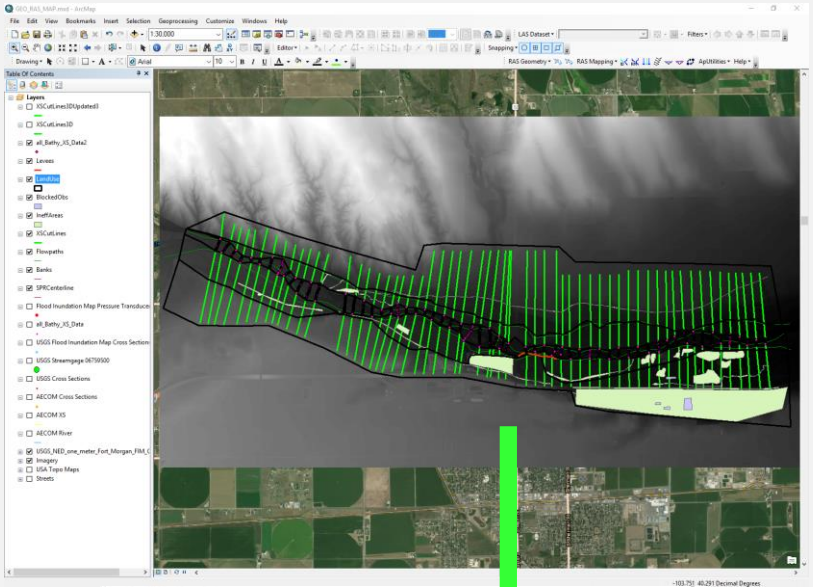


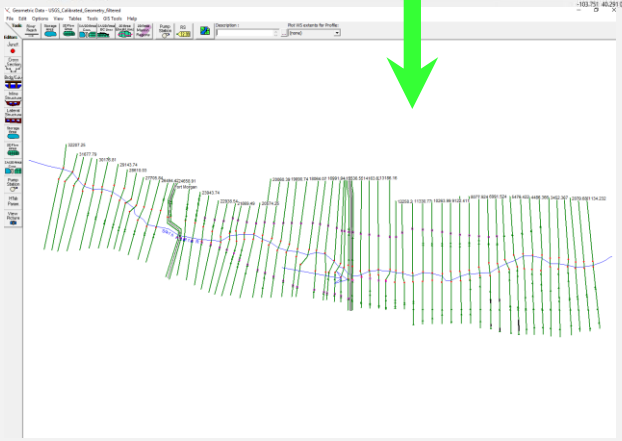


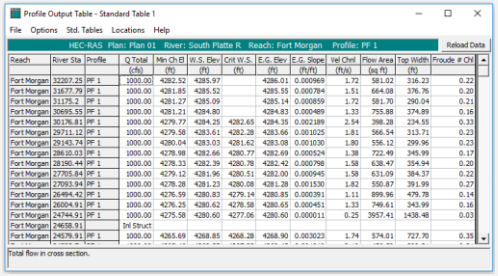
3. Model Flood Heights

Hydraulic Modeling

- Any appropriate model is accepted.
  - USACE HEC-RAS is common
  - Model must be peer-reviewed and documented.
- Calibrate model to streamgage record and topography
  - Well-developed rating curves are crucial.



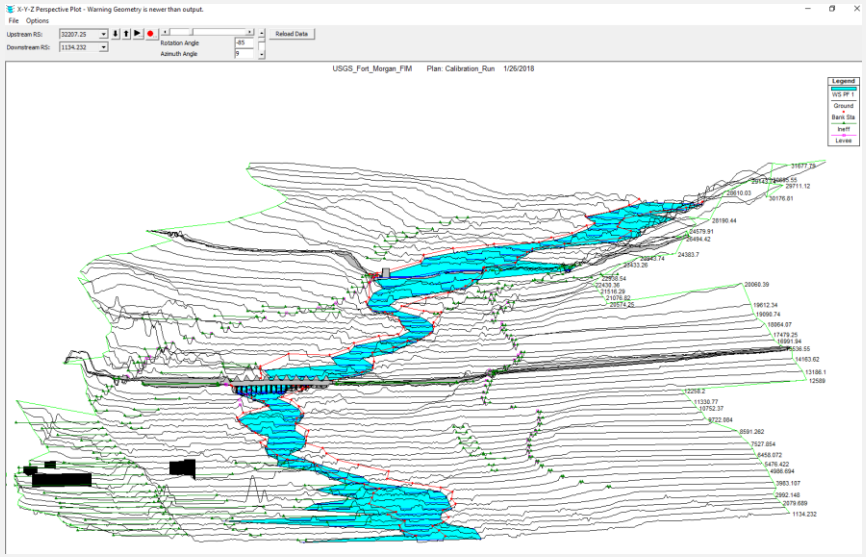




3. Model Flood Heights

Hydraulic Modeling

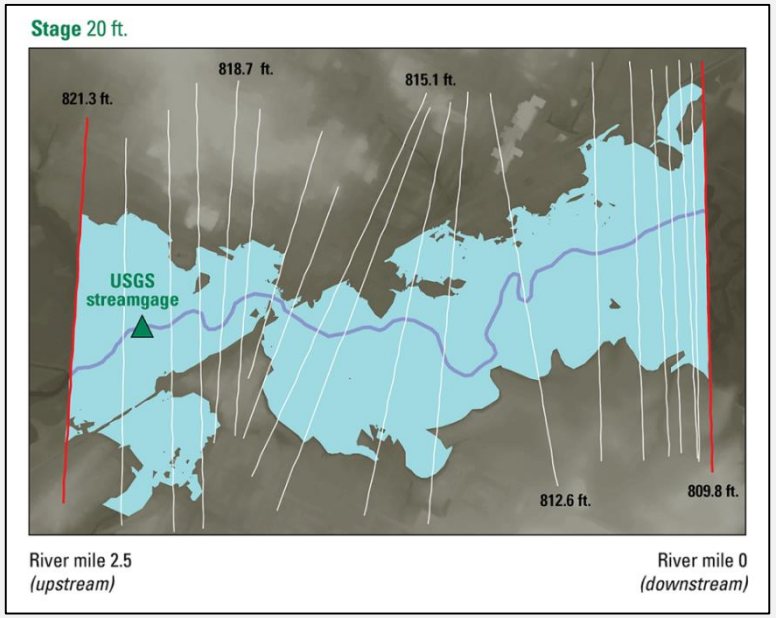
- Modeled flood scenarios are chosen to reflect local conditions (bridge conditions, levees, temporary structures, etc.).
- In highly complex flow situations, a 2D model or unsteady flow model might be warranted.



4. Delineate Flood Extents

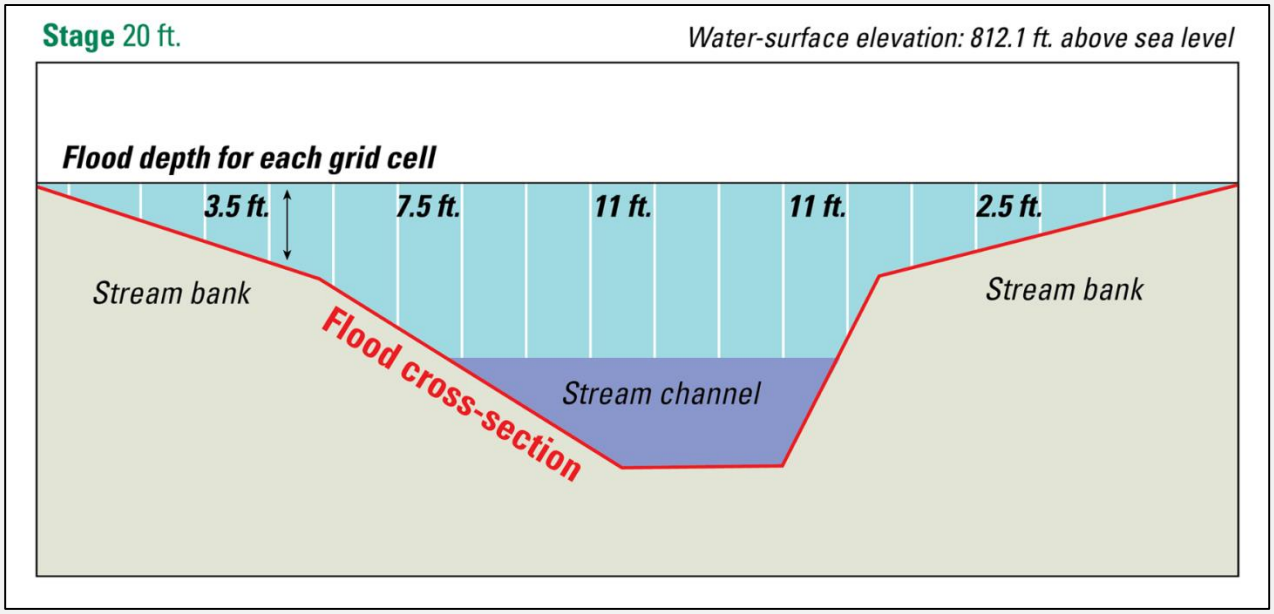
Geospatial Processing

- Create TIN models using cross sections and the modeled water surface profile.
- Intersect the TIN with the DEM to generate predicted inundated areas depth grids.
- Clean up and QA data.
- Repeat for all modeled water surface profiles to generate a library of maps.



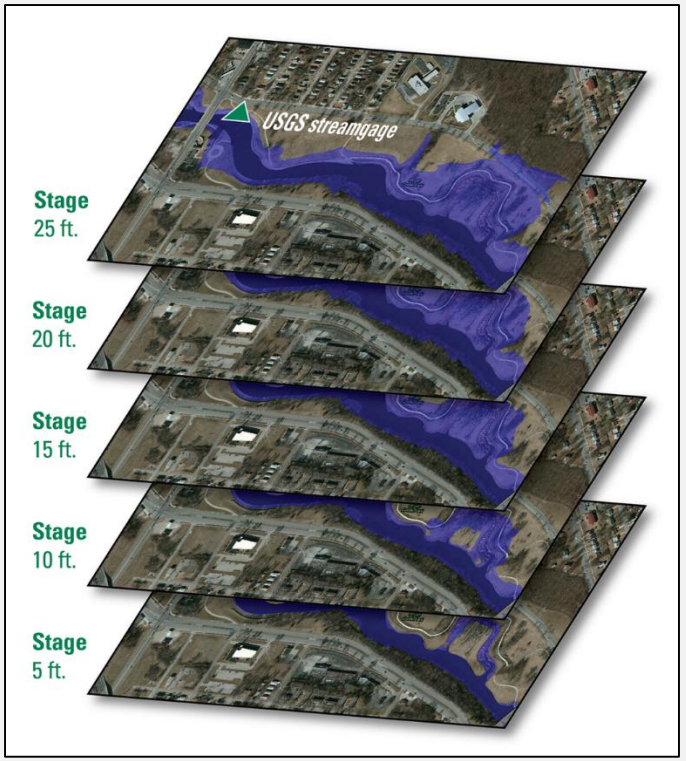
5. Compute Flood Depths

- **Flood extents are processed with the topographic data to produce estimated depths across the floodplain.**



6. Process Map Library

- The series of flood inundation maps are incorporated into the USGS Flood Inundation Mapper Website.
- Maps are overlaid onto city maps to aid in planning and response.
- Maps, data, and corresponding report must complete USGS review process prior to public dissemination.



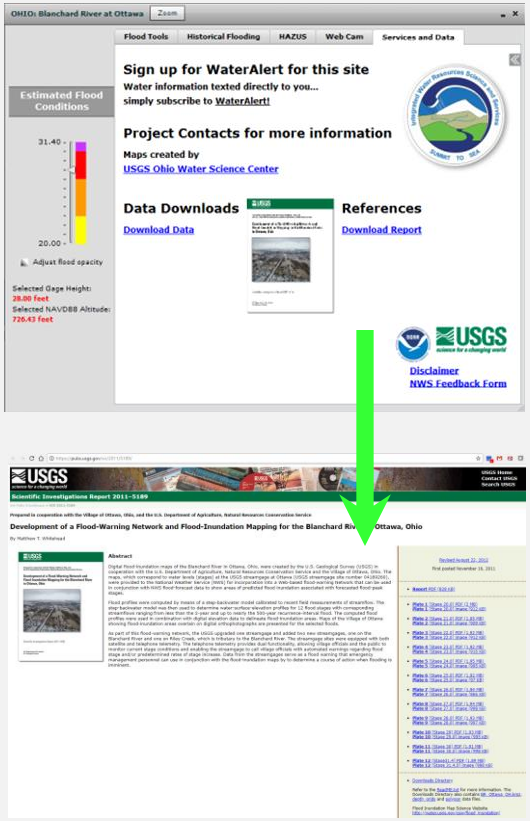
USGS

7. Publication

- **Publicly available on the USGS Flood Inundation Mapper:**

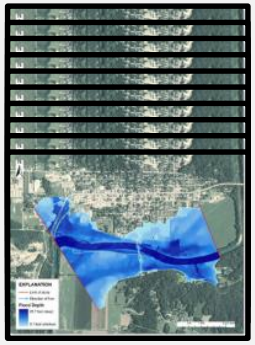
https://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html

  - **Final Report**
    - **Study area and scope**
    - **Hydraulic model calibration and performance**
    - **Accuracy assessment**
    - **Uncertainty and use limitations**
  - **Hydrologic data**
  - **GIS FIM layers with metadata**
  - **Hydraulic model**



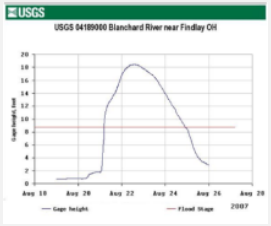
USGS FIM Mapper – more than just maps

Turns the modeled map data into an operational tool by combining data together with tools that enhance the utility and don't require any modeling or GIS software or skills.



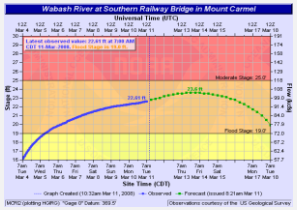
Flood Library

+

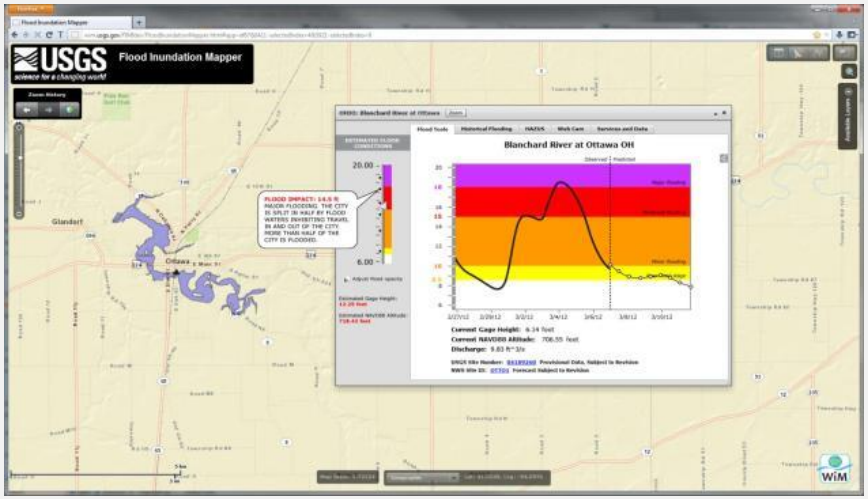


USGS Real-time streamgage

+



NWS Flood Forecast

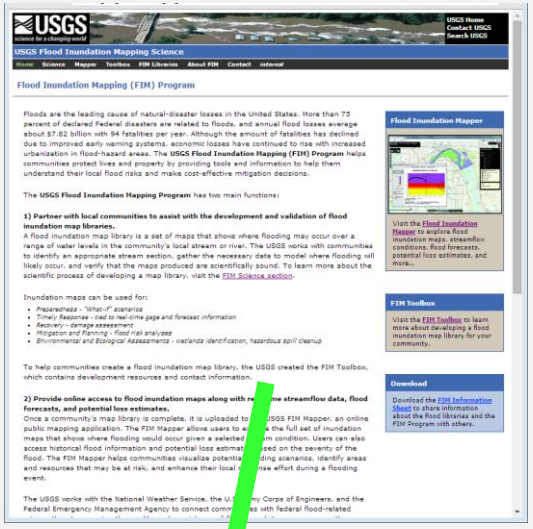


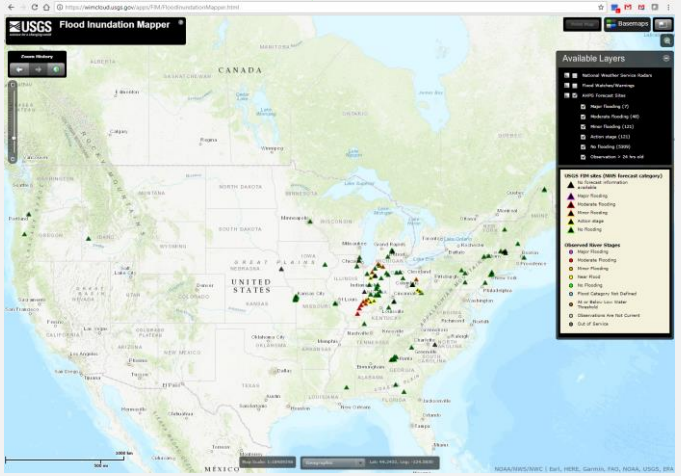
USGS FIM Program Website

https://water.usgs.gov/osw/flood_inundation/

- Outline of FIM Science and library development processes
  - Toolbox
- Information Sheet
  - Two page pdf
- Mapper
- Training
- Mobile-Friendly USGS FIM Mapper:

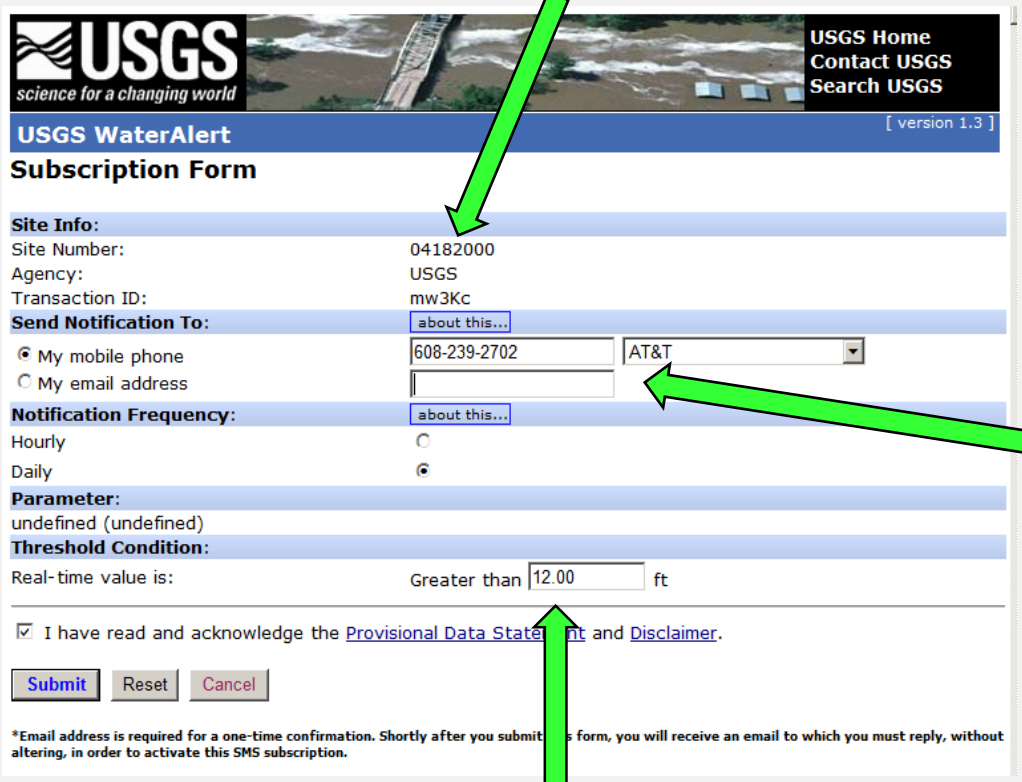
https://fim.wim.usgs.gov/fim/





WaterAlert form

Site number, sent by mapper



Contact info

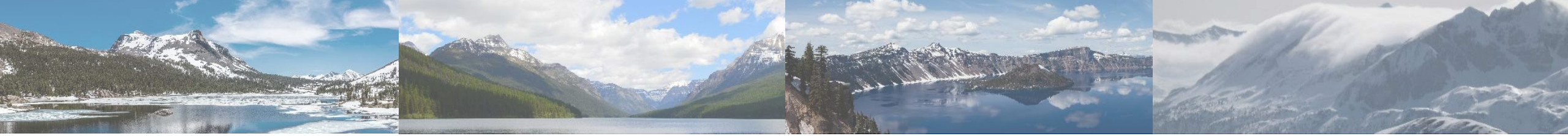
Threshold level, selected by mapper

USGS

Questions and Contact Information

Mike Kohn, P.E
USGS Colorado Water Science Center
mkohn@usgs.gov
303.236.6924

https://water.usgs.gov/osw/flood_inundation/

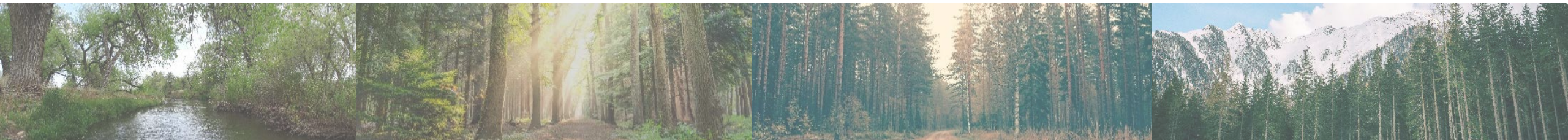


Projecting changes in future rainfall extremes across Colorado due to a changing climate

Page Weil, PE

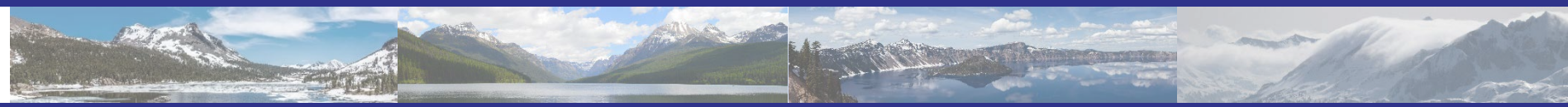
CASFM 2019

Lynker



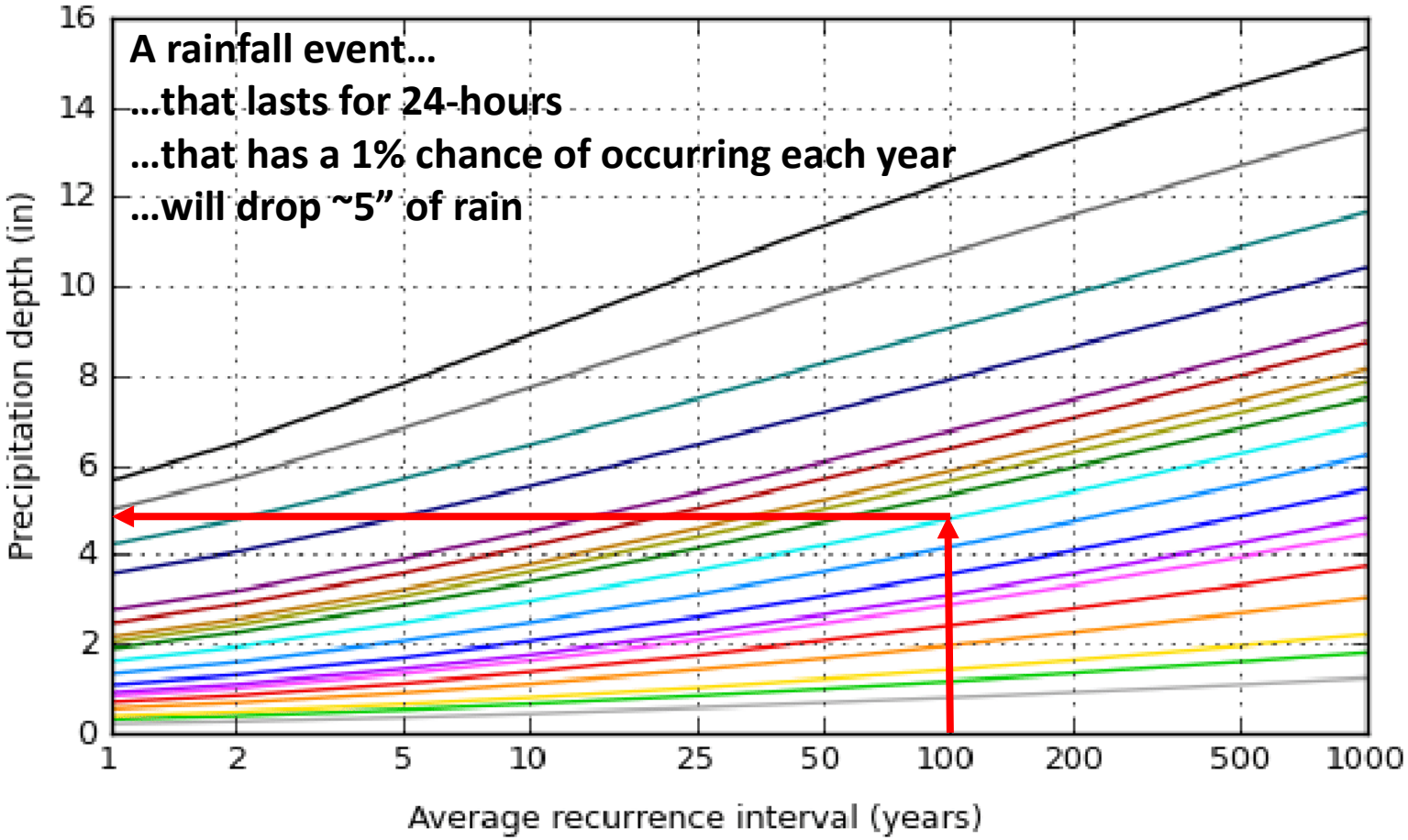
Motivating Question

How to put climate change adaptation tools into the hands of real practitioners?



Intensity-Duration-Frequency (IDF) Curves

- NOAA Atlas-14 Archive; CONUS-wide database of rainfall intensities. Includes estimates at ungaged sites.
- Starting point for many H&H designs (MHFD)

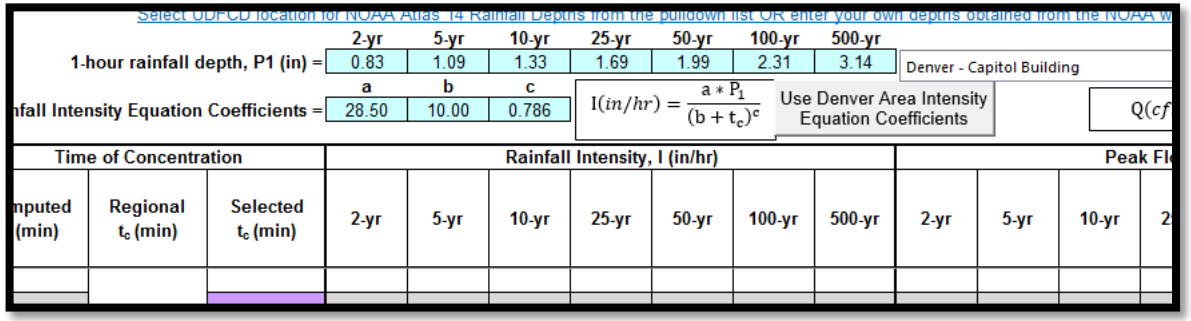


IDF Curve at Stapleton Airport Station

Hydraulic Structure Design

- Design Frequency ≈ Safety Margin

- H&H designs are often performed:
  - 1. Calculate discharge for storm of design intensity/duration/frequency
  - 2. Determine optimal culvert size
  - 3. Specify the use of the next largest size



Select UDFCD location for NOAA Atlas 14 Rainfall Depths from the pulldown list OR enter your own depths obtained from the NOAA w

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	
1-hour rainfall depth, P1 (in) =	0.83	1.09	1.33	1.69	1.99	2.31	3.14	Denver - Capitol Building
	a	b	c					
nfall Intensity Equation Coefficients =	28.50	10.00	0.786	$I(in/hr) = \frac{a * P_1}{(b + t_c)^c}$		Use Denver Area Intensity Equation Coefficients		Q(cf

Time of Concentration			Rainfall Intensity, I (in/hr)							Peak Fl			
nputed (min)	Regional t_c (min)	Selected t_c (min)	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	2

MHFD H&H Design Tool for “Rational Method”

Table 7.2 Table of Design Frequencies

Drainage Type		Frequency
A.	Cross Drainage	
	Multilane Roads - including interstate	
	In Urban Areas	100-year*
	In Rural Areas	50-year
	Two-Lane Roads	
	In Urban Areas	100-year
	In Rural Areas	
	Q_{50} : ≥ 4000 cfs	50-year
	Q_{50} < 4000 cfs	25-year
	Culvert Outlet Scour Protection	10-year
	Pedestrian Walkways and Bikeways	2 to 5-year
	Bridge Foundation Scour	100 and 500-year
B.	Parallel Drainage	
	Roadway Overtopping and Revetment	Same as for Cross Drainage
	Side Drains	2 to 10-year#
C.	Storm Drains	
	Major System	100-year
	Minor System	2 to 5-year
D.	Detour Culverts	monthly discharges for 2 to 5-year

Notes: *Urban cross culverts (not Interstate); if Q_{100} < 100 cfs, consider designing the culvert using the storm drain Minor System Frequency.
#Side drains shall not cause water to flow onto the highway at a greater probability than applies to cross drainage.

CDOT Drainage Design Manual, Chapter 7

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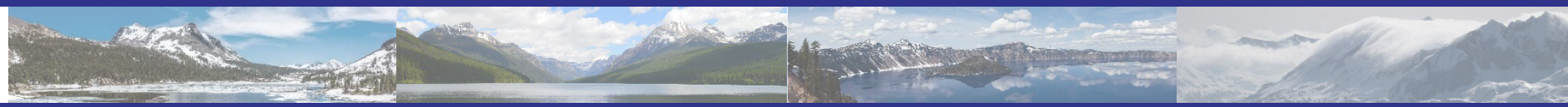
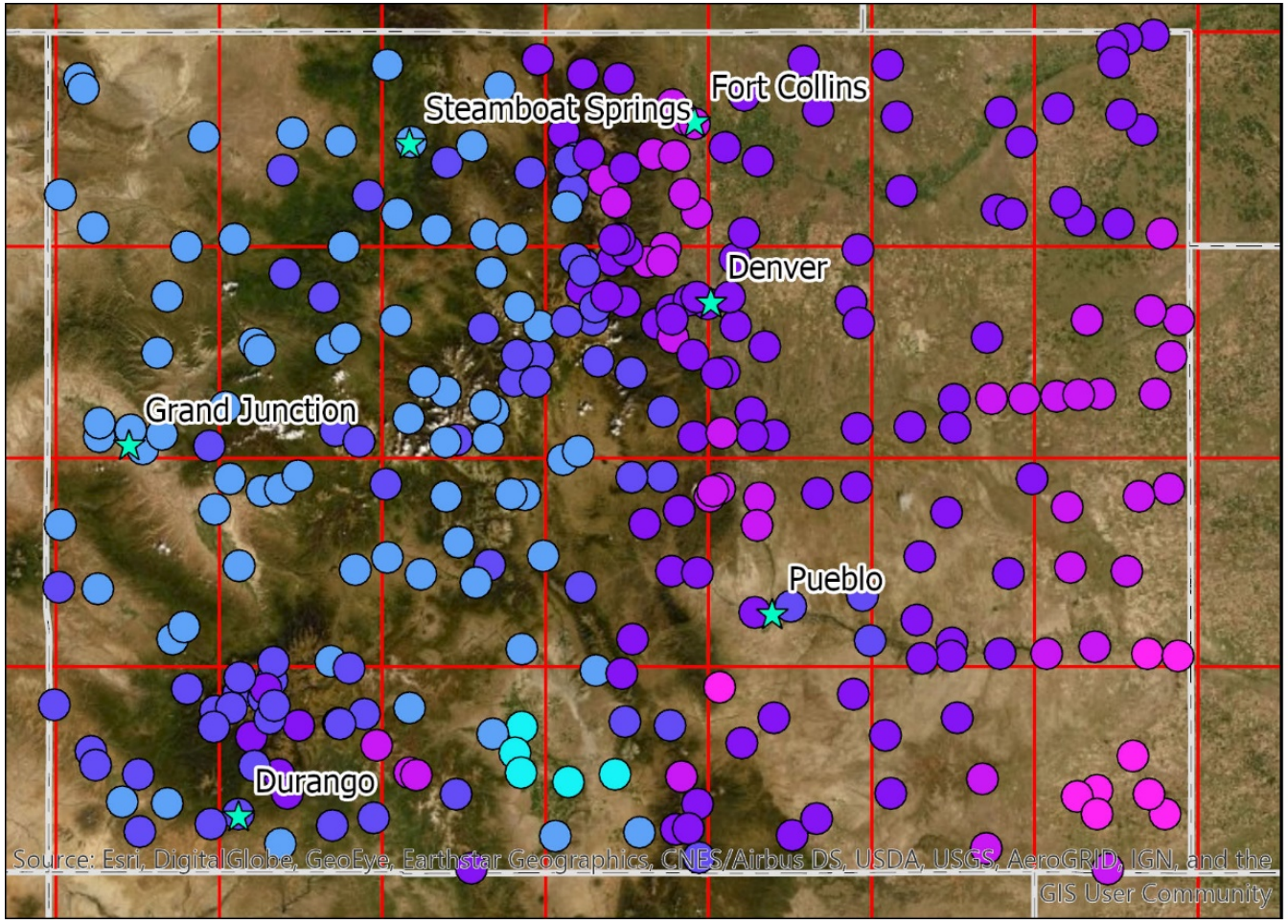


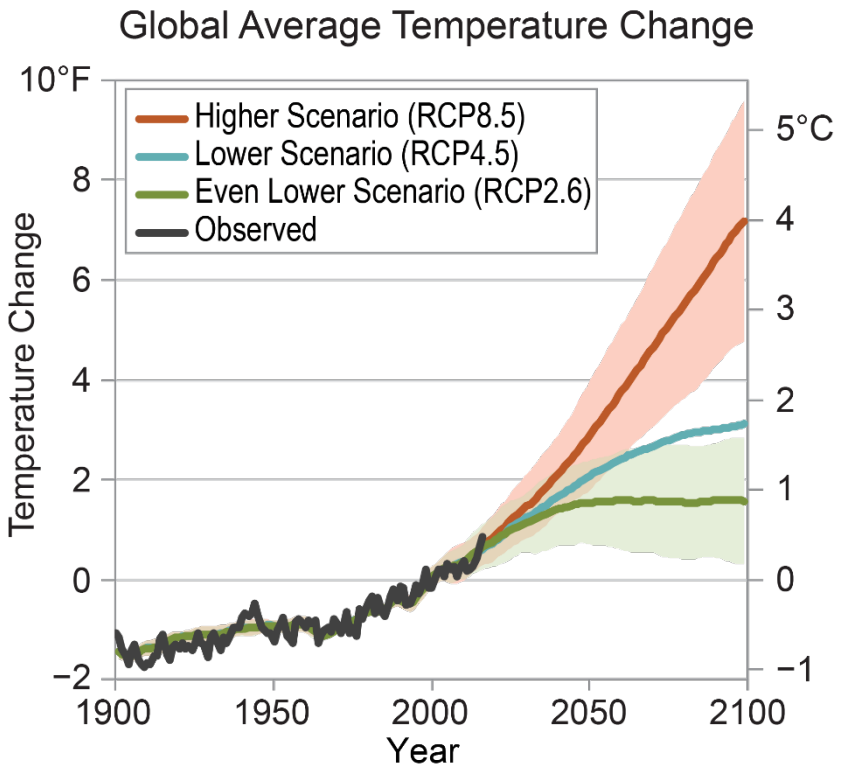
CO Stations Studied

- 100-year 24-hour event depth (inches in 24 hours)
- Global Climate Model Grid



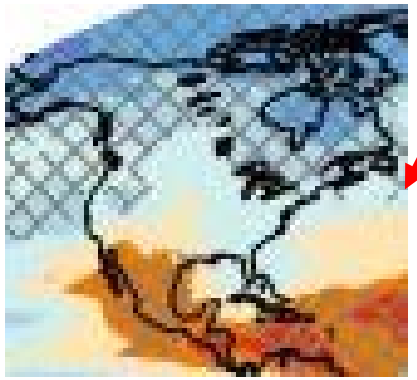
Climate Change Is Happening

Where We Are:

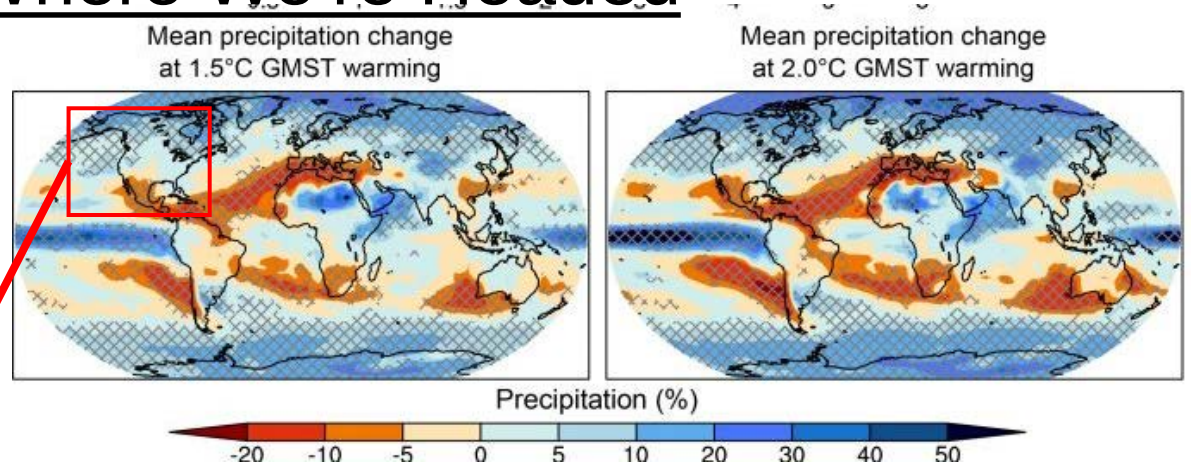


IPCC 2015, National Climate Assessment, 2018

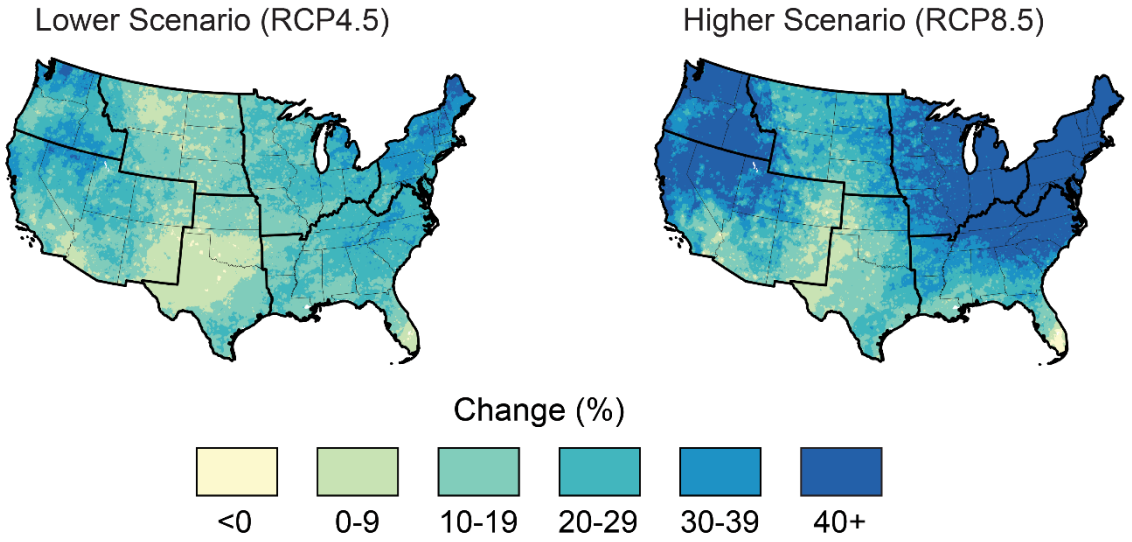
Mean rainfall change is uncertain, peak rainfall is different



Where We're Headed



Projected Change in Total Annual Precipitation Falling in the Heaviest 1% of Events by Late 21st Century



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Warmer Means Wetter

- For every 1°C increase in Temp, the atmosphere can hold 7% more water vapor

- Warmer Mean Temps mean...
  - …the atmosphere can hold more water vapor
  - …and more can fall as rain
  - …extreme events will become more intense/frequent

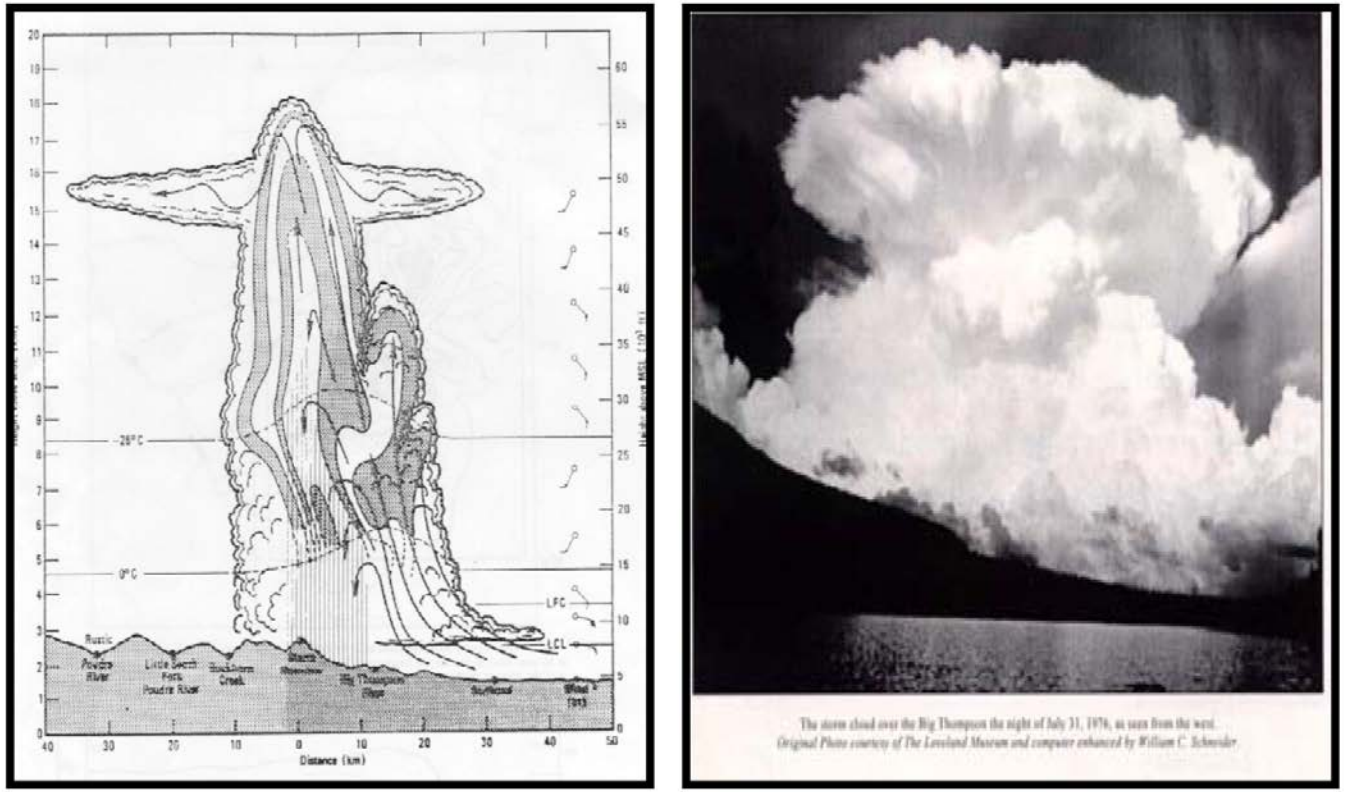
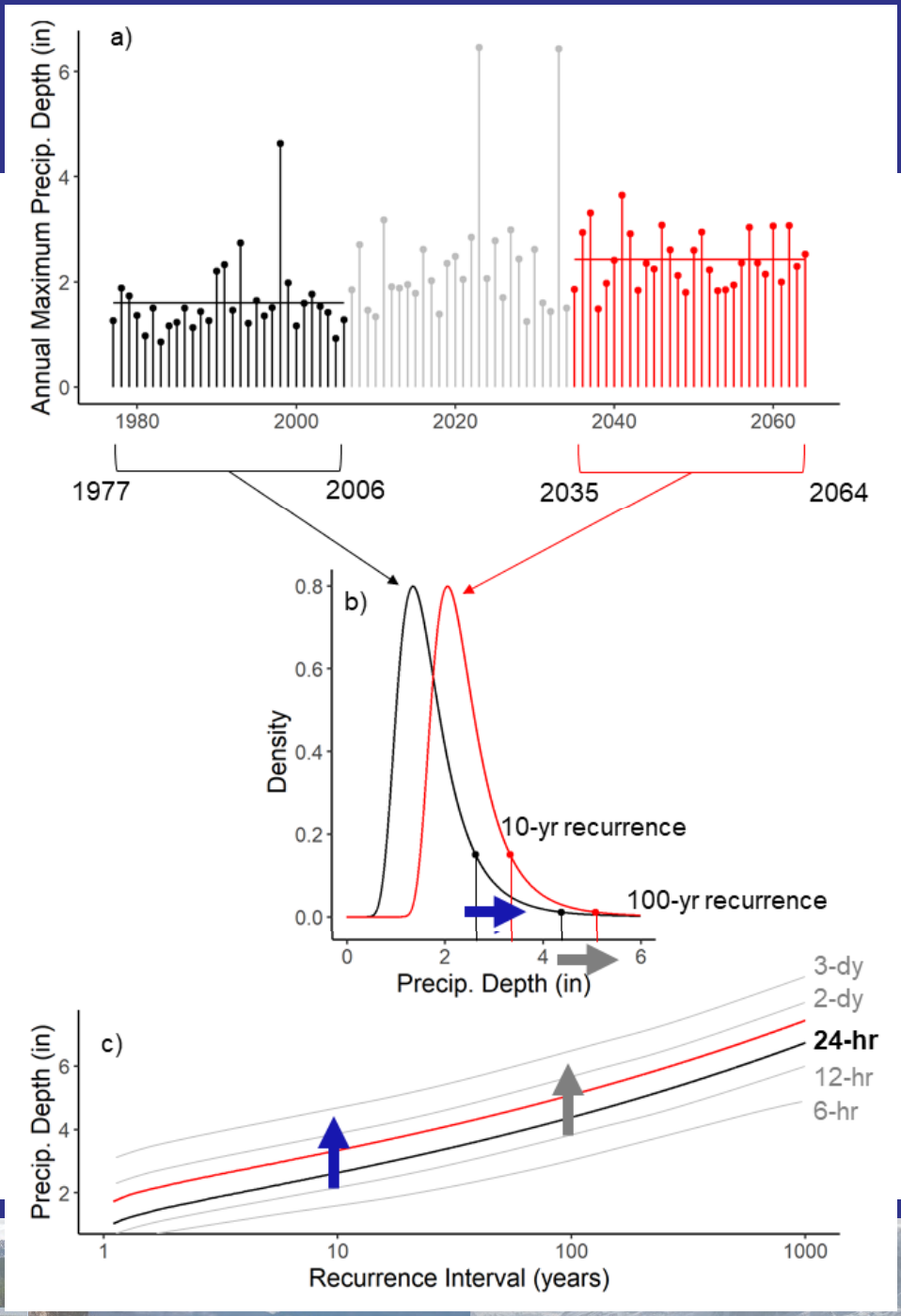


Figure 31: Actual Photo and Schematic of the Big Thompson Flash Flood Storm

Delta Method

- Extract Historic and Future Rainfall from GCM (24-hour event), ~3000 datapoints per grid cell
- Create historic and future distributions and extract relative change in event (ie, 100-year)
- Shift existing IDF curve by relative change



Change by Station (%)

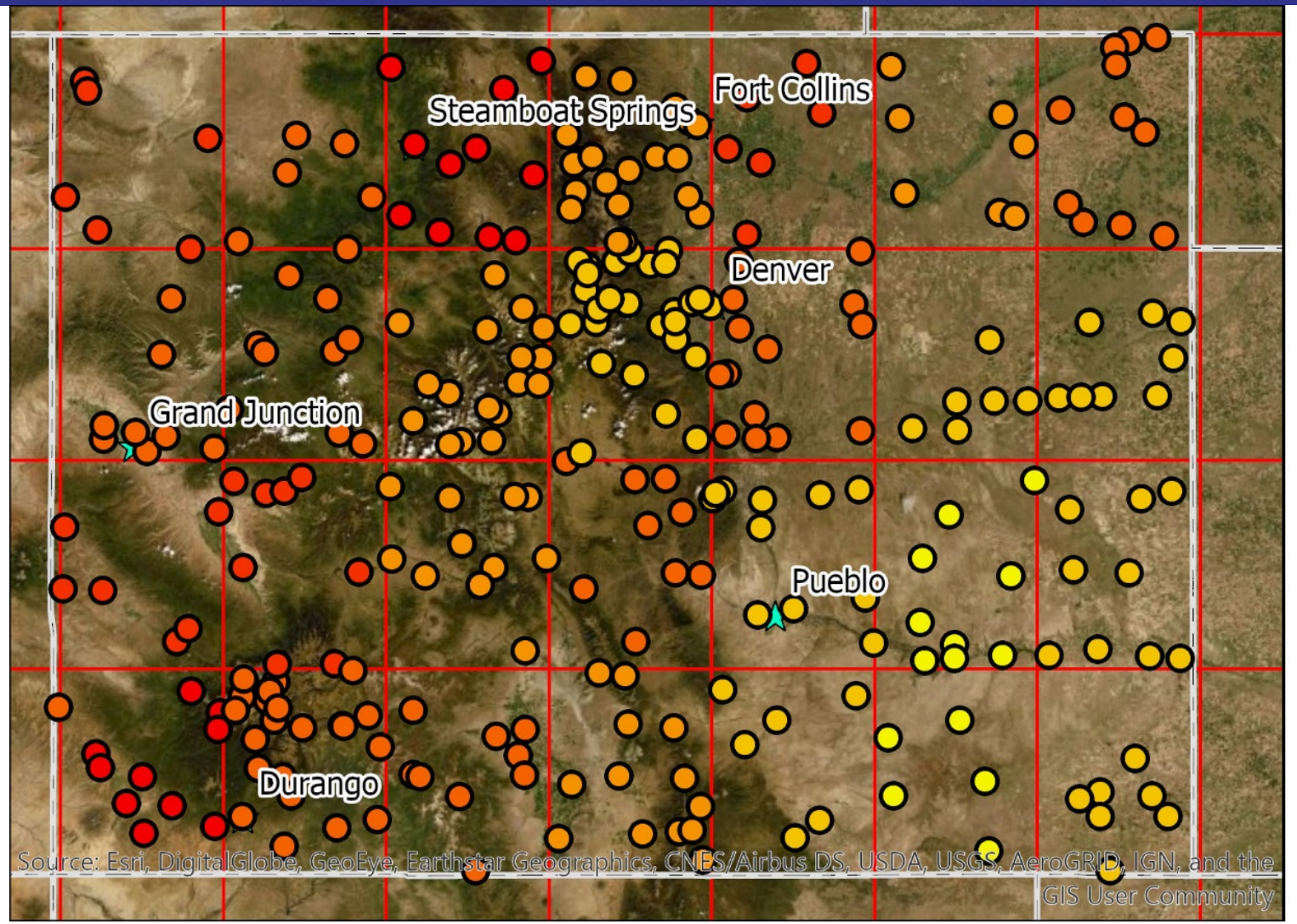
% Increase in 24-hour…

…100-year event

…at 2°C warming

Jumps at grid edges due to 1-degree cells.

Assessing other downscaling projects

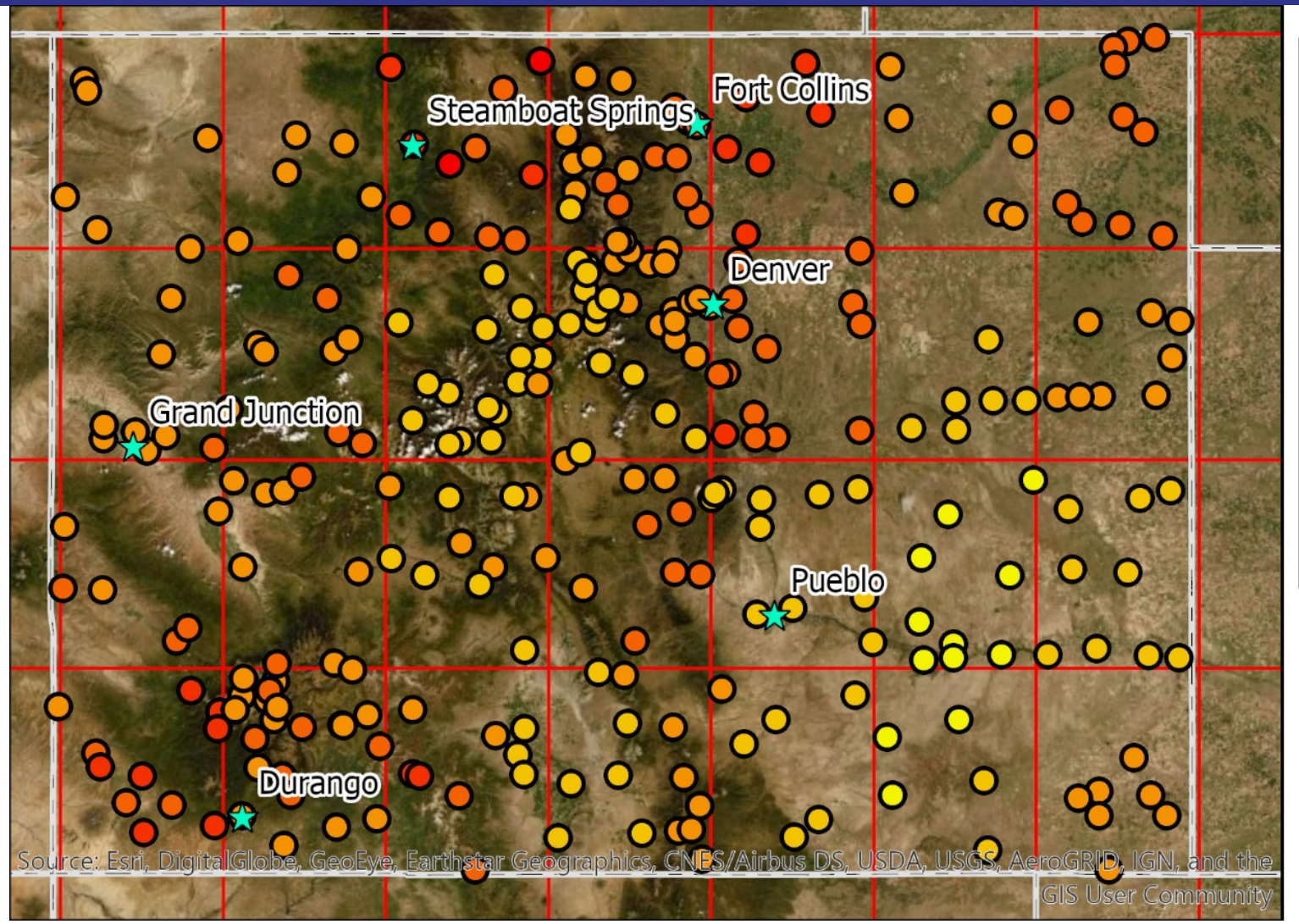


Lynker

Change by Station (inches)

Additional inches of rain…

- …during 24-hour
- …100-year event
- …at 2°C warming



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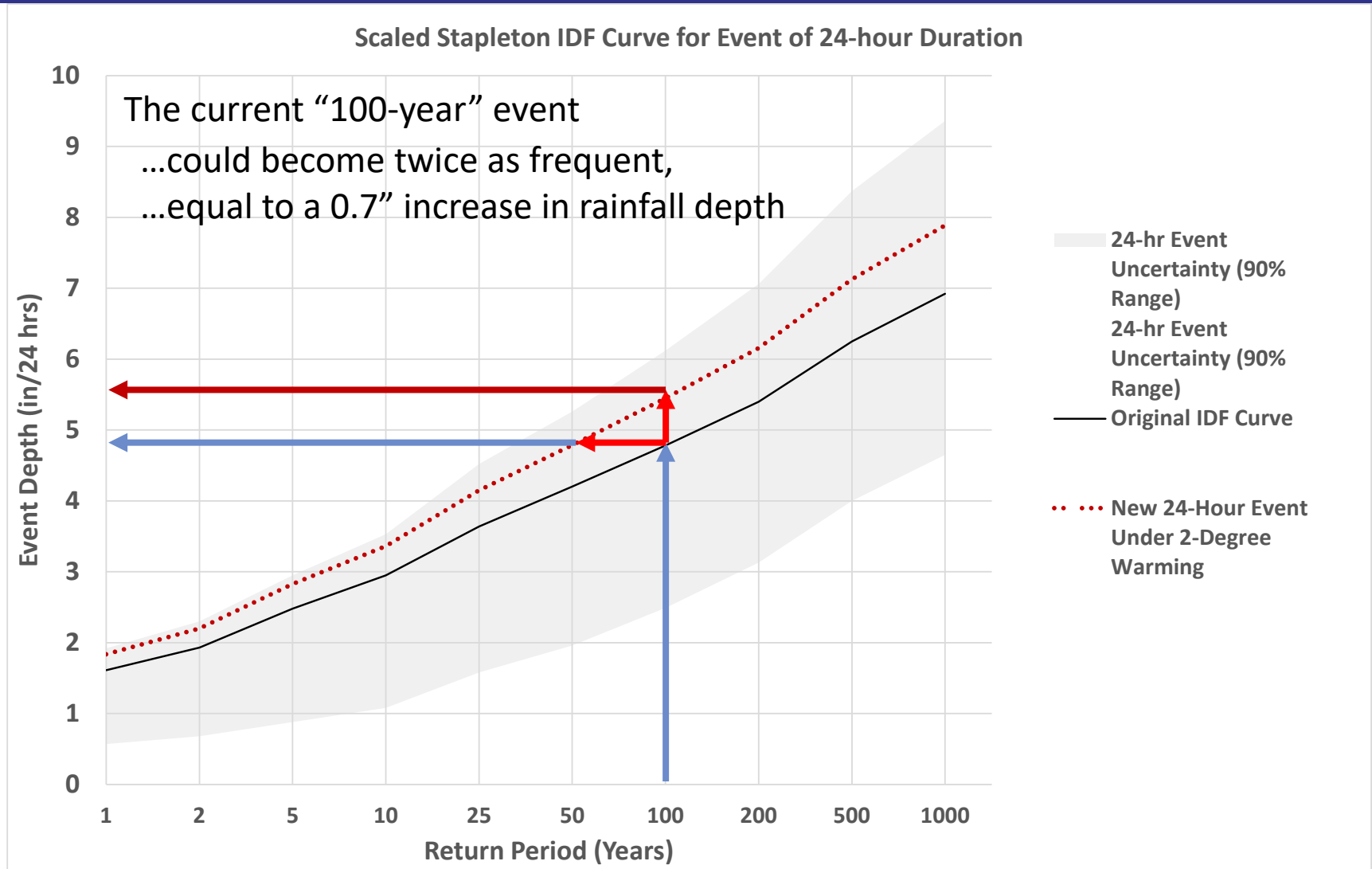
Point Results

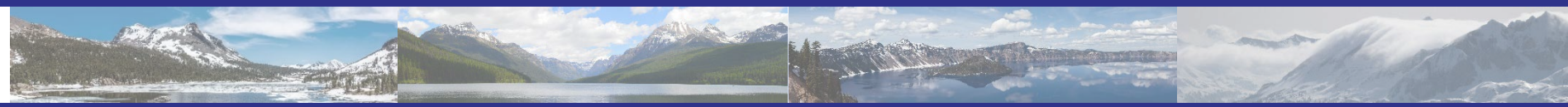
Stapleton Station

Climate change will shift estimates and error bounds.

Method extends to all event durations

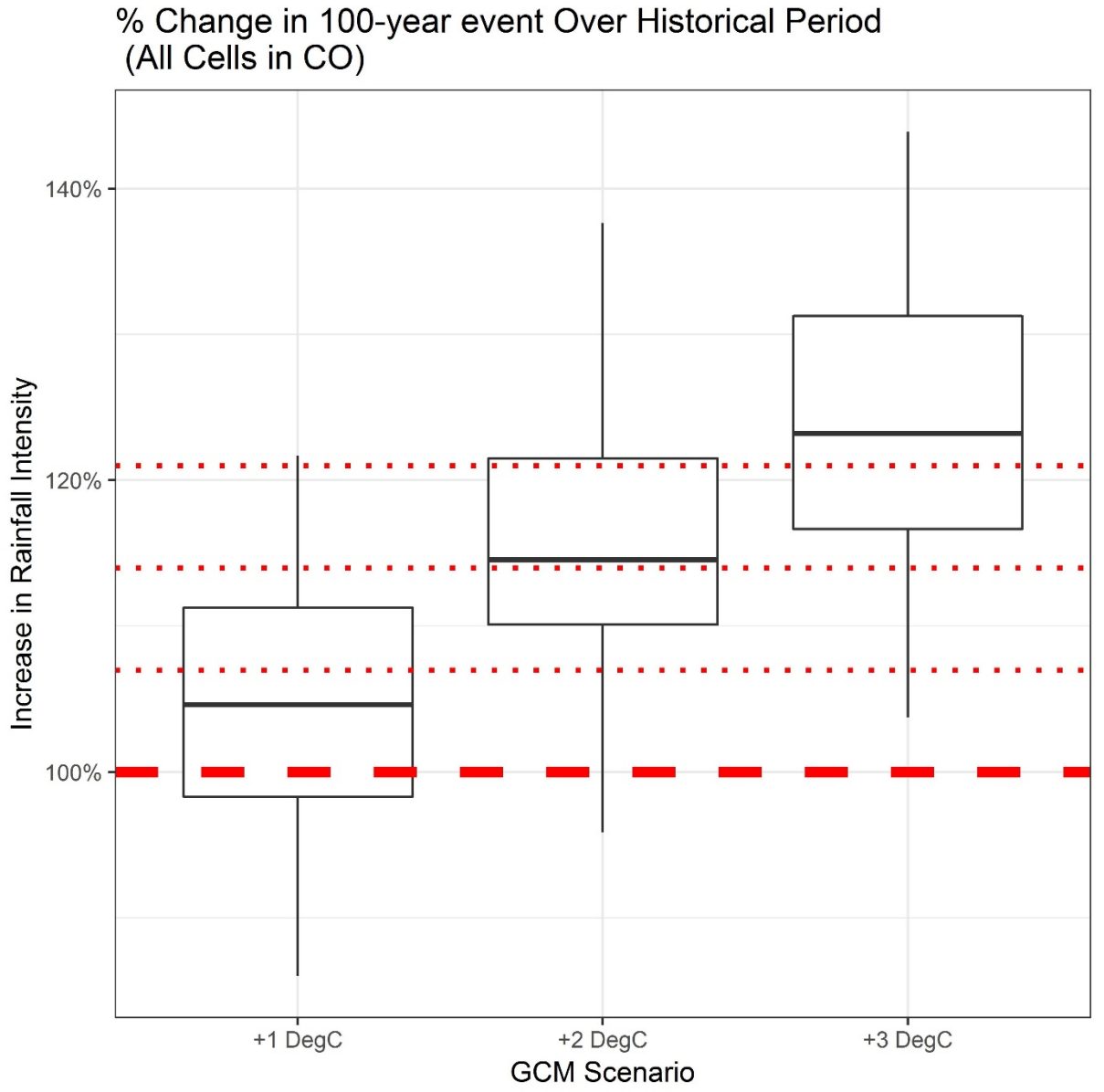
(5 min to 60 days)





Change in Extreme Rainfall by Scenario

- We use future global average temperature, not a future time period.
- Warmer models show larger increase aligned with 7% per degree warming



Implications of Frequency Shift

- Frequency-Based designs may be underestimating peak discharge
  - Critical facilities may be exposed to higher risk than expected
- New Designs can Incorporate Climate Adjustments in Frequency

Boulder Creek Normal Flow (<1-year event)

Boulder Creek, Sep 2013, 40-Year Flow Event

So What Do We Do?

Mitigation and Limiting Emissions are important but the earth is a big ship with a small rudder

Adaptation and Resiliency are how we move forward protecting our communities while the world wrestles with CO2 emissions.

Statewide Action: As of 2019, CWCB has recommended a 7% safety factor to be applied to PMP estimates for Dam Safety based on a “1-degree warmer world”.

How Can Designers Use This?

Local Mandate:

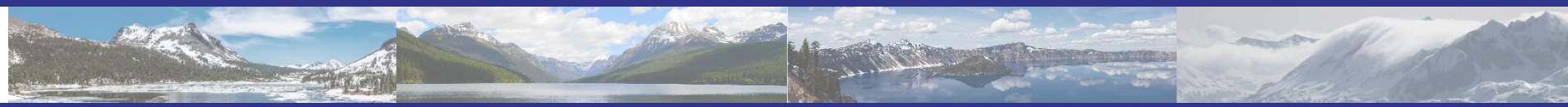
- Municipalities need to decide that climate change adaptation is a priority for their community.
- What facilities should include climate change adjustments in their design?

Local Action:

- Identify “No Regrets” actions (New Designs)
- Design decision by H&H engineers backed up by planning mandate.

Apply best available data:

- **IDF Curves:** NOAA Atlas 14, MHFD, others
- Projected event changes from CWCB project

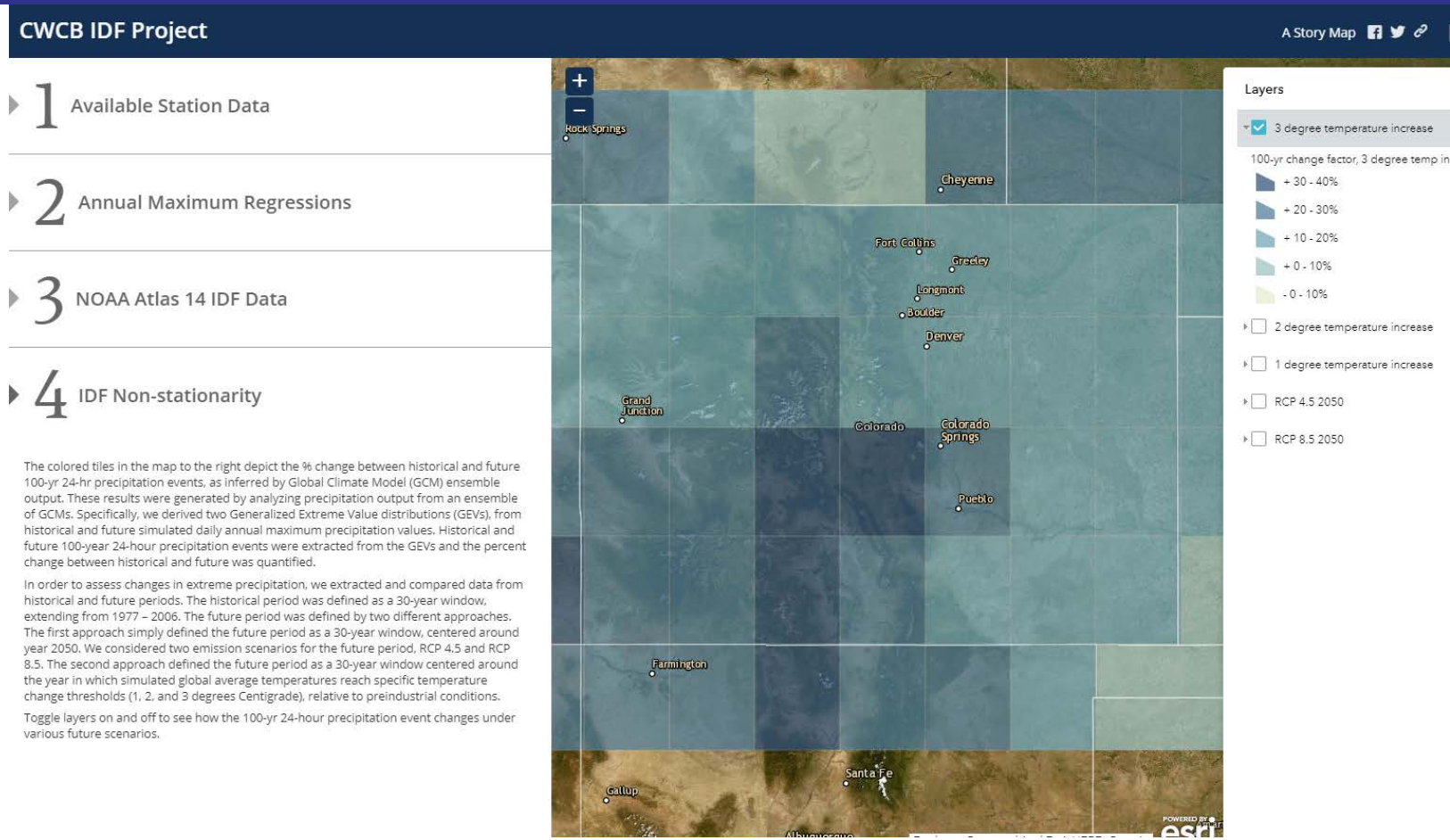


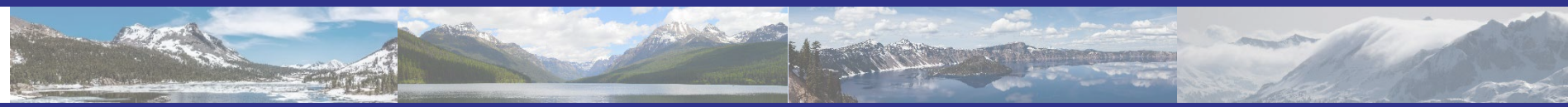
Gridded Results Browser

ArcGIS StoryMap with relative increases in 100-year, 24-hour events

CWCB next steps project

https://arcg.is/1KaW5S





Questions for you

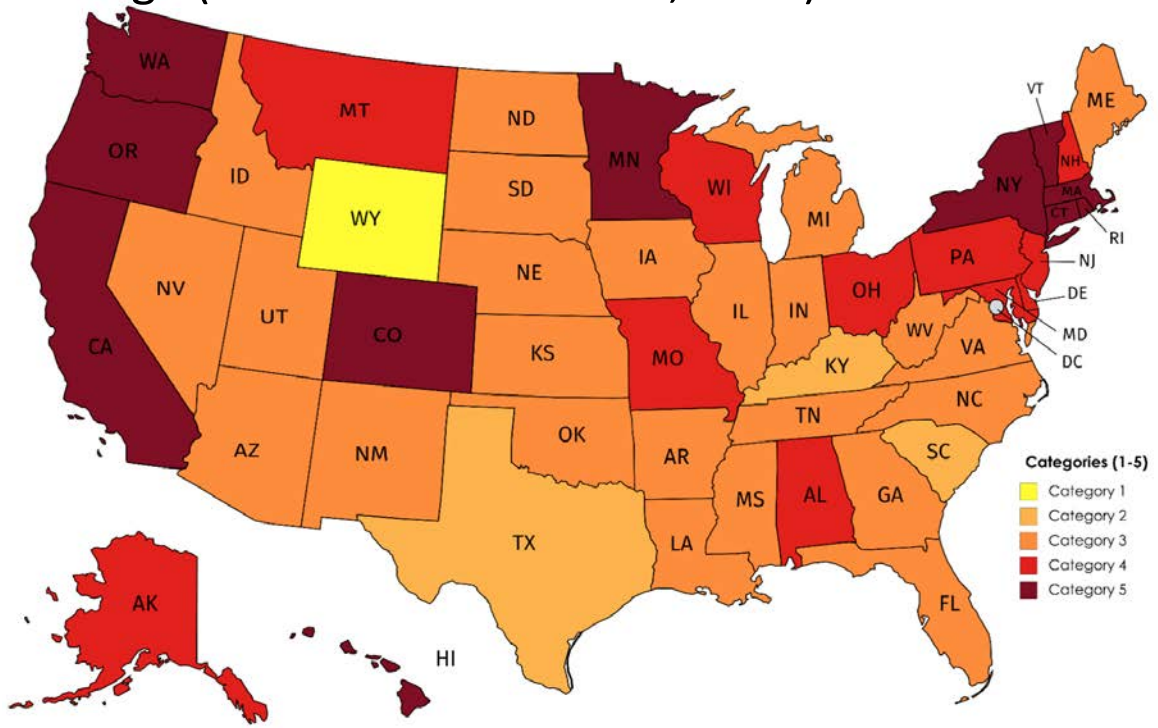
Is your local government considering climate change adaptation?

What tools do you need to present climate change risks in a way that is ~~politically sensitive~~ can reach your community?

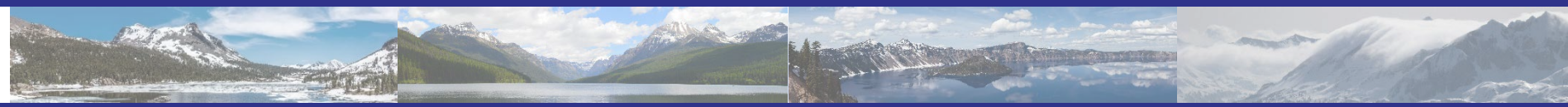
Questions for me?

Page Weil, PE
pweil@lynkertech.com

State Hazard Mitigation Plans that Include Climate Change (Columbia Law School, 2019)



Category 4 - Thorough discussion of climate change impacts on hazards with more inclusion of quantitative info. 18 States have this or better



Extra Slides

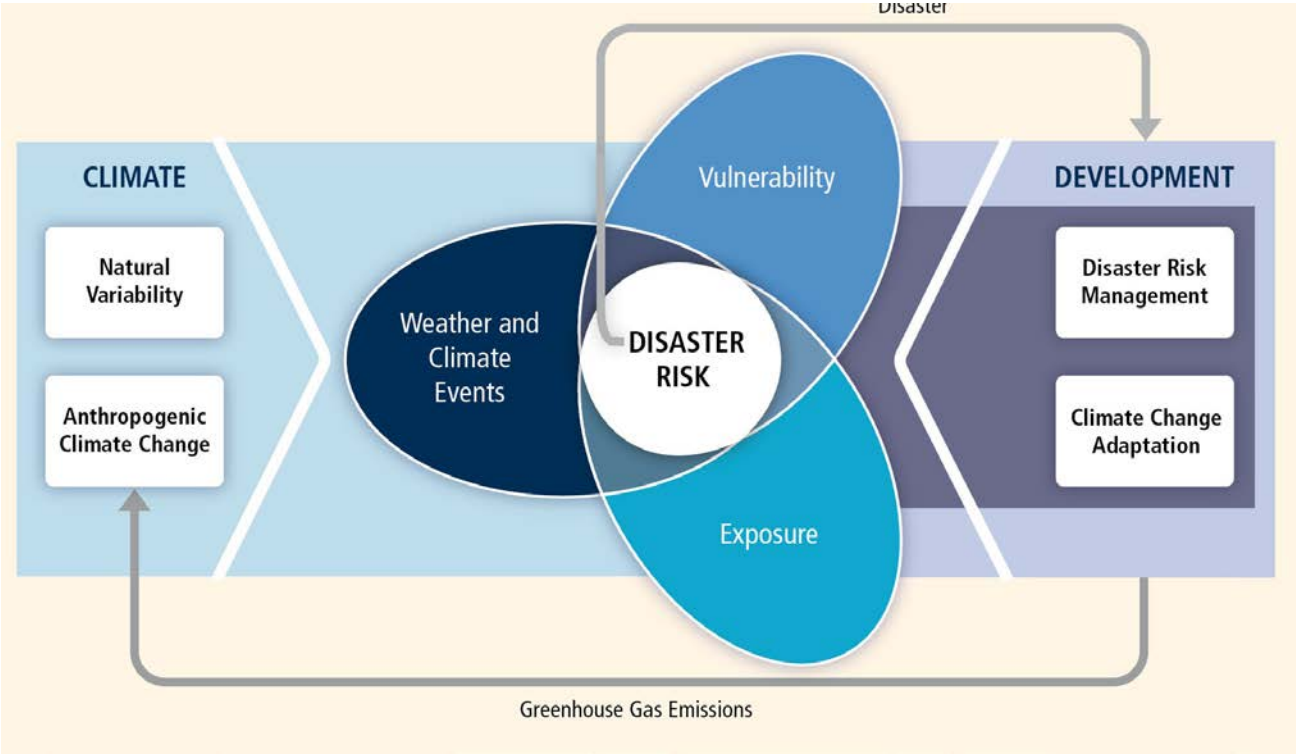



Motivation

- Risk
  - Hazard
  - Vulnerability

- Media coverage on Climate Change is inconsistent and the messages are muddled

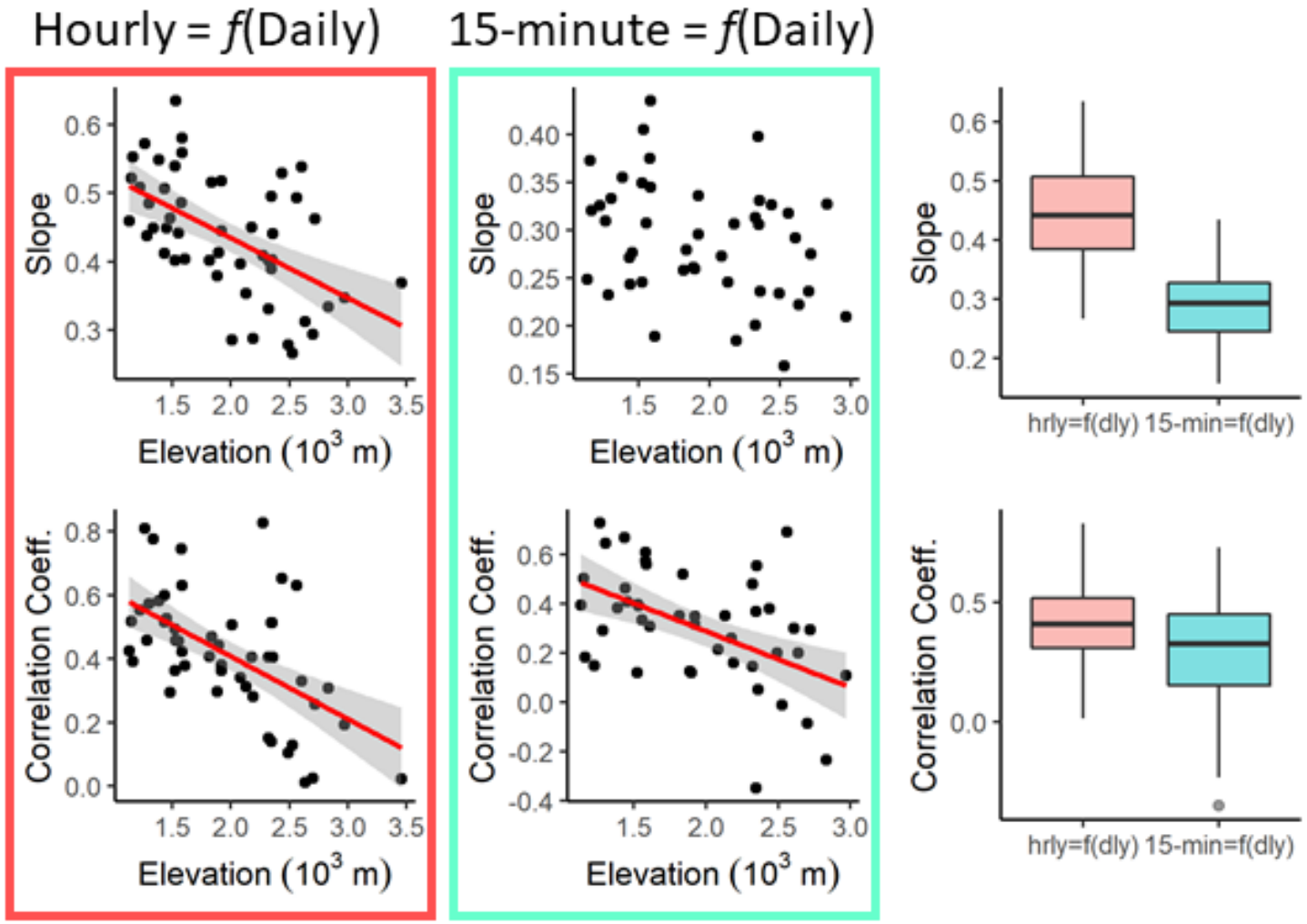
- What are some design criteria CO can consider when adapting to climate change?



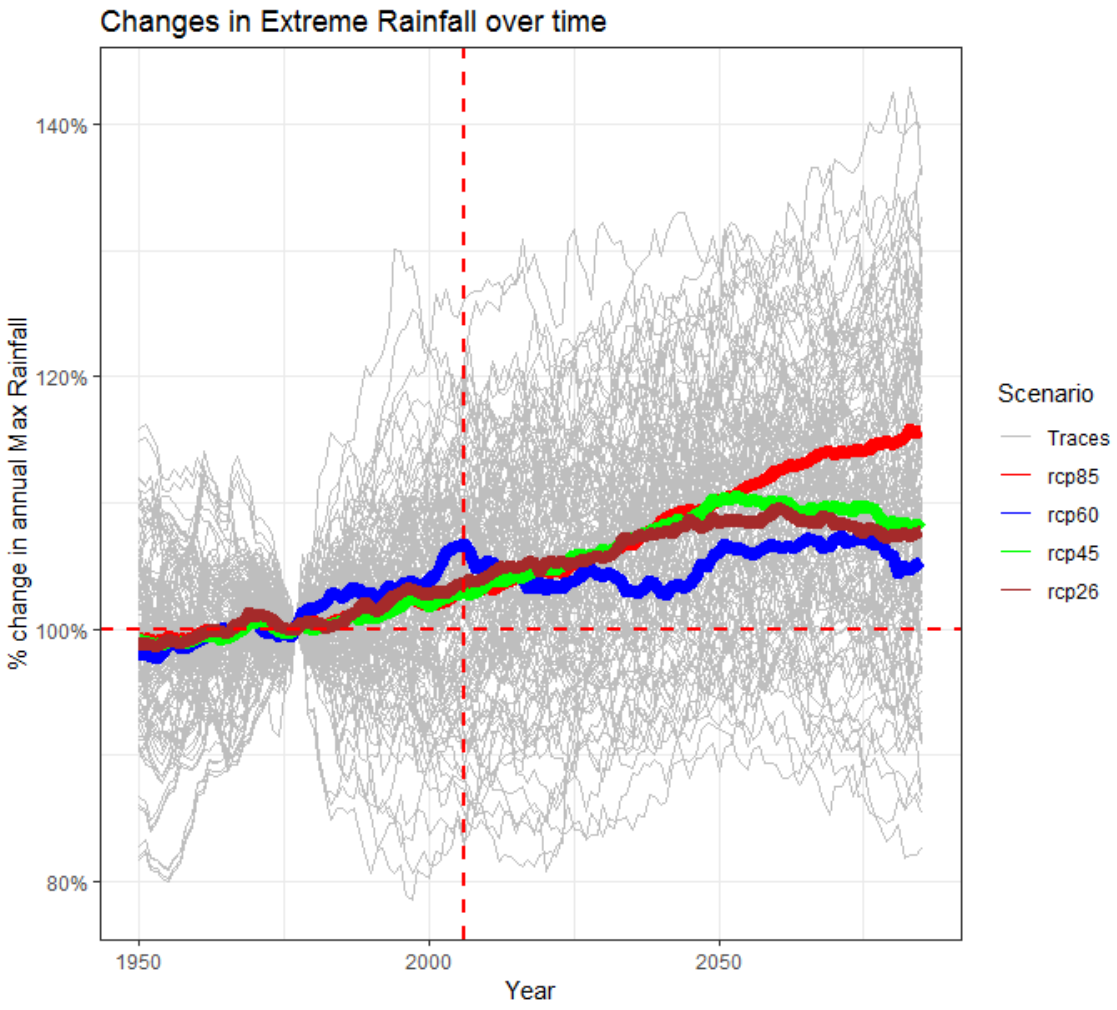
IPCC SREX Report

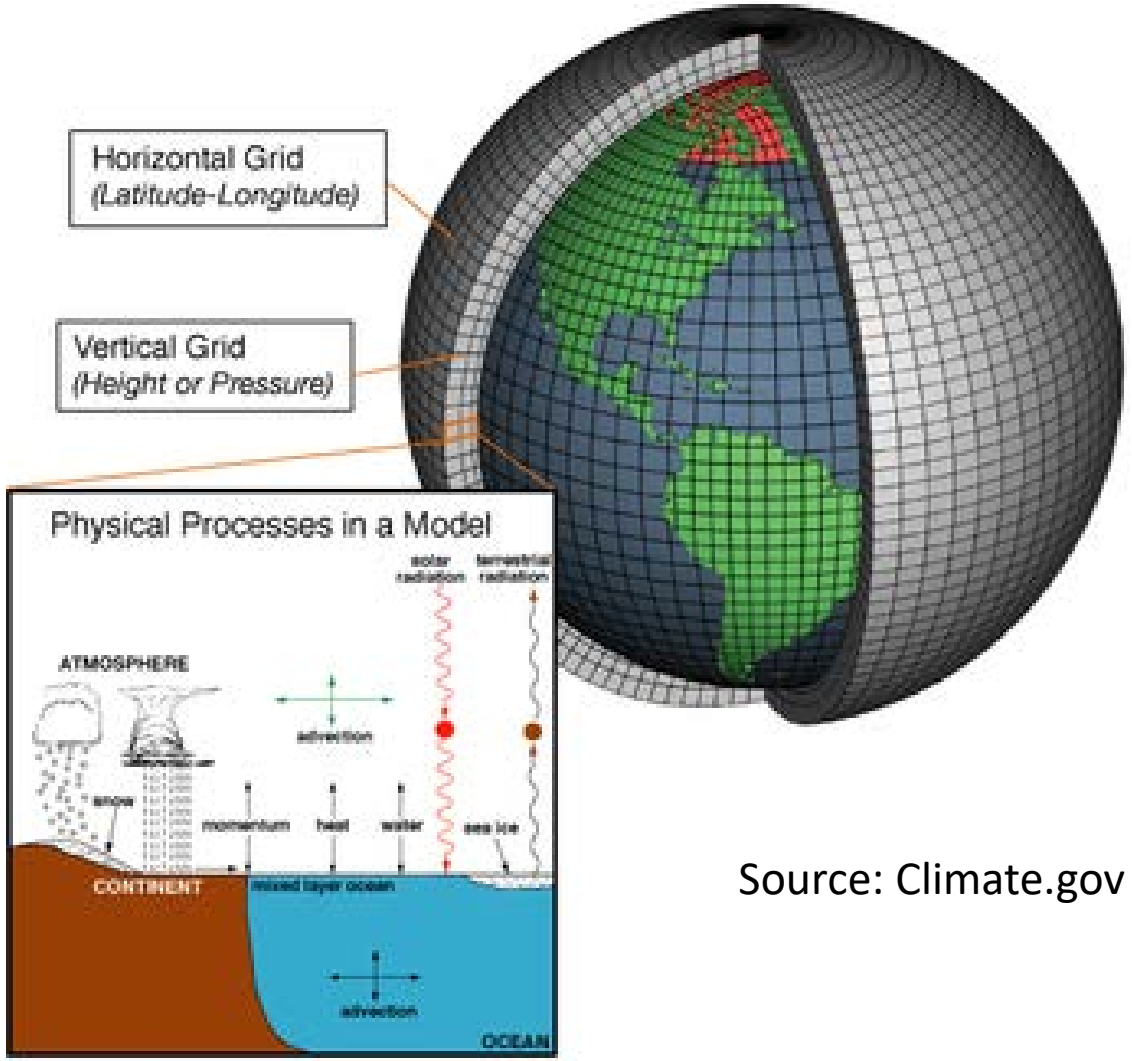
Extend to Shorter Durations

- Relationship between hourly and daily storm intensity varies with elevation.
- Allows us to extend projections to more IDF curve products

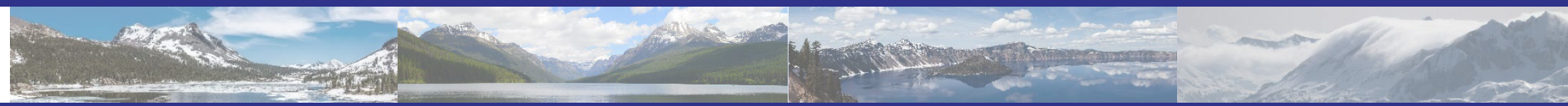


Basics of Global Climate Models



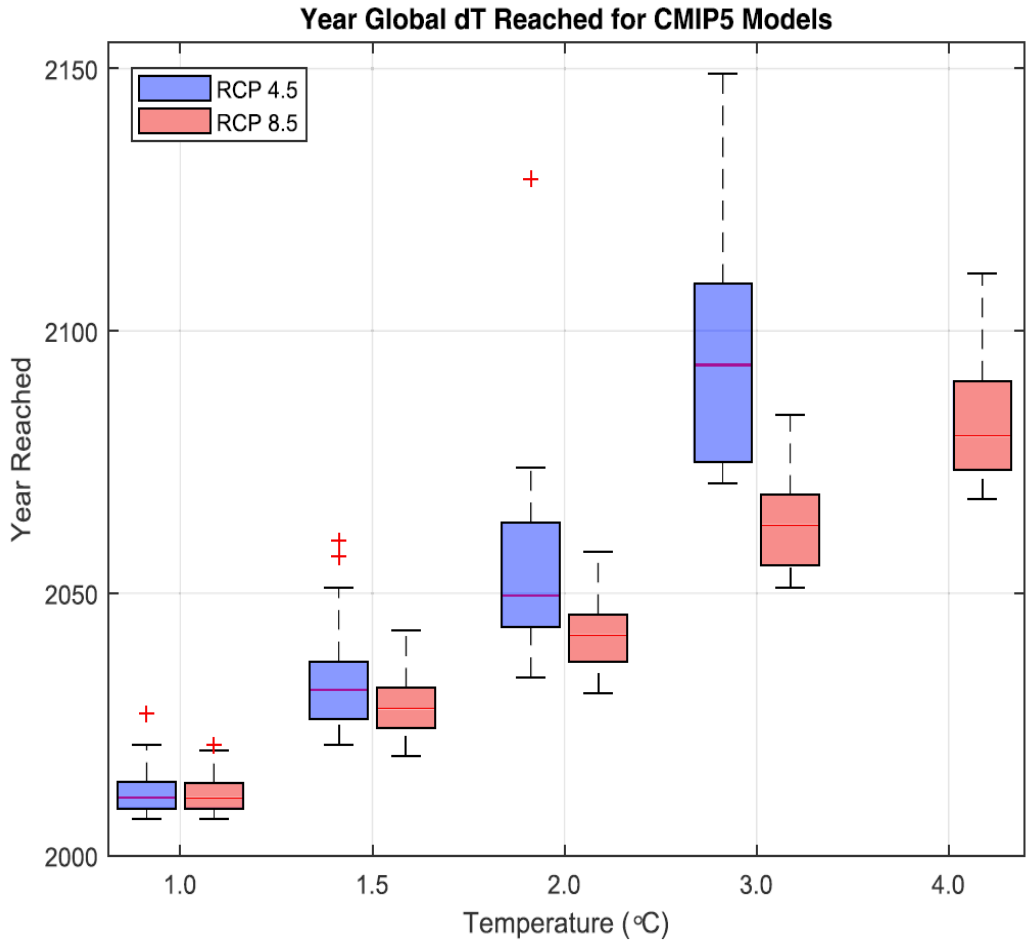


Source: Climate.gov



Planning Horizon

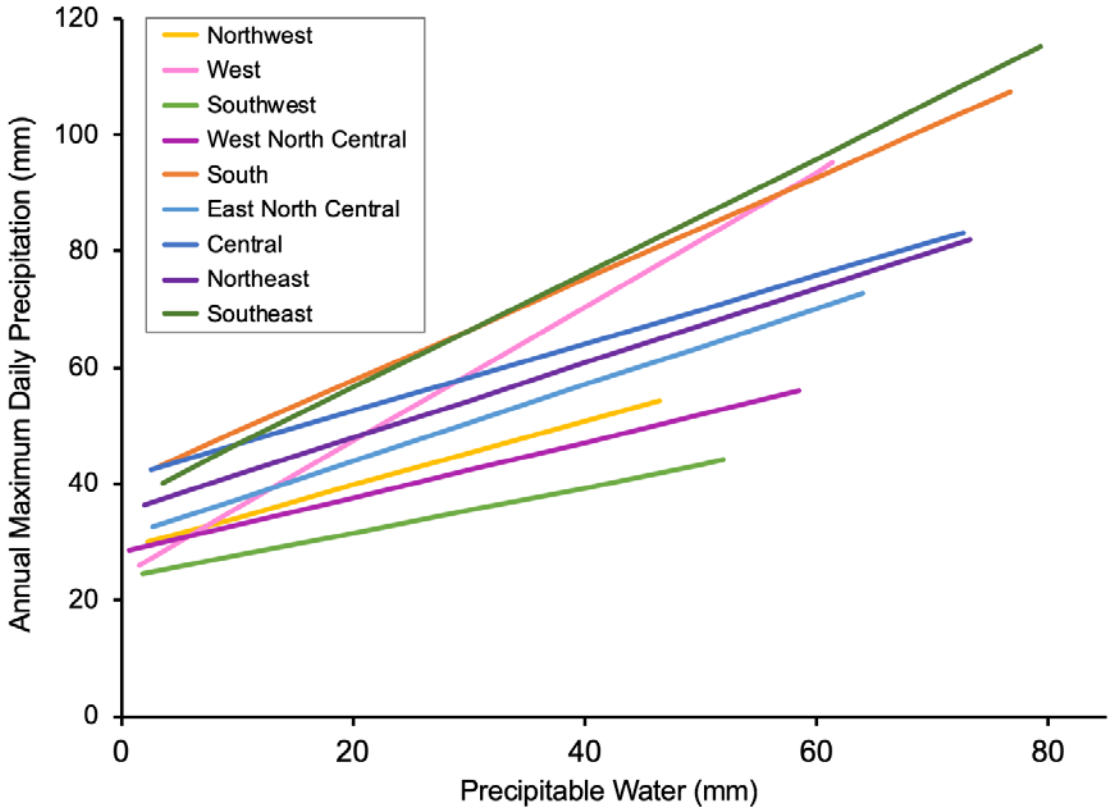
- CO Water Plan uses 2050 as the representative planning horizon
- Benefits of using temperatures instead of years for planning
- Paris Accord has targets at 1.5 and 2°C (relative to pre-industrial conditions)
  - We are already at 0.75°C



Wobus et al 2018

Warmer Means More Intense Rainfall

- Warmer Mean Temps mean...
  - …the atmosphere can hold more water vapor
  - …and more can fall as rain
  - …extreme events will become more intense/frequent
- Clausius-Clapeyron Scaling
  - 7% increase in water vapor per degree of temp increase.



Kunkel, K., & Easterling, D. R. (2017). An Approach Toward Incorporation of Global Warming Effects Into Intensity-Duration-Frequency Values, H22B-04, presented at 2017 AGU Fall Meeting, New Orleans, LA, 11-15 Dec 2017. New Orleans, LA.

What Can We Do About It?

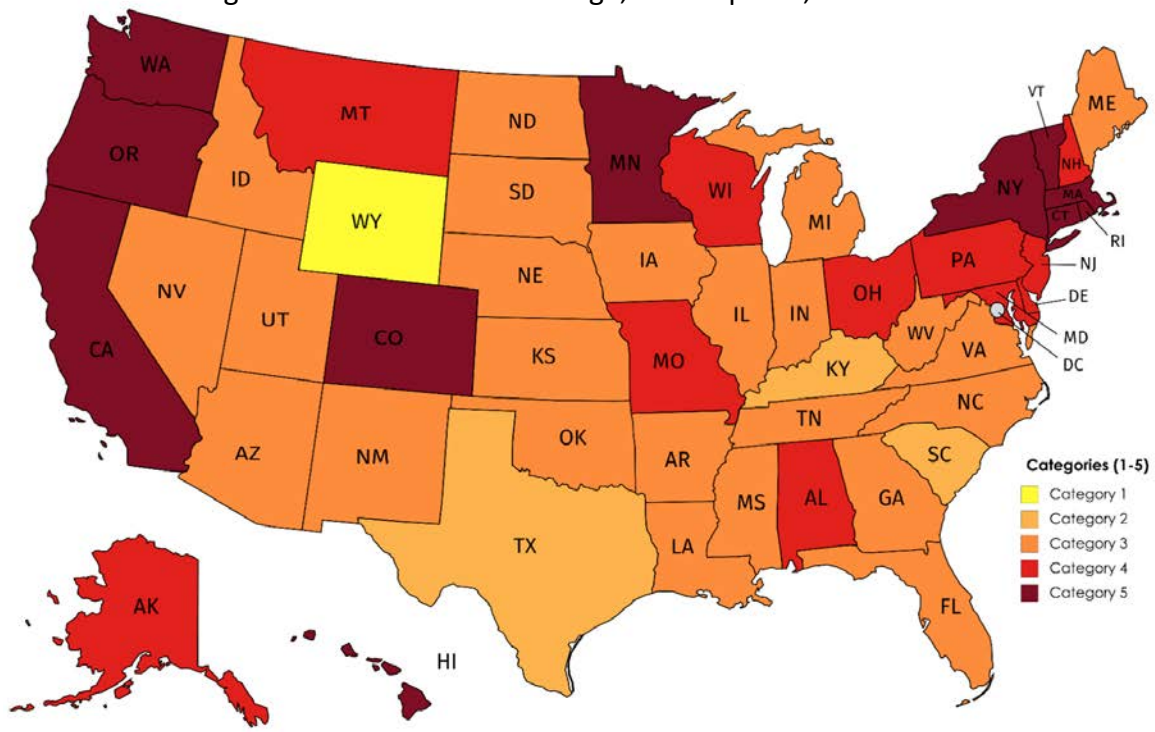
Mitigation is important but we're a big ship with a small rudder.

Local Action: Climate-Adjusted IDF curves can be used by any H&H designer

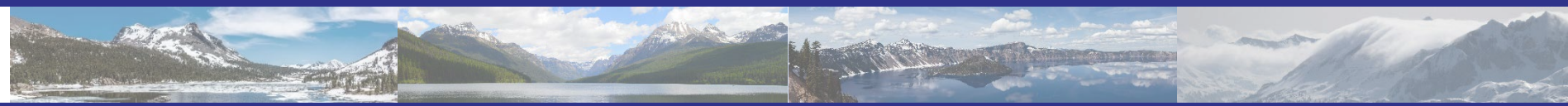
Local Mandate: Municipalities need to decide that climate change I take their own action on climate resilience.

Statewide Action: As of 2019, CWCB has recommended a 7% safety factor to be applied to PMP estimates for Dam Safety based on a "1-degree warmer world".

State Hazard Mitigation Plans & Climate Change; 2019 Update, Columbia Law School

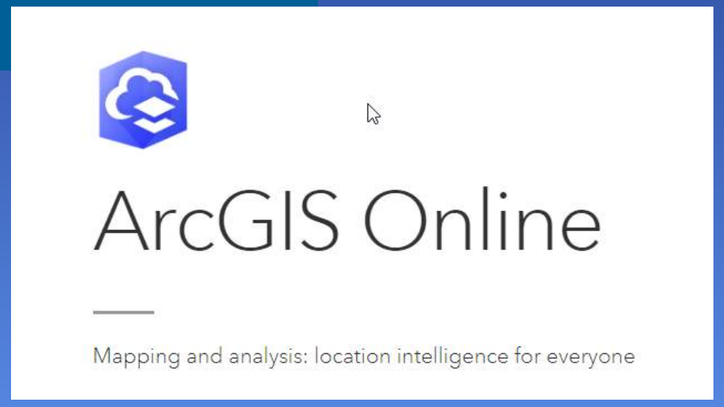


Category 3- Significant discussion of climate change but typically more qualitative in nature. 32 States have this or less.



Using ArcGIS Pro and ArcGIS Online for Hydraulic Field Applications and Stakeholder Outreach

Anthony Alvarado, PE, CFM
Brian Varrella, PE, CFM
Brianna Corsi, EI



CASFM Conference
Crested Butte, Colorado
September 2019

AYRES ASSOCIATES

CASFM

CDOT

Overview

- ArcMap to ArcGIS Pro
  - You need to go pro!
- Field Data Collection Tools
  - CDOT C-Plan with Collector/Survey123
- Utilizing ArcGIS Online
  - From paper/PDFs to a live map
  - Benefits and Limitations

SH7 Lower ArcGIS Pro Basemap - Basemap - ArcGIS Pro

Project | Map | Insert | Analysis | View | Edit | Imagery | Share | XTools AGP

Anthony (Ayres Associates)

Cut | Copy | Copy Path | Paste | Clipboard

Explore | Bookmarks | Go To XY | Navigate

Basemap | Add Data | Add Preset | Layer

Select | Select By Attributes | Select By Location | Attributes | Clear | Selection

Infographics | Measure | Locate | Inquiry

Pause | View Unplaced | More | Convert To Annotation | Labeling

Download Map | Sync | Remove | Offline

Contents

Search

Drawing Order

- Wetland
- <all other values>
- Edge of Water/Thalweg 15Aug14
- Wetlands
- Waters of the U.S.
- Right of Entry 23Apr19
- River Rehab LDA 14Dec18
- Revetment LDA 14Dec18
- Yeh and Associates
- RS&H
- FEMA
- FIR Plans
  - Edge of Oil
  - Stationing
  - Alignment
  - Grading
  - Cross-Sections
  - Concrete Box Culverts
  - Reinforced Concrete Pipes
  - Riprap
- 20252_Microstation
- Inactive/Working Layers
- IMAGERY
- Map Series Indeces
- Other Imagery
  - 0.5ft_SH7_Imagery.ecw
  - Pre Flood Imagery
  - 2015_SH7_MP19-33_NAIP.ecw
  - 2013_PostFlood_LiDAR_SH7.tif
  - Post-Flood IR Sept 26 2013

Co... | Cat... | Pop... | Ele... | Cre... | Attr... | Mo...

Map Series - Sample Project Area | Map Series - River Rehab | Basemap

esri

ArcGIS® Pro

Initializing

1365+00 23.7
1370+00 23.8
1375+00 23.9
1380+00 24.0
1385+00 24.1
1390+00 24.2
1395+00 24.3
1400+00 24.4
1405+00 24.5
1410+00 24.6
1415+00 24.7
1420+00 24.8
1425+00 24.9
1430+00 25.0
1435+00 25.1
1440+00 25.2
1445+00

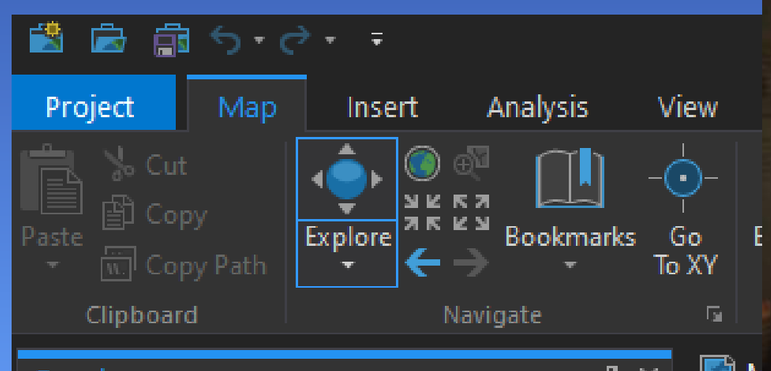
CPW Fishing Hunting Pullout

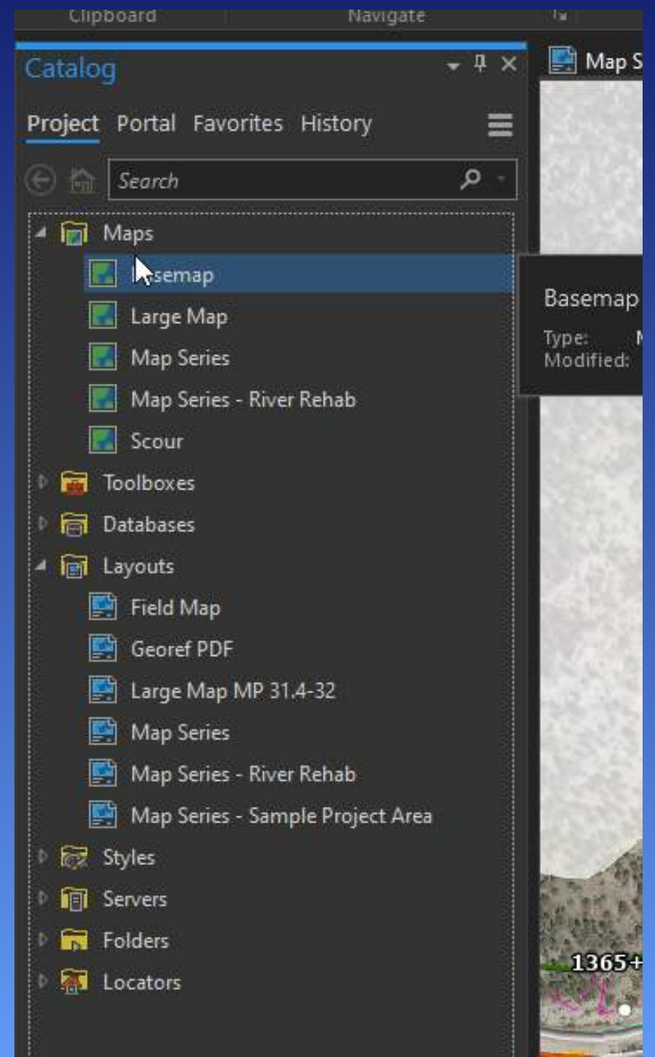
CPW Fishing Hunting Pullout

1 IN = 426 FT | 105.3905566°W 40.1716982°N | Selected Features: 0

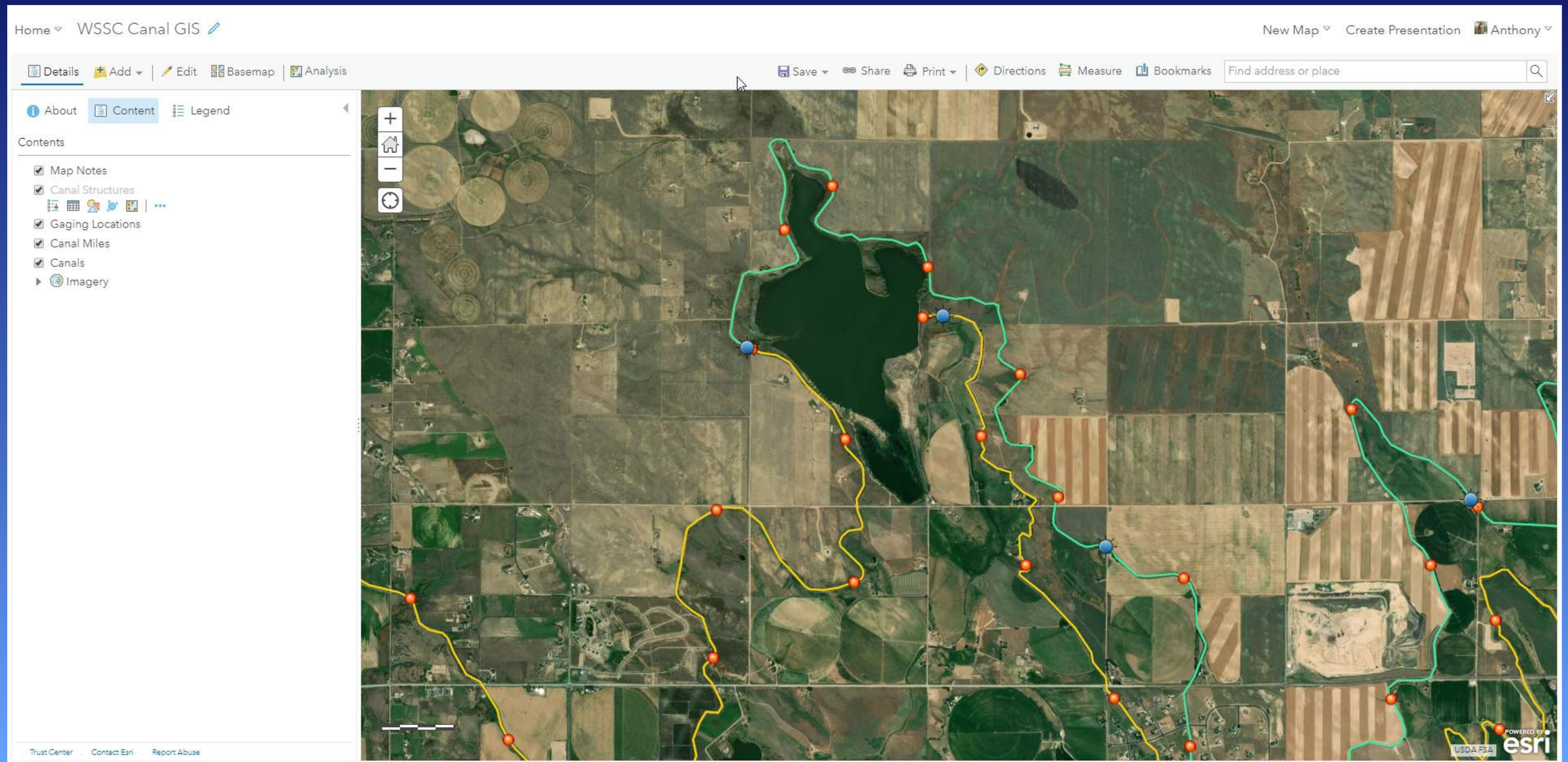
Benefits of Going Pro

- 64-bit Processing = SPEED
- Ribbon interface = MORE INTUITIVE
- Project-based = MULTIPLE LAYOUTS
- Easier feature editing
- Better integration with ArcGIS Online

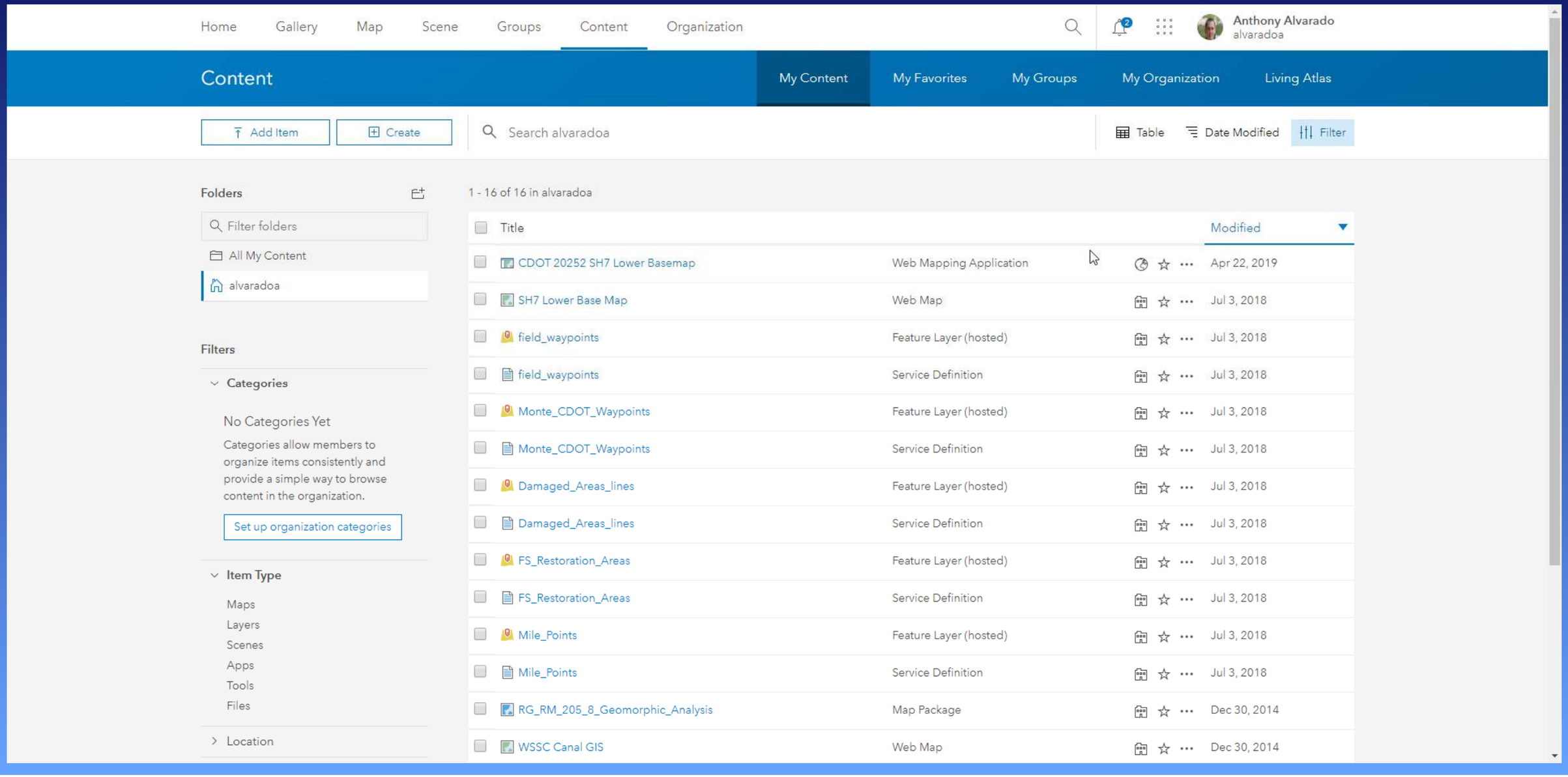




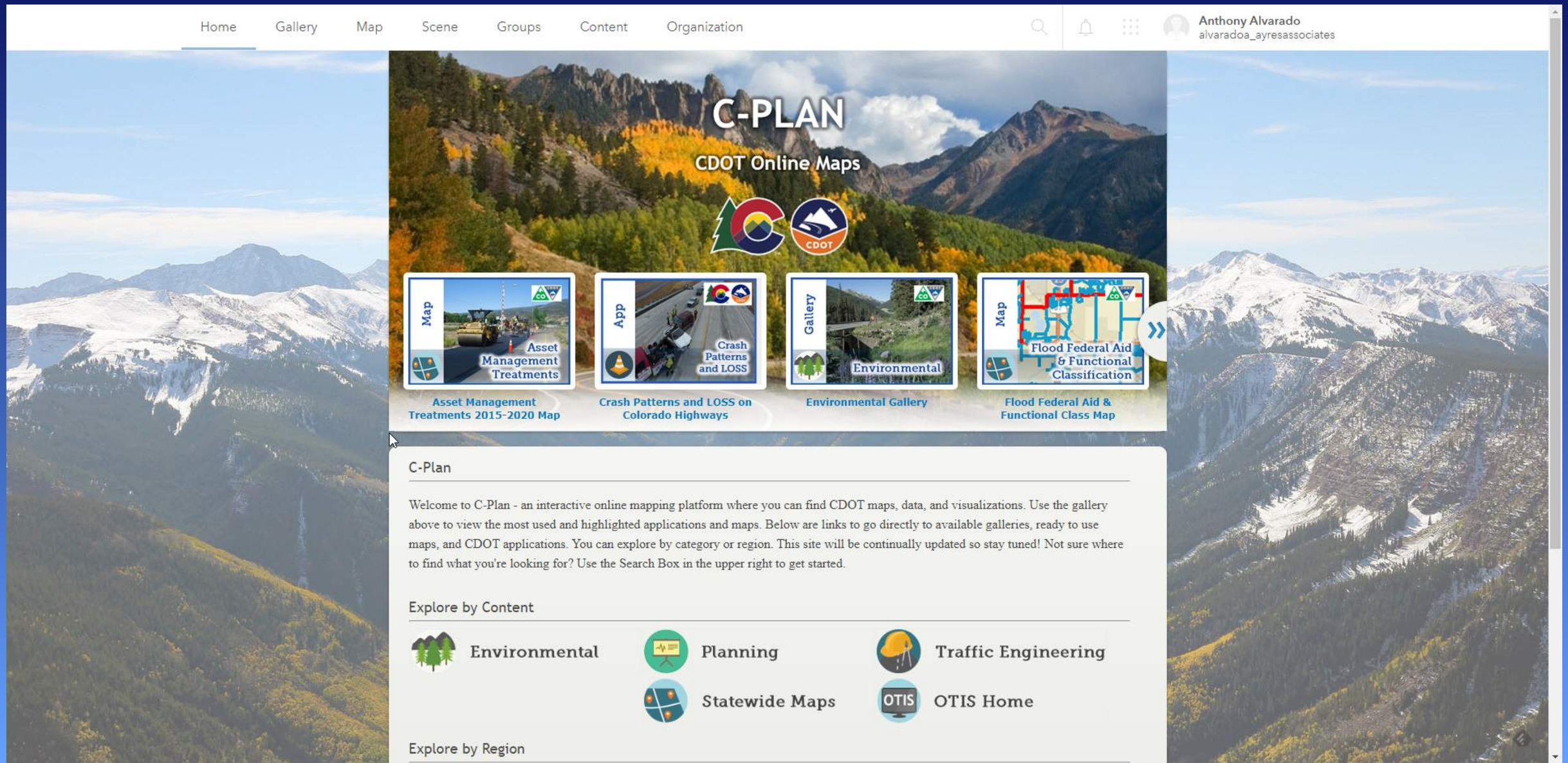
What is ArcGIS Online?



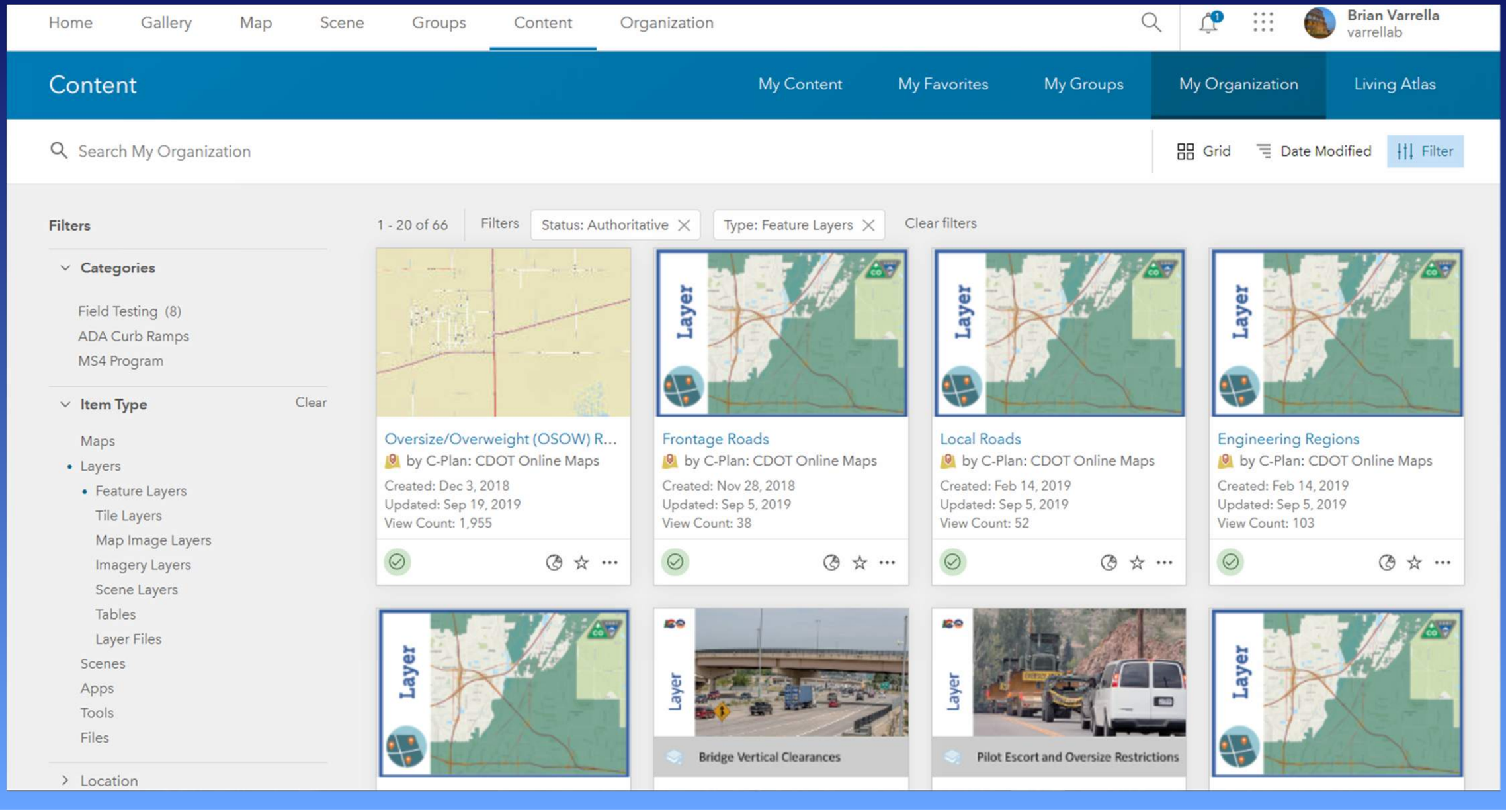
What is ArcGIS Online?



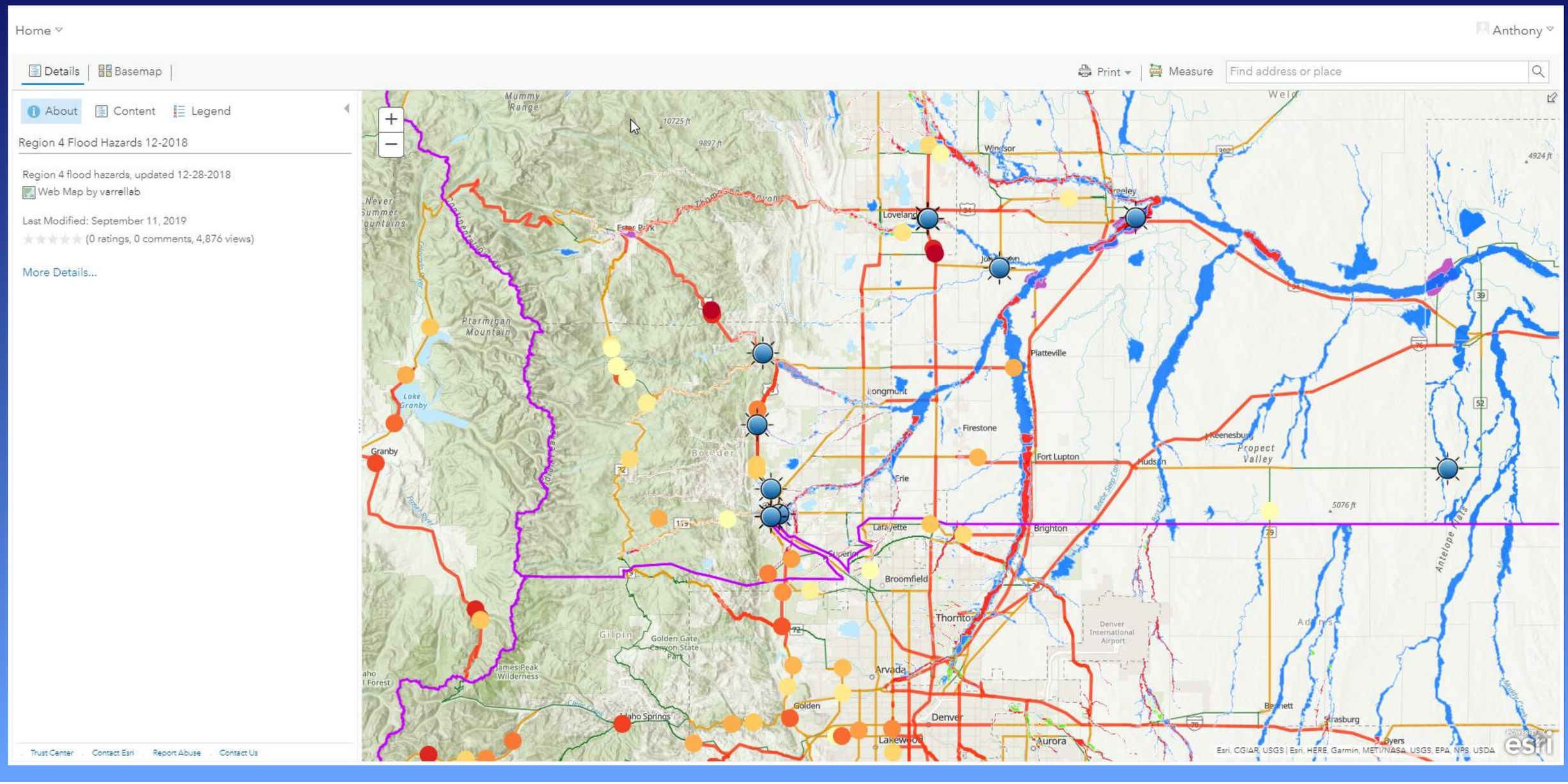
CDOT C-Plan


Home
Gallery
Map
Scene
Groups
Content
Organization
Anthony Alvarado
alvaradoa_ayresassociates
C-PLAN
CDOT Online Maps
CDOT
Map
Asset Management Treatments
Asset Management Treatments 2015-2020 Map
App
Crash Patterns and LOSS
Crash Patterns and LOSS on Colorado Highways
Gallery
Environmental
Environmental Gallery
Map
Flood Federal Aid & Functional Classification
Flood Federal Aid & Functional Class Map
C-Plan
Welcome to C-Plan - an interactive online mapping platform where you can find CDOT maps, data, and visualizations. Use the gallery above to view the most used and highlighted applications and maps. Below are links to go directly to available galleries, ready to use maps, and CDOT applications. You can explore by category or region. This site will be continually updated so stay tuned! Not sure where to find what you're looking for? Use the Search Box in the upper right to get started.
Explore by Content
Environmental
Planning
Traffic Engineering
Statewide Maps
OTIS
OTIS Home
Explore by Region

CDOT C-Plan

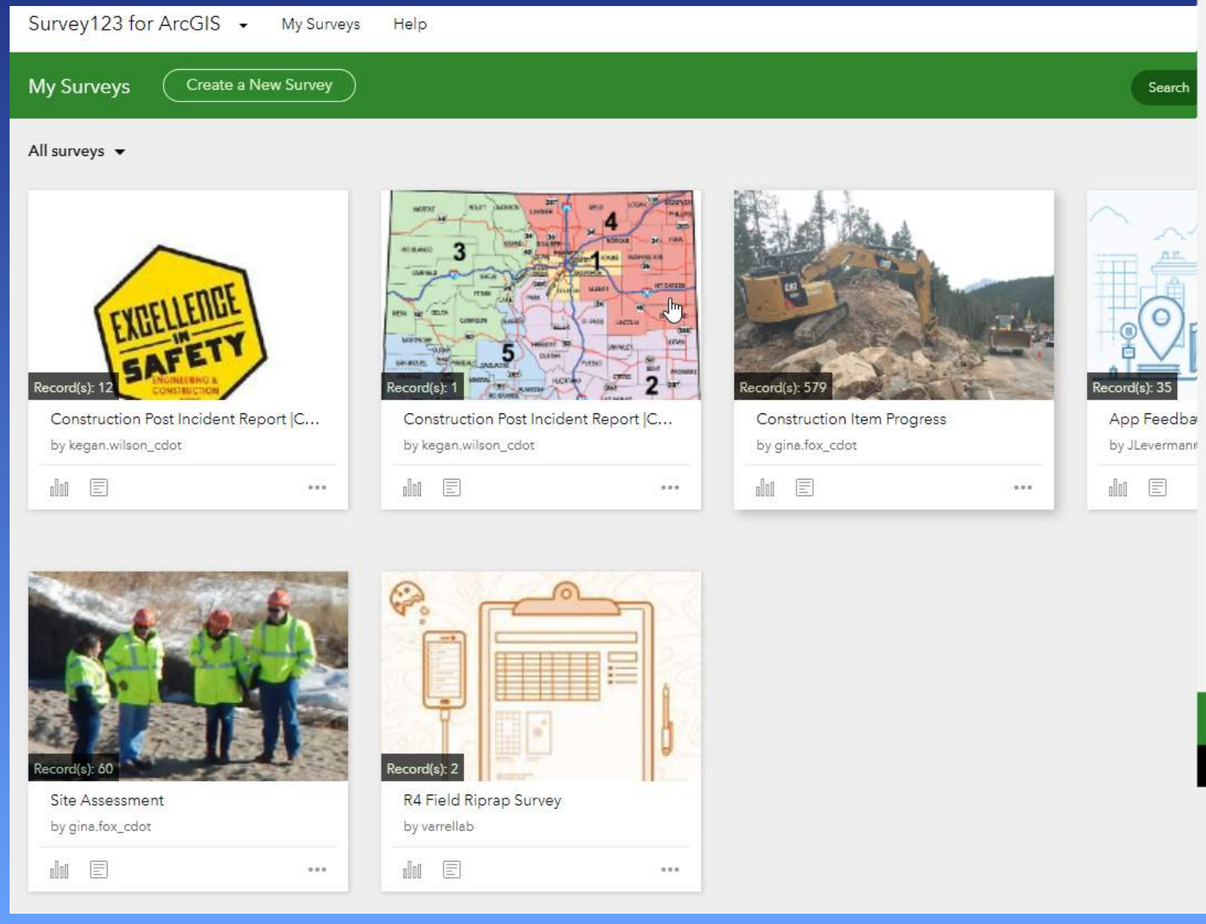

Home
Gallery
Map
Scene
Groups
Content
Organization
Brian Varrella
varrellab
Content
My Content
My Favorites
My Groups
My Organization
Living Atlas
Search My Organization
Grid
Date Modified
Filter
Filters
1 - 20 of 66
Filters
Status: Authoritative
Type: Feature Layers
Clear filters
Categories
Field Testing (8)
ADA Curb Ramps
MS4 Program
Item Type
Clear
Maps
Layers
Feature Layers
Tile Layers
Map Image Layers
Imagery Layers
Scene Layers
Tables
Layer Files
Scenes
Apps
Tools
Files
Location
Oversize/Overweight (OSOW) R...
by C-Plan: CDOT Online Maps
Created: Dec 3, 2018
Updated: Sep 19, 2019
View Count: 1,955
Frontage Roads
by C-Plan: CDOT Online Maps
Created: Nov 28, 2018
Updated: Sep 5, 2019
View Count: 38
Local Roads
by C-Plan: CDOT Online Maps
Created: Feb 14, 2019
Updated: Sep 5, 2019
View Count: 52
Engineering Regions
by C-Plan: CDOT Online Maps
Created: Feb 14, 2019
Updated: Sep 5, 2019
View Count: 103
Bridge Vertical Clearances
Pilot Escort and Oversize Restrictions

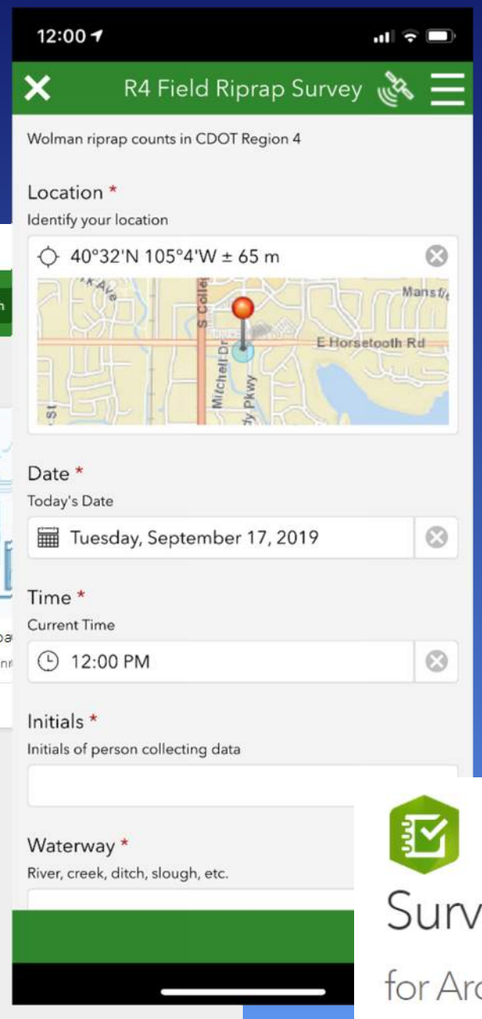
CDOT C-Plan

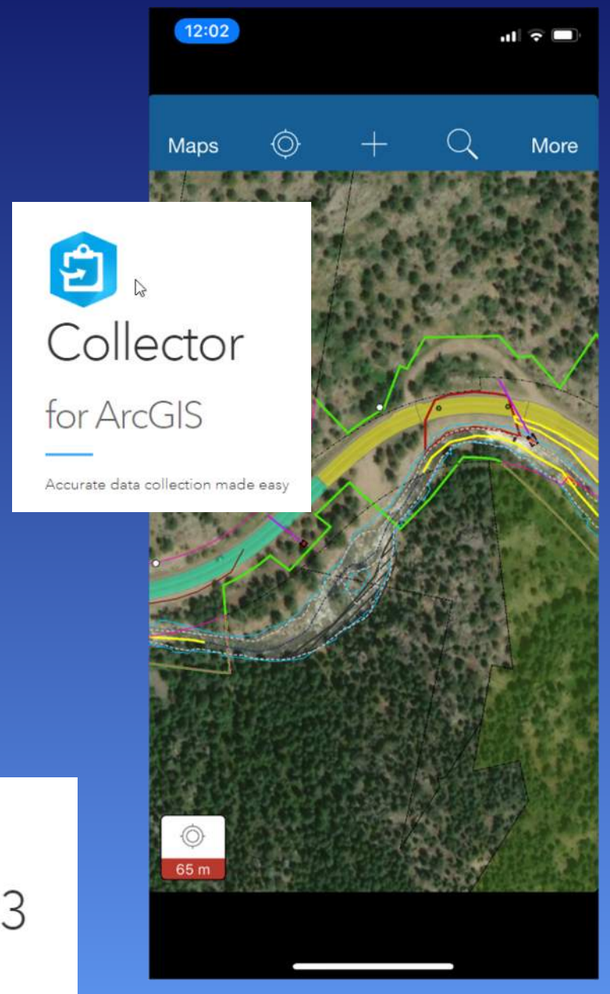

Home
Anthony
Details
Basemap
Print
Measure
Find address or place
About
Content
Legend
Region 4 Flood Hazards 12-2018
Region 4 flood hazards, updated 12-28-2018
Web Map by varrellab
Last Modified: September 11, 2019
(0 ratings, 0 comments, 4,876 views)
More Details...
Trust Center
Contact Esri
Report Abuse
Contact Us
Mummy Range
10725 ft
9897 ft
Never Summer Mountains
Ptarmigan Mountain
Lake Granby
Granby
Boulder
Estes Park
Loveland
Windsor
Greeley
Platteville
Longmont
Firestone
Fort Lupton
Hudson
Keenesburg
Prospect Valley
Erie
Lafayette
Brighton
Broomfield
Thornton
Denver International Airport
Arvada
Golden
Denver
Lakewood
Aurora
Gilpin
Golden Gate Canyon State Park
James Peak Wilderness
Idaho Springs
Bennett
Strasburg
Byers
Antelope Flats
5076 ft
4924 ft
Esri, CGIAR, USGS | Esri, HERE, Garmin, METI/NASA, USGS, EPA, NPS, USDA
esri

CDOT C-Plan – Field Data Collection

- **Maps & info at your fingertips!**







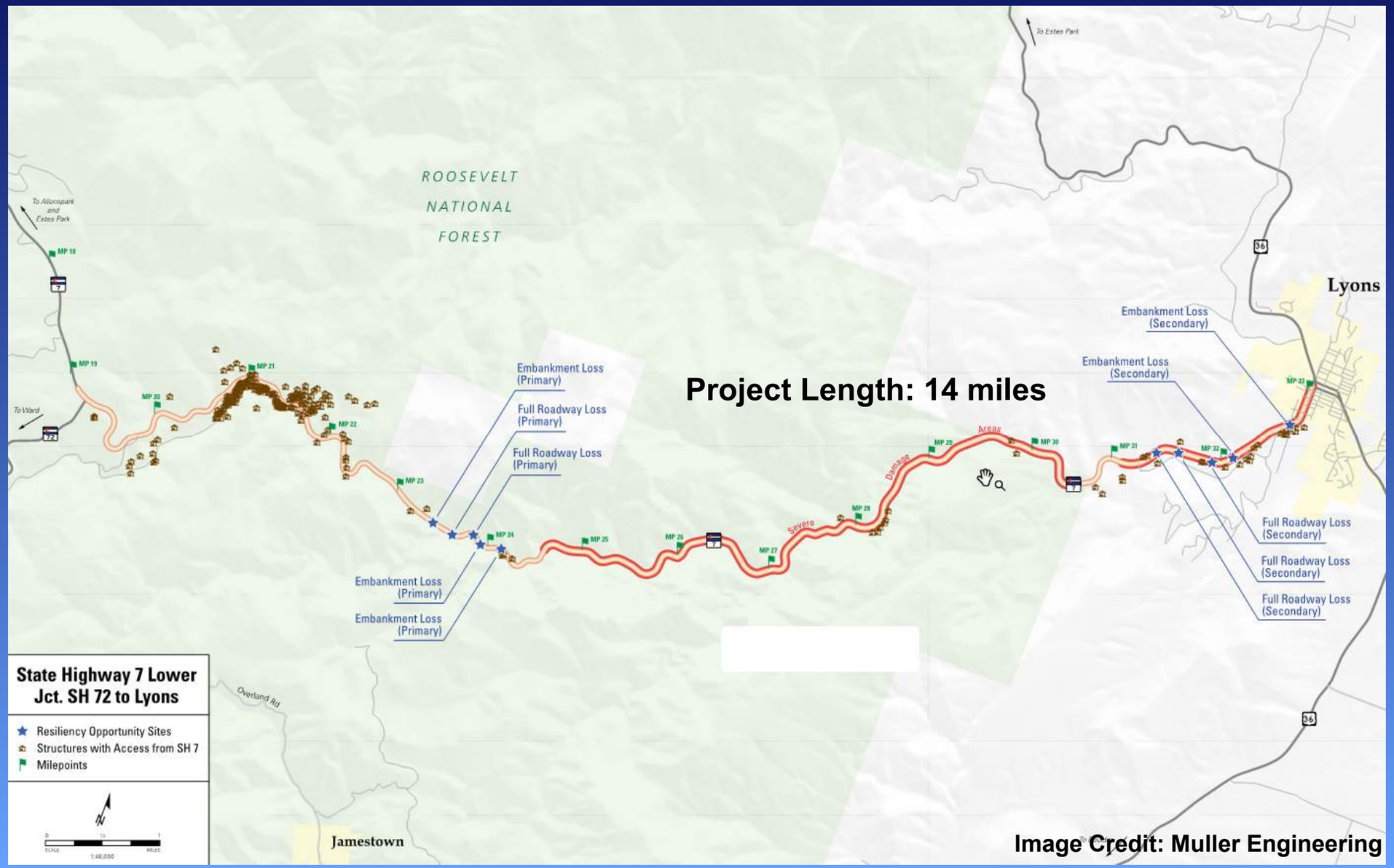
Collector for ArcGIS

Accurate data collection made easy

Survey123 for ArcGIS

Smarter forms, smarter data collection

CDOT SH7 Lower Project



Project Length: 14 miles

Image Credit: Muller Engineering

RS&H

MULLER ENGINEERING COMPANY

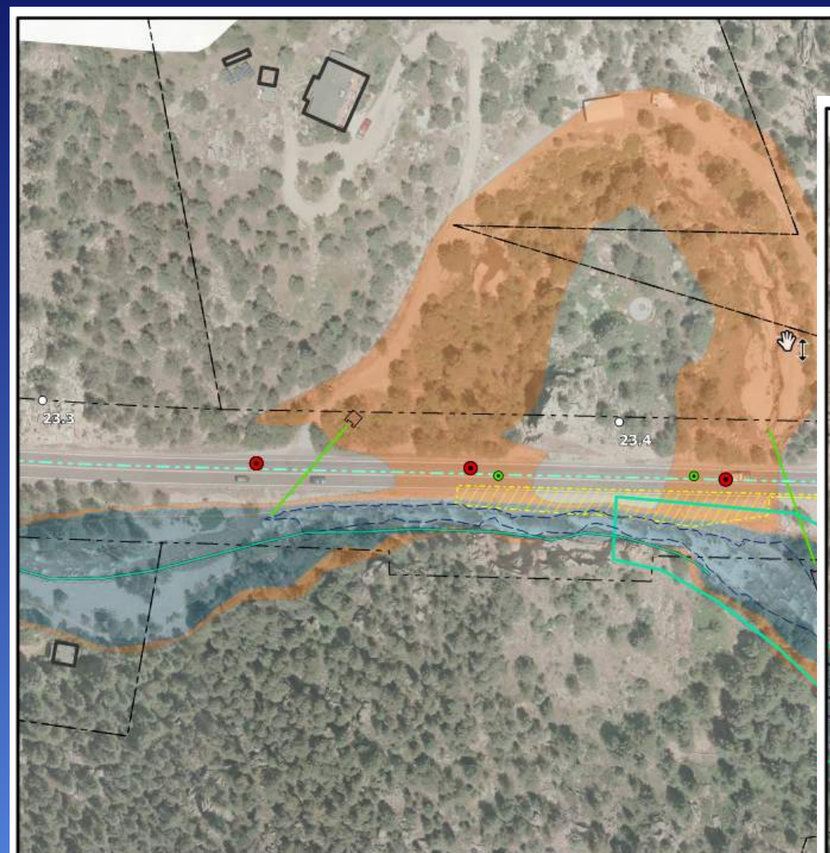
AYRES ASSOCIATES

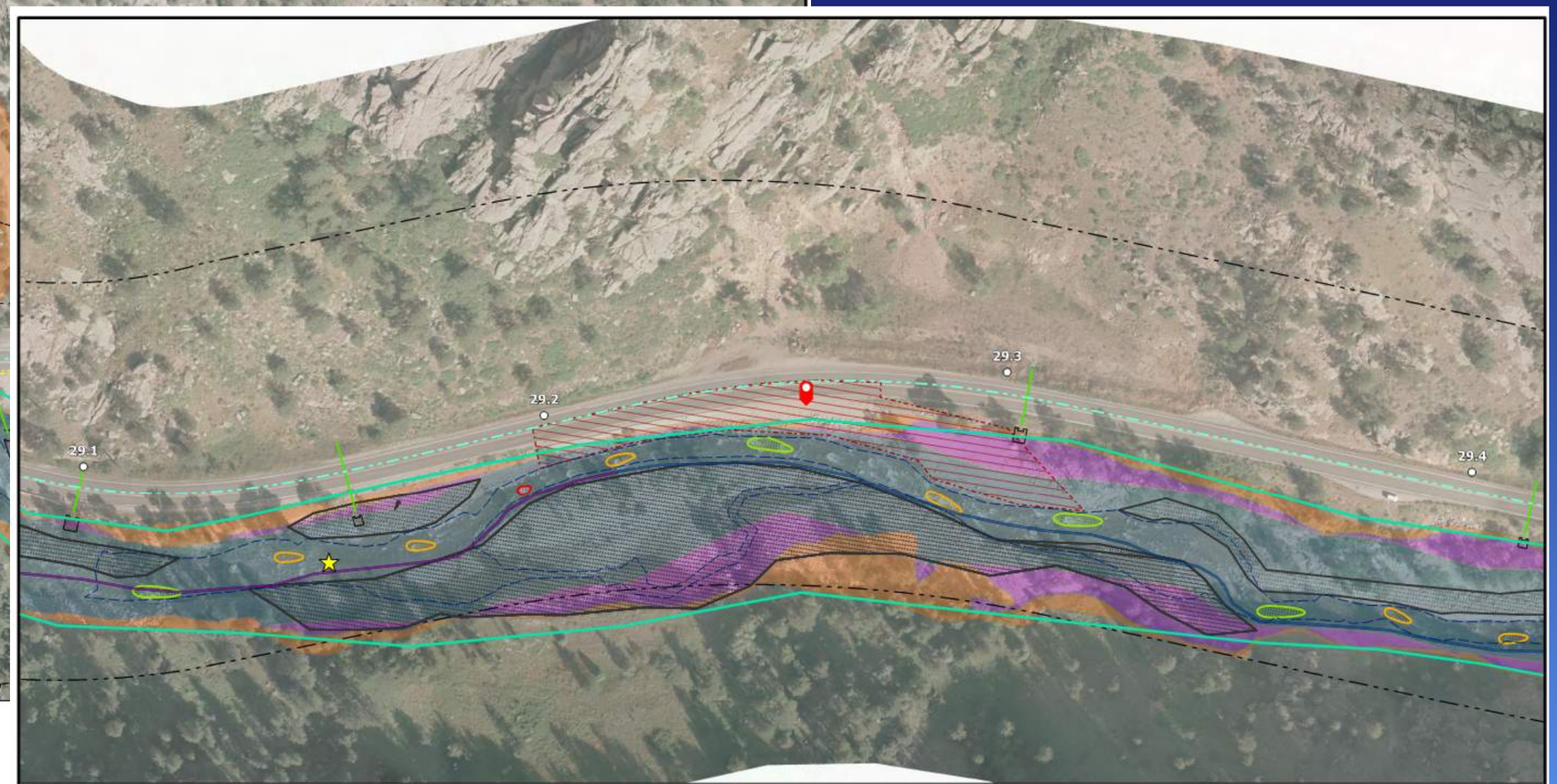
JACOBS

olsson

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SH7 Lower Atlas





- Mile Points
- Fishing
- Hiking
- CPW Priority Pulloffs
- Wolman Count Locations
- Boring Locations 12-3-18
- Proposed Boring Locations 2-1-19
- 2018 Safety Recommendations
- Forest Service Roads
- Forest Service Trails
- Boulder County Trails
- Anticipated CLOMR Areas
- Bathymetric Survey
- BC Building Footprints
- Boulder Parcels
- Boulder County Open Space

FS Restoration Sites
Priority Level
- High
- Medium
- Low-Medium
- Low

FIR Plans
- Alignment
- Concrete Box Culverts
- RCPs
- Riprap

CDOT Damage Areas
- Bridge Structure
- Ditch Scour
- Overtopping
- Embankment Loss
- Material Slide
- Complete Roadway Loss

Proposed River Features
- Pool Type A
- Pool Type B
- Pool Type C
- Pool: Protect in Place
- FP Bench

Boulder County Regulated Floodplain
- A, AE Floodway
- 100-yr Floodplain
- 500-yr Floodplain

STATE HIGHWAY 7 LOWER ALONG SAINT VRAIN CREEK

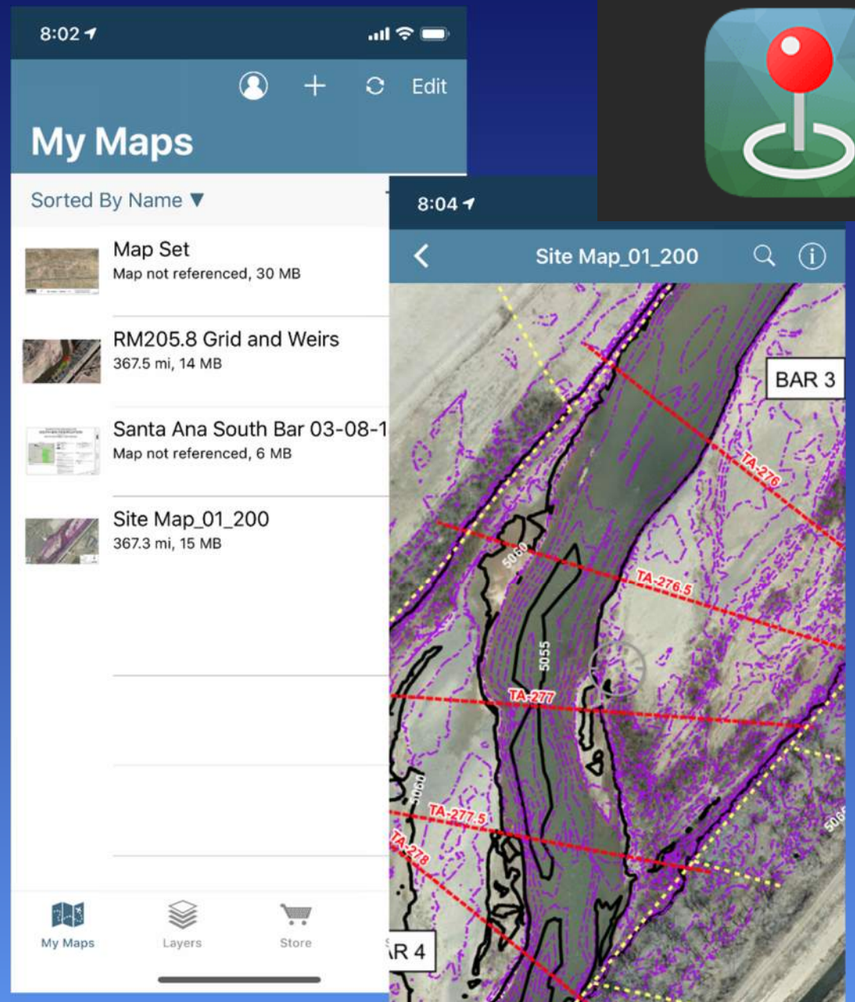
SCALE: 1 IN = 100 FT
AERIAL IMAGERY TAKEN 2014
LAST REVISED: 4-01-19

0 50 100 200 300 Feet

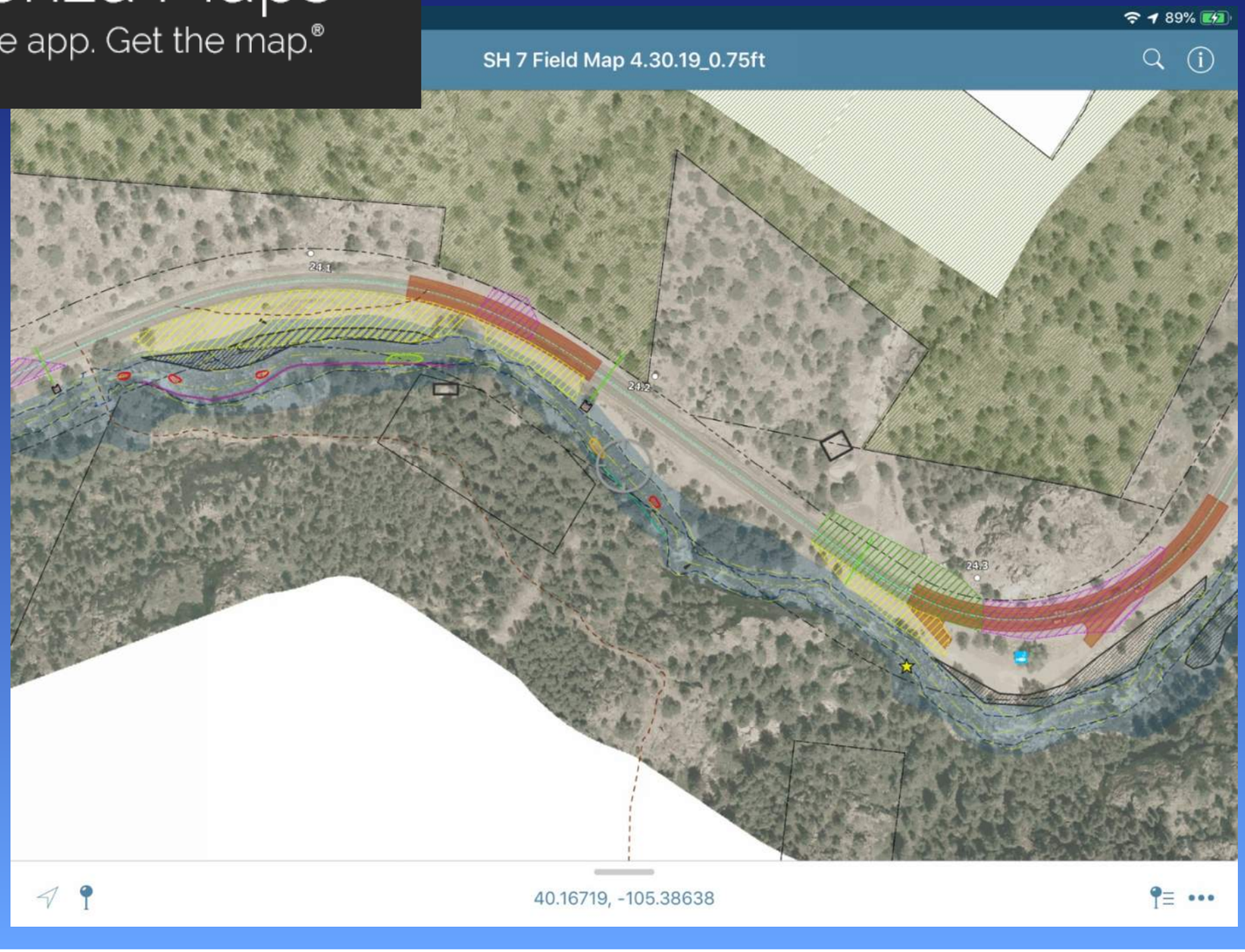
AYRES ASSOCIATES | MULLER ENGINEERING COMPANY

PLATE 36 of 48

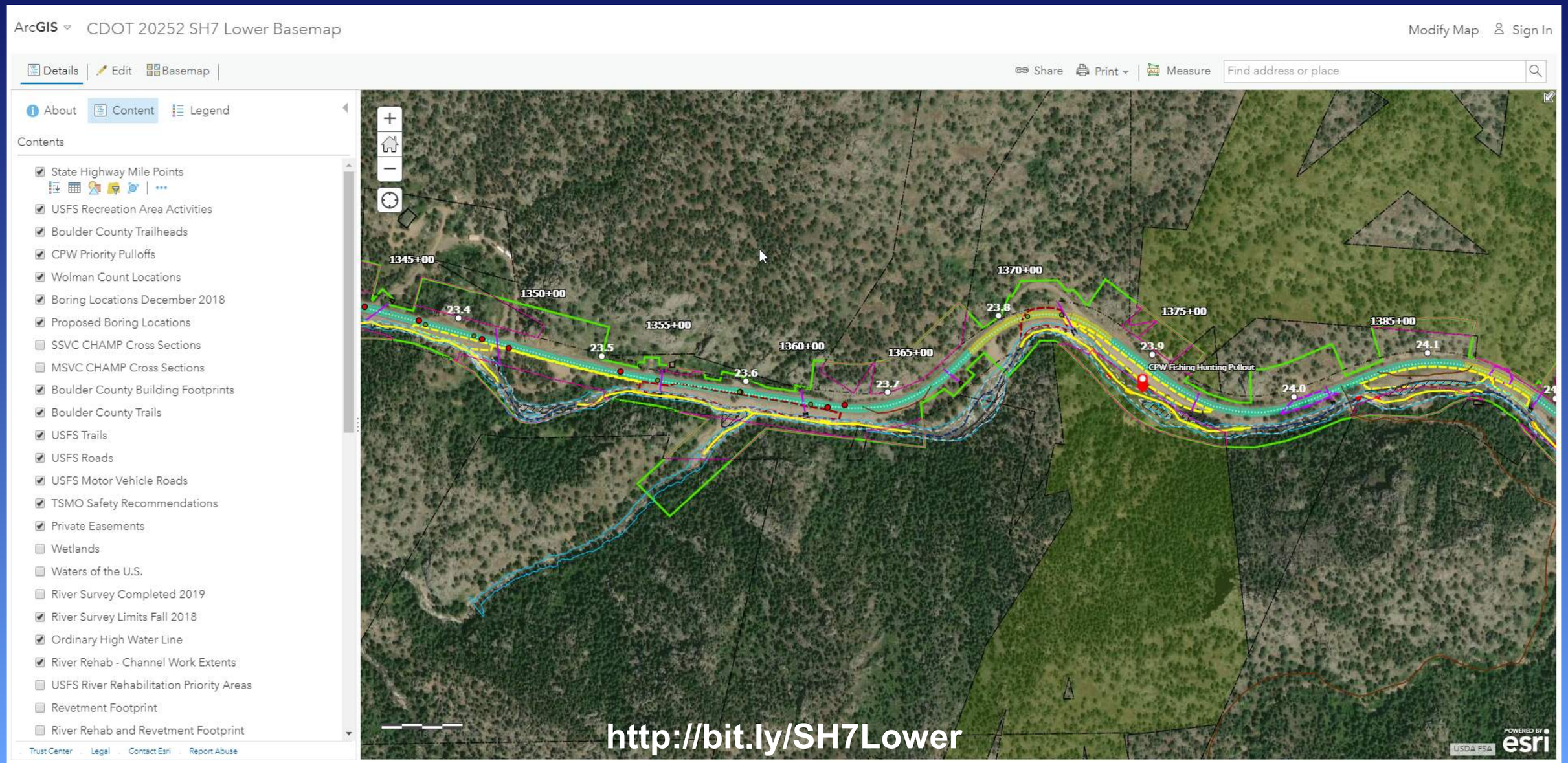
Field Data Collection – Avenza Maps



Avenza Maps
Get the app. Get the map.®



SH7 Lower ArcGIS Online Map



SH7 Lower ArcGIS Online Map

DEMONSTRATION

ArcGIS Online Map – Benefits

- Only need basic proficiency in ArcGIS
  - No need for a GIS Server
- Easy to turn on and off
- Less paper, even with iteration
- Easier for stakeholders to use
- Immediate updates – *live nesting!*
  - No waiting for next map revision!

ArcGIS Online Map – Limitations

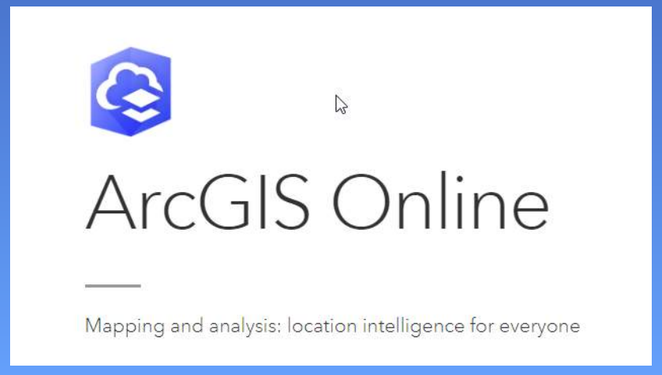
- Might still need paper maps for the field for stakeholders
  - Offline access to Collector needs a GIS server
- Cannot group layers
- Cannot utilize raster layers
- Does not support complex symbolization

ArcGIS Online Map – Basic Tips

- Export shapefiles to ArcGIS Online using Pro
- Add to online map and check layer styles
- Each feature then needs to be shared individually publicly to then share the full map
- Set your permissions correctly within your organization

Summary

- ArcGIS Pro is a significant upgrade over ArcMap
- Direction of GIS is improving field data collection
- ArcGIS Online can feasibly replace paper maps as a communication tool



THANK YOU!

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Brian Varrella, PE, CFM
brian.varrella@state.co.us

Brianna Corsi, EI
corsib@ayresassociates.com

SH7 Lower Project Map: http://bit.ly/SH7Lower