



2015 APWA ANNUAL FALL CONFERENCE

DAM BREAK INUNDATION AREA MODELING AND MAPPING FOR AN EMERGENCY ACTION PLAN

Benjamin D. Miner, MPA, PE

October 7, 2015




CURRENT EVENTS

KSL.com News Sports Brandview TV Radio Live Weather 72°

MARKETPLACE
Classifieds Cars Homes Jobs Local Deals

NEWS / BIZ / [More sections »](#)

Advertise with us Report this ad



Gerry Broome/AP Photo

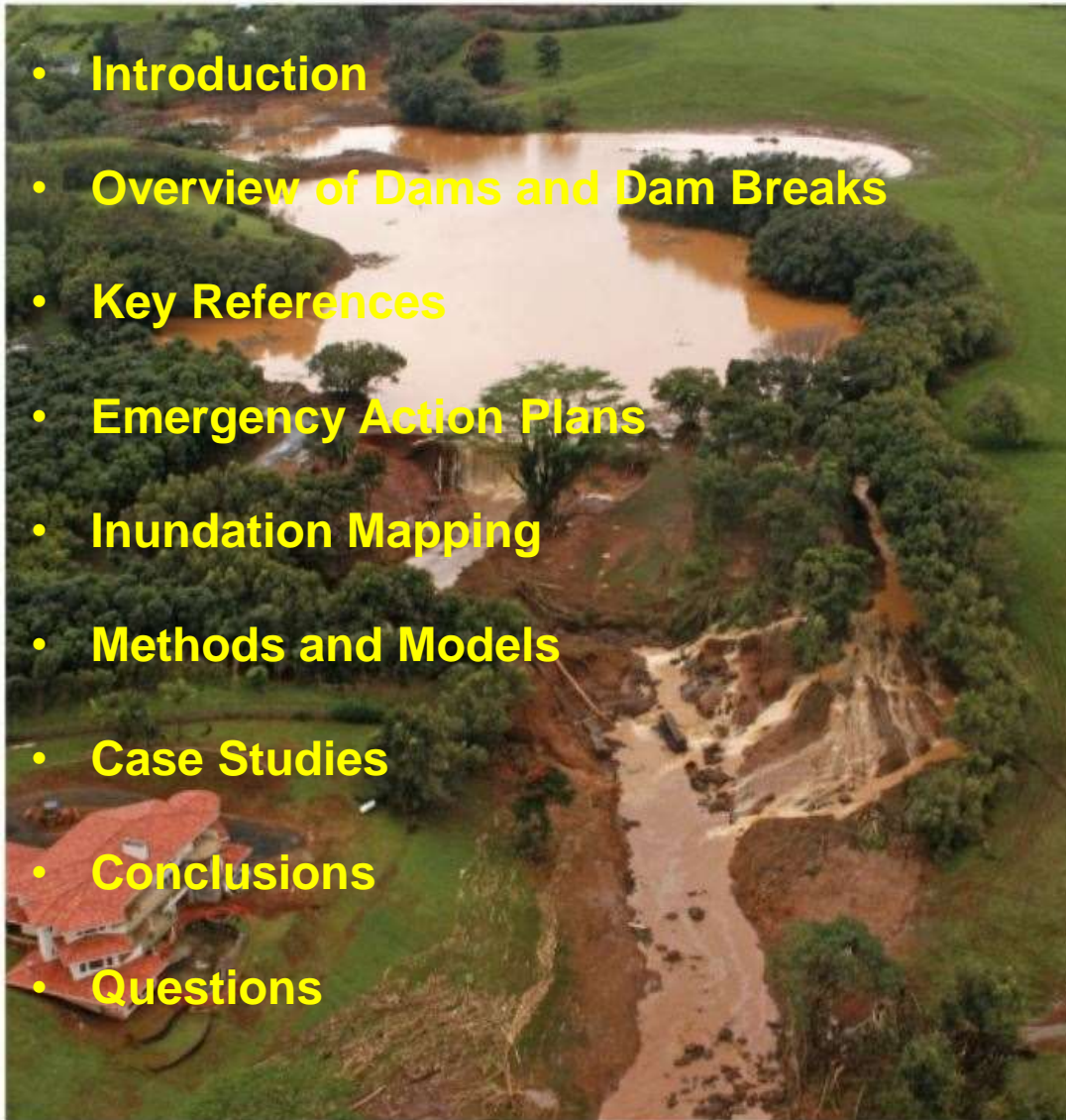
The Latest: Dam breaches, neighborhood evacuated

By The Associated Press | Updated - Oct 5th, 2015 @ 3:55pm

Flooding and Dam Breach in South Carolina this week.

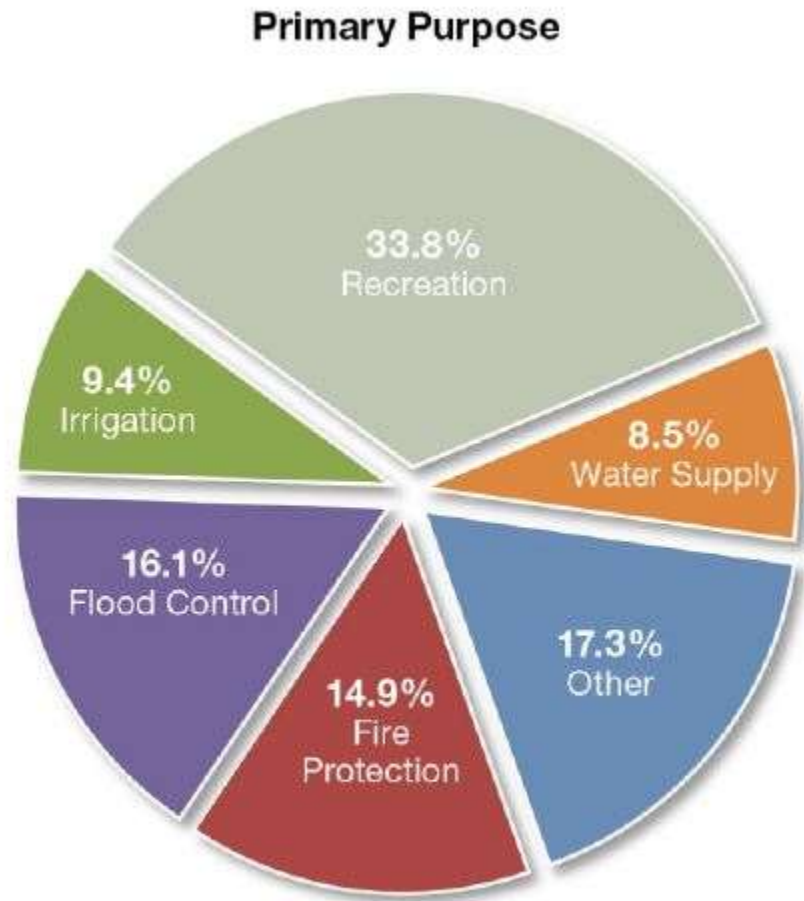
PRESENTATION OUTLINE

- Introduction
- Overview of Dams and Dam Breaks
- Key References
- Emergency Action Plans
- Inundation Mapping
- Methods and Models
- Case Studies
- Conclusions
- Questions



INTRODUCTION

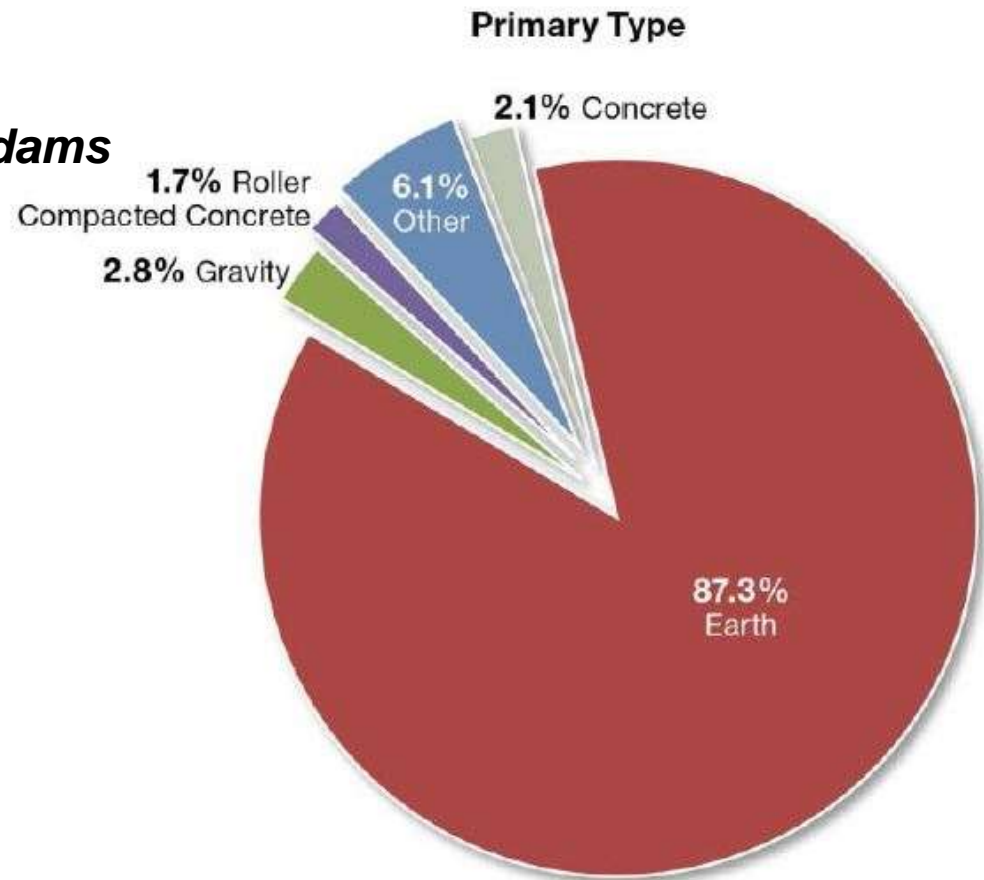
- *Why do we need dams?*



Source: FEMA 2013

INTRODUCTION

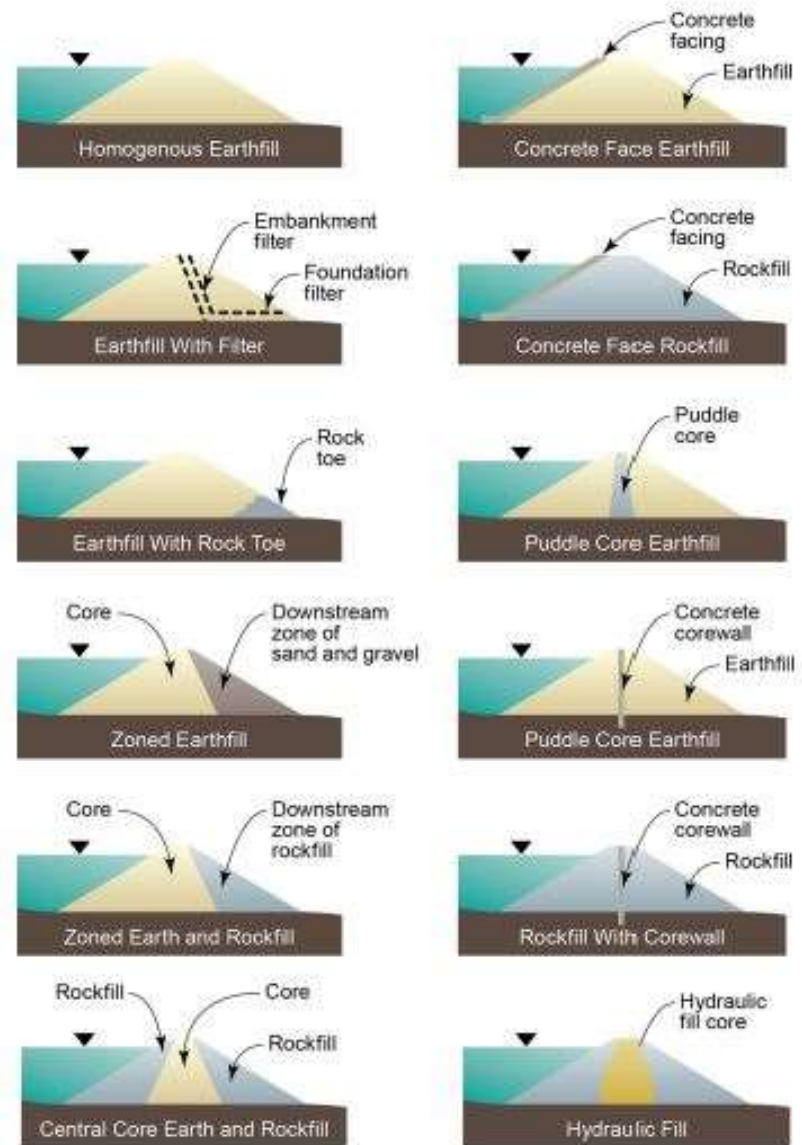
- *What materials are dams made of?*



Source: FEMA 2013

INTRODUCTION

- *How are dams made?*
 - *Simple/Difficult?*



Source: Adapted from Foster et al., 1998

Source: FEMA 2013

INTRODUCTION

- **UNFORTUNATELY DAMS FAIL**



Taum Sauk Dam,
Missouri

INTRODUCTION

- *How do dams fail?*

Table 4-1: Causes of Dam Failure 1975-2011

Cause of Failure	Number of Dam Failures	Percentage of Dam Failure
Flood or Overtopping	465	70.9%
Piping or Seepage	94	14.3%
Structural	12	1.8%
Human Related	4	0.6%
Animal Activities	7	1.1%
Spillway	11	1.7%
Erosion/Slide/Instability	13	2.0%
Unknown	32	4.9%
Other	18	2.7%
Total number of dam failures	656	

Source: FEMA 2013

KEY REFERENCE

- ***Utah Dam Safety Guide to Emergency Action Plans Development and Implementation. Utah Division of Water Rights – Dam Safety Section. 2003***
- ***{73-5a Utah Code, Annotated}***
- ***{R655-10, 11 & 12 Utah Administrative Code}***

UTAH
DAM SAFETY GUIDE
TO
EMERGENCY ACTION PLANS
DEVELOPMENT AND IMPLEMENTATION
2003

JERRY D. OLDS, P.E.
State Engineer

RICHARD B. HALL, P.E.
Assistant State Engineer - Dam Safety

Compiled by: Matthew C. Lindon, P.E.
Dam Safety Section
Division of Water Rights
Department of Natural Resources
1594 West North Temple
Salt Lake City, UT 84116

Reprinted: March, 2003

KEY REFERENCE

- ***Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures.*** FEMA. July 2013



Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures

First Edition

FEMA P-946 / July 2013



FEMA

EMERGENCY ACTION PLANS

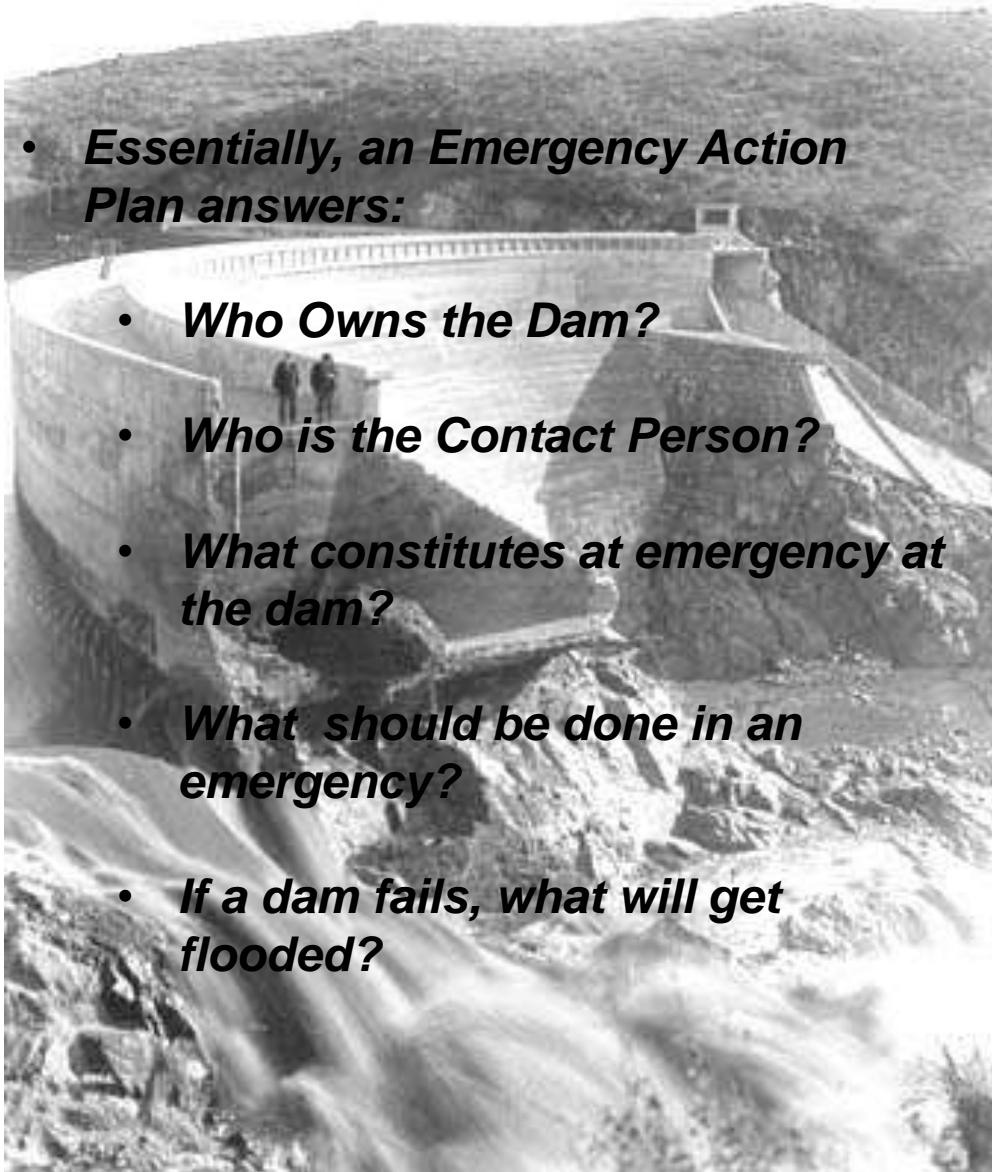
“An Emergency Action Plan, or EAP, is a formal plan that identifies potential emergency conditions at a dam and prescribes the procedures to be followed to minimize property damage and loss of life.”

“An emergency, in terms of dam operation, is defined as a condition which develops unexpectedly, endangers the structural integrity of the dam and/or downstream property and human life, and requires immediate action.”

REF: UTAH DIVISION OF WATER RIGHTS – UTAH DAM SAFETY GUIDE

EMERGENCY ACTION PLAN

- *Essentially, an Emergency Action Plan answers:*
 - *Who Owns the Dam?*
 - *Who is the Contact Person?*
 - *What constitutes an emergency at the dam?*
 - *What should be done in an emergency?*
 - *If a dam fails, what will get flooded?*



EMERGENCY ACTION PLAN

“The EAP should address this question?”

**THE DAM JUST FAILED /
IS FAILING, NOW WHAT?**

EMERGENCY ACTION PLANS

4.1.1 Part I -- Introductory Section

4.1.2 Part II -- Responsibilities

4.1.3 Part III -- Emergency Procedures

4.1.4 Part IV -- Preventive Actions

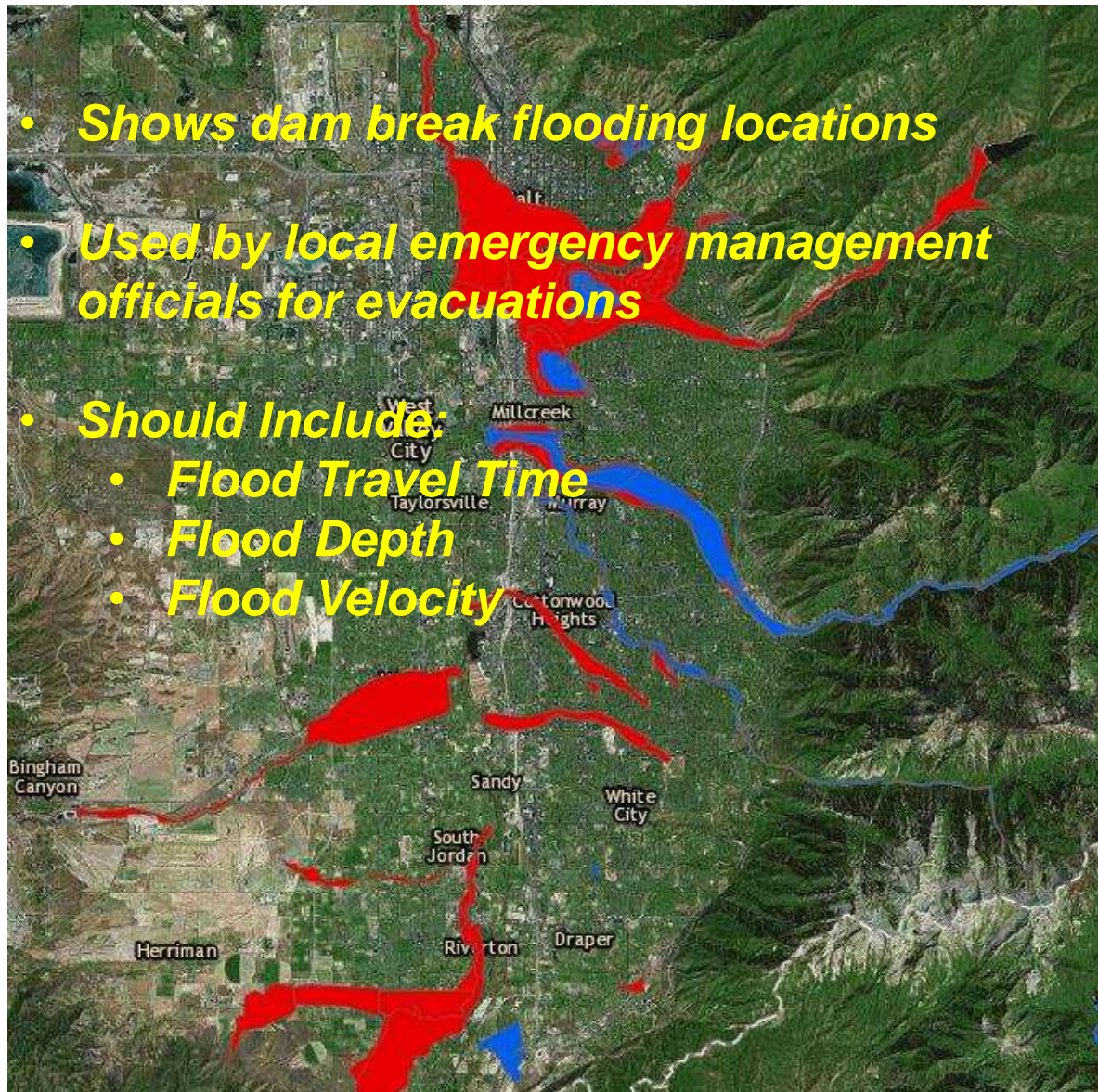
4.1.5 Part V -- Inundation Maps

4.1.6 Part VI -- Appendices

REF: UTAH DIVISION OF WATER RIGHTS – UTAH DAM SAFETY GUIDE

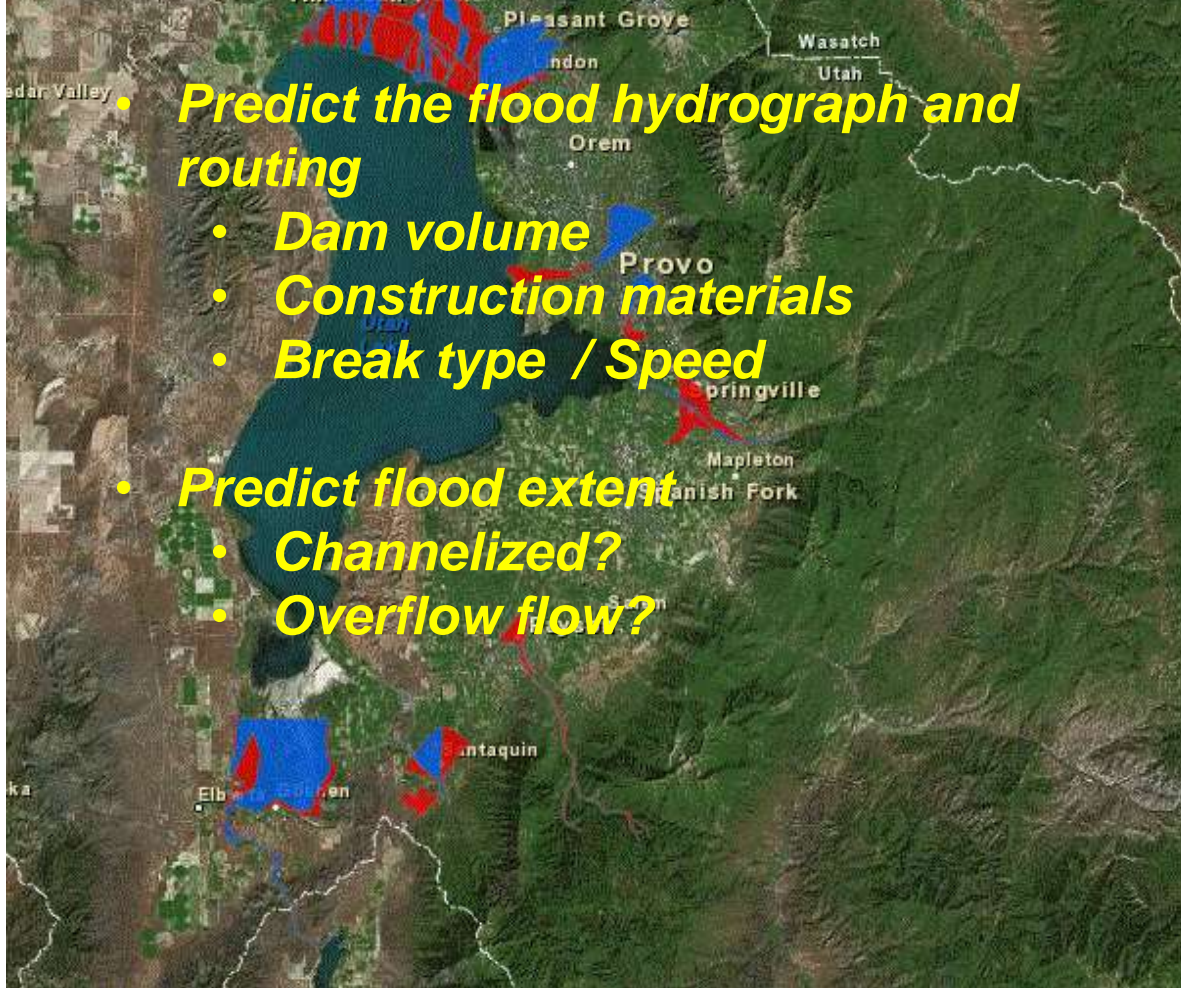
INUNDATION AREA MAP

- *Shows dam break flooding locations*
- *Used by local emergency management officials for evacuations*
- *Should Include:*
 - *Flood Travel Time*
 - *Flood Depth*
 - *Flood Velocity*



INUNDATION AREA MAP

- **BASIC INUNDATION MAPPING PROCESS**



INUNDATION AREA MAP

- **DAM BREAK HYDROGRAPH DEVELOPMENT**

- **Sunny Day Failures**



- **Hydrograph is dependent on dam's size and structure**
- **Consider likely modes of failure and locations / consider most severe cases**
- **Often associated with piping failures.**
- **Less warning**

- **Rainy Day Failures**

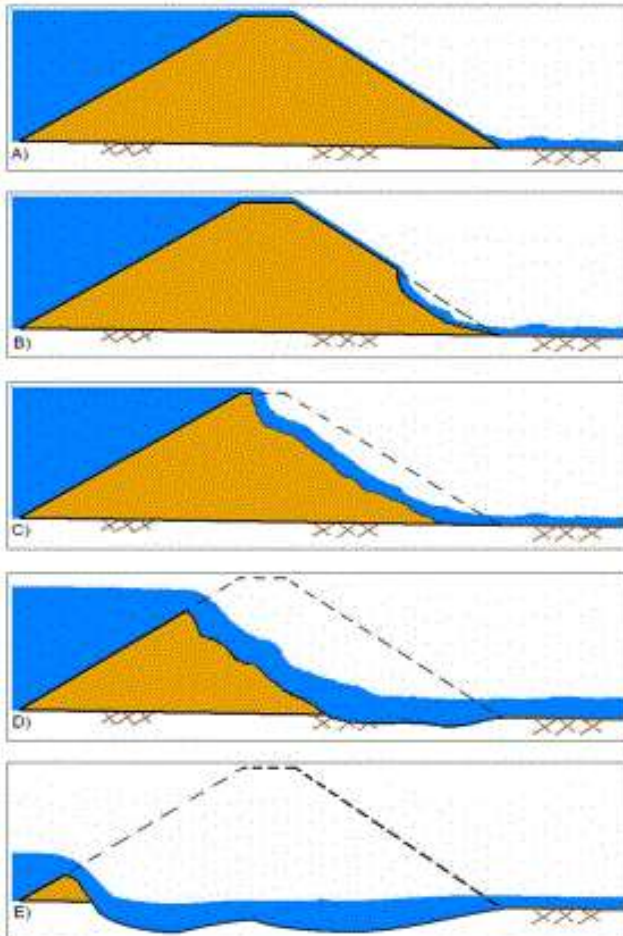


- **Hydrograph is dependent on dam's characteristics and on the upstream hydrology**
- **Often associated with overtopping failures**
- **Combines rainfall flooding and dam break flooding**

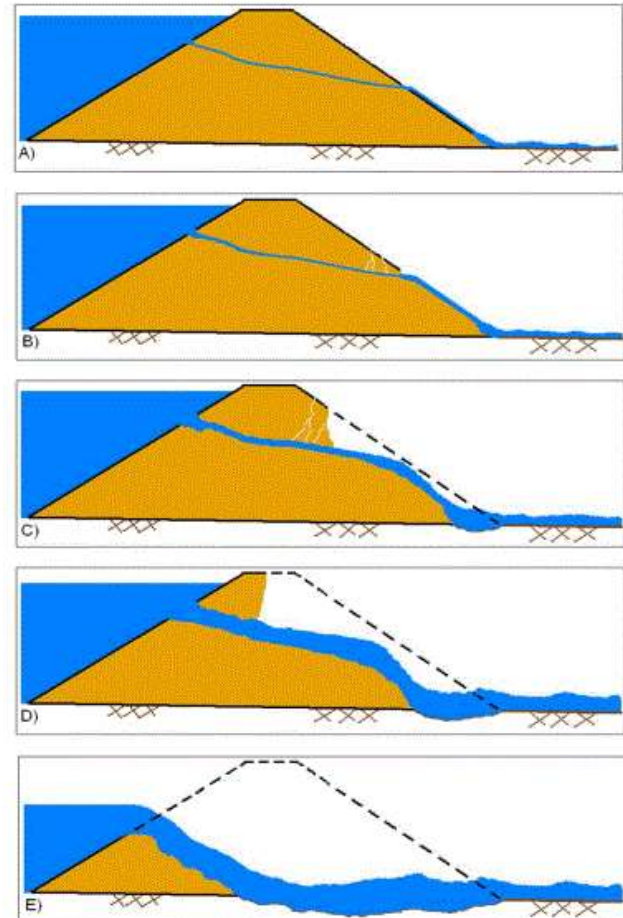
INUNDATION AREA MAP

- DAM BREAK HYDROGRAPH DEVELOPMENT**

OVERTOPPING



PIPING



METHODS AND MODELS

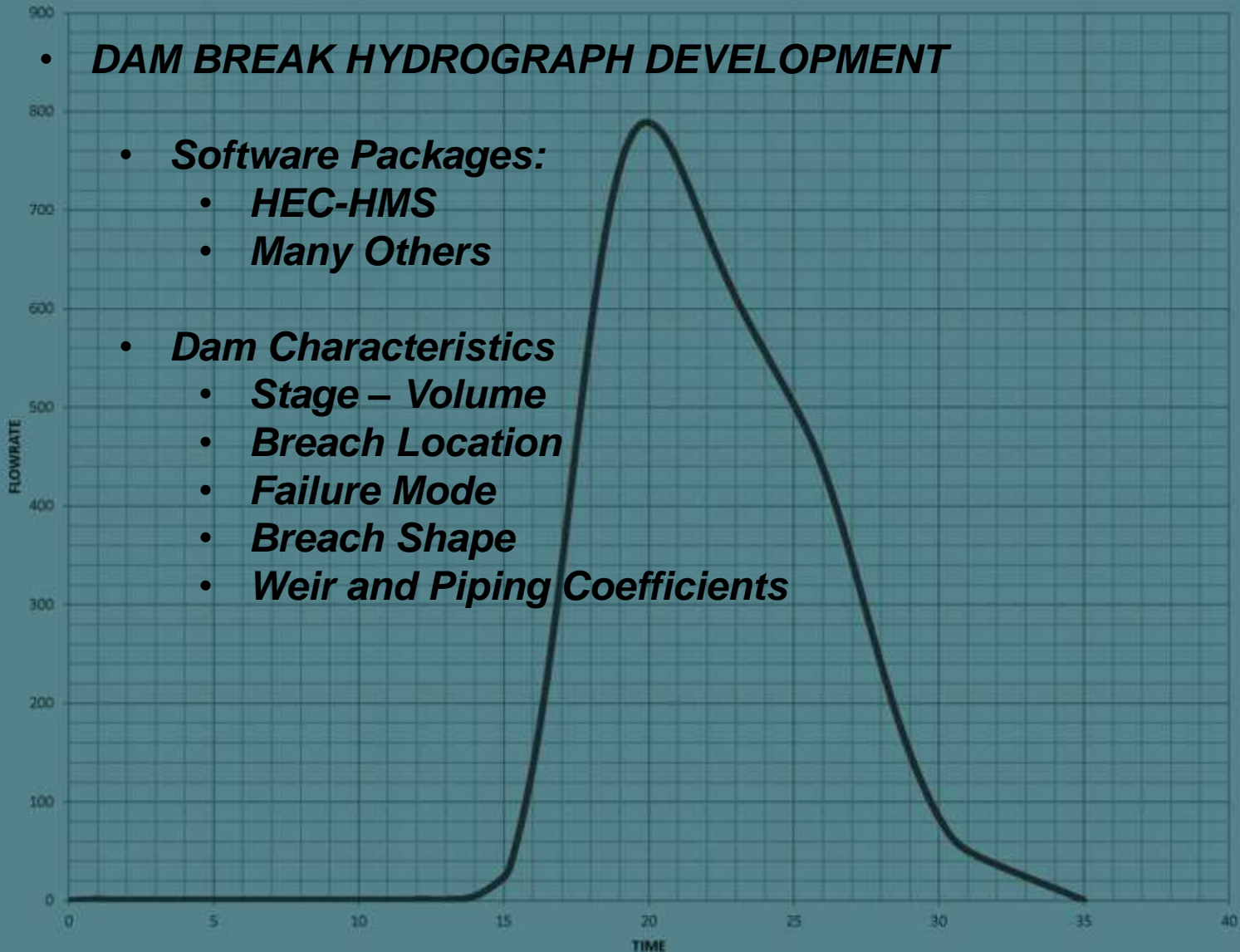
- **DAM BREAK HYDROGRAPH DEVELOPMENT**

- **Software Packages:**

- **HEC-HMS**
- **Many Others**

- **Dam Characteristics**

- **Stage – Volume**
- **Breach Location**
- **Failure Mode**
- **Breach Shape**
- **Weir and Piping Coefficients**



METHODS AND MODELS

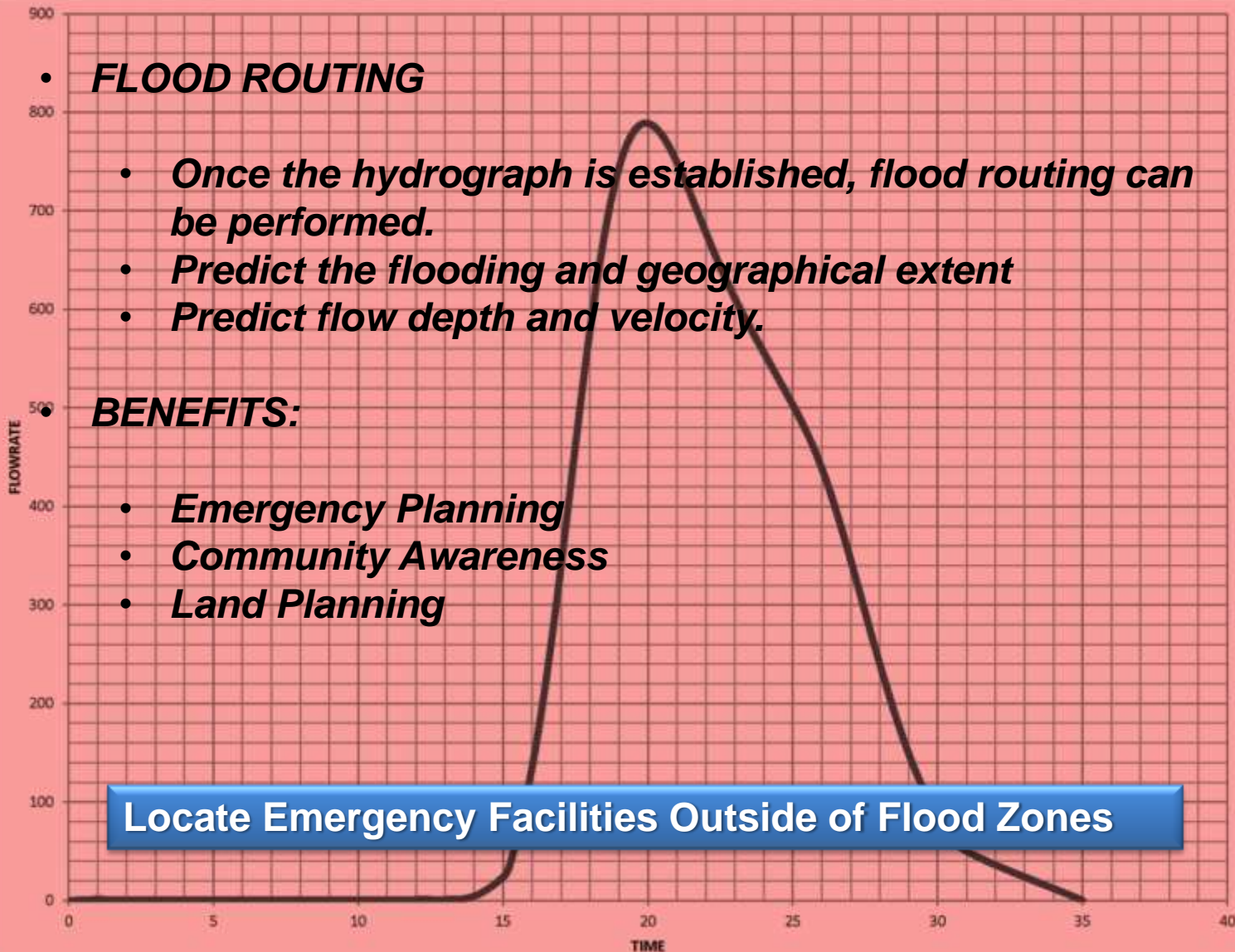
- ***FLOOD ROUTING***

- *Once the hydrograph is established, flood routing can be performed.*
- *Predict the flooding and geographical extent*
- *Predict flow depth and velocity.*

- ***BENEFITS:***

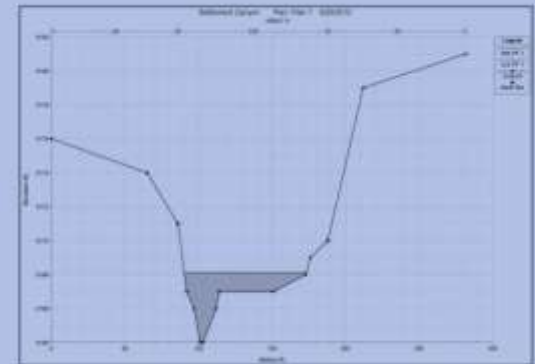
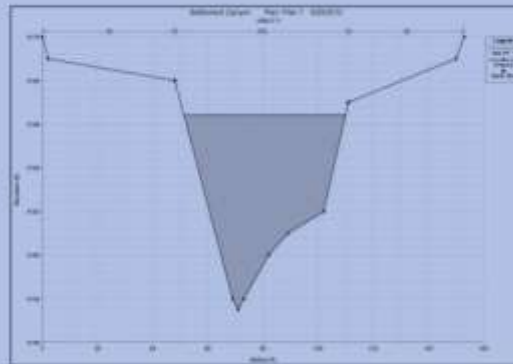
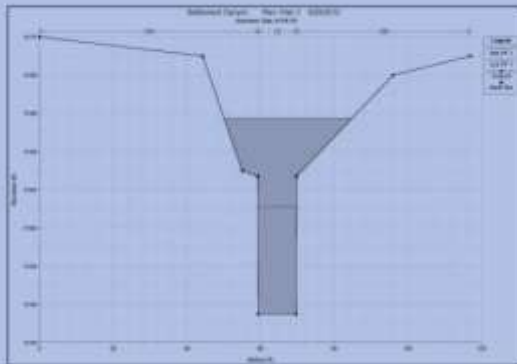
- *Emergency Planning*
- *Community Awareness*
- *Land Planning*

Locate Emergency Facilities Outside of Flood Zones



METHODS AND MODELS

- **FLOOD ROUTING – One Dimensional**
 - **Software Packages:**
 - **HEC-1 (outdated), HEC-HMS**
 - **HEC-2, HEC-RAS**
 - **Many Others**
 - **HEC-RAS**
 - **Steady and Unsteady Flow, Routing, *Hydraulics***
 - **New HEC-RAS 5.0 (Beta) has 2 Dimensional Functionality**
 - **Typically Requires Well Defined Cross Sections**



METHODS AND MODELS

- ***FLOOD ROUTING – Two Dimensional Models***
 - ***Routes full hydrograph, not just peak flows (assuming unsteady flow)***
 - ***Model flows vary with time***
 - ***Volume conservation is provided***
 - ***Defined channel is not required***
 - ***Water “Flows in the Model”***

METHODS AND MODELS

- ***FLOOD ROUTING – Two Dimensional***
 - ***Software Packages:***
 - ***HEC-RAS 5.0 (Beta) Limited Distribution***
 - ***FLO2D***
 - ***Aquaveo – WMS***
 - ***Others***

METHODS AND MODELS

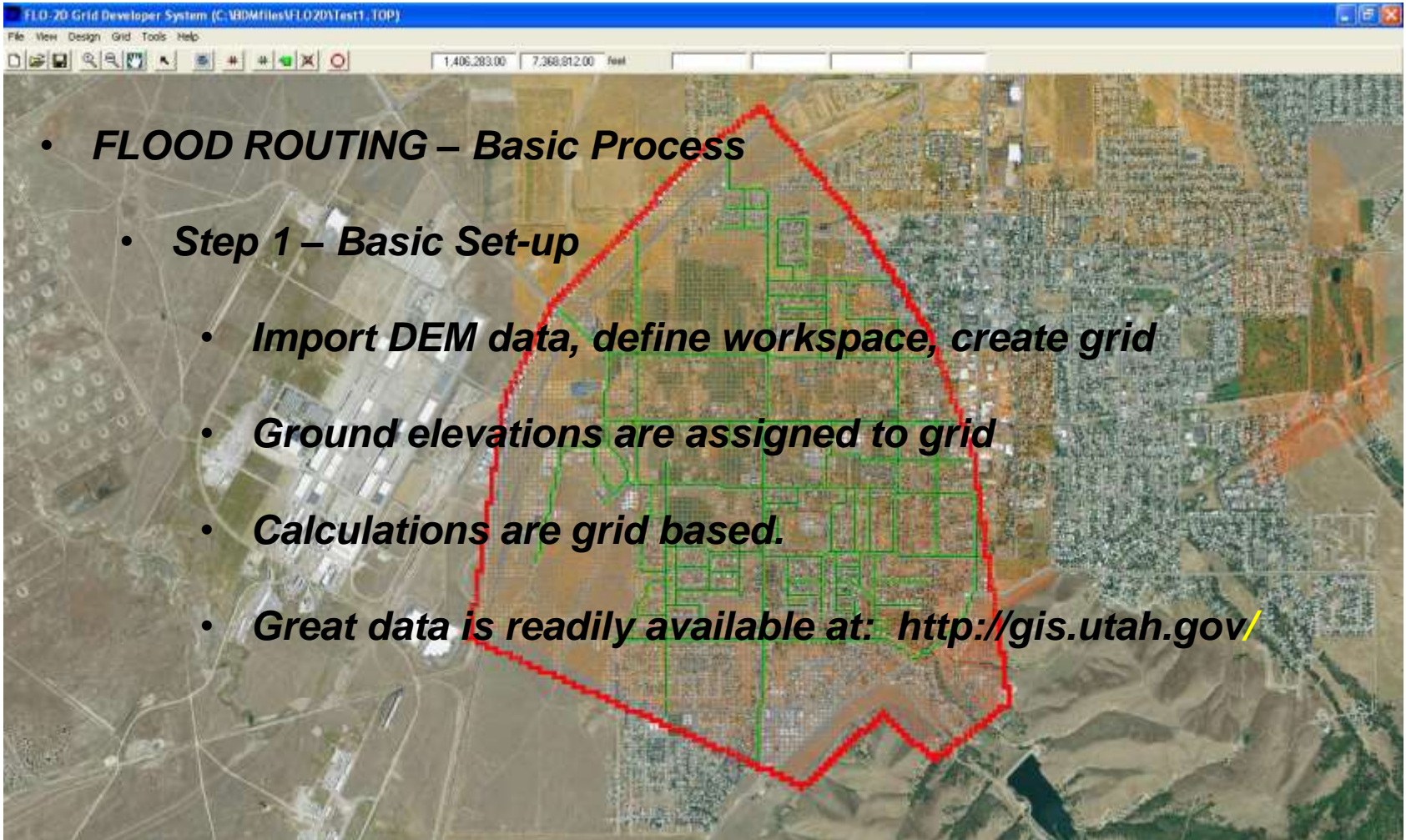
- ***FLOOD ROUTING – Two Dimensional Models***
 - ***HAL Often Uses FLO2D***
 - ***Free version is available***
 - ***Client can receive model with software purchase***
 - ***Accepted by FEMA for hydraulic applications***
 - ***Accepted by Utah Division of Water Rights – Dam Safety Section (Consult with the Dam Safety Staff prior to project to ensure applicability)***

METHODS AND MODELS

- ***FLOOD ROUTING – Basic Process***

- ***Step 1 – Basic Set-up***


- ***Import DEM data, define workspace, create grid***
 - ***Ground elevations are assigned to grid***
 - ***Calculations are grid based.***
 - ***Great data is readily available at: <http://gis.utah.gov/>***



METHODS AND MODELS

- **FLOOD ROUTING – Data**

- **Great data is readily available at: <http://gis.utah.gov/>**
- **Project specific land surveying**
- **Project specific aerial surveying**

**UTAH AGRC**
Automated Geographic Reference Center

Home » Data » Elevation and Terrain Data

NewsDataDeveloperAbout

Search...

Search

Elevation and Terrain Datasets for Utah

USGS DEMs

A digital elevation model (DEM) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. The USGS produces five different digital elevation products. Although all are identical in the manner the data are structured, each varies in sampling interval, geographic reference system, areas of coverage, and accuracy, with the primary differing characteristic being the spacing, or sampling interval, of the data. The AGRC has a statewide collection of 10, 30, and 90 meter DEMs.

- **10, 30, & 90 Meter Elevation Models (USGS DEMs)**

USGS NED

The National Elevation Dataset (NED) is the primary elevation data product of the USGS. The NED is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. The AGRC has a statewide collection of 10 and 30 meter DEMs.

- **10 & 30 Meter Elevation Models (USGS NED)**

LiDAR

Light Detection and Ranging elevation data is an optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light often using pulses from a laser. Currently this is the most accurate elevation dataset AGRC has but it is only available for a few areas of the state. In addition to the bare-earth DTMs and first-return DSMs, most LiDAR data also has point clouds of elevation information. Take a look at [Exploring LiDAR](#) for more information.

- **.5 Meter LiDAR (2013-2014)**
- **1 Meter LiDAR (2011)**
- **2 Meter LiDAR (2006)**
- **2 Meter Contours from LiDAR (Salt Lake County Only)**

Auto-Correlated DEM

AGRC has a statewide coverage of 5 Meter Auto-Correlated DEMs in addition to some 2 meter areas. The DEMs were created from the imagery collected during the 2006 NAIP and HRO aerial photography flights. **The auto-correlation process is not as rigorous as other methods of elevation modeling such as photogrammetry, lidar mapping, radar mapping, etc, and therefore end-users should be aware that anomalies are expected within the elevation dataset.** In comparison to the USGS NED dataset, the 2 and 5-meter DEM provides higher resolution and horizontal accuracy but anomalies are present within the data.

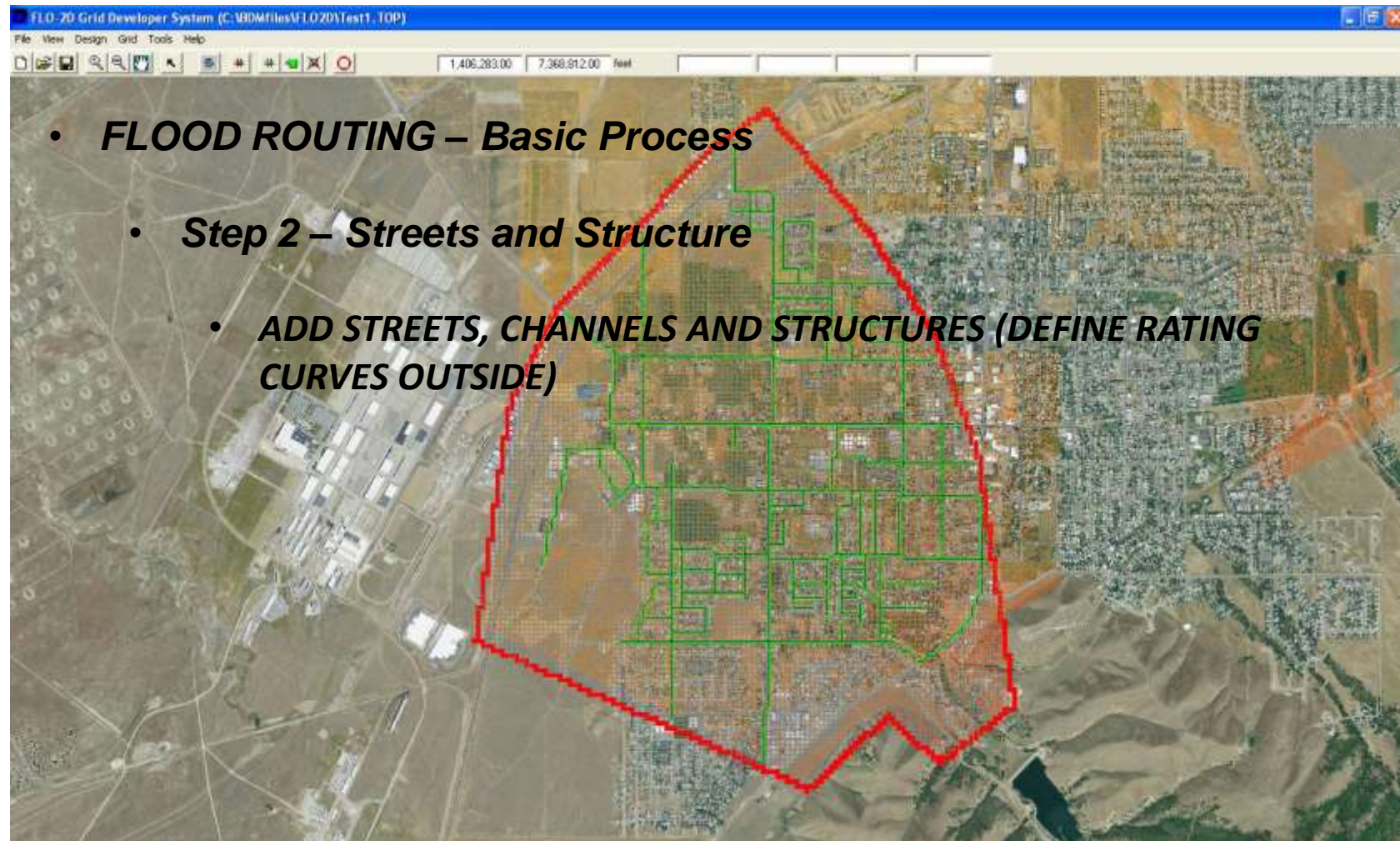
- **2 Meter Auto-Correlated Elevation Models**
- **5 Meter Auto-Correlated Elevation Models**

* All elevation and terrain data from the AGRC has a UTM NAD83 zone 12 north meters projection

Data Navigation ↓

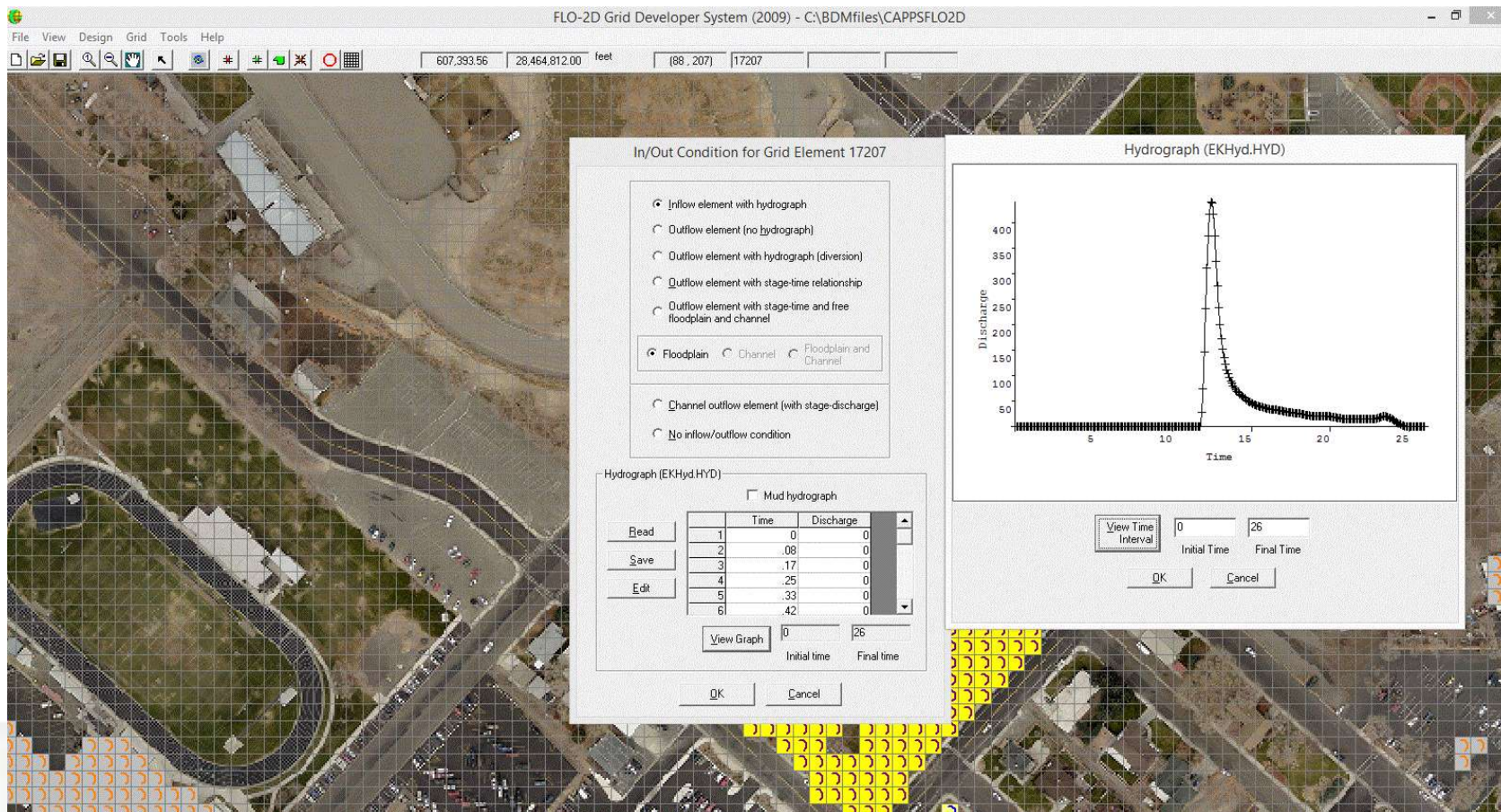
- Addresses (3)
- Aerial Photography (13)
- Bioscience (4)
- Boundary Data (13)
- Cadastral (5)
- Climate and Weather (3)
- Demographic (3)
- Economy (3)
- Elevation and Terrain Data (12)
 - Elevation and Terrain Data Overview
 - 10, 30, & 90 Meter Elevation Models (USGS DEMs)
 - 10 & 30 Meter Elevation Models (USGS NED)
 - .5 Meter LiDAR (2013-2014)
 - 1 Meter LiDAR (2011)
 - 2 Meter LiDAR (2006)
 - 2 Meter Contours (Salt Lake County Only)
 - 500 Foot Contours
 - 5 Meter Auto-Correlated Elevation Models
 - 2 Meter Auto-Correlated Elevation Models
 - USGS Scanned Topographic Maps (DRGs)
 - Vintage USGS Topographic Maps
- Energy (7)
- Environment (4)
- Farming (4)
- Geoscience (16)
- Health (6)
- History (3)
- Indices (8)
- Location (8)
- Planning (7)
- Political (6)
- Recreation (7)
- Society (9)
- Transportation (5)

METHODS AND MODELS



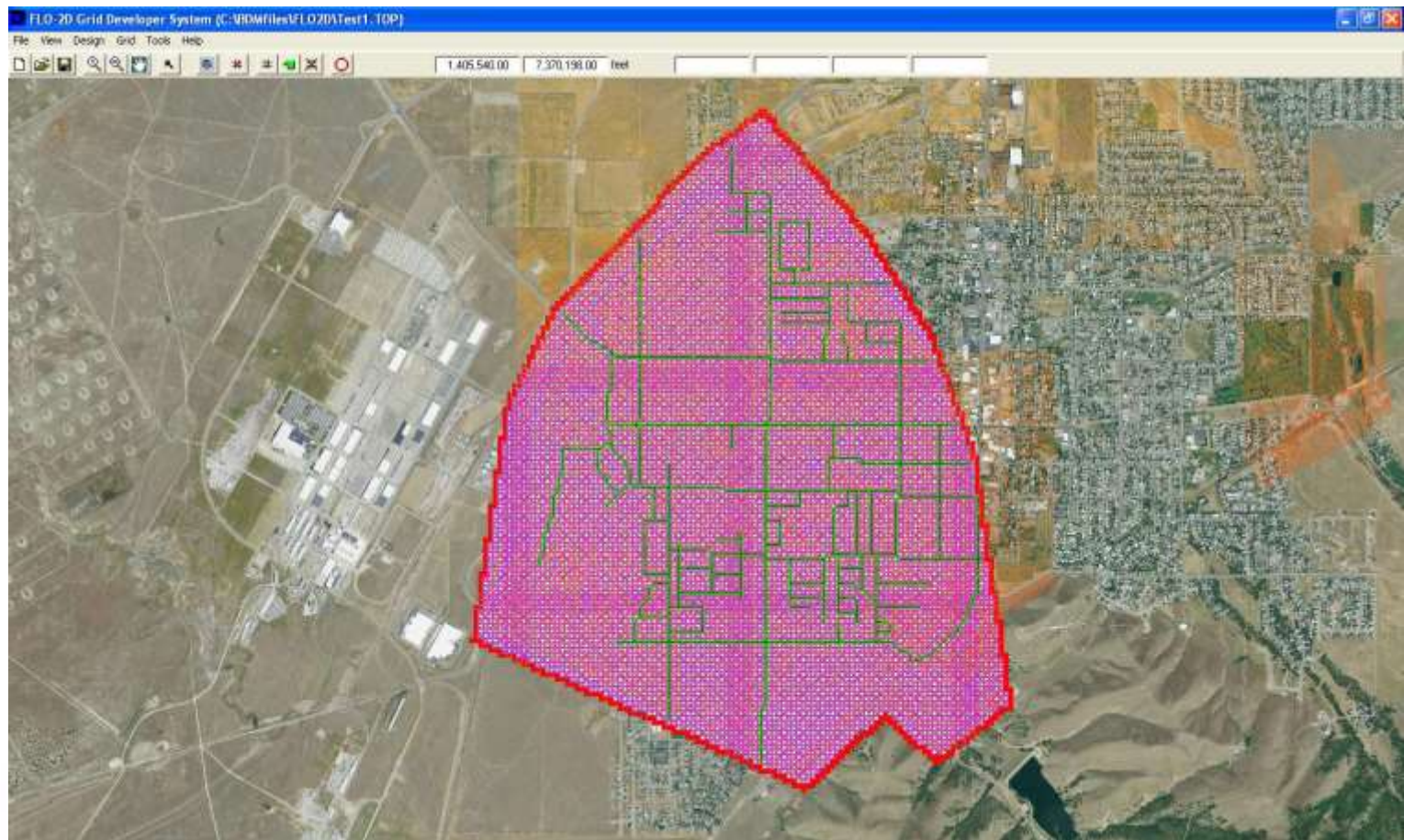
METHODS AND MODELS

- **FLOOD ROUTING – Basic Process**
 - **Step 3 – Add Inflows and Outflows**



METHODS AND MODELS

- ***FLOOD ROUTING – Basic Process***
 - ***Step 4 – Define infiltration and blocked areas***



- **Step 5 – Interpretation and Results**



CASE STUDIES

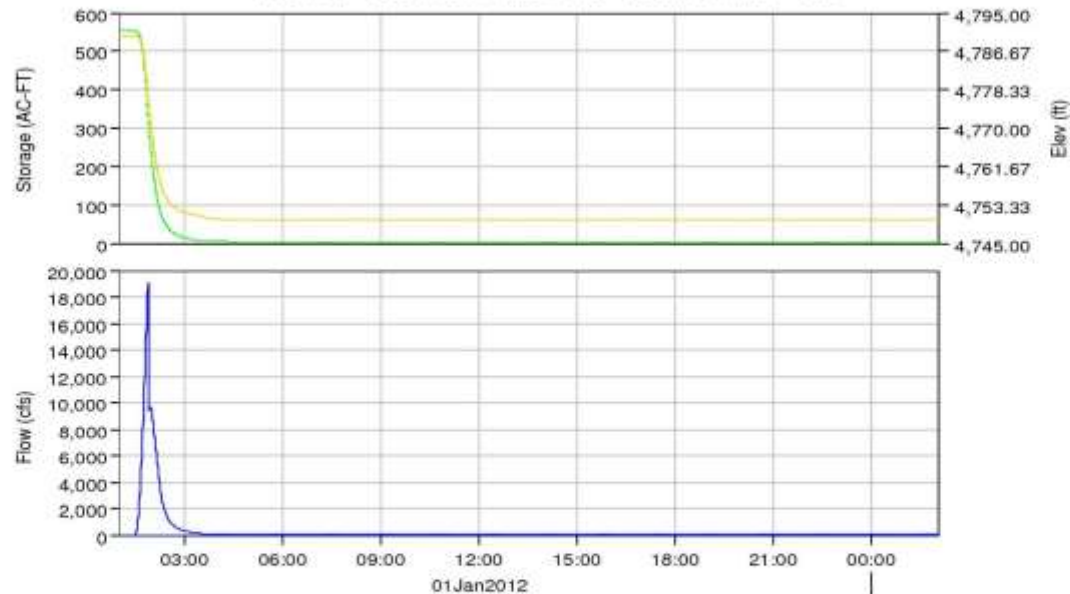
- **EXAMPLE DAM NO. 1**

- ***Purpose of Dam:***

- ***Raw Water Intake for Water Treatment Plant***
 - ***Size 550 AF***
 - ***Analysis “Sunny Day Failure”***
 - ***Breach Hydrograph Method: HEC-HMS***
 - ***Elevation Data***
 - ***2 Meter LIDAR from Utah AGRC***

CASE STUDIES

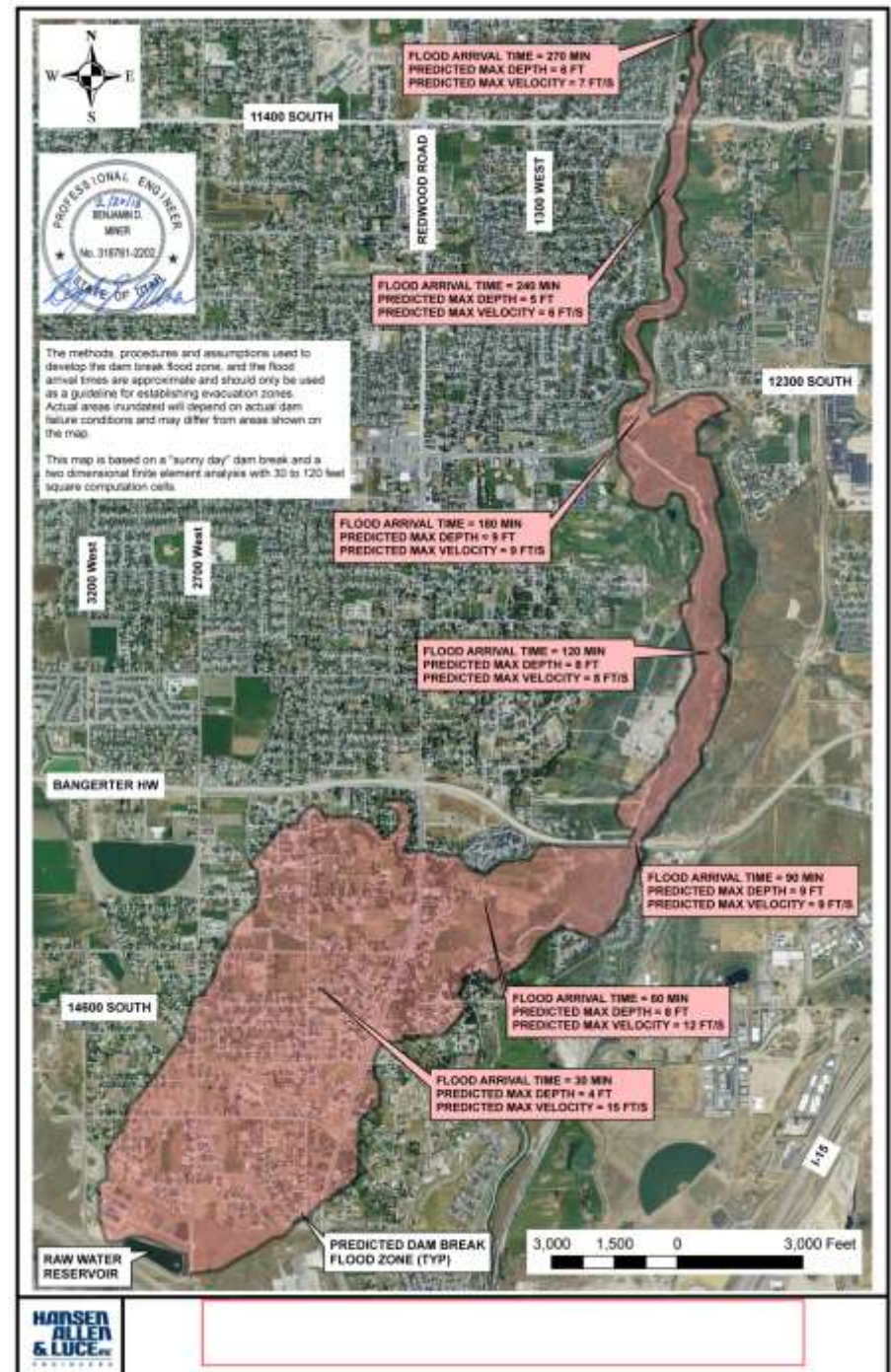
- **EXAMPLE DAM NO. 1**
 - ***Breach Hydrograph (at Dam)***



CASE STUDIES

- **EXAMPLE DAM NO. 1**

- **Results**



CASE STUDIES

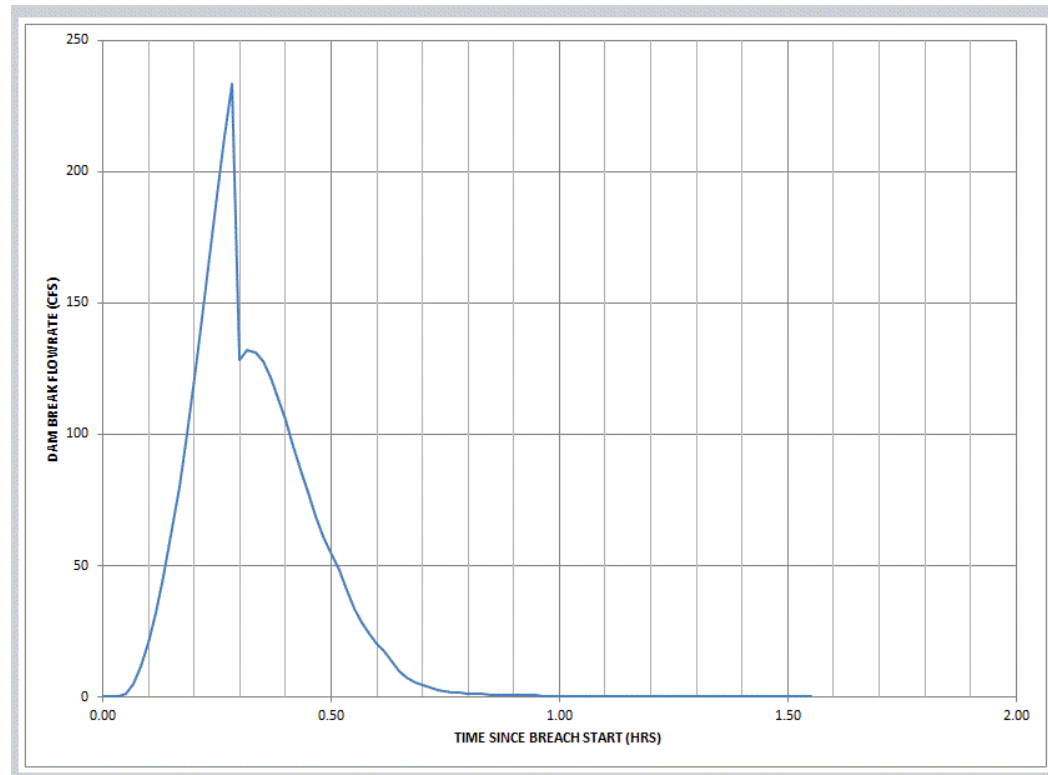
- **EXAMPLE DAM NO. 2**

- ***Purpose of Dam:***

- ***Municipal Irrigation***
 - ***Size <20 AF***
 - ***Analysis “Sunny Day Failure”***
 - ***Breach Hydrograph Method: HEC-HMS***
 - ***Elevation Data***
 - ***10 Meter DEM from Utah AGRC***

CASE STUDIES

- **EXAMPLE DAM NO. 2**
 - ***Breach Hydrograph (at Dam)***



CASE STUDIES

- **EXAMPLE DAM NO. 2**

- **Results**



CASE STUDIES

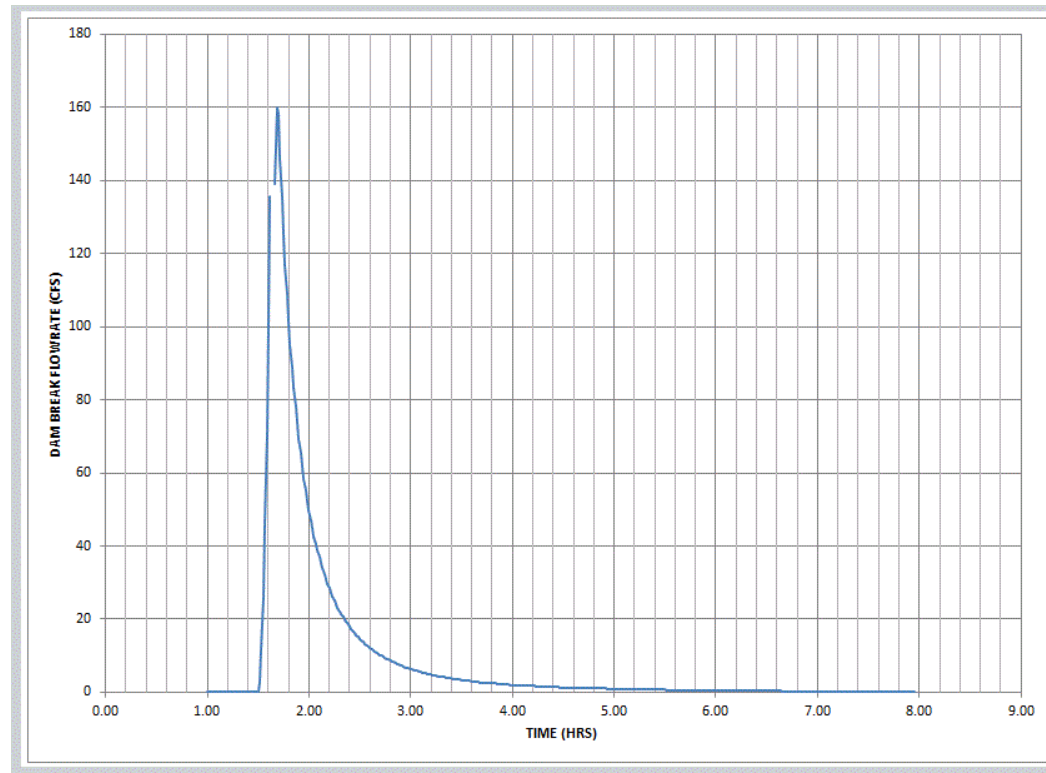
- **EXAMPLE DAM NO. 3**

- ***Purpose of Dam:***

- ***Municipal Irrigation***
 - ***Size <20 AF***
 - ***Analysis “Sunny Day Failure”***
 - ***Breach Hydrograph Method: HEC-HMS***
 - ***Elevation Data***
 - ***10 Meter DEM from Utah AGRC***

CASE STUDIES

- **EXAMPLE DAM NO. 3**
 - ***Breach Hydrograph (at Dam)***



CASE STUDIES

- **EXAMPLE DAM NO. 3**

- **Results**



CONCLUSIONS

- *The Emergency Action Plan relies on an accurate inundation area map.*
- *Two dimensional models can be a cost effective approach to model complex downstream scenarios.*
- *Two dimensional models are easily attainable and becoming easier to use.*
- *Two dimensional models often yield better results than traditional one dimensional models.*

QUESTIONS ?