



# Emergency Operations Data and Post-incident Recovery

Bill Kappel, Applied Weather Associates, United States  
Ed Beadenkopf, AtkinsRéalis, United States

# Enhancing Dam Safety in Puerto Rico

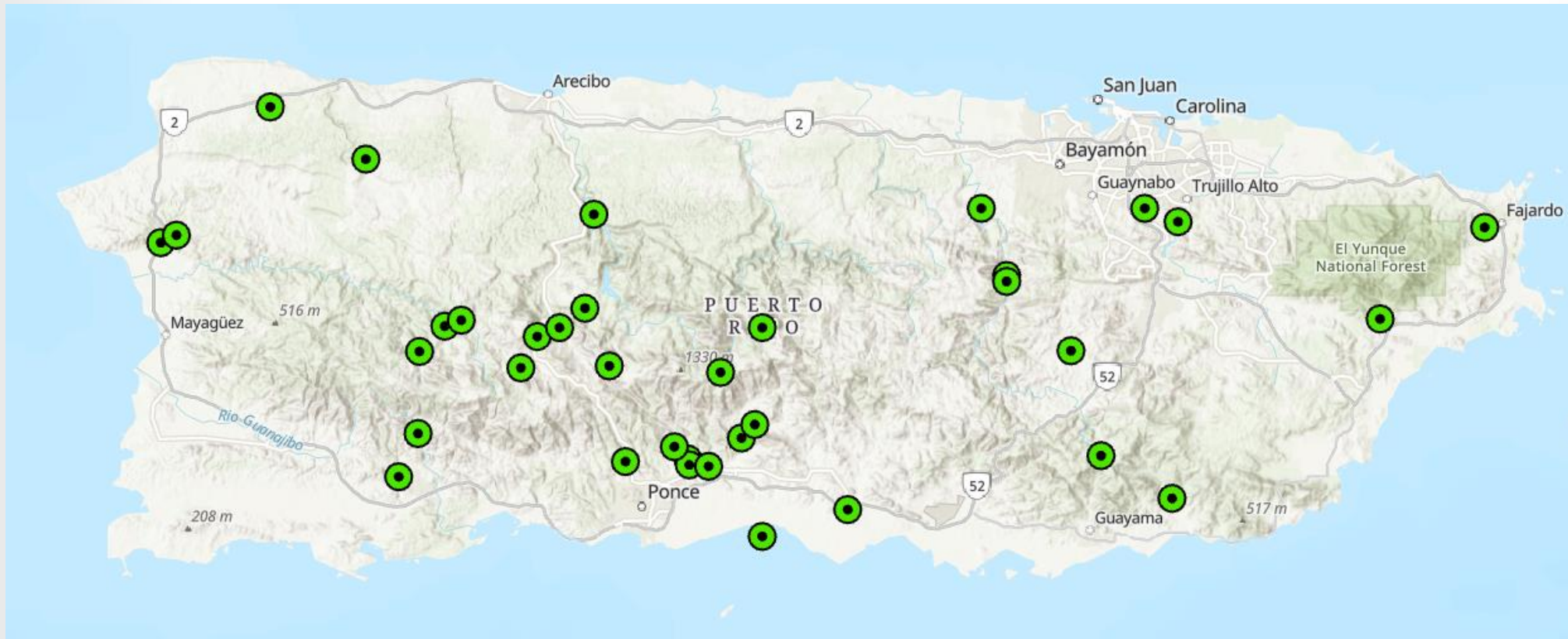
*FEMA provides technical assistance and funding to Puerto Rico to support dam safety. This includes funding for instrumentation at dams and a modern communication and warning system. Adding an **early detection component** to the early warning system is needed to more fully address the dam risk associated with extreme precipitation events.*

## **Presentation Agenda:**

- ✓ The technical support provided by FEMA
- ✓ How this support can be leveraged to enhance the emergency warning system (EWS) under development
- ✓ What next steps can be taken
- ✓ How this enhanced EWS improves dam safety in Puerto Rico

# Understanding Puerto Rico Dam Risk

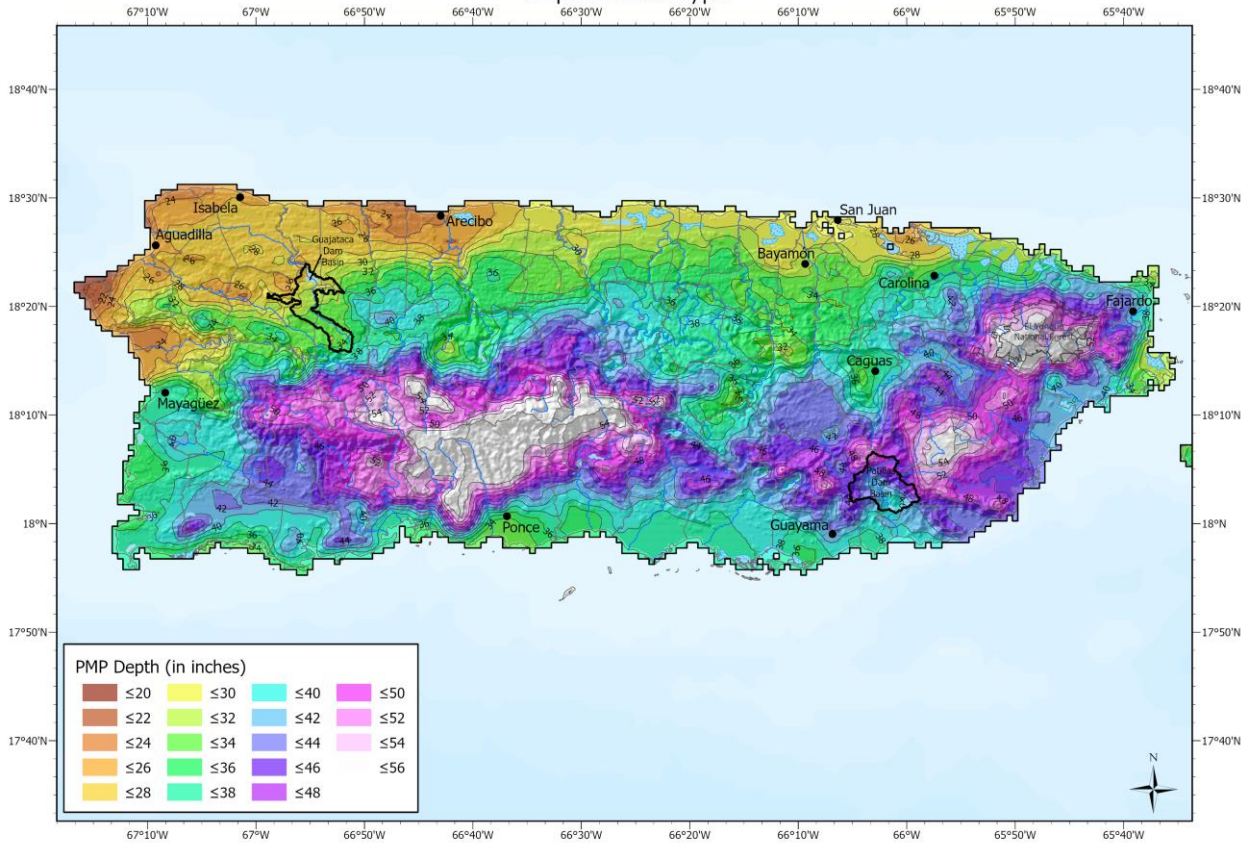
Aging dam infrastructure lacking flood warning with significant population at risk



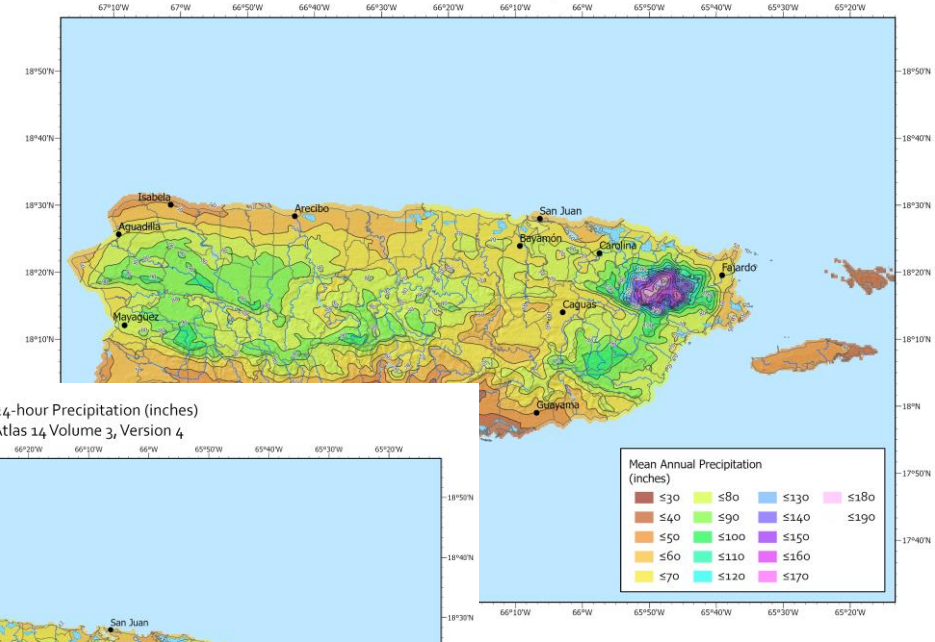


# Detailed Rainfall Data

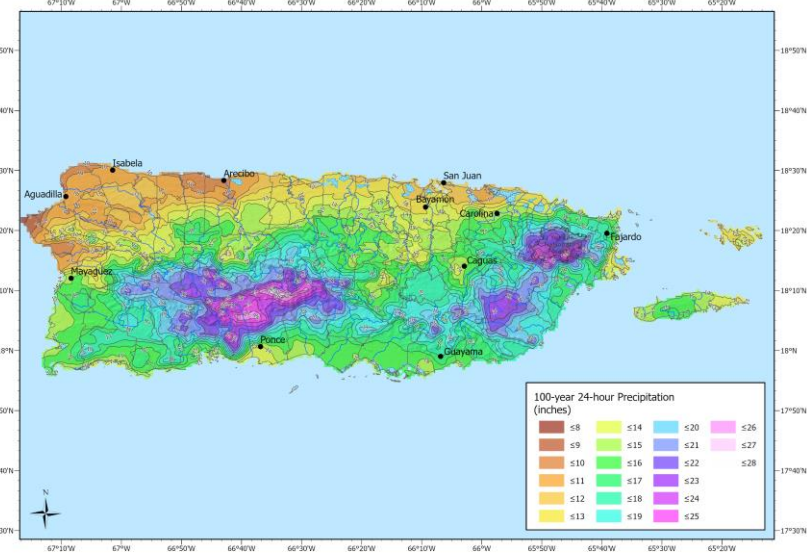
Puerto Rico Gridded 100 mi<sup>2</sup> 72-hour PMP (inches)  
Tropical Storm Type



33yr (1963-1995) Average Annual Precipitation (in)  
PRISM Climate Group

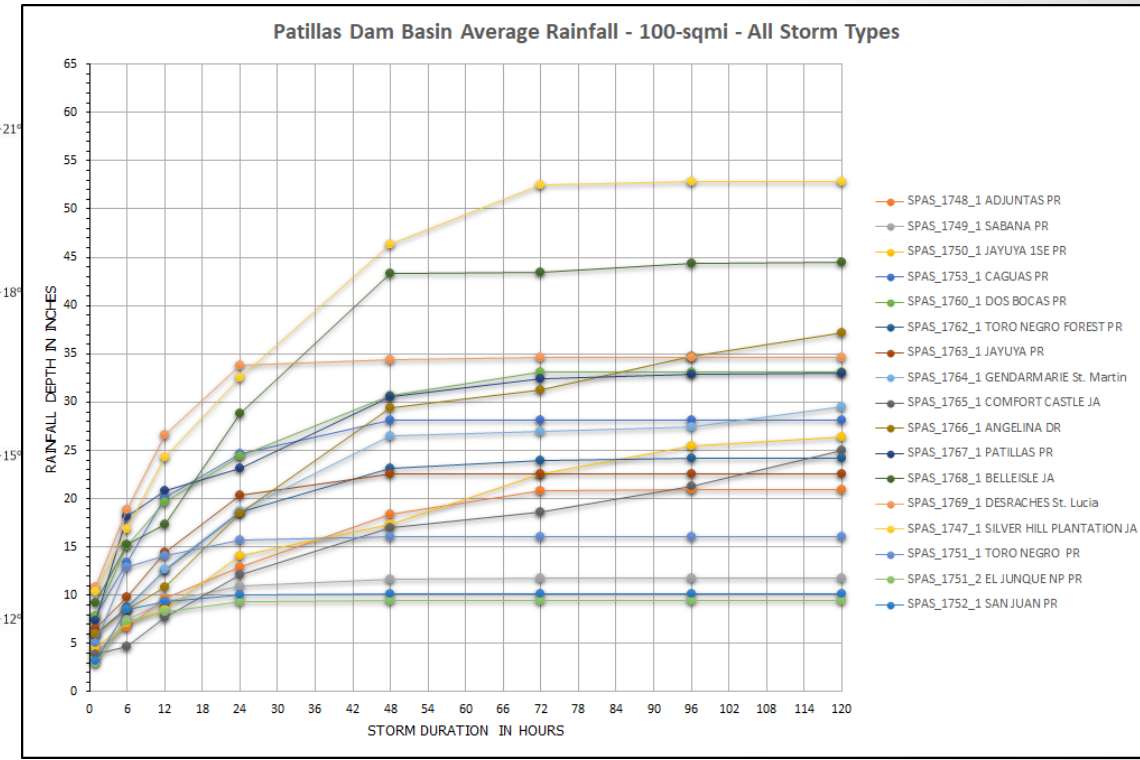
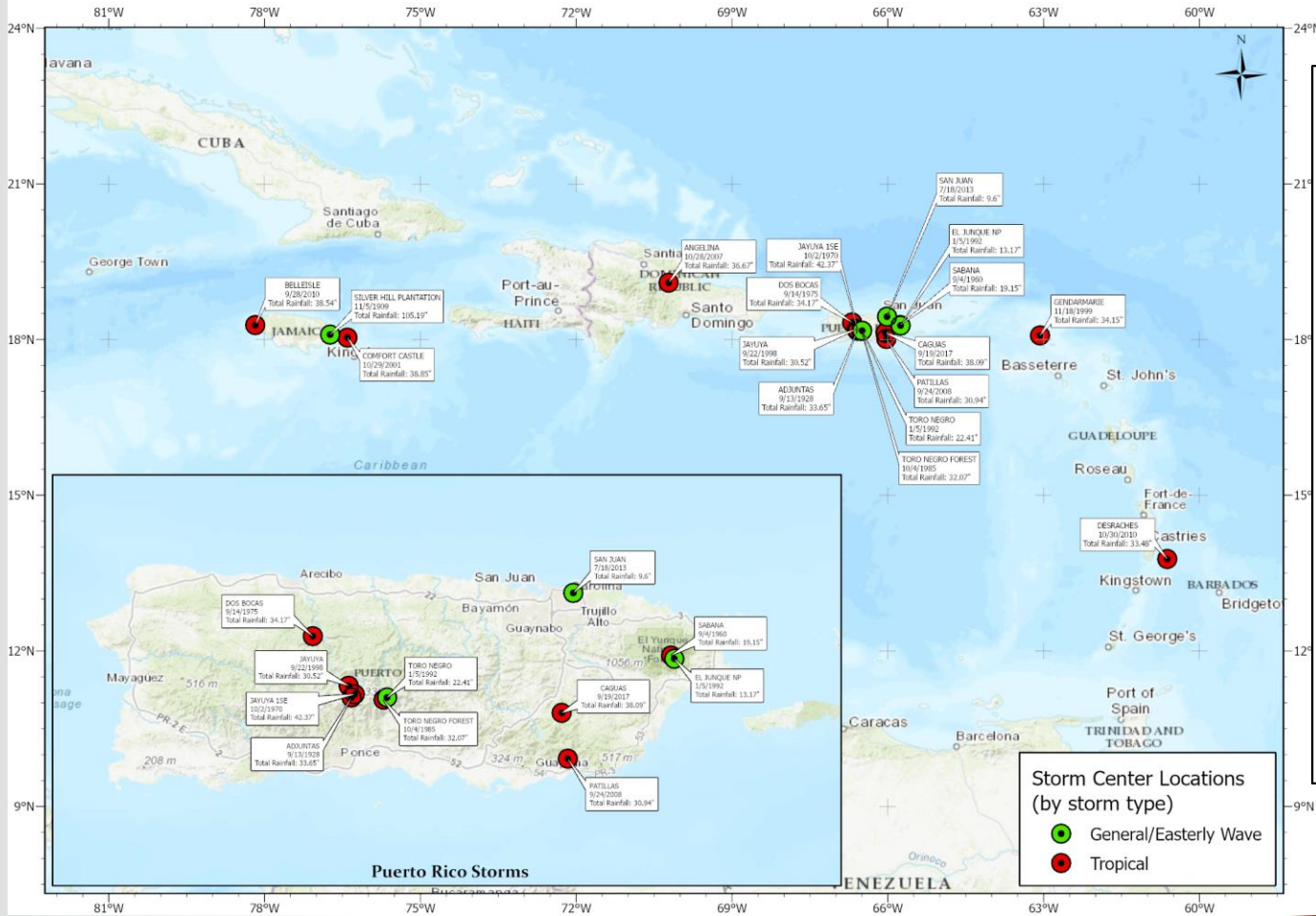


100-year 24-hour Precipitation (inches)  
NOAA Atlas 14 Volume 3, Version 4



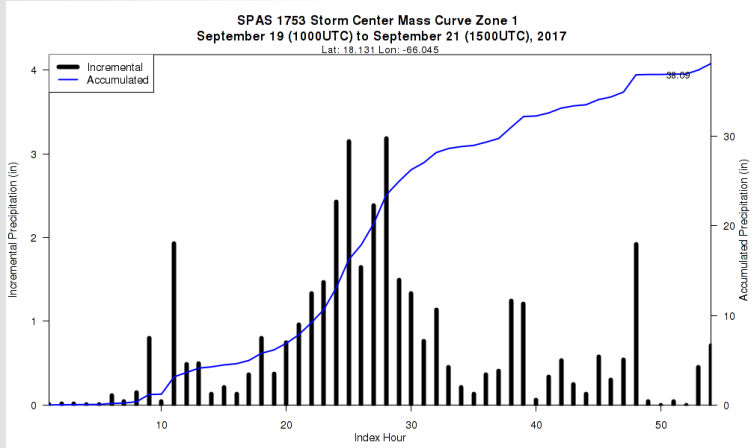
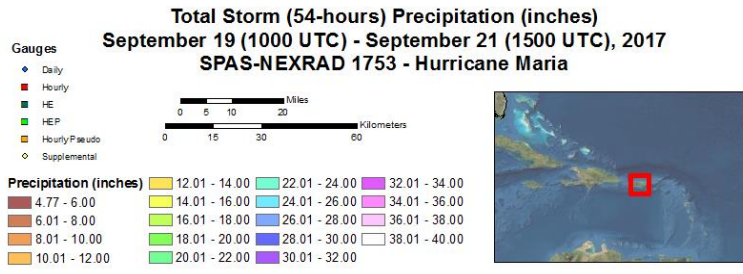
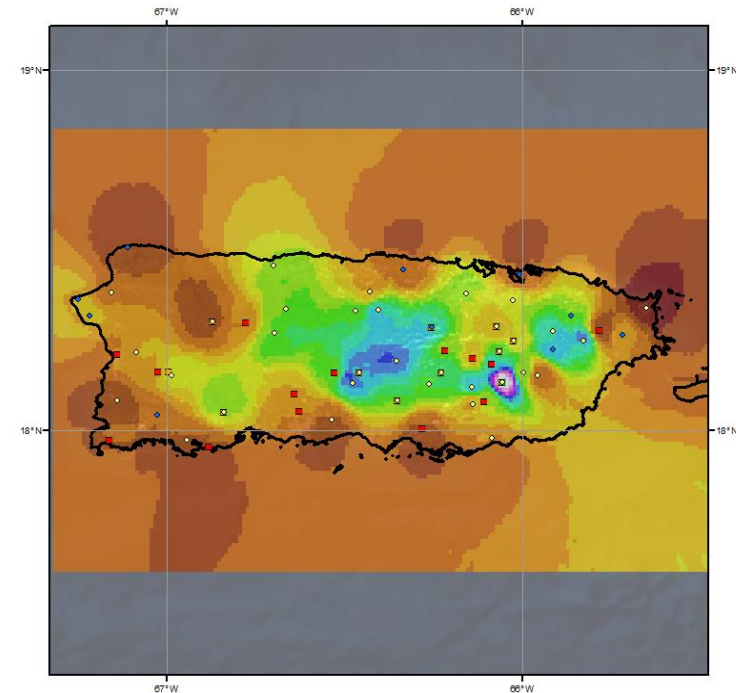
# Detailed Rainfall Data

Locations of Short List Storm Events  
Puerto Rico PMP



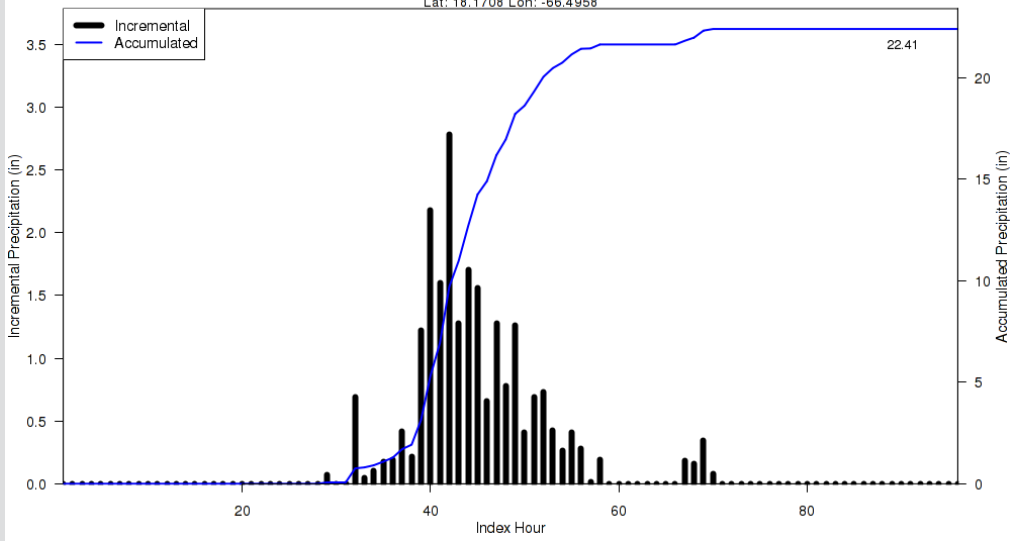
# Detailed Rainfall Data-Maria Sept 2017

Storm 1753 - September 19 (1000 UTC) - September 21 (1500 UTC), 2017												
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)												
Area (mi <sup>2</sup> )	Duration (hours)											
	1	2	3	4	5	6	12	18	24	48	54	Total
0.4	5.29	8.37	11.32	14.06	16.40	18.11	22.81	25.98	27.83	37.91	38.09	38.09
1	5.25	8.30	11.21	13.93	16.27	17.94	22.79	25.84	27.70	37.74	37.95	37.95
10	4.98	7.90	10.82	13.43	15.48	17.28	22.29	25.42	27.27	36.89	37.06	37.06
25	4.41	7.00	10.45	12.98	14.97	16.71	21.70	24.84	26.47	33.20	33.33	33.33
50	3.94	6.41	9.66	11.94	13.77	15.33	21.15	24.33	25.71	30.40	30.46	30.46
100	3.44	5.74	8.38	10.27	11.91	13.49	20.35	23.66	24.89	28.36	28.37	28.37
150	3.11	5.35	7.74	9.80	11.41	12.93	19.79	23.05	24.20	27.26	27.35	27.35
200	2.86	5.04	7.31	9.45	11.03	12.52	19.34	22.50	23.59	26.50	26.61	26.61
300	2.54	4.73	6.74	8.75	10.32	11.70	18.56	21.44	22.51	25.36	25.54	25.54
400	2.40	4.46	6.36	8.21	9.75	11.03	17.88	20.59	21.67	24.58	24.76	24.76
500	2.27	4.23	6.00	7.75	9.23	10.42	17.22	19.90	21.03	23.71	23.88	23.88
1,000	1.85	3.38	4.80	6.20	7.35	8.47	14.48	17.05	18.56	20.92	21.06	21.06
2,000	1.54	2.60	3.72	4.83	5.75	6.81	11.60	13.96	15.41	17.92	18.06	18.06
3,500	1.35	2.19	3.14	3.95	4.71	5.61	9.60	11.80	13.11	15.64	15.77	15.77
5,000	1.19	1.89	2.89	3.58	4.18	4.98	8.56	10.61	11.82	14.16	14.27	14.27
7,500	0.91	1.60	2.38	3.04	3.61	4.43	7.48	9.40	10.44	12.58	12.67	12.67
10,000	0.81	1.40	1.97	2.65	3.20	3.84	6.76	8.60	9.54	11.56	11.64	11.64
11,731	0.75	1.30	1.82	2.44	2.95	3.48	6.29	8.04	8.97	10.93	11.01	11.01

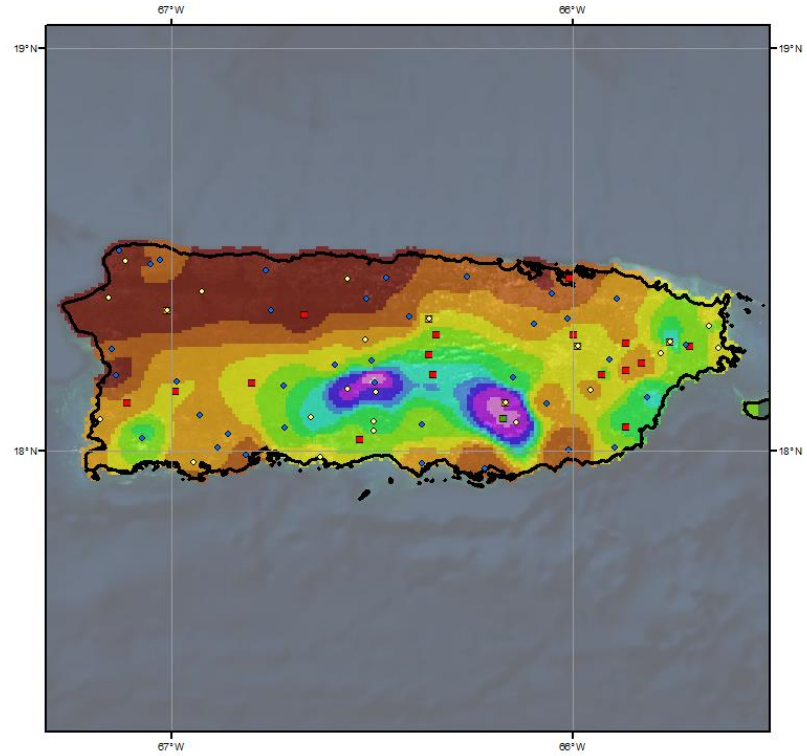
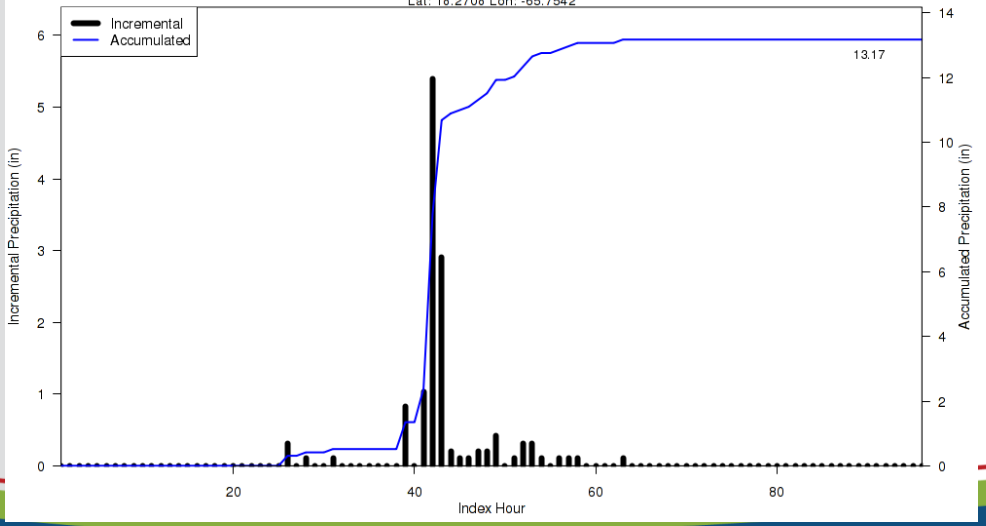


# Detailed Rainfall Data-Three Kings Jan 1992

SPAS 1751 Storm Center Mass Curve Zone 1  
January 4 (0500AST) to January 8 (0400AST), 1992  
Lat: 18.1708 Lon: -66.4958



January 4 (0500AST) to January 8 (0400AST), 1992  
Lat: 18.2708 Lon: -65.7542



- Gauges
- Daily
  - Hourly
  - HEP
  - Hourly Pseudo
  - Supplemental

Precipitation (inches)

0.40 - 2.00	6.01 - 8.00	14.01 - 16.00
2.01 - 4.00	8.01 - 10.00	16.01 - 18.00
4.01 - 6.00	10.01 - 12.00	18.01 - 20.00
	12.01 - 14.00	20.01 - 22.00
		22.01 - 24.00

# FEMA Support for Dam Risk Management

FEMA is engaged with Puerto Rico to support local efforts to reduce dam risk and increase preparedness

- Grant Funding

- Dam modifications
- Dam rehabilitations
- Instrumentation at dams
- Early Warning System (EWS)

- Technical Support

- Outreach and training to municipalities to understand the risk of potential dam failures
- Hazard mitigation planning to include dam risk
- Watershed modeling of flood hazards and risk
- Scenario-based tabletop exercises to enhance emergency operations planning
- Evacuation planning with the US Army Corps of Engineers

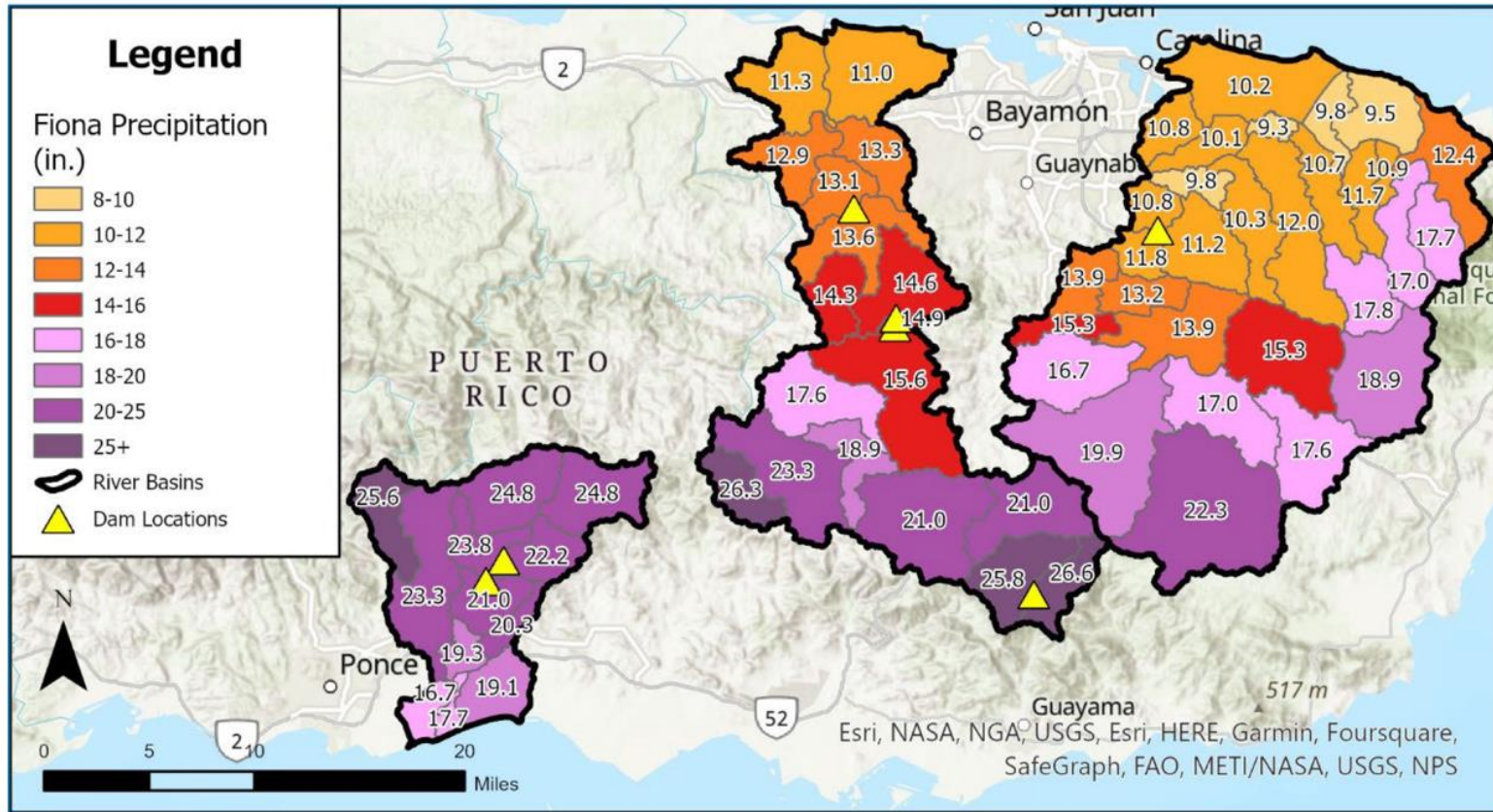
# FEMA Facilitated Dam Risk Preparedness Planning

## Preparing for Dam-related Emergencies Collaborative Technical Assistance Program (CTA)

- 9-month stakeholder outreach and training program
- To increase awareness of dam risk
- To foster engagement among all impacted stakeholders
- To test the emergency notification and response plans
- To identify gaps and after-actions



# FEMA Funded a Pilot Watershed Modeling Effort

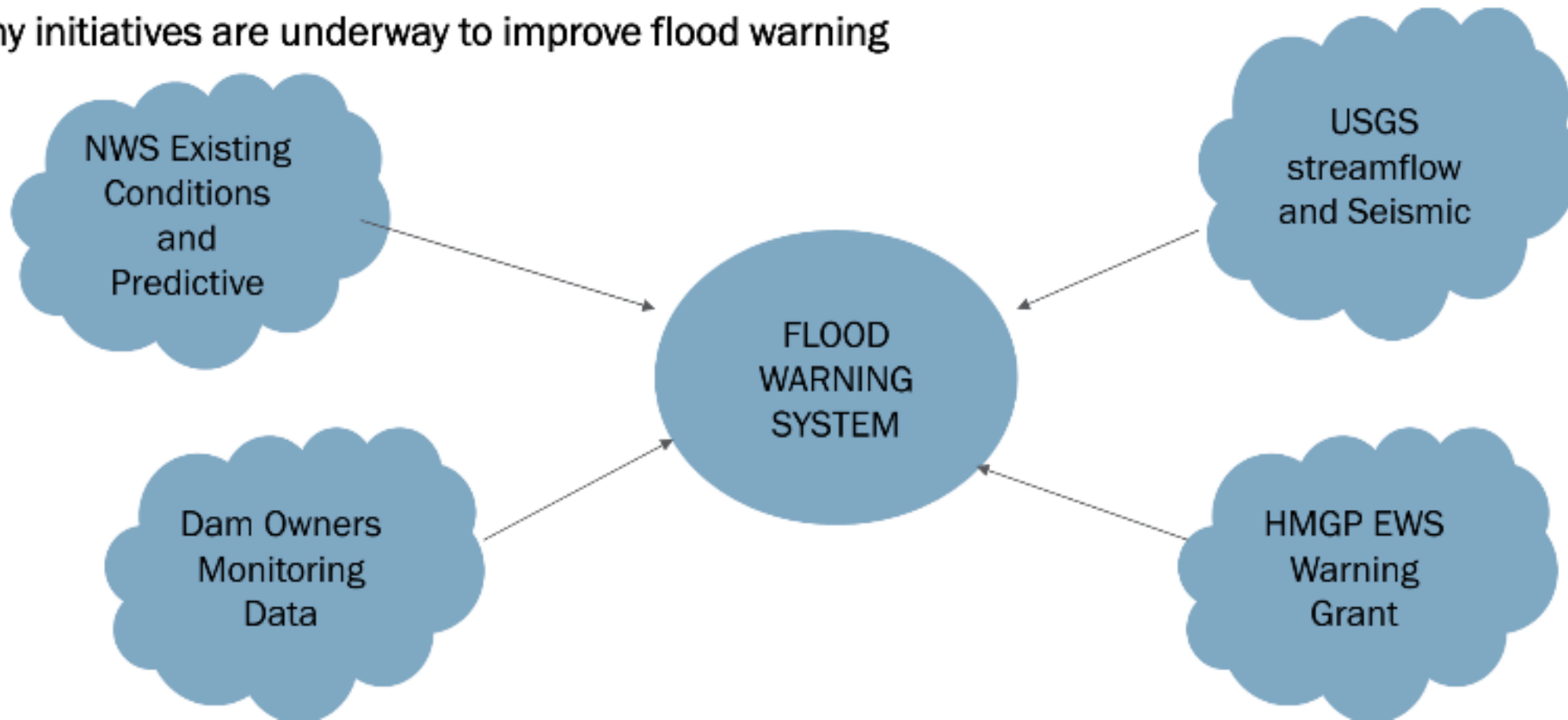


- HEC-HMS and HEC -RAS 2D watershed modeling-Fiona
- No dams failed but devastating flooding and economic damages occurred
- Modeling showed impact of dams and operations on flooding
- Applicable modeling for early detection



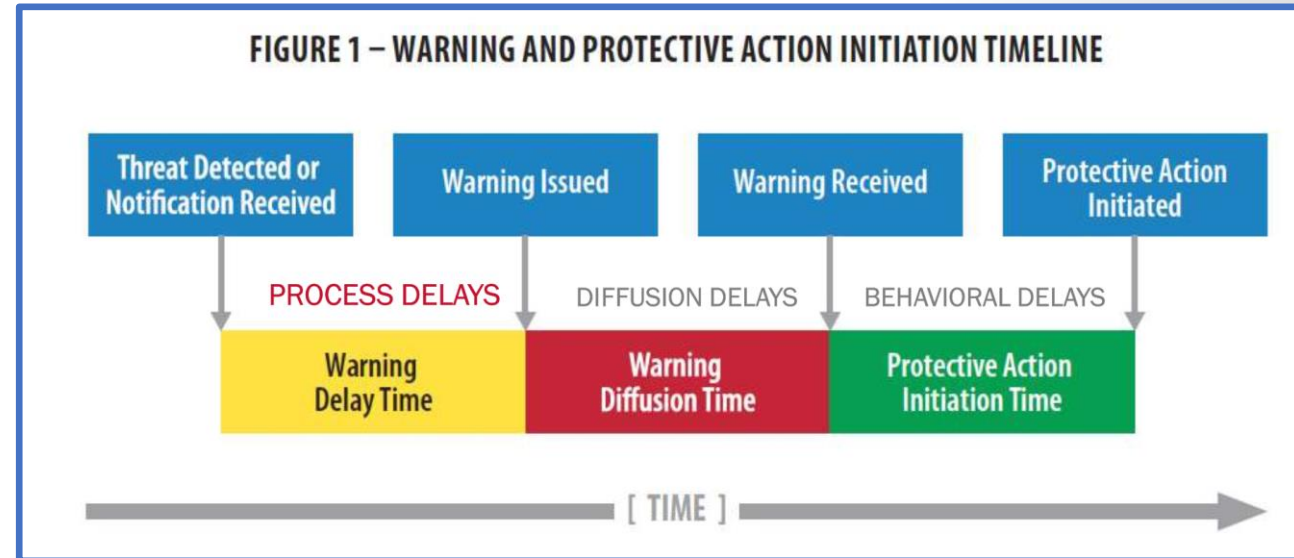
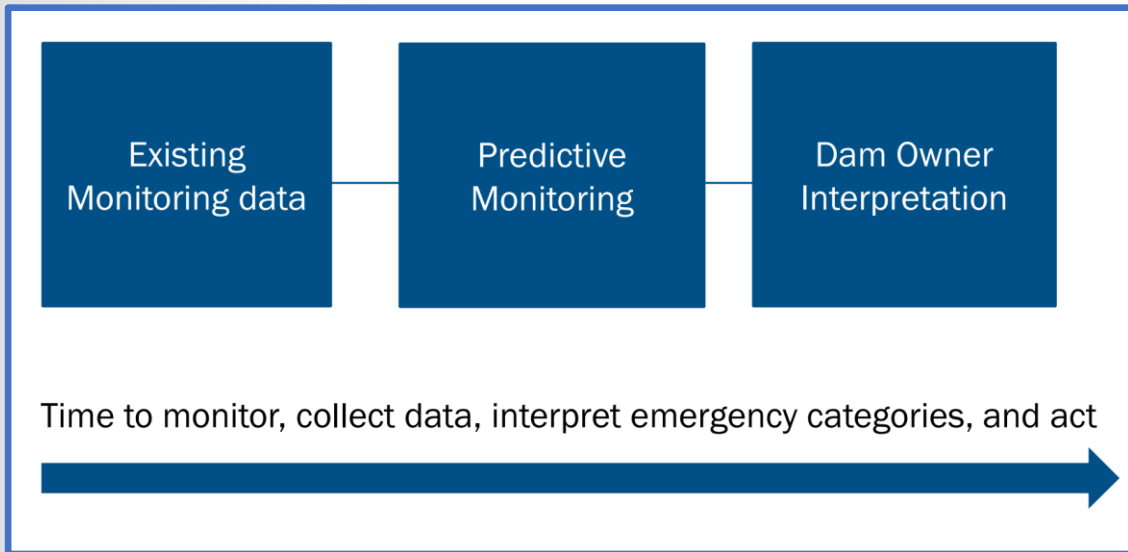
# Enhancing the EWS

Many initiatives are underway to improve flood warning



# Enhancing the EWS- Importance of Early Detection

Early detection increases warning time for evacuations



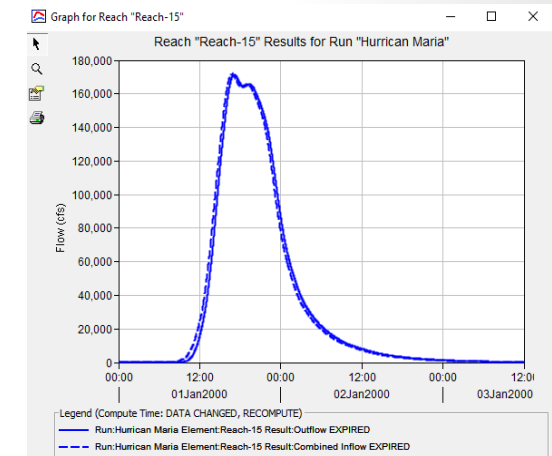
Dennis S. Mileti and John H. Sorensen, *A Guide to Public Alerts and Warnings for Dam and Levee Emergencies* (United States Army Corps of Engineers: 2015)

# The Need for Watershed-based Modeling

Hydrologic and 2D Hydraulic modeling of the watershed response

- Most dams on Puerto Rico lack watershed-based models
  - Models that include all dams in series and on tributaries
- Model define basin flows
  - Timed to real time rainfall inputs QPF
- Hydraulic models provide depth, velocity and timing of resultant hydrographs at the dam sites
- Providing dam owners estimates for near future conditions as added information to what is observed
- **Modeling increases the time to ACT!**

Maria Rainfall	
Atkins Model- La Plata Dam Outflow	171,489 (cfs)
USGS Gage No. 50045010 Recorded on 2017-09-20	180,000 (cfs)



# Enhancing the EWS- Role of Watershed Modeling

## PREDICTIVE PRE-STORM

- Watershed-based hydrologic and 2D hydraulic models
- Using Integrated inputs from strategically located gages
- QPF for watershed modeling
- Incorporate reservoir operations rules for gates structures
- Enhanced EAPs incorporating dam specific instrumentation and watershed data
- Watershed specific Emergency Operations Plans for evacuation planning and response

## CURRENT DURING EVENT

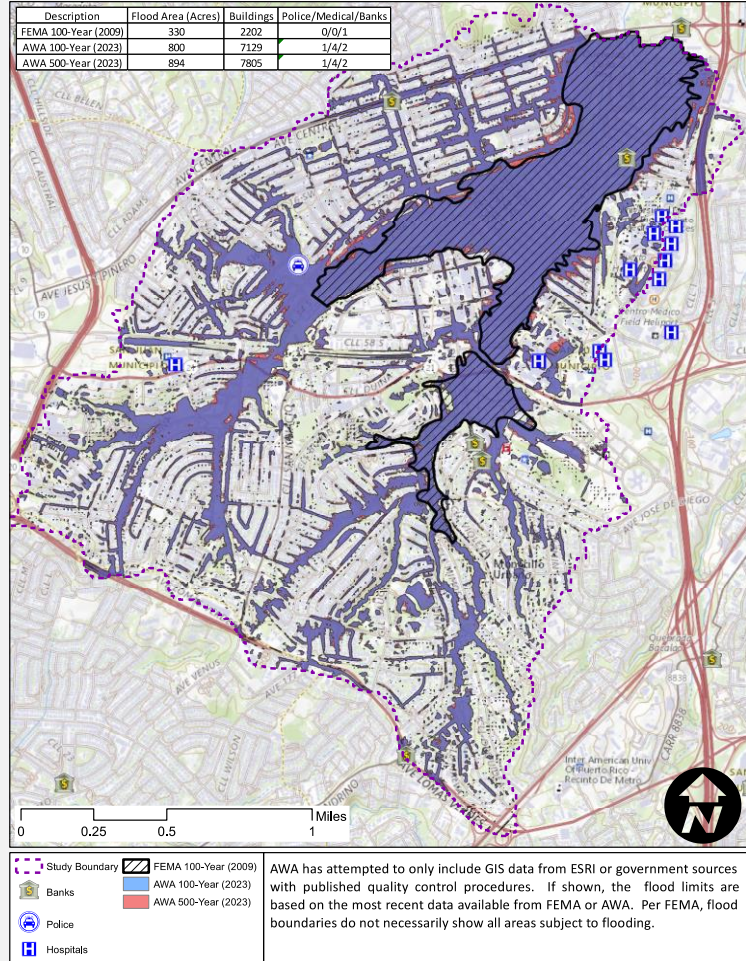
- **Monitoring of instruments and the dam's performance**
- Near real time watershed modeling of existing conditions
- Short term Predictive QPF watershed modeling
- Implementation of operations rules
- Predictive flood maps with depth, timing, and velocities
- **Monitor EAP triggers for incident levels**
- **EAP notifications and public warning communications**

## POST EVENT

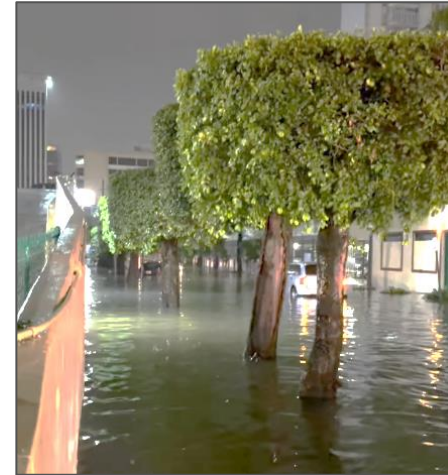
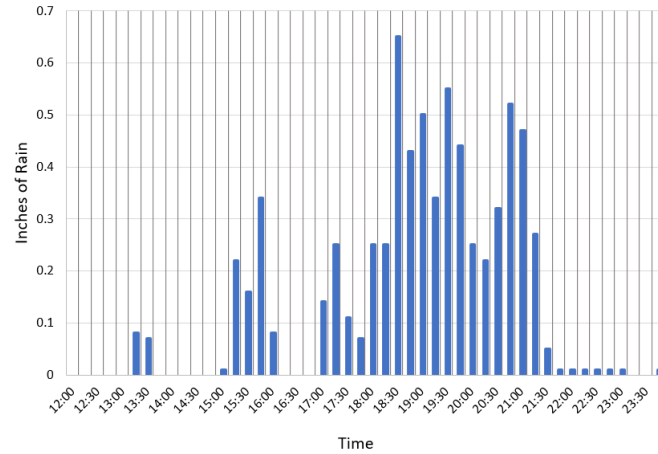
- Verification of model results to observed conditions
- Lessons learned
- Refinements to models and emergency preparedness and response protocols
- Rapid damage assessments

# Who Is Flooded: San Juan, Puerto Rico

San Juan, Puerto Rico Mapping Example  
AWA Mapping vs. Available FEMA Mapping (2009)



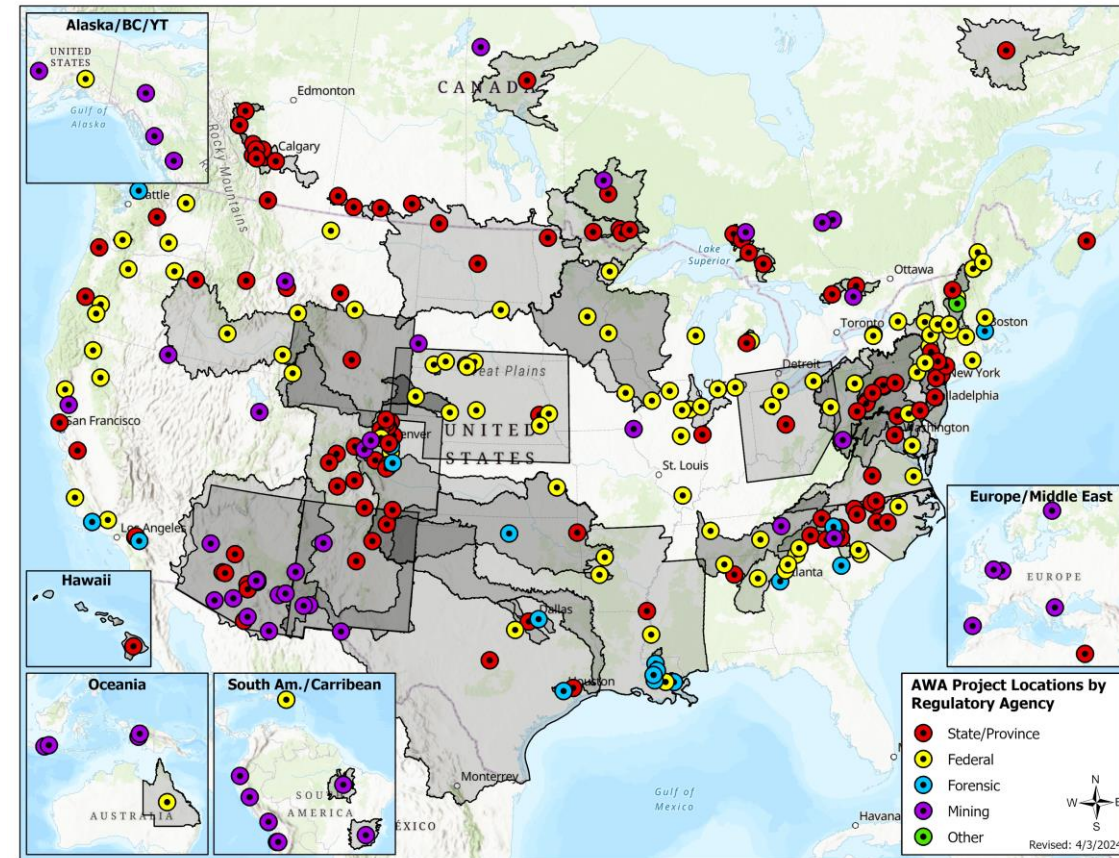
Rainfall in San Juan on October 27, 2023 (USGS Station)



# Real Time and Predictive Hydrological Inputs

Applied Weather Associates extreme precipitation analyses

- Evaluate rainfall and stream gages
- Identify key locations for sensors
- Provide QPF in advance of & during events



# Recommended Next Steps

## Leverage FEMA work to enhance the EWS in the La Plata Watershed

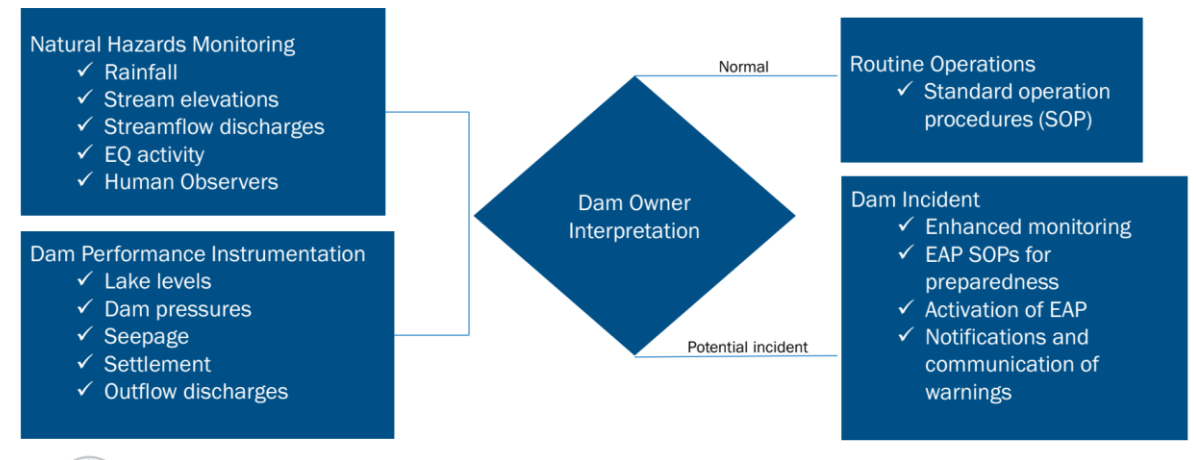
- Calibrated HEC HMS hydrological HEC RAS 2D hydraulic models exists
- Identify and add additional low-cost rain and stream gages in ungagged areas of the upper watershed
- Develop USACE ResSim modeling of the operatorial rules for La Plata Dam gates
- Use of USACE LifeSIM model under development for evacuation planning downstream of LaPlata Dam
- Develop the data collection to interface with the EWS
- Test watershed results to refine the application for other watersheds

# The Dam Safety Value of the Enhanced EWS

Enhancing the EWS to add early detection for extreme precipitation events

- Provides the dam owner additional information and time for decisions for operational releases
- Provides predictive hydrological loading data for use in defining EAP incident levels and notifications
- Provides predictive flood flow data for use in flood warning and evacuations downstream of the dams
- Increases the time for the public to evacuate

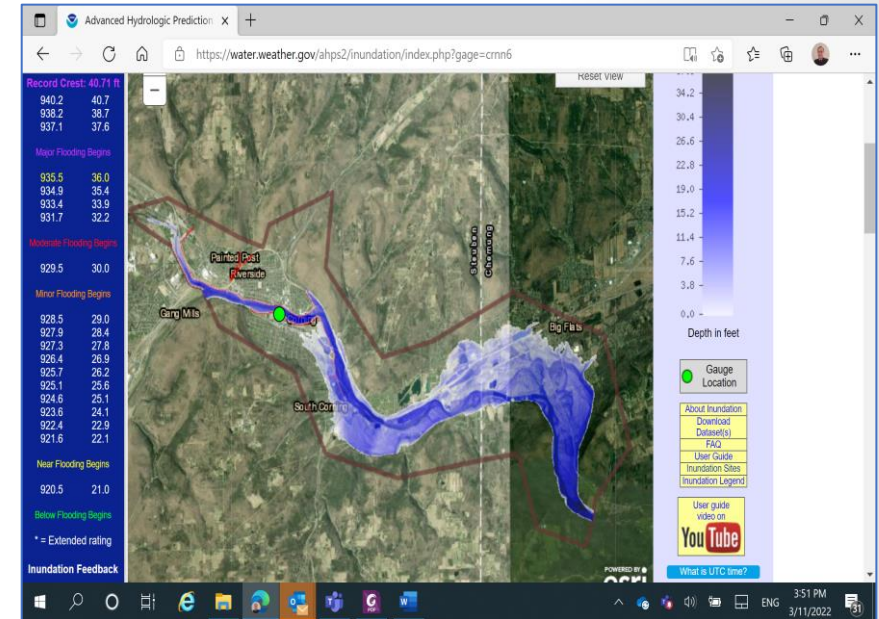
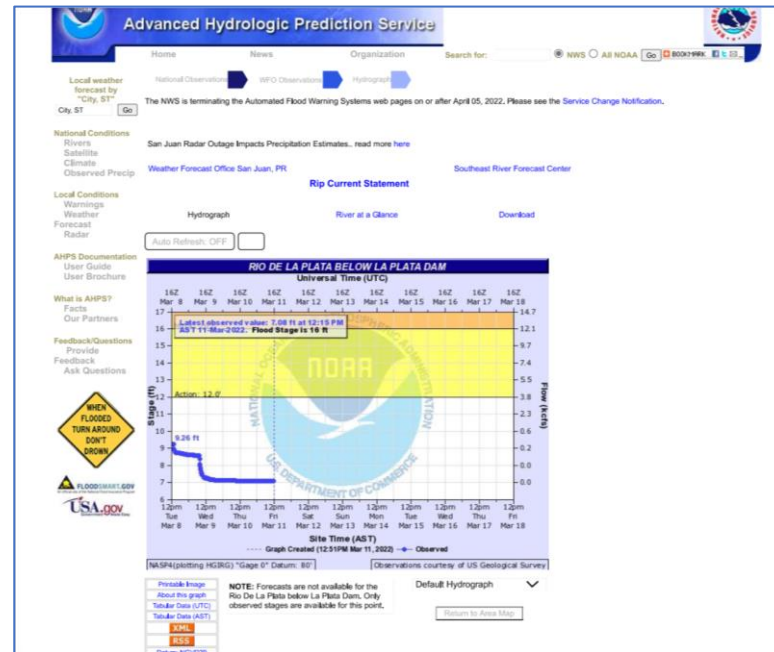
## Components of Early Detection



# Added Value of the Enhanced EWS

The predictive flood flows produce predictive flood inundation areas

- Enhanced EWS produces datasets for NWS advanced products
- Library of flood inundation maps based on projected flood stage



Example predictive flood stage

# Thank you!



Bill Kappel  
President/Chief Meteorologist  
Applied Weather Associates  
Monument, CO USA  
billkappel@appliedweatherassociates.com  
(719) 964-3395

[www.appliedweatherassociates.com](http://www.appliedweatherassociates.com)



Edward G. Beadenkopf, PE, CFM  
Vice President AtkinsRealis  
Alexandria, VA USA  
edward.beadenkopf@atkinsrealis.com  
703-622-1936

[www.atkinsrealis.com](http://www.atkinsrealis.com)