An Overview of the Hurricane Matthew in North Carolina Dam Risk Management Assessment Report

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Abstract-- In October of 2016, there were 20 dam breaches in North Carolina. A FEMA Dams Team deployed to North Carolina to support response and recovery efforts, including development and publication of the Hurricane Matthew in North Carolina Dam Risk Management Assessment Report (FEMA P-1090), available at https://www.fema.gov/media-library/assets/documents/131866. This report was written to improve coordination, resilience, and communication for reducing future risks for dams and dam failures. The report focused on 12 state regulated breached dams and 8 breached dams exempt from regulation at the time of Hurricane Matthew with 30 general comments and strategic recommendations separated into categories of Regulation, Preparedness, Response, Recovery, and Mitigation. This paper provides an overview of the report.

I. INTRODUCTION

The purpose of this paper is to provide an overview of the Hurricane Matthew in North Carolina Dam Risk Management Assessment Report (FEMA P-1090), referenced herein as the Report. The Report was developed by a team from FEMA. A review team for the Report included FEMA Headquarters (Dam Safety, National IMAT, Mitigation), FEMA Regions (IV and VIII), the North Carolina Joint Field Office (JFO), the State Dam Safety Regulator, the State Risk Management Section, the State Emergency Management Division, and two members representing the Association of State Dam Safety Officials (one private sector dam engineer and an engineer who is the Chief of another state dam safety program). A purpose, introduction, and methodology were included to provide context for the Report and the storm event. The Report assesses the risk management of dams in North Carolina before, during, and after Hurricane Matthew in the following areas:

- State Flood Risk Program;
- Flood Insurance Studies (FIS);
- FEMA Mitigation Planning;
- The North Carolina Dam Safety Program;
- Coordinated Response to Reduce Risk at Dams;
- State and Federal Response to Dams during Hurricane Matthew; and
- Dam-related Efforts in Recovery

Thirty general comments and strategic recommendations were provided as part of the Report to improve dam risk management in North Carolina, but many relate to challenges across the country. Some recommendations may be beneficial to other states and organizations. Appendices provided in the Report include information on each breached dam and other key references.

This paper is organized as follows:

A. Risk and Regulation

B. Coordinated Effort to Reduce Risk at Dams during Hurricane Matthew
C. State and Federal Response to Dams during Hurricane Matthew
D. Dam-related Efforts in Recovery
E. General Comments and Strategic Recommendations from the Report
F. Appendices

Figure 1 is a map of the 7-day observed precipitation totals from the National Oceanic and Atmospheric Administration (NOAA) and the locations of the 20 breached dams. Figure 2 is a map of the recurrence interval estimates from the North Carolina Department of Public Safety, Emergency Management, Risk Management Section (NCEM-RM) and the locations of the 20 breached dams.

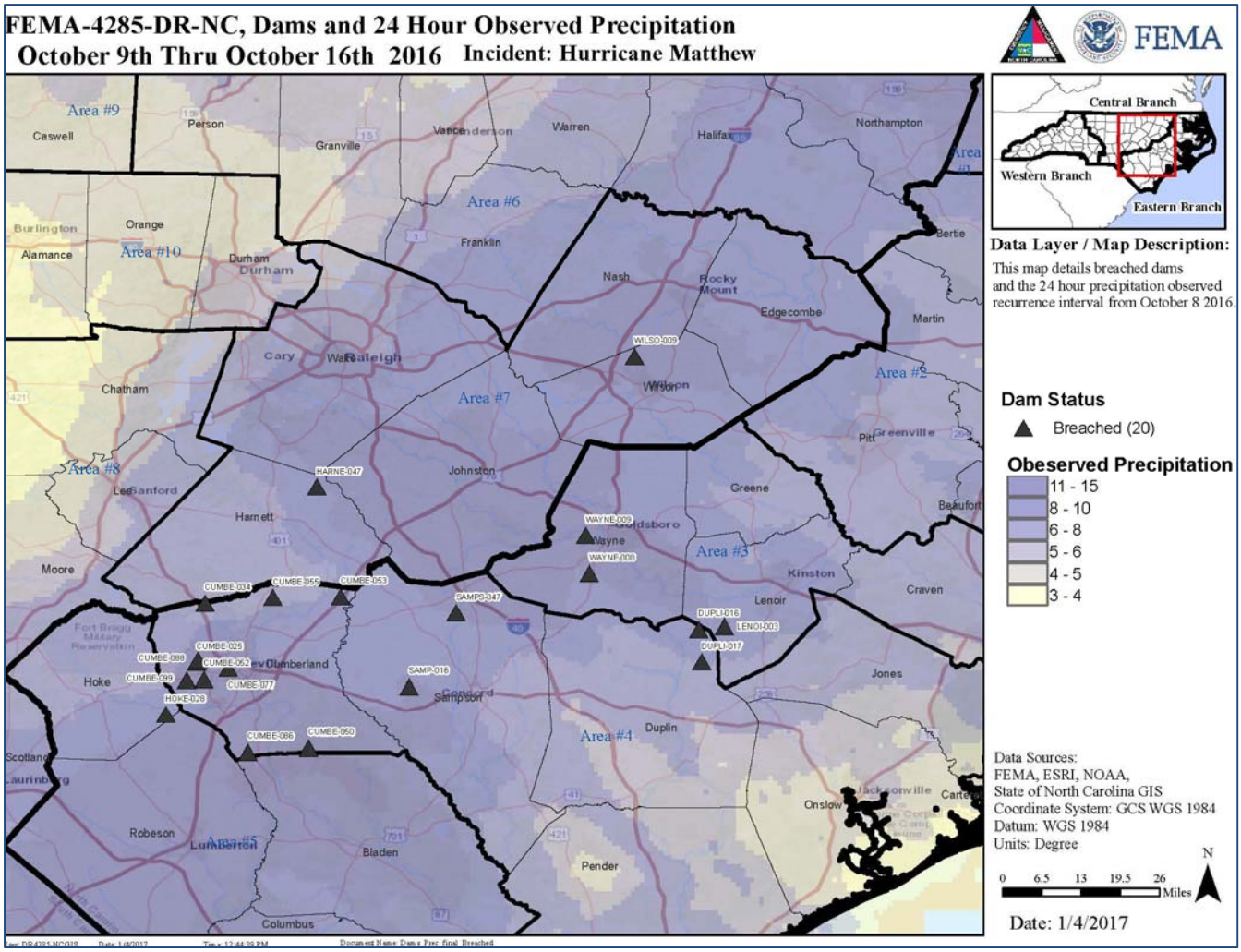

Figure 1: NOAA 7-day Observed Precipitation Totals and Breached Dams

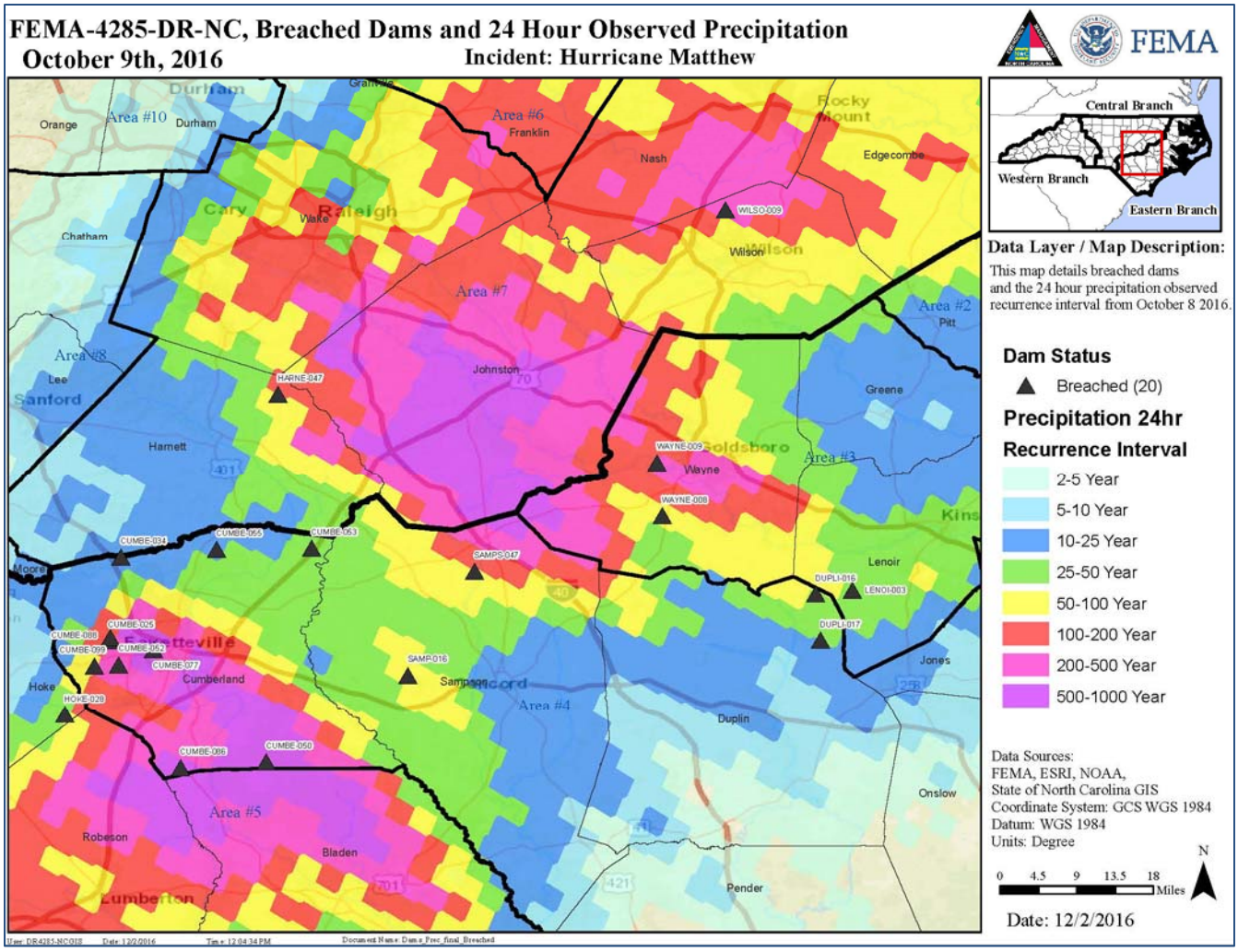

Figure 2: Breached Dams and Hurricane Matthew (October 8, 2016) 24-hour Recurrence Interval estimates from North Carolina Department of Public Safety, Emergency Management, Risk Management Section (NCEM-RM)

II. OVERVIEW OF THE REPORT

A. Risk and Regulation

The Report includes information on the Risk Management Section, which is part of the North Carolina Department of Public Safety, Emergency Management (NCEM-RM). An overview is provided on the NCEM-RM's web applications:

- Flood Risk Information System (FRIS) (http://fris.nc.gov/fris/Home.aspx?ST=NC)
- North Carolina Flood Inundation Mapping and Alert Network (FIMAN) (https://fiman.nc.gov/fiman/)
- Risk Management Portal (https://rmp.nc.gov/portal/)

In areas having dam breaches, information is provided on dams from each County's effective FIS with preliminary FIS information, where available. The Counties included are as follows:

- Cumberland County;
- Duplin County;
- Harnett County;

- Hoke County;
- Lenoir County;
- Sampson County;
- Wayne County; and
- Wilson County.

Furthermore, where available, dam information and summaries were highlighted from the latest approved state and multi-jurisdictional mitigation plans from:

- North Carolina Enhanced State Plan;
- Cumberland-Hoke Regional Hazard Mitigation Plan;
- Sampson/Duplin Regional Hazard Mitigation Plan;
- Cape Fear Regional Hazard Mitigation Plan;
- Neuse River Basin Regional Hazard Mitigation Plan Sampson County; and
- Nash-Edgecombe-Wilson Regional Hazard Mitigation Plan.

An overview of the state dam safety program is included in the Report. The North Carolina Dam Safety Program is part of the Division of Energy, Mineral, and Land Resources within the Department of Environmental Quality (NC DEQ DEMLR). State regulations are cited on:

- The definition of a dam;
- The dam inventory process;
- Hazard potential classifications;
- Exemptions to state regulations;
- Permitting;
- Spillway design requirements;
- Inspections; and
- EAPs and inundation mapping.

B. Coordinated Effort to Reduce Risk at Dams during Hurricane Matthew

The Report provides an overview on the EAP Activations at:

- H.F. Lee Cooling Pond;
- Weatherspoon Cooling Pond;
- Sutton Cooling Pond;
- Lake Benson; and
- Woodlake Dam,

as well as an overview of the evacuations downstream of:

- Lake Benson Dam;
- Lake Wilson Dam; and
- Woodlake Dam.

The coordinated efforts at Woodlake Dam included over 15 organizations. In addition to the information on downstream evacuations and the EAP activation, the Report provides an overview of the risk reduction measures implemented at this dam including:

Figure 3: National Guard and others placing sandbags at Woodlake Dam (NC DEMLR)

- Situational awareness and monitoring fly overs by the Civil Air Patrol;
- A Dam Failure Flash Flood Warning from the National Weather Service (NWS);
- Three 8" diameter and five 12" diameter siphon pumps;
- 1300 sand bags placed on key areas of the spillway to reduce erosion of the damaged area (Figure 3);
- Customs and Border Patrol (CBP) helicopter monitoring missions;
- United States Army Infrared camera helicopter operations to help provide key information for improved decision making; and
- Opening of two large bottom drains at the dam.

C. State and Federal Response to Dams during Hurricane Matthew

The Report provides information on North Carolina's response to dams during Hurricane Matthew with overviews regarding:

- The North Carolina Emergency Operations Center (EOC);
- North Carolina's State Preparedness and Resource Tracking Application (NCSPARTA);
- Pre-Event Actions at NC DEQ DEMLR;
- NC DEQ DEMLR Dam Safety at the North Carolina Emergency Operations Center (EOC); and
- North Carolina Department of Public Safety (NCDPS), Emergency Management, Risk Management Section (NCEM-RM).

The Report covers the response of FEMA and other federal agencies to dams during Hurricane Matthew including:

- Overview of FEMA Hurricane Liaison Team (HLT);
- FEMA Region IV Regional Response Coordination Center (RRCC);
- Web Emergency Operations Center (WebEOC);
- Disaster operational use of Decision Support System for Water Infrastructure Security (DSS-WISE) Lite Modeling;
- FEMA National Response Coordination Center (NRCC);
- FEMA Region IV Incident Management Assistance Team (IMAT) at the North Carolina Emergency Operations Center (EOC);
- FEMA Region IV Dam Safety at the North Carolina Emergency Operations Center (EOC) and RRCC;
- Department of Homeland Security Infrastructure Protection (DHS-IP) at the North Carolina Emergency Operations Center (EOC); and
- United States Geological Survey (USGS) High Water Mark collection (HWM) in North Carolina.

D. Dam-related Efforts in Recovery

The Report provides information on NC DEQ DEMLR's post-event actions and activities including a list of dams that overtopped without breaching.

An overview of FEMA's Public Assistance (PA) relating to dams is provided with information on a site visit to Jessup Mill Pond/Smith Lake Dam (Figure 4).

Figure 4: Jessup Mill Pond/Smith Lake Dam breach (FEMA)

E. General Comments and Strategic Recommendations from the Report

The Report provides 30 General Comments and Strategic Recommendations grouped into Regulation, Preparedness, Response, Recovery, and Mitigation. They include the following:

Regulation

General Comment #1: Emergency Action Plans (EAPs)
Since September 20, 2014, North Carolina requires EAPs for state regulated high and significant hazard dams to be in accordance with the Coal Ash Management Act of 2014. NC DEQ DEMLR noted a few EAP activations during this event. It is unclear how the existing EAPs compare to best practices for life and property safety downstream, such as FEMA P-64 Federal Guidelines for Dam Safety; Emergency Action Planning for Dams (July 2013).

- **General Recommendation #1: Consider Comparison of Emergency Action Plans (EAPs) to Current Best Practices for Life and Property Downstream**
  NC DEQ DEMLR should consider a small pilot project to review a sample of existing EAPs to compare them to current federal guidance and best practices, such as FEMA P-64 Federal Guidelines for Dam Safety; Emergency Action Planning for Dams July 2013. Based on the findings from the pilot program, NC DEQ DEMLR should consider the best strategy forward for improving EAPs and existing EAP guidance.

General Comment #2: Current Spillway Design Requirements
The North Carolina Administrative Code requires very large dams to pass the Probable Maximum Precipitation (PMP). Large, medium, and small high hazard dams are required to pass ¾ PMP, ½ PMP, and 1/3 PMP, respectively. Reference Chapter 7, Section 7.6 in this report for more information on size classification and spillway requirements

- **General Recommendation #2: Current Spillway Design Requirements**
  NC DEQ DEMLR should consider analyzing the percent Probable Maximum Precipitation (PMP) and recurrence interval experienced at each breached and overtopped dam site and determine whether any updates to the spillway design section of the North Carolina Administrative Code are needed.

General Comment #3: Exemptions to State Regulation
Eight (8) of the North Carolina inventoried dam breaches that occurred during this event were dams exempt from state regulation. The consequences of one dam breach (Smith Lake Dam; Cumbe-050) contributed to a state road, NC-53, being washed out. Further, based on NC DEQ DEMLR inspection reports reviewed for this report, some exempt dams were inspected after a five year period and others had inspection cycles upwards of ten years. The dam safety section of the North Carolina Administrative Code allows for exemptions. Reference Chapter 7, Section 7.4 in this report for more information on exemptions to state regulation.

- **General Recommendation #3: Exemptions to State Regulation**
  NC DEQ DEMLR should consider re-evaluating and possibly amending the policies and procedures for determining whether dams are regulated and the frequency by which their status is reassessed.

General Comment #4: Breached Impoundments
NC DEQ DEMLR records at the NC EOC show that there were multiple impoundments which breached during this event that were not on the North Carolina dam inventory.

- **General Recommendation #4: Statewide Assessment of Impoundments**
  NC DEQ DEMLR, in coordination with NCEM-RM, should consider performing a statewide assessment of impoundments utilizing the highly accurate LiDAR data available in North Carolina. The data can be analyzed relatively quickly to determine whether there are impoundments warranting more detailed assessment for incorporation into the state dam inventory or to be regulated as a dam.

General Comment #5: Monitoring and Notification of Breached Dams
The Coal Ash Management Act of 2014 requires the EAP to include “emergency notification procedures to aid in warning and evacuations during an emergency condition at the dam”. According to the state, most dam failures occurred without prior monitoring or notification. (Monitoring can include geotechnical, structural, or environmental instrumentation and early warning systems.)

- **General Recommendation #5: Monitoring and Notification of Dams**
  In order to better support warning and evacuation processes included in EAPs, NC DEQ DEMLR should consider reviewing the guidance and regulations which govern emergency notification procedures. NC DEQ DEMLR should consider improvements to guidance for dam owners on remote sensors and other instrumentation to help facilitate more accurate monitoring during heavy rainfall events. This guidance might include having dam owners provide key thresholds for notifications to encourage timely EAP activation and increased warning time for evacuations.

General Comment #6: NC DEQ DEMLR Funding for Emergency Dam Response Operations
NC DEQ DEMLR currently has the authority by state statute to "take such measures as may be essential to provide emergency protection to life and property, including the lowering of the level of a reservoir by releasing water impounded or the destruction in whole or in part of the dam or reservoir. The Environmental Management Commission may recover the costs of such measures from the owner or owners by appropriate legal action." However, DEMLR has no funding source by which they can actually carry out this authority. This hampered their efforts, in particular, at Woodlake Dam.

- **General Recommendation #6: NC DEQ DEMLR Funding for Emergency Dam Response Operations**
  The state of North Carolina should consider funding options for NC DEQ DEMLR to execute the authority to "take such measures as may be essential to provide emergency protection to life and property, including the lowering of the level of a reservoir by releasing water impounded or the destruction in whole or in part of the dam or reservoir." These funds would assist in more pro-active risk reduction to residents of North Carolina from dam incidents and breaches.

General Comment #7: Woody Vegetation and Trees on Dams
Inspection reports and photographs from the breached dams reviewed for this report indicate woody vegetation and trees on the embankment, which may have been one of the contributing factors to the breach of eleven of these dams.

- **General Recommendation #7: Woody Vegetation and Trees on Dams**
  NC DEQ DEMLR should consider further assessing the breached dams to more fully understand and document the woody vegetation on these dams and their potential impacts. DEMLR is encouraged to maximize the usage of best practices regarding woody vegetation and trees on dams found in FEMA P-534 (Technical Guidance for Dam Owners: Impacts of Plants on Earth Dams) for their policies, procedures, inspection reports, among others.

<u>Preparedness</u>

General Comment #8: Emergency Action Plan (EAP) Activations and Evacuations
NC DEQ DEMLR records at the NC EOC show that five EAPs were activated and residents below three dams were evacuated during this event.

- **General Recommendation #8: Lessons Learned from Emergency Action Plan (EAP) Activations and Evacuations**
  NC DPS and NC DEQ DEMLR should consider assessing the five EAP activations and three evacuations that occurred during this event and develop lessons learned. These lessons learned may be incorporated into policies, procedures, and protocols and inform outreach, training, and exercise efforts.

General Comment #9: Dam Exercises for State Regulated Dams
Currently, state regulations do not require the exercise of state regulated dams.

- **General Recommendation #9: Dam Exercises for State Regulated Dams**
  NC DEQ DEMLR, in coordination with NC DPS, should encourage amenable dam owners and jurisdictions to voluntarily exercise their EAPs, EOPs, and evacuation plans.

General Comment #10: Inclusion of Dams in State-Level Exercises

It is unclear whether state-level exercise scenarios include realistic and challenging dam incidents and breaches that will adequately test policies, procedures, protocols, and authorities between various state agencies and EOC operations.

- **General Recommendation #10: Inclusion of Dams in State-Level Exercises**
  North Carolina Department of Public Safety (NC DPS), in coordination with NC DEQ DEMLR, should consider including realistic and challenging simulated dam incident and dam breaches in state-level exercises. These dam-related scenarios should incorporate complex conditions such as multiple dam breaches, road closures, and communication challenges. This will help test existing policies, procedures, protocols, EOC and dam safety operations, communications, reporting, confirmations, North Carolina's State Preparedness and Resource Tracking Application (NCSPARTA) usage, coordination, and accessing breached or flooded dam sites.

General Comment #11: Staffing for EAP Submittal Reviews

Five additional positions to assist in reviewing EAPs were included in the Coal Ash Management Act of 2014. The Act states the owner of high and intermediate hazard dams shall develop Emergency Action Plans and they will update the EAPs and send them in annually for review and approval. The positions are at present two-year term positions. As of October 2016, 675 of the 1,184 high hazard dams have EAPs. There are more than 300 additional intermediate hazard dams regulated by the state. The state has a backlog of 147 EAPs for review.

- **General Recommendation #11: Staffing for EAP Submittal Reviews**
  Due to the sheer number of EAPs required in the state and the annual statutory review requirement in the law, NC DEQ DEMLR should consider permanent position(s) for reviewing, coordinating, and potentially exercising EAPs and providing outreach and training to dam owners, community officials, emergency managers, and other appropriate stakeholders.

General Comment #12: NC DEQ DEMLR Access to EAP Tool

Currently, NCEM-RM controls access to the EAP tool. NC DEQ DEMLR has only one authorized user to access this tool. See General Comment #11 above for the level of effort involved with EAP reviews by DEMLR.

- **General Recommendation #12: Increase NC DEQ DEMLR Personnel Access to EAP Tool**
  NCEM-RM should consider coordinating with NC DEQ DEMLR to develop an agreeable number of authorized DEMLR users and then provide those users with the commensurate access and authorities to fully utilize the EAP Tool for NC DEQ DEMLR. It is important for life safety issues, such as dam breach, to have back-up plans and multiple points of coordination amongst the area's emergency responders. Allowing for multiple people would increase the ability to respond as needed should an emergency flood event occur.

General Comment #13: Communication of Emergency Action Plans (EAPs) Downstream

If there is more than one county impacted by a potential dam breach, it is unclear whether each county in the inundation zone is receiving a copy of the dam owner's EAP. It is also unclear whether or not each county in the inundation zone across state borders receives a copy of the dam owner's EAP. This includes dams that are in North Carolina that could impact neighboring states or dams in neighboring states that could impact North Carolina.

- **General Recommendation #13: Communication of Emergency Action Plans (EAPs) Downstream**
  NC DPS, in coordination with NC DEQ DEMLR, should develop processes and procedures to ensure downstream states, counties, and jurisdictions potentially impacted by inundation from a breached dam are provided EAPs and inundation maps. These should be integrated by locals into their Emergency Operations Plans (EOPs), evacuation planning and maps, and consequence planning.

General Comment #14: Awareness of Emergency Action Plans (EAPs) and Downstream Consequences
It is unclear as to the degree of understanding of EAPs, inundation maps, and the potential downstream consequences associated with dam breaches by dam owners, local officials, county and city engineers, floodplain managers, planners, the general public, and emergency managers. This includes either dam breaches within their local jurisdictions or by dams outside of their jurisdictions that would still impact them.

- **General Recommendation #14a: Emergency Action Plans (EAPs) and Downstream Consequence Education and Training**
  NC DEMLR DEQ, in coordination with NC DPS, with assistance from FEMA Region IV or others if requested, should provide training workshops and outreach materials to dam owners, local officials, and emergency managers to improve awareness of EAPs, inundation and evacuation maps, and the consequences of dam failures with the potential to impact their local jurisdiction.

- **General Recommendation #14b: Assessment of Consequences to Dam Breach**
  NC DPS should consider providing workshops or outreach material to their local EMAs, local officials, or others in analyzing dam owner inundation maps to more fully determine and understand the potential risks, vulnerabilities, and consequences associated with potential dam failures for their given areas. NC DPS should consider coordinating with NC DEQ DEMLR, FEMA Region IV Dam Safety, or others as needed.

General Comment #15: Emergency Action Plan (EAP) and Inundation Map Integration into Emergency Operations Plans (EOPs) and Evacuation and Consequence Planning
It is unclear to what degree state and local communities and emergency managers are integrating EAPs into EOPs and using EAP and inundation maps for informing their own development of consequence planning and evacuation maps.

- **General Recommendation #15: Integrate Emergency Action Plans (EAP) and inundation maps into Emergency Operations Plans (EOPs) and Evacuation and Consequence Planning**
  State and local communities should consider integrating EAP and inundation map information to help inform the development of their EOPs, evacuation maps, and consequence planning.

<u>Response</u>

General Comment #16: Dam Site Accessibility
Some dam sites with reported incidents were initially inaccessible to state regulators attempting to assess the damages due to road closures, debris, and flooding conditions. In addition, the building for the Fayetteville Regional Office (FRO) was flooded by 8-9 feet during the event, preventing access to files in the office during response operations. The lack of access to sites delayed dam assessments or

confirmations until after the water receded. Critical files, including hardcopy EAPs, were in-accessible through the FRO.

- **General Recommendation #16: Dam Site Accessibility**
  NC DEQ DEMLR, in coordination with NC DPS, should consider developing plans, procedures, and protocols for developing backups to accessing key dam file related information, utilizing alternative methods to quickly and accurately assess dams of concern, and enable timely clarification or confirmations of reported incidents during future events when roadways are inaccessible.

General Comment #17: Accuracy of Dam-Related Reports – Rumor Control
There were numerous reports of dam breach or failures that were inaccurate, which created a challenge for NC DEQ DEMLR in dealing with getting ground truth and accurate situational awareness.

- **General Recommendation #17: Dam Assessments and Reporting – Event Facts**
  NC DEQ DEMLR and NC DPS should consider developing or clarifying policies, procedures, or protocols for dam assessments, dam reporting, and confirming dam breaches and incidence in order to provide timely and consistent updates on the dam-related incidents and breaches and refute inaccurate information. A Communications Team or Point of Contact in the EOC that focuses on Rumor Control and clarification of the information is one way to accomplish this. NC DEQ DEMLR should consider having a staff member to update NCSPARTA regularly so that the latest updates are promptly placed in the system for all agencies and Public Information Officers (PIOs) to pull for reports.

General Comment #18: High Water Marks (HWMs) around Dams
FEMA and USGS do not currently have a standard operating procedure in place for collecting HWMs around dams.

- **General Recommendation #18: High Water Marks (HWMs) around Dams**
  FEMA and USGS should consider developing procedures and protocols for collecting HWMs around dams during flooding events.

General Comment #19: Dam Safety and the FEMA Qualification System (FQS)
FQS does not have a title for FEMA dam safety liaisons to the RRCC, EOC, or JFO operations.

- **General Recommendation #19: Dam Safety and the FEMA Qualification System (FQS)**
  FEMA Dam safety liaisons should be considered by FEMA Headquarters for inclusion into the FQS for deployments to the RRCC, EOC, or JFO during dam-related events. A FEMA Dam Safety liaison has knowledge that can help inform the NRCC, RRCC, EOC, and JFO operations on dam related matters.

General Comment #20: Dam Safety Subject Matter Expertise in the National Response Coordination Center (NRCC), Regional Response Coordination Center (RRCC), Emergency Operations Center (EOC), and Joint Field Office (JFO)
There is currently no policies, procedures, guidance, or job aids for FEMA dam safety liaisons for carrying out NRCC, RRCC, EOC, or JFO operations.

- **General Recommendation #20: Policies, Procedures, or Guidance for FEMA Dam Safety Subject Matter Expertise in the National Response Coordination Center (NRCC),**

Regional Response Coordination Center (RRCC), Emergency Operations Center (EOC), or Joint Field Office (JFO)
FEMA should develop policies, procedures, or guidance for dam safety subject matter expertise in the NRCC, RRCC, EOC, or JFO. A FEMA Dam Safety liaison has knowledge that can help inform the NRCC, RRCC, EOC, and JFO operations on dam related matters.

General Comment #21: Awareness of FEMA Support Capabilities for Dam Incidents during Response in Federally Declared Emergencies and Disasters
It is unclear the degree to which state personnel at the North Carolina EOC were aware of some of the Category B Emergency Protective Measure capabilities that exist for dams, accessible through FEMA IMATs during a federally declared emergency. During this incident, multiple pumps were provided through FEMA IMAT Infrastructure at the North Carolina EOC to the state to the local government, which helped reduce the risk of failure at the dam.

- **General Recommendation #21: Training on FEMA Category A and B Measures Applicable to Dams during Federally Declared Emergencies and Disasters**
  FEMA PA and FEMA Dam Safety should consider developing Fact Sheets and providing training to NC DEQ DEMLR, NC DPS, or others on Public Assistance Category A (Debris Removal) and Category B (Emergency Protective Measures) measures that can potentially be used for dams during emergency situations. These measures (i.e. pumps, siphons, debris removal from clogged spillways, clogged outlet works, clogged trash racks) should be considered for incorporation into training the state does with local jurisdictions as well. These can be critical resources or concepts available in helping to reduce the risk of dam failure. FEMA PA, FEMA Dam Safety, NC DEQ DEMLR, and NC DPS should consider developing a list of potential options for use by dam owners and local jurisdictions to help reduce the potential for dam failure during future events. It is important to note these categories are merely mechanisms for reimbursement. However, some of the concepts can be used regardless of whether reimbursement occurs or not.

General Comment #22: Dams in National Response Coordination Center (NRCC) Operations
It is unclear to what degree the NRCC has risks related to dams and dam breach incorporated into their planning, protocols, processes, and procedures for response operations.

- **General Recommendation #22: Dams in National Response Coordination Center (NRCC) Operations**
  The NRCC, in coordination with Essential Support Function (ESF) #3 (Infrastructure) and FEMA Headquarters Dam Safety Program, should consider reviewing their processes, procedures, protocols, and planning factors to further incorporate dam risk.

General Comment #23: Decision Support System for Water Infrastructure Security (DSS-WISE) Lite
The DSS-WISE Lite program was utilized on a dam of concern at the RRCC and NC EOC. Currently, policies and protocols do not exist for using this dam breach modeling program during a disaster at the RRCC or EOC.

- **General Recommendation #23: Develop FEMA Operational Protocols for Decision Support System for Water Infrastructure Security (DSS-WISE) Lite**
  FEMA should develop policies, procedures, and protocols for FEMA usage of the DSS-WISE Lite program at the RRCC and EOC's during a potential flooding emergency or disaster operation.

Recovery

General Comment #24: Dam Breach and Consequences
At this time, there is minimal information regarding the cause of the twenty dam breaches and the consequences to those communities, both upstream and downstream of the dams.

- **General Recommendation #24: Dam Breach Analysis and Consequences**
  NC DEQ DEMLR should consider analyzing the probable failure modes of the breached dams identified in this report. NC DPS, in coordination with NC DEQ DEMLR, should consider analyzing some of the downstream consequences of the twelve regulated dam breaches and use this data to foster dam safety resilience. Appendix A includes considerations for additional analysis for each breached dam.

General Comment #25: Private Dams on Public Roads
A few of the private dams that breached had public roads on them. For a neighborhood where the road was the only access route, the houses were inaccessible by vehicles until such time as the locals were able to restore vehicular access.

- **General Recommendation #25: Private Dams on Public Roads**
  NC DEQ DEMLR should consider coordinating with NC DPS, NC DOT, or others to develop procedures or protocols for providing information on dams of particular high public safety concern, due to inherent vulnerabilities (i.e. lack of adequate spillway capacity), NODs, or other reasons. These organizations can then use this information as is appropriate for inclusion into general annual budget planning, operations plans, emergency operations plans, mitigation plans, and coordination as needed.

Mitigation

General Comment #26: Dams Largely Not Referenced in North Carolina Flood Insurance Studies (FIS), Flood Risk Information System (FRIS), and Flood Inundation Mapping and Alert Network (FIMAN)
Based on the information reviewed for this report, the Flood Insurance Studies (FIS), North Carolina's Flood Risk Information System (FRIS), and North Carolina's Flood Inundation Mapping and Alert Network (FIMAN) appear to largely not reference dams, nor analyze dams in the hydraulic modeling. FEMA has minimal policies and procedures in place for incorporating dams and dam risk into Flood Insurance Studies.

- **General Recommendation #26: Dam Risk Communication in North Carolina Floodplain Management Program**
  Under their own authority, the North Carolina Department of Public Safety, Emergency Management, Risk Management Section (NCEM-RM) should consider coordinating with NC DEQ DEMLR along with FEMA Region IV Risk MAP and Dam Safety to develop a strategy to more effectively capture dam risk. This will better enable communication of this information with appropriate entities in North Carolina. These measures might include, but are not limited to, referencing the dam name or State Dam ID on Flood Insurance Rate Maps (FIRMs), inclusion of dam outlet systems in the hydraulic modeling for the Flood Insurance Studies (FISs), and consideration of dams in hydrologic analysis for FISs. This might also include dams and residual dam risk in non-regulatory flood products and information into FRIS and FIMAN products as appropriate.

General Comment #27: Dam Risk and Mitigation Planning
Dam failure is listed as a lesser hazard in the North Carolina Enhanced Mitigation Plan. Based on information reviewed for this report, several of the multi-jurisdictional hazard mitigation plans state the likelihood of occurrence of a dam failure impacting the multi-jurisdictional area is "unlikely".

- **General Recommendation #27: Dam Risk and Mitigation Planning**
  NCEM-RM, in coordination with NC DEQ DEMLR, should consider undertaking more robust dam risk analyses and sharing this data with state and local mitigation planners and other relevant stakeholders tasked with updating mitigation plans.

General Comment #28: Topographical Data in Decision Support System for Water Infrastructure Security (DSS-WISE) Lite
The DSS-WISE Lite program was utilized on a dam of concern by NC DEQ DEMLR. However, North Carolina has very accurate LiDAR data, while the program uses 30-meter Digital Elevation Model (DEM). The state was unable to utilize their LiDAR data in DSS-WISE, as errors occurred that prevented the model from completing. The state was able to run the model using 30-meter DEM, which is less accurate.

- **General Recommendation #28: FEMA inclusion of LiDAR data in Decision Support System for Water Infrastructure Security (DSS-WISE) Lite**
  FEMA should consider investing resources to update the DSS-WISE Lite program enabling users to incorporate more accurate LiDAR data, where available.

General Comment #29: Dam Risk Awareness
Based on the number of inaccurate reports of dam failures and breaches received at the North Carolina EOC, there appears to be a lack of general understanding and awareness of dam terminology, dam incidents, failure modes, basic dam operations, spillway activations, EAP requirements, and other dam-related topics.

- **General Recommendation #29: Dam Awareness Training and Outreach**
  NC DEQ DEMLR, in coordination with NC DPS, should consider providing dam awareness training and outreach on dam terminology, dam operations, spillway types, common failure modes, and EAPs for state and local emergency managers, local floodplain managers, county and city engineers, planners, local officials, and others. FEMA Region IV Dam Safety is available to support these efforts where appropriate and upon request by the state.

General Comment #30: Home Owner's Associations (HOA) and Dam Awareness
Based on information from the state, it is unclear how HOAs with dam ownership are made aware of their dam related responsibilities.

- **General Recommendation #30: Home Owner's Associations (HOA) and Dam Awareness**
  NC DEQ DEMLR, in coordination NC DPS or others, with support from FEMA Region IV as appropriate, should consider providing training, outreach, and exercises to amenable HOAs in helping them better understand their risks and carry out their responsibilities in maintaining, operating, repairing, rehabilitating, or removing their dams. This should include encouraging coordination between HOAs where a dam impacts multiple neighborhoods.

F. Appendices

Appendix A provides an important summary on each breached dam of key information pulled from the 2016 National Inventory of Dams (NID) and the North Carolina Dam Inventory (October 2016). An example table is provided below.

Example of Table of Information for Each Breached Dam from Appendix A

Fields where the 2016 NID Matches the Oct 2016 NC Dam Inventory* Information			
NID/State Field	**NID/State Value**	**NID/State Field**	**NID/State Value**
NID Dam Name		County	
Stream or River		Owner Type	
NID Hazard Class		State Hazard Class	
NID ID		EAP	
Dam Type		Year Modified	
Purpose		Surface Area (ac-ft)	
Length (ft)		Condition Assessment	
Drainage Area (sq mi)		Normal Storage (ac ft)	
Nearest Downstream City/Town		Nearest Downstream City/Town	
Fields where the 2016 NID Differs from the Oct 2016 NC Dam Inventory* Information			
NID Field Name	**2016 NID Value**	**State Field Name**	**State Value**
Dam Height (ft)		N/A	
Drainage Area (sq mi)		Drainage Area (ac)	
Structural Height (ft)		Structural Height (ft)	
State ID		State ID	
Year Completed		Year Constructed	
Max Storage (ac-ft)		max impoundment capacity (ac-ft)	
FIRM & FIS data taken from FEMA mapping service center and NC FRIS (Flood Risk Information System) website			
FIRM Panel		FIS Effective Date	
FIRM Effective Date		Preliminary Date	

In addition, Appendix A includes the following information for each breached dam where information is available:

- Pre-event image from Google Earth Streetview;
- Cropped FEMA FIRM in area of each dam;
- Dam Site Area Map from Google Earth;
- Dam post-event photo from NC DEQ DEMLR;
- General Dam Comments; and
- Considerations for Dam.

Appendices B – F provide additional context and references as follows:

- Appendix B: Emergency Operational Planning for Dams Overview
- Appendix C: Resources and Useful Links
- Appendix D: National Inventory of Dams (NID) Field Definitions
- Appendix E: Acronyms
- Appendix F: Association of State Dam Safety Officials (ASDSO)

III. AUTHOR BIOGRAPHIES

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Mrs. Katy Goolsby-Brown has been with the Federal Emergency Management Agency (FEMA) since June 2010. Katy received a bachelor's of science degree in Civil Engineering from the Georgia Institute of Technology in Atlanta, Georgia and is professionally licensed as a Professional Engineer (PE) in Georgia. Her responsibilities include: Regional Dam Safety team lead, Benefit-Cost Analysis and Engineer reviews for hazard mitigation grant applications, and instructor for the Introduction to Benefit-Cost Analysis course (L-276) and the Overview of Community Dam Safety, Preparedness and Mitigation 1-day training.

Katy has been involved with Hazard Mitigation Assistant (HMA) review of the engineering/technical and Benefit Cost Analyses (BCA) portions of the mitigation projects for the Pre-Disaster Mitigation (PDM) and Flood Mitigation Assistance (FMA) grants for FEMA headquarters. Also, she has reviewed the engineering/technical and Benefit Cost Analyses (BCA) portions of Hazard Mitigation Grant Program (HMGP) projects on multiple disasters for FEMA Region IV.

John Plisich
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John (Bud) Plisich serves as a Civil Engineer for FEMA region IV's Mitigation Division, Risk Analysis Branch (RA) in Atlanta, GA. He joined FEMA in late Feb 2000.

John's job involves two roles, one for Building Sciences and the other for dam safety in which he coordinates from an engineering perspective, with multiple federal, state, local government agencies as well as universities, private individuals, trade organizations, non-profits, Architect-Engineering firms, home and building owners on issues ranging from coastal, riverine, wind, building code, dam safety, tornado and other issues relating to mitigation efforts, grant projects and disaster recovery rebuilding operations. Both efforts support FEMA organizations internally as is appropriate (Floodplain management and insurance (FMI), Hazard Mitigation Assistance (HMA), Public Assistance (PA), National Preparedness (NP), Dam Safety, FEMA HQ among others.

Bud has deployed with FEMA in response to many events, including tornadoes, tropical storms, flooding and hurricanes. He's deployed on three FEMA Mitigation Assessment Teams (MAT) for Hurricane Katrina, Tornadoes in 2011 and Hurricane Sandy.