

GUIDANCE DOCUMENT FOR EAPS

Connecticut's dam safety statutes were modified in 2013. They now require owners of Class C High Hazard and Class B Significant Hazard dams to prepare Emergency Action Plans (EAP) for their dams. This requirement became effective on February 3, 2016 when CT DEEP adopted Section 22a-411a-2 of the regulations of Connecticut State Agencies which define the components and general requirements of an EAP.

New and updated EAPs for Class C High Hazard dams must be submitted to DEEP Dam Safety no later than twelve (12) months from the effective date of the regulations, i.e. February 3, 2017.

New and updated EAPs for Class B Significant Hazard dams must be submitted to DEEP Dam Safety no later than eighteen (18) months from the effective date of the regulations, i.e. August 3, 2017.

The CT DEEP published an EAP template which can be found at www.ct.gov/deep/dams. This document provides the necessary format as well as useful advice, and explanations of the components that form the framework for an acceptable EAP. A checklist is also included to ensure that the EAP is both a complete and operational document.

Missing from this template, however, is a discussion of breach modeling and the preparation of an inundation map for a hypothetical dam breach flow. The inundation map is a fundamental element of the EAP document and provides the basis of the actions required to be undertaken in the event of a dam failure. The EAP identifies the areas to be evacuated as well as the timing of any potential evacuations.

The breach modeling and inundation mapping must be prepared by a professional engineer while the other portions of the EAP can possibly be undertaken by the dam owner. The EAP template, in addition to the regulations themselves, provides the dam owner with enough guidance and information to successfully prepare the narrative portion of this document.

The inundation map must use elevations based on a reference to Geodetic North American Vertical Datum (NAVD88) and must show at a minimum:

1. The name and address or location of the dam
2. Pertinent downstream features such as buildings, homes, railroads, bridges, schools, hospitals, camp grounds, other dams, and any other significant facilities, etc.
3. The inundation zone for wet weather, i.e. flood conditions, with arrows indicating the direction of the flood wave
4. A north arrow and bar scale
5. Pertinent downstream cross sections, such as roads (identify the road names)

In addition, the following information must either be shown on the inundation map or on a separate document if map space is limited.

6. An estimated timeline that shows arrival times of peak floodwaters expressed in hours and minutes and incremental increase in water depth above the baseline elevation at critical intersection(s), structure(s), or inhabited structure(s).
7. A list of all streets, roads, and highways, including the address of the residences and businesses subject to flooding.
8. A location map sufficient in scale to clearly show the exact location of the impoundment in relation to the surrounding area, other dams in the area, and the delineation of the drainage area. Said map shall include a north arrow, a bar scale, and the size of the drainage area noted in square miles.
9. A description of the method or computer model used to prepare the inundation map.
10. Identification of any road closures
11. Identification of any evacuation routes.
12. Identification of any emergency shelters

DEEP Dam Safety recommends that the inundation map utilize the Connecticut 2012 color orthophotos as the base mapping with a scale of 1"=500' for both Class C High Hazard and Class B Significant Hazard dams. The color orthophotos are available at www.cteco.uconn.edu. (The Connecticut 2016 orthophotos and lidar are scheduled to be available through this website by December 31, 2016.)

MODELING THE BREACH - SELECTING BREACH PARAMETERS AND DETERMINING BREACH OUTFLOWS

Many computer programs such as HEC-RAS, HEC-HMS, NWS-DAMBRK and NWS-FLDWAV are available to model dam breach outflow hydrograph computations and downstream flood routing. These models require that the potential breach characteristics or parameters be estimated independently of the model. These breach parameters include the elevation of the water surface in the impoundment, the breach width and depth, the breach development time, the failure location and the failure mode. Reasonable values for the breach size and development time are needed to make a reliable estimate of the breach flows.

The DEEP requires that the breach inundation mapping show the "wet weather" breach inundation area. The wet weather condition is a conservative approach in determining the extent of the area affected by the breach wave. Pre-breach conditions shall include the water level in the impoundment to be at the top of dam, or at the highest elevation reached during the occurrence of the spillway design storm. If the modeler is routing a storm event through the

impoundment and then downstream, it would be appropriate to continue to use the spillway discharge as calculated for either of those events. If the storm isn't being routed through the impoundment and then downstream, it is suggested that the 100 year FEMA discharge be used in the areas below the dam as a base flow on which to add the breach flow. (This is not necessarily the case for determining breach flows when they are used to select hazard classifications, or to modify hazard classifications.)

The breach characteristics and breach outflows can be estimated in several ways; including: comparative analysis (comparing the subject dam to historical failures of dams of similar size, materials and water volume); regression equations (equations developed from historical dam failures in order to predict peak outflow or breach size and development time); and physically based computer models (computer programs that attempt to model the physical breaching process by using sediment transport/erosion equations, soil mechanics, and principles of hydraulics).

Some of the methods for making these selections are discussed in FEMA P-946 which can be found at www.fema.gov/federal-guidelines-dam-safety .

While many federal agencies have published guidelines in this regard, another valuable source is the document entitled "Comparison of Dam Breach Parameter Estimators" by D. Michael Gee, Senior Hydraulics Engineer, Corps of Engineers Hydrologic Engineering Center.

SIMPLIFIED INUNDATION MAPPING

The high cost of detailed engineering studies for breach modeling may present an impediment to the development of an EAP. More detailed studies are required when the dam is large, where there are a high number of people at risk and complex hydraulic factors such as; cascading dam failure, split flow, backwater from a downstream bridge or culvert are present. When these factors are not present, simplified inundation mapping presents an alternate approach for modelers. Simplified inundation mapping uses conservative estimates of inundation limits and is appropriate for small sized dams with a limited number of homes and a small population in the evacuation area. This section and the following section, "Photo Based Mapping", pertain primarily to Class B Significant Hazard dams.

Inundation mapping shows the area potentially at risk in the event of a dam failure. This area starts at the dam and continues downstream to a point where the breach flood no longer poses a risk to life and property. In general, the routing should be carried downstream until the incremental increase in water depth (above the no breach elevation) is 1.5 feet or less. The area downstream of a dam should always be inspected by the engineer to verify the following: the number of residences and structures; the existence of road crossings and bridges for their potential to create backwater and the over-all characteristics of the downstream channel or floodplain.

Simplified procedures for delineating inundation limits include, but are not limited to, the Simplified Dam Break Flood Forecasting Model (SMPDBK) and HEC-HMS. These models quickly estimate peak flows, peak flood elevations and flood arrival times at critical downstream points using cross section data created from USGS 7.5 minute quadrangle maps. The best available topographic data should be used to route dam breach outflows downstream. Digital Elevation Model (DEM) topographic data is available free of charge from the USGS and can be used with a variety of Geographic Information Systems (GIS)-based software packages to create cross-sections in place of costly field surveying.

PHOTO BASED MAPPING

Photo based inundation mapping can also be used when a limited number of easily identified structures are located downstream of a dam. They are prepared by using aerial photography and topographic maps where the structures downstream of a dam have been field verified. This approach should be conservative (i.e. overestimate where public safety is concerned) in identifying at-risk structures. Several websites with aerial photographs and topographic maps are available to the public and include USGS National Map Seamless Server (<http://seamless.usgs.gov/index.php>) and Google Earth. Photo based inundation mapping should also include flood prone areas using FEMA flood insurance rate maps. These maps are available free online from the FEMA Mapping Service (<http://msc.fema.gov>). Once the at-risk downstream structures are identified on an aerial photo of the area downstream of the dam, the inundation area can be delineated by comparing the contour lines of the downstream area to the height of the dam.

The depth and timing of the breach flood can be calculated using existing FEMA mapping and information provided in the Flood Insurance Studies. The timing and depth of the breach flood can be calculated at critical downstream cross sections using hydraulic equations, topographic mapping, the bed slope (not the water surface slope), FEMA profiles and other sources of hydraulic information such as bridge studies.

DAMS WITH EXISTING INUNDATION AREAS

Many of the dams that are now required to prepare an EAP pursuant to the newly adopted regulations, already have an inundation area mapped for a hypothetical breach flow. Many of these studies were prepared using one of the following methods: ACOE Phase I “rule of thumb” analysis; superimposing the volume of flood water behind the dam onto the downstream

watercourse or by a variety of computer programs with a breach routing subroutine. These EAPs will require updating to meet DEEP's 2016 regulatory standards.

As many of these inundation maps are 30 to 35 years old, the engineer should assess the validity of an existing inundation area. The assumptions about the hypothetical dam breach and the methods used to create the mapping should also be examined. The engineer should contact DEEP's Dam Safety section to discuss which modifications are needed to bring the breach flood delineation map to current regulatory standards.

UPDATING EAPS

The current regulations require that an EAP be updated every two (2) years to reflect significant changes to the EAP. Although it is not expected that updates will be needed to the scope of the inundation zone, some changes may be required when there are additional residence(s) built within the downstream inundation area. Otherwise, minor changes, such as contact persons or phone numbers, can easily be made to the narrative portion of the EAP. The revised pages with the date of the revision noted on each revised page should be made available to the EAP document holders as well as to the DEEP. Revisions and updates to the EAP should be recorded in the form provided in Appendix F-2 of the EAP template.

CONCLUSIONS/SUMMARY

1. The methodologies discussed in this document are strictly for inundation mapping and emergency action planning and are not to be used for hazard classification of a dam or re-classification of a dam's hazard potential.
2. The scope of this document should in no way be considered complete. There are many approaches and methods available to engineers for determining the inundation areas of a hypothetical dam breach.
3. This document is intended to demonstrate some of the flexibility available to the engineering community. It is not intended to be comprehensive or authoritative nor should any of the suggested methodologies or approaches be used without site specific approval from DEEP dam safety.
4. There may be very specific occasions when the methodologies discussed in this document may be accepted for a Class C High Hazard dam but not without prior approval from DEEP Dam Safety.

5. Engineers should keep in mind that documents such as the one prepared by the National Dam Safety Review Board Emergency Action Plan Workgroup entitled "Simplified Inundation Maps for Emergency Action Plans" exist and may prove useful for generating simplified inundation mapping.