State of California
Office of Administrative Law

In re:
Department of Water Resources

Regulatory Action:

Title 23, California Code of Regulations

Adopt sections: **335, 335.2, 335.4, 335.6, 335.8, 335.10, 335.12, 335.14, 335.16, 335.18**

NOTICE OF APPROVAL OF EMERGENCY REGULATORY ACTION

Government Code Sections 11346.1 and 11349.6

OAL Matter Number: 2018-0703-02

OAL Matter Type: Emergency Readopt (EE)

This is the second readoption of emergency rulemaking action no. 2017-1009-03E by the Department of Water Resources, which established criteria for dam owners to prepare and submit inundation maps for review and approval pursuant to Water Code sections 6160 and 6161.

OAL approves this emergency regulatory action pursuant to sections 11346.1 and 11349.6 of the Government Code.

This emergency regulatory action is effective on 7/18/2018 and will expire on 10/17/2018. The Certificate of Compliance for this action is due no later than 10/16/2018.

Date: July 12, 2018

Nicole C. Carrillo
Attorney

For: Debra M. Cornez
Director

Original: Karla Nemeth, Director
Copy: Kristen Martin

STATE OF CALIFORNIA--OFFICE OF ADMINISTRATIVE LAW

NOTICE PUBLICATION/REGULATIONS SUBMISSION

EMERGENCY

(See instructions on reverse)

For use by Secretary of State only

STD. 400 (REV. 01-2013)

OAL FILE NUMBERS	NOTICE FILE NUMBER	REGULATORY ACTION NUMBER	EMERGENCY NUMBER
	Z-		2018-0703-02EE

For use by Office of Administrative Law (OAL) only

2018 JUL -3 P 1:56

OFFICE OF ADMINISTRATIVE LAW

ENDORSED - FILED
In the office of the Secretary of State
of the State of California
JUL 12 2018
2:40 PM

NOTICE | REGULATIONS

AGENCY WITH RULEMAKING AUTHORITY: Dept. Water Resources

AGENCY FILE NUMBER (If any):

A. PUBLICATION OF NOTICE (Complete for publication in Notice Register)

1. SUBJECT OF NOTICE	TITLE(S)	FIRST SECTION AFFECTED	2. REQUESTED PUBLICATION DATE

3. NOTICE TYPE	4. AGENCY CONTACT PERSON	TELEPHONE NUMBER	FAX NUMBER (Optional)
☐ Notice re Proposed Regulatory Action ☐ Other			

OAL USE ONLY	ACTION ON PROPOSED NOTICE	NOTICE REGISTER NUMBER	PUBLICATION DATE
	☐ Approved as Submitted ☐ Approved as Modified ☐ Disapproved/ Withdrawn		

B. SUBMISSION OF REGULATIONS (Complete when submitting regulations)

1a. SUBJECT OF REGULATION(S): Inundation Maps

1b. ALL PREVIOUS RELATED OAL REGULATORY ACTION NUMBER(S): 2017-1009-03E, 2018-0404-01EE

2. SPECIFY CALIFORNIA CODE OF REGULATIONS TITLE(S) AND SECTION(S) **(Including title 26, if toxics related)**

SECTION(S) AFFECTED (List all section number(s) individually. Attach additional sheet if needed.)

ADOPT: 335, 335.2, 335.4, 335.6, 335.8, 335.10, 335.12, 335.14, 335.16, 335.18

AMEND:

TITLE(S): 23

REPEAL:

3. TYPE OF FILING

- ☐ Regular Rulemaking (Gov. Code §11346)
- ☐ Resubmittal of disapproved or withdrawn nonemergency filing (Gov. Code §§11349.3, 11349.4)
- ☐ Emergency (Gov. Code, §11346.1(b))
- ☐ Certificate of Compliance: The agency officer named below certifies that this agency complied with the provisions of Gov. Code §§11346.2-11347.3 either before the emergency regulation was adopted or within the time period required by statute.
- ☐ Resubmittal of disapproved or withdrawn emergency filing (Gov. Code, §11346.1)
- ☒ Emergency Readopt (Gov. Code, §11346.1(h))
- ☐ File & Print
- ☐ Other (Specify) _____
- ☐ Changes Without Regulatory Effect (Cal. Code Regs., title 1, §100)
- ☐ Print Only

4. ALL BEGINNING AND ENDING DATES OF AVAILABILITY OF MODIFIED REGULATIONS AND/OR MATERIAL ADDED TO THE RULEMAKING FILE (Cal. Code Regs. title 1, §44 and Gov. Code §11347.1)

5. EFFECTIVE DATE OF CHANGES (Gov. Code, §§ 11343.4, 11346.1(d); Cal. Code Regs., title 1, §100)

- ☐ Effective January 1, April 1, July 1, or October 1 (Gov. Code §11343.4(a))
- ☐ Effective on filing with Secretary of State
- ☐ §100 Changes Without Regulatory Effect
- ☒ Effective other (Specify) July 18, 2018

6. CHECK IF THESE REGULATIONS REQUIRE NOTICE TO, OR REVIEW, CONSULTATION, APPROVAL OR CONCURRENCE BY, ANOTHER AGENCY OR ENTITY

- ☐ Department of Finance (Form STD. 399) (SAM §6660)
- ☐ Fair Political Practices Commission
- ☐ State Fire Marshal
- ☐ Other (Specify)

7. CONTACT PERSON	TELEPHONE NUMBER	FAX NUMBER (Optional)	E-MAIL ADDRESS (Optional)
Kristen Martin	(916) 227-2170		mapregs@water.ca.gov

8. **I certify that the attached copy of the regulation(s) is a true and correct copy of the regulation(s) identified on this form, that the information specified on this form is true and correct, and that I am the head of the agency taking this action, or a designee of the head of the agency, and am authorized to make this certification.**

SIGNATURE OF AGENCY HEAD OR DESIGNEE: Karla Nemeth

DATE: 6-21-18

TYPED NAME AND TITLE OF SIGNATORY: Karla Nemeth, Director

For use by Office of Administrative Law (OAL) only

ENDORSED APPROVED

JUL 12 2018

Office of Administrative Law

California Code of Regulations
Title 23. Waters
Division 2. Department of Water Resources
Chapter 1. Dams and Reservoirs
Article 6. Inundation Maps

§ 335. Scope of Regulations

(a) Inundation maps shall be prepared for dams and critical appurtenant structures regulated by the state, except dams classified by the department as low hazard as described in Section 335.4. The regulations in this article apply to inundation maps and supporting technical studies necessary to develop the maps. Owners are responsible for preparing and submitting these documents to the department.

(b) The provisions of this article apply to all owners of state jurisdictional dams except dams classified by the department as low hazard, including those regulated pursuant to Title 18, Code of Federal Regulations, Part 12.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Sections 6002, 6160 and 6161, Water Code. Title 18, Code of Federal Regulations, Part 12.

§ 335.2. Definitions

(a) For purposes of this Article, the terms listed below shall have the meanings noted:

(1a) "Breach" refers to an ~~sudden~~ opening through a dam or critical appurtenant structure. ~~system that drains the reservoir.~~

~~(b) "Breach elevation" refers to the elevation of the water in a reservoir at full reservoir conditions.~~

~~(c) "Breach time" refers to the modeled time elapsed from initial dam failure to total dam failure.~~

(d2) "Critical appurtenant structure" refers to a ~~man-made~~ barrier or hydraulic control structure that impounds the same reservoir as the dam and is 25 feet or more in height; impounds a minimum of 5,000 acre-feet of water at ~~full reservoir conditions~~the maximum possible storage elevation; or that the department determines poses a significant or higher

downstream hazard ~~has the~~ potential per section 335.4(a).~~to inundate downstream life or property, including but not limited to~~

(A) Typical critical appurtenant structures include emergency spillways, gated spillways, and saddle dams. A critical appurtenant structure may contain multiple water-barrier features, including but not limited to gates, flashboards, and concrete monoliths. The height of a critical appurtenant structure shall ~~be determined as follows: saddle dams shall~~ be measured from the ~~downstream toe to the maximum water storage elevation; all other critical appurtenant structures shall be measured from the~~ upstream toe or downstream toe, whichever elevation is higher, to the maximum possible storage elevation, except for the following cases:

1. For a structure comprising gates constructed on a concrete control structure, such as a spillway with multiple radial gates, its height shall be measured from the upstream toe of the concrete control structure to the maximum possible storage elevation.

2. If gates are affixed to a concrete dam, the height shall be measured from the base of the gates to the maximum possible storage elevation.
~~to the maximum water storage elevation.~~

(B) ~~A critical appurtenant structure may contain multiple water-barrier features, including but not limited to gates, flashboards, and concrete monoliths. Power system penstocks, lined spillway chutes, and low level outlets whose failure would not exceed the downstream channel capacity are not considered critical appurtenant structures as they pertain to inundation maps.~~ A penstock or low-level outlet shall be considered a critical appurtenant structure if the department determines it poses a significant or higher downstream hazard potential, as defined in section 335.4(a).

(e3) "Critical facilities" refers to ~~lifeline infrastructure and~~law enforcement facilities, ~~including but not limited to~~fire stations, schools, hospitals, ~~skilled nursing facilities~~prisons, and major roads~~, public water and electric utilities, and communication infrastructure, as described in Section 8589.5 of the Government Code~~.

(4f) "Cross-section" refers to a linear representation perpendicular to a watercourse and its adjacent floodplain, capturing the topography perpendicular to the flow direction.

(5g) "Dam system" refers to a dam and all critical appurtenant structures that impound the same reservoir.

~~(h) "Deflood time" refers to the time elapsed from the flood wave arrival time until water at the measured location recedes to within one foot of its preflood water elevation.~~

(6~~i~~) "Dynamic routing" refers to hydraulic flow routing based on the shallow water equations to compute changes in discharge, velocity, and stage with respect to time at various locations along a watercourse. ~~The most common form of the equations is the Saint-Venant equations.~~

(7~~j~~) "Failure scenario" refers to the modeled simulation of a complete failure of a dam or critical appurtenant structure which results in the ~~uncontrolled~~ unintended release of water.

(8~~k~~) "FEMA P-946" refers to the "Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures" dated July 2013~~, hereby incorporated by reference~~.

~~(l) "Flood surcharge" refers to the volume in a reservoir above the maximum certified water storage elevation resulting from a storm event.~~

(~~m~~9) "Flood wave arrival time" refers to the elapsed time from the initiation of the failure scenario until the arrival of the leading edge of the flood wave ~~comprising a one (1) foot rise above the ground elevation or water surface elevation before the failure scenario~~.

~~(n) "Freeboard" refers to the vertical distance between the lowest point along the top of a dam, dike, berm, levee, or other similar feature and the surface of the water contained therein.~~

~~(o) "Full reservoir conditions" refers to the maximum water storage elevation authorized in the department's Certificate of Approval for the dam.~~

(~~p~~10) "Hydraulic model" refers to a computer model used to simulate the spatial and temporal changes of water depth and velocity conveyed through a watercourse.~~simulation of conveyance of water through a watercourse.~~

~~(q) "Hydrologic model" refers to a simulation of watershed processes such as precipitation, infiltration, and runoff. Hydrologic models perform simplified forms of dynamic routing.~~

(~~r~~11) "Inundation area" refers to the area downstream of the dam or critical appurtenant structure that would experience a rise in water surface elevation as the result of a failure scenario.~~that would experience a rise in water surface elevation of at least one (1) foot as the result of a failure scenario.~~

(12) "Inundation boundary" refers to the perimeter of the inundation area.

(13~~s~~) "Inundation map" refers to a map showing the impacts of a failure scenario, such as where and when flooding would occur, and may contain multiple sheets. ~~area that would result in flooding from a failure scenario.~~

(14) "Maximum possible storage elevation" refers to the maximum reservoir elevation to which water can be physically impounded without spilling.

(15) "NAVD88" refers to the North American Vertical Datum of 1988 computed by the National Geodetic Survey.

~~(t) "One-dimensional model" refers to a numerical hydraulic model in which variables such as velocity and depth vary in one direction along a watercourse.~~

~~(u) "Peak flow" refers to the maximum rate of water discharge.~~

~~(v) "River mile" refers to the distance from a fixed point along a watercourse, measured along the thalweg.~~

(16) "Projection" refers to a method by which the curved surface of the Earth is portrayed onto a flat surface.

(17) "Raster" refers to a data format that represents geographic information as a grid of cells, where each cell contains a value.

(18~~w~~) "Sequential dam failure" refers to a failure scenario of an upstream dam system that results in the failure of one or more downstream dam systems.

(19~~x~~) "Storm-induced loading condition~~failure~~" refers to a failure scenario in which the extent of the inundation area is greater than that of a sunny day failure scenario.

(20~~y~~) "Sunny day failure" refers to a failure scenario of the dam system ~~during~~ at ~~full~~the maximum possible storage elevation ~~reservoir conditions~~ with non-flood season inflow.

~~(z) "Thalweg" refers to the line connecting the lowest point of a watercourse.~~

(~~aa~~21) "Toe" refers to the junction of the slope of a dam or critical appurtenant structure with the natural ground surface.

(22~~bb~~) "Two-dimensional hydraulic model" refers to a ~~numerical~~ hydraulic model in which variables such as velocity and depth vary in two horizontal directions along a watercourse.

(23~~cc~~) "Watercourse" refers to a stream or open conduit, including but not limited to canyons and floodplains.

(24) "Vector" refers to a data format that represents geographic information as point, line, or polygon features.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 8589.5, Government Code; Sections 6002, 6002.5, 6004.5, 6005, 6007.5, 6008 and 6161, Water Code.

§ 335.4. Downstream Hazard Potential Classification

(a) The department classifies the downstream hazard potential of all state jurisdictional dams based on a sunny-day loading condition ~~shall classify the public safety risk of all state jurisdictional dams~~ as follows:

(~~a~~1) Low Hazard Potential. ~~Dams assigned the low hazard potential classification are those where failure or mis-operation of the dam system would result in n~~No probable loss of human life and low economic and/~~or~~ environmental losses. Losses are expected to be principally limited to the owner's property.

(2~~b~~) Significant Hazard Potential. ~~. Dams assigned the significant hazard potential classification are those dams where failure or mis-operation of the dam system would result in n~~No probable loss of human life but can cause economic loss, environmental damage, ~~disruption of lifeline~~impacts to critical facilities, or other significant impacts.

(3~~c~~) High Hazard Potential. ~~Dams assigned the high hazard potential classification are those where failure or mis-operation of the dam system will probably~~ Expected to cause loss of at least one human life.

(4~~d~~) Extremely High Hazard Potential. ~~Dams assigned the extremely high hazard potential classification are dams that would otherwise be classified as high hazard dams, but where failure or mis-operation of the dam system would probably~~ Expected to cause considerable loss of human life ~~and~~ or would ~~affect~~ result in an inundation area with a population of 1,000 persons or more~~, or where critical facilities could be impacted~~.

(b) If a dam owner contends that their dam should be assigned a different hazard potential classification, the dam owner may request a re-evaluation by providing a justification and supporting documentation to the department for its re-evaluation. The dam owner shall comply with this article during the re-evaluation of the hazard potential classification.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6002.5, 6009, 6160 and 6161, Water Code.

§ 335.6. Inundation Map Updates

(a) The owner of a dam shall update all inundation maps for the dam system under each of, but not limited to, the following circumstances:

(~~a~~1) The department determines there is a significant change in the dam or critical appurtenant structure.

(~~b~~2) There is a significant change in downstream development that involves people and property.

(~~c~~3) The department changes the hazard classification of the dam.

(~~d~~4) No less frequently than every 10 years.

(b) When an inundation map is being updated for its 10-year cycle, a new model simulation may not be required.

(1) If all the following conditions are met, a new model simulation is not required:

(A) No significant change to the dam or critical appurtenant structures,

(B) No significant change to downstream development or terrain,

(C) No significant changes to model assumptions, and

(D) No significant changes to inundation modeling state-of-practice.

(2) If a new model simulation is not performed for a 10-year map update, the dam owner shall submit the following:

(A) Updated map(s) with updated aerial imagery, critical facilities, map preparation date, the California-licensed professional civil engineer's seal, along with all map requirements in section 335.14.

(B) A written explanation of why a new model simulation is not required, as described in section 335.6(b)(1), and all changes made to update the inundation map(s).

(c) A new model simulation must be performed if there is a significant change to the dam, critical appurtenant structures, downstream development or terrain, model assumptions, or inundation modeling state-of-practice. In this case, the dam owner shall submit the map(s), geospatial files, and technical study per section 335.16. The technical study must include a description of all changes to the model and map(s).

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6006, 6007 and 6161, Water Code.

§ 335.8. Civil Engineering

Inundation maps and technical studies shall be prepared by, or under the direction of, a civil engineer who is registered pursuant to California law and authenticated as provided in the Business and Professions Code, Division 3, Chapter 7 commencing with Section 6700.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6161, Water Code; Section 6700, Business and Professions Code.

§ 335.10. Reporting Standards

Inundation maps and technical studies prepared in accordance with this Article shall utilize the following standards and conventions, unless otherwise indicated:

(a) Reservoir storage and other water volumes shall be reported in acre-feet.

(b) Water discharge shall be reported in cubic feet per second.

~~(c) Geographic locations shall be reported in California Coordinate System or Universal Transverse Mercator coordinates relative to NAD83. Coordinates shall be specified commensurate with the precision of the analysis.~~

(~~d~~c) Elevations shall be reported in feet above a specified vertical datum such as NAVD88 ~~or NAVD29~~. Elevations may also be reported relative to an established local datum.

(de) Geospatial data shall be submitted in NAD 1983 Teale (California) Albers projection, with the units specified in feet.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6161, Water Code.

§ 335.12. Technical Study

A single technical study shall be prepared for each dam system for which inundation maps are required.

(a) Study contents. The technical study shall include the following:

(1) The name of the dam, department dam number, national dam ID number, and name or description of any critical appurtenant structures.

(2) The location of the dam and all critical appurtenant structures.

(3) The name and location of cities, towns, counties, and any populated area that could be affected by a failure scenario.

(4) A brief narrative of the hydrologic, meteorologic, and topographic features of the watershed, dam site, and downstream areas.

(5) An engineering description of the dam, including the type of construction (e.g., earth, rock, or concrete). Include a description of the features comprising each critical appurtenant structure (i.e., a description of all the gates and concrete structures comprising a gated spillway structure).

(6) Elevation of the crest and upstream toe for the dam and each critical appurtenant structure. Report the elevation of the downstream toe of the dam.

(7) A reservoir storage capacity curve that shows the relationship between reservoir elevation, surface area, and volume from the base of the reservoir to the dam crest.

(8) A spillway rating curve that shows the relationship between stage and discharge.

(9) The type of terrain data used, including any modifications made to the terrain.

(10) A summary of the modeled failure scenarios for the dam system. For each failure scenario, include the breach hydrograph immediately downstream of the dam or critical appurtenant structure.

(11) The modeling methodology, the reasons for its use, and the name, version, release date and author of the modeling software. Report all assumptions, failure parameters, calibration and sensitivity analyses of the model, including the model's response to changes made to the roughness or other friction coefficients. Report modifications made to stabilize the model or accelerate its computational runtime, and the effects such modifications have on the modeled inundation results. Describe known limitations of the modeling method utilized. Provide justification for determining the downstream extent of the inundation boundary.

(12) Digital files comprising the following for each failure scenario:

(A) A vector file of the inundation area boundary.

(B) ~~Raster~~ Geospatial files of the flood wave arrival time, maximum depth, and peak velocity~~, and deflood time~~. For inundation maps developed using a two-dimensional hydraulic model, the file format of the flood wave arrival time, maximum depth, and peak velocity shall be raster files.

(13) The department may request additional information during the course of its review.

(b) Modeling Requirements.

(1) An ~~two-dimensional, open channel,~~ unsteady ~~flow,~~ hydraulic model appropriate for the downstream development and terrain shall be used ~~to evaluate each failure scenario for a dam system, except as described below~~. The model must be capable of performing dynamic routing to approximate the temporal and spatial changes in inundation magnitude and extent. In areas of lateral spreading, a two-dimensional hydraulic model is generally appropriate.

~~(2) A one-dimensional hydraulic model may be used that is capable of computing spatial and temporal changes to water surface elevation, velocities, and flows at each cross section. A one-dimensional model may be used only in the following circumstances:~~

~~(A) To simulate levee overtopping as a subcomponent of the two-dimensional model of the failure scenario.~~

~~(B) Where the flood wave would be confined to a canyon or narrow watercourse in which the direction of flow is dominantly in the downstream direction.~~

(~~2~~3) Upon pre-approval of the department, the dam owner ~~of a significant hazard dam~~ may submit an alternative model for review that produces the inundation extent and timing described in section 335.12(b)(1)~~use a hydrologic model, rather than a hydraulic model, if~~

~~the dam impounds less than 100 acre-feet of water and the flood wave produced by the failure scenario would be confined to a canyon or narrow watercourse in which the direction of flow is dominantly in the downstream direction~~.

(3~~4~~) Each model shall utilize ~~the best available terrain~~ elevation data that is appropriate for the downstream development and terrain that would potentially be impacted by the failure scenario. The horizontal resolution of the data shall be ten meters or finer~~, consisting of the finest resolution discretization available~~.

(c) Failure Scenarios. A sunny day failure scenario is required for each dam and critical appurtenant structure. A storm-induced failure scenario is not required, but may be submitted in lieu of a sunny day failure scenario.

(1) Each failure scenario shall assume the following:

(A) The reservoir is at the maximum possible storage elevation.

(B) A breach of the full height of the dam or critical appurtenant structure. The height of the dam is defined in Water Code section 6002 and the height of the critical appurtenant structure is defined in section 335.2(a)(2).

(C) The impoundment associated with the full height shall consist entirely of water.

(D) If a dam owner chooses to include the effects of sediment, the owner may also submit a second failure scenario depicting the effects of sediment release along with supporting documentation to the department for consideration. However, modeling sediment release is not required.

(2) ~~Each f~~Failure scenarios for dams shall comply with the following:

(A) The dam owner shall select one of the following methods that are applicable to the dam for estimating breach parameters, except breach height, prescribed in section 335.12(c)(1)(B):

1. Table 9-3 of FEMA P-946 (2013), incorporated here by reference.

2. Chapter 2, Appendix II-A, Table 1 of Federal Energy Regulatory Commission's *Engineering Guidelines for the Evaluation of Hydropower Projects* (August 2015), incorporated here by reference.

3. A sensitivity analysis using equations appropriate for the dam in Table 2 of U.S. Department of the Interior's *DSO-98-004 Prediction of Embankment Dam Breach Parameters* (July 1998), incorporated here by reference, that produces the largest peak outflow.

4. Upon pre-approval by the department, alternative breach parameters that fulfill the purpose of section 335.12(c)(2)(A).
~~employ a complete and nearly instantaneous loss of the dam or critical appurtenant structure, and utilize breach parameters as described in FEMA P-946 (2013). The geographic extent of the model simulation shall terminate in accordance with FEMA P-946 (2013).~~
(3) Failure scenarios for critical appurtenant structures shall comply with the following, as applicable:

(A) For saddle dams, failure scenarios shall be modeled as described in section 335.12(c)(2).

(B) For gated critical appurtenant structures, all gates shall be breached simultaneously together with the control structure.

(C) Multiple gates affixed to concrete dams shall be failed collectively but separately from the dam.

(D) All critical appurtenant structures, except for saddle dams, shall assume a nearly instantaneous and complete failure.

(E) For any type of critical appurtenant structure and upon pre-approval by the department, the dam owner may assume an alternative failure mode that produces the largest peak outflow, as substantiated by a sensitivity analysis.

(4) If a failure scenario is expected to cause the failure of any downstream dams or critical appurtenant structures, the failure of those downstream dams and critical appurtenant structures shall be included in the model and map.
~~Failure scenarios shall be modeled as follows:~~

~~(1) For gated critical appurtenant structures, such as a spillway with multiple radial gates, the failure scenario shall consist of the complete failure of all gates together with the concrete control section breached to the upstream toe.~~

~~(2) A sequential dam failure scenario is required for an upstream dam system that causes the failure of one or more downstream dam systems, as described in FEMA P-946 (2013). A sequential dam failure scenario shall employ an overtopping failure mode for all downstream dam systems impacted by the routing of the flood wave downstream. The~~

~~owner of the upstream dam system is responsible for preparing the sequential failure scenario.~~

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6161, Water Code.

§ 335.14. Inundation Maps

(a) Inundation maps shall be prepared for each failure scenario ~~to satisfy the FEMA P-946 (2013) and the requirements of this section~~as described in section 335.12. Inundation maps must contain the following model outputs as rasters, contours, points, or cross-sections at appropriate time and space intervals displayed over current aerial imagery:

(1) Inundation boundary,

(2) Flood wave arrival time,

(3) Maximum depth, and

(4) Maximum velocity.

~~(a) Temporal contours. Two separate inundation maps shall be prepared for each failure scenario, with contours depicting time increments appropriate for the failure scenario for flood wave arrival time and deflood time.~~

(b) ~~Depth grid. All inundation maps shall depict the entire inundation area with discrete categories of maximum flood wave depths, with a legend showing each depth range.~~ If using a raster for items in section 335.14(a), ~~T~~the opacity ~~of the maximum flood wave depth layer~~ shall be adjusted to display the underlying ~~base map~~aerial imagery.

(c) The inundation boundary shall be displayed as a one-foot maximum depth, except where the flood wave would be confined to a channel or canyon or where the flood wave no longer poses a threat to life or critical facilities.

(e~~d~~) General information. Each inundation map shall contain the following general information:

(1) The name of the dam, the department's dam number, the national dam ID number, and the county in which the dam is located.

(2) The failure scenario. If a storm-induced failure scenario is depicted, the return period shall be reported on the inundation map.

(3) The map background with suitable aerial imagery.

(4) Callouts identifying the location of the dam, all critical appurtenant structures, and all critical facilities affected by the failure scenario. The downstream watercourse and flood control features, such as dams, levees, weirs, pumps, and control structures shall be labeled.

(5) The identity of any jurisdictions, including boundary delineations or place marks identifying the city, county, or other governmental agency jurisdictional boundaries affected by the inundation area.

(6) An arrow indicating north.

(7) An appropriate scale bar and the stated map scale.

(8) Vertical elevation datum.

(9) Map collar information, including horizontal reference grid ticks.

(10) An index showing the relationship of the map sheet to the other map sheets if the map has multiple sheets.

(11) The date of preparation of the map ~~,~~ and the simulation date of the model.

(12) The signature, seal, and licensed civil engineer number of the engineer responsible for preparing the map.

(13) All features on maps shall be clearly labeled with text boxes and legends, as appropriate.

(14) A statement that the information shown is approximate and should be used as a guideline for emergency response and preparation purposes.

~~(15) A statement verifying the inundation map has been prepared in accordance with sound engineering practices and the analysis has been performed correctly to the best of the engineer's knowledge.~~

(15) For flood waves that are confined within a channel but not shown within the inundation boundary as allowed by section 335.14(c), a statement indicating high flows may continue beyond the inundation boundary.

(16) Labels identifying low-lying areas where the flood recession is expected to be slow and affect lives or critical facilities.

(d) Map Layout. All inundation maps shall be prepared at a scale and quality to clearly display an aerial view of the extent of flooding. A map scale such as that described in Section 11.3.3 of FEMA P-946 may be applied. ~~Each of the inundation maps shall be printed on paper sized 11×17 inch or larger, with a minimum resolution of 300 dots per inch. All inundation maps shall apply an appropriate map scale as described in FEMA P-946 (2013). For failure scenarios with a large inundation area, each inundation map may comprise more than one sheet.~~

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 8589.5, Government Code; Sections 6160 and 6161, Water Code. Business and Professions Code section 6700.

§ 335.16. Submission of Inundation Maps and Technical Study

The owner of a dam shall submit inundation maps and the supporting technical study to the department as specified below:

(a) An electronic color copy of each new and revised inundation map in portable document format (PDF extension) and geospatial files for the inundation boundary, flood wave arrival time, maximum depth, and maximum velocity. For inundation maps developed using a two-dimensional hydraulic model, the geospatial file format of the flood wave arrival time, maximum depth, and maximum velocity shall be raster files.

~~If practical, two hard color copies of each inundation map should also be submitted.~~

(b) Technical Study: ~~Two~~ One hard copy and an electronic copy ~~including digital content~~.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 6161, Water Code.

§ 335.18. Department Review and Approval

~~(a) The department shall evaluate each inundation map and technical study that is submitted for consistency with the requirements of this article and shall notify the dam owner in writing that the map and study have been approved, are incomplete, or are disapproved and the reasons therefor, as follows:~~

~~(1) Approved. The department has evaluated the inundation map(s) and technical study and determined that they satisfy the requirements of this article.~~

~~(2) Incomplete. The department has evaluated the inundation map(s) and technical study and determined that one or both do not satisfy the requirements of this article as a result of minor problems identified by the department. A dam owner shall remedy any deficiencies and submit the corrected map and study.~~

~~(3) Disapproved. The department has evaluated the inundation map and technical study and determined that one or both do not satisfy the requirements of this article due to unresolved problems associated with an incomplete submittal. When an inundation map or technical study is disapproved, the dam owner shall submit a new map and technical study that satisfy this article.~~

~~b) Inundation maps submitted to the department for review by January 1, 2018, shall be evaluated for consistency with the FEMA P-946 (2013).~~
Upon receipt of a complete submittal pursuant to section 335.16, the department shall evaluate it for consistency with the requirements of this article. The department shall provide comments to the dam owner and an opportunity to correct deficiencies and provide further explanation. The department may approve inundation maps upon a demonstration of compliance with Water Code sections 6160 and 6161 and substantial compliance with this article. Substantial compliance means that the submittals were made in a good faith attempt to conform to requirements in this article and other applicable law, and the department determines that the submittal is sufficient in view of the particular circumstances to fulfill the purpose of the requirements. Upon approval of the inundation maps, the department will provide written notification to the dam owner.

Note: Authority cited: Sections 6078 and 6162, Water Code. Reference: Section 8589.5, Government Code; Sections 6161 and 6431, Water Code.

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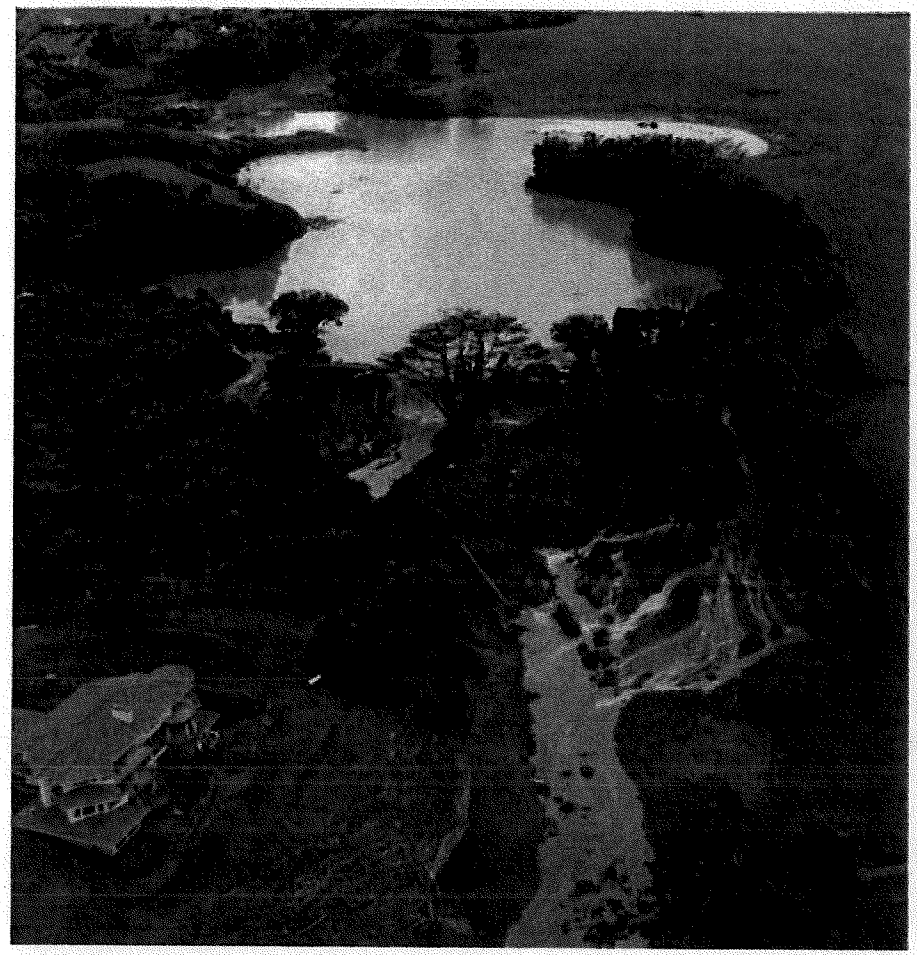

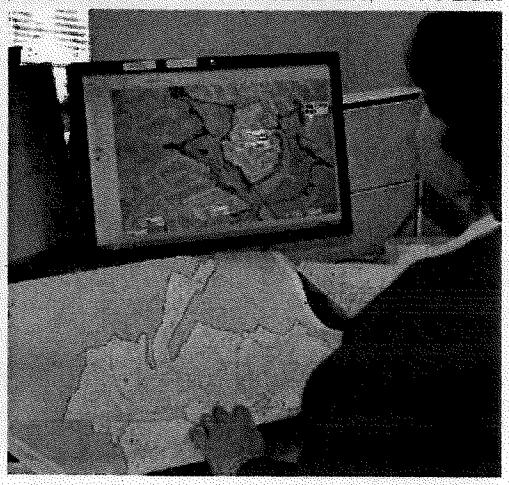

Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures

First Edition

FEMA P-946 / July 2013

FEMA

Table 9-3: Typical Breach Parameters or Range of Parameters

Earth-Fill Dams	
Average breach width	½ to 5 times the dam height
Side slope of breach	0:1 to 1:1
Breach formation time	0.1 to 4 hours
Concrete Gravity Dams	
Breach width	A multiple of monolith widths
Side slope of breach	0:1
Breach formation time	0.1 to 0.5 hours
Concrete Arch Dams	
Breach width	Entire dam width
Side slope of breach	0:1 to valley wall slope
Breach formation time	Nearly instantaneous, $\leq$ 0.1 hour

Dam breach parameter selection guidance published in Chapter 2, Appendix II-A of FERC's *Engineering Guidelines for the Evaluation of Hydropower Projects* (FERC, 1993) is widely referenced as an acceptable method by regulating authorities and is provided in the following table. Refer to pages 2-A-10 and 2-A-11 of that document for comments on using Table 9-4.

Table 9-4: FERC Suggested Breach Parameters

Parameter	Value	Type of Dam
Average width of breach (BR)	BR $\doteq$ Crest length	Arch
	BR = Multiple slabs	Buttress
	BR = Width of 1 or more	Masonry, Gravity monoliths
	Usually $\overline{BR} \leq 0.5$ W	
	HD $\leq \overline{BR} \leq$ 5HD.....	Earth-fill, rock-fill
	(usually between 2HD to 4HD).....	Timber Crib
	$\overline{BR} \geq 0.8$ x Crest Length.....	Slag, Refuse
Horizontal component of side slope of breach (Z)	$0 \leq Z \leq$ slope of valley walls.....	Arch
	Z = O	Masonry, Gravity Timber Crib, Buttress
	¼ $\leq Z \leq$ 1.....	Earthen (engineered and compacted)
	$1 \leq Z \leq 2$.....	Slag, Refuse (non-engineered)

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Engineering Guidelines for the Evaluation of Hydropower Projects

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Status of Proposed New Chapters and Proposed Revisions

Updated: June 4, 2018

CHAPTER II

SELECTING AND ACCOMMODATING INFLOW DESIGN FLOODS FOR DAMS

August 2015

TABLE 1
SUGGESTED BREACH PARAMETERS
(Definition Sketch Shown in Figure 1)

Parameter	Value	Type of Dam
Average width of Breach ($\overline{BR}$) (See Comment No. 1)*	$\overline{BR}$ = Crest Length	Arch
	$\overline{BR}$= Multiple Slabs	Buttress
	$\overline{BR}$ = Width of 1 or more	Masonry, Gravity Monoliths
	Usually $\overline{BR} \leq 0.5$ W	
	HD $\leq \overline{BR} \leq$ 5HD	Earthen, Rockfill,
	(usually between 2HD & 4HD)	Timber Crib
	$\overline{BR} \geq 0.8$ x Crest Length	Slag, Refuse
Horizontal Component of Side Slope of Breach (Z) (See Comment No. 2)* Buttress	$0 \leq Z \leq$ slope of valley walls	Arch
	Z = O	Masonry, Gravity Timber Crib,
	$¼ \leq Z \leq 1$	Earthen (Engineered, Compacted)
	$1 \leq Z \leq 2$	Slag, Refuse (Non-Engineered)
Time to Failure (TFH) (in hours) (See Comment No. 3)*	TFH ≤ 0.1	Arch
	$0.1 \leq$ TFH ≤ 0.3	Masonry, Gravity, Buttress
	$0.1 \leq$ TFH ≤ 1.0	Earthen (Engineered, Compacted) Timber
Crib Engineered	$0.1 \leq$ TFH ≤ 0.5	Earthen (Non Poor Construction)
	$0.1 \leq$ TFH ≤ 0.3	Slag, Refuse

Definition:

HD	-	Height of Dam
Z	-	Horizontal Component of Side Slope of Breach
$\overline{BR}$	-	Average Width of Breach
TFH	-	Time to Fully Form the Breach
W	-	Crest Length

Note: See Page 2-A-11 for definition Sketch
**Comments: See Page 2-A-9 - 2-A-10*

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Prediction of Embankment Dam Breach Parameters

A Literature Review and Needs Assessment

DSO-98-004

Water Resources Research Laboratory

July 1998

generally only qualititative or visual in nature. The digital image database is especially interesting.

Predicting Breach Parameters from Case Study Data

Table 2 summarizes the relations proposed by previous investigators for predicting breach parameters (e.g., geometry, time of formation) from case study data. The earliest contributions were made by Johnson and Illes (1976), who published a classification of failure shapes for earth, gravity, and arch dams. For earth dams, the breach shape was described as varying from triangular to trapezoidal as the breach progressed. The great majority of earth dam breaches are described as trapezoidal in the literature.

Table 2. — Breach parameter relations based on dam-failure case studies.
For explanations of symbols see the *Notation* section at the end of this report.

Reference	Number of Case Studies	Relations Proposed (S.I. units, meters, m^3/s, hours)
Johnson and Illes (1976)		$0.5h_d \le B \le 3h_d$ for earthfill dams
Singh and Snorrason (1982, 1984)	20	$2h_d \le B \le 5h_d$ 0.15 m $\le d_{ovtop} \le$ 0.61 m 0.25 hr $\le t_f \le$ 1.0 hr
MacDonald and Langridge-Monopolis (1984)	42	Earthfill dams: $V_{er} = 0.0261(V_{out} * h_w)^{0.769}$ [best-fit] $t_f = 0.0179(V_{er})^{0.364}$ [upper envelope] Non-earthfill dams: $V_{er} = 0.00348(V_{out} * h_w)^{0.852}$ [best-fit]
FERC (1987)		B is normally 2-4 times h_d B can range from 1-5 times h_d Z = 0.25 to 1.0 [engineered, compacted dams] Z = 1 to 2 [non-engineered, slag or refuse dams] t_f = 0.1-1 hours [engineered, compacted earth dam] t_f = 0.1-0.5 hours [non-engineered, poorly compacted]
Froehlich (1987)	43	$\overline{B}^* = 0.47K_o(S^*)^{0.25}$ K_o = 1.4 overtopping; 1.0 otherwise $Z = 0.75K_c(h_w^*)^{1.57}(\overline{W}^*)^{0.73}$ K_c = 0.6 with corewall; 1.0 without a corewall $t_f^* = 79(S^*)^{0.47}$
Reclamation (1988)		$B = (3)h_w$ $t_f = (0.011)B$
Singh and Scarlatos (1988)	52	Breach geometry and time of failure tendencies B_{top}/B_{bottom} averages 1.29
Von Thun and Gillette (1990)	57	B, Z, t_f guidance (see discussion)
Dewey and Gillette (1993)	57	Breach initiation model; B, Z, t_f guidance
Froehlich (1995b)	63	$\overline{B} = 0.1803K_o V_w^{0.32} h_b^{0.19}$ $t_f = 0.00254 V_w^{0.53} h_b^{(-0.90)}$ K_o= 1.4 for overtopping; 1.0 otherwise