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

Initial Statement of Reasons

Introduction

Senate Bill 92 (SB 92), which was signed by Governor Brown on June 27, 2017, added new sections to the Water Code requiring owners of all state-jurisdictional dams, except low hazard dams, to prepare inundation maps and EAPs for dams and critical appurtenant structures. Owners must submit inundation maps for dams and critical appurtenant structures to the Department of Water Resources (department) for review and approval. Water Code section 6161(a)(3) requires that owners develop an emergency action plan (EAP) based on the department-approved inundation map(s) and submit the EAP to the California Governor's Office of Emergency Services (Cal OES). Water Code section 6161(d) specifies EAP submission deadlines that are based on dam hazard classification. Water Code section 6161(c) requires that the department make the inundation maps publicly available.

Inundation maps were previously regulated by Cal OES; however, SB 92 transferred this authority from Cal OES to the department. Regulations concerning inundation maps were previously contained in CCR Title 19. Because the department is now responsible for regulating dam inundation maps, the proposed regulations would be added to Title 23.

Inundation maps provide a graphical representation of the timing and extent of flooding expected by the failure of a dam or critical appurtenant structures such as large gated spillways and saddle dams. Inundation maps are an essential tool for the development of Emergency Action Plans (EAPs) that are used by dam owners and emergency managers to plan for and respond to dam-related emergencies. Inundation maps inform emergency managers the possible evacuation extent, timing, and magnitude expected by the failure of the dam or critical appurtenant structure.

On October 19, 2017, the department's Division of Dam Safety (DSOD), which implements the Dam Safety Program, adopted interim emergency regulations describing the requirements for inundation maps to clarify and make specific the provisions of SB 92. The emergency regulations are only effective for up to one year after adoption. Therefore, the proposed permanent regulations are necessary to provide a permanent inundation map standards. In addition, the proposed regulations provide additional clarification beyond that provided in the emergency regulations; this is important because some of the statutory deadlines have not yet been reached and ongoing updates of the maps are required every ten years or sooner.

DSOD has made several efforts to reach out to and listen to the community of dam owners, engineers, emergency managers, and dam safety officials from other states and organizations in an effort to draft

inundation map regulations that are the least burdensome while still being effective for emergency preparedness. The purpose of outreach before the regular or permanent rulemaking formally begins is to improve the regulations. Since SB 92 was signed in June 2017, DSOD staff has fielded many calls and emails from dam owners and engineers with questions and comments on the new requirements, including the emergency regulations. In early 2018, DSOD conducted a poll of other state dam safety organizations about how other states administer inundation maps. In January 2018, DSOD co-hosted a workshop with Cal OES for dam owners on the new requirements for inundation maps and EAPs. During that workshop, owners and engineers asked questions about the emergency regulations for inundation maps. DSOD listened to these questions and revised the proposed permanent regulations to provide more clarity and flexibility, where appropriate. In February 2018, DSOD hosted two separate focus groups with dam owners and emergency managers to solicit feedback on the draft inundation map regulations. As a result of this feedback, DSOD made improvements to the regulations by making them more performance-based and less prescriptive. The revised regulations were then posted online for informal public comment on May 4, 2018.

Between May 4 and May 21, DSOD received 64 comments from 20 people. Comments fell into two categories: general and modeling. General comments included revising definitions and other provisions for clarity. Modeling comments focused on clarifying breach parameters, sequential dam failures, sedimentation, and determining when a new model is necessary. Several commenters noted their appreciation that DSOD incorporated dam owner and focus group feedback in the version posted for comment on May 4. Based on the comments received by May 21, DSOD incorporated additional revisions into the regulations.

Problem Statement

Dam owners must be prepared for emergencies, including the potential failure of their dams and critical appurtenant structures, regardless of the condition of those structures. Since lives and properties are located downstream of dams, emergency preparedness is necessary for public safety and welfare. Emergency management agencies (EMAs) need to make quick and informed decisions during emergencies. An inundation map is an essential tool in planning for and responding to dam-related emergencies.

Senate Bill 92 requires that inundation maps be prepared for extremely high, high, and significant hazard dams and their critical appurtenant structures. However, it does not describe the information to be displayed on inundation maps, hazard classifications, failure scenarios, modeling assumptions, acceptable engineering methodologies, qualifications for those preparing maps, required documentation and reporting standards, map submission requirements for new and enlarged dams, and details on map updates. While SB 92 contains general parameters for identifying critical appurtenant structures, regulations are necessary to specify and implement the statute.

Overall Purpose

The proposed regulations are necessary to identify information that is required to be displayed on inundation maps and to specify acceptable engineering methods for developing that information. This is necessary to ensure that approved inundation maps are an effective emergency planning and response tool. The standardization of information and uniformity of modeling and maps are especially important to facilitate ease of use and comprehension during an emergency. Since the inundation maps reflect a hypothetical event, standardized assumptions for the dam failure are needed so that the maps are

understood in context. The proposed regulations address this, and define appropriate modeling and mapping standards.

The purpose of the proposed regulations is to interpret, clarify, and make specific the provisions of the amended sections of 6160 and 6161 of the Water Code, by making specific the requirements for the preparation of inundation maps. These regulations include the following:

- Define the allowable engineering methods for simulating the extent, timing, and intensity of flooding produced by the hypothetical failure of a dam or its critical appurtenant structures using computer modeling.
- Define uniform assumptions for modeling the condition of the reservoir and dam prior to the failure.
- Address unique situations such as dams in series, in which the failure of an upstream dam may impact a downstream dam.
- Define the required components of an inundation map.
- Provide a standardized and uniform set of requirements for the presentation of the inundation extent, timing, and intensity information produced by computer modeling.
- Describe the requirements for the submission of supporting information needed to prepare the inundation model and map.
- Clarify the conditions that prompt submission of inundation map updates.
- Define the department's hazard potential classifications.
- Clarify the requirements for inundation map development and submission for dams jointly regulated with the Federal Energy Regulatory Commission (FERC).
- Add requirements for inundation map development and submission as part of the application approval process for new and enlarged dams.

Necessity and Purpose of each Provision

CCR Title 23. Article 2. Section 310(f)(5). Applications for Construction or Enlargement

(f)(5): The purpose of subdivision (f)(5) is to establish that inundation maps must be submitted as part of a dam construction or enlargement application. It is necessary to require inundation maps be submitted as part of construction or enlargement applications because DSOD must approve both maps and applications, and maps must be approved by DSOD before any new construction is performed to prepare for a dam-related emergency. This subsection addresses how inundation maps will be submitted for proposed dam-related projects that will be new storage facilities or enlarged to store more water.

CCR Title 23. Article 6. Section 335. Scope and Applicability of Regulations

(a): The purpose of subdivision (a) is to describe the scope of this article and detail which dams must prepare inundation maps. It is necessary to clarify the applicability and limit of the regulations to state jurisdictional dam owners, as defined. In addition, the intended use of the inundation maps within the EAP for use as an emergency management tool is made clear.

(b): The purpose of subdivision (b) is to clarify that state jurisdictional dam owners that are jointly regulated by both DSOD and the Federal Energy Regulatory Commission (FERC) are subject to the requirements of Water Code section 6161 and are also subject to the requirements of this article. Subsection (b) specifies these owners must prepare and submit inundation maps in accordance with this

article. Subjecting all state jurisdictional, non-low hazard dam owners to the same requirements ensures inundation maps are prepared to a uniform set of standards to facilitate ease of use during an emergency.

Some provisions of this article and those of Water Code section 6161, as they pertain to inundation maps, differ but do not conflict with their counterparts in the FERC guidelines. For example, Water Code section 6161(a) requires maps for critical appurtenant structures, while FERC guidelines do not. Subsection (b) clarifies that jointly regulated dam owners are required to prepare and submit those additional maps. Where discrepancies occur between this article and FERC, mechanisms are in place in these proposed regulations to avoid conflict with FERC requirements, as described in applicable sections below.

CCR Title 23. Article 6. Section 335.2. Definitions

(a) The purpose of subsection (a) is to define terms as they are used in the regulations. It is necessary to provide definitions because there are many technical engineering terms related to computer modeling that need to be clarified to provide guidance to dam owners, engineers, and the public. Though this provides purpose and necessity for all definitions in subsection (a), there are select terms below for which further necessity is provided.

(a)(2): It is necessary to define critical appurtenant structure because there are many types of appurtenant structures that could be considered critical and need clarification in the regulations. SB 92 added Section 6002.5 to the Water Code to define a critical appurtenant structure as a water surface barrier or hydraulic control structure that is 25 feet or more in height, impounds 5,000 acre-feet of water or more, or that the department determines poses a significant downstream hazard potential. This statutory definition is repeated in Section 335.2(a)(2) of the proposed regulations to provide a foundation for the following definition that clarifies the statute, such as defining the way in which height is to be measured. Examples are provided for clarity to dam owners, since a wide range of appurtenant structures fall under the state's jurisdiction such as emergency spillways, gated spillways, and saddle dams.

(a)(2)(A): It is necessary to describe how gated structures will be regarded as critical appurtenant structures to clarify that these additional features are part of the appurtenance and together they comprise one unit. A critical appurtenant structure may contain multiple water barriers such as gates or monoliths.

(a)(2)(B): It is necessary to describe how the height of critical appurtenant structures will be measured because the designs of critical appurtenant structures vary, and heights must be measured according to each structure's design and potential failure mechanism. To determine this barrier height, the maximum possible water storage elevation of a dam system is used to define the top of the barrier height. The bottom of the structure is defined by using either the upstream toe or the downstream toe, whichever is higher. By selecting the higher toe elevation, the hydraulic head and potential volume that could be released under a failure scenario is appropriately defined.

(a)(2)(B)1.: It is necessary to describe how the height of gated critical appurtenant structures will be measured because the most conservative failure mechanism is the failure of the concrete control structure to which the gates are mounted.

(a)(2)(B)2.: It is necessary to describe how the height of dam-mounted gated critical appurtenant structures will be measured because clarity is needed for how to measure the height of this type of structure. If the dam-mounted gates and the dam are measured together, this would result in the same height and inundation map as the dam. Therefore, it is necessary to establish a standard.

(a)(2)(C): It is necessary to describe the criteria with which penstocks and low-level outlets will be considered critical appurtenant structures because they must be identified as appurtenant structures that are potentially critical. In addition, a standard is needed to establish how such structures would be evaluated by DSOD as critical because the statutory height and impoundment criteria are not definitively applied to conduits. It is unclear how the height criterion could be applied to a gated conduit. The definition of height in subsection (B) is linked to the upstream or downstream toe, which is not applicable to an outlet or penstock; therefore, the height criterion is not applicable to these structures. The impoundment criterion is also not applicable to outlets or penstocks because the impoundment of water behind an outlet gate is not the primary purpose of this type of gate; rather, the impoundment is incidental to the outlet gate's primary function of regulating the flow through a conduit. Unlike higher-level spillway gates or saddle dams, whose primary function is the impoundment of water, outlet gates are primarily used to release and regulate the reservoir storage to meet downstream delivery requirements and for emergency reservoir drawdown. Outlet gates only impound water in the closed position. Outlet gates are operated frequently as part of their normal operations. Flood detention outlet gates are typically required to be kept fully opened to maintain flood storage. These examples highlight that the main purpose of an outlet gate is not impoundment.

Lastly, the legislative intent for application of this criterion to a sudden release of the entire impoundment of 5,000 ac-ft or more of water cannot feasibly be applied to an outlet structure. The failure of an outlet gate would generally result in a slow, gradual release of the impoundment through the conduit. A sudden release of the entire impoundment is not possible through the constricted opening of a conduit. Based on the reasons described above, DSOD concluded that the third statutory criterion, "if the department determines it poses a significant downstream hazard potential," is the most appropriate criterion to use for penstocks and outlets.

(a)(3): It is necessary to define critical facilities as those listed in subsection (a)(3) because those are facilities with concentrated populations that warrant evacuation during a dam-related emergency and their locations are publicly known. Emergency managers expressed concern that publishing sensitive critical facilities, such as energy infrastructure, on publicly available inundation maps would compromise their security. In addition, emergency managers noted that each individual EMA is responsible for maintaining up-to-date records of critical facilities in their jurisdiction, and DSOD, dam owners, and consulting engineers do not have access to up-to-date information, which is constantly changing. The locations of sensitive critical facilities are more appropriate for inclusion in EAPs rather than on inundation maps.

(a)(10): It is necessary to define failure scenario because this term is used throughout the regulations, and Water Code section 6161 requires "…an inundation map that shows the area that would be subject to flooding under *various failure scenarios* unique to the dam and the critical appurtenant structures of the dam." Various failure scenarios is interpreted by DSOD to mean the collective failure scenarios for a dam and its critical appurtenant structures that account for various applicable failure conditions, such as

failure into different water courses depending on breach location, sequential dam failures, breach parameters, and other appropriate modeling assumptions. Because of the high cost of developing inundation maps for each dam and critical appurtenant structure, and the confusion that can be created by having too many inundation maps in an EAP of similar failure mechanisms, DSOD believes it is appropriate to require one map per structure depicting a failure that considers various applicable failure conditions. DSOD recognizes that dam owners must balance their resources between emergency preparedness, which includes inundation maps and EAPs, and maintaining the physical condition of their dam and critical appurtenant structures.

CCR Title 23. Article 6. Section 335.4. Downstream Hazard Potential Classification

(a): The purpose of subsection (a) is to provide descriptions of hazard classifications, based on federal hazard classifications, which DSOD uses to classify the hazard of jurisdictional dams. Hazard potential describes the impacts downstream of a dam that could be affected by its failure. Hazard potential does not relate to the condition of the dam.

(a)(1): It is necessary to define Low Hazard Potential because dams in this category are not subject to these regulations and not required to prepare inundation maps.

(a)(2): It is necessary to define Significant Hazard Potential because dams in this category are subject to these regulations and are required by Water Code section 6161(d)(1)(C) to submit an EAP by January 1, 2021.

(a)(3): It is necessary to define High Hazard Potential because dams in this category are subject to these regulations and are required by Water Code section 6161(d)(1)(B) to submit an EAP by January 1, 2019.

(a)(4): It is necessary to define Extremely High Hazard Potential because dams in this category are subject to these regulations and are required by Water Code section 6161(d)(1)(A) to submit an EAP by January 1, 2018. Note this deadline has already passed; however, at the date of this writing, not all maps for extremely high hazard dams have been received.

(b): The purpose of subsection (b) is to provide guidance to dam owners who would like to request that DSOD reevaluate the hazard classification of their dam. It is necessary to provide guidance to owners because many dam owners have contacted DSOD requesting this guidance.

CCR Title 23. Article 6. Section 335.6. Modeling Requirements

The purpose of modeling requirements is to provide guidance in how to apply failure scenarios. Water Code section 6161(a)(1) specifies that inundation maps must show various failure scenarios unique to the dam and critical appurtenant structures. DSOD interprets this statutory provision to mean that various complete failure scenarios unique to each structure are required, as applicable, under a single loading condition. Additional failure scenarios, such as partial failures, would be difficult to define given the variability of the probability of failure of each structure, and it would be cost-prohibitive for many dam owners to comply with the statute while maintaining their dam in satisfactory condition. Since the Water Code does not specify the details of those failure scenarios, nor how they should be simulated, dam owners lack clear and consistent direction for fulfilling this legislative mandate. This section is necessary to provide clear guidance to the dam owners on the modeling requirements.

(a): The purpose of subdivision (a) is to clarify the meteorological, reservoir, and breach assumptions for failure scenarios of dams and critical appurtenant structures. Various complete failure scenarios unique

to each structure are required, as applicable, under a single loading condition. Additional failure scenarios, such as partial failures, would be difficult to define given the variability of the probability of failure of each structure, and it would be cost-prohibitive for many dam owners to comply with the statute while maintaining their dam in satisfactory condition.

It is necessary to require a sunny-day loading condition because it establishes a common standard among the wide variety of dams that are subject to the statutory requirements. In addition, storm-induced loading conditions are more expensive to model and design storms vary. However, storm-induced loadings are acceptable, but not required. A sunny-day loading condition can result in more loss of life or property due to the element of surprise inherent to the occurrence of an emergency outside of the wet season.[1] Conversely, during the wet season, EMAs and the public may already be on-alert, as they will have been warned to take precautions based on rainfall-runoff forecasts. Several storm events may have already occurred, prompting EMAs and others to begin preparing for a potentially catastrophic event that could overwhelm California's flood control infrastructure.

Notwithstanding the catastrophic nature of a sunny-day loading condition and a resulting conservative inundation area, a sunny-day loading condition is less expensive to analyze than a storm-induced loading. A storm-induced loading condition requires a hydrologic assessment and a spillway analysis, if applicable, that can be costlier than simply assuming a full reservoir. Section 335.6(a) offers dam owners the flexibility of choosing the meteorological assumptions they deem most reasonable and realistic. Since either assumption reflects a hypothetical, catastrophic failure scenario of the dam or critical appurtenant structure, either or both is acceptable. To avoid any conflict with the FERC requirement of considering both sunny-day and storm-induced loadings, the proposed regulation allows dam owners to use either or both meteorological assumptions.

Though not required, a storm-induced loading condition may be modeled. Since the proposed regulation requires the initial storage in the reservoir to reflect the maximum possible storage elevation, no surcharge volume will exist in the reservoir at the time of failure. As such, the failure may be triggered by the arrival of the storm-induced, inflow hydrograph, or, if applicable, at its peak. These regulations refrain from prescribing the specific trigger mechanism for the breach and instead defer these decisions to the dam owner or consultant. Such decisions largely depend on the ability of the selected software to model various trigger mechanisms.

(a)(1): The purpose of subdivision (a)(1) is to define reservoir modeling assumptions. This subdivision is necessary to provide owners with a uniform standard for modeling the initial condition of the reservoir before and during the breach of the dam or critical appurtenant structure.

The proposed regulation remains silent on the drawdown of the reservoir through the breach. Though level-pool routing is more numerically stable than dynamic routing, if applied incorrectly, level-pool routing may lead to inaccurate results that are overly conservative.[2] Though costlier, using dynamically routing to model the reservoir flowing through the breach accounts for the sloped water surface profile that forms during drawdown and provides more realistic results than level-pool routing, in most cases. Dynamic routing is recommended for reservoirs that are long and shallow because they behave more

[1] https://damsafety.org/sites/default/files/files/EAPWG%20Final%20SIMS.pdf
[2] Goodell, Christopher & Wahlin, Brian. (2009). Dynamic and Level Pool Reservoir Drawdown-A Practical Comparison for Dam Breach Modeling.

like rivers during drawdown. Deep reservoirs can be adequately characterized by level-pool routing. Due to the lack of literature on the exact specifications of a “long and shallow” reservoir, these regulations refrain from requiring particular drawdown methods for various reservoir configurations. If, on the other hand, elevation data that sufficiently captures the reservoir bathymetry exists, the two-dimensional nature of movement of water through the breach may be modeled with a two-dimensional model.

(a)(1)(A): It is necessary to require the reservoir to be at the maximum possible storage elevation because it establishes a conservative but reasonable standard for all dams to model the reservoirs full to the physical barrier, regardless of legal restrictions. Assuming a failure at the maximum possible storage elevation builds in additional conservatism inherent to the release of a larger volume of water than that which may result from a release at the certified maximum level. The maximum possible storage elevation is the same metric used to determine if a dam falls under the state’s jurisdiction, as per the definition of a dam in Water Code section 6002.

(a)(1)(B): It is necessary to prescribe the breach of the full height of the structure because it establishes a uniform standard and makes specific the breach height modeling requirement. Breaching the full height of the structure ensures owners implement conservative but reasonable assumptions in the breach model. Since the height varies depending on the structure, this subsection includes a reference to the height for dams and critical appurtenant structures. This reference is intended to offer clarity and ease to owners in identifying the height of their respective structure, since the height definitions are included in both the Water Code and the proposed regulation.

(a)(1)(C): It is necessary to require the impoundment be modeled as water because it establishes a uniform and reasonably conservative standard regardless of the material impounded by the dam. While most dams impound water, many dams are partially filled with flowable sediment, and some dams impound mine tailings. For reservoirs that are partially or completely filled with sediment or tailings, this provision requires dam owners to consider the impoundment as water. Though in some cases more conservative, this requirement reflects the reality that sediment can in fact be dredged and its presence is not indicative of a permanent state of the reservoir. Lastly, sediment is currently not well understood in all its complexities and as such, can in most cases be flowable, in other cases remain suspended.

(a)(1)(D): It is necessary to provide a means for a dam owner to model the effects of sediment because owners may want to model the actual conditions of their reservoir, including the effects of sediment, potentially resulting in a different modeled inundation area. It is necessary for owners to provide supporting documentation so DSOD can review the sediment characteristics, including flowability, and verify the resulting inundation map.

(a)(2): The purpose of subdivision (a)(2) is to define allowable breach modeling assumptions of the dam. The proposed regulation does not mandate the use of a breach model for preparing the breach outflow hydrograph. For convenience, some owners may wish to use the same software to compute the breach hydrograph as they would the downstream inundation routing. Or, they may wish to select a different tool to produce the breach hydrograph and enter the hydrograph into an inundation model.

(a)(2)(A): It is necessary to provide allowable methods of estimating breach parameters to provide guidance to dam owners. Providing owners multiple options for computing breach parameters is necessary because there is much uncertainty inherent to the estimation of breach parameters. Owners

need the flexibility of selecting breach parameters that are most appropriate for their unique site-specific conditions. This subsection allows for the use of one of four approaches for selection of dam breach parameters, ranging from easiest and least expensive to requiring more effort to model and hence costing more. These four alternatives afford dam owners the flexibility of selecting an approach that is most suitable to their dam and the availability of resources for performing the analysis. This subsection is performance-based, as the fourth option allows owners that elect to use a different approach to do so, after receiving pre-approval from DSOD.

Although dam owners are afforded the flexibility in selecting breach parameters appropriate for their dam, the breach height (or depth) is prescribed as the full height in section 335.6(a)(1)(B). Although the results of a study cited by USBR DSO-98-004 indicate that sensitivity of peak outflow to breach height is small relative to the breach width, prescribing the breach height is important because it ensures the full impoundment is considered during the breach. This prescription ensures that some degree of conservatism is built into the breach parameter selection. Since the recommended ranges of breach parameters provided by FEMA P-946 and FERC only reference breach width, formation time, and breach side slopes, prescribing the breach height as the full height of the dam provides dam owners with guidance for selecting this parameter.

(a)(2)(A)(1): It is necessary to include Table 9-3 of FEMA P-946 because it references industry standards developed based on empirical data produced by dam-failure case studies. These recommended ranges of parameters provide owners with an appropriate upper and lower bound for quick selection of parameters.

(a)(2)(A)(2): It is necessary to include Chapter 2, Appendix II-A, Table 1 of Federal Energy Regulatory Commission's *Engineering Guidelines for the Evaluation of Hydropower Projects* (August 2015) because it references Federal Energy Regulatory Commission standards developed based on empirical data produced by dam-failure case studies. Some dams are regulated by both DSOD and the Federal Energy Regulatory Commission. These recommended ranges of parameters provide owners with an appropriate upper and lower bound for quick selection of parameters.

(a)(2)(A)(3): It is necessary to include the option of performing a sensitivity analysis using equations in Table 2 of USBR's DSO-98-004 appropriate for the dam that produces the largest peak outflow because it references industry standards for sensitivity analyses. Since there is large uncertainty in characterizing breach parameters, performing a sensitivity analysis on these equations is important to understand how each potential parameter set interacts with the model and influences the results. Since these equations are based on dam-failure case studies as described in DSO-98-004, they provide an important link between dam break modeling and reality. Dam owners may elect to perform a sensitivity analysis and select the parameters that provide the most conservative result.

(a)(2)(A)(4): It is necessary to allow for alternative methods for estimating breach parameters approved by DSOD to provide dam owners the ability to propose an alternative method, including simplified methods for estimating breach parameters and avoid an entirely prescriptive standard.

The proposed regulation does not mandate the use of a breach model for preparing the breach outflow hydrograph. For convenience, some owners may wish to use the same software to compute the breach hydrograph as they would the downstream inundation routing. Alternatively, they may wish to select a different tool to produce the breach hydrograph and enter the hydrograph into an inundation model.

(a)(2)(B): It is necessary to require a dam to be failed in different locations that would affect different watercourses because the reality of these types of dams is that they will not fail as one unit. Also, breach parameters referenced in section 335.6(a)(2) may not address this unique situation. This subsection addresses dams that are uniquely configured such that their failure would release the reservoir in various directions, impacting multiple watercourses. An example of such a dam is one with a very long length compared to its height. This subsection clarifies that each dam section located upstream of each respective watercourse must be failed independently of the other. This provision ensures that these types of dams are not unrealistically assumed to fail as a single unit, and is intended to address the range of possible inundation areas due to failure at different locations within a dam.

(a)(3): The purpose of subdivision (a)(3) is to define allowable breach modeling assumptions of critical appurtenant structures. Since Water Code section 6161 requires inundation maps for the failure of critical appurtenant structures, but provides no direction on the type of failure scenario to apply to various critical appurtenant structures, this subsection is necessary to offer clarity. Because CAS designs vary widely, the proposed regulations require a complete failure, which is conservative and simple to model.

(a)(3)(A): It is necessary to define allowable breach parameters for saddle dams as the same criteria for dams in subsection (a)(2)(A) because saddle dams are constructed of the same materials as dams so their failure would mimic that of a dam.

(a)(3)(B): It is necessary to clarify that gated critical appurtenant structures must include the failure of all gates simultaneously together with the control structure because this is the worst-case, most conservative failure scenario for this type of structure. Since critical appurtenant structures vary widely across the state, these regulations refrain from prescribing a lesser-case scenario such as that of the failure of a subset of gates. Doing so would be overly prescriptive and would require provisions for all the various combinations of gates throughout the state. Modeling the failure of a subset of gates would be cost-prohibitive for many dam owners and would be overly prescriptive. Also, the height of a critical appurtenant structure, as described in section 335.6(a)(2)(B)(1), considers the control structure together with its gates, from the upstream toe of the control structure to the maximum possible storage elevation.

(a)(3)(C): It is necessary to clarify that if multiple gates are affixed to a dam, they must be failed collectively but separately from the dam because in this situation, the critical appurtenant structure is the gate set, not the gates together with the dam. The definition of a critical appurtenant structure in section 335.6(a)(2)(B)(2) considers the height measurement from the base of the gates, not the base of the dam.

(a)(3)(D): It is necessary to require a nearly instantaneous and complete failure for all critical appurtenant structures, except for saddle dams, because this provides a conservative failure mode that can be applied to the wide variety of critical appurtenant structures throughout the state. Since there are many types of critical appurtenant structures and since there is limited guidance in literature for the modeled failure of critical appurtenant structures, this requirement is important because it is applicable to all structures.

(a)(3)(E): It is necessary to allow an alternative failure mode for modeling critical appurtenant structures, if approved by DSOD, because if industry guidance for modeling these types of failures becomes readily

available, this provision would offer dam owners the ability to use such guidance as part of their modeling approach.

(a)(4): The purpose of subdivision (a)(4) is to require that downstream dams be considered in failure scenarios. It is necessary to require modeling of any expected failures of downstream dams and critical appurtenant structures because the impact of the failure may be felt beyond downstream dam systems, potentially impacting lives and critical facilities further downstream. These impacts must be accounted for in the model and map. In these cases, simply assuming the downstream dam is capable of absorbing the upstream failure is not sufficient. An analysis must be performed to ensure this is the case.

As part of the rule-making for the proposed regulations, DSOD invited engineers with an expertise in dam break inundation modeling to provide feedback during a focus group meeting. The question of the sequence of failures of the structures at the downstream dam system was raised during the focus group meeting. Specifically, DSOD solicited feedback on the industry approach to failing the downstream dam system to inform any provisions prescribing the exact failure mode for the downstream dam system. Feedback received revealed that much variability exists in modeling the downstream dam system failure, since dams across the state widely vary.

(b): The purpose for establishing inundation modeling assumptions is to provide guidance for owners on the use of appropriate modeling tools.

(b)(1): It is necessary to establish that the elevation data used for inundation modeling be appropriate for the downstream development and terrain because it guides owners in selecting appropriate terrain data that the model will heavily rely upon to characterize the inundation. Capturing the spatial variability in topography is especially important for densely populated areas.

It is necessary to require that elevation data have a horizontal resolution of 10 meters or finer because areas with less topographic variation may be better suited to courser resolution terrain datasets that sufficiently capture the topography but also enhance computational runtime. This requirement is reflective of the freely available USGS National Elevation Dataset, available nationally at resolutions of 1/3 arc-second (about ten meters).[3]

The possibility of prescribing specific elevation datasets for various types of downstream terrain was explored as part of this rulemaking. Because of the potentially cost-prohibitive nature of acquiring fine-resolution terrain data, such as the flying of Light Detection and Ranging (LiDAR), along with the complexities inherent to the various terrain types statewide, DSOD has refrained from prescribing the specific elevation data requirements.

(b)(2): The purpose of establishing modeling software requirements is to clarify an acceptable modeling approach for simulating the routing of the flood wave as it propagates through channel(s) and/or adjacent floodplains.

(b)(2)(A): It is necessary to require an unsteady hydraulic model that is capable of dynamic routing to approximate the temporal and spatial changes in inundation because such models are important for simulating the rapidly-varying flows produced by dam breaks. It is necessary to provide guidance for when two-dimensional models are appropriate; however, requiring two-dimensional models in all cases

[3] https://lta.cr.usgs.gov/NED

of lateral spreading is unnecessarily prescriptive and doesn't allow for engineering judgement. In addition, two-dimensional modeling is more expensive; prescribing it in regulations may mean that some owners cannot comply with the statute. The USACE offers HEC-RAS[4] freely available for download in the public domain, whose unsteady, one- and two-dimensional modeling capabilities are widely used in industry and applicable for fulfillment of these inundation modeling and mapping requirements.

(b)(2)(B): It is necessary to allow dam owners to submit an alternative inundation model for DSOD pre-approval because advances in modeling technologies may warrant the use of an alternative approach. Also, this provision allows for a performance-based standard, rather than an overly prescriptive modeling requirement that may not apply in all cases. This subsection does not preclude the selection of software most appropriate and fitting to the downstream terrain. DSOD will review the appropriateness of the selected modeling software given the downstream terrain. Specifically, a two-dimensional hydraulics model is recommended for application to most topography, a coupled one-dimensional model for channelized flow and two-dimensional model for adjacent flat areas. Or, if downstream topography is such that flows are channelized immediately downstream of the dam but expand to flat areas further downstream, inundating populated areas, those flat areas should be modeled using a two-dimensional model with high resolution input.

CCR Title 23. Article 6. Section 335.8. Technical Memorandum

(a): The purpose of subdivision (a) is to require a technical memorandum that documents the modeling assumptions used to prepare the inundation map(s). The technical memorandum is necessary because DSOD needs to understand the modeling assumptions and other information used to prepare the inundation map(s) to review and approve the map(s).

(a)(1): It is necessary to include the name and location of the dam and critical appurtenant structures in the technical memorandum because DSOD must verify which dam is being described.

(a)(2): It is necessary to include a description of the dam and critical appurtenant structures in the technical memorandum because this informs the modeling assumptions. For example, an embankment dam would have different breach parameters than a concrete gravity dam.

(a)(3): It is necessary to include the reservoir storage capacity curve in the technical memorandum because DSOD must verify the volume of water released in the inundation map.

(a)(4): The purpose of subdivision (a)(4) is to include modeling assumptions used to prepare the inundation map(s).

(a)(4)(A): It is necessary to include a description of the modeled failure scenario(s) in the technical memorandum because DSOD must understand what failure scenarios are being presented in the inundation maps for approval. Failure scenarios for a dam and its critical appurtenant structures account for various applicable failure conditions, such as failure into different water courses depending on breach location, sequential dam failures, breach parameters, and other appropriate modeling assumptions.

[4] http://www.hec.usace.army.mil/software/hec-ras/

(a)(4)(B): It is necessary to include a description of the modeling software in the technical memorandum because DSOD must verify the software used to develop the inundation map(s) is capable of performing modeling pursuant to section 335.6(b)(2) to review and approve an inundation map.

(a)(4)(C): It is necessary to include a description of the modeling assumptions in the technical memorandum because DSOD must verify that the modeling assumptions are appropriate for the dam or critical appurtenant structure pursuant to section 335.6 to review and approve an inundation map.

(a)(4)(D): It is necessary to include a description of the breach parameters in the technical memorandum because DSOD must verify that breach parameters meet the requirements of section 335.6(a)(2)(A) and are appropriate for the type of dam or structure that is modeled to review and approve an inundation map.

(a)(4)(E): It is necessary to include a description of the type of terrain data used to develop the inundation map(s) in the technical memorandum because DSOD must verify the data resolution is appropriate for the downstream development and terrain pursuant to section 335.6(b)(1) and DSOD must understand the limitations of the data to review and approve an inundation map.

(a)(4)(F): It is necessary to include a description of any sensitivity analyses in the technical memorandum because DSOD must understand the sensitivity, or variation of results due to different inputs, of the model to review and approve an inundation map.

(a)(4)(G): It is necessary to include a description of any modifications made to stabilize or accelerate the model in the technical memorandum because DSOD must understand modifications and how they could affect the model output to review and approve an inundation map.

(a)(4)(H): It is necessary to include a description of the determination of the downstream inundation boundary in the technical memorandum because DSOD must verify that the inundation boundary is displayed as a one-foot maximum depth or that the flood wave is contained within the channel at the downstream boundary pursuant to section 335.10(c) to review and approve an inundation map.

(a)(5): The purpose of subdivision (a)(5) is to include the signature and seal of the California-licensed civil engineer responsible for preparing the technical memorandum. It is necessary to include the signature and seal on the technical memorandum because inundation maps and the technical memorandum documenting their preparation are technical engineering documents that must be prepared and authenticated by a California-licensed civil engineer.

CCR Title 23. Article 6. Section 335.10. Inundation Maps

The purpose of section 335.10 is to ensure the inundation map's usefulness to emergency managers during a dam-related incident. During an emergency, EMAs and others must be able to quickly and easily identify inundation results at any given location within the inundation area. They must also be able to quickly discern the level of applicability of the map to the specifics of the incident. The maps will be reviewed by DSOD in accordance with the parameters set forth in this section and for overall effectiveness as an emergency management tool.

(a): The purpose of clarifying the required information displayed on a map, along with the format of the information displayed, is to establish standards for the display of information on the maps while offering flexibility for inundation results that may not fit the mold of one mapping standard. Also, since these

regulations are not prescribing the modeling software to be used, variation in modeled output between the various software may warrant the use of varying mapping formats.

Despite this flexibility, the three options offered for display of results reflect the most appropriate mapping formats to achieve the overall objective of quick and clear presentation of information. The target audience is emergency managers and the public, so the maps should be prepared with recognition of these end users.

Should cross-sections or points be chosen to display results on the map, these regulations state they must be displayed at appropriate intervals. These regulations refrain from prescribing the exact intervals because this can vary widely between different inundation areas and map scales. Rather than mandating one specific set of intervals, the dam owner or consultant can select the interval that would best fit the inundation area. These intervals should be selected to provide results to an adequate degree of detail, capturing any major or abrupt changes in inundation results. However, intervals should not be selected such that information becomes "cluttered" on the map, with map features that conflict. DSOD will review these intervals for clarity and efficacy as an emergency management tool.

Rasters may also be presented on the map. Most two-dimensional hydraulic models output rasters by default; as such, this is the recommended approach for display of results. Displaying results in raster format allows for the spatial variation of results to be readily discernable, so that interpolation between any two locations is not necessary. This is of great benefit during an emergency and is especially recommended for heavily populated areas with much spatial variation in results. Rasters mostly require less post-processing than other formats, and they may be displayed on the map in classified format or as gradations. Contoured lines or filled contours may also be used, if the inundation results are best depicted in this form, and may be overlaid on top of the raster.

DSOD hosted a focus group meeting in February 2018 to solicit feedback from emergency managers on the required information to be displayed on the map. This feedback was incorporated into the regulations.

(a)(1): The purpose of subsection (a)(1) is to require the inundation boundary be displayed on the map.

It is necessary to require the inundation boundary be displayed on the map because emergency managers need this information to make evacuation decisions. Emergency managers may elect to issue evacuation notices for areas beyond the mapped inundation boundary, should site-specific conditions warrant such measures.

(a)(2): The purpose of subsection (a)(2) is to require the flood wave arrival time be displayed on the map.

It is necessary to require the flood wave arrival time be displayed on the map because arrival times serve as the most critical information for emergency response since they reveal how fast the flood wave is expected to progress to populated or otherwise critical locations, providing the basis for appropriate evacuation protocols. Arrival times convey how much lead time is available for warning of downstream communities. Arrival times serve as the most critical information for characterizing the emergency response.

(a)(3): The purpose of subsection (a)(3) is to require the maximum depth be displayed on the map.

It is necessary to require the maximum depth be displayed on the map because maximum depth conveys the severity of the flooding at any given location, and show how deep the flooding is expected to get across the inundation area. Maximum depth information also allows emergency managers to prioritize the allocation of resources to the most severely impacted areas.

(a)(4): The purpose of subsection (a)(4) is to require the maximum velocity be displayed on the map.

It is necessary to require the maximum velocity be displayed on the map because it aids emergency managers in the dispatch of swift-water rescue teams where rapid flows are expected. Velocity information, combined with maximum depths, can inform emergency managers of the severity of flooding in areas inhabited by small children, for example, who may be easily swept away with fast-moving, albeit shallow, waters.

(b): The purpose of requiring the adjustment of the raster's transparency is to help ensure inundation map clarity.

It is necessary to require the adjustment of the raster's transparency because it is necessary to set a standard for map clarity. Aerial imagery shows emergency managers the terrain characteristics within the inundation area. Emergency managers use the aerial imagery to distinguish between populated, developed areas and rural, uninhabited areas. Aerial imagery can also reveal the locations of major arteries and other critical facilities. Aerial imagery is important for emergency management and should be clearly visible, even if layers are overlaid on top of the aerial imagery. This provision, although prescriptive, ensures the aerial imagery layer is not compromised by the addition of other layers.

(c): The purpose of clarifying the display of the inundation boundary is to a one-foot maximum depth is to ensure that the inundation area in its entirety is depicted on the map.

It is necessary to require a one-foot maximum depth be displayed because it ensures the entire inundation area is captured on the map. A one-foot maximum depth conveys to emergency managers a lesser severity of flooding in which damage may have occurred, and where most trucks may still be able to safely pass. If the flood wave no longer poses a threat to life or critical facilities but the inundation area is extended to one foot, the additional inundation extent beyond the point of impact will serve little value for emergency management. Otherwise, the inundation area may extend longer than reasonably necessary, resulting in additional unnecessary cost to the dam owner, rendering the map less effective. Extending the map to a one-foot depth in these cases may cause unnecessarily long computational run times. If flows become channelized and the model and map do not need to reflect a recession to a one-foot depth, a note on the map indicating high flows are expected beyond the inundation extent within the channel is required in section 335.10(d)(15).

(d): The purpose of requiring the information in (d) be displayed on the map is because it relays important information about the map to emergency managers.

(d)(1): It is necessary to require the identifying information in (d)(1) so that emergency managers can quickly identify the dam that caused the flooding. The DSOD dam number is necessary in case the dam incident is reported to DSOD. The national dam ID number is necessary for identifying the dam in the National Inventory of Dams. The county name is important for quickly locating the dam in its respective county and identifying the local EMA with jurisdictional authority.

(d)(2): It is necessary to require the meteorological loading condition be reported on the map because emergency managers need to know what meteorological condition was assumed to prepare the map in order to understand the limits of applicability of the map to the on-the-ground conditions.

(d)(3): It is necessary to include a note regarding sediment because it informs emergency managers if the failure considered the effects of sediment accumulation in the reservoir and sediment transport through the breach.

(d)(4): It is necessary to require the labeling of the dam because it identifies the location of the source of the flooding.

(d)(5): It is necessary to require critical facilities on the map because emergency managers need to plan their emergency response according to the locations of these facilities. Symbols for critical facilities allows for other inundation information to not be covered up. This can be especially important in densely populated areas, where many critical facilities may exist.

(d)(6): It is necessary to require the labeling of channels and flood control features within the inundation area because it allows emergency managers to understand where such flood control infrastructure exists and their potential vulnerabilities. Flood control infrastructure may help pump or divert flood flows into flood control basins or bypasses.

(d)(7): It is necessary to require delineations of governmental jurisdictions because it allows emergency managers to quickly identify the locations of cities and towns and other jurisdictions impacted by the flood.

(d)(8): It is necessary to require a north arrow because it orients emergency managers. This is a standard element of most maps.

(d)(9): It is necessary to require a scale bar because it allows for measurements on the map to be made with an understanding of the correct scale. This is necessary to help emergency managers judge distance on the map appropriately, which is very important during an emergency. This is a standard element of most maps.

(d)(10): It is necessary to require the labeling of the datum as NAVD88 because this regulation requires all elevations reported to this datum.

(d)(11): It is necessary to require an index for multiple map sheets because it facilitates the organization of the map sheets, which is very important during an emergency.

(d)(12): It is necessary to require the preparation date of the map because it allows emergency managers to interpret the information on the map in its proper context. If information appears outdated, the map preparation date will indicate when the map was prepared. This can assist in determining if the information provided on the map is applicable to the circumstances of the emergency. Reporting the map preparation date is also necessary to determine if the map requires updates per Water Code section 6161.

(d)(13): It is necessary to require the simulation date of the model because DSOD needs it to determine if the model needs to be updated during the ten-year update cycle for the map.

(d)(14): It is necessary to require the signature, seal, and license number of the civil engineer responsible for preparing the map because inundation maps display information that is developed through breach and hydraulic modeling, which necessitates preparation by a qualified engineer. DSOD polled other states and found that many require maps to be prepared and stamped by a registered professional engineer. This requirement is necessary to ensure the map(s) are prepared professionally with the backing of the Business and Professions Code. This certification on the map also designates it was prepared by or under the direction of a licensed civil engineer with expertise and experience in performing inundation studies.

(d)(15): It is necessary to require a statement that the information on the map is approximate because the model may not capture the complexities of the actual emergency. This disclaimer is necessary for communicating to emergency managers the uncertainty inherent to preparing the model and map. This informs emergency managers that they should also rely on site-specific conditions to inform their decision-making.

(d)(16): It is necessary to require a statement if high flows are expected beyond the inundation boundary because emergency managers informed DSOD this information is valuable to display on the map. During an emergency, it may not be readily understood that high flows should be expected even if the flood wave becomes channelized. Stating so is important for emergency management.

(d)(17): It is necessary to require the identification of low-lying areas where ponding is expected to impact lives or critical facilities because such low-lying areas may take longer to drain or recede, potentially endangering lives or critical facilities. Identification of low-lying areas is a valuable tool provided by inundation modeling. Such information allows emergency managers to prioritize resources appropriately.

(e): The purpose of requiring an appropriate map scale is to ensure the information on the maps is clearly understood by emergency managers.

It is necessary to require an appropriate map scale because clear layout of information on the maps facilitates their successful use during an emergency.

CCR Title 23. Article 6. Section 335.12. Reporting Standards

The purpose of section 335.12 is to facilitate standardization of information on the inundation maps and supporting document submittals. Establishing a standard for the reporting of information is important as it minimizes confusion during an emergency.

(a): It is necessary to require the reporting of volumes in acre-feet because it establishes a standard that is readily understood by emergency managers.

(b): It is necessary to require discharge be reported in cubic feet per second because it establishes a standard that is readily understood by emergency managers.

(c): It is necessary to require depth be reported in units of feet because it establishes a standard that is readily understood by emergency managers.

(d): It is necessary to require time be reported in minutes, hours, or both because it establishes a standard that is readily understood by emergency managers.

(e): It is necessary to require elevations be reported in feet above NAVD88 because it establishes a standard that is readily understood by emergency managers.

(f): It is necessary to require the projection of NAD 1983 Teale (California) Albers for geospatial files because it preserves the area of displayed features and establishes a single standard projection that is appropriate for geospatial datasets across the state of California. A different and larger projection of the United States is referenced as the FERC geospatial projection standard, so dams regulated by both FERC and DSOD would need to provide DSOD with a different set of geospatial files in the California projection. This is necessary because the California projection is smaller; smaller projections inherently provide more precise locations of map features specific to the smaller geographic projection, in this case, the State of California. DSOD considered three California projection-based coordinate systems: Teale Albers, the California State Plane Coordinate System (State Plane) and the Universal Transverse Mercator (UTM) coordinate system. Both the State Plane and UTM systems comprise multiple projections, or zones, depending on the location of the geographic area that is being depicted; Teale Albers is a single projection across the state. If State Plane or UTM systems are allowed, the projection of each geospatial file would depend on the location of the dam and inundation area. Emergency managers who use geospatial files of inundation maps during emergencies would need to determine the projection in order to use the files. Using a single state-wide projection, Teale Albers, would eliminate potential confusion regarding geospatial file projection during an emergency. The Teale Albers projection was selected because it both preserves the area of displayed features and establishes a single standard projection across the state.

In addition to improving dataset precision of geospatial files for emergency managers, projecting geospatial data in a different projection incurs minimal cost for its added benefit.

(g): It is necessary to require geospatial files be labeled with the loading condition because it identifies the meteorological assumption implemented during the modeling.

(h): It is necessary to require dates be reported as month, day, and year because it establishes a standard that is readily understood by emergency managers and clarifies when the approved map needs to be updated. In industry dates are sometimes reported as month and year; requiring a day makes clear the 10-year update cycle of the map.

CCR Title 23. Article 6. Section 335.14. Submittals to DSOD

The purpose of section 335.14 is to clearly outline the required submittals to DSOD in one place in the regulations to eliminate confusion about the required submittals.

(a): The purpose of subsection (a) is to identify the required documents and files that must be submitted in digital files.

(a)(1): It is necessary to require a color PDF of each map because Water Code section 6161(a) requires an electronic copy of the inundation map; this statutory requirement is repeated here for clarity and consistency. A color copy of the map is necessary to ensure the map features are clear.

(a)(2): It is necessary to require the submission of geospatial files to assist DSOD with its review of the modeled output. In addition, DSOD held a focus group meeting with emergency managers to solicit comments regarding the use of geospatial files by emergency managers. Some emergency managers throughout the state have GIS capabilities that are leveraged during an emergency to create maps.

These emergency managers create their own inundation maps using the modeled output supplied by the dam owners overlaid on top of their own unique layers. As such, the transmittal of the raw modeled output, projected to a standard projection prescribed in the regulation, is of the utmost importance for emergency managers and ensuring the efficacy of the emergency management tools supplied by dam owners per these inundation mapping requirements.

It is necessary to specify the required file format for geospatial files produced by two-dimensional hydraulic models because the standard output from such models is typically in raster format and emergency managers prefer to receive geospatial files in raster format.

(b): The purpose of subsection (b) is to describe the submittal requirements for the technical memorandum. The requirement of one hard copy and one PDF copy is necessary because it ensures DSOD is able to use the technical memorandum to facilitate its review of the map. Also, once the map requires updates, a hard copy of the technical memorandum is necessary for DSOD to have on-file so it can determine what updates are needed.

(c): The purpose of subsection (c) is to require submittal of the model to DSOD if needed during DSOD's review. This provision is necessary because if DSOD finds problems in the modeled inundation magnitude and timing, the source of any problems may only be discovered by reviewing the model. DSOD may need to review the modeled assumptions and input data. If DSOD requires other information for the purpose of completing its review, this provision allows DSOD to request it.

CCR Title 23. Article 6. Section 335.16. Updates to Inundation Maps and Supporting Documentation

(a): The purpose of subdivision (a) is to provide guidance to dam owners regarding when inundation maps must be updated. Subsection (a) details the statutory requirements for when inundation maps must be updated. It is necessary to provide the statutory requirements for when inundation maps must be updated in subsection (a) because it is convenient and clear for dam owners that all information on map updates is located in one place: section 335.16.

(b): The purpose of subdivision (b) is to provide guidance to dam owners that a new model simulation may not be necessary.

(b)(1): The purpose of subdivision (b)(1) is to provide guidance to dam owners that a new model simulation is not required under certain conditions. It is necessary to define these conditions because model simulations are expensive and unnecessary if all of the following conditions are met.

(b)(1)(A): It is necessary to establish as a condition that there is no significant change in the dam or critical appurtenant structures because there would be no resulting change in the inundation map.

(b)(1)(B): It is necessary to establish as a condition that there is no significant change in the downstream development or terrain because there would be no resulting change in the inundation map.

(b)(1)(C): It is necessary to establish as a condition that there are no significant changes in the modeling assumptions because there would be no resulting change in the inundation map.

(b)(1)(D): It is necessary to establish as a condition that there is no significant change to inundation modeling state-of-practice because there would be no resulting change in the inundation map.

(b)(2): The purpose of subdivision (b)(2) is to establish submittal requirements if a new model simulation is not performed for a 10-year map update. It is necessary to define these submittal requirements to clarify that submittals are still required and define them.

(b)(2)(A): It is necessary to require an updated inundation map or maps because it is required in statute and some map information may have changed, even if the modeled inundation has not changed. Information that is subject to changes that must be updated on the map includes aerial imagery, critical facilities, the map preparation date, and the licensed engineer's seal. It is necessary to require the licensed engineer's seal because evaluating the need to update an inundation model includes verifying unchanged modeling assumptions and state-of-practice, which should be evaluated by an engineer. It is necessary to require all other unchanged map details as required in section 335.10. It is particularly important in this case to distinguish the map date from the model simulation date.

(b)(2)(B): It is necessary to require a written explanation of why a new model simulation is not necessary and all changes to the inundation map(s) for DSOD verification.

(c): The purpose of subdivision (c) is to provide guidance to dam owners that a new model simulation is required under certain conditions, and to establish the submittal requirements when a new model simulation is performed to update the inundation map(s). It is necessary to require a new model simulation when there is a significant change to the dam, critical appurtenant structures, downstream development or terrain, model assumptions, or inundation modeling state-of-practice because any of these conditions could result in a change to the inundation area. It is necessary to establish submittal requirements for when a new model simulation is run to provide guidance to dam owners. It is necessary to require the same submittals described in section 335.14 for DSOD review and approval. Necessity for each submittal requirement is provided under section 335.14 in this statement of reasons.

CCR Title 23. Article 6. Section 335.18: DSOD Review and Approval

The purpose of section 335.18 is to describe the process and standards that DSOD will use to approve inundation maps, clarify how deficiencies in the submittals made under section 335.14 will be addressed, and allow DSOD to approve inundation maps that were prepared under existing emergency regulations that are substantially compliant with the proposed regulations. It is necessary to describe the process and clarify how deficiencies will be addressed to provide guidance to dam owners and allow DSOD to approve that are substantially compliant with the proposed regulations.

In October of 2017, DSOD adopted emergency regulations governing inundation maps. Many dam owners, especially those with EAPs due by January 1, 2019, have been operating under the emergency regulations. Inundation maps often take months to prepare, and maps may be prepared under the emergency regulations and then submitted after the permanent regulations are adopted. These permanent regulations will replace emergency regulations that became effective in October 2017. In some respects, the permanent regulations provide more flexibility to dam owners. Even though some of the requirements in the permanent regulations are refined, it is DSOD's expectation that inundation maps that meet the requirements in the emergency regulations will also substantially comply with, and therefore satisfy, the requirements in these permanent regulations.

CCR Title 23. Article 6. Section 335.20. Inundation Map and EAP Requirements for New and Enlarged Dams

(a): The purpose of subdivision (a) is to establish that inundation maps and submittals required by section 335.14 must be submitted before DSOD approves any construction or enlargement application. It is necessary to require that inundation maps and associated submittals be submitted before a construction or enlargement application is approved because an inundation map is needed for emergency preparedness to protect public safety before construction or enlargement of the dam begins. The intent is for DSOD to review the inundation map concurrent with construction.

(b): The purpose of subdivision (b) is to establish that inundation maps must be approved by DSOD and an EAP must be submitted to Cal OES (pursuant to Government Code section 8589.5) before DSOD issues a Certificate of Approval. It is necessary to require that inundation maps be approved and an EAP be submitted before a Certificate of Approval is issued because an approved inundation map and a draft EAP are needed for emergency preparedness to protect public safety before water is allowed stored behind the dam.

Economic Impact Assessment

The Department has determined that the proposed regulations are not major regulations as defined in the Administrative Procedures Act. The statutory requirement to prepare inundation maps applies only to dams with a hazard classification of significant, high, and extremely high; dams that are classified as low hazard are not required to prepare inundation maps and thus not subject to the proposed regulations.

The proposed regulations make specific the statutory requirement by establishing standards for the development of inundation maps. The estimated economic impact of the proposed regulations will affect businesses and private individuals that own dams, rate-payers of services from affected privately and publicly owned dams such as water and power, and engineering businesses and private individuals that develop inundation maps. The estimated economic and fiscal impacts are detailed in the Form 399: Economic and Fiscal Impact Analysis, along with the Form 399 attachment.

Most dam owners do not possess the required qualifications to prepare inundation maps, so they will hire engineering businesses with the requisite qualifications. As a result, this regulation is expected to create new engineering businesses or cause existing engineering businesses to expand, and will, similarly, create new jobs in this field. DSOD estimates that this regulation could lead to the creation of up to 10 new businesses or business expansions. Since dam owners will incur costs to comply with the regulation, dam owners may decide, based on the increased cost of doing business, to discontinue use of dams and associated businesses or eliminate positions. Since many factors go into the decision to discontinue a business and eliminate positions, it is difficult to predict how many businesses or jobs would be eliminated due to this regulation.

Out of the 937 of dams subject to the regulations (extremely high, high, or significant hazard), 559 are owned by public agencies and 378 are owned by private entities, consisting of individuals and business enterprises. Businesses that own dams include small businesses, associations, and investor-owned utilities. While DSOD does not keep records of which dams are owned by small businesses, DSOD estimates that approximately 95 dams are owned by small businesses. Some private entities own more than one dam. There are 258 private owners of the 378 privately owned dams. The Department has already received inundation maps for some dams to meet the earliest statutory deadlines. There are 338

privately owned dams that have not yet submitted inundation maps and would be subject to the proposed regulations.

The Department estimates the initial cost to develop one inundation map based on the proposed regulations is $25,000. The statute requires inundation maps for each dam and critical appurtenant structure. Because of this, some dam owners will have to develop more than one map. The Department assumes that, on average, extremely high hazard dams will need four maps at an estimated cost of $100,000; high hazard dams will need two maps at an estimated cost of $50,000; and significant hazard dams will need one map at an estimated cost of $25,000. The Department estimates that the proposed regulations would result in initial costs to develop inundation maps for the remaining 338 privately owned dams of $12,925,000.

The statute requires that inundation maps be updated every 10 years or sooner. The regulations specify that revising inundation maps would not require a new inundation model under certain conditions; therefore, many updated maps are expected to cost significantly less than $25,000. The Department estimates ongoing costs for all privately owned dams to update inundation maps will be $315,000 annually. In addition, the costs to state and local-agency-owned dams would likely be passed along as an indirect cost to rate-payers. The indirect and induced costs from publicly owned dams are assumed to be equal to the direct costs for the publicly owned dams, totaling $16,675,000 over the time period between adoption of the regulations and 12 months after full implementation.

The privately owned dams are generally used in the following industries in California: water and energy supply, agriculture, and homeowner's associations. The regulations will, therefore, impose direct compliance costs on these types of California businesses. The regulations may result in minor reductions in business competitiveness in California as some similarly-situated dam-owners and associated businesses outside of California may not be subject to these types of requirements and costs. However, many of the industries supported by dams do not generally compete for customers with out-of-state businesses.

The proposed regulations benefit the State by protecting public safety and welfare, as well as the environment, by establishing uniform standards for inundation maps to ensure their validity and usefulness for emergency preparedness in the event of dam-related emergencies. Benefits consist of saving lives and reducing property damage through better emergency planning and more precise evacuation in emergencies related to dams and critical appurtenant structures. The proposed regulations provide dam owners with standards for inundation maps that will, in turn, support the preparation of emergency action plans (EAPs) for dams and critical appurtenant structures. Inundation maps developed in accordance with the proposed regulations improve the ability of dam owners and emergency management agencies to warn the population at risk before and during an emergency. As a result, there is an expected reduction in loss of life, property damage, and impacts to the environment.

As explained above, the regulation is expected to result in both positive and adverse impacts to California business. The Department has made the initial determination that the proposed regulatory action may potentially have significant statewide adverse economic impacts directly affecting businesses. Businesses and individuals who own dams that are not considered low hazard are required by statute to develop inundation maps, and the proposed regulatory action requires maps to be prepared by engineers using computer models. Projected compliance requirements include hiring a registered civil engineer to perform inundation modeling of the dam and each critical appurtenant

structure, developing maps based on the modeled results, and documenting modeling assumptions in a technical memorandum. Privately-owned dams are generally used in the following industries: water and energy supply, agriculture, and homeowner's associations.

Dams subject to these regulations are owned by different business types, ranging from large investor-owned utilities to small businesses. The cost to comply with this regulation may be significant for some dam owners. The Department has, therefore, made an initial determination that the adoption of this regulation may have a potentially significant, statewide adverse economic impact directly affecting business. It is uncertain, though, whether the regulation will impact the ability of California businesses to compete with businesses in other states. The Department has considered proposed alternatives that would lessen any adverse economic impact on business.

Documents Relied Upon

Christopher B Burke Engineering, Ltd (CBBEL) for Indiana Department of Natural Resources, "Simplified Procedure for Estimating Approximate Dam Breach Inundation Area for EAP Light Studies," dated July 2009.

FERC, "Chapter 2: Selecting and Accommodating Inflow Design Floods for Dams," *Engineering Guidelines for the Evaluation of Hydropower* Projects, dated August 2015.

FERC, "Chapter 6: Emergency Action Plans," *Engineering Guidelines for the Evaluation of Hydropower* Projects, dated July 2015.

FEMA P-946 (2013) *Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures*, dated July 2013.

FEMA 333 (2004) *Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams*, dated January 2004.

FEMA P-64 (2013) *Federal Guidelines for Emergency Action Planning for Dams*, dated July 2013.

Goodell, C. and Wahlin, B., "Dynamic and Level Pool Reservoir Drawdown-A Practical Comparison for Dam Breach Modeling," dated 2009.

National Dam Safety Review Board Emergency Action Plan Workgroup, "Simplified Inundation Maps for Emergency Action Plans," dated September 2009.

US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, "HEC-RAS River Analysis System, 2D Modeling User's Manual," dated February 2016.

US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), "Interagency Elevation Inventory," https://coast.noaa.gov/inventory/.

US Department of the Interior, US Geological Survey, "National Elevation Dataset (NED)," https://lta.cr.usgs.gov/NED, dated January 2015.

Wahl, T.L., US Department of the Interior, Bureau of Reclamation, Dam Safety Office, Water Resources Research Laboratory, "DSO-98-004 Prediction of Embankment Dam Breach Parameters," dated July 1998.

Benefits

The proposed regulations benefit the State by protecting public safety and welfare, as well as the environment by establishing uniform standards for inundation maps to ensure their validity and usefulness for emergency preparedness in the event of dam-related emergencies. The proposed regulations ensure that appropriate information is displayed on inundation maps to help emergency managers effectively respond to a dam-related emergency and protect public safety and welfare. Benefits consist of saving lives and reducing property damage through better emergency planning and more precise evacuation in emergencies related to dams and critical appurtenant structures. As a result, there is an expected reduction in loss of life, property damage, and impacts to the environment.

Alternatives

Government Code section 11346.2 requires a state agency responsible for preparing a regulation to consider and evaluate reasonable alternatives to the proposed regulatory action and provide reasons for rejecting those alternatives. This section discusses alternatives evaluated and provides the reasons these alternatives were not included in the proposal.

Alternative 1 – No Regulation

This alternative considers the possibility of allowing the inundation mapping emergency regulations to expire and relying upon Water Code sections 6160 and 6161 requiring dam owners to develop inundation maps for their dams and critical appurtenant structures without the benefit of adopted regulation to provide guidance and direction for acceptable engineering methodologies to prepare maps. This alternative was not selected because the quality of modeling and maps would vary widely and not be reliable for emergency response. Emergency managers indicated that for inundation maps to be useful they must show maximum depth and flood wave arrival times; some inundation maps prepared before the additions to SB 92 only show inundation extent without maximum depths or arrival times. The engineering methodology used to prepare such maps, if any, is unknown, rendering them ineffective for use during an emergency. Since the intent of Water Code 6161 was for the maps to be useful, regulations clarifying the statute are necessary to ensure efficacy of maps during an emergency.

Regulations are needed to clarify the statutory intent of the definition of a critical appurtenant structure. Water Code section 6161 requires maps for dams and critical appurtenant structures and Water Code section 6002.5 defines a critical appurtenant structure. However, no guidance is provided in statute on how the determination of a critical appurtenant structure's height is to be made. Water Code 6002.5 defines the height of such structures to be 25 feet or more, but does not clarify how this measurement should be applied to the multitude of structures appurtenant to California dams. The statute also does not clarify the way in which many unique appurtenant structures, such as gates on dams, outlets, etc., should be applied to the statutory definition of a critical appurtenant structure. Therefore, regulations are needed to offer clarify and uniformity.

The statute makes no mention of the information to be displayed on inundation maps. Without a uniform set of guidelines detailing the required elements of a map, dam owners are left to independently navigate the multitude of inundation modeling and mapping resources publicly available.

Such resources include federal and private guidelines, or those produced by other states or owners, written to address the unique qualities of the dams those entities own or regulate. These resources vary widely in their recommended approach for modeling and mapping, and the statute does not clarify which approach is acceptable. These regulations are necessary to clearly present acceptable modeling and mapping approaches to ensure inundation maps are prepared and submitted in accordance with a uniform set of standards.

The statute refrains from describing the required qualifications of the preparer of the model and map. Regulations are needed to clarify those minimum qualifications to ensure maps are prepared in accordance with acceptable industry tools and practices. Such qualifications ensure maps are prepared to an acceptable degree of quality to ensure their efficacy during an emergency.

Alternative 2 – More Prescriptive Regulation

More prescriptive standards could be included to provide a more consistent and standardized approach to the development and preparation of inundation maps. This alternative would require specific terrain datasets and resolution, breach parameters, breach and inundation modeling methods and computer software specifications for use in developing the inundation map. This alternative was not selected because this level of prescription is not necessary; each inundation model depends on many factors, and engineers are qualified to make those judgments. In general, more prescriptive regulations would be costlier to dam owners.

The emergency regulations require deflood time, or the time for a flood to recede, to be included on inundation maps to help inform emergency managers when evacuated areas can be repopulated. DSOD received feedback from dam owners, consulting engineers, and emergency managers expressing concerns over this requirement for several reasons. Dam owners expressed overall concern about the high cost of preparing inundation maps.

Consulting engineers expressed concern that modeling deflood time can be difficult and expensive, especially in confined areas where flood wave recession does not occur quickly, resulting in unnecessarily long computational runtimes, increasing modeling costs. Additionally, if a two-dimensional hydraulic model is not used, deflood time may not be a standard output and would require additional cost to post-process.

Emergency managers informed DSOD that deflood time would be used during the emergency planning phase, and not during emergency response. Deflood time is not needed to initiate evacuations; rather it is used to inform planning of repopulation at the end of an evacuation. However, since site-specific conditions during an actual emergency may differ significantly from the modeled deflood assumptions, emergency managers would rely instead on real-time information and on-the-ground conditions to inform their repopulation decision-making. For example, it may still be raining during an emergency, so emergency managers would repopulate evacuated areas only when on-the-ground conditions were actually safe, and not based on a deflood map. Because of this, emergency managers expressed concern that deflood maps may be misleading to the public and may cause confusion and panic during an emergency.

As a result of this feedback from dam owners, consulting engineers, and emergency managers, DSOD determined that the value of deflood times does not merit its cost, and thus did not include a

requirement for deflood times on inundation maps. Though deflood times are not required to be on inundation maps, dam owners may elect to prepare this information and include it in their EAP.

Section 335.6 requires the consideration of downstream dams or critical appurtenant structures if the failure of the dam or critical appurtenant structure in question results in those downstream failures. However, the proposed regulation does not prescribe the exact way in which the downstream dam or critical appurtenant structures should be failed. For example, the proposed regulation does not specify that the downstream dam should be breached at the time of the peak inflow from the flood wave produced by the failure of the dam in question. Also, the proposed regulation does not specify the downstream dam to fail together with its critical appurtenant structures or independently of those structures. Such prescription would ignore the multitude of site-specific conditions that should factor into the decision-making for how downstream dams and critical appurtenant structures should be failed. Such prescription would also ignore the probable failure mode and unique characteristics of the dam system in question.

Section 335.6 provides owners of dams that are partially impounded by sediment or tailings the option to model and map the effects of sediment release if they submit documentation analyzing such effects. However, the proposed regulation does not prescribe that these owners must do so. Instead, they may simply model the original capacity of the reservoir assuming the impoundment entirely consists of water. Since studies characterizing sediment are expensive, these regulations do not mandate that such studies be undertaken. Instead, these regulations offer owners the option of performing such studies if they deem the benefits outweigh the costs. Excluding the requirement of performing expensive sediment studies to accompany the inundation model and map shows that the proposed regulations offer a uniform set of guidelines but are not overly prescriptive.

Section 335.6 requires a sunny-day loading condition but clarifies that a storm-induced loading condition may be submitted instead. A storm-induced loading condition often includes a hydrology study which can increase costs for dam owners. A sunny-day loading condition only requires the reservoir at the maximum possible storage elevation for the modeled initial condition. This assumption is simpler to model than a storm-induced failure and can result in very conservative inundation results. Nevertheless, it is important to offer owners the option to consider storm-induced loadings on the dam in case their specific circumstances warrant they do so. Requiring a storm-induced loading assumption would be overly prescriptive; instead, a sunny-day loading is a conservative baseline requirement and the option to model other loadings is included.

Alternative 3 – Less Prescriptive Regulation

Less prescriptive regulations would provide less information to prepare inundation maps. This alternative would allow for the most flexibility for dam owners or their consultants to determine the datasets, methods, and models for use in developing and preparing inundation maps for their dams and critical appurtenant structures. This alternative was not selected because there are engineering methodologies that are necessary to use in the development of inundation maps that render them useful for emergency response. For example, without specifically requesting that the highest resolution of readily available digital elevation data, with a minimum resolution of 10 meters or finer be used for terrain data, model results may not accurately represent the inundated area and significantly differ with results obtained by DSOD from their independent analysis. This would potentially result in a less reliable EAP.

Support for Determination of Adverse Economic Impact on Business

The Department has made the initial determination that the proposed regulatory action may potentially have significant statewide adverse economic impacts directly affecting businesses. Businesses and individuals who own dams that are not considered low hazard are required by statute to develop inundation maps, and the proposed regulatory action requires maps to be prepared by engineers using computer models. Projected compliance requirements include hiring a registered civil engineer to perform inundation modeling of the dam and each critical appurtenant structure, developing maps based on the modeled results, and documenting modeling assumptions in a technical memorandum. Privately-owned dams are generally used in the following industries: water and energy supply, agriculture, and homeowner's associations.

Dams subject to these regulations are owned by different business types, ranging from large investor-owned utilities to small businesses. The cost to comply with this regulation may be significant for some dam owners. The Department has, therefore, made an initial determination that the adoption of this regulation may have a potentially significant, statewide adverse economic impact directly affecting business. It is uncertain, though, whether the regulation will impact the ability of California businesses to compete with businesses in other states. The Department has considered proposed alternatives that would lessen any adverse economic impact on business.

Consistency with Federal Law

The Federal Energy Regulatory Commission (FERC) regulates hydropower facilities, including dams. State-jurisdictional hydropower dams in California are subject to dam safety regulation by both FERC and the Department. In Chapter 6 of "Engineering Guidelines for the Evaluation of Hydropower Projects," FERC requires dams under its jurisdiction to produce dam inundation maps for two failure scenarios: sunny-day and the Probable Maximum Flood (PMF). FERC requires inundation maps for dams, but not for their critical appurtenant structures.

The Federal Emergency Management Agency (FEMA), as part of the National Dam Safety Program, published federal guidelines for inundation mapping (FEMA P-946). These guidelines are a resource for state and local governments to develop guidelines for dam safety and for dam owners to develop inundation maps. As such, relevant sections in FEMA P-946 have been referenced in the proposed regulation.

Section 335(b) of the proposed regulation clarifies that state-jurisdictional dams jointly regulated with FERC and subject to Water Code section 6161(a)(1) are also subject to the requirements of the proposed regulation. Water Code section 6160(d) requires that owners of these dams prepare EAPs in accordance with FERC guidelines, but does not require that these jointly regulated dam owners prepare inundation maps exclusively per FERC guidelines. Therefore, dam owner jointly regulated with FERC are responsible for preparing inundation maps in accordance with both state and federal requirements.

The proposed regulation is consistent with the FERC inundation mapping requirements in the following ways. FERC requires the results displayed for both the sunny-day and PMF loading conditions, while the proposed regulation requires either the sunny-day or storm-induced loading conditions. Jointly regulated dam owners subject to Water Code 6161(a) may submit results reflecting both the sunny-day and PMF loading conditions to both DSOD and FERC, as doing so would satisfy both state and federal requirements. Section 335.10 requires the display of the inundation boundary, flood wave arrival time,

maximum depth, and maximum velocity, all but one of which are also required by FERC. Though not required by FERC, during this rule-making the maximum velocity was determined to be necessary for inclusion on the map (see necessity description in this ISOR). Jointly regulated dam owners subject to Water Code 6161(a) may submit maps to both DSOD and FERC showing the FERC-required results (peak flood stage, flood wave arrival time, time to peak discharge, maximum water surface elevation, and peak discharge) and the additional state-required maximum velocity. Additionally, the flood wave arrival time definition in the proposed regulation has been modified from the previous definition in the emergency regulation to ensure consistency with the FERC definition. The proposed regulation also requires the display of critical facilities on the map, which, in addition to the FERC-required labeling of local roads, drainages, and other landmarks, may be submitted to both DSOD and FERC by jointly-regulated dam owners subject to Water Code 6161(a). Lastly, though FERC does not require maps for critical appurtenant structures, such maps may be submitted to both DSOD and FERC.

The proposed regulation is consistent with the FERC inundation modeling requirements in the following ways. Section 335.6 cites the use of FERC breach parameters as an acceptable approach for estimating breach parameters. Section 335.6 requires the use of an unsteady hydraulic model for modeling the inundation. Such a hydraulic model is in tandem with the FERC requirement of using a hydraulic model, and the FERC-recommended use of HEC-RAS is consistent with the provisions of section 335.6. A steady-state hydraulic model, though cited in the FERC guidelines, may be used per the proposed regulation only upon DSOD pre-approval.

The proposed regulation is consistent with the FERC submittal requirements in the following ways. Section 335.14 requires the submittal of geospatial files and section 335.12 specifies the required projection of those geospatial files. Due to the differences in scale between the state of California and the United States, the projection required in the proposed regulation differs from that of the FERC-required projection. In this case, jointly regulated dam owners subject to Water Code 6161(a) may submit the geospatial files to FERC and DSOD in the projection required by each, as converting between projections requires minimal effort and in this case, though not in conflict, projection requirements necessarily differ.

The proposed regulation, written in response to SB 92, differs in some ways with FERC requirements, but as demonstrated in this section, is not in conflict with FERC requirements or other federal laws. The department determines that the differing state regulations are authorized by law, and the cost of the differing state regulations is justified by the benefit to public safety, public welfare, and the environment.