DELTA STEWARDSHIP COUNCIL

Delta Levees Investment Strategy

Technical Memorandum 2.3:
Tolerable Risk

Peer Review (Draft Revision 0)

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Attachment A

Table 3-1: Existing Regulations, Standards, and Guidance Concerning Flood-prone Lands

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ACRONYMS AND ABBREVIATIONS

AEP	annual exceedance probability
ASCE	American Society of Civil Engineers
ASFPM	Association of State Floodplain Managers
Cal EMA	California Emergency Management Agency
Council	Delta Stewardship Council
CVFPP	Central Valley Flood Protection Plan
Delta	Sacramento-San Joaquin Delta
DLIS	Delta Levees Investment Strategy
DWR	California Department of Water Resources
EAALL	expected annual agricultural land loss
EACH	expected annual change in habitat
EAD	expected annual damage
EAF	expected annual fatalities
EAW	expected annual water supply disruption risk score
FEMA	Federal Emergency Management Agency
HMP	Hazard Mitigation Plan
HSE	Health and Safety Executive
MOU	Memorandum of Understanding
NCLS	National Committee on Levee Safety
NRC	National Research Council of the National Academies
PL 84-99	Public Law 84-99
State	State of California
TRG	tolerable risk guidelines
USACE	U.S. Army Corps of Engineers
USBR	U.S. Department of the Interior Bureau of Reclamation

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1. INTRODUCTION

The Delta Stewardship Council's (Council) *Delta Plan* calls for a risk-informed analysis to guide investments in the Sacramento-San Joaquin Delta (Delta) levee system (Council 2013, p. 272, Risk Reduction Recommendation 4); as such, the Delta Levees Investment Strategy (DLIS) methodology will enable a risk-informed evaluation of trade-offs (costs and benefits) amongst various potential investments.A critical step in prioritizing investments to reduce flood risk is first identifying the level of risk that is tolerable to the State of California (State) and to others who benefit from Delta levees.

Flood risk can never be fully eliminated. *Tolerable risk* is defined as the risk that society is willing to live with in order to secure certain benefits (HSE 2001). In contrast to "flood control" or "flood protection," which emphasize reducing the probability of floods, discussions of tolerable risk enable clear communication of risk by presenting both the probabilities and the consequences of flooding. Tolerable risk guidelines (TRG) can be a way to inform decisions through development of a comprehensive understanding of the probabilities and consequences of Delta levee failure. Where funding is limited, TRG provide a way to allocate scarce resources, manage flood risk in the Delta with alternative options, and determine what actions should be taken first.

This technical memorandum provides guidance on the tolerability of flood risks to the Delta and to State interests in order to inform State policy decisions regarding evaluation of investment options that reduce flood risk. Along with Technical Memorandum 3.1, *Methodology*, this technical memorandum also enables transparency in the decision-making process on investments to reduce flood risk.

This technical memorandum first explains the concept of TRG as it applies to flood safety and then discusses existing guidance and regulations. Maps of baseline risks to State interest will highlight areas of relative concern, and may help identify both individual and societal risks. This technical memorandum explains how F-N curves, in conjunction with the methodology described in Technical Memorandum 3.1, will help characterize flood risk and can be used to identify areas where urgent actions are needed. This technical memorandum also provides insight on how the methodology described in Technical Memorandum 3.1 can apply tolerable risk guidelines and criteria to identify and prioritize a suite, or portfolio, of investments available to reduce risk of flooding from levee failure to tolerable levels.

2. BACKGROUND ON LEVELS OF FLOOD PROTECTION AND TOLERABLE RISK

2.1 Appropriate Levels of Flood Protection

The National Research Council of the National Academies (NRC) report titled *Levees and the National Flood Insurance Program: Improving Practices and Policies* (2013) defines level-of-protection as the flood recurrence interval that a specific structure is designed to withstand. Current practice regarding levels of flood protection in the Delta is based on standards or guidelines generally promulgated by federal or State agencies. Figure 2-1 below illustrates levee guidance as described in the *Delta Plan* (Council 2013, p. 258).

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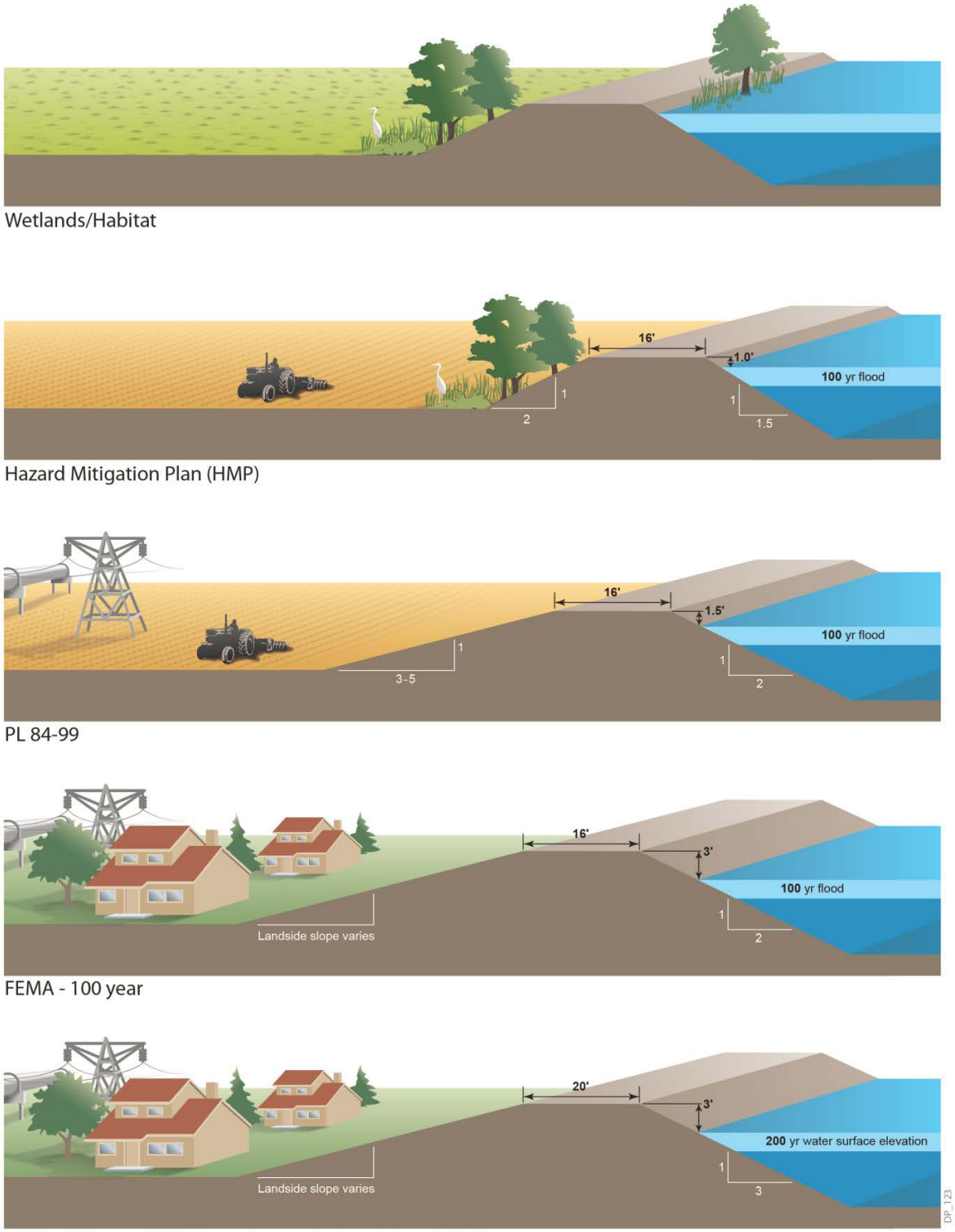
Figure 2-1. Levee Guidance in the Delta Plan (Council 2013)



Hazard Mitigation Plan (HMP) guidance resulted from negotiations between the Federal Emergency Management Agency (FEMA), the California Department of Water Resources (DWR), the California Office of Emergency Services (now the California Emergency Management Agency [Cal EMA]), and the Delta levee-maintaining agencies. HMP guidance was intended to serve as interim guidance aimed at reducing the likelihood of flood damage in the Delta so that FEMA disaster assistance would not be repeatedly requested for the same islands after minor floods. The Memorandum of Understanding (MOU) documenting the interim guidance has expired and has not been renewed (DWR 2013, p. B-3).

Public Law 84-99 (PL 84-99) guidance is a minimum requirement established by the U.S. Army Corps of Engineers (USACE) for levees that participate in its Rehabilitation and Inspection Program (33 United States Code 701n) (69 Stat. 186). Delta islands or tracts that meet this standard may be eligible for USACE funding for levee rehabilitation, island restoration after flooding, and emergency assistance. The PL 84-99 standard for levee geometry defines a minimum levee height and a factor of safety for slope stability, but is not associated with a flood recurrence interval or level of protection (such as a one percent annual exceedance probability [AEP] flood). In 1987, the USACE developed a Delta-specific standard based on the Delta's soil and levee foundation conditions (Council 2013).

The FEMA "100-year" standard is intended to reduce the frequency of flooding of low-lying lands by providing a "one percent" AEP level of protection. This standard, often referred to as the insurance standard, provides criteria that levees must meet to protect against the flooding that is the basis for FEMA's flood insurance rate maps (44 Code of Federal Regulations 65.10). Levees must meet prescribed requirements for levee freeboard, slope stability, seepage, erosion, and settlement. In communities where levees meet these requirements, new developments on the protected side of the levee are not required to meet federal flood-proofing standards and can obtain federally guaranteed mortgages without purchasing flood insurance.

The DWR Urban Levee Design Criteria establishes criteria for levee height and geometric design, and includes requirements for freeboard, slope stability, seepage, erosion, settlement, and seismic stability (DWR 2012a). The criteria are intended to provide protection against a flood that has a 0.5 percent chance of being equaled or exceeded in any given year (a "200-year" level of flood protection). Flood-prone urban or urbanizing areas with 10,000 or more residents must meet this standard by 2025 (Government Code 65865.5(a) (3)).

Depending on the circumstances, each of these standards or guidelines has been considered for use in the Delta as levels of protection to be attained or sustained. The HMP and PL 84-99 criteria, however, are disaster rehabilitation guidelines based primarily on levee geometry with little or no consideration of performance of either the levee or its foundation. The FEMA 100-year criterion is an insurance standard that includes levee performance requirements. The DWR Urban Levee Design Criteria is a levee design standard that must be used for urban areas by 2025.

These standards or guidelines do not represent flood safety standards. Use of any of them as an "appropriate level of protection" creates the misimpression that the risk of flooding can be eliminated. The standards or guidelines are not performance based, nor do they account for the probability of floods larger than those prescribed by their water surface metric. None address residual risk or the consequences of flooding on life loss, property damage, water supply disruption, the ecosystem, or on the Delta as a place.

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2.2 Tolerable Risk

Eliminating flood risk is impossible (NRC 2013); *residual risk* is defined as the risk that remains after considering the mitigating effects of structural, non-structural, and other risk reduction measures (NRC 2013). The NRC report states that "residual risk is always present behind a levee, because no levee is fail-safe."

Because risk cannot be eliminated, it is useful to consider risk on a continuum ranging from those risks that are unacceptable, where the risk cannot be justified except under extraordinary circumstances, to risks that are broadly acceptable, where risk is regarded as negligible (USACE 2011). In between there is a range of risks that are tolerable – risks that are not negligible yet are risks that people are willing to accept in order to secure certain benefits (HSE 2001; USACE 2010).

The concept of tolerable risk enables consideration of residual risk and the consequences of flooding on loss of life, property damage, water supply disruption, the ecosystem, and on the Delta as a place. Tolerable risk is based on judgment regarding the probability of an adverse event occurring, and, if an event does occur, the consequences that event may cause. Decisions informed by tolerable risk avoid the need to define what *appropriate* means in the term "appropriate level of protection" – i.e., appropriate to whom? Instead, tolerable risk enables analysis and deliberation of the question: "*How safe is safe enough*?" Tolerable risk represents a global shift from flood control management to flood risk management (Sayers et al. 2013).

Tolerable risk is based on comprehensive evaluation of both the probabilities of adverse events and their consequences. This evaluation:

- Demonstrates that risks are neither negligible nor something to be ignored.
- Supports risk-informed policy setting and decision-making.
- Informs decisions about ways to reduce risk and the costs of implementation.
- Enables quantitative evaluation of trade-offs (e.g., structural solutions such as levee building and non-structural solutions such as improved evacuation procedures).
- Can prove useful in allocating scarce resources.
- Can be regularly reviewed to respond to changing conditions.

Application of the concept of tolerable risk to decision-making on flood risk reduction offers many advantages. As adopted from the USACE (2011), through the DLIS methodology, tolerable risk:

- Enables the decision-making process to focus on the most serious risks and to prioritize actions accordingly.
- Enables taking actions commensurate with risks, which improves efficiency.
- Enables rational consideration of non-monetizable benefits.
- Promotes consistency in that similar approaches can be taken in similar circumstances to achieve similar ends.
- Promotes equity in that everyone's interests and safety can be treated with fairness.
- Promotes efficiency by using available resources to achieve the greatest benefit.

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- Provides transparency in the decision-making process.
- Enables clear communication of the risks and risk-based decisions to those most affected.
- Provides clarity on who is responsible for identifying, managing, and communicating risk.

Because absolute protection is not attainable, evaluation of tolerable risk provides a rational basis for making decisions on reducing risks to *as low as reasonably practicable*, or ALARP (HSE 2001). The process also enables consideration of individual risks, such as those faced by Delta residents concerned with life safety and property damage, as well as societal risks, such as the State's interests in water supply reliability and ecosystem enhancement.

Application of tolerable risk is consistent with application of the best available science in risk management. It is widely used for flood risk management; for example, the Dutch flood investment priorities and levels of protection are risk-informed (Eigenraam et al. 2014). Recent national policy in the Netherlands establishes a maximum flood-safety life-risk guideline that limits the risk to which both individuals and society as a whole can be exposed (Delta Programme 2015, pp.16-17). Following Hurricane Katrina, the National Committee on Levee Safety (NCLS) recommended that life safety be paramount when considering actions to reduce risk, and that tolerable risk guidelines be used to inform decisions on levee safety (NLCS 2009).

The USACE and the U.S. Bureau of Reclamation (USBR) apply tolerable risk principles to management of dam safety and to aid in determining how to spend maintenance and improvement funds (USACE 2011). Draft guidance by the USACE for applying tolerable risk to levees is currently circulating for review. In addition, the Water Resources Reform and Development Act of 2014 requires that levees managed in the federal system use the levee safety action classification to stipulate actions to reduce risk. This action classification system is used by the USACE for its dams and levees, and is guided by principles of tolerable risk. Specifically, levee systems that pose unacceptable risks to life safety are classified as needing urgent action to reduce risks to tolerable levels.

The DLIS methodology described in Technical Memorandum 3.1 is a risk-based analysis used to compare trade-offs amongst investments and enables characterizing risk behind levees in a manner generally compatible with that proposed by the USACE. Areas with greater risk tend to be areas with greater consequences, and TRG will encourage taking actions evaluated by the DLIS methodology that will reduce risks to tolerable levels. The USACE's use of TRG in its levee safety program is focused on life safety. The DLIS methodology similarly enables a focus on life safety while also considering additional metrics to further characterize risk to other State interests, including water supply, ecosystem, and agriculture.

3. TOLERABLE RISK METHODOLOGY

3.1 Existing Regional, State, and Federal Guidance

While levees and land use in the Delta are bound by the guidelines and regulations stipulated in State and federal statutes, there are wide-ranging standards and approaches on flood safety both nationally and abroad. A key step in framing a discussion of tolerable risk in the Delta is a review of existing standards, guidelines, and regulations associated with levee safety and land use in flood-prone areas (see Table 3-1 in Attachment A).

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The information in Table 3-1 provides insight to representative standards and guidance used in other parts of the United States and the world, including the Netherlands and Canada, and by relevant professional associations such as the American Society of Civil Engineers (ASCE) and the Association of State Floodplain Managers (ASFPM). Information in Table 3-1 will support discussions on existing standards and various approaches to flood management. For example, findings and results from the DLIS methodology will identify the current levels of risk in the Delta; Table 3-1 enables comparison of current levels of risk tolerance or standards in the Delta to those implemented elsewhere in relevant locations. This will in turn offer insight and inform policies to reduce risk in the Delta.

3.2 Baseline Risk to State Interests

3.2.1 Delta Risk Maps

As discussed in Technical Memorandum 2.2, *Levee Hazards, Risks, and Consequences,* and Technical Memorandum 3.1, *Methodology*, the DLIS methodology will assess risks to State interests, life safety, and property, expressed as expected annual fatalities (EAF) and expected annual damages (EAD); water supply reliability, expressed as expected annual water supply disruption risk score (EAW); Delta agriculture, expressed as expected annual agricultural land loss (EAALL); and the Delta ecosystem, expressed as expected annual change in habitat (EACH).

Development of baseline risk maps like those shown for the Netherlands (Figures 3-1 and 3-2 below) can be informative for identifying where risks in the Delta are relatively high. The DLIS methodology will enable comparison of actions to reduce risk of life loss and property damage, and risks to water supply reliability, ecosystem habitat, and agricultural lands. For example, if life safety is given the highest priority, then reducing risks to the islands showing the highest EAF would be the logical choice on which to focus investments. On the other hand, if life safety and reduced property damage are both high priorities, the DLIS methodology will show where to make investments that maximize life safety *and* property protection benefits.

Maps can also help distinguish between individual risks and societal risks. Specifically, areas where there is higher relative risk (for example, areas where mass casualties or widespread damages could be high) can be a proxy for societal risk. In contrast, areas with lower life safety or flood damage risk are likely more important for individual risk than societal risk.

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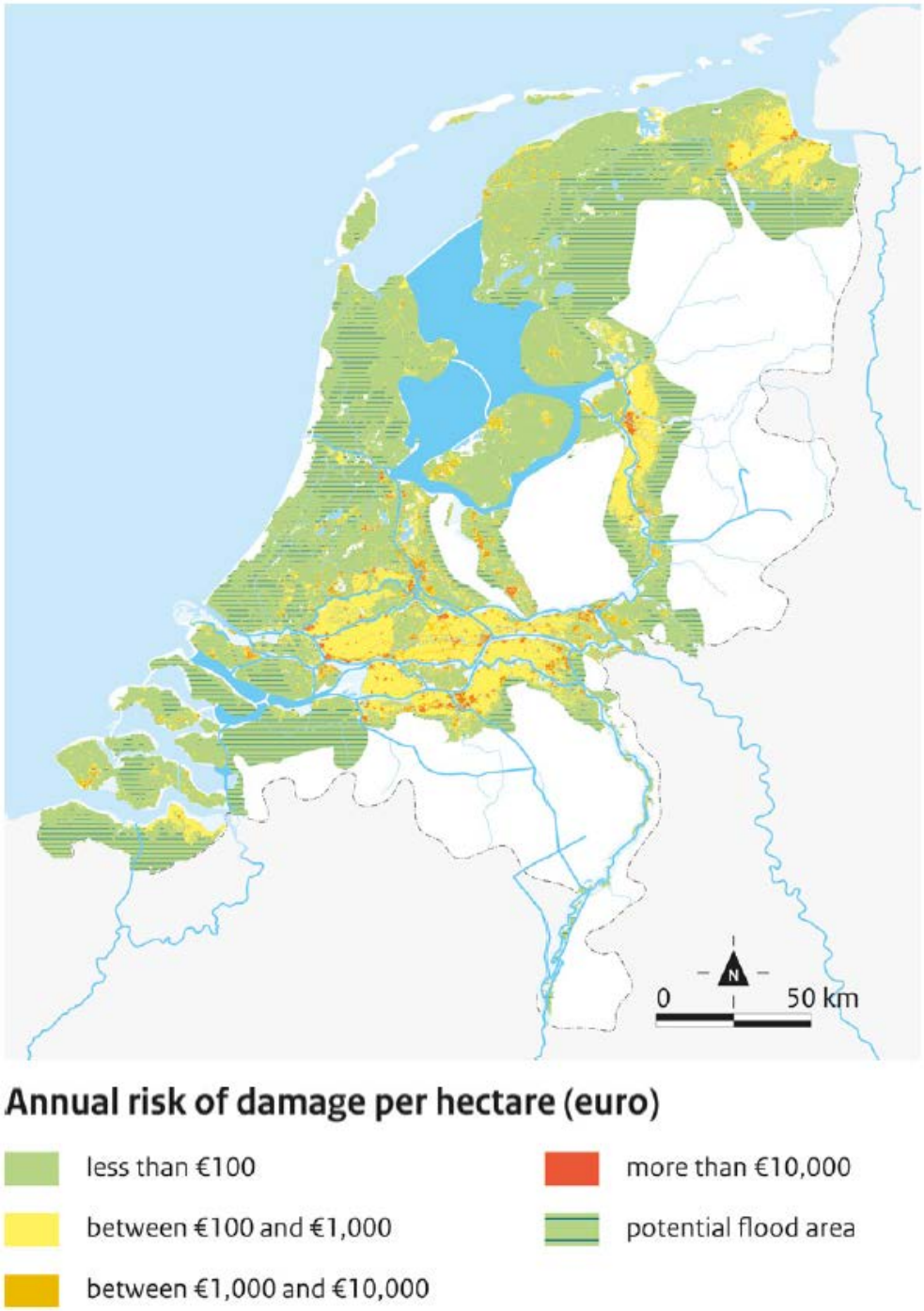
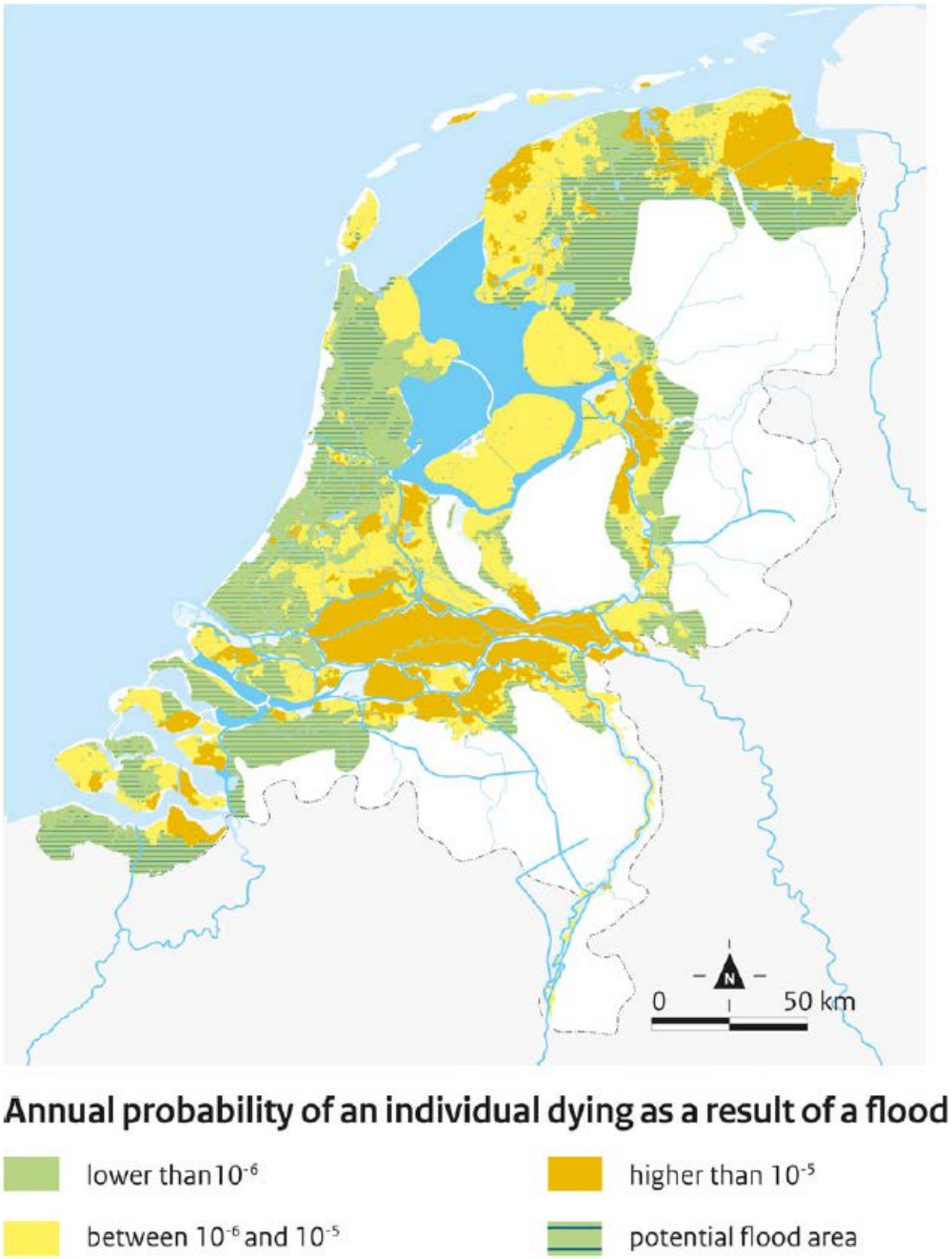
Figure 3-1. Flood Risk Map (EAD) in the Netherlands



Source: Delta Programme 2015, p. 18.

Figure 3-2. Flood Risk Map (EAF) by 2020 in the Netherlands



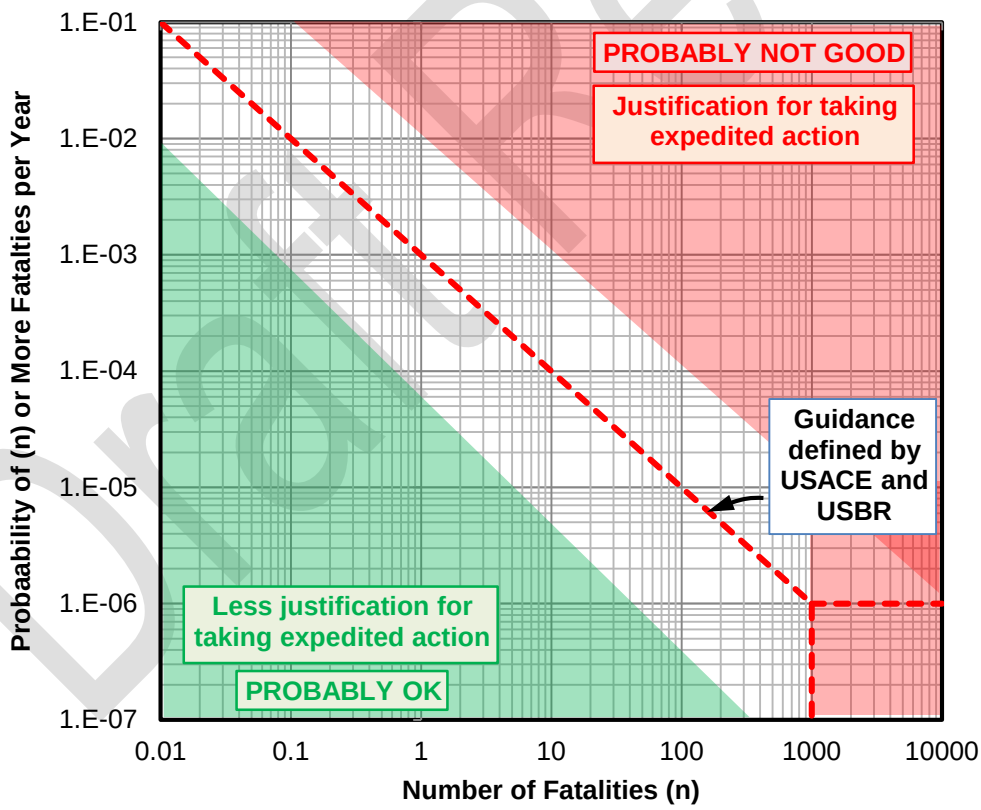
Source: Delta Programme 2015, p. 18.

3.2.2 F-N Curves

F-N graphs (Figure 3-3 below) are a graphical representation of societal risk that relates the probability of N or more events per year to N, the number of events. A common use of F-N graphs (and one that is used in the analysis of Delta levee risks) is to relate the probability of N or more fatalities per year due to levee failure to the number of fatalities. The points on an F-N curve are calculated for the range of conditions that create the events. For example, a Delta island may have possible flood depths ranging from 1 to 15 feet. If calculations are performed at 1-foot increments, points on the island's F-N curve could be shown for each of the 15 1-foot increments.

F-N curves are typically drawn with logarithmic scales for the X-axis (horizontal) and Y-axis (vertical). The consequences are shown on the X-axis, with less severe consequences on the left and more severe consequences on the right. The frequency of an event is shown on the Y-axis, with more frequent events toward the top and less frequent events toward the bottom. For example, 10^{-2} represents an event with a 1.0 percent chance of occurring in any one year (1/100) whereas 10^{-6} represents a one in one million chance, or a 0.0001 percent chance of occurring in any one year (1/1,000,000).

Figure 3-3. F-N Graph



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F-N curves are useful for determining tolerable levels of risk. For example, on Figure 3-3, if a curve plots toward the upper right (in the red region), the risk is less acceptable; i.e., a high frequency event that causes many fatalities is considered unacceptable. On the other hand, a curve that plots toward the lower left (in the green region) is probably in the broadly acceptable range. The middle area of the graph along an imaginary line sloping from the upper left to lower right is considered to be indicative of the limit of tolerable risk, which is generally set by analysis and policy.

The diagonal line on Figure 3-3 represents guidance for dam safety that is used by the USBR and the USACE (USACE 2011). This diagonal line represents the best judgment of those organizations to identify the upper limit of tolerable risk. Guidance by the USBR and the USACE indicates there is reason to take expedited action to reduce risk for curves plotting above this line. On the other hand, if a curve plots below the line, there is less justification to take expedited action.

Because most levees in the Delta have water against them year-round, they function more like dams than other levees that have water against them only during high water events. For this reason, it is prudent to use the USBR/USACE guidance to describe tolerable risk limits for the Delta.

The F-N plot shown on Figure 3-4 includes several examples of risk drivers as shaded areas representing the range in the number of fatalities to be expected (horizontal) and the range in the frequencies of events that cause them (vertical). Several common examples were selected for illustration, including expectations for commercial aviation, for dams in general, and for New Orleans during Hurricane Katrina.

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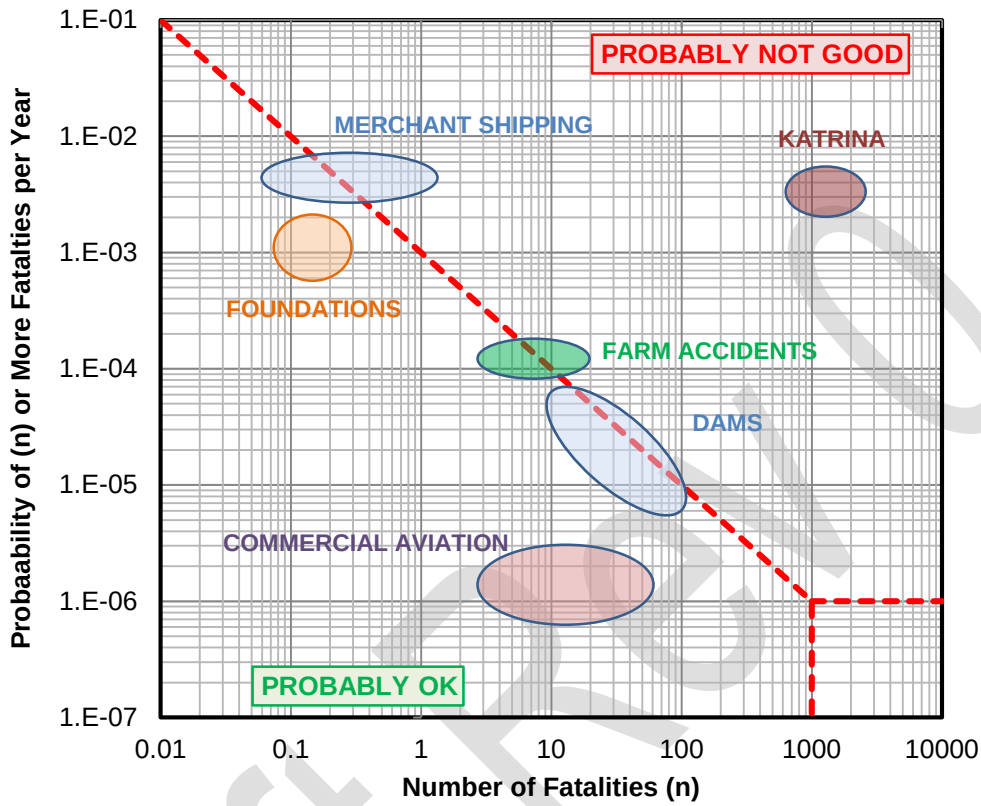
Figure 3-4. F-N Graph Showing Example Risks



The probability of N or more fatalities per year from a levee failure on a Delta island is determined using the following steps (refer also to Technical Memorandum 3.1, *Methodology*):

1. For each possible river stage S_j (ft), calculate the annual probability $P_{s,j}$ of that stage occurring. Each river stage will produce a flood depth D_j (ft). River stage probabilities are generally presented as a stage-recurrence curve.

2. For each river stage S_j, calculate the conditional probability of levee failure $P_{c,j}$ at that stage. Conditional probabilities of levee failure are generally presented as levee fragility curves. For the Delta islands and tracts, the conditional probability of levee failure is a composite probability that includes geotechnical, seismic, and wind/wave effects on levee fragility.

3. For each river stage S_j, calculate the joint probability of levee failure as

$$P_{f,j} = P_{s,j} \times P_{c,j}$$

4. For each river stage S_j, calculate the depth of flooding as

$$D_j = S_j - E_i,$$

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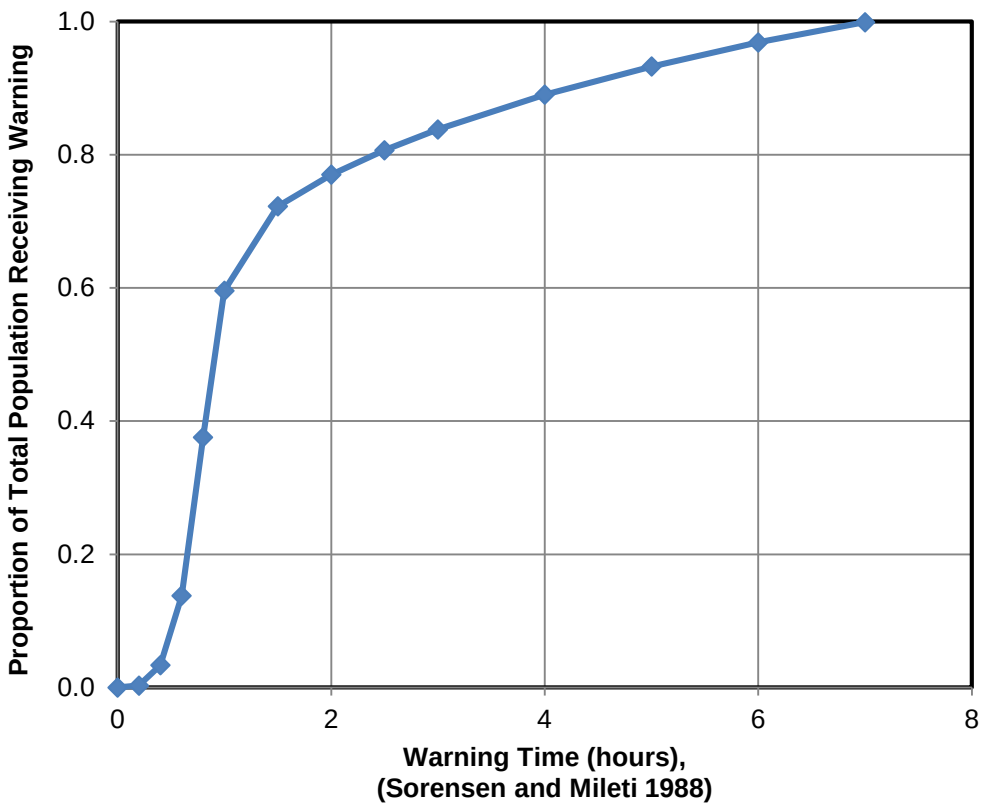
where E_i is the average elevation in feet of the levee-protected land on the island or tract being analyzed.

5. Calculate the proportion of the total population, T_p, who would be warned of the impending flood, F_{rw}, by piecewise linear interpolation from the curve presented on Figure 3-5 (Sorensen and Mileti 1988). For slow rising floods in the Delta, warning times are assumed to be more than 8 hours. For levee failures due to seismic events, the warning time is assumed to be zero.

6. Estimate the proportion of the total population, T_p, who would be willing to respond to a flood warning, F_w. For example, a value of F_w equal to 1.0 was used in an analysis reported in the Central Valley Flood Protection Plan (CVFPP; DWR 2012b) and summarized by Cowdin et al. 2015).

7. Estimate the proportion of the total population, T_p, who would be able to respond to a flood warning, F_c. For example, a value of F_c equal to 0.7 was used in an analysis reported in the CVFPP (DWR 2012b) and summarized by Cowdin et al. (2015).

Figure 3-5. Evacuation and Warning Time



8. Calculate the proportion of the total population, T_p, who would be exposed to flood water as

$$E_p = T_p \times (1 - F_{rw} \times F_w \times F_c).$$

9. For each depth of flooding D_j, calculate the mortality rate

$$R_m = \Phi((\ln(D_j/3.2808)-5.2)/2)$$

where Φ is the standard normal distribution function and *ln* is the natural logarithm. The mortality function is used to estimate the ratio of fatalities per exposed population, E_p, for each possible depth of flooding. The derivation of the mortality function is described in Jonkman and Vrijling (2008). The USACE is also using this mortality rate computation in its risk characterization approach to Levee Safety Action Classification.

10. For each depth of flooding D_j, calculate the probability of fatalities, $P_{m,j}$, as

$$P_{m,j} = P_{f,j} \times R_m$$

11. For each depth of flooding D_j, calculate the expected number of fatalities, N_j, as

$$N_j = P_{m,j} \times E_p$$

12. Sort the array of expected number of fatalities and joint probabilities of levee failure, (N_j, $P_{m,j}$), in order of increasing number of fatalities.

13. Calculate the cumulative probability of exceedance for each ordered number of fatalities as

$$P_{e,j} = \Sigma P_{m,i} \text{ for } i = 1 \text{ to } k, \text{ for } k = 1 \text{ to number of river stages}$$

14. Plot $P_{e,j}$ versus N_j

The value of F-N curves is in the comparisons that can be made from the graphs as shown on Figure 3-6 below.

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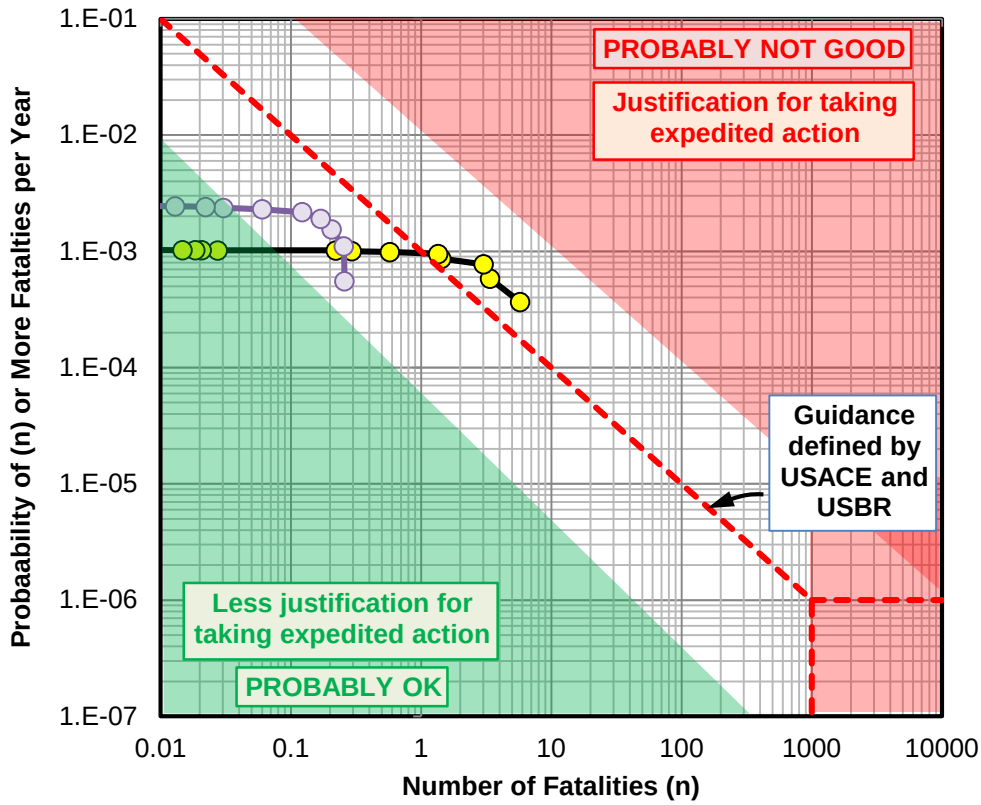
Figure 3-6. Example of an F-N Curve



Recalling that each point on an F-N curve is for a specific flood inundation depth, it may be concluded that the one or more points nearest to the guidance line defined by the USACE and USBR represent the inundation depths of greatest risk at Island A on Figure 3-6 (light yellow line). It may be observed that, for every possible inundation depth, Island A is in a tolerable risk region, while several inundation depths at Island B (heavy dark line) are in a risk region with justification for taking expedited action, which would imply that Island B is at greater risk that Island A.

F-N curves also visually demonstrate the impact of actions taken to reduce risk. Action such as increasing levee height to withstand greater flooding – i.e., reducing flood frequency – will move the curves down. For example, increasing levee height on Island B will move the curve down, perhaps to below the guidance line defined by the USACE and USBR. In California, there is a legislated requirement to increase levee heights in urban and urbanizing areas from a 100-year (1×10^{-2} AEP) level of protection to a 200-year (0.5×10^{-2} AEP) level of protection (Water Code 9601 (f) and 9602 (g)) – in effect, moving the curve down. Conversely, a poorly maintained levee that is degrading will cause the curve to move up, indicating that a more frequent event will likely cause the same number of fatalities.

For fatalities, reducing the number of people exposed to an event moves the curve to the left, and hence reduces expected fatalities. This might occur through improved evacuation protocols, by building code

updates in levee-protected areas (Health and Safety Code 50465), or by improved risk communication in flood-prone areas encouraging people to be better prepared in the event of flooding (Water Code 9121).

F-N plots are generally used to indicate the number of fatalities (EAF) that may occur as a result of a particular event, such as a levee breach. However, with appropriate metrics, the consequences may also be expressed as property damages in dollars (EAD). For the Delta, F-N plots will be developed for flood events and their consequences based on EAF and EAD, as well as risks for water supply disruption, ecosystem damage, and loss of agricultural land. See Technical Memorandum 3.1 for a detailed discussion on these metrics.

4. FINDINGS

4.1 Baseline Delta Risk Maps

Future versions of this memo will present risk maps drawn from the methodology described in Technical Memorandum 3.1.

4.2 Delta F-N Curves

F-N Curves will be produced for all 176 DLIS islands and tracts. Because of the difficulty in visualizing and comparing 176 curves on the same graph, one point will be chosen to represent each island and tract such that a Delta-wide F-N plot will be drawn using 176 representative points. For each island, the point of maximum curvature on the F-N curve will be used as the representative point, because it is the closest point on the curve to the societal risk limit, or the point on the curve farthest into the “unacceptable” region. The point of maximum curvature represents the least tolerable combination of high probability of occurrence and high loss of life.

There will be five Delta F-N plots, one for each of five State interests, including: life loss, property damage, water supply disruption risk score, ecosystem habitat change, and agricultural land loss. Except for life safety (defined by USACE and USBR for dams), there are no previously defined tolerable risk limit lines; therefore, the F-N plots for these other risks will likely not include a tolerable limit line. F-N plots, however, are still helpful in describing relative risk of islands and in characterizing overall risks to other State interests such as water supply, ecosystem function, and Delta agriculture.

This section will present F-N plots for the State interests based on the methodology described above.

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Attachment A

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Table 3-1. Existing Regulations, Standards, and Guidance Concerning Floodprone Lands

		LAND USE OR ASSET TYPE						OTHER ACTIONS				
		Urban	Rural / Agricultural	Small Communities	Critical Infrastructure	Deep Floodplains	Ecosystem	Flood Proofing or Mitigation	Bypasses	Emergency Preparedness	Life Safety Guideline	Remarks
FEDERAL REGULATION	44 CFR60.3/9.11	1/100 year WSE or insurance			1/500 year WSE + 1 foot	Not specifically addressed, 1/100 year WSE or insurance would apply.	Minimize destruction, loss, or degradation of wetlands; restore and preserve natural and beneficial floodplain and wetland values.	1/100 year WSE + 1 foot, insurance	Not applicable			
FEDERAL REGULATION	44 CFR65.10	1/100 year WSE + 1-foot freeboard *(needs to be checked)*					Not applicable	Not applicable	Not specifically addressed, although levees adjacent to bypasses would need to meet 1/100 year WSE + 1-foot freeboard plus all other criteria.	Not applicable		If a levee is to be accredited to remove the insurance requirement, it must meet 1/100 year WSE, + 1-foot freeboard, plus seepage criteria, etc. However, FEMA does not specify that a levee has to be used for any type of land use.
FEDERAL REGULATION	EO 11988/EO 13690	1/100 year + 2 feet, 1/500 year, and action cannot increase risk in floodplain.			1/500 year WSE	Not specifically addressed, 1/100 year + 2 feet, 1/500 year, and action cannot increase risk in floodplain requirement would apply.	Preserve the natural and beneficial values served by floodplains.	1/100 year + 2 feet, and action cannot increase risk in floodplain.	Not specifically addressed, 1/100 year + 2 feet, 1/500 year, and action cannot increase risk in floodplain requirement would apply.	Not applicable		
STATE REGULATION	Senate Bill 5	1/200 year WSE, seismic, seepage criteria, etc.	WC 9601 C. The level of flood protection afforded rural and agricultural lands by the original flood control system would not be adequate to protect those lands if they are developed for urban uses.	Not specifically addressed		Not specifically addressed *(needs to be confirmed)*	WC 9616. "Increase and improve the quantity, diversity, and connectivity of riparian, wetland, flood plain, and shaded riverine aquatic habitats, including the agricultural and ecological values of these lands. (11) Promote the recovery and stability of native species populations and overall biotic community diversity." (specific to the plan's requirements)	Notification in levee-protected areas of State Plan of Flood Control, Voluntary building code updates (Health and Safety Code 50465).	WC 9613 (c) Investigate/evaluate feasibility of bypass expansion to reduce flood stage upstream and south of Paradise Cut.	WC 8201 (b)(6) Emergency response plan required (within local plans of flood control).	Not applicable	
FEDERAL GUIDANCE	USACE Levee Policy	No minimum standard level of safety recommended based on life and economic risk, cost-benefit analysis, and national economic development index. *(need to confirm)*			1/500 year WSE due to EO 11988.	No minimum standard level of safety recommended based on life and economic risk, cost-benefit analysis, and national economic development index. *(need to confirm)*	Not addressed	No minimum standard, life safety paramount, based on cost-benefit analysis and national economic development index.	Not applicable		Under development	USACE has different authorities for emergency response and ecosystem restoration. This row is specific to levee safety and standards.
FEDERAL GUIDANCE	USACE (Public Law 84-99) (33 United States Code 701n) (69 Statute 186)	1/50 year WSE + 1.5-foot freeboard					Not applicable	Not applicable	Not specifically addressed, but geometric and freeboard considerations would likely be required.	Not applicable		
FEDERAL GUIDANCE	United States Bureau of Reclamation/USACE Dams (USACE 2011)	1/1,000 year probability of failure applies to all dams where life safety is concerned. Does not specifically address each of these land uses.					Not applicable			Requires Emergency Action Plans.	Hazard-based - 1/1,000 year likelihood of failure	
FEDERAL GUIDANCE	FEMA: Hazard Mitigation Plan Levees (Delta Stewardship Council 2013)	Geometric configuration (no recurrence interval or WSE) + 1-foot freeboard, although does not specifically address all these land uses.					Not addressed, only applies to levees.					For disaster rehabilitation. Memorandum of Understanding (MOU) is currently expired. Delta Protection Commission is quoted as saying "No engineer familiar with the Delta considers the HMP geometry to be adequate for even basic flood protection."
FEDERAL-STATE GUIDANCE	CALFED Bay Delta Program: Levee Stability Program (USACE 2006)	Public Law 84-99			Not addressed but implied		Promote and support ecosystem restoration and protection of the Delta's environmental assets, water quality, and critical habitat of special status species.	Not addressed		Improve joint Delta emergency response and coordination, update and clarify roles and responsibilities, and enhance communications and public education.	Not addressed	Levees of particular importance are those that protect water quality, lives, and critical infrastructure.

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		Urban	Rural / Agricultural	Small Communities	Critical Infrastructure	Deep Floodplains	Ecosystem	Flood Proofing or Mitigation	Bypasses	Emergency Preparedness	Life Safety Guideline	Remarks
FEDERAL-STATE GUIDANCE	California Department of Water Resources Bulletin 198-82 (DWR 1982)	1/300 year WSE + 3-foot freeboard *(to be confirmed)*	1/300 year WSE + 1.5-foot freeboard *(to be confirmed)*	1/100 year WSE for any urban development. Also states under the "System plan" that all levees would have less than 1/100 year failure probability. *(to be confirmed)*	Not addressed	Not suitable for urbanization	Not addressed (except in vegetation on levees issue)	Not addressed				
STATE GUIDANCE	Central Valley Flood Protection Plan (CVFPP) (DWR 2012)	1/200 year WSE, seismic	Site-specific improvements, based on levee inspections and other critical levee integrity needs. Level based on Non Urban Levee Evaluation (NULE). All-weather access roads to facilitate flood fighting/inspection.	Target 1/100 year WSE. Additional investment prioritized based on relative flood threat, population, likelihood of flooding, proximity to flooding, depth of flooding, financial feasibility, and multiple benefits.	State Systemwide Investment Approach says to prioritize critical infrastructure of statewide importance, but offers no specific standard. *(need to confirm)*	Greater than 200 year WSE for urban areas in deep floodplains (flood depth greater than 3 feet in 200 year flood).	Supported by the conservation strategy document. Preference for multi-benefit projects.	Recommended. (*To be filled in)*	Selected levee setback locations.	Recommended	Not addressed	Preference allocated toward multi-benefit projects. CVFPP allocates a $100,000 threshold per household in small community. Where cost of levee/improvements exceeds threshold, non-structural means will be considered.
STATE GUIDANCE	Delta Plan (Delta Stewardship Council 2013)	1/200 year WSE, seismic	Protect agriculture and local working landscapes, and cultural, historic, aesthetic, and recreational resources (Delta as a Place).	"Protect small communities and critical infrastructure of statewide importance that are located outside of urban areas."	"Protect small communities and critical infrastructure of statewide importance that are located outside of urban areas."	Not addressed.	Protect existing and provide for net increase in channel margin, floodplain, and wetland habitat.	(Risk Reduction Policy 2): 1/100 year WSE + 1 foot, + SLR (55 inches at Golden Gate) except for specific communities.	(Risk Reduction Policy 3 and Risk Reduction Recommendation 5): Protect floodways and fund and implement San Joaquin River flood bypass.	(Risk Reduction Recommendation 1): Implement emergency preparedness and response; emergency stockpiles; and plans to reduce long-term outage of utilities and infrastructure.	Not addressed	
STATE GUIDANCE	Economic Sustainability Plan (Delta Protection Commission 2012)	1/200 year WSE, seismic	PL 84-99 recommended for non-project levees. Also: recommends "higher standard *(300 yr?*) for lowland levees and those critical to salinity intrusion."	"New Delta standard" - *(greater than 300, but also PL 84-99)*	Implied water supply corridor for "higher standard" (p 74).	Not specifically addressed. *Assume that as minimum, PL 84-99 would apply.*	Restore Franks Tract and Western Sherman, restore mid-channel berms, encourage growth on waterside of levee, restore complexity of waterways, and modify channel geometry,	Not addressed	Construct new and improve existing bypasses, restore historical floodplains upstream of the Delta.	Flood contingency maps, stockpile systems, etc.	Not addressed	
PROFESSIONAL ORGANIZATION	Association of State Floodplain Managers (ASFPM 2011)	No minimum standard; however, objective is reducing flood losses and no adverse impact (NAI).			1/500 year WSE		Restore and preserve natural coastal and riverine dynamics (natural and beneficial functions of floodplains).	Recommend mitigation and insurance behind levees.	Not addressed			All risk reduction should apply No Adverse Impact (i.e., no transfer of risk to others).
INTERNATIONAL	Netherlands (Delta Programme 2015)	Varies based on risk (high hazard, damage potential, life loss). Ranges from 1/300 year to 1 /100,000 year probability of failure, with additional "safety layers" required (i.e., non-structural) in deep floodplains (where evacuation is not possible). Technical Memorandum Revision will provide more detail/separation.					Not applicable	Multi-layered safety recommended in areas with reduced levee standards, high consequence rate, deep floodplains, etc.	Room for the river, expanding floodplains in 39 locations to increase conveyance capacity of riverine system by up to 18,000 cubic meters per second for climate change.	In deep floodplain polders (higher population), requires emergency response plan.	1/100,000 likelihood of dying (individual); even lesser likelihood than 1/100,000 likelihood of dying if societal risk (large groups of victims, serious damage).	Use flood probability standards, not flood overtopping standards.
INTERNATIONAL	Red River Basin Commission (Canada and United States) (RRBC 2011)	1/200 to 1/250 year	For Cropland: 1/10 to 1/25 year summer flood; Residences and Farmsteads: 1/100 to 1/200 year	100 to 200 year (although not specifically addressed in this category)	1/500 to 1/700 year	Not specifically addressed (but 1/200 to 1/700 year likely applies)	Not addressed		No new development in areas of high risk of flooding unless elevated/flood-proofed.	Critical transportation preservation including road elevations above 1/100, 1/200, and 1/500 year events.		(Red River Basin Commission 2011)
US-OTHER REGULATION	Charlotte-Mecklenburg County, North Carolina (2015)	Required to consider Community Base Flood Elevation (which is 1/100 year WSE that accounts for watershed buildout and future hydrology conditions). Floodplain maps and mitigation requirements exist even with a levee in place.			1/500 year WSE or Community Base Flood Elevation	Community Base Flood Elevation	Control the alternation of natural floodplains, stream channels, and natural protective barriers	Mitigation and insurance required behind all (and accredited) levees.	Not addressed specifically in floodplain ordinance.			Community Base Flood Elevation is determined using future land use conditions having a 1% annual exceedance probability (AEP). (FEMA base flood is smaller, does not use future conditions.)
US-OTHER GUIDANCE	New York City, Office of Long Term Sustainability (2013)	Not specifically addressed	Not applicable		1/500 year WSE	Not applicable	Not addressed		Not applicable	Other means	Not addressed	

Notes:
CFR = Code of Federal Regulations
EO = Executive Order
FEMA = Federal Emergency Management Agency
HMP = Hazard Mitigation Plan
PL = Public Law
USACE = U.S. Army Corps of Engineers
WC = Water Code
WSE = water surface elevation

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