Technical Memo

Date:	February 23, 2022
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	HDR – Don Thompson, Keith Ferguson, Verena Winter
Subject:	Dam Safety Standards and Seismic Fault Study Review

1.0 Introduction

The Draft Environmental Impact Statements (EISs) prepared by the Washington State Department of Ecology (Ecology; pursuant to the State Environmental Policy Act) and the U.S. Army Corps of Engineers (USACE; pursuant to the National Environmental Policy Act) evaluate anticipated impacts associated with construction and operation of a proposed Flood Retention Only - Expandable (FRE) facility (i.e., the Chehalis River Basin Flood Damage Reduction Project [proposed project]) in the Chehalis Basin, Washington State. The Chehalis Basin Flood Control Zone District (District) is the project proponent. A seismic study that included a fault study was conducted in June 2021. This technical memo summarizes federal and state dam safety standards and provides a preliminary assessment of the seismic condition at or near the site and how it would affect the project.

The Chehalis Basin Flood Control Zone District (District) is in the process of planning and design of a flood control facility to reduce future risks to life and property within the Chehalis River basin. The design and construction of new flood retention structures in the United States is highly regulated by state and federal authorities, and requires engineers and contractors to comply with rigid design and construction standards and factors of safety to a level on par with, or exceeding, the nation's most important and critical infrastructure.

2.0 Dam Safety Standards

Federal guidelines for dam safety best management practices are presented in "Federal Guidelines for Dam Safety," FEMA P-93, published by the Federal Emergency Management Agency (FEMA). The guidelines were prepared by an ad hoc interagency committee based on a review of dam safety policies prepared by Federal agencies that have responsibility for planning, design, construction, operation, or regulation of federal dams. The most current version of FEMA P-93 is dated 2004 and is currently in the process of being updated to include the most recent advances in dam safety engineering. More specific technical guidelines and standards have been prepared, most notably by USACE, U.S. Bureau of Reclamation (Reclamation) and the Natural Resources Conservation Service (NRCS). USACE and Reclamation design standards for concrete dams differ slightly, but do not significantly deviate

from each other. NRCS standards mainly address embankment dams, which do not apply to the FRE project.

Federal dam safety standards for design of the FRE will be based on the most current edition of FEMA P-93 supported by technical design standards developed by the USACE. While Reclamation and USACE have independently developed design standards for roller-compacted concrete (RCC), Reclamation's RCC standards were published in 2017, and references the USACE's design standards published in 2000. Both standards are similar, but Because Reclamation's technical information is based on more contemporary experience with RCC, Reclamation's standards will also be considered in the design. When presented with the decision of which standard's value or approach to use, the decision will be made based on industry best management practices and the design team's judgement of the value or approach that best satisfies the design and functional objectives of the FRE facility while meeting regulatory requirements.

The State Dam Safety Office requires all new dams over a small nominal size to apply for reservoir and construction permits. Like most states, Washington State does not specify a set of design standards for concrete dams, including roller-compacted concrete, but instead defers to federal standards.

2.1 USACE Standards

This section describes the principal documents that will govern the design of the main project features. These features include the RCC FRE facility and integrated spillway; intake structure; fish passage sluices; sluice gates and bulkheads; stilling basin; collect, handle, transfer, and release (CHTR) facility; diversion tunnel; temporary fish passage facilities during construction; and temporary cofferdams. The technical standards are based on meeting prescribed factors of safety under normal and extreme hydrologic and seismic loading conditions.

2.1.1 USACE Engineering Regulation 1110-2-1156 – Safety of Dams – Policy and Procedures

This Engineer Regulation (ER) prescribes USACE's guiding principles, policy, organization, responsibilities, and procedures for implementation of risk-informed dam safety program activities and its risk management process. The risk-informed program measures the probability and severity of undesirable consequences or outcomes. The intent of the regulation is to ensure that officials within USACE comply with FEMA P-93 and all dams and appurtenant structures are designed, constructed, and operated safely and effectively under all conditions.

2.1.2 USACE Engineering Manual 1110-2-2006 – Roller-Compacted Concrete

This Engineer Manual (EM) provides information and guidance on the selection of materials, mixture proportioning, design and construction considerations, equipment, techniques, inspection and performance of RCC. This will apply to the FRE facility excluding the conventional concrete facings, which are covered under EM 1110-2-2000.

Analysis of sliding stability of the FRE facility is covered under EM 1110-2-2200 with careful consideration in selecting cohesive strengths because of uncertainties of the bond at lift joints. EM 1110-2-2006 requires that the internal angle of friction must be verified by tests performed

on samples prepared during laboratory design of RCC mixtures and cores taken from test sections prepared during the design phase.

2.1.3 USACE Engineering Manual 1110-2-2000, Change 2 – Standard Practice for Concrete for Civil Works Structures

Similar to the RCC manual, this EM also provides information and guidance on selecting materials for conventional concrete used in civil works structures. This will apply to the FRE facility's upstream face, retaining walls along the stilling basin, at the diversion tunnel entrance and exit, CHTR facility, intake tower, and the spillway crest, chute, training walls and flip bucket. USACE requires that this manual also be used in conjunction with EM 1110-2-2006.

2.1.4 USACE Engineer Manual 1110-2-2100 – Stability Analysis of Concrete Structures

This EM describes requirements for static methods used in analyzing the stability of hydraulic structures. The requirements will apply to retaining walls along the stilling basin, at the diversion tunnel entrance and exit, CHTR facility, intake tower, spillway training walls, and flip bucket.

2.1.5 USACE Engineering Manual 1110-2-2200 – Gravity Dam Design

This EM provides guidance for the analysis and design of concrete dams, including RCC dams. The EM will be used to determine stability of the FRE facility against sliding as described in Section 4 with design and construction details for the upstream and downstream facings, treatment of lift joints, transverse contraction joints, and reducing uplift described in Section 9. These topics augment the discussion of the same topics addressed in EM 1110-2-2006.

2.1.6 USACE Engineering Manual 1110-2-2400 – Structural Design and Evaluation of Outlet Works

This manual presents guidance for the design of outlet works structures with special emphasis on intake towers, but also including approach and discharge channel structures, trashracks, bulkheads, gates, valves, and mechanical and electrical operating equipment. All of these features are present in the current preliminary design layout.

2.1.7 USACE Engineering Manual 1110-2-1603 – Hydraulic Design of Spillways

This EM presents hydraulic design guidance for spillways including energy dissipators. This will be applicable for design of the spillway chute conventional concrete facing, flip bucket, and the baffle blocks and end sill in the outlet works stilling basin. Spillway training wall height is affected by bulking, and will be determined using EM 1110-2-1601, Hydraulic Design of Flood Control Channels.

2.1.8 USACE Engineering Regulation (ER) 1110-2-1806 – Earthquake Design and Evaluation for Civil Works Projects

This ER provides guidance for establishing design earthquakes with associated performance requirements, and is supplemented by additional guidance in ER 1110-2-1156 and EM 1110-2-6000, Selection of Design Earthquakes and Associated Ground Motions (currently under technical review). The horizontal uniform hazard spectra from the probabilistic seismic hazard analysis for estimated 500-, 1,000-, 2,500-, 5,000-, and 10,000-year return periods were

developed and plotted, and represent the sum of the hazards from various regional seismic sources included in the seismic source characterization model for the Chehalis FRE facility site (Shannon & Wilson, Preliminary Design Earthquake Time Histories, 2015). The estimated hazard curves from the probabilistic seismic hazard analysis for horizontal ground motion versus mean annual rate of exceedance or return periods indicate, based on current knowledge, that the Cascadia Subduction Zone interface is the dominant contributor to the ground motion hazard at the site for 500- to 10,000-year return periods. Results from this study will be reviewed during the design phase and updated as additional data about the Doty fault is obtained. Response of the FRE facility and expected consequences over a range of return periods will be evaluated for establishing an acceptable level of risk.

2.1.9 EM 1110-2-6053 – Earthquake Design and Evaluation of Concrete Hydraulic Structures

This EM provides guidance for performance-based design and evaluation of concrete hydraulic structures, and describes procedures on how to design a hydraulic structure to have a predictable performance for specified levels of seismic hazard. The EM is applicable to the FRE facility, intake, stilling basin, and CHTR facility.

2.1.10 EM 1110-2-2901 – Tunnels and Shafts in Rock

This EM provides technical criteria and guidance for design and construction of tunnels and shafts in rock. It covers geological and geotechnical explorations, design considerations, construction, linings, instrumentation, and monitoring. This EM applies to design of the diversion tunnel.

2.1.11 EM 1110-2-3800 – Blasting for Rock Excavations

This EM provides guidance for planning, design, monitoring, and execution of blasting programs. It is intended as a guide for engineers and geologists designing excavation programs. This EM is applicable for design of the anticipated FRE facility foundation excavation limits, diversion tunnel, and quarries.

2.1.12 EM 1110-2-3506 – Grouting Technology

This EM provides technical criteria and guidance for civil works grouting applications, and includes information of procedures, materials, and equipment for use in executing a grouting project. This manual is applicable to minimize leakage and reduce uplift in design of the FRE facility's grout curtain.

2.1.13 ER 1110-2-8152 – Planning and Design of Temporary Cofferdams and Braced Excavations

This ER and supporting manuals are applicable for the upstream and downstream cofferdams. It provides criteria and guidance for safe working conditions and life protection, optimizing cost versus risk of damage and securing the integrity of permanent structures during the temporary use of cofferdams. The ER allows for alternate contractor-proposed designs subject to meeting the approved design criteria. Design guidance for cellular cofferdams is contained in EM 1110-2-2503, Design of Sheet Pile Cellular Structures, and provisions for earth cofferdams are in EM 1110-2-1902, Slope Stability, and -2300, General Design and Construction Considerations for

Earth and Rock-Fill Dams. The regulation stipulates that the crest elevation of cofferdams must be determined from risk-based analysis procedures whereby failure or inundation would result in a potential risk to life or exceeds 10 percent of the project cost of the permanent structures.

2.1.14 ER 1110-2-1405 – Hydraulic Design for Local Flood Risk Management Projects

This ER prescribes the design procedure and rationale for the hydraulic design of a local flood risk management project. The regulation mainly pertains to levees and channel improvements but may need to be met during the design phase.

2.2 Other Federal Agencies

Other federal agencies with direct interest in dam safety have adopted dam safety management practices, and Reclamation and NRCS have also developed their own technical standards. In addition, the National Marine Fisheries Service Northwest Region (NMFS) within the U.S. Department of Commerce has published “NMFS Anadromous Salmonid Passage Facility Design” (2011) to provide design criteria for Pacific salmonids to safely pass dams and other barriers. The NMFS criteria only addresses safe and timely fish passage. The CHTR facility will be designed to meet design criteria prescribed by NMFS coupled with USACE EMs and ERs to meet federal requirements for structural integrity and public safety.

3.0 Seismic Study Review

The Washington Department of Natural Resources conducted an in depth investigation of the existing Doty fault to determine the length and activity level of the fault. This provides an understanding of potential seismic activity around the proposed FRE facility. HDR performed a high level review of the “Geologic and Geophysical Assessment of Tectonic Uplift and Fault Activity in the Doty and Willapa Hills, Southwest Washington: Final Report” (June 30, 2021). The focus on this review was to identify if the information in this report could potentially affect the proposed location and design of the FRE facility. Below are the major findings from the review.

1. The maximum credible earthquake event from the Doty fault has increased from a moment magnitude M6.9 to M7.3. There also appear to be some updates to estimated slip rates for the Doty fault. These updates will affect the contribution of the crustal fault hazard slightly from the seismic hazard characterization provided in the HDR’s 2015 report. Therefore the site specific hazard evaluation should be updated to incorporate the new Doty fault characterization information.
2. The overall length of the Doty fault including the possible rupture length has increased as a result of the new M7.3 estimate. The increased fault length appears mostly as a northwestern extension moving away from the FRE site.
3. There is no new information suggesting any fault hazard traversing the FRE site. Hence there is no new concern for a fault rupture in the FRE foundation.

It should be noted that the proposed design for the FRE facility has not been based on a seismic structural response analysis. To date, the cross-sectional properties of the FRE facility

have been based on HDR's experience with other similar projects in a comparable seismic hazard location. An initial 2-dimensional (2D) is planned for the next phase of project design development. Depending on the 2D analysis results, a 3D non-linear evaluation of the proposed FRE facility may be required for preliminary design. The design team anticipates that the FRE facility section will be finalized based on risk-informed evaluation of the structure response consistent with the current federal dam safety requirements and best practices considering the potential consequences of a dam failure. This approach will provide the state confirmation that the facility design will conform to federal guidelines for dam safety risk analysis. Updating of the estimated seismic hazards at the site and development of ground motion time histories for use in the structural analyses of the facility will be required for the design to proceed.