

Date: 12/04/2025

File Code: 210-16-11

Subject: ENG- Engineering Geology
Seismic Evaluation – East Clear Creek Watershed Plan

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Purpose and Background

A preliminary seismic analysis for the East Clear Creek Agricultural Water Management Plan was performed using parameters defined by NRCS policy found within Part 302- National Instruction: Interim Guidance for Seismic Hazard Data Collection and Evaluation for the Planning and Design of NRCS Structures (210-302-NI, 1st Ed., July 2021) and Technical Release 210-60: Earth Dams and Reservoirs (210-60-TR, March 2019). For NRCS structures, minimum seismic evaluation procedures require producing a Peak Ground Acceleration Value (PGA (g)) for a project site. For structures where a PGA has been found to be less than or equal to 0.07 g, no further seismic analysis of the structure is required (USDA-NRCS, 2019). For structures that have a PGA of 0.20 g or less, evidence must be provided that shows engineering judgement has evaluated that the structure is well-built, with a foundation of well performing material such as those with rock or dense clay (USDA-NRCS, 2019)¹. Additionally, when building dams and similarly classed structures, adequate factors of safety, seepage control and freeboard must be analyzed to ensure proper design and intent (USDA-NRCS, 2019). For structures that have a PGA of over 0.20 g, additional and further special seismic analyses are required that are proportionate with the type of structure being designed or built (USDA-NRCS, 2019).

Methods

Using the United States Geological Survey Earthquake Hazard Toolbox, a Peak Ground Acceleration (PGA) value was generated using the 2023 Disaggregation model. Within this modelling toolbox, a variety of outputs are generated, including 3D disaggregation plots, geographic plots of suspected earthquake energy sources, PGA, and highest modeled magnitudes of an earthquake within the given region. Inputs into the model are straight forward and include geographic location, return period/exceedance probability, and site class selections. The return period/exceedance probability is directly correlated to how the NRCS defines low, significant, and high consequence of failure scenarios, as seen within Chapter Four of TR-60, Seismicity and Earthquake Loading, Table 4-1. Determination of which consequence of failure scenario to utilize during analysis, and as such the appropriate return period within the model, is determined from

hydraulic modeling of the breach routing of a dam while at normal pool elevation rather than top of dam elevations. Consequence of failure designations should not be conflated with dam hazard class designations, as they are determined differently. Site Class designations are determined from velocity measurements of the upper 30 meters (~100 feet) of subsurface material at a given site. Shear wave velocity can be measured directly but is commonly translated from in-situ density data derived from Standard Penetration Testing (SPT) during drilling operations. Please see Figure 302-1 from 210-302-NI for full Site Class definitions.

Results

The preferred alternative project measures for this Agricultural Water management plan include structural inputs for installation, replacement, and modernization of diversion structures used for irrigation canals. Additionally, modeling from USGS within the National Seismic Hazard Model (2023) places Nebraska as a whole within a low seismic risk region, including the watershed and project area. Further, as defined by current Fault Classification scenarios used by the USGS for mapping active Quaternary Faults, there are no faults that are classified as active or present within the surface in Nebraska, or the East Clear Creek Project Area, as a whole (USGS, 2026; Crone and Wheeler, 2000). As such, a Low Consequence of Failure Scenarios (Return Period: 1000 years) was determined appropriate and commensurate for the level of hazard and design that this project will encompass. The upper 30 meters of soil under the project site were defined as a “stiff soil” using an assumed Site Class of D for modeling purposes (USDA-NRCS, 2021). Site class assumption was based off well logs, published literature, and local knowledge of the subsurface material conditions within the project area and watershed. Please see Appendix A for full PDF copies of all USGS modeling scenarios. Results of the models are as follows:

Diversion Structures Regional Location

Consequence of Failure: Low

Return Period: 1000 years
PGA: 0.04104 g (4.104×10^{-2})

Discussion

PGA Analysis

When using a low consequence of failure, a PGA of less than 0.07 g was derived for the general diversion structure implementation and replacement locations, with 0.04104 g determined for the project area. As per NRCS policy, when a PGA of 0.07 g or less is found, no further seismic analyses are required (USDA-NRCS, 2021 and 2019).

Historical Earthquakes

Historical earthquakes within a 100 km (~62 mile) radius of the East Clear Creek Project Area were identified from 1600 to present using the USGS Earthquake Hazards – Earthquake Catalog per NRCS TR-60 guidelines (USDA-NRCS, 2019). From this search, recorded earthquakes occurred within the years 1990-2018. This search yielded no earthquakes having been recorded

directly within the East Clear Creek Project Area. Within an extended 100-km search radius of the East Clear Creek Project Area, thirty-two (32) earthquakes were located, ranging from 2.0-4.1 in magnitude recorded within the years 1990-2018 (Figure 1). Of these 32 earthquakes, twenty-seven (27) were recorded within a clustered zone in Custer County in 2018; however, only one earthquake was rated above a 4.0 magnitude – a 4.1 within Custer County to the northeast of the project area, also within 2018 (Figure 1). Earthquakes of a magnitude of 4 or higher are the designated parameter of minimum earthquake magnitude identification for project sites within NRCS policy, based off historical trends of damaging ground shaking and risk associated predominantly with earthquakes that are >4.0 in magnitude (USDA-NRCS, 2019).

Within Nebraska, there has been earthquake and seismic activity noted as occurring in cluster spikes, particularly within Custer County, and have been notably documented within 2017, 2018, and 2023 primarily within southeastern Webster County and central Custer County (USGS, 2026; Filina et al., 2018). However, within these activity clusters, only one earthquake was reported to be over 4.0 magnitude, the aforementioned 4.1, located within Custer County. Primarily, most of the spikes in activity registered between a 2.0-3.5 magnitude earthquake and were not noted to cause any noticeable damage. These cluster spikes of seismic activity have also been reported within the neighboring states of Colorado and Kansas and are notably associated with Induced Seismic Zones as identified within the USGS 2023 National Seismic Hazard Model (NSHM), which are likely and potentially related to hydraulic fracturing at wastewater injection well sites associated with petroleum exploration and operations. However, research is still ongoing in determining the causality for the clustering of the quakes within these regions, particularly within Nebraska, where no official induced seismic zones have been identified as of yet. Research currently suggests that seismic activity in Nebraska is related to basement fault reactivation and/or readjustment; the link to basement readjustment being associated with wastewater injection through the mechanism of the fracturing at these well sites taking advantage of preexisting crustal weaknesses has not been fully explored and cannot be determined a cause for seismic activity with authority at this time (USGS, 2026; Filina, 2018).

As noted above, while not officially associated with an official structural or tectonically active zone, ongoing and recent research into Nebraska seismicity suggests that this earthquake activity, particularly within the southern and eastern portions of the state, may possibly be associated with the reactivation of basement faults along the Nemaha Tectonic Zone, Mid- Continent Rift, and the Humboldt Fault Zone, structural zones that are found primarily within the dense and deeply underlying basement rock of the state (Filina et. al., 2018; Burberry et. al., 2015; Bakun et. al., 2004)¹. These research studies have identified hundreds of deep basement faults via the use of

¹ The Mid-Continent Rift (MCR), Nemaha Tectonic Zone (NTZ), and the Humboldt Fault/Fault Zone (HFZ) are ongoing areas of seismicity research within the state of Nebraska. While recent studies in 2015 and 2018 by Burberry and Filina indicate the likelihood of Quaternary displacement within these areas, the USGS does not currently classify any of these zones as active within the Quaternary. The MCR and NTZ are bounded by faults in the basement; the MCR is thought to be responsible for some recent seismic events within Nebraska, but this has not been confirmed by USGS (Burberry et. al., 2015; Crone and Wheeler, 2000; Burchett et. al., 1985). USGS currently classifies the HFZ as a “Class C” fault, based upon classifications made by Crone and Wheeler in 2000. A Class C fault is defined as a feature in which “geological evidence is insufficient to demonstrate the existence of a tectonic fault or Quaternary slip...” The Crone and Wheeler research is part of the data that composes the USGS Quaternary Fault Database, which is the database NRCS policy and procedure refers to for identifying Quaternary faults. However, NRCS policy also states to use local literature and research when

historical logs, and gravity and magnetic maps of the basements subsurface (Filina et. al., 2018) (Figure 2). However, these structural zones do not have any faults classified within them that are currently defined as active per NRCS policy or within current USGS catalogs of seismic research (USGS, 2025; Crone and Wheeler, 2000).

Due to the nature of the ongoing research within the Nebraska region, it should be noted that these zones of basement faulting have been acknowledged in this analysis as being structural features that could possibly generate seismically induced ground motion in the project region, despite current USGS classifications. However, the magnitude of the earthquakes that have been possibly linked to these basement features is relatively low. In total, nearly 90% of all earthquakes in Nebraska's reporting history are registered below a 4.0 magnitude. Overall, it is not believed that any activation of these deep basement faults poses any risk to the East Clear Creek Project Area.

Other Seismic Analysis

Beyond producing a PGA analysis, a preliminary seismic hazard evaluation for the preferred alternative was performed by locating the region as denoted within the 2023 USGS National Seismic Hazard Model Map (Figure 1). As seen within the map, the project area is located within a low hazard region (<5-25% chance of damaging earthquake shaking). The NRCS also requires that no structures be built over an active fault, which is defined within NRCS policy as within the Holocene, or the past 10,000 years (USDA-NRCS, 2019).² Dams located on capable faults must be able to demonstrate an ability to withstand any potential offset by potential ground movement or seismic events. Capable faults are defined by NRCS as those with no displacement within the past 10,000 years (Holocene-Recent) but *do* have documented movement within the past 10,000-35,000 years (Late Pleistocene) (USDA-NRCS, 2019). They are also further defined as a capable fault if there is not adequate data to document whether the fault has experienced movement within the past 35,000 years (USDA-NRCS, 2019). As discussed in previous sections, the East Clear Creek Project Area is *not* located over any identified Holocene active faults, nor is the site believed to be located directly over the existence of any capable faults. The only faults below the project site are deep within basement rocks several thousand feet below the site and pose little to no risk to any planned structures.

Conclusion

The seismic PGA modeling for the project region being rated at ~0.04 g has shown that there is a low seismic risk within the watershed and does not necessitate further seismic evaluation based off NRCS policy guidelines. Further, no earthquakes have ever been recorded within the watershed and only one earthquake above >4.0 (4.1) has ever been recorded within the 100-km surrounding region. There are no currently mapped active or capable surficial faults within the

necessary for identifying faults and structural features. Within southeastern Nebraska, this recent research should be referred to when NRCS structures have been identified as being within or atop these possibly active zones.

² The NRCS currently defines the Holocene as 10,000 years to Recent. However, updates to the official Geologic Timescale have updated the demarcation of the Holocene at 11,700 years. It is anticipated that future edits to NRCS policy will incorporate this edition and update its definition of active faults as those with documented displacement within the past 11,700 years.

region, or within the state of Nebraska- only basement faults located in *deeply* underlying basement rock of the region. Seismicity studies have shown that seismicity in the region is likely attributed to these deep basement faults via tectonic readjustment from pre-existing crustal weaknesses. While there may be some potential for these faults to be associated with activation and readjustment due to induced seismicity, there is not enough data or evidence to fully support this claim at this time. As such, the seismic evaluation for the East Clear Creek Project Area demonstrates that the project is unlikely to be affected by any damaging seismicity within the project life of the measures considered within the Watershed Plan.

Disclaimer and Signature

The interpretation of subsurface conditions, conclusions, and recommendations contained herein are the sole opinion of the author and are for in-service NRCS use only. This report describes general characteristics of the earth materials observed, however, conditions may vary. Earth materials are typically not homogeneous in classification, characteristics, or strength, and may differ between points of geologic exploration. Please do not hesitate to contact me to discuss these findings, or if further assistance is needed. I can be reached at my office phone of 402-437-4035 or by email at alessandra.sealander@usda.gov.

Respectfully submitted,

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Figure 1. Historical Earthquakes within a 100 km radius of the East Clear Creek Project Area and the NSHM within Nebraska

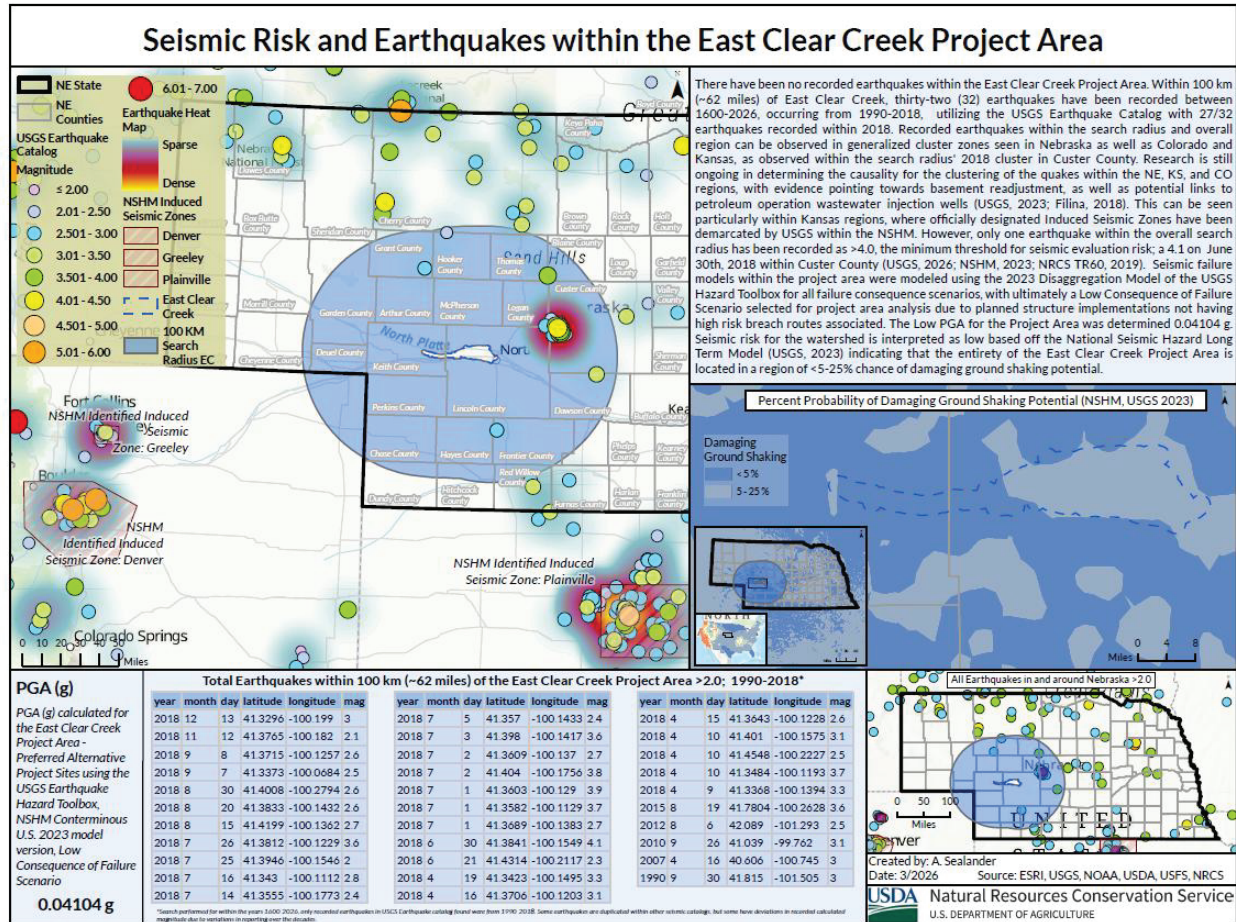
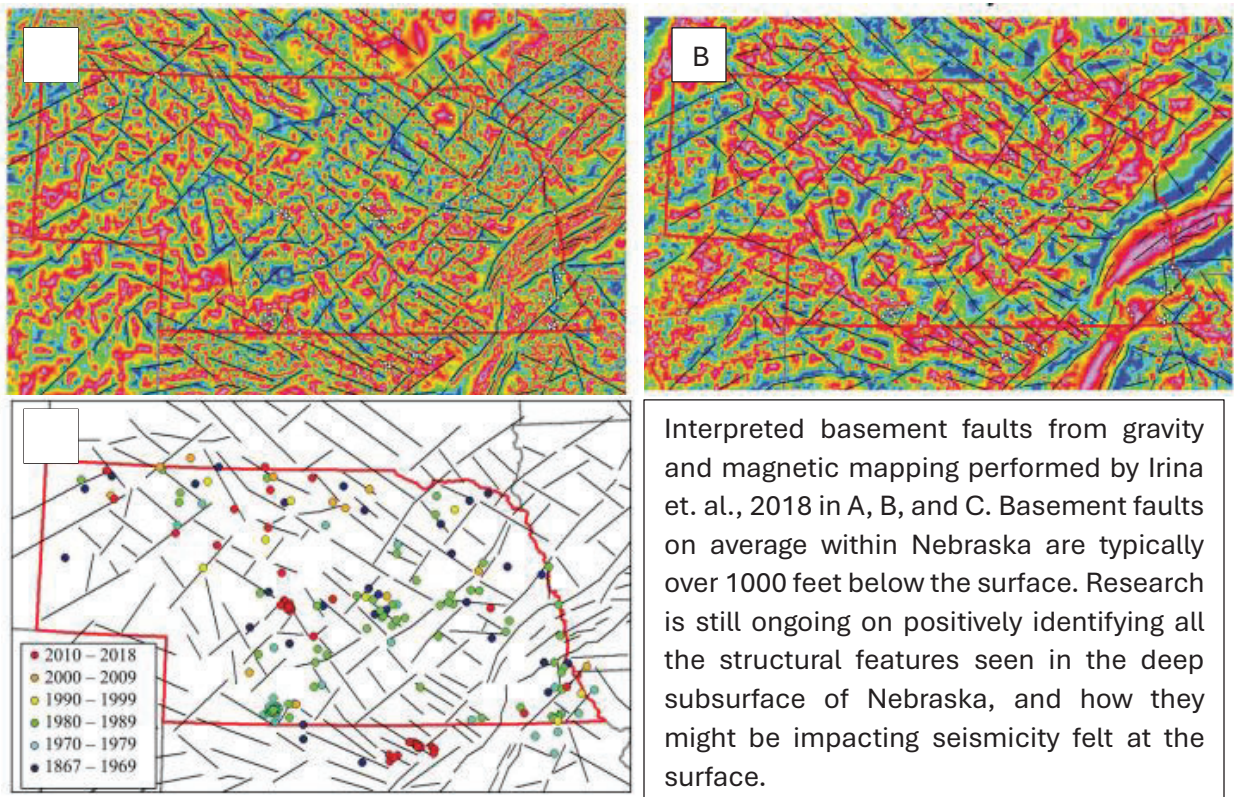


Figure 2. Prominent Structural Basement Features in Nebraska



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