



# **Larimer County Analysis – Technical Memorandum No. 8 Natural Hazard Mitigation Plan**

Prepared for:  
**Larimer County**

Prepared by:  
**Northern Integrated Supply Project  
Water Activity Enterprise**

**February 2020**

## **MEMORANDUM**

Northern Integrated Supply Project  
Glade Reservoir  
Larimer County 1041 – Geologic Hazards

B&V Project Number 403758  
B&V File 188754/34.3000  
February 14, 2020

To: Larimer County Planning Department  
From: Tim Engemoen, Black & Veatch and Sean Kearney, AECOM

## **Introduction**

This technical memorandum is written in support of Larimer County Planning Department’s 1041 Permit for the Glade Unit construction and documents the natural geologic hazards and proposed mitigation plans associated with the construction of the Glade Unit. The geologic hazard analysis has been completed in accordance with Larimer County Land Use Code Section 8.3, and the mitigation goals are public safety and the protection of the Glade Unit facilities.

## **Project Background**

The Northern Integrated Supply Project (NISP) will provide a new raw water supply to several municipal water providers in Northern Colorado. NISP includes the following facilities located in Larimer County: the Glade Unit; the Glade Pump Station; raw water distribution piping; and the relocation of U.S. Highway 287. The Glade Unit features the Glade Reservoir Dam, which is an earthen embankment that will impound an off-channel reservoir complete with the hydraulic structures required by the State Engineer’s Office: the High Level Outlet Works (HLOW); Low Level Outlet Works (LLOW); and spillway. Glade Reservoir Dam is located just to the north of the junction of U.S Highway 287 and State Highway 14, about 10 miles northwest of Fort Collins. The Glade Unit includes an expansion of the existing Poudre Valley Canal (PVC) and a new forebay constructed downstream of the dam at an elevation that will allow delivery of water from the PVC by gravity. A Control Gate Structure will be constructed to control flow to the existing portion of the PVC downstream of the forebay. The existing PVC Diversion Structure will be demolished and a new Poudre River Diversion Structure built to allow increased diversion of flow from the Poudre River. A portion of the existing Munroe Gravity Canal alignment will be inundated by Glade Reservoir, this open canal will be replaced by the Munroe Canal Bypass (MCB), a conduit and several control structures that will convey flow beneath the reservoir. The Glade Unit also includes: the Glade Pump Station, which will pump water from the forebay into Glade Reservoir; the Electrical/Control building that will distribute power throughout the site and provide control of the various hydraulic features; the Surge Building that will house surge tanks to protect the pump station discharge conduit; and numerous buried conduits with control valve vaults that connect these facilities. Raw water will be conveyed off site via several buried conduits that are being constructed under different NISP contracts. The Glade Unit will include recreational amenities for the general public, including a Visitor Center, campgrounds, a boat ramp, trails and restroom facilities.

Glade Reservoir will submerge a portion of the existing U.S. Highway 287 alignment which will be relocated to the east of the reservoir. An existing power transmission line and several power distribution lines will be inundated by the reservoir which will be relocated as part of the Glade Unit construction. A general location map of the Glade Unit facilities is presented on Figure 1.

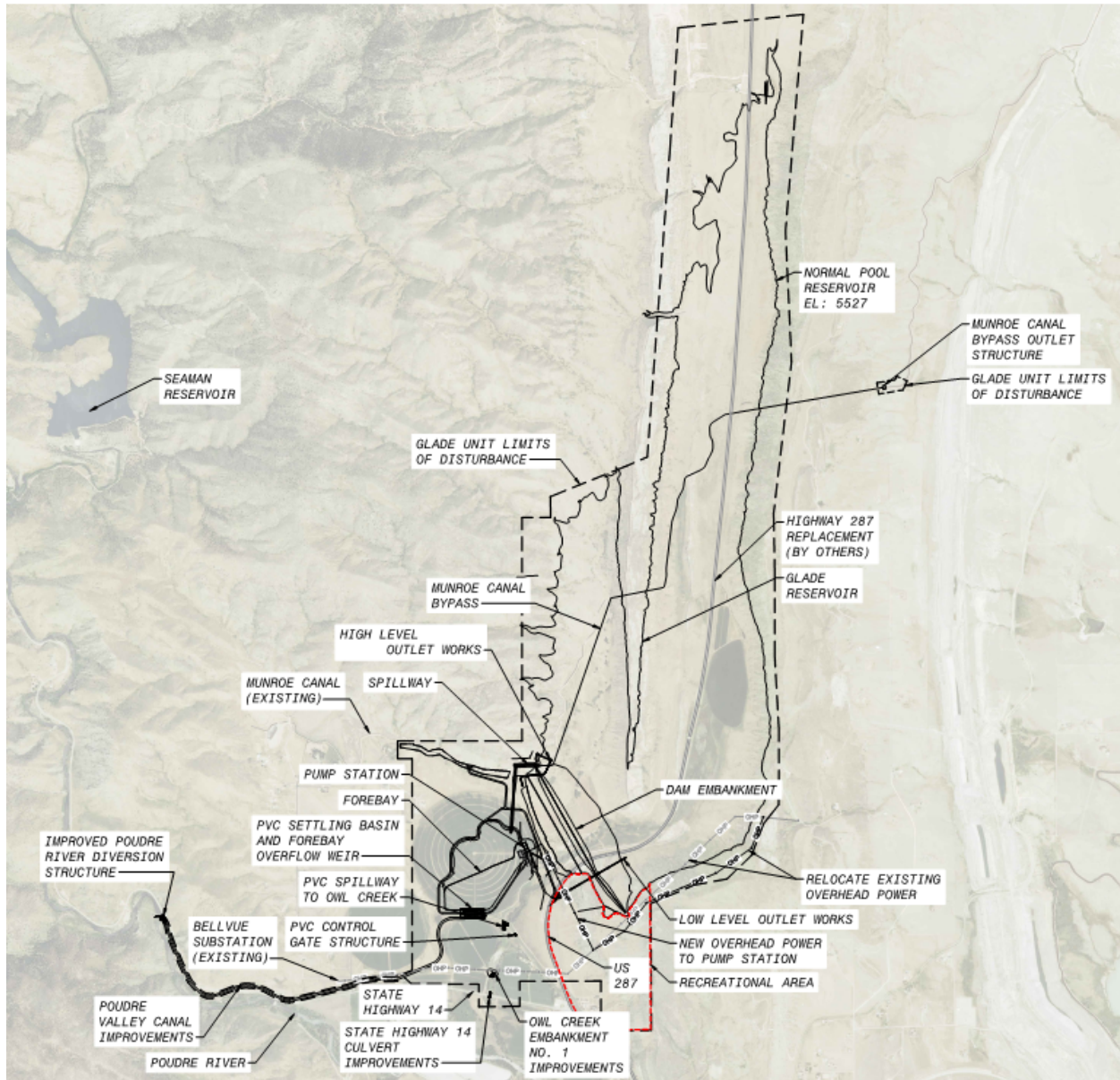


Figure 1 - Glade Unit Overview

The NISP Water Activity Enterprise (NISP Enterprise or Enterprise) assumes financial responsibility for construction of all infrastructure required for the project. The Enterprise is a permanent entity with access to adequate funds to cover project construction and maintenance. The Enterprise’s budget will include routine and capital maintenance funds. Northern Water’s past performance under other USACE

permits demonstrates its commitment to assure that projects will be fully implemented and maintained by the Enterprise.

## Geologic Hazards

Several geologic hazards have been identified within the Glade Unit project area. The geologic hazards identified are flooding, landslides, rockfalls, debris flows, faults, collapsible soils and ground subsidence.

### Flooding

Potential flooding hazards are shown on Figures 2 through 6 (included in Attachment C to the 1041 Permit Project Description), as depicted by the 100-year floodplain delineation. As shown in this set of figures, the only facility that will be constructed within the 100-year floodplain will be the new Poudre River Diversion Structure. The remaining facilities all fall outside of the floodplain and are not at risk of inundation.

### Landslides

Figure 23 (included in Attachment C to the 1041 Permit Project Description) shows the landslide hazards within the Glade Unit project area. Three landslides have been identified through field mapping and drilling in the vicinity of the left abutment (left side of dam while standing on the water looking downstream) of the dam embankment. Of these three, only one is anticipated to impact the footprint of the embankment. Drilling within this landslide indicated that these deposits are up to 47 feet thick. The remaining two landslides lie within the recreational area. Additional areas along the east rim of the reservoir have been mapped but do not pose a significant risk to the project.

### Rockfalls

Rockfall hazards have been mapped within the Lytle Formation on the bluffs above areas proposed as recreation use. Two areas were identified as being moderate to high risk and one area was identified as being low risk. Large blocks of sandstone have been dislodged and released downslope as toppling failures. The risk of these bluffs releasing blocks increases during heavy precipitation events especially if they are followed by freeze thaw cycles. Figure 24 (included in Attachment C to the 1041 Permit Project Description) shows the rockfall hazards present at the site.

### Debris Flows

The Colorado Geologic Survey (CGS) generated an open file report titled “Debris Flow Susceptibility Map of Larimer County, Colorado” in 2015. Debris flow hazards were identified at the project site within this report. The hazard states that the areas identified on the map are potentially susceptible to debris flows/mudflows during extreme precipitation events. The hazard map factors in slope angle and channel geometry as input parameters for run-out zones. CGS has mapped areas within the Glade unit that are favorable to debris flow conditions. Figure 25 (included in Attachment C to the 1041 Permit Project Description) shows the debris flow hazards present at the site.

## Faults

There are two earthquake faults mapped within the Glade unit. The Bellvue Fault and North Fork Fault have been intercepted at depth by test holes advanced during the project's geotechnical investigations. The Bellvue Fault contains an east and west splay, is a north-south trending reverse fault that intersects the North Fork Fault within the vicinity of the embankment footprint. The North Fork Fault is an east-west trending reverse fault that is mapped through the right abutment (right side of dam while standing on the water looking downstream) of the dam embankment. Both faults are inactive and do not present a seismic risk to the project.

## Collapsible Soils and Ground Subsidence

Collapsible soils tend to consolidate due to porous conditions developing after deposition which can greatly reduce soil strength. Collapsible soils are generally dry, low density, silty soils with high void space or air gaps between the soil grains where the soil particle binding agents are highly sensitive to water. When exposed to and weakened by water, the binding agents break, soften, or dissolve such that the soil grains shear against each other and re-orient in tighter, denser, configurations. This reconfiguration causes a net volume decrease in the soil mass that, in turn, results in settlement of the ground surface. This condition can occur just by the weight of the soil itself, called the overburden, or the weight of a structure, such as a structure foundation or dam abutment. The Colorado Geologic Survey has mapped eolian (windblown) deposits and soluble rock (Lykins Formation) at the site. The Lykins Formation contains soluble gypsum beds that have the potential to go into solution which can create subsurface voids. These voids have the potential to collapse and cause subsidence to the ground above it. Figure 26 (included in Attachment C to the 1041 Permit Project Description) shows the collapsible soils present.

## Geologic Hazard Mitigation

Mitigation strategies for the identified geologic hazards are described below.

### Flooding

In general, flooding hazards are not present at the Glade Unit and therefore do not require mitigation. The Poudre River Diversion Structure is the only facility that is located within the 100-year flood plain and will be designed to withstand flooding events as it's situated in the Poudre River. This structure is an unoccupied structure and will be replacing the existing diversion structure located in the exact same location.

### Landslides

The landslide hazard located on the left abutment below the dam embankment will be mitigated by removing the landslide material down to competent bedrock during construction. The other two mapped landslides in the recreation use areas are not anticipated to be a risk but should be monitored periodically through onsite inspection of the slopes. Slope monitoring devices (inclinometers) could be installed and monitored if slope movement is detected during onsite surveys. These slope areas should not be undercut at the toe or overloaded at the top. Excessive irrigation should be avoided.

## Rockfalls

The rockfall hazards on the left abutment and along existing U.S. Highway 287 will be addressed where recreation areas are being constructed. Potential mitigation methods consist of locating infrastructure and recreation features outside of rockfall areas, slope scaling, trim blasting, mid slope catchment benches, rockfall drapes/netting, rock dowels or rock bolts.

## Debris Flows

The addition of the Glade Reservoir will help to attenuate flows during storm events which will work to reduce velocities downstream and reduce debris flow potential. Additional features could be added during detailed design to mitigate this hazard if determined necessary by additional investigations.

## Faults

Existing faults at the site are not considered to be a geologic/seismic hazard risk to the project. The two faults identified at the Glade unit are inactive and do not rupture the ground surface. AECOM completed a Site-Specific Seismic Hazard analysis for the site dated May 21, 2019. The results of this study have been incorporated into the overall design process.

## Collapsible Soils and Ground Subsidence

The mitigation method for the potentially collapsible soils will be removal. Collapsible soils within the dam embankment, forebay and borrow areas will be removed and used as borrow material in construction. The risk of subsidence from soluble gypsum beds in the Lykins Formation will be mitigated through extensive staged grouting of the bedrock units in the Lykins Formation.