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Project No.: 476-00-12-01

Mr. Carl Roner Associate Civil Engineer Contra Costa County Flood Control and Water Conservation District 255 Glacier Drive Martinez CA 94553-4825

SUBJECT: Safety Evaluation of Drop Structure 2 of the Walnut Creek Channel—Response to Comments at the July 24, 2012 Public Meeting

Dear Carl:

On July 24, 2012, the findings of the *Safety Evaluation of Drop Structure 2 of the Walnut Creek Channel* report (the Report) were presented at a public meeting in Walnut Creek. Several comments were provided by the public at the meeting. The comments were recorded and summarized by Contra Costa County Flood Control and Water Conservation District (CCCFCWCD) staff. Also, a letter by Mr. Benoit A. V. J. McVeigh was submitted to the County (dated August 3, 2012) providing a written summary of the verbal comments he provided at the meeting. A copy of this letter is attached, including the schematic of a horizontal rack mentioned in the letter.

Provided below are the comments and our responses to the comments.

COMMENT 1 – SAFETY CABLES

Loose safety cables would create a U shape along the water surface that would provide an opportunity for a person to grab and hold onto. As a person grabs the cable, the shape of the cable would change from a U shape to a V shape, providing a spring effect that would allow the person to successfully grab and hold onto the cable. The person would then pull themselves up the cable (against the current) to a ladder located where the cable is connected to the channel banks. Alternatively, the person could simply hold onto the cable until they were rescued.

An alternative approach would be to use tight cables crossing the channel at a diagonal. These cables would catch a person and the current would then help push a person along the cable to a ladder at the downstream end of the cable.

Several cables (of each type) could be installed about every quarter mile along the channel.

RESPONSE 1

Safety Evaluation

As described on page 7-5 of the Report for a loose cable, a person would not be able to pull themselves along a cable against the current due to the supercritical flow with a velocity of up to 28 feet per second. To illustrate how difficult this would be, the force on a person in the flowing water was approximated. The person would be holding onto a cable with just their head above water, and there body essentially horizontal, but below the water surface. For this approximation, the person was assumed to be similar to a cylinder six feet long and 1.5 feet in diameter, completely submerged, but still horizontal. At a flow of 18,000 cubic feet per second (cfs), the water velocity would be 28 feet per second, and the force of the flowing water on the cylinder would be 1,250 pounds. At a flow of 5,000 cfs, the water velocity would be 18 feet per second, and the force of the flowing water on the cylinder would be 528 pounds. At a flow of 2,000 cfs, the water velocity would be 13 feet per second, and the force of the flowing water on the cylinder would be 274 pounds. At a flow of 1,000 cfs, the water velocity would be 10 feet per second, and the force of the flowing water on the person would be 162 pounds. Also, because the person would have clothes on (essentially increasing the roughness of the cylinder) the forces would increase by at least 20 percent, and probably significantly more). The magnitude of these forces would make it very difficult (if not impossible) for a person to hold onto or pull themselves up a cable to a ladder.

The cables would likely be mounted to the channel walls near the top of the walls to ensure that the ends of the cables were not submerged at high flow. When the channel was not flowing nearly full, the ends of the cables would be above the water surface and the person would have to pull themselves up the cables above the water surface to reach the walls. If the cables were mounted lower in the channel, the ends would be submerged at higher flows and a person could not pull themselves all the way to the wall without going underwater.

The suggested tight cables would not have the slack to float up or down with changes in the water level. Thus, tight cables would only work if the water level was just at the level of the cable. A system with a tight cable somehow connected to "floats" and then connected to the channel walls could resolve this issue of changing water levels. Still, a victim could get wedged between the cable and the channel wall at the downstream of the diagonal cable and then not be able to escape up the ladder.

For loose or tight cables, even if a person did reach the channel wall, it would be very difficult for them to get their legs onto the escape ladder because the force of the flowing water would push their legs out from under them.

The Contra Costa County Fire Protection District (CCCFPD) rescue staff expressed great concern about using cables in the supercritical flow channel. The concerns are that when a person is very cold from being trapped in the water for even just a few minutes, they are unable to rescue themselves. Also, a person could get injured when impacting the cable or could get wrapped around the cable and drown while trapped on the cable.

COMMENT 2 – HORIZONTAL OR VERTICAL RACK

Since the safety rack options studied in the report would cause a hydraulic jump that would exceed the upstream channel top, could a horizontal or vertical rack be constructed part way down the existing drop structure so the jump wouldn't exceed the channel top.

RESPONSE 2

Safety Evaluation

For a vertical or horizontal rack, the impact of the person against the rack could seriously injure the person. For a flow of 18,000 cfs, the velocity would be 28 feet per second; the impact of the person against the rack would be equivalent to falling from a height of 12 feet onto the rack. Additionally, as the water flows over the crest of the drop structure, the velocity would increase, and after it had dropped by about 6 feet the velocity would be about 34 feet per second. This would result in an impact equivalent to falling from a height of 18 feet onto the rack. At either velocity, impacting against an uneven steel rack would probably cause significant injury to the person.

After the initial impact on the rack, a victim would very likely be trapped against the face of the rack and would not get washed up or along the face of the rack due to several factors. The evaluation of the forces on a cylinder presented above is also relevant to a person trapped against a rack. If the same cylinder was pressed against the rack, the cross sectional area would increase by a factor of five. This would result in a five-fold increase in the force on the cylinder (person). As the water flows over the crest of the drop structure, the velocity would increase, and after it had dropped by about 6 feet the velocity would be about 34 feet per second. The force on the cylinder is proportional to the square of the velocity. For example, for a flow of 18,000 cfs, if the water velocity increased from 28 feet per second to 34 feet per second, the resulting force would increase by a factor of 1.47. These two effects would result in a total increase in the force on the cylinder by a factor of about seven, resulting in a total force of about 9,000 pounds holding the cylinder against the rack.

A horizontal rack from the top of crest of the face of the drop would be below the water level in the downstream channel for the design flow of 18,000 cfs. Consequently, if the person wasn't trapped against the rack, a horizontal rack would result in the victim being washed off the end of the rack and back into the downstream channel. Additional vertical or sloped racks could be installed at the end of the horizontal rack, which would prevent the person from being washed off the end of the rack and into the downstream channel. This would, however, result in the accumulation of large debris that could impact, injure, or crush a person against the rack.

A sloped rack was previously evaluated in Chapter 7 of the Report. As was described on page 7-3 of the Report, the cross bars of the rack could entrap a victim and cause them to drown. This would be the case for either a horizontal or vertical rack. Use of a horizontal, sloped, or vertical rack with the upstream super critical flow would create a condition that is considered to be more dangerous than the existing submerged hydraulic jump.

Hydraulic Evaluation

The supercritical flow velocity in the upstream channel is about 28 feet per second, and the depth of flow is about 12.9 feet. A hydraulic jump in the upstream channel would cause the subcritical flow water depth to increase to about 19.3 feet, which would exceed the top of the channel walls by about 5 feet.

An accurate hydraulic evaluation of the flow through a rack located part way down the face of the drop structure is very complex and would require physical scale modeling to evaluate accurately. As the flow starts down the face of the existing drop structure it would accelerate to a velocity faster than in the upstream channel (faster than 28 feet per second). A rack located part way down the face of the drop would cause a hydraulic jump, but because the water velocity would be faster than 28 feet per second, the depth of the subcritical flow would be greater than 19.3 feet. The length of the hydraulic jump is typically four to six times the length of the subcritical flow depth. For Drop Structure 2, the length of the jump would be greater than 80 to 120 feet. The length of the face of the drop structure is only 36 feet. Consequently, the jump would extend upstream of the top of the face of the existing drop structure regardless of where the rack was positioned along the face of the existing drop structure. This would cause the flow to exceed the top of the channel at the rack and upstream for as much as 120 feet. Also, if debris accumulated on the rack, this condition would be made even worse.

COMMENT 3 – GROUTED SLOPING BOULDER DROP STRUCTURE

The Grouted Sloping Boulder Drop Structure (GSBDS) was eliminated from consideration because it was not a "proven technology" with documented uses in other supercritical channel conditions. However, this doesn't prove that the GSBDS wouldn't work. Additional evaluations should be undertaken to determine if the GSBDS could work in a supercritical channel. The Army Corps of Engineers should be requested to commission an analysis of the GSBDS structure, including a model study, to determine if it could be implemented, due to the number of deaths that have occurred here.

RESPONSE 3

Safety Evaluation

As discussed on pages 8-10 and 8-11 of the Report, the GSBDS would have 20 inch high boulders. At low flows, a victim trapped in the flow could impact against the boulders at velocities of up to about 18 feet per second (12 miles per hour), which could severely injure the victim. At the bottom of the GSBDS, the victim would still flow through a hydraulic jump that would be very turbulent and dangerous. Thus the GSBDS would replace the submerged hydraulic jump with a condition that is still very dangerous. After being severely impacted by traveling down the structure, the victim would still have to rescue themselves from the channel downstream of the GSBDS.

Hydraulic Evaluation

Because no examples of the use of a GSBDS were located, there is great uncertainty about how a GSBDS would function with upstream supercritical flow. Some of the concerns include the issue that the first row of boulders would throw the water into the air like would occur with the baffle chute drop structure. Also, the 20-inch boulders may not provide enough roughness to dissipate the energy of the upstream supercritical flow. In which case, larger or taller boulders might be needed, which would lead to a structure more like a baffle chute drop structure (evaluated on pages 8-1 through 8-4 of the Report and found to be inappropriate for upstream supercritical flow). The hydraulic jump at the end of the GSBDS could occur farther downstream than anticipated which would cause erosion and scour of the earthen channel.

Additional Comments

The suggestion to request assistance from the Army Corps of Engineers can be pursued, however, the Army Corps of Engineers has limited programs and authorities and many competing interests and needs across the country. CCCFCWCD staff checked with the Army Corps of Engineers, and this work would not fall under the continuing authorities program. It would require a special authorization and an appropriation by Congress to commission an Army Corps of Engineers study of a replacement for this structure, which would require a high level of political support. The cost to perform the necessary studies would be several hundred thousand dollars and the process would take several years to complete. Due to the process required, the extensive model studies already performed for the original design of this structure, and the lack of any retrofit examples for upstream supercritical flow, we feel it is unlikely that any significantly safer structure can be developed here. Consequently, we do not recommend additional evaluations be undertaken for the re-design of this structure. The issue is whether the structure meets current industry standards for safety. From the studies undertaken to date, the current structure appears to meet the industry standard for drop structures with upstream supercritical flow.

COMMENT 4 – VERTICAL DROP STRUCTURE

The existing structure could be replaced with a vertical drop structure.

RESPONSE 4

Safety Evaluation

Replacement of the existing structure with a vertical structure would not eliminate the submerged hydraulic jump. Consequently, it would not provide an increase in safety at Drop Structure 2. In fact, in the 1966 physical scale model study of this drop structure, 15 vertical drop structures were evaluated with the physical scale model and they resulted in higher levels of turbulence than the existing structure, which makes them less safe than the existing structure. The 1966 physical scale model study is presented in Appendix 3B of the Report.

Hydraulic Evaluation

Part IV, paragraph 30 (Pages 17-18) of the 1966 physical model study states that various slopes of the drop were considered and concluded that "*The use of a trajectory shape in lieu of a vertical drop is beneficial in stabilizing the nappe and in increasing the effective length of the stilling basin*". The existing structure has a trajectory shape. The existing structure was selected over 15 vertical drops structure configurations that were also tested. The goal of the 1966 study was to determine a drop structure that would dissipate the energy most efficiently, with a stable nappe, with minimum turbulence, and without causing negative pressures that would ultimately damage the drop structure. The existing structure was selected out of 21 different configurations tested because it provided the best hydraulic performance.

CONCLUSION

The comments and suggestions discussed above do not provide a meaningful increase in the safety of the channel and drop structure and each has significant concerns about the potential for self-rescue and causing flooding. The facilities proposed by the CCCFPD are the only alternatives that provide some increase in safety without introducing new potential impacts to victims or channel hydraulic performance. The CCCFCWCD's fencing and inspection and repair program, the public outreach and education program, and additional signage will help keep people from entering the channel in the first place and consequently appear to be more valuable than the physical modification of the drop structure.

The existing drop structure and concrete channel appear to meet current industry safety standards, and no improvements were identified that would significantly improve the safety of the drop structure and upstream supercritical flow channel. The programs and improvements being pursued by the CCCFCWCD meet or exceed what most other agencies are doing. By implementing the Creek and Channel Safety Program, the CCCFCWCD will improve the safety of the drop structure and channel system.

Sincerely,

WEST YOST ASSOCIATES

Douglas T. Moore

Engineering Manager R.C.E. #C058122

attachments