DUNLAP SPILLGATE HINGE INSPECTION REPORT

BLACK & VEATCH PROJECT NO. 400368

PREPARED FOR

Guadalupe-Blanco River Authority

13 AUGUST 2019

BLACK & VEATCH

Table of Contents

LIST OF FIGURES

1.0 Introduction

The Guadalupe-Blanco River Authority (GBRA) owns and operates the Guadalupe Valley Hydroelectric System (GVHS) on the Guadalupe River near Seguin and Gonzales, Texas. The system consists of six dams put into services between 1928 and 1932. The six dams include a total of 15 spillgates each 12'-0" tall by 85'-0" to 98'-8" wide. The spillgates are original construction and are now approximately 90 years old. In the last three years two of the 15 spillgates have without warning suffered catastrophic failure. Each failure resulted in the sudden discharge of water and the draining of the associated lake.

- During a flood event in 2016 Gate No. 1 at the Lake Wood Dam failed with a portion of the gate washing downstream.
- In May 2019 spillway gate No. 2 at Lake Dunlap Dam catastrophically failed. The Dunlap failure was recorded by the dam's security cameras. Within approximately 4 seconds the entire 85-foot-wide x 12-foot-tall gate dislodged and washed downstream. The cause of the Dunlap failure is unknown; although based on review of the video a structural failure of the upstream hinges is suspected. The hinges are a critical part of the gates. Failure of a hinge or hinges could result in the catastrophic failure of a gate.

GBRA requested Black & Veatch develop and implement a plan to evaluate the condition of the upstream hinges at Lake Dunlap Dam. The purpose of the evaluation was to, based on the condition of the hinges, determine if the gates at other dam locations are still safe to remain in service.

2.0 Hinge Assembly Dive Inspection

On July 26, 2019 U.S. Underwater Services, LLC was contracted to inspect the failed Gate No. 2 and retrieve a hinge assembly from Gate No. 1. The reason for the inspection was to determine which elements of the Gate No. 2 hinge assembly remained attached to the concrete spillway and to evaluate the condition of an unfailed hinge assembly from Gate No. 1. A four-member dive team inspected, from the upstream side of the spillway, the upstream hinge area of Gate No. 2. The inspections included all thirteen of the upstream hinge connection points.

The major components of each hinge assembly include the castings which are anchored to the concrete spillway, the hinge plates which are anchored to the gate truss, and the pin which connects the castings to the hinge plates. A failure of any one of these three components could result in a catastrophic failure of the gate. See original construction drawings Figure 5-20 and Figure 5-21 which presents the typical cross section of the gate assembly and hinge connection.

The following are the findings from the dive inspection of the Lake Dunlap Dam Gate No. 2 upstream hinge locations:

- All of the thirteen hinge casting pairs which are partly embedded in the concrete were found to be in place still anchored to the concrete. The hinge pins of all thirteen hinge assemblies were still in place and connected to the castings.
- The concrete structure to which the hinge castings are anchored was in fair condition with no severe damage observed.
- At all thirteen hinge locations the hinge plates previously connected to the hinge pins were missing. It is presumed the hinge plates were ripped from the hinge pins during failure of the gate. Small broken pieces of hinge plates were found at some hinge locations. The

portion of the hinge plates that were found were in poor condition with significant corrosion observed. Photos of the hinge plate pieces recovered during the inspections are included in Figure 5-1.

- The upstream leaf and the downstream leaf of the gate assembly were washed downstream of the spillway and were not inspected.

3.0 Hinge Assembly Visual Inspection

On August 7, 2019 one hinge assembly from Lake Dunlap Dam Gate No. 1 was removed from the gate and brought onto dry land for inspection. Removal of the hinge assembly was labor intensive; requiring almost 2 weeks for the diver and contractor teams to access the hinge assembly and then cut it from the gate. The design of the gates does not provide for removal or replacement of the hinge assemblies. The destructive removal of a hinge assembly prevents that gate from being put back into service without significant repairs to replace the hinge assembly. Once the hinge assembly was on dry land, it was disassembled and cleaned with a wire brush to visually inspect the three components of the assembly; the castings, the hinge plates, and the pin. See Figure 5-2 to Figure 5-5.

- The castings were found to be in fair condition with little sign of wear or corrosion. See Figure 5-6 and Figure 5-7.
- The hinge plates were found to be in poor condition. The hinge plates exhibit significant corrosion on the upstream side of the hinge plates with less corrosion on the downstream side of the hinge plates. The notch in the hinge plates for the pin shear key is still well defined on the downstream side of the connection whereas on the upstream side corrosion has eliminated any indication of the notch. See Figure 5-8 to Figure 5-15.
- The hinge pin is the most degraded of the three components of the hinge assembly. The hinge pin has lost approximately one-third to one-half of its cross-sectional area. The section loss is not uniform around the circumference of the pin. It is not apparent if the section loss is a result of corrosion alone or a combination of corrosion and wear. See Figure 5-16 to Figure 5-19.
- The components of the inspected hinge assembly were no longer interacting with each other as intended. The hinge components were all still held together but no longer functioning as an engineered hinge. The design of the hinge includes two steel shear keys between the hinge plates and the pin. While there were visual indications that the hinge assembly had been constructed with the shear keys, the severe section loss on the pin and to a lesser extent the hinge plates showed that the shear keys had not been present for an extended period of time. The purpose of the shear keys is to prevent rotation of the pin within the hinge plates. By connecting the pin and the hinge plates, rotation is forced to occur between the pin and the castings. The surface areas in contact between the pin and the castings is much larger than the surface area in contact between the pin and the hinge plates. This larger surface area results in a much lower stress between the rotating parts and presumably less wear on the hinge assembly. What was found during inspection and disassembly of the hinge assembly is that because of severe section loss there was no longer a tight fit of the pin through the hinge plates but instead there were extreme gaps between the pin and hinge plates resulting in a loose and misaligned connection.

It is our engineering opinion that for the hinge assembly inspected; the castings are probably suitable for continued use, the hinge plates are highly questionable for continued use, and the hinge

pin is unacceptable for continued use. As a failure of any one of the critical components can result in a failure of the entire hinge assembly, all three critical components must be suitable for continued use of the hinge assembly. As the condition of the pin is unacceptable and the condition of the hinge plates is questionable, the inspected hinge assembly is not acceptable for continued use.

After visual inspection of the hinge assembly, it was decided that neither destructive nor nondestructive laboratory testing of the assembly or its components would provide any data which would change our engineering opinion regarding the suitability of the hinge assembly for continued use. Our opinion is based on the observable 90 years of corrosion and not on any nonvisible flaw in the materials or original design.

The opinions above are based on visual inspection of only one hinge assembly. Inspection of additional hinge assemblies could increase the certainty of this opinion. However, due to the destructive nature of the inspection, inspection of hinge assemblies on additional gates would require destructive testing of the gates which would render them nonfunctional. If additional hinge assemblies where to be removed and inspected, it is likely that the relative degradation of the three critical components might change. However, based on the age and exposure of these structures there is little reason to expect all three critical components of any hinge assembly to be in fair condition and suitable for continued use.

4.0 Hinge Assembly Visual Inspection Conclusion

In conclusion, it is our engineering opinion that if the inspected hinge assembly is representative of the condition of the hinges on the other gates then the hinge assemblies are no longer adequate for continued service and thus the remaining gates at all other dams in the system are no longer adequate for continued service.

5.0 Figures

Figure 5-1 Hinge Plate retrieved from Gate No. 2

Figure 5-2 Hinge Assembly

Figure 5-3 Hinge Assembly

Figure 5-4 Castings, Hinge Plates, and Pin

Figure 5-5 Wire Brushing to Clean Hinge Plates

Figure 5-6 Casting

Figure 5-7 Casting

Figure 5-8 Hinge Plates

Figure 5-9 Hinge Plates

Figure 5-10 Hinge Plates

Figure 5-11 Hinge Plates

Figure 5-12 Hinge Plates

Figure 5-13 Hinge Plates

Figure 5-14 Hinge Plates

Figure 5-15 Hinge Plates

Figure 5-16 Pin

Figure 5-17 Pin

Figure 5-18 Pin

Figure 5-19 Pin

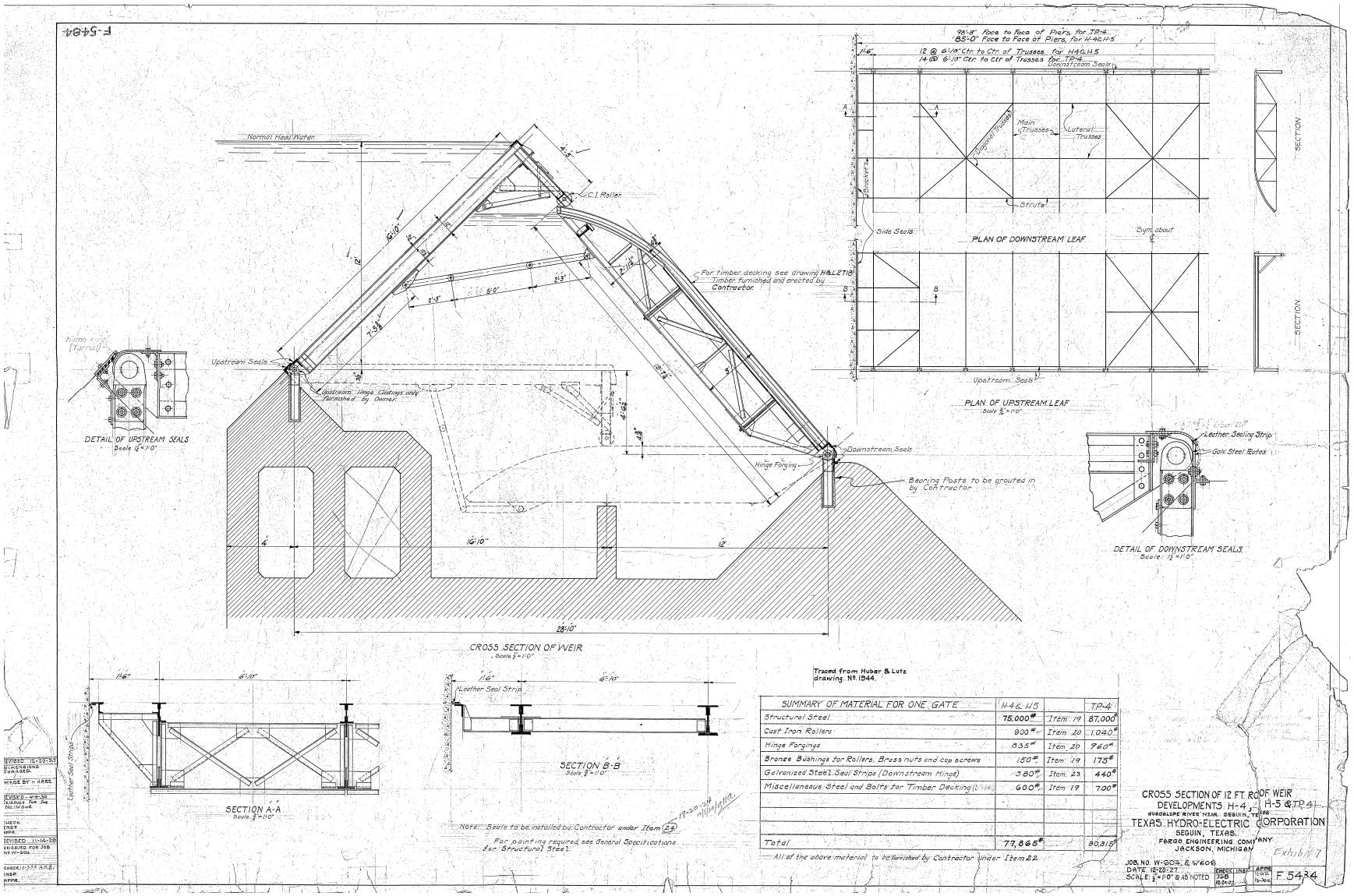

Figure 5-20 Gate Sectional Drawing

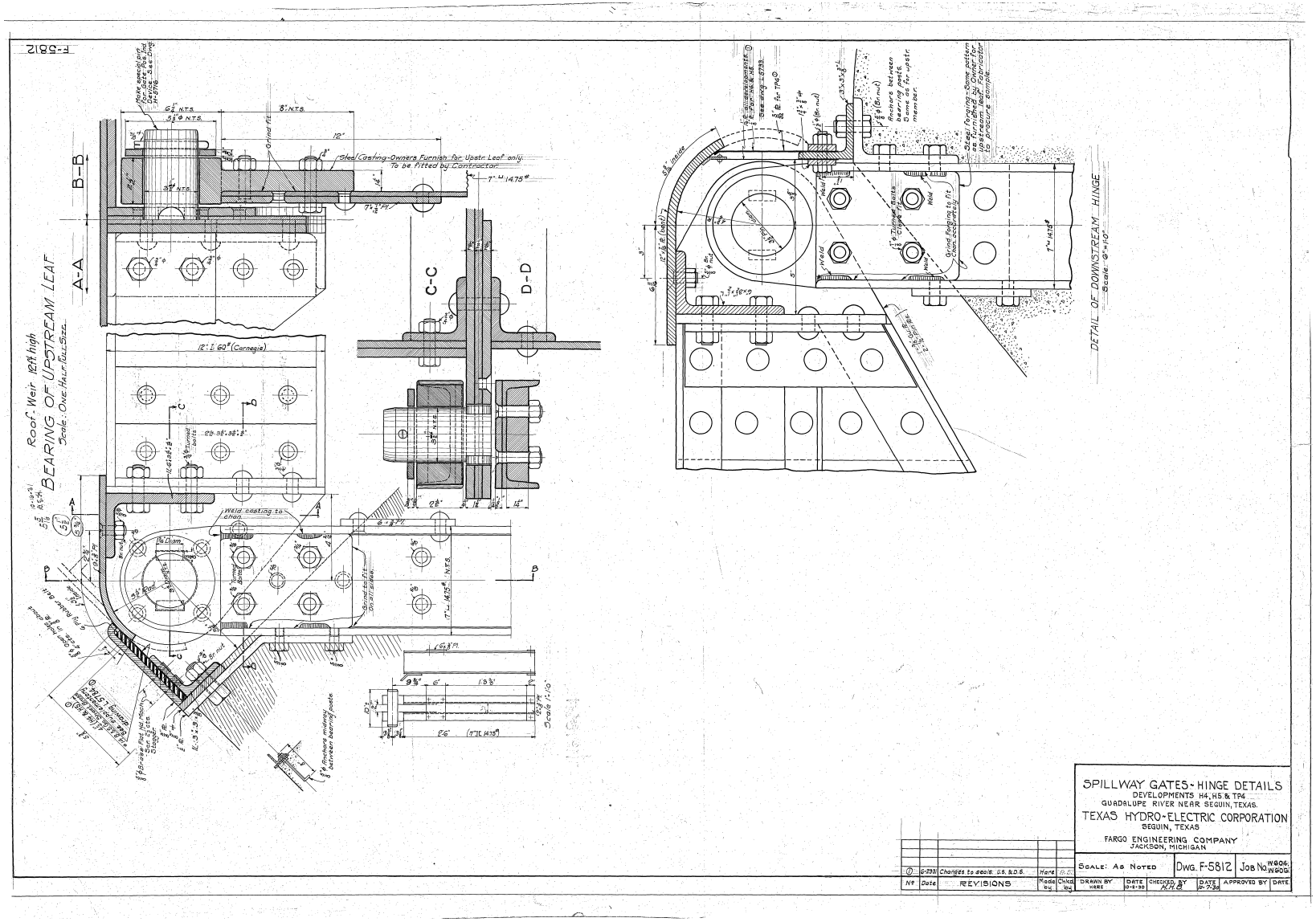

Figure 5-21 Hinge Detail Drawing