the girder and a single girder cannot be removed without destabilizing the span. This results in the need to remove the superstructure, deck and barrier in the approach spans as part of any rehabilitation effort. The existing approach span substructure has several areas of spalled concrete and would require wider cap beams to accommodate the new bridge width. The existing approach span columns have reinforcing steel embedded into the unreinforced concrete footings. Any part of the bridge to remain would have to be evaluated for inclusion in the final structure and the wider roadway will cause additional overturning loads from Live Load that the unreinforced footings wouldn't be able to withstand. Therefore, complete replacement of the approach spans (superstructure and substructure) is recommended for any rehabilitation.

New approach span substructure should be similar to other girder options mentioned elsewhere: square concrete columns with web walls supported on drilled shafts and rock sockets. It is possible to rebuild the approach span girders to match the shape of the girder in the existing bridge, but it would require the girders to be cast-in-place using extensive formwork supported from the ground. This formwork would be extensive enough to restrict the use of the NPS service road and was not considered further. Similar to Alternative 1 and 3, if a rehabilitation of the bridge is considered, new prestressed concrete or haunched steel plate girder spans should be used.

To widen the bridge the existing cap beams supported by the spandrel columns above the arch will need to be lengthened. The cap beams are integral with the existing spandrel columns and the columns have areas of deterioration. Replacement of the cap beams and columns is recommended to carry the additional load from the increased roadway width. New cap beams will need to be wider than existing and constructed from higher strength reinforcing steel in common use today.

The existing arches were analyzed to determine their ability to carry current highway design loads. A wider roadway will allow either arch to see a greater lane fraction of the applied live load than the current bridge. This increased lane fraction results in an HS20 loading requiring 111% of the available capacity of the arch which is unacceptable. Next, a 3S2 designated rating truck was considered and resulted in a live load that needed 95% of the available operating capacity to support the applied load considering load factors applicable to operating conditions. MoDOT's written policy is to post bridges at 86% of the operating rating. Performance of these calculations found the bridge posting load would be 44 Tons based on the capacity of the arches and assuming the new portions of the bridge do not control the rating. This value exceeds the required posting limit and a rehabilitated bridge would not need to be posted for the given rating trucks.

A bridge rehabilitation would have to accept the existing concrete arches not supporting the full HS20 design load and would also need to accept a possible reduced service life of the structure as the anodes are consumed and the possibility of corrosion of the arch concrete returns.

8 Bridge Rail Alternatives Considered

The bridge rails at both sites are a significant part of the character of the existing bridges. The bridge rail is the portion of the bridge most readily observed by the traveling public and a change of bridge rail is considered an impact to the historic nature of the bridge.

Unfortunately, the rail on both bridges fails to meet current standards for crash worthiness and general safety. Options to replace the bridge rails are presented below.

Existing Bridge Rails

The existing rail for the bridge over the Current River is a continuous concrete curb and rail supported on concrete spindles. The concrete curb was originally 7” above the roadway surface but subsequent overlays have nearly buried the entire curb. The rail height is 36 inches above the curb for most of the bridge length reaching 39 inches tall at the posts at each pier. The front of the rail and the typical condition can be seen in Figure 8-1. The back of the rail and a typical post can be seen in Figure 8-2.

The existing rail on the bridge over the Spring Valley is similar to the rail over the Current River except the curb is not continuous and allows roadway drainage to flow over the side of the deck. The height of the intermittent curb is 9” above the deck. The rail height is 30 inches above the curb with posts at various points along the bridge reaching 33 inches tall. A view of the curb, rail and a post can be seen in Figure 8-3.

Figure 8-1. Existing Current River Bridge Rail – Front Face

Figure 8-2. Existing Current River Bridge Rail – Back Face with Post

Figure 8-3. Existing Spring Valley Bridge Rail – Front Face

Standard MoDOT Type D Barrier Curb

One option for the replacement of the bridge rail is the MoDOT Type D barrier curb. This is a 42 inch tall concrete barrier with a single sloping front face. It is the standard barrier curb used on most new construction in the state at this time. The height of this barrier combined with the solid face will limit the sight of the traveling public. The appearance of this barrier curb is a departure in form compared to the existing rail. A formliner pattern can be applied to the back side of this barrier only. This barrier curb is the least cost option considered for this project at approximately $105 per linear foot if formliner is not used. A typical view of this type of barrier can be seen in Figure 8-4.

Figure 8-4. MoDOT Type D Concrete Barrier Curb

Photo from Google Earth.

Vertical Concrete Barrier and Steel Tube Rail

This bridge rail option consists of a 24 inch tall concrete barrier with an 18 inch tall single steel tube rail bolted to the top. This barrier is in place on the bridge carrying Route 19 over Sinking Creek. The overall height of the barrier / railing is 42 inches, but the open rail allows improved site lines from the bridge. The appearance of this barrier curb is a departure from the existing rail but matches the other bridge in the historic district on this route. A formliner pattern can be applied to the back side of this barrier only and a broken fin type pattern was used on the bridge over Sinking Creek. The average bid for this barrier and rail in January 2017 was $190 per linear foot plus the cost of formliner. This rail was used in the cost estimates shown in Section 9 and a unit cost of $200 per linear foot for the concrete barrier and rail combination was assumed. Views of this type of barrier in place on the bridge over Sinking Creek can be seen in Figure 8-5 and Figure 8-6.

Figure 8-5. Vertical Concrete Barrier and Steel Tube Rail – Front Face

Figure 8-6. Vertical Concrete Barrier and Steel Tube Rail – Back Face

Concrete Corral Rail and Steel Rail

This bridge rail option consists of a 32 inch tall concrete barrier with a solid top rail and recessed lower portion. This rail is based on the Kansas DOT Corral Rail. The concrete barrier can be topped with a decorative or structural steel rail. This barrier is in use on the bridge carrying Route 19 over the Missouri River in Hermann, MO. The height of the concrete barrier would limit site lines from the bridge but not as severely as the standard MoDOT Type D barrier curb. A formliner pattern can be applied to the back side of this barrier and to the front side in the recessed portion only; the solid top rail cannot have formliner. The bids for this barrier and rail in August 2015 varied considerably. The winning bid for the combined barrier and rail was $180 per linear foot not including formliner and is estimated to cost approximately $230 per linear foot in 2019. A view of this type of barrier on the bridge in Hermann, MO can be seen in Figure 8-7.

Figure 8-7. Corral Rail and Steel Rail

Photo from Google Earth.

Open Concrete Curb and Rail with Concrete Posts

This bridge rail option is a 42 inch tall concrete barrier with a solid curb and top rail and includes a 6 inch wide “window” every 18 inches. The barrier height and thickness can be increased at points of interest to create the look of posts. This barrier is in use on the bridge carrying Route 76 over Lake Taneycomo in Branson, MO which was also a historic arch structure. The height of the concrete barrier could limit site lines from the bridge but the windows will allow a similar view as the existing bridge rail. The appearance of this rail is the closest to the existing rail of the options considered during this study. The average bid for this barrier in October 2009 was $185 per linear foot and is estimated to cost approximately $240 per linear foot in 2019. Views of this type of barrier on the bridge in Branson, MO can be seen in Figure 8-8 and Figure 8-9.

Figure 8-8. Open Concrete Curb and Rail with Concrete Posts – Front Face

Photo from Google Earth.

Figure 8-9. Open Concrete Curb and Rail with Concrete Posts – Back Face

Photo from Google Earth.

Historic Replacement Rail Developed by Oregon DOT

Recently, the Oregon DOT replaced some historic rail on a bridge in the Columbia River Highway District using a "stealth" rail. The rail consisted of a structural steel rail connected to the bridge deck surrounded by a precast concrete shell formed to mimic the shape of the existing bridge rail. The rail they utilized met design standards for safety and was designed for a TL-4 loading but was not crash tested. To remove snag hazards in the original bridge rail configuration, various shadow lines were included in the new rail and a continuous curb was included along the bottom to increase safety. ODOT is in the process of having their stealth rail design crash tested at a research facility in Texas. A "stealth" rail configuration similar to the existing bridge rail could be designed for this project. The thin spindles of the existing bridge rails may limit the effectiveness of this approach. The cost of this rail option was not available during preparation of this report but is expected to exceed the other options considered. Views of the stealth rail used by ODOT can be seen in Figure 8-10 and Figure 8-11.

Figure 8-10. Oregon DOT Stealth Rail Installation

Photo from Oregon DOT.

Figure 8-11. Oregon DOT Stealth Rail Complete-In-Place

Photo from Oregon DOT.

9 Alternatives Cost Analysis

Cost estimates were developed for the full suite of alternatives described above at both bridge sites. All cost estimates were developed based on fiscal year 2019 prices. Prices should be adjusted to the fiscal year of expected construction. Some alternatives will require the acquisition of new permanent right-of-way and others will require construction easements. The land surrounding both project sites is part of the Ozark National Scenic Riverways and new right-of-way will involve acquisition of park land. Assessing the value of this land or the value for temporary use and necessary remediation of the land or for an in-kind swap of park land for existing state right-of-way is beyond the scope of this study and no right-of-way costs are included in the cost estimates.

Several of the options considered include removal of the existing pedestrian bridge downstream of the Current River Bridge which will require relocation of the existing utilities.