Mt.Murphy Road Bridge
Structural Analysis and Rehabilitation Feasibility

Prpared For

County of El Dorado

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Mt. Murphy Road Bridge at South Fork of the American River Structural Analysis and Rehabilitation Feasibility

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1. Introduction

Mt. Murphy Road Bridge carries Mt. Murphy Road over the South Fork of the American River, in Coloma, California. The steel truss was constructed in 1915 and its approach spans were reconstructed in 1931 using reinforced concrete through-girder. The existing structure is eligible for listing on the National Register of Historic Places (NRHP), therefore rehabilitation of the existing structure needs to be considered as an alternative to replacing the bridge.

The steel truss span over the current low flow channel is 165-feet in length and has a clear width of 10'-0" between face of curbs. The two southern approach spans, starting from the abutment, measure 70-feet and 59-feet, respectively, and have a clear width of 13'-4" between curbs. The northern approach consists of three 65'-6" spans with 13'-4" between curbs.

The abutments and bents are cast-in-place reinforced concrete and part of the original 1915 construction. The piers located in the river are founded on spread footings. Analysis of 100-year and 50-year recurrence interval storm events indicates that scour is a significant concern for both the existing and any proposed foundations.

The bridge has a sufficiency rating of 0.0/100 and is both structurally deficient and functionally obsolete. The steel truss is posted for reduced load capacity with 14 tons for a two axle vehicle, 21 tons for a three axle and 27 tons for a four axle vehicle.

2. Objective

The purpose of this project phase (Phase 1A) is to evaluate rehabilitation of the existing structure to determine if it is a feasible alternative to carry forward. This includes determining how much of the structure needs to be replaced or repaired to accommodate full code compliant, live load. Any fatal flaws to rehabilitating the existing structure will be determined. Additionally, an analysis will be performed to determine whether additional pedestrian loading can be added to both the truss span and the approach spans. Findings of the vulnerability assessment are presented in Section 5 of this report.

Four alternatives are proposed for rehabilitation of the existing structure as described in sections 6.1, 6.2, 6.3 and 6.4 of this report:

Case A	Evaluate rehabilitation of existing bridge to support existing dead load plus full HL-93 live load.
Case B	Evaluate addition of 4-foot wide sidewalks on each side of the existing bridge in addition to one lane of HL-93 live load. Case B involves replacing the existing floorbeams with longer and deeper floorbeam sections to support the additional superstructure width required to accommodate sidewalks on each side of the bridge.
Case C	Evaluate converting the existing bridge to a pedestrian only structure. Case C, addresses rehabilitating the existing structure to support 90 psf pedestrian loading and constructing a new crossing for motorized travel.
Case D	Evaluate the existing bridge for the posted live load trucks. Approximate the maximum truck that the bridge can accept without significant changes to the existing members.

3. Background Information

3.1 Prior Studies

The bridge has been inspected regularly with the last routine inspection occurring on 7/6/2012. An underwater investigation was conducted on 9/11/2012 and a recent fracture-critical inspection was performed on 11/15/2011.

On September 25, 1980, the County posted the bridge for reduced live load of 14 tons for two axles, 21 tons for 3 axles and 27 tons for four axles. The posted loads are based on load rating calculations of the existing structure performed by Caltrans and found in the bridge inspection report dated October, 1979. The conclusion was that the truss is not sufficient for code recommended live load trucks. The truss was then load rated for legal loads, which resulted in the posted loads controlled by the floorbeams, see Figure 1.

Figure 1 - Structurally Deficient and Functionally obsolete: shared vehicular and pedestrian use and posted truck loads

A Caltrans fracture critical inspection found that the eye-bar diagonal members have visible cracks in the turnbuckle loops at the bottom of many members. The report notes that they are approximately 1" long and parallel to the direction of loading and appear to be related to the forging process. These members are considered fracture critical and are recommended for in-depth investigation propagation of the cracks, see Figure 2.

Figure 2 - Fracture critical diagonal eye-bar truss

3.2 As-Built Plans

As-built plans were obtained for reference in preliminary evaluation of the existing structure; however some details were either missing or not legible. After the initial preliminary structural evaluation, a field investigation was conducted on November 4, 2013 to assess as-built plan details that are not clear as well as to inspect members suspected of having structural vulnerability per the preliminary evaluation.

3.3 Field Investigation

No in-depth field inspection was conducted as part of this work. A walk through review was conducted on November 1, 2013 to assess the general condition of the controlling members, primarily to estimate the estimated amount of corrosion to include in the analysis.

The truss members are in good condition overall. There is minor rusting and primer coat is exposed in many areas. Field measurements of members accessible from the bridge deck indicate there is minimal section loss of the steel truss members. A condition factor of 0.95 is recommended for capacity reduction of steel in "good" condition, per the Manual for Bridge Evaluation (MBE) Table 6A.4.2.3-1. The condition factor is a reduction of the nominal capacity to account for increased uncertainty in the resistance of deteriorated elements.

The southern and northern approach spans are in "fair" condition and a condition factor of 0.85 will be used to reduce member capacity. Visual inspection of the bridge soffit identified longitudinal and transverse cracks visible in the soffit. In addition, there is exposed rebar due to low concrete cover. There is very large stone aggregate and the presence of other material (hay, pine needles and even a hack saw blade) that reflect poorly on the quality of concrete used for the approach spans, abutments and piers.

The deck slab is cracked and aggregate is exposed in many areas due to wear and abrasion. There is a longitudinal crack that runs the length of the southern approach approximately 12" below the top of girder; most likely a construction joint prior to placing the remaining upper portion of the rail girder.

3.4 Approach Spans

The approach spans were reconstructed in 1936-1937, replacing the old timber trusses with a reinforced concrete deck and through-girder superstructure. The northern approach spans consists of three 65’ long variable depth spans, while the southern approach consists of a 69’ and 59’ variable depth spans. The typical section consists of a 7.7" thick deck slab with through-girders that also act as traffic barriers and provide a clear road width of 13'-4". The clear width reduces to 10'-8" at the truss span piers, see Figure3. Figure 4 shows large, stone aggregate in the concrete.

Figure 3 - Expansion joint at end of truss spans showing sub-standard approach, barriers and transition

Figure 4 - Exposed large aggregates on underside of approach spans

3.5 Steel Truss

The main span steel truss is 162'-0" long with a concrete deck supported on rolled steel stringers on rolled steel floorbeams. The concrete deck was added in 1931 and replaced a timber deck. Truss members consist of rolled sections, plates and eye-bars. A more detailed description of the truss members is presented below.

The top chord members are rolled channels, laced together on the top and bottom side at the ends panels and laced together over the three center panels.

The interior vertical members are rolled channels laced together. The verticals at each end of the truss span are rolled steel angles connected by lacing bars.

The bottom chords are steel plates. The last two panels at each end of the truss consist of four rolled angles connected by lacing bars.

Diagonal members at the center panel consist of one 1- 1/8" steel bar, while all other diagonals consist of two steel plates with eye-bar turnbuckle connections at the ends. Diagonal members are essentially tension-only eye-bars, which cannot resist cycles of compression induced by earthquake loading.

The main truss has top and bottom lateral bracing member and overhead lateral bracing trusses that run transversely at each panel point. Several of these have been damaged by truck strikes. This lateral truss is not specifically evaluated as part of this vulnerability assessment, but will require member replacement at the truck strike locations and rehabilitation of many existing members, see Figure 5. Top and bottom lateral bracing members and the overhead lateral bracing frames are single rolled angles.

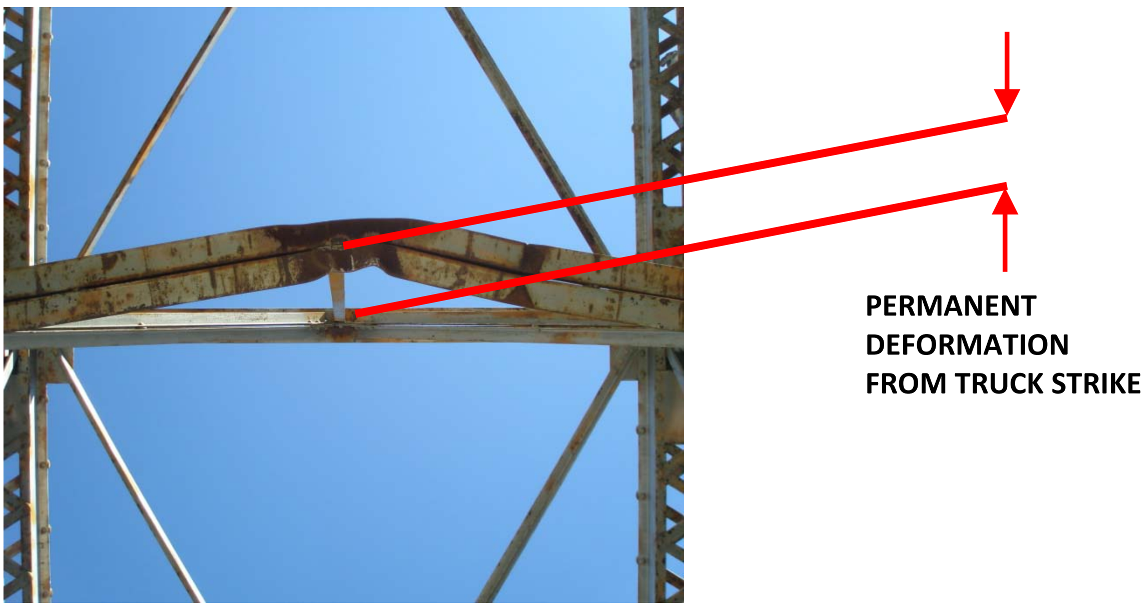

Figure 5 - Truck strike in upper lateral bracing frame (on bridge, looking straight up)

3.6 Foundations

The foundations at the abutments and piers are cast-in-place reinforced concrete structures founded on spread footings. These foundations are scour critical due to the high velocity of the river flows and the small footprint of the existing foundations. A Bridge Scour Plan of Action was prepared on September 9, 2010 with a report summary stating that bridge foundation was unknown and scour potential would be evaluated when more pertinent information regarding the foundations becomes available. A 1982 report states that the structure is likely founded on firm strata on an outcropping of decomposed granite immediately upstream. A hydraulics review conducted on December 19, 2005 concludes there is a slight possibility of problems. The 1982 report noted that the pier at the east end of the truss was scoured down to the top of the footing. The pier footing along the northern face is exposed by up to 1.6'. The exposure decreases to approximately 6" along the west and east faces of the pier. The pier concrete is moderately abraded throughout, see Figure 6. The proposed ultimate countermeasure in the report is to replace the bridge but daily monitoring during flood events was also required.

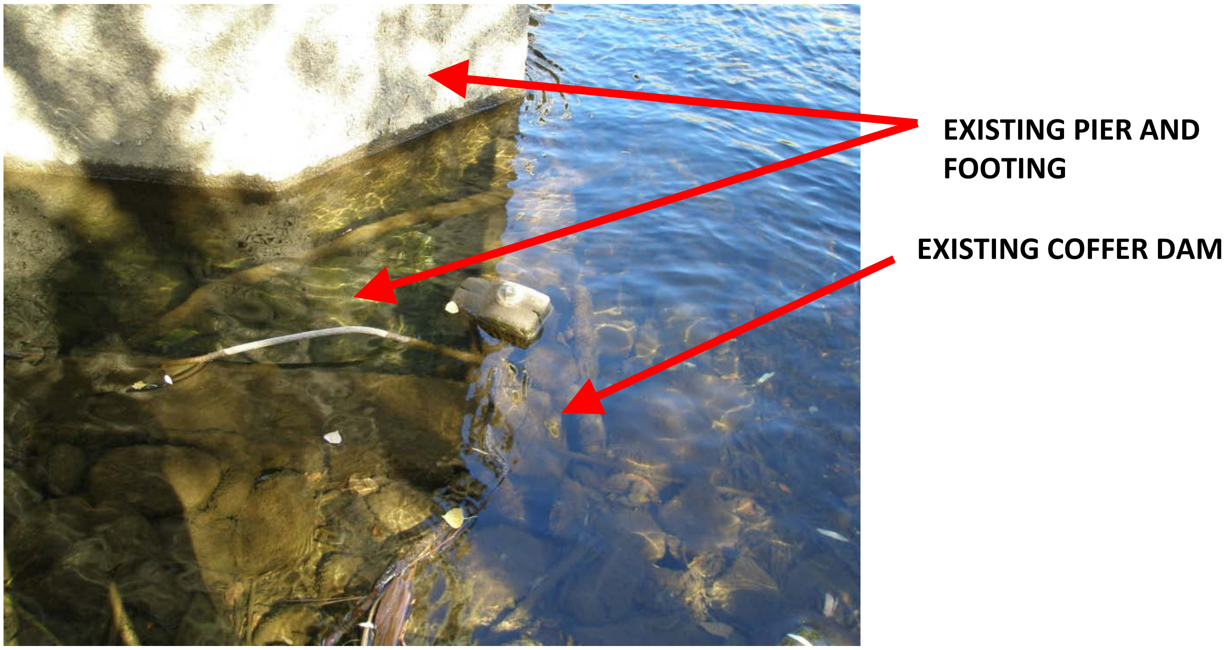

Figure 6 - Existing Pier at South end of Truss Span, North truss span pier similar

4. Study Approach

A three-dimensional finite element model was built to determine member demands to compare with calculated capacity of existing structural elements and reduced by condition factors per the MBE. The approach and truss structures are evaluated for existing dead loads plus one lane of HL-93 live load as defined in the AASHTO LRFD Bridge Design Specifications (Case A). The bridge was also evaluated for load Cases B, C and D as described in the Sections 6.2, 6.3 and 6.4 respectively.

Capacities of truss members were determined in accordance with the AASHTO LRFD Bridge Design Specifications, 4th Edition, with Interims through 2008. The ability of the bridge to resist current live loads was expressed as a Demand to Capacity Ratio (DCR). DCR values less than 1.0 indicate that the members fully comply with the current bridge design code; DCR values greater than 1.0 indicate a deficiency in the member. For the purpose of this analysis, steel truss members are assumed to have 30 ksi yield strength per AASHTO MBE. The assumed deck slab and approach slab concrete strength is 2.5 ksi and reinforcing steel strength is 33 ksi per MBE.

Funding from the Highway Bridge Program (HBP) would likely not be approved for rehabilitation efforts that do not fully address functional obsolescence, therefore a detailed DCR summary is not provided for load Cases B-D. Instead, discussion of the analysis performed and the required rehabilitation measures are presented to better understand the effort required to preserve the existing structure.

No analysis was performed for of the abutments and piers and rehabilitation measures therefore are estimated based on judgment and experience with past projects.

5. Analysis of the Existing Bridge Historic Structure

The bridge has a sufficiently rating of 0.00/100 and is both structurally deficient and functionally obsolete. The bridge superstructure has a condition rating of 5 per the latest bridge inspection report. The bridge will require significant improvements to strengthen it sufficiently to support existing dead load and one lane of HL-93 live load for compliance with the AASHTO Bridge Design Specifications.

The bridge is also functionally obsolete with a narrow steel truss span only providing 10'-8" of width between face of curbs while the approach spans provide 13'-4" clear between curbs. Roadway approaches, barriers and transitions are sub-standard and currently there is no safe passage for shared vehicular and pedestrian traffic, see Figures 1 and 4.

5.1.1 Approach Spans

The north approach is 196’ long, consisting of three, 65’ long reinforced concrete deck slab and through-girder superstructure, continuously supported on reinforced concrete abutments and piers. The northern approach superstructure girders are adequate to resist dead load plus HL-93 live load flexure (DCR = 0.88) and shear demand (DCR = 0.95) from the longitudinal analysis.

The south approach is 129’ long, consisting of 70’ and 59’ simply supported spans with reinforced concrete deck slab and through-girder superstructure supported on reinforced concrete abutments and piers. The southern approach through-girders are deficient for positive bending at midspan with a DCR = 1.17 for the 70’ span and 1.13 for the 59’ span. Shear capacity was found to be acceptable with a max DCR = 0.95.

Transversely, the deck slab for both the northern and southern approach spans are lightly reinforced and not adequate to support of HL-93 wheel loads. The DCR = 2.68 for the slab. This is based on a conservative transverse strip analysis and a more refined three dimensional analysis of the deck slab would likely produce a lower DCR. However, significant cracking in the deck slab, as noted during field investigations and as documented in bridge inspection reports, indicates that the deck slab is showing signs of distress and will require strengthening.

5.1.2 Steel Truss

The steel truss was analyzed in a three dimensional model using the CSi Bridge computer program. The following are the results of the analysis for various truss members, deck supporting members and the deck slab.

Floorbeams

Floorbeams are rolled W15x5-1/2 sections located at each panel point, see Figure 7. They are connected to the truss vertical members and support the deck stringers. Factored Strength-l demand produces a DCR of 1.86 for Case A.

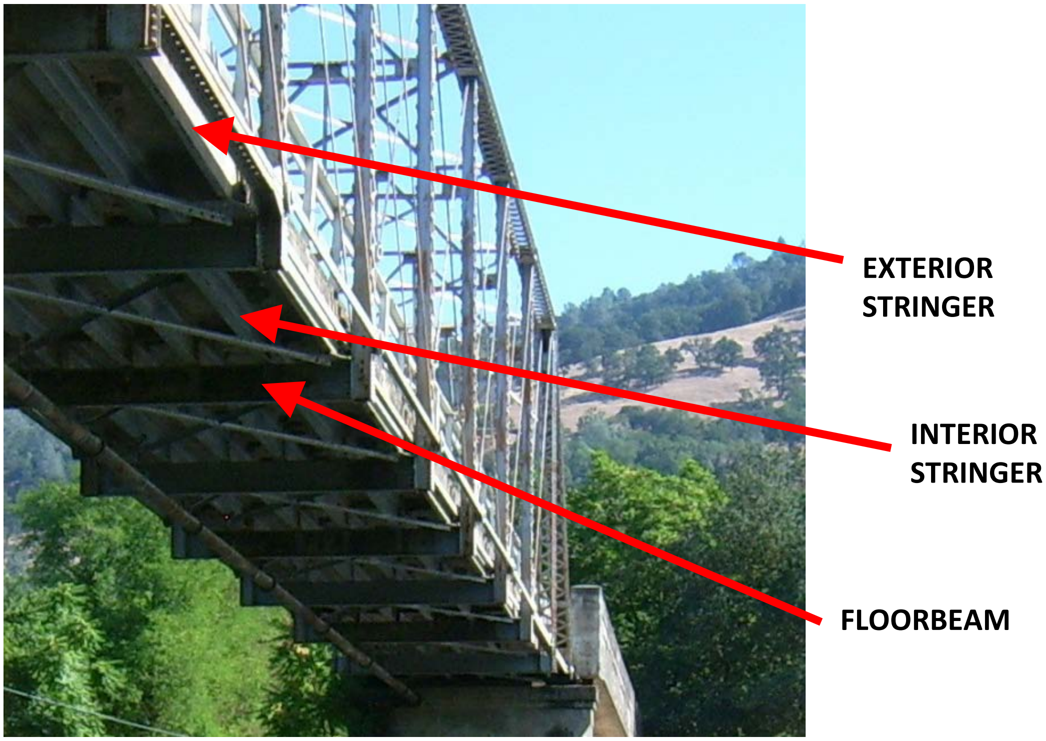

Figure 7 - Steel Truss Span

Stringers

Exterior stringers are rolled C12x5 and interior stringers are rolled W12x5 sections that are simply supported between panel points, see Figure 1. By inspection, interior stringer demands will be larger for dead load plus one lane of HL-93 live load. Factored Strength-l demand produces a DCR of 1.62.

Deck

The existing deck slab is lightly reinforced and not adequate to support HL-93 wheel loads. Factored Strength-l demand produces a DCR of 3.78.

Truss Members

The truss consists of bottom chords, top chords, verticals and diagonal members. There are numerous truss members that are not adequate for dead load plus one lane of HL-93 live loads and most would require replacement or a significant strengthening retrofit. Table 1 below, shows a summary of steel truss vulnerabilities for load cases A, C and D. Case B assumes that members will require replacement for support of pedestrian walkways in additional to code compliant live load evaluated in Case A, therefore DCR for Case B are not reported in the Table 1 DCR summary.

Table 1 - Existing Steel Truss DCR Summary

Location	Panel Point Locations	Truss Member Description	Demand / Capacity (DCR)		
			HL-93 (Case A)	Ped Loads (Case C)	Posted Loads (Case D)
Bottom Chord	P0-P2 & P7-P9	4 Ls 3x2.5x3/8 Laced	0.88	0.66	0.67
Bottom Chord	P2-P3 & P6-P7	2 Bars 4x1-1/16	1.26	0.99	1.01
Bottom Chord	P3-P4 & P5-P6	4 Bars 4x11/16	0.88	0.71	0.71
Bottom Chord	P4-P5	4 Bars 4x3/4	1.27	1.00	1.00
Top Chord	P0 (Bottom)-P1 (Top)	Diagonal top chord member at ends of the truss, 2-10" Cs Laced + 15x5/16 plate + 2-3x1/2 Fluts	0.51	0.36	0.37
Top Chord	P1-P3 & P6-P8	2-10"x20# Cs	1.33	0.90	0.92
Top Chord	P3-P6	Interior 3 panels, same section as diagonal top chord member	0.81	0.55	0.56
Vertical	P1 & P8	4 Ls 2.5x2.5x5/16	0.47	0.18	0.34
Vertical	P2-P7	2-7"x12.25# Cs	0.70	0.42	0.51
Diagonal	P1-P2 & P7-P8	2 Bars 3x3/4	1.79	1.21	1.30
Diagonal	P2-P3 & P6-P7	2 Bars 2.5x5/8	1.94	1.16	1.39
Diagonal	P3-P4 & P5-P6	2 Bars 2x1/2	2.07	0.58	0.93
Diagonal	P3-P4 & P5-P6	1-1" square bar	NA	NA	NA
Diagonal	P4-P5	1-1.125" square bar (both diagonals in this panel)	NA	NA	NA

5.1.3 Foundations

No analysis was performed for the foundation as a part of the phase. Visual inspection and reference to bridge inspection reports indicate that the foundations are vulnerable to scour at the piers supporting the truss span over the river. A 1982 bridge inspection report noted that the pier at the east end of the truss was scoured down to the top of footing. The pier footing along the northern face exposed approximately 1.6'. The exposure decreases to approximately 6" along the west and east faces of the pier. Pier concrete is moderately abraded throughout.

Per review of the as-built plans, the foundations are lightly reinforced resulting in seismic vulnerabilities. Transverse confinement reinforcing bars are spaced at 24" along the length of the pier columns, which is not adequate for ductility capacity requirements in the current Caltrans Seismic Design Criteria. Column longitudinal reinforcing is not sufficiently developed into the pier cap or footing connections resulting in connection vulnerability to resist tension loads from transverse overturning analysis. The piers are also vulnerable to overturning since there are no piles below the footings to take tension forces and the footings are relatively shallow.

6 Rehabilitation Recommendations

6.1 Case A - Rehabilitation of the Existing Bridge for AASHTO HL-93 Live Load

The existing Mt. Murphy Road Bridge is eligible for listing on the National Register of Historic Places and while it is not yet known if it is actually historic, rehabilitation of the existing structure needs to be considered. The first rehabilitation assessment evaluates measures required to strengthen the existing structure to support dead load and one lane of HL-93 live load per AASHTO Bridge Design Specifications. The following sections provide recommendations for rehabilitation of the as-built structure based on the results of the vulnerability assessment presented in Section 5.

6.1.1 Approach Spans

The vulnerability assessment presented in Section 5 indicates that the northern approach span girders are adequate to resist existing dead load plus one lane of HL-93 live load, and therefore no strengthening retrofit is required. Transversely, the thin deck slab is lightly reinforced and not adequate for support HL-93 wheel loads. Strengthening retrofit of the existing deck slab on top and bottom or replacement of the deck slab will be required. To avoid full replacement of the deck slab, strengthening could likely be accomplished by using carbon fiber planks transversely along the length of the deck slab. A polyester concrete application on the top surface of the deck will be required, after placement of the carbon fiber planks, to smooth out the surface without significantly changing the deck thickness. The polyester concrete will also serve to seal the deck from future water infiltration through the existing cracks.

The southern approach spans are simply supported and the bottom face of the through-girders in each span is showing signs of transverse cracking. Analysis indicates that the girders are overstressed for Case A loading and strengthening would be required with carbon fiber plank type retrofit along the bottom surface of the through-girders to increase flexural capacity. The deck slab would be strengthened similar to the northern approach spans.

6.1.2 Steel Truss

The main span steel truss has many structural issues and would need either replacement or strengthening of nearly all the members to resist existing dead load plus HL-93 live load.

The interior stringers and floorbeams are overstressed and require replacement with heavier sections.

Since replacement of the stringers and floorbeams is required below the deck, the concrete deck would likely be replaced with a light-weight concrete deck to reduce to the dead load applied to the truss.

Bottom chord members between Panels 2-7 require replacement with larger sections. The bottom chord at the interior panels consists of multiple plates connected by pins. These pins will require inspection to evaluate their condition.

Top chord members between Panels 2-6 are overstressed for compression loading and will require replacement.

Upper lateral bracing has a truck strikes at every panel point along the truss and requires complete replacement.

Diagonal truss members are overstressed and require replacement due to fatigue cracks in the turnbuckles at the ends of the eye-bar members. In addition, the eye-bar diagonal members would also be replaced because they are essentially tension-only eye-bars, which cannot resist compression induced by earthquake loading.

Connections need to be designed for the ultimate capacity of the members framing into them, and they will require strengthening with new gusset plates and additional bolts at all locations that members are strengthened.

Expansion joints at the abutments and piers are in poor condition and should be replaced along with the floorbeams, stringers and deck.

Bridge bearings and pins connecting truss members will be inspected and may require replacement depending on condition observed during retrofit construction.

Sandblasting and painting of the remaining portions of the truss will be required. Due to the age of the structure, lead paint is likely to be encountered which may require full tenting of the structure during the retrofit and painting operations. There is also extensive mercury contamination in the area, which may have to be mitigated during retrofit construction work on any of the piers.

6.1.3 Foundations

The existing abutments and piers will be protected in place during retrofit construction. Existing pier footings located within the river flood limits have a small footprint and are considered scour critical. A pier underpinning retrofit consisting of additional footing concrete and piling will be constructed to mitigate scour and seismic vulnerabilities. Scour protection will also be recommended for protection of the retrofitted pier footings. The pier columns will require seismic retrofit to address inadequate transverse confinement reinforcing bars, which results in poor ductility capacity to resist seismic movements. The pier column connection to the superstructure and footing is vulnerable to tension loads from seismic overturning due to inadequate development of longitudinal column bars. Likewise the reinforcing bars also lack flexural capacity needed to sustain the lateral earthquake loads. It would be extremely costly and difficult to perform these retrofits and maintain the historic shape and proportions of the existing piers since the footings would have to be enlarged and the columns enlarged with steel casings or added concrete and bar reinforcing.

6.1.4 Cost Estimate

The estimate for Case A of $6,500,000 is based on the preliminary quantities required to fix the structural deficiencies identified in Section 5 and the rehabilitation/retrofit recommendations listed in Section 6.1. See Appendix Section A.1 for the complete Case A planning level cost estimate. Note that at this early stage of the project, for comparison purposes, the estimates include only high level bridge and roadway costs. Costs for the environmental document preparation, right of way acquisition, and engineering and construction management are not included and would increase the total project cost.

6.2 Case B - Rehabilitation of the Existing Bridge for Support of Pedestrian Sidewalks and HL-93 Live Load

The Case B concept involves retrofit and widening of the existing bridge to support four foot wide pedestrian sidewalks on each side plus strengthening to accept full HL-93 live load. Four foot wide sidewalks are the minimum allowed by AASHTO.

6.2.1 Approach Spans

In addition to the retrofit work required to widening the existing structure, the retrofit recommendations summarized in Section 6.1.1 are still required.

To accommodate the additional width of pedestrian walkways, the existing approach span superstructure would be widened using a prestressed concrete U-girder superstructure constructed on widened abutments and piers. The U-girder superstructure was selected to be similar to the existing approach spans and blend with historic features of the approach spans. U-girder and deck slab superstructures typically have a depth-to-span ratio of 0.06, per Caltrans Bridge Design Aids, and provides an economical bridge type for the existing approach span depth and lengths.

6.2.2 Steel Truss

The truss floorbeams would be replaced with longer, heavier sections to accommodate additional superstructure width needed for support of adjacent pedestrian walkways. Section 5 of this report identified numerous truss members that are structurally deficient and require replacement to resist dead load plus HL-93 live load. By inspection of the truss vulnerabilities indentified in Section 5, adding longer and heavier floorbeam sections for support of pedestrian walkways would further increase demand on the existing truss resulting in additional members requiring replacement or retrofit strengthening. Most of the truss members will require replacement resulting in significant loss of historic nature of the bridge.

6.2.3 Foundations

Retrofit of the existing pier foundations would be similar to Section 6.1.3, in addition to widening the existing piers and footings to support the increased superstructure width. Widening of the abutments will require construction of new approach retaining walls and granular backfill.

6.2.4 Cost Estimate

The estimate for Case B of $14,200,000 is based on the preliminary quantities and retrofit construction required to fix the structural deficiencies identified in Section 5, in addition to bridge widening to accommodate parallel pedestrian walkways. See Appendix Section A.2 for the complete planning level cost estimate. Note that at this early stage of the project, for comparison purposes, the estimates include only high level bridge and roadway costs. Costs for the environmental document preparation, right of way acquisition, engineering and construction management are not included and would increase the total project cost.

6.3 Case C - Rehabilitation of Existing Bridge for Pedestrian Use and Construct New Bridge

Case C involves rehabilitation of the existing bridge to support full width pedestrian loading and constructing a new bridge for vehicular loading. It is assumed that no vehicles would be allowed on the pedestrian structure except a light-weight maintenance vehicle.

6.3.1 Approach Spans

The northern and southern approach span deck slab and through-girders are adequate to resist flexure and shear demands from dead load plus 90 psf pedestrian loading over the full 13'-4" width between curbs. No retrofit required.

6.3.2 Steel Truss

The diagonals between Panels P1-P2 / P7-P8 and P2-P3 / P6-P7 are overstressed for dead load plus 90 psf pedestrian loading over the full 10' width between existing curbs, with a max DCR = 1.21. However, all diagonal members are considered fracture critical and would be replaced. The remaining truss members, floorbeams, stringer and concrete deck are adequate for existing dead load plus pedestrian loading and do not require retrofit.

Bridge bearings and pins connecting truss members would be inspected and may require replacement depending on the condition observed. Overhead lateral bracing frame members damaged by truck strikes would be replaced.

6.3.3 Foundations

Retrofit and repair of the existing abutment and piers will be similar to Section 6.1.3 to address scour, seismic and detailing issues.

6.3.4 Cost Estimates

Case C has two estimates. One estimate to rehabilitate the existing bridge as a pedestrian only bridge of $1,700,000 and one to provide a completely new vehicular and pedestrian bridge of $15,300,000. The reason for providing separate estimates is because the Highway Bridge Program will not pay for the rehabilitation of the old bridge as a pedestrian only structure but they will pay for a new vehicular bridge that makes accommodations for pedestrians. See Appendix Sections A.3 and A.4 for the complete planning level cost estimates. Note that at this early stage of the project, for comparison purposes, the estimates include only high level bridge and roadway costs. Costs for the environmental document preparation, right of way acquisition, engineering and construction management are not included and would increase the total project cost.

6.4 Case D - Evaluate Existing Bridge for Posted Vehicular Loads

Case D involves evaluating the existing bridge for vulnerabilities to support current posted live loads.

6.4.1 Approach Spans

The truss span is currently posted for reduced vehicular loading; however the approach spans are not. The approach spans were not load rated during in this vulnerability analysis and will need to be evaluated if the structure is not rehabilitated.

6.4.2 Steel Truss

The truss was evaluated for posted truck loads as defined by the sign posted on the approaches to the bridge. The latest bridge inspection report contains load rating calculations for support of the posted live loads used for this evaluation. Analysis of the existing structure for the current posted truck loads indicates that the diagonal members are overstressed with a max DCR = 1.21 for the 27 ton, 4 axle truck and DCR = 1.16 for 21-ton, 3 axle truck. This is based on a condition factor reduction of section capacity of 0.85 and an assumed 5% section loss for corrosion. Structural steel strength of 33 ksi per the MBE was used, however it should be noted that the load rating calculations performed by Caltrans and documented in the latest bridge inspection report use 40 ksi steel strength which results in structural capacity that is adequate for the current posted loads. Load rating calculations performed in 1980 used the Load Factor Design (LFD), whereas load rating using the slightly heavier truck associated with the current Load and Resistance Factor Design (LRFD) would result in more restrictive load posting. Testing of structural steel is required determine the actual steel strength to use for analysis of the current posted loads and evaluate the reduced truck load the bridge can safely support without retrofit.

6.4.3 Posting Recommendations

Analysis of the posted loads shows that the diagonal members from Panel 1 - Pane 4 of the steel truss are overstressed approximately 15-20 percent. Replacement of these diagonal members is recommended to maintain the current load posting. If the diagonal members are not replaced then the bridge should be reposted with a lower truck weight of 20 tons for a three axle truck. Alternately, further evaluation could be performed after material testing is performed to determine the actual strength of the steel used for the truss.

6.4.4 Cost Estimate

There is no cost estimate for analysis Case D. Retrofitting the bridge for lower than full live load would not be fundable by the Highway Bridge Program and so is not worth considering. Since the number of members needing replacement would be smaller than Case A, the cost would be less than Case A, but would still be substantial since retrofitting for seismic and for scour would still be recommended.

7 Discussion and Conclusions

These recommendations address structural deficiencies identified from loading associated with analysis Cases A - D. The following is a summary of the report findings and recommendations for the existing Mt. Murphy Road Bridge.

7.1 Historic Issues

The original Mt. Murphy Road Bridge was constructed in 1915 consisting of timber approach spans and a riveted, steel truss. The timber approach spans were replaced in 1931 with reinforced concrete through-girder and deck slab superstructure. Today, only the steel truss span over the South Fork of the American River and its concrete piers remain from the original construction and is eligible for listing on the Nation Register of Historic Places.

The Grange is an existing structure on the National Register of Historic Places and located along Highway 49 in the Gold Discovery State Park. The structure is and cannot be relocated, however the Grange have indicated that there could be some flexibility in right-of-way encroachment to accommodate the project with the preference for a replacement bridge capable of accommodating pedestrians.

7.2 Functional Obsolete (FO) and Structural Deficient (SD)

The following is a summary of structural deficiencies and functional obsolete issues for each analysis case evaluated.

Table 2 - Rehabilitation Summary

Analysis Case	Description of Rehabilitation Alternative	Estimate	Pros & Cons	Design Exceptions Required
Case A	Rehabilitate existing structure to support 1-lane of HL-93 live load.	$6,500,000 (SD Estimate)	Pros: 1) Keeps the charm of a one lane bridge 2) Load postings removed. Cons: 1) Rehabilitation cost likely will not be approved for HBP funding, requires significant County funds 2) Bridge closed during retrofit construction or expensive temporary bridge required 3) Long-term maintenance cost will be substantial compared to a new bridge 4) Approximately $700/SF of existing bridge deck 5) Bridge still subject to delays due to one way traffic.	1) Sub-standard approach roadway and bridge widths 2) No safe passage for pedestrians 3) Sub-standard vertical clearance 4) Metal railing on truss would likely need to be designed for lower crash level due to width limitations.

			6) Loses all historical value since a majority of the truss needs to be replaced.	
Case B	Construct pedestrian walkways adjacent to existing bridge. Rehabilitate existing structure to support 1-lane of HL-93 live load and the adjacent walkways attached to the existing structure.	$14,200,000 (SD+FO Estimate)	Pros: 1) Preserves charm of a one lane bridge 2) Provides safer passage for pedestrian traffic. 3) Load postings removed Cons: 1) HBP funding requires design exceptions and is not guaranteed. 2) Bridge closed during retrofit construction or expensive temporary bridge required 3) Approximately $1,550/SF of existing bridge deck 4) Loses all historical value since a majority of the truss needs to be replaced. 5) Long-term maintenance cost will be substantial compared to a new bridge	1) Sub-standard bridge width, single lane with no shoulders 2) Sub-standard vertical clearance 3) Metal railing on truss would likely need to be designed for lower crash level due to width limitations.
Case C	Rehabilitate existing structure for support of pedestrian loading only and light maintenance vehicle. Bridge replacement to be constructed on new alignment.	$1,700,000 for Rehabilitation as a pedestrian bridge and $15,300,000 for a replacement bridge	Pros: 1) Preserve existing historic structure for other uses 2) Provide safe passage for pedestrians and two way vehicular traffic 3) Lower maintenance and inspection costs compared to the rehabilitation options 4) Approximately $555/SF for new 45’-6” wide bridge deck is lowest cost of all alternatives Cons: 1) Cost for rehabilitation of existing bridge not supported by the HBP 2) Requires more right of way	

			than other alternatives	

7.3 Highway Bridge Program Funding

Replacement or rehabilitation of the existing bridge will be funded through the HBP. Caltrans has indicated that the HBP will not approve funding for rehabilitation of bridge structural deficiencies unless all the functional obsolescence issues are addressed. Since Mt Murphy Road Bridge is eligible for the National Register of Historic Places, according to FHWA criteria, a vulnerability assessment of the existing structure and preliminary rehabilitation cost estimates were developed to assess the feasibility of rehabilitation versus bridge replacement.

7.4 Recommendation

Comparison of cost estimates to rehabilitate the existing Mt. Murphy Road Bridge structure indicates that rehabilitation for full truck loadings is feasible. However, the $6,500,000 cost to rehabilitate only the structural deficiencies of the existing bridge would have to be borne entirely by the County without any Federal participation. Widening the existing bridge for pedestrians for $14,200,000 is also feasible but is very expensive and requires several difficult design exceptions. HBP funding for widening the existing bridge is also not certain and the County may have to pay all or part of the widening costs. Neither option would preserve the bridge as historic if it were actually listed as historic. Looking at the $554 cost per square foot of bridge deck for the replacement shows that replacement is three times as efficient as retrofitting and widening the old bridge. Therefore, it is recommended that the existing Mt. Murphy Bridge be replaced with a new structure to be determined in Phase 1B of this study process.

Appendix A - Cost Estimates

A.1 Rehabilitation of Existing Structure plus One Lane of HL-93 Live Load (SD Estimate)

[ ] GENERAL PLAN ESTIMATE   [X] ADVANCE PLANNING ESTIMATE

RCVD BY:

IN EST:

OUT EST:

BRIDGE: Mt Murphy Road Bridge (Retrofit for SD)	BR. No.: 25C-0004	DISTRICT:	
TYPE:		RTE:	Mt Murphy Road
CU:		CO:	El Dorado
EA:		PM:	
LENGTH (FT): 489.00	WIDTH (FT): 14.25 & 18.67	AREA (SF)=	8,400

DESIGN SECTION:

# OF STRUCTURES IN PROJECT :	01	EST. NO.	1
PRICES BY :	Hans Larsen	COST INDEX:	2012
PRICES CHECKED BY :	Hans Strandgaard	DATE:	12/18/2013
QUANTITIES BY:	Hans Larsen	DATE:	12/18/2013

	CONTRACT ITEMS	TYPE	UNIT	QUANTITY	PRICE	AMOUNT
1	REMOVE CONCRETE (CY)		CY	45	$300.00	$13,500.00
2	PREPARE CONCRETE BRIDGE DECK SURFACE		SF	6,050	$0.25	$1,512.50
3	LEAD COMPLIANCE PLAN		LS	1	$5,000.00	$5,000.00
4	STRUCTURE EXCAVATION (BRIDGE)		CY	107	$50.00	$5,350.00
5	STRUCTURE EXCAVATION (TYPE A)		CY	55	$150.00	$8,250.00
6	STRUCTURE BACKFILL (BRIDGE)		CY	6	$60.00	$360.00
7	24" CIDH CONCRETE PILING		LF	320	$300.00	$96,000.00
8	SEAL COURSE CONCRETE		CY	20	$300.00	$6,000.00
9	STRUCTURAL CONCRETE, BRIDGE FOOTING		CY	80	$600.00	$48,000.00
10	STRUCTURAL CONCRETE, BRIDGE		CY	202	$700.00	$141,400.00
11	STRUCTURAL CONCRETE, LIGHTWEIGHT		CY	28	$750.00	$21,000.00
12	DRILL AND BOND DOWEL		LF	1,219	$30.00	$36,570.00
13	FURNISH POLYESTER CONCRETE OVERLAY		CF	1,010	$80.00	$80,800.00
14	JOINT SEAL (MR = 1")		LF	85	$35.00	$2,975.00
15	BAR REINFORCING STEEL (BRIDGE)		LB	64,107	$1.50	$96,160.50
16	FURNISH STRUCTURAL STEEL (BRIDGE)		LB	95,000	$4.00	$380,000.00
17	ERECT STRUCTURAL STEEL (BRIDGE)		LB	95,000	$16.00	$1,520,000.00
18	CLEAN AND PAINT STRUCTURAL STEEL (EXISTING BRIDGE)		LS	1	$40,000.00	$40,000.00
19	CUSTOM METAL RAILING		LF	330	$400.00	$132,000.00
20	FIBER PLANK RETROFIT		SF	6,050	$30.00	$181,500.00
21	TEMPORARY BRIDGE		LS	1	$1,000,000.00	$1,000,000.00
22	ROADWAY APPROACH CONSTRUCTION (WALLS + FILL)		LS	1	$50,000.00	$50,000.00

SUBTOTAL	$3,866,378
TIME RELATED OVERHEAD	$386,638
MOBILIZATION (@ 10 %)	$472,557
SUBTOTAL BRIDGE ITEMS	$4,725,573
CONTINGENCIES (@ 25%)	$1,181,393
BRIDGE TOTAL COST	$5,906,966
COST PER SQ. FOOT	$703.18
BRIDGE REMOVAL (CONTINGENCIES INCL.)	
AESTHETIC IMPROVEMENTS (@10%)	$590,697
GRAND TOTAL	$6,497,663
BUDGET ESTIMATE AS OF	$6,500,000

ROUTING

1. DES SECTION
2. OFFICE OF BRIDGE DESIGN - NORTH
3. OFFICE OF BRIDGE DESIGN - CENTRAL
4. OFFICE OF BRIDGE DESIGN - SOUTH
5. OFFICE OF BRIDGE DESIGN - WEST
6. OFFICE OF BRIDGE DESIGN SOUTHERN CALIFORNIA

COMMENTS:
1) Construct infill walls at approach span piers
2) Strengthen pier columns, all piers
3) Retrofit footings, all piers
4) Fiber plank retrofit bottom of through-girders on southern approach spans
5) Fiber plank retrofit top and bottom of deck slab, all approach spans
6) Assume temporary bridge rental for 2 yrs
7) Assume temporary supports needed during replacement of truss members, steel erection unit cost increased
8) Assume lump sum cost for construction of Ret. Walls, railings and placement of backfill for roadway approaches

Escalated Budget Estimate to Midpoint of Construction *

Escalation Rate per Year 5.0%

Years Beyond Midpoint	Escalated Budget Est.
1	$6,825,000
2	$7,166,000
3	$7,524,000

Years Beyond Midpoint	Escalated Budget Est.
4	$7,900,000
5	$8,295,000

* Escalated budget estimate is provided for information only, actual construction costs may vary. Escalated budget estimates provided do not replace Departmental policy to update cost estimates annually.

A.2 Rehabilitation of Existing Structure and Construction of Adjacent Pedestrian Walkways (SD + FO Estimate)

[ ] GENERAL PLAN ESTIMATE   [X] ADVANCE PLANNING ESTIMATE

RCVD BY: IN EST: OUT EST:

BRIDGE:	Mt Murphy Road Bridge (Retrofit for SD + FO)	BR. No.:	25C-0004
TYPE:		DISTRICT:	
CU:		RTE:	Mt Murphy Road
EA:		CO:	El Dorado
		PM:	
LENGTH (FT):	489.00	WIDTH (FT):	14.25 / 18.67
AREA (SF)=	8,400		

DESIGN SECTION:			
# OF STRUCTURES IN PROJECT :	01	EST. NO.	1
PRICES BY :	Hans Larsen	COST INDEX:	2012
PRICES CHECKED BY :	Hans Strandgaard	DATE:	12/18/2013
QUANTITIES BY:	Hans Larsen	DATE:	12/18/2013

	CONTRACT ITEMS	TYPE	UNIT	QUANTITY	PRICE	AMOUNT
1	REMOVE CONCRETE (CY)		CY	45	$300.00	$13,500.00
2	PREPARE CONCRETE BRIDGE DECK SURFACE		SF	6,050	$0.25	$1,512.50
3	LEAD COMPLIANCE PLAN		LS	1	$5,000.00	$5,000.00
4	STRUCTURE EXCAVATION (BRIDGE)		CY	160	$50.00	$8,000.00
5	STRUCTURE EXCAVATION (TYPE A)		CY	85	$150.00	$12,750.00
6	STRUCTURE BACKFILL (BRIDGE)		CY	10	$60.00	$600.00
7	24" CIDH CONCRETE PILING		LF	920	$300.00	$276,000.00
8	SEAL COURSE CONCRETE		CY	30	$300.00	$9,000.00
9	STRUCTURAL CONCRETE, BRIDGE FOOTING		CY	132	$600.00	$79,200.00
10	STRUCTURAL CONCRETE, BRIDGE		CY	330	$700.00	$231,000.00
11	STRUCTURAL CONCRETE, LIGHTWEIGHT		CY	48	$750.00	$36,000.00
12	DRILL AND BOND DOWEL		LF	1,140	$30.00	$34,200.00
13	FURNISH POLYESTER CONCRETE OVERLAY		CF	1,010	$80.00	$80,800.00
14	JOINT SEAL (MR = 1")		LF	192	$35.00	$6,720.00
15	BAR REINFORCING STEEL (BRIDGE)		LB	96,160	$1.50	$144,240.00
16	FURNISH STRUCTURAL STEEL (BRIDGE)		LB	221,682	$4.00	$886,728.00
17	ERECT STRUCTURAL STEEL (BRIDGE)		LB	221,682	$16.00	$3,546,912.00
18	CLEAN AND PAINT STRUCTURAL STEEL (EXISTING BRIDGE)		LS	1	$40,000.00	$40,000.00
19	CUSTOM METAL RAILING		LF	978	$400.00	$391,200.00
20	FIBER PLANK RETROFIT		SF	6,050	$30.00	$181,500.00
21	PC/PS CONCRETE SLAB (SPAN = 59' TO 70')		SF	6,050	$200.00	$1,210,000.00
22	TEMPORARY BRIDGE		LS	1	$1,000,000.00	$1,000,000.00
23	ROADWAY APPROACH CONSTRUCTION (WALLS + FILL)		LS	1	$250,000.00	$250,000.00

SUBTOTAL		$8,444,863
TIME RELATED OVERHEAD		$844,486
MOBILIZATION (@ 10 %)		$1,032,150
SUBTOTAL BRIDGE ITEMS		$10,321,499
CONTINGENCIES	(@ 25%)	$2,580,375
BRIDGE TOTAL COST		$12,901,873
COST PER SQ. FOOT		$1,535.88
BRIDGE REMOVAL (CONTINGENCIES INCL.)		
AESTHETIC IMPROVEMENTS (@10%)		$1,290,187
GRAND TOTAL		$14,192,061
BUDGET ESTIMATE AS OF		$14,200,000

ROUTING

1. DES SECTION
2. OFFICE OF BRIDGE DESIGN - NORTH
3. OFFICE OF BRIDGE DESIGN - CENTRAL
4. OFFICE OF BRIDGE DESIGN - SOUTH
5. OFFICE OF BRIDGE DESIGN - WEST
6. OFFICE OF BRIDGE DESIGN SOUTHERN CALIFORNIA

COMMENTS:
1) Construct infill walls at approach span piers
2) Strengthen pier columns, all piers
3) Retrofit footings, all piers
4) Fiber plank retrofit bottom of through-girders on southern approach spans
5) Fiber plank retrofit top and bottom of deck slab, all approach spans
6) Assume temporary bridge rental for 2 yrs
7) Assume temporary supports needed during replacement of truss members, steel erection unit cost increased
8) Assume lump sum cost for construction of Ret. Walls, railings and placement of backfill for roadway approaches
9) Environmental, ROW and Engineering costs not included

Escalated Budget Estimate to Midpoint of Construction *

Escalation Rate per Year   5.0%

Years Beyond Midpoint	Escalated Budget Est.
1	$14,910,000
2	$15,656,000
3	$16,439,000
4	$17,261,000
5	$18,124,000

* Escalated budget estimate is provided for information only, actual construction costs may vary. Escalated budget estimates provided do not replace Departmental policy to update cost estimates annually.

A.3 Retrofit for Conversion to Pedestrian Bridge (Case C Estimate)

	GENERAL PLAN ESTIMATE	X	ADVANCE PLANNING ESTIMATE

RCVD BY:

IN EST:

OUT EST:

BRIDGE: Mt Murphy Road Bridge (Retrofit for Pedestrian Use) BR. No.: 25C-0004 DISTRICT:

TYPE: RTE: Mt Murphy Road

CU: CO: El Dorado

EA: PM:

LENGTH (FT): 489.00 WIDTH (FT): 14.25 & 18.67 AREA (SF)= 8,400

DESIGN SECTION:

# OF STRUCTURES IN PROJECT :	01	EST. NO.	1
PRICES BY :	Hans Larsen	COST INDEX:	2012
PRICES CHECKED BY :	Hans Strandgaard	DATE:	12/18/2013
QUANTITIES BY:	Hans Larsen	DATE:	12/18/2013

	CONTRACT ITEMS	TYPE	UNIT	QUANTITY	PRICE	AMOUNT
1	LEAD COMPLIANCE PLAN		LS	1	$5,000.00	$5,000.00
2	STRUCTURE EXCAVATION (BRIDGE)		CY	107	$50.00	$5,350.00
3	STRUCTURE EXCAVATION (TYPE A)		CY	55	$150.00	$8,250.00
4	STRUCTURE BACKFILL (BRIDGE)		CY	6	$60.00	$360.00
5	24" CIDH CONCRETE PILING		LF	320	$300.00	$96,000.00
6	SEAL COURSE CONCRETE		CY	20	$300.00	$6,000.00
7	STRUCTURAL CONCRETE, BRIDGE FOOTING		CY	80	$600.00	$48,000.00
8	STRUCTURAL CONCRETE, BRIDGE		CY	202	$700.00	$141,400.00
9	DRILL AND BOND DOWEL		LF	1,219	$30.00	$36,570.00
10	JOINT SEAL (MR = 1")		LF	85	$35.00	$2,975.00
11	BAR REINFORCING STEEL (BRIDGE)		LB	64,107	$1.50	$96,160.50
12	FURNISH STRUCTURAL STEEL (BRIDGE)		LB	20,000	$4.00	$80,000.00
13	ERECT STRUCTURAL STEEL (BRIDGE)		LB	20,000	$16.00	$320,000.00
14	CLEAN AND PAINT STRUCTURAL STEEL (EXISTING BRIDGE)		LS	1	$40,000.00	$40,000.00
15	CUSTOM METAL RAILING		LF	330	$400.00	$132,000.00

SUBTOTAL		$1,018,066
TIME RELATED OVERHEAD		$101,807
MOBILIZATION (@ 10 %)		$124,430
SUBTOTAL BRIDGE ITEMS		$1,244,302
CONTINGENCIES	(@ 25%)	$311,076
BRIDGE TOTAL COST		$1,555,378
COST PER SQ. FOOT		$185.16
BRIDGE REMOVAL (CONTINGENCIES INCL.)		
AESTHETIC IMPROVEMENTS (@10%)		$155,538
GRAND TOTAL		$1,710,916
BUDGET ESTIMATE AS OF		$1,700,000

ROUTING

1. DES SECTION
2. OFFICE OF BRIDGE DESIGN - NORTH
3. OFFICE OF BRIDGE DESIGN - CENTRAL
4. OFFICE OF BRIDGE DESIGN - SOUTH
5. OFFICE OF BRIDGE DESIGN - WEST
6. OFFICE OF BRIDGE DESIGN SOUTHERN CALIFORNIA

COMMENTS: 1) Construct infill walls at approach span piers
2) Strengthen pier columns, all piers
3) Retrofit footings, all piers
4) Assume temporary supports needed during replacement of truss members, steel erection unit cost increased
5) Environmental, ROW and engineering costs not included

Escalated Budget Estimate to Midpoint of Construction *

Escalation Rate per Year 5.0%

Years Beyond Midpoint	Escalated Budget Est.
1	$1,785,000
2	$1,874,000
3	$1,968,000

Years Beyond Midpoint	Escalated Budget Est.
4	$2,066,000
5	$2,169,000

* Escalated budget estimate is provided for information only, actual construction costs may vary. Escalated budget estimates provided do not replace Departmental policy to update cost estimates annually.

A.4 Bridge Replacement (Case C Estimate)

[ ] GENERAL PLAN ESTIMATE [X] ADVANCE PLANNING ESTIMATE

RCVD BY:

IN EST:

OUT EST:

BRIDGE:	Mt Murphy Road Bridge (Bridge Replacement)	BR. No.:	25C-0004
TYPE:		DISTRICT:	
CU:		RTE:	Mt Murphy Road
EA:		CO:	El Dorado
		PM:	
LENGTH (FT):	550.00	WIDTH (FT):	45.50
AREA (SF)=	25,025		

DESIGN SECTION:			
# OF STRUCTURES IN PROJECT :	01	EST. NO.	1
PRICES BY :	Hans Larsen	COST INDEX:	2012
PRICES CHECKED BY :	Hans Strandgaard	DATE:	12/18/2013
QUANTITIES BY:	Hans Larsen	DATE:	12/18/2013

	CONTRACT ITEMS	TYPE	UNIT	QUANTITY	PRICE	AMOUNT
1	PC BULB-T GIRDER (APPROACHES)		SF	13,650	$180.00	$2,457,000.00
2	CUSTOM TIED-ARCH (SPAN = 250')		SF	11,375	$450.00	$5,118,750.00
3	TEMPORARY BRIDGE		LS	1	$1,000,000.00	$1,000,000.00
4	ROADWAY APPROACH CONSTRUCTION (WALLS + FILL)		LS	1	$500,000.00	$500,000.00

SUBTOTAL	$9,075,750
TIME RELATED OVERHEAD	$907,575
MOBILIZATION (@ 10 %)	$1,109,258
SUBTOTAL BRIDGE ITEMS	$11,092,583
CONTINGENCIES (@ 25%)	$2,773,146
BRIDGE TOTAL COST	$13,865,729
COST PER SQ. FOOT	$554.08
BRIDGE REMOVAL (CONTINGENCIES INCL.)	
AESTHETIC IMPROVEMENTS (@10%)	$1,386,573
GRAND TOTAL	$15,252,302
BUDGET ESTIMATE AS OF	$15,300,000

ROUTING

1. DES SECTION
2. OFFICE OF BRIDGE DESIGN - NORTH
3. OFFICE OF BRIDGE DESIGN - CENTRAL
4. OFFICE OF BRIDGE DESIGN - SOUTH
5. OFFICE OF BRIDGE DESIGN - WEST
6. OFFICE OF BRIDGE DESIGN SOUTHERN CALIFORNIA

COMMENTS:
1) Bridge width = 6.75'+4'+12'+12'+4'+6.75'
2) Assumes replacement on existing Mt Murphy Road alignment
3) Average per square foot cost of Bulb-T and Tied Arch = $300/SF
4) Environmental, ROW and engineering costs not included

Escalated Budget Estimate to Midpoint of Construction *

Escalation Rate per Year 5.0%

Years Beyond Midpoint	Escalated Budget Est.
1	$16,065,000
2	$16,868,000
3	$17,711,000
4	$18,597,000
5	$19,527,000

* Escalated budget estimate is provided for information only, actual construction costs may vary. Escalated budget estimates provided do not replace Departmental policy to update cost estimates annually.

References

AASHTO LRFD Bridge Design Specifications, Sixth Edition, 2012

Manual for Bridge Evaluation, First Edition, 2008

LRFD Guide Specification for Design of Pedestrian Bridges, December 2009

Caltrans Bridge Design Aids

Caltrans Cost Data, 2012

Caltrans Comparative Bridge Cost, January 2012