SH 82 Grand Avenue Bridge Rehabilitation Feasibility Study

Prepared For:

The Colorado Bridge Enterprise
The Colorado Department of Transportation, Region 3

Prepared By:

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Introduction

The Colorado Department of Transportation (CDOT) in conjunction with the Colorado Bridge Enterprise (CBE) has begun the process to address the deficiencies of the Grand Avenue Bridge (Structure F-07-A) in Glenwood Springs, Colorado. The structure carries State Highway 82 over 7th Street, the Union Pacific Railroad, the Colorado River, Interstate 70, North River Street (Frontage Road) and the Glenwood Hot Springs parking lots. The bridge is rated as Functionally Obsolete and has a sufficiency rating of only 43.

The original structure was constructed in 1953. It is a nine-span, 676-foot- long bridge. The nine spans are composed of three continuous steel units, supported by reinforced concrete piers on shallow foundations. Originally, the bridge carried two lanes of traffic with a curb-to-curb width of 30 feet. In 1968, the original sidewalks were removed and two lanes of traffic were added to the bridge along with a cantilevered sidewalk. In 1985 a pedestrian bridge was built adjacent to the bridge and most of the sidewalk was removed. A short stretch of sidewalk on the south end still remains and provides access to the pedestrian bridge.

One of the goals of the CBE is to evaluate the economic effectiveness on whether to repair or replace CDOT rated “poor” bridges. A complete list of the CBE Goals can be found in Appendix A. This document discusses the feasibility of rehabilitating the existing Grand Avenue Bridge. It assumes that the bridge will continue to carry four lanes of traffic. Use of a couple or other alternative, which would reduce the number of traffic lanes to two on Grand Avenue was not considered.

Problems with the Existing Bridge

The Grand Avenue Bridge is almost 60 years old and is no longer compatible with current traffic conditions and standards. Problems with the existing bridge include:

- The bridge is too narrow. The bridge has four, 9’-4” lanes and no shoulders, making driving across the bridge unsafe and uncomfortable. The public has noted concern about this issue at recent public outreach meetings.
- The vertical clearance directly over 7th Street is only 13’-1” (12’-0” turning from Wing Street) and there is evidence of multiple vehicle collisions/scrapes.
- The existing bridge was constructed with about 22’-6” of vertical clearance over the Union Pacific Rail Road (UPRR). This does not meet the current federal standard of 23-feet. UPRR standards, which should be met in new bridges if economically feasible, require 23’-4” of vertical clearance.
- The piers on either side of I-70 are too close to the highway. They create a pinch point on I-70, preventing any widening of I-70 or modifications to the westbound off-ramp or eastbound on-ramp.
- The deck and girders do not meet current design standards, and the inventory rating of the bridge is low. The 60-year-old bridge is carrying a greater live load than it was originally designed to carry (4 lanes vs. 2 lanes).
- The sufficiency rating of the bridge is low, only about 43%.
- The bridge is considered “functionally obsolete” by the threshold in the National Bridge Inventory (NBI). This is due to inadequate width and underclearances.

- Pier 5 is located in the Colorado River on a spread footing that does not extend below the calculated 500-year scour depth.
- The bridge is old. The structure has been modified twice to meet changing traffic demands, and is currently carrying more traffic than it was ever designed to handle. The bridge is also experiencing some spalling, delamination, and corrosion. Though these problems can be repaired as part of a rehabilitation, unforeseen maintenance problems could occur at any time, and it is reasonable to assume that a brand new bridge would require less maintenance than a rehabilitated 60-year-old bridge.

Scour Details

A qualitative assessment of the potential scour conditions of the Grand Avenue Bridge was completed based on a review of existing hydraulic documents. Based on this evaluation, it was determined that though Pier 5 is currently protected from scour by riprap, a rehabilitation would require more substantial mitigation.

Sufficiency Rating Details

A bridge's sufficiency rating is an attempt to represent the structural and functional condition of a bridge with a single number. The rating is determined by a formula that assigns a percentage rating from 100 percent (completely sufficient) to zero percent (completely deficient) to a given bridge. Factors of the sufficiency rating include measurement of structural capacity as well as functional items, such as roadway width and bridge clearances, which are evaluated based on a scale from zero to nine. The sufficiency rating formula is defined in the FHWA's 1995 report, "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (Report No. FHWA-PD-96-001).

Based on information from CDOT's 2010 "Structure Inspection and Inventory Report", the Grand Avenue Bridge has a sufficiency rating of about 43%. Table 1 lists all the factors that negatively impact the sufficiency rating of the bridge and indicate what percentage they reduce the rating by.

Table 1: Factors Negatively Impacting Sufficiency Rating

Factor	Issue	Reduction
Inventory Rating	The current load rating of the bridge is 25.3 tons. The deck controls the rating, but the rating of girders is also substandard (31.2 tons). A rating of 36 tons is required for no reduction in sufficiency rating. Because rehabilitation will require that the deck and girders be upgraded/replaced to meet current design standards and carry an HL-93 load, the final load rating of the rehabilitated bridge will be more than 36 tons and there will be no reduction.	11%
Bridge Roadway Width	The bridge is currently 37.5' wide and too narrow for the number of lanes it carries. • To have no reduction in sufficiency rating a bridge cannot be more than 2' narrower than the approach roadway. To meet this criterion the Grand Avenue Bridge would have to be widened to 66.5'. • If the bridge were widened to have four standard 12-foot lanes with 6-foot shoulders, the total width would be 60 feet	19%

Table 1: Factors Negatively Impacting Sufficiency Rating		
Factor	**Issue**	**Reduction**
	and the rating would increase by 12%. • While 12-foot lanes are preferable, a reduction in lane width (11 feet) for urban roadways is permissible by AASHTO. In addition, Chapter 7 of AASHTO states "On long bridges, defined as bridges with overall lengths in excess of 60m [200ft], the offsets to parapets, rails, or barriers may be reduced to 1.2m [4ft] where shoulders or parking lanes are provided on the arterials." Two 4-foot shoulders and four 11-foot lanes would require a 52-foot wide deck. If the bridge were widened to 52', the sufficiency rating would increase by 2%.	
Underclearances	The vertical clearance at 7th street and the lateral clearance at I-70 (distance from the edge of the traveled way to the nearest pier) are substandard. To increase the sufficiency rating the bridge would need to be raised at 7th Street and the piers near I-70 would have to be relocated. (The vertical clearance over the UPRR does not meet current UPRR standards, but this does not affect the sufficiency rating based on FHWA criteria.)	4%
Detour Length	The 2010 inventory report indicated a 62-mile detour length, though the detour for heavy vehicles is over 100 miles and the detour for light commercial traffic is most likely only 5 miles. For rating purposes, the detour for all commercial vehicles should be used, and a detour of 100 miles or more results in a reduction in sufficiency rating of 20%. This reduction cannot be addressed through rehabilitation of the bridge.	20%
Traffic Safety Features	Bridge rail and guardrail, including ends and transitions do not meet current standards. Replacement of bridge rail and guardrail will eliminate this reduction.	3%
	% Possible:	100%
	Total Reduction:	57%
	Sufficiency Rating:	43%

Functional Obsolescence Details

The bridge is functionally obsolete. This means that certain geometric characteristics have a rating below 4 on the "Structure Inspection and Inventory Report." There are four locations on the bridge that contribute to this classification.

- The I-70 Eastbound right horizontal clearance from edge of traveled way to bridge pier is substandard (Rating Code = 3).
- The I-70 Westbound right horizontal clearance from edge of traveled way to bridge pier is substandard (Rating Code = 3).
- The vertical clearance over 7th Street is substandard (Rating Code 3).
- The bridge curb-to-curb bridge width (37.5 feet) is substandard (Rating Code 2).

These geometric characteristics also contribute to the low sufficiency rating. All four of these substandard geometric characteristics would need to be corrected for the bridge not to be classified as functionally obsolete.

Feasibility of Rehabilitation

Rehabilitation of the Grand Avenue Bridge may be a viable option, but the owner, users, and local community must understand that rehabilitation is a major undertaking and cannot fix every problem associated with the bridge in its current condition.

A rehabilitation project could:

- Widen the bridge.
- Bring the load rating of the deck and girder up to current code.
- Increase the vertical clearance at 7th Street and the UPRR.
- Partially mitigate scour issues.
- Replace the current bridge rail and approach guardrail.
- Increase the sufficiency rating of the bridge.

It would be preferable to mitigate all underclearance issues as part of rehabilitation, but in this case it is not reasonably achievable. Lateral underclearance issues at I-70, could only be mitigated by relocation of Piers 6 and 7. This would require complete replacement of spans 7, 8, and 9.

The following problems would likely not be mitigated as part of rehabilitation:

- Increasing the lateral underclearance at I-70.
- Significantly reducing the current maintenance demands.
- Removing the “functionally obsolete” categorization from the bridge.

General Rehabilitation Work

Rehabilitating the bridge will require that it be widened. Two options for widening the bridge are shown below in Figure 1. Both options require widening the piers, adding girders, and replacing the deck and bridge rails.

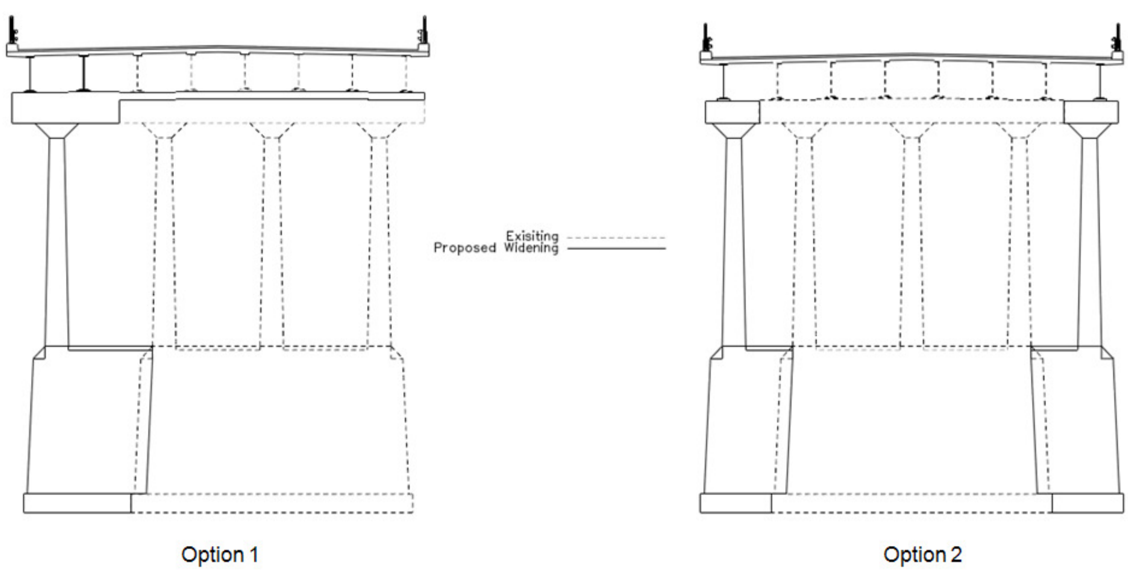


Figure 1: Widening Schematic

In addition, any rehabilitation would include bringing all of the structural elements up to current design standards. In this case, the standard would be Load and Resistance Factor Design, including HL-93 loading. Analysis of every structural element, including girders, stiffeners, cross-frames, splices, bearings, abutments, pier caps, pier columns, and footings, would be required. Any element not satisfying the current code requirements would need to be rehabilitated.

Girder Rehabilitation

For the girders, a preliminary level analysis was conducted to determine the level of rehabilitation required. A description of the analysis including assumptions is provided in Appendix B. In general, making the girders composite with the deck would provide enough additional strength for existing girders to carry the HL-93 loads. However, fatigue is a major problem and some other issues will require attention. Concerns for rehabilitating the girders include:

- Over the piers where the girders are continuous, the compression flanges are overstressed due to Lateral Torsional Buckling. This could be mitigated by adding bottom flange bracing on either side of each pier affected.
- In the positive moment region of Span 4 and Span 6 (See Appendix C for exact locations) portions of girder do not have a design fatigue life that extends to 2015, the assumed date of rehabilitation[1]. If the bridge is rehabilitated, these sections of girder will need to be replaced. Removing a section of girder between the pier and the nearest existing field splice in each span would constitute removal and replacement of about 116-feet of girder per line of girders, almost 20% of the total girder length for the bridge.
- At the cover plate location in the positive moment region of Span 3 (See Appendix C for exact location), the fatigue life of the girder will not extend 30 years beyond rehabilitation. If the bridge is rehabilitated, the cover plates in this location will have to be replaced. Additional work may be required to ensure adequate fatigue life.
- At seven stiffener locations along each girder line (See Appendix C for locations), the fatigue life of the base metal where the stiffeners are connected will not extend 30 years beyond rehabilitation. If the bridge is rehabilitated, fatigue at these locations will have to be mitigated by strengthening the girders with plates or some other method rehabilitation.
- The girders do not meet the requirements of AASHTO 6.10.11.1.1 which requires that stiffeners used as connection plates for cross-frames be attached to both flanges. If this requirement is not waived, the stiffeners at all cross-frame locations will have to be retrofitted.

[1] Preliminary analysis of the remaining fatigue life of the existing girders was conducted for two distinct cases. The first case was an evaluation of the remaining fatigue life of the existing bridge in its current state (no rehabilitation). For this case, fatigue life was determined using AASHTO's Manual for Bridge Evaluation, 1st Edition, which allows riveted connections to be considered a Category C fatigue detail. The results of the evaluation case showed that the existing girders have approximately 38 more years of fatigue life. However, if the bridge were to be rehabilitated, it would have to meet the AASHTO LRFD Bridge Design Specifications, where riveted connections are considered a Category D fatigue detail. In this case, the girders have significantly less fatigue life and at some locations the design fatigue life will have expired by the time rehabilitation occurs. See Appendix B for additional details on fatigue analysis.

- The exterior cover plates over all piers are two to five inches too short according to AASHTO 6.10.12.1 which requires the length of a cover plate, in feet, to be greater than (*Lcp/6 + 3*). Where *Lcp* is the depth of the steel section in inches. If this requirement is not waived, all the exterior cover plates at all pier locations will have to be replaced.

The summary of rehabilitation work below includes required girder repairs, based on the preliminary analysis. Not all structural elements were analyzed in detail (see Appendix B), so it is conceivable that further analysis could uncover additional required repairs.

Summary of Required Rehabilitation Work

The following work would be required to rehabilitate the bridge:

- Excavate down to existing footing depth (including any shoring and/or dewatering) at all 8 piers. Pier 5 work is in the middle of the Colorado River.
- Prepare subgrade under portions of piers to be widened.
- Tie into existing footings and pier caps by doweling or some other method and construct widened portion of substructures
- Provide structural scour countermeasures for pier(s) in the river
- Repair existing spalling and delamination on piers
- Rehabilitate portions of existing piers that do not meet current standards.
- Widen abutments and replace retaining walls at both bridge ends as necessary.
- Strengthen piers adjacent to I-70, 7th Street and the UPRR to carry impact loads as required.
- Demolish existing deck and bridge rail in phases (to allow traffic to remain on portions of the bridge). The bridge superstructure would have to be analyzed for its ability to carry required loads with partially removal.
- Raise existing grade of bridge to provide vertical clearance (this work will need to be completed in phases as well).
  - Lift all girders in all spans off of their current bearings.
  - Install risers on existing pier caps for new bearings.
  - Install new bearings.
  - Lower existing girders back into place.
  - Complete minor curb, gutter, and roadway work at 7th as necessary.
  - Complete roadway work on both bridge approaches to adjust vertical alignment to connect into the elevated bridge.
- Bring existing girders up to current code
  - Install shear studs to make replacement deck composite.
  - Provide bottom flange bracing, in all girder bays, on each side Piers 2, 3, 5, 6, 8 & 9.
  - In the positive moment region of Span 4 and Span 6, remove the section of girder between the pier and the nearest field splice. This constitutes removal and replacement of about 116-feet of girder per line of girders, almost 20% of the total girder length for the bridge.
  - At the cover plate location in the positive moment region of Span 3, replace the cover plates and complete additional work to ensure adequate fatigue life as required.
  - At seven stiffener locations along each girder line (42 total), strengthen the girders with plates to mitigate fatigue OR use an alternate method.

  - Waive AASHTO 6.10.11.1.1 OR retrofit all stiffeners at cross-frame locations.
  - Waive AASHTO 6.10.12.1 OR replace exterior cover plate at all pier locations.
- Paint all existing girders and steel components that remain in place.
- Install bearings for new girders.
- Install new girders for widening.
- Construct new deck and bridge rail in phases.

Conclusions and Recommendation

Table 2 summarizes the major problems associated with the Grand Avenue bridge in its current state and the reasonableness of mitigating these problems as part of a rehabilitation project.

Table 2: Rehabilitation Summary

Major Issue	**% Reduction in Sufficiency Rating**	**Contributes to Bridge Being "Functionally Obsolete?"**	**Rehabilitation Options**	**Required Work to Rehabilitate**
Bridge is too narrow.	19.00%	Yes	Widen the bridge.	• Add additional girders to the bridge. • Replace the existing deck and bridge rails. • Widen the existing piers. Includes excavating to existing footing depth at all pier locations, including Pier 5 which is in the middle of the Colorado River.
Bridge has a low load rating.	10.39%	No	Replace the deck and rehabilitate the girders as necessary.	• Complete an extensive analysis of the existing bridge to determine the capacity of all the structural elements. • Install shear studs for new composite deck. • Replace the existing deck and bridge rails. • Provide bottom flange bracing, in all girder bays, on each side Piers 2, 3, 5, 6, 8 & 9. • In the positive moment region of Span 4 and Span 6, remove the section of girder between the pier and the nearest field splice. This constitutes removal and replacement of about 116-feet of girder, almost 20% of the total girder length for the bridge. • At the cover plate location in the positive moment region of Span 3, replace the cover plates and complete additional work to ensure adequate fatigue life as required. • At seven stiffener locations along each girder line (42 total locations), strengthen the girders with plates to mitigate fatigue OR use an alternate method of fatigue rehabilitation. • Waive AASHTO 6.10.11.1.1 OR retrofit all stiffeners at cross-frame locations. • Waive AASHTO 6.10.12.1 OR replace exterior cover plate at all pier locations. • Conduct other repairs determined by extensive analysis.

Table 2 (Cont.): Rehabilitation Summary				
Major Issue	**% Reduction in Sufficiency Rating**	**Contributes to Bridge Being "Functionally Obsolete?"**	**Rehabilitation Options**	**Required Work to Rehabilitate**
Vertical clearance at UPRR does not meet current standards.	NA	No	Raise entire bridge superstructure 1 foot.	• Lift all girders in all spans off of their current bearings. • Install risers on existing pier caps for new bearings. • Install new bearings. • Lower existing girders back into place. • Complete roadway work on both bridge approaches to adjust vertical alignment to connect into the elevated bridge.
Vertical clearance at 7th street does not meet current standards.	4.00%	Yes	Raise entire bridge superstructure 0.83 feet.	• Lift all girders in all spans off of their current bearings. • Install risers on existing pier caps for new bearings. • Install new bearings. • Lower existing girders back into place. • Complete minor curb, gutter, and roadway work at 7th street to ensure proper clearance is achieved. • Complete roadway work on both bridge approaches to adjust vertical alignment to connect into the elevated bridge.
Piers adjacent to I-70 are too close to the highway, creating a pinch point at I-70.	4.00%	Yes	Not feasible to fully address with rehabilitation.	At minimum, piers will need to be strengthened for vehicle impact loading.
The bridge has potential to scour.	NA	Yes	Provide scour mitigation.	Install a ring of driven piles or drilled shafts, or use some other method to mitigate scour.
The bridge is almost 60 years old and will require more maintenance than a new bridge	NA	No	Rehabilitation will repair existing spalling, delamination, and corrosion, but these problems could occur at new locations after rehabilitation. Also, additional unforeseen maintenance problems could arise after rehabilitation.	

A prospective rehabilitation of the Grand Avenue Bridge would be a massive undertaking requiring extensive analysis, design, and major reconstruction. Rehabilitation would provide a wider bridge that meets current design standards and mitigates vertical clearance issues at 7th Street and the UPRR. However, it would not provide a solution to the lateral underclearance at I-70. Even after rehabilitation, the bridge would still be considered functionally obsolete.

Constructing a new bridge would provide the following benefits that a rehabilitation project could not:

- Location of piers could be determined based on current conditions and future plans.
    - The pinch point at I-70 could be mitigated.
    - The need for a pier in the Colorado River could be eliminated.
- The entire structure would be new and money spent would contribute to a structure with a 75 year design life instead of a 30 year design life.
- The cost of future maintenance would be greatly reduced.
- The needs of the local community could be better incorporated into a new design.

In consideration of the above, it is the recommendation of the study team and the Project Work Group (PWG) that the existing Grand Avenue Bridge over the Colorado River be replaced in lieu of rehabilitation. Replacing the existing structure provides a longer-term solution, mitigates all clearance issues and best serves the public as a whole.

Colorado Bridge Enterprise
Program Goals

Accelerate the construction of Colorado's worst bridges to improve public safety

- Evaluate economic effectiveness on whether to repair or replace CDOT rated "poor" bridges
- Poorest bridges should be the highest priority
- Work safely in project execution

Program delivery plan that evaluates various options, encourages creativity, and a variety of solutions

- Use accelerated construction techniques and innovative project delivery
- Establish policy to add eligible bridges [allowable by the FASTER legislation] to the program within financial constraints
- Develop a plan to replace the I-70 viaduct

Be transparent with utilization of public funds

- Regular and accurate reporting to ensure transparency
- Outreach to Stakeholders/Public education
- Execute work in alignment with Statewide Transportation Plan and consistent with statewide investment category goals and objectives for safety, mobility, system quality and program delivery

Build responsible, cost effective projects and optimize use of revenues

- Streamline processes and procedures
- Creatively take advantage of market conditions to finance the program
- Determine appropriate project delivery methodology

Create jobs

- Encourage and build small business participation
- Create competitive bidding environment for small and large contractors and consultants

Appendix B: Preliminary Level Girder Analysis Description

The existing girders of the Grand Avenue Bridge were analyzed using a line girder model. Only the existing girders were considered in the analysis and quantity and size of any new girder lines was not determined. The existing girders were assumed to remain at their current spacing. It was also assumed that new girders would be outboard of the existing girders, so they were analyzed as interior girders only. For the analysis, it was assumed that as part of a retrofit, the girders would be made composite with a newly constructed concrete deck.

The vehicular live load consisted of HL93 loading for strength analysis. The design truck, design tandem, and design double truck were considered in combination with the design lane load for strength analysis. The fatigue truck was considered for fatigue analysis. Live loads were distributed by AASHTO approximate distribution factors.

Fatigue analysis for the existing girders was conducted for the pre- and post-rehabilitated condition. For each condition, a separate stress range was calculated, resulting in an allowable number of fatigue cycles for minimum design life. These values were compared to the estimated number of fatigue cycles the girder has already undergone or will undergo. Girder locations that exceeded the allowable number of fatigue cycles before the required design life were deemed to have inadequate fatigue life for rehabilitation. For this analysis, it was assumed that rehabilitation would occur sometime around 2015, so this date serves as the cutoff for the pre-rehabilitation condition. According to Bridge Enterprise, a rehabilitation project must have a 30 year design life and, therefore, the required design life must extend to 2045. Locations were identified where the minimum design fatigue life expires before 2045 under a rehabilitated condition. These locations are shown in Appendix C.

The following is a list of assumptions that were used in the analysis of a rehabilitated superstructure:

- Shear studs can be welded to existing girders (existing steel is weldable)
- 8 in. composite deck (no sacrificial wearing surface)
- 3 in. HMA wearing surface
- 7'-3" Tributary Girder Spacing
- Existing Girder Material Properties
    - Fy=33 ksi
    - Fu=66 ksi
- Plastic limits could be reached given LRFD compactness criteria is met
- Rivet Properties
    - Diameter = 3/4 in.
    - Factored Shear Resistance = 21 ksi
- Rivet connection at Angle-Flange and Web interface for built-up members adequate for shear transfer
- Demand controlled by locations of maximum loading, i.e., girder checked at discrete locations, not tenth points
- The girder base metal was assumed to control fatigue life
- Steel assumed to have acceptable fracture toughness

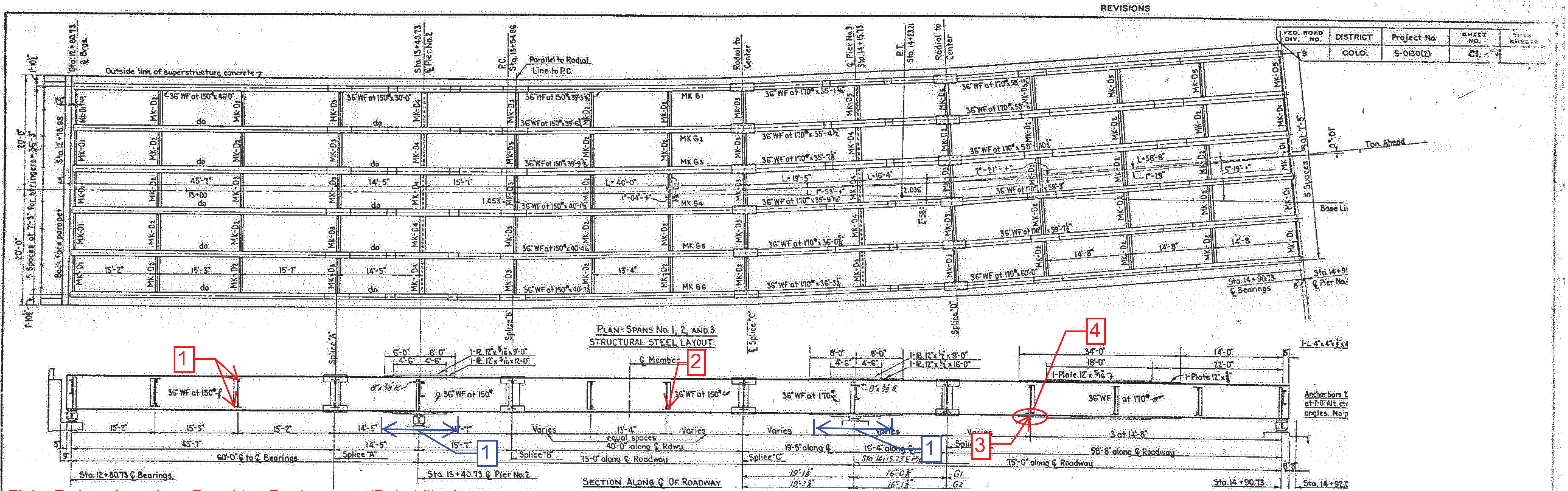
- For minimum design fatigue life, girder base metal was analyzed as a Category D fatigue detail
- Fatigue Damage for varying stress ranges was evaluated using Miner's Rule
    - $\sum n_i/N_i \leq 1.0$
        - n_i = # of cycles at stress range, s_i
        - N_i = # of allowable cycles at stress range, s_i
- Rehabilitation was assumed to occur in 2015
- Minimum required fatigue life = 30 years after rehabilitation, as required by Bridge Enterprise. Elements required to have a fatigue life lasting until year 2045
- 1 truck passage results in 1.5 stress cycles near supports and 1 cycle elsewhere
- Traffic Data
    - ADT = 29,000 in 2010
    - Growth Rates = 1.5% (1952-2010) 2% (2010-future)
    - Truck Traffic = 4.1% of ADT
    - Direction Distribution = 55%
    - AASHTO Single Lane Distribution Factors

The following items were neglected in analysis:

- The horizontal curvature in spans 2 and 3
- Consideration of lateral flange bending
- Colorado Permit Vehicle loading
- All loads other than DC, DW, LL, and IM.

The following structural components were not analyzed/considered:

- Field splices
- Stiffeners
- Cover plate end requirements [AASHTO 6.10.12.2]
- Cross-frames
- Riveted and welded connections
- Construction loading and construction specific limit states
- Deck pour sequence
- Service limit states
- Composite deck strength limit states



Finite Fatigue Locations Requiring Replacement/Rehabilitation

1. Base metal of net section at cross frame location was analyzed. Stress range was measured at the extreme rivet locations connecting cross frame to web.

2. Base metal of net section at cross frame location was analyzed. Stress range was measured at the extreme rivet locations connecting web to cross frame.

3. Base metal of net section at cross frame location was analyzed. Stress range was measured at the extreme fiber of flange cover plate.

4. Base metal of net section of flange cover plate region was analyzed. Stress range was measured at the extreme fiber of flange cover plate(s).

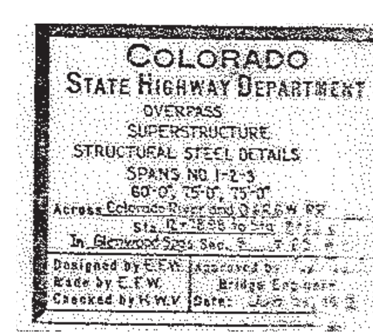
Notes:

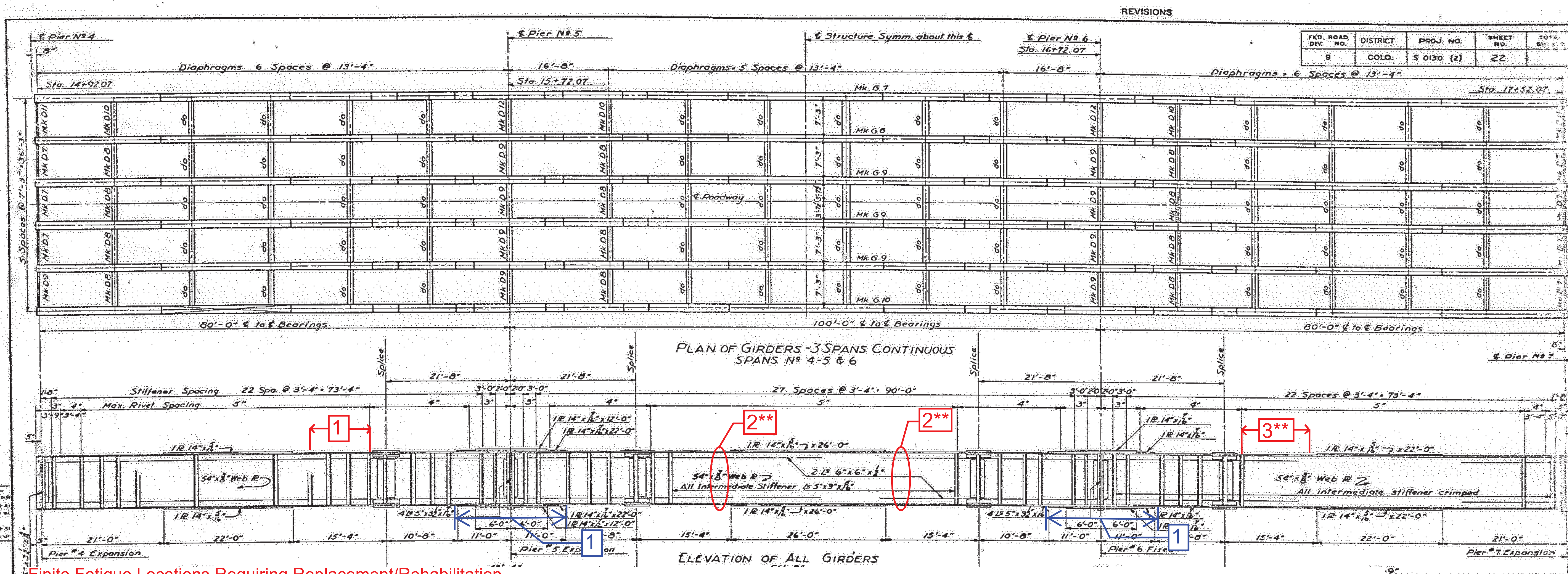
*These locations are based on analysis of fatigue damage that will occur in the current configuration up to 2015 and the fatigue damage that will occur as a rehabilitated composite superstructure until 2045.

Strength Limit Locations Requiring Replacement/Rehabilitation

1. Sections over piers are controlled by Lateral-Torsional Buckling of the bottom flange under a rehabilitated, composite superstructure. One of the following will be required:

   a. Supplementing existing bottom flange cover plates with additional cover plates
   b. Replacing existing bottom flange cover plates with adequate cover plates
   c. Decrease the bracing length by additional cross-frames or bottom flange bracing





Finite Fatigue Locations Requiring Replacement/Rehabilitation

1. Base metal of net section was analyzed. Stress range was measured at the extreme rivet locations connecting web to flange angles. There is approximately 13 feet of girder within this zone where the base metal fatigue life will not extend to 2015.

2. Base metal, of net section at transverse stiffener locations, was analyzed. Stress range was measured at the extreme rivet locations connecting web to flange angles. There is one transverse stiffener at each location where the base metal of the girder will require replacement/rehabilitation.

3. Base metal of net section was analyzed. Stress range was measured at the extreme rivet locations connecting web to flange angles. There is approximately 13 feet of girder within this zone where the base metal fatigue life will not extend to 2015.

Notes:

*These locations are based on analysis of fatigue damage that will occur in the current configuration up to 2015 and the fatigue damage that will occur as a rehabilitated composite superstructure up until 2045.

**Not all stiffeners are shown

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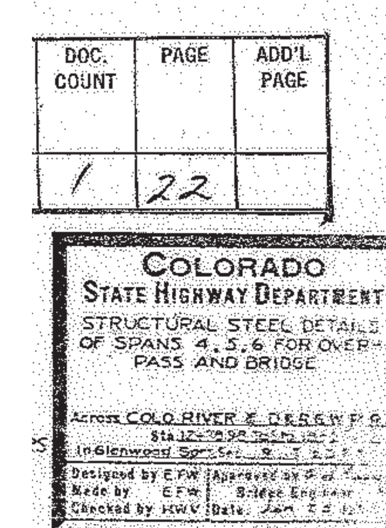
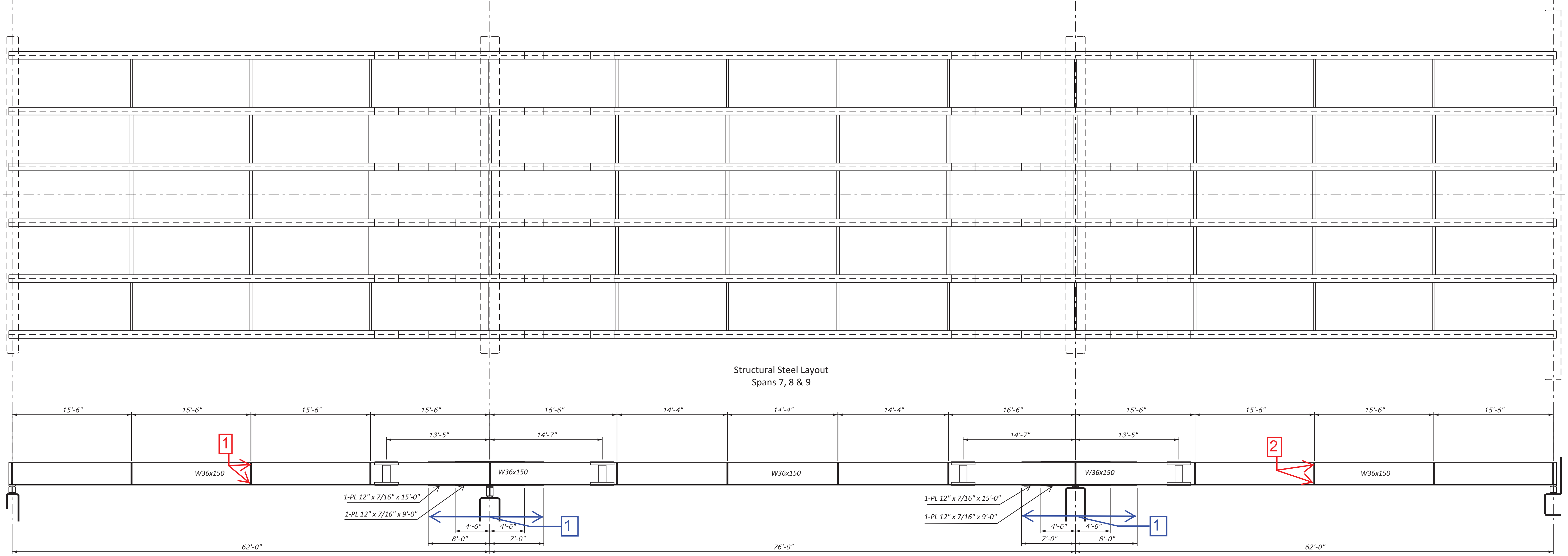
    a. Supplementing existing bottom flange cover plates with additional cover plates
    b. Replacing existing bottom flange cover plates with adequate cover plates
    c. Decrease the bracing length by additional cross-frames or bottom flange bracing





Finite Fatigue Locations Requiring Replacement/Rehabilitation

1. Base metal of net section at cross frame location was analyzed. Stress range was measured at the extreme rivet locations connecting web to cross frame.

2. Base metal of net section at cross frame location was analyzed. Stress range was measured at the extreme rivet locations connecting web to cross frame.

Notes:

*These locations are based on analysis of fatigue damage that will occur in the current configuration up to 2015 and the fatigue damage that will occur as a rehabilitated composite superstructure up until 2045

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