US 51 Ohio River Bridge Engineering and Environmental Study

ITEM NOS. 1-100.00 & 1-1140.00

Bridge Rehabilitation Fact Sheet

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EXECUTIVE SUMMARY

The purpose of this white paper is to inform the reader about the “No-Build” and “Rehabilitation” alternatives for the existing bridge. Appropriate actions can then be developed for an approved environmental document to either repair or replace the existing bridge. The year 2015 was chosen as the base year for comparison of the alternatives.

The two alternatives are summarized as follows:

The "No-Build" Alternative – The goal of this alternative is to continue current maintenance practices to keep the bridge open as long as possible. Estimates indicate the bridge could remain functional under the assumed restrictions described below, possibly until the year 2030 at which time either a new bridge would accommodate traffic or no bridge would be available. This would involve an investment of approximately $3-$6 million dollars in direct costs through 2030 plus the cost of either the economic impact of having no bridge or the cost of a bridge replacement. It is assumed that the bridge would remain fully operational until 2020 and could operate at reduced legal loads for truck traffic until 2025. After 2025 no truck traffic would be allowed on the existing bridge. Around 2030 the existing bridge would cease to be operational, and traffic would either shift onto a new bridge structure or no bridge would operate to carry traffic at this location. User costs have not been included in the cost above.

It is anticipated that the bridge would require additional monitoring and inspection, and those costs are included. Traffic restrictions due to inspection and maintenance will increase as the bridge deteriorates. Single lane closures have been estimated at two weeks per year over 15 years of operation. Full closures for repairs were estimated at one week every two years over the same period. Seismic retro-fit costs have not been included in this appraisal and could be significant (see Section 4).

The "Rehabilitation" Alternative – The goal of this alternative is to invest in a major rehabilitation to maintain the bridge and keep it functional until the year 2045 at which time either a new bridge would accommodate traffic or no bridge would be available. This would involve an investment of approximately $45 - $55 million dollars in direct costs through 2045 plus the cost of either the economic impact of having no bridge or the cost of a bridge replacement. Because of the condition of the existing structure, it is assumed that this major rehabilitation can be delayed until around 2020. The goal of the rehabilitation alternative would then be to keep the bridge fully operational for 25 years until 2045 after which time the existing bridge would be closed due to condition or traffic would shift onto a new bridge structure. User costs have not been included in the cost above. Seismic retro-fit costs have not been included in this appraisal and could be significant (see Section 4).

A major rehabilitation will include inspection, rehab engineering, blast cleaning and painting, and reconstruction all of which would occur over an 18-24 month period. Additional miscellaneous repairs and regular inspections over a 25 year period can also be expected.

The investment shown above includes $1.8 million in non-direct costs associated with approximately 52 weeks of single lane closure during the rehabilitation plus an estimate of

10 weeks of single lane closure for miscellaneous repairs and inspection activities for the remaining portion of the 25 year period.

The No-Build and Rehabilitation alternatives do not address the functionally obsolete characteristics of the bridge. The serviceable life of the bridge, with restrictions, for the No-Build alternative is estimated to cease by 2030. It is estimated that the Rehabilitation Alternative can extend the serviceable life of the bridge by an additional 15 years to 2045.

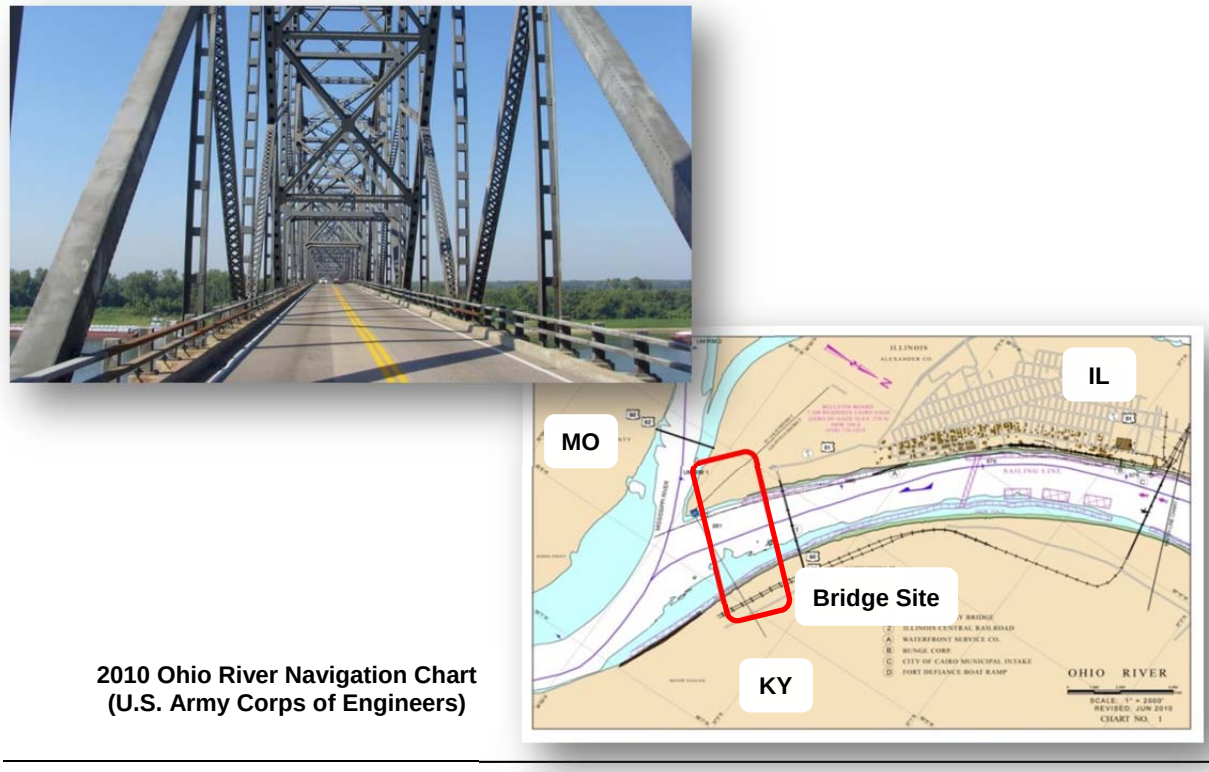
1. INTRODUCTION

The purpose of this white paper is to present the "No-Build" and the "Rehabilitation" alternatives for the existing US 51 Cairo Bridge over the Ohio River between Alexander County, Illinois and Ballard County, Kentucky.

This document is an extension of the US 51 Cairo Bridge over the Ohio River Existing Bridge Deficiencies White Paper dated May 2013. In the Existing Bridge Deficiencies White Paper, the bridge's condition was evaluated through previous bridge inspection reports, load rating analysis, and previous rehabilitation plans. A preliminary engineering was performed to provide a preliminary evaluation of the existing river piers using current AASHTO LRFD design criteria for bridge scour, seismic loading, barge impact and river pier foundations.

The information contained in both of these documents is intended to provide information about the present condition and the "No-Build" and "Rehabilitation" alternatives for the existing bridge so that appropriate actions can be developed and an environmental document approved to either repair or replace the existing bridge.

The No-Build alternative is defined as a minimal repair strategy with continuation of maintenance activities and no major repairs. Under the no-build alternative, the bridge would continue to be classified as structurally deficient and also considered functionally obsolete. The Rehabilitation alternative is defined as a structural repair and strengthening to increase the Sufficiency Rating (SR) above 50 and provide a minimum Operating Rating (OR) of 36 tons with a desired remaining service life of 25 years. The bridge would no longer be classified as structurally deficient after the rehabilitation alternative; however, it would still be classified as functionally obsolete.



2010 Ohio River Navigation Chart
(U.S. Army Corps of Engineers)

REMAINING SERVICE LIFE

The 2012 bridge inspection report rated the physical condition of the 75 year old bridge as satisfactory (NBI - 6). Key factors which can reduce the remaining service life for the US 51 Cairo Bridge include:

1. Existing Paint System – The current calcium-sulfonate overcoat system has been in place for 5 years and is showing signs of distress. KYTC Bridge Maintenance has seen a reduced service life on several bridges throughout the state that are currently using this type of paint overcoat system. The primary concern is the paint system would fall short of its estimated 10 to 15 year service life, allowing further deterioration of the structural steel.
2. Existing Structural Steel – The primary concern for the structural steel is deterioration and formation of pack rust between the members. Deficiencies from deterioration and pack rust can reduce the material thickness of the steel members over a period of time which results in a reduced load carrying capacity.
3. Existing Bridge Deck – The existing bridge deck and overlay was placed in 1980. The overlay is beginning to show signs of failure through cracks and spalling. This could be an indication of larger issues underneath the overlay. It is estimated that the existing bridge deck has seen more than half of its useful service life, estimated end around 2030.
4. Current Live Loads – The current live loads utilizing the bridge are heavier than those used in the original bridge design. Over a period of time, fatigue from these heavier loads can reduce the service life which can result in a future posting of the bridge. When enforced, posting the bridge allows the KYTC to restrict the weight of the vehicle crossing the bridge to a specified value.
5. Extreme Events – The original bridge design pre-dates the code requirements for seismic loading and barge impact design. Exposure to one of these extreme events has the potential to negatively impact the remaining service life.

In the No Build alternative, the bridge has a limited remaining service life. This is based on the assumption that the bridge will only be maintained at its current operational level. All bridge members deteriorate at a unique rate which is dependent on exposure conditions and the quality of the protection system. There are currently no widely accepted methods for calculating remaining service life for a structure such as this. For the US-51 Bridge, little change in structural condition and capacity is anticipated over the next three to five years. In general, it should be expected that within 5-10 years the bridge will be posted for truck traffic, and within 10-20 years could be closed to all truck traffic if significant repairs or rehabilitation do not occur.

It is important to note that the existing bridge is considered structurally deficient due to the capacity of the members and not because of the condition of the structure. This means that the bridge has a limited structural capacity, and virtually no reserve capacity. Failure to maintain the paint system or the bridge deck will lead to corrosion and deterioration of the members and reduction in the load carrying capacity. The result will be further reduction to the bridge posting, removal of all truck traffic, and eventually closure. As the paint system continues to deteriorate, the number of localized failed areas will increase and additional member section loss is likely.

2. NO-BUILD ALTERNATIVE

As previously stated, the No-Build alternative is defined as a minimal repair strategy with continuation of maintenance activities. It is assumed that ongoing low cost maintenance activities will continue to be performed to maintain the bridge in an operational condition. These future maintenance activities do not include major investments in repair work to increase the capacity on any bridge superstructure or substructure components for live load, seismic, or barge impact.

ASSUMPTIONS ON REPAIR AND MAINTENANCE

Included Activities

Maintenance recommendations are generally provided to KYTC following the biennial bridge inspection or as needed through the local District office. The recommendations contained in this report document maintenance activities to maintain the structural integrity of the bridge for the travelling public. The No-Build alternative includes these recommended minimal repair and maintenance activities:

1. Bridge Deck Patching – repair spalled concrete in the overlay and deck. These spalls are typically a finite size and located in isolated areas along the deck.
2. Steel Member Repairs – repair of structural steel members to maintain the operational capacity of the bridge. Steel members may include stringers, girders, floor beams or truss members.
3. Concrete Patching on Substructure – repair spalled concrete in the piers or abutments. These spalls are typically a finite size and located in isolated areas along the pier caps. Crack injection is assumed to be included with these repairs.
4. Deck Joint Repair – repair/replace joint seal elements to protect the structural steel below.
5. Bridge Rail Repair – replace sections of bridge rail that have deteriorated from corrosion or impact damage. The existing bridge rail utilizes steel longitudinal elements and steel posts.

Not Included Activities

The activities listed below either increase the load carrying capacity of the bridge or would represent a major capital investment by KYTC. Therefore, the activities below are not included in the No-Build alternative:

1. New Paint System – applied to the entire bridge truss and approaches.
2. Deck Replacement – placed full width using phased construction.
3. Strengthening of Structural Steel Members – retrofit to increase the member capacity.
4. Seismic Retrofit – strengthen bridge elements for a specified seismic event.

Appraisal of Remaining Service Life

The Project Team Bridge Engineers utilized their project experience with the Milton-Madison Bridge over the Ohio River as a case study. The deterioration rate experienced by the Milton-Madison Bridge is believed to be aggressive as compared to what is expected for the Cairo Bridge and is useful to provide a lower bound of the remaining service life. The estimate for a more realistic upper bound of the remaining service life was established by reviewing the historical inspection reports and repair plans of the Cairo Bridge. It is useful to characterize the remaining service life for the no-build alternative in three phases.

No Build Alternative	Lower Bound (year)	Upper Bound (year)
Full Vehicular Traffic	Current – 2018	Current – 2018
Posted for Reduced Truck Traffic *(assumed)*	2018 – 2023	2023 – 2030
Closed to Truck Traffic *(assumed)*	2023	2030

PHASE 1 - Full Vehicular Traffic

The bridge will require inspection and maintenance during this period. It is assumed that there will be inspections every two years, including updating the load rating and gusset plate rating. Increasingly frequent repairs to the concrete deck and overlay are anticipated.

PHASE 2 – Posted for Reduced Truck Traffic

Maintenance repairs and inspections are increasingly necessary to keep the bridge functioning even with the removal of most trucks from the bridge. The inspection frequency is anticipated to be required on an annual basis. Deterioration will continue to be monitored during inspections and should be used to update the member load rating and gusset plate ratings.

PHASE 3 – Closed to Truck Traffic

Maintenance repairs and inspections are required to keep the bridge functioning even with posting to close the bridge to trucks. The inspection frequency is anticipated to increase to approximately every six months or less. At this stage the deterioration is increasing at a rate to which maintenance repairs cannot maintain the structural integrity of the bridge and a posting to remove trucks from the bridge is required. It is anticipated that the bridge will be deteriorated such that a major rehabilitation, including extensive steel repairs, is required to avoid full closure.

Even with the investments discussed above, it is estimated that around year 2020 the bridge will see a reduction in allowable truck traffic and around 2025 the bridge will cease to be functional to all truck traffic and may be limited or possibly even closed to all vehicular traffic. Although the years stated are estimated, we feel the bridge will go through the phases as described above. The actual years will be dependent on the deterioration rate of the US 51 Cairo Bridge.

Under the No Build alternative the bridge will remain classified as structurally deficient. The sub-standard geometrics will remain and therefore the bridge would also remain functionally obsolete.

3. REHABILITATION ALTERNATIVE

The service life of a bridge can be extended through major rehabilitation, strengthening and maintenance. The basic assumption for this alternative is that a full rehab of the bridge will take place around 2020. The goal of the rehabilitation, routine maintenance and inspections, is to extend the life of the bridge for 25 or more years (thru 2045 or beyond).

ASSUMPTIONS ON REHABILITATION

Included Activities

A rehabilitation alternative would include both maintenance repairs and strengthening retrofits. Maintenance items are generally provided to KYTC following the biennial bridge inspection or as needed through the local District office. The strengthening retrofits considered with this alternative include those necessary to increase the capacity of all superstructure members to a minimum operating rating (OR) of 36 tons and a sufficiency rating (SR) above 50.

The recommended rehabilitation activities include:

1. New Paint System – applied to the entire truss and approaches.
2. New Bridge Deck – placed full width to the entire truss and approaches using phased construction. Work also includes new expansion joints and new bridge barrier rail. Light weight deck options can also be considered in lieu of the strengthening discussed below.
3. Strengthening of Structural Steel Members – retrofit to increase the member capacity of 18 through truss members to meet the OR and SR requirements. See Figure 1. Strengthening of the approach spans is not necessary to meet the OR goal.
4. Steel Member Repairs – repair structural steel elements per bridge inspection recommendations. Steel elements may include stringers, girders, bearings, floor beams or truss members.
5. Concrete Patching on Substructure – repair spalled concrete in the piers or abutments. These spalls are typically a finite size and located in isolated areas along the pier caps.

Not Included Activities

The Rehabilitation alternative would allow for removal of the structurally deficient classification. It does not address any of the sub-standard geometrics and therefore the bridge would remain classified as functionally obsolete. The rehabilitation alternative does not include cost for a seismic retrofit. Seismic considerations are discussed separately in Section 4 – Seismic.

It is important to note that the data for this paper is based primarily on the 2012 Fracture Critical Inspection. These inspections are limited primarily to the truss members of the bridge, especially the fracture critical members. The floor support system members have limited information available from these inspections. *Before preparation of any actual construction plans, it is imperative that a full in-depth inspection be performed to properly determine the*

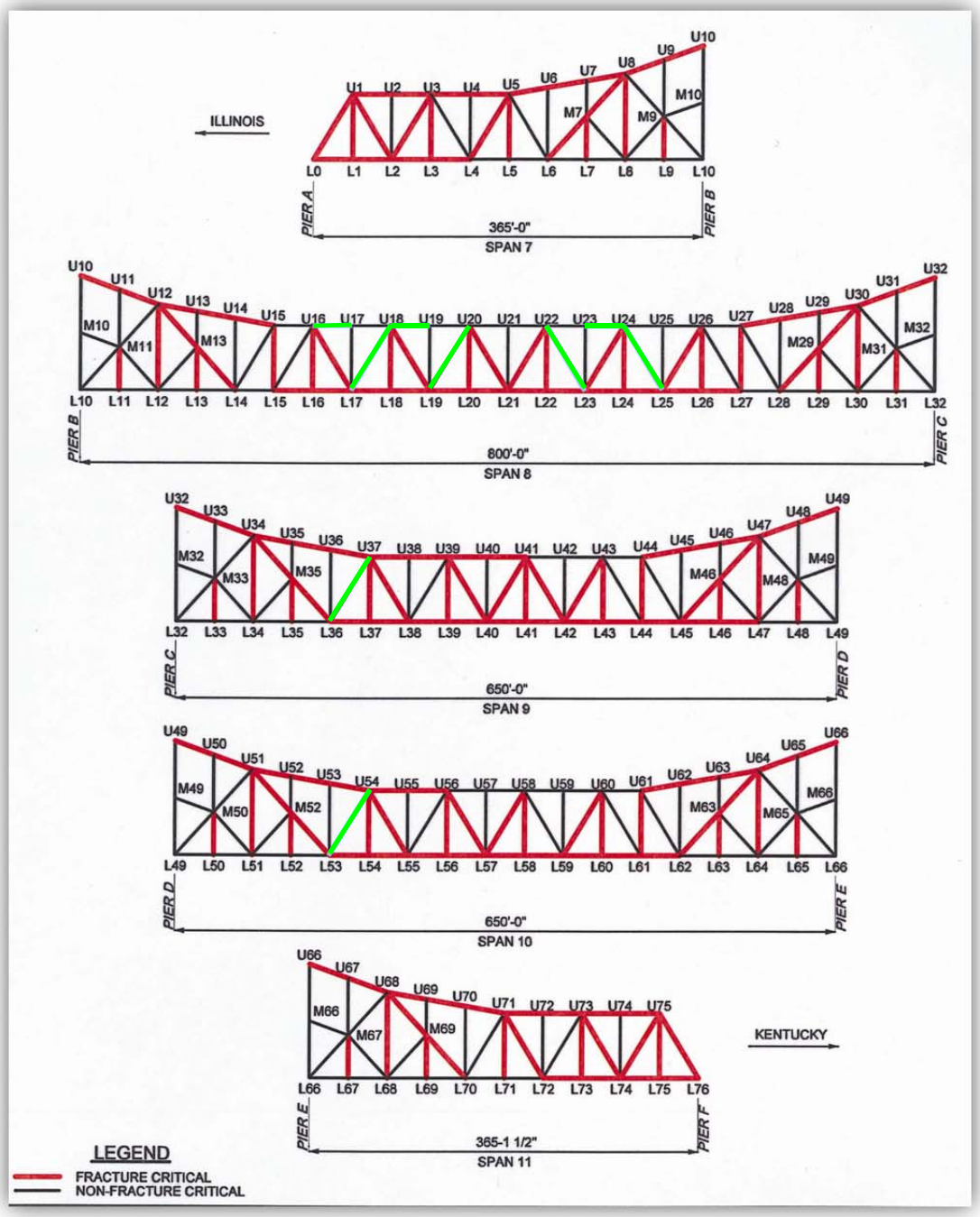


Figure 1 - Through Truss Layout

= truss members designated for strengthening to increase OR greater than 36 tons and increase SR over 50

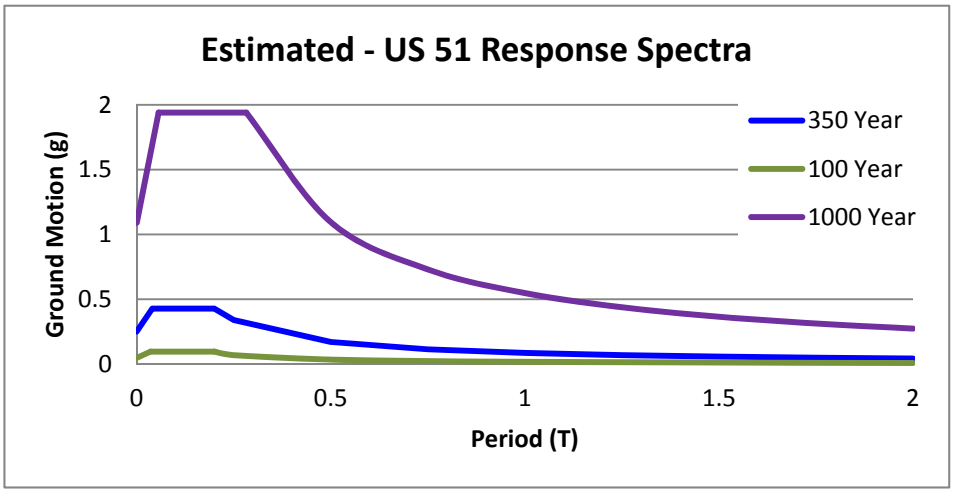
4. SEISMIC

The FHWA Seismic Retrofitting manual states retrofitting a bridge with a short service life is difficult to justify for two reasons: it is not economical and the design earthquake is unlikely to occur during the remaining life of the structure. On the other hand, a bridge that is almost new or being rehabilitated to extend its service life should be retrofitted for the longer remaining service life. This approach has been adopted for the evaluation of the no-build and the rehabilitation.

No-Build Implications/expectations
Under the no-build scenario, no improvements would be made to the existing bridge that would improve its performance during a seismic event. The existing bridge was not designed for seismic forces, and based on very preliminary results could experience significant damage or possible collapse during a large earthquake.

Preliminary analysis of the river piers for the 1,000 year return period event demonstrated that the existing pier columns do not have adequate flexural capacity to resist the forces generated. Similar analysis of the river pier foundations indicated they would be overstressed for the 350 year and 1,000 year return periods. As discussed in the *US-51 White Paper Geotechnical Study*, additional engineering analyses are needed. Further study of the seismic response of the existing structure should be considered.

Rehabilitation
Evaluation of return period - The FHWA Seismic Retrofitting manual indicates that the level of seismic event and retrofit should be a function of the remaining service life of the bridge. Careful consideration should be given to selection of the return period(s). The figure below illustrates the difference in magnitude between a 100year, 350year, and 1,000year response spectrum at this site.



A site specific seismic study is necessary to determine the appropriate response spectra.

Accelerations shown are preliminary and should not be used for design.

The FHWA seismic retrofitting manual advocates a dual level seismic event, consisting of lower level "functional" event and upper level "safety evaluation" event, should be considered for bridges such as the US-51 Bridge. The 1,000 year return period is the recommended upper level event where estimated service life is 75 years, while the 100 year return period is used as a lower level elastic response. For US-51 a lesser upper level event may be warranted based

on a shorter service life (assumed to be 25+ years). This would correspond to a 350-500 year return period. According to the manual, a reduced upper level return period for evaluating existing bridges is a compromise between the need to provide life safety and adequate performance for these less frequent motions, and the limited resources of the owner.

Extending the remaining service life warrants further examination of the likelihood of a seismic event and consideration of seismic events. By including seismic retrofits with other forms of structural rehabilitation, some savings in mobilization may be realized. A partial list of seismic retrofit needs is included below:

- Superstructure
  - The 1998 KTC Report 98-20 evaluated the susceptibility of the US 51 Cairo Bridge to a 50year return earthquake. This study found that the main bridge could resist this quake without yielding or buckling any truss members, or without failing the bearings.
  - Recommend additional study be performed considering a conservative anticipated service life.

- Bearings/Restrainers
  - The 1998 KTC Report 98-20 indicated the bearings would not fail under the 50 year return period event.
  - The KTC report recommends the approach span bearings be retrofitted to increase the anchor bolt shear resistance and to include bearing restrainers due to limited seat width.
  - Recommend additional study including investigation of seat width, restrainers, and consideration of isolation/energy dissipation devices.

- Piers/Columns
  - Preliminary analysis of the river piers for the 1000 year event demonstrated that the existing piers did not have adequate flexural capacity to resist the forces. The columns on top of the pier wall have limited capacity.
  - Retrofit options for the piers include, reducing superstructure demands (isolation), flexural strengthening by encasement and providing shear wall between columns.

- Foundations
  - Preliminary analysis shows overstressed foundations. A refined 3D analysis including passive resistance of the adjacent soils would be needed to more accurately appraise the foundation capacity.
  - Strengthening of the foundations thru addition piles may improve performance.
  - Determination of the appropriate return period (risk) and additional refined analysis is necessary before conclusions can be drawn.

Prior to performing any rehabilitation on the existing bridge, the seismic retrofit needs of the existing bridge should be evaluated. Additional study in the form of site specific geotechnical exploration and site specific seismic evaluation are needed before any additional analysis and or retrofit can be performed. Although the exact level of seismic retrofit is not clearly known for the US 51 Bridge, it can be assumed it will be required and will be a significant additional expense. Estimation of the seismic retrofit cost estimate is beyond the scope of this fact sheet.

5. No Build and Rehabilitation Cost Estimate

The planning level cost estimate of the No-Build alternative is estimated at $3.75 million (2013 dollars). The cost estimate is based on the assumptions described in Section 2.1. This cost does not include any user cost or economic impact associated with detours.

No Build Alternative	
• Repairs to Maintain Bridge (Est.)	$2,500,000
• Inspection and Rating Costs (Est.)	$1,250,000
Estimated Total Cost:	**$3,750,000**

The planning level cost estimate of the Rehabilitation alternative is estimated at $50.1 million (2013 dollars). The cost estimate is based on the assumptions listed in Section 3.1. This cost includes $3.1 million for ongoing maintenance repairs and inspections to maintain the bridge in operation. This cost does not include any user cost or economic impact associated with detours.

Rehabilitation Alternative	
• Rehab Bridge (Est.)	$45,600,000
• Inspection and Rating Costs (Est.)	$2,000,000
• Repairs to Maintain Bridge (Est.)	$2,500,000
• Seismic Retrofit(s)	Not Included
Estimated Total Cost:	**$50,100,000**

6. Anticipated Closure Schedule

Construction impacts have been estimated for both the No-Build and the Rehabilitation of the bridge and are shown below.

No Build Alternative (over 15 year period 2015 – 2030)

- Single Lane Closure — 2 weeks / yr (30.0 weeks)
- Full Closure for Emergency Repairs — 1 week / 2yr (7.5 weeks)
- Posted to Truck Traffic — 2020
- Closed to Truck Traffic — 2025
- Closed to All Traffic — 2030

Rehabilitation Alternative (over 25 year period 2020 – 2045)

Rehabilitation of the existing bridge is anticipated to take 12 months to complete. Work on the structure will be intermittent and may be limited during the winter months.

- Single Lane Closure during rehab — 52 Weeks
- Single Lane Closure (2020-2045) — 10 Weeks (misc. maint.)
- Closed to All Traffic — 2045