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Hoover Dam Bypass
Colorado River Bridge

Type Study

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1.0 Executive Summary

The Hoover Dam Bypass is a new transportation facility designed to greatly enhance mobility in the vicinity of the historic Hoover Dam by relocating through traffic off of the dam and on to a new high speed 4 lane roadway. The selected Sugarloaf alignment alternative location of this facility carries the roadway approximately ¼ mile downstream of the Dam, requiring a long span bridge across the Black Canyon, with a profile that peaks approximately 280 feet above the Dam crest.

This Type Study for the Colorado River Bridge was developed by the Design Team of CFLHD and HST, and was guided by direction from the Project Management Team, the Structural Management Group, and the Design Advisory Panel. Each of these groups provided oversight and advice to the Design Team as bridge designs were developed for consideration by the Executive Managers. The bridge evaluation program began with a Screening Study, which reduced the candidate bridge types down to the deck arch. Deck arch designs were developed for both a shorter arch span – one that extends from the Arizona side of the canyon to the rock knoll near the Nevada switchback – and for the longer arch span – which traverses the rock knoll and extends behind the knoll in Nevada. Geotechnical engineering and mapping studies undertaken during this type study have confirmed that either span option is viable, so the decision between the two is a matter of economics and aesthetics.

Bridge designs were developed through preliminary engineering and cost estimating. Engineering focused on defining the requisite proportions and material requirements for the various alternatives, with the primary focus being visual presentation and cost estimating for each of the alternatives. The following alternatives are described within this report.

- short span solid rib steel arch, with a steel box superstructure
- short span solid rib concrete arch, with a concrete box superstructure
- short span composite comprised of a concrete arch and a steel box superstructure
- long span Vierendeel steel arch frame, with a steel box superstructure
- long span solid rib concrete arch, with a concrete box superstructure
- long span trussed rib steel arch, with a plate girder superstructure

The Design Advisory Panel and the Structures Management Group evaluated the bridge designs throughout the preliminary design process. The Design Advisory Panel preferred the solid arch solutions, favoring the Vierendeel somewhat less, and judging the trussed rib solution to be unacceptable in aesthetic terms for the Hoover Dam Bypass site. The Structures Management Group favored the solid rib solutions, both at the long and short spans. This preference was based on weighting criteria that included inspection and maintenance requirements, construction complexity, vulnerability to sabotage, and long-term durability.

The construction cost estimating process focused on site-specific cost factors through the development of a construction-type 'build' cost estimate for two of the six basic alternatives. These site cost factors were applied to the remaining alternatives to strengthen the reliability of all estimates. The result of the cost estimating process for the preferred short span alternatives is shown in the following table.

Hoover Dam Bypass
Colorado River Bridge
Type Selection Rankings

Bridge Alternative	Estimated Construction Cost Without Sidewalk	Ratio
Concrete composite	$84,170,000	1.00
Concrete short solid rib	$87,538,000	1.04
Steel Solid Rib	$96,405,000	1.15

The recommended preferred alternative is the concrete composite. The advantages of the concrete composite alternative include the following.

- the concrete composite alternative blends the best of both concrete and steel, using concrete in compression for the arch, and lighter steel for the upper structure
- the concrete composite offers advantages for accelerated schedule, since the concrete arch can follow on an early foundation excavation contract without the wait for fabrication of arch steel
- the concrete composite alternative is the lowest projected cost for the favored solid rib alternatives, and the blend of concrete and steel design detail options allows the greatest flexibility to design for cost efficiency

The Design Team recommends that the project proceed with the concrete composite alternative in final design.

2.0 Project Setting and Site Description

The Hoover Dam Bypass is a new transportation facility, designed to greatly enhance mobility in the vicinity of the historic Hoover Dam by relocating through traffic off of the dam and on to a new high speed 4 lane roadway. The selected Sugarloaf alignment alternative location of this facility carries the roadway approximately ¼ mile downstream of the Dam, requiring a long span bridge across the Black Canyon, with a profile that peaks approximately 280 feet above the Dam crest.

The Black Canyon below Hoover Dam is an 800 feet deep gorge carved by the Colorado River through a rugged, hard rock landscape forged by eons of geologic transformations. The dramatic rock cliffs reveal a palate of geology that ranges from clear basalts to ash flows and seams of dikes and in-fills from the volatile geologic history, which collectively paint an incredible mosaic of colors and forms on the cliffs below the Dam. The new bridge will soar across this dramatic landscape with a span of between 1090 and 1330 feet, framing the view of Black Canyon from the Dam below and offering a breathtaking perch above the entire Hoover Dam site.

Hoover Dam is one of the engineering wonders of the world – an internationally recognized civil engineering landmark that is known as much for its grandeur as it is for its engineering achievement and utility. There are large dams around the world, but few are recognized for their elegance and grace in a setting as spectacular as Black Canyon. Hoover Dam is a magnate for millions of visitors in large part because the designers and builders of the Dam expressed an art for engineering that went beyond the austere and functional. They created a colossal civil engineering facility with a unique identity – one with both strength and grace, and one that has been the standard of excellence in dam design for over 70 years.

This dramatic setting for the Hoover Dam Bypass would be spectacular even in the absence of the Dam. The natural beauty and drama of this rugged rock gorge begs for simple elegance with a sweeping crossing of the River. The focus on the form and detail of this new bridge structure will be more like that for a major urban bridge due to the millions of eyes that will set first on the bridge as they enter the Black Canyon to visit Hoover Dam. The Bridge will frame the viewscape from the Dam, from the Visitor's Center, from the Café, and even from Lake Mead. Millions of visitors to the Dam will be drawn to near-field detailed views of the bridge structure as they tour the dam and visitor's center below. The bridge will frame Hoover Dam for future generations, viewed by association with the dam in person, in print and in the countless videos celebrating the setting and accomplishments of the Hoover Dam monument.

It is into this setting that we introduce a major new bridge crossing of the Colorado River for the Hoover Dam Bypass. This new bridge must be worthy of its setting and surroundings, as well as satisfy the utilitarian needs for the transportation corridor. The objective of the bridge design effort is to provide the maximum value to the public. Just as the appointing and features of the dam add tremendous value to visitors, so too will the right blend of engineering and architecture maximize value to both those visiting the dam or recreating on the Lake and River below, and those driving across the Bypass carrying commerce along Route 93.

3.0 Aesthetic Goals and Guidelines

The EIS lays out goals for the bridge design in terms of its asset to the visual resource of the Hoover Dam National Monument and Recreation Area. (EIS – 3.7) "Three criteria were used to evaluated the project areas proposed visual quality: vividness, intactness, and unity." …"Intactness of the proposed project area is demonstrated by the integrity of the features…unity is achieved by the mixture of natural elements and human-made alterations..." The EIS goes on to say "…Recreationists are considered a sensitive user group because their viewing of the Dam, the lake, the river and the canyon is expected to last up to several hours…recreationists...value...aesthetic quality..."

The Bridge will be one of the longer arches in the US, and a major engineering structure. There is no way to "hide" a 2000-foot long bridge over the canyon, so the Dam will now share its site with the new bridge crossing. Following the guidelines of the EIS, the bridge structure should have "unity" with the site. Just as the Dam is so perfectly seated into the canyon walls that it seems to 'grow' from the earth, so too must the new bridge spring from the canyon as though it belongs to the site. The rugged elegance and simplicity of the rock canyon site must be matched by the bridge form in order for this unity to exist.

The Design Advisory Panel (DAP) recommended a canon for the new bridge design. The essence of their charge was to strive for engineering excellence in the design of today that honors the engineering excellence that went into the Dam in its day. The designers and builders of Hoover Dam expressed a pride in and respect for the visual impact of their work on future generations. These features, as much as any engineering achievements, are what separate Hoover Dam from other large piles of rock and concrete. The drive for engineering excellence at Hoover Dam took the builders beyond a minimum functional level to achieve an expression of form and a grace of detail that has made Hoover Dam the enduring landmark that it is today. This same simple elegance is the aesthetic goal for the new bridge.

The guidelines for architecture follow the design tenets noted above. The objectives may be summarized as follows:

- develop visual unity with the dam and the canyon walls that frame the bridge
- develop a visual aesthetic that compliments the views from vantage points assumed by recreationists, including visitors to the dam and pedestrians/hikers within the LMNRA
- develop an engineering solution that respects the creativity and commitment to engineering excellence that went in to the design of the dam

4.0 Superstructure Design and Renderings

4.1 Introduction

The Colorado River Bridge type study follows on the decision process of the Structures Management Group, Project Management Team and Executive Managers, selecting the deck arch as the preferred solution for the Colorado River Crossing. Geotechnical engineering ran a parallel path with the bridge type study, and the geology of the potential skewback foundations in Nevada is only now confirmed. The aesthetics, alignment options, and logistics also differ for the short and long span options. Therefore, the preliminary design process followed a parallel path for two span lengths. One – termed the short span – calls for landing the arch on the rock knoll at the Highway 93 switchback leading down to the dam in NV. The second – termed the long span – calls for landing beyond the fault line west of the switchback, with an alignment that is approximately 30 feet to the south at the station of the skewback foundation. Roadway alignments were also being developed as the type study progressed. The ground profiles within the range of alternatives are sufficiently similar that a single ground profile was used for all the alternatives.

The type study is being advanced with 6 deck arch alternatives, 3 for each span length. On the assumption that steel is relatively more efficient at the longer spans, there are two alternatives in steel for the long span layout, and two alternatives in concrete for the short span layout. The remaining two alternatives are a short span steel solid rib arch and a long span concrete rib arch. Four of the six alternatives are appropriate at either span. The long span Vierendeel truss (see descriptions, below) would not be offered at the shorter span due to the effect that the high arch rise would have on the geometry of the spandrels. The long span concrete with integral crown would be less efficient and more massive at the crown with a taller rise to span ratio, and would defer to either the concrete composite or short span concrete with an open spandrel at the crown for the shorter arch span. Preliminary engineering and visual evaluations were limited to the 6 alternatives described below. However, in order to have a full complement of pricing and technical evaluations, the SMG asked that we address the alternative span variations for those alternatives that can be designed at either span. Therefore, the cost estimate for the concrete composite alternative was extrapolated to the longer span and the steel trussed rib was reduced to the shorter span using classical span to weight ratios.

All of the preliminary design was based on a full roadway width that includes a full-length sidewalk on the north side of the bridge. The bridge framing system is symmetric about the centerline of the structure, and so is offset from the roadway centerline due to the eccentric sidewalk. This sidewalk is a feature that is the subject of further studies, and is addressed in the project summaries as an evaluation item. The basic cost estimates in this type study all include the sidewalk. A margin is assigned for the value of the sidewalk in the project summaries.

Bridge designs follow the tenets of the AASHTO LRFD Code, which will serve as the basic code for final design. Alternatives were evaluated for selected loads, such as dead load, live load, wind and earthquake, using engineering judgment as to what critical elements would affect the feasibility and economy of design. The project bridge design criteria have been published as a separate document (Appendix C).

4.2 Range of Design Elements

The objective of this type study is to develop designs with the greatest value to the project. Value in the context of Hoover Dam Bypass is a blend of engineering excellence, aesthetic impact and economics of construction. There are macro and micro aspects to each of these barometers. The type study endeavored to test a range of factors in order to view the spectrum of options that should lead to the preferred solution for the bridge.

There is a vast array of design elements that affect construction economy. The type study addresses designs in steel and concrete, as well as a combination of concrete arch and steel superstructure. Designs also vary in the techniques assumed for construction, in the way in which end spans merge with the rock excavation at the abutments, and in the way approach spans blend with the spandrel spacing over the arch. Each of these choices has advantages and disadvantages when measured against one criteria or another. However, it is the best blend that will provide the greatest value, and choices for that blend are what this type study seeks to create.

The steel alternatives consist of a long-span trussed-rib option, a short-span solid-rib option, and a long-span Vierendeel-rib option. The concrete alternatives consist of a long span twin rib box arch with an integral crown, a short span all concrete twin box rib arch with a twin concrete box girder deck, and a short span composite concrete system comprised of a concrete arch with steel columns and a composite steel box girder deck system. The six alternatives chosen for study seek to address the range of both aesthetic and engineering options. Yet there are additional "blends" of design – mix of box girders vs. plate girders, concrete vs. steel columns, various deck and deck forming systems, mix of span lengths from the approach to the arch, range of deck length vs. abutment height – that can be evaluated as design elements, and apply to a number of options. The variable bridge lengths among the alternatives are the result of balancing span lengths and abutment heights. These differences are not significant in relation to the relative costs of the alternatives, but will affect the eventual cost of whichever alternative is chosen.

Cost is a major element in determining value, and each of the six alternatives includes a preliminary construction cost estimate based on the work of this type study. This bridge site is quite unique, and the experience with long span arch construction rare in contemporary US bridge building practice. Therefore, the type study cost estimating effort goes beyond the conventional level of estimating to include two more detailed cost estimates – what we term "build" estimates. For these two alternatives, construction cost estimators developed erection means and methods, price equipment, material, labor and risk separately, in a similar fashion to the way in which a general contractor would bid the job. While the level of detail does not match the effort required of a general contractor, the process of developing a build estimate evidences issues of design economy and construction requirements that can greatly affect the eventual construction bid. These build estimates increase the reliability of the estimating process for the two chosen alternatives, and also increase the knowledge base for the other 4 estimates. Both the long span trussed rib and the short span composite were evaluated by the build method. One last point with respect to construction cost is as important as any other. In any major construction project, the two most defining factors beyond the mere scope of the work for cost are competition and risk. Those projects that do not generate competition and those that involve unmitigable risks are likely to deviate from normal measures of construction pricing. Neither of these issues is addressed within the context of engineering cost estimates. These issues are, nevertheless, important to consider when completing the final design and developing construction specifications and bidding protocol.

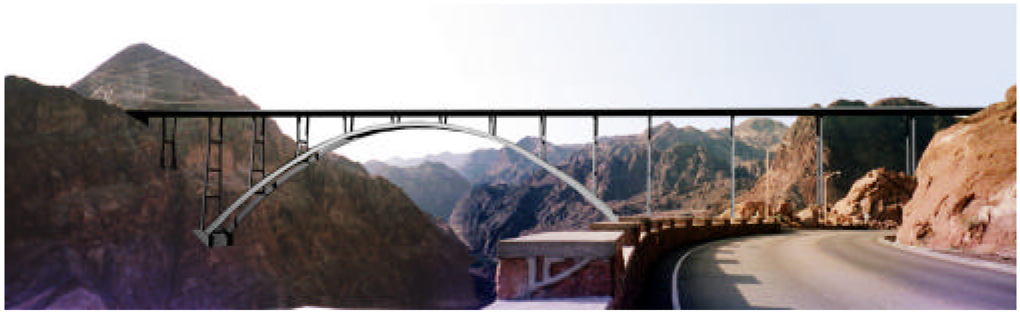
4.3 Short Span Alternatives:

4.3.1 Site Layout: The short span layout for the arch spans from the rock knoll at the NV switchback to the hard-rock face on the AZ side of the canyon. The elevation of the arch springing is established by the rock knoll, being low enough to provide adequate width for the skewback foundation, as well as low enough to keep the thrust line of the arch within the rock mass behind the knoll. The resulting excavation will include rock anchor tie-backs to contain the existing roadway. The arch span of this arrangement is now 1090 feet to the theoretical springing. The rise of arch options varies with alternative, but is generally in the range of 285 to 290 feet, for a span to rise ratio of under 4.

Given the span of the canyon and depth to the river, all designs are based on the use of a high-line cable crane and stayed erection of the arches. Various schemes for local access and erection are accommodated in the construction cost estimates, including benching for intermediate work areas and pioneering access roads along the approaches.

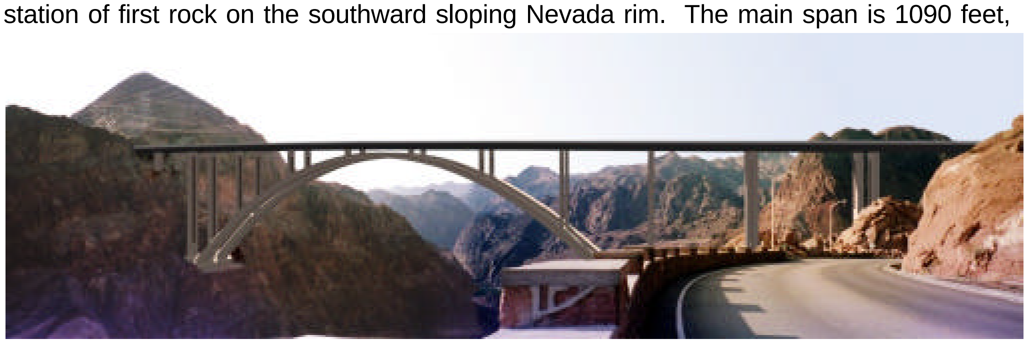
4.3.2 Short Span Design Options:

Steel Solid Rib: The short-span solid-rib alternative is a traditional engineering solution for a canyon crossing such as this. While a trussed-rib alternative will often be a more economical steel solution for spans in excess of approximately 700 feet, the solid-rib configuration is attractive because of its superior aesthetics, with aesthetic enhancements due to the solid rib framing, configuration of piers, and geometric blend of the piers, arch ribs and deck system. The overall structure is 2015 feet long. It is comprised of a 1090-foot main arch span, a 690-foot Nevada approach, and a 235-foot Arizona approach. The superstructure consists of steel box girders spanning approximately 120 feet on the main span and up to 180 feet on the approach spans, with a composite concrete deck. The box girders were chosen over plate girders because of the improved aesthetics of the box girders when viewing the bridge from the dam vistas below. Bent-leg spandrel columns with Vierendeel bracing are being proposed to provide a light open appearance. The variable depth main span arch is inclined to match the plane of the spandrel columns, thereby resulting in a splayed rib configuration. The approach span bents are also a bent-leg Vierendeel-braced



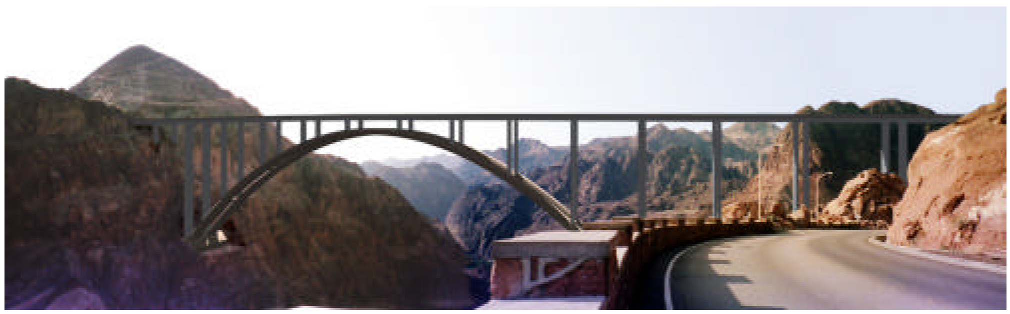
configuration for consistency. Vertical spandrel columns and a regular vertical spandrel framing are also an option. The arch ribs will be fabricated from Grade 70 steel, while the spandrel columns, girders, and Vierendeel bracing will be fabricated from Grade 50 steel.

Concrete Solid Rib: This concrete alternative is a classical twin rib concrete arch, with cast-in-place spandrel columns, and a cast-in-place concrete box girder deck. The arch tapers from 18 feet deep at the skewbacks to 12 feet deep at the crown, and will be cast in place with stay support and form travelers. The overall length of the bridge is 1907 feet, with stepped wall abutments stationed to limit bridge length to the station of first rock on the southward sloping Nevada rim. The main span is 1090 feet,



with typical spandrel spans of 155 feet. Columns are cast in place box sections, both in the approach spans and in the spandrels. The assumption is that the twin box girder decks will be either incrementally launched from the Arizona abutment or cast on a traveling formwork truss. The box girder will be longitudinally post tensioned as launched, and transversely post-tensioned within each box. An alternative approach is to design both the columns and deck superstructure as precast segmental. While this alternative would increase the demands on lifting equipment, it would reduce the construction schedule for the critical path spandrel columns and deck erection. A closure strip will be cast between the boxes after erection. The arch crown is open spandrel, which is more appropriate for the high rise of the short span arch layouts. The arch is designed for 8,000 psi concrete, based on 56 day strength, but can be more efficient with 10,000 psi concrete. Columns and roadway box girders are based on 6,000 psi 28 day strength.

Concrete – Steel Composite: The concrete composite alternative combines a twin rib concrete arch with steel spandrels and a conventional steel box girder with composite concrete deck. The focus of this alternative is to blend the economy of a concrete arch with the light weight and speed of erection of a steel deck structure. The span to rise ratio is ideal for concrete. This allows the efficient use of high strength concrete in compression, casting the arch while structural steel is being fabricated and delivered to the site. The bridge is 1896 feet in length, with nominal 120 foot spans as typical in order to maintain the aesthetic balance with the arch spans. The arch design is based on 10,000 psi concrete 56 day strength, with all other concrete elements based on a



6,000 psi 28 day strength. In order to contain steel fabrication costs, the spandrel columns are comprised of three steel tube sections, connected with shear plates over their full height. Column connections with reinforced concrete are designed to develop the strength of the steel shell using a composite connection. Spandrel columns are unfilled steel tubes. Approach columns are either concrete filled steel tubes, unfilled steel tubes or reinforced concrete sections. The skewback column will be concrete filled in order to provide the additional capacity needed during arch erection. The roadway integral diaphragms for the steel box girders are post-tensioned concrete, both for economy and to avoid FCM requirements for steel diaphragms. The deck boxes are conventional steel bathtubs, erected span by span using a girder launcher. The depth for these boxes is increased over normal roadway requirements in order to accommodate the connections with the integral diaphragms and to provide a stiffer and more durable deck system.

4.4 Long Span Alternatives:

4.4.1 ***Site Layout:*** The long span layout for the arch departs the AZ canyon wall in approximately the same location as for the short span layout. The preferred roadway alignment heading is slightly to the SW of the short span alignment when reversing station from AZ to NV. The long span traverses the rock knoll at the switchback, and founds just beyond the fault line behind the knoll in NV. A portion of the knoll must be removed to provide clearance for the arch to pass. The arch span for this arrangement is now 1325 feet to the theoretical springing. This dimension is also subject to some tuning for the final design, depending upon final roadway alignment and rock excavation requirements. The rise will vary with alternative, and generally ranges from 276 to 290 feet, for a span to rise ratio of about 4.5 to 4.8.

4.4.2 Design Options:

Steel Vierendeel Arch: The Vierendeel-rib alternative is an option that was advanced to provide the maximum opportunity for aesthetic expression. The proposed structure is 2015 feet long with a 1325-foot main span. The variable depth arch ribs will be vertical and parallel, and comprised of Grade 70 steel.

The struts between the top and bottom chords of the ribs will be normal to the chords. The spandrels will consist of parallel tubular columns and be inclined to match the slope of the rib struts. The spandrels and ribs will have Vierendeel bracing. The superstructure will be similar to the superstructure proposed for the solid-rib alternative. The spans on the Nevada approach will be supported by a bent similar to those on the main span, except that it will be oriented vertically. Due to the inclination of the "ray" spandrels in the main span, the deck above includes a tie beam, much the same as for a tied arch. The tie will be a separate framing member connecting the inclined spandrels. This alternative would be erected vertically at each springing, and rotated down to closure through a temporary hinge at the spring line.

Concrete Solid Rib: The concrete arch for the longer span is a twin rib box girder. The overall bridge length is 1990 feet, with typical spans of 150 feet. The box is tapered in

elevation, and splayed in plan. The arch crown is integral with the deck, which lessens second order effects and blends well with the aspect ratio for the long span alternative. The spandrel columns are also concrete, and assumed to be cast-in-place. Precast segmental columns may be considered, depending upon the capacity of erection equipment. Cast in place concrete will be pumped out to form travelers and jump forms using a stayed form traveler operation. The deck system is similar to the short span solid rib concrete, being a twin box girder structure. However, due to the integral crown, we anticipate the use of a span by span cast in place operation using a formwork truss, similar to the construction scheme used for Alsea Bay in Oregon and on several viaducts throughout Europe. Precast segmental is also an option for the deck box girder. The box girder will be longitudinally post tensioned, and transversely post-tensioned within each box section. A closure strip will be placed after deck boxes are completed.

Steel Trussed Rib: The long-span trussed rib alternative is a traditional engineering solution to a long span steel arch crossing. Before the advent of modern stay cable erection methods, high strength steels and high strength concretes, the trussed arch rib and suspension spans were the only alternatives considered for spans in this range. The proposed structure consists of a 1325-foot main span arch with 455-foot and 235-

foot approaches on the Nevada and Arizona sides of the river respectively, for a total structure length of 2015 feet. The variable depth trussed-ribs are vertically oriented with parallel and vertical spandrel columns. The superstructure is comprised of steel plate girders spanning approximately 130 feet with a composite concrete deck. The approach spans are similarly comprised of vertical column bents supporting a steel plate girder superstructure with spans to 160 feet. The top and bottom chords of the ribs will be fabricated from Grade 70 steel. The vertical and diagonal web members of the trusses will be Grade 46 structural tubing. Main span and approach span columns will be fabricated from Grade 50 steel. All bent and rib bracing members will be also fabricated from structural tubing. The deck will be 5000 psi cast-in-place concrete with stay-in-place metal forms and uncoated reinforcing steel.

5.0 Geotechnical and Substructure

Nevada Skewback

As we embarked on the bridge screening program and type study, there were questions about both the exact rock topography and quality on the Nevada side of the canyon. The rock knoll at the switchback in the current US93 alignment leading down to the dam has been assumed as the founding for the arch since the time of the Phase B bridge studies in 1992. Final corridor mapping (circa November, 2001) confirmed that the topography would permit placement of the skewback footing, but rock quality and stability had to be ascertained due to the existing steep side slope resulting in an open excavation on two sides (east and south) rather than just to the front as is more typical. The preliminary geotechnical program included geologic mapping of the ground surface and canyon walls and completing a limited number of borings in order to determine the condition and suitability of the rock for founding on both the rock knoll and on the rock mass beyond the knoll in Nevada. These studies show that the rock at the Nevada knoll is of sufficient quality to support a foundation for any of the various alternatives. The rock quality varies among the three landings (long and short span in NV, and common location in AZ) with the AZ skewback being the lowest in strength. However rock strengths at all landings are sufficient to support the nominal working loads required for design.

Substructures are all cast-in-place concrete on rock substrate. All typical footings will be keyed a minimum of 1 foot into rock. This criterion is particularly relevant in NV, where the topography falls off precipitously to the south, resulting in footing excavations that “day-light” rather than being depressed into the rock stratum. Footings will be designed to preclude uplift for all but the seismic load case. Other criteria are traditional, and are covered in the Code.

The abutments represent a special design consideration for layout of the bridge. The steep slope and irregular rock profile at both abutments make stationing of the abutments variable. In the extreme, the options are to end the bridge structure at first contact with rock, or to extend the bridge structure until the full width of bridge is on rock. Owing to the extreme falloff in ground profile from north to south (across the width of the bridge), the difference in the rock-line from left to right can be as much as 50 feet. This means that the longer bridge with a uniform

Arizona Skewback

abutment height will require substantial rock excavation, while the shorter bridge will require a very tall abutment wall in one corner. The overall effect will be influenced by the minimum clear height under the bridge, which is also an elective item. Higher abutment walls may be constructed using tie-backs, or backfilled using soil-cement to minimize active pressure on the wall.

The choice of span length affects the rock excavation conditions on the Nevada side of the river. The short span alternative requires significantly less rock excavation due to the open south exposure. However, due to the rock fracture pattern to the north, the high wall supporting the existing roadway will be rock bolted for its full height. The long span skewback extends back into the rock slope behind the knoll. The fracture pattern in this area indicates that the back wall slope will stand at 1/4H:1V, and the northeast side will stand at 1/2H:1V, but both slopes may require either local notching of the cut face or local rock bolting. In addition, a portion of the knoll must be removed in order to permit the arch to extend past the knoll and land on the long span springing. The preliminary geotechnical information serves to confirm that both the long and the short span are feasible from a foundation engineering standpoint.

6.0 Roadway Geometrics, Hydraulics and Drainage

The roadway profile used for the bridge type study was taken from a moment in time during the development of the roadway studies. The entire bridge in on a tangent, and the present range of roadway alignments avoids any superelevation on the bridge. The profile also avoids any sag curve on the bridge, and ascends from NV at a 1.25% grade, descends to AZ at 1%, and peaks with a 500 ft vertical curve near mid span. While the long span alignment alters the stationing and profile due to the change in alignment, the two are close enough for preliminary design purposes (also true of the ground profile) to allow the same geometric data for all alternatives. Once the preferred span length is selected, the bridge profile will be modified to “tune” the roadway geometrics to the selected bridge type. The PVI will be moved towards or to the center of the main span, and the grade on the NV side adjusted to match the movement of the PVI towards NV.

The overall roadway width is 97’-10”. This includes 4 – 12 ft travel lanes, 10 foot outside and 4 ft inside shoulders, 2 foot shy distances at each barrier, and an 8 foot sidewalk. This results in the roadway template being 4.5 feet offset from the bridge structure centerline due to the 8 foot sidewalk (9 feet with railing) to the north. The decision regarding the full-length sidewalk will affect not only the roadway geometrics but also the bridge design itself. The bridge centerline would move 4.5 feet to the south, and the structure shifted to be symmetric with the roadway alignment if the sidewalk is omitted.

Since the roadway template is carried on to the bridge, with 10 foot shoulders and the addition of 2 foot shy distance to the traffic barriers, this broad width and 2% crossfall results in sufficient hydraulic capacity to eliminate the need for drains on the bridge. Complete hydraulic computations are contained in the roadway computation package.

7.0 Construction Procedures

Each of the drawing sets illustrates the anticipated construction procedure for the given alternative. Due to the topography of the site, all of the alternatives will need a high line cable crane for general site access. This is an expensive, and relatively slow crane operation, and both excavation and approach construction will be supplemented with conventional boom cranes located throughout the site.

Given the long span and deep gorge, there are only two practical methods for arch erection. One is the use of tower and stays, similar to a cable-stayed bridge. This system is illustrated on the type study plans for the six alternatives studied, and is assumed for the cost estimates that are a part of the type study. The second method for arch erection is to provide temporary hinge movement at the springing, and erect the arch halves vertically at each skewback. Once complete, the arch halves can then be lowered with cables to complete main span closure out over the gorge. The advantage of such a method is that material delivery and access is vertical over land, rather than horizontal over the gorge. Such an operation is less dependent upon the slow high line cable crane, and is also more readily accessible for labor-intensive operations during construction. The Vierendeel arch would be the most likely candidate for this vertical method of construction, in part to keep deflections out of the arch that would otherwise complicate fit-up of the arch struts. However, the temporary works for tieback anchors would be similar to stay erection, and the equipment for lowering would be substantial.

All options begin with excavation for the skewback foundations. This is a time consuming and deliberate process that requires access for a variety of heavy equipment. On the NV side, we anticipate constructing a work platform just behind the knoll, accessing this point directly from the US93 roadway at the switchback. A conventional track crane can be stationed to service both the skewback excavation and work on the first land pier. Rock will be removed using skip pans and trucked away using the highway for access. On the AZ side, access is a bit more precarious. The assumption made for our estimating work is that a high capacity tower crane will be set up on the southern approach footing, servicing the skewback and entire approach span. Other approaches may include setting up a ringer (high capacity track mounted crane) just south of the footing area, or a larger ringer in the abutment area. Since the excavation operations on the two rims are independent, we anticipate this work being done in parallel with separate equipment, but perhaps common crews.

The AZ approach provides large areas of close access for laydown and material handling. On the NV side, the immediate area behind the bridge is more restricted due to the switchyard. However, there is ample laydown area upstation near the warehouse. Due to the roadway geometrics and topography, any incrementally launched solution would likely come from the AZ side of the canyon. A severe limitation on material delivery to AZ would compromise this strategy (large, long components can not negotiate crossing the dam), in which case the station of the NV approach spans from the abutment out towards the river may be used as an elevated launching platform.

The high line crane is a rather expensive piece of equipment, and quite vital to the erection process. Often time erectors will use two high lines, both for redundancy and for combined lifts of heavier loads. The capacity needed for the high line is a function of the design. The steel arch solid rib, for instance, may require the largest capacity in order to keep the number of arch sections to a minimum. The trussed rib may exact the highest cycle duty from the high line, since every piece of the structure may be delivered with the highline. The Vierendeel may largely avoid the high line for arch construction if erected vertically (although it would be needed for deck erection), and the concrete alternatives may need only enough capacity for reinforcing and form delivery. The composite will fall somewhere in between steel and concrete alternatives, since the high line would also be needed for setting spandrel columns.

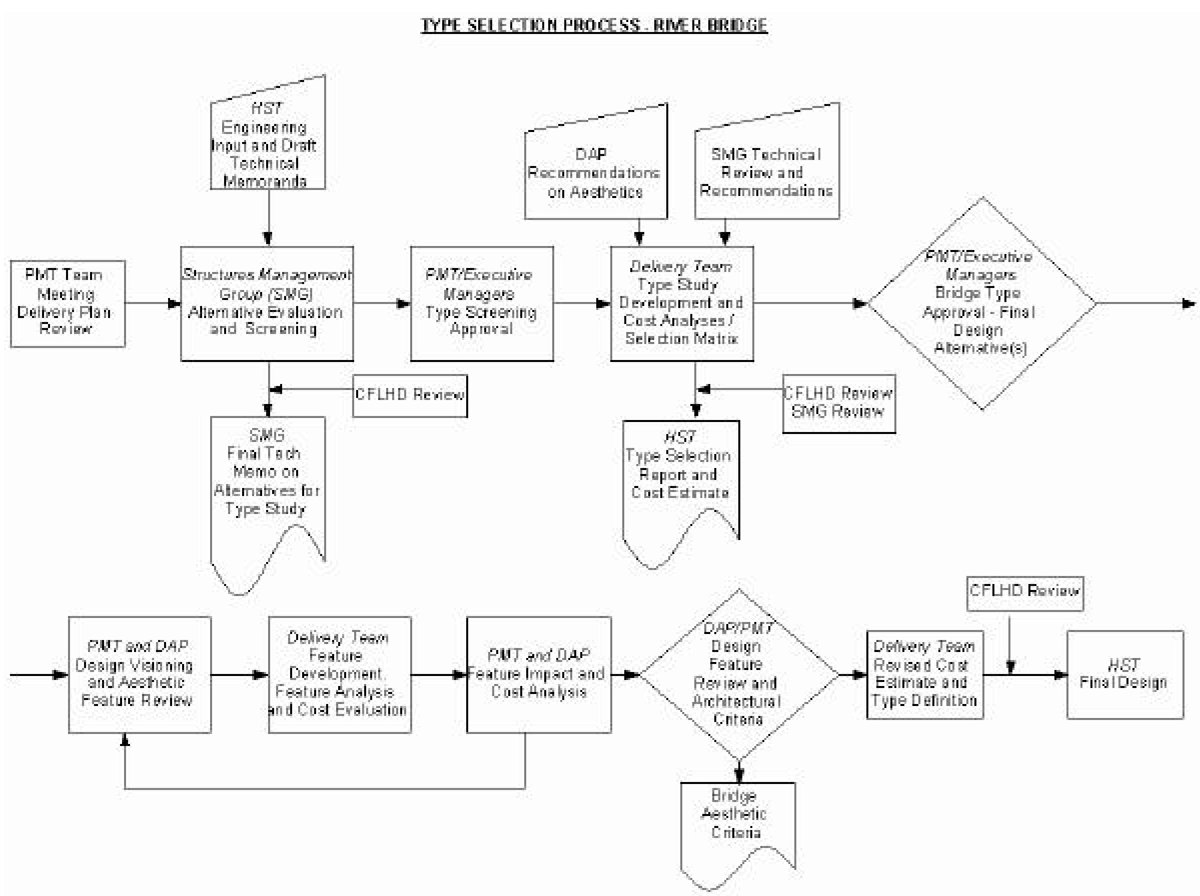
The high line configuration assumed in the detailed estimating process is shown on the composite drawings. The span for the high line is approximately 2300 feet. This length is governed by both access requirements for lifting in front of the towers, and by the need to clear the live electrical lines in AZ with the luffing lines offset approximately 150 feet from a 300 foot tall tower. The capacity assumed for the composite is 35 tons. The high line for the solid steel rib is based on twin 50 ton cranes. Since capacity and speed cost money, and time costs money as well, each contractor will look at cable crane capacity somewhat differently, and the ultimate choice of crane may vary with each proponent.

Construction schedules are included with the detailed cost estimates in Appendix B.

8.0 Evaluation

8.1 Process

The Delivery Plan for the project sets out both a development and a decision process for the River Bridge type selection. Guidance is provided to the project by the Project Management Team (PMT) and by the Design Advisory Panel (DAP). The PMT consists of representatives from FHWA, ADOT, NDOT, BOR, NPS, WAPA. The DAP consists of representatives from the Nevada and Arizona State Historic Preservation Offices, the Advisory Council on Historic Preservation, the National Historic Landmark Coordinator, Native American tribal representative, an independent architectural historian, and an independent landscape architect, FHWA, ADOT, NDOT, BOR, NPS, and WAPA. The DAP is charged with reviewing and recommending aesthetic elements of the project, including the Bridge. The Structural Management Group (SMG) - comprised of the Designers, CFLHD, and the Bridge Engineers from Arizona and Nevada – was established to review the technical elements of design development. Both of these panels offer recommendations to the PMT, who in turn present recommendations to the Executive Committee for final decisions.



8.2 Development of Alternatives

The Hoover Dam Bypass Bridge has been the subject of previous studies for the Sugarloaf Alignment. The most recent technical studies were the Phase B Corridor Studies, published in January 1992. These studies began with an evaluation memorandum (1991) that considered fourteen bridge configurations for the three corridors. The bridge options were reduced to the two most favored options for each alignment, with the evaluations based on site constraints, aesthetics and expected construction costs. These studies recommended that both solid rib steel arch and concrete cable-stayed alternatives be considered for the crossing of the Colorado River on the Sugarloaf Alignment. The Phase B bridge length was similar to the present structure, however, the current roadway width has increase from 77 feet at Phase B to 97'10" for this type study. That increase is the result of increase shoulder widths and a sidewalk on the north side of the bridge.

Bridge development has progressed according to the delivery plan for the Hoover Dam Bypass Project. The screening process considered all relevant bridge forms for the crossing, as stipulated in the EIS. The SMG participated in a bridge type screening that reduced bridge candidates down to deck arch designs. Long span alternatives were not envisioned in the Phase B studies (long span being an option to bridge over the rock knoll at the NV switchback, and extend the main span to the NV slope). The number and range of alternatives was selected in order to address the design options for both long and shorter spans, since at the time of screening the Phase B span length was not confirmed through mapping and geotechnical evaluation. Of these alternatives, 4 would apply to either span length, with two of the long span alternatives being only appropriate for the geometry of the longer option.

The geotechnical investigation has paralleled the bridge type study. The preliminary geotechnical survey has concluded that either of the two span layouts is acceptable from a geotechnical standpoint. Therefore, since both the topographical and geotechnical data confirm the feasibility of the short span layout, the only reason to go to the long span layout would be either economics or aesthetic preference.

8.3 DAP Input

The Design Team presented design development to the DAP in 3 separate meetings, with each serving to further define the DAP's preferences for bridge architecture, character and appearance. Bridge options were presented to DAP for feedback in October, prior to the screening process. A workshop was held with the DAP in early December, after the screening process established the deck arch as the preferred bridge form. This workshop allowed the DAP to review specific bridge development, and to provide input on guidelines for preliminary design and architectural development. A third meeting in February allowed the DAP to review the preliminary designs within the type study, and to offer their preferred alternatives and preferences on architectural priorities for final design.

In reviewing the alternatives presented for this type study, the DAP opined on a variety of characteristics. Their input follows both the tenets of their charge to the design team (see Section 3, above) and their own aesthetic guidelines for the character of the corridor and the visibility of the main river bridge. The DAP evaluated alternatives based on the descriptions and renderings produced from the type study plans. Their input on the bridge options was separated into three categories; Acceptable, Unacceptable, and Controversial. The latter category was reserved for the Vierendeel alternative, which evoked strong commentary both pro and con. All solid rib options were considered acceptable by some or all of the DAP. The trussed arch was judged unacceptable by consensus among the DAP members. With exception of the trussed rib, all remaining concepts were acknowledged as appropriate candidates for the site. DAP input is factored into the decision process for the recommended bridge types for final design.

8.4 SMG Evaluation

The Design Team presented type study development and engineering process to the SMG in meetings that paralleled the dialog with the DAP. The SMG guided the screening process, has provided technical input on the development of alternatives, and has guided the technical rating of the various preliminary design options presented in this Type Study. The SMG process involved the development of consensus ranking criteria for technical aspects of both the screening process and the type selection process. (The screening program is described more fully in Tech Memo 02.)

The SMG ranked the candidate bridge types within the type study for six criteria:

1. Inspection requirements: Access for and detail of inspection. Criterion is to judge the difficulty and cost of routine inspections.

2. Construction Complexity: Criterion is to judge the contractor’s risk during construction for unforeseen items that arise during the course of routine work. Such items as fit-up, geometry, tolerances, and demands on accuracy and detail affect the degree of difficulty for the construction.

3. Vulnerability: Toughness of structure as impediment to terrorist threat, impacts, explosions, etc.

4. Estimate Volatility: An assessment of how stable and predictable market prices are for the construction cost estimate.

5. Construction Duration: Anticipated schedule of main bridge construction activities.

6. Serviceability: A measure of the frequency and cost of routine repairs. This ranking also reflects an assessment of what the ultimate life span might be for each alternative, and what the ensuing life cycle costs may be for the chosen alternative.

The SMG applied these criteria within a ranking matrix. As noted earlier in this report, the SMG added variations for two alternatives to the original list of 6 that were studied. The short span trussed rib and the long span concrete composite were not specifically engineered, but were extrapolated from the original group for estimating purposes in order to complete an array of choices. The group agreed on a consensus weighting for each criteria, and then individually ranked each bridge for the criteria.

HOOVER DAM BYPASS - RIVER BRIDGE TYPE SELECTION FEATURE-IMPACT ANALYSIS

Bridge Options	Inspection requirements	Construction Complexity	Vulnerability	Estimate Volatility	Construction Duration	Serviceability		TECHNICAL RATING
Steel Solid Rib								
Concrete short solid Rib								
Steel Trussed Rib (long)								
Concrete composite								
Steel Vierendeel								
Concrete solid rib (long)								
Trussed Rib Short								
Composite Long								
Impact Weight	3	4	3	3	4	4		

The type selection rankings are factored into the decision process for the recommended bridge types contained in this report.

8.5 Estimating Process

The Hoover Dam Bypass River Bridge is a rare, if not unique, bridge structure for the US construction industry. The design will be one of the longest arch bridges in the US, at a site with significant access restrictions and logistical challenges. These characteristics make general reference to other similar bridge projects – general reference being the more common approach to preliminary cost estimating for bridge works – an unreliable approach to defining programmatic costs for budgeting purposes. In order to address the characteristics of this site, the Design Team conducted a more detailed preliminary design and fundamental construction cost estimate for two of the six alternatives covered by the type study. One alternative was selected from each of the long and short span layouts in order to obtain site related costs for each configuration. In order to support these estimates, more detailed engineering drawings were necessary than would otherwise be developed for a traditional type study. The detailed cost estimates were developed by construction and fabrication cost estimators retained by the Design Team. Direct supply and construction costs were forecast based on the preliminary drawings provided to the estimators. Costs were escalated to the assumed construction schedule, and profit margin was applied to direct costs. The equivalent unit prices for the various bid items were then modified if necessary for the character of the work, and applied to the other four alternatives within this study. In order to balance out a more complete family of alternatives, the steel truss rib was extrapolated to the short span layout using a pro-ratio of steel weight for span length. The composite concrete was extrapolated to the long span using a scale factor for the arch concrete and rebar adopted from the long span concrete option. In this way the full range of cost options across both span lengths could be included in the final evaluation of bridge types. Estimates and a summary table are included in Appendix B.

One of the major cost items in the estimates for steel alternatives is the fabricated and delivered cost of structural steel. Steel costs and steel industry fortunes in the US have been a political topic of late, with future actions having potential to impact the eventual cost for any steel or composite alternative. Note that for the steel solid rib alternative, steel supply is about 60% of the cost, so the cost for this single source of supply dominates the steel rib estimate. The raw material (steel plate) may represent one quarter to one third of the fabricated cost, so the level of price competition for fabrication is also critical. Even if the current tariff and supply issues increase the raw material cost 20 cents per pound, the fabrication cost is still a large portion of cost that is subject to price competition.

The construction cost estimates show that the concrete composite is projected to be the least costly alternative design of the three top-ranked short span options. Cost projections are determined for the present economic climate, and are subject to some uncertainty. Factors affecting these estimates include the level of competition in the marketplace at the time of bidding, general economic conditions for material and labor costs at the time of bidding, and the risk profile created within the contract specifications for the construction contract. Many of these items are beyond the control of the project, and are part of the basis for contingency that is included in the estimate.

Construction schedules were developed with the cost estimates, and those for the build estimates are included in the Appendix B. The general construction durations for the short rib alternatives are as follows.

Baseline (composite concrete) – 40 months

Steel Solid Rib – 38 months

Short Span Concrete – 46 months

Short Span Concrete w/precast deck – 40 months

Accelerated composite – 34 months

The accelerated composite addresses the case where all foundation rock excavation for the river bridge is included with an earlier Arizona approach contract, leaving the bridge contractor with early access to construction of the bridge proper. The sequence of bridge construction would then differ from the normal case, since work would begin immediately on the arch skewbacks, rather than with excavation for the skewbacks and construction of the approaches.

Of interest in evaluating the estimated cost is a comparison of item costs across the spectrum of the top 3 rated short span solid rib alternatives. The following table is extracted from the estimated construction costs (without markup) for various components.

Hoover Dam Bypass
Cost Estimate - Group Summaries
Short Span Solid Rib Alternatives

ITEM		Composite	Concrete	Steel (W)
Arch[1]		$11,636,229	$13,708,948	$24,903,168
	ratio	100%	118%	214%
Spandrel Columns[2]		$4,379,266	$2,393,880	$5,143,557
	ratio	100%	55%	117%
Approach Columns[3]		$12,248,611	$6,064,469	$8,171,761
	ratio	100%	50%	67%
Deck Structure[4]		$11.088.846	$16.689.095	$11.273.758
	ratio	100%	151%	102%
Other costs (incl markup)		$50,523,930	$54,622,807	$53,469,825
	Base Estimate	$89,877,000	$93,479,000	$102,962,000
		100%	104%	115%

Footnotes

1) Arch is combination of arch material supply, erection and all tieback costs. Using "average" unit steel price of $1.50/lb for arch reduces steel arch cost to $21.5 million.

2) Concrete spandrel columns have no cap - it is integral with the deck. This distorts comparison for this item. In addition, there are 25% fewer piers with the concrete alternative.

3) There are more columns in the composite than in the other two alternatives - ~30% by length.

4) Deck for concrete includes cap/diaphragms, which are in with columns for other two alternatives.

This breakdown of component costs illustrates one of the strengths of the composite concept. The range of cost within the arch element shows a significant favor for concrete. In the case of the approach columns, they may prove to be more economical in concrete than the present steel solution used for the composite, and this is an element of design flexibility that can be optimized in final design. (This type of consideration must include column weight, equipment and schedule requirements for material delivery, among other things.) The added number of columns in the composite (assumed in preliminary design for reasons of aesthetics and constructibility) also merits scrutiny as an element of cost control during final design.

Summary of Base Construction Cost Estimates (with full sidewalk)

Concrete composite	Concrete short solid rib	Steel Solid Rib(w)	Composite Long	Concrete long solid rib	Steel Vierendeel	Trussed Rib Short	Steel Trussed Rib Long
$89,877,000	$93,479,000	$102,962,000	$99,213,000	$114,722,000	$136,625,000	$90,822,000	$98,821,000

9.0 Recommendations

The Colorado River crossing of the Hoover Dam Bypass is joining one of the most famous civil engineering landmarks in the world, and pairing off in such close proximity that the visual presentations of each will henceforth be tied together as one. This circumstance creates a special duty for design – an obligation to present a design that meets the challenge of visual appeal and engineering excellence that the designers of the dam met in their day. Heightening this challenge is the need to provide value, and design within funding limitations for the project.

The type study process has been systematic and structured according to the project delivery plan, involving stakeholders through the DAP, SMG and PMT throughout design development. The ranking of alternatives takes into account input received throughout the process, and melds that input with the engineering studies and construction cost estimating efforts undertaken by the design team.

The DAP's input is that all options except the trussed rib are acceptable; with some DAP members expressing reservations about the dominance of the Vierendeel form. The SMG structure evaluation is summarized below for each of the alternatives according to the criteria that the SMG developed. The two "extrapolated" alternatives are included, although not addressed in the engineering type study drawings.

The SMG process resulted in a first ranking of the concrete short solid rib on the basis of the technical criteria chosen by the SMG (see section 8.4), with other solid ribs in a second tier position. In terms of layout and character of design in the view of the DAP, the three preferred

HOOVER DAM BYPASS - RIVER BRIDGE TYPE SELECTION FEATURE-IMPACT ANALYSIS

TECHNICAL EVALUATION OF BRIDGE ALTERNATIVES

Bridge Options	Average Technical Ranking	Relative Technical Ranking	Relative Technical Grade	Number of First Ranking	Number of Second Raking	Number of Third Ranking	Number of Fourth Ranking	Number of Fifth Ranking	Number of Sixth Ranking	Number of Seventh Ranking	Number of Eigth Ranking
Concrete short solid rib	93.88	1.00	A	8	0	0	0	0	0	0	0
Concrete solid rib (long)	82.63	0.88	B	0	4	2	0	2	0	0	0
Steel Solid rib	78.75	0.84	B	0	3	3	2	0	0	0	0
Concrete composite	76.38	0.81	B	0	1	2	4	0	0	1	0
Composite Long	72.13	0.77	C	0	0	0	1	6	1	0	0
Trussed Rib Short	63.13	0.67	D	0	0	0	1	0	5	2	0
Steel trussed rib (long)	62.25	0.66	D	0	0	1	0	1	2	4	0
Steel Vierendeel	37.88	0.40	F	0	0	0	0	0	0	0	8

short span alternatives – concrete short solid rib, steel solid rib, and composite/concrete rib with steel superstructure – are similar. The engineering characteristics of the three differ, which leads to the separation observed in the SMG technical ranking.

The recommendation of the Design Team is to proceed with the short span Composite Concrete Alternative. The basis for this recommendation is presented throughout this report, and is summarized in the numerical weighting table below. This table accumulates ratings from the DAP, the SMG and numerical weighting of both cost and schedule related to a relative scoring with a maximum of 8 points (since there are 8 alternatives). The cost scoring received double the weight of other criteria.

Hoover Dam Bypass
Colorado River Bridge
Type Selection Rankings

Cost Weighting 2

Bridge Alternative	DAP Aesthetic Ranking[1]	SMG Technical Ranking	Estimated Construction Cost With Sidewalk	Ratio	Ranking[2]	Schedule (Months)	Ratio	Schedule Ranking	Score[3]
Concrete composite	**5**	**6.51**	$89,877,000	1.00	**8.00**	40	1.05	**7.60**	**35.1**
Concrete short solid rib	**5**	**8.00**	$93,479,000	1.04	**7.69**	46	1.21	**6.61**	**35.0**
Steel Solid Rib*	**5**	**6.71**	$102,962,000	1.15	**6.98**	38	1.00	**8.00**	**33.7**
Composite Long	**5**	**6.15**	$99,213,000	1.10	**7.25**	43	1.13	**7.07**	**32.7**
Concrete solid rib (long)	**5**	**7.04**	$114,722,000	1.28	**6.27**	49	1.29	**6.20**	**30.8**
Trussed Rib Short	**1**	**5.38**	$90,822,000	1.01	**7.92**	40	1.05	**7.60**	**29.8**
Steel Trussed Rib (long)	**1**	**5.30**	$98,821,000	1.10	**7.28**	42	1.11	**7.24**	**28.1**
Steel Vierendeel	**3**	**3.23**	$136,625,000	1.52	**5.26**	48	1.26	**6.33**	**23.1**

* Weathering steel option
1-DAP rankings were Acceptable, Controversial, and Unacceptable, rated as 5, 3 and 1.
2-Highest Rank is preferred based reciprocal of cost ratio times a maximum score of 8. Schedule sim.
3-Score is summation of rankings with multiple on cost alone

Score = DAP+SMG+(Cost * weight)+Schedule

The composite alternative was developed to address the specific conditions at this site and the ambition of schedule acceleration. This alternative has advantages in terms of structural design efficiency and in terms of construction.

- the span to rise ratio at the shorter span length is ideal for a concrete arch
- the blend of concrete for the arch and steel for the superstructure uses concrete to its best advantage in compression, and steel to its best advantage in bending. This is not only a technical advantage, but this blend of materials adds greater design flexibility to control costs
- the blend of steel and concrete allows the arch construction to commence at the outset while steel is being fabricated for the superstructure. This mix of construction is particularly beneficial if an early rock excavation program is employed in order to streamline the project schedule. In this case, the bridge would be let with rock excavation complete, which would allow bridge construction to move directly into arch construction without the wait for steel fabrication.
- the lighter steel superstructure will be faster to erect than a cast-in-place all-concrete superstructure, which should also assist with streamlining the project schedule.

Alternatives to the Recommendation.

The evaluation conducted by the Design Team is based on relative priorities given to aesthetics, technical ranking, schedule and budget. The relative standing of the alternatives can be viewed using different priorities than reflected in the above evaluation. If either schedule or budget is considered relatively less important to the project, the relative rating of the concrete short rib solution surpasses that of the composite. Thus, an alternative selection would place more emphasis on the SMG technical ranking, and could have the short span concrete solid rib as preferred.

Hoover Dam Bypass
Colorado River Bridge
Alternative Type Selection Ranking

Bridge Alternative	DAP Aesthetic Ranking[1]	SMG Technical Ranking	Estimated Construction Cost With Sidewalk	Ratio	Ranking[2]	Schedule (Months)	Ratio	Schedule Ranking	Score[3]
Concrete short solid rib	**5**	**8.00**	$93,479,000	1.04	**7.69**	46	1.21	**6.61**	**27.3**
Concrete composite	**5**	**6.51**	$89,877,000	1.00	**8.00**	40	1.05	**7.60**	**27.1**
Steel Solid Rib*	**5**	**6.71**	$102,962,000	1.15	**6.98**	38	1.00	**8.00**	**26.7**
Composite Long	**5**	**6.15**	$99,213,000	1.10	**7.25**	43	1.13	**7.07**	**25.5**
Concrete solid rib (long)	**5**	**7.04**	$114,722,000	1.28	**6.27**	49	1.29	**6.20**	**24.5**
Trussed Rib Short	**1**	**5.38**	$90,822,000	1.01	**7.92**	40	1.05	**7.60**	**21.9**
Steel Trussed Rib (long)	**1**	**5.30**	$98,821,000	1.10	**7.28**	42	1.11	**7.24**	**20.8**
Steel Vierendeel	**3**	**3.23**	$136,625,000	1.52	**5.26**	48	1.26	**6.33**	**17.8**

* Weathering steel option
1-DAP rankings were Acceptable, Controversial, and Unacceptable, rated as 5, 3 and 1.
2-Highest Rank is preferred based reciprocal of cost ratio times a maximum score of 8. Schedule sim.
3-Score is summation of rankings with multiple on cost alone

Score = DAP+SMG+Cost+Schedule

If the concrete solid rib alternative is selected, then the issue of alternative designs becomes a question to address in the final design program. In the case of the composite, both materials are represented within the design solution, and the best economy of each will be blended into the design. In the case of an all concrete (or all steel) solution, the bidding process would not include competition throughout the broader supply chain of alternate materials. Historically, design alternatives have been used to improve competitiveness and lower final bid prices by broadening the base for competition among material supply chains, fabricators and contractors.

The general basis for alternative designs is that a) there are competing alternatives that both meet the requirements and standards for the project; and b) both alternatives are estimated to be close in cost, where fluctuations in material or supply pricing can swing bids one way or the other. Variations of estimates within 10% are generally considered to be the same within estimating reliability. If a selection is made for the concrete solid rib, the range of estimates between concrete and steel alternatives is approximately 10%. Thus, alternatives then would have merit in terms of expanded competition.

10.0 Closure

The Executive Committee met in Las Vegas, Nevada on April 26, 2002 to review the Draft Type Study and evaluated the array of options identified in the text of this document. The Executive Committee focused on the following issues:

1. The purpose and objectives for the bridge design being
    a. design of a world class facility
    b. design with respect for schedule and budget
    c. design for pedestrian access across the canyon
2. Review of the advantages and disadvantages of proceeding with alternative designs for both the concrete solid rib and steel solid rib alternatives
3. Review of the architectural, engineering and operational attributes of the various alternatives
4. Reviews of input from stakeholders through public input, Design Advisory Panel input, PMT input and Structural Management Group input on the design options presented in the type study, along with other alternatives
5. Evaluation of bridge design details and bridge roadway template

The Executive Committee issued the following findings and decisions by consensus:

I. Proceed into final design with the concrete composite alternative.

II. Reduce the combined shoulder shy distances on the bridge by 2 feet for each of the inside and outside shoulders while satisfying AASHTO minimum requirements.

III. Provide a six-foot clear width sidewalk for the full length of the bridge on the north side.

IV. Consider concrete columns or a further blend of concrete and steel elements in the bridge design in order to lower the expected cost of the structure, while maintaining the respect for aesthetics. Maintain a box girder superstructure as a fundamental element of the bridge aesthetic.

V. Present a revised construction cost estimate for the bridge structure based on findings I through III, above. This revised estimate will be used as the new programmatic cost estimate.

The revised cost estimate is contained at the end of Appendix B.