

**Heavy Movable Structures, Inc.**

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## **“A Quickly Deployable Emergency Bridge Lift System”**

**by**

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## **A Quickly Deployable Emergency Bridge Lift System**

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### **Introduction**

Boeing 737 and 757 aircraft are manufactured at the company's Renton, Washington facility. This facility is connected to the Renton Airport, where the planes undergo flight preparation and testing, by two bridges spanning the Cedar River (Figure 1). During the manufacturing cycle, each plane crosses these bridges a number of times.

In recent years, flood waters have disrupted manufacturing activities and threatened the southernmost of these two bridges. Loss of this South Bridge, as it is known, would have a severe economic impact on Boeing and the local economy, and so in a joint action, the US Army Corps of Engineers, The Boeing Company and the City of Renton resolved to correct this situation with a three point plan:

1. To dredge the river to increase flow capacity.
2. To construct 5 ft. high levees along the river adjacent to the factory and airport. (With deployable closures at the bridges.)
3. To devise a means of lifting the South Bridge 8 ft. under emergency flood conditions, such that the bottom of the bridge girders will clear the tops of the levees by 1 ft. under the most extreme flood conditions.

### **The Bridge to be Lifted**

The primary structure of the South Bridge consists of nine 37" deep, 170' long built-up girders spanning continuously between two shoreline abutments over two intermediate piers (Figure 2). The center span, between piers, is 120 feet compared to 25' from the piers to abutments. This span relationship means that under virtually all combinations of dead load and live load, uplift is created at the shoreline abutments. This ranges from 20 kips per girder, for dead load only, to 97 kips per girder when supporting large aircraft. The total weight of the bridge, including transverse steel structure and 8' thick concrete deck, is almost exactly 1000 kips.

## **Design Criteria**

The as-built structure of the bridge and its primary use of transporting aircraft imposed a challenging array of criteria on the task of converting it to a "sometimes" movable bridge. Key among there were the following:

- Development of a mechanism that will uniformly lift the 170' long 1000 kip span, and in the full up position will react lateral loads due to wind, seismic forces, and debris impact.
- Development of a mechanism capable of reacting the large uplift loads on the girder ends when a large aircraft is mid span. This mechanism must also be capable of "preloading" the girder ends for the dead load condition.
- Additions to the transverse steel structure of the bridge to allow it to be supported at discrete lift points.
- The entire system must be deployed and operated in less than 2 hours, and all above-deck components must be removable when not in use to provide unobstructed underwing clearance for current and future aircraft designs.

## **System Description**

To satisfy all of the above criteria, a system (Figure 3) was designed using four hydraulic cylinders as the lifting elements. The cylinders mount to the bridge via one-eighth turn, cam action "bayonet fittings" (Figure 4). Hydraulically operated wedge blocks at each girder end (Figure 5) react the large uplift loads, and 2.50 inch thick shim plates (Figure 6) under the girders at the intermediate piers provide a means of applying and removing the bridge's dead load camber. Hydraulic power, cylinder transport, a crane for the cylinder installation, and all other items needed to effect a lift operation are provided by a dedicated special purpose utility vehicle (Figure 7).

When a lift operation is required, the utility vehicle is driven onto the bridge deck. The boom hoist is used to remove the manhole covers and position the hydraulic cylinders in the bayonet mounts. A pair of hydraulic cylinders are used to rotate the cylinder in its bayonet mount to the load ready position. At this point, a lock bolt is installed to assure that the cylinder cannot rotate out of position while in service. When the cylinder is installed, supply, return and vent lines are connected within the manhole by use of hoses with quick

disconnect fittings at each end. Once this procedure is completed at all four cylinder locations, the truck is then driven off the bridge. Hoses are then used to connect the truck mounted hydraulic power unit to the bridge deck piping, located in a manhole near the southeast corner of the bridge deck.

The first motion in a lift operation is to "flex" the bridge by raising it at Piers 2 and 3 approximately one half inch. This allows the shim plates to be removed from their service positions. Each shim plate (located at each girder on both piers) is retracted by a dedicated hydraulic cylinder. When all of the shim plates have been withdrawn, the bridge deck is then lowered until it is resting on the piers. This removes the uplift on the wedge blocks at abutments 1 and 4. All 18 wedge blocks on each abutment are withdrawn by a pair of push tubes which are actuated by a single hydraulic cylinder. The push tube lock mechanisms (one located on each side of the bridge) must be accessed from a manhole cover and manually unlocked prior to actuating wedge blocks. After the wedge blocks are unlocked and withdrawn, the entire span is ready to be raised. Lifting the bridge 96" takes approximately 14 minutes.

The lift, wedge block and shim cylinders are controlled by manually operated mobile service valves located on the utility vehicle. During the lift operation, oil is evenly supplied to each of the four cylinders through a mechanical flow divider which will keep the cylinder extensions equal to within the structure tolerance requirement of the deck. When the bridge is in the full up position, the truck mounted hydraulic power unit can be disconnected from the bridge to move the truck to another location.

Lowering the bridge and preparing it for service is accomplished by essentially reversing the sequence.

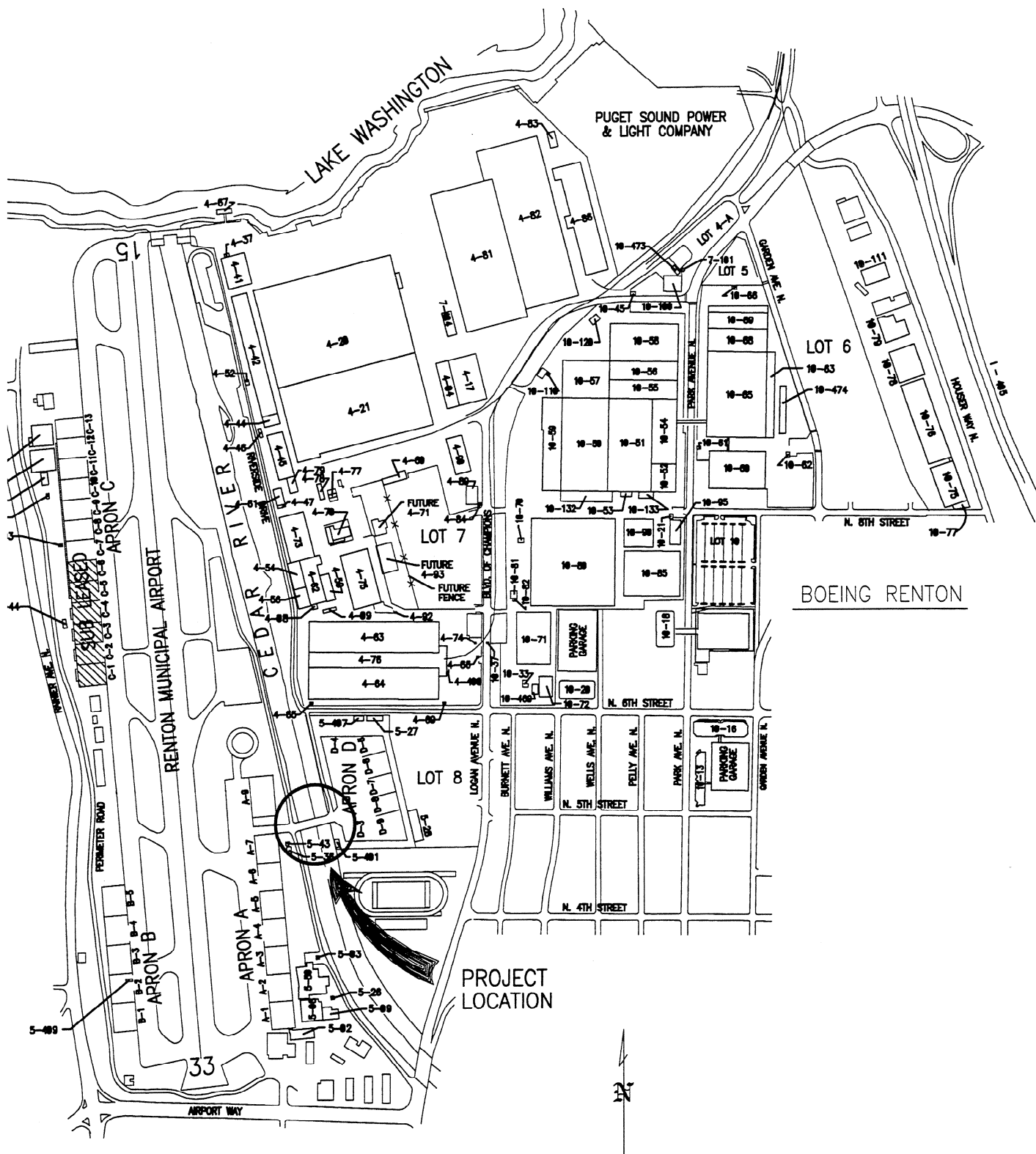
## **Construction**

Construction scheduling and phasing of this project was complicated by two unusual constraints:

1. The Cedar River salmon run is on the endangered species list. Construction of all work below the "normal high water" mark is limited to a "fish window" of about eight weeks duration, and must be done under the most stringent environmental observation and controls.

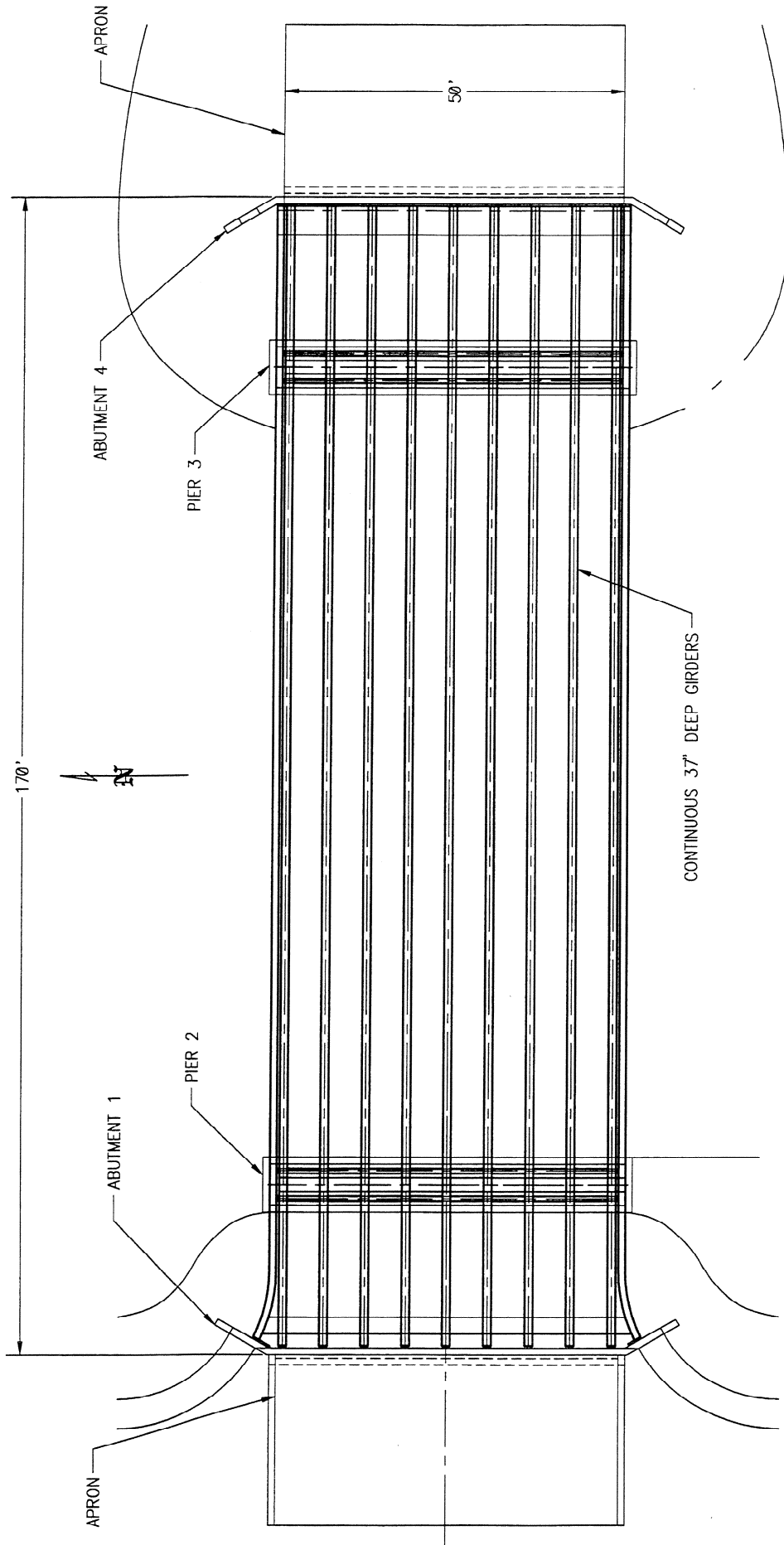
2. As airplanes near completion at Boeing, delays in delivery are measured in thousands of dollars per hour. Because of this, the Boeing Company has limited the total time the Bridge can be out of service to a single 5-day period.

At the press deadline for this paper, the major structural modifications have been completed, the bayonet mounts are installed, all bridge mounted hydraulic piping has been pressure tested and flushed, and the utility vehicle has been commissioned. The main lift cylinders have been supplied and tested. The first lift of the bridge deck is scheduled for August 3, 1998, at which time the bridge will stay up for 3 days while installation of the shim plates and wedge blocks are completed. It promises to be a very interesting week!



AREA MAP

FIGURE 1



PLAN OF BRIDGE STRUCTURE  
BRIDGE DECK NOT SHOWN

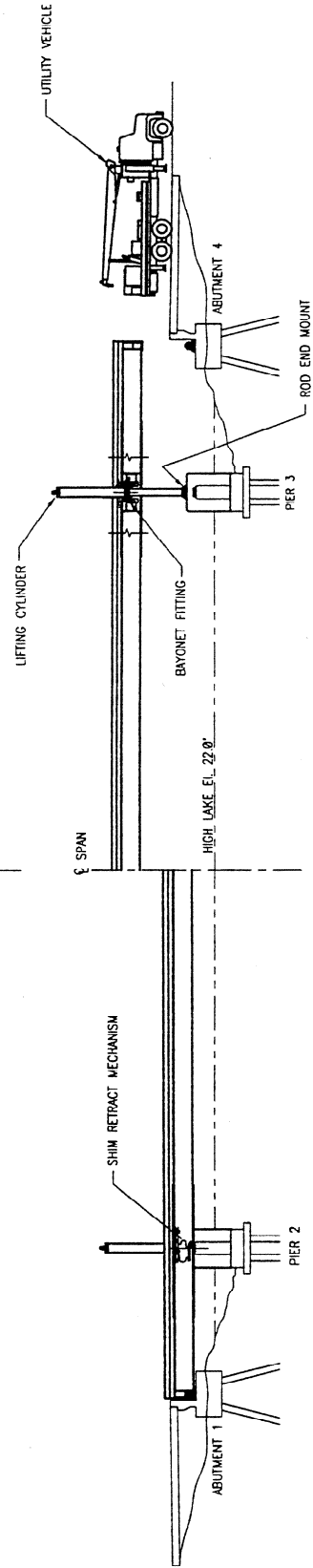
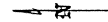
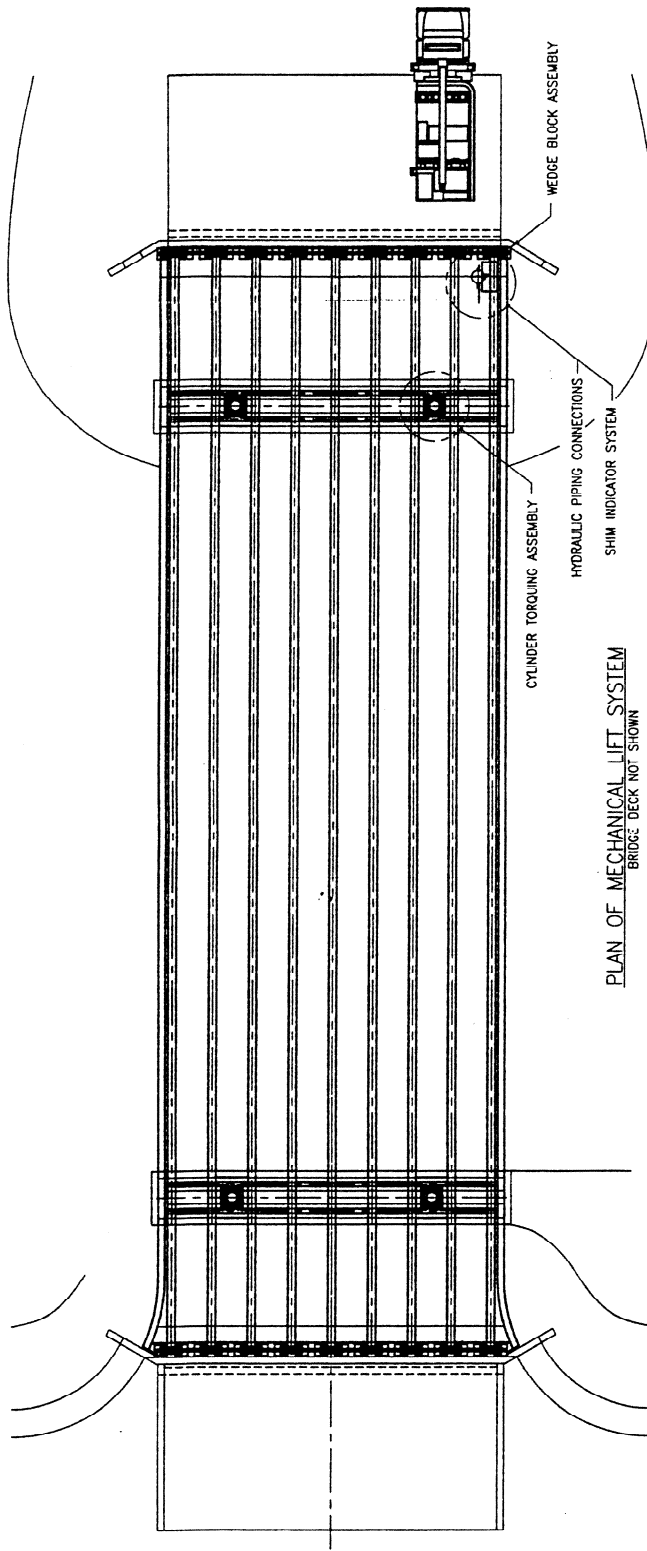
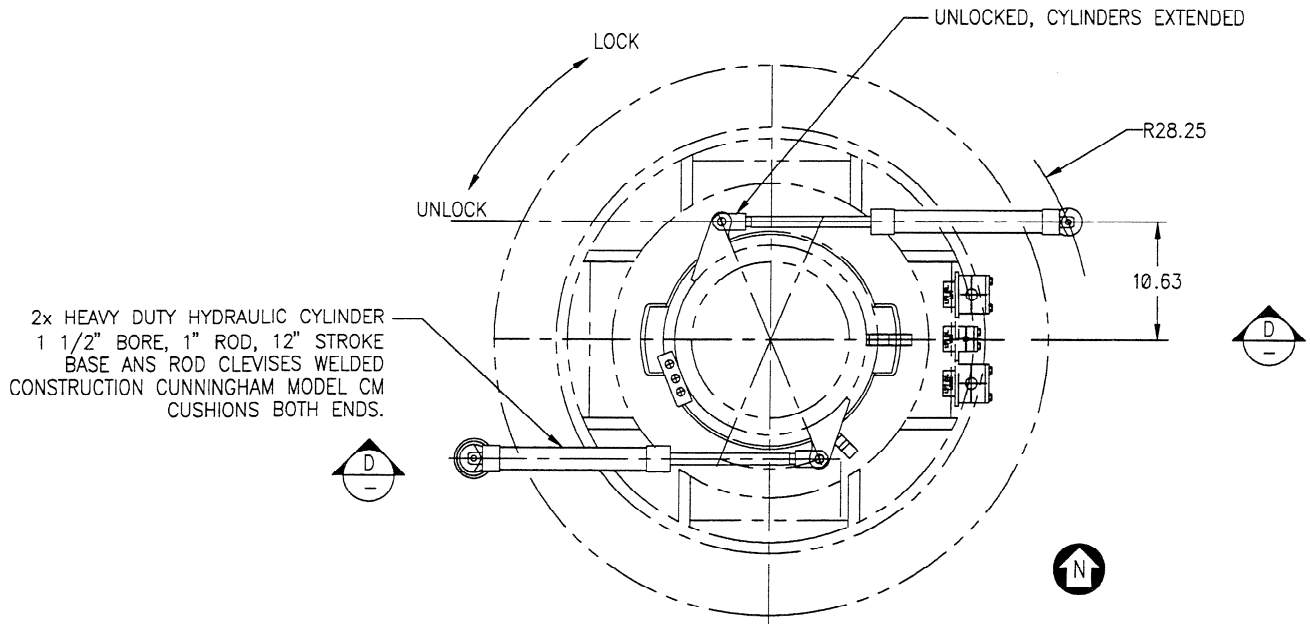


FIGURE 3





POSITIVE-LOCKING QUICK RELEASE PIN  
T-HANDLE, STAINLESS STEEL  
Ø 3/4 X 3" GRIP  
MC MASTER CARR# 90980A750  
2 PLACES

### CYLINDER TORQUING TOOL ASSEMBLY

(1) REQD, SHOWN IN UNLOCKED POSITION  
HOSES NOT SHOWN; TOOL CONNECTS TO  
WEDGE BLOCK HYDRAULIC CIRCUIT; REF. M14

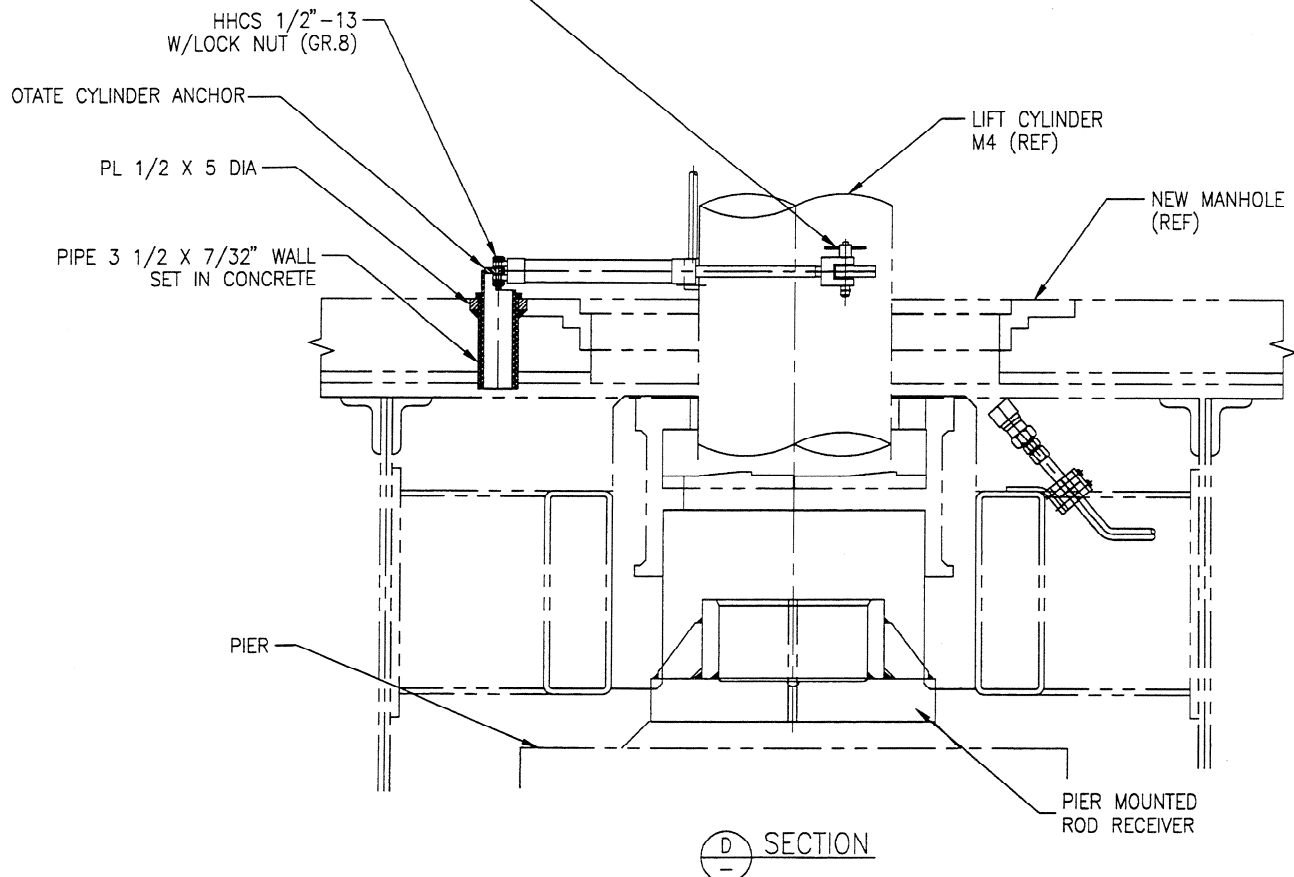
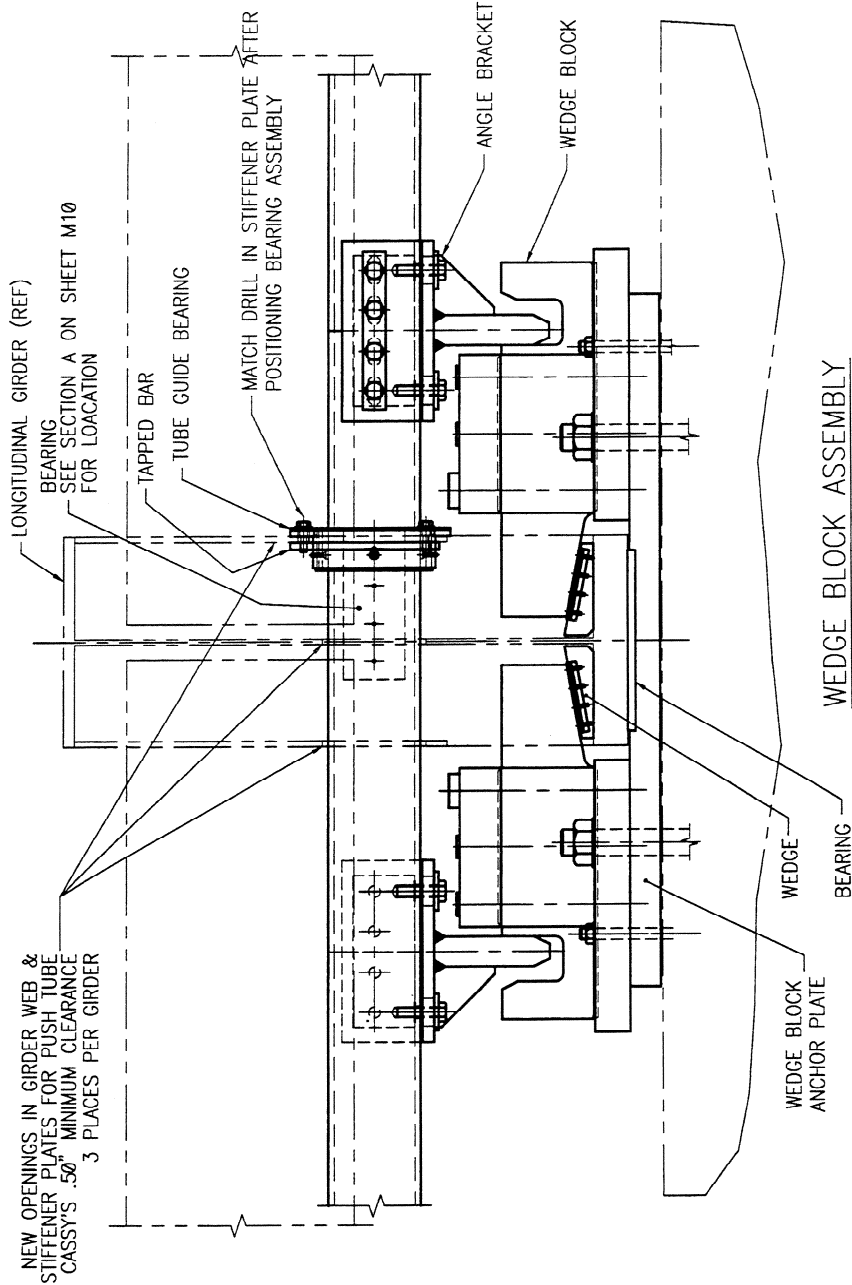
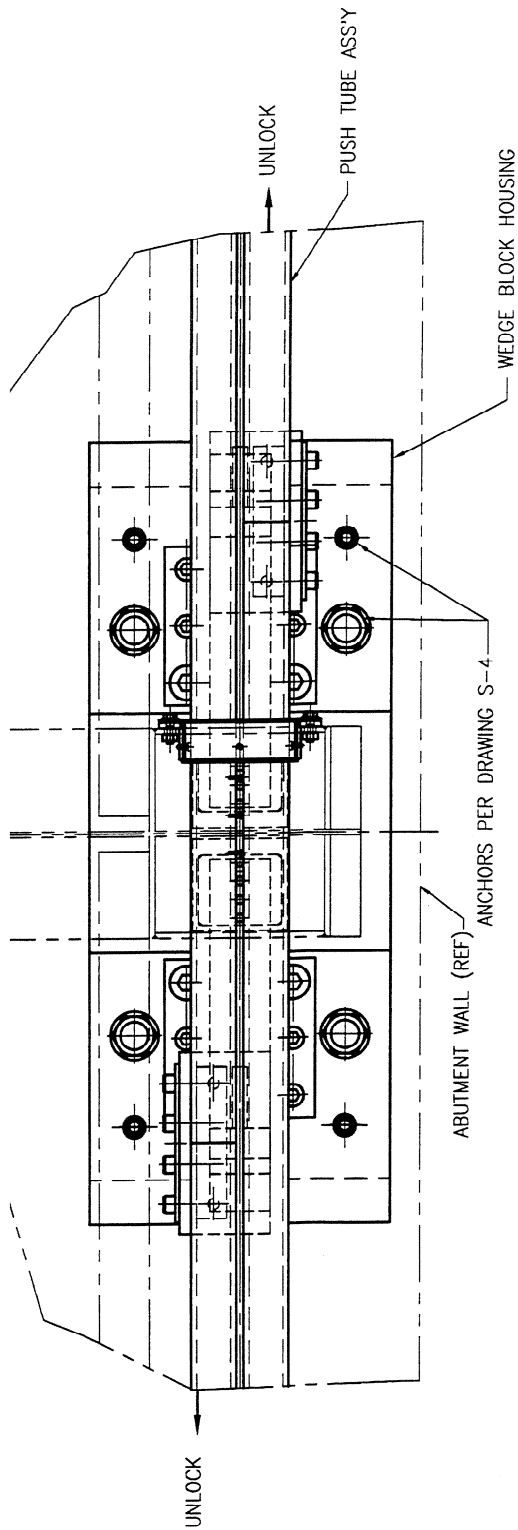


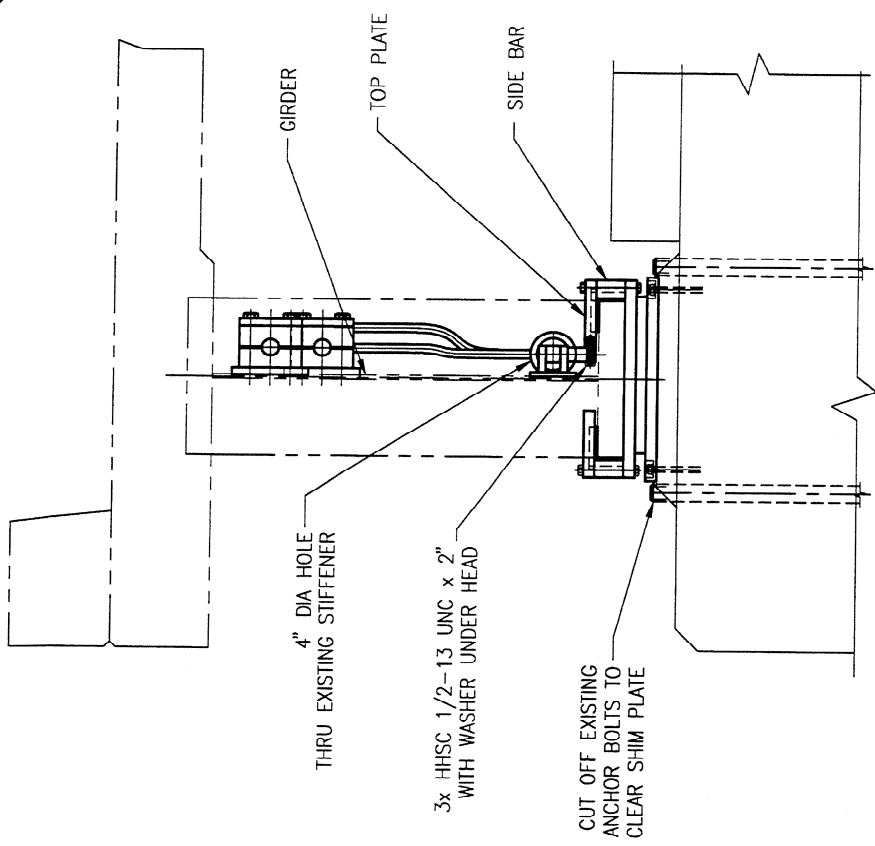
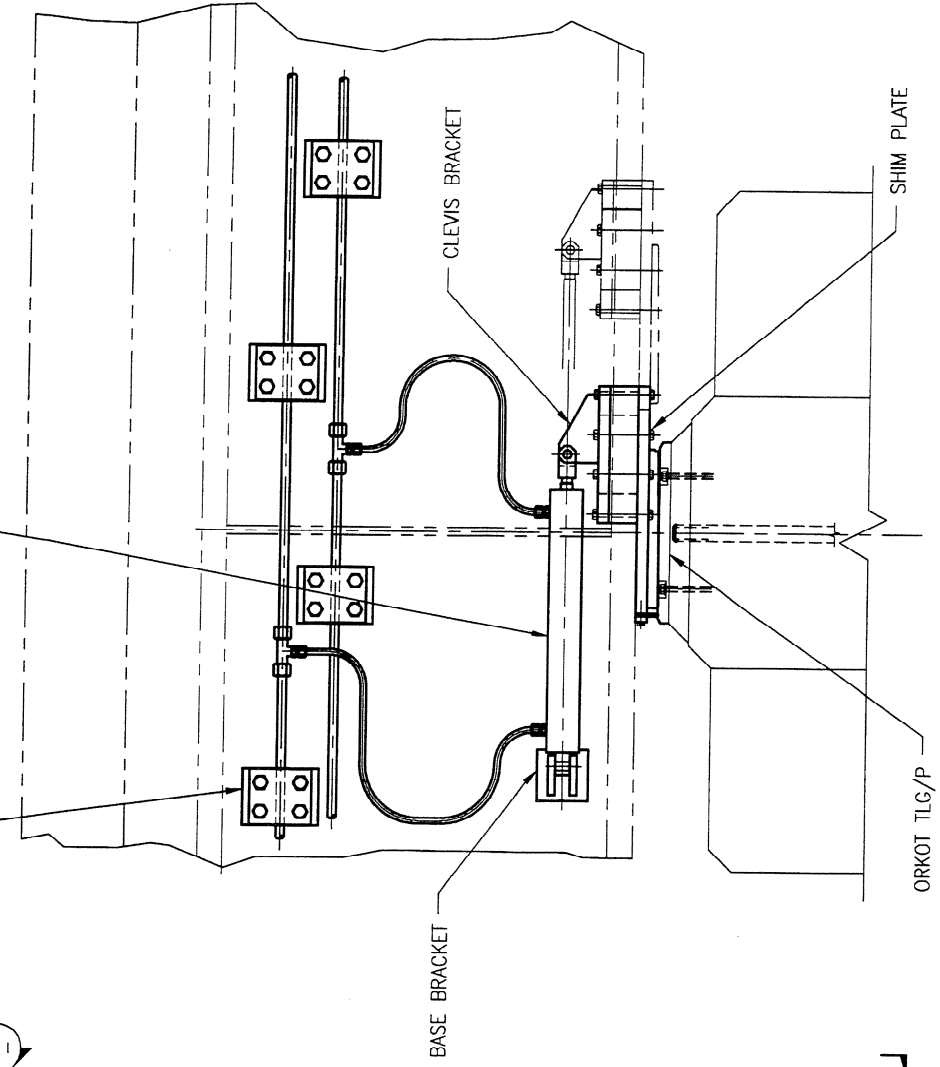
FIGURE 4



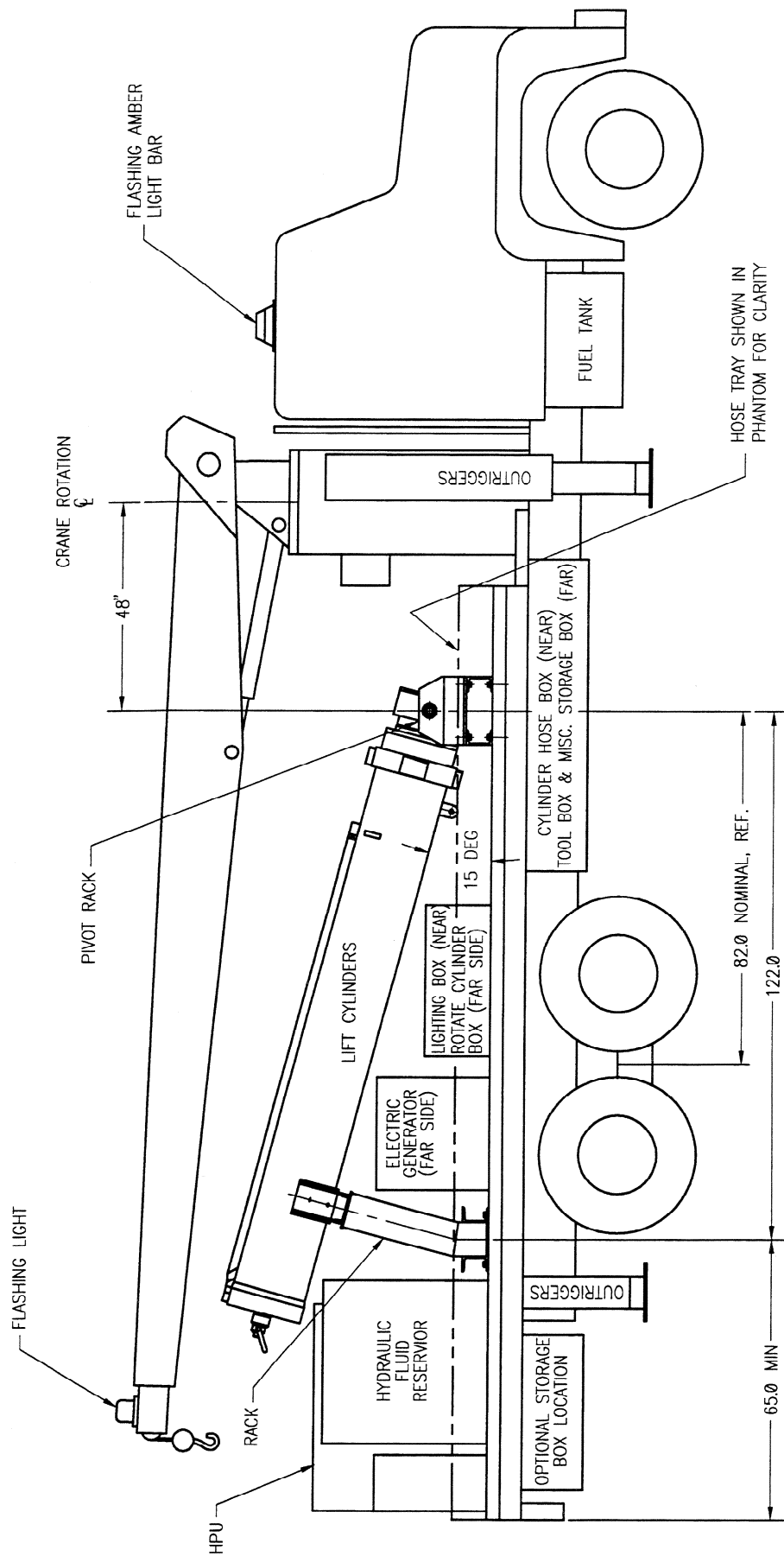
NEW OPENINGS IN GIRDER WEB &  
STIFFENER PLATES FOR PUSH TUBE  
CASSYS .50" MINIMUM CLEARANCE  
3 PLACES PER GIRDER

CYLINDER, 2" BORE,  
 ROD DIA. 1", STROKE 18"  
 WELDED CONSTRUCTION  
 CUSHIONS BOTH ENDS  
 CUNNINGHAM MODEL CM  
 W/ STAINLESS STEEL CLEVIS PINS

PIPE CLAMP 3/4"  
 WELDED BASE  
 W/POLYPROPYLENE SADDLES  
 (TYP)



**SHIM RETRACT MECHANISM**  
 (LOCATED PIER 2 & PIER 3 TOTAL 18 PLACES)  
 DETAIL 8 NOT SHOWN IN BOTH VIEWS  
 LOOKING WEST AT PIER 2



UTILITY VEHICLE ASSEMBLY