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June 2, 2009

Ms. Kay Ball
RBF Program Manager
Louisville Water Company
550 S. Third Street
Louisville, KY 40202

Subject: Riverbank Filtration (RBF) Tunnel and Pump Station
Evaluation of Proposed Bridge Pier Location

Dear Kay:

We have completed our analysis of the proposed bridge piers in the vicinity of Louisville Water Company's Riverbank Filtration Tunnel and Collector Well No. 3 based on design information provided to us by H.W. Lochner, Inc. Enclosed with this letter are the following two technical memoranda summarizing our evaluation and recommendations:

"Evaluation of the Impact of Bridge Piers on RBF Tunnel"

"Evaluation of the Impact of Bridge Piers on RBF Collector Well Screens"

Based on the results of our evaluation, we recommend that all bridge piers be located a minimum of 40 feet away from the tunnel in the horizontal direction. Additionally, the design needs to stipulate that no drilling fluids shall be used for construction for any pier shaft within 400 to 500 feet for bentonite and 1,000 feet for polymer fluids (both distances are in the horizontal direction from the end of the downriver lateral in Collector Well No. 3).

We suggest a review of the final design plans and specifications to ensure that these items are adequately addressed. In the meantime, please let me know if you or the bridge design engineer would like to meet to review our recommendations or discuss the project.

Sincerely,

JORDAN, JONES & GOULDING

David L. Haas, P.E.
Project Manager

Enclosures

cc: Mr. Jim Brammell, P.E., LWC; Mr. Wojciech Klecan, P.E., JIG





Technical Memorandum

Date: May 26, 2009

Prepared For: Kay Ball, Louisville Water Company

Prepared By: Wojciech Klecan, P.E., Tao Jiang, P.E. Ph.D.

Subject: Evaluation of the Impact of Bridge Piers on RBF Tunnel

Project: LWC Riverbank Filtration Tunnel and Pump Station (02223.007)

Background

The Kentucky Department of Highways is planning to build a bridge across the Ohio River, and the bridge pier foundations will be in the vicinity of the B.E. Payne Water Treatment Plant Riverbank Filtration (RBF) Tunnel. The bridge is being designed by H.W. Lochner, Inc., and it currently has three options – 6 span, 7 span and 8 span, as shown on the attached sheets. The horizontal clear distance between the tunnel and the nearest pier for each option is about 80 feet, 42 feet, and 20 feet, respectively. Each pier is comprised of two drilled shafts with a maximum diameter of 8 feet. The shafts are assumed to socket in the bedrock. Foundation loads for each pier are shown on the attached table.

The RBF tunnel is located in the bedrock, and its crown is about 40 feet below the top of rock in the area that may be affected by the piers. The tunnel is lined with 10-inch thick plain concrete of 5,000 psi compressive strength.

This objective of study is to estimate the impact of the proposed bridge piers on the tunnel lining.

Geotechnical Conditions

An approximately 100-foot thick layer of sand and gravel extends over the site from the surface to the top of the bedrock. The bedrock primarily consists of limestone with generally thin widely spaced beds of shale. There are two shale layers crossing the tunnel: a 1.5-foot thick shale layer crossing at about the tunnel springline and a 1-foot thick shale layer running close to the crown of the tunnel.

The limestone is horizontally stratified, and is generally stronger in the vertical direction than in the horizontal direction. The elastic rock properties are assumed as below:

Limestone – Horizontal modulus: 60,000 ksf, Vertical modulus: 120,000 ksf
Friction angle: 50 degrees, Cohesion: 13 ksf

Shale Layer – Modulus: 24,000 ksf, Friction angle: 41 degrees, Cohesion: 6.3 ksf

Modeling and Results

The two-dimensional finite element program, Phase2 V6.0 by Rocscience, was utilized to analyze the influence on the tunnel from the bridge piers. In the model, the limestone was assumed to be transversely isotropic with different modulus in vertical and horizontal directions. The shale layer was assumed isotropic. The tunnel lining was modeled as Timoshenko beam. The overlying sand and gravel was treated as uniform external pressure, and not physically included in the model.

The load from the pier will act as a point on the bedrock. The 2-D program cannot directly model a point load, but is able to analyze a strip load. An axis-symmetrical model and a plain strain model were thus setup to find the equivalent stripe load by correlating the stresses generated by the point load and the stripe load at a fixed point at the tunnel in the bedrock. The equivalent stripe load was then applied on the top of rock to simulate the piers in the 2-D plain strain model, and this stripe load has taken into account of the 3-D effects of the point load. The results are as follows:

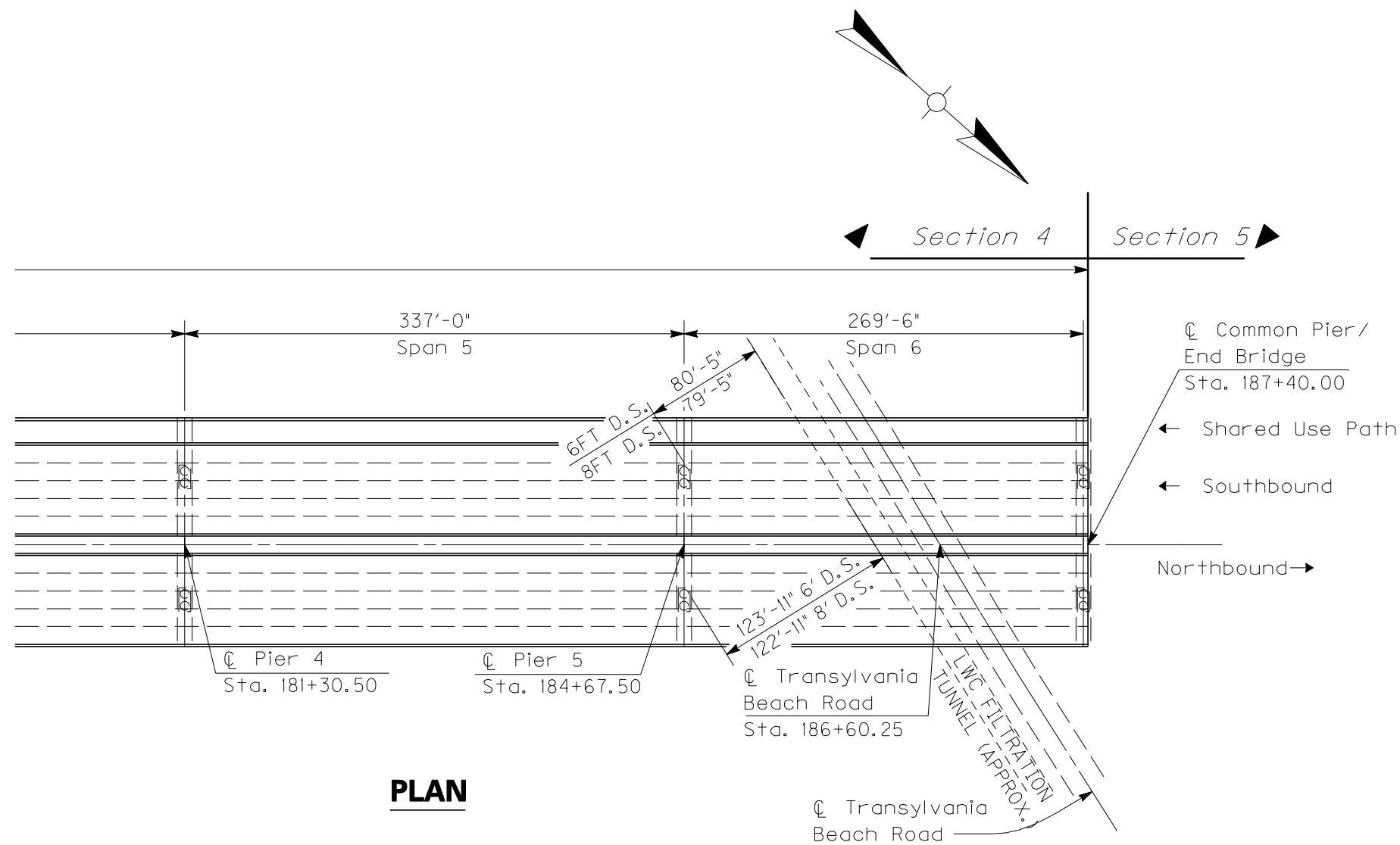
Bridge Option	Distance Piers to Tunnel (ft)	Pier Loads (ksf)*	Equivalent Stripe load (ksf)	Piers' Impact on Tunnel			
				Bending (kip-ft)	Tensile (psi)	Thrust (psi)	Shear (psi)
8 Span	20	83	21	0.48	29	34	6
7 Span	42	90	23	0.37	22	24	4
6 Span	80	101	25	0.03	1.8	3	0.3

*Developed from the loads that H.W. Lochner, Inc. provided (see attached).

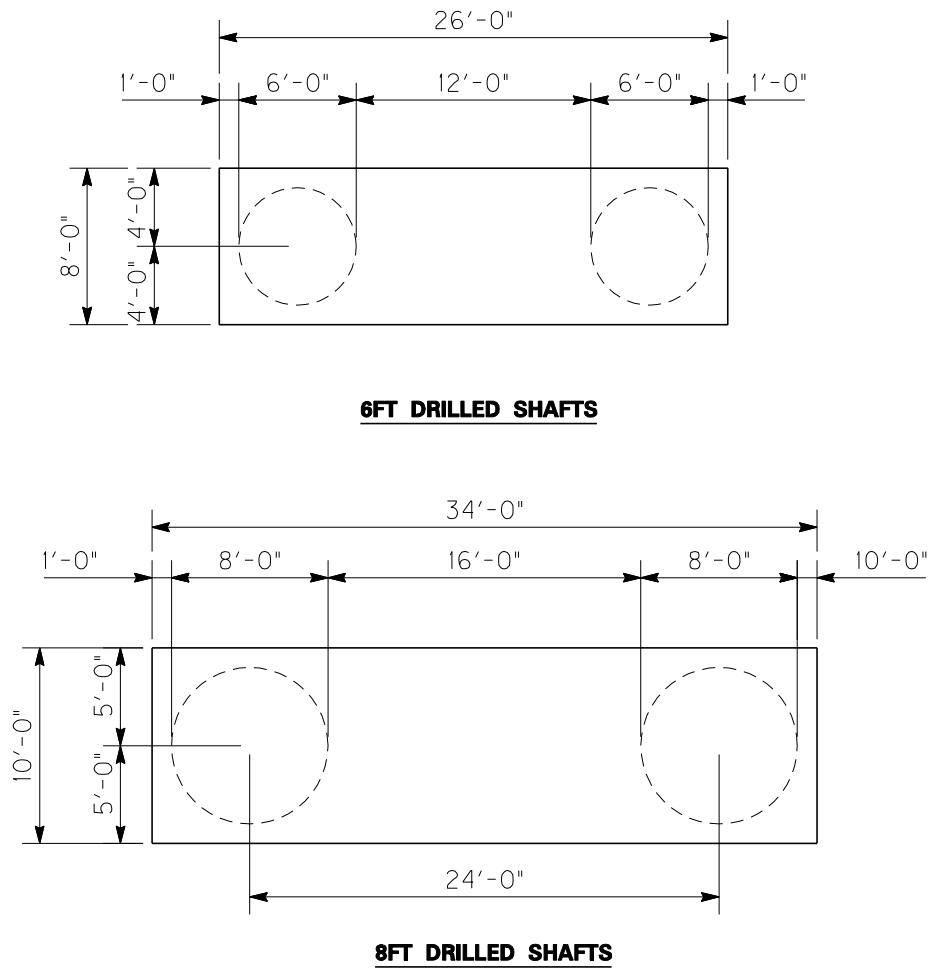
Summary and Recommendation

The results indicate that the impact on the RBF tunnel from the bridge pier foundation appears to be minor for the three options proposed by H.W. Lochner Inc., based on the estimated rock properties and the derived equivalent stripe load. However, given the level of accuracy using this simplified analytical method and possible variations in geotechnical properties of the bedrock, we recommend that the bridge piers be located at least 40 feet away from the tunnel in the horizontal direction, as shown on the attached sketch.

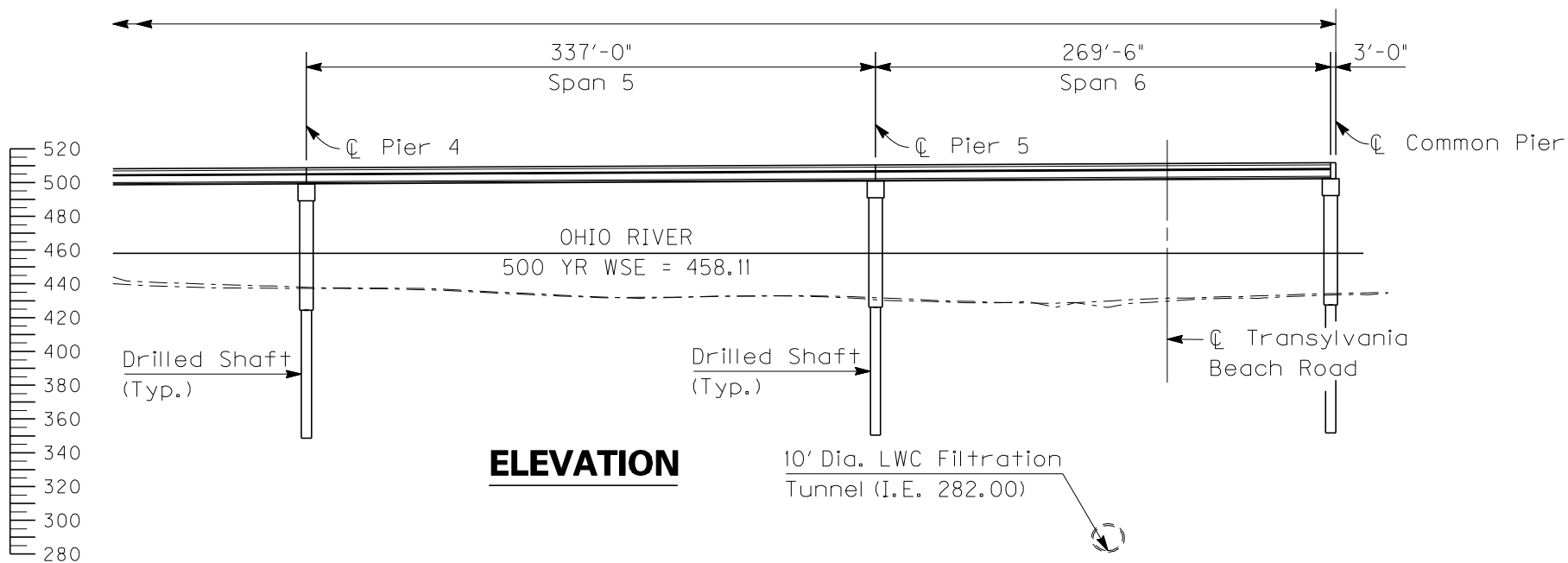
A separate memorandum is being prepared to address construction methods to protect the aquifer in the vicinity of the collector wells.



PLAN

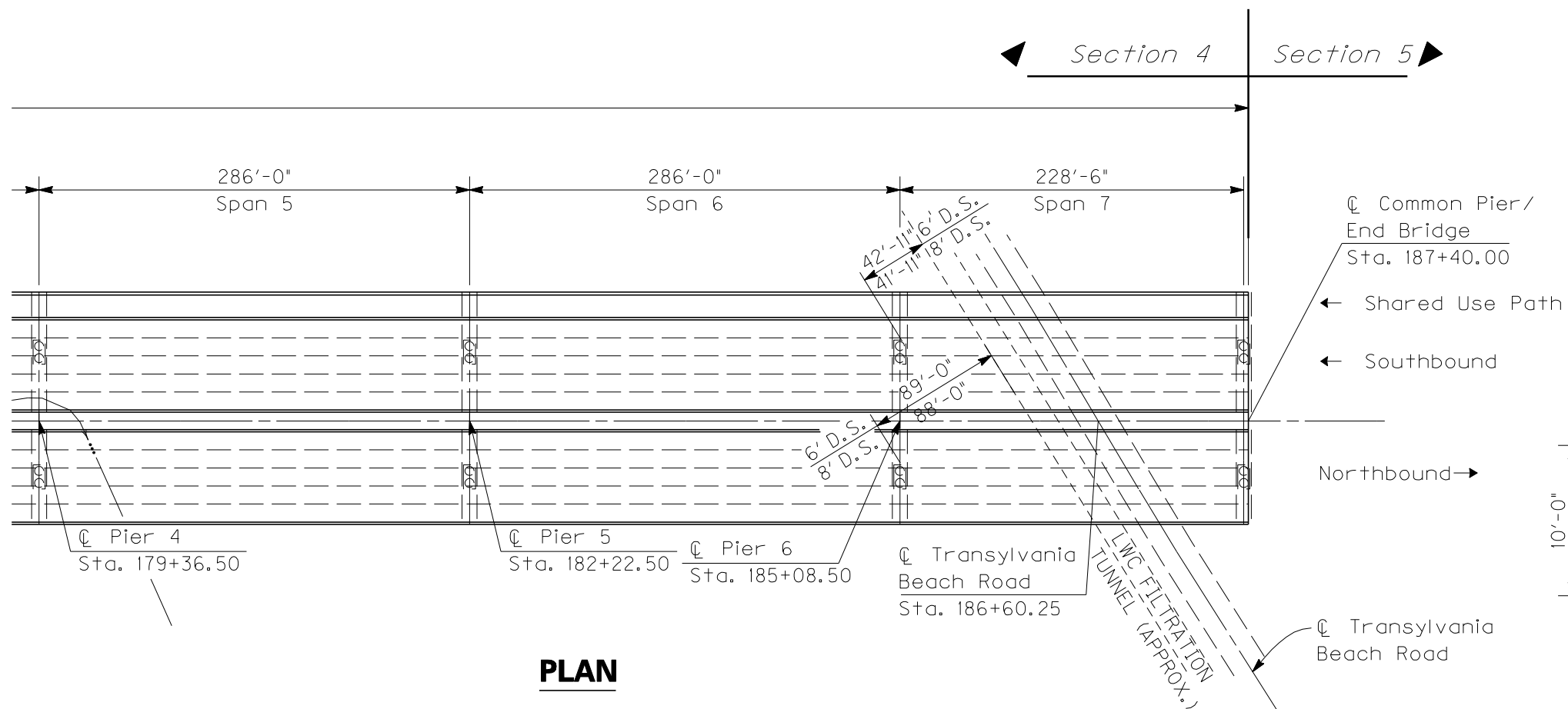


PIER FOOTING PLANS

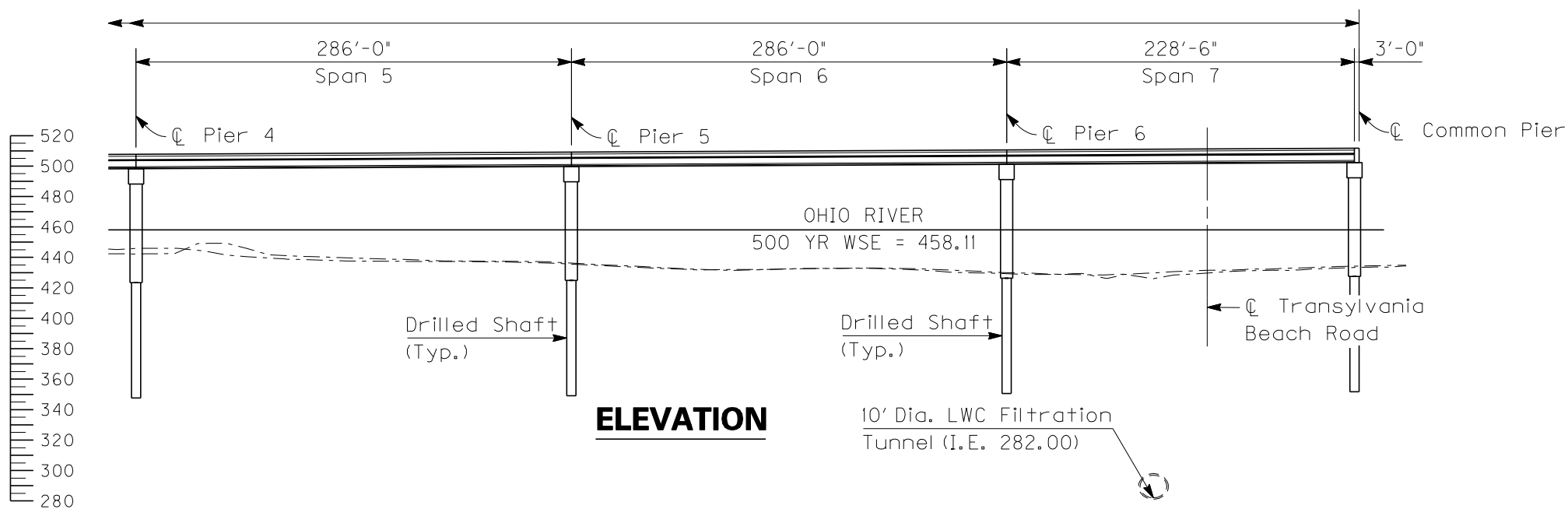


ELEVATION

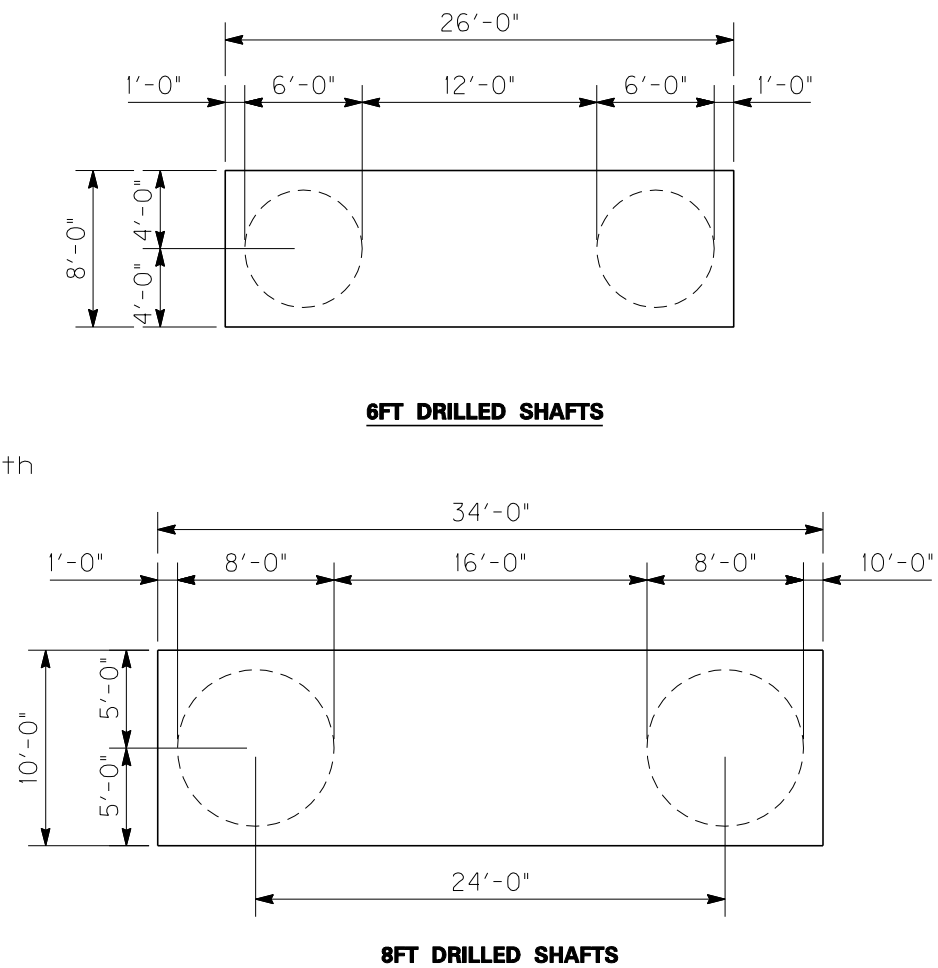
REVISION		DATE
DATE: 04/2008	CHECKED BY	
DESIGNED BY:		
DETAILED BY:		
Commonwealth of Kentucky DEPARTMENT OF HIGHWAYS		
COUNTY JEFFERSON		
ROUTE KY 841	CROSSING Transylvania Beach Road	
RIVER APPROACH-6 SPAN OPTION		
PREPARED BY LOCHNER H.W. LOCHNER, INC. CONSULTING ENGINEERS AND PLANNERS		SHEET NO. DRAWING NO.



PLAN

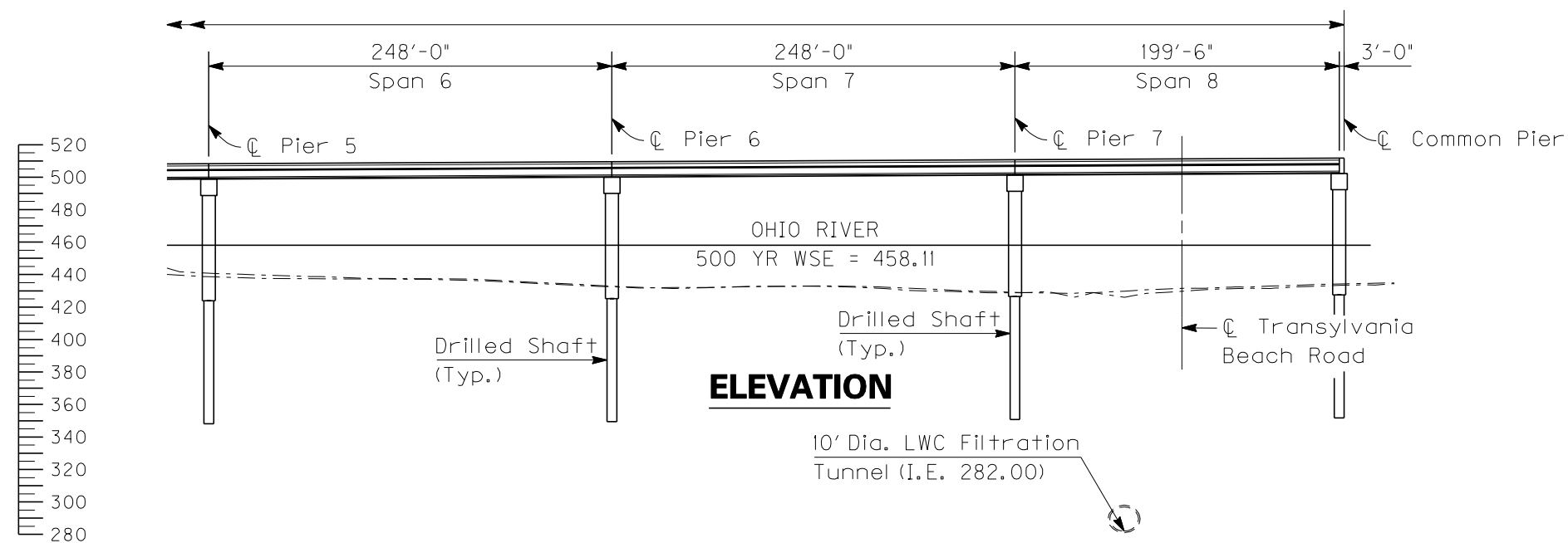
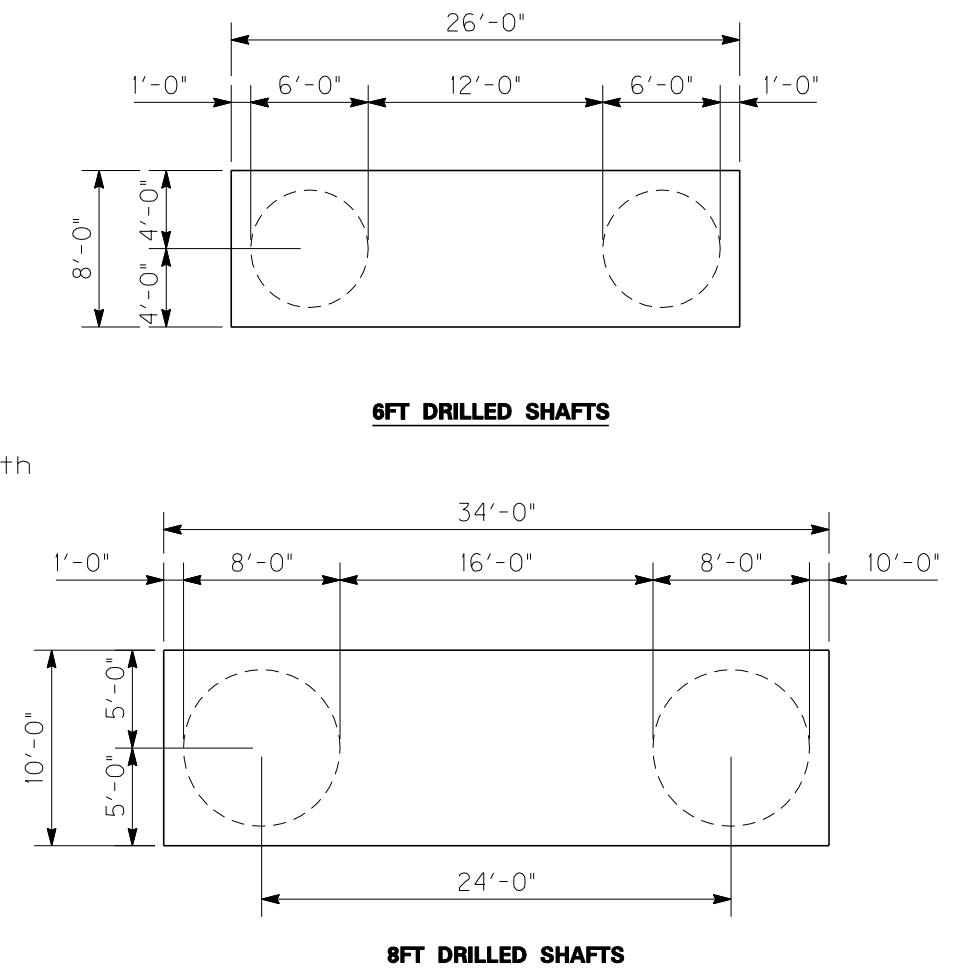
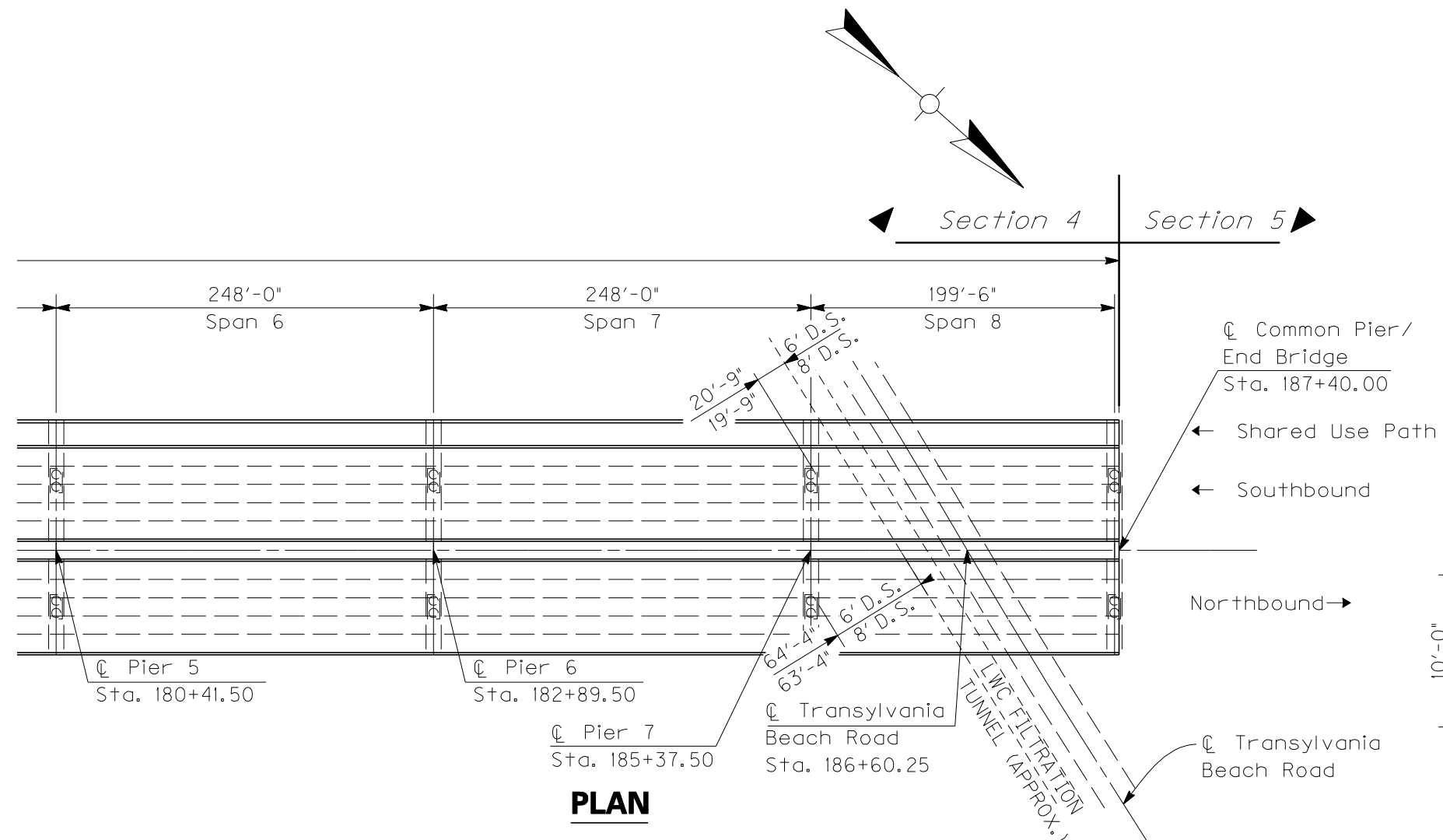


ELEVATION



PIER FOOTING PLANS

REVISION		DATE	
DATE: 04/2008		CHECKED BY	
DESIGNED BY:			
DETAILED BY:			
Commonwealth of Kentucky DEPARTMENT OF HIGHWAYS			
COUNTY JEFFERSON			
ROUTE KY 841		CROSSING Transylvania Beach Road	
RIVER APPROACH-7 SPAN OPTION			
PREPARED BY LOCHNER			SHEET NO.
H.W. LOCHNER, INC. CONSULTING ENGINEERS AND PLANNERS			DRAWING NO.



REVISION		DATE	
DATE: 04/2008		CHECKED BY	
DESIGNED BY:			
DETAILED BY:			
Commonwealth of Kentucky DEPARTMENT OF HIGHWAYS			
COUNTY JEFFERSON			
ROUTE KY 841	CROSSING Transylvania Beach Road		
RIVER APPROACH-8 SPAN OPTION			
PREPARED BY LOCHNER H.W. LOCHNER, INC. CONSULTING ENGINEERS AND PLANNERS			SHEET NO. DRAWING NO.

ITEM NUMBER

PROJECT: LOUISVILLE BRIDGES

SUBJECT: RIVER APPROACH OVER LWC

BCR

Mar-08

LOADS - 6' DIAM. DRILLED SHAFTS

WDB

Apr-08

Foundation Data:

No. of Shafts per Row: 2
 Total No. Shafts per Footing: 2
 Shaft Diameter: 6

SQUARE FOOTING DIMS.:CLEAR BTWN SHAFTS = $(2 - 1) \times (3 \times 6 - 6) = 12$ LENGTH DIMENSION = $2 \times 6 + (1 \times 12) + 2 = 26$

NO. ROWS SHAFTS = 1

WIDTH DIMENSION = $1 \times 6 + (0 \times 12) + 2 = 8$ FOOTING WEIGHT (kip) = $26 \times 8 \times 5' \times .150 = 156$ SHAFT WEIGHT (kip) = $\text{PI} \times 6^2 / 4 \times 110\text{ft} \times .150 \times 2 = 933$

933

FOUNDATION LOADS PER FOOTING FOR PIER NEAREST LWC FILTRATION TUNNEL			
<i>Loads do not include drilled shafts</i>			
	8 Span Structure	7 Span Structure	6 Span Structure
SB Pier Loads	6613	7284	8358
NB Pier Loads	6822	7569	8602
SB Pier Shaft Loads	3307	3642	4179
NB Pier Shaft Loads	3411	3785	4301
<i>Including drilled shaft weight</i>			
	8 Span Structure	7 Span Structure	6 Span Structure
SB Pier Loads	7546	8217	9291
NB Pier Loads	7755	8502	9535
SB Pier Shaft Loads	3773	4109	4646
NB Pier Shaft Loads	3878	4251	4768
<i>(ALL LOADS IN KIPS)</i>			

H. W. LOCHNER, INC.

PROJECT: LOUISVILLE BRIDGES

SUBJECT: RIVER APPROACH OVER LWC

LOADS - 8' DIAM. DRILLED SHAFTS

BCR

Mar-08

WDB

Apr-08

Foundation Data:

No. of Shafts per Row: 2
Total No. Shafts per Footing: 2
Shaft Diameter: 8

SQUARE FOOTING DIMS.:

CLEAR BTWN SHAFTS = $(2 - 1) \times (3 \times 8 - 8) = 16$

LENGTH DIMENSION = $2 \times 8 + (1 \times 16) + 2 = 34$

NO. ROWS SHAFTS = 1

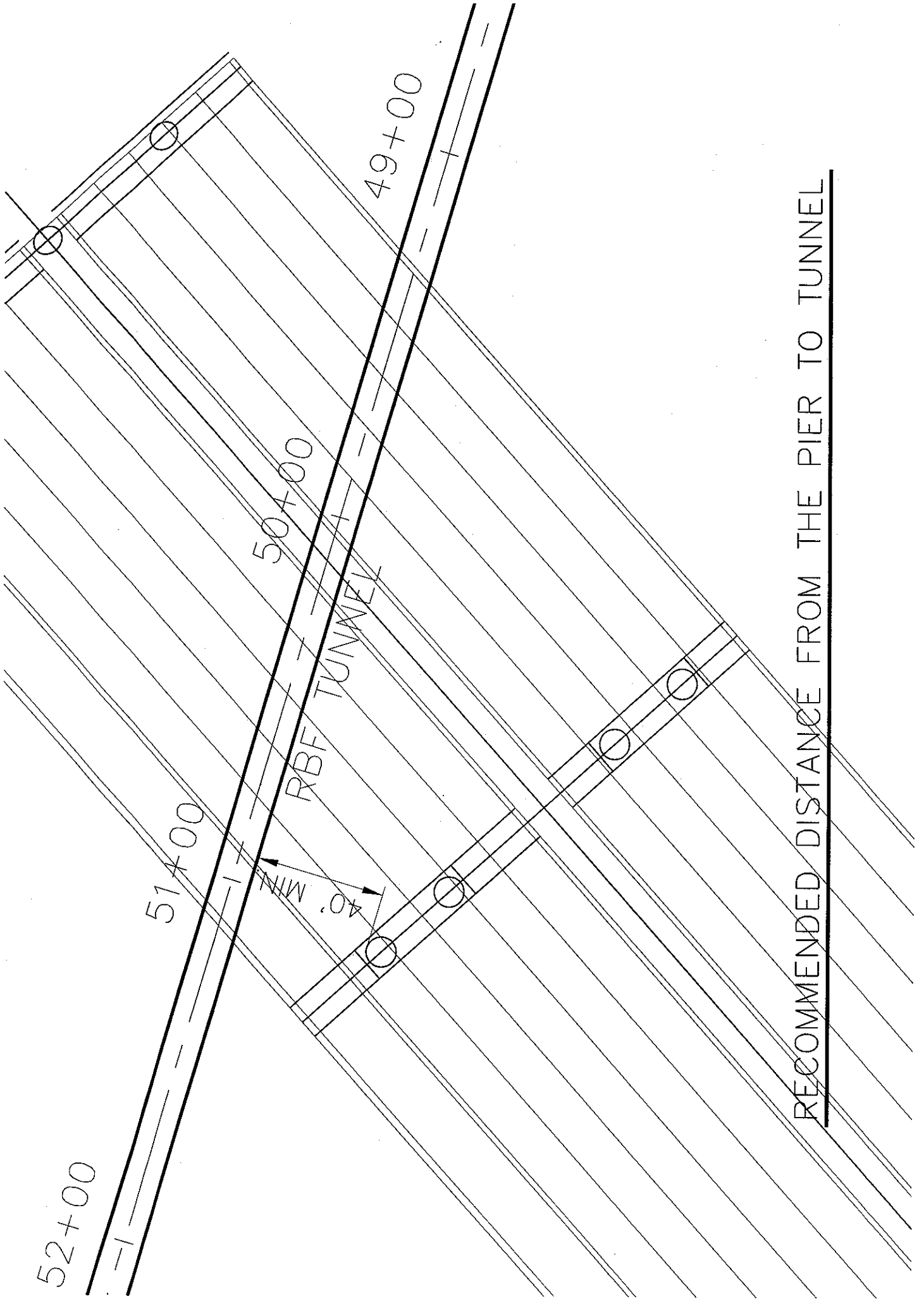
WIDTH DIMENSION = $1 \times 8 + (0 \times 16) + 2 = 10$

FOOTING WEIGHT (kip) = $34 \times 10 \times 5' \times .150 = 255$

SHAFT WEIGHT (kip) = $\text{PI} \times 8^2 / 4 \times 110\text{ft} \times .150 \times 2 = 1659$

1659

FOUNDATION LOADS PER FOOTING FOR PIER NEAREST LWC FILTRATION TUNNEL			
<i>Loads do not include drilled shafts</i>			
	8 Span Structure	7 Span Structure	6 Span Structure
SB Pier Loads	6712	7383	8457
NB Pier Loads	6921	7668	8701
SB Pier Shaft Loads	3356	3692	4229
NB Pier Shaft Loads	3461	3834	4351
<i>Including drilled shaft weight</i>			
	8 Span Structure	7 Span Structure	6 Span Structure
SB Pier Loads	8371	9042	10116
NB Pier Loads	8580	9327	10360
SB Pier Shaft Loads	4185	4521	5058
NB Pier Shaft Loads	4290	4663	5180
<i>(ALL LOADS IN KIPS)</i>			



RECOMMENDED DISTANCE FROM THE PIER TO TUNNEL



Technical Memorandum

Date: May 26, 2009

Prepared For: Kay Ball, Louisville Water Company

Prepared By: David Schafer, David Schafer and Associates
Wojciech Klecan, P.E., JJC

Subject: Evaluation of the Impact of Bridge Piers on RBF Collector Well Screens

Project: LWC Riverbank Filtration Tunnel and Pump Station (02223.007)

Background

The Kentucky Department of Highways is planning to build a bridge, supported on piers across Ohio River. The pier foundation will be in the vicinity of the RBF tunnel. According to the bridge designer (H.W.Lochner, Inc.), each pier will comprise of two 8-foot diameter drilled shafts. It is presumed that each drilled shaft will extend a short distance into the bedrock. Based on design drawings provided by Lochner, the nearest pier will be located approximately 250 feet from the downriver lateral in Collector Well No. 3 (CW-3).

Drilled Shaft Construction

The typical sequence for constructing a large diameter drilled shaft in this type of ground is described below:

- A temporary steel casing is installed through the sands and gravels down to the top of the bedrock by using a vibrating hammer or oscillator while the soil inside the casing is removed using a single flight, single cut earth auger or bucket auger. The casing is kept full of water up to the level of the external hydrostatic head.
- A socket is formed in the bedrock using a single flight, single cut rock auger or a short core barrel.
- Remaining soil material and rock fragments are removed by air lifting.
- Reinforcement steel is lowered into the shaft.
- A tremie pipe is lowered down the shaft to within a few feet of the base.
- Concrete is placed in the shaft as the casing is withdrawn. The fluid pressure of the concrete keeps the shaft stable.

Normally, the foundation contractor will extract the steel casing for reuse on the next shaft. Very rarely, the casing becomes stuck and must be left in place. Filling the drilled shafts with material other than concrete is not normally undertaken.

The 8-foot diameter drilled shafts can be constructed as outlined above without the use of bentonite or polymer slurry to stabilize the sides of the shaft. However, under some circumstances, the contractor may need to resort to using drilling fluids. For example, if skin friction becomes too high during the final stages of installing the steel casing or the Contractor has difficulty in removing rock fragments when drilling the socket into the bedrock.

Evaluation of Potential Effects on Aquifer

There are three potential areas of concern when performing construction next to existing water wells as is being done here:

1. Mechanical effects such as excavation, vibration, caving, sloughing, etc.
2. Invasion of drilling fluids if they are used.
3. Invasion of cement.

The mechanical effects should have no effect on the structural or hydraulic integrity of CW-3. The distance of separation between the nearest shaft and the well screen laterals is large enough to attenuate these effects at the location of the well screens. Any reduction of permeability of the sediments in the vicinity of the construction shafts will be sufficiently localized that it will have no effect on the overall hydraulic performance of the well/aquifer system.

Likewise, invasion of cement will be no problem. Because concrete (cement, sand and gravel) is being used for the piers, bridging will occur over a short distance near the borehole face and invasion of cement products will be limited in extent. There is no chance that these materials could move to the screen laterals in CW-3.

The only possible concern is invasion of drilling fluids. If fluids are not used, this element of concern will be moot. This would mean that the pier construction would be considered non-threatening with respect to the integrity and performance of CW-3.

However, if the contractor elects to use drilling fluids, there is a small probability of deleterious effects. Drilling fluids can move many tens of feet through unconsolidated aquifer materials if they are sufficiently coarse. Anecdotal examples of this include 1) drilling near an existing well and observing drilling fluid emerging from the existing well, 2) grouting a well near a stream and observing neat cement (having a consistency similar to drilling mud) emerging in the stream, and 3) losing many thousands of gallons of drilling fluid to the formation while drilling coarse sand and gravel aquifers.

In fractured rock settings, neat cement having a consistency similar to that of drilling mud has been observed to move hundreds of feet from the injection point. While travel distances in sand and gravel

aquifer materials are generally less than in fractured rock, some portions of the glacial aquifer at Louisville consist of very coarse pebbles and cobbles. In these kinds of materials, there would be little resistance to movement of viscous fluids and it could mirror the response seen in fractured formations. Movement of drilling fluid through the typical 30- to 40-slot coarse sands that make up the bulk of the glacial aquifer would be minimal. Nonetheless, flow through the exceptionally coarse seams and channels could be extensive and the possibility of reaching the collector well, however remote, cannot be ruled out completely.

Loss of significant volumes of drilling fluid could pose two problems – plugging and biochemical activity. Bentonite mud, if it reached a collector well lateral, could flood the well and move into the remaining laterals. This could result in plugging of the formation pores around the screens and a reduction in well yield. Redevelopment would be costly and might not be effective at removing all of the bentonite.

Polymer drilling fluids lost to the aquifer would biodegrade over time. This could present a problem whether or not the materials reached the collector well. Decomposition of the polymer would create reducing conditions, liberating iron from the minerals comprising the natural formation sediments. The released iron could affect water quality to a minor extent and could contribute to incrustation of the well screens. The severity of these effects would depend on the quantity of fluid lost to the aquifer. Small quantities of lost fluid would likely have a negligible effect, but loss of massive quantities could present problems although these would be difficult to quantify. Even polymer products touted by the manufacturer as not supporting bacterial growth can degrade in this manner and cause reducing conditions.

Summary and Recommendation

If drilling fluids were used in the pier shaft construction, it is probable that no deleterious effects would accrue. However, the possibility of loss of massive quantities of drilling fluid to the formation cannot be ruled out. If that occurred, use of bentonite could risk flooding the well and clogging the screens and adjacent formation pores, while use of polymers could trigger chemical reactions resulting in undesirable reducing conditions in the affected portion of the aquifer. It would be prudent to eliminate these risks by avoiding the use of drilling fluids in the bridge pier construction.

If construction proceeds without the incorporation of drilling fluids, there should be no deleterious side effects that would compromise the integrity of the existing collector well.

To ensure the integrity of the CW-3 well screens, the use of drilling fluids should be prohibited for any pier shaft that is constructed within 400 to 500 feet for bentonite and 1,000 feet for polymer fluids (or prohibit the use of polymers altogether).