RTA/ CP 128-07

D to M Streets Track & Signal Project DRAFT

Post and Beam Concept Evaluation

Technical Memorandum

Prepared for: *Sound Transit*

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July 24, 2009

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1. Introduction

The goal of this concept assessment was to determine a feasible structural layout for the "Post and Beam" concept in order to determine a conceptual-level quantity-based estimate of cost. This technical memorandum documents the structure type, structural layout, quantity takeoffs, and unit price-based cost estimates.

2. Project Background

2.1 General

The D-to-M Streets Track & Signal Improvements Project is a 1.4-mile section of new track to be constructed by Sound Transit on acquired right-of-way that connects the Tacoma Dome Station with Sound Transit's Lakeview Subdivision rail right-of-way. The project currently consists of a pedestrian-only undercrossing at A Street and a rail bridge crossing over a lowered Pacific Avenue.

Along with the new track and grade-separated crossings at A Street and Pacific Avenue, the D-to-M Street segment includes construction of retaining walls, embankment (or retained fill), several at-grade crossings, and signal work in downtown Tacoma.

2.2 Post and Beam Concept

The Post and Beam concept was originally presented to the project team during meetings with the Project Advisory Committee in the fall of 2008. The concept entails supporting the rail line on an elevated viaduct from the east side of the B Street Gully to South C Street, passing under I-705 while maintaining the pedestrian undercrossing at A Street and the grade separation at Pacific Avenue.

This concept has several key potential supporting features:

- An elevated structure could provide a more open feeling where there is sufficient ground clearance by providing space under the structure. This allows a physical as well as a visual connection between the north and south sides of the track as opposed to having the rail line supported by retaining walls or embankment.
- Supporting the structure on deep foundations may reduce the need for shoring to support the tracks during construction of shallow foundations. These types of foundations are typical for certain low-height forms of development. This would not be the case if the tracks were supported by walls or embankment.

This concept also has several detrimental features:

- The open space under the structure may become a gathering place for persons engaged in undesirable activities and require increased monitoring by law enforcement or fenced to prevent vagrancy.
- If there are deeper excavations required to construct foundations adjacent to the structure, the unbalanced load on the piers may require shoring to prevent lateral displacement of the train structure which would limit or complicate mid-level future development potential.

- The repetitive span arrangement requires a column in the middle of Pacific Avenue which will create a traffic hazard as well as reducing the southbound left turn pocket queue capacity.
- Additional structures introduce ongoing maintenance and inspection costs that would be unnecessary otherwise; additionally, all structures have a finite life-span requiring replacement at some future date.

The term “Post and Beam” comes from the residential and commercial building industry. It refers to the idea of vertical posts supporting horizontal beams which, in turn, support a large square footage of floor area. There are typically many posts and beams in any given building.

This term is not typically used in the bridge construction industry. The term “post” is replaced by the term “column,” and the term “beams” is replaced by “girders.” Because bridges are linear and carry higher loads due to vehicle traffic, the columns are fewer and larger and the girders are larger and span greater distances.

3. Design Considerations

3.1 Bridge Type

Fitting with the concept of Post and Beam (or Girder and Column) where the rails are supported from below by girders that are, in turn, supported on columns, two different types of girders were evaluated in this study:

- Precast prestressed concrete girders (AASHTO Type IV)
- Rolled steel girders (W36x300)

These types of girders were selected because of their common usage for rail structures, as well as their relatively inexpensive unit costs. Evaluation of these types of girders will provide an appropriate high/low range of costs for estimating purposes.

The structure would support a single track ballasted section on a concrete deck with emergency egress walkways on both sides. Appendix A contains typical sections of each girder type.

3.2 Span Length

Rail structures are typically supported by simple spans. Depending on the span length, a certain depth of girder is required to carry the loads, control stresses in the materials, and limit deflection of the girders.

The depth of structure from Top-of-Rail (TOR) to the soffit or bottom of the girder for each girder type is as follows:

- Prestressed Concrete Girders – approximately 7'-8"
- Rolled Steel Girders – approximately 6'-0"

Both the concrete and steel girder types selected for this study allow spans up to approximately 60' in length.

3.3 Span Layout

A span layout was created based on keeping the maximum span length within the range of the selected girder types. The structure would begin on the east side of the B Street Gully and end just east of South C Street.

The structure would be elevated along its entire length and consist of 23 spans ranging from 40' to 57' in length with the majority of spans being either 50' or 55' for consistency and ease of fabrication. Appendix B contains a conceptual plan and elevation.

The following were considered in determining the span layout:

- Abutment A1 would be located on the east slope of the B Street Gully and would be approximately 15'-17' in height from TOR to original ground depending on the girder type considered. The first Pier P1 would be located on the western slope, which allows for a single 55' span centered over the gully. Providing a span at this location would eliminate the need for protection of the existing storm and sanitary sewers at this location.
- The span layout between Piers P3 and P5 would be arranged to minimize the number of piers that need to be constructed under I-705.
- A shorter 47' span would be located just west of A Street to facilitate a more consistent span arrangement between the B Street Gully and A Street.
- The A Street crossing would be a single 55' span. Piers would be located outside of the walkway footprint.
- A series of 50' spans would be used to facilitate pier spacing between A Street and Pacific Avenue.
- The proposed Pacific Avenue roadway would consist of three southbound lanes and a bike lane with a southbound left-turn lane to E. 26th Street. It also consists of two northbound lanes and a bike lane near the structure. Pedestrians would pass under the structure on 12' wide sidewalks on each side of the street. The clear distance from back of sidewalk to back of sidewalk would be approximately 109'.

  Because this span length is outside the range of the selected girder types, a two-span bridge would be required. A two-span crossing would require a center support with span lengths of 57' over the southbound lanes and 51' over the northbound lanes. These span lengths would be controlled by maintaining the face of column 12' from the curb line. For this study, the proposed Pacific Avenue roadway layout is unchanged from its proposed horizontal and vertical layout, with the exception of the center turn lane being reduced by approximately 75' in length to accommodate the center pier column, safety barrier, and traffic attenuators.
- Shorter spans would be used to facilitate the span arrangement between Pier P18 at Pacific Avenue and the western abutment at A2. These shorter spans also would accommodate track curvature by minimizing track eccentricity.
- Abutment A2 would be located just east of South C Street and would be approximately 12'-14' in height from TOR to original ground, depending on the girder type being considered.

3.4 Vertical Alignment

The track grade would increase at a constant 2.85% from near East C Street, across both A Street and Pacific Avenue, and continue westward. The grade would flatten out once it reaches the crest of the hill near Chandler Street.

At A Street, the TOR elevation would be approximately 8.6' above the existing centerline of the roadway. This would require lowering A Street to maintain the 10' minimum clearance.

At the Pacific Avenue crossing location, the TOR elevation would be approximately 8.9' above the existing centerline of the roadway. This would require lowering Pacific Avenue to accommodate the City of Tacoma's standard structure vertical clearance of 16.5' over the roadway.

In certain areas, particularly between A Street and Pacific Avenue, the bottom of the structure would be below the existing grade. In these areas, excavation would be required to allow for construction of the columns and to maintain a minimum clearance for inspection and maintenance.

In addition, between Pacific Avenue and South C Street, some additional excavation would be required to provide minimum access and to comply with the open "Gateway" urban design aesthetic.

3.5 Structure Width

As shown in Appendix A, the supporting girders would be underneath the track section, which eliminates any interference between the main structural elements and the train clearance envelope, as is the case with a through-type of structure.

Sufficient width would need to be provided to allow for emergency egress from the elevated structure. The typical section horizontal dimensions shown in Appendix A are typical for deck-supported railway structures. The total out-to-out width of the bridge deck and walkways would be 19'-0".

3.6 Abutments/Foundations/Columns/Pier Caps

Soils in this area of the alignment consist primarily of granular fill materials of varying depth. Deposits of compressible cohesive soils and poor fill materials are found in the B Street Gully.

Abutments

The abutments are conceived as extended pile abutments with wrap-around MSE walls. These types of abutments are appropriate for a rail structure and minimize costs compared to large cast-in-place abutments. The wing walls that would extend parallel to the track behind the abutments are envisioned as MSE walls and would range from 30' to 50' in length depending on location.

Foundations

Due to relatively poor granular fill materials near the structure, deep foundations would be required to support the weight of the bridge and train loading. Deep foundations are conceived as 8' diameter drilled shafts. The shafts would range from 10'-60' in length and would be founded a minimum of 10 feet into the underlying native materials.

Columns

The columns would be 6' diameter cast-in-place columns cast integral with the shafts. In certain areas, particularly between A Street and Pacific Avenue, the original ground would need to be excavated to provide clearance beneath the structure. The columns are assumed to have a 2' minimum embedment below finished grade. In order to provide a minimum clearance of 10 below the girder soffit and taking into account the 5.5' deep pier cap, the columns would need to be set at a minimum height of 6.5'. The columns for the entire structure would range from 6.5' to 17' in length.

Pier Caps

The pier caps, as shown in the typical sections in Appendix A, would be cast-in-place concrete hammerhead-type caps cast integral with the columns. The cap would have a consistent depth of 5.5'. The superstructure girders would sit on elastomeric bearing pads and would transmit forces transversely to the caps through concrete shear keys.

4. Scenarios Evaluated

4.1 General

Each of the girder types was evaluated for the entire alignment to identify conceptual-level construction costs. The same span layout and substructure configuration were used for each type of girder. Appendix C contains the costs associated with each of the scenarios evaluated below.

4.2 Baseline Scenario

The current design for the track from the east side of the B Street Gully to South C Street consists of embankments and retaining walls supporting the track, along with grade-separated crossings over A Street and Pacific Avenue. The cost estimate for this scenario includes items that would be eliminated if the Post and Beam concept were implemented.

This scenario requires more embankment construction and less bridge structure. However, the Pacific Avenue and A Street Bridges account for the majority of the total construction cost. A construction cost contingency (20%) consistent with the 30% cost estimate was used for this scenario.

4.3 Prestressed Concrete Girder Scenario

The use of prestressed concrete girders would result in the lowest total cost for the Post and Beam structure. However, the minimum required vertical clearance at both Pacific Avenue and A Street would be violated due to the depth of the concrete girder section. This would require additional lowering of both roadways and connecting streets, as well as increasing the size of associated retaining walls. A detailed quantification of this additional cost is outside the scope of this study. Assuming the project limits are not expanded and increased grades due to lowering of the roadways and utilities fall within acceptable limits, the increase in construction costs likely falls in the $3 to $4 million range.

Due to the deeper section, more excavation would be required in certain areas along the alignment to provide the minimum access clearance. This would reduce the total length of the columns and shafts for this alternative, thereby reducing total construction cost of the structure. A 30% contingency was applied to the direct construction costs due to the conceptual nature of this estimate.

4.4 Rolled Steel Girder Scenario

The use of rolled steel girders would result in the highest total cost for the structure. Because the structure depth for the steel girders would be similar to the depth used for the current roadway design, there would be no need to provide additional lowering at either Pacific Avenue or A Street. Because of the shallower section, less excavation would be required to provide the minimum clearance, resulting in a larger total length of columns and shafts and an associated increase in structure cost. A 30% contingency was applied to the direct construction costs due to the conceptual nature of this estimate.

4.5 Hybrid Concrete/Steel Scenario

This scenario combines both the concrete and steel girder scenarios. By using steel spans at Pacific Avenue and A Street, the proposed vertical profiles at Pacific Avenue and A Street would not be affected. The result is the lowest total cost for the structure. This cost is approximately 18% more than the baseline cost. A 30% contingency was applied to the direct construction costs due to the conceptual nature of this estimate.

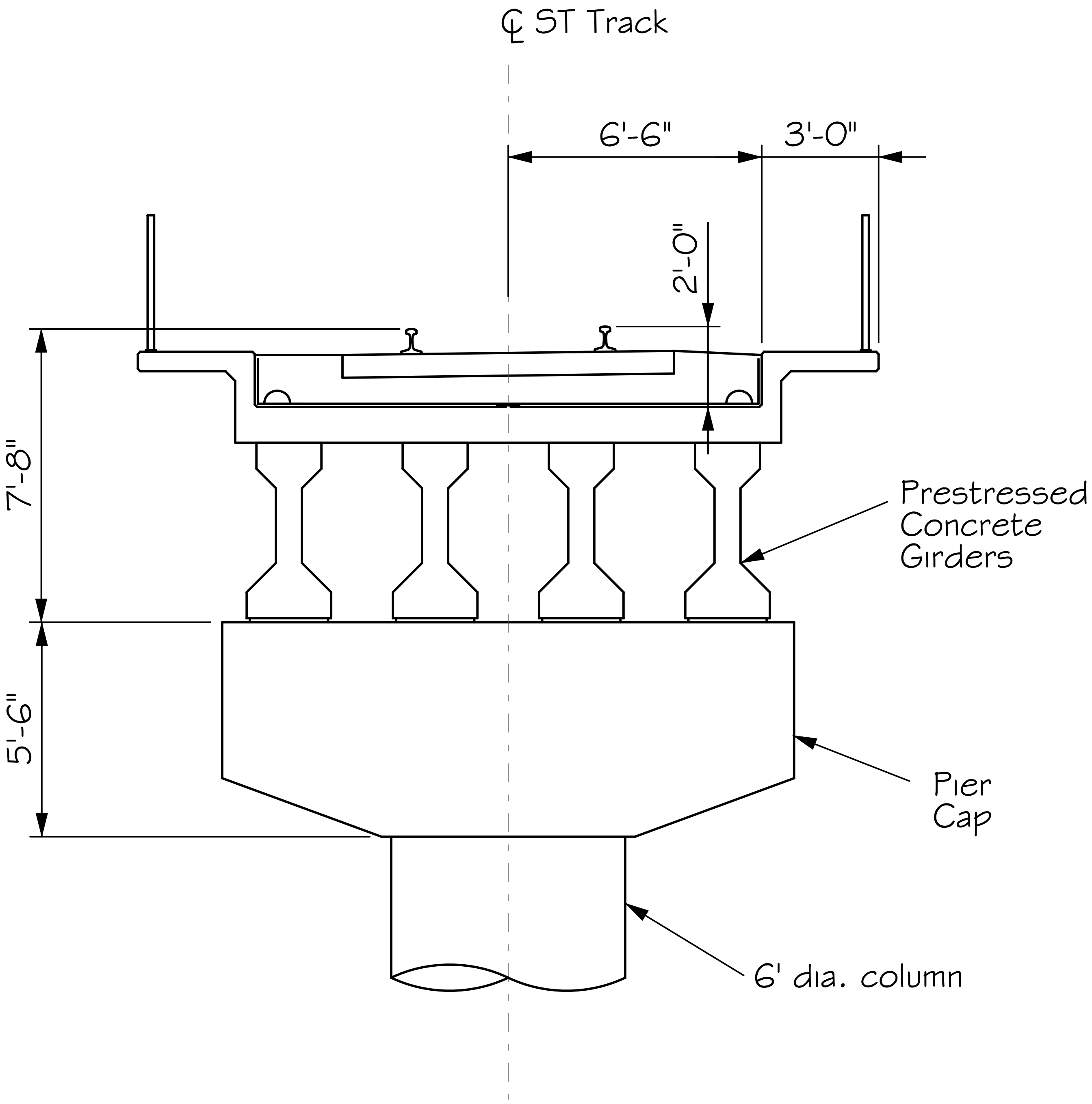
5. Construction Costs

Quantity-based construction cost estimates were developed for each scenario. Unit pricing was determined based on cost data developed for the 30% design cost estimate. See Appendix C for the quantities and unit prices associated with each of the scenarios.

Scenario	Total Cost (Millions)
Baseline	$5.51 M
Prestressed Concrete Girders (AASHTO Type IV)	$10.35 M
Rolled Steel Girders (W36x300)	$10.90 M
Hybrid Concrete/Steel Girders	$6.50 M

Appendix A

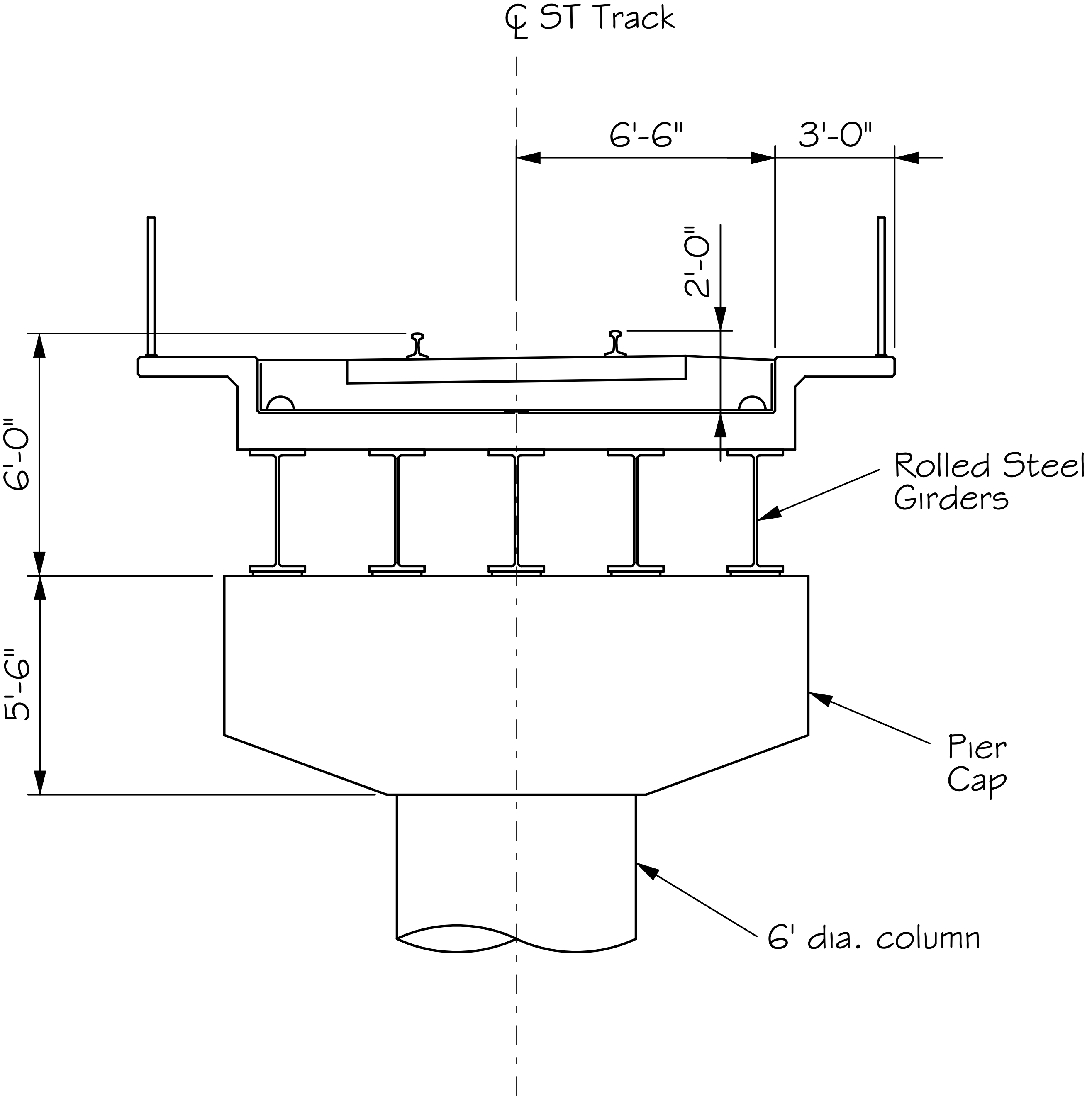
Typical Sections



Post & Beam Typical Section
Precast Prestressed Girders
(AASHTO Type IV)

Sound Transit
D to M Street Project

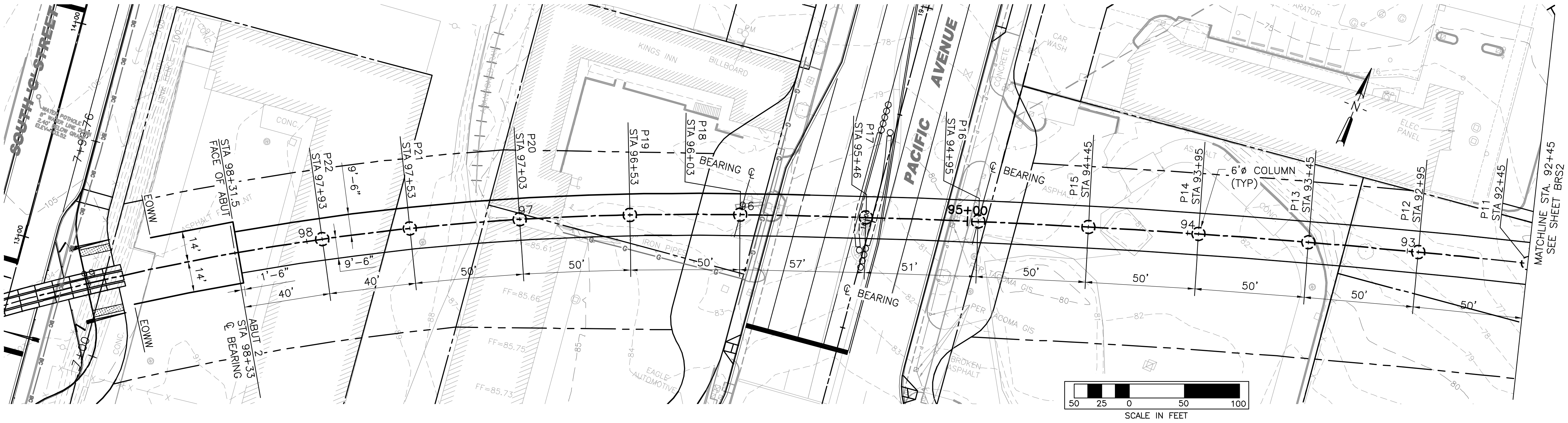
Parsons Brinckerhoff, Inc.
July 2009

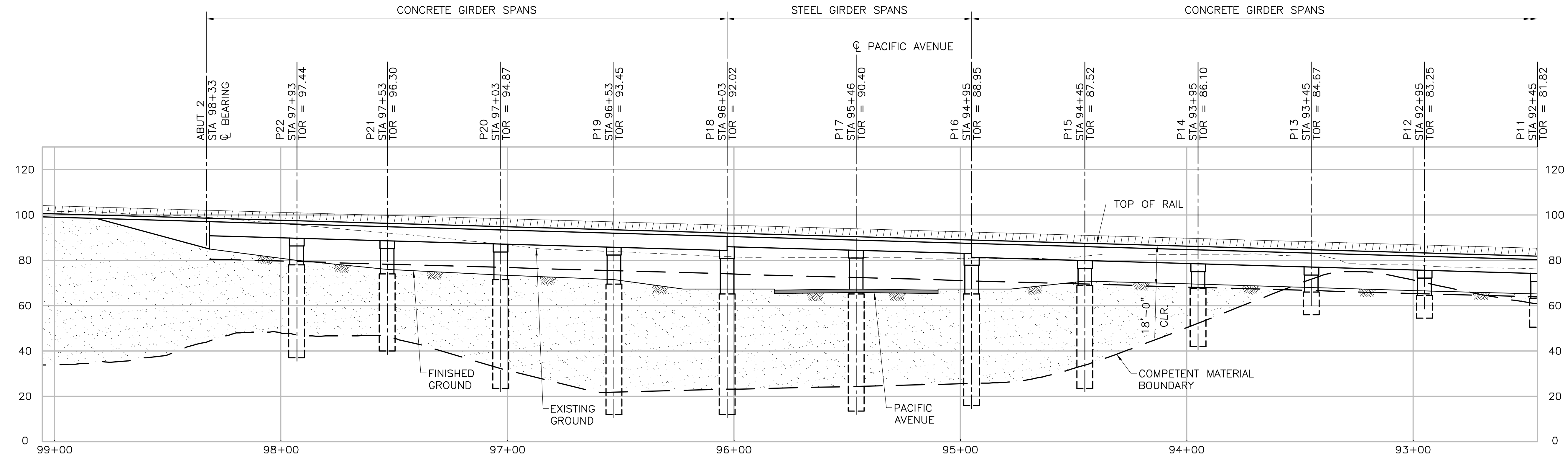


Post & Beam Typical Section
Rolled Steel Girders
(W36 x 300)

Appendix B

Span Layout





No.	Date	Dsn.	Chk.	App.	Revisions

PUBLIC WORKS
DEPARTMENT
Approved:
CONSTRUCTION DIVISION
Work Order No.:
Date:

Designed By: T. WILSON
Drawn By: E. NELSON
Checked By:
Approved By:

999 3RD AVENUE, SUITE 2200
SEATTLE, WASHINGTON 98104
PH: 206-382-5200

Scale: AS NOTED
Filename: D2M–VIADUCT STUDY
Contract No.: RTA/CP 128–07
Date: 20090803

SOUND TRANSIT D-TO-M STREETS
TRACK & SIGNAL PROJECT

VIADUCT STUDY
'B' STREET GULLY TO S. 'C' STREET
SHEET 1 OF 2

Drawing No.: BRS1
Rev.:
Sheet No.:
of

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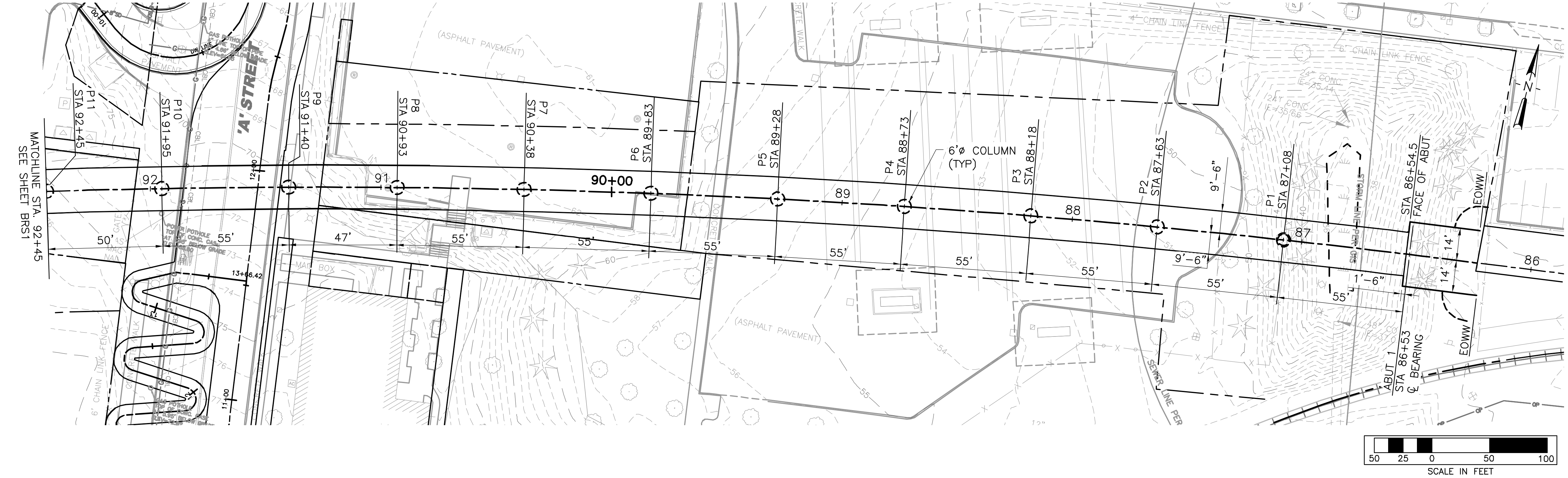

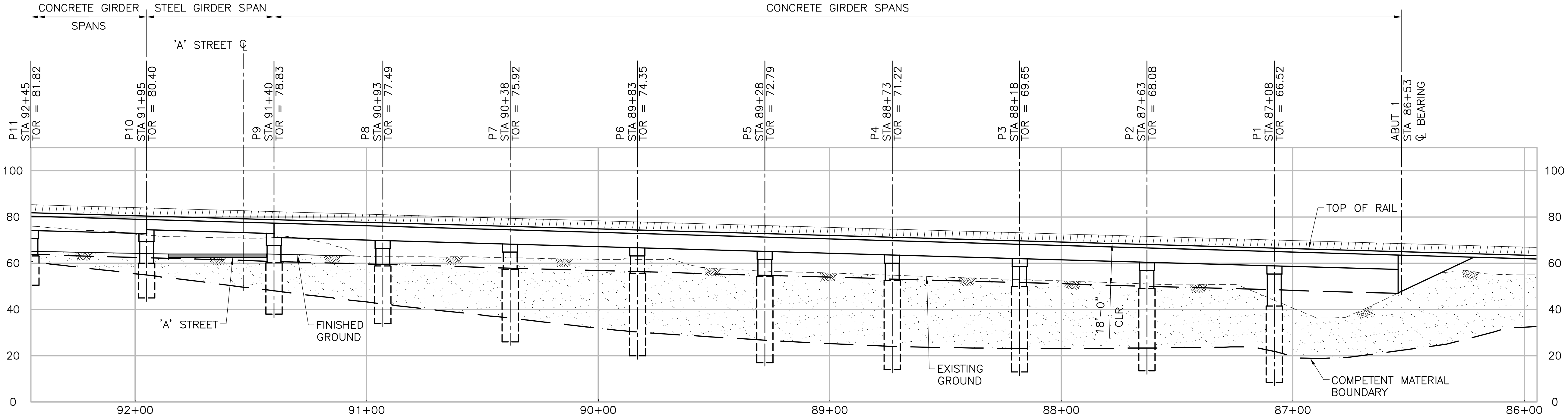

No.	Date	Dsn.	Chk.	App.	Revisions

Tacoma

PUBLIC WORKS DEPARTMENT

Approved:

CONSTRUCTION DIVISION

Work Order No.:

Date:

Designed By: T. WILSON

Drawn By: E. NELSON

Checked By:

Approved By:

PB 100 YEARS

999 3RD AVENUE, SUITE 2200
SEATTLE, WASHINGTON 98104
PH: 206-382-5200

SOUNDTRANSIT

Scale: AS NOTED

Filename: D2M-VIADUCT STUDY

Contract No.: RTA/CP 128-07

Date: 20090803

SOUND TRANSIT D-TO-M STREETS
TRACK & SIGNAL PROJECT

VIADUCT STUDY
'B' STREET GULLY TO S. 'C' STREET
SHEET 2 OF 2

Drawing No.: BRS2

Rev.:

Sheet No.: of

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Appendix C

Cost Estimates

Concept Level Bridge Cost Estimate

Embankment & Walls with Pacific Avenue and A Street Bridges

Bridge Types: ***Pacific Ave: 3-Span Through Plate Girder***
A Street: 2-span Prestressed Slab

Wall Types: ***W-7: MSE Wall***
W-9: MSE Wall (A Street Bridge Abutment Only)
W-11: MSE Wall

Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**
Pacific Avenue Bridge	1	LS	$ 2,561,446	$ 2,561,446
A Street Bridge	1	LS	$ 440,432	$ 440,432
Retaining Wall W-7	1	LS	$ 57,037	$ 57,037
Retaining Wall W-9	1	LS	$ 60,000	$ 60,000
Retaining Wall W-11	1	LS	$ 410,911	$ 410,911
Storm and Sanitary Sewer Protection (B St.)	1	LS	$ 850,000	$ 850,000
Structural Excavation (incl'd haul)	1,204	CY	$ 25.00	$ 30,100
Embankment	9,922	CY	$ 12.00	$ 119,064
Track Ballast	900	CY	$ 40.00	$ 36,000
Track Subballast	900	CY	$ 32.00	$ 28,800
Subtotal				$ 4,593,790
Contingency (20%)				$ 918,758
Total				**$ 5,512,548**

Average Track Foot Costs:

# of tracks:	1	ea
Total track length:	1180	ft
Cost / Track ft:	**$4,672**	

Concept Level Bridge Cost Estimate

Post and Beam - 23 span viaduct

Main Span Type: ***Prestressed beams (AASHTO Type IV)***
Spans: ***Various lengths ranging from 40' min. to 57' max***
Abutments: ***4' to 9' exposed height MSE abutments***
Wingwalls: ***MSE***
Piers: ***Single 6' dia columns on 8' dia shafts***

Description	**Quantity**	**Unit**	**Unit cost**	**Total Cost**
Structural Excavation (incl'd haul)	1,500	CY	$ 25.00	$ 37,500
Ballast	555	CY	$ 40.00	$ 22,200
Concrete Class 5000 - Deck	732	CY	$ 925.00	$ 677,100
Concrete Class 4000 - Substructure	633	CY	$ 1,060.00	$ 670,980
Steel Reinforcing Bar	301,800	LB	$ 2.00	$ 603,600
Bridge Approach Slab	103	SY	$ 86.00	$ 8,858
Prestressed Girders - AASHTO Type 4	4,720	LF	$ 160.00	$ 755,200
Elastomeric Bearing Pads	184	EA	$ 565.00	$ 103,960
Drilled Shaft, 8'-0" dia.	835	LF	$ 800.00	$ 668,000
Pedestrian Railing	2,360	LF	$ 150.00	$ 354,000
Waterproofing	17,700	SF	$ 5.50	$ 97,350
Structural Earth Wall	1,584	SF	$ 60.00	$ 95,040
Bridge Drain System	2,475	LF	$ 150.00	$ 371,250
Additional Lowering of Roadways	1	LS	$ 3,500,000	$ 3,500,000
Subtotal				$ 7,965,038
Contingency (30%)				$ 2,389,511
Total				**$ 10,354,549**

Average Square Foot Costs:

Length:	1180	ft
Width:	19	ft
Area:	22420	sf
Cost / SF:	**$462**	

Average Track Foot Costs:

# of tracks:	1	ea
Total track length:	1180	ft
Cost / Track ft:	**$8,775**	

Concept Level Bridge Cost Estimate

Post and Beam - 23 span viaduct

Main Span Type: ***Rolled Steel Girders (W36x300)***

Spans: ***Various lengths ranging from 40' min. to 57' max***

Abutments: ***4' to 9' exposed height MSE abutments***

Wingwalls: ***MSE***

Piers: ***Single 6' dia columns on 8' dia shafts***

Description	**Quantity**	**Unit**	**Unit cost**	**Total Cost**
Structural Excavation (incl'd haul)	1,200	CY	$ 25.00	$ 30,000
Ballast	555	CY	$ 40.00	$ 22,200
Concrete Class 5000 - Deck	732	CY	$ 925.00	$ 677,100
Concrete Class 4000 - Substructure	660	CY	$ 1,060.00	$ 699,600
Steel Reinforcing Bar	308,820	LB	$ 2.00	$ 617,640
Bridge Approach Slab	103	SY	$ 86.00	$ 8,858
Structural Low Alloy Steel	1,770,000	LB	$ 2.60	$ 4,602,000
Elastomeric Bearing Pads	230	EA	$ 565.00	$ 129,950
Drilled Shaft, 8'-0" dia.	846	LF	$ 800.00	$ 676,800
Pedestrian Railing	2,360	LF	$ 150.00	$ 354,000
Waterproofing	17,700	SF	$ 5.50	$ 97,350
Structural Earth Wall	1,584	SF	$ 60.00	$ 95,040
Bridge Drain System	2,475	LF	$ 150.00	$ 371,250
Subtotal				$ 8,381,788
Contingency (30%)				$ 2,514,536
Total				**$ 10,896,324**

Average Square Foot Costs:

Length:	1180	ft
Width:	19	ft
Area:	22420	sf
Cost / SF:	**$486**	

Average Track Foot Costs:

# of tracks:	1	ea
Total track length:	1180	ft
Cost / Track ft:	**$9,234**	

Concept Level Bridge Cost Estimate

Post and Beam - 23 span viaduct

Main Span Type: ***Prestressed Concrete Girders (AASHTO Type IV)***
Rolled Steel Girders (W36x300): A Street, Pacific Avenue
Spans: ***Various lengths ranging from 40' min. to 57' max***
Abutments: ***4' to 9' exposed height MSE abutments***
Wingwalls: ***MSE***
Piers: ***Single 6' dia columns on 8' dia shafts***

Description	**Quantity**	**Unit**	**Unit cost**	**Total Cost**
Structural Excavation (incl'd haul)	1,500	CY	$ 25.00	$ 37,500
Ballast	555	CY	$ 40.00	$ 22,200
Concrete Class 5000 - Deck	732	CY	$ 925.00	$ 677,100
Concrete Class 4000 - Substructure	635	CY	$ 1,060.00	$ 673,100
Steel Reinforcing Bar	302,320	LB	$ 2.00	$ 604,640
Bridge Approach Slab	103	SY	$ 86.00	$ 8,858
Prestressed Girders - AASHTO Type 4	4,068	LF	$ 160.00	$ 650,880
Structural Low Alloy Steel	244,500	LB	$ 2.60	$ 635,700
Elastomeric Bearing Pads	190	EA	$ 565.00	$ 107,350
Drilled Shaft, 8'-0" dia.	835	LF	$ 800.00	$ 668,000
Pedestrian Railing	2,360	LF	$ 150.00	$ 354,000
Waterproofing	17,700	SF	$ 5.50	$ 97,350
Structural Earth Wall	1,584	SF	$ 60.00	$ 95,040
Bridge Drain System	2,475	LF	$ 150.00	$ 371,250
Subtotal				$ 5,002,968
Contingency (30%)				$ 1,500,890
Total				**$ 6,503,858**

Average Square Foot Costs:

Length:	1180	ft
Width:	19	ft
Area:	22420	sf
Cost / SF:	**$290**	

Average Track Foot Costs:

# of tracks:	1	ea
Total track length:	1180	ft
Cost / Track ft:	**$5,512**	

Appendix D

Quantity Backup

POST AND BEAM - BASELINE QUANTITIES - EARTH WORK

	BASELINE STATION NUMBER	STAT CUT FACT	STATION CUT AREA	STATION CUT VOLUME	ADJUSTED STATION CUT VOLUME	STAT FILL FACT	STATION FILL AREA	STATION FILL VOLUME	ADJUSTED STATION FILL VOLUME
	88+00.00	1	0	0	0	1	828.11	763	763
	88+25.00	1	0	0	0	1	810.83	759	759
	88+50.00	1	0	0	0	1	784.58	739	739
	88+75.00	1	0	0	0	1	751.58	711	711
	89+00.00	1	0	0	0	1	715.57	679	679
	89+25.00	1	0	0	0	1	674.76	644	644
	89+50.00	1	0	0	0	1	641.61	609	609
	89+75.00	1	0	0	0	1	449.32	505	505
	90+00.00	1	0	0	0	1	500.12	440	440
	90+25.00	1	0	0	0	1	505.88	466	466
	90+50.00	1	0	0	0	1	498.96	465	465
	90+75.00	1	0	0	0	1	459.42	444	444
	91+00.00	1	0	0	0	1	455.4	424	424
A Street Bridge Span	91+25.00	1	0	0	0	1	151.38	281	281
	91+50.00	1	0	0	0	1	132.85	132	132
	91+75.00	1	0	0	0	1	140.68	127	127
	92+00.00	1	0	0	0	1	122.85	122	122
	92+25.00	1	0	0	0	1	111.48	108	108
	92+50.00	1	0	0	0	1	102.81	99	99
	92+75.00	1	0.12	0	0	1	82.3	86	86
	93+00.00	1	0.38	0	0	1	88.59	79	79
	93+25.00	1	0.85	1	1	1	90.09	83	83
	93+50.00	1	17.32	8	8	1	1.82	43	43
	93+75.00	1	8.46	12	12	1	14.59	8	8
	94+00.00	1	2.15	5	5	1	43.98	27	27
	94+25.00	1	0.19	1	1	1	88.78	61	61
Pacific Avenue Bridge Span	94+50.00	1	0	0	0	1	113.77	94	94
	94+75.00	1	0	0	0	1	179.82	136	136
	95+00.00	1	0	0	0	1	152.88	154	154
	95+25.00	1	0	0	0	1	159.96	145	145
	95+50.00	1	0	0	0	1	171.42	153	153
	95+75.00	1	0	0	0	1	204.77	174	174
	96+00.00	1	0	0	0	1	203.23	189	189
	96+25.00	1	0	0	0	1	215.11	194	194
	96+50.00	1	0	0	0	1	221.79	202	202
	96+75.00	1	0	0	0	1	356.05	268	268
	97+00.00	1	0	0	0	1	300.32	304	304
	97+25.00	1	0	0	0	1	233.68	247	247
	97+50.00	1	0	0	0	1	139.35	173	173
	97+75.00	1	0	0	0	1	140.25	129	129
	98+00.00	1	0	0	0	1	133.42	127	127
	98+25.00	1	0	0	0	1	130.74	122	122
	98+50.00	1	0	0	0	1	152.2	131	131
	98+75.00	1	10.45	5	5	1	117.1	125	125
	99+00.00	1	308.15	147	147	1	0	54	54
	99+25.00	1	335.7	298	298	1	0	0	0
	99+50.00	1	282.69	286	286	1	0	0	0
	99+75.00	1	217.21	231	231	1	0	0	0
	100+00.00	1	236.54	210	210	1	0	0	0

Total Excavation: 1204 cy

Embankment: 12025 cy

Exclude A Street Bridge Span[1]: 662 cy

Exclude Pacific Ave Bridge Span[1]: 1441 cy

Total Embankment: 9922 cy

[1] Embankment for bridge spans is excluded as earth work costs for these sections are included in the lump sum bridge costs

POST AND BEAM - BASELINE QUANTITIES - RETAINING WALLS

Description	Takeoff Quantity	Unit	Total Cost/Unit	Total Amount
Retaining Wall W-7				
Metal Bin Retaining Walls				
Structural Earth Wall	930.00	sf	$61.33	$57,037
Metal Bin Retaining Walls				*$57,037*
Retaining Wall W-7	**930.00**	**sf**	**$61.33**	**$57,037**
Retaining Wall W-9				
Reinforcing In Place				
Steel Reinf. Bar, Grade 60	2,351.00	lb	$1.95	$4,583
Reinforcing In Place				*$4,583*
Placing Concrete				
Concrete Class 4000	9.40	cy	$257.14	$2,417
Placing Concrete				*$2,417*
Precast Wall Panels				
Concrete Fascia Wall Panel	1,045.00	sf	$45.86	$47,920
Precast Wall Panels				*$47,920*
Railings, Pipe				
Wall Railing	131.00	lf	$99.83	$13,077
Railings, Pipe				*$13,077*
Excavating, Bulk Bank Measure				
Structural Excavation	19.30	cy	$16.30	$315
Excavating, Bulk Bank Measure				*$315*
Hauling				
Hauling Excavated Material	19.30	cy	$4.99	$96
Hauling				*$96*
Cofferdams				
Timber Lagging, 3"	1,045.00	sf	$14.28	$14,919
Cofferdams				*$14,919*
Sheet Steel Piles				
Furnish Soilder Pile	329.00	vlf	$60.92	$20,042
Sheet Steel Piles				*$20,042*
Fixed End Cassion Piles				
Drilled Shaft, 24" Dia	329.00	vlf	$99.24	$32,650
Fixed End Cassion Piles				*$32,650*
Metal Bin Retaining Walls				
Structural Earth Wall	680.00	sf	$61.33	$41,704
Metal Bin Retaining Walls				*$41,704*
Geotextiles For Subsurface Drainage				
Geotextile Drainage Mat	75.00	sy	$30.54	$2,290
Geotextiles For Subsurface Drainage				*$2,290*
Retaining Wall W-9[1]	**1,725.00**	**sf**	**$104.36**	**$180,014**
1 Only 1/3 of Wall W-9 supports the track embankment at the A St. Bridge =				**$60,000**
Retaining Wall W-11				
Metal Bin Retaining Walls				
Structural Earth Wall	6,700.00	sf	$61.33	$410,911
Metal Bin Retaining Walls				*$410,911*
Retaining Wall W-11	**6,700.00**	**sf**	**$61.33**	**$410,911**

POST AND BEAM - BASELINE QUANTITIES - BRIDGES

Description	Takeoff Quantity	Unit	Total Cost/Unit	Total Amount
Pacific Ave. Bridge				
Reinforcing In Place				
Steel Reinf. Bar, Grade 60	68,259.00	lb	$1.95	$133,072
Reinforcing In Place				*$133,072*
Concrete In Place				
Bridge Approach Slab	103.00	sy	$84.76	$8,730
Concrete In Place				*$8,730*
Railings, Pipe				
Pedestrian Railing	426.00	lf	$148.12	$63,099
Railings, Pipe				*$63,099*
Elastomeric Sheet Waterproofing And Access.				
Waterproofing	5,700.00	sf	$5.38	$30,675
Elastomeric Sheet Waterproofing And Access.				*$30,675*
Facility Area Drains				
Bridge Drainage System	520.00	lf	$167.25	$86,970
Facility Area Drains				*$86,970*
Excavating, Bulk Bank Measure				
Structural Excavation	262.00	cy	$16.31	$4,272
Excavating, Bulk Bank Measure				*$4,272*
Backfill, Structural				
Select Backfill	29.00	cy	$19.81	$574
Backfill, Structural				*$574*
Hauling				
Hauling Excavated Material	262.00	cy	$4.99	$1,308
Hauling				*$1,308*
Fixed End Cassion Piles				
Drilled Shaft, 4'-6" Dia	365.00	vlf	$383.16	$139,853
Drilled Shaft, 7'-0" Dia	459.00	vlf	$592.26	$271,847
Fixed End Cassion Piles				*$411,700*
Segmental Conc. Unit Masonry Retaining Walls				
Structural Earth Wall	713.00	sf	$78.05	$55,650
Segmental Conc. Unit Masonry Retaining Walls				*$55,650*
Bridges, Highway				
Structrual Low Allow Steel	462,072.00	lb	$2.58	$1,189,651
Concrete Class 4000 - Substructure	368.00	cy	$1,046.06	$384,949
Concrete Class 4000 - Deck	121.00	cy	$916.04	$110,841
Fixed Pin Bearing	6.00	ea	$6,690.00	$40,140
Expansion Pin Bearing	6.00	ea	$5,575.00	$33,450
Bridges, Highway				*$1,759,030*
Track Material				
Ballast	168.00	cy	$37.90	$6,366
Track Material				*$6,366*
Pacific Ave. Bridge	**1.00**	**ls**	**$2,561,445.82**	**$2,561,446**
A-Street Bridge				
Reinforcing In Place				
Steel Reinf. Bar, Grade 60	9,900.00	lb	$1.95	$19,300
Reinforcing In Place				*$19,300*
Concrete In Place				

POST AND BEAM - BASELINE QUANTITIES - BRIDGES

Bridge Approach Slab	103.00	sy	$84.76	$8,730
Concrete In Place				*$8,730*
Precast Concrete Channel Slabs				
Prestressed Concrete Slab	100.00	lf	$1,036.95	$103,695
Precast Concrete Channel Slabs				*$103,695*
Railings, Pipe				
Pedestrian Railing	208.00	lf	$148.12	$30,809
Railings, Pipe				*$30,809*
Elastomeric Sheet Waterproofing And Access.				
Waterproofing	801.00	sf	$5.38	$4,311
Elastomeric Sheet Waterproofing And Access.				*$4,311*
Facility Area Drains				
Bridge Drainage System	180.00	lf	$167.25	$30,105
Facility Area Drains				*$30,105*
Excavating, Bulk Bank Measure				
Structural Excavation	108.00	cy	$16.31	$1,761
Excavating, Bulk Bank Measure				*$1,761*
Backfill, Structural				
Select Backfill	21.00	cy	$19.81	$416
Backfill, Structural				*$416*
Hauling				
Hauling Excavated Material	108.00	cy	$4.99	$539
Hauling				*$539*
Fixed End Cassion Piles				
Drilled Shaft, 3'-0" Dia	180.00	vlf	$216.43	$38,957
Drilled Shaft, 4'-6" Dia	320.00	vlf	$383.16	$122,611
Fixed End Cassion Piles				*$161,568*
Bridges, Highway				
Concrete Class 4000 - Substructure	66.00	cy	$1,046.06	$69,040
Concrete Class 4000 - Deck	7.00	cy	$916.03	$6,412
Elastomeric Bearing Pad	4.00	ea	$557.50	$2,230
Bridges, Highway				*$77,682*
Track Material				
Ballast	40.00	cy	$37.90	$1,516
Track Material				*$1,516*
A-Street Bridge	**1.00**	**ls**	**$440,431.99**	**$440,432**

POST AND BEAM - PRESTRESSED GIRDER OPTION QUANTITIES

By: T. Wilson
Date: 7/12/09
Ckd: L. Hull
Date: 7/13/09

Location	**Station**		**Span**	**TOR El.**	**Soffit El.**	**Top of Support El.**	**OG or Prop El.**	**Support[1,2] Length**	**Top of Shaft El.**	**Shaft Tip El.**	**Shaft[3] Length**
A1	86+53			64.95	57.28	51.78	47.00	6.78	45.00	11.50	33.5
		B Street Gully	55								
P1	87+08			66.52	58.85	53.35	43.50	11.85	41.50	8.50	33.0
			55								
P2	87+63			68.08	60.41	54.91	51.00	5.91	49.00	13.50	35.5
		Under I-705	55								
P3	88+18			69.65	61.98	56.48	52.00	6.48	50.00	13.00	37.0
		Under I-705	55								
P4	88+73			71.22	63.55	58.05	54.50	5.55	52.50	14.00	38.5
		Under I-705	55								
P5	89+28			72.79	65.12	59.62	57.00	4.62	55.00	17.00	38.0
			55								
P6	89+83			74.35	66.68	61.18	61.50	4.50	56.68	20.00	36.7
			55								
P7	90+38			75.92	68.25	62.75	62.00	4.50	58.25	26.00	32.3
			55								
P8	90+93			77.49	69.82	64.32	63.00	4.50	59.82	34.00	25.8
			47								
P9	91+40			78.83	71.16	65.66	64.31	4.50	61.16	38.00	23.2
		A Street	55								
P10	91+95			80.40	72.73	67.23	62.00	7.23	60.00	45.00	15.0
			50								
P11	92+45			81.82	74.15	68.65	75.50	4.50	64.15	50.50	13.7
			50								
P12	92+95			83.25	75.58	70.08	77.50	4.50	65.58	60.00	10.0
			50								
P13	93+45			84.67	77.00	71.50	82.00	4.50	67.00	61.50	10.0
			50								
P14	93+95			86.10	78.43	72.93	79.00	4.50	68.43	42.00	26.4
			50								
P15	94+45			87.52	79.85	74.35	71.00	5.35	69.00	23.50	45.5
			50								
P16	94+95			88.95	81.28	75.78	67.20	10.58	65.20	16.00	49.2
		NB Pacific Ave	51								
P17	95+46			90.40	82.73	77.23	67.20	12.03	65.20	13.50	51.7
		SB Pacific Ave	57								
P18	96+03			92.02	84.35	78.85	67.20	13.65	65.20	12.00	53.2
			50								
P19	96+53			93.45	85.78	80.28	71.50	10.78	69.50	12.00	57.5
			50								
P20	97+03			94.87	87.20	81.70	73.50	10.20	71.50	23.50	48.0
			50								
P21	97+53			96.30	88.63	83.13	76.00	9.13	74.00	40.00	34.0
			40								
P22	97+93			97.44	89.77	84.27	80.00	6.27	78.00	37.00	41.0
			40								
A2	98+33			98.58	90.91	85.41	87.00	4.50	80.91	34.00	46.9

Subtotal	24	Ea	Subtotal	1180	LF	Subtotal	167	LF	**Total LF shafts**	**835**	**LF**
Cap vol	19.1	CY	Girders/Span	4	Ea	6' dia. col area	28.30	SF			
Total CY caps	**458**	**CY**	**Total LF grdrs**	**4720**	**LF**	**Total CY columns**	**175**	**CY**			
			Vol deck / LF	0.62	CY						
			Total CY deck	**732**	**CY**						

1 Support is either a column or abutment
2 Support length assumes 2' min embedment below original ground (O.G.). In areas where excavation is required to install the superstructure a minimum support height of 10' is maintained (5.5' pier cap + 4.5' minimum support ht.)
3 A minimum shaft length of 10' tipped in good material is assumed where applicable.

🟦 Elevations assume some re-grading of Paramount Electric and Eagle Tire property beyond "Gateway" concept

🟩 Elevations assume some re-grading of Equilon and McCraken properties

POST AND BEAM - ROLLED STEEL GIRDER OPTION QUANTITIES

By: T. Wilson
Date: 7/12/09
Ckd: L. Hull
Date: 7/13/09

Location	**Station**		**Span**	**TOR El.**	**Soffit El.**	**Top of Support El.**	**OG or Prop El.**	**Support[1,2] Length**	**Top of Shaft El.**	**Shaft Tip El.**	**Shaft[3] Length**
A1	86+53			64.95	58.95	53.45	47.00	8.45	45.00	11.50	33.5
		B Street Gully	55								
P1	87+08			66.52	60.52	55.02	43.50	13.52	41.50	8.50	33.0
			55								
P2	87+63			68.08	62.08	56.58	51.00	7.58	49.00	13.50	35.5
		Under I-705	55								
P3	88+18			69.65	63.65	58.15	52.00	8.15	50.00	13.00	37.0
		Under I-705	55								
P4	88+73			71.22	65.22	59.72	54.50	7.22	52.50	14.00	38.5
		Under I-705	55								
P5	89+28			72.79	66.79	61.29	57.00	6.29	55.00	17.00	38.0
			55								
P6	89+83			74.35	68.35	62.85	61.50	4.50	58.35	20.00	38.4
			55								
P7	90+38			75.92	69.92	64.42	62.00	4.50	59.92	26.00	33.9
			55								
P8	90+93			77.49	71.49	65.99	63.00	4.99	61.00	34.00	27.0
			47								
P9	91+40			78.83	72.83	67.33	64.31	5.02	62.31	38.00	24.3
		A Street	55								
P10	91+95			80.40	74.40	68.90	62.00	8.90	60.00	45.00	15.0
			50								
P11	92+45			81.82	75.82	70.32	75.50	4.50	65.82	50.50	15.3
			50								
P12	92+95			83.25	77.25	71.75	77.50	4.50	67.25	60.00	10.0
			50								
P13	93+45			84.67	78.67	73.17	82.00	4.50	68.67	61.50	10.0
			50								
P14	93+95			86.10	80.10	74.60	79.00	4.50	70.10	42.00	28.1
			50								
P15	94+45			87.52	81.52	76.02	71.00	7.02	69.00	23.50	45.5
			50								
P16	94+95			88.95	82.95	77.45	67.20	12.25	65.20	16.00	49.2
		NB Pacific Ave	51								
P17	95+46			90.40	84.40	78.90	67.20	13.70	65.20	13.50	51.7
		SB Pacific Ave	57								
P18	96+03			92.02	86.02	80.52	67.20	15.32	65.20	12.00	53.2
			50								
P19	96+53			93.45	87.45	81.95	71.50	12.45	69.50	12.00	57.5
			50								
P20	97+03			94.87	88.87	83.37	73.50	11.87	71.50	23.50	48.0
			50								
P21	97+53			96.30	90.30	84.80	76.00	10.80	74.00	40.00	34.0
			40								
P22	97+93			97.44	91.44	85.94	80.00	7.94	78.00	37.00	41.0
			40								
A2	98+33			98.58	92.58	87.08	87.00	4.50	82.58	34.00	48.6

Subtotal	24	Ea	Subtotal	1180	LF	Subtotal	193	LF	**Tot LF shafts**	**846**	**LF**
Cap vol	19.1	CY	Girders/Span	5	Ea	6' dia. col area	28.30	SF			
Total CY caps	**458**	**CY**	Girder wt. / ft.	300	Lbs/ft	**Total CY columns**	**202**	**CY**			
			Total LBS steel	**1,770,000**	**Lbs**						
			Vol deck / LF	0.62	CY						
			Total CY deck	**732**	**CY**						

1 Support is either a column or abutment
2 Support length assumes 2' min embedment below original ground (O.G.). In areas where excavation is required to install the superstructure a minimum support height of 10' is maintained (5.5' pier cap + 4.5' minimum support ht.)
3 A minimum shaft length of 10' tipped in good material is assumed where applicable.

🟦 Elevations assume some re-grading of Paramount Electric and Eagle Tire property beyond "Gateway" concept

🟩 Elevations assume some re-grading of Equilon and McCraken properties

Sound Transit
D to M Street Project

Parsons Brinckerhoff, Inc.
July 2009

POST AND BEAM - PRESTRESSED/ROLLED GIRDER OPTION QUANTITIES

By: T. Wilson
Date: 7/12/09
Ckd: L. Hull
Date: 7/13/09

Abut/Pier	Station	Location	Span	TOR El.	Soffit El.	Top of Support El.	OG or Prop El.	Support[1,2] Length	Top of Shaft El.	Shaft Tip El.	Shaft[3] Length
A1	86+53			64.95	57.28	51.78	47.00	6.78	45.00	11.50	33.5
		B Street Gully	55								
P1	87+08			66.52	58.85	53.35	43.50	11.85	41.50	8.50	33.0
			55								
P2	87+63			68.08	60.41	54.91	51.00	5.91	49.00	13.50	35.5
		Under I-705	55								
P3	88+18			69.65	61.98	56.48	52.00	6.48	50.00	13.00	37.0
		Under I-705	55								
P4	88+73			71.22	63.55	58.05	54.50	5.55	52.50	14.00	38.5
		Under I-705	55								
P5	89+28			72.79	65.12	59.62	57.00	4.62	55.00	17.00	38.0
			55								
P6	89+83			74.35	66.68	61.18	61.50	4.50	56.68	20.00	36.7
			55								
P7	90+38			75.92	68.25	62.75	62.00	4.50	58.25	26.00	32.3
			55								
P8	90+93			77.49	69.82	64.32	63.00	4.50	59.82	34.00	25.8
			47								
P9	91+40			78.83	71.16	65.66	64.31	4.50	61.16	38.00	23.2
		A Street	55								
P10	91+95			80.40	72.73	67.23	62.00	7.23	60.00	45.00	15.0
			50								
P11	92+45			81.82	74.15	68.65	75.50	4.50	64.15	50.50	13.7
			50								
P12	92+95			83.25	75.58	70.08	77.50	4.50	65.58	60.00	10.0
			50								
P13	93+45			84.67	77.00	71.50	82.00	4.50	67.00	61.50	10.0
			50								
P14	93+95			86.10	78.43	72.93	79.00	4.50	68.43	42.00	26.4
			50								
P15	94+45			87.52	79.85	74.35	71.00	5.35	69.00	23.50	45.5
			50								
P16	94+95			88.95	81.28	75.78	67.20	10.58	65.20	16.00	49.2
		NB Pacific Ave	51								
P17	95+46			90.40	84.40	78.90	67.20	13.70	65.20	13.50	51.7
		SB Pacific Ave	57								
P18	96+03			92.02	84.35	78.85	67.20	13.65	65.20	12.00	53.2
			50								
P19	96+53			93.45	85.78	80.28	71.50	10.78	69.50	12.00	57.5
			50								
P20	97+03			94.87	87.20	81.70	73.50	10.20	71.50	23.50	48.0
			50								
P21	97+53			96.30	88.63	83.13	76.00	9.13	74.00	40.00	34.0
			40								
P22	97+93			97.44	89.77	84.27	80.00	6.27	78.00	37.00	41.0
			40								
A2	98+33			98.58	90.91	85.41	87.00	4.50	80.91	34.00	46.9

Subtotal	24	Ea	Subtotal	1180	LF	Subtotal	169	LF	**Total LF shafts**	**835**	**LF**
Cap vol	19.1	CY	Vol deck / LF	0.62	CY	5' dia. col area	28.30	SF			
Total CY caps	**458**	**CY**	**Total CY deck**	**732**	**CY**	**Total CY columns**	**177**	**CY**			

Total length prestressed girder spans	1017	LF
Prestressed Girders/Span	4	Ea
Total LF prestressed grdrs	**4068**	**LF**

Total length steel girder spans	163	LF
Steel Girders/Span	5	Ea
Steel Girder Wt./Ft	300	Lbs/Ft
Total LBS Steel	**244,500**	**Lbs**

🟦 Elevations assume some re-grading of Paramount Electric and Eagle Tire property beyond "Gateway" concept

🟩 Elevations assume some re-grading of Equilon and McCraken properties

🟨 Steel spans over A Street and Pacific Avenue NB and SB

🟪 Top of support elevation reflects shallower steel superstructure

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1 Support is either a column or abutment
2 Support length assumes 2' min embedment below original ground (O.G.). In areas where excavation is required to install the superstructure
a minimum support height of 7.5' is maintained (3.5' pier cap + 4' minimum support ht.)
3 A minimum shaft length of 10' tipped in good material is assumed where applicable.

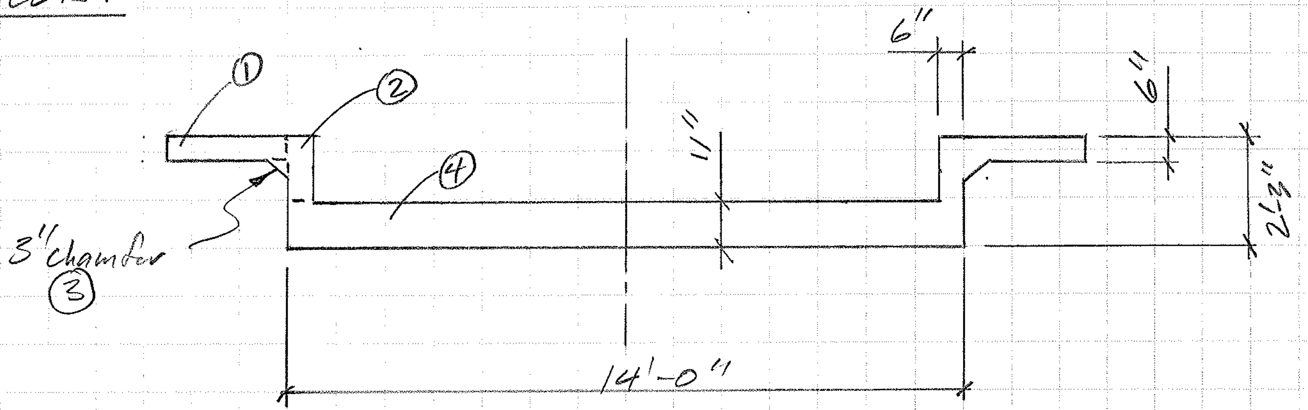
K:\160136_DtoM_Street\Technical\Structures\Post and Beam\Post & Beam Quantities - rev2.xls

PB Americas, Inc.
COMPUTATION SHEET

Subject D to M street Project
Post & Beam alternative Study

Page 2 of 7
Made by TRW
Date 5-12-09
Checked by LAH
Date 7/9/09

Deck:



Section	Area		#	Total A
①	(3'-6"/12"/1)(6"/12"/1)	= 1.25 SF	2 ea	2.50 SF
②	(2.25' - 11"/12)(0.5')	= 0.67 SF	2 ea	1.33 SF
③	½(3"/12)(3"/12)	= 0.03 SF	2 ea	0.06 SF
④	(14')(11"/12)	= 12.83	1 ea	12.83 SF
				16.72 SF

Vol of conc / ft length:

(16.72 SF)(1')/27 CF/CY = <u>0.62 CY / lf</u>

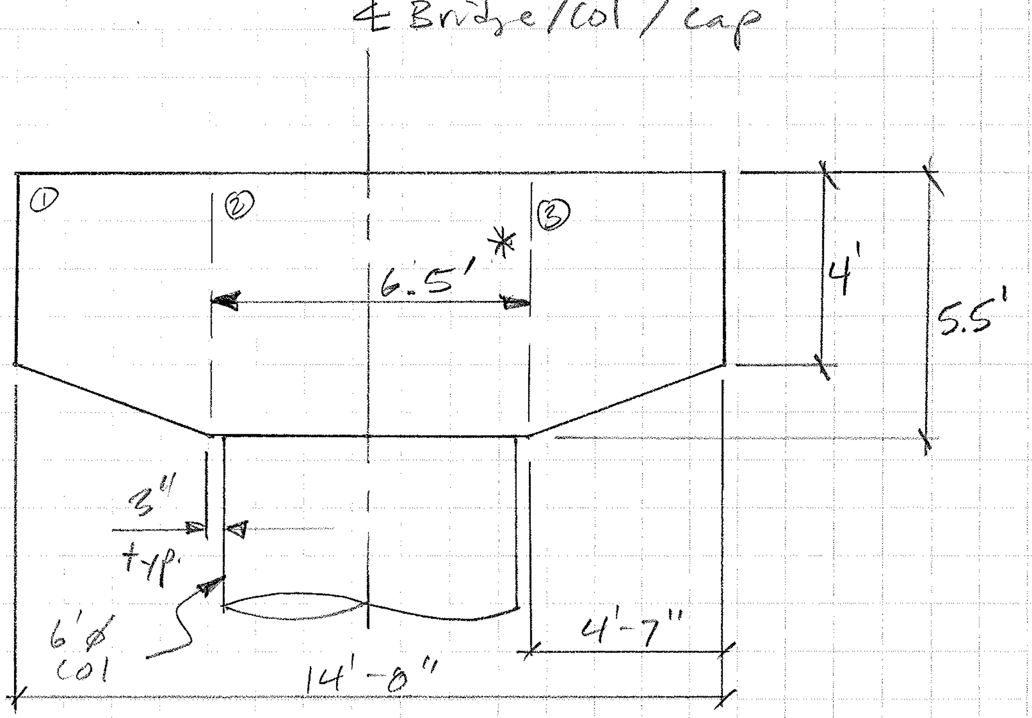
Average lbs / CY (from Caltrans BDA) = <u>225 lbs/CY</u>

PB Americas, Inc.
COMPUTATION SHEET

Subject D to M street Project
Post & Beam alternative Study

Page ______ of ______
Made by TRW
Date 7-12-09
Checked by LAH
Date 7/13/09

Pier Cap:



* Cap is the same dimension in the longitudinal direction.

Section	Area	Length	Vol
①	$\left(\frac{4'+5.5'}{2}\right)(4.50') = 21.76$ SF	6.5'	141.4 CF
②	$(5.5')(6.5') = 35.75$ SF	6.5'	232.4 CF
③	21.76 SF	6.5'	141.4 CF
			515.2 CF

Volume of Concrete:

515.2 CF / 27 CF/CY = 19.1 CY each

(use 200 lb/CY for steel r/f bar)

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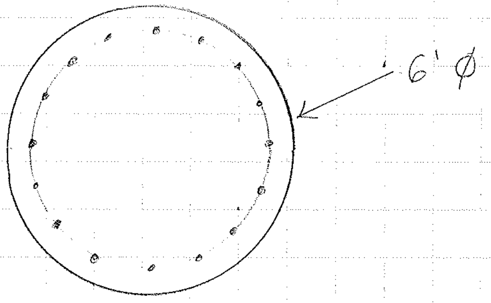
Column:

- The column is assumed to be a 6' ϕ circular reinforced concrete column with 1½% reinforcing steel area and typical size spiral confinement reinforcing.



$A = \pi(6'/2)^2$
$= 28.3\text{ SF}$

$W_{STL} = 0.015(28.3\text{ SF})(490\text{ lb/SF}) = 208\text{ lb/ft}$

$l_{spiral} = 2\pi(3' - 1.5''/12) \times (12''/3''\text{ spacing})$
$= 72.3'$

#4: 72.3'(0.668 lb/ft) = 48.3 lb
#5: 72.3'(1.043 lb/ft) = 75.4 lb

ave = 61.9 lb/ft col

$\text{Tot } A_{STL} = (\text{main stl} + \text{spiral})$
$= 208 + 61.9 \cong 270\text{ lb/ft length}$

$$\text{lbs/cy} = \frac{270\text{ lb/ft}}{(28.3\text{ sf})(1')/27}$$

$= 257.6\text{ lb/cy}$ say 260 lb/cy

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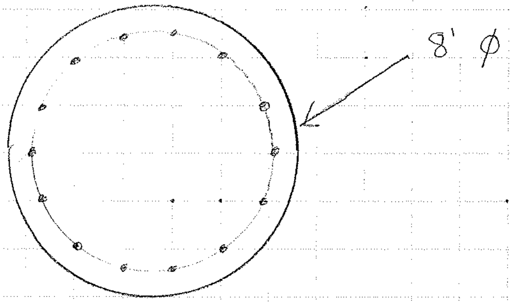
Shaft:

- The shaft is assumed to be an 8' φ shaft supporting a 6' φ column. The shaft is reinforced w/ 1% steel and typical spiral reinforcing.



$A = \pi (8'/2)^2$
$= 50.3$ SF

$W_{STL} = 0.01 (50.3\text{ SF})(490\text{ lb/sf}) = 246.5$ lbs/lf

$l_{spiral} = 2\pi (4' - 3''/12)(12''/4''\text{ spacing})$
$= 70.7'$

#5: $70.7'(1.043\text{ lb/ft}) = 73.7$ lbs

Total lb/ft = (main + spiral)
= 246.5 + 73.7
= 320.2 lbs

$$\text{lbs/CY} = \frac{320.2\text{ lbs}}{(50.3\text{ SF})(1')/27}$$

= 171.9 lbs/cy

use 175 lb/CY

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Steel Reinforcing Bar: (Prestressed alternative)

Item	Tot Volume	lbs/cy	total wt.
Pier Cap	458 cy	200 lb/cy	91,600 lbs
Deck	732 cy	225 lb/cy	164,700 lbs.
Columns	175 cy	260 lb/cy	45,500 lbs
shafts	(835' of shaft r/f bar included in LF cost)		
			301,800 lbs

Steel Reinforcing Bar: (Rolled steel alternative)

Item	Tot Volume	lbs/cy	Total wt.
Pier Cap	458 cy	200 lb/cy	91,600 lbs
Deck	732 cy	225 lb/cy	164,700 lbs
Columns	202 cy	260 lb/cy	52,520 lbs
Shafts	(846' of shaft r/f bar included in LF cost)		
			308,820 lbs

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Steel Reinforcing Bar: (Hybrid alternative)

Item	Tot Vol.	lbs/CY	total wt.
Pier Cap	458 CY	200 lb/CY	91,600 lbs
Deck	732 CY	225 lb/CY	164,700 lbs
Columns	177 CY	260 lb/CY	46,020 lbs
Shafts	(835 LF of shaft r/f bar included in LF cost)		
			302,320 lbs

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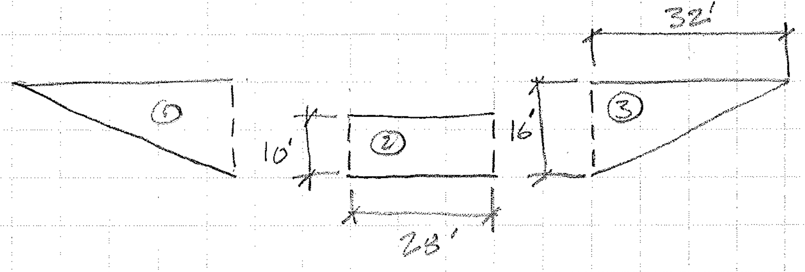
Waterproofing:

Area / ft: (1' + (14' − 2(0.5')) + 1') = 15 SF/ ft length

Total area = (1180 LF)(15 SF/ft) = 17,700 SF

Structural Earth Wall:



① ½ (32')(16') = 256 SF
② (10')(28') = 280 SF
③ ½ (32')(16') = 256 SF

792 SF x 2 abuts = 1,584 SF

Elastomeric Bearing Pads:

Prestressed:
(23 spans)(2 supports)(4 ea/support) = 184 ea

Rolled Beams:
(23 spans)(2 supports)(5 ea/support) = 230 ea

Hybrid:
(20 spans)(2 supports)(4 ea/support) +
(3 spans)(2 supports)(5 ea/support = 190 ea

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Bridge Drainage System:

ℓ of structure = 1180 LF

\# drains = 2 sides

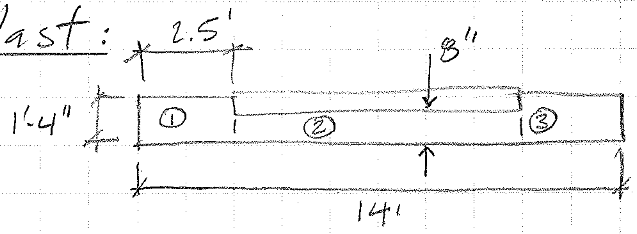
2360 LF

Downpipe (assumed ½ of col length) 225 LF/2 = 113 LF

Total length = 2360 LF + 113 LF = 2473 LF

Say 2475 LF

Ballast:



① (2.5')(1.38') = 3.33 SF
② (9')(0.67') = 6.03 SF
③ (2.5')(1.33') = 3.33 SF

12.69 SF (1')/27 = 0.47 CY/LF

Total vol.:
(0.47 CY/LF)(1180 LF) = 554.6 CY

Say 555 CY