Parkway Infrastructure Engineers

Hatch Mott MacDonald

TECHNICAL MEMO

To Linda Riley

From Biljana Rajlic

Date March 13, 2012

Project # 285380

Reference Tunnel watertightness

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Revision History					
Revision	**Date**	**Status**	**Prepared By**	**Checked By**	**Reviewed By**
A	Nov 29, 2011	For issue to MTO	NMc	AL	BR
B	Mar 6, 2012	For issue to MTO	NMc	AL	BR
C	Mar 13, 2012	For issue to MTO	NMc	AL	BR

	Name, Title	Signature	Date
Prepared By	Nancy McGee, Structures Coordinator	Nancy McGee	13 March 2012
Reviewed By	Andy Lambert, Structures Coordinator	Andy Lambert	13 March 2012
Approved By	Biljana Rajlic, Structures Lead	Biljana Rajlic	13 MARCH 2012

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Content Summary

The following document is divided into three main parts:

Part 1) Rev A Tunnel watertightness Memo issued to PIC/WEMG on November 29, 2012.
This is the original document submitted to HMQ outlining design team's concept and explaining how it meets the intent of the watertight clause in the Project Agreement.

Part 2) Rev B Tunnel watertightness Memo issued to PIC/WEMG on March 6, 2012.
This part is a document issued by the design team in response to HMQ's (originated by AECOM) comments, and is also a Variation notification because the RSS abutments are not by definition "watertight".

Part 3) HMQ Memo response and comments
This part is included as an appendix and contains HMQ comments (originated by AECOM) on Tunnel watertightness Rev A.

PART 1 – ORIGINAL TUNNEL WATERTIGHTNESS MEMO (REV A)

1. Introduction

In a design review meeting with MTO/IO Structures on November 1, 2011, the PA (Project Agreement) requirement for tunnels to be watertight was discussed. The design team took away the action to demonstrate how the proposed design addresses the intent of the PA, and to provide information about the water table level and where the drains discharge to.

This memo is to address the above meeting action.

2. The PA requirement for tunnels to be watertight

In relation to waterproofing, the PA requires that tunnels be watertight with no water intrusion (Schedule 15.2, Part 2, 4.2 Design Criteria, (g)(i)), as follows:

> (g) Waterproofing
>
> (i) The Tunnel structure shall be constructed as a watertight facility with no water intrusion permitted through the structure.
>
> (ii) Spray-on materials or bentonite-based boards shall not be used.
>
> (iii) Contraction joints shall be equipped with continuous waterstops that are embedded in the concrete structure.
>
> (iv) All waterproofing materials shall be resistant to damage from chemicals in the groundwater such as hydrogen sulphide.

In the meeting on Nov 2, 2011, MTO mentioned that their understanding of 'watertight' is that a watertight item submerged in water will not leak.

The reason for the PA requirement for prevention of water intrusion is not immediately clear, but is likely to be for some or all of the following reasons, especially taking into consideration that the highway may be depressed below existing ground water levels:

- Seepage of water through the abutment could result in surface flows that might freeze on cold days, causing a safety hazard on surfaces;
- Seepage of water through the deck or top of abutments could result in large growths of ice, which could create a safety hazard if they broke off and fell;
- Structures stained by seeping water would be aesthetically undesirable;
- Persistent water seepage through the structure could reduce the design life of the structure.

3. Watertightness of the proposed structure

The design will meet the PA intent, and prevent the above issues from occurring, by waterproofing the tunnel deck and by draining water from behind the abutments such that the water table is permanently lowered to below the abutment walls. This will prevent ingress of water into the tunnels.

It is not proposed to attempt to make the RSS abutment walls 'watertight' as defined by HMQ. To achieve this would be highly complex, if not completely impracticable, due to the differential movements expected after construction. It would be further complicated because any waterproofing layer behind the concrete facing panels would have to be pierced by numerous structural connections between the panels and the steel straps. (It should be also noted that the current design is generally the preferred standard engineering solution for RSS walls. Structurally, it is preferable for retaining structures to be drained rather than watertight, if at all possible.)

4. Proposed abutment drainage

The drainage of water from behind the abutments will be achieved by the use of the following drains, as indicated in Figure 1:

1) deck drain at the level of the top of the deck, or immediately on top of the deck;

2) 150mm subdrain behind the abutment pile cap;

3) 150mm subdrain at the toe of the RSS wall, just behind the facing panels;

4) 150mm subdrain below and behind the RSS wall (or, as shown in the sketch, at the bottom of the RGM (Reinforced Granular Mat)

Where necessary, an additional temporary subdrain may also be used at the bottom of the cut slope to lower the water table during construction, but this does not form part of the permanent design.

This is a similar arrangement to the standard detail shown in Figure 3 of the "Semi-Integral Abutment Bridges" MTO manual report no BO-99-03 (see Figure 2 in this memo).

The water table behind the abutment will thus be permanently drawn down to the level of the drainage placed at/below the RSS wall. This will be at least 1m below the finished highway grade in front of the abutments.

The RSS backfill is typically a well-graded material so that migration of fines (which can cause clogging of the subdrains) is not expected. However, by proposing several subdrains the design allows for redundancy in the drainage system should there be a blockage in one of the pipes. Further redundancy is created by the provision of outlets every 60-80m from these subdrains to the roadway drainage system. A plan layout of the drainage system for a typical tunnel is shown in Figure 3 in this memo.

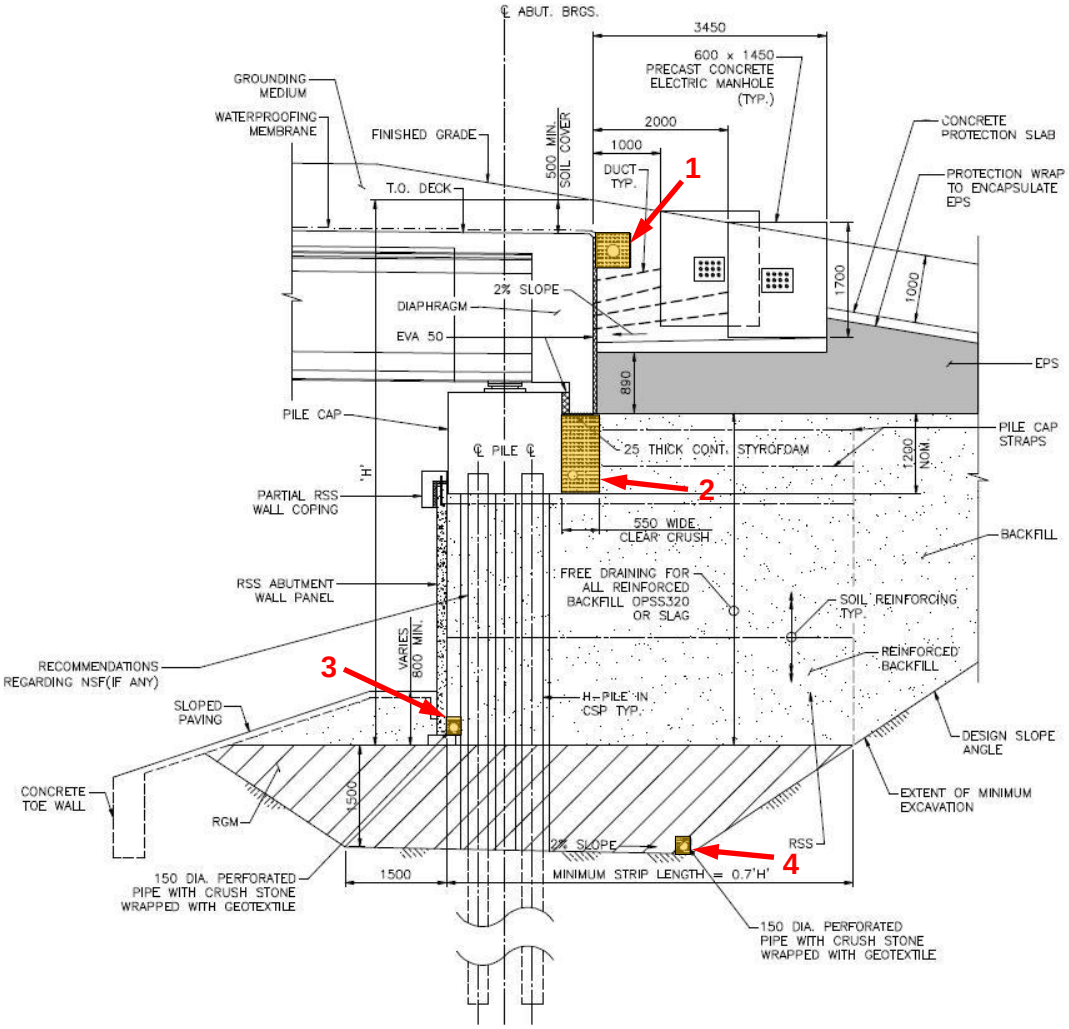

Figure 1: Drains in a typical WEP tunnel abutment

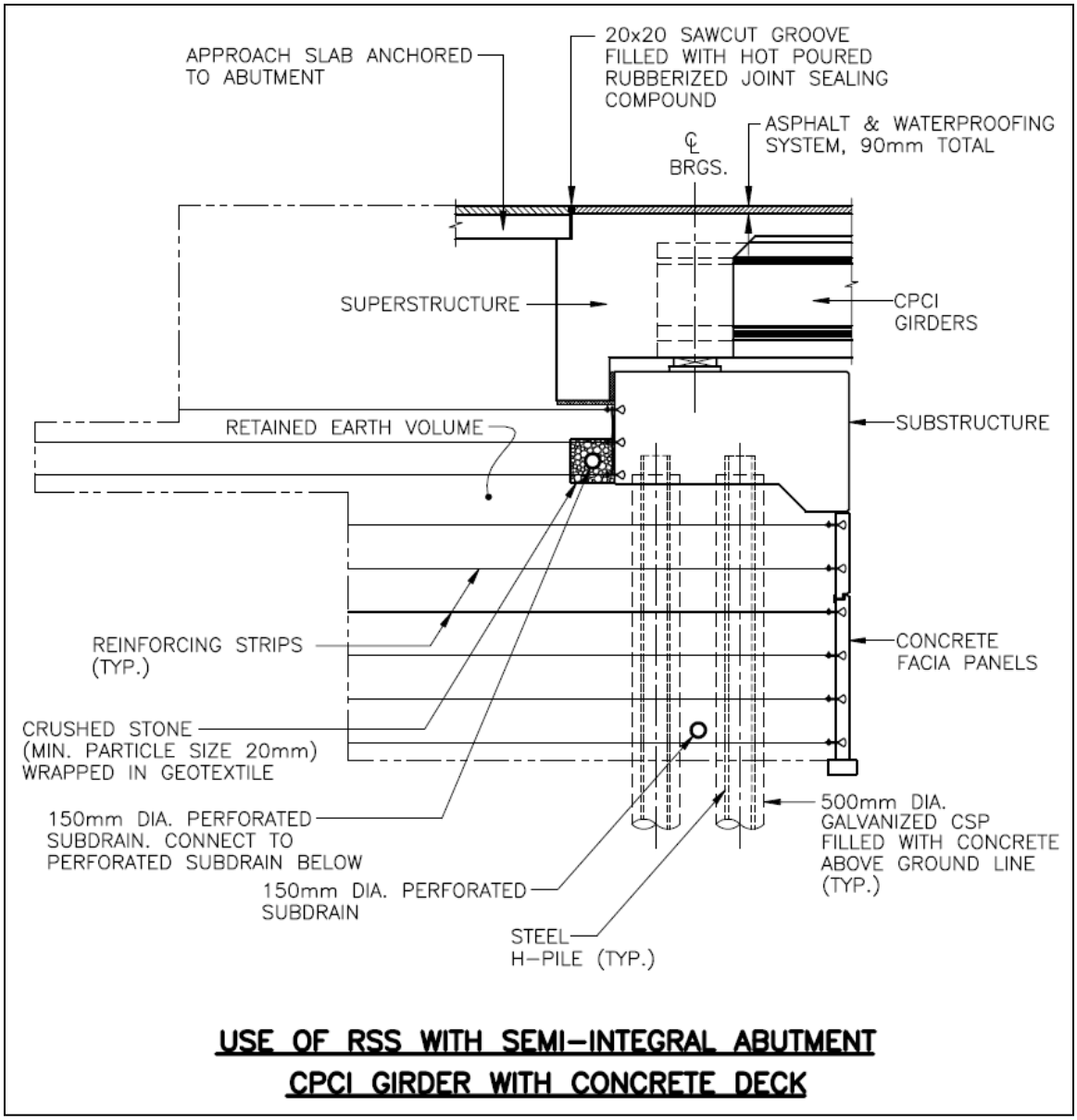

Figure 2: Standard detail as shown in figure 3 of "Semi-Integral Abutment Bridges" MTO manual report no BO-99-03, Figure 3

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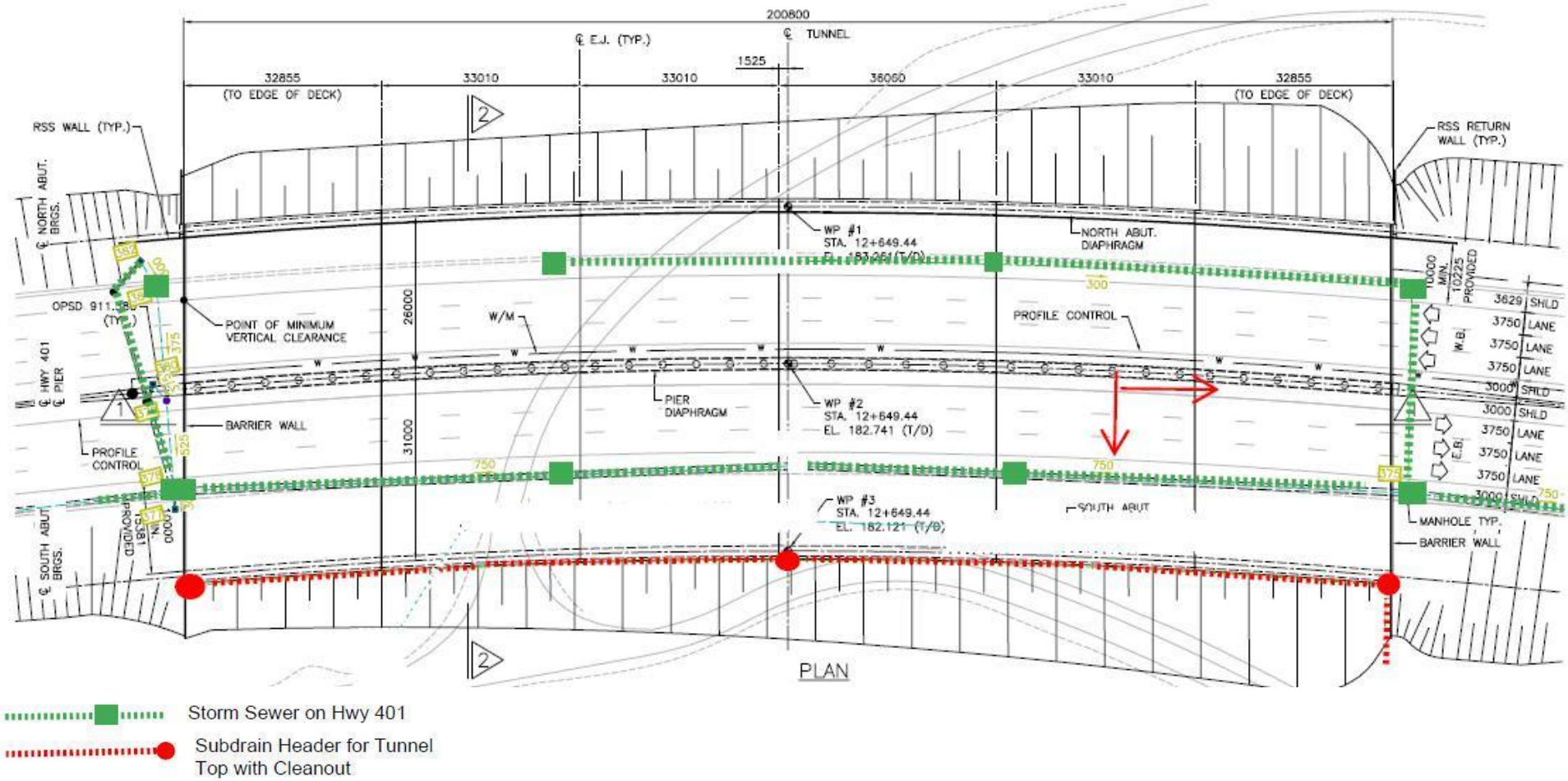


Figure 3: Layout of drains in a typical tunnel. Abutment drains have outlets to the storm sewer catchbasins, which are indicated here as green squares.

5. Seals for abutment joints

Along the length of tunnel abutments there may be a number of expansion joints (also referred to as expansion-contraction joints). These joints will be made watertight by use of a seal. The proposed seal is shown in Figure 4 below.

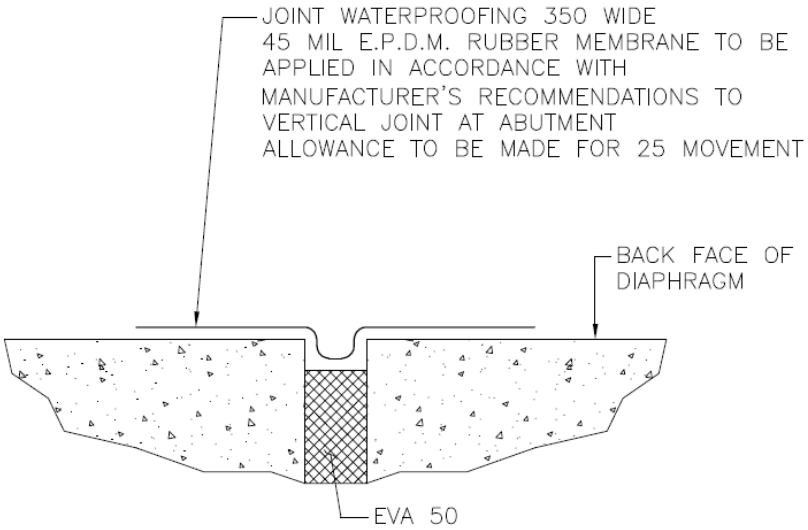


Figure 4: Plan on detail of seal at abutment expansion joint

6. Conclusion

As explained in this memo, the design fully complies with the intent of the PA.

With controlled drainage behind abutments there will be no ingress of water through the RSS wall or abutment into the tunnel. This is the design team's understanding of the PA clause that requires the tunnels to be watertight.

PART 2 – RESPONSE TO HMQ COMMENTS (SEE APPENDIX)

1. Introduction

WEMG requested that HMQ review the proposed design details for tunnel RSS abutments in relation to PA Schedule 15-2, Part 2, Article 4.2 (g) (i) which requires that all Tunnel structures be constructed as watertight facilities with no water intrusion permitted through the structure (ref WEP-PIC-LET-WEM-0192, dated December 6, 2011).

AECOM reviewed this letter, and responded with comments for consideration (ref MEM-2012-01-13-AECOM Comments On WEMG Tunnel Watertightness Abutment Details-60197370).

This memo is in response to AECOM's comments, and is also a Variation Notification because the RSS abutments are not by definition "watertight".

2. AECOM comment #1: design philosophy

No response required.

3. AECOM comment #2: fifth subdrain suggested

> AECOM comment: "…It is suggested that a fifth subdrain be provided at the top of the EPS, directly behind the abutment cap. Refer to the enclosed Figure 1 markup. This additional subdrain is warranted because the EPS could act as an impervious layer, preventing water from migrating down to subdrain #2."

Since the issue of revision A of this memo, the precast concrete manholes removed from this location. A typical section is now as shown in Figure 5 below. It can be seen that there is no need for the suggested fifth subdrain.

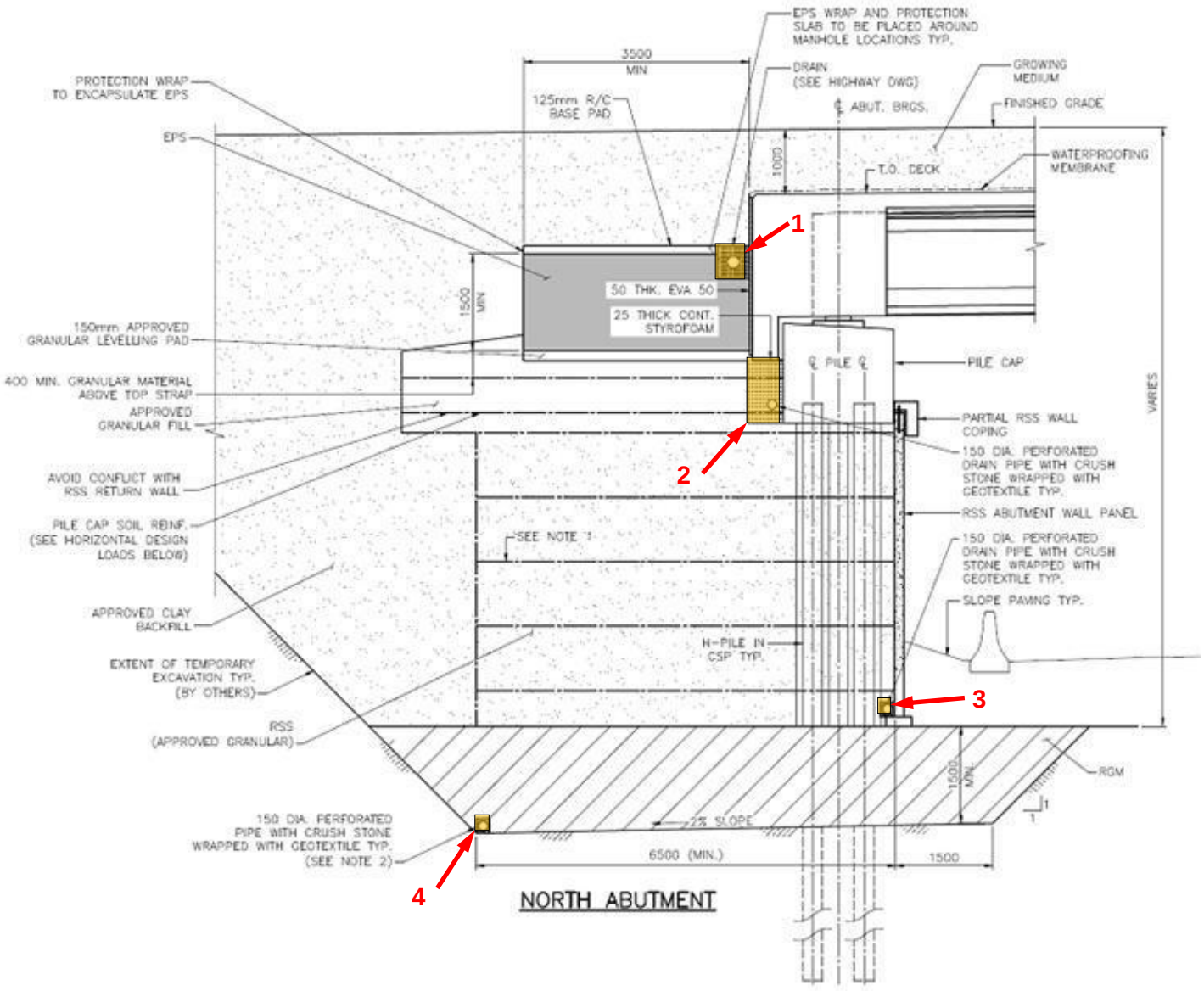


Figure 5 – Drains in a typical WEP tunnel abutment (extract from Structures design submission)

4. AECOM comment #3: confirmation of water table draw-down

AECOM comment: "…the claim that the water table will be '…permanently drawn down…" should be confirmed for each site by a qualified hydrogeologist…Hydrogeological information will also be required in determining the size of subdrains and outlet pipes…."

The design team has undertaken hydrogeological modelling to determine the construction and permanent dewatering requirements for the project. The modelling has demonstrated that

negligible inflows will occur from groundwater discharges into the subgrade portion of the WEP from groundwater flow through the subgrade. Total groundwater inflows for the subgrade are estimated to be less than 400m^3/day for the whole project. The reason for the low inflows is simply that the cut is through low-permeability material.

The permanent drawdown will be to the elevation of the subdrain system.

The hydrogeological modelling output shows that the maximum quantity of water to be drained from behind an abutment will be approximately 20 litres per day per metre of abutment. The subdrain system proposed provides a much greater drainage capacity. For example, one single 150mm diameter perforated subdrain laid to only 0.5% slope would have a capacity in the order of 100 times greater than this.

Further information is provided in Geotechnical Investigation and Design Reports for Permanent Cuts and Tunnels and in the Hydrogeological Assessment for Construction Dewatering and Permanent Dewatering.

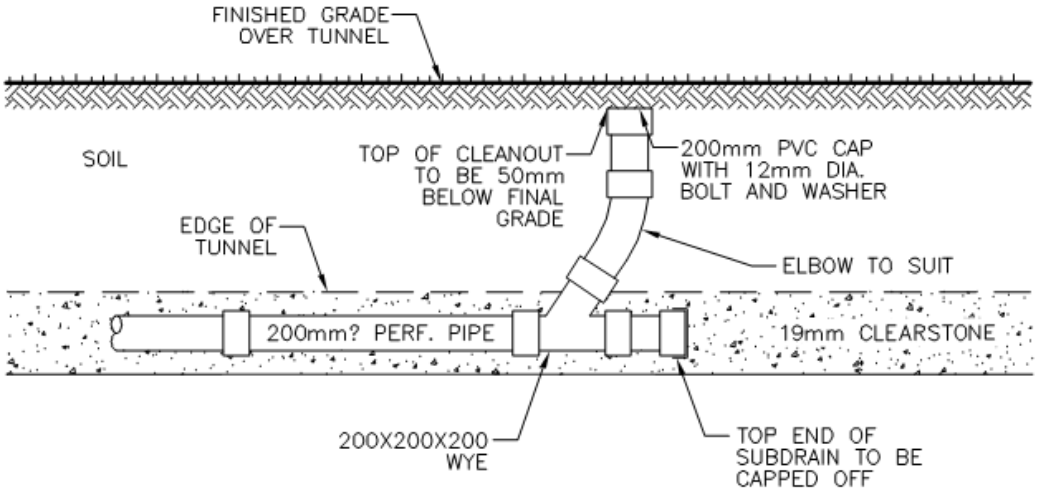
5. AECOM comment #4: monitoring subdrain system

> AECOM comment: "…As each of the 5 lines of subdrains has a specific purpose for the drainage of a specific area of the structure, the subdrain system may not provide sufficient redundancy in the event that one or more pipes become blocked. WEMG should propose a means of monitoring the performance of the subdrain system and removing any plugs. Further detail should also be provided for the "Cleanouts" shown in Figure 3."

WEMG is of the opinion that the subdrain system will provide sufficient redundancy in the event that one or more pipes become blocked. The system is to be installed according to the requirements of OPSS 405, and the subdrains will have sufficient slope for the water to drain properly.

Inspection of the subdrains will be part of the detailed structures inspection that is specified to happen every year. Any blockages should be minimal but will be identified through the normal inspection process.

Further detail for the "Cleanouts" has now been provided in the Highways design submissions. Typical details are shown in Figure 6.



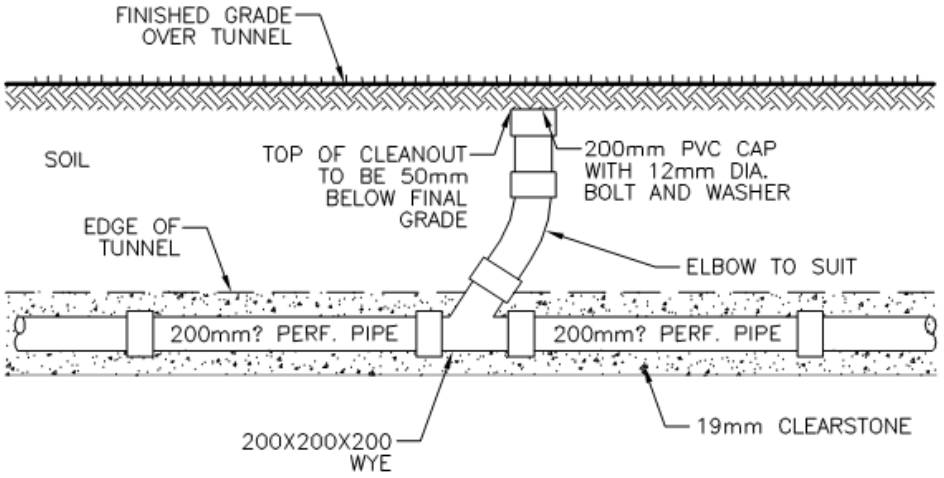


Figure 6: Typical cleanout details (extract from Highways design submission)

6. AECOM comment #5: sealing of abutment joints

AECOM comment: "…the edges of the rubber membrane should be sealed to prevent the ingress of water between the concrete and the membrane."

WEMG fully agrees with this comment, and Tunnel drawings will specify that the rubber membrane be fully sealed to the concrete surface with an appropriate adhesive system around all edges, as shown in Figure 7.

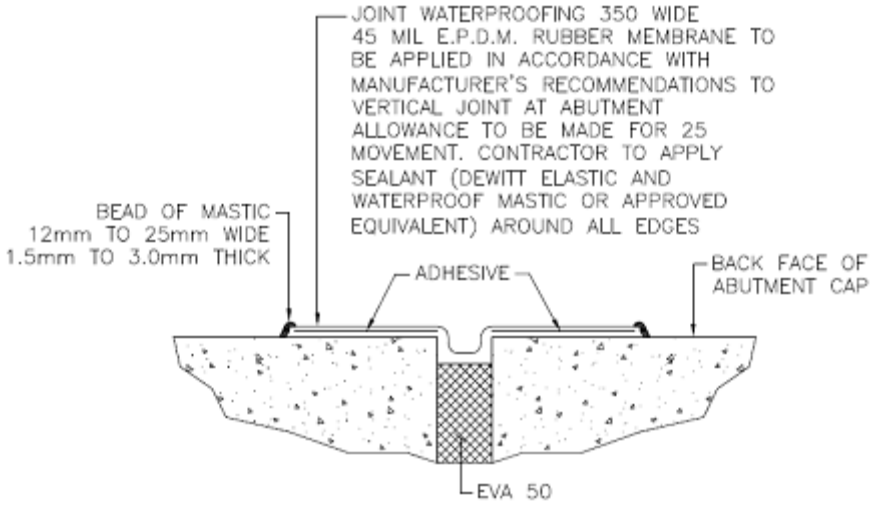


Figure 7: Abutment joint seal (extract from Structures design submission)

7. Conclusion

WEMG requests that HMQ grant a Variation from PA Schedule 15-2, Part 2, Article 4.2 (g) (i), which requires that all Tunnel structures be constructed as watertight facilities. Although the tunnel abutments will not be by definition "watertight", they will be drained to prevent water intrusion through the RSS structure.

PART 3 – HMQ's COMMENTS ON REV A (IN APPENDIX THAT FOLLOWS)

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Memorandum

To	Dennis Regan (MTO)	Page	1
CC	Brian Ruck, Mike Shallhorn		
Subject	Review and comments on WEMG's Request for Review and Acceptance of Structural Tunnel Watertightness Abutment Details		
From	Simon Ng		
Date	January 13, 2012	Project Number	60197370

This memo is prepared in response to letter *WEP-PIC-LET-WEM-0192* dated December 6, 2011 received from WEMG. WEMG has requested HMQ review of proposed design details for the RSS walls and tunnel abutment foundations in relation to PA Schedule 15.2, Part 2, Article 4.2 (g) (i) which requires that all Tunnel structures be constructed as watertight facilities with no water intrusion permitted through the structure. AECOM has reviewed WEMG's letter and offers the following comments for HMQ consideration.

1) AECOM generally concurs with PIC's list of reasons for why preventing water intrusion is required. We also concur with PIC's philosophy that from a structural perspective it is preferable to drain water away from the structure rather than to retain it in a watertight structure, as the latter objective is difficult to achieve and would require the design to resist forces resulting from hydraulic pressures.
2) With respect to the four (4) lines of subdrains identified in Section 4 of WEMG's letter, it is suggested that a fifth subdrain be provided at the top of the EPS, directly behind the abutment cap. Refer to the enclosed Figure 1 markup. This additional subdrain is warranted because the EPS could act as an impervious layer, preventing water from migrating down to subdrain #2.
3) With respect to the 4th paragraph in Section 4 of WEMG's letter, the claim that the water table will be "...permanently drawn down..." should be confirmed for each site by a qualified hydogeologist, as there is no information provided on the volume of groundwater which must be handled. Hydogeological input will also be required in determining the size of the subdrains and outlet pipes. In addition, the ability to effectively convey the water collected in the tunnel's subdrain system into the highway storm drainage system must be confirmed for each site.
4) With respect to the 5th paragraph in Section 4 of WEMG's letter, the term 'well-graded material' infers some percentage of fines, which can clog the subdrains. As each of the 5 lines of subdrains has a specific purpose for the drainage of a specific area of the structure, the subdrain system may not provide sufficient redundancy in the event that one or more pipes become blocked. WEMG should propose a means of monitoring the performance of the subdrain system and removing any plugs. Further detail should also be provided for the "Cleanouts" shown in Figure 3.
5) The proposed details at abutment joints referenced in Section 5 of WEMG's letter are in general conformance with OPSD 3950.100, November 2011. Evafoam has been substituted for the fibreboard filler specified in the OPSD, which is an improvement. The only comment to be directed to WEMG with respect to the abutment joints is that the edges of the rubber

membrane should be sealed to prevent the ingress of water between the concrete and the membrane.

It is noted that WEMG presented their letter to demonstrate how their proposed design addresses the intention of the Project Agreement and as such, once the above comments have been addressed, a Variation Notification should be made to clarify how the design intent has been fulfilled even though the RSS wall is not by definition “watertight”. We should emphasize that the design intent is fulfilled only if the drains are operational during the lifetime of the structure, and thus assurances on performance and methods to maintain their operation needs to be addressed. Aside from the comments above, AECOM has no further concerns with the design presented in relation to the PA requirement for the Tunnel structures to be constructed as watertight facilities.

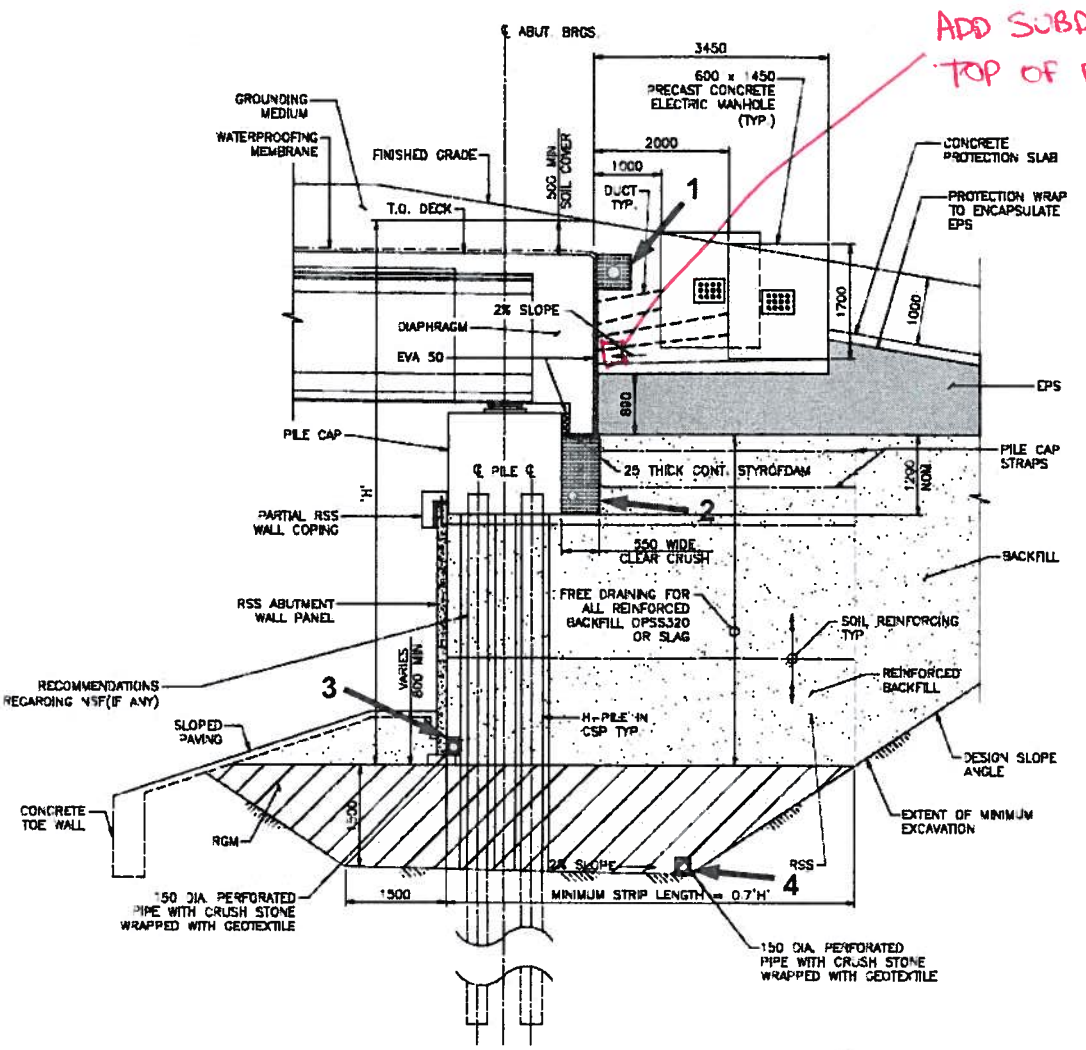

Figure 1: Drains in a typical WEP tunnel abutment

This Sheet was included as an attachment in HMQ (AECOM) Comment Responses to the Rev A memo. It has been included again here in Tunnel Watertightness Rev C 285380-03-119-0039 for completeness.