M54 to M6 Link Road

TR010054

Volume 6

6.3 Environmental Statement Appendices

Appendix 13.8: Groundwater Technical Note

Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

January 2020

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

M54 to M6 Link Road

Development Consent Order 202[ ]

6.3 Environmental Statement Appendices

Appendix 13.8: Groundwater Technical Note

Regulation Number	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010054
Application Document Reference	6.3
Author	M54 to M6 Link Road Project Team and Highways England

Version	**Date**	**Status of Version**
1	January 2020	DCO Application

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1 Introduction

1.1 Highways England is developing a link road between the M54 and M6 to provide a link between Junction 1 of the M54, M6 North and the A460 to Cannock. The M54 to M6 Link Road (herein referred to as 'the Scheme') aims to reduce congestion on local / regional routes, particularly the A449 and A460 and deliver improved transport links to encourage the development of the surrounding area.

1.2 As part of the proposed construction of the Scheme, localised dewatering may be required during both the construction and operational phases. The Scheme would include the construction of three permanent cuttings and the excavation of a temporary borrow pit. Based on the results of groundwater level monitoring between July and November 2019, it is likely that dewatering would be required for one of the cuttings and for the borrow pit during the construction phase. During operation the roads drainage system would manage the possibility of groundwater levels above the base of the cutting. This would be achieved using cut off drains and filter drains. This Technical Note provides a preliminary assessment of the likely volumes of groundwater that would require abstraction during construction and operation of the Scheme.

2 Approach and Methodology

2.1 To calculate the likely volumes of groundwater that would require dewatering the following approach has been taken. Groundwater inflow rates have been calculated using the maximum (1.33×10^{-6} m/sec) and average (4.8×10^{-6} m/sec) permeability (k) values, calculated for the superficial deposits from in-situ falling head tests on boreholes drilled along the route in 2019 during the ground investigation. No tests have been carried out on the underlying sandstone aquifer. For the purpose of the assessments, the following assumptions have been made:

- For the cuttings, planar groundwater flow has been assumed from both sides of the cuttings with steady-state conditions established after two years of operations.
- An unconfined aquifer storage coefficient (S) of 10%.
- Construction dewatering of 500 days (t).
- Extent of dewatering (L_0) for the cutting is determined from the equation $L_0 = \sqrt{12kDt}/S$ where D is the amount of drawdown required.
- D for construction is 1.4 m and for operations 0.4 m.
- Extent of dewatering (R_0) for the borrow pit is determined from the equation.
- $R_0 = C\,(H - h)\sqrt{k}$ where C is an empirical number, taken as 2000 (Cashman & Preene); H is the rest water level; and, h is the depressed water level required.
- For the borrow pit, the perimeter is 870 m.
- The groundwater level across the borrow pit is 1 m below ground level.
- The borrow pit is 10 m deep and hence 9 m of dewatering is required.
- Lateral flow only is assumed, with no vertical flow through the base of the cutting or borrow pit.
- Incident rainfall is excluded.

3 Cuttings

3.1 Three cuttings would be constructed as part of the Scheme (Refer to Figure 2.1 Environmental Masterplan Overview [TR010054/APP/6.2]). The cutting through the new M54 Junction 1 (beneath Featherstone Overbridge) and the cutting east of Brookfield Farm would be above the groundwater level in the underlying superficial, fluvio-glacial deposits and Sherwood Sandstone, and hence dewatering would not be required to facilitate construction.

3.2 The central cutting which runs north-east from Dark Lane to the south of Brookfield Farm for 695 m would be locally below the groundwater level and would require dewatering during both construction and operation. At the Hilton Lane Overbridge, the road would be in a cutting of a depth up to 6.8 m below existing ground level. It is therefore assumed that the ground level would be reduced by up to 7.8 m, assuming an allowance of 1 m for construction. The proposed road level would fall to the north-east from approximately 137.6 m Above Ordnance Datum (AOD) to approximately 133.6 m AOD. Based on the results of the groundwater level monitoring along this section of the Scheme, it is concluded that the groundwater level varies between approximately 138 m AOD beneath most of the proposed cutting to approximately 134 m AOD beneath the north eastern end of the cutting.

3.3 Based on the groundwater level monitoring, the groundwater level would likely be above the assumed construction level and that construction dewatering would be required during construction of the cutting. There are no groundwater abstractions in close proximity to this section of the Scheme and hence the dewatering would have no impact on existing groundwater sources. However, Watercourse 4 flows in a north-westerly direction approximately 60 m north of the cutting. The groundwater level in the vicinity of Watercourse 4, is similar to the stream level and it is likely that there is hydraulic continuity between the groundwater and the surface water, with groundwater providing baseflow to the stream and the associated ponds.

3.4 Preliminary calculations indicate that only limited groundwater inflows would occur during construction, as the drawdown required is approximately 1.5 m. The calculated groundwater inflow to the cutting during dewatering is small at between approximately 6 m^3/day and 10 m^3/day. The calculations are provided in Annex A.

3.5 During the operation of the Scheme, the drawdown required would be reduced to approximately 0.4 m. The calculated groundwater inflow to the cutting during operational drainage would be small (i.e. less than 1.5 m^3/day) and it is likely that groundwater drainage would be sufficient during periods of high groundwater level.

4 Borrow Pit

4.1 The proposed borrow pit adjacent to Dark Lane would be up to 60,000 m^2 in area and up to a maximum of 10 m deep, providing an estimated 546,500 m^3 of construction materials (Refer to Figure 2.9 Construction works [TR010054/APP/6.2]). However, not all of this material is likely to be required as it represents a worst case. Therefore, the amount of dewatering needed in practice may be less than that reported in this note. The borrow pit would be backfilled using material obtained from the construction of the Scheme, which is considered unsuitable on engineering parameters. The principal water resource features in the vicinity of the proposed borrow pit are Watercourse 3, located 50 m from the south-western boundary of the Scheme, the ponds of Kings Pools Fishery to the north-west (west of the A460), the ponds south-west of Hilton Hall (south-east of the watercourse) and groundwater in the superficial deposits/sandstone aquifer. It is assumed that there is hydraulic continuity between the sandstone and the overlying superficial deposits. It is understood from discussions with the landowner that the ponds of Kings Pools Fishery are off-line from Watercourse 3 and only receive a surface water input during periods of high flows in the stream.

4.2 No ground investigation has been carried out at the proposed borrow pit. Based on a review of the logs of the nearest borehole (BH14) and trial pit (TP12) drilled as part of the 2019 ground investigation, it is likely that the borrow pit would be excavated into sand, possibly extending into the underlying sandstone aquifer. The ground level at the borrow pit is approximately 135 m AOD. The extrapolated groundwater level is shallow, within 2 m of the ground surface, and hence significant dewatering would be required to maintain a dry operational area irrespective of natural seasonal variations in the groundwater level. It is likely that dewatering of up to 9 m may be required during construction. It is also likely that Watercourse 3 and the ponds of Kings Pools Fishery are reliant, at least in part, on baseflow discharge from the sandstone aquifer. Dewatering of the borrow pit would lower the groundwater level around the borrow pit and would have a moderate impact on both groundwater and surface water resources if mitigation measures were not implemented.

4.3 Based on the highest groundwater levels recorded in November 2019, preliminary calculations show that the estimated groundwater inflow to the borrow pit would be between approximately 740 m^3/day and 1233 m^3/day for the maximum required drawdown of 9 m. The calculations are provided at Annex B. Table 1 provides the estimated groundwater inflow rates during the progressive excavation of the borrow pit.

Table 1: Estimated groundwater inflow rates to the borrow pit

Drawdown (m)	Estimated groundwater inflow rates			
	Maximum k (1.33 x 10^{-5} m/sec)		Average k (4.8 x 10^{-6} m/sec)	
	(m^3/sec)	(m^3/day)	(m^3/sec)	(m^3/day)
2	3.2 x 10^{-3}	274	1.9 x 10^{-3}	165

Drawdown (m)	**Estimated groundwater inflow rates**			
	Maximum k (1.33 x 10^{-5} m/sec)		**Average k (4.8 x 10^{-6} m/sec)**	
	(m^3/sec)	**(m^3/day)**	**(m^3/sec)**	**(m^3/day)**
4	6.3 x 10^{-3}	548	3.8 x 10^{-3}	329
6	9.5 x 10^{-3}	822	5.7 x 10^{-3}	494
9	1.4 x 10^{-2}	1233	8.6 x 10^{-3}	740

4.4 As the borrow pit would be backfilled as part of the Scheme construction, there would be no requirement for any operational dewatering.

4.5 When backfilling the borrow pit the use of lower permeability (i.e. clayey) backfill material would be minimised as this could impede groundwater flow across the area with potential to increase flood risk. In addition, the material to be re-used should be assessed for any contamination and the risk of impact on groundwater quality due to leaching following standard waste management practices.

5 Sensitivity Analysis

5.1 This sensitivity analysis has been prepared to analyse the robustness of the groundwater level monitoring data used in the assessment; on the potential impacts that climate change could have on groundwater levels; and, on the potential impacts on the need for dewatering of the cuttings during both construction and operation.

5.2 Groundwater level information is available for 19 boreholes monitored between July and November 2019. Between September and November 2019, the groundwater level rose in response to the heavy rainfall during the autumn period by between approximately 0.6 m and a maximum of 2 m in boreholes BH18 and BH25. The groundwater level rise in the sandstone bedrock was less than in the superficial deposits with the groundwater level typically rising by between approximately 0.4 m and 0.8m apart from borehole BH07 in which a rise of 1.43 m was recorded. The groundwater levels recorded in November are the highest recorded, reflecting the heavy rainfall in the recent (2019) autumn period.

5.3 Typically, groundwater reaches its highest level in March/April at the end of the winter recharge period. Accordingly, the groundwater level may rise further over the winter months. Given the nature of the strata and the proximity of the boreholes and the Scheme to watercourses, which form the discharge point for the groundwater, a further rise of more than 1 m is considered unlikely. If groundwater level monitoring was continued monthly over the winter period it would help to confirm the variation in the groundwater level over the winter period.

5.4 In order to assess the impacts of possible rises in groundwater level, a sensitivity assessment has been undertaken to consider the impact of a rise of 1 m and 2 m in the groundwater level on the need for dewatering of the cuttings and on the predicted volume of groundwater inflow where dewatering could be needed.

5.5 As reported above, there are three cuttings which form part of the Scheme. For the purpose of the impact assessment, it is assumed that the construction level in each cutting is 1 m below the final road level.

5.6 As stated in paragraph 3.1, the cutting to the north (east of Brookfield Farm) and south (through the new M54 Junction 1, beneath Featherstone Overbridge) would be above the groundwater level in the underlying superficial, fluvio-glacial deposits and Sherwood Sandstone and hence dewatering would not be required to facilitate construction.

5.7 At the Featherstone Overbridge, the groundwater level varies between 131 m AOD and 133 m AOD, approximately 4 m below the assumed construction level. Should the groundwater level rise by 2 m, the groundwater level would remain below the formation level. It is therefore unlikely that dewatering would be required during construction or operation to manage groundwater inflows.

5.8 Based on the results of the groundwater level monitoring in the vicinity of the proposed cutting east of Brookfield Farm, it was concluded that the groundwater level varied between 129 m AOD in the south-west and 124.5 m AOD in the north-east. As the groundwater level is approximately 3 m to 6 m below the assumed construction level no dewatering would be required. Should the groundwater level rise by 2 m, the groundwater level would remain below the formation level. No dewatering would be required during construction or operation to manage groundwater inflows. As reported in paragraphs 3.2 to 3.5 the central cutting between Dark Lane and Brookfield Farm would be locally below the groundwater level and would require limited dewatering during both construction and operation of the Scheme. If the groundwater level was to rise by a further 1 m, as a result of a response to natural fluctuations in recharge and/or climatic change, additional dewatering at the cutting would be required during construction together with accommodation for additional groundwater drainage during operation. The calculated inflow of groundwater to the cutting during construction varies between approximately 13 m^3/day and 21 m^3/day for the average and maximum permeability values reported respectively. During operations, the predicted groundwater inflow to the cutting varies between approximately 5 m^3/day and 8 m^3/day.

5.9 If the groundwater level was to rise by 2 m, the calculated inflow of groundwater to the cutting during construction varies between approximately 21 m^3/day and 36 m^3/day for the average and maximum permeability values. During operations, the predicted groundwater inflow to the cutting varies between approximately 11 m^3/day and 18 m^3/day.

5.10 Table 2 provides a summary of the calculated groundwater flows to the Hilton Lane Overbridge cutting during both construction and operations, for different groundwater levels. The calculations are provided at Annex C.

Table 2: Predicted groundwater inflow to the central cutting (m^3/day)

Groundwater inflow (m^3/day)		
Construction	**Permeability (m/day)**	
	1.15	**0.41**
Baseline*	9.4	5.8
GWL +1m	21.3	12.7
GWL +2m	35.8	21.5
Operation		
Baseline*	1.2	0.6
GWL +1m	7.8	4.7
GWL +2m	17.7	10.5
*Based on recorded groundwater levels November 2019		

6 Groundwater Ingress and Implications for Future Road Drainage

6.1 Earthworks drainage has been incorporated within the preliminary design of the Scheme at the top and bottom of embankments to capture any groundwater ingress using filter drains. The area associated with the cuttings outlined in this technical note have been incorporated within the sizing of attenuation pipes. The attenuation provided as part of the Scheme is conformant with the standards set out in the Design Manual for Roads and Bridges – CG 501 'Design of highway drainage systems'. It is not anticipated that any further measures would be required to remove groundwater from the cutting during operation of the Scheme.

Annex A: Dewatering calculations - cutting between Dark Lane and Brookfield farm

CALCULATION SHEET

AECOM

Project: M54 Junct. 1 → M6 J11 | Ref:

Section: Calculation of Dewatering Volumes in Hilton Lane O/B Cutting | Job No: 60536736

Date: 3/12/2019

Made by: Phil | Checked by: MB. | Sheet No: 1 of 3

Assumptions:-

Proposed Road Level. ~~137.4~~ 137.6 m AOD (in SW) to 133.6 (in NE) m AOD

Construction Level (assumed) 136.6 m AOD to 132.6 m AOD.

Groundwater Level (Nov. 2019). 138 m AOD (in SW) to 134 m AOD (in NE).

Cutting length. 2+480 → 3+135 = 655 m.

Assume d/w required for whole length of cutting.

" d/w " of 1.4 m during construction.

Permeability of glacial deposits:-

max − 1.33×10^{-5} m/sec (1.15 m/day)

mean − 4.8×10^{-6} m/sec. (0.41 m/day)

Assume planar flow (linear) to BOTH sides of cutting excavation.
Steady-state conditions

Modelled as a series of linear pumping wells. Extent of d/w (L_o) calculated by

$$L_o = \sqrt{\frac{12kDt}{S}}$$

where D = amount of dewatering required 1.4 m
S = storage coefficient 10% assumed for unconfined sand
t = length of pumping (days) = 500

$\therefore L_o = \sqrt{\frac{12 \times 1.15 \times 500 \times 1.4}{0.1}}$ OR $L_o = \sqrt{\frac{12 \times 0.41 \times 500 \times 1.4}{0.1}}$

$= \sqrt{~~69000~~\ 96600}$ $= \sqrt{~~24600~~\ 34440}$

= ~~262 m~~ ~~310 m~~ 311 = ~~157 m~~ 185.

$\therefore i = 1.4 / ~~262~~\ 311$ = 1.4 / ~~157~~ 185

= ~~5.3~~ 4.5 $\times 10^{-3}$ = ~~0.009~~. 0.0076.

CALCULATION SHEET

AECOM

Project:	Ref:
Section: HILTON LANE O/B CUTTING.	Job No: 60536736
	Date: 3/12/2019
Made by: PHIL Checked by: MB	Sheet No: 2 of 3

INFLOW TO EXCAVATION FOR CUTTING. $= Q = k.i.A$

Where $A = 655 \times 1.4$ / side of cutting

$\therefore Q = 1.15 \times 4.5 \times 10^{-3} \times 655 \times 1.4$

$= 5.49 \times 10^{-5}\ m^3/sec$

$= 4.7\ m^3/day$

Assume similar flow from other side of cutting:-

$Q = 4.7 \times 2 = 9.4\ m^3/day$

SAY $10\ m^3/day$.

For $k - 4.8 \times 10^{-6}\ m/sec$.

$Q = 4.8 \times 10^{-6} \times 0.0076 \times 655 \times 1.4$

$= 3.34 \times 10^{-5}\ m^3/sec$

$= 2.9\ m^3/day$

TOTAL flow from both sides $= 2.9 \times 2 = 5.8\ m^3/day$

SAY $6\ m^3/day$.

DURING OPERATIONAL PERIOD.

DRAWDOWN IMPOSED reduced from 1.4m to 0.4m

Assume steady-state after 2 years (estimate)

$\therefore L_o = \sqrt{\frac{12 \times 1.15 \times 730 \times 0.4}{0.1}}$ OR $L_o = \sqrt{\frac{12 \times 0.41 \times 730 \times 0.4}{0.1}}$

$= \sqrt{40296}$ $\qquad = \sqrt{14366.4}$

$= 200.7m$ $\qquad = 120m$.

$i = 0.4/200.7$ $\qquad = 0.4/120$

$= 1.99 \times 10^{-3}$ $\qquad = 0.003$

CALCULATION SHEET

AECOM

Project:		Ref:	
Section:	HILTON LANE O/B CUTTING.	Job No:	60536736
		Date:	3/12/2019
Made by: PHIL	Checked by: MB.	Sheet No:	3 of 3

PERMANENT INFLOW TO CUTTING. $Q = K.i.A.$

Where $A = 655 \times 0.4$ / side of cutting

$\therefore Q = 1.15 \times 1.99 \times 10^{-3} \times 655 \times 0.4$

$= 0.6\ m^3/day$

Assume similar inflow from opposite side $Q = 0.6 \times 2 = 1.2\ m^3/day$

For $K = 4.8 \times 10^{-6}\ m/sec$

$Q = 4.8 \times 10^{-6} \times$ ~~0.0076~~ 0.003 $\times 655 \times 0.4$

= ~~9.56~~ 3.77 $\times 10^{-6}\ m^3/sec$

= ~~0.8~~ 0.3 m^3/day.

With similar inflow from opposite side $Q = 0.3 \times 2 = 0.6\ m^3/day$

FOR OPERATIONAL PHASE ASSUME GW INFLOW OF c. 1 – 1.5 m^3/day.

Annex B: Dewatering calculations - Hilton borrow pit

CALCULATION SHEET

AECOM

Project:	M54 J1 → M6 J11	Ref:	
Section:	BORROW PIT INFLOWS.	Job No:	60536736
		Date:	3/12/2019
Made by: PHIL.	Checked by: MB	Sheet No:	1 of 3

HILTON BORROW PIT.

Assumptions:-

Area of borrow pit — 59,800 m^2

Perimeter of borrow pit — 870m.

Depth of borrow pit — 10m

GWL — 1m bgl

Max. dewatering — 9m

Glacial deposits/sandstone

Max k — 1.33×10^{-5} m/sec

Mean k — 4.8×10^{-6} m/sec.

Extent of impact i.e. zero d/d (R_o) determined by:-

$$R_o = C\,(H-h)\,\sqrt{k}.$$ [Sichardt C750 p 123]

where C = 3000 (Cashman + Preene)
H is rest water level
h is depressed water level required.

Assumes lateral GW flow ONLY and partially penetrating conditions. No vertical flow through base. Steady-state conditions
Inflow calculated using:-

$$Q = k.i.A$$

where $i = d/d / R_o$

A = perimeter × d/d required = 870 × d/d.

CALCULATION SHEET

AECOM

Project:		Ref:	
Section:	BORROW PIT INFLOWS	Job No:	60536736
		Date:	3/12/2019
Made by: PHIL	Checked by: MB.	Sheet No:	2 of 3

(A) i) Using max. K. of 1.33×10^{-5} m/sec. d/d of 2m

$R_o = 2000 \times 2 \times \sqrt{1.33 \times 10^{-5}}$

$= 4000 \times 3.65 \times 10^{-3}$

$= 14.59$ m.

$\therefore \quad i = 2/14.59 \quad = 0.137.$

$Q = 1.33 \times 10^{-5} \times 0.137 \times [870 \times 2]$

$= 3.17 \times 10^{-3}$ m³/sec

$= 274$ m³/day.

ii) Assume 4m d/d

$R_o = 2000 \times 4 \times 3.65 \times 10^{-3}$

$= 29.17$ m

$\therefore \quad i = 4/29.17 \quad = 0.137$

NOTE: i is a CONSTANT as d/d and R_o increase proportionally.

$Q = 1.33 \times 10^{-5} \times 0.137 \times [870 \times 4]$

$= 6.35 \times 10^{-3}$ m³/sec

$= 548$ m³/day.

For d/d.	R_o (m)		
6m	43.8	$Q = 9.5 \times 10^{-3}$ m³/sec	822 m³/day
9m	65.7	$Q = 1.43 \times 10^{-2}$ m³/sec	1233 m³/day.

CALCULATION SHEET

AECOM

Project:	Ref:
Section: BORROW PIT INFLOW	Job No: 60536736
	Date: 3/12/2019
Made by: PHIL Checked by: MB	Sheet No: 3 of 3

(B) Using average k. of 4.8×10^{-6} m/sec

d/d 2m $\quad R_0 = 2000 \times 2 \times \sqrt{4.8 \times 10^{-6}}$

$= 4000 \times 2.19 \times 10^{-3}$

$= 8.76$ m.

$\therefore \; i = 2/8.76 = 0.228$.

$Q = 4.8 \times 10^{-6} \times 0.228 \times [870 \times 2]$

$= 0.0019 \; m^3/sec$

$= 165 \; m^3/day$.

D/D required	R_0 (m)		
4m	17.52	$Q = 0.0038 \; m^3/sec$	329 m^3/day
6m	26.28	$Q = 5.7 \times 10^{-3} \; m^3/sec$	494 m^3/day
9m	39.42	$Q = 0.0086 \; m^3/sec$	740 m^3/day.

Annex C: Dewatering calculations varied groundwater levels – Cutting between Dark Lane and Brookfield Farm

Project:	M54 Junct 1. → M6 Junct 11	Ref:	T10699
Section:	IMPACT OF POSSIBLE INCREASED GW. LEVELS' - HILTON LANE O/B CUTTING	Job No:	60536736.
SENSITIVITY ANALYSIS		Date:	16/12/2019
Made by:	PHIL.	Checked by:	Sheet No: 1. of 4

ASSUME THAT GWL (max) rises by up to 2m above highest level recorded.

TWO SCENARIOS – 1) + 1m.

2) + 2m.

ASSUMPTIONS

PROPOSED ROAD LEVEL: 137.6m AOD (in SW) to 133.6m AOD (in NE)

CONSTRUCTION LEVEL (assumed): 136.6m AOD to 132.6m AOD

GROUNDWATER LEVEL (Nov. 2019): 138 m AOD (in SW) to 134m AOD (in NE).

CUTTING LENGTH: 655m.

Permeability of glacial deposits: MAX: 1.33×10^{-5} m/sec – 1.15 m/day.

AVER: 4.8×10^{-6} m/sec – 0.41 m/day.

Planar flow (linear) to BOTH sides of cutting.

STEADY STATE CONDITIONS. STORAGE COEFFICIENT – 10%.

CONSTRUCTION PERIOD (below GWL) – 500 days

EXTENT OF D/W (L_o) CALCULATED BY:-

$$L_o = \sqrt{\frac{12kDt}{S}}$$

DURING CONSTRUCTION

ORIGINAL D/D REQUIRED – 1.4m.

SCENARIO 1

GWL + 1m ∴ D/D required – 2.4m.

$$L_o = \sqrt{\frac{12 \times 1.15 \times 500 \times 2.4}{0.1}} \quad \text{OR} \quad L_o = \sqrt{\frac{12 \times 0.41 \times 500 \times 2.4}{0.1}}$$

$$= \sqrt{165600} \qquad = \sqrt{59040}$$

$$= 407m \qquad = 243m$$

∴ Hydraulic gradient (i)

$i = 2.4/407$ OR $i = 2.4/243$

$= 0.0059$ $= 0.0099$

INFLOW TO CUTTING $Q = K\,i\,A$.

where $A = 655 \times 2.4$ per side of cutting

$\therefore Q = 1.15 \times 0.0059 \times 655 \times 2.4$

$= 10.66\ m^3/day$

Assume identical flow from other side of cutting

$Q = 10.66 \times 2 = 21.3\ m^3/day.$

For $K = 0.41\ m/day$

$Q = 0.41 \times 0.0099 \times 655 \times 2.4$

$= 6.36\ m^3/day$

TOTAL INFLOW $= 6.36 \times 2 = 12.7\ m^3/day.$

DURING OPERATIONAL PERIOD

DRAWDOWN IMPOSED REDUCED TO 1.4m

Assumes steady-state after 2 years.

$\therefore L_o = \sqrt{\frac{12 \times 1.15 \times 730 \times 1.4}{0.1}}$ OR $L_o = \sqrt{\frac{12 \times 0.41 \times 730 \times 1.4}{0.1}}$

$= \sqrt{141036}$ $= \sqrt{50282}$

$= 375m$ $= 224m$

$\therefore i = 1.4/375$ $i = 1.4/224$

$= 0.0037$ $= 0.00625$

CALCULATION SHEET

AECOM

Project: M54 Junct 1 — M6 Junct 11 | Ref:

Section: HILTON LANE O/B CUTTING. | Job No: 60586736

SENSITIVITY ANALYSIS | Date: 16/12/2019.

Made by: PHIL | Checked by: MB | Sheet No: 3 of 4

INFLOW TO COMPLETED CUTTING. $Q = KiA$.

Where $A = 655 \times 1.4$ per side of cutting

$\therefore Q = 1.15 \times 0.0037 \times 655 \times 1.4$

$= 3.9\ m^3/day$

TOTAL INFLOW: $3.9 \times 2 = 7.8\ m^3/day$ ✓

OR

$Q = 0.41 \times 0.00625 \times 655 \times 1.4$

$= 2.35\ m^3/day$

TOTAL INFLOW: $2.35 \times 2 = 4.7\ m^3/day$ ✓

SCENARIO 2 CONSTRUCTION

GWL — +2m. $\therefore$ D/D required for construction — 3.4m

$L_o = \sqrt{\dfrac{12 \times 1.15 \times 500 \times 3.4}{0.1}}$ OR $L_o = \sqrt{\dfrac{12 \times 0.41 \times 500 \times 3.4}{0.1}}$

$= \sqrt{234600}$ $= \sqrt{83640}$

$= 484m$ ✓ $= 289\ m.$ ✓

$\therefore i = 3.4/484$ $i = 3.4/289$

$= 0.007$ ✓ $= 0.0118$ ✓

INFLOW TO CUTTING. $Q = KiA$

$= 1.15 \times 0.007 \times 655 \times 3.4$

$= 17.9\ m^3/day$ ✓

TOTAL INFLOW $= 17.9 \times 2 = 35.8\ m^3/day$ ✓

OR: INFLOW $= 0.41 \times 0.0118 \times 655 \times 3.4$

$= 10.77\ m^3/day$

TOTAL INFLOW $= 10.77 \times 2 = 21.5\ m^3/day$

DURING OPERATIONAL PERIOD.

DRAWDOWN REQUIRED — 2.4m

$\therefore L_o = \sqrt{\frac{12 \times 1.15 \times 730 \times 2.4}{0.1}}$ OR $L_o = \sqrt{\frac{12 \times 0.41 \times 730 \times 2.4}{0.1}}$

$= \sqrt{241776}$ $= \sqrt{86198.4}$

$= 492m$ $= 293m$

$\therefore i = 2.4/492$ $i = 2.4/293$

$= 0.0049$ $= 0.0082$

INFLOW TO CUTTING $Q = KiA$

$\therefore Q = 1.15 \times 0.0049 \times 655 \times 2.4$

$= 8.86\ m^3/day$

TOTAL FLOW $= 8.86 \times 2 = 17.72\ m^3/day$

OR

$Q = 0.41 \times 0.0082 \times 655 \times 2.4$

$= 5.3\ m^3/day$

TOTAL FLOW $= 5.3 \times 2 = 10.5\ m^3/day.$