APPENDIX D1: BRIDPORT SAND INFLOW – DUPUIT EQUATION

Objective: Quantify the potential inflow from the Bridport Sand into the underlying Inferior Oolite.

Approach: Using an analytical tool to quantify inflow – the Dupuit Equation.

Restrictions: The Dupuit Equation has a number of assumptions which are not fully met, therefore caution must be exercised in using the result. However, the result should allow a 'ball park' value to be obtained.

Equations: The equation has been taken from Fetter (2001). *Applied Hydrogeology*. Fourth Edition.

The discharge per unit width, q'_x, at any section x distance from ther origin is given by:

$$q'_x = \frac{K(h_1^2 - h_2^2)}{2L} - w(L/2 - x)$$

Where:

q'_x is the flow per unit width at x (m^2/d)

x is the distance from the origin (m)

K is the hydraulic conductivity (m/d)

h_1 is the head at the origin (m)

h_2 is the head at L (m)

L is the distance from the origin at the point where h_2 is measured (m)

w is the recharge rate (m/d)

The other equation, which is shown on the attached figure (35), is used to calculate the maximum elevation (h_{max}) of the water table at the divide.

Groundwater Inflow:

The Dupuit Equation has been applied to the Bridport Sand/Inferior Oolite (BS/IO) cross-section as shown on Figure 35. The equation has been used to:

- Locate the groundwater divide (d)
- Calculate the maximum head at the groundwater divide (h_{max})
- Calculate the discharge per unit length into the Inferior Oolite.

Infiltration: The average recharge is 364 mm/annum. Approximately 2/3 of the BS/IO is overlain by the Lower Fullers Earth, hence the infiltration rate has been reduced by 2/3 to 121 mm/annum (0.0004046 m/d).

Results: The q, d and h_{max} values for a range of K values have been calculated and are shown on the attached excel sheet.

Prepared by: [signature]　　**Approved by:** S. Colebrook

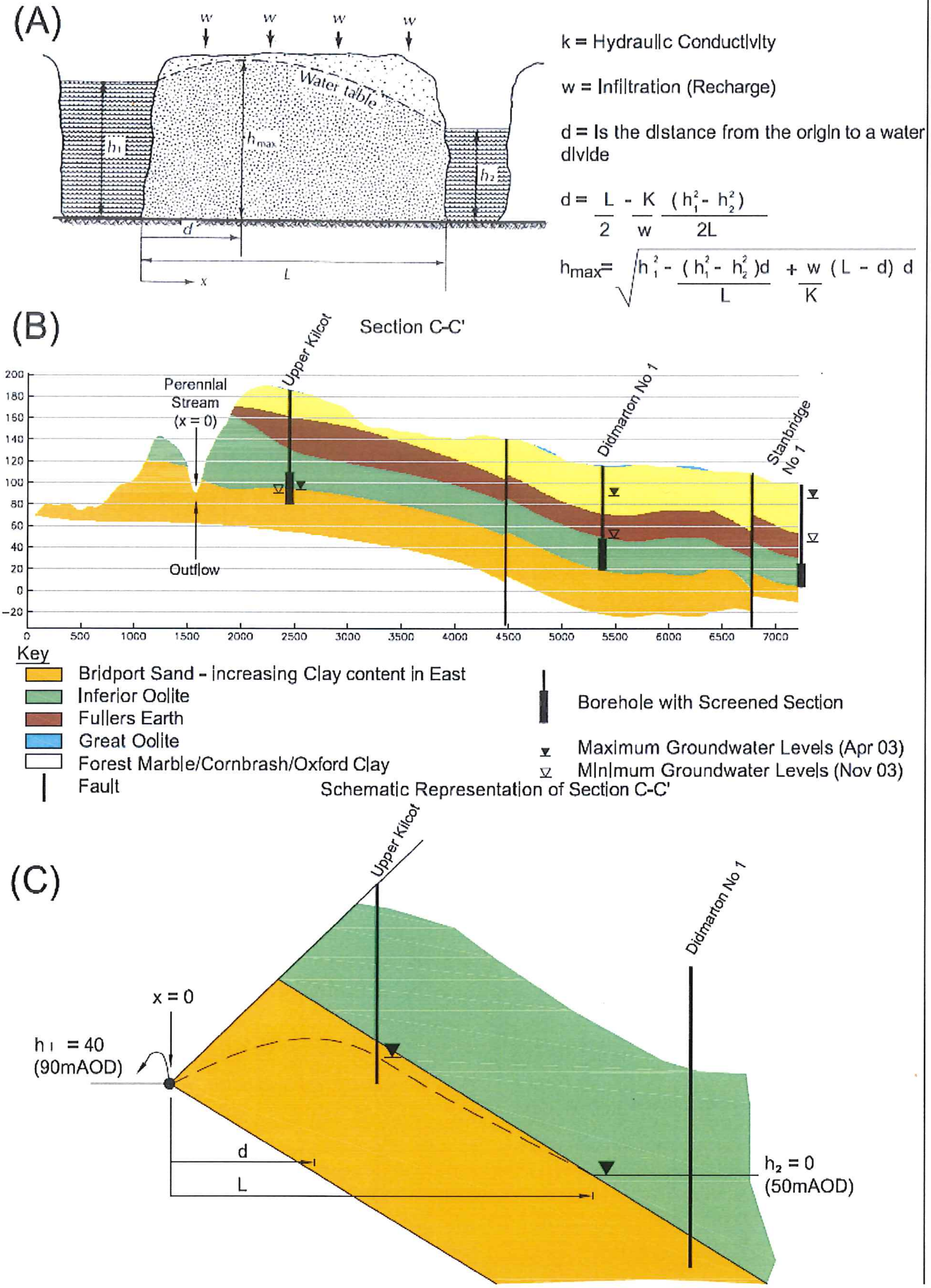


Figure 35 Bridport Sand inflow: Analytical investigation

Estimating Bridport Sand Inflow to the Inferior Oolite Using Dupuit's Equation

Inputs												
K (m/d)	10	2	1.25	1	0.8	0.6	0.5	0.4	0.25	0.1	0.05	m/d
h1 (m)	40	40	40	40	40	40	40	40	40	40	40	m
h2 (m)	0	0	0	0	0	0	0	0	0	0	0	m
L (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	m
w (m/d)	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	0.000332	m/d
x (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	m
Outputs												
q - inflow to IO	3.164	1.031	0.831	0.764	0.711	0.657	0.631	0.604	0.564	0.524	0.511	m3/d/m
	3.16	1.03	0.83	0.76	0.71	0.66	0.63	0.60	0.56	0.52	0.51	ML/d/km
d (m)	-6544	-109	494	696	856	1017	1098	1178	1299	1420	1460	m
hmax (m)	54.95	40.02	**40.80**	**41.96**	**43.63**	**46.60**	**48.98**	52.45	61.94	91.00	125.41	mAOD
Hmax > h1	14.95	0.02	**0.80**	**1.96**	**3.63**	**6.60**	**8.98**	12.45	21.94	51.00	85.41	m

Where

K	Hydraulic conductivity of Bridport Sand
h1	Water level at Bridport Sand Springs
h2	Water level in Inferior Oolite
L	Distance from Spring outflow to Inferior Oolite water table
w	Infiltration 121mm/a Annual Average 364mm, but only one third of area receives recharge so input figure reduced by a third
x	Distance from Spring (origin)
d	Distance from spring (origin) to the groundwater divide
hmax	head at groundwater divide

APPENDIX D2: DIFFUSE LEAKAGE THROUGH THE LOWER FULLERS EARTH

Objective: Determine the potential diffuse leakage through the Lower Fullers Earth into the Inferior Oolite.

Approach: Using Darcy's Law to calculate throughflow.

Undertake calculation using data from November 2003 when the gradient was into the Inferior Oolite, giving maximum head gradients.

$$Q = KiA$$

Where:

- Q is flow through the aquifer (m^3/d
- K is the hydraulic conductivity (m/d)
- i is the hydraulic gradient (m)
- A is the cross sectional area (m^2)

Procedure:

- Contour the Inferior Oolite water table in November 2003
- Contour the Great Oolite water table in November 2003
- Overlie the contour plots and plot the head difference between the aquifers
- Contour the head diffences at 5 m intervals
- Calculate the area between each contour interval with the component boundary (see Figure attached)
- Calculate flow through the Lower Fullers Earth

Results: A range of K values were applied and to calculate the hydraulic gradient the Lower Fullers Earth is assumed to have thickness of 20 m. The results are shown on the attached excel spreadsheet

Prepared by: **Approved by:**

A	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
1	22536275	1.00E-06	8.64E-02	52.5	20	2.625	5111227	5111.227
	22536275	1.00E-07	8.64E-03	52.5	20	2.625	511122.7	511.1227
	22536275	1.00E-08	8.64E-04	52.5	20	2.625	51112.27	51.11227
	22536275	1.00E-09	8.64E-05	52.5	20	2.625	5111.227	5.111227
	22536275	1.00E-10	8.64E-06	52.5	20	2.625	511.1227	0.511123
	22536275	1.00E-11	8.64E-07	52.5	20	2.625	51.11227	0.051112

Total	k m/s	ML/d
	1.00E-06	18205.4
	1.00E-07	1820.5
	1.00E-08	182.1
	1.00E-09	18.2
	1.00E-10	1.8
	1.00E-11	0.2

B	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	23158333	1.00E-06	8.64E-02	45	20	2.25	4501980	4501.98
	23158333	1.00E-07	8.64E-03	45	20	2.25	450198	450.198
	23158333	1.00E-08	8.64E-04	45	20	2.25	45019.8	45.0198
	23158333	1.00E-09	8.64E-05	45	20	2.25	4501.98	4.50198
	23158333	1.00E-10	8.64E-06	45	20	2.25	450.198	0.450198
	23158333	1.00E-11	8.64E-07	45	20	2.25	45.0198	0.04502

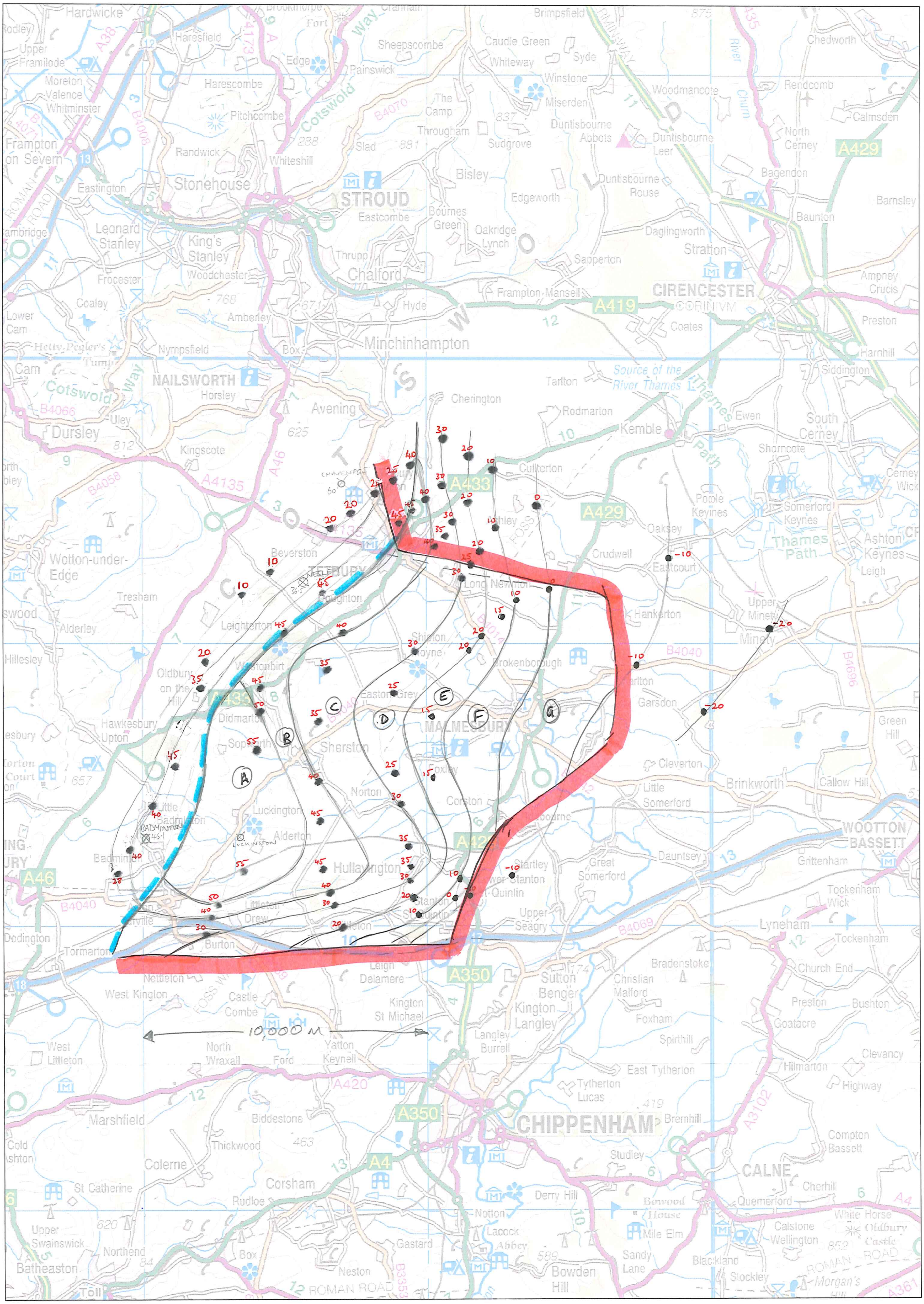
C	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	34740544	1.00E-06	8.64E-02	35	20	1.75	5252770	5252.77
	34740544	1.00E-07	8.64E-03	35	20	1.75	525277	525.277
	34740544	1.00E-08	8.64E-04	35	20	1.75	52527.7	52.5277
	34740544	1.00E-09	8.64E-05	35	20	1.75	5252.77	5.25277
	34740544	1.00E-10	8.64E-06	35	20	1.75	525.277	0.525277
	34740544	1.00E-11	8.64E-07	35	20	1.75	52.5277	0.052528

D	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	22648114	1.00E-06	8.64E-02	25	20	1.25	2445996	2445.996
	22648114	1.00E-07	8.64E-03	25	20	1.25	244599.6	244.5996
	22648114	1.00E-08	8.64E-04	25	20	1.25	24459.96	24.45996
	22648114	1.00E-09	8.64E-05	25	20	1.25	2445.996	2.445996
	22648114	1.00E-10	8.64E-06	25	20	1.25	244.5996	0.2446
	22648114	1.00E-11	8.64E-07	25	20	1.25	24.45996	0.02446

E	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	16519416	1.00E-06	8.64E-02	15	20	0.75	1070458	1070.458
	16519416	1.00E-07	8.64E-03	15	20	0.75	107045.8	107.0458
	16519416	1.00E-08	8.64E-04	15	20	0.75	10704.58	10.70458
	16519416	1.00E-09	8.64E-05	15	20	0.75	1070.458	1.070458
	16519416	1.00E-10	8.64E-06	15	20	0.75	107.0458	0.107046
	16519416	1.00E-11	8.64E-07	15	20	0.75	10.70458	0.010705

F	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	16659460	1.00E-06	8.64E-02	5	20	0.25	359844.3	359.8443
	16659460	1.00E-07	8.64E-03	5	20	0.25	35984.43	35.98443
	16659460	1.00E-08	8.64E-04	5	20	0.25	3598.443	3.598443
	16659460	1.00E-09	8.64E-05	5	20	0.25	359.8443	0.359844
	16659460	1.00E-10	8.64E-06	5	20	0.25	35.98443	0.035984
	16659460	1.00E-11	8.64E-07	5	20	0.25	3.598443	0.003598

G	Area (m2)	k m/s	k (m/d)	dh	dl	Gradient	Q (m3/d)	Q ML/d
	24856657	1.00E-06	8.64E-02	-5	20	-0.25	-536904	-536.904
	24856657	1.00E-07	8.64E-03	-5	20	-0.25	-53690.4	-53.6904
	24856657	1.00E-08	8.64E-04	-5	20	-0.25	-5369.04	-5.36904
	24856657	1.00E-09	8.64E-05	-5	20	-0.25	-536.904	-0.5369
	24856657	1.00E-10	8.64E-06	-5	20	-0.25	-53.6904	-0.05369
	24856657	1.00E-11	8.64E-07	-5	20	-0.25	-5.36904	-0.00537



Marcus Hodges Environment Limited Consulting Hydrogeologists and Environmental Engineers www.mhe.co.uk	Drawn: Drafted: Checked By: Date:	Scale: 1:125,000 Ref:	Drawn:	Drg Title:: HEAD DIFFERENCES BETWEEN THE GREAT AND INFERIOR OOLITE (NOVEMBER 2003)

APPENDIX D3: STORAGE RELEASE FROM THE INFERIOR OOLITE

Objective: Determine the potential unit release of water from the Inferior Oolite.

Approach: Water Balance.

Results: During the 2003 pumping trial towards the end of October steady state conditions occurred in the Inferior Oolite aquifer following a number of abstraction rate reductions.

Prior to steady state conditions being achieved the Inferior Oolite water levels were declining at a rate of 0.22 m/d.

Steady state was achieved when abstraction rates were reduced by 5 Ml/d.

It is assumed that the under steady state conditions no release of water from the Inferior Oolite is occurring; prior to steady state conditions 5 Ml/d was being released for a 0.22 m/d drop in water level.

Determining Specific Yield (S_y):

If the area over which the decline in Inferior Oolite water levels occurs is known then the S_y of the Inferior Oolite can be calculated.

The subcrop area of the Inferior Oolite has been calculated using information from cross sections (A to D on Figure 3.1) and the compartment boundary (Figure 4.1).

The Inferior Oolite sub crop water table area is shown on the attached figure.

Width 1: 3.85 km
Width 2: 0.80 km
Width 3: 1.80 km
Width 4: 3.20 km

Extrapolating between cross section lines and compartment boundaries the Inferior Oolite water table area is calculated to be approximately 46 km^2.

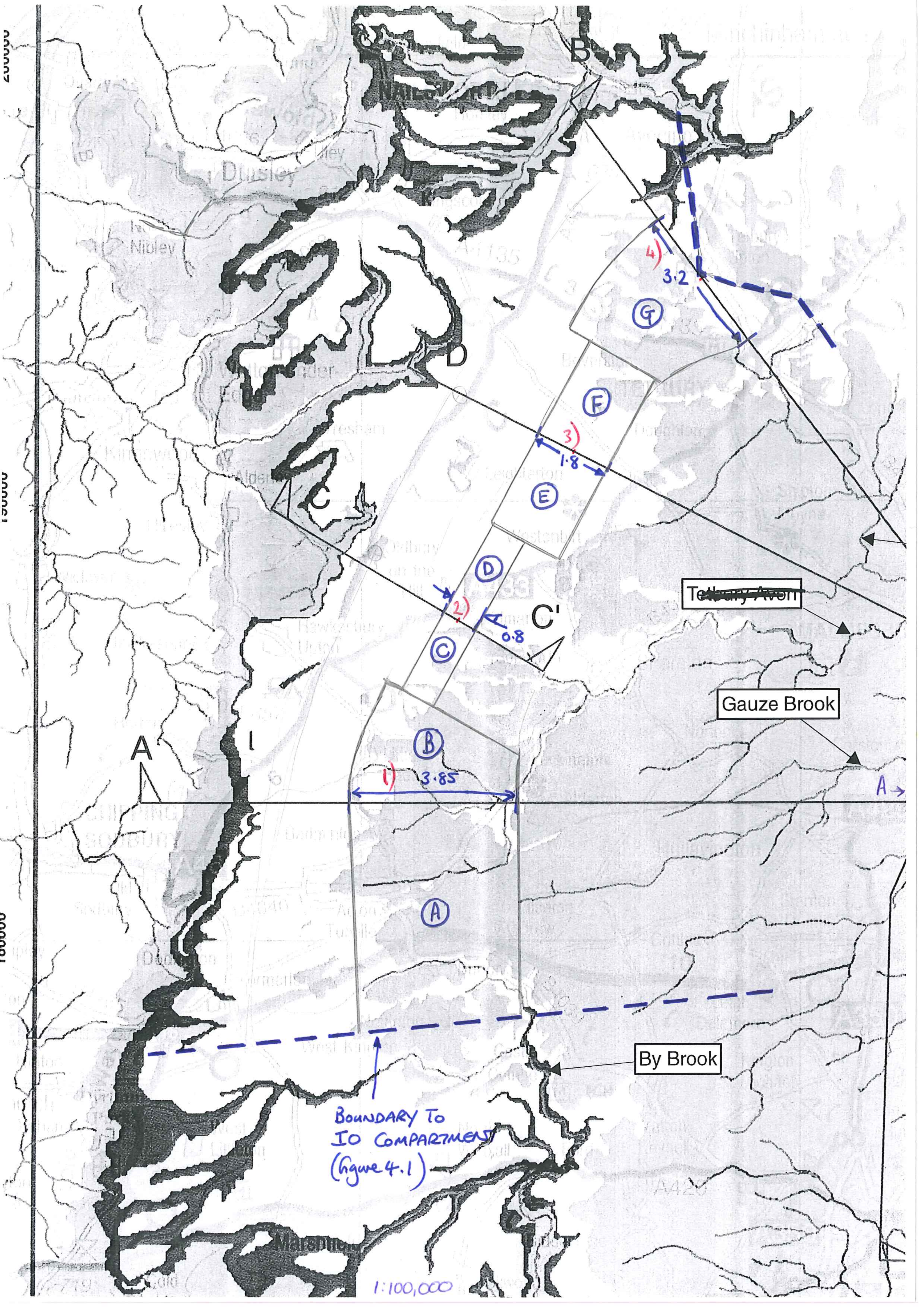
Area x height = Volume

Therefore: 46 km^2 x 0.22 m = 10120000 m^3
= 10120 Ml

But this volume represents only 5 Ml of water which gives a S_y value of 0.00049 (0.05%).

Prepared by:

Approved by: S. Colebrook

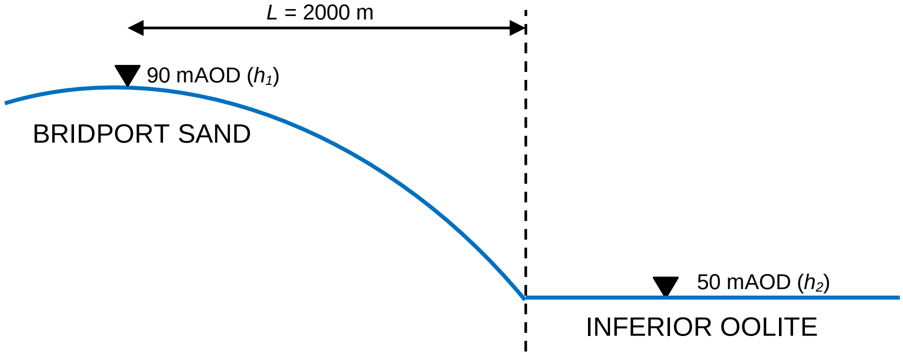


B
D
C
C'
A
A→
G
F
E
D
C
B
A
1) 3.85
2) 0.8
3) 1.8
4) 3.2
Tetbury Avon
Gauze Brook
By Brook
Dursley
Nibley
A420
BOUNDARY TO IO COMPARTMENT (figure 4.1)
1:100,000

APPENDIX D4: **BRIDPORT SAND RATE OF INFLOW TO INFERIOR OOLITE**

Objective: Determining the rate of inflow from the Bridport Sand to the Inferior Oolite.

Approach: Unconfined Aquifer – use Dupuit Equation.



$$q' = \frac{K(h_1^2 - h_2^2)}{2L}$$

Where:

q'	is inflow (m^3/d/m)
K	is (Bridport Sand) hydraulic conductivity (m/d)
h_1	is water level at groundwater divide (m)
h_2	is water level at adjoining Inferior oolite (m)
L	is distance from groundwater divide to Inferior oolite (m)

Results: The results for various hydraulic conductivity values are shown on the excel sheet attached and assume that the subcrop length of active aquifer is 18 km.

Prepared by: **Approved by:** S. Colebrook

Bridport Sand Inflow into Inferior Oolite

K	2.5	1.5	1.25	1	0.8	0.6	0.4	0.12	m/d
h1	90	90	90	90	90	90	90	90	m
h2	50	50	50	50	50	50	50	50	m
L	2000	2000	2000	2000	2000	2000	2000	2000	m

q'	**3.5**	**2.1**	**1.75**	**1.4**	**1.12**	**0.84**	**0.56**	**0.168**	**m3/d/m**
q'	**63**	**37.8**	**31.5**	**25.2**	**20.16**	**15.12**	**10.08**	**3.024**	**Ml/d**

Width 18 km

Where

K	Hydraulic conductivity
h1	estimated head a brdiport Sand divide
h2	Water level in Bridport Sand adjacent to Inferior Oolite
L	Distance from groundwater divide to Inferior Oolite

Source: K:\52205\Data\Malms\Calculations\Bridport Sand inflow.xls

APPENDIX D5: STORAGE RELEASE FROM BRIDPORT SAND

Objective: Determine the water level drop in the Bridport Sand for a given release of water.

Inputs: *Water to be released*:

32 Ml/d for 100 days (3200 Ml).

This has been designed to simulate the Bridport Sands providing the majority of the water abstracted for stream support in 2003

Bridport Sand Area:

Within the boundary of the Inferior Oolite compartment used for stream support (Figure 4.1), the Bridport Sand subcrop length is 18 km. The width is estimated to be 2 km. This gives a Bridport Sand area of 36 km^2

Results: Assuming various storage values for the Bridport Sand the release of water per m decline in water level can be calculated:

Storage (S_y)	Release per m decline in water level (Ml)
10	3600
15	5400
20	7200
25	9000
28	10080

A release of 3200 Ml would cause a water level decline of between 0.32 m (Sy = 28%) to 0.89 m (Sy = 10%).

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