UNIVERSITY OF PRETORIA
DEPARTMENT OF GEOLOGY
GLY 265 – GROUNDWATER

13 August 2010 Test 1

DURATION: 50 minutes **MARKS:** 50

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MODERATOR/S: Prof J. L. van Rooy

Instructions: Complete Section A and Section B in full. Write legibly, keep answers concise and show all steps where calculations are involved. Good luck!

Formulas:

Cooper-Jacob: $s = \frac{2.3Q}{4\pi T}\log\left(\frac{2.25Tt}{r^2 S}\right)$ For $t_2/t_1 = 10$ $T = \frac{2.3Q}{4\pi\Delta s}$ $S = 2.25T\frac{t_0}{r^2}$

Dupuit-Thiem: $T = \frac{Q}{2\pi(\Delta s)}\ln\frac{r_2}{r_1}$ For $r_2/r_1 = 10$ $T = \frac{2.3Q}{2\pi(\Delta s)}$ $s = \frac{Q}{2\pi T}\ln\frac{R}{r}$

Radial converging flow: $\ln\frac{x^2 - r^2}{x_0^2 - r^2} = \frac{R \cdot t}{D \cdot n_{eff}}$

Hazen-Zischang: $K = C \cdot d_{10}^2 \frac{0.79 + 0.03 \cdot T}{86.4}$

Material	C_U	Valid for d_{10}	C
Sand, sand with gravel	1 – 3	0.1 – 0.6 mm	0.0139
Sand, sand with gravel	3 – 10	0.1 – 0.6 mm	0.0116
Sandy loam	< 5	0.1 – 0.6 mm	0.0093
Sandy clay loam	< 5	0.08 – 0.6 mm	0.0070
Clay loam, sandy clay	< 5	0.06 – 0.6 mm	0.0046

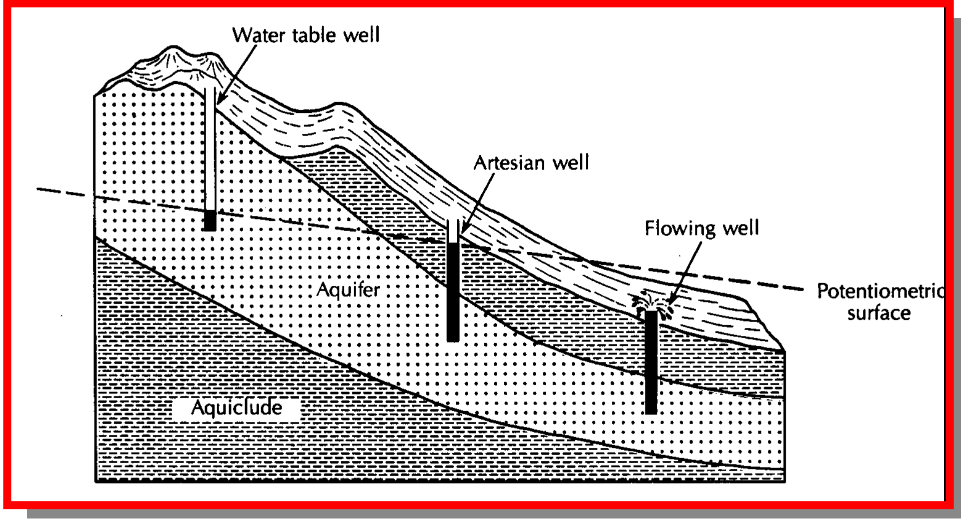
SECTION A – THEORY ***[20]***

Complete **<u>all the questions</u>** from Section A.

1. Precipitation reaching the surface can flow as surface runoff or infiltrate into the subsurface. Briefly outline the processes which can occur when water infiltrates. [4]
   - ➔ **Infiltration to interflow; interflow to springs and runoff, or percolation to recharge; recharge into aquifer and baseflow**

2. Define hydraulic head. Specifically refer to the terms involved in Bernoulli's equation. [4]
   - ➔ **Water rises in piezometer proportional to the total fluid energy at the point at which the bottom of the piezometer is open**
   - ➔ **Total mechanical weight per unit weight of water**
   - ➔ $h = \frac{v^2}{2g} + z + \frac{P}{\rho g}$ **= velocity head + elevation head + pressure head**

3. Schematically distinguish between confined and unconfined aquifers. [4]



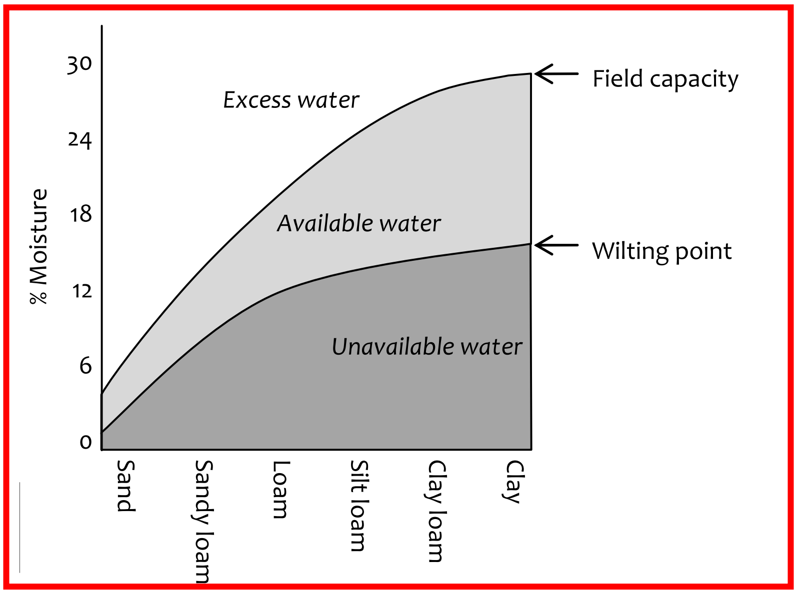
4. Define the following concepts so that the differences between them are clear:

   a. Wilting point [2]
   - ➔ **Volume water content below which plants are unable to withdraw soil water**

   b. Field capacity [2]
   - ➔ **Maximum amount of water that the unsaturated zone of a soil can hold against the pull of gravity**

   c. Saturation [2]
   - ➔ $S = \frac{V_{water}}{\underbrace{V_{water} + V_{gas}}_{\text{Volume of pore space}}}$

   d. Porosity [2]
   - ➔ **n = Vv / Vt**


% Moisture
30
24
18
12
6
0
Excess water
Available water
Unavailable water
Field capacity
Wilting point
Sand
Sandy loam
Loam
Silt loam
Clay loam
Clay

SECTION B – CALCULATIONS **[30]**

Complete **one question** from Section B. The formula sheet is attached in the Appendix. Remember to hand in the relevant Appendix with your answer book.

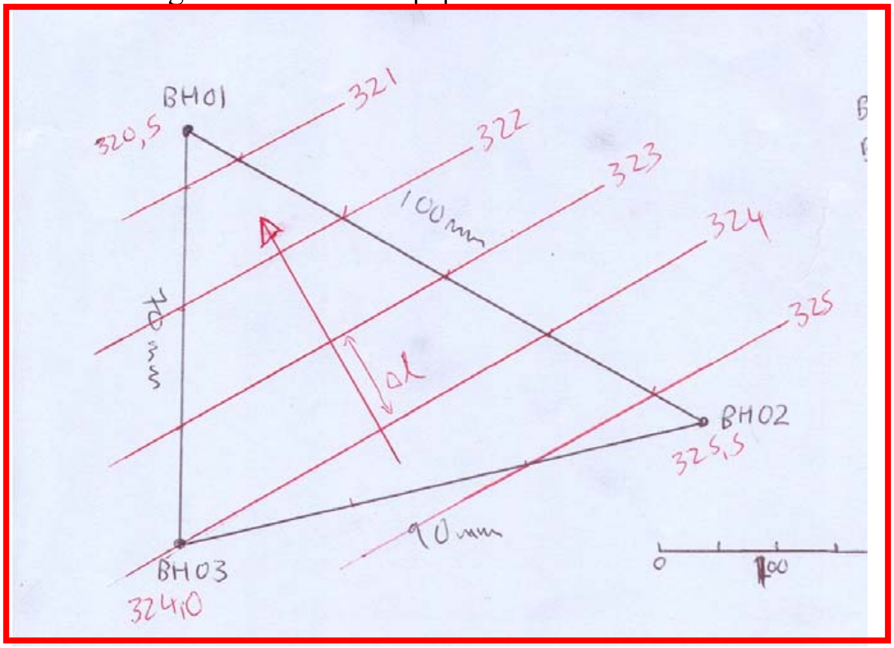
Question 1:

Three boreholes and a factory are indicated according to the scale supplied. The water levels above mean sea level as measured in the three boreholes were 320.50m (BH01), 325.50m (BH02) and 324.00m (BH03) respectively). The following additional information is available:

- Viscosity = 1.10 x 10^{-3} N/s.m^2
- Density of water = 1 kg/ℓ
- Gravitational acceleration = 9.81 m/s^2
- Effective porosity = 22%
- Water temperature = 15°C
- Particle size distribution
- Aquifer thickness = 25m
- Recharge = 300mm
- Extent of the influence of BH01 = 4 km

For the data supplied:

1. Construct the 321m, 322m, 323m, 324m and 325m water table contours and indicate the direction of groundwater flow. [5]



2. Calculate the discharge per day for a 100m wide cross-section perpendicular to the isopietic lines. [8]

Gradient = i = dh / dl = (1m drop in contour) / (17mm x 100m/20mm) = 0.01176	**[1]**
Area = A = 100m x 25m = 2 500m^2	**[1]**
Hydraulic conductivity = K → grading acc. Hazen-Zischang **C_U = d_{60} / d_{10} = 1.0mm / 0.3mm = 3.33 > 3 → C = 0.0116**	**[3]**

$K = C \cdot d_{10}^2 \frac{0.79+0.03 \cdot T}{86.4} = (0.0116)(0.3)^2 \frac{0.79+0.03(15)}{86.4} = 1.5 \times 10^{-5} m/s =$ **1.296 m/d**	
Q = KiA = (1.5 x 10^{-5} m/s)(0.01176)(2500m^2) = 4.405 m^3/s = 38 m^3/d	**[3]**

3. Calculate the specific discharge and average linear velocity (all units in metres and days, where applicable). [4]

q = Q / A = (38 m^3/d) / (2500m^2) =1.5 x 10^{-2} m/d	**[2]**
v = q / n = (1.5 x 10^{-2} m/d) / 0.22 = 6.9 x 10^{-2} m/d	**[2]**

4. Calculate the intrinsic permeability and transmissivity (all units in metres and days, where applicable). [4]

$k = \frac{K\mu}{\rho g} = \frac{(1.5\text{x}10\text{-}5\,m/s)(0.001 N/s.m^2)}{(1000 kg/m^3)(9.81 m/s^2)} = 1.529\text{x}10^{-12} m^2$	**[2]**
T = Kb = (1.296 m/d) (25m) = 32.375 m^2/d	**[2]**

5. Borehole BH01 is being observed with regards to a non-reactive solute being released from the factory indicated. Calculate the travel time of this solute. [3]

$\ln \frac{x^2 - r^2}{x_o^2 - r^2} = \frac{R \cdot t}{D \cdot n_{eff}}$ $\ln \frac{(0km)^2 - (4km)^2}{(0.5km)^2 - (4km)^2} = \frac{(0.3m) \cdot t}{(25m) \cdot (0.22)}$ $t = 0.28 years = 102 days$	**[3]**

6. Complete the above calculation but assuming a porosity of 47%. Explain the deviation in the answer from the answer in Question 5. [6]

$\ln \frac{x^2 - r^2}{x_o^2 - r^2} = \frac{R \cdot t}{D \cdot n_{eff}}$ $\ln \frac{(0km)^2 - (4km)^2}{(0.5km)^2 - (4km)^2} = \frac{(0.3m) \cdot t}{(25m) \cdot (0.47)}$ $t = 0.62 years = 225 days$	**[3]**
Reason – Continuity. Moreporosity = larger cross-sectional flow area, therefore flux decreases according to continuity (A' becomes A.n)	**[3]**

Question 2:

A dam is indicated by the dotted line and rainfall data is supplied for five rain gauges P01 (765mm), P02 (749mm), P03 (702mm), P04 (731mm) and P05 (692mm). The following additional information is available for the catchment indicated on the diagram:

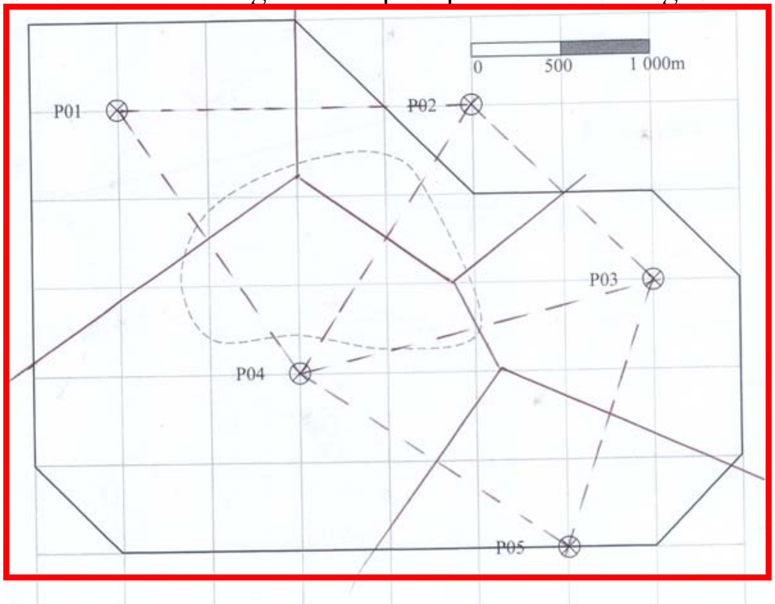
- Viscosity = 1.10 x 10^{-3} N/s.m^2
- Density of water = 1 kg/ℓ
- Gravitational acceleration = 9.81 m/s^2
- Porosity = 22%
- Water temperature = 15°C
- Recharge = 2.5% of MAP
- Stream inlet = 60% of stream outlet
- Stream outlet = 2.6 x 10^5 m^3/a
- Evapotranspiration = 500mm

For the data supplied:

1. Calculate the arithmetic average precipitation per year. [2]

P = (P1 + P2 + P3 + P4 + P5) / 5 = 727.8mm

2. Calculate the average annual precipitation according to the Thiessen method. [7]



→ [3]

	P	Blocks	Wi	Pi
P01	**765 mm**	**8.50**	**0.222**	**169.8**
P02	**749 mm**	**3.25**	**0.085**	**63.7**
P03	**702 mm**	**6.50**	**0.170**	**119.3**
P04	**731 mm**	**15.00**	**0.392**	**286.6**
P05	**692 mm**	**5.00**	**0.131**	**90.7**
		TOT= 38.25	**1.000**	**730.1**

Average Precipitation = 730.1mm **→ [4]**

3. Calculate the precipitation volume (m^3/y) and precipitation yield (ℓ/km^{2}s). [5]

VP = 730.1mm/a = 0.731m/a **[2]**
(0.731m/a)(38.25 blocks x 500m long x 500m wide) = 6.990 x 10^6 m^3/a

QP = (6.990 x 10^6 m^3/a)(1000ℓ/m^3) / (38.25x0.5km x0.5km)(24x60x60x365 s/a) **= 23.3 ℓ/km^2.s**	**[3]**

4. Formulate the water budget and determine the surplus or deficit water in the system. How can this water possibly be accounted for? [6]

IN – OUT = dV/dt **(Prec + ROin) – (ET + ROout + Rech) = dV/dt in dam** **[(6.990 x 10^6 m^3/a) + (1.560 x 10^5 m^3/a)] – [(0.5m x area 9.56 x 10^6 m^2) + (2.6 x 10^5 m^3/a) + (2.5% x 6.990 x 10^6 m^3/a)]** **dV/dt = [(6.990 x 10^6 m^3/a) + (1.560 x 10^5 m^3/a)] – [(4.78 x 10^6 m^2) + (2.6 x 10^5 m^3/a) + (1.748 x 10^5 m^3/a)] = 1.931 x 10^6 m^3/a**	**[4]**
Abstraction unaccounted for? Interflow?	**[2]**

5. What will the influence of a farmer pumping 10ℓ/s from a borehole be on the water budget? And if an additional 100ℓ/s volume of water is pumped from the dam (indicated by the dotted line) to supply water to a local community? [3]

Qfarm = 10 ℓ/s = 3.15 x 10^5 m^3/a > recharge!	**[1]**
Qdam = 100 ℓ/s = 3.15 x 10^6 m^3/a > runoff stream inlet!	**[1]**
Both unsustainable	**[1]**

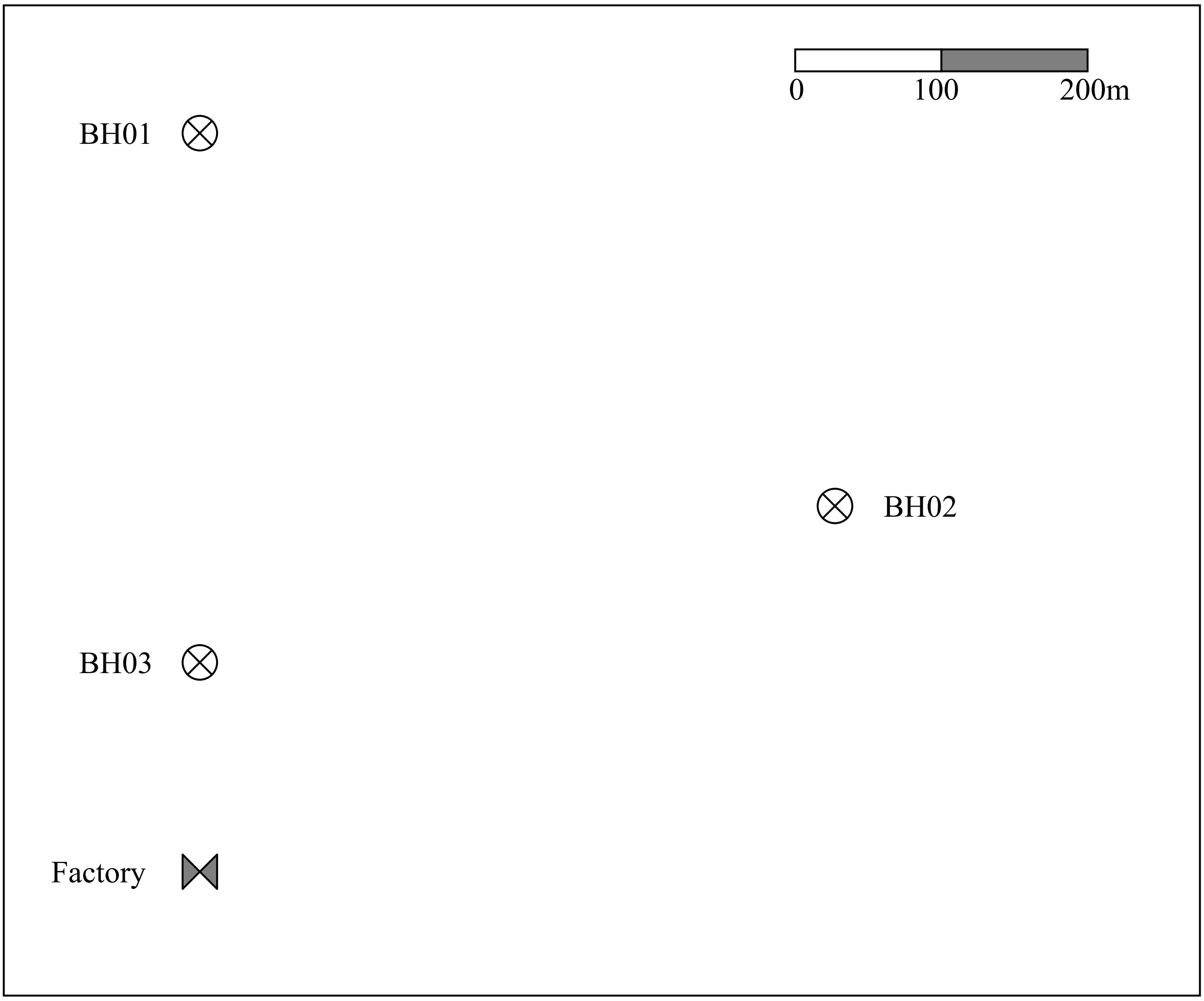
6. Assume the aquifer is 25m thick with a transmissivity of 1.25 x 10^{-2} m^2/d and a hydraulic gradient of 0.0025. Calculate the hydraulic conductivity, specific discharge, linear velocity and intrinsic permeability. [7]

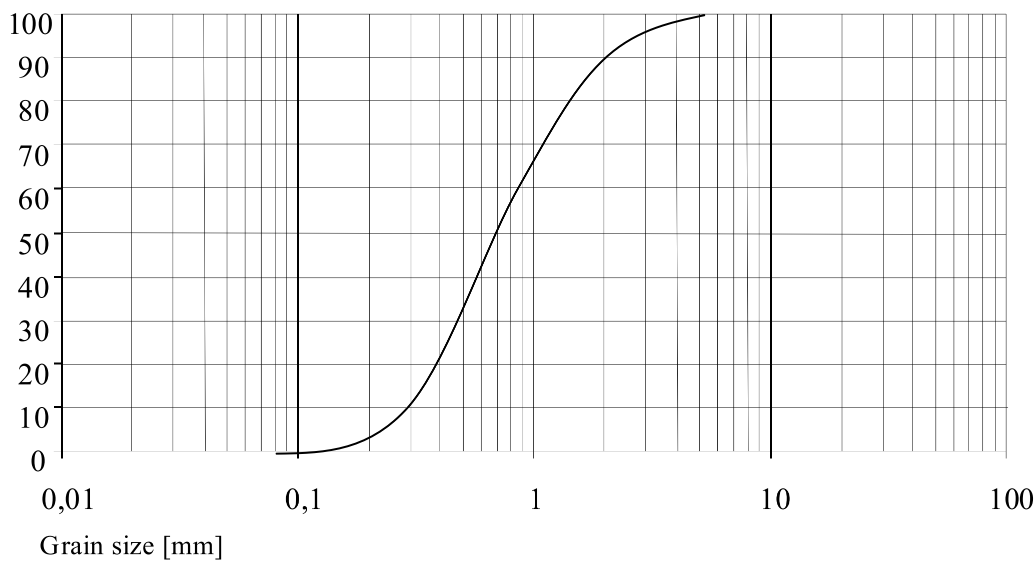
K	**[1]**
q	**[2]**
V	**[2]**
k	**[2]**

[50]

Name	Student Number	GLY 265 Test 1 (UP 2010)

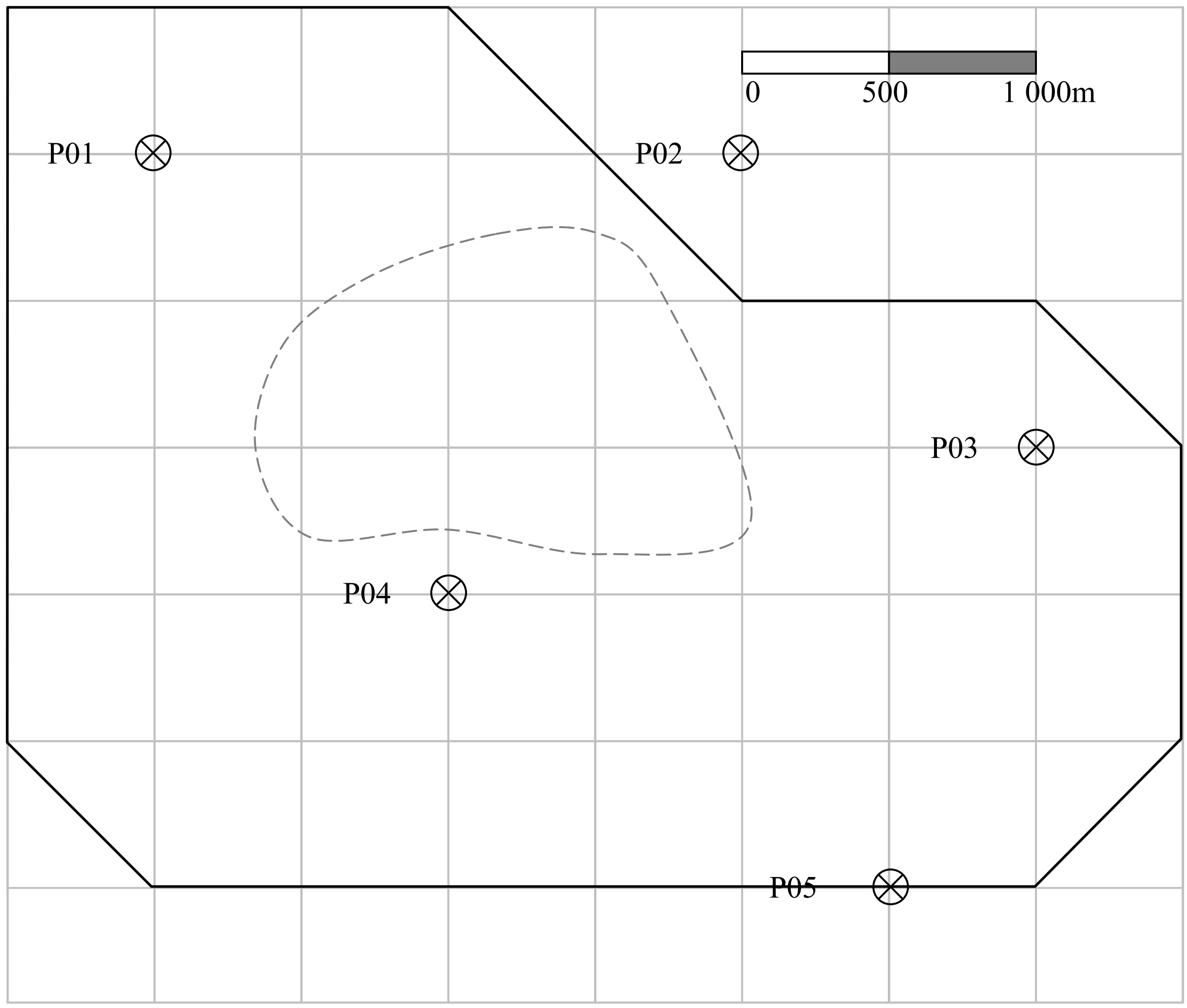
APPENDIX – SECTION B QUESTION 1 (TO BE HANDED IN)





Surname Initials	Student Number	GLY 265 Test 1 (UP 2010)

APPENDIX – SECTION B QUESTION 2 (TO BE HANDED IN)



	P				
P01	765				
P02	749				
P03	702				
P04	731				
P05	692				