UNIVERSITY OF VICTORIA
FINAL EXAM
April 2020

Last Name: ____	
First Name: ____	
STUDENT NUMBER: V00__________________	

Course Name & Number	**GEOG 370 – Hydrology**
Section(s)	**A01**
CRN:	**21684**
Instructor:	**Matthew Asplin**
Duration:	**Due: 11:59pm April 9th, 2020**

This exam has a total of 18 pages including this cover page.

Students must count the number of pages and report any discrepancy immediately to the Instructor.

Exam Instructions

- This exam is worth 45% of your final grade and will be graded out of **80 marks.**
- Type answers directly into the exam file in the space provided, and reformat the exam as needed to keep your answers unbroken. **Remember to fill out the info in the cover page!**
- Please rename your exam file as follows: ***LASTNAME_FIRSTNAME***_*GEOG370_FINAL_EXAM.DOCX*
- This exam is open book, and you may use calculators, attached equation sheet, Excel, etc.
- Please feel free to answer in point form, sentence, or full-paragraph format.
- Please show an example of work for calculations, either in text or the word equation editor.
- Final answers must have units. (*example, either form is acceptable:* m^3 / s ***or*** $m^3\ s^{-1}$)

1. You are standing on some sandy loam soil in a small forested ravine, and you are about 100 metres away from a creek. It's a warm humid day in July with no wind, and a thunderstorm moves in over your location, and it begins to rain *VERY* hard (rates >50mm / hr). Please describe how the rain will work its way through the local hydrological system, and **use the terms listed below in your answer** in the appropriate context to describe your answer. Please consider all aspects of the hydrological cycle (precipitation, surface water, soil water, groundwater, etc.). *10 marks*

   Horton overland flow, Confined aquifer, Hydrograph, Actual Evapotranspiration, Canopy interception

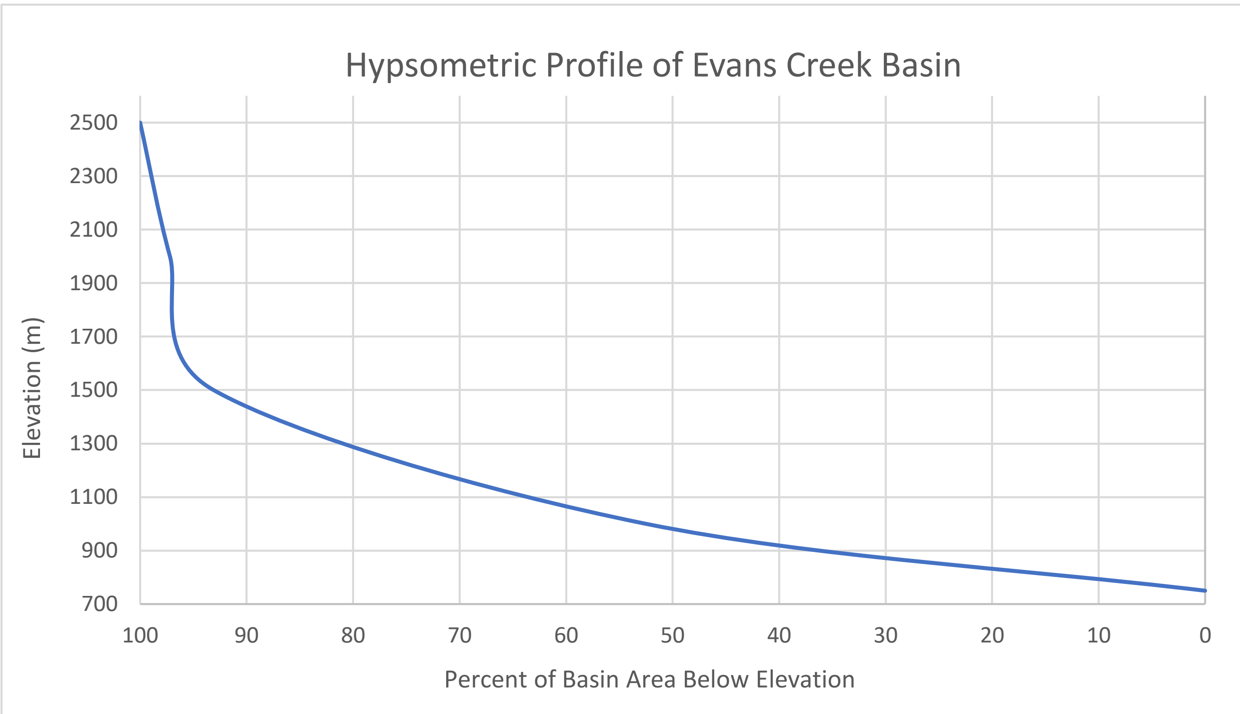
Since the region is forested, there will be a significant amount of canopy interception, but the system will still experience Horton overland flow due to the precipitation rate exceeding the infiltration rate. Sandy loam soil has large pore spaces and so it can accommodate high volumes of water with a high(er) infiltration rate, meaning that the soil is unlikely to become saturated. However, if the system is over a confined aquifer, low surface area available for infiltration will cause the soil to become saturated quicker. Water infiltrating through the soil will fill the capillary spaces first (due to particle adhesion) and, upon saturation, will move through the pore spaces to contribute to the groundwater table, where it will enter the stream through groundwater flow. Water entering the stream through means other than baseflow will cause a rise in the stream's hydrograph which peaks shortly after the thunderstorm passes and precipitation ceases. The hydrograph will remain high (although falling) for a few days until it is once again dominated by baseflow. A few days after precipitation ends, high temperature and available radiation (characteristic of weather in July) combined with high water content throughout the system would cause the actual evapotranspiration rate to equal the potential evapotranspiration rate, as there is both sufficient energy and water available. This may be counteracted by the humidity of the air and the lack of high winds, as accumulation of moist air will lead to a low vapour pressure deficit and evaporation rate. The type of aquifer below the system will also influence evaporation rates, as an area with a confined aquifer will have less surface area capable of sustaining evaporative processes than an area with an unconfined aquifer. In an area with high humidity, no wind, and a confined aquifer, it may take a while for excess water to be evaporated out of the system.

2. Using the below output from an analysis in Watershed Analysis, calculate the total area of the Evans Creek watershed and the necessary inputs in the table below so that you can create a hypsometric profile for the basin. Create a graph with appropriate labels using Excel – (note: save the graph as an image file and insert into your word document). *6 marks*

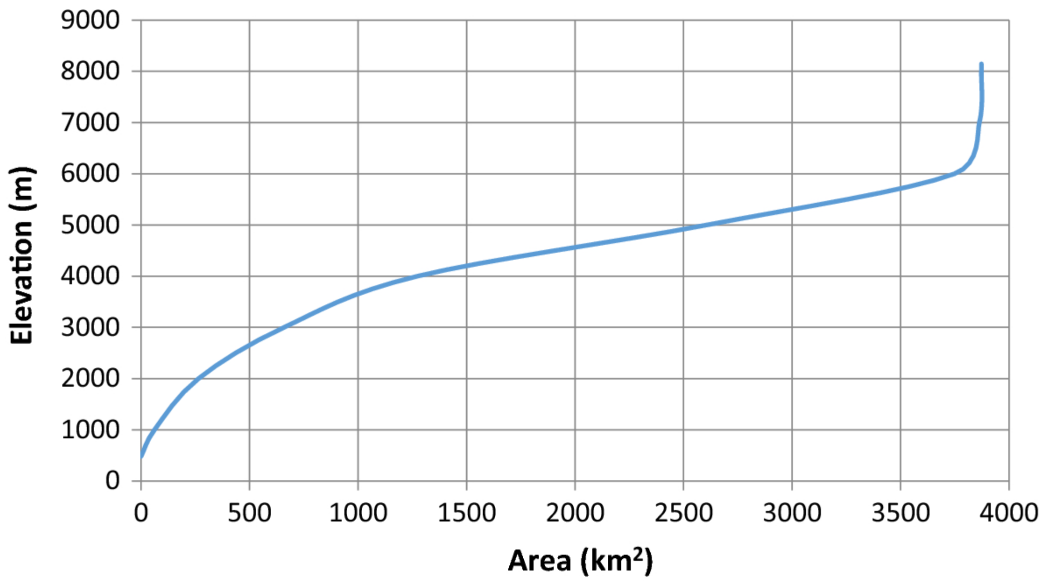
   Output from ArcGIS Watershed analysis for Evans Creek

Elev. (m)	Cell Count	Surface Area (km^2)	Surface Area (%)	Cumulative Surface Area (km^2)
0-750	0	0	0	0
>750-1000	200,400	180.36	52.5	180.36
>1000-1500	155,000	139.5	40.6	319.86
>1500-2000	15,600	14.04	4.1	333.9
>2000-2500	10,900	9.81	2.9	343.71

(*show at least 1 sample calculation – use equation editor if needed*)



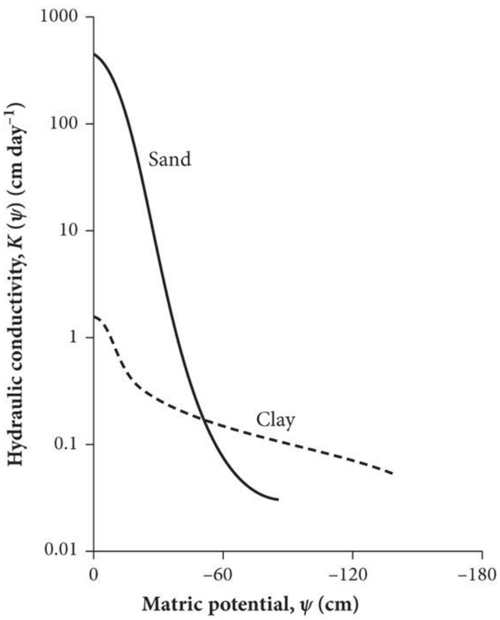
3. Compare the surface area calculations you performed for Evans Creek to the hypsometric profile for Budhigandaki Catchment in Nepal. Which watershed(s) are predominantly snow dominated? Briefly describe why. *2 marks*



The Budhigandaki watershed is snow-dominated since a large portion of its surface area is above what would be considered a snowy, alpine elevation. The large amount of high elevation land in this catchment would receive lots of snow, meaning that there would be large volumes of snow influencing the region's hydrology. In the Evans Creek watershed, the amount of land area above the snowline is much lower, meaning that less snow would be caught and therefore contribute to the watershed's hydrology.

However, this depends on the geography of the area – in some regions, 40.6% of surface area above 1000 m would be a significant amount of land above the snowline, meaning that this basin would be snow-dominated as well.

4. Using the figure below, explain the general relationship between *hydraulic conductivity*, *matric potential* and *soil type*. *3 marks*



When soil is dry, there is a higher matric potential because the capillary forces are working to pull water in towards the soil particles. Matric potential decreases with saturation since the capillary spaces are already filled. Dry sand has a lower matric potential than dry clay, as there is lower total pore volume, and the large pores between the grains have lower adhesive forces than in clay. The hydraulic conductivity of dry clay is greater than dry sand because the pore spaces are smaller and small pores fill with water very quickly due to the high matric potential of the soil particles. Once clay is saturated, the hydraulic conductivity is lower than saturated sand because water does not move as well through small pore spaces.

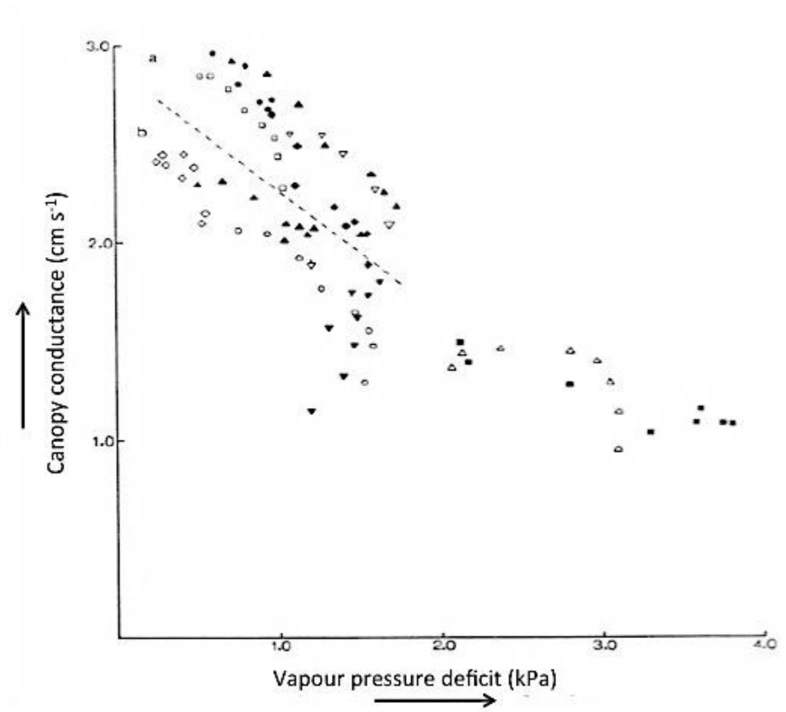
5. Based on our discussion in class and lecture notes, describe how the interaction of winds, vegetation, and topography affects the distribution and morphology of snow on an open prairie surface, versus a coastal forest in a mountainous area with some areas of clearcut logging present (*i.e.*, clearings in the forest)? *5 marks.*

Snow accumulates more in open areas than in vegetated areas as there is no interception by trees. Winds at higher elevations are stronger, so the snow may be subject to turbulent eddies, mechanical fragmentation, and redistribution due to windblow. Since windblown snow is less dense than regular snow (due to snow particles breaking up), snow accumulating at high elevations is less dense than snow in prairie regions. Heavily forested areas experience redistribution of snow from the canopy as well, suggesting that a forested, mountainous landscape would have a shallow, less dense, more variable snow pack. This is due to lower rates of snow accumulation due to interception by trees, fragmentation caused by strong winds at high elevations, and high rates of redistribution from strong winds and significant canopy cover. This also suggests that snow packs in prairie regions are deeper, denser, and more constant than snow packs at higher elevation, as they are less vulnerable to strong winds and do not experience significant interception or fragmentation.

6. A freak March snowstorm drops 80 cm of snow at the Victoria airport. Measurements from a snow pit at the site identified that this snowpack has an average density of 200 kg m^{-3}. What is the snow water equivalence (in mm) for this precipitation event? *Assume that water density is 1000 kg m^{-3}. 2 marks*

16 cm

7. Use the figure below from the paper by P. Dye, '*Estimating water use by Eucalyptus grandis with the Penman-Monteith equation*,' to answer the following questions.



a. Explain the term *canopy conductance* and its influence on evapotranspiration. *2 marks*

Canopy conductance refers to how well a tree canopy uses water and is expressed as a ratio of daily water use (by the plant) to vapour pressure deficit. Evapotranspiration will be higher in a canopy with a low conductance value because the vapour pressure deficit will be high and water use by the plant will be low; therefore, most water being transported through the plant is being evapotranspired rather than used by the plant.

b. In this case, explain why canopy conductance appears to have an inverse relationship with vapour deficit. *2 marks*

Canopy conductance and vapour pressure deficit have an inverse relationship because water use by the plant decreases as vapour pressure deficit increases. When there is a high vapour pressure deficit, water use in the plant is low since water is being transported quickly through the plant to accommodate the negative pressure at the stomata.

8. A strong warm front is forecast to hit Coastal British Columbia and end an Arctic outflow that has been persisting for weeks in Late February. You are monitoring a river channel in a mountainous part of the coastline, with a surface consisting of coniferous forests and loamy soils at low elevations, and exposed bedrock and thin soils higher in elevation, and a large snowpack is present. Describe the expected storm hydrograph for the river channel and be sure to include key features of the hydrograph in your discussion. *10 marks*

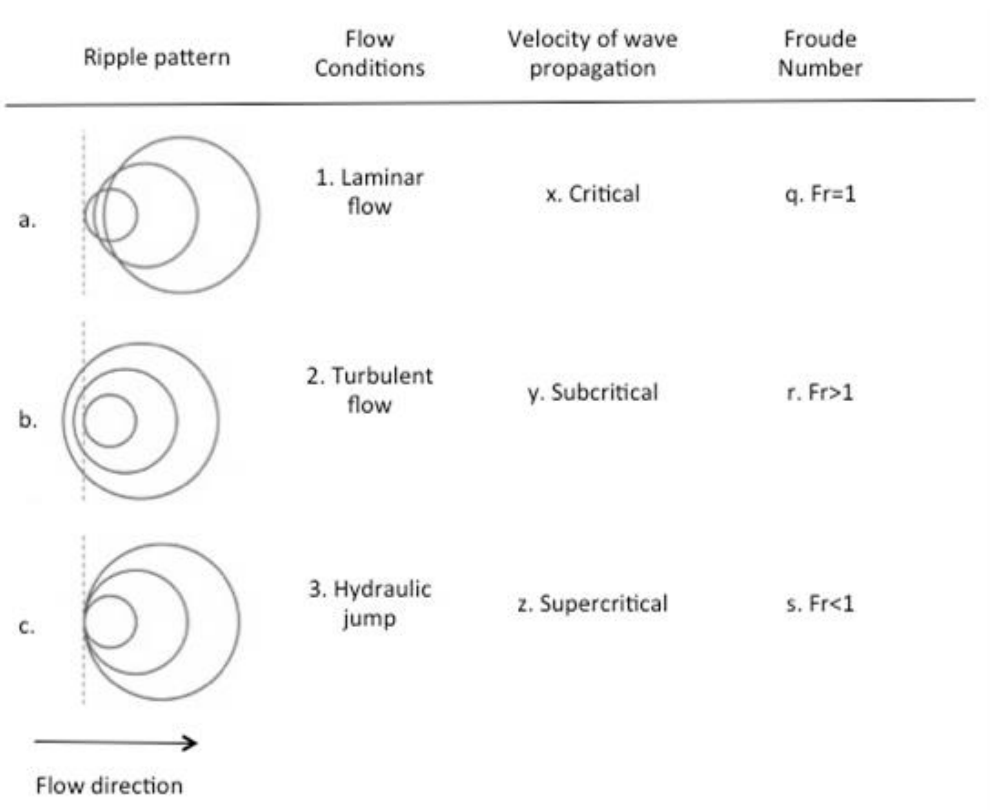
9. Based on our discussion in class, identify and briefly describe two reasons why you might wish to construct infiltration ponds or injection wells to enhance aquifer recharge. *2 marks*

Artificial recharge is useful for water management since some aquifers take 1000s of years to recharge. This can supplement natural groundwater recharge and provide water for essential services such as agriculture, by storing water for off-season growing. Excessive withdrawals from aquifers can lead to geological hazards such as ground subsidence and saltwater intrusion, and so artificial recharge can reduce these risks by replenishing groundwater supply.

10. Briefly discuss the concept of precipitation recycling in a watershed and give an example of it in the real world (*e.g.*, a real-world example of a watershed where precipitation recycling occurs regularly throughout the entire year). *3 marks*

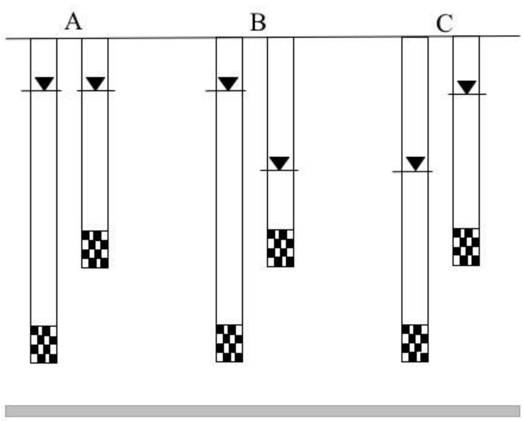
Precipitation recycling describes the percentage of precipitation falling on a watershed that originated from within that watershed. To have a high recycling ratio, you need a high evaporation rate and a low advective moisture term. This means that water evaporating (and therefore falling) from the watershed does not include water that has been transferred in from another region. If your advective moisture term is high, your evaporation and precipitation will include this transferred water, and your recycling ratio will be low.

11. Match the ripple patterns with their flow conditions, wave propagation characteristic, and corresponding Froude number (e.g., a1xq, b2yr, etc.). *3 marks*



a	___1__	__z____	__r____
b	___2___	__y____	__s____
c	___3___	__x____	___q___

12. Using the information on the diagram below, answer the following questions.



$h = z + \psi$

a. Which of figures A, B, or C depicts an *upward* hydraulic gradient? *1 mark*

B

b. Consider the following scenario: C, the right piezometer, has a screen (intake) level of 65 masl and a water level of 10 m above it, while A, the left piezometer, has a screen (intake) of 50 masl and a water level of 15 m. Which piezometer has the highest *hydraulic (total) head* (in m) and which well has the highest pressure head? *2 marks*

C → $z(65) + \Psi(10) = 75$ m
A → $z(50) + \Psi(15) = 65$ m

Well C has the greatest hydraulic head at 75 m, where Well A has the greatest pressure head at 15 m.

13. Using your knowledge of the causes and intensifying factors in river flooding, please describe how you would assess the flood risk each year for a city like Winnipeg, Manitoba (e.g., flat flood plain, cold continental climate). 4 *marks*

The risk of spring flooding in Manitoba is high since the region experiences a very cold climate, leading to high snow accumulation. In the case of a flood, the flat terrain would exacerbate the hazard since excess water has no choice but to spread out. To properly assess the flood risk each year, climatic variations must be considered since the temperature during the winter/spring would directly influence the amount of snow accumulated, and therefore the degree of flooding and the severity of hazard. In the spring following a particularly cold winter, the flood risk would be high since the snowpack will be large and the meltwater discharge will be high.

14. Describe how the Red River Floodway affects flood discharge to mitigate flood risk in the City of Winnipeg. *2 marks*

The Red River floodway uses an artificial side channel to divert excess water from the Red River and minimize the volume of water flowing through the river during flood conditions. This reduces the risk of flooding since water discharge through the river is lower and there is less opportunity for it to breach the riverbanks.

15. Describe the seasonal evolution of alpine glacier water reserves in a mid-latitude alpine glacier in the northern hemisphere, including the seasonal evolution of the overlying snowpack. *6 marks*

In this type of environment, snow accumulates from fall to early spring, when temperatures are cold enough to lead to the development of a snowpack. The lower the temperature, the larger the snowpack and the greater the volume of water available for melt later in the year. Water reserves are very high in late winter/early spring but are difficult to access as they are stored as ice and snow. During spring, the snow starts to melt and the glacier begins to experience some runoff, though this is still quite low as the system of drainage channels within the glacier is not well developed yet. From spring the late summer, surface runoff and streamflow are significant as the snowpack melts away and glacial ice begins to melt due to reduction in surface albedo. The glacier has a well-developed drainage system at this time, and water previously stored as ice is now being discharged as liquid water. In late summer, glacial meltwater can provide a buffer to streams that would otherwise experience low flows and high temperatures following the melt of the snowpack. Once fall returns, snow begins to accumulate again and the system is dominated by groundwater flow.

Questions 16 and 17: The Senior Hydrologist for the Park has asked you to help them calculate some in-situ numbers for a few hydrological parameters. Using data from a hydrometeorological station (table below) set up next to Evans Creek, answer the following questions. The hydrometric station is located at 1500 m, which has an atmospheric pressure of approximately 850 mbar.

16. Consider air at your site on a nice sunny July day. Using the information in the table below, calculate the: (a) saturation vapour pressure (in mbar) and (b) specific humidity (in g kg^{-1}) at noon. *5 marks*

Daily 1-hour Average Temperature and Relative Humidity from Evans Creek Hydrometeorological Monitoring Station, July 1.

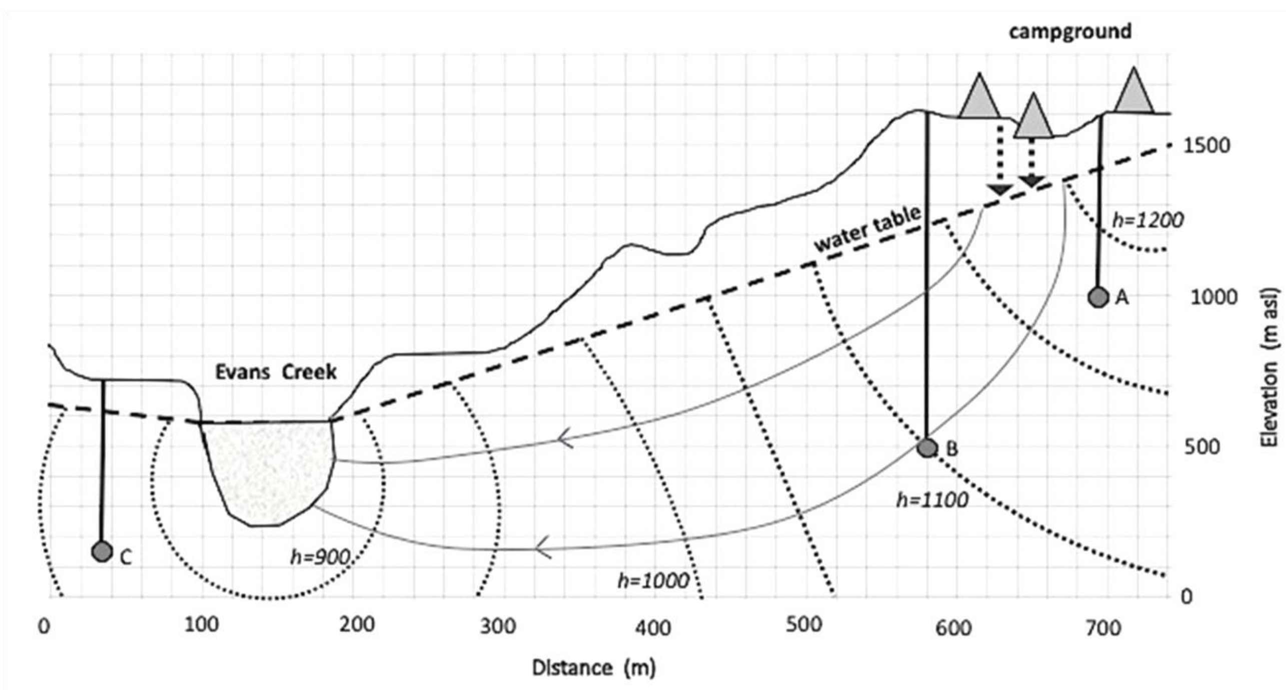
Time	T (˚C)	RH (%)	Time	T (˚C)	RH (%)	Time	T (˚C)	RH (%)
00:00	6	70	08:00	8	55	16:00	16	30
01:00	6	70	09:00	8	55	17:00	17	30
02:00	6	70	10:00	10	50	18:00	16	30
03:00	5	70	11:00	12	45	19:00	14	35
04:00	5	60	12:00	14	45	20:00	12	40
05:00	5	60	13:00	14	45	21:00	12	40
06:00	6	60	14:00	16	30	22:00	8	50
07:00	7	55	15:00	16	30	23:00	8	50

e_s = 16 mbar
e_v = 7.2 mbar
q = 5.27 g kg^{-1}

17. For the same July day above, use the Hamon Equation to estimate evaporation at the creek site (in mm day^{-1}). Additional information from your monitoring station tells you that the daily net radiation received is Q^* = 200 W m^{-2} and average wind speed during the afternoon period (measured at 2 m) was 10 m s^{-1}. Mean daylength is 15-hours at this time of year.
4 marks

23.4 mm day^{-1}

Questions 18 and 19: Groundwater flow in the area is not well understood. Three wells were recently installed inside the watershed boundary to learn more about the subsurface flow in the area. In particular, they are concerned about a campground in the watershed and possible contamination of the creek. Using information from the figure below and the questions below, perform some groundwater flow analysis.



Cross-section view showing the water table and flow net system that has developed in a uniform sand deposit. Dashed lines are piezometric contours (lines of equal hydraulic head); solid lines are potential flow lines. The deposit is bounded by impermeable bedrock. Three wells (A - C) have been established along the hillslope for monitoring purposes. The intake for each well is located at the middle of the borehole (solid circle).

18. Determine the pressure heads (**ψ_p**) at wells A and C. *2 marks*

ψ(A) = 175 m
ψ(C) = 775 m

19. Assuming that waste material entering below the campground travels at the same rate as groundwater, estimate the travel time in the aquifer (in days) before that material will enter Evans Creek. *4 marks*

Some information to note:

- The aquifer has a uniform K of 1 m day^{-1} and porosity of 0.3 for the sandy substrate.
- The flow lines in the figure delineate a groundwater flow tube that provides discharge from the area around the campground to Evans Creek.
- The estimated flow tube length is 600 m with a width of 100 m

Bonus Question: Using your knowledge of hydrology, what is patently false in the tweet below?
1 mark

-------- end of the exam --------