



## INTRODUCTION

### General Instructions:

The completion of this Lab does NOT require a formal Lab report or write up. Instead you will present your data by completing a Lab Template. This template is available as a separate document. **Only the completed LAB3: FLOWNETS RESULTS needs to be turned in for credit!!!**

### Reading Assignments:

In preparation for this Lab, READ the following in your FREE Open Access Textbook(s):

- Kresic, 2024, Hydrogeology 101: Lecture 3.4.1
- Freeze & Cherry, 1979, Groundwater: Chapter 5
- Ancillary Reading - unknown source:  
<https://www.civil.uwaterloo.ca/maknight/courses/CIVE353/Lectures/week%204/flownet-construction.pdf>

(Optional) and if you have it, READ the following in your *optional* Textbook:

- Hölting & Coldewey, 2019, Hydrogeology: - *nothing in book* -

## GENERAL INSTRUCTIONS ON COMPLETING THE LAB and GRADING:

### For ALL assignments use a citation's database:

ZOTERO citations database

ZOTERO is a citations database that incorporates itself into Word and your Browser.

Free open source software available at <https://www.zotero.org/>

*Note: You may use a different citations database, if desired. But you MUST use a citations database!*

NOTE: After downloading and installing ZOTERO, take an hour or two to become familiar with the operation of the software. One of your first tasks will be to set the citation style to the United States Geologic Survey (USGS) format in ZOTERO. The USGS citation system will be required for this course and your final product.

**Loading the USGS citation format into ZOTERO:** Once Zotero Standalone is installed, click on "Preferences" under the Edit tab. Once there click on "Cite" and go to the "Styles" tab. Click on the "Get additional styles..." below the Styles Manager Box. When the Zotero Styles Repository Window opens, click on the "geology" button within the "Fields" section. A list of geology journals should now appear. Scroll down to the U.S. Geological Survey and click on it. The U.S.G.S style will now be part of your Zotero system and you can set your citations to be formatted accordingly in Zotero.

### General Writing Instruction Summary:

- Use professional language, which means AVOID first person expressions such as "I", "we", "our". Use normal prose, active voice and third party language. Do NOT use informal wording, contractions, jargon, slang terms, or superlatives. Exclude similes/metaphors (and humor!)
- Use present tense to report well accepted facts, e.g. 'Pyrite is a sulfide mineral'. Use past tense to describe specific results, e.g. 'When acid was applied, the specimen effervesced'
- Be quantitative wherever relevant (stats, numbers etc.).

Subscript & Superscript

Use appropriate subscript and superscript, especially when it comes to chemical formulas and mathematical units..

Acceptable examples: 2.9 g/cm<sup>3</sup>, H<sub>2</sub>O, PO<sub>4</sub><sup>3-</sup>, a<sub>g</sub>=9.8m/s<sup>2</sup>

Unacceptable examples: 2.9 g/cm3, H2O, PO4 3-, ag=9.8m/s^2

- Use precise concrete language, no ambiguity e.g, 'correlated' ≠ 'related'. Use simple language – no unnecessary "frills" (distractions). Pay attention to sentence structure and grammar



### **COMPILING TABLES, FIGURES and EQUATIONS**

GRAPHICS are the heart of any report. Nothing is more true than in science that a picture is worth a thousand words. Always compile graphics first and then write your text focusing on your graphic. In order to create good graphics and photographs, follow the instructions below.

#### **Cameras and Photos:**

Cell phones with a 7.2MP camera are usually ok. When taking pictures, lighting and background is key. This means dark objects should be photographed with light or white backgrounds (sheet of paper) and visa versa for light objects. Having adequate lighting will also help to get sharp, crisp, in focus pictures. Blurry and out of focus pictures are not acceptable.

#### **Graphics:**

You should be able to modify, enhance, annotate or overlay graphics. Minimum resolution is 300dpi. Make sure graphics are crisp, clear and any label is easily readable. All graphics should have a caption stating the author and/or citation. Preferably use lossless graphic formats, such as .tif or .bmp. Unfortunately .jpg is NOT lossless and will degrade a little every time you open and save it again in order to manipulate picture contents.

**Graphics Editor Software:** You will need a graphics editor and learn how to use it. Windows comes with its default Windows Paint editor. It is found in the Windows Accessories Folder. For a more advanced option with many more professional features you may try GIMP: <https://www.gimp.org/> This is a FREE, open source image editor working across all computing platforms (Windows, Apple, Linux, etc.). The software comes with ample documentation and examples on how to manipulate any picture or graphic.

**Screen Capture Software:** A screen capture or snipping software is advantageous in order to only grab the part of a graphic from the screen that is important or necessary. Windows 10 comes with a default snipping tools, such as “Snip & Sketch” found in its own folder or “Snipping Tool” found in the Windows Accessories Folder. Note: When snapping a picture, make sure it is large enough on the screen to capture enough pixels to have adequate resolution for the final product.

**NOTE:** Compiling acceptable and good looking graphics and photographs is very involved and can not be rushed. These are often the heart of any report and should be compiled BEFORE writing. Last minute thrown together graphics will without doubt lower your grade.



COMPOSITION, LAYOUT, WRITING & GRAMMAR SUMMARY

Language

The following list is an example of common faults in language usage and attribution.

Errors / Mistakes / Faults	Examples with margin <i>Fault Counts &amp; Codes</i>
Spelling: incl. capitalization errors & spacing	The mineral <u>florite</u> has a <u>mohs</u> hardness of four.   Nicolas Steno <u>_</u> was trained in the classical texts on science.
Grammar: incl. punctuation, superfluous words, transpositions	Isometric crystals are also isotropic Here light propagates at the same speed.    Rocks are composed of many many <u>(minerals mixed.)</u>
Style: incl. paragraph, repetitive expressions / words, erroneous expression / words, sub- or superscription, unprofessional style, word insertion	<i>Para.</i> ... in the geologic sciences.¶Near the end of the 19 <sup>th</sup> a new theory ...    <i>rep</i> ... is a <u>light colored</u> mineral. These <u>light colored</u> minerals are often <u>light</u> ...   Stalactites hang from the <u>sealing?</u> of a limestone cave.   <i>sup</i> The density of quartz is 2.65 g/cm <sup>3</sup> .    I was investigating the outcrop with <u>my group</u> .   Sodium sulfate forms a chalky, <u>incoherent</u> precipitate. <i>amorphous?</i> ^
Sentence: incl. grammar, run-on, strings of nouns	The density of gold is greater <u>then?</u> the density of silver.   Pyrite has a symmetrical crystal <u>structure</u> , it is cubic.    <u>Skarn mineral zonation?</u> is apparent in the sample.

Content

Errors in content are spelled out. Severe infractions may count for multiple errors.

Errors / Mistakes / Faults	Examples with margin <i>Fault Counter &amp; Codes</i>
Unclear / erroneous statements	<i>unclear, units?</i> Mohs hardness of the mineral in question is 16.5.
False / nonsense	<i>Nonsense</i> <del>Glaciation cause severe metamorphism of the region</del>

TABLES, FIGURES & EQUATIONS SUMMARY

**Tables**

Each table must be sufficiently complete that it could stand on its own, separate from text.

**Only HORIZONTAL lines are allowed in tables. Do NOT use any VERTICAL lines.**

DO consecutively number and caption tables and refer to them accordingly within your text. Captions go ABOVE the table.

DO provide a short description of your table within the caption.

DO place your tables appropriately, closest to their mention in the text.

DO make sure tables are legible and reproduce well. Print can be smaller than text, with an 8pt size minimum.

DO appropriately label columns. Do NOT forget units for numeric values.

AVOID splitting tables across pages.

**Figures**

Each figure must be sufficiently complete that it could stand on its own, separate from text.

DO number and caption figures consecutively and refer to them accordingly within your text. Captions go BELOW the figure.

DO provide a short description of your figure within the caption.

DO place your figures appropriately, closest to their mention in the text.

DO use appropriate citations for figures that are NOT your own. If you use a figure that has been modified by you, the phrase “modified after....” is most appropriate. Photos should show the name of the photographer.

DO make sure figures are legible and reproduce well. Print can be smaller than text, with an 8pt size minimum. Use a minimum resolution of 300dpi. This is a common publication standard.

AVOID cluttering of figures with too much detail. Simplify if necessary.

AVOID moire patterns in photos, a nuisance in copied or scanned pictures. Most scanners come with a moire pattern removal tool.

**GRAPHS**

*Understand graphs: Bar graphs and/or line graphs are used when plotting nominal vs. ratio or interval data. Scatter plot graphs are used when plotting numeric vs. numeric data.*

DO make sure that the graph axis are appropriately labeled and scaled. Axis should have titles as well as scalar units.

DO use electronic means to generated graphs. Hand drawn graphs are no longer acceptable.

**Equations & Computations**

- Equations should contain explanation of symbols used.
- A reader should be able to follow where your values or numbers come from. Indicate accordingly.
- WRITE DOWN UNITS!!!!
- Show equations used before indicating any computation

Acceptable Example:  $F = m \times a = 0.034\text{kg} \times 9.8\text{m/s}^2 = 0.33\text{kgm/s}^2$

where  $m$  is mass of the object in kg as determined with a triple beam balance and  $a$  is the gravitational acceleration.  $F$  indicates force expressed in  $\text{kgm/s}^2$  or  $N$  (Newtons).

Unacceptable example: The answer is 0.33. This is obtained by multiplying gravity by 0.034.

**Introduction: What are Flow Nets?**

Flow nets are **graphical representations** used in hydrogeology to visualize and analyze the flow of groundwater within porous media. They provide a visual aid for understanding the direction and magnitude of groundwater flow in aquifers. Typically employed in steady-state flow conditions, flow nets help hydrogeologists and engineers analyze groundwater flow patterns around wells, barriers, and other subsurface structures.

In a flow net, equipotential lines and flow lines are drawn to represent the groundwater flow field. Equipotential lines connect points with the same hydraulic head, and flow lines indicate the direction of groundwater movement perpendicular to the equipotential lines. The spacing of these lines reflects the rate of flow, with lines closer together indicating higher flow rates.

Flow nets are valuable tools for solving complex groundwater flow problems, aiding in the design and analysis of well fields, determining seepage beneath dams, and assessing potential contaminant migration paths. **They provide a clear visual representation that simplifies the understanding of complex hydrogeological systems**, making them an essential tool in groundwater engineering and resource management.



**Instructions:**

During this LAB you will use the tool of drawing flownets to scale in order to predict flow parameters in the subsurface and to calculate groundwater flow. NEATNESS COUNTS! You will need the following materials this LAB exercise:

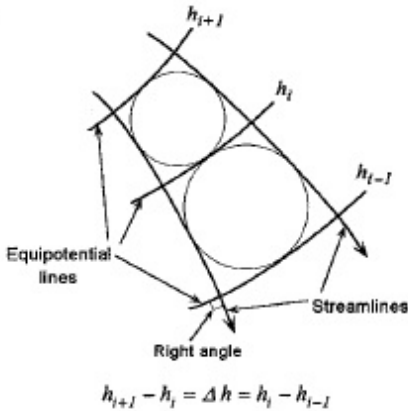
- Graph Paper
- Calculator
- Pencil(s)
- ERASER
- Ruler / Protractor

(Optional) Watch YouTube video: <https://youtu.be/wQu-Qtys-y8>

**BIG NOTE: This is a TRIAL & ERROR approach. You have to try various attempts before you can settle on a final result to do your calculations. You will have to probably make several iterations by hand using PENCIL.**

**FLOWNETS Summary & Rules**

- Rule 1: Equipotential lines are always parallel to constant head boundaries.
- Rule 2: Equipotential lines are always perpendicular to no-flow boundaries.
- Rule 3: Flow lines and equipotential lines are always perpendicular and form curvilinear squares in a homogeneous, isotropic medium.
- Rule 4: Flow lines can never intersect. In other words, flow lines constitute imaginary no-flow boundaries in that there is no flow across a flow line.
- Rule 5: Flow tubes however may merge or split if equipotential lines are satisfied.

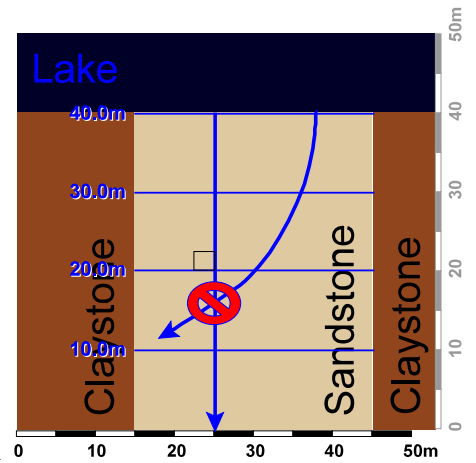


What if my Aquifer curves?

Start with boundaries! Draw known equipotential & flow lines! Follow the Rules!

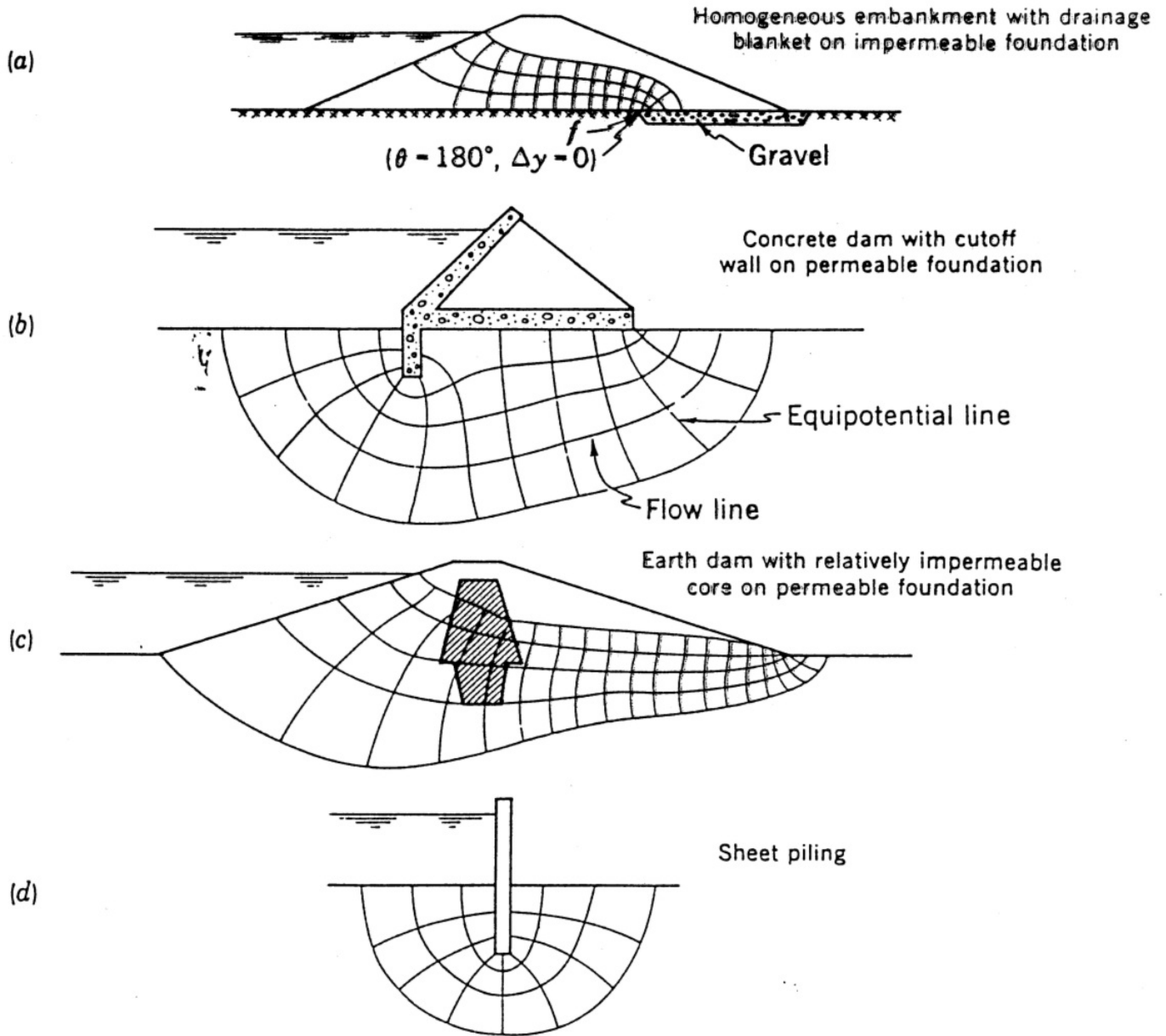
Start (sketch) set of equally spaced flow lines... Trial & Error Method!

Start (sketch) equipotential lines. Try to make curvilinear squares with flowlines...





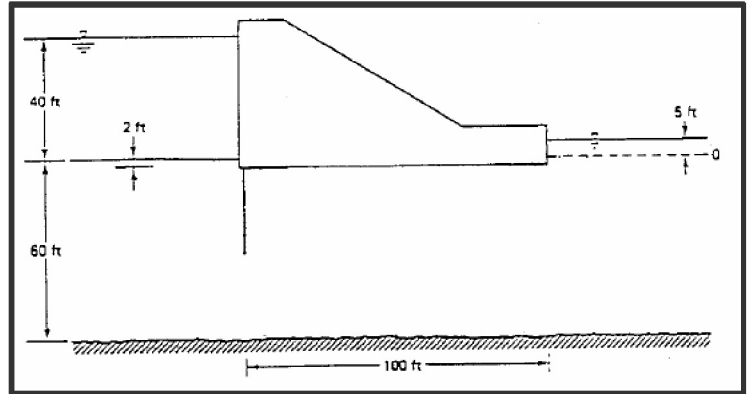
Flownet Examples



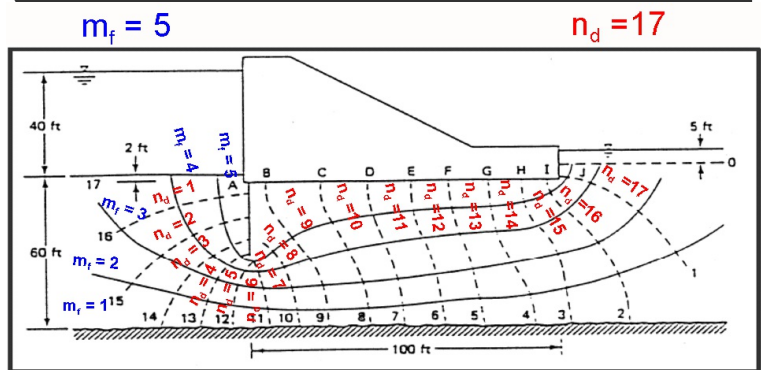


**Flownet Construction & Calculation Example**

A concrete dam is constructed on a permeable stratum underlain by an impermeable rock. A row of sheet pile is installed at the upstream face. If the permeable soil has a hydraulic conductivity of 150 ft/day, determine the rate of flow or seepage under the dam.



Solution: The flow net is drawn with:  $m_f = 5$  and  $n_d = 17$



Solve for the flow per unit width: 
$$Q = \frac{m_f}{n_d} k_f H = \left( \frac{5}{17} \right) (150 \frac{ft}{day}) (35 ft) = 1544 \frac{ft^3}{day} / ft$$

**YOUR FLOWNET ASSIGNMENTS**

**1. FLOW-NET OF A HORIZONTAL AQUIFER**

Draw a flow-net on the provided map using the flow-net procedures and rules by:

- Drawing remaining equipotential lines at a contour interval of 0.5 m (i.e. h = 15.0, 14.5, ..., 10.0)
- Draw the flow lines (flow tubes)!
- Do the associated Flow Calculations

**2. FLOW-NET AROUND A GROUNDWATER PUMPING WELL**

Draw a flow-net on the provided map using the flow-net procedures and rules by:

- Drawing the flow lines (flow tubes)! The flow lines should start just outside of the 84.0 m contour and converge toward the pumping well.
- Do the associated Flow Calculations.

The maps for the LAB a part of the [LAB3: FLOWNETS RESULTS](#) page.

**Only turn in the [LAB3: FLOWNETS RESULTS](#) page for grading after completion.**