ENGR 151 Project 1

Monday September 11th 2023

This assignment is due Monday September 25th 2023 at 11:59PM

Figure 1: The Oroville Dam.

1 Overview

Dams are barriers that restrict water flow. They generate reservoirs of water for human use, such as drinking water or irrigation. Flooding of a valley due to the construction of a new dam may result in destruction of environment or heritage sites and displacement of people. Dams may be used to generate hydroelectric power, which is a clean source of energy. The amount of energy is significant, the Three Gorges dam in China generates nearly 23 GigaWatts of power; by comparison, large fossil fuel or nuclear power stations may produce a few GigaWatts of power at most. In this project you are involved in planning a new dam by considering the reservoir created by the dam and the hydroelectric power generated.

2 Hydroelectric power

Hydro-electricity is generated by turbine blades driven by water flowing downstream from the reservoir down a drop. We can estimate the power generated from the mass flow of the water (i.e. kg of water flowing through system per second), the height of drop, and built in efficiencies using the formula efficiencies using the formula

$$P = m \times g \times H \times \eta \,, \tag{1}$$

where $g = 9.81$ ms^{-2} is the earth's gravitational acceleration, H is the effective drop the water experiences (the "*head*") and η is the net efficiency of all components.

3 Design of code

There are three parts to this project, which include writing functions to calculate the maximum power generated, visualize the reservoir, and calculate the volume of water in the reservoir. A file is provided on the canvas website named `project1_data.mat`, which provides topographic data for a valley (array name `valley`) and linear x and y axes (array names `x` and `y`) as references, both in meters. The `valley` array gives the height of the ground surface in meters. This can be loaded into MATLAB using the command `load project1_data.mat`.

A dam is to be constructed between two regions of high ground, as indicated by the gray region in figure 2. **The dam is built along the line given by the equation**

$$y = 2200 - 0.8x \,. \tag{2}$$

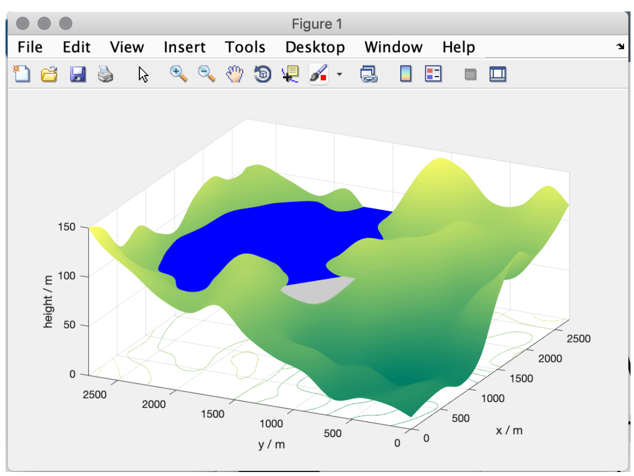

Figure 2: Topological data to be used in the tasks. Green surface indicates the ground level, blue the water and gray the dam.

You should use this data to carry out the following tasks:

1. Write a function to calculate the **maximum** power generated for given efficiency, mass flow rate and height map data using equation 1. The "head", H, i.e. the effective drop the water undergoes, should be calculated from the difference between the dam height and the ground level at all points in the valley beyond the dam and then the maximum value taken. You may assume the mass flow rate will just be a single number supplied (equal to the inflow from an upstream river).

2. Visualize the water reservoir using a surface plot of landscape and water surface, taking into account the dam position. To do this, use `surfc(X,Y,valley,'edgecolor','none');` to generate a surface plot of the landscape of the valley. Then using `hold on`, add another surface using `surf(X,Y,water,'edgecolor','none','facecolor','b');` with `colormap summer`. (The specification `'edgecolor','none'` gets rid of the edges, which on such high resolution data make the whole thing look black, and `'facecolor','b'` simply makes the "water" look blue.) The array representing the water needs to have a constant value (since the water is flat). However, we only want to visualize the surface if the ***specified* water level is higher than the ground level** and **if the water belongs to the reservoir** (to the shallower side of the dam line, as defined by equation 2 and illustrated in figure 3). To achieve this, we can set all the elements of the array that violate these restrictions to the value `NaN`, i.e. "not a number". The plotting tool will interpret these values by just not plotting them **(note this NaN trick is only for plotting, do not use it in any numerical calculations)**. If all this is correct, your figure should look similar to figure 2, if the water level is at **80 meters** except for the gray dam feature (don't worry about adding this).

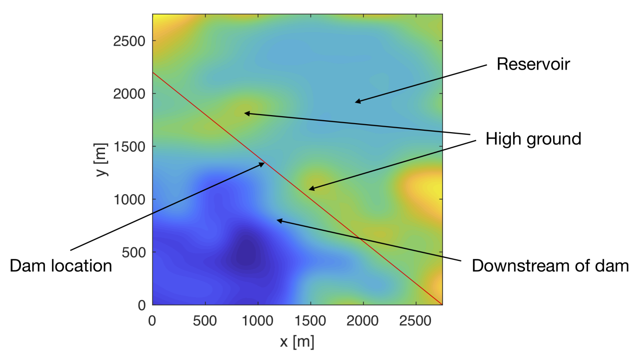

Figure 3: Topological data shown from elevated view with red line to show equation 2.

3. Write a function that finds the volume of water in the reservoir formed by the dam for a given height of the water surface, taking into account the dam position. You can make use of the logic you developed in the previous task to isolate the area of the reservoir.

4 Specifics for project credit

These instructions should be followed precisely for credit, failure to carry out the instructions by e.g. incorrect naming of file may lead to loss of credit.

Tasks:

1. The function should be named `hydropower_max` and take **three inputs**, mass-flow rate (in million kg / second) and the dam height in meters. It should calculate the

maximum power generated according to equation 1 and return it as a single value. To test your code is working, use the following values given in Table 1:

Table 1: Maximum powers as a function of input parameters with a turbine efficiency of $\eta = 0.7$. (A GW is 10^9 W).

Dam height [meters]	mass flow rate [million kg s^{-1}]	Power [GW]
75	1.2	0.62
75	1.5	0.77
80	1.5	0.82

2. The figure should be generated by a single function named `reservoir_image`, which takes **one input**, the water height, and returns **one output**, which is the matrix describing the limited water surface (including the NaNs) you created. You may use `saveas(gcf,'reservoir_image.jpg');` to save the figure as a picture in the working directory.

3. The function should be named `reservoir_volume`, take **one input**, which is the water height and return **one output** which is the volume. (Hint: The volume of a cuboid of water in an area of dimensions Δx, Δy and of depth h, which is the difference between the water surface level and the ground level, is $\Delta x \times \Delta y \times h$). Inspect the data x and y before calculating Δx, Δy, and you will find the mesh is equally-spaced. You may approximate the water volume as being made of a series of cuboids of different heights.

   To test your code is working, it should reproduce the following values given in table 2:

   Table 2: Known reservoir volumes as a function of water height

Water surface height [meters]	Reservoir volume [million cubic meters]
70	3.61
75	11.24
80	21.17

   Note that for credit, your code will be tested against data and should agree with the instructor code to within 1% error.

For all the three tasks, **make sure your codes are vectorized**.

5 Hints for success

Break the problem into pieces and test each part along the way. Use modular construction, making functions that perform pieces of the task where appropriate and test each piece individually to make sure it works before moving on to the next. Remember, each function needs its own .m file. Start early so you can encounter any stumbling blocks along the way and **make use of office hours** to discuss how to implement algorithms.

6 Grading

You should submit your three files for the three tasks to Canvas under `Project 1`. The Matlab grader will evaluate the results of your submission and provide a maximum score of 100 points (Task 1: 30 pts; Task 2: 40 pts; Task 3: 30 pts).

Please take a look at the file `Style_Expectations.pdf` in the 'Files' of the canvas site for the information on the style and commenting of your code. Start to follow the good practices! For the first two projects, the code style will not be part of your credit, but it will be taken into account from Project 3.