

## Locating Potential Sites for Pumped Hydroelectric Energy Storage

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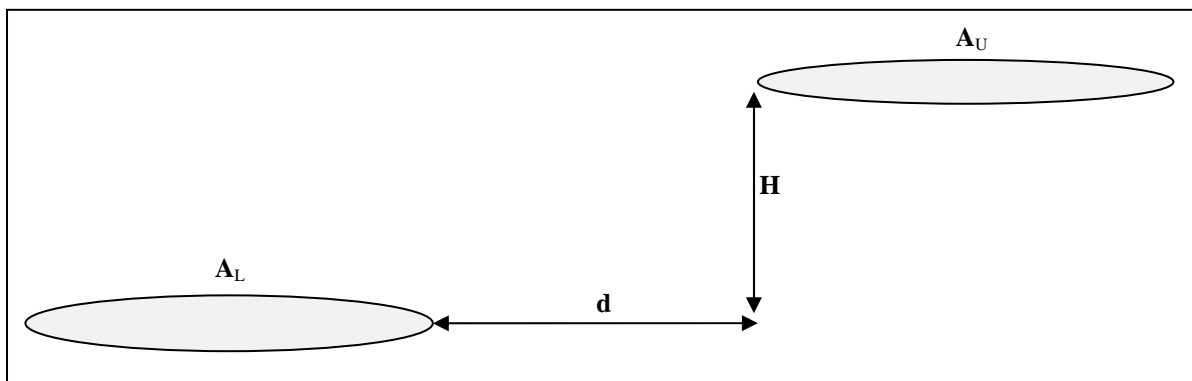
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Pumped-hydroelectric energy-storage (PHES) is the largest and most mature form of energy storage currently available. However, the capital costs required for a PHES are extremely large and suitable sites for PHES are deteriorating. Therefore, identifying the remaining sites available for PHES is becoming vital so that the most beneficial location is chosen: in terms of capacity and economics. As a result, the aim of this work is to develop a computer program that will scan a terrain and identify if there are any feasible PHES sites on it.

At the outset of this project, there were two primary concerns that needed to be addressed: 1) obtaining suitable data and 2) writing the software. The first issue was resolved by contacting the national mapping agency of the Republic of Ireland, Ordnance Survey Ireland (OSI). OSI was able to provide 10 m resolution height data for all of the Republic of Ireland [1]. In addition, OSI referred us to a software company, Atlas Computers Limited [2], who had experience using this data. Therefore, to tackle the second major issue (creating the program), a collaboration was developed with Atlas Computers Limited.

Atlas Computers Limited had already developed a Survey Control Centre (SCC) to manipulate the data provided by OSI. The SCC converted the 10 m resolution height data for the Republic of Ireland, into a Delaunay Triangulated Irregular Network model (TIN). A TIN model displays the 10 m data as a 3D terrain that can then be analysed using different constraints. Consequently, the specific constraints that need to be fulfilled at a suitable PHES location could be searched for using the TIN model.

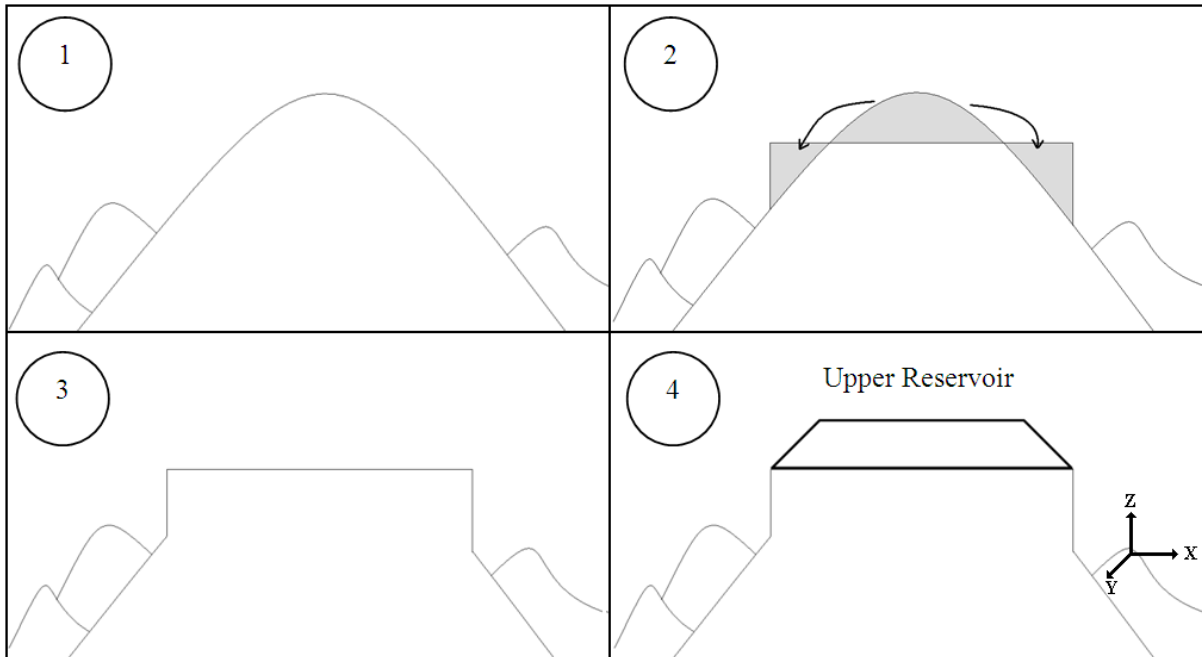
To search the TIN model for pumped-hydro facilities, an additional algorithm was added to the SCC to search for locations with the specific constraints associated with PHES facilities. This was based on searching the TIN to find adjacent polygonal areas of acceptable flatness,  $A_U$  and  $A_L$ , with a minimum acceptable vertical separation,  $H$ , and a maximum acceptable horizontal separation,  $d$ , as portrayed in Figure 1. The program created could only identify regular-shaped polygons as the areas for the reservoirs, and hence a circle was chosen.



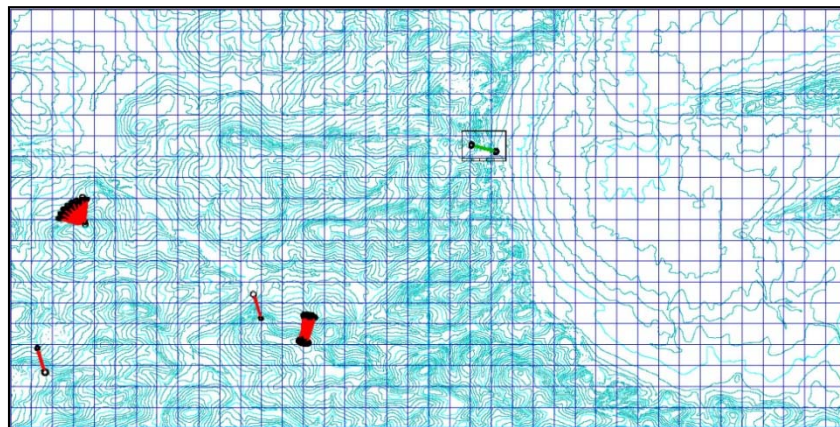
**Figure 1: Area layout investigated by computer program**

The upper and lower reservoir areas identified by the program had to be flat. Flatness in this case is specified in terms of the maximum allowable 'cut' and 'fill' excavation-volumes,  $E_U$  and  $E_L$ , which are required to construct a polygon at an arbitrary datum, where the software selects an optimal value for that datum. In other words, the level of flatness required was specified by quantifying the maximum amount of earth that could be moved in order to make the site flat,  $E$ , as displayed in Figure 2. The earth that must be moved to make the area flat must be obtained within the investigated site i.e. the circular area. There was an  $E$  value for the upper reservoir,  $E_U$ , and an  $E$  value for the lower reservoir,  $E_L$ .

To test the operation of the model, an initial analysis was carried out on a 20 km x 40 km area in Ireland. After the three searches were completed, five potential locations for PHES facilities were identified. These are illustrated in Figure 3. Only one location which is marked with a rectangle was identified from the first search, while the other four locations were identified during the second search, and no locations were found during the third search.



**Figure 2: Earth moving procedure within the program to make the investigated area flat**



**Figure 3: Potential PHEs-sites identified after the initial analysis**

Based on the assumptions made and using the parameters specified in the program during, the five facilities identified by the program represent a combined power capacity of 710 MW, and a combined storage capacity of 8,634 MWh. Therefore, it is clear that the program developed has provided an excellent first step to evaluate the potential for suitable PHEs-locations across a specified terrain. However, even though the program provided some very significant results already, a number of improvements are necessary.

To conclude, this paper has provided a brief description of the program developed for identifying feasible locations to construct PHEs facilities, the results obtained to date using the program, and finally, future improvements to advance the program's capabilities are identified. The program has proven to date that it can identify feasible locations for PHEs, however, further investigation is necessary to improve the site-selection.

## References

1. Ordnance Survey Ireland. Discovery Height Data. Ordnance Survey Ireland, 2009. See also: <http://www.osi.ie/en/alist/pc-discovery-data.aspx?article=d5c4e8a1-df42-44c1-9f3e-f5683e514e4e>.
2. Atlas Computers Ltd. Survey Control Centre. Atlas Computers Ltd., 2007. See also: <http://www.atlascomputers.ie>.