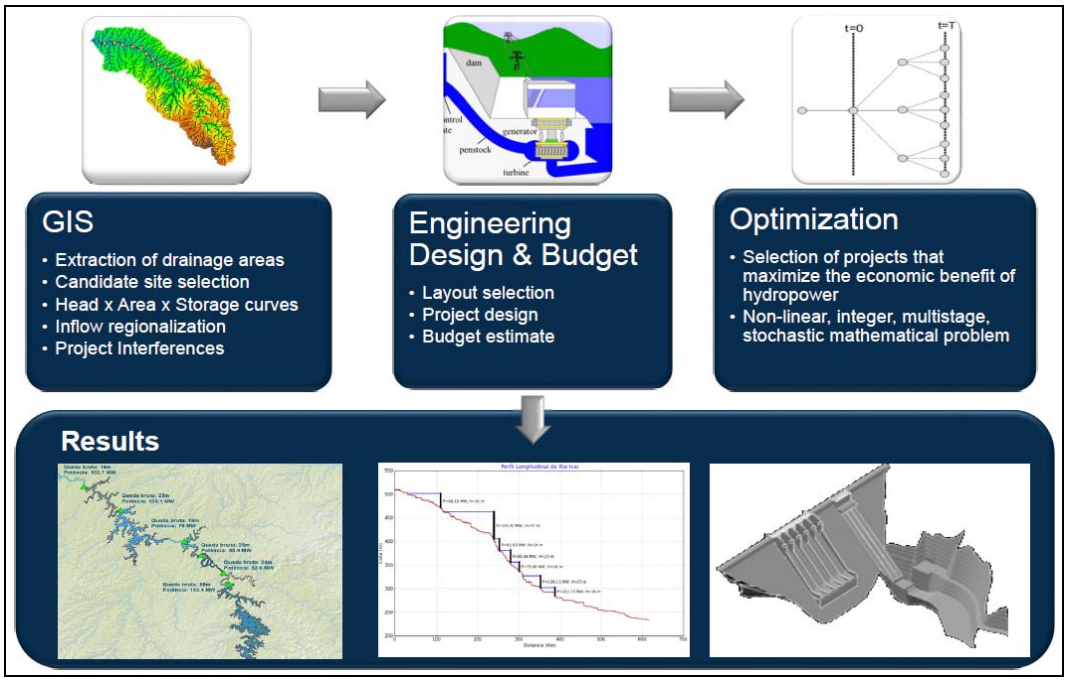
December 2015

Overview

HERA[1] is a computational tool for the determination of the best exploitation scheme of hydropower plants in river basins. It is the result of a multidisciplinary team including civil engineers, hydrologists, computer scientists, GIS specialists, operations research specialists and environmental engineers. HERA selects the combination of projects in a river basin that maximizes the economic benefit of power production while considering socio-environmental constraints. It has three main components:

1. Pre-processing in GIS (Geographic Information System) of the topographic and hydrologic data. This task may be executed in the "clouds" through distributed processing scheme to abbreviate computational time. One attractive aspect of this scheme is the use of public domain data, such as NASA's SRTM (Shuttle Radar Topographic Mission);
2. An automatic engineering and electromechanical equipment design with budget estimation. Various designs are tested for each location at this stage by varying project layout and type;
3. Formulation and solution of a non-linear, integer mathematical programming problem for the selection of candidates that maximizes the objective function with a visualization of this selection.

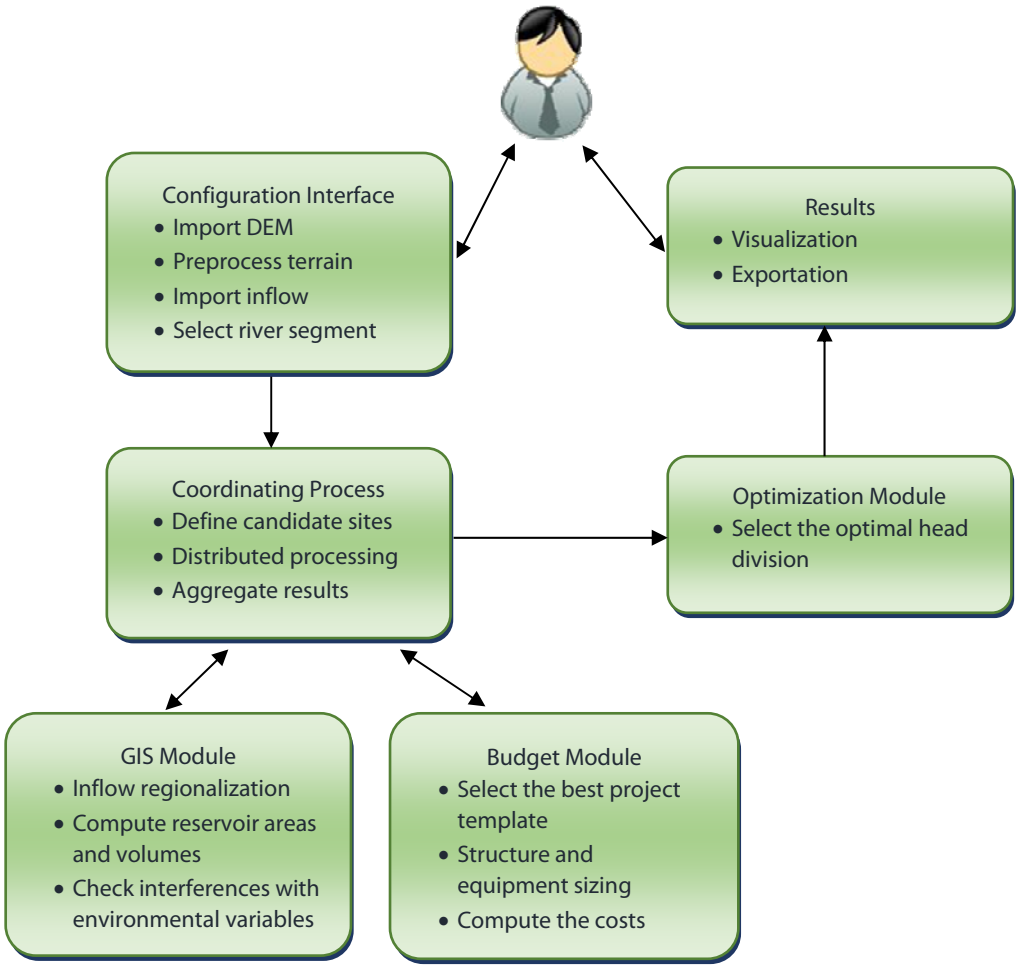


[1] *Hydropower and Environmental Resource Assessment*

HERA results include the selection of hydropower projects from possibly several thousand of alternatives, including engineering design and physical characteristics: reservoir area and storage, installed capacity, expected and firm power production, investment costs including civil works, equipment and socio environmental components. HERA can be used by planning agencies of governments or investors examining greenfield river basins with hydropower potential.

Innovation: whereas several products and solutions exist in the market for evaluating the hydro potential based on GIS modeling that combine hydrological with topographical data into a "theoretical" physically potential, HERA innovates by assessing the set of projects that are actually economically and environmentally feasible. Their location, engineering design and impacts (on neighboring infrastructure, displaced people, vegetation suppression requirements and others) are simulated and the result is internalized in the project development cost. HERA combines different areas of knowledge, such as geoprocessing, hydrology, computer programming, structural engineering and visualization components. By integrating automatic calculation with geoprocessing techniques, cloud computing and optimization methods, HERA allows "zillions" of combinations of head partition alternatives to be intrinsically assessed, something unthinkable when considering traditional engineering procedures and methods.

HERA process flowchart

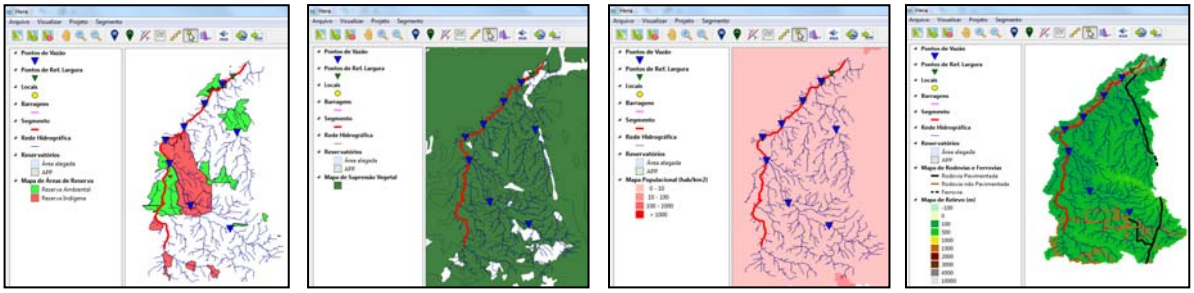


HERA flowchart

Input data

The import of a Digital Elevation or Terrain Model (DTM) is the starting point for HERA. From the DTM the drainage network is inferred and drainage areas, river profiles, cross section and other functions determined. The other required information is the set of gauging stations (location and inflows time series). From the inflow data HERA determines monthly mean inflows for assessing the expected power production of the candidate projects. Statistical methods are also used to define project floods with different occurrence probabilities that are used in the design of spillways, cofferdams and others structures. Several layers of georeferenced data listed below may be imported to HERA to estimate costs related to the impacts of the candidate reservoirs on the existing infrastructure and environment. They may also pose "hard" constraints (e.g. where projects cannot be built).

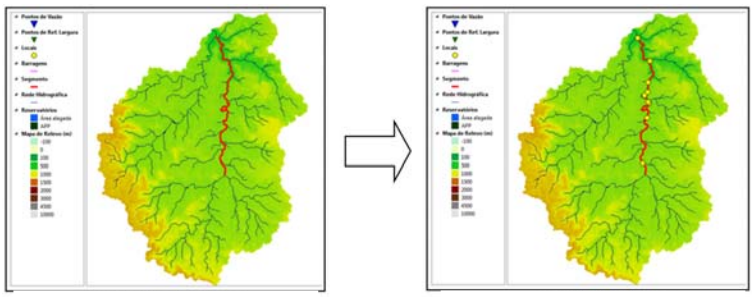
- Environmental protected areas and indigenous/traditional peoples territories → impacts of the reservoir with those areas
- Vegetation → the costs of vegetation removal
- Population density → number of families to be relocated and its costs
- Urban and rural areas → costs of land acquisition
- Roads, bridges and railroads → costs of relocating such structures



Layers of data imported to HERA

Candidate projects selection

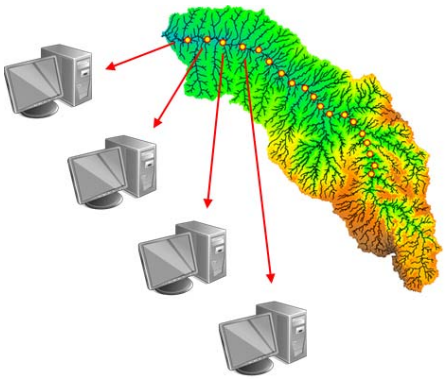
The selection of the river of interest from the hydro networks is quite straightforward: all needed to is a mouse click for the initial and ending points of the river from the hydro network map for the river (left). Candidate sites can now be selected for the river either manually for locations of interest or automatically, where the selected river is divided in a user-selected number of points which are equally vertically spaced along the river (right).



River segment **Candidate sites**

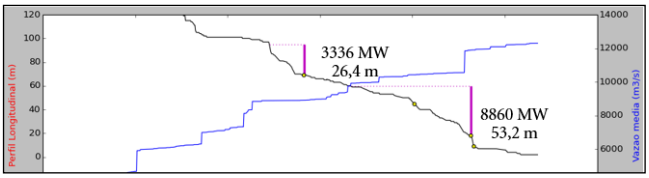
For each candidate site HERA evaluates the angle of the dam axis that minimizes the distance between the abutments identified from The DTM. The next step is to simulate the reservoir flooded area from the dam geometry with the DTM. Polygons are drawn and islands inside the reservoir considered in the final wet area and storage calculation. An optional buffer around the perimeter of the reservoir may be user defined to consider environment protection (as in many jurisdictions).

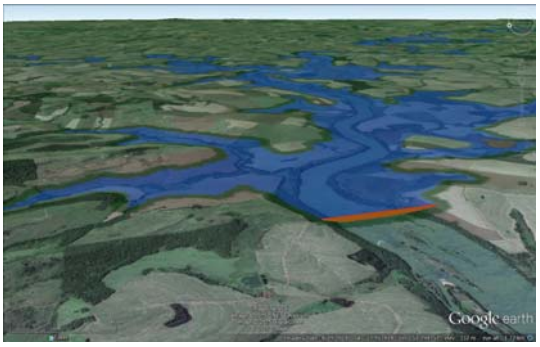
In a second step, HERA computes the intersections between the candidate project flooded area and the layers of data in order to calculate the socio-environmental costs. Finally, after calculating the dimensions of the main hydropower structures with an engineering module, HERA uses a budget estimation module that provides civil construction and electromechanical costs. Several engineering alternatives and layouts are tested in each location; thus the engineering/budget modules are intensively called as an "inner loop" of HERA's candidate project definition process. HERA features cloud computing / distributed DTM geoprocessing to reduce computational execution time.



Results and applications

HERA results include the optimum hydropower exploitation scheme (engineering design and budget), GIS based maps, and features such as export of the optimum planned projects to Google Earth.





HERA can be used as an evaluation tool for head division alternatives, contributing to increase rationality on the development of hydroelectric power plants around the world, especially in the developing nations. The benefits of reservoirs related to the increase of water security is another application, in the context of economic x environmental tradeoffs assessment and water to energy nexus. During the last decades, run-of-river power plants have been prioritized due to their relatively smaller environmental impacts. A recent application of HERA for the Tapajos river basin in Brazil produced a hydropower exploitation scheme different from the planned one by the Government. Large savings are found by the optimum alternative (hydropower with regulating reservoirs) with respect to the official scheme based purely on river or river plants. The scheme, however flooded an additional area. HERA may be used by producers, regulatory/energy planning/environmental agencies in an objective and dispassionate way, thus facilitating the comprehension of development alternatives and the harmonization of hydropower with environmental protection. HERA has a large scope of application: any hydrographic basin in the world can be investigated as long as the basic information (DTM and hydrology) is available.

In June/2015 PSR won the GDF Suez (now Engie) Innovation Award, in the category "Operating and Technical Performance" after submiting the HERA project.