Virtual Hydropower Prospecting – a Foundation For Water Energy Resource Planning and Development

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Topics

• Water energy resource assessment of U.S. natural streams
  – Basic natural stream resource assessment
  – Feasibility assessment
  – Virtual Hydropower Prospector – a GIS application

• Water Energy Resource Assessment of Brazil Project
  – Background
  – Technical Approach
  – Project Status
  – Project End State
Water Energy Resource Assessment Of U.S. Natural Streams
Water energy resource assessment of U.S. natural streams

- **Funded by the U.S. Department of Energy Hydropower Program**
  - Idaho National Laboratory – lead
  - U.S. Geological Survey – Earth Resources Observation Systems Data Center
  - U.S. Geological Survey – Water Science Center

- **Basic resource assessment** – published April 2004*

- **Feasibility assessment** – published January 2006*

- **Virtual Hydropower Prospector* GIS application** – launched on the Internet July 2005

* Accessible at: http://hydropower.inl.gov
Elements of a resource assessment

• **Basic natural stream resource assessment**
  – Resource spatial distribution
  – Resource gross power potential

• **Feasibility assessment**
  – Feasible potential projects
  – Project realistic power potential

• **Virtual Hydropower Prospector – a GIS application**
  – Water energy resource site & feasible project locator
  – Preliminary feasibility assessment tool
Basic Natural Stream Resource Assessment
Basic assessment methodology

• **Stream reach power potential (USGS data processing)**
  – Derive synthetic hydrography using digital elevation models
    • 3D hydrography divided into stream reaches (avg. 2 mi)
    • Stream reach catchments ⇒ drainage areas
  – Obtain reach hydraulic head from 3D hydrography
  – Obtain reach flow rate from hydrologic region specific flow rate regression equation(s)
  – Estimate reach gross annual mean power by combining hydraulic head and flow rate

• **Zones where development unlikely identified using GIS**
  – Federal exclusion zones
  – Environmental exclusion zones

• **Developed reaches identified by matching plants and reaches using GIS**
Basic natural stream resource assessment results for the United States

- Reach population having power potential $\geq 10$ kWa is:

  500,000 reaches
  Gross power: 300,000 MWa
Resource power potential by state and power category
Feasibility Assessment
Feasibility criteria

• Development not improbable
  – Not in federal exclusion zone
  – Not in environmental exclusion zone

• Site accessibility – within 1 mile of a road

• Load proximity
  – Within 1 mile of either
    • Power line
    • Substation
    • Power plant

  OR
  Within the 90th percentile of distances of hydro plants in the same power class to a city or populated area boundary in the hydrologic region
Project development criteria

- Working stream flow – the lesser of:
  - Half the reach flow rate
  - Sufficient flow rate to produce 30 MW

- Penstock
  - Maximum length equal to the maximum length for a majority of low power or small hydro plants in the region, respectively
  - Actual length chosen to be minimum length providing 90% of hydraulic head provided by maximum penstock length
  - Positioned on reach to maximize hydraulic head for given length
U.S. potential projects by power & technology classes

- Feasible projects having hydropower potential ≥ 10 kW

130,000 projects

Hydropower potential: 30,000 MWa

Feasible Projects
127,758

- Microhydro
  93,821
  73%

- Small Hydro
  5,420
  4%

- Low Power Conventional Turbines
  22,485
  18%

- Low Power Unconventional Systems
  6,032
  5%

- Low Power Unconventional Systems
  1,640 MWa
  6%

- Microhydro
  3,052 MWa
  10%

Feasible Project Hydropower Potential
29,438 MWa

Small Hydro
18,450 MWa
63%
Feasible hydropower potential by state and power category
Concentrations of small hydro & low power potential projects in the conterminous U.S.
Virtual Hydropower Prospector
Virtual Hydropower Prospector

- Web-based GIS tool
- Served from the Idaho National Laboratory
- Constructed using ESRI ArcIMS 9.0 and Visual Studio’s InterDev
- No special software or licenses required to use
- Displays water energy resource sites and feasible project sites in the 20 U.S. hydrologic regions
- Displays context features needed to perform preliminary feasibility assessments
- Provides tools for locating and selecting features of interest
- Goes beyond geographic location and provides attribute information about selected features
VHP Desktop

- Thumbnail Map
- Legend
- Information Window
- Toolbar
- Map View
Features displayed

• Water energy features
  – Water energy resource sites (500,000 sites)
  – Feasible potential projects (130,000 sites)

• Hydrography (5 feature sets)

• Power system
  – Hydro plants
  – Other plants
  – Power lines
  – Substations

• Transportation
  – Roads
  – Railroads

• Areas and places
  – Cities
  – Populated areas
  – County boundaries
  – State boundaries
  – Hydrologic region boundaries

• Land Use
  – Excluded areas
    • Federally designated
    • Environmentally sensitive
  – Bureau of Indian Affairs (BIA)
  – Bureau of Land Management (BLM)
  – Bureau of Reclamation (BOR)
  – Department of Defense (DOD)
  – U.S. Forest Service (FS)
  – U.S. Fish & Wildlife Service (FWS)
  – U.S. National Park Service (NP)
Water Energy Resource Assessment of Brazil Project
Background

• **Funded under the International Power Partnerships Program**
  – U.S. Department of Energy
  – Edison Electric Institute

• **IPP Program objectives**
  – Fund projects that will reduce greenhouse gas emissions
  – Foster partnerships between U.S. and foreign industries

• **Contributing organizations**
  – Idaho National Laboratory
  – U.S. Geological Survey – Earth Resources Observation Systems Data Center
  – U.S. Geological Survey – Water Science Center
  – HydroPartners, LLC
    • Ecology Brasil
Background (Continued)

• Brazil performed “river inventories” during the 1960’s (based on topo maps and field reconnaissance) custodian: Electrobras

• Brazil performed stream flow modeling studies covering the country’s 76 sub-basins custodian: Brazilian National Water Agency (ANA)
Basic resource assessment

• Hydrography
  – Digital elevation models (DEMs)
    • Shuttle Radar Topography Mission (SRTM) 90m resolution – USGS available
    – Mapped hydrography – Brazil

• Stream flow rate prediction
  – Brazilian produced stream flow modeling – used for 30% of the country
  – Stream flow modeling for 70% of country produced by USGS Water Science Center
    • Data from approximately 1850 stream gages
Basic resource assessment (Continued)

• Status
  – Synthetic hydrography produced for all of Brazil
  – Stream flow models available for 70% of land area of Brazil
  – By end of February 2009
    • Hydropower parameters available for 70% of land area of Brazil
      – Reach gross hydraulic head
      – Reach estimated average flow rate
      – Reach estimated gross power potential
    • Stream reaches compared to mapped hydrography
    • Stream reaches flagged relative to exclusion zones
Virtual Hydropower Prospector do Brasil

- **Water energy features**
  - Water energy resource sites (all stream reaches)
  - Feasible potential projects

- **Water features (12 feature sets)**

- **Power system**
  - Hydro plants
  - Other plants
  - Power lines
  - Substations

- **Transportation**
  - Roads
  - Railroads

- **Areas and places**
  - State boundaries
  - Municipality boundaries
  - Capitals
  - Villages
  - Settlements

- **Land Use**
  - Excluded areas
    - Conservation areas
    - Aboriginal lands
  - PROBIO lands
Virtual Hydropower Prospector do Brasil (Continued)

• Status
  – Initial version available for stakeholder review
    • All context data layers active
    • All map navigation active
    • All information tools active
Virtual Hydropower Prospector do Brasil (Continued)
Project end state

- Assessment report (in English)
  - Will address the national hydropower potential
  - Appendix will provide state summaries

- Virtual Hydropower Prospector do Brasil (in English)
  - Will display results of resource assessment
  - Will provide relation to context features for customized preliminary site evaluation

- Assessment data may be incorporated into similar GIS application hosted in Brazil (in Portuguese)

- Project completion scheduled for Fall 2009
Conclusions

• **Tools and techniques enabling Virtual Hydropower Prospecting have been developed**

• **Virtual Hydropower Prospecting has successfully been applied for the United States**

• **The Virtual Hydropower Prospector provides a tool to ensure optimally beneficial new hydropower development**

• **Brazil’s natural stream water energy resources are being assessed to facilitate energy planning and development**

• **The techniques employed and tools developed for the U.S. and Brazil can be applicable anywhere in the world.**
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