Iowa Hill Pumped-storage Project Investigations

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Project Goals

The overarching goal of the Iowa Hill Pumped-storage Project Investigations was to advance the project through the Federal Energy Regulatory Commission licensing phase, by:

- Reducing geotechnical uncertainty and therefore refine Sacramento Municipal Utility District's (SMUD's) understanding of construction costs
- Defining value streams associated with the project.

Objectives of Geotechnical Investigations

- Identify geotechnical defects in subsurface that may result in delays and costly remedial measures
- Determine depth of weathered zone, landslides, and toppled rock in project area
- Develop detailed information through the powerhouse cavern, tunnels, and shafts on geologic structures, contacts and shears as well as on minimum in-situ stresses that will inform design of underground features
- Evaluate extent and impact of water bearing geologic structures.

Objectives of Value Stream Modeling Analysis

- Determine ancillary service requirements to balance variable renewable generation
- Value pumped-storage relative to gas generation in providing on-peak energy and ancillary services
- Define and quantify value streams of Iowa Hill with future anticipated levels of variable renewable generation
- Analyze net benefits of variable speed versus fixed speed turbines.

Next Generation Hydropower (HydroNEXT)

Optimization

- Optimize technical, environmental, and water-use efficiency of existing fleet
- Collect and disseminate data on new and existing assets
- Facilitate interagency collaboration to increase regulatory process efficiency
- **Identify revenue streams for ancillary services**

Growth

- Lower costs of hydropower components and civil works
- Increase power train efficiency for low-head, variable flow applications
- Facilitate mechanisms for testing and advancing new hydropower systems and components
- **Reduce costs and deployment timelines of new PSH plants**
- Prepare the incoming hydropower workforce

Sustainability

- Design new hydropower systems that minimize or avoid environmental impacts
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies to evaluate and address environmental impacts
- Increase resilience to climate change

Next Generation Hydropower (HydroNEXT)

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The Impact

- Demonstration of the value of variable-speed turbine pumped storage at the Iowa Hill Project, in the form of
  - Operational flexibility for integrating variable renewable resources in SMUD Balancing Authority
  - Ancillary services
  - Reliable capacity
  - Improved operations of other components of 688 MW Upper American River Project
  - Reduction of curtailment of wind and solar resources

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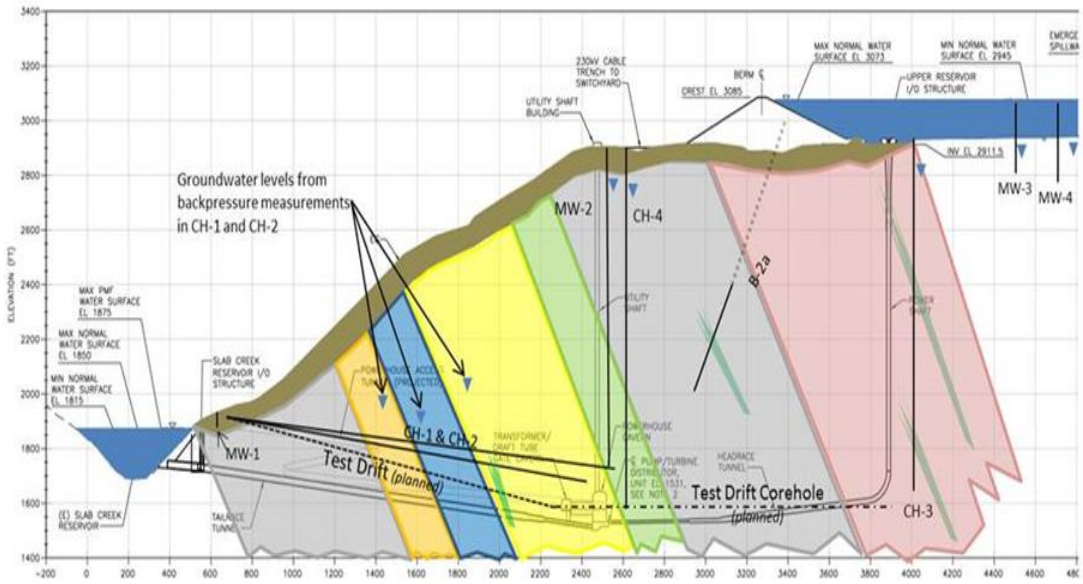
The Impact

- Demonstration of the importance and value of detailed geotechnical information in designing an underground pumped-storage facility. Improved understanding of geotechnical conditions will reduce uncertainty in estimating underground construction costs.

Technical Approach (Geotechnical)

- Four core drilling operations at Iowa Hill project site
  - Two horizontal bores from lower reservoir (1,473 / 2,010 ft)
  - Two vertical bores from on top of Iowa Hill (1,487 / 1,458 ft)
- Horizontal test drift from lower reservoir with additional bores into powerhouse cavern area (1,600 ft)
- Field and laboratory testing of core samples

Technical Approach (Geotechnical)



- Residual Soil/Weathered Rock
- Marble with Interbedded Phyllite and Meta-Wacke
- Phyllite with Interbedded Meta-Wacke and Marble
- Metawacke with Interbedded Quartzite
- Interbedded Meta-Wacke and Phyllite
- Quartzite
- Quartz Diorite Dike (typ)
- Interbedded Metawacke/Phyllite/ Quartzite/Marble

Accomplishments (Geotechnical)

- Iowa Hill comprised of metamorphic rock that is competent and capable of spanning underground powerhouse cavern
- Informed location and orientation of underground facilities
- Contributed to a lower construction cost contingency estimate of 21.5 percent
- Hydraulic conductivity of rock was low, indicating limited impacts on groundwater resources
- Helped to refine functional design

Technical Approach (Value Modeling)

- Regional study that focused primarily on the SMUD Balancing Authority (BA), but also California and the Western Interconnection.
- This region was examined for five different renewable energy build-out scenarios ranging from a base case of 20% to a high penetration case of 50%, with varying levels of wind and solar.
- Multiple cases simulated within the PLEXOS power market model
  - with and without Iowa Hill
  - with and without Ancillary Services (AS) trading between BAs within the study area
  - adjustable-speed vs. fixed-speed technology
  - reciprocating engines as an option to Iowa Hill.
- Primary value streams analyzed were energy, AS, and capacity.
- Separate value streams examined were in the area of renewable curtailment and improvement in operation of the Upper American River Project.

Accomplishments (Value Modeling)

- Greater Iowa Hill value in energy and ancillary service revenues with increasing levels of renewable penetration in SMUD BA
- Greater Iowa Hill value under higher penetrations of wind than solar
- Adjustable-speed turbines provide more benefits than fixed-speed turbines (65% more saving in High-Wind)
- Reduction in variable generation curtailment (valued up to $1.5M/year in SMUD Balancing Authority)
- Reduce cycling of existing gas-fired plants by as much as 50%
- Increased Upper American River Project generation due to improvements in operating efficiency and reduction in spill events (best in dry years).

Project Plan & Schedule

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Task	Description	Completion Date
	Assistance Agreement Initiation	February 2012
1	GEOTECHNICAL INVESTIGATION	
1.1	Environmental Permitting (delayed milestones)	July 2014
1.2	Field Mapping, Access, and Spoil Pile Stabiliz.	March 2014
1.3	Rock Coring – Tunnel Alignments	January–March 2014
1.4	Rock Coring – Pressure Shaft/Tunnel	February 2014
1.5	Risk Workshop	March 2014
1.6	Geotechnical Test Drift.	Not performed
1.7	Rock Coring – Powerhouse Cavern	Not performed
1.8	Rock Coring – Vertical Shaft	May 2015
1.9	Laboratory and Field Testing	March 2014/May 2015
2	VALUE STREAM MODEL ANALYSIS	
	Project Cancelled	February 2016
	Final Technical Report Submitted	July 2016

Reasons Project was Cancelled

- Increase current debt by approximately 50 percent
- Removes other capital projects from consideration, such as grid modernization and aging infrastructure
- Rate increases over several years that would be higher than increases of surrounding utilities
- Load growth has slowed in service area, delaying need for large capacity projects
- Current studies indicate SMUD only needs 50 MW of capacity in near term
- Over past decade, the costs of competitive technologies such as battery storage have come down faster than expected, and they are scalable.

Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,377.304k	$3,419.393k	$405.138k	$856.008k	$48.263k	$77.248k

- Total expenditures at end of project amounted to less than half budget (Tasks 1.6 and 1.7 not performed)

	Original Budget	Final Expenditure
DOE	$4,961.138k	$2,042.219k
SMUD Cost-share	$7,845.178k	$4,705.236k
SMUD Share of Total	61.3%	69.7%

Research Integration & Collaboration

- Partners, Subcontractors, and Collaborators:
- Geotechnical Investigation Contractors
  Jacobs Associates, Crux Subsurface, Foxfire
- Value Stream Modeling Contractors/Collaborators
  Electric Power Research Institute, Energy Exemplar/Argonne National Laboratory

Communications and Technology Transfer:

- DOE Reports (geotechnical investigation; value modeling)
- DOE Final Technical Report
- Workshops – CPUC (January 2014)
- Industry Conferences – National Hydropower Association (2014), Northwest Hydroelectric Association (2015), HydroVision (2016)

Next Steps and Future Research

FY17/Current research: The Iowa Hill Pumped-Storage Project was cancelled in FY16.

Proposed future research: No further work is contemplated.