



Pumped Storage Development then and now

Mike Manwaring, PG
Regional Sector Lead, Energy
Michael.Manwaring@stantec.com



Stantec's History in Pumped Storage

Global PSH Experience:

- > 17,500 MW of Constructed PSH
- > 17,000 MW of Refurbished PSH

Engineer-of-Record:

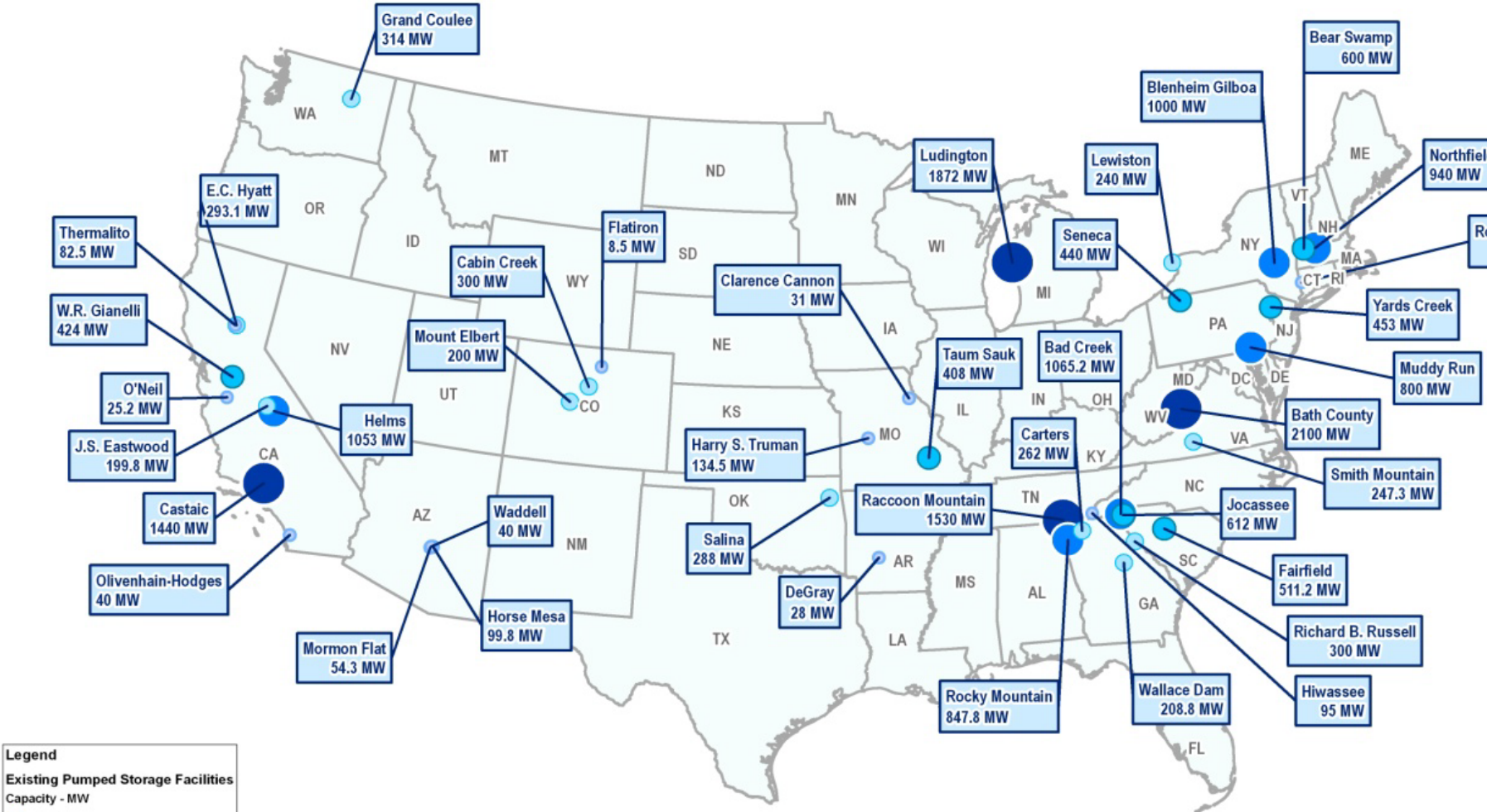
- Last two U.S. PSH projects built:
 - ✓ 40 MW Lake Hodges (California)
 - ✓ 1,035 MW Rocky Mountain (Georgia)
- Largest PSH plant in the world
 - ✓ 3,003 MW Bath County (Virginia)



Bath County PSH, Virginia

Operating U.S. Pumped Storage Fleet

Existing Pumped Storage
Projects in the US



Legend

Existing Pumped Storage Facilities

Capacity - MW

- 5 - 150
- 151 - 350
- 351 - 650
- 651 - 1,050
- 1,050 - 2,150

States

General PSH Fleet Statistics

- 43 Operating PSH Plants
- 1/3 Federal & 2/3 Non-Federal
- Oldest: 1929 15.5 MW (CT)
- Youngest: 2012 40 MW (CA)
- Smallest Plant: 15.5 MW
- Largest Plant: 3,003 MW
- Smallest Unit: 4.2 MW
- Largest Unit: 500.5 MW

Map information was compiled from the best available accuracy and completeness. © 2010, HDR/DTI
Sources: Federal Energy Regulatory Commission
<http://www.ferc.gov>
Environmental Systems Research Institute

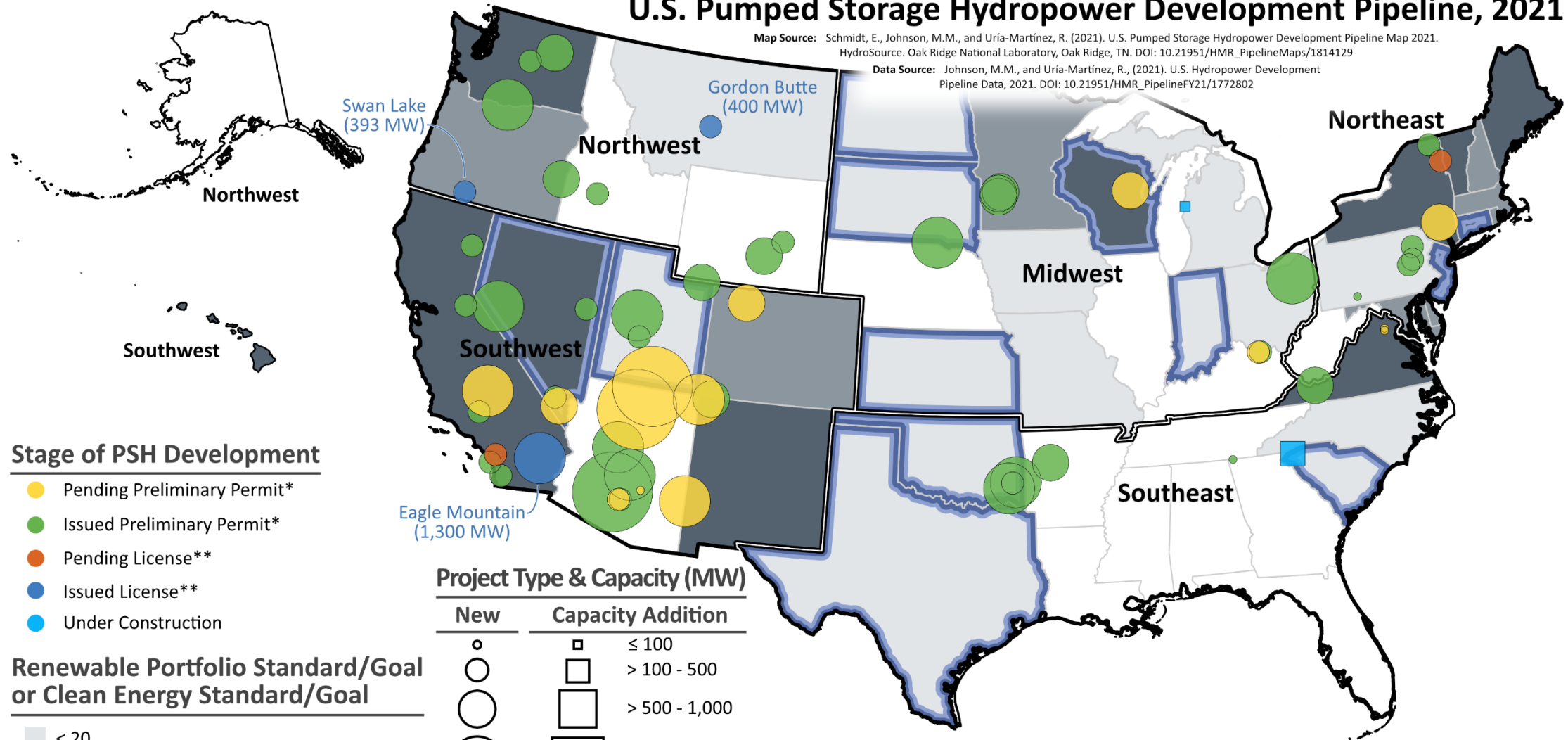


U.S. Pumped Storage Development Pipeline

U.S. Pumped Storage Hydropower Development Pipeline, 2021

Map Source: Schmidt, E., Johnson, M.M., and Uria-Martinez, R. (2021). U.S. Pumped Storage Hydropower Development Pipeline Map 2021. HydroSource. Oak Ridge National Laboratory, Oak Ridge, TN. DOI: 10.21951/HMR_PipelineMaps/1814129

Data Source: Johnson, M.M., and Uria-Martinez, R., (2021). U.S. Hydropower Development Pipeline Data, 2021. DOI: 10.21951/HMR_PipelineFY21/1772802



Stage of PSH Development

- Pending Preliminary Permit*
- Issued Preliminary Permit*
- Pending License**
- Issued License**
- Under Construction

Renewable Portfolio Standard/Goal or Clean Energy Standard/Goal

- < 20
- ≥ 20 - < 50%
- ≥ 50
- None
- Renewable Energy Goal Target

Project Type & Capacity (MW)

New		Capacity Addition	
			≤ 100
			> 100 - 500
			> 500 - 1,000
			> 1,000 - 2,000
			> 2,000

*Projects in the Pending Preliminary Permit and Issued Preliminary Permit stages are undergoing feasibility studies and have high attrition rates.

**Pending License includes projects that have applied for authorization from FERC or Bureau of Reclamation. Issued License includes projects that have received federal authorization from one of the two agencies.





Lake Hodges PSH San Diego, California

Owner: San Diego Co Water Authority
Commissioned at 40 MW (2012)
Part of “Emergency Storage” Project
Most recent U.S. PSH Built



U.S. PSH Development History

Era	PSH Development Cause	Focus of Plant Operations	New PSH Development Challenges and Barriers	Technology Advancements
1960 - 1990s	U.S. PSH coincided w/ development of nuclear and large coal plants	System flexibility; Weekend pump cycle ; Energy arbitrage	Plant costs; Deregulation ; PSH new technology	Tech: Complex underground caverns ; Design: Pump/turbine efficiencies ; tunnel hydraulics
2000s	Early renewables growth (wind/ solar); upgrades of existing plants	Bulk system management; Daily (evening) generation ; charging overnight	Large CapEx ; undefined ROI / market revenue uncertainty; FERC Licensing timelines	Tech: U/G Construction Design: Adjustable Speed Pump/ Turbines
2010s	Bulk grid management; renewables growth; Plant modernization (GWs)	Duck Curve; Evening natural gas ramping ; regional RE integration	Low-cost natural gas, IRPs did not foresee LDES need ; market revenue uncertainty	Tech: RCC dams; Design: CFD modeling, Closed Loop PSH
2020s	Renewable integration; Grid Resiliency; System/Grid inertia needs	Multiple unit stops/starts ; Regional grid resiliency; renewable integration	Long-term PPAs (revenue certainty); Energy Storage competition ; FERC Licensing	Tech: Advanced TBMs, Liner systems Design: Modular PSH; Economic & Operations models
2030s	Replacement thermal retirements ; provide system flexibility; decarbonized grid	System flexibility; grid stabilization / grid management; energy security	Competing ES resources; long-term PPAs; Recognizing revenue for system benefits	Market Designs : revenues for energy security, decarbonized grid, RE integration, flexibility

Evolving Landscape in Pumped Storage

- ✓ **(New)** Interest in **LDES** from Utilities, Existing PSH Owners, Green Funds
- ✓ Grid Managers/Regulators understand LDES is critical to decarbonize
 - PSH offers grid security & resiliency benefits
 - Recognition of the need for different energy storage “tools”
- ✓ DOE Actively Engaged - National Labs & Direct Funding Opportunities
 - Assess different storage technologies roles - define the “toolbox”
 - Understand Environmental Impacts (CLPSH, GHGs, LIHI Certification)
- ✓ FERC & Regulatory Agencies:
 - Recognize PSH is different than conventional Hydropower
- ✓ Project Operations (existing plants and new project designs)
 - Much more frequent unit Stops/Starts BUT lower overall MWhs
 - Examples: Northfield Mountain PSH (MA) | Bad Creek PSH (NC/SC)
 - New development focusing on very fast response in pump & generation



Rocky Mountain PSH Rome, Georgia

Owner: Oglethorpe Power
Commissioned at 848 MW (1995)

Upgraded to 1,035 (2011)

3 x 365 MW Units Each

Most recent large-scale PSH built



Challenges for new Pumped Storage Development

1. Project Costs vs Revenue: How does a PSH project get paid?

✓ Payment for Full Suite of Services:

- Energy Security, Grid Resiliency, Renewable Integration, Fleet Optimization, Decarbonization
- Options: Long-term PPA, Rate Recovery, Performance Based Payments

✓ Early PSH Project costs must be realistic

2. Project Development Timeline: 7-to-10-years is too long

✓ *Utility Concerns*: energy markets vs technology innovation

✓ Asset planning horizons (IRPs) are starting to include LDES

✓ Options: Expedited Licensing (closed loop)



Dinorwig PSH Wales, United Kingdom

Owner: First Hydro (Engie)
Commissioned at 1,800 MW (1984)
6 x 300 MW Units Each

*Uber fastest response
~ 110 MW / second*



QUESTIONS?

Pumped Storage Developments then and now

Mike Manwaring, PG
Regional Sector Lead, Energy
Michael.Manwaring@stantec.com