SAND2019-10953C

Siting Energy Storage for Resilient Distribution Systems

Randy C. Brost, rcbrost@sandia.gov, 505-284-1483

Project Goals:

- Algorithm to design storage and other distribution system components to assure societal benefit during long-term outage.
- Explore semantic graphs for resilient distribution system design.

Why Semantic Graphs?

- Highly flexible representation for data spanning mixed topic areas.
- Graph analysis is a strong tool for managing large problem combinatorics.
- Explicit analysis of both data and relationships.
- Avoids weighting function problems.

FY19 Progress:

- Grid semantic graph:
  - Electrical model
  - Geospatial data
  - Societal benefit data
  - Existing + potential
  - Threat models (flood, fire, landslide,…)
- Resilient distribution configuration design
- Storage / PV / diesel temporal analysis
- Python code in progress, open source planned

FY20 Future Work:

- Improved power/energy analysis
- Multi-temporal
- Multi-threat
- Life-cycle cost analysis
- Geospatial equity
- Real data

Algorithm Summary:

Input: Grid model, Service priorities, Threat, Duration, Control flags.
Output: Set of designs, with selected nodes, edges, switches, capacities.

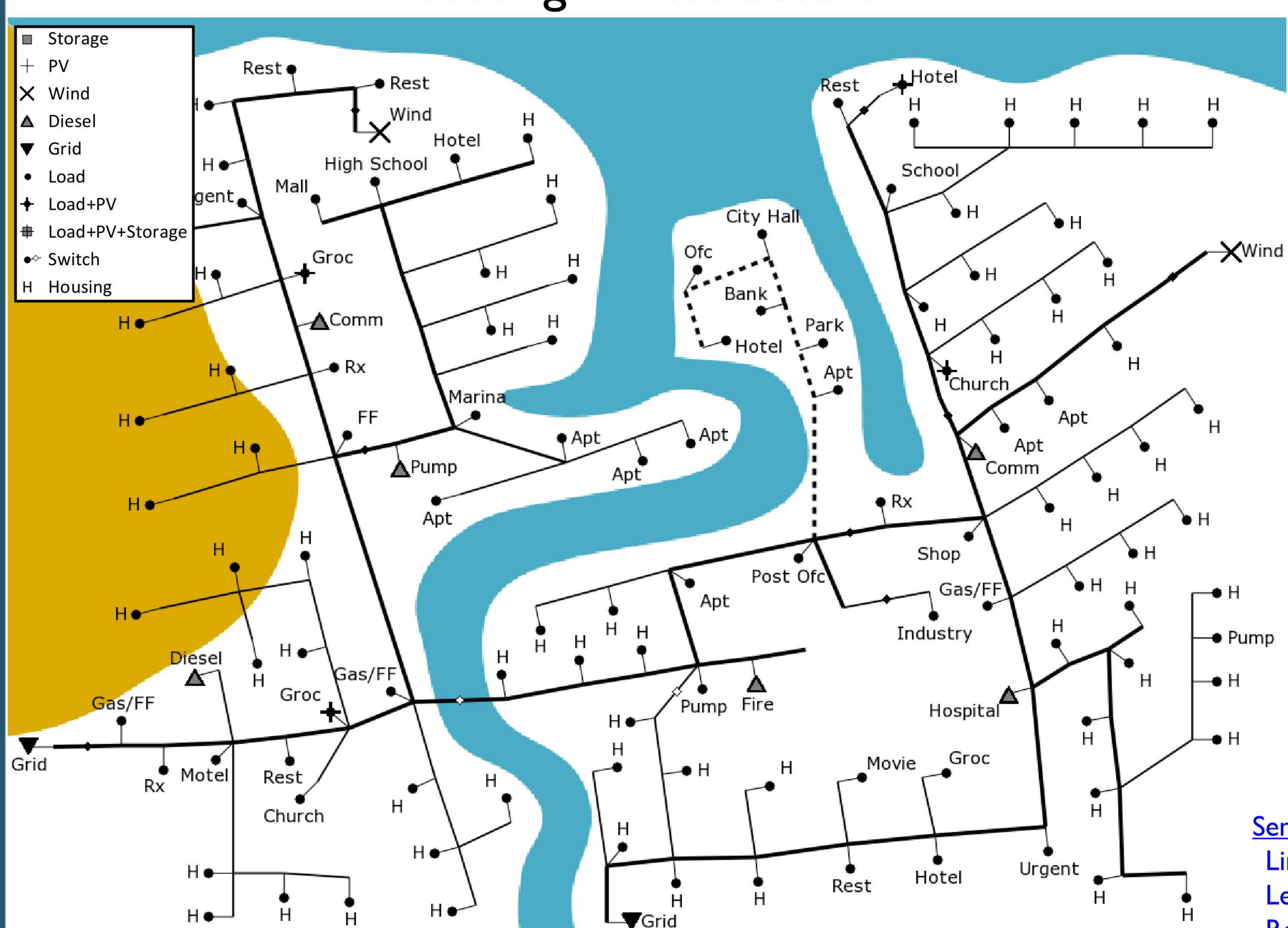
Algorithm:

1. First attempt a solution with only existing primary generation. If this fails, attempt again allowing existing + new generation.
2. Add all nodes which can operate stand-alone for the given duration.
3. Determine services still unfulfilled after stand-alone nodes.
4. Find all nodes which contribute a required service.
5. Select node set covering all required services.*
   - Near existing generation, if capable of covering duration.
   - If none exist, near each other.
6. Add centralized generation:
   a. Select primary, based on design duration:
      - Very short-term: Diesel.
      - Short-term: Diesel backed by storage (for efficiency).
      - Long-term: Storage backed by PV, then diesel (for endurance).
   b. Place primary:
      i. Find primary closest to each load (minimum line resistance). *[For fast analysis, use distance maps, not crossing damage.]*
      ii. Select edges connecting load and primary.
   c. Place secondary:
      i. Find secondary closest to each primary. (Attempt existing first, then new)
      ii. Select edges connecting primary and secondary.
   d. Capacity analysis:
      i. Find connected components.
      ii. Estimate storage, PV, diesel power and energy requirements.**
      iii. Set new generation capacity parameters.
7. If critical nodes remain without power, add collocated generation.
8. If capacity permits, include additional nodes.

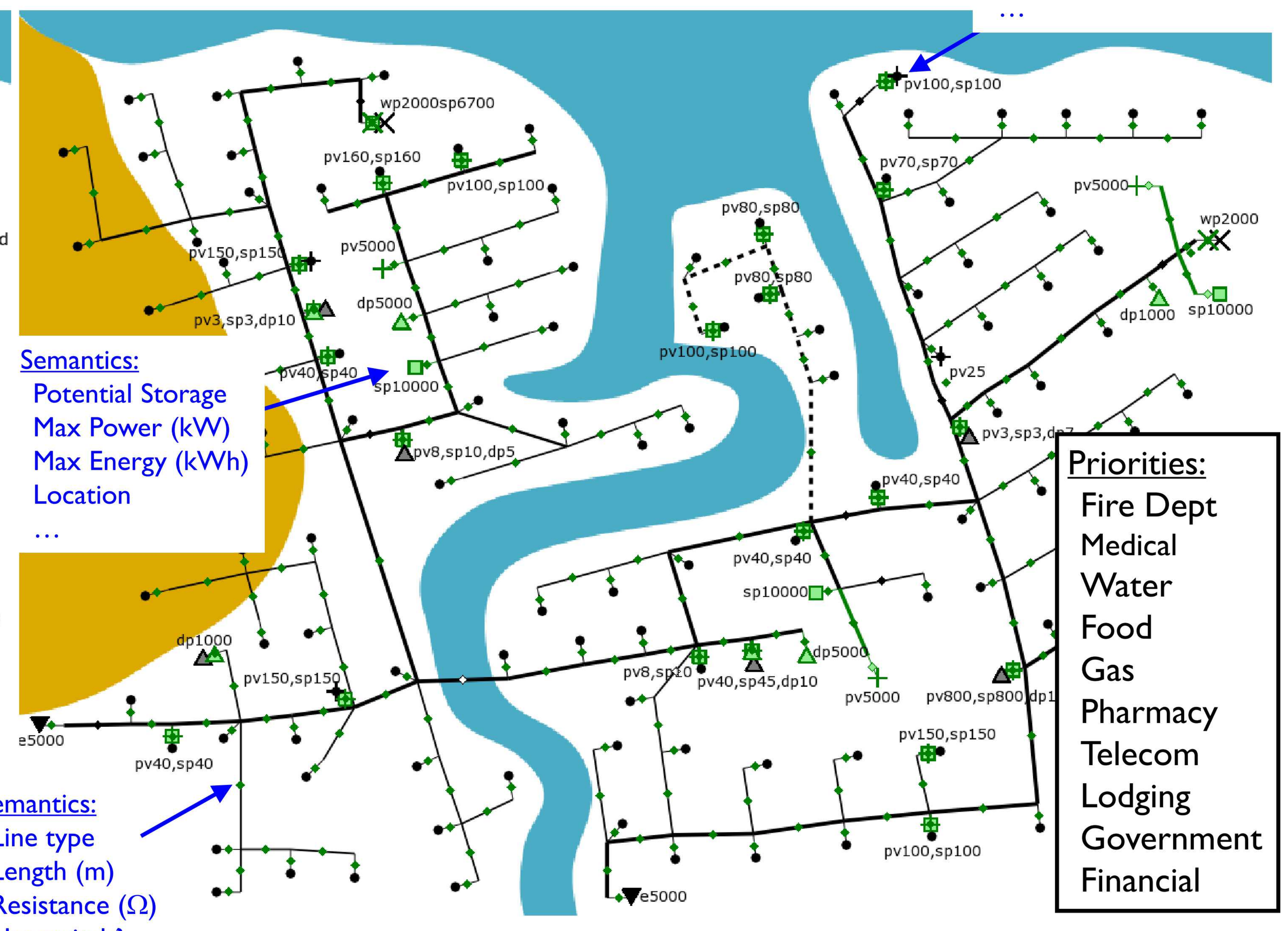
* Single solution, or enumeration (future branch-and-bound pruning).
** Calculations are currently a simplified approximation.
Blue indicates implementation not complete.

Example:

Existing Infrastructure

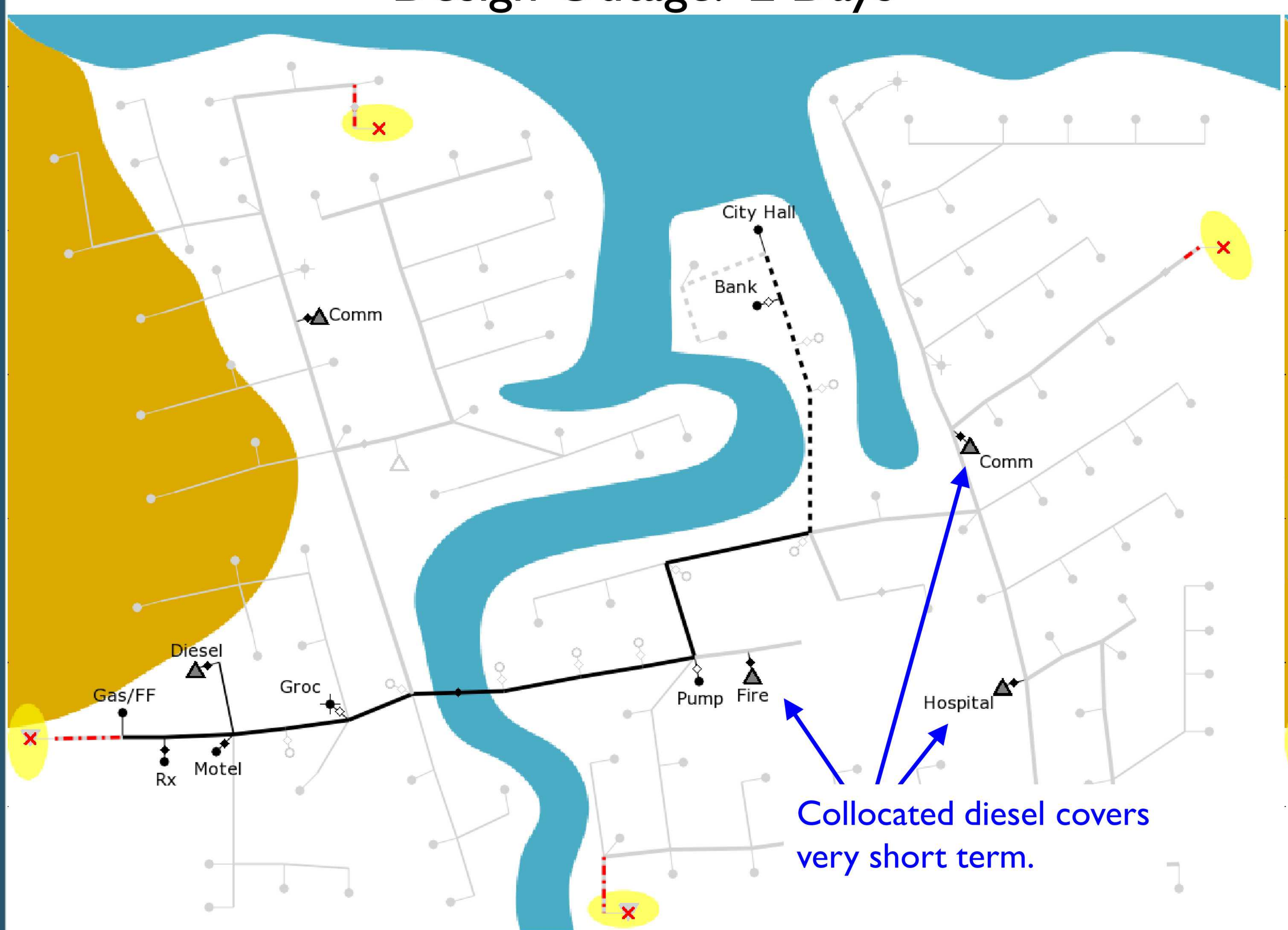


Potential Additions

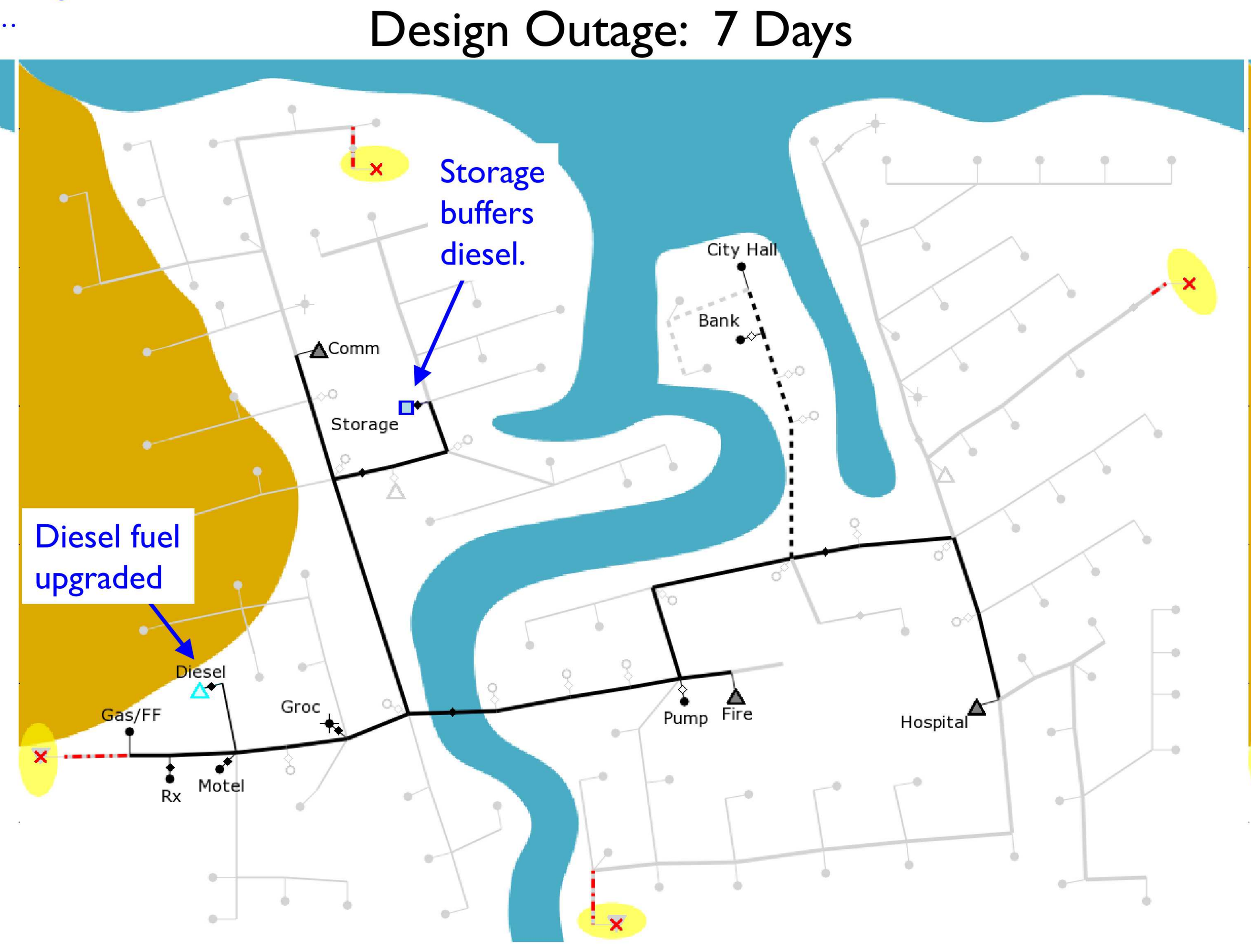


Output:

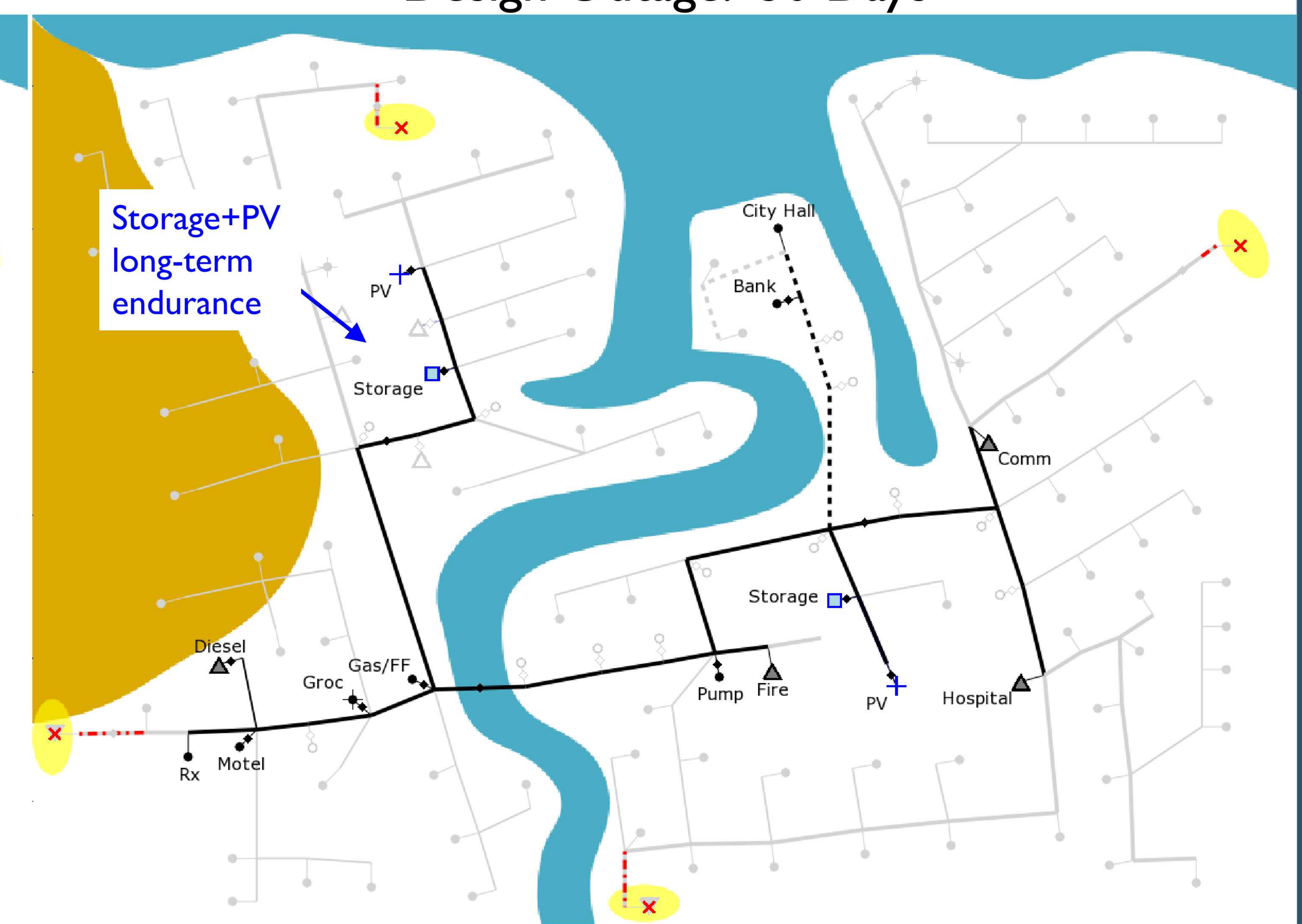
Design Outage: 2 Days



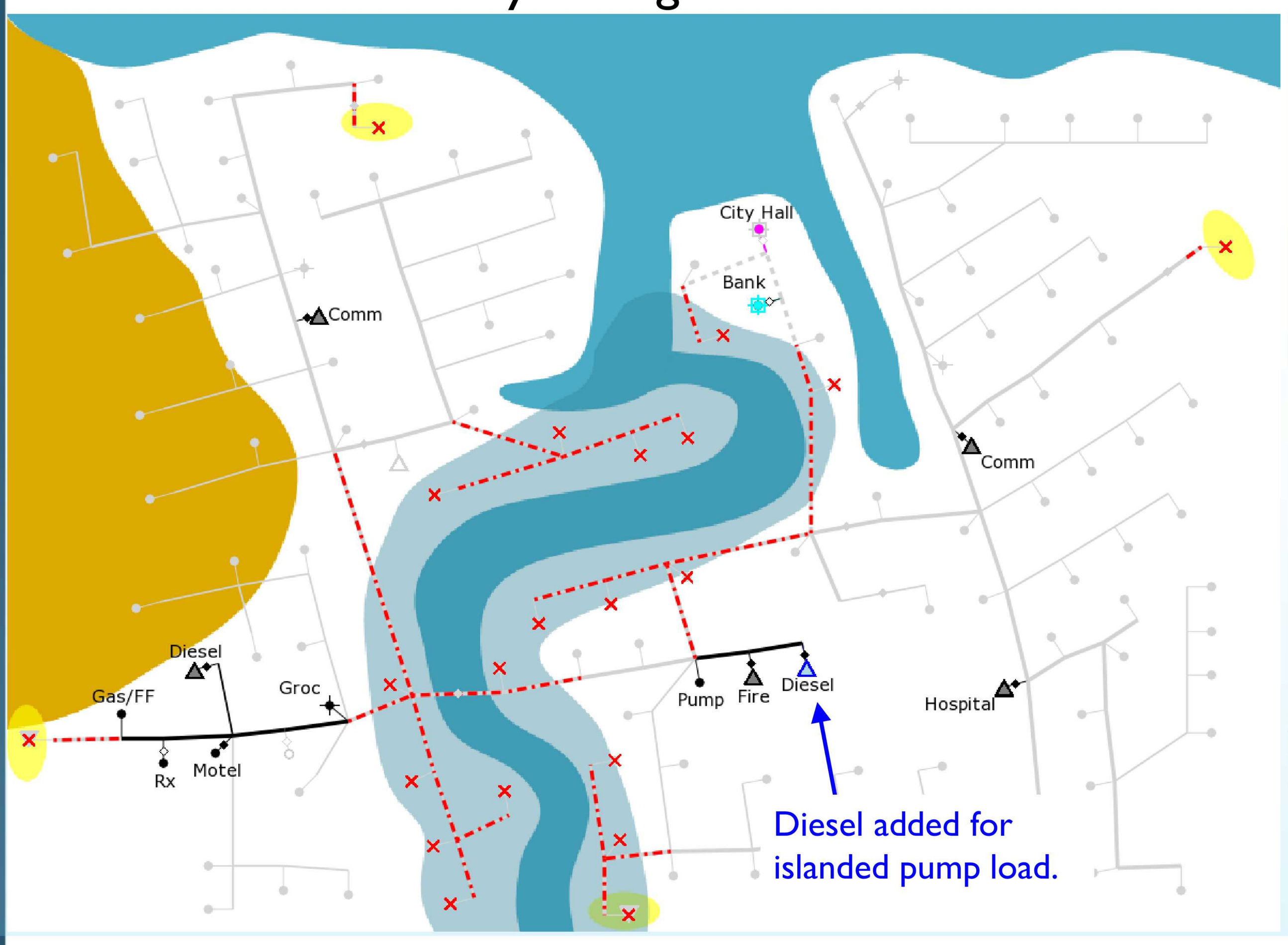
Design Outage: 7 Days



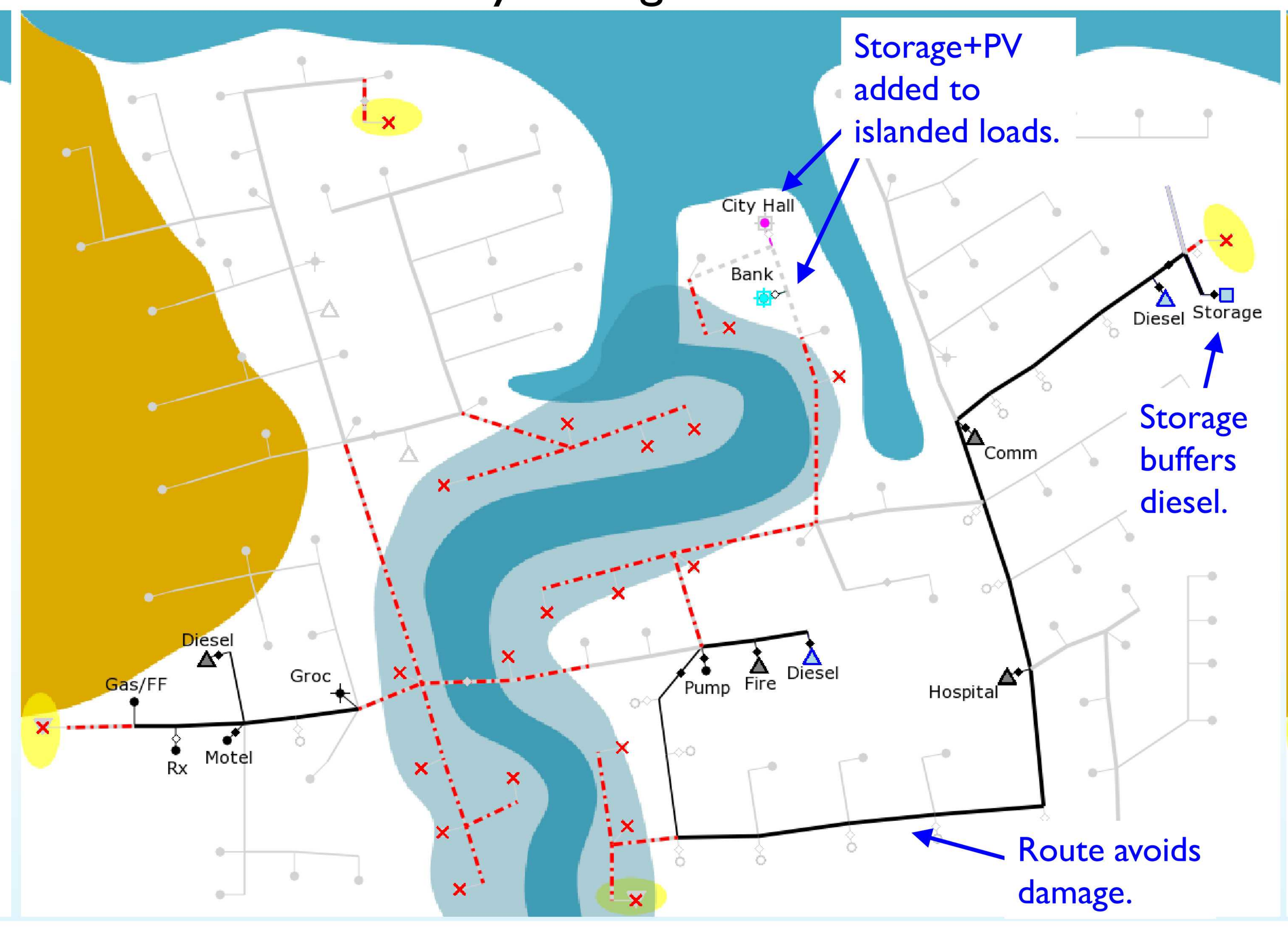
Design Outage: 30 Days



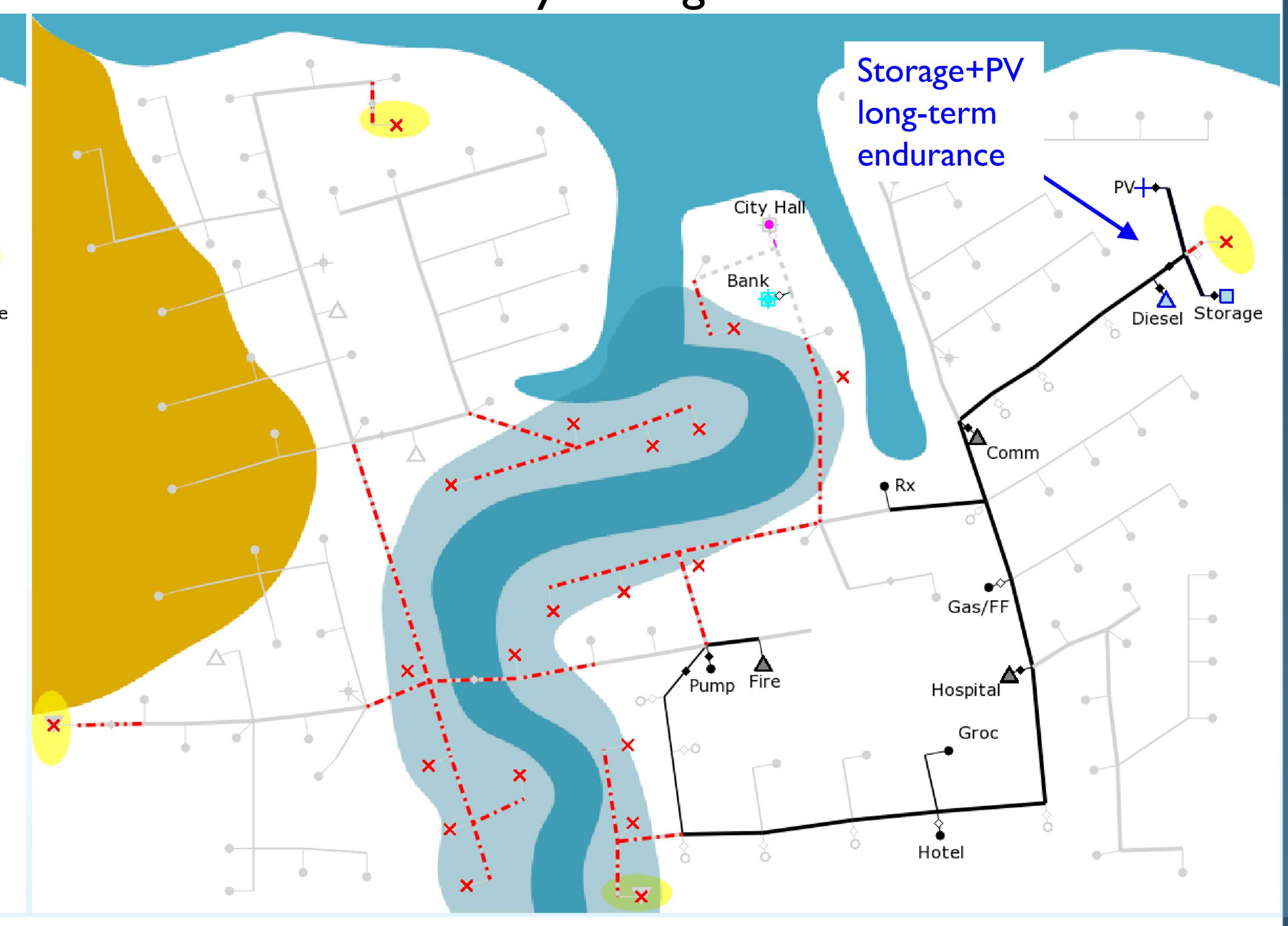
2-Day Outage + Flood



7-Day Outage + Flood



30-Day Outage + Flood



The author would like to thank Dr. Imre Gyuk and his colleagues at the Energy Storage Program at the U.S. Department of Energy for funding this research.