Underground vs. Overhead Transmission

Based on white paper provided by HDR, Inc.
Report contains conceptual estimates

• Chelan PUD does not have experience with underground transmission.
• Cost estimates are based on the conceptual design of one consultant using experience nationwide.
• Specific construction methods and materials along with other assumptions are stated in the report provided to Chelan PUD. These specific methods may not be the methods chosen for a specific project.
• Cost estimates could be significantly different for a site specific feasibility.
• Substation taps require double circuit construction for redundancy to eliminate prolonged outages
### Underground
- Based on level terrain, urban setting
- If on hilly/mountainous terrain, cost increases two-fold or more
- Substation tap requires redundant supply
- Life Expectancy **40+ years**
- Not included:
  - Environmental studies
  - Local, state, federal permits
  - Easements, land acquisition

### Conceptual Estimate

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Double Circuit 1000 A 2,500-kcmil CU</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNDERGROUND</td>
<td>$4,218,000</td>
</tr>
<tr>
<td>SURVEY, GEOTECH, ENGINEERING AND OTHER</td>
<td>$463,000</td>
</tr>
<tr>
<td>CONTINGENCY (30%)</td>
<td>$1,404,000</td>
</tr>
<tr>
<td>DOUBLE CIRCUIT COST PER MILE</td>
<td>$6,086,000</td>
</tr>
</tbody>
</table>

**RESULT:** Total Project Cost for 1 Mile Double Circuit = **$6,307,000**

### Overhead
- Based on level terrain, urban setting
- If on hilly/mountainous terrain, costs could increase two-fold
- Life Expectancy **80+ years**
- Not included:
  - Environmental studies
  - Local, state, federal permits
  - Easements, land acquisition

### Conceptual Estimate

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Double Circuit 1000A 964-kcmil AAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERHEAD</td>
<td>$673,000</td>
</tr>
<tr>
<td>SURVEY, GEOTECH, ENGINEERING AND OTHER</td>
<td>$42,000</td>
</tr>
<tr>
<td>CONTINGENCY (30%)</td>
<td>$185,000</td>
</tr>
<tr>
<td>DOUBLE CIRCUIT COST PER MILE</td>
<td>$800,000</td>
</tr>
</tbody>
</table>

**NOTE:** A termination support structure inside the substation is required for a project. Is not part of per-mile costs but is added to the project total --- **$200,000**

**RESULT:** Total Project Cost for 1 Mile Double Circuit = **$1,000,000**
Right of Way (ROW)

**Concern:** Very limited land use within the ROW
- Trees
- Driveways
- Buildings

- Generally 100 ft. ROW
- Land use mostly impacted at structure locations
- Can still have trees and buildings in ROW under many circumstances
Construction Methods - Underground

Conduit and Trenches

- Required for entire length
- Backfill for thermal characteristics

**Figure 18-13 Conduit Placement**

**Figure 18-14 Conduit Backfilling**
Construction Methods - Underground

Vaults

- Required at least every 2500 ft (limitations in the length of cable run)
- 8ft x 20ft x 10ft (or larger)
- For cable splicing and anchoring on hilly/mountainous terrain
Construction Methods - Underground

Splices
• Requires specialized equipment and highly trained personnel
• Relatively short cable runs (2500ft maximum)

NOTE: Hilly terrain requires more vaults and elaborate restraint systems to keep cables from creeping downhill. Costs may double or more.
Construction Methods - Underground

Transitions

- Steel structure required at overhead transmission line
- Substation termination is inside the fence
Construction Methods - Overhead

Direct buried steel poles
- Most poles directly embedded (no foundations)
- Installation using conventional excavation equipment and line trucks
Construction Methods - Overhead

Foundations and guy-wires

• Angles and dead-end structures may have foundations and/or guy wires
**Repair Considerations**

**Underground**

- Must stock materials or accept 4 to 6 month lead time for parts
- Repairs require skilled specialists to perform
  - Chelan PUD not likely to perform repairs in-house

**Overhead**

- Typically hours to repair, maybe 2 days
- We already stock standardized parts
- Crews currently perform this work daily

*26.3.2 Repair Time for 115 kV Cable Fault*

For 115 kV systems, we estimate a minimum of 10 days to repair a cable failure provided that:

- All spare parts such as cable and splices are available from on hand stock.
- Fault finding equipment and trained personnel are available in-house to locate the fault.
- Trained personnel, equipment and special tools are available in-house to:
  - Undo two splices
  - Remove the faulted cable
  - Redo two splices
  - Conduct proof tests before re-energizing the line.

*If other entities need to be contracted* for fault finding and to make the repairs then the repair time may be longer depending on time requirements to have contracts in place and the time requirements for contracted companies to mobilize to locate and make the repairs. Under this scenario, repair times could easily approach 20 days or longer.

**Substations must have a means for redundant supply lines, otherwise a fault could result in power outage for 20 days or longer**
SUMMARY - Substation Tap Installation

Cost for 1 mile tap to substation:
All calculations assume 7% discount rate and 2.5% general inflation

** Conceptual Estimates **

SCENARIO 1: Double Circuit **Underground**, varied terrain installation
$6,307,000 to $12,614,000 Installation Cost
$20,700 annual inspection for 79 years (50% higher than single circuit inspection costs)
$2,000,000 re-cable project at year 40
NPV = ($7,122,000) to ($13,429,000)

SCENARIO 2: Double Circuit **Overhead**, varied terrain installation
$1,000,000 to $2,000,000 Installation Cost
$1,300 annual maintenance for 79 years
NPV = ($1,028,000) to ($2,029,000)
## SUMMARY - Substation Tap Installation

<table>
<thead>
<tr>
<th>Description</th>
<th>Underground Line</th>
<th>Overhead Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>Minimal since cables are buried</td>
<td>Visual impact from lines and poles</td>
</tr>
<tr>
<td>Atmospheric Phenomena</td>
<td>Practically immune to weather conditions and events</td>
<td>Very susceptible to weather events</td>
</tr>
<tr>
<td>Public safety (just for comparison, Overhead Lines are also considered very safe)</td>
<td>Cables are buried and have limited electrocution hazard</td>
<td>Higher potential for electrocution hazard due to bare overhead wires</td>
</tr>
<tr>
<td>Human activities (Theft, Vandalism, Terrorism etc.)</td>
<td>More protected</td>
<td>Full exposure</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Difficult to reroute, reconfigure or upgrade</td>
<td>Relatively easy to reroute, reconfigure and upgrade</td>
</tr>
<tr>
<td>Fault Location</td>
<td>Difficult and requires specialized equipment and trained personnel</td>
<td>Faults can be easily located</td>
</tr>
<tr>
<td>Repair Time</td>
<td>10-20 days if all materials and personnel are available</td>
<td>Typically less than a day to 2 days</td>
</tr>
<tr>
<td>Repair Complexity</td>
<td>Difficult to repair and requires skilled personnel</td>
<td>Relatively easy and District staff is very efficient and experienced</td>
</tr>
<tr>
<td>Installation Costs</td>
<td>6.3 - 12.6 times more costly than overhead</td>
<td>Much less costly</td>
</tr>
<tr>
<td>Life Cycle Costs</td>
<td>6.9 - 13.1 times more costly</td>
<td>Much less costly</td>
</tr>
<tr>
<td>Life Expectancy</td>
<td>40+ years</td>
<td>30+ years</td>
</tr>
<tr>
<td>Reliability</td>
<td>Faults rarely occur however take a long time to repair</td>
<td>Faults are more frequent but are typically smaller and can be repaired much more rapidly</td>
</tr>
<tr>
<td>Practical Uses</td>
<td>Relatively flat urban areas or crossing under waterbodies and short distances</td>
<td>All geographies, topographies and distances</td>
</tr>
</tbody>
</table>