June 2011

SHARYLAND
LOMA ALTA HVDC PROJECT

CONFIDENTIAL

STRATEGIC PROJECTS
B&V ENERGY

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HVDC TECHNOLOGY

Technology: Why HVDC ?

- Power flow is controllable
- Bypasses congested AC circuits w/o inadvertent flow
- Bipole DC performs similar to dbl-ckt AC line under contingencies
- Protects against cascading outages
- Power flow can be maintained at reduced levels during loss of one pole by switching to monopole with metallic return
- Can carry more power with reduced losses for a given size of conductor
- Lower cost per MW of delivered capacity ($/MW) for large systems

Technology: Voltage Source Converters

- VSC marketed as HVDC Light by ABB and as HVDC Plus by Siemens
- Insulated Gate Bipolar Transistor (IGBT) technology does not require strong AC sources for commutation
- Low Short Circuit ratio requirements
- Does not have minimum transfer requirements
- Minimal filtering is required at the terminals
- Smaller terminal footprint and easier to "harden" to improve reliability
- Present technology being used on underground and submarine lines but has limited use and experience on overhead lines
- Allows use of solid dielectric cable technology for submarine cables

Technology: Classic HVDC

- Extensive track record up to ±800 kV
- Converter terminals typically less expensive than VSC terminals but reactive compensation requirements drive up costs
- Thyristor valve technology requires strong AC sources for commutation
- Higher Short Circuit ratio requirements often resulting in need for synchronous condensers or other devices
- Minimum transfer requirements
- Filtering required at the terminals
- Large footprint required at terminals

Technology: Why Metallic Return?

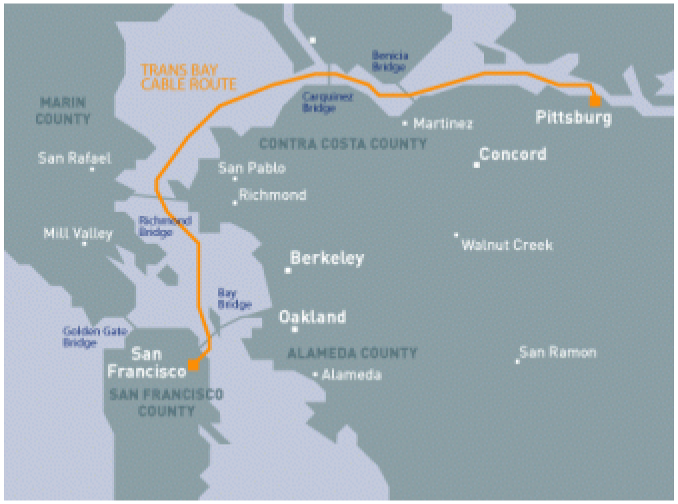
- Improved operational reliability and flexibility
- Bipole operation does not require separate return path; monopole operation will require return path
- Sustained use of earth return during monopole operation often not permitted for environmental reasons (e.g. impact on other buried utilities)
- Planned events, such as planned maintenance, requiring sustained monopole operation may use metallic return
  - ➢ Metallic return configuration achieved by controlled switching procedures
  - ➢ Metallic return can include a separate return conductor or can be implemented by switching to the remaining unused pole if serviceable
- Unplanned events may use earth return for initial period (minutes) and then switch to metallic return (hours to weeks)

Technology: Example Submarine Projects

Project Name:	Cross Sound
Location:	New York – Conn.
Voltage:	± 150 kV HVDC
Capacity:	330 MW
Technology:	ABB HVDC Light (VSC)
Sea Route:	25 miles
Land Route:	1 mile
Project Status:	In commercial operation since 2002

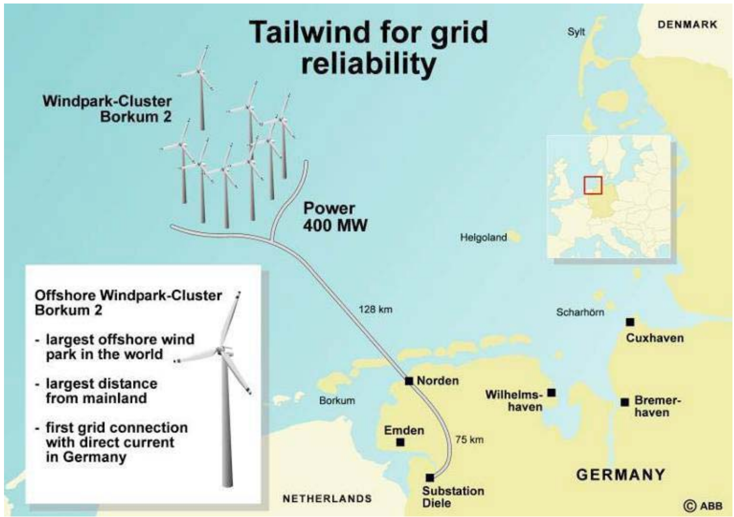
Technology: Example Submarine Projects

Project Name: Trans Bay
Location: San Francisco Bay
Voltage: ± 200 kV HVDC
Capacity: 400 MW
Technology: Siemens HVDC Plus (VSC)
Sea Route: 53 miles
Land Route: 1 mile
Project Status: In commercial operation since 2010



Technology: Example Submarine Projects

Project Name: BorWin1
Location: North Sea
Voltage: ± 150 kV HVDC
Capacity: 400 MW
Technology: ABB HVDC Light (VSC)
Sea Route: 77 miles
Land Route: 46 miles
Project Status: In commercial operation since 2009

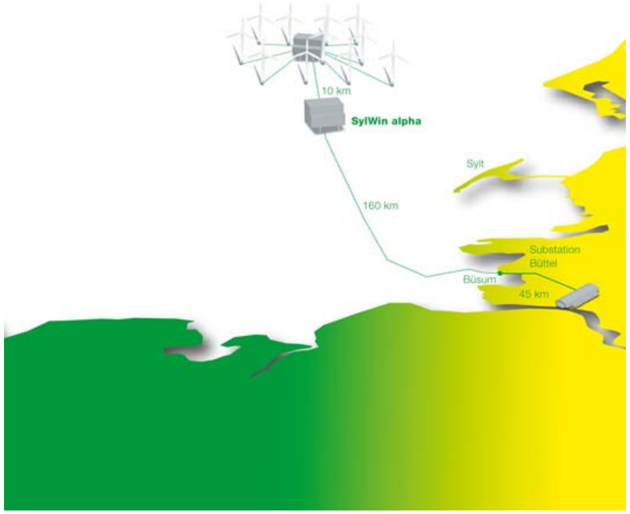


Technology: Example Submarine Projects

Project Name: DolWin1
Location: North Sea
Voltage: ± 320 kV HVDC
Capacity: 800 MW
Technology: ABB HVDC Light (VSC)
Sea Route: 46 miles
Land Route: 56 miles
Project Status: 2013 Completion

Technology: Example Submarine Projects

Project Name:	SylWin1
Location:	North Sea
Voltage:	± 320 kV HVDC
Capacity:	864 MW
Technology:	Siemens HVDC Plus (VSC)
Sea Route:	99 miles
Land Route:	28 miles
Project Status:	2014 Completion



Technology: Example Submarine Projects

Project Name:	MAPP
Location:	Chesapeake Bay
Voltage:	± 320 kV HVDC
Capacity:	2000 MW
Technology:	ABB HVDC Light (VSC)
Sea Route:	39 miles
Land Route:	44 miles
Project Status:	2015 Completion

Technology: Example Submarine Projects

Project Name: Atlantic Wind Connection
Location: Mid-Atlantic Coast
Voltage: ± 320 kV HVDC
Capacity: 7000 MW (total)
2000 MW (max per project phase)
Technology: VSC
Sea Route: ~600 miles
Land Route: ~50 miles
Project Status: 2016-2020
Staged Completion

Technology: Submarine Cable Installation

Cable Laying

Cable Burial Plowing

COST ESTIMATES & SCHEDULE

Order of Magnitude Cost Estimates

- Cost estimates include:
  - ➢ HVDC converter stations
  - ➢ AC substations adjacent to each converter station
  - ➢ Synchronous condensers at southern terminal for HVDC Classic
  - ➢ Lattice tower structures and 2 conductors per pole on overhead option
  - ➢ 1 cable per pole on underground/submarine option
  - ➢ Metallic neutral cable
- Cost estimates do not include:
  - ➢ Upgrades to existing system not included in the report
  - ➢ Cost of remote interconnection
  - ➢ Cost of right-of-way/site
  - ➢ Owner's costs
    - Development/permitting costs
    - CCN Process
    - Financing costs
    - Construction management

Estimated Project Cost – Overhead Option

	VSC Technology	HVDC Classic
General		
Peak Delivered Power (MW)	1000	1000
Line Voltage	+/- 320 kV HVDC	+/- 400 kV HVDC
Miles of Bipole HVDC Overhead Lines	220	220
Line Rating		
Line Losses at Peak Line Loading	3.2%	2.0%
Terminal Losses at Peak Load (2 Terminals)	2.0%	1.5%
Total Peak Losses	5.2%	3.5%
Conductor Rating (MW)	1,052	1,035
Conductor Size Per Pole	(2) 1943 TWD	(2) 1943 TWD
Total Project Capital Costs		
Bipole HVDC Overhead Lines ($M)	$264	$266
Two HVDC Converter Stations ($M)	$300	$260
AC Substations ($M)	$40	$40
Reactive Compensation [Synch. Cond.] ($M)	$0	$60
System Impacts ($M)	TBD	TBD
Total Capital Cost ($M)	$604	$626
Capital Cost per MW of Delivered Capacity ($/MW)	$604,000	$626,000

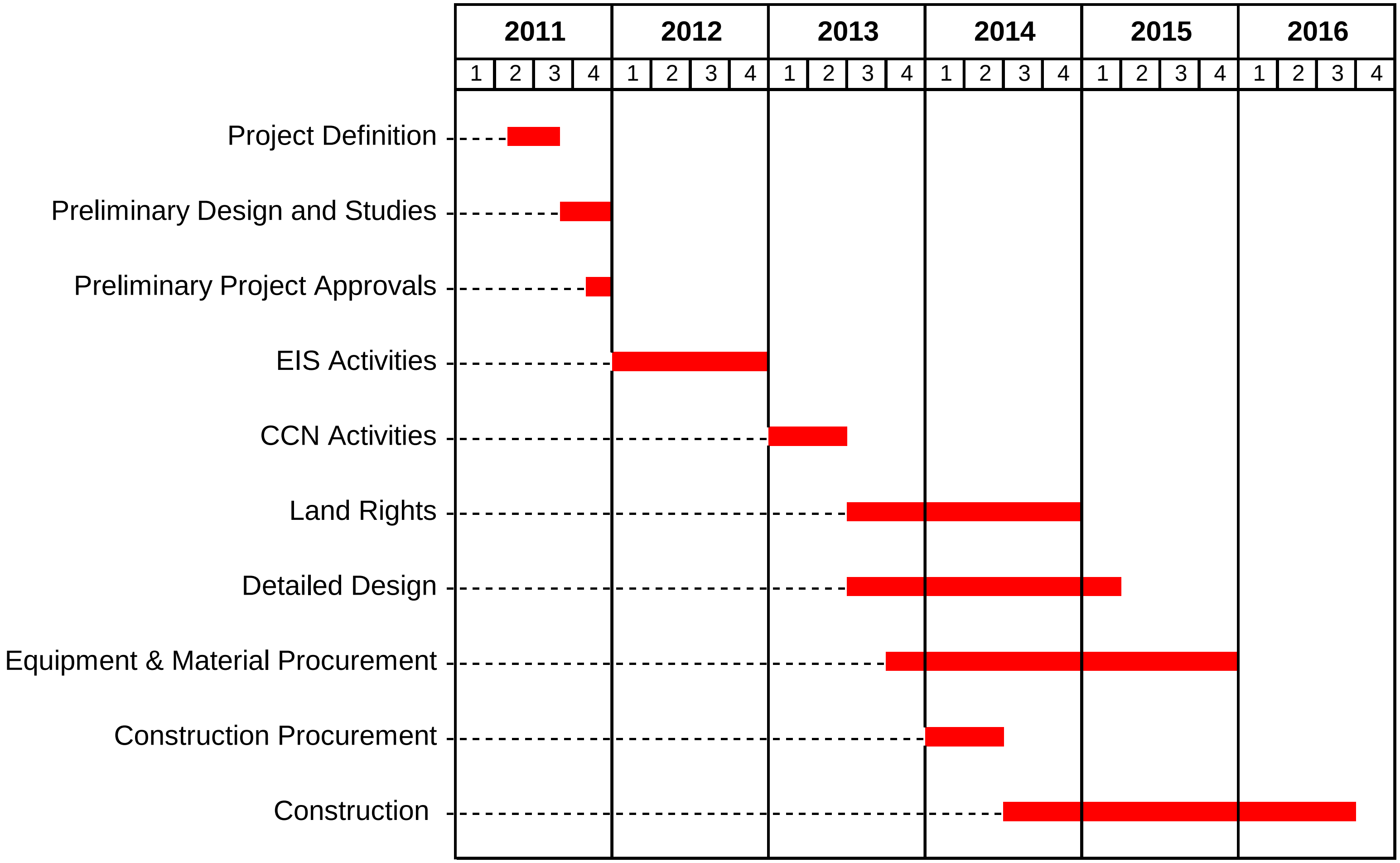
- **Further cost optimization of converters would reduce project cost**

Estimated Project Cost – Submarine Option

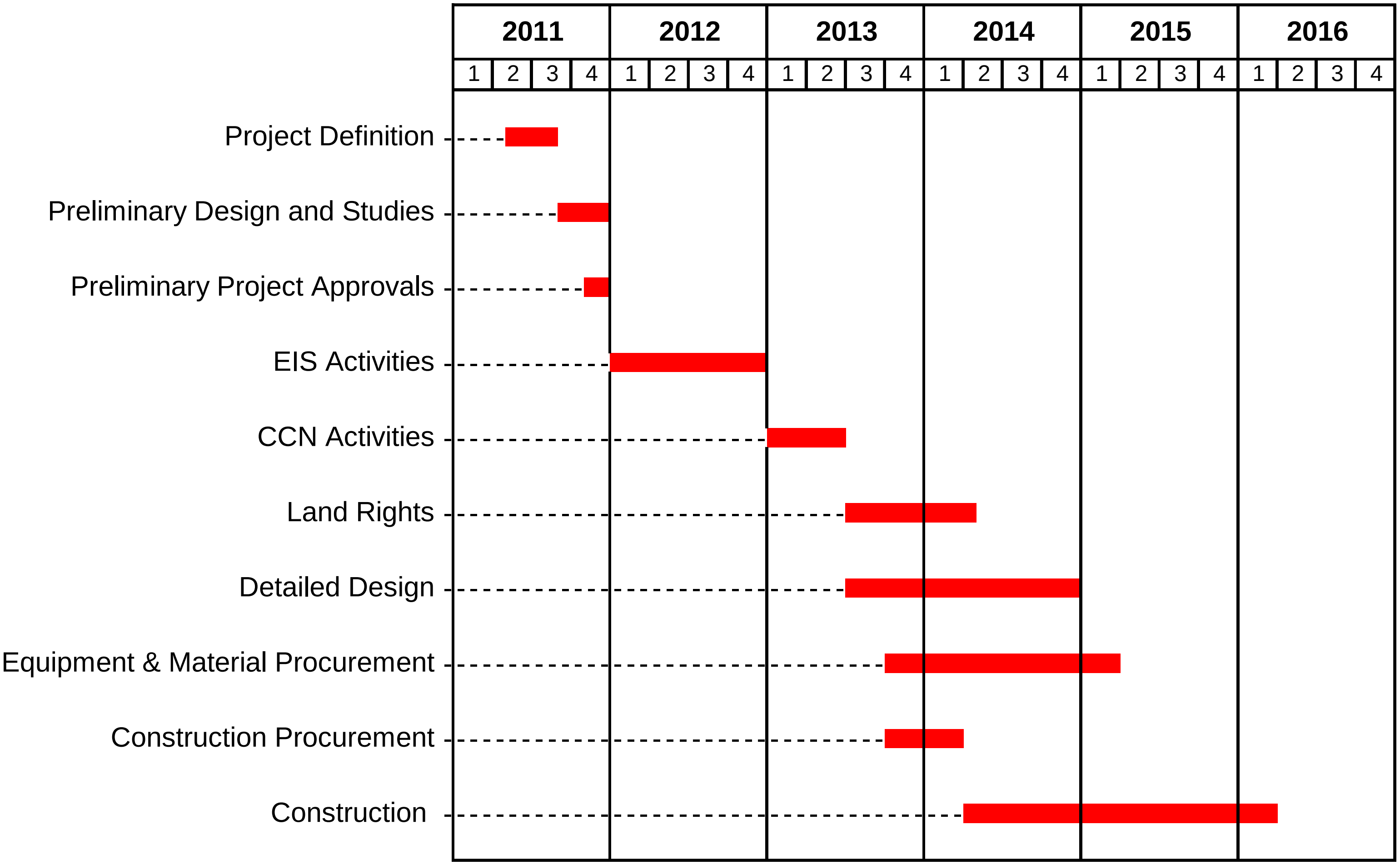
General	
Peak Delivered Power (MW)	1000
Line Voltage	+/- 320 kV HVDC
Miles of Alignment	160
Miles of Bipole HVDC Submarine Lines	150
Miles of Bipole HVDC Underground Lines	10
Line Rating	
Line Losses at Peak Line Loading	5%
Terminal Losses at Peak Load (2 Terminals)	2%
Total Peak Losses	7%
Cable Rating (MW)	1,070
Submarine Cable Size Per Pole	(1) 2400 mm^2 CU
Underground Cable Size Per Pole	(1) 2500 mm^2 CU
Total Project Capital Costs	
Bipole HVDC Submarine Lines ($M)	$525
Bipole HVDC Underground Lines ($M)	$45
Two HVDC Converter Stations ($M)	$300
AC Substations ($M)	$41
System Impacts ($M)	TBD
Total Capital Cost ($M)	$911
Capital Cost per MW of Delivered Capacity ($/MW)	$911,000

- **Further cost optimization of converters would reduce project cost**
- **Cable costs based on longest distance to Northern Terminal**

High Level Schedule – Overhead Option



High Level Schedule – Submarine Option



CONCLUSIONS & NEXT STEPS

Conclusions

- Both Submarine and Overhead Options:
  - Provide fully controllable 1,000 MW capability, and ability to manage congested AC circuits
  - Protects against cascading outages
  - Can carry more power with reduced losses for a given size of conductor
  - Lower cost per MW of delivered capacity ($/MW) for large systems
- Submarine Option:
  - ➢ Most reliable alternative to ERCOT for coastal region
  - ➢ HVDC/VSC is the preferred choice for submarine transfer of 1000 MW
- Grid connected HVDC options at Loma Alta, Pawnee, and Corpus Christi area (White Point, Las Brisas or Barney Davis) appear to be viable

Next Steps

- Recommend ERCOT to perform UPLAN-based economic assessment
  - Identify production cost savings following incorporation HVDC line vs. AC solutions
- Review Power System Studies to determine optimal capacity and performance requirements
  - AC power flow analysis
  - Reactive power requirements of existing system
  - Assess most viable technology (HVDC or HVDC light) for Pawnee project
  - Dynamic and SSTI Analysis
- Perform field/route constraints review and update preliminary route and permitting requirements
- Update cost estimates

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Together

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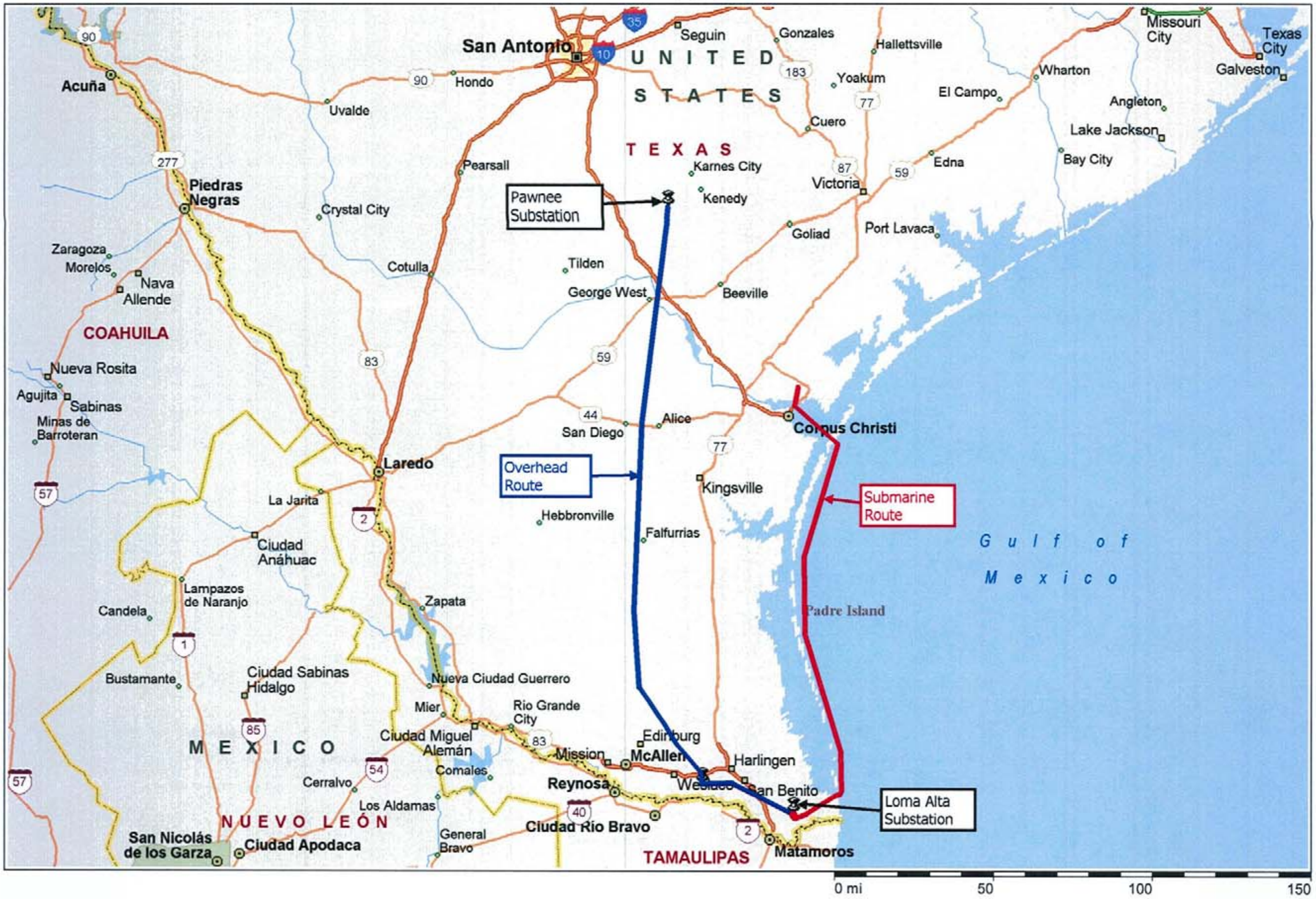
Appendix Maps

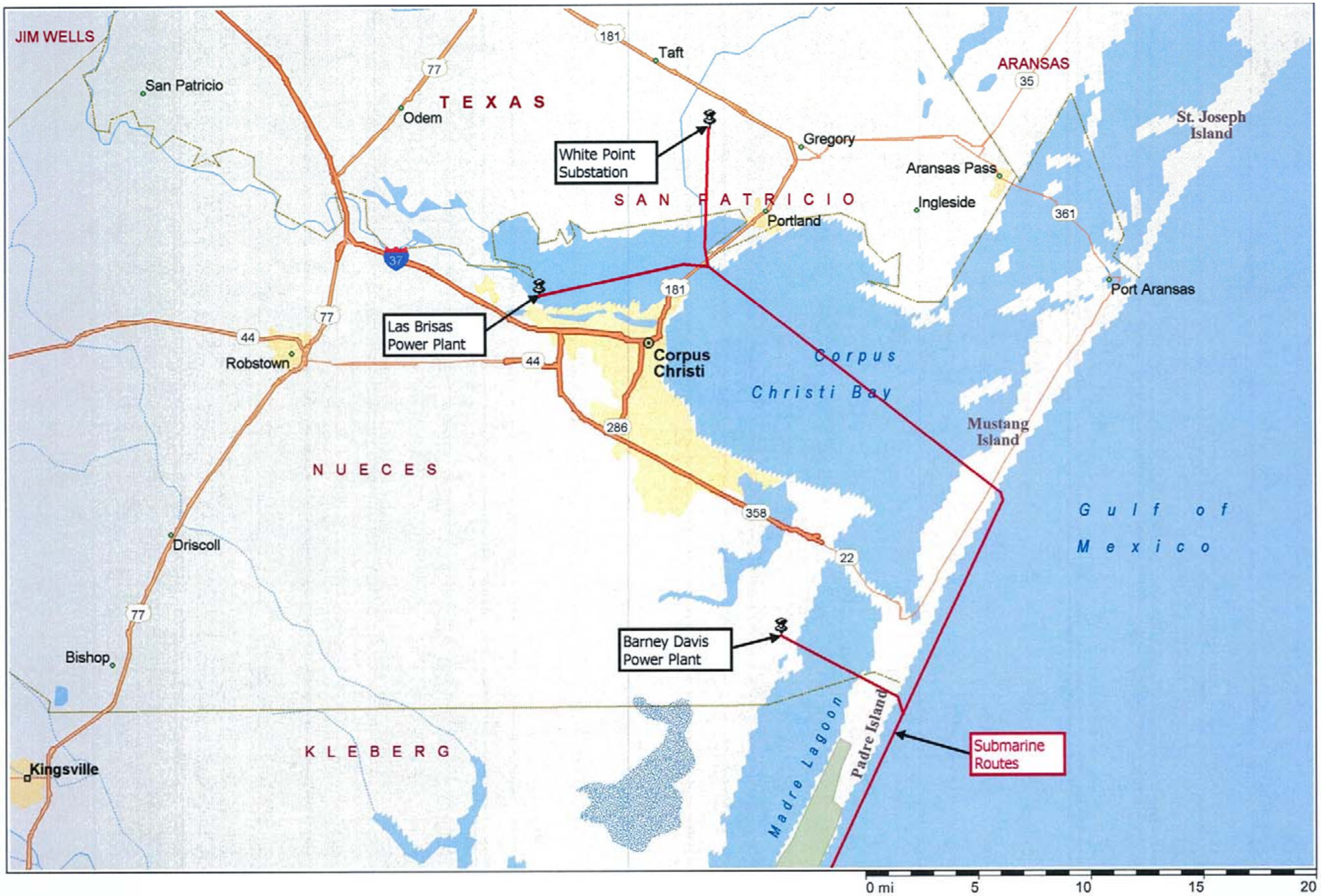


Pawnee Substation

Overhead Route

Submarine Route

Loma Alta Substation


JIM WELLS
San Patricio
181
Taft
77
TEXAS
Odem
ARANSAS
35
St. Joseph Island
White Point Substation
Gregory
Aransas Pass
SAN PATRICIO
Ingleside
Portland
361
37
181
Port Aransas
Las Brisas Power Plant
77
44
Robstown
44
Corpus Christi
Corpus Christi Bay
Mustang Island
286
NUECES
Gulf of Mexico
358
Driscoll
22
77
Barney Davis Power Plant
Bishop
Madre Lagoon
Padre Island
Submarine Routes
Kingsville
KLEBERG
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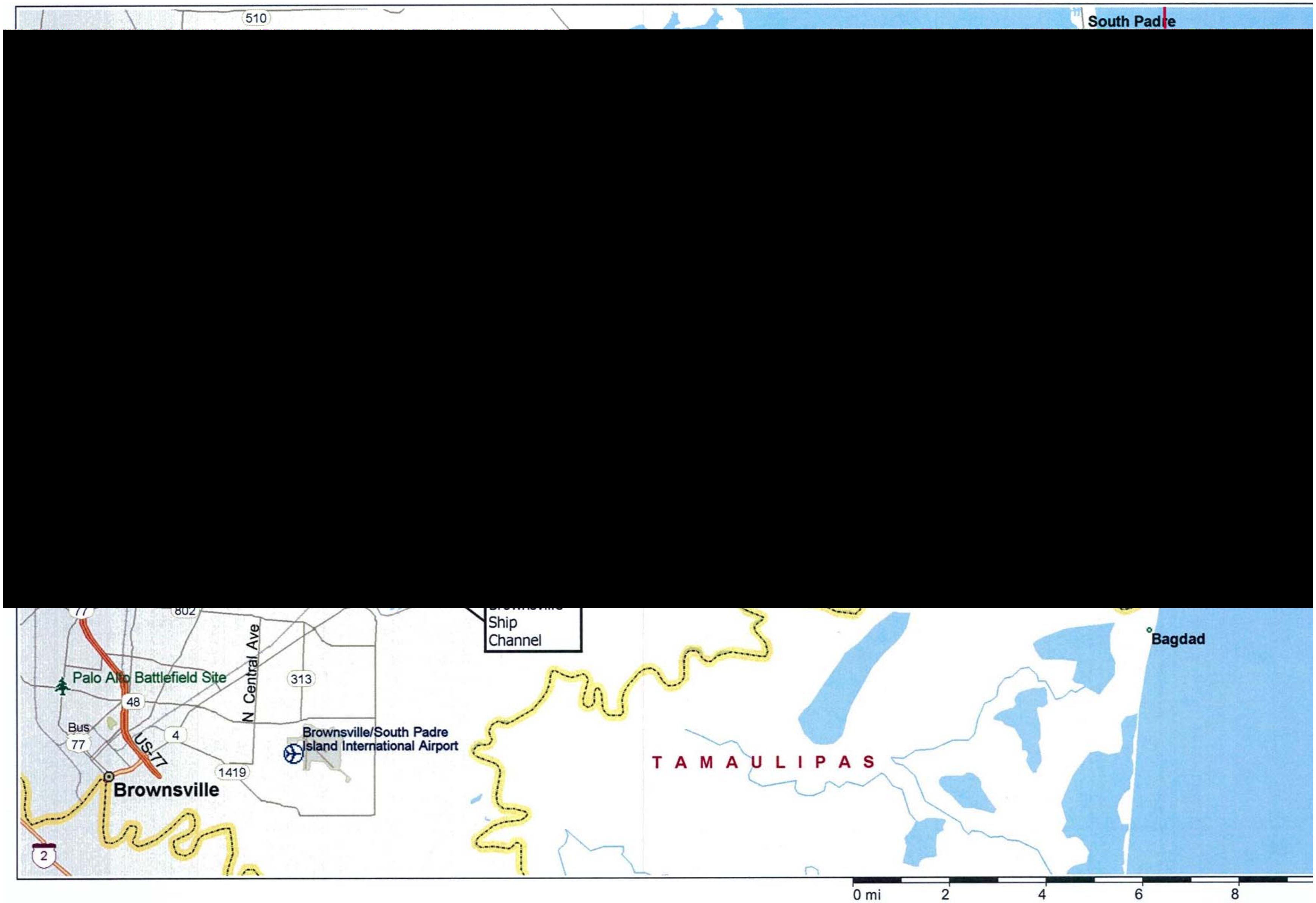

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South Padre
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Brownsville/South Padre
Island International Airport
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