138 Kilovolt Transmission Line Underground Cost Analysis

Report SL-015392

Revision 0

Report

Project No.: 12974.197

S&L Nuclear QA Program Applicable:

☐ Yes

☒ No

6751 N. Sunset Blvd. Suite E400
Glendale, AZ 85305
312-269-2000
www.sargentlundy.com

LEGAL NOTICE

This deliverable was prepared by Sargent & Lundy (S&L) for the use of Tucson Electric Power (Client) in accordance with the contract agreement between S&L and Client. This deliverable was prepared using the degree of skill and care ordinarily exercised by engineers practicing under similar circumstances. Client acknowledges: (1) S&L prepared this deliverable subject to the particular scope limitations, budgetary and time constraints, and business objectives of Client; (2) information and data provided by others, including Client, may not have been independently verified by S&L; and (3) the information and data contained in this deliverable are time-sensitive and changes in the data, applicable codes, standards, and acceptable engineering practices may invalidate the findings of this deliverable. Any use or reliance upon this deliverable by third parties shall be at their sole risk.

ISSUE SUMMARY AND APPROVAL PAGE

This is to certify that this document has been prepared, reviewed and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0405, which is based on ANSI/ISO/ASSQC Q9001 Quality Management Systems.

Contributors

Prepared by:

Name	Title	Signature	Date
Jason Jocham	Project Manager	[signature]	2/11/20

Reviewed by:

Name	Title	Signature	Date
Calvin Yanaga	Engineering Manager	[signature]	2/11/20

Approved by: Jason Jocham

[signature]

Jason Jocham
Project Manager

2/11/20

TABLE OF CONTENTS

FIGURES AND TABLES

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition/Clarification
AC	Alternating Current
DC	Direct Current
DTS	Distributed Temperature Sensing
ft	Foot
GCC	Ground Continuity Conductor
HDD	Horizontal Directional Drill
HDPE	High Density Polyethylene
HVED	High Voltage Extruded Dielectric
HV	High Voltage
Kcmil	1000 circular mils
kV	Kilovolt
mil	Thousandth of an inch
PVC	Polyvinyl Chloride
ROW	Right of Way
XLPE	Cross-linked polyethylene

EXECUTIVE SUMMARY

SCOPE OF WORK

Tucson Electric Power (TEP) is proposing to install a new overhead single circuit 138 kilovolt (kV) alternating current (AC) transmission line from the Kino Substation (currently under construction) extending approximately 7 miles northwest to the existing DeMoss-Petrie Substation with a new proposed intermediate substation north of the University of Arizona. The line is being developed to help satisfy growing energy needs and strengthen reliability for TEP customers within the project area. During preliminary community meetings, TEP has received multiple questions regarding the cost of undergrounding the proposed transmission line. In response to those questions, TEP has enlisted Sargent and Lundy (S&L) to prepare estimated costs to place the proposed 138kV transmission line underground. The material and construction costs in this report represent a 1.5 mile stretch of underground 138-kV transmission circuit in urban, central Tucson. In Addition, this report provides an overview of a 138kV cross-linked polyethylene cable (XLPE) underground transmission line along with information on operation, maintenance and repairs.

OVERVIEW OF PROJECT DESIGN

For the purposes of this study it is assumed one cable per phase is required to meet the required ampacity. The duct banks would be installed via open-cut trench and then backfilled with thermally corrective fill to improve cable operating performance. Several roadways are located within the study area. It has been assumed that arterial roadways would be crossed by means of a jack and bore method. The cost estimate utilized anticipated construction methods and expected geological and environmental conditions. Detailed assumptions are provided in Section 4 of this report.

SUMMARY

Underground transmission line installation, although possible, is significantly more expensive compared to overhead alternatives. Per estimates provided in this document, the cost of undergrounding would be approximately 11 times greater than a comparable overhead installation. In addition to the initial installation cost, there are operational, system loss, performance, maintenance, and reliability concerns when compared to overhead construction.

- Operational and Reliability Concerns – With the installation of the transmission line conductors in a concrete-encased duct bank, repairs to damaged conductors are lengthy and costly. Areas where the underground transmission are placed may also be disrupted due to repairs of the underground conductor.

- System Losses – No analysis was performed to determine the additional system losses associated with the underground cable system compared with an overhead line. Underground transmission lines have capacitance losses, due to the fact the cable has a thin layer of insulation to the ground versus overhead cables. Underground cables generally heat up more quickly, both by the fact that soil can thermally insulate the cables, and the sheath in the design of the underground cable which creates additional heat by induced current. Bonding methods can mitigate heating due to induced current in underground lines but, if not correctly managed, can result in damage to the cable jacket.

1. STUDY DESCRIPTION

1.1. OVERVIEW

The purpose of this document is to generate an indicative cost estimate to inform TEP and interested parties of the estimated construction costs for underground 138kV construction. It also provides information on operation, maintenance, and repair concerns for underground transmission lines. S&L developed the cost estimate for a segment of 138kV underground 1.5 miles long based on an urban environment in central Tucson and assumed the crossing of several large arterial roads via trenchless installations to limit disruptions to the community.

2. UNDERGROUND CABLE SYSTEMS

XLPE Cable is the most common type of cable used for underground transmission lines being installed at transmission level voltages. XLPE cable systems have become the preferred underground cable system for underground cable installations in the United States. Therefore, XLPE has been selected as the cable system for this study.

2.1. SYSTEM RATINGS

When designing underground transmission lines, the most important concept to consider is the ampacity, or the rating, of the conductor. The largest impact to the ampacity is the thermal performance of the underground system as whole. The calculation for determining the allowable ampacity of the underground conductor is complicated with many design factors that have effects on the thermal performance of the conductor. These factors include items such as soil thermal resistivity, cable size, cable depth, and cable separation.

2.1.1. Soil Thermal Resistivity

Soil thermal resistivity has a large impact on the allowable cable ampacity. The thermal resistivity is an important factor for design of underground electric cable systems. It is a measure of how a soil resists heat flow away from the cable. Due to this, thermal properties of the soils/backfill installed around the cable have a direct impact on cable ampacity. The entire area surrounding the cable can affect the ampacity, including changes in layers and materials around the cable. Concrete and asphalt placed on top of the cable would affect the rating of the cable, most likely in a negative way, dependent on their thermal resistivity. Therefore, to ensure proper cable design modeling of the system is required.

2.1.2. Cable Size

The conductor size of the cable has the most obvious impact to the ampacity of the cable. An increase in the conductor size has a direct correlation to an increase in ampacity. There is a limit to the allowable cable size. At present, 5000-6000 kcmil is the largest conductor size used for XLPE type cables.

2.1.3. Cable Depth

Depth of the cables has an impact on the ratings of the cable. The deeper the cable is in the soil, the harder it is for the surrounding soil to dissipate the heat. Typically, larger cables are required for deeper installations.

2.1.4. Cable Separation

Other cables in proximity can also generate heat and adversely affect the cable ampacity. This condition is called mutual heating. This can be reduced by increasing the separation of the cables. Optimal separation is determined by weighing the separation distance against the amount of excavation required. Increasing the separation too much would require larger excavation which in turn drives up project cost.

2.2. INSTALLATION METHODS

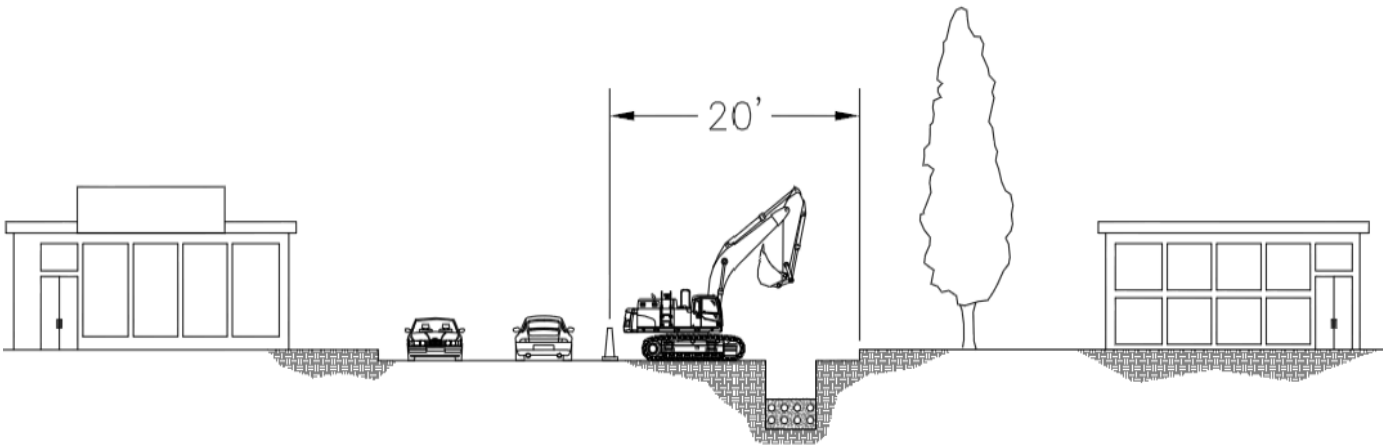
There are multiple types of installations for an underground transmission line. These include: 1) use of open trenches with installation of a duct bank, 2) direct embedment, 3) trenchless type such as Horizontal Directional Drill (HDD) or jack and bore. The most common method in the U.S. is duct bank-type installations. Duct banks are installed to provide mechanical protection for the cable. Short lengths of a couple hundred feet of trench are opened at a time. For this project, S&L would recommend the duct bank installations where open trench is feasible and jack and bore installations for the short distances under major arterial roadways to reduce impacts to the local community.

There are multiple steps for installation of an underground transmission line. First, all necessary information should be acquired such as geotechnical studies, existing underground utility locations and acquiring all permits required for the project. Secondly, the civil installation includes the excavation of the soil for the duct bank, installation of the duct bank described later, installation of the man vaults, backfilling the excavations with thermally corrective fill to the desired compaction and restoring the ground surface around the duct bank. Next contractors would mandrel the duct bank to ensure proper installation with no obstructions. Finally, the electrical construction includes the installation of all cables (electrical and communications), splicing, and grounding of the cables and other equipment. After the civil and electrical installations are complete, the system is tested before it is placed in operation.

2.2.1. Open Trench

Open trench construction would consist of cutting the asphalt road or concrete sidewalk and utilizing excavation equipment to remove any sub-grade material and soil to the desired depth of the proposed duct bank. The excavated material would be removed for disposal or stockpiled for use as backfill after completion of the duct bank (provided the properties of the soil meet the design criteria). Excavations usually happen in sections to limit the amount of open trench; this would be determined during detailed design. In urban environments, which is the basis for this cost estimate, shoring would be utilized to keep excavations open and limit the width of the excavation. The expected construction width in urban areas is 20 feet (Figure 2.1) for the trench, excavation and working space. The construction contractor would be required to provide traffic control devices to ensure safety for workers and the public.

Figure 2-1 — Typical Urban Open Trench Construction



Once a portion of the trench is excavated and clear to the proper depth, polyvinyl chloride (PVC) duct would be placed into the open trench. Individual PVC ducts would be used to house each cable and/or communication wires to be installed. The ducts would be held in place utilizing plastic duct spacers to ensure all the required separation per the design are met (see figure 2.2). In an urban environment, utilities that cannot be relocated prior to the construction of the duct bank would increase construction cost and time. Existing utilities that must remain in the Right of Way (ROW) would be required to be supported during the open excavation and avoided by re-routing the duct bank or changing duct configuration to accommodate the existing infrastructure. These types of details would be determined during detailed design. Duct bank spacers are placed three to five feet apart to keep the PVC ducts in the desired configurations. The area would then be framed and filled with high strength thermally corrective concrete (see figure 2.3), with the top portion having a red dye added to identify danger during future excavation. After the concrete has hardened the trench is backfilled and the surface returned to pre-construction conditions.

Figure 2-2 — Open Trench Spacers

Figure 2-3— Open Trench Concrete

2.2.2. Trenchless Installation

There are two types of trenchless methods that are commonly utilized when open trenching may not be allowed. Horizontal Directional Drill (HDD) and jack and bore. Trenchless type installations are used in areas were open trench is not allowed such as major road crossings, intersections, railroads, bodies of water, and other environmentally sensitive areas. For the urban environment in this estimate, jack and bore was used to cross under arterial roadways due to the short crossings, under 400 feet. Jack and bore installations consist of installing a non-metallic casing such as high-density polyethylene (HDPE), fiberglass or reinforced concrete pipe, and then installing the smaller ducts within the larger casing. Jack and bore can only be installed in a straight path.

Jack and bore must be installed via a send and receive pit excavated on either side of the crossing. Send pits are typically 30' long x10' wide to the required depth of the bore approximately 16' deep. Depth may vary based upon existing utilities. This size is required for the boring equipment and for placing the casings which are approximately 20' sections but vary dependent on send pit sizes. Receive pits are commonly smaller in size averaging 10' long x 10' wide to the same depth as the send pit. Due to the depth of the excavation shoring would be required to maintain the safety of all workers in the pit based on the assumption there would not be enough room to bench the excavation. The excavated material must also be considered for storage during the jack and bore process. This can lead to an even larger area required for the jack and bore process. Casings can vary in size from 14 to 80+ inches in diameter, depending on project requirements.

Figure 2-4 — Jack and Bore – Send Pit

Figure 2-5 — Jack and Bore – Equipment

2.2.3. Vaults

Man-vaults would be required along the route for cable installation, splicing, inspection, maintenance requirements and access for future repairs. Man-vault spacing, and location are determined by maximum cable reel length, cable pulling tensions, and side wall pressures. Typical distance between vaults is expected to be 1,500 to 2,500 feet for the XLPE cable. The size of man-vaults is based on the type of cable system installed. Typical dimensions for man vaults are between 25-35 feet long by 7-10 feet wide by 10-12 feet tall dependent on voltage. Excavations are expected to 37 feet long by 12 feet wide by 12 - 16 feet deep dependent on existing infrastructure. Typically, man vaults are pre-cast and delivered to the site for installation. After installation, the over excavation is backfilled.

Figure 2-6 – Man Vault Placement

Figure 2-7 – Man Vault Backfill

2.2.4. Cable Installation and Testing

After the civil portion of the underground installation (no conductors placed in ducts at this time) is complete, the duct bank would be tested and cleaned by pulling a mandrel and swab through each of the ducts. This is done to ensure all ducts are concentric with correct clearance for cable, are clean of debris and are ready for cable pulling. Once each duct is cleared the cables can be installed. The typical cable pulling setup would be to set the reel of cable at one end of the pull and place a winch truck at the opposite end. Direction of pull between man vaults would be determined based on the direction that results in the lowest pulling or sidewall tensions. Once all the cables are pulled into a man-vault from each direction, splicing of the cable could commence. This process is repeated until all the cables have been pulled and spliced or terminated.

Figure 2-8 – XLPE Cable Reel

Figure 2-9 – XLPE Cable Installation

After completion of the installation, all splices and terminations of the cable must be tested before being placed in service. Testing includes a jacket integrity test using a specified DC voltage to ensure the jacket is continuous from end to end. Historically, an AC soak test would also be performed where the cable would be connected at rated voltage without load and left to “soak” for 24 hours. This enables the insulation to be stressed prior to current flow.

2.3. MAINTENANCE

Underground transmission lines require routine maintenance to ensure the cables continue to operate with uninterrupted service. Maintenance is primarily visual inspection of terminations, splices, man vaults, arrestors, grounds, riser structures, and cables. This type of maintenance is dependent on the utility but is recommended every 6 to 12 months for standard maintenance and a higher intensity maintenance performed in five-year intervals. To accommodate for visual inspections, the line would have to be de-energized and lane closures maybe necessary to allow inspectors access into the vaults.

2.3.1. Cable Failure and Repair

Underground transmission lines, in general, are reliable. However, should a cable failure occur, the time to restore service can be lengthy. Overhead lines, utilizing standard material, can usually be placed back into service in a matter of days. On the other hand, underground transmission lines may be out of service for months as new cable is ordered. Accurately locating the cable failure is extremely important. Overhead line faults are relatively easy to identify and correct as visual inspections provide a quick analysis and plan for repair. Locating a failure for underground lines is much more difficult as visual inspection is nearly impossible. Therefore, other methods are used to locate the failure(s). The most common method of locating a fault is to apply a capacitor discharge signal and detect return signal using an acoustical device.

Once the fault is located, a specialized contractor such as the cable manufacturer would need to make the repairs. Faults may be so great that the cable cannot be reused and depending on the level of failure, could fuse to the duct. In this case, if the duct has a spare, a new cable would need to be purchased, manufactured and pulled. If there is no spare position in the duct bank, then a replacement duct bank would need to be installed.

3. PRELIMINARY DESIGN

This assessment is based on a 1.5-mile route in an urban location of central Tucson, which would require installation of the duct bank in the road, road shoulder, or sidewalk area dependent on location. S&L has assumed that most of the line would be installed in road or road shoulder. It is also assumed that most of the existing storm drains would be avoided by this placement limiting the amount of existing infrastructure interactions. At this stage, no preliminary modeling, surveys or other design support activities have been performed. A full list of assumptions is provided in section 4.

3.1. DESIGN INPUTS

Table 3-1 – Preliminary Cable Data

CONDUCTOR SIZE	6000 KCMIL
CONDUCTOR MATERIAL	COPPER
CABLE DIAMETER	4.86 INCHES
CABLE WEIGHT	24.4 LB/FT
AMPACITY*	2180 A

* Ampacity based off standard documentation and conditions; project specific ampacity would be determined at detailed design.

Based on the cable size, it is expected that the duct bank would require 8" ducts to supply enough space for the specified conductor. S&L recommends a single spare cable be installed during the initial installation to increase reliability of the new underground transmission line by reducing outage times in the event of a fault. In addition, S&L would recommend a spare duct be installed in the event that if catastrophic damage occurs in a duct, TEP can install a new cable without developing an entirely new duct bank. It is assumed the permanent right of way width required for the duct bank would be 30 feet wide

For communication wires and Ground Continuity Conductor (GCC), TEP requested use of 3" conduits. A single 3" duct would be utilized for the installation of one 96 count single mode fiber optical cable for communication support for the transmission line. A second 3" duct would be utilized for the installation of a fiber optic cable that would be used for distributed temperature sensing fiber (DTS). The DTS would be used to monitor the temperature of the conductors in the duct bank to ensure the protection of the conductor. The third duct would house the GCC to support the cable grounding method which would be finalized during detailed design. Finally, S&L recommends a fourth 3" duct be installed as a spare in the event that there is damage to one of the 3" ducts.

S&L identified, using preliminary GIS data that up to 12 crossings of sewer lines could be expected in a 1.5-mile segment of underground line in central Tucson. During actual design of the 138kV underground transmission line, it is expected to encounter storm water, communications, and gas lines may, are expected to be encountered which may result in higher installation cost. It is expected that these interferences will be encountered multiple time on the project due to the urban nature of the route.

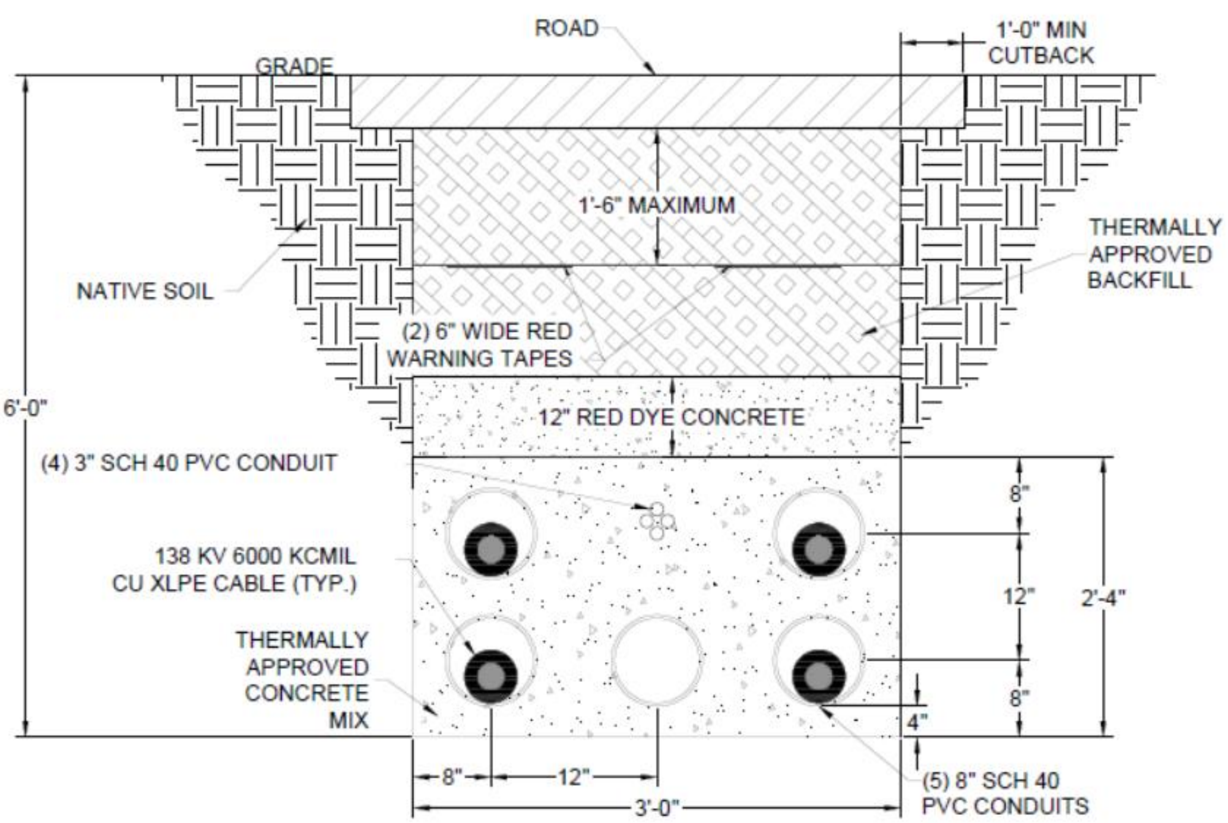
3.2. ELECTRICAL DESIGN

For the purposes of this estimate, a 6000 kcmil cable was chosen in order to provide a comparable ampacity rating to the standard 954 ACSS HS “Rail” conductor utilized on new TEP overhead 138kV line designs. No electrical calculations have been performed to determine preliminary cable ampacity and electrical characteristics. To perform this work, CYMCAP, a cable ampacity program developed by Eaton would be used to model the underground transmission layout. The modeling would include modeling of all material placed around the conductor, depth and configuration of duct banks/bores along the route. If determined during the detailed modeling of the system that the ampacity is not met, more conductor area would be required; this may potentially require a second cable per phase. This could have significant impacts to the design, increasing the duct bank size and requirement of additional materials. In addition, no EMF calculations have been performed at this stage.

3.3. OPEN CUT TRENCH PARAMETERS

Since data has not been gathered for underground infrastructure along the sample route, S&L assumes the average depth of the duct bank would be at minimum, 6 feet. Most existing underground infrastructure would be crossed by open trench except when in designated road jack and bore crossings. The duct bank would have five 8” PVC ducts for cables and four 3” PVC ducts. Below is a preliminary representation of the proposed duct bank design.

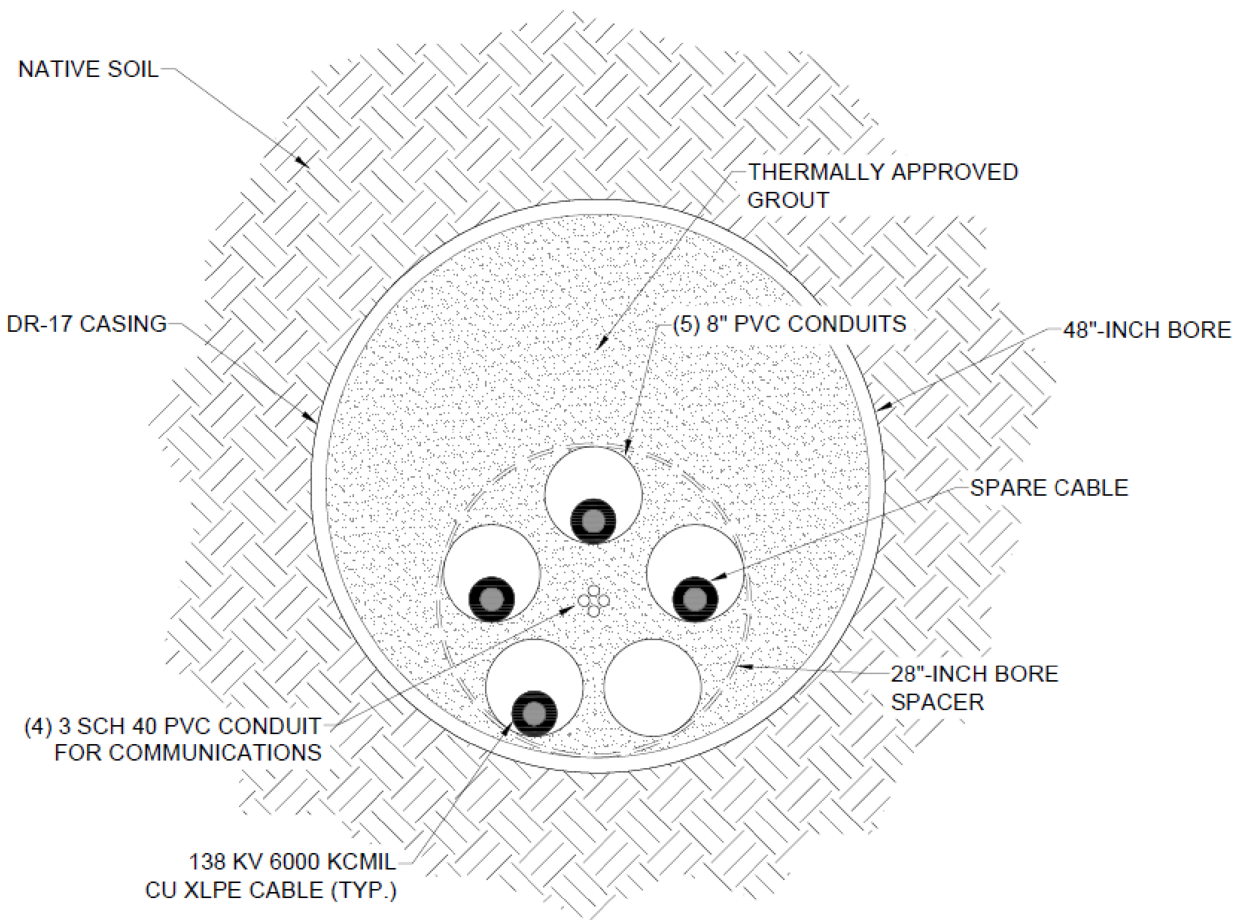
Figure 3-1 — Preliminary Duct Bank Layout



3.4. TRENCHLESS DESIGN PARAMETERS

It is expected that trenchless installations would be required under every major arterial roadway (greater than 4 lanes of traffic). For this study, it was assumed that there would be three crossings requiring a jack and bore, each approximately 200-ft in length. S&L has estimated the bore casing would be 48" in diameter to support the duct installation. It is expected the boring would be filled with thermal grout such as bentonite to aid in heat dissipation. Depth of the bore would be determined during detailed design once all existing infrastructure and other required inputs clarify the design.

Figure 3-2 — Preliminary Bore Layout



4. COST ESTIMATE

4.1. COST ESTIMATE ASSUMPTIONS

This cost estimate is based on standard pricing and/or pricing attained for a 1.5-mile-long underground line in urban, central Tucson. There are many factors that can affect the overall cost of the transmission line.

Below is a list of assumptions for this estimate:

1. Costs are based on 2020 costs. No escalation is included. Therefore, cost of materials can fluctuate and affect the overall estimate.
2. Subsurface Conditions - No underground infrastructure was considered for this study. Existing infrastructure can have major effects on construction and therefore would have significant impacts on cost. At this stage S&L has assumed a 6' deep trench and 16' deep trenchless installations would be acceptable.
3. Soil types, such as rock, have impacts on cost. At this stage S&L assumed no rock or caliche would be encountered within the study area.
4. The City may have special requirements that may impact the current restoration estimate assumptions. S&L has assumed the project would only require repair of the removed asphalt, curbs, and sidewalks. If more is required by the City, this would increase the cost.
5. Estimate does not include any environmental costs. This could increase costs based on level of environmental requirements for the project. This would be defined in the detailed design stage of the project.
6. Assumes single point bonding scheme.
7. Assumes 6,000kcmil conductor.
8. Estimate does not include any costs for right of way, easement acquisition, or temporary construction easements.
9. Duct installation cost includes excavation, shoring, duct placement, placement of concrete (including red dye), and compaction of soil above.
10. No spare material has been included, unless identified otherwise.
11. Only three arterial roads requiring jack and bores were assumed for the study.
12. No sales tax has been included on material.
13. A 20% contingency due to unknowns is included.
14. Materials used in the cost estimate meet all applicable industry standards.
15. Construction would be performed by qualified and experienced contractors.
16. S&L assumes 5 ducts for conductor and 4 ducts for communication and other cables.
17. Vaults are assumed to be installed approximately every 2,000 feet.
18. Asphalt repair assumes 7' wide repair.
19. Excavation assumes 30% swell of soils for hauling purposes.

4.2. COST ESTIMATE

ITEM	DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE ($/UNIT)	TOTAL MATERIAL COST ($)	LABOR UNIT PRICE ($ UNIT)	TOTAL LABOR COST ($)	TOTAL OVERALL COST ($)
EARTHWORK AND DUCT BANK INSTALLATION							
1	8-inch PVC Conduit, Per ft	39000	$8.18	$319,020.00	$0.00	$0.00	$319,020.00
2	3-inch PVC Conduit, Per ft	31200	$1.67	$52,104.00	$0.00	$0.00	$52,104.00
3	Conduit Duct Spacers, Each	2600	$30.00	$78,000.00	$0.00	$0.00	$78,000.00
4	Man Vault, Each	5	$45,000.00	$225,000.00	$25,000.00	$125,000.00	$350,000.00
5	Duct Installation, Per ft	7200	$0.00	$0.00	$240.00	$1,728,000.00	$1,728,000.00
6	Haul Away, cubic ft	170900	$2.00	$341,800.00	$0.00	$0.00	$341,800.00
6	Asphalt Replacement, sq. ft	41500	$4.75	$197,125.00	$0.00	$0.00	$197,125.00
7	Sidewalk/Curb Replacement, ft	1700	$140.00	$238,000.00	$0.00	$0.00	$238,000.00
8	Landscape Restoration, sq. ft	8120	$4.00	$32,480.00	$0.00	$0.00	$32,480.00
9	Utility Relocation, lot	10	$30,000.00	$300,000.00	$22,500.00	$225,000.00	$525,000.00
10	Steel plating, monthly rental	10	$14,400.00	$144,000.00	$0.00	$0.00	$144,000.00
11	Traffic Control, days	410	$1,000.00	$410,000.00	$0.00	$0.00	$410,000.00
TRENCHLESS INSTALLATION (JACK AND BORE)							
12	Jack and Bore, Per ft	620	$675.00	$418,500.00	$675.00	$418,500.00	$837,000.00
13	Mobilization / Demobilization, lot	1	$0.00	$0.00	$50,000.00	$50,000.00	$50,000.00
14	Bore Spacer, each	130	$275.00	$35,750.00	$0.00	$0.00	$35,750.00
15	Bore Grout, cubic ft	12200	$1.85	$22,570.00	$0.00	$0.00	$22,570.00
16	Haul Away, cubic ft	15900	$2.00	$31,800.00	$0.00	$0.00	$31,800.00
17	Bore Pit Excavation, cubic ft	28100	$0.00	$0.00	$14.50	$407,450.00	$407,450.00
18	Excavation Pit Soil Removal, Replacement and Compaction, cubic ft	27400	$6.00	$164,400.00	$0.00	$0.00	$164,400.00
19	Asphalt Replacement, sq. ft	1800	$4.75	$8,550.00	$0.00	$0.00	$8,550.00
20	Shoring, per ft	400	$80.00	$32,000.00	$0.00	$0.00	$32,000.00
CABLE AND ACCESSORIES							
21	XLPE Cable, per ft	31200	$120.00	$3,744,000.00	$0.00	$0.00	$3,744,000.00
22	Spare XLPE Cable on reel, per ft	2100	$120.00	$252,000.00	$0.00	$0.00	$252,000.00
23	Terminators, each	6	$7,200.00	$43,200.00	$9,000.00	$54,000.00	$97,200.00
24	Spare Terminators, each	2	$7,200.00	$14,400.00	$0.00	$0.00	$14,400.00
25	Arresters, each	6	$2,500.00	$15,000.00	$1,500.00	$9,000.00	$24,000.00
26	Spare Arrester, each	2	$2,500.00	$5,000.00	$0.00	$0.00	$5,000.00
27	Splices, each	20	$3,600.00	$72,000.00	$9,000.00	$180,000.00	$252,000.00
28	Spare Splices, each	4	$3,600.00	$14,400.00	$0.00	$0.00	$14,400.00
29	Grounding System for Vault, each	5	$4,000.00	$20,000.00	$3,000.00	$15,000.00	$35,000.00
30	Grounding System for Structure, each	2	$3,500.00	$7,000.00	$1,500.00	$3,000.00	$10,000.00
31	Cable Clamps, each	218	$100.00	$21,800.00	$0.00	$0.00	$21,800.00

ITEM	DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE ($/UNIT)	TOTAL MATERIAL COST ($)	LABOR UNIT PRICE ($ UNIT)	TOTAL LABOR COST ($)	TOTAL OVERALL COST ($)
32	Continuity Conductors, per ft	7800	$3.50	$27,300.00	$0.00	$0.00	$27,300.00
33	Cable Installation, Splicing, grounding, days	60	$0.00	$0.00	$9,000.00	$540,000.00	$540,000.00
34	Jacket integrity test, lot	1	$0.00	$0.00	$300,000.00	$300,000.00	$300,000.00
35	Discharge/Withstand Test, lot	1	$0.00	$0.00	$120,000.00	$120,000.00	$120,000.00
FIBER OPTIC INSTALLATION							
36	Fiber Optic Cable, per ft	8000	$1.50	$12,000.00	$0.00	$0.00	$12,000.00
37	Hand Vaults for Fiber, each	2	$700.00	$1,400.00	$0.00	$0.00	$1,400.00
38	Excavation for Hand Vaults & Haul away, cubic ft	70	$2.00	$140.00	$14.50	$1,015.00	$1,155.00
39	Sidewalk/Curb Replacement, ft	20	$140.00	$2,800.00	$0.00	$0.00	$2,800.00
40	Fiber Optic Cable splices, each	4	$1,000.00	$4,000.00	$4,000.00	$16,000.00	$20,000.00
41	Temp. Sensing Fiber System, lot	1	$215,000.00	$215,000.00	$0.00	$0.00	$215,000.00
TERMINATION (RISER STRUCTURES)							
42	Structure, each	2	$90,000.00	$180,000.00	$50,000.00	$100,000.00	$280,000.00
43	Foundation Installation, each	2	$35,000.00	$70,000.00	$0.00	$0.00	$70,000.00
ENGINEEERING/ MANAGEMENT/ MISC.							
44	Engineering, lot	1	$0.00	$0.00	$750,000.00	$750,000.00	$750,000.00
45	Geotechnical Including Thermal, lot	1	$0.00	$0.00	$150,000.00	$150,000.00	$150,000.00
46	Underground Utility Survey	1	$0.00	$0.00	$125,000.00	$125,000.00	$125,000.00
47	Construction Management, lot	1	$0.00	$0.00	$350,000.00	$350,000.00	$350,000.00
48	Mobilization / Demobilization, lot	1	$0.00	$0.00	$200,000.00	$200,000.00	$200,000.00
49	Permitting	1	$0.00	$0.00	$0.00	$0.00	$0.00
50	Environmental Compliance & Monitoring	1	$0.00	$0.00	$0.00	$0.00	$0.00
SUMMARY							
Summary of Cost				**$7,772,539.00**		**$5,866,965.00**	**$13,639,504.00**
Summary of Cost with Contingency (20%)				**$9,327,046.80**		**$7,040,358.00**	**$16,367,404.80**

5. PRELIMINARY SCHEDULE

5.1. PRELIMINARY SCHEDULE

Task Name	Duration (Months)
Engineering and Permitting Portion	**12**
Material Procurement	**6**
Civil Construction Portion	**10**
Electrical Construction	**4**

6. CONCLUSIONS

TEP's typical installation cost for a 138kV overhead transmission line is approximately $1 million a mile for a design in an urban environment. Based on the underground estimate developed in this analysis, an underground transmission line would cost approximately $16.4 million or about 11 times the cost of an overhead transmission line. It should also be recognized that there is a higher annual cost of maintenance for an underground transmission line due to additional maintenance and inspection costs associated with an underground line versus and overhead line.