Underground Utilities Feasibility Study for Halifax Regional Municipality

Kinectrics Report: 10986-001-RA-0001-R00

March 04,2005
Client Purchase Order: 2070201278

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PRIVATE INFORMATION

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01	Mar 4	Additional cost estimates added	John Kuffel

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EXECUTIVE SUMMARY

The purpose of this study was to:

- provide HRM with information in response to the recent NSPI (Nova Scotia Power Inc.) requirements that negatively impact the aesthetics of HRM streetscapes;
- undertake a cost-benefit analysis of installing underground services for various development scenarios in HRM;
- review financing options available to HRM for underground services;
- confirm whether or not the following public perception is correct: having underground utility services will solve or reduce the power outage problems that HRM has experienced recently; and
- look at what some other cities in Canada are doing with regard to underground utility servicing.

Cost/benefit analysis

The cost benefit analysis identified cost items and benefit items. Where possible, a dollar figure was estimated and assigned to each item. The cost items were based on three different system designs, present practice, all utilities (i.e. power, cable, telephone) sharing a trench, and direct burial of low voltage lines as armoured cable. These assumptions are critical to the analysis because the present practice can be double the lowest cost estimate. Most cities that install their utilities underground use common trenches. However the difficulty of achieving this in HRM should not be underestimated. A commercial and joint ownership agreement would need to be negotiated and agreed upon as well as a technical common trench standard. To achieve this some direction from the NSURB might be required, however it has been achieved in other cities so there are models on which to base an agreement. Similarly a change to direct burial of low voltage lines close to houses would require negotiation with the utilities involved.

The benefit items included: improved aesthetics, improved utility reliability, increased number and size of street trees (which addressed improved air quality, reduced wind speed, reduced heating and cooling costs), reduced damage from motor vehicle accidents, and reduced tree trimming costs. Only some of these benefits could be assigned a dollar value. The largest benefit, improved aesthetics (which includes effects on the mental and emotional health of residents and the overall quality of life), cannot be assigned a dollar value.

In all development scenarios analyzed, the costs outweighed the quantifiable benefits by a margin of 5 to 15 times. Therefore, the decision to place utilities underground must be based on the weight a municipality places on aesthetic benefits.

Options for HRM

The development scenarios analyzed in this study include the following:

- Downtown: place all utilities on all streets underground
- Industrial: place all utilities on all streets underground
- Urban Residential: place all utilities on all streets underground
- Urban Residential: place all utilities on local streets underground
- Urban Residential: place only service drops (lines from street to house) underground
- Suburban Residential: place all utilities on all streets underground
- Suburban Residential: place all utilities on local streets underground
- Suburban Residential: place only service drops (lines from street to house) underground

A first option for HRM is to put all low voltage and communication lines (service drops) underground in new residential areas. These are the most visible wires because they are closest to the ground and they cross the street to reach individual buildings. The cost has been estimated to vary between $1,400 and $3,800 per lot above the cost of an overhead system. The variation is dependent on dwelling unit density and the direct burial option.

The suitability of requiring underground lines in new residential areas depends on the willingness of the residents to pay the increased costs. There is a concern that the requirement for underground wires may drive the price of houses within HRM above the marketable value and thus encourage development just outside the HRM boundary.

This option, in which only the low voltage and communication lines are buried, does not allow space for more street trees because the high voltage power lines still are overhead. It does however improve the visual aesthetics because most of the impact of overhead lines comes from the lower voltage wires that are larger in diameter and closer to the observer.

A second option for HRM is to put all utility lines in new residential areas underground. The increased cost of this has been estimated as $2,500 to $5,500 per lot, again depending on the lot size and whether the direct burial of low voltage lines option is used. Putting all lines underground would allow the placement of large trees along the street in a similar manner to that of most existing streets. The quantifiable benefits would offset $600 to $750 of the cost per lot.

In terms of the downtown areas, there is an existing HRM policy, introduced in 1977, to convert the overhead lines to underground in an area of downtown Halifax called “The short term pole free zone”. This policy allows for the undergrounding of utilities in the downtown area with a 50/50 cost sharing arrangement between HRM and NSPI (MTT have also agreed to this). NSPI has confirmed they are still prepared to honour this agreement within the existing designated area. Extending the pole free zone may not be possible unless another agreement can be reached with NSPI.

It has been found that it is feasible to convert areas of existing overhead lines to underground in high priority commercial retail areas. Three examples are: Spring Garden Road between Robie street and Brunswick street at an estimated cost of 1.7 million dollars; Gottingen Street between Cogswell street and North street at an estimated cost of 1.7 million dollars; and Quinpool Road between Robie street and Connaught Avenue at an estimated cost of $ 1.9 million dollars. This equates to approximately $1000 - $1200 per metre of road.

The conversion of more widespread areas, such as the Capital District, would only be feasible if spread over a long time period. The estimated cost for the entire capital district would be 40.7 million dollars.

For both industrial development and rural (un-serviced) residential development, it is less feasible to install underground utilities. These development scenarios have substantially higher costs per lot and significantly lower benefits.

Financing options

There are three financing options for covering the cost of putting utilities underground. The first option is that the property owner pays the difference in cost between installing overhead and underground. (The utility pays the base cost of what it would be for overhead). This is done either directly in the purchase price of the property, indirectly through an improvement tax imposed by the Municipality, or through a premium on the power bill.

The second option has higher levels of government cover the cost. This is usually done in areas with heritage recognition.

The third option has the utilities pay the cost of the underground system. This option is only possible where the utility regulator i.e. Nova Scotia Utility and Review Board (NSURB) requires it or it is mandated in Provincial Legislation. For example, it is used in the province of Quebec in downtown areas.

Other assumptions addressed

It is often assumed that in areas where rock terrain is prevalent, the rock blasting necessary can increase the cost of placing utilities underground. There are several areas of HRM where rock blasting is required. However, in many of these areas, the construction method for new development is to blast a large trench for water and sewer services, so a larger blast area to accommodate utilities is not a major impediment. For existing development where rock must be blasted, the increased cost is approximately 20% of the total cost.

An alternative to putting electric power lines underground is to require overhead systems to be designed using covered cable systems, such as Hendrix cable. This allows trees to be trimmed much closer to the lines and improves reliability. The increased capital cost is at least 25% over an equivalent conventional overhead system. The benefits of reduced outages due to tree contact, lower tree trimming costs, and increased urban tree canopy reduce the net increased cost to about 10%. Benefits of improved appearance is only achieved if the lines are hidden by trees because the covered cables are larger and spaced close together, increasing their visual presence if they are not hidden by trees.

Reliability is not necessarily improved by having underground utilities. This is because underground equipment has its own failures and many power outages are caused by failure at the higher voltage systems that are located above ground. Placing all distribution lines underground could reduce outages by about 50%, but the costs of doing this are prohibitive. Placing utility lines underground only in new residential areas will reduce outages by up to 50% in the new area if the new development is large enough to require an entire circuit (>500 houses). For small in-fill developments reliability would improve a very small amount since the outages on the short supply lines affect very few houses. Having underground service drops (from streets to houses) would improve reliability even less. This is because it is only during extreme weather events (i.e. hurricanes or severe ice storms) when overhead lines can be torn off the sides of buildings that the low voltage lines have significant failures.

Other cities in Canada

Within the last 25 years, seven of the ten largest Canadian cities as well as other cities around the world have been requiring all electric power and communication lines to be installed underground in new residential areas. This requirement is driven by the benefit of having an improved streetscape appearance and having more space in urban areas for large trees.

In all development scenarios, costs outweigh the quantifiable benefits, some by a large margin. A municipal decision has to be based on the weight given to the un-quantifiable benefits, such as aesthetics.

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1 OVERVIEW OF THE ISSUES

Underground utility infrastructure is more expensive than overhead but results in improved appearance and can increase reliability. It can also lead to increased investment by property owners and increased tourism and other economic activity.

Seven of the ten largest Canadian cities require underground utilities in all new residential developments, primarily for aesthetic reasons.

Changes to NSPI tree policy in 1997 severely restricted the size of trees near residential streets, particularly in areas of high density housing. The change was made to improve reliability and lower tree trimming costs.

The changes in NSPI tree policy will reduce the number of large street trees in new developments changing the urban ambiance. If applied to existing streets it would alter the appearance of streets all over HRM.

Street trees contribute to aesthetics of existing streets, and also to community mental heath and enjoyment, lower noise levels, better air quality, lower wind speeds, lower heating and cooling costs.

In order for HRM to continue to have well designed streets that provide a pleasant environment, HRM must take action.

There are several alternatives available for actions to preserve the traditional pleasant tree lined street:

- persuade NSPI to return to the previous tree trimming policies.
- require utility wires to use covered conductor and eliminate tree trimming
- require partial undergrounding of utility wires in new residential areas
- require all utility wires to be underground in new residential areas

The differential cost of underground wires in new developments is usually paid by the property owners.

The cost of going underground may drive house prices within HRM above the marketable level and encourage undesirable development just outside the HRM boundary.

The least expensive underground option that will allow for large street trees is to have overhead wires on arterial/collector streets and all wires underground on local streets.

Present costs for undergrounding could be reduced by development of a “common trench” arrangement between the various utilities and design changes allowing for direct burial of the lines to individual houses. These cost reduction techniques are used in many other cities.

2 STREET SCENE AESTHETICS

HRM has many well designed streets that provide a pleasant environment. This depends upon aesthetically pleasing design of streets and buildings and on trees. On the older streets the trees are planted on both sides and are allowed to grow through the over head utility wires. This allowed tree growth is key to the pleasant environment. Figure 1 is an example from Norwood Street in HRM. The trees hide the overhead wires as well as providing shade and colour.

Figure 1 Large Trees Hide the Power Lines

In response to continued pressure to improve reliability in recent years, Nova Scotia Power Inc. (NSPI) has altered their policies around trees, preventing a continuation of the status quo. In new developments they have asked for 20 foot easements onto lots on both sides of the street (recently reduced to only one side of the street) and insist on this being clear cut before line installation. They also have asked for a tree height restriction under lines by allowing only certain species of tree. If present over head utility system design does not change, new areas of the city will not have the well designed streets that provide a pleasant and life enriching streetscape. If a height restriction is enforced on existing streets then the many pleasant streetscapes in HRM will be destroyed.

As can been seen in Figure 2 (Dahlia Street in HRM), small trees under the power line are not as effective at hiding the line.

Figure 2 Small Trees Do Not Hide The Power Lines

The age of the overhead wires, the design of the system and the level of maintenance are also factors in the appearance of the street. Figure 3 shows a busy intersection (Spring Garden and Robie in HRM) at which the leaning, overloaded, pole detracts from the visual aesthetics. As power systems age and are gradually altered this type of poor appearance is inevitable. It could be corrected through maintenance but it is hard for NSPI to justify the maintenance cost to the NSURB when technically it is not required. HRM could petition the review board to allow aesthetic maintenance in urban areas, where power lines contribute heavily to the appearance of a street and where NSPI obtains more revenue per unit of cost.

Figure 3 Poor Maintenance and Design Detracts From Visual Appeal

Figure 4 illustrates the difference in aesthetics with and without an overhead power line by comparing the two sides of the street (Morris Street in HRM).

HRM could assist NSPI in obtaining more funding for undergrounding of wires by petitioning the NSURB. Since electricity rates are the same everywhere in the province NSPI receives a disproportionate amount of revenue from areas that are less expensive to service, such as large urban areas like HRM. Some of this revenue could be re-invested by having different maintenance and utilities standards in urban areas. This is justified because the power lines have a larger detrimental visual impact in urban areas. Part of the different utilities standards could include underground wiring on streets such as Morris street in Figure 4.

Figure 4 Comparison Of Aesthetics On Two Sides of The Same Street

Figure 5 shows the Morris street scene as it might look with the overhead wires replaced with underground. The addition of trees on the right hand side of the street would improve the appearance even more, as would the use of lower more decorative street light fixtures.

Figure 5 Altered Street Scene To Simulate Underground Wiring

The conclusion is that underground wiring improves the appearance of city streets both by the removal of the unsightly wires and by allowing room for increased use of street trees.

3 OUTLINE OF ALTERNATIVES

In order for HRM to continue to have well designed streets that provide a pleasant environment, HRM must take action. The new tree policies of NSPI are threatening to change the character of the region's streets.

The following alternatives will be discussed:

1 Persuade NSPI to return to the previous tree policies and to allow maintenance for improved appearance.
2 Change the design of the over head wires to allow better reliability with the old tree policies (covered conductor or Hendrix cable)
3 Require new developments to be partially underground, (low voltage and communication wires)
4 Require new developments to be partially underground (all wires on local streets)
5 Require new developments to be fully underground.
6 Slowly convert all OH to UG (most benefits but most cost)

3.1 OPTION 1 RETURN TO PREVIOUS TREE POLICIES

This is the least cost option that will maintain the possibilities of street trees on all streets. It is a return to the old status quo. It would mean that NSPI would continue to use overhead lines to provide service. However it would do nothing to improve the reliability of electric service. The existing reliability is similar to that provided in most Canadian cities.

The major drawback to selecting option 1 is the probability of success. Initial discussions with NSPI have indicated that they will not revert to the old tree policies. NSPI anticipates that the new policies will reduce their tree trimming costs and increase system reliability during storms.

Another drawback is that the overhead power lines in some areas of HRM are becoming old. The leaning poles, scarred by collisions, and the drooping wires, become more unsightly every year. It is difficult for NSPI to justify, to the NSUARB, maintenance that is purely aesthetic. This maintenance issue could be addressed separately from the other issues in this report by HRM presenting a case to the review board.

Another option would be to request a shorter tree trimming cycle that would allow the clearance distances to be reduced. At the present time the trees are trimmed ten feet back from the lines. This large distance is used to allow for re-growth before the next tree trimming. There is some evidence that the large reduction in the crown of the tree caused by this trimming practice may stimulate faster new growth in the tree and partially offset the benefit. The large reduction in the crown of the tree lowers the valuable benefits of the tree, especially the aesthetic benefit. A shorter tree trimming cycle combined with smaller clearances would give the same overall reliability while maintaining the maximum benefits. It would however be more expensive than the present policy. Again HRM may need to present the case for the increased maintenance cost too the NSUARB. The benefits of smaller clearance distance mainly apply in urban areas.

A full investigation of this option is not within the scope of this study, which is a feasibility study on underground wires. However, this option has been discussed between HRM and NSPI staff and will continue to be a part of the mediated dispute resolution process presently underway.

3.2 OPTION 2 COVERED CABLE OVERHEAD SYSTEMS

There are technical options available for the design of overhead power systems that could address the tree policy and reliability issues while maintaining the overhead lines. Conductors covered with a layer of polyethylene are available that allow trees to contact the conductor without causing a power outage. The covered conductors can be combined with a steel messenger wire ("Hendrix cable") to increase the mechanical strength of the line to allow it to withstand branches or trees falling on to it. The Hendrix company claims these systems reduce tree related power outages by 90%, which in HRM would amount to an overall reduction in power outages of 25%.

The major drawback to this option is that it costs more than conventional overhead systems. The increase in cost has been estimated as 25% by some utilities (Ref 26) but up to 300% by NSPI. The cost differential is larger for single phase lines than for three phase lines. The cable itself is about 10% more and then there are additional costs caused by the need for more frequent poles and guy wires, insulating spacers and increased costs in making connections to the covered conductors. In areas where there are no trees, or in the winter when leaves are absent, the conductors have a larger visual presence than conventional conductors because they are larger in diameter. The aesthetic improvement is therefore questionable unless the covered conductor allows NSPI to change the tree policies to allow large trees to grow through the line. Covered conductors that are in contact with tree branches also produce more radio noise than lines clear of contact.

The increased cost is partially offset by the benefits of reduced tree trimming costs, reduced power outages and increased urban tree canopy. In some urban areas, such as Summerside, tree trimming on these lines is completely eliminated. However many utilities only reduce the tree clearances required so a reduction in tree clearance is a more reasonable expectation. Other benefits are about 50% of those of a completely underground system. In residential areas these benefits when present valued amount to 12-15% of the cost of the regular overhead system.

This is the second lowest cost option and it is also being discussed by HRM staff with NSPI. In some situations it may be the best solution. It is often used in areas of heavy tree cover where trimming is undesirable or very expensive. It is also most appropriate when there are few connections to the line. A full investigation of this option is not within the scope of this study, which is a feasibility study on underground wires. However, this option has been discussed between HRM and NSPI staff and will continue to be a part of the mediated dispute resolution process presently underway.

Ref 26 Terry Orban, "Spacer Cables Revisited", T&D World, Dec 2002

3.3 OPTION 3 REQUIRE NEW DEVELOPMENTS TO BE PARTIALLY UNDERGROUND (LOW VOLTAGE AND COMMUNICATION LINES ONLY)

This is a compromise option between the fully overhead and fully underground options. Most of the visual impact of overhead wires can be attributed to the low voltage (120V) secondary conductors and the telephone and broadband cables. These lines have the largest effect on the aesthetics because they are larger in diameter than the high voltage power conductors, they are generally black, and they are mounted lower on the poles close to the observer. This option does not allow for more trees close to the street because the high voltage overhead wires are still present.

The drawback is an increase in cost and an increase in the complexity of planning utilities so that the wires installed early in the process are not damaged by later utilities. The increase in cost is 70% of putting all utility lines underground. The improvement in reliability would be modest or negligible. Secondary conductors do not cause many outages. The biggest gain would be after major storms, such as Hurricane Juan, where the secondary overhead lines can be ripped off the houses and take a long time to repair, delaying powering up the entire line. Undergrounding these lines would solve that problem, but it does not occur very often.

3.4 OPTION 4 REQUIRE NEW DEVELOPMENTS TO BE PARTIALLY UNDERGROUND (ALL WIRES UNDERGROUND BUT ONLY ON LOCAL STREETS)

This is another compromise between the fully overhead and fully underground options, only closer to the fully underground. It is a very common design choice for new developments in most of North America. All of the utility wires are underground on residential streets, except for the larger three phase power lines that supply power to an area or an adjacent area. This option achieves most of the benefits of an underground system but it also has most of the costs. The cost increase over an overhead system has been estimated as low as $1,800 to $3,100 per 35 foot lot in urban residential areas.

The benefits are the improved appearance on most residential streets from the removal of the wires from view and the increase in the space to plant trees. The only drawback compared to the fully underground system is that the main streets still have overhead lines. This limits the reliability improvement and does not improve the appearance. The appearance aspect could be compensated for by requiring wider street verges or larger setbacks on the main streets.

3.5 OPTION 5 REQUIRE NEW DEVELOPMENTS TO BE FULLY UNDERGROUND

In this option all the utility wires in a new residential development are required to be underground. This is also a very common design choice everywhere in North America. It obtains the full benefits of underground utilities but at the full cost also. It addresses the problem in all new areas, but it does nothing to alter street scenes if NSPI begins enforcing the new tree policies in existing areas.

The major drawback to this option is the cost. For example in an urban residential area the extra cost is about $2,500 to $3,700 per 35 foot lot.

If just the utility lines in new developments are placed underground the improvement in reliability is limited by the size of the development. If the development is large enough to require an entire circuit (>500 houses) then the outages to the area could be reduced by about 50% compared to overhead wires. However, it is much more likely that the developments will be smaller in-fill developments and only the local streets will be underground. This will reduce outages by about 5% since the outages on the lines on local streets affect only a few customers.

3.6 OPTION 6 CONVERT ALL OVERHEAD LINES TO UNDERGROUND

This option includes option 5 and extends it to actively converting all existing overhead lines to underground. This would be very expensive and in most jurisdictions where it has been attempted the city has to pick up the cost. No examples of successful implementation have been found. Some cities have stated this as a policy and begun the conversion but have backed away because of the cost. Toronto is an example. Some cities still place existing overhead wires underground when a street is being rebuilt. Winnipeg is an example. In many cities moving utility wires underground only occurs as part of a "beautification" project in a tourist or commercial area. This is a feasible option for HRM.

This option could improve the reliability of the power system by reducing the outages by about 50%. However, to achieve this improvement the entire circuit must be underground. There will be little reliability improvement from piecemeal conversion to underground.

3.7 SURVEY OF CANADIAN PRACTICE

A survey was conducted of the ten largest Canadian cities to determine which options they are using. In addition to the big ten, Gatineau and New Westminster were included in the survey because they were known to have requirements that new utility wires be installed underground.

The results of the survey are shown in the following table. Fully 70% of major Canadian cities require new utilities of utility wires in residential areas to be installed underground. Only one city, Edmonton, required it in industrial areas. Only two of the ten largest cities had a bylaw or official policy in place that defined this requirement. In most cities it was just understood and accepted as part of the development approval process.

Table 1 Requirements for Underground Utilities in Large Canadian Cities

	Toronto	Montreal	Calgary	Ottawa	Edmonton	Winnipeg	Mississauga	Vancouver	Quebec	Hamilton	Gatineau	New Westminster
Underground required in residential areas?	Y	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Official policy or bylaw in place?	Y	N	N	N	N	Y	Y	N	N	N	Y	Y

3.8 NEXT STEPS TOWARD UNDERGROUND UTILITY LINES

If a decision is made to require underground utility wires in new residential areas or to convert some existing overhead lines to underground it is important that certain steps be performed before the policy is implemented. The estimate of costs prepared for this report found a large difference between costs for how undergrounding is done at the present time in HRM and costs for similar underground systems in other urban areas in North America. It is very important that this be addressed before any undergrounding policy is implemented in order to minimize the costs.

There are two main factors that contribute to existing costs being high are:

- Separate routing and conduits for each utility
- The use of conduit for secondary utility lines

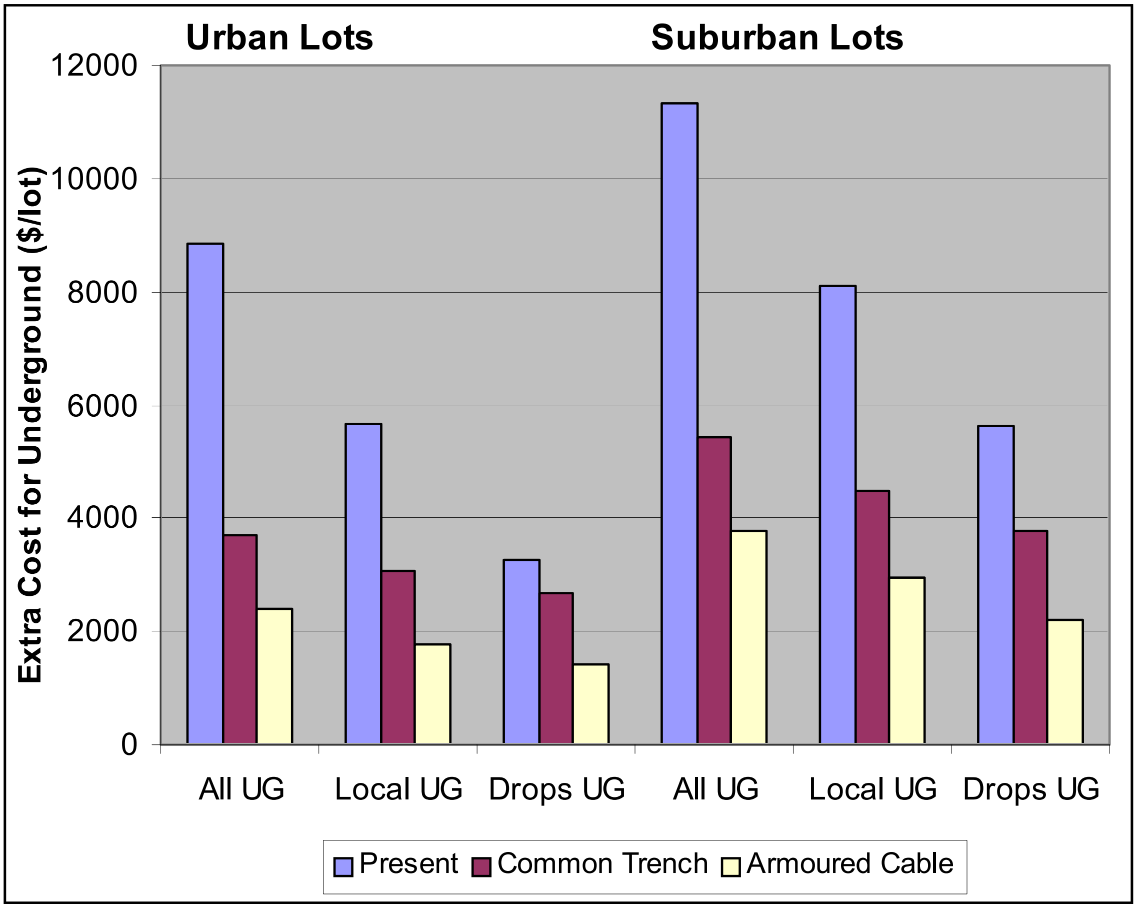
Most urban areas that require underground utility lines have developed a common trench standard and a shared ownership and maintenance policy between the different utilities. This allows for cost savings in system installation. The communication utilities (telephone and cable systems) often share conduit space and their conduit is usually in the same bank of conduits as the power lines. This means only one bank of conduits needs to be installed in a trench and the total length of trenching is minimized. An example of a common trench standard is included later in this report.

The second factor that contributes to high costs at the present time is the installation of conduit by developers and then the pulling of cables at a later time by the utilities. For example the secondary lines from the pad mounted transformers to the URD boxes at each lot line costs up to $134 per metre at the present time and costs to install a phone line are over $1,500 per house. A solution to this problem would be to use more expensive cables that could be installed more easily. Armoured cable is available that can be directly buried in a trench with no conduit. It has similar reliability to that installed in conduit and for low voltage cables it has an extremely long life. Direct burial is not as suitable for high voltage power lines because of the limited life of high voltage cable due to the electrical stresses. The armoured cable seems expensive compared to regular cable, but if an agreement can be made that it can be installed by the developer at the time the trench is dug (this opens up the installation of the wires to competitive bids) then the installation cost savings more than make up for the higher cable costs and slightly higher maintenance costs. For example an armoured 500MCM secondary power cable, the largest typically installed by NSPI, costs $30 per metre. Trenching costs must be added to this and the cost of the utilities to make the connections at the ends but installed costs of $70 per metre should be easily achievable. A downside for the utilities is that the direct buried cables are more expensive to change in response to changing requirements in the future, such as higher load levels. The principal of lowest long term cost can be used to demonstrate the superiority of the direct buried option.

The difficulty of achieving the required cooperation from the utilities involved should not be underestimated. For example, it will require commercial and joint ownership agreements. It may require some direction from the NSUARB. It will probably require the use of an experienced mediator. However, experienced mediators are available and the task is possible because the required cooperation has been achieved in most other urban areas.

The costs estimates presented in this report assume that these changes have been implemented and result in cost estimates per lot that are similar to those in other urban areas. The effects of the different design options are summarized for areas of different lot sizes in Figure 6.

Figure 6 Potential Cost Reductions



4 FINANCING OPTIONS

The costs of the utility infrastructure can be shared by the property developers, the utility companies, the municipality and the property owners. All of these groups eventually pass on the cost to the property owners.

A survey has been conducted of the funding arrangements for underground utilities in cities in Canada. The ten largest Canadian cities were surveyed: Toronto, Montreal, Vancouver, Mississauga, Edmonton, Calgary, Ottawa, Hamilton, Winnipeg, Quebec City. In addition to the big ten, Gatineau and New Westminster were included in the survey because they were known to have requirements that new utility wires be installed underground.

There can be different cost sharing arrangements for power, gas, telephone, cable, water and sewer utilities. The utilities that can be overhead or underground are power, telephone and cable. The costs are very different for power, but very similar for telephone and cable. Therefore the survey concentrated on the cost sharing arrangements for the electric power utility infrastructure.

The survey results break down into two separate situations, new developments and redevelopments.

4.1 NEW DEVELOPMENTS

4.1.1 Survey Results

In seven of the cities surveyed the developer paid the entire cost of the installation of underground power lines. In four cases the power utility paid the cost of an equivalent overhead system and the developer paid the increased cost of putting the lines underground. In the remaining case the city paid the increased cost of putting the lines underground and recovered the cost through a local improvement tax. The survey results are summarized in the following table.

Table 2 Survey of Cost Sharing Models

	Toronto	Montreal	Calgary	Ottawa	Edmonton	Winnipeg	Mississauga	Vancouver	Quebec	Hamilton	Gatineau	New Westminster
Developer pays all electrical system costs	Y			Y	Y		Y	Y		Y		Y
Developer pays differential electrical system costs		Y*	Y			Y			Y*			
City pays for differential electrical system costs											Y	

*Note: In these cases the utility will pay the entire cost if they determine that the system must be underground. They consider it must be underground in downtown commercial areas.

In cases where the developer pays the entire cost of the underground power system they would also pay the cost of an overhead system. The difference arises from the manner in which the regulated monopoly power utilities are funded. Provincial legislation usually determines to what extent they are required to contribute to the capital costs. In Nova Scotia, the utility companies pay the cost of an equivalent overhead system.

In cases where the developer pays only the differential cost, they usually pay the entire cost up front and then are rebated the cost of an equivalent overhead system as each property owner begins to pay for service. This rebate system is often used for telephone and cable costs as well, but in this case the rebate is usually the entire cost. This rebate system is used in Nova Scotia.

In some smaller municipalities, not included in the survey, and where the power utility is owned by the municipality, the utility constructs all the lines and the cost is recovered from power rates from all users. This is the same financing arrangement that is used for overhead utilities in many jurisdictions.

The concern that arises in passing on the cost of undergrounding utilities to the property owners is the increase in the cost of purchasing the property. Many developers in the HRM area consider the cost of housing within HRM to be already at the limit of what the market will bear. Further increases in costs, even if quite small, could drive development to just outside the HRM boundary where costs are lower. This would create lower tax revenues for HRM and problems with transportation and servicing. The city of Gatineau has overcome this problem by the city paying for the utility infrastructure. This results in no increase in the cost of new homes. The city recovers the costs from the property owners slowly over time using a local improvement tax.
(Reference: phone conversation with Mario Deforge, Senior Planner, City of Gatineau)

Another cost sharing model has been used within HRM in the Cowie Hill development. In this case the increased cost of putting the lines underground was covered by a premium added to the power bill. The premium was $1.00 per house or condo and $0.75 per apartment.

4.1.2 Example of Required Underground Policy

The city of New Westminster, B.C. has had the following bylaw requiring underground utility wires in areas of new utilities since 1988. (Bylaw 5798)

> *4.5 Where any parcel is proposed to be subdivided or is proposed to be developed in a manner requiring a building permit, the owner shall locate and pay for design and utilities of underground civil ductwork and underground wiring on the land being subdivided or developed and on the highway immediately adjacent to the land being subdivided or developed. Underground civil ductwork shall be provided by the owner in accordance with the standards prescribed in Schedule "H". Underground wiring shall be provided by the owner in accordance with the Canadian Electrical Code.*
>
> *"highway" includes a street, road, lane, bridge, viaduct and any other way open to public use, but does not include a private right of way on private property.*

The cost sharing for this requirement is outlined in section three of the bylaw as follows:

> *3.5 Subject to Section 3.7, all works and services required to be installed pursuant to this bylaw shall be designed, constructed and installed by the owner at the owner's expense, to the satisfaction of the City Engineer.*
>
> *3.6 Unless otherwise agreed pursuant to Part 7 of this bylaw, all works and services required to be provided by the owner under this bylaw, shall be completed prior to final approval of the proposed subdivision or issuance of the building permit as the case may be.*
>
> *3.7 Unless otherwise agreed by the City Engineer, all works and services required to be provided by the owner pursuant to this bylaw on property owned by the City prior to the approval of the subdivision plans or issuance of the building permit, as the case may be, shall be constructed by the City at the expense of the owner of the land being subdivided or developed.*

4.2 REDEVELOPMENTS

In any area with overhead utilities, the property owner usually has the option of having an underground service drop (the lines from the street to the house) and assuming the differential cost. This change can be initiated by individual property owners and is paid for by them.

For the primary power lines it is more difficult. In some places the customers form groups that pressure the local utility to convert the overhead lines to underground. In many areas this is done by applying pressure to the regulatory agency, but in others such as California and British Columbia, there are laws requiring the utility to underground the wires if certain conditions are met. In West Vancouver and North Vancouver and several states in the US, groups of citizens can initiate the process. In Vancouver it requires 50% of the citizens to petition and the city contributes 25% of the cost through general tax levy and 75% through a surtax on the affected citizens (Ref 1). In California 2/3 of the citizens in a local area must sign the petition, then costs are shared 1/3 by the utility, 1/3 by the city, and 1/3 by the affected citizens. This is enabled through state legislation.

The process can also be initiated by the municipality. Typically this takes the form of a "beautification" project often along main streets, in commercial and tourist districts, or at entrances to neighborhoods. The empowering legislation of the municipality usually allows them to unilaterally implement local improvements and collect the capital contribution through property tax surcharges on all residents in the affected area or throughout the municipality. In this case the municipality pays the full cost of removing the overhead wires and burying the new lines. Sometimes, in Quebec for example, the power utility will rebate to the city for the cost of an equivalent overhead system but in these cases the city must also pay the residual value of the old overhead lines. In Winnipeg the city has a policy of moving the utility infrastructure underground at times of street renewals. The city pays the full cost.

The process is seldom initiated by the utility companies. They do not typically have the legal authority to impose customer contributions for the main lines from unwilling customers. In fact their empowering legislation usually forces them to provide service at the least long term cost, preventing them from initiating a change that is based on benefits such as aesthetics or mental health which are hard to quantify.

In Quebec, the provincial government has had a program, since November 2000, to help fund utility undergrounding in heritage, cultural and tourist sites. In the first three years of the program 18 km of distribution line were reconstructed underground at a cost of 60 million dollars. On average the cost sharing between the partners is 33% from the provincial and municipal governments, 17% from telecommunications companies, and 50% from Hydro Quebec. These costs are much higher than average (a factor of 5), probably because they include expensive surface restoration and lighting fixtures in tourist and cultural areas. It may also be possible to obtain funding from the Canadian federal government through the "Heritage Canada" program.

Ref 1 "Underground Versus Overhead Distribution Systems", Canadian Electrical Association report 274 D 723, 1992 page 6-5.

5 DISCUSSION OF THE BENEFITS OF UNDERGROUND UTILITIES

This section contains a general description of the benefits of undergrounding utilities. The detailed calculations of the benefits that can be given a hard dollar value are in Section 7.

5.1 IMPROVED VISUAL APPEARANCE

The visual appearance of municipal street space is often cited as the largest benefit of undergrounding utility infrastructure. A search of the published literature located no references that could assign a monetary value to this benefit. However, many municipalities in North America require all new utility utilities to be underground even though the costs usually outweigh the quantifiable benefits. The main factor in the decision is the improved visual appearance. The following two photographs of Portland Hills Drive in Dartmouth illustrate the difference.

Notice that the benefits of improved visual appearance and increased tree cover require all utilities to be undergrounded. Much of the visual effect of overhead wires is caused by the telephone and cable company equipment because it tends to be black, larger diameter and closer to the observer.

A part of the improved visual appearance of areas with underground utilities is the increase in the space available for planting large trees. The space is increased because the clearance necessary to wires underground is less than the clearance necessary to overhead lines. Trees are known to have beneficial effects on mental health, stress reduction and people's moods (Ref 17). They improve the overall quality of life and increase people's enjoyment of their surroundings.

Part of the effect is a change in the character of the community. The ambiance is more natural, less man-made or technological. People become less stressed, more relaxed. The mental health effects cannot be accurately measured but simply walking down a street with underground services and a street with over head services will uncover the difference. The pictures on the following page illustrate the sense of openness, and space that is achieved with underground utilities.

As an example of the health effects, studies show that hospital patients with window view of trees recover significantly faster and with fewer complications than comparable patients without such views (Ref 16). They also state "the psychological impact of trees on people's moods, emotions and enjoyment of their surroundings may be the greatest benefit that urban forests provide" (Ref 10, 17).

Ref 10 www2.treesaregood.com International Society of Arboriculture, 2004

Ref 16 R.S. Ulrich, "View Through a Window May Influence Recovery from Surgery", Science 224 : 420-421, 1984.

Ref 17 Henry F. Arnold, "Trees in Urban Design –Second Edition", Van Nostrand Reinhold: New York, 1993.

Figure 7 Street Scene with Overhead Utilities (Portland Hills Drive in HRM)

Figure 8   Simulated Street Scene with Underground Utilities

Another benefit of increasing the number of trees is the reduction in noise pollution (Ref 10, 17). Trees provide a natural absorber for sound because their leaves and needles are loosely suspended and do not reflect sound waves well.

Shade trees can be used to screen unwanted views. They can hide a particular spot, like a junkyard, or generally screen wide areas, softening rigid outlines of rectangular buildings and obscuring damages in old buildings. (Ref 14).

5.2 Increased Economic Investment

Commercial and residential areas with underground lines tend to attract higher levels of investment in businesses and homes. Similarly to the effect of trees on residential property values, this benefit only exists as a relative one between areas of underground and overhead wires. Its value would depend on the relative prevalence of each type of construction. The effect would be strongest in municipalities that had very few underground areas. No published studies were found that could assign a dollar value to this benefit, although several stated it as a benefit. Therefore it was not included in the cost and benefit study.

5.3 Reduced Power Outages

The amount of the reduction in service outages, the increase in reliability, with underground systems depends on the design of the systems (both overhead and underground). Many factors affect reliability, including design, component quality and maintenance practices. In order to isolate the effect of system design assumptions other factors must be assumed to be uniform and the "best practice" in the industry.

Although most utilities with underground systems experience better reliability in the underground portion of their systems this benefit is often debated. Underground systems are generally recognized to have fewer interruptions, but it is sometimes stated that the interruptions have longer durations. The cause of the longer durations is the length of time required to locate the fault and repair an underground cable. However, this longer interruption of service only exists in poorly designed underground systems that were built using the same radial configuration as is used in systems using overhead utilities. Properly designed underground systems are constructed in open loops using faulted circuit indicators.

Open loop systems are defined in Section 11 Appendix A Definition of Terms and are illustrated in Figure 20 on page 81. The open loop design creates an alternate route for power to flow to every customer. In these open loop underground systems, power can be restored after a line fault more quickly than in overhead systems, since power is restored by a switching operation before any repair is completed. The properly designed open loop system has been assumed in the reliability calculations of this feasibility study.

Ref 14 Francis W. Holmes "Shade Trees – The Friends of the Poor and the City Dweller", Journal of Arboriculture 3(9), September, 1977

A completely underground system could eliminate the outages caused by tree contact, lightning, adverse environment (fire, salt spray etc.) and perhaps most of the foreign interference (such as cars hitting poles) and adverse weather. This is approximately 50% of the customer interruptions and 60% of the customer hours of interruption. This provides an upper bound on the reliability improvement of undergrounding the power system. It is an upper bound because there will be some outages from these causes even in an underground system since the underground distribution system will be supplied by overhead systems at higher voltage. Foreign interference can be caused by dig ins to the underground cable for example. Adverse weather such as a hurricane can cause flooding damage to pad mounted equipment in an underground system. If only parts of a power system are placed underground, then the remaining overhead portions will be subject to the same environmental outages.

A detailed analysis of the reduction in interruptions that can be expected with underground power lines is presented in Section 7.

5.4 Improved Air Quality

This benefit is created by the increased number and size of trees possible in an area with underground utilities. The trees increase oxygen levels, reduce particulates, and reduce carbon dioxide levels. However there can be a counterbalancing negative effect where trees can decrease air quality. In areas of high nitrogen oxides (car exhaust) ground level ozone can form from a chemical reaction with volatile organic compounds given off by the trees. Ground level ozone is a major component of smog. However the net effect of trees is positive, an improvement in air quality and subsequent reduced health care costs. The net effect has been given a dollar value by previous studies (Ref 11). The results of that work have been used in this study.

5.5 Reduced Heating and Cooling Energy Use

This benefit is created by the increased number and size of trees possible in areas served by underground utilities. The shading by trees and the reduction of wind speed reduces the need for heating and cooling. It is most significant in areas where there are low buildings and little room around them for trees (i.e. high density residential). This benefit has been assigned a dollar value in previous studies (Ref 8, 10). In this study only reduced heating benefits have been considered in residential areas, since the amount of residential air conditioning in the HRM area is small.

Ref 8 "Tree Trivia", Tree Canada Foundation, 2004

Ref 10 www2.treesaregood.com International Society of Arboriculture, 2004

Ref 11 David Nowak, Daniel Crane, Jack C. Stevens, Myriam Ibarra, "Brooklyn's Urban Forest", United States Department of Agriculture Forest Service General Technical Report NE-290, March 2002.

5.6 Reduced Motor Vehicle Accidents

Reducing the number of wood and concrete poles beside roadways decreases the damages claims in accidents. It may not reduce the actual number of collisions because there will still be street light standards and trees to hit. The average damage is reduced because the light standards break more easily than wood utility poles. A dollar value has been estimated for this benefit in previous studies (Ref 2) and this value has been used in the benefit calculations in this study.

5.7 Reduced Tree Trimming Costs

There is a clear benefit to putting power lines underground in the reduction of the cost to trim the branches of the trees near the power lines. Although it is clearly a benefit, the estimated dollar value varies widely. It depends on the number of trees and how often they are trimmed, which in turn depends on how far back from the line they are trimmed. An average value has been used in this report.

5.8 Reduced Power Line Energy Losses

This is a potential benefit that has been cited in other studies. It depends heavily on the design of the overhead and underground systems. Underground systems are often built with larger conductors to have more allowance for future load growth than in overhead systems because of the difficulty in replacing underground conductors. The conductors are also larger because they are rated for lower currents because of the poor heat dissipation underground. The larger conductors have lower electrical losses. However, the overhead system could be built with the larger conductors also, so this is not, strictly speaking, a benefit of the undergrounding but a result of different design decisions. For this reason it was not included as a quantifiable benefit in this study

5.9 Reduced Maintenance Costs

This is another benefit that is often cited in other studies but it's value is not clear. Some other studies claim reduced maintenance costs, some claim increased maintenance costs. It depends on the design of the systems and the quality of the components. Since previous studies have found both positive and negative dollar values for this benefit, its predicted effect will be small and disputable so it was assumed to be zero in this study.

Ref 2 "Putting Cables Underground Working Group Report", Government of Australia, 1998

5.10 Increased Property Values

Property evaluators use a 10-20% increase for treed properties. (Ref 21) Most studies claim an increase in property value based on improved visual appearance of the neighbourhood (Ref 22). In other studies (Ref 23) trees have been found to have little influence on perceptions of property value. In areas where developers can choose either overhead or underground, they tend to choose underground in areas of larger, higher priced homes. Property values are always relative to other areas of the local market. If utilities are undergrounded everywhere then the effect on property values will not be present.

Although this is probably a real benefit, it was impossible to quantify it based on previous studies.

5.11 Increased Tree Cover

As well as the quantifiable effects mentioned above, increased numbers of trees increase absorption of rain water, decrease summer air temperatures, raise water tables, and reduce noise. No published information was found that could assign a dollar value to these benefits. Therefore they were not included in the cost/benefit study.

Ref 21 "Trees Could Make a Difference in the Selling Price of Your Home", Journal of Arboriculture 11(4), April 1985.

Ref 22 Clay Martin, Robert Maggio, David Appel, "The Contributory Value of Trees to Residential Property in the Austin Texas Metropolitan Area", Journal of Arboriculture 15(3), March 1989

Ref 23 Brian Orland, Joanne Vining, Angela Ebreo, "The Effect of Street Trees on Perceived Values of Residential Property", Environment and Behavior, May 1992.

5.12 Reduced Risk of Electrical Contact Accidents

This is another often cited benefit in other studies. An in depth Australian study (Ref. 2) found that undergrounding increased the risk of accidents, due to dig ins. Other studies have claimed that overhead lines are worse. Assigning a dollar value based on insurance company estimates of the damage settlements, results in a very small cost either way (Ref 2), so this controversy was avoided by not including reduced risk of electrical contact accidents as a benefit.

Some cities regard overhead lines as too hazardous for use in areas where children play, such as school yards and parks. The danger when flying kites is often cited. These cities, such as Calgary, have policies prohibiting overhead lines in school yards and parks.

5.13 Benefits To Telephone And Cable Utilities

The benefits of undergrounding of telephone and cable utilities are reduced service outages and lower maintenance costs. The reduced service outages are much harder to quantify than for power systems due to a lack of studies on the worth of this reliability to customers. Generally it would be much lower than for electric power, with the possible exception of retail stores where payment systems depend on communication. However as communication becomes based more and more on wireless technologies this benefit will be reduced in the future.

The benefit of reduced maintenance costs produces a similar discussion to that with power utilities, with some estimates being higher and some lower. For this reason this has not been considered a quantifiable benefit in this study.

Ref 2 "Putting Cables Underground Working Group Report", Government of Australia, 1998

6 CALCULATION OF COSTS

6.1 ASSUMPTIONS

The basic costs data used in the analysis is presented in Appendix 4 along with the references for that data. The major reference was a study of underground and overhead distribution system costs conducted by the Canadian Electrical Association. A few of these numbers were modified by cost data supplied by the Urban Development Institute in Halifax and by Nova Scotia Power Inc. because these values were considered to be more representative of actual costs in the Halifax market.

A cost estimate is made for an area served by a “typical” power system circuit in areas of four types of land use, downtown, industrial, urban residential and suburban residential. Costs for areas of un-serviced lots and rural areas were not estimated in detail because a preliminary estimate showed they would be too expensive.

In areas of new construction it has been assumed that the increased cost of blasting a larger trench to include the utility lines will be insignificant, based on discussions with developers and consulting engineers in the HRM area. For areas of redevelopment it has been assumed that blasting will be required for 50% of all trenches. This is an average scenario and the actual cost of blasting may be more or less for specific projects than estimated in this general study. Long runs will usually have areas of cut where blasting is required and areas of fill where it is not required.

The costs vary with the design of the underground and overhead systems. For example, the underground systems are much more expensive if the cables are installed inside plastic pipes (called ducts or conduit). Ducts are preferable to directly burying the cable in the ground because they reduce the number of cable failures by mechanically protecting the cable and reduce future maintenance costs by eliminating the need to dig up the cable. However the use of ducts requires manholes and concrete vaults and the price increase is substantial.

There were three different systems designs selected for cost estimation. The first is a system where all three utilities (power, telephone and broadband cable) are installed in separate rigid ducts and use different routing. This is the present design practice by the utilities in the HRM area. However this design practice results in the highest possible cost. A second cost estimate was made for a system that used a common shared trench for all utilities and with the communications utilities sharing a duct. This is a very common design in other cities. A third cost estimate was made for a system in which all the lines under roads are installed in duct, but all the lines along the lot lines and into the houses are direct buried. This is another common design in other cities. The direct burial was assumed to be using armoured cable so that the reliability would be similar to a duct system. The armour is an aluminum covering that mechanically protects the cable much like a duct. Although armoured cable is more expensive in equipment costs, the savings in installation costs will be substantial

Another variation in design that affects costs is the choice between padmounted equipment and vault mounted equipment. Equipment such as transformers and switches is less expensive if it is mounted on concrete pads at the ground surface. The equipment is located within a grounded metal enclosure on top of the concrete pad. This system is less visually appealing than a system in which the transformers and switches are mounted in concrete vaults completely underground and out of sight. The vault mounted equipment is more expensive because it has to be carefully sealed to prevent water seeping in since underground vaults are often filled with water in the spring. Vault mounted equipment also tends to have a higher failure rate because of this extra failure mechanism.

Some of the cost in already developed areas is surface restoration cost, the cost to replace road surfaces or sod after the system has been buried. That cost can be reduced by sharing with other projects that require surface restoration (such as road rebuilding or water and sewer line replacement). The detailed cost estimates include both new and redevelopment scenarios. In the redevelopment scenario the calculation includes the cost of removing the existing overhead infrastructure.

A full cost benefit study of all options was beyond the scope of this project. Instead the full range of possibilities was identified and then prioritized on the basis of an initial cost estimate. The original list of options consisted of all permutations of the following:

- five power distribution system designs
    - all overhead
    - all underground
    - arterial/collector streets overhead and the rest underground
    - arterial/collector streets underground and the rest overhead
    - all lines overhead except service drops underground

- six land use areas
    - Commercial Downtown Core
    - Urban residential
    - Suburban residential
    - Unserviced lots
    - Rural
    - Industrial

- five types civil works projects in combination
    - None (already developed area) Under sod
    - None (already developed area) Under sidewalks
    - None (already developed area) Under roads
    - Road Resurfacing
    - Major Sewer and Water Rebuilds

Arterial/collector streets are major streets designed for through traffic. Typically they have a main three phase power line from which single phase lines are tapped to supply smaller streets. The distinction between urban, and suburban residential is based on density of dwelling units. In this study urban is more than 12 per hectare (more than 5 per acre) and suburban is less than twelve.

Based on the rough cost estimate and a review of the published literature to determine what other cities had found to be practical, the following options were identified as a priority for detailed cost and benefit analysis:

1. Commercial downtown core area with all lines underground
2. Industrial area with all lines underground
3 Urban residential area with
   - 3.1 all lines underground
   - 3.2 arterial/collector street overhead, everything else underground
   - 3.3 low voltage lines and service drops underground, rest overhead
4. Suburban residential area with
   - 4.1 all lines underground
   - 4.2 arterial/collector street overhead, everything else underground
   - 4.3 low voltage lines and service drops underground, rest overhead

Cost estimate for the downtown and industrial areas were only made with the first and second system design option (present design and common trench). The third system design option (direct buried armoured cable for low voltage lines) is most applicable to residential areas.

6.1.1 Downtown Core Area Assumptions

The costs and benefits are considered for a totally underground system as compared to a totally overhead system. The estimate is based on the benefits for one "typical" distribution circuit in the downtown core area. The typical circuit has been assumed to be a 13.8 kV circuit, with 25 commercial customers in high rise buildings and 1000 residential customers all in 25 medium rise buildings (40 units each), a total peak load of 10 MW, a total line length of 2 km. The overhead power system was assumed to be divided into four sections by fuses and be an open loop configuration because of the sensitivity of the customers to the duration of power outages. The underground system was assumed to have a potentially open point at every major building, divided into four sections by fuses and be an open loop configuration with 16 manholes. All transformers were assumed to be located in transformer rooms with metering right at the transformer (no secondary circuit failures were modeled). All telephone cables were 200 pair cables on all streets.

6.1.2 Industrial Area Assumptions

The benefits and costs are considered for a totally underground system as compared to a totally overhead system. The industrial area has been assumed to be light industry in an "industrial park" setting with 6.7 km of line per circuit and 4 MW of peak load from 183 individual loads with a load factor of 0.7 (based on Akerley circuit 124H-301). There are five fuses and all lines are in open loops for both overhead and underground using 27 manholes. The open loop design has been assumed for the overhead lines because this is a common design in industrial areas where outage duration is critical to customers. The overhead lines have a low failure rate of 0.05 f/km/y because of large clearances to trees and few animals. The telephone system was assumed to have 100 pair cables on all streets.

6.1.3 Urban Residential Area Assumptions

The benefits and costs are considered for an overhead system, an underground system, a system with just the secondaries and service drops underground and a system with all but the arterial/collector streets underground. The “typical” circuit used in the analysis is based on Kempt Road DS circuit #423. It has 6 km of three phase line and 11 km of single phase laterals, each individually fused. Twenty five percent of the 3 phase lines are large conductor lines (trunk sections). The assumed load is an average of 8 MW from 3200 customers served from 266 distribution transformers of 100 kVA. The lot size is 35’ x 125 (10.6 x 37.5 m). The service drop conductors were assumed to be 16 feet (5m) and fail at half the rate of the high voltage conductors. The overhead lines are assumed to be a radial configuration and the underground lines are assumed to be in open loops with 68 manholes. Telephone lines on all streets are 100 pair cables. Electric heat is assumed to be 20% of the energy sales in residential areas. (Ref 25)

6.1.4 Suburban Residential Area Assumptions

The benefits and costs are considered for an overhead system, an underground system, a system with just the secondaries and service drops underground and a system with all but the arterial/collector streets underground. The “typical” circuit used in the analysis is based on Penhorn circuit #302. It has 4 km of three phase line and 10 km of single phase laterals, each individually fused. The lot size is 70’ x 150’ (21 x 45m). The assumed load is an average of 4 MW from 1350 customers served from 169 distribution transformers of 50 kVA. The service drop conductors were assumed to be 50 ‘ (15 m) long and fail at half the rate of the high voltage conductors. The overhead lines are assumed to be a radial configuration and the underground lines are assumed to be in open loops with two manholes per km. Telephone cables were 100 pair on local streets and 200 on arterial/collector streets while coax cables were one and four.

Ref 25 “2003 Renewal Annual Information Form”, Nova Scotia Power Inc., May 17, 2004.

6.2 COSTS IN A DOWNTOWN AREA

The costs of overhead and underground utilities were calculated for the example downtown area served by one power distribution circuit in a spreadsheet model. The results are shown in the tables below. Table 3 contains the cost breakdown for the common trench system design used in this study. All of the duct costs are included with the power components since it is assumed they would all be installed together as one bank.

The last three rows in the table present three different totals of the figures above as explained in the notes.

Table 3 Cost Estimate in a Downtown Area

	Costs for Example Area ($)	
	Overhead	Underground
Power	690,000	2,400,000
Telco	46,000	55,000
Cable	64,000	77,000
Trenching in Rock	0	400,000
Surface Restoration	0	200,000
Removal of Overhead Equip.	0	48,000
Street Lights	60,000	180,000
Annual Maintenance	45,000	54,000
Total for redevelopment alone [Note 1]	905,000	3,400,000
Total for redevelopment with major street work [Note 2]	905,000	3,100,000
Total in new area [Note 3]	905,000	2,700,000

Note 1 sum of above
Note 2 sum of above but missing half of trenching and surface restoration
Note 3 sum of above but missing trenching, surface restoration and removal of OH

The costs in Table 3 can be presented as costs per metre of road by dividing by the meters of road in the example area. This results in a more general figure which is useful for comparisons. However, this figure was calculated for the example area only and in other specific example cases it could vary from the values presented here.

The lines labeled "present cost" are an estimate based on separate routing for each utility and separately installed ducts and cables. The "common trench" indicates the estimate based on common trenches and shared telecommunications duct.

Table 4 Cost per Metre of Road in Downtown Area

	Costs per metre of Road ($/m)	
	Overhead	Underground
Total in new area -present costs	450	3,900
Total in new area -common trench costs	450	1,400
Total for redevelopment with major street work – common trench costs	450	1,500
Total for redevelopment alone – common trench costs	450	1,700

Similarly the costs in Table 3 can be presented as costs per lot for comparison purposes. The number of lots is 50, based on 25 commercial buildings and 25 multi-unit residences. The cost per lot in downtown areas needs to be interpreted carefully. In downtown areas cost per metre of road (Table 4) is a better measure of cost.

Table 5 Costs per Lot in Downtown Area

	Costs per Customer ($/customer)	
	Overhead	Underground
Total in new area -present costs	18,000	155,000
Total in new area - common trench costs	18,000	55,000
Total for redevelopment with major street work – common trench costs	18,000	62,000
Total for redevelopment alone – common trench costs	18,000	68,000

6.3 COSTS IN AN INDUSTRIAL AREA

The costs of overhead and underground utilities were calculated for the example industrial area served by one power distribution circuit in a spreadsheet model. The results are shown in the tables below. Table 6 contains the cost breakdown for the common trench system design used in this study. All of the duct costs are included with the power components since it is assumed they would all be installed together as one bank.

The last three rows in the table present three different totals of the figures above as explained in the notes.

Table 6 Cost for Example Circuit in an Industrial Area

	Costs for Example Area ($)	
	Overhead	Underground
Power	1,090,000	3,700,000
Telco	122,000	148,000
Cable	186,000	228,000
Trenching in Rock	0	1,340,000
Surface Restoration	0	525,000
Removal of Overhead Equip.	0	161,000
Street Lights	201,000	603,000
Annual Maintenance	122,000	153,000
Total for redevelopment alone [Note 1]	1,721,000	6,860,000
Total for redevelopment with major street work [Note 2]	1,721,000	5,900,000
Total in new area [Note 3]	1,721,000	4,800,000

Note 1 sum of above
Note 2 sum of above but missing half of trenching and surface restoration
Note 3 sum of above but missing trenching, surface restoration and removal of OH

The costs in Table 6 can be presented as costs per metre of road by dividing by the meters of road in the example area. This results in a more general figure which is useful for comparisons. However, this figure was calculated for the example area only and in other specific example cases it could vary from the values presented here.

The lines labeled "present cost" are an estimate based on separate routing for each utility and separately installed ducts and cables. The "common trench" indicates the estimate based on common trenches and shared telecommunications duct.

Table 7 Costs Per Metre of Road in an Industrial Area

	Costs per metre of Road ($/m)	
	Overhead	Underground
Total in new area – present costs	260	980
Total in new area - common trench costs	260	720
Total for redevelopment with major street work - common trench costs	260	880
Total for redevelopment alone - common trench costs	260	1,000

Similarly the costs in Table 6 can be presented as costs per lot for comparison purposes.

Table 8 Cost Per Lot in an Industrial Area

	Costs per Customer ($/customer)	
	Overhead	Underground
Total in new area – present costs	9,400	36,000
Total in new area - common trench costs	9,400	26,000
Total for redevelopment with major street work - common trench costs	9,400	32,000
Total for redevelopment alone - common trench costs	9,400	37,000

6.4 COSTS IN AN URBAN RESIDENTIAL AREA

The costs of overhead and underground utilities were calculated for the example urban residential area served by one power distribution circuit in a spreadsheet model. The results are shown in the tables below. Table 9 contains the cost breakdown for the armoured cable system design used in this study. All of the duct costs are included with the power components since it is assumed they would all be installed together as one bank.

The last three rows in the table present three different totals of the figures above as explained in the notes.

Table 9 Cost for Example Circuit in an Urban Residential Area

	Costs for Example Area ($)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Power	2,310,000	8,120,000	6,560,000	4,900,000
Telco	348,000	557,000	539,000	540,000
Cable	374,000	658,000	656,000	630,000
Trenching in Rock	0	2,530,000	1,430,000	0
Surface Restoration	0	2,075,000	1,625,000	800,000
Removal of Overhead Equip.	0	408,000	264,000	41,000
Street Lights	510,000	1,860,000	1,435,000	1,860,000
Annual Maintenance	448,000	484,000	450,000	448,000
Total for redevelopment alone Note 1	3,990,000	16,700,000	13,000,000	9,220,000
Total for redevelopment with major street work Note 2	3,990,000	14,800,000	11,870,000	9,286,780
Total in new area Note 3	3,990,000	11,700,000	9,680,000	8,445,980

Note 1 sum of above
Note 2 sum of above but missing half of trenching and surface restoration
Note 3 sum of above but missing trenching, surface restoration and removal of OH

The costs in Table 9 can be presented as costs per metre of road by dividing by the meters of road in the example area. This results in a more general figure which is useful for comparisons. However, this figure was calculated for the example area only and in other specific example cases it could vary from the values presented here.

The lines labeled "present cost" are an estimate based on separate routing for each utility and separately installed ducts and cables. The "common trench" indicates the estimate based on common trenches and shared telecommunications duct. The "armoured cable" indicates the third design option using direct buried armoured cable for all low voltage lines.

Table 10 Cost Per Metre of Road in an Urban Residential Area

	Costs Per Metre of Road ($/m)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Total in new area – present costs	235	1,900	1,300	850
Total in new area -common trench	235	930	810	740
Total in new area -armoured cable	235	690	570	500
Total for redevelopment with major street work - armoured cable	235	870	700	550
Total for redevelopment alone - armoured cable	235	980	770	550

Similarly the costs in Table 9 can be presented as costs per lot for comparison purposes.

Table 11 Cost Per Lot in an Urban Residential Area

	Costs Per Lot ($/lot)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Total in new area – present costs	1,200	9,900	6,800	4,800
Total in new area -common trench	1,200	4,900	4,300	3,200
Total in new area - armoured cable	1,200	3,700	3,000	2,600
Total for redevelopment with major street work - armoured cable	1,200	4,600	3,700	2,900
Total for redevelopment alone - armoured cable	1,200	5,200	4,100	2,900

6.5 COSTS IN A SUBURBAN RESIDENTIAL AREA

The costs of overhead and underground utilities were calculated for the example suburban residential area served by one power distribution circuit in a spreadsheet model. The results are shown in the tables below.

The last three rows in the table present three different totals of the figures above as explained in the notes.

Table 12 Cost for Example Circuit in a Suburban Residential Area

	Costs for Example Area ($)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Power	1,630,000	5,410,000	4,530,000	3,250,000
Telco	243,000	313,000	301,000	305,000
Cable	258,000	411,000	410,000	384,000
Trenching in Rock	0	2,030,000	1,300,000	0
Surface Restoration	0	1,560,000	1,260,000	506,000
Removal of Overhead Equip.	0	336,000	240,000	33,000
Street Lights	420,000	1,500,000	1,150,000	1,500,000
Annual Maintenance	340,000	400,000	370,000	340,000
Total for redevelopment alone Note 1	2,890,000	11,960,000	9,560,000	6,320,000
Total for redevelopment with major street work Note 2	2,890,000	10,400000	8,500,000	6,400,000
Total in new area Note 3	2,890,000	8,000,000	6,800,000	5,800,000

Note 1 sum of above
Note 2 sum of above but missing half of trenching and surface restoration
Note 3 sum of above but missing trenching, surface restoration and removal of OH

The costs in Table 12 can be presented as costs per metre of road by dividing by the meters of road in the example area. This results in a more general figure which is useful for comparisons. However, this figure was calculated for the example area only and in other specific example cases it could vary from the values presented here.

The line labeled "present cost" is an estimate based on separate routing for each utility and separately installed ducts and cables. The "lowered costs" are estimated based on common trenches and armoured cable secondary lines.

Table 13 Cost Per Metre of Road in a Suburban Residential Area

	Costs Per Metre of Road ($/m)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Total in new area – present costs	210	1300	990	750
Total in new area -common trench	210	730	640	570
Total in new area - armoured cable	210	570	490	420
Total for redevelopment with major street work - armoured cable	210	740	650	460
Total for redevelopment alone - armoured cable	210	860	740	460

Similarly the costs in Table 12 can be presented as costs per lot for comparison purposes.

Table 14 Cost Per Lot in a Suburban Residential Area

	Costs Per Lot ($/lot)			
	Overhead	Underground	Arterial/collector Overhead	Service Drops Underground
Total in new area – present costs	2,100	13,500	10,000	8,000
Total in new area -common trench	2,100	7,600	6,600	5,900
Total in new area - armoured cable	2,100	5,900	5,000	4,300
Total for redevelopment with major street work - armoured cable	2,100	7,700	6,800	4,700
Total for redevelopment alone - armoured cable	2,100	8,900	7,900	4,700

6.6 SUMMARY OF COSTS

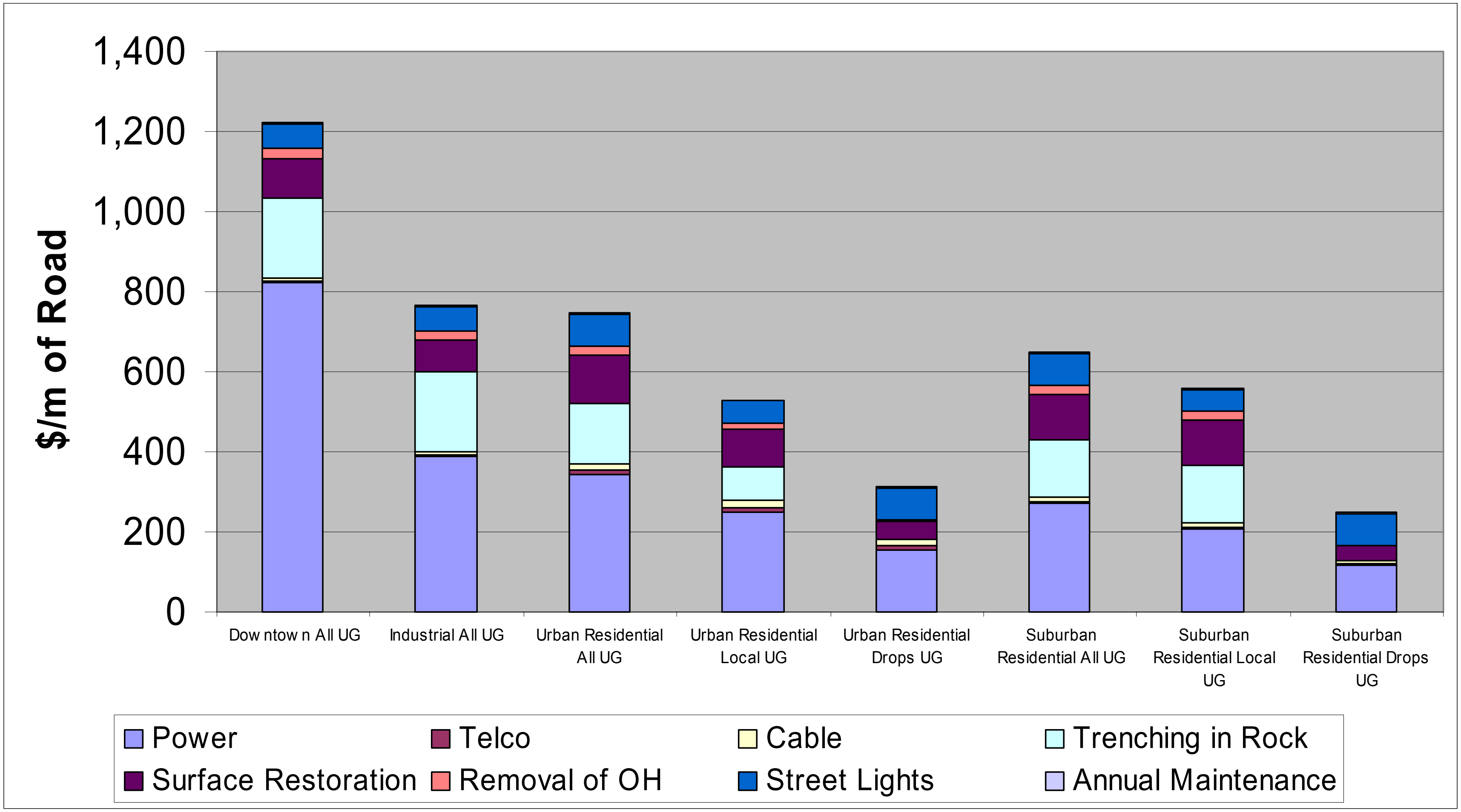
The following table summarizes the cost of the completely underground system expressed in dollars per metre of road for easy comparison with the benefits summary in section 7.6. The cost in a new development has been reduced by the NSPI rebate of 90% of the cost of an overhead system.

Table 15 Summary of Costs per Metre of Road

	Downtown Core	Industrial	Urban Residential			Suburban Residential		
System Design	All UG	All UG	All UG	Arterial /collector OH	Drops UG	All UG	Arterial / collector OH	Drops UG
New Development – present cost	3,600	830	1,700	1,200	720	1,200	880	640
New Development – shared trench	1,100	570	800	690	610	620	530	460
New Development – armoured cable			560	450	370	470	370	310
New Development – lowest cost in addition to an overhead system	920	460	450	330	260	370	280	210
Redevelopment with Major Street Work – lowest cost	1,500	880	870	700	550	740	660	450
Redevelopment alone – lowest cost	1,700	1,000	980	760	550	850	770	450

Figure 9 shows the contribution of the different elements to the cost. When interpreting the figure keep in mind that the surface restoration and removal of overhead costs do not apply in new developments and the cost of trenching is greatly reduced.

Figure 9 Cost Contributors (increased cost of underground in $/m of road)



7 CALCULATION OF BENEFITS

Based on the rough cost estimate and a review of the published literature to determine what other cities had found to be practical, the following options were identified as a priority for detailed cost and benefit analysis:

1 all lines underground in commercial downtown core areas
2 all lines underground in industrial areas
3.1 all lines underground in urban residential areas
3.2 all lines underground in suburban residential areas
4.1 arterial/collector lines overhead, rest underground in urban residential areas
4.2 arterial/collector lines overhead, rest underground in suburban residential areas

The options 3.3 and 4.3 that were included in the cost calculations are not included here because they were determined to have no quantifiable benefits. This is discussed in section 7.4.2.

Each of these will be considered in detail in sections 7.3, 7.4, 7.5 and 7.6. Section 7.1 contains a summary of all the benefits. Section 7.2 contains some calculations and discussion that are common to all. Subsequent sections contain detailed discussions in support of the statements in the summary.

7.1 SUMMARY OF BENEFITS

The benefits of each of the individual studies have been summarized in the following table. The values presented in the table are the present value of the benefits over the estimated forty year life of the utility infrastructure. They are expressed as thousands of dollars per metre of road so that they can be directly compared with the costs expressed in this way.

Table 16 Present Value Dollar Benefit per Metre of Road in Six Scenarios

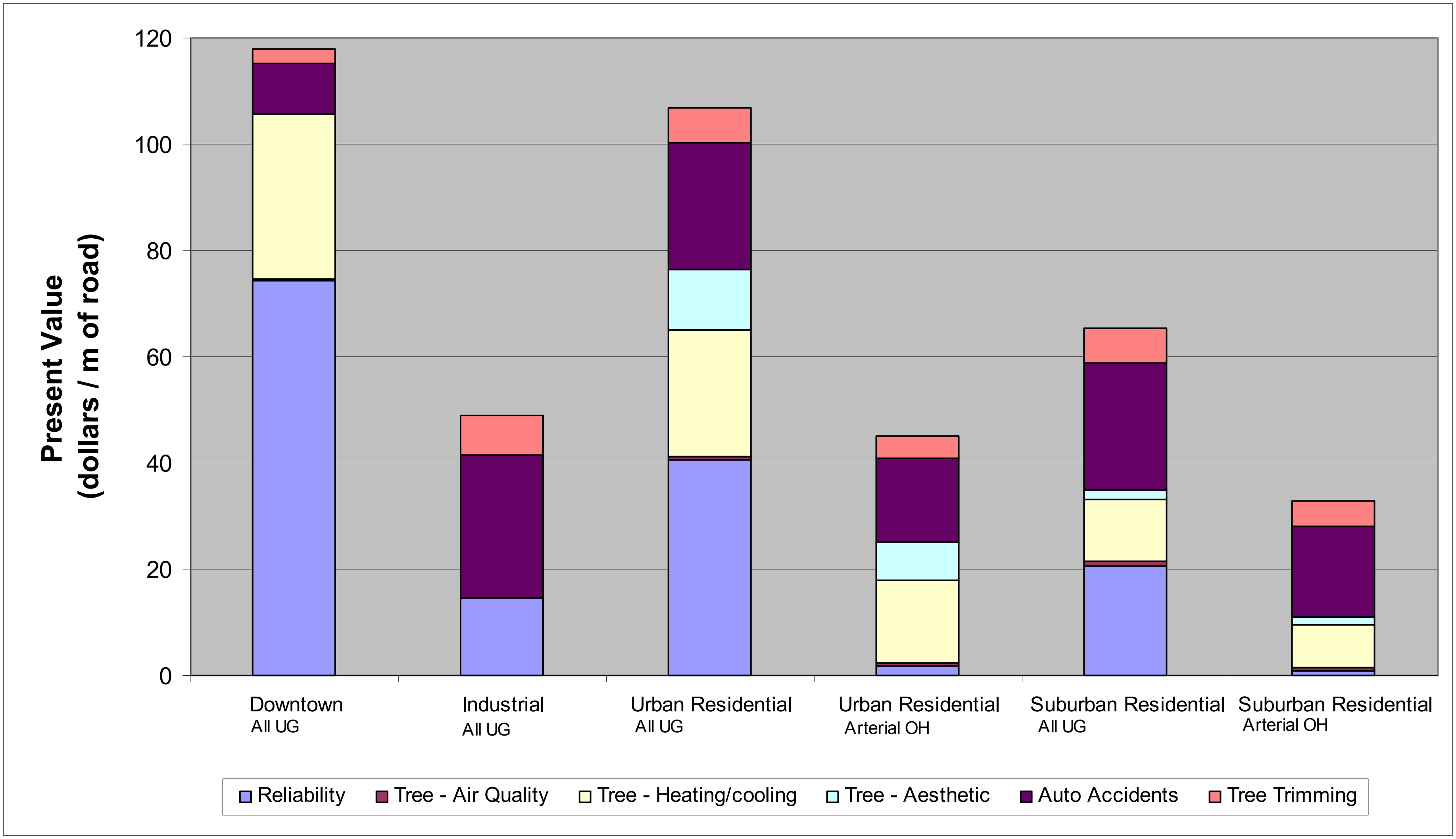
	Downtown Core	Industrial	Urban Residential	Urban Residential	Suburban Residential	Suburban Residential
System Design	All UG	All UG	All UG	Arterial and Collector OH	All UG	Arterial and Collector OH
Reliability	74	15	41	2.0	21	0.86
Tree – Air Quality	0.09	0.00	0.48	0.31	0.96	0.69
Tree - Heating/cooling	31	0	24	16	11	8.0
Tree - Aesthetic	-13	0.00	11	7	1.9	1.3
Auto Accidents	9.60	27	24	16	24	17
Tree Trimming	2.60	7.30	6.60	4.20	6.60	4.70
Total	104	49	107	45	65	33

The largest benefits are clearly in the commercial downtown core areas where outages cause more financial harm and in the urban residential areas where large numbers of customers are affected by each outage. In general the lower the density of land use the lower the benefit per metre of road.

The benefits are lower in industrial areas because the difference between the failure rates of the overhead and underground lines in these areas is less and there is enough room away from the lines to plant trees.

The benefits are higher in urban residential areas than in suburban because the increase in tree cover near underground lines is more significant in areas where there is little room to plant trees.

Figure 10 Summary of Quantifiable Benefits



7.2 GENERAL METHOD

The input data for the calculations and the sources of these data has been described in Appendix D, "Rationale for Benefits Data".

7.2.1 Economic Assumptions

The annual savings need to be converted into present value to compare with the capital cost of undergrounding. The simplest way would be to multiply the annual savings by the number of years the system is expected to be in service (typically assumed to be about 40 years). However, this would ignore the fact that a savings of $100 ten years from now is not worth $100 today. In a correct financial analysis the savings in future years must be lowered (discounted) to account for this time value of money. Different financial assumptions can be used but an annual discount rate of 8% is often used by electric utilities based on the rate of return on the long term bonds they issue. The discount (divide by 1.08^N where N is the number of years in the future) should be applied to each years benefit over the forty year estimated life of the underground cable. When this is summed over all the years it produces an overall factor of 12 that can be multiplied by the annual savings to produce the present value of the savings over 40 years. If a 6% annual discount were used the factor would be 15. This would increase the dollar value of benefits by 25% but it would not change any conclusions in this study.

7.2.2 Power System Reliability

A rough estimate of the average decrease in outage statistics, customer-interruptions and customer-interruption-hours, can be obtained by examining the causes of outages in the HRM area. The causes of existing outages in HRM have been provided by NSPI in the following table.

Table 17 Causes of Power Outages in HRM

Cause	Events	Customer Interruptions	Customer Hour Interruptions	% of events	% of CI	% of CH
Unknown/other	1973	245109	340999	26.0	16.2	12.4
Scheduled	113	35551	24492	1.5	2.3	0.9
Loss of Supply	330	153490	295401	4.3	10.1	10.7
Tree Contact	964	332492	779340	12.7	22.0	28.3
Lightning	273	24146	58898	3.6	1.6	2.1
Defective Equipment	1496	265421	436283	19.7	17.5	15.8
Adverse Weather	820	216565	456475	10.8	14.3	16.6
Adverse Environment	154	63804	99036	2.0	4.2	3.6
Human Element	74	26488	8803	1.0	1.8	0.3
Foreign Interference	1402	150356	256871	18.4	9.9	9.3
Total	7599	1513422	2756598			

A completely underground system could eliminate the outages caused by tree contact, lightning, adverse weather, adverse environment (fire, salt spray etc.) and perhaps most of the foreign interference (such as cars hitting poles). This is approximately 50% of the customer interruptions and 60% of the customer hours of interruption. This provides an upper bound on the reliability improvement of undergrounding the power system. It is an upper bound because there will be some outages from these causes even in an underground system, especially foreign interference caused by dig ins. The actual reduction in outages has been calculated based on sample circuits in each of the types of service area. This analysis based on outage causes has only been used to show that the increased reliability found in the detailed calculations is reasonable.

Underground systems are generally recognized to have fewer interruptions, but it is often stated that the interruptions have longer durations (Ref 4). The cause of the longer durations is the length of time required to locate the fault and repair an underground cable. This longer duration only exists in poorly designed underground systems. Properly designed systems are constructed in open loops (as defined in Appendix A) using faulted circuit indicators.

The open loop design creates an alternate route for power to flow to every customer. In these open loop underground systems power can be restored after a line fault more quickly than in overhead systems, since power is restored by a switching operation before any repair is completed. The properly designed open loop system has been assumed in the reliability calculations of this feasibility study.

The costs of service interruptions used in this analysis are estimates of the costs to the customers. The costs to the utility company are included under maintenance costs. The reduced revenue of the utility company has been ignored because it is lower than the customer costs by several orders of magnitude. The customer cost surveys on which the input data is based have reported a wide variation in customer costs of service interruption. The average values have been used in this analysis, but the variation in the underlying surveys causes the actual benefit to be uncertain, typically by a factor of five for residential customers. The costs of outages to industrial and commercial customers are even more highly variable and depend on the unique characteristics of each customer. These costs could be different than the average by a factor of ten or more.

The benefit of increased reliability in underground systems has been based on a well designed underground system compared with the existing overhead system. However, there are alternative ways of improving the reliability, by changing the design of the overhead system. Overhead systems can be made more reliable by having automatic switching restore power, or by closing the open loop and having two sources of supply at all times. Quality and strength of utilities, frequency of maintenance, and priority of service restoration all play a role.

The benefits of improved reliability discussed above have been for systems that are of uniform utilities standards everywhere. Since most of the existing lines in HRM are overhead, if a small in-fill housing development is constructed with underground wires, it will not experience the full benefit of underground utilities. In fact, the residential circuits used as examples in this project, both have most of their customer outages caused by faults on the main lines, since these faults affect all customers on the circuit. This means that for small in-fill developments the increased reliability will be negligibly small.

Ref 4 *Brad Johnson, “Out of Sight, Out of Mind?”, Edison Electric Institute, January 2004.*

7.2.3 Tree Cover Assumptions

A factor that could reduce the benefit of maximum tree cover is the occurrence of occasional hurricanes. If a normal large tree requires 25 years to reach a substantial size and has a life of 100 years, then the benefits will be achieved for 75% of the time. However, if a hurricane occurs every 50 years and blows down the large trees, then the benefits will only be achieved for 50% of the time, since the trees will need to be replanted every 50 years. This analysis has assumed that the hurricanes are infrequent enough to allow large trees to grow.

The method used to estimate the maximum increase in the number of trees in an area with underground utilities is illustrated in the following diagrams. The first diagram shows an area with overhead power lines. This diagram indicates no trees planted under the lines. In many cities trees are allowed to grow through the power lines by utilizing careful pruning practices, but NSPI has indicated that in HRM the risk of high winds requires a more complete tree cutting strategy.

The second figure shows the additional 4 trees that would be possible if the power lines were underground.

In the detailed benefit calculations it is assumed that there are in fact short trees planted under the power lines. An HRM urban forester estimates that the reduction in tree canopy on a street with overhead lines would actually be about 35%. If there were no trees at all under the power lines then the reduction would be 50%. The 35% reduction has been assumed in the benefit calculations.

The benefits of improved reliability and increased tree cover are the most difficult to estimate and are therefore estimated separately in detail for each scenario in the following sections. The benefits of reduced motor vehicle accidents, reduced tree trimming costs have been estimated by other studies on the basis of the length of the distribution circuit and are estimated for each scenario together in the third subsection.

Figure 11 Street Space with Overhead Power Lines

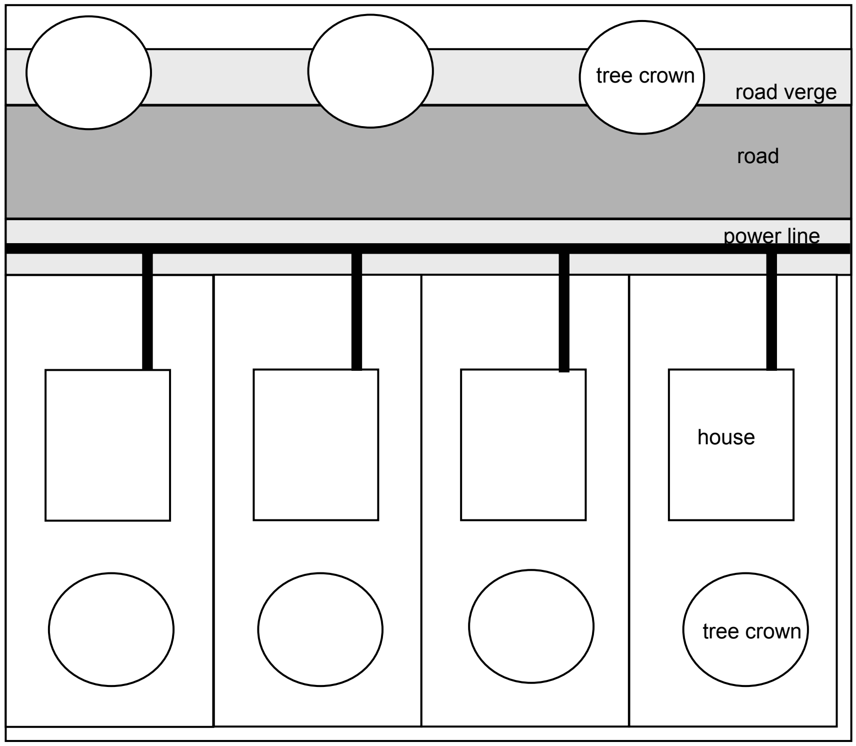
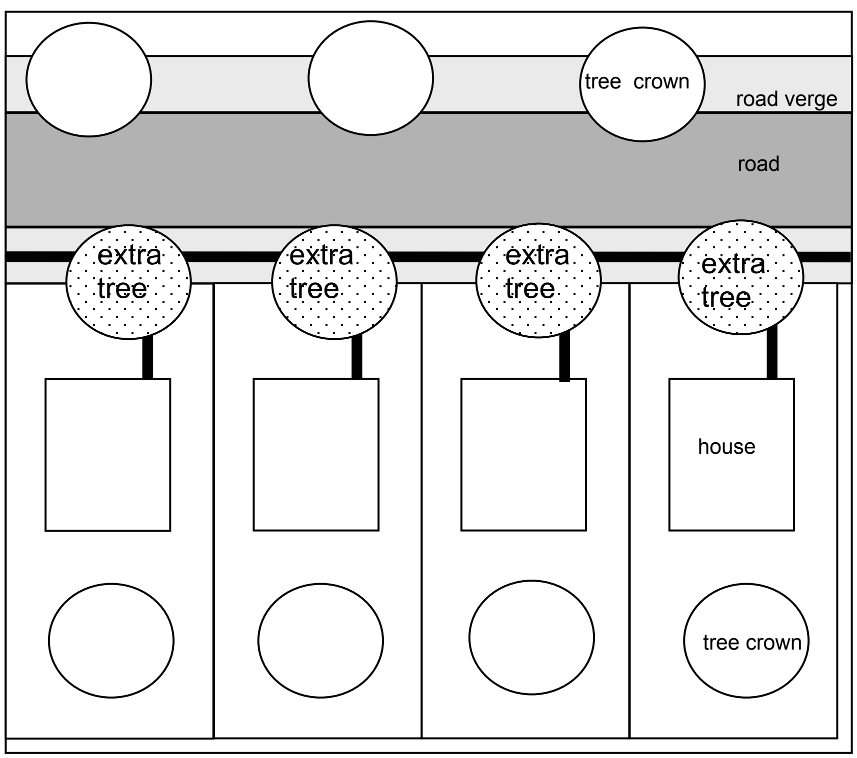


Figure 12 Street Space with Underground Power Lines



7.3 BENEFITS IN A DOWNTOWN URBAN CORE AREA

The benefits are considered for a totally underground system as compared to a totally overhead system. The estimate is based on the benefits for one "typical" distribution circuit in the downtown core area. The typical circuit has been assumed to be a 13.8 kV circuit, with 25 business customers in high rise buildings and 1000 residential customers in 25 medium rise apartment buildings (40 units per building), a total peak load of 10 MW, a total line length of 2 km. The overhead power system was assumed to be divided into four sections by fuses and be an open loop configuration because of the sensitivity of the customers to the duration of power outages. The underground system was assumed to have a potentially open point at every load, divided into four sections by fuses and be an open loop configuration. All transformers were assumed to be located in transformer rooms with metering right at the transformer (no secondary circuit failures were modeled).

7.3.1 Reliability Improvement

The expected improvement in reliability achieved by putting power lines underground depends on the lengths of line, the loading on the line, how the line sections are interconnected, the relative failure rates of the equipment and the relative restoration times. The values used in the analysis are shown in Appendix D with the appropriate references.

The results of the reliability modeling show the overhead circuit should experience 407 customer interruptions per year due to the distribution lines. This would result in 407 hours of customer interruption per year, assuming a one hour restoration time by switching. As an underground circuit it would experience 135 customer interruptions and 203 customer hours of interruption due to faults on the distribution lines. In addition there would be about 400 customer interruptions from other causes in both types of system.

The dollar value that can be assigned to this improvement depends on the specific customers on the circuit, but using general average values for commercial customers of 7 $/kW interrupted and 16 $/kW-h and for residential customers 2 $/kW-h the total worth of these outages to the customers is estimated to be $55,000 on the overhead circuit and $25,000 on the underground. These values are very approximate and could vary by a factor of five. Particularly in the HRM area, the perceived benefit of increased reliability by customers might be heightened at the present time because of recent power outages.

The total dollar value of the improved reliability is $30,000 each year. Over a forty year life of the underground cable, and discounting the future savings at an annual rate of 8%, produces a present value of $360,000.

7.3.2 Increased Tree Cover

Increased tree cover has three quantifiable benefits, increased air quality, improved appearance, and increased shading of the buildings resulting in reduced heating and cooling costs.

The number of trees affected by a single urban downtown core circuit can be calculated from the length of the circuit (typically about 2 km of road) and the spacing of large trees in the HRM street tree standards (spacing = 15 - 25 m so an average of 20m has been used). After discussion with HRM urban foresters, the reduction in tree canopy on streets with overhead power lines has been assumed to be 35%, instead of assuming a 50% reduction caused by no trees on one side of the street, because smaller trees can still be planted under power lines. This means that on the typical circuit an equivalent of 65 more trees could be planted in an area served by underground power lines. However, inspection of downtown areas of HRM reveals that other factors limit the number of trees that are actually planted where trees could be planted. These factors include the concrete sidewalks, cafés etc. The number of trees that would actually be planted has been estimated as 16, which is 25% of the maximum possible. The benefit of this in air pollution abatement is estimated as $37 per year or a present value of $440 over 40 years.

The benefit of the improved appearance of increased tree cover has been estimated as averaging $1050 per tree (Ref 20) based on the compensatory value of the tree if it is damaged or destroyed. This benefit is worth $17,800 on the downtown urban circuit. However, there are costs associated with trees in downtown urban areas that are not present in other areas. A tree in a concrete and pavement area requires soil to be provided and a watering system. The cost of this averages $5,000 per tree. The net benefit is therefore $-63,000. This is a one time value which can be converted to an equivalent per year benefit to compare with the other per year benefits, as $-5,300 per year.

The heating and cooling costs of the buildings supplied by the circuit depends on a large number of factors, especially the design of the building and the climate surrounding it. However, studies have shown that in treed areas heating and cooling costs are reduced by about 10 – 15%. Other studies have shown that 25% of the energy cost of commercial buildings is a result of heating and cooling. On a typical downtown core circuit of 10 MW the annual energy sales would be about 40 GW-hr. The difference between an area of overhead power lines and an area of underground power lines would be 65% of the savings due to trees (assumes a 35% reduction in canopy on streets with overhead power lines). This will be reduced by another factor of 4 because the maximum number of trees will not actually be planted. Using the more conservative 10% savings on heating and cooling due to trees, the total savings on the buildings supplied by one circuit would be $13,000 per year (40,000,000 x 0.25 x 0.1x 0.65 x 0.25 x 0.08 $/kW-hr) or a present value of $156,000 over 40 years.

7.3.3 Other Benefits

Other benefits can be easily calculated based on the km of power line.

Reduced motor vehicle accidents 2,000 $/km/yr x 2 km = 4,000 $/yr

Reduced tree trimming costs $550 $/km/yr x 2 km = 1,100 $/yr.

The total of these benefits is 5,100 $/yr which has a present value of $62,000.

Ref 20 David Nowak, Daniel Crane, John Dwyer, "Compensatory Value of Urban trees in the United States", Journal of Arboriculture 28(4), July 2002.

7.4 BENEFITS IN AN INDUSTRIAL AREA

The benefits and costs are considered for a totally underground system as compared to a totally overhead system. The industrial area has been assumed to be light industry in an "industrial park" setting with 6.7 km of line per circuit and 4 MW of peak load from 183 individual loads (based on Akerley circuit 124H-301). All lines are in open loops for both overhead and underground. The open loop design has been assumed for the overhead lines because this is a common design in industrial areas where outage duration is critical to customers and is used on the actual Akerley circuits. The overhead lines were assumed to have a low failure rate of 0.05 f/km/y because of large clearances to trees and few animals.

7.4.1 Reliability Improvement

The results of the reliability modeling of a "typical" industrial circuit show the overhead circuit would experience 63 customer interruptions and 63 customer hours of interruption each year due to faults on the distribution lines. The underground circuit would experience 17 customer interruptions and 25 customer hours of interruption. In addition both types of circuit would experience about 60 customer interruptions due to other causes.

The dollar value that can be assigned to this depends on the specific customers on the circuit, but using general average values for industrial customers of 1.51 $/kW and 7.45 $/kW-h a reduction of 46 customer outages would be worth $1500 (46 x 21 x 1.51) and the reduction of 38 customer hours of outage would be worth $5900 (38 x 21 x 7.45). These values are very approximate and could vary by a factor of ten. Particularly in the HRM area, the perceived benefit of increased reliability by customers might be heightened at the present time because of recent power outages.

The total dollar value of the improved reliability is 7,400 dollars per year. Over a forty year life of the underground cable, and discounting the future savings at an annual rate of 8%, produces a present value of $88,000.

7.4.2 Increased Tree Cover

Increased tree cover in industrial areas would have similar benefits to that in the downtown core, however there is usually more room adjacent to the buildings in industrial areas so these benefits do not depend on the type of power line. Since there is sufficient room for trees in both cases, no benefit can be assigned to undergrounding the power lines.

7.4.3 Other Benefits

Other benefits can be easily calculated based on the km of power line.

Reduced motor vehicle accidents 2,000 $/km/yr x 6.7 km = 13,400 $/yr

Reduced tree trimming costs $550 $/km/yr x 6.7 km = 3,700 $/yr.

The total of these benefits is 17,100 $/yr which has a present value of $205,000.

7.5 BENEFITS IN AN URBAN RESIDENTIAL AREA

The benefits and costs are considered for an overhead system, an underground system, a system with just the secondary lines and service drops underground and a system with all but the arterial/collector streets underground.

The “typical” circuit used in the analysis is based on Kempt Road DS circuit #423. It has 6 km of three phase line (on arterial/collector roads) and 11 km of single phase laterals, each individually fused. Twenty five percent of the 3 phase lines are large conductor lines (trunk sections). The assumed load is an average of 8 MW from 3200 customers served from 266 distribution transformers of 100 kVA. The lot size is 35’ x 125 (10.6 x 37.5 m). The service drop conductors were assumed to be an average length of 16 feet (5m) and fail at half the rate of the high voltage conductors. The overhead lines are assumed to be a radial configuration and the underground lines are assumed to be in open loops.

7.5.1 Reliability Improvement

The results of the reliability modeling of a “typical” urban residential circuit show an overhead circuit would experience 6646 customer interruptions and 16,600 customer hours of interruption due to faults on the distribution lines. An underground circuit would experience 494 customer interruptions and 863 customer hours of interruption, assuming the load could be restored by switching. An arterial/collector road underground circuit would experience 6355 customer interruptions and 9532 customer–hours of interruption annually. A circuit with only secondary lines and service drops underground would have the same reliability as an overhead system since the failure rate of overhead and underground low voltage lines is very nearly the same. In addition all types of circuit would experience about 4,200 customer interruptions from other causes.

The dollar value that can be assigned to this depends on the specific customers on the circuit, but using average values for residential customers of $2 per kW-h the fully underground system would save $57,500 per year or a present value of $690,000 over forty years. The circuit with overhead lines on arterial/collector roads would save $2,700 per year or a present value of $32,800. This value is low because of the design of the circuit. It had no sectioning on the main three phase line. This means that any fault on that line affects all the customers, and this line then dominates the outages. In contrast the laterals are very short and individually fused.

7.5.2 Increased Tree Cover

Increased tree cover has three quantifiable benefits, increased cleaning of the air, improved appearance and increased shading of the buildings resulting in reduced heating and cooling costs. There will be two separate estimates calculated, one for all lines underground, and one for the power lines on arterial/collector streets being overhead and the rest underground. If only the secondary lines and service drops are underground no increase in the number of trees can be confidently assumed. The trees would have to be planted by home owners on their property. No doubt many would do so, but many do so with overhead wires as well. The trees are allowed to grow up through the conductors since they are low voltage and covered with insulation. In this study no increase in trees has been assumed for underground secondary lines and service drops.

The number of trees affected by a single urban residential circuit being fully underground can be calculated from the length of the circuit (17 km of road) and the distance between large trees (HRM street tree standard is 15 – 25m so 20 m can be assumed). After discussion with HRM urban foresters, the reduction in tree canopy on streets with overhead power lines has been assumed to be 35%, instead of assuming 50% reduction (no trees under the power lines), because smaller trees can still be planted under power lines. This means that on the typical circuit an equivalent of 297 (850 x 0.35) more trees could be planted in an area served by underground power lines. The benefit of this in air pollution abatement is estimated as $684 per year or a present value of $8,200 over 40 years. This would be reduced to 192 trees if the arterial/collector roads have overhead wires, which would be a savings of $441 per year or a present value of $5,300 over forty years.

The aesthetic value of the 297 trees in a fully underground area would be $311,850 based on compensatory value. The cost of a tree is estimated to be $400, so the net benefit is $193,000 or $16,000 per year for comparison with other benefits. For a system with overhead wires on the arterial/collector streets this would be reduced to $125,000 and $10,400 per year.

The heating and cooling costs of the buildings supplied by the circuit depends on a large number of factors, especially the design of the building and the climate surrounding it. However, studies have shown that in residential areas with mature trees annual energy savings are about 10% (Ref 12, page 106). On the “typical” urban residential circuit the annual electricity sales would be about 61 GW-hr. Space heating represents 20% of this total (Ref 25) and a 10% saving on this would be 1.2 GW-h or about $97,000 per year. In HRM the residential air conditioning load is small so it has been neglected.

However the difference between an area of overhead power lines and an area of underground power lines would be less than this since both types of systems allow some tree growth. If all lines were underground then the increased trees on one side of the street might create 35% of the above savings (65% of the canopy would be available even with overhead lines). This would be $34,000 per year or a present value of $407,000 over 40 years.

An estimate of the effect of undergrounding the power lines on all but arterial/collector streets results in a similar net effect. The non-arterial/collector streets are 65% of the total road length, and the power lines only affect one side of the road so the increase in trees due to undergrounding the lines on all but arterial/collector streets would be $22,000 (0.65 x 34000) or $265,000 over 40 years.

7.5.3 Other Benefits

Other benefits can be easily calculated based on the km of power line.
Reduced motor vehicle accidents 2,000 $/km/yr x 17 km = 34,000 $/yr
Reduced tree trimming costs $550 $/km/yr x 17 km = 9,350 $/yr.
The total of these benefits is 43,350 $/yr which has a present value of $520,000.

For the case of arterial/collector roads being overhead utilities the resulting benefits would be reduced proportional to the length of road that remains overhead (35%). In this case the total annual savings would be $28,200 or a present value of $338,000.

Ref 12 E. Gregory McPherson, David J. Nowak, Rowan A. Rowantree, “Chicago’s Urban Forest Ecosystem – The Results of the Chicago Urban Forest Climate Project”, United States Department of Agriculture Forest Service General Technical Report NE-186, 1994.

Ref 25 “2003 Renewal Annual Information Form”, Nova Scotia Power Inc., May 17, 2004.

7.6 BENEFITS IN A SUBURBAN RESIDENTIAL AREA

The benefits and costs are considered for an overhead system, an underground system, a system with just the secondary lines and service drops underground and a system with all but the arterial/collector streets underground. The "typical" circuit used in the analysis is based on Penhorn circuit #302. It has 4 km of three phase line and 10 km of single phase laterals, each individually fused. The lot size is 70' x 150' (21 x 45m). The assumed load is an average of 4 MW from 1350 customers. The overhead lines are assumed to be a radial configuration and the underground lines are assumed to be in open loops.

7.6.1 Reliability Improvement

The results of the reliability modeling of the "typical" suburban residential circuit show the overhead circuit experienced 2,700 customer interruptions and 4,100 customer hours of interruption due to faults on the distribution lines. The underground circuit experienced 169 customer interruptions and 321 customer hours of interruption. The circuit with arterial/collector roads overhead would experience 2680 customer interruptions and 4020 customer hours of interruption. All types of circuit would experience an additional 1,400 customer interruptions from other causes.

The dollar value that can be assigned to this depends on the specific customers on the circuit, but using general average values for residential customers of 2 $/kW-h the underground circuit would save $24,000 per year or a present value of $289,000 over forty years. The circuit with arterial/collector roads overhead would save $1,000 per year or a present value of $12,000 over forty years. These values are very approximate and could vary by a factor of five. Particularly in the HRM area, the perceived benefit of increased reliability by customers might be heightened at the present time because of recent power outages.

7.6.2 Increased Tree Cover

Increased tree cover has three quantifiable benefits, increased cleaning of the air, improved appearance and increased shading of the buildings resulting in reduced heating and cooling costs. There will be two separate estimates calculated, one for all lines underground, and one for the power lines on arterial/collector streets being overhead and the rest underground. If only the secondary lines and service drops are underground no increase in the number of trees can be confidently assumed. The trees would have to be planted by home owners on their property. No doubt many would do so, but many do with overhead wires as well. The trees are allowed to grow up thorough the conductors since they are low voltage and covered with insulation. In this study no increase in trees has been assumed for underground secondary lines and service drops.

The number of trees affected by a single suburban residential circuit on arterial/collector streets can be calculated from the length of the circuit (14 km of road) and the distance between large trees (assumed 20m). After discussion with an HRM urban forester, the reduction in canopy on streets with overhead power lines has been assumed to be 35%, instead of the 50% reduction that would be caused by having no trees under power lines. This was done because the small trees that are permitted under power lines would provide some of the benefits of larger trees. This means that on the typical circuit 490 more trees could be planted in an area served by underground power lines. The benefit of this in air pollution abatement is estimated as $1120 per year or a present value of $13,500 over 40 years. If the lines on arterial/collector roads are left overhead, then the increase in trees would be 348 for a savings of $800 per year or a present value of $9,600.

The aesthetic value of the trees based on their compensatory value and deducting the $400 cost per tree would be $318,500 if all lines are underground. This is equivalent to $26,500 per year. If the arterial/collector streets have overhead lines the aesthetic benefit is estimated as $226,000 or $18,800 per year.

The heating and cooling costs of the buildings supplied by the circuit depends on a large number of factors, especially the design of the building and the climate surrounding it. However, studies have shown that in residential areas with mature trees annual energy savings are by about 10% (Ref 12, page 106). On the "typical" suburban residential circuit the annual energy sales would be about 24 GW-hr, with 20% of that used for space heating. A savings of 10% represents about $38,000 per year. However the difference between an area of overhead power lines and an area of underground power lines would be less than this since both types of systems allow some tree growth. Using the estimate of 35% reduction in canopy for areas with overhead lines the difference in a fully underground area would be $13,300 per year or a present value of $159,600 over forty years. If the arterial/collector streets are overhead this would be reduced to $9,400 per year or $113,000 present value over forty years.

7.6.3 Other Benefits

Other benefits can be easily calculated based on the km of power line.
For an underground system:
Reduced motor vehicle accidents 2,000 $/km/yr x 14 km = 28,000 $/yr

Reduced tree trimming costs $550 $/km/yr x 14 km = 7,700 $/yr.

The total of these benefits is 35,700 $/yr which has a present value of $428,000.

For a system with arterial/collector streets overhead that would be $25,700 per year or a present value of $308,000 over forty years.

Ref 12 E. Gregory McPherson, David J. Nowak, Rowan A. Rowantree, "Chicago's Urban Forest Ecosystem – The Results of the Chicago Urban Forest Climate Project", United States Department of Agriculture Forest Service General Technical Report NE-186, 1994.

8 COMPARISON OF COSTS AND BENEFITS

The following tables present the comparison of the extra costs of putting the utility wires underground and the quantifiable benefits. In all cases the system design chosen for comparison is the lowest cost option.

Table 18 Comparison of Costs and Benefits in Dollars Per Metre of Road

	Downtown Core	Industrial	Urban Residential	Urban Residential	Suburban Residential	Suburban Residential
System Design	All UG	All UG	All UG	Arterial/collector OH	All UG	Arterial/collecto r OH
Benefit	104	49	107	45	65	33
Retrofit Cost	1,700	1,000	980	760	860	770
New Cost	920	460	450	330	370	280

Table 19 Comparison of Costs and Benefits in Dollars Per Lot

	Downtown Core note 1	Industrial	Urban Residential	Urban Residential	Suburban Residential	Suburban Residential
System Design	All UG	All UG	All UG	Arterial and Collector OH	All UG	Arterial and Collector OH
Benefit	4,000	1700	580	240	380	140
Retrofit Cost	68,000	34,500	5,200	4,000	8,900	8,000
New Cost	36,800	15,800	2,400	1,800	3,800	2,900

Note 1 The downtown area cost per lot needs to be interpreted carefully. Each lot represents a large building.

It is clear that in all cases studied that the cost outweighs the quantifiable benefits by at least a factor of five and often more than 15 times. This is consistent with other studies. The Australian study found a ratio of about 10 on average.

However, many of the benefits are not quantifiable. The improved appearance, improved urban ambiance, increased willingness to invest and other real but not quantifiable benefits have been considered by the citizens of most North American urban areas to be worth the extra cost. This will be discussed further in section 8.2.

8.1 ACCURACY OF THE COST / BENEFIT ESTIMATE

The costs and benefits have been calculated as accurately as possible without specific projects in mind. The values used have been average values, but the range of variation in many of the variables is large. This means that in any one project the costs and benefits may be quite different than calculated here, but the average over many projects should be close to the values calculated.

A small sensitivity study was performed to determine the possible range of the variation in the final results. Placing a reasonable range of variation (10% and 90% probability points) the benefits are expected to vary from the calculated value by +/- 50%. Although this is a wide range it does not affect the conclusions since the benefits are at least 300% below the costs.

The costs are better known and they could be expected to vary by +/- 15% on average.

8.2 DISCUSSION OF FINDINGS

In interpreting these results it must be remembered that many of the most significant benefits could not be assigned a clear dollar value. These benefits include improved appearance and improved mental health of citizens. However these benefits that could not be quantified must be included in any consideration of recommendations for action since they are real benefits.

Two of the options described in section 3 where not part of the detailed cost/benefit study for undergrounding utilities. They were: Option 1 Return to Previous Tree Policies and Option 2 Covered Cable Overhead Systems. The costs and benefits of these options will be briefly outlined in the next two paragraphs and findings discussed

A return to previous tree policies would allow all of the benefits of trees described in the detailed study to be achieved. There would be no decrease in auto accidents. There would be no change in reliability since the reliability in this study has been compared to the existing system which is mainly constructed under the old tree policies. The cost of this option would be no decrease in tree trimming costs. The net affect would be almost zero quantifiable benefits. The true benefits would be the improved appearance of the street space as indicated in the difference between Figures 1 and 2. However, this option is not likely to be achievable.

The covered cable overhead systems (such as Hendrix) would achieve the benefits of increased trees while increasing reliability and decreasing tree trimming costs. The reliability benefit would be similar to that of using underground wires since the tree outages would be almost eliminated. Tree outages are eliminated because the covering prevents short circuits due to branches and the strong steel cable that supports the Hendrix system can withstand trees falling onto it. However, the reduced auto accidents would not be achieved since the poles will remain. In fact the auto accident damage may increase because the increased weight of the covered cable requires more frequent pole placements and more guy wires. The improved appearance non-quantified benefit would be partially achieved because of the trees but the wires would be just as visible when there are no trees. The cost is estimated as 125% of the regular overhead system cost, but NSPI has made an estimate that is considerably higher so this cost is uncertain. Taking an urban residential area as an example, the total benefit would be about $35 per metre of road compared to increased costs of $59 per metre of road. Whether this option should be pursued depends on an assessment of the visual appearance improvement.

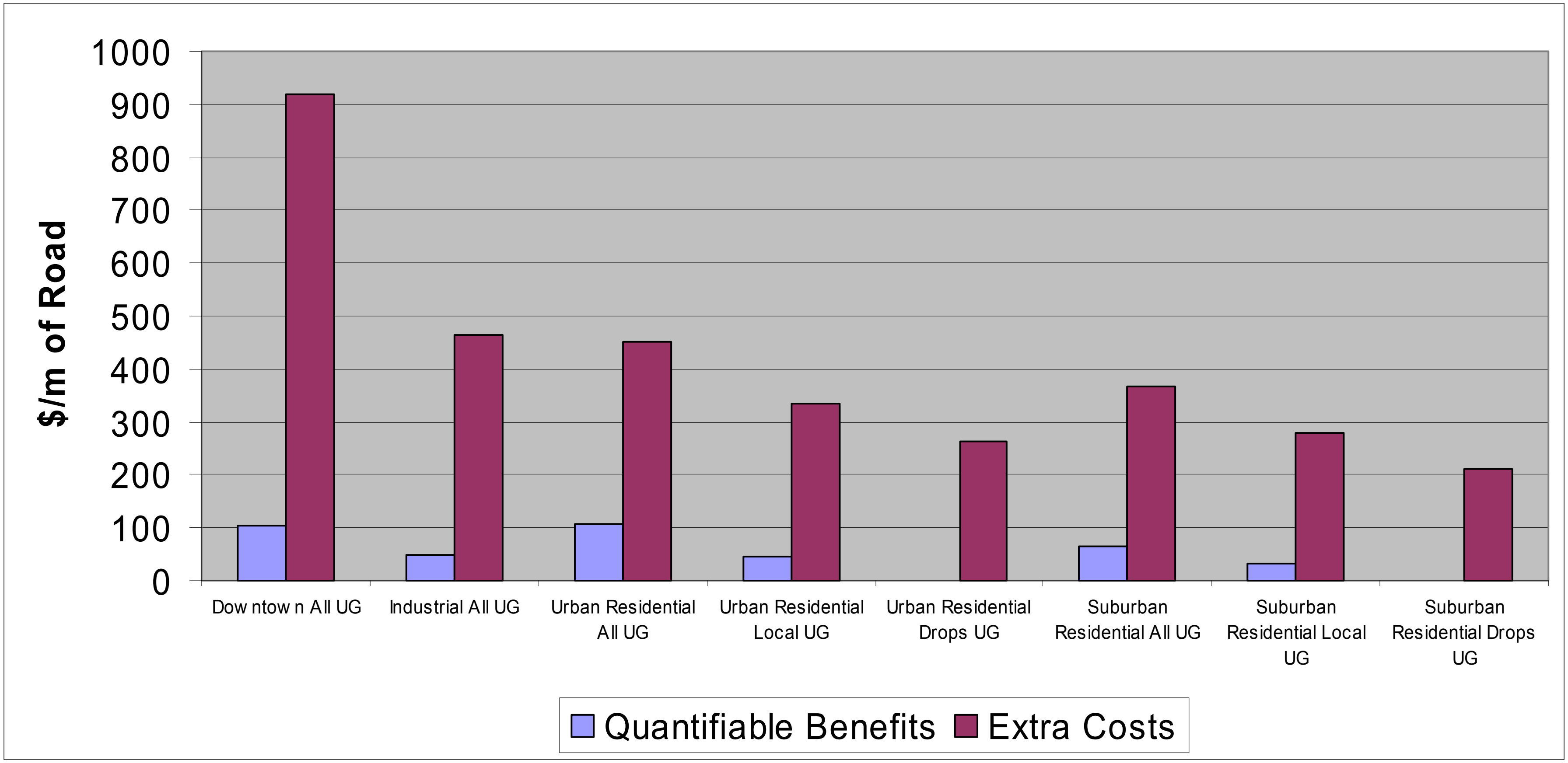
The third option outlined in section 3 was to require underground secondary lines and service drops in areas of new construction. The costs and benefits for this are shown in Figure 13. There are no benefits because the overhead and underground service drops have similar failure rates and similar abilities to allow trees to grow. The non-quantifiable benefits of improved appearance are partially achieved. Much of the visual impact of overhead wires is caused by the secondary and service drop wires because they are closer to the observer, they are large diameter and they are black in colour. They also cross the street and so are in the middle of the field of view when looking down the street. The improved appearance is achieved at a substantial increase in cost, $2,600 per lot in new urban residential areas and $4,300 per lot in suburban areas. This is more than 70% of the cost of an entirely underground system. Since the benefits are not fully achieved and the costs are substantial this option may not be the most desirable. However, if the more complete undergrounding is not chosen this option does have some merit and should be considered.

The fourth option in section 3 was to place all wires on local streets underground and only leave the large three phase lines down arterial and collector streets as overhead. This is a very popular option for utilities in North America. It avoids some of the costs but achieves most of the benefits, especially the non-quantified benefits. It is particularly appropriate in areas of high density housing where the street and driveways take up a substantial portion of the land area leaving little room for trees. In new urban residential areas the increased cost is estimated to be $1,800 per lot. In new suburban areas the increased cost is estimated to be $2,900 per lot. In already developed areas the costs and the disruption to the lives of the residents are both large. The costs increase to an estimated $4,000 and $8,000 per lot in urban and suburban residential areas respectively.

The fifth option in section 3 was to require all new construction to be underground. This would include the main lines down arterial and collector streets. The increase in cost over option 4 is fairly small, $600 per urban lot and $900 per suburban lot in areas of new construction. Most of the benefit of increased reliability is achieved in this option and not in option 4. However, the non-quantified benefits of improved appearance are not increased significantly. This happens because the arterial/collector streets are a smaller proportion of the total street length and they tend to have wider road verges leaving more room for trees away from the overhead wires. The selection of option 4 would be largely based on the non-quantifiable benefits. The main reason for not selecting option 5 is that option four represents a compromise between a fully overhead and a fully underground system, yet it achieves most of the important un-quantifiable benefits. It is anticipated that there will be some resistance to requiring underground utilities and this resistance might be lessened by choosing a compromise.

Option six in section three is not recommended because of the large costs of converting all lines to underground. The one exception is in areas of high commercial value such as near tourist attractions, especially if some of the surface restoration and trenching costs can be shared with other large civil works projects such as sewer replacement or road upgrading. The conversion to underground can be selected under these conditions on a case by case basis. Many cities do a few of these “beautification” type projects each year to spread out the large costs as much as possible. Economic development or infra-structure renewal funds are sometimes available from higher levels of government to help with the costs.

Figure 13 Comparison of Costs and Benefits for Underground Utilities in Areas of New Construction



9 STANDARD DESIGN FOR STREET SPACE

9.1 RECOMMENDED CROSS SECTIONAL STREET SPACE

The current HRM street specifications were reviewed in the context of underground services. The current street specifications do not require underground services so this report provides revised streetscape cross sections to illustrate where the underground utility services and underground gas lines should be located. It was assumed that a common trench would be used for underground electrical and communication cables.

Proposed streetscape cross sections are shown for four types of HRM's street specifications. The four street types are: Rural Minor Collector, Urban Local Industrial, Urban Major Collector, and Urban Local. As part of this exercise, it became apparent that two of the four street types could incorporate some modifications to better accept the underground services and better promote street aesthetics in terms of street trees and decorative street lighting. Therefore, also included are two "enhanced" streetscape cross sections specific to the Urban Major Collector and the Urban Local.

The Urban Major Collector is enhanced by increasing the overall right-of-way width by three metres. This allows for a three metre boulevard in the center of the street on which street trees can be planted. Also, the two outside lanes are reduced in width by half a metre to allow an increase of half a metre in width to the area allocated for street trees and street lights on each side of the street.

The Urban Local is enhanced by reducing the traveled way from 9 metres to 7 metres. Also, the sidewalk width is reduced from 1.8 metres to 1.5 metres. This allows for the area for street trees and street lamps to be widened from 1.5 metres to 2.2 metres on one side of the street and from 3.5 metres to 4.5 metres on the other side. This provides more space for the proposed gas line so it is off set from the street trees. It is also proposed that the street lamp base be installed on a concrete pedestal so that it can better withstand minor pressures from snowplowing and vehicle impacts.

Figure 14   Urban Major Collector Cross Section

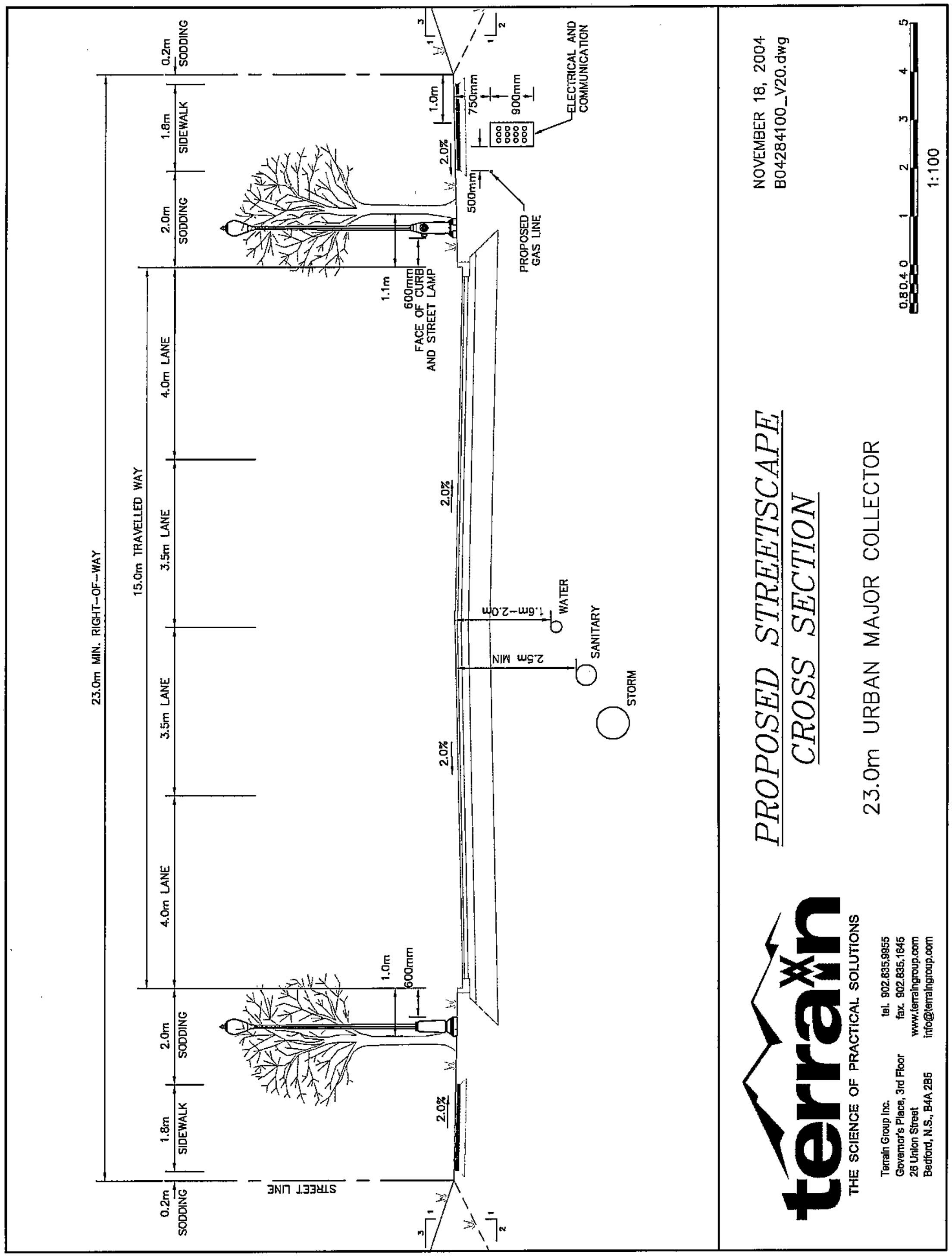


Figure 15 Urban Local Industrial Cross Section

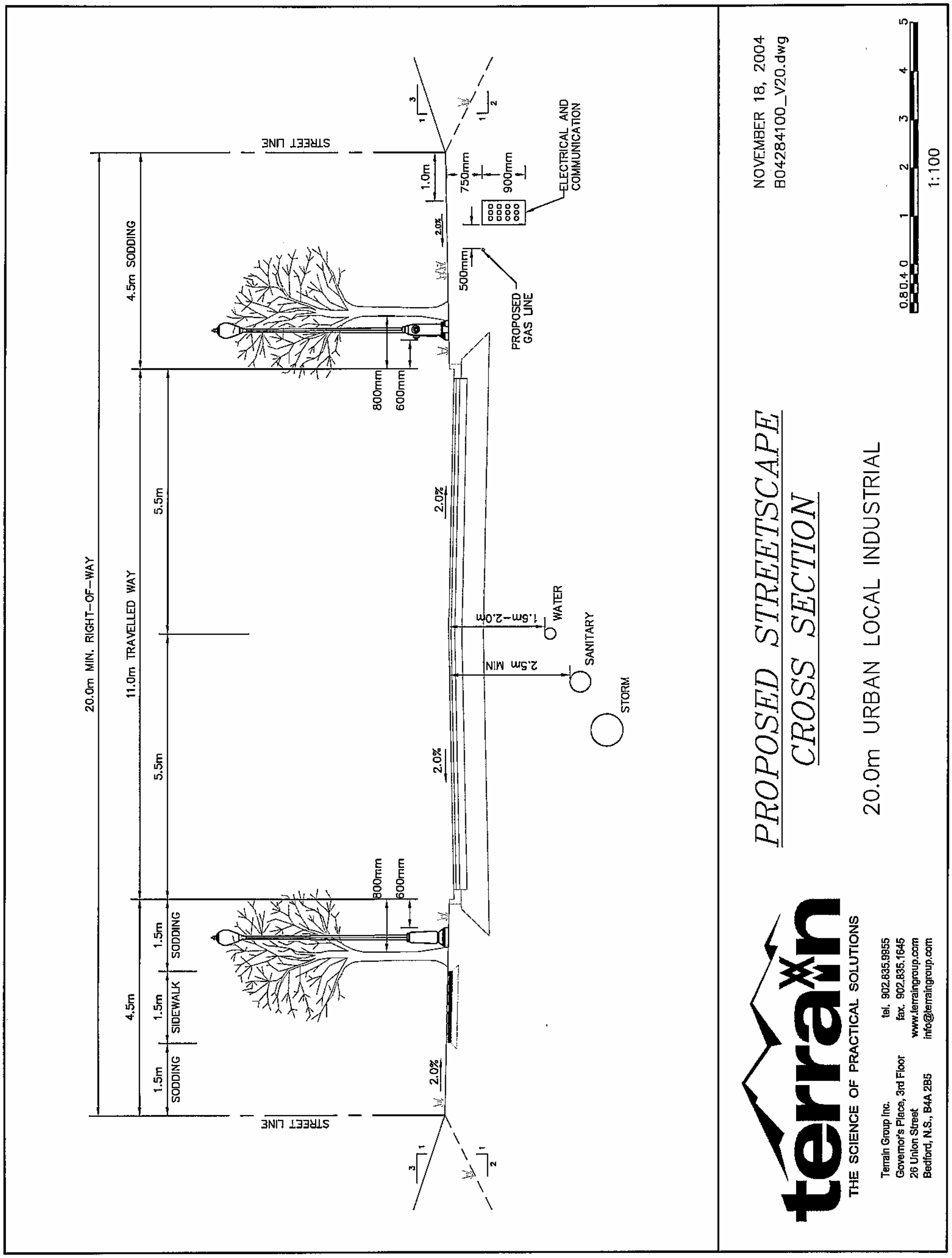


Figure 16   Urban Local Cross Section

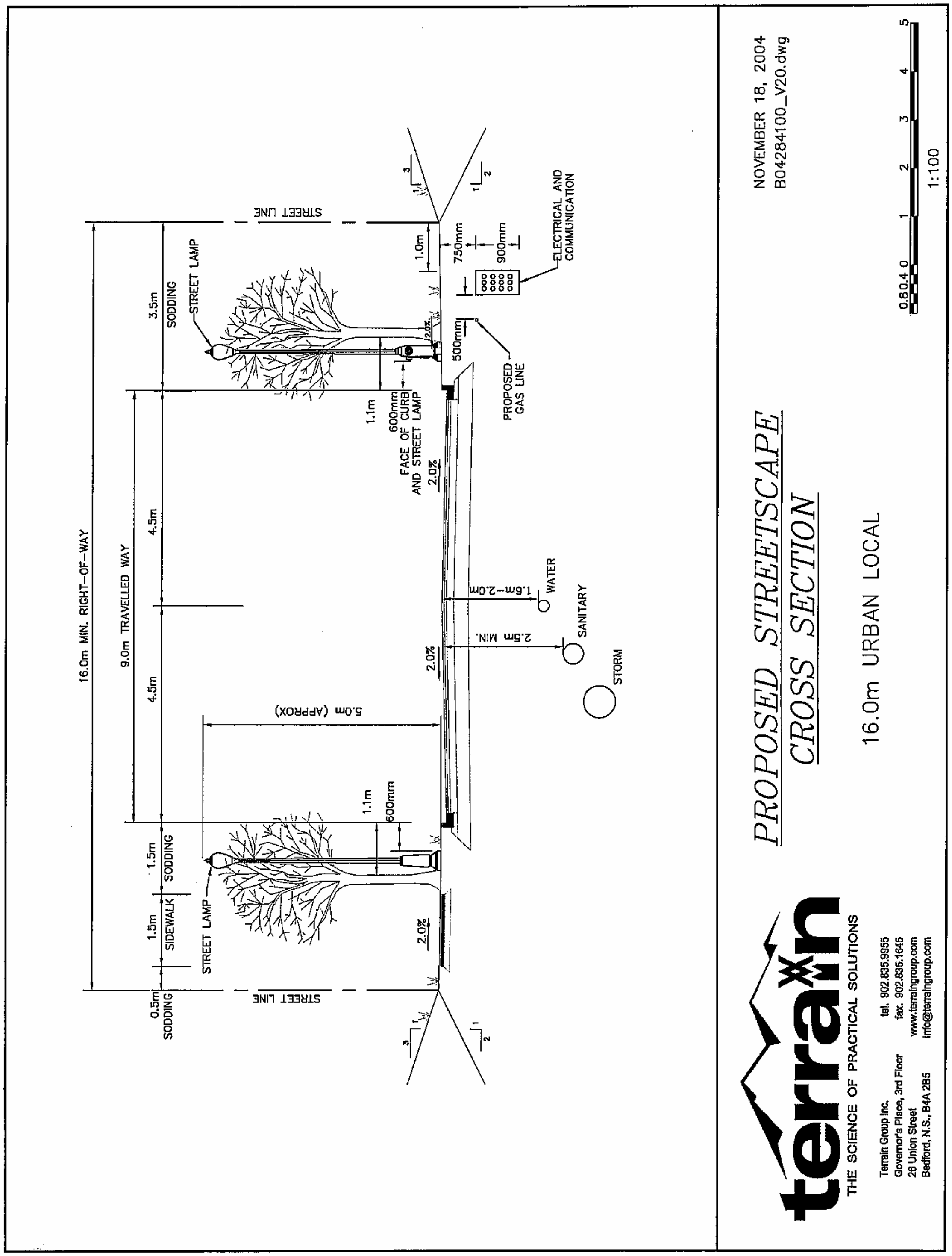


Figure 17 Urban Local Enhanced Cross Section

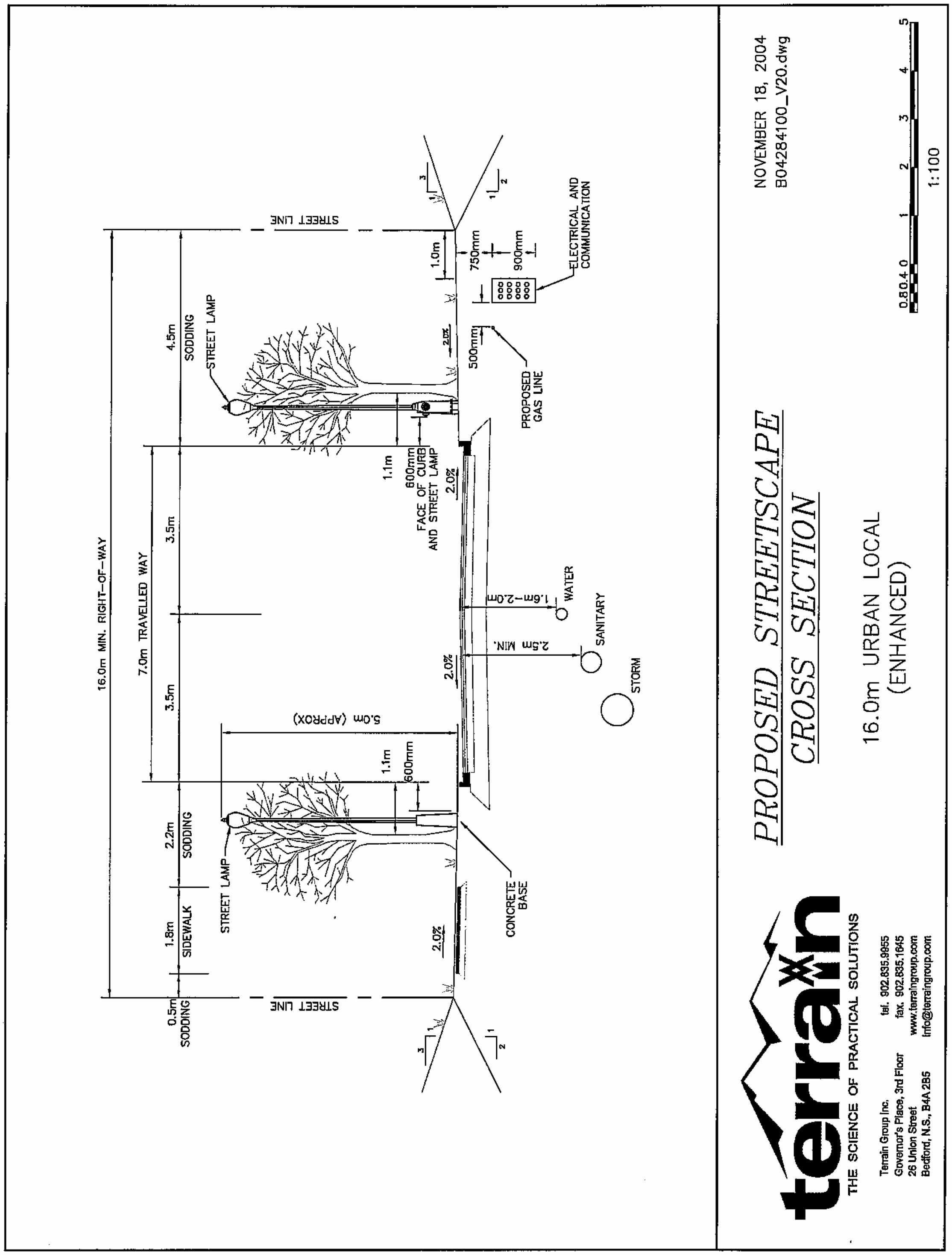


Figure 18 Rural Minor Collector Cross Section

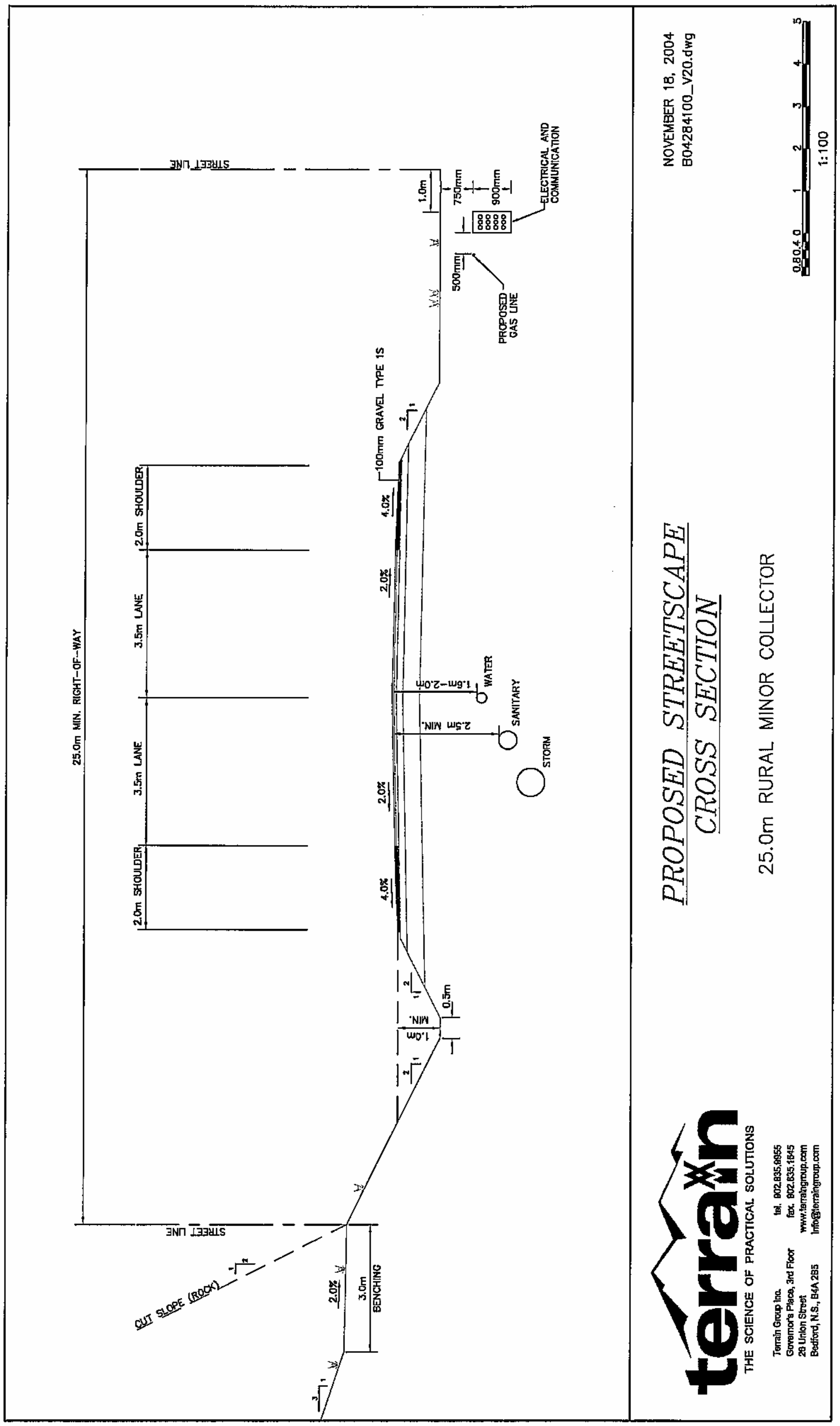
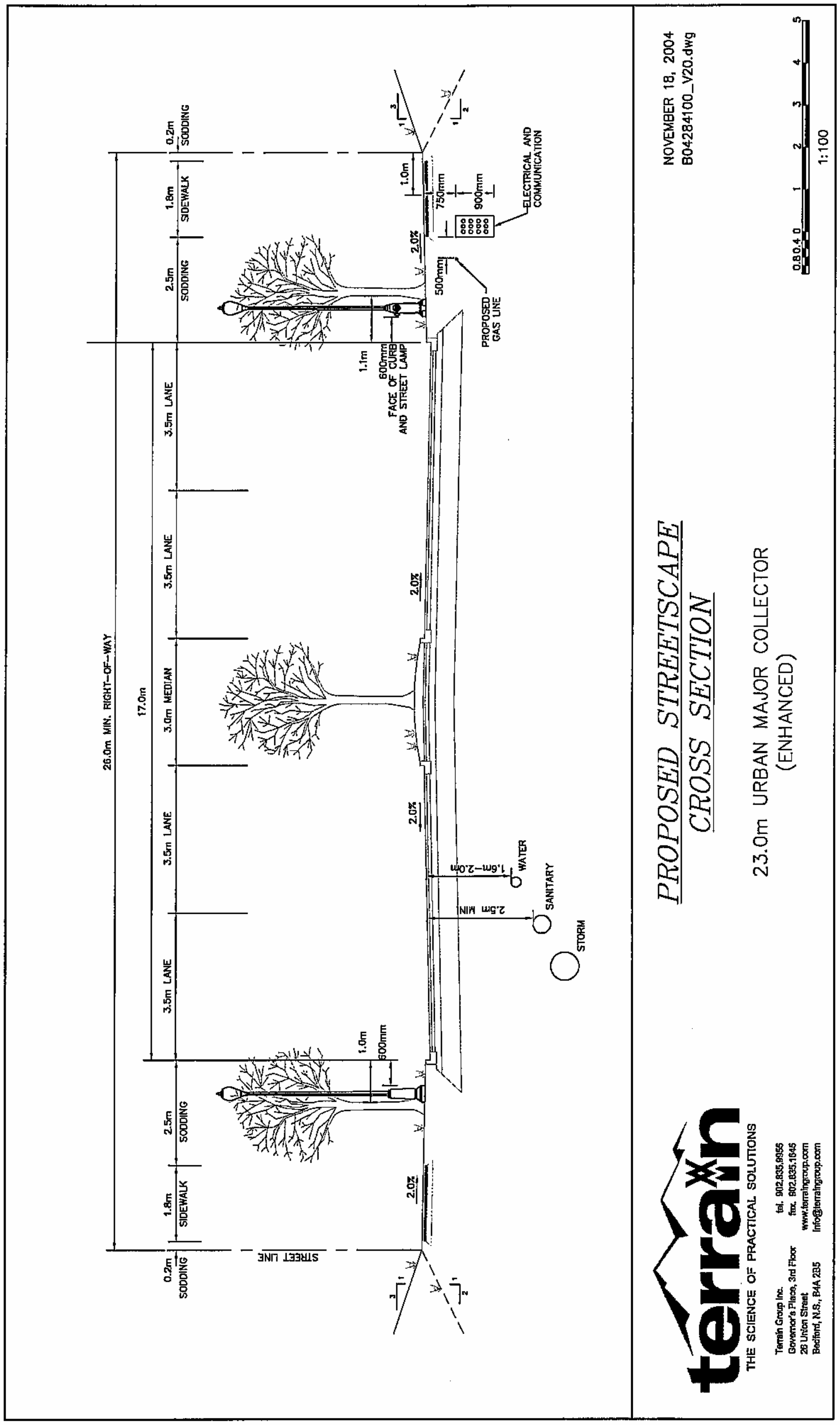


Figure 19   Urban Major Collector Enhanced Cross Section



9.2 EXAMPLE JOINT TRENCH STANDARDS

The Tacoma Power joint trench standard is presented here as an example. It is used because it is very recent and embodies good layout and design as well as content. It would have to be adapted to be applicable in Canada, although the requirements of standards in the two countries are very similar.

Customer Requirements
Residential
Joint Utility Trench

Scope

This standard describes the excavation and backfill requirements for joint utility trench for residential developments

In This Standard

Purpose

The purpose of this standard is to show the excavation requirements of multiple utilities installed within a common trench. The arrangements have been approved by the coordinating utilities within Pierce County.

It is intended that this standard be used in conjunction with Tacoma Power **Standard C-UG-1100 "Conduit & Vault Systems"** when the customer/developer will be installing the **electrical** and **data** conduit and enclosure system for Tacoma Power.

Design Requirements

The process described below is intended to ensure a coordinated installation of the following utilities within a common trench:

- Power & Tacoma Power Data
- Telephone
- CATV
- Natural Gas

Water, Sewer, and Roof Drains are installed within separate trenches outside of the joint utility easement.

Design Requirements (continued)

System Design

Detailed engineering drawings of the project shall be submitted to the utilities involved 2 to 3 months prior to installation. Please provide these drawings in the AutoCad 12 or later format with separate layers identified to Tacoma Power.

The information required on the drawings are:

Utilities, with Stub-out Locations	Road and Land Features
• Water	• Curb
• Sanitary Sewer	• Road with centerline
• Storm Drain	• Slope
• Storm Water Retention	• Property & right-of-way lines
• Roof Drain	• Survey monuments
	• Easements

Easements

A ***minimum*** 10-foot unobstructed easement is required parallel to, and on both sides of, the road right-of-way.

The maximum slope from back to front shall be 2%.

The easement shall be clear of all obstructions of construction including:

- Sidewalks
- Drainage systems
- Dry wells
- Fire hydrants
- Storm systems
- Sewer stubs
- Water meters
- Permanent structures
- Street light poles

Trenches 48" or Greater in Depth

Trenches that are 48 inches or greater in depth shall meet the requirements of ***Part N of WAC 296-155***, "Excavation, Trenching, and Shoring". Qualified workers shall determine the required safety mitigation methods as allowed by state law. Side sloping of the trench is the most common method of mitigation.

Staking Requirements

Coordination

A meeting will be required between the developer and the joint utility representative to coordinate the setting of survey stakes & marks and location of road crossings.

Stakes

Survey stakes shall include:

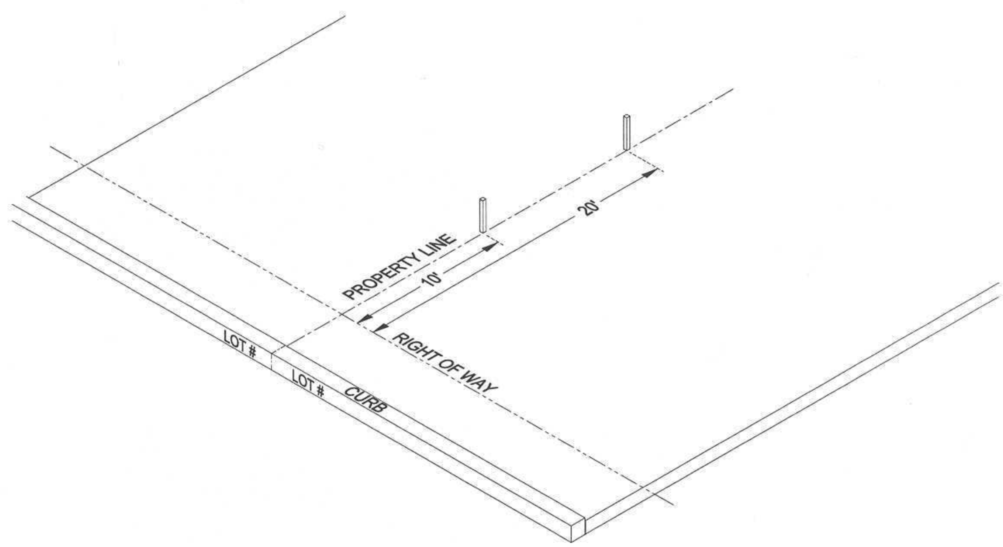
- Lot numbers
- Grade adjustment
- Offset distance

Additional staking may be required as determined during the coordination meeting.

Figure #1

Stake locations

- After paving, stakes shall be installed in 10 foot and 20 foot offsets for each lot corner.
- Lot corners shall be painted on the curb with the lot centerline marked. Temporary lot corners shall be staked and identified.



Road Crossings

Road Crossings will be identified by the joint utilities. They shall be installed prior to paving and curb as identified in the coordination meeting.

Depth

Road Crossings must be installed with a minimum of ***36" of cover***, measured from finished surface grade to top of highest conduit, or in a ***minimum 42" deep trench***, whichever is deeper. The conduit shall be terminated and capped 5 feet from the back of road curb as shown in Figure 2.

Any variations in depth of the crossings must be approved by the participating joint trench utilities.

Conduits

All conduits shall be installed per joint utility requirements and capped with approved devices. Install spacers between conduits to allow conduit couplers later. Tacoma Power requires plastic pipe caps or plugs.

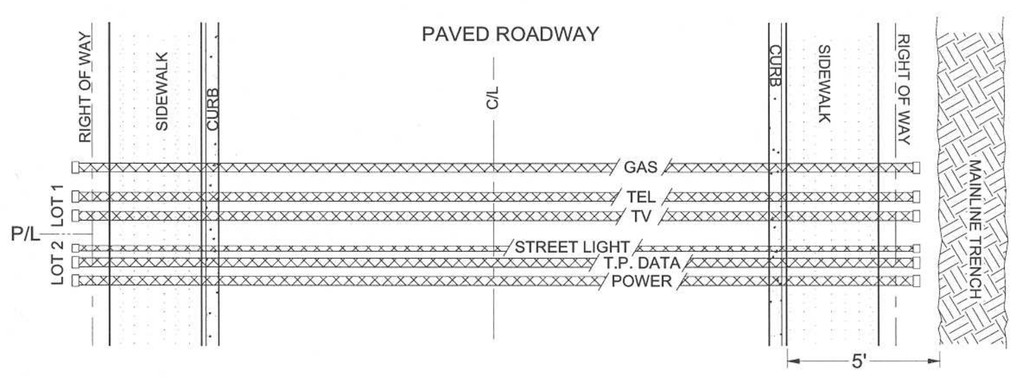
Tacoma Power - Electrical	**Gray** Schedule 40 PVC in either 2½", 4", or 5" sizes
Tacoma Power - Data	**Green** Schedule 40 PVC in 2 or 4 inch

Marking

Both ends of road crossings shall be marked with conduit markers.

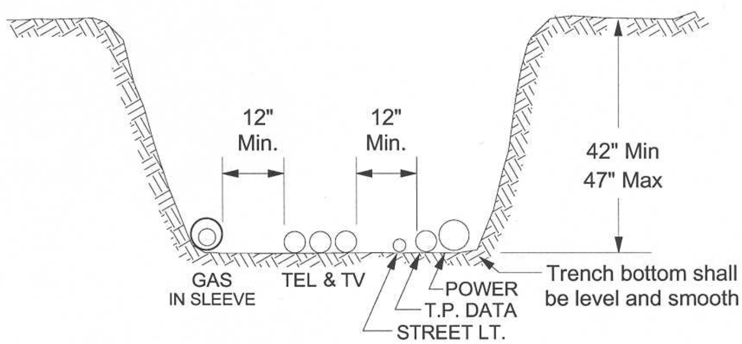
Figure #2

Plan View of Typical Utility Road Crossing



Road Crossings (continued)

Figure #3 Typical Cross Section View of Utility Road Crossings



(looking toward mainline trench)

Joint Trench Requirements

The following shall be followed in the installation of joint utilities.

Coordination

- The joint trench utilities will share facility designs in order to achieve the best common design for the project.
- A meeting will be required between the developer and the joint utility representative to coordinate the route of the trench and locations of transformers, junction boxes, and secondary service boxes.

Fire Hydrants and Water Meters

Fire hydrants and water meters shall maintain a distance from the utility trench as required by the serving water utility and fire department.

Trench Maintenance

Whoever is providing the trenching shall be responsible for the maintenance of the trench during the installation of the joint utilities. This maintenance will include but is not limited to:

- Removal of any water accumulation in the trench
- Trench depth and width per the standard.

Joint Trench Requirements (continued)

Prior to Excavation

Trench will be allowed to be opened when the following has occurred:

- All required fees have been paid.
- Any required permits have been obtained
- All easements have been obtained
- Curb and base pavement layer have been installed
- Lot lines and lot numbers shall be painted on the curb and center of road.
- Lots graded to within 6 inches of finished grade
- Sanitary sewer and water stub-outs have been installed when required

Closing of Trench

Only after all participating utilities have installed and approved their facilities may the trench be backfilled. This may occur in segments at the approval of the joint utilities.

Trench Construction

Joint Utility Trenches shall be provided as listed below.

Dimensions

The trenches shall be of the ***minimum*** dimensions unless approved by Tacoma Power:

Width at bottom	42" minimum
Depth from grade	42" minimum, 47" maximum
Spoils	No closer than 2 feet from edge of trench

Backfill

The trench shall be backfilled with native backfill upon approval by the joint utilities. If the native material is determined to be unsuitable, backfill material will need to be imported.

The backfilling of the trench is to be done with reasonable care so as not to damage the conduit systems and enclosures that were installed. It shall also meet the compaction requirements of the applicable city or county involved.

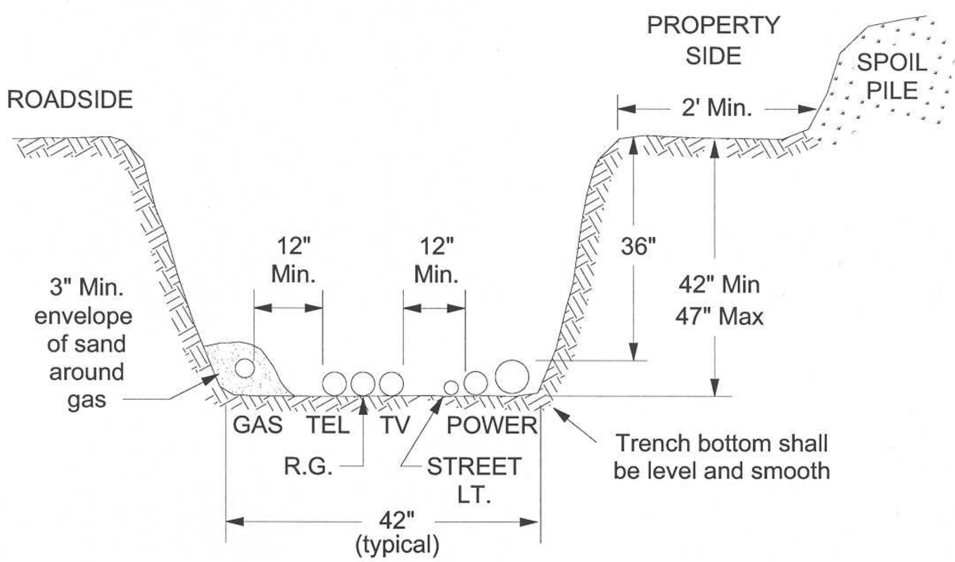
Trench Construction (continued)

Sanding

As required by the natural gas utility, sanding will be needed in the trench to bed the natural gas line.

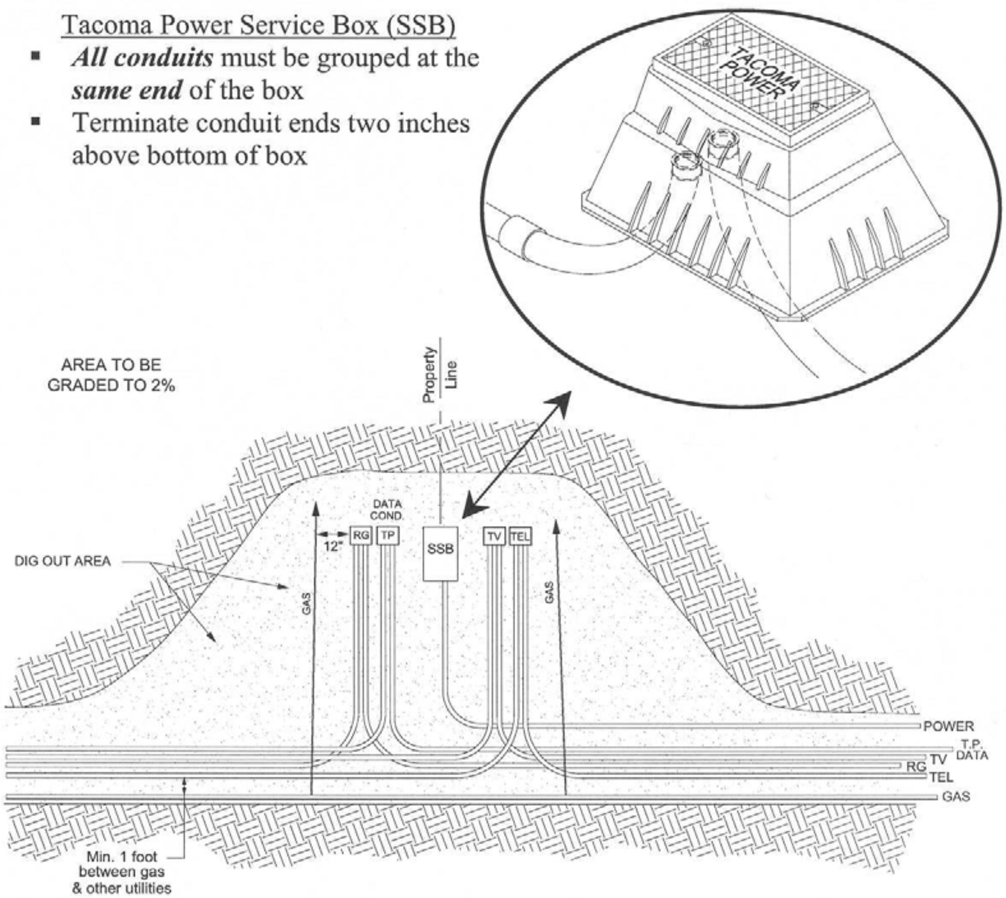
In rocky conditions other joint utility trench partners may require sanding of the trench prior to conduit installation.

Figure #4 Typical Trench Cross Section of Mainline Trench



Trench Construction (continued)

Figure #5 Services Layout



This configuration keeps all the utilities in the same planned relationship, minimizes congestion, and digging up the wrong utility.

Trench Construction (continued)

Figure #6 Electrical Transformer Layout (Isometric View)

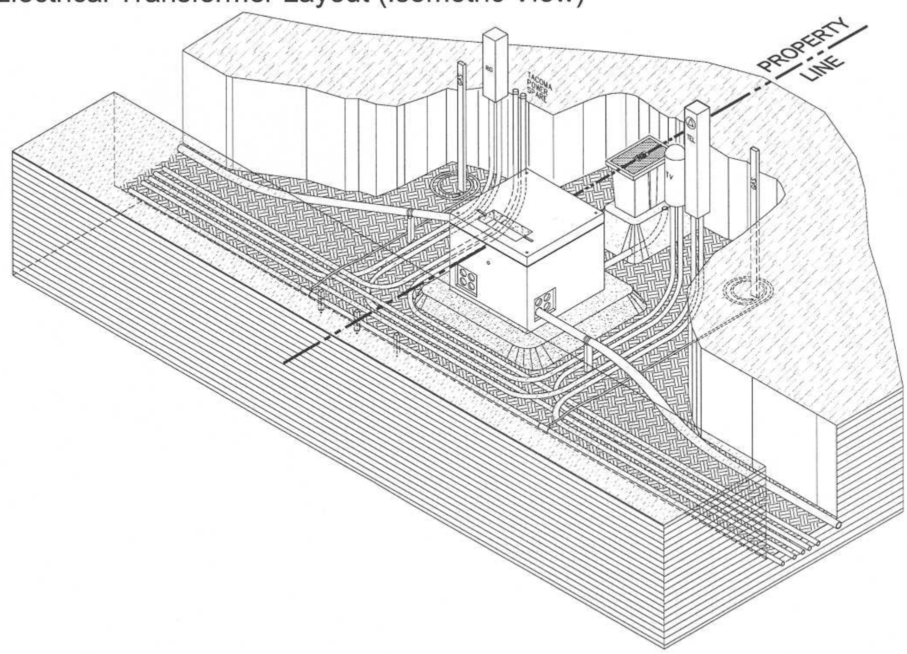
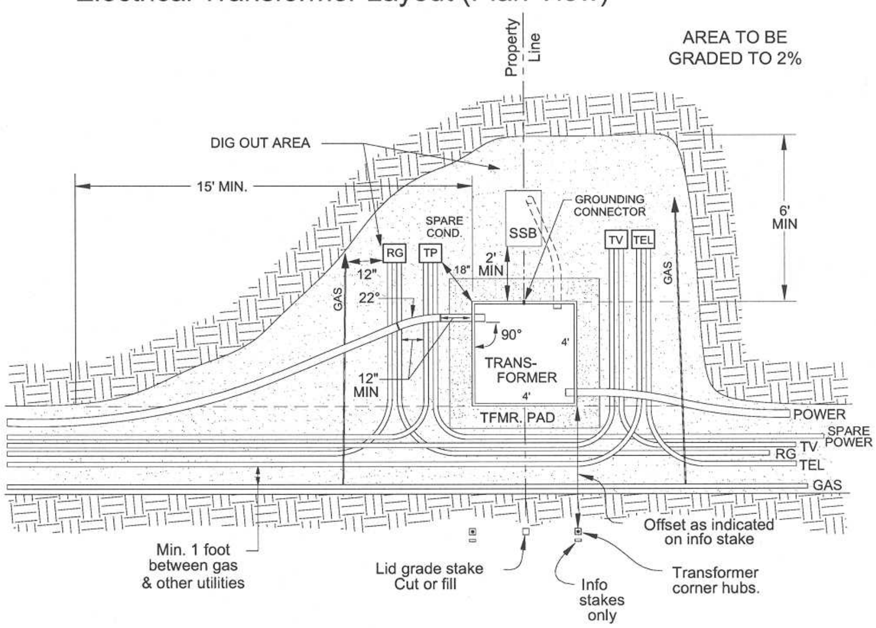
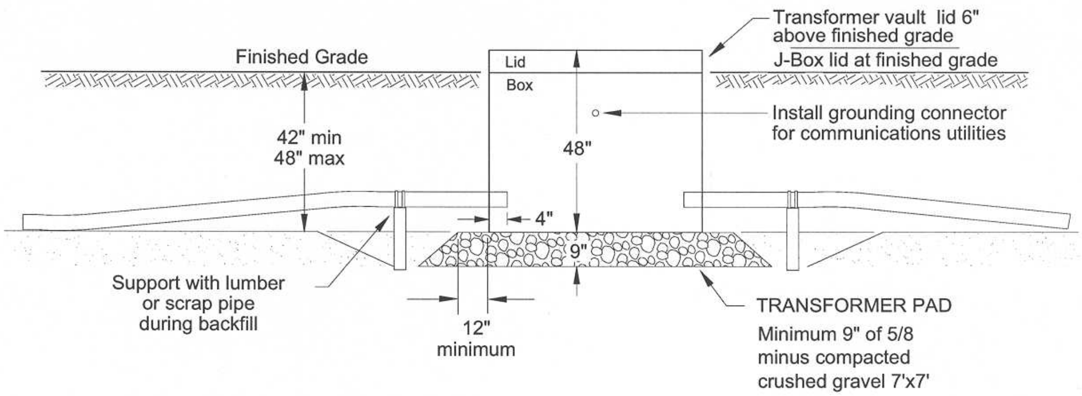


Figure #7 Electrical Transformer Layout (Plan View)



Trench Construction (continued)

Figure #8 Electrical Transformer Layout (Cross Section View)



Source

Tacoma Power standards
A-UG-001/ S604.0110
C-UG-110/ S604.0112
C-UG-115/ S604.1112

Reference

Tacoma Power standards C-UG-1100 "Conduit & Vault Systems"

10 DISCUSSION OF OPPORTUNITIES FOR UNDERGROUNDING IN HRM

10.1 Completion Of The Short Term Pole Free Zone

In 1977 an agreement was reached between HRM and NSPI to underground the existing overhead lines in an area of downtown Halifax. The area was divided into a "short term" pole free zone and a "long term" pole free zone.

The "short term pole free zone" was bounded approximately by Terminal Street on the south, Cunard and Cogswell streets on the north, the harbour on the east, and Brunswick and Barrington streets on the west.

It was agreed that the short term zone would be implemented and the costs would be shared. HRM would pay for the civil costs such as trenching, installation of ducts and vaults; and NSPI would install the new electrical equipment and remove the old overhead system. This area has almost been completed and both parties are still willing to complete it. Approximately 9 km of underground line have been installed and there is 1 km still to be converted. Since the costs are split approximately 50/50 the HRM share of this completion will be about $850,000.

10.2 Completion Of The Long Term Pole Free Zone

The "long term pole free zone" was approximately bounded by Morris and South streets on the south, Cunard on the north, Robie on the west and by the short term pole free zone on the east.

There are citizens with properties in the "long term" pole free zone who would like to see it completed also. This would require a new agreement with NSPI on cost sharing since the old agreement was for the short term area only. It is not known if NSPI would be willing to consider the same cost sharing arrangement.

Another funding arrangement would be to convince the NSURB that the cost of the undergrounding should be covered fully by NSPI. The argument can be made that since all customers pay the same rates at the present time, the NSPI customers in dense urban areas, where costs to supply power are lower, are subsidizing the customers in rural areas. This situation could be rectified by instructing NSPI to spend the same amount of money per kW-h of electricity sold in all areas. This would allow NSPI to pay for a larger share of the cost of undergrounding.

Another funding arrangement would see HRM shoulder the entire cost of the undergrounding and recoup the expense through a local improvement tax. The cost could be justified on the basis of increased tourism and other economic activity.

Another finding possibility would be to approach the province of Nova Scotia and point out that the province of Quebec is getting ahead of Nova Scotia in competition for tourism. Quebec recognizes that increased tourism in a city benefits all of the province. The province will therefore subsidize the cost of undergrounding utilities in tourist areas by supplying 50% of the costs and forcing the utility to pay another 25%. The province of Nova Scotia could be encouraged to even the playing field and make a similar arrangement in Nova Scotia.

The possibility of a grant through Heritage Canada is another funding option that is being explored by staff at HRM.

The Long Term Pole Free Zone consists of 12.7 km of road. The total cost to convert the utility wires to underground, above the cost of an equivalent overhead system is 18 million dollars if it is done slowly over time in conjunction with major street redevelopment so that road resurfacing costs can be shared.

10.3 Converting The Entire Capital District To Underground

There has been some interest expressed in the conversion of the entire Capital District to underground wiring. This area would include both the short and long term pole free zones as defined in 1977. It would also include the area around Quinpool Road between Robie and Connaught and an area north of the long term pole free zone to North Street, including part of Gottingen Street. This would cost an estimated 22.7 million dollars in addition to the 18 million to convert the “long term pole free zone”

Rather than plan for such large scale conversions, it may be advisable to proceed more slowly. If just the priority “heritage” and “tourist commercial” areas are planned for, it may be easier to obtain funding from partners. The three streets in sections 10.4, 10.5 and 10.6 have been suggested as “priority” areas.

10.4 Converting Spring Garden Road To Underground

The section of Spring Garden road between Robbie Street and Brunswick at the present time has very old overhead utility wires. They detract from the visual ambiance of the neighbourhood. This section of street is part of the “long term pole free zone” but since it is not clear that the whole zone will ever be converted, Spring Garden road could be converted on a priority basis as a special project. The section of road is 1 km long and contains about nine intersections. A conversion of all overhead utility wires to underground is estimated to cost 1.7 million dollars. If done in conjunction with major street work this could be reduced to 1.4 million.

10.5 Converting Gottingen Street To Underground

Another section of road that has been suggested as a priority conversion area is Gottingen Street between Cogswell and North streets. This is within the Capital District but outside the “long term pole free zone”. Again the overhead wires detract visually from the ambiance of this commercial retail area. The section of road is about 1 km long and would also cost about 1.7 million dollars to convert to underground.

10.6 Converting Quinpool Road To Underground

Quinpool Road between Robie and Connaught also has retail potential that may be impacted by the presence of unsightly overhead wires. The section is 1.1 km long and is estimated to cost 1.9 million dollars to convert to underground.

10.7 Municipal By-Law For New Utilities

Most (70%) large Canadian cities require all new utilities in residential areas to use underground wiring. In many places this is done through the development approval process. The undergrounding is a requirement that must be met before a development plan is approved. In many other cities a bylaw or official policy has been passed by city council making the requirement official.

10.8 OPPORTUNISTIC CONVERSIONS

When major redevelopment work is taking place, either a street is being rebuilt, sewer or water lines are being repaired or buildings are being torn down and rebuilt, it is always an opportunity to place utility lines underground with the least increase in costs. The costs of restoring the surface can be shared between the various concurrent projects. Often this is seen as a "beautification project" and is undertaken in retail commercial, heritage, or tourist areas.

The opportunistic conversion are not restricted to just the lines down the streets. Redevelopment of a building is an excellent time to move the service drop wires underground. This is often the desire of the property owner but it can also be required by the city. This requirement could be in anticipation of future undergrounding of the utility wires on the entire street or it could be just an improvement in appearance locally. If the ground is being torn up for other reasons, the incremental cost of underground service drops is very small.

10.9 Citizen Initiated Conversions

Many cities in North America have a policy or bylaw that provides a mechanism for citizens to initiate the process of undergrounding the existing overhead utilities in their neighbourhood. The process is begun by a citizens group collecting a petition requesting the change with at least 50% (in some cases 60%) of the residents signatures. Once the signatures have been collected the citizens group collects the money necessary for a cost estimate to be prepared. Once the costs are known, if a majority of citizens still agree to the proposal, then the contract is let and the work is done.

The arrangements for cost sharing vary from city to city. In some places the citizens carry the full cost, often through a local improvement tax imposed by the city. In some places the city pays for some of the cost through the general tax levy. In some places the province contributes, and in some places the utility review board requires the utility to contribute also.

Cities that have had this process for many years (some have had it for over 20 years) have found that very few neighbourhoods are converted. It is rare that a majority of the citizens are willing to carry the cost.

11 Appendix A DEFINITION OF TERMS

Arterial/collector street
For the purposes of this study, an arterial/collector street is a major street designed for through traffic. It would typically have a main three phase power line from which single phase lines are tapped to serve the local streets.

Local Street
A local street is a street not designed for through traffic. The power system is usually a single phase line.

Urban Residential Area
For the purpose of this study an urban residential area has been defined as an area with 12 or more housing units per hectare of land area (>5 units per acre). Typically this is either single family homes on small lots with 10-15 m frontage (33-50 foot) or a mix of townhouses and duplexes with larger lot single family units.

Suburban Residential Area
A suburban residential area has been defined as 2 –12 housing unites per hectare (1 to 5 units per acre).

Unserviced Lot Area
An area of un-serviced lots has been assumed to have less than 2 units per hectare (lot size one acre and larger).

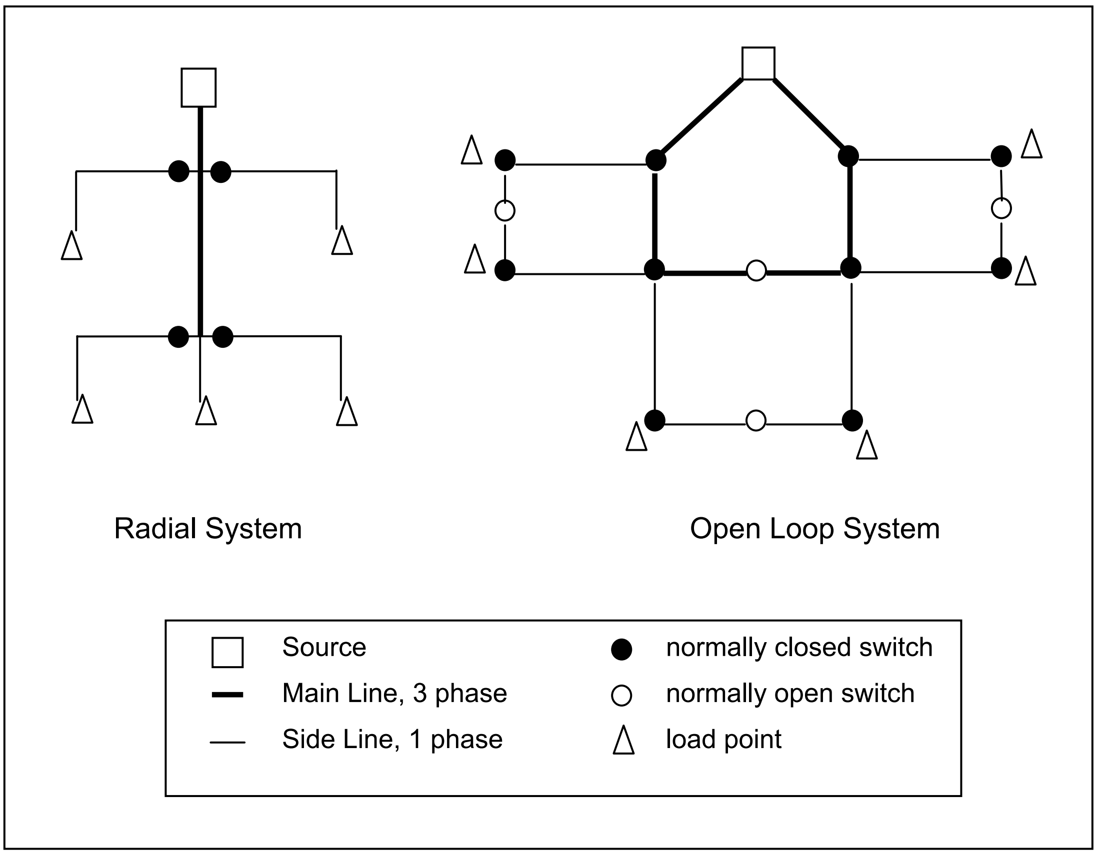
Primary Power Lines
A primary distribution line is a high voltage line that brings power to transformers that lower the voltage to the level used by customers. The high voltage is usually between 4,000 and 35,000 volts and the line is located along the edge of the road. The line can be three phase, with three high voltage conductors and one grounded neutral conductor or single phase, with one high voltage conductor and one grounded neutral conductor. The single phase lines are typically along local streets.

Secondary Power Lines
A secondary line is the low voltage line, typically 120 volts for residential and 600 volts for industrial/commercial loads. It is located along the edge of the road from the transformer and occurs on all types of roads.

Service Drops
The line from the road into the building is called a service drop. The main distinction with secondary lines is that service drops run perpendicular to the road and serve a single customer.

Open Loop / Radial Distribution Systems
Electric power distribution systems can be designed in many configurations. An “open loop” system has a uniform size of conductor and all points can be energized from at least two directions. The “radial” system has larger conductors near the power source and the conductors at the other end of the system are not adjacent to other conductors, they just end like the branches of a tree. The open loop system has loops of conductors, but there is an open switch in the loop so that power normally only has one route to flow between the source and the load. The distinction is illustrated in Figure 20 below.

Figure 20 Radial and Open Loop Systems



The radial system is the oldest and most common because it is less expensive to build. However the radial system must be repaired in order to restore service after an equipment failure. A radial system provides adequate reliability when the lines are overhead because repairs can usually be made quickly, typically 0.5 to 2 hours. However, when underground utilities lines are used, the repair time is often 4 to 24 hours and a radial system provides poor reliability because of the long power interruptions after a failure. An “open loop” configuration allows power to be restored after a failure, by simply switching the loop to a different arrangement which isolates the failed equipment. The repair time is the same but the reliability is improved because the customers experience a shorter interruption. Open loop systems typically require about 10% more line in a urban residential area to provide the loop.

12 Appendix B SUMMARY OF OTHER COST/BENEFIT STUDIES

12.1 CEA 274 D 723 UNDERGROUND VERSUS OVERHEAD DISTRIBUTION SYSTEMS

This study was a review of the qualitative and quantitative factors affecting the decision to build overhead or underground power lines. It was published in 1992 by the Canadian Electrical Association, a cooperative venture of the larger Canadian electrical utilities. The report is a good source of input data for the present feasibility study since it was based in Canada.

The report draws no firm conclusions about feasibility. It states that the comparison must be based on more than just first costs, but first costs are usually 2 or 3 times higher for underground. It is sometimes argued that over head systems are more flexible to adapt to changing future needs but this report found that “the cost of purchasing and installing cable in an existing duct and manhole systems is very close to the cost of achieving the same amount of capacity with a new overhead line.” This is only true if extra ducts were installed during the initial installation.

The report states that “the impact of reliability considerations ….universally favors underground configurations”.

On ongoing operations and maintenance the report says “utilities report higher average routine O&M expenses on overhead systems…between 2 and 4 times the level of underground systems.”

Funding options are discussed in a general way including premium rate categories (which have never been used in practice), development charges, cost sharing with municipalities, and customer contributions.

The report includes case studies conclude that in new suburban residential development the underground option increases long term costs by 9%, which could be paid for by a capital contribution of $1,900 per residence or 0.0063 $/kW-h increase in rates. In urban residential-commercial areas the increased cost was 12% or $2,600 per customer or 0.008 $/kW-h.

12.2 PUTTING CABLES UNDERGROUND WORKING GROUP REPORT OF THE AUSTRALIAN GOVERNMENT

This is the largest and most comprehensive feasibility study ever conducted. It was a 1.5 million dollar study completed in 1998. It considered the costs and benefits of undergrounding all power lines in Australia.

In Australia, underground utilities are already required (municipal bylaws) in new utilities in residential and commercial areas, but undergrounding of existing overhead systems is not required.

The study included telephone and cable systems as well as power lines, which provides good estimates for costs for these utilities.

In general the quantifiable benefits were about 10% of the costs for replacing existing systems. This assumed that no other major civil works projects were done in conjunction with the utility undergrounding.

This comprehensive and recent study has been used as the source of many coast and benefit data for the present study of the HRM area.

The results of the study are summarized in Table 1. The dollar values have been converted to Canadian 2004 dollars.

Table 20 Benefits of Undergrounding in Australian Study

Type of Benefit	Annual Benefits ($/km of line)	
	Minimum	Maximum
Reduced motor vehicle accidents	1,358	2,793
Maintenance costs	18	1,531
Tree trimming	35	1,120
Reduced transmission losses	0	292
Total	1,411	5,736

13 Appendix C RATIONALE FOR COST INPUT DATA

The basis for most of the cost estimates is the CEA report "Underground Versus Overhead Distribution Systems" CEA 274D723 (Ref.1). The values in this report were compared with costs from other individual utilities that are known to Kinectrics through other projects (Ref. 3) to give an estimation of the variation or error in the value used. Typically the variation in cost estimates between different sources is less than 15%. Another key source of cost data, especially for non-power utility components is the extensive cost/benefit project conducted in Australia (Ref.2).

Some cost data specific to the HRM area was available from the Urban Development Institute and Nova Scotia Power Inc. This data was used whenever it was available because it was considered to be more accurate in the HRM area than the industry averages in the other sources.

All cost data has been stated in year 2004 Canadian dollars.

13.1 OH LINE CAPITAL COST

The values in CEA 274D723 were: single phase line 12 $/m , three phase line 40 $/m, and main trunk three phase 55 $/m. These are similar to Kinectrics estimates for other clients, but in rock or swamp they can be increased by 15 $/m. However, cost tends to be higher in urban areas with average values based on original capital costs reported on financial summaries ranging from 50 to 100 $/m (Ref. 3).

A cost of single phase line 35 $/m and three phase line 55 $/m have been adopted as best estimates for the HRM area based on information from NSPI. Add 15 $/m for increased conductor size on a trunk line (near the station).

13.2 UG LINE CAPITAL COST

The costs for underground utilities depend heavily on the style of installation and the quality of cable used. Since reliability improvement is one of the goals of undergrounding in HRM, the cost estimates have assumed that high quality cables will be installed in concrete encased ducts. Since the capital cost of the conductor in the cable is a small fraction of the total cost and replacing it is very expensive, it is a good practice, followed by most utilities, to install large size conductors (at least 500 MCM) so that future operational flexibility is maximized. The following costs are based on prices from manufacturer price lists and on CEA 274D723.

Single phase line
cable 20 $/m (from NSPI)
duct 20 $/m (2 single ducts (one spare) installed, but not including trenching costs)
concrete 25 $/m
Total 65 $/m

Three Phase Line

cable 50 $/m (from NSPI)
isolation points 100$/m (estimate from NSPI)
duct 75 $/m (3W2H, three spare ducts)
concrete 50 $/m
Total 275 $/m (for trunk line add 45 $/m to the cable cost, estimate from NSPI)

The additional costs vary with the circumstances of installation and are therefore estimated separately so they can be included or not included as appropriate.

Trenching 90 $/m in dirt (Ref. 2, 3)
200 $/m in rock (Ref. 2)

Manholes/vaults $10,000 each (Ref. 1, 3)
the number per km depends on the service area type.
1 in suburban residential, 4 in urban residential and industrial , 8 in commercial/business

restore sod surface 25 $/m (Ref. 1)
restore sidewalk 50 $/m (Ref. 1)
restore road 75 $/m (Ref. 1)

13.3 OH SECONDARY AND SERVICES CAPITAL COST

Secondary - 16 $/m (from NSPI)
Service drop – 15 $/m (from NSPI)

13.4 UG SECONDARY AND SERVICES CAPITAL COST

Secondary – 70 $/m (Ref.1)
Service Drop - 33 $/m (from UDI)

13.5 OH LINE MAINTENANCE COST

Average values for annual maintenance cost for provincial utilities, such as NSPI and Hydro One, range from 1 to 1.4 $/m. Urban utilities can be somewhat higher at 1.6 $/m (Ref. 3). Tree trimming alone is typically 0.5 to 1 $/m, the higher value in urban areas.

An annual maintenance cost of 1.5 $/m has been adopted as a best estimate for the HRM area.

13.6 UG LINE MAINTENANCE COST

The CEA 274D723 report does not include consideration of maintenance costs. An average of urban utilities was calculated as 1.9 $/m/y (Ref. 3). The value in Ref. 2 is too low to be credible (0.3) and the value in Ref. 4 is too high (6). These references were not included in the average.

13.7 OH SECONDARY AND SERVICES MAINTENANCE COST

0.4 $/m (Ref 3)

13.8 UG SECONDARY AND SERVICES MAINTENANCE COST

0.4 $/m (Ref 3)

13.9 LINE TRANSFORMERS

(all Ref 1)
Pole Top 25 kVA – $2,800 installed max 3 customers
Pole Top 100 kVA - $4,200 installed max 12 customers
Pad mount 100 kVA - $6,300 installed max 12 customers
Submersible 100 kVA - $6,300 installed max 12 customers

(NSPI estimates)
Pole Top 25 kVA – $1,800 installed max 3 customers
Pole Top 100 kVA - $4,000 installed max 12 customers
Pad mount 100 kVA - $8,900 installed max 12 customers
Submersible 100 kVA - $8,900 installed max 12 customers

13.10 OH EQUIPMENT REMOVAL AND DISPOSAL NET COSTS

This section does not include the residual value of the overhead equipment. The residual value will depend on the age of the overhead equipment being replaced. Over head equipment is usually depreciated over 40 years for tax purposes, but periodic maintenance will affect the residual value.

power line	15 $/m (Ref 2)
coax cable line	4.5 $/m (Ref. 2)
telco line	

13.11 OH STREET LIGHTING CAPITAL AND MAINTENANCE COSTS

installed cost - 30 $/m of road (Ref. 2)

13.12 UG STREET LIGHTING CAPITAL AND MAINTENANCE COSTS

installed cost - 100 $/m (light standards plus armoured cable)
maintenance cost -

13.13 OH TELCO AND COAX CABLE LINE CAPITAL AND MAINTENANCE COSTS

(assumes shared poles)

Telco installed cost 10 pair – 6.6 $/m (1.6 (Ref 5) plus 5 $/m installation cost)
Telco installed cost 100 pair – 16 $/m (11 + 5)
Telco installed cost 200 pair – 22 $/m (17 + 5)

Coax installed cost – 5.7 $/m (0.7 Ref 4) + 5$/m installation cost)

Telco service drop – 80 $/drop
Coax service drop – 70 $/drop

Telco maintenance cost –
Coax maintenance cost – 0.02 $/m (Ref. 2)

13.14 UG TELCO AND COAX CABLE LINE CAPITAL AND MAINTENANCE COSTS

(assumes adding to existing duct)

Telco installed cost 10 pair – 6.25 $/m (2.25 (Ref 5) plus 4 $/m installation cost)
Telco installed cost 100 pair – 19 $/m (15 + 4)
Telco installed cost 200 pair – 28 $/m (24 + 4)
Coax installed cost – 7$/m (Ref. 2 or Ref 4 plus 4 $/m installation cost)

Telco service drop – 92 $/drop (Ref. 2, assumes 15 m drop)
Coax service drop – 80 $/drop (Ref. 2)

Telco maintenance cost –
Coax maintenance cost –

(with no common trench assumption UDI estimates the following for both Telco and coax cable)
Main line cost 240 $/m (includes pedestals etc.)
Service drop 66 $/m

13.15 TREE PLANTING COSTS

Since the benefit of planting more trees is included on the benefits side of the calculation, the cost of planting those trees should be included on the cost side.

The cost of planting a 6 – 8 foot tall tree is estimated to be about $250. (Ref 19) This was in a rural area with deep soil available and no surface restoration costs.

Another reference (Ref 17) estimates that a large urban tree costs $1700 for the tree (5-6" caliper) and $1300 for growing medium, drainage, aeration and irrigation systems, and surface restoration.

HRM urban forester estimated $400 per tree for residential areas and $5,000 per tree for downtown areas. The downtown area assumes that soil must be brought in and a watering system installed. These estimates were use din the analysis.

14 Appendix D RATIONALE FOR BENEFITS INPUT DATA

The benefits of putting electric power cables underground have been identified by various studies as:

- increased reliability
- reduced motor vehicle accidents
- reduced tree trimming costs
- reduced maintenance costs
- increased property values
- improved appearance
- improved urban environment
- reduced energy losses

The negative consequences of putting electric power cables underground have been identified by various studies as:

- increased capital costs
- increased risk of fatal and non-fatal electrical contact accidents

It is difficult to assign a dollar value to many of the benefits. However, even if a specific dollar value cannot be assigned, a qualitative estimate can be made based on the following data from published reports. All values have been converted to Canadian 2004 dollars.

14.1 INCREASED RELIABILITY INPUT DATA

There is some dispute within the electrical utility industry about the relative reliability of overhead and underground utilities. The dispute is caused by a wide variation in the performance of both types of systems, which in turn is caused by differences in design of the system, and quality of techniques and materials used in the utilities.

The published literature agrees that the frequency of outages is lower on underground systems, usually by a factor of about three. The duration of those outages varies enough in the published reports that the customer-hours of outage has been claimed to be both lower and higher for underground systems. The difference in the outage duration is largely caused by a single key difference in the design of underground systems. The present industry standard design for underground system is too use open loops. This allows the power to any customer to be restored after a cable fault by a simple and timely switching operation. Typical outage duration in this case is less than one hour. However some utilities have underground systems that were designed as radial lines, the same as for an overhead system. This design would now be considered an error in design, since power can only be restored by a full repair of the cable, which typically requires 4 to 8 hours.

Given the lack of agreement in the published literature, the relative reliability that could be expected in the HRM area is best determined by a study of the existing lines and the effects of replacing them with modern materials and designs for underground lines.

This reliability study requires failure rate data for the various power system components. This data is available in reports published by the Canadian Electrical Association, as well as in text books on power system reliability and technical papers. Data specific to NSPI in the Halifax area was used when it is available (overhead line failure rate 0.33 failures/km/y and underground 0.11 failures per km/y). The reliability study then reproduced the reported SAIFI and CAIDI index figures.

Power System Component Failure Rates (Ref 1)

	Failures/yr (/km)	Useful Life	Isolation Time	Repair Time
OH line	0.05	40	1 hr	1.5
Aerial Cable	0.02	30	1	3
D.B. cable	0.025 - 0.019	20	1.5	8
duct cable	0.025	20	1.5	6
C.E. duct cable	0.02 – 0.014	25 – 35	1.5	4
dist trans	0.003	40	0.5	2.5
breaker	0.09	40	1	16
fuse	0.003	40	1	1
switch	0.001	40	1.5	4
elbow	0.0015	20	1.5	4
cable splice	0.001	30	1.5	4
arrester	0.002	40	1	1

note – second failure rate value and life value for cables is for premium quality cable, tree retardant, strand filled, jacketed (most cable installed today)

In order to estimate the dollar value of a change in reliability, data is required on the cost of outages to customers.

Value of lost load (Ref 1) (1991$ x 1.26 to convert to 2004 $))

outage duration	Value of lost load ($/kW demand not supplied)			
	Residential	Commercial / office building	Agricultural	Industrial
2 sec				
1 minute	0.001	5.3	0.7	1.8
20 minutes	0.1	11	0.38	4.3
1 hour	0.5	23	0.73	10.1
2 hours				
4 hours	5.5	77	2.3	28
8 hours	17.6	133	4.6	62
1 day				
2 days				
linear cost functions				
$/kW	0	7	0.13	1.51
$/kW-hr	2.01	16	0.56	7.45

These values can vary by a factor of 5 between different references.

14.2 REDUCED MOTOR VEHICLE ACCIDENTS INPUT DATA

The poles that support overhead lines are often installed close to the side of roadways and are often involved in collisions with vehicles. The damage to vehicles and their contents is often larger when the collision is with a utility pole than it is with other structures at roadside because of the rigidity and strength of the poles. There are few studies that quantify this effect but Ref 2 estimated 1358 – 2793 $/km line/yr

14.3 REDUCED TREE TRIMMING COSTS INPUT DATA

The cost of trimming trees near overhead power lines varies with the number of trees, the rate of tree growth and the cost of labour. The estimates for tree trimming costs vary between the references 35-1120 $ / km (Ref 2) 500-600 $/km (Ref 3) A reasonable average would be 550 $/km.

14.4 REDUCED MAINTENANCE COSTS INPUT DATA

Maintenance costs other than tree trimming can also be less on underground systems. The largest cost on overhead lines is the poles, which are not used in underground systems. However, cable location services are a cost of underground that is not required in overhead systems. Estimates of the difference vary widely, 18-1531 $/km less for underground (Ref 2), 3% of installed cost for OH and 2% for UG (Ref 4) but because of installed cost difference both work out about the same 1000 – 2000 $/km. Other references claim underground lines are more expensive to maintain by a factor of four (Ref 5).

The best assumption for the HRM service area is the Canadian reference that concludes there is no difference in maintenance costs.

14.5 INCREASED PROPERTY VALUES INPUT DATA

There is a tendency for property values to increase in areas served by underground power lines relative to areas served by overhead. This is reported in Australia (Ref. 2). However, it is also recognized that the effect is often temporary (when all lines are underground the difference goes to zero) and that property values are affected by many other factors.

Other studies have found that trees increase the value of residential properties by up to 20% and an average of 5 to 10% (Ref 13), and another study found 13-19% (Ref 14). At 5% of $150,000 this is $7,500 for a single detached house.

A more recent study found that when individuals were shown altered pictures of houses with different numbers of trees, the trees did not affect the perceived value of the house or its attractiveness (Ref 15).

The best reference study (Ref 2) concludes that the impact on property values ranges from 0-5% increase in areas served by underground lines, but in the final analysis this effect should be ignored.

14.6 IMPROVED APPEARANCE INPUT DATA

Improved appearance is an often cited and widely accepted benefit of undergrounding, however it is very difficult to assign a dollar value. No reference studies have been found that make any attempt to assign a dollar value directly to improved appearance.

However one of the largest factors in the improved appearance is the increase in the number of trees. There is a solid background of research in support of the compensatory value of trees. These estimates of the dollar worth of a tree are used in court cases to award damages for destroyed trees, to estimate the risk from damage from insects and disease, and real estate value assessments.

The Council of Tree and Landscape Appraisers in the USA has created a detailed assessment formula for individual trees. It is based on four tree and site characteristics, trunk area, species, condition and location. Data for costs of individual species are available from the International Society of Arboriculture publications. This data and calculation method could not be used directly in the present study because they relate to individual trees. The USDA Forest Service has funded several studies of urban forests that have used these formulas extensively. A summary of these studies (Ref 12) concludes that the average compensatory value of a tree in 8 cities with a total of 23,000 trees was 1050 dollars per tree.

14.7 IMPROVED URBAN ENVIRONMENT INPUT DATA

Underground power lines provide more space for the growth of trees in urban areas. Urban trees provide many environmental benefits including reduced carbon dioxide levels in the air, increased oxygen levels in the air, decreased particulates in the air, increased absorption of rainwater, raised water tables, decreased building heating costs by reducing wind, decreased building cooling costs by providing shade, reduced noise. The psychological impact of trees on people’s moods, emotions and enjoyment of their surroundings may be one of the greatest benefits urban forests provide. (Ref 6).

Data on dollar values are available for a very few of these benefits.

Reduced residential heating costs by 10-15% (Ref 6) and “up to 30%” (Ref 7)
Reduced particulates in the air by 7,000 particles per litre of air per tree (Ref 6)
Reduced air conditioning costs, 10-15% (Ref 8)
Non-treed urban areas are 12 ºF hotter than treed areas (Ref 7)

Value of net air quality effect is $125,000 per percent of total ground area covered or $2.30 per large tree (Ref 9).

14.8 REDUCED ENERGY LOSSES

Data from many utilities shows lower losses on underground lines than on overhead lines. There are three main reasons for this. First, underground lines are often shorter since they are too expensive to install in long line situations. Secondly they are loaded farther below their current rating because of the practice of installing very large conductors underground to improve operational flexibility. The cost of the conductor is a very small proportion of the total cost of an underground line and once it is installed it is expensive to change the conductor size. Most utilities therefore install larger conductors than are needed in order to reduce the future risk of the line being inadequate. Thirdly the lower losses are caused by the lower ampacity limits on underground cables with the same conductor diameter as overhead lines. Larger conductors are needed to carry the same current underground because of the poor heat transfer away from the cable.

In this study it was decided that lower losses should not be considered as a benefit of underground lines. There are two reasons for this. First the lower losses are not inherent to underground lines. Overhead systems could be designed with larger conductors and have similar losses. Secondly, other studies (Ref 2) found that the value of the reduced losses ranged from zero to only $292 $/km.

14.9 INCREASED RISK OF FATAL AND NON-FATAL ELECTRICAL CONTACT ACCIDENTS INPUT DATA

Underground cables increase the risk of electrical contact accidents by a factor of three. These accidents occur on overhead lines at a rate of 200 per year per million km of line. Between 1 and 4 % of these are fatal and insurance industry average death cost is $850,000 per life. (increase of between 0.004 and 0.014 $/m)
(Ref 10)

15 REFERENCES

1. “Underground Versus Overhead Distribution Systems”, Canadian Electrical Association report 274 D 723, 1992

2. “Putting Cables Underground Working Group Report”, Government of Australia, 1998

3. Kinectrics reports for southern Ontario urban utilities, privately published 1990-2004

4. Brad Johnson, “Out of Sight, Out of Mind?”, Edison Electric Institute, January 2004.

5. Manufacturers Websites June 2004 (telephone and coax cable prices)

6. “Guide to Value Based Distribution Reliability Planning” Canadian Electrical Association Report CEA 273 D 887, 1996.

7. “The Feasibility of Placing Electric Distribution Facilities Underground”, North Carolina Utilities Commission, November 2003. as quoted in “Out of Sight, Out of Mind?” Edison Electric Institute January 2004.

8. “Tree Trivia”, Tree Canada Foundation, 2004

9. Arthur Plotnik, “The Urban Tree Book”, Three Rivers Press

10. www2.treesaregood.com International Society of Arboriculture, 2004

11. David Nowak, Daniel Crane, Jack C. Stevens, Myriam Ibarra, “Brooklyn’s Urban Forest”, United States Department of Agriculture Forest Service General Technical Report NE-290, March 2002.

12. E. Gregory McPherson, David J. Nowak, Rowan A. Rowantree, “Chicago’s Urban Forest Ecosystem – The Results of the Chicago Urban Forest Climate Project”, United States Department of Agriculture Forest Service General Technical Report NE-186, 1994.

13. “Electrocutions and Underground Cabling”, Bureau of Transport and Communications Economics, Government of Australia, 1997

14. Francis W. Holmes “Shade Trees – The Friends of the Poor and the City Dweller”, Journal of Arboriculture 3(9), September, 1977

15. R. Bruce Hull, “How the Public Values Urban Forests”, Journal of Arboriculture 18(2), March 1992.

16. R.S. Ulrich, “View Through a Window May Influence Recovery from Surgery”, Science 224 : 420-421, 1984.

17. Henry F. Arnold, “Trees in Urban Design –Second Edition”, Van Nostrand Reinhold: New York, 1993.

18. Brown University Ecological Studies Web Site, 2004

19. Akbari H., Taha H., “The Impact of Trees and White Surfaces on Residential Heating and Cooling Energy Use in Four Canadian Cities”, Energy 17(2), 1992

20. David Nowak, Daniel Crane, John Dwyer, “Compensatory Value of Urban trees in the United States”, Journal of Arboriculture 28(4), July 2002.

21. “Trees Could Make a Difference in the Selling Price of Your Home”, Journal of Arboriculture 11(4), April 1985.

22. Clay Martin, Robert Maggio, David Appel, “The Contributory Value of Trees to Residential Property in the Austin Texas Metropolitan Area”, Journal of Arboriculture 15(3), March 1989.

23. Brian Orland, Joanne Vining, Angela Ebreo, “The Effect of Street Trees on Perceived Values of Residential Property”, Environment and Behavior, May 1992.

24. E. Gregory McPherson, David J. Nowak, Rowan A. Rowantree, “Chicago’s Urban Forest Ecosystem – The Results of the Chicago Urban Forest Climate Project”, United States Department of Agriculture Forest Service General Technical Report NE-186, 1994.

25. “2003 Renewal Annual Information Form”, Nova Scotia Power Inc., May 17, 2004.

26. Terry Orban, “Spacer Cables Revisited”, T&D World, Dec 2002