SUBJECT AREA: **First Nation and Metis Engagement, TLE Selection**

REFERENCE: **EIS, Chapter 4, Appendix 4B**

QUESTION:

Please provide an explanation for the following statement: “Provincial Crown land, where there is a transmission line, does not become ineligible for TLE selection”.

RESPONSE:

Manitoba Hydro does not purchase Crown Land. An easement is obtained that allows us to build, operate and maintain a transmission line on that property. Therefore it is still Crown Land available for TLE selection.

SUBJECT AREA: Routing, None

REFERENCE: EIS, Chapter 4, Appendix 4B

QUESTION:

Please provide details of Manitoba Hydro's research of routing methodologies.

RESPONSE:

Please refer to response SSC-IR-010.

SUBJECT AREA: **Routing, None**

REFERENCE: **EIS, Chapter 4, Appendix 4B**

QUESTION:

Please explain how “no go” areas are incorporated into the transmission line routing process, provide a complete list of “no go” areas and explain what is meant by “selected TLEs” and “federal land”.

RESPONSE:

The incorporation of “No-Go” areas as referred to in Appendix 4B under the *“Summary of Concerns and Comments from Peguis First Nations”* was generally a discussion around the constraints most likely to be avoided. Manitoba Hydro has incorporated “no go” areas into its Areas of Least Preference as described in Section 5.3.3.1 that are features to avoid when routing a transmission line due to physical constraints, regulations limiting development, or areas that would require extensive mitigation or compensation.

Selected TLE’s – please refer to response SSC-IR-033.

Federal land – Any lands belonging to Her Majesty in right of Canada or which the Government of Canada has power to dispose (i.e. Indian Reserves, national parks).

SUBJECT AREA: **First Nation and Metis Engagement, None**

REFERENCE: **EIS, Chapter 4, Appendix 4C**

QUESTION:

Please provide more details about, and a map outlining, the northern and southern zones and Areas 1 – 3.

RESPONSE:

Appendix 4C 1.1 describes the northern zone as starting approximately south of the Village of Marchand and extending to the north edge of the corridor (northern portion of the study area). The southern zone is described as starting south of the Village of Marchand and extending south to the US border.

See Map 11-3 from Chapter 11 of the EIS.

SUBJECT AREA: Heritage Resources, None

REFERENCE: EIS, Chapters 6 and 12, sections 6.3.2 and 12.4

QUESTION:

Section 6.3.2 states that "The provincial inventory of Centennial farms (i.e., farmstead that have remained with the same family for 100+ years) contains 15 sites". The Manitoba Historical Society's website contains a list of centennial farms (http://www.mhs.mb.ca/docs/farm/index.shtml). That list contains nearly 300 sites. Please explain the discrepancy.

RESPONSE:

The locations of known heritage resources, including Centennial Farms, were considered during the three rounds of route selection. The preliminary alternative routes, the preferred route and the Final Preferred Route were analyzed for proximity to known heritage resources. The 15 sites identified as Centennial Farms are those sites that were within the MMTP project area and were used for routing analysis.

SUBJECT AREA: **Heritage Resources, None**

REFERENCE: **EIS, Chapters 6 and 12, sections 6.3.2 and 12.4**

QUESTION:

Section 6.3.2 states that "There are no centennial farm sites within the Final Preferred Route ROW". Section 12.4 states that "No centennial farms are located within the Existing Corridor and the Final Preferred Route PDA or LAA". The Manitoba Historical Society's website contains a list of centennial farms (http://www.mhs.mb.ca/docs/farm/index.shtml). One of those centennial farms – the one owned by Bernard and Marge Fournier – is within the Final Preferred Route ROW. Please explain with reference to MCWS/MH-I-007 dated April 29, 2016 and, specifically, confirm whether Manitoba Hydro denies that the Fournier farm is a centennial farm.

RESPONSE:

The Centennial Farm program is administered through the Manitoba Historical Society and the farm locations are forwarded to the Manitoba Historic Resources Branch for inclusion in an electronic database of the farms. The Fournier farm was not listed in the Centennial Farm database received from the Historic Resources Branch for the MMTP heritage background in April 2013. The Fournier farm is listed on the Manitoba Historical Society's website.

As stated in MCWS/MH-I-007, the land in question was examined in conjunction with the Final Preferred Route and the farmyard was determined to be outside of the defined Project Development Area (PDA) and the Local Assessment Area (LAA).

SUBJECT AREA: **Biosecurity, None**

REFERENCE: **EIS, Chapter 15, section 15.1.1.5.3**

QUESTION:

Please provide a copy of Manitoba Hydro's current Agricultural Biosecurity Policy.

RESPONSE:

A copy of the current Agricultural Biosecurity Policy is filed as SSC-IR-218_Attachment1.

Corporate Policy

Agricultural Biosecurity - P853

Number:	**P853**
Revised:	**3/3/2017**
Owner:	**Corporate Environment Manager**
Contact:	**For interpretation or further information on this policy, contact:** **Corporate Environment Manager**

Approvals | Definitions | Policy | Procedure | Related Information

DEFINITIONS

agricultural biosecurity: the protection of crops and livestock systems against the threats to production from disease, pests and invasive species

agricultural land: land zoned for agricultural use by the provincial government, a municipality, planning commission or planning district

POLICY

1. Policy Statement

To prevent the introduction and spread of diseases, pests, and invasive plant species in agricultural land and livestock operations, Manitoba Hydro employees and contractors will follow this corporate policy and the relevant Agricultural Biosecurity Standard Operating Procedure.

2. Purpose

Biosecurity is a growing concern in the agricultural sector on a global scale. With the increased awareness of animal and crop safety, the implementation of biosecurity protocols is a necessary requirement to ensure the health of agricultural operations and the surrounding environment.

Manitoba Hydro staff and contractors have the potential to impact agricultural biosecurity through construction and/or maintenance activities requiring access to agricultural land. Acknowledging this risk, the purpose of this Agricultural Biosecurity corporate policy is to ensure that Manitoba Hydro staff and contractors take necessary precautions to protect the health and sustainability of the agricultural sector.

PROCEDURE

Agricultural Biosecurity Responsibilities

Responsibility: Operating and Corporate Groups

1. Each Operating or Corporate Group requiring access to agricultural land is responsible to develop and maintain an Agricultural Biosecurity Standard Operating Procedure (SOP). The SOP must include, at a minimum, the following items:

    - assessment of the potential biosecurity risk
    - suitable procedures to manage the risk

2. Document compliance with the SOP. This may be done through a biosecurity checklist, or at the discretion of each Operating or Corporate Group through another practical method such as a job plan or an existing environmental checklist.

3. Ensure that all staff and contractors who work on agricultural land are aware of and have access to the SOP.

4. Send a copy of each SOP developed under this policy to the Corporate Environment Department for filing.

Responsibility: Staff and Contractor

5. All Manitoba Hydro staff and contractors who carry out work on agricultural land will:

    - refer to and be aware of the Standard Operating Procedure (SOP) and this Agricultural Biosecurity corporate policy
    - be able to inform a landowner or producer leasing the land about the SOP, if asked
    - be able to provide a copy of SOP to landowner or producer leasing the land, if asked, whether

6. Comply with requirements of SOP and this corporate policy.

Responsibility: Corporate Environment Department

7. File each SOP received.

SUBJECT AREA: **Biosecurity, None**

REFERENCE: **EIS, Chapter 15, section 15.1.1.5.3 and Appendix 15B**

QUESTION:

Please provide the most recent Agricultural Biosecurity Standard Operating Procedures.

RESPONSE:

The most recent Property Department Standard Operating Procedures and associated appendix specific to the MMTP are available under “Additional materials” on the Manitoba Hydro website here https://www.hydro.mb.ca/projects/mb_mn_transmission/document_library.shtml.

The most recent Transmission Business Unit Agricultural Biosecurity Standard Operating Procedures (SOP) is filed as SSC-IR-219_Attachment1.

Agricultural Biosecurity Standard Operating Procedures
Transmission Business Unit

1. PURPOSE OF THE PROCEDURE

This Standard Operating Procedure (SOP) provides guidance and direction to individuals who may be required to enter agricultural land and the levels of cleaning necessary to reduce the likelihood of soil and manure transport of invasive organisms (diseases, pests, and invasive species).

2. SCOPE

This SOP describes the risk, techniques, record, and document controls for activities related to transmission construction and maintenance and its associated infrastructure, on agricultural land in Manitoba.

3. APPLICABILITY

This SOP applies to the following:

- Land zoned as agricultural (e.g. pasture, cropland, livestock areas).
- All employees of Manitoba Hydro as well as external individuals such as contractors or consultants who conduct work on behalf of the Transmission Business Unit.
- Additional measures may be prescribed in a project's Environment Act Licence or in the project's Environmental Protection Plan. These measures will be project specific and will not apply to all departments within the Business Unit.
- Additional measures may be implemented for agricultural areas where there is documented evidence of invasive organisms (diseases, pests, and invasive species).

This SOP **does not** apply to the following:

- Government road allowances.
- Gravel or paved driveways or roadways.

4. GENERAL INFORMATION

Agricultural biosecurity is the protection of crops and livestock systems against the threats to production from invasive organisms (diseases, pests, and invasive species). Human activity is one of the factors in the spread of invasive organisms, and the responsibility for agricultural biosecurity rests with all stakeholders.

Agricultural land is land zoned for agricultural use by the provincial government, a municipality, planning commission or planning district.

5. GENERAL CONSIDERATIONS

1. If existing farm level biosecurity measures exist, Transmission staff and contractors will strive to meet the requirements of the agricultural operation when access is required.
2. Activities will try to avoid access through areas that may contain manure.
3. Regular maintenance activities (including patrols) on agricultural lands will typically be scheduled after crops have been harvested and conducted primarily after freeze up.
4. Staff from other Business Units carrying out work for Transmission will be required to follow these procedures during the course of their work.

6. RESPONSIBILITY

All Transmission staff and contractors who carry out work on agricultural land will:

- Refer to and comply with the requirements of the SOP and the Agricultural Biosecurity Policy.
- If requested, be able to provide a copy of this SOP to the landowner or producer leasing the land.
- Be able to inform a landowner or producer leasing the land about the SOP, if asked.

It is expected that all individuals who require access onto agricultural land and are conducting activities for the Transmission Business Unit, including contractors, will be trained on the Agricultural Biosecurity Policy and this SOP.

Internal Training

A computer based training (CBT) course will be made available for training purposes. All individuals required to undergo training will complete the CBT and will have fulfilled the training requirement.

External Training

The Agricultural Biosecurity Policy and the SOP will be incorporated into the safety and environmental orientation prior to the start of work. Training records will be stored with the individual projects files. Contractors will be required to view the three biosecurity videos available from Corporate Environment as a part of their training.

7. ASSESSMENT OF RISK

The Transmission Business Unit elected to use a risk matrix to identify the potential biosecurity risk. The matrix identified the perceived risk to agricultural land from maintenance and construction activities by taking the frequency a hazard may occur and multiplying it by the consequence or severity of the hazard to determine the level of acceptable risk. The following two levels of risk were identified from the matrix; low risk and higher risk.

Low Risk

During the winter season when the ground is frozen and there is snow cover, it is not anticipated that activities conducted during this time will effectively transfer invasive organisms (diseases, pests, and invasive species) to other agricultural lands and therefore the risk can be considered low. When the ground is dry and undisturbed the risk of transferring these pathogens is minimal, however, avoiding bare ground reduce the risk. Visible inspections will be expected to occur and are described in the biosecurity procedures. The risk can be managed and further minimized by avoiding wet areas and cleaning equipment effectively when leaving the field.

Higher Risk

The higher risk will be located in areas where the ground conditions are very wet and the accumulation of heavy soils such as clay may occur on footwear and in the tracks of vehicles or heavy equipment. It also applies to livestock settings or areas where manure has been spread. There are a number of ways this condition can be mitigated such as avoiding the excessively wet areas, additional cleaning procedures, or rescheduling the work until ground conditions are more favourable.

Although the last method is preferred, it is not always possible because the activity may be dependent upon a specific timeline, seasonal changes, or an emergency situation where it is essential to return infrastructure to normal operating conditions.

Additional measures may be implemented when there is documented evidence of invasive organisms (diseases, pests, and invasive species) that are of concern to Manitoba Agriculture, Food and Rural Development.

For the majority of activities conducted within the Transmission Business Unit, the level of risk is anticipated to be low risk. With continual educational awareness and effective implementation of biosecurity procedures, the goal is to further minimize the risk to agricultural lands.

8. PRESCRIBED ACTIONS

Emergency

In emergency situations the Manitoba Hydro Act will prevail in order to return services to normal operating conditions. All efforts will be made to assess the risks to agricultural land and personal safety to determine the most appropriate measures to be taken.

Low Risk

Low Risk Activities are those that are typically completed in frozen conditions, or on dry ground with little soil disturbance.

1. Ensure all equipment and clothing is clean prior to entering onto agricultural land.

2. When leaving the field, check clothing, footwear, and equipment for seeds, soil, or manure and if required, brush off prior to leaving the field. The use of a brush will remove most surface soil, plant material, and foreign matter from clothing and equipment.

3. Fill out the Vehicle and Equipment Cleaning Record and submit with the Biosecurity Checklist.

Higher Risk

This type of risk will involve activities on wet or heavy soils, such as clay, with the potential for large soil accumulations on equipment and footwear. It also applies to livestock settings or in cases where manure is confirmed to have been spread on fields.

1. If possible, schedule activities to occur when ground conditions are more favourable.

2. If activities cannot be rescheduled, ensure that proper care and attention is paid to cleaning equipment and footwear prior to leaving the site.

3. Equipment may require fine cleaning to remove remaining soil. This includes pressure washing to rinse off remaining soil or manure. Initial cleaning (i.e. mechanical brushing) should be done at the field approach, and full pressure washing can be completed off site if the equipment is taken directly to a commercial wash facility. In cases where there is a risk of spreading soil (such as vehicle tires), pressure washing must occur before leaving the site. Disinfecting of the equipment through the use of a disinfectant such as Virkon should be applied to all surfaces that have been in contact with soil.

4. Use safety footwear that can be easily cleaned. Use a brush to remove visible soil or manure and disinfect or change footwear when leaving the field.
   - Disinfectants such as 1% Virkon may be carried in a household spray bottle or a larger container if required.
   - Any waste solution associated with disinfection is to remain on the field where it was used. It must be disposed of at least ten metres from a drain or drainage ditch.

5. Fill out the Vehicle and Equipment Cleaning Record and submit with the Biosecurity Checklist.

9. PERSONAL PROTECTIVE EQUIPMENT

Safety of the individual will always be of the highest importance at Manitoba Hydro. Corporate safe work procedures and protocols are in place to protect not only the individual(s) directly involved in the activity or work, but also as it relates to public safety.

Personal protective equipment (PPE) will be worn as per the manufacturer's specifications and as directed by Manitoba Workplace Health and Safety Regulation 217/2006, Part 6 Workplace Safety and Health Regulations.

10. CONTACT INFORMATION

If there are any questions or concerns from the public related to biosecurity at Manitoba Hydro, contact the Customer Contact Centre at 1-MB-HYDRO (1-888-624-9376) or via email at environment@hydro.mb.ca.

11. APPROVAL

(Original signed by)

Shane Mailey
Vice President
Transmission

Sept 22, 2016
Date

NOTE: This procedure will be reviewed annually by management. As conditions change or new information becomes available, this document may be revised prior to the annual review date. Printed copies are not controlled, so check with management for the latest version.

SUBJECT AREA: **Property, None**

REFERENCE: **EIS, Chapter 15, section 15.1.1.4 and Appendix 15C**

QUESTION:

The brochure at Appendix 5C indicates that an advance payment of $225 will be made at the time of an easement agreement. The "Manitoba-Minnesota Transmission Project Compensation & Land Access" enclosure to letters recently sent out by Manitoba Hydro indicates that Manitoba Hydro will now pay 50% of the market value of the land at the time of signing. When did Manitoba Hydro decide to change the amount being paid, and why?

RESPONSE:

The $225.00 advanced payment is rooted in a long standing practice to pay a minimum of $225.00 for any transmission line class easement. In discussion with landowners on the Bipole III Transmission Project, $225.00 at the time of signing was recognized as being too insignificant in the overall land acquisition strategy. Manitoba Hydro reviewed property acquisition strategies over the course of 2016. The result of that being the decision to move to 50% of the market value for MMTP.

SUBJECT AREA: **Property, None**

REFERENCE: **EIS, Chapter 16, Section 16.3.2.1.1**

QUESTION:

Please provide a copy of the review conducted by Prairie Research Associates and any updated review conducted since that time.

RESPONSE:

Please refer to SSC-IR-221_Attachment.

AGRONOMIC AND LAND USE ASSESSMENT STUDY

Phase 3: Analysis of the Relationship Between the Proximity to High Voltage Transmission Lines and Urban Residential Property Values

Preliminary Results

Draft: For Discussion Only

June 7, 2016

Prepared for:

Manitoba Hydro

WINNIPEG | OTTAWA | EDMONTON | REGINA

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Volume 1 – Technical Report and Literature Review

Table of Contents

Volume 2 – Copies of Reference Material Cited

Executive Summary

Overview and purpose

Manitoba Hydro contracted PRA Inc. to conduct a "detailed study conducted on the agronomic and land use effects of transmission line development on agricultural and other lands in Manitoba." The overall goal of this study is to use Manitoba information to statistically measure proximity to high-voltage transmission lines (HVTLs) and the effect on agricultural operations and non-urban residential land values, often described as "ex-urban" properties. This work is comprised of three phases. Phase 1 is an internal feasibility report intended to ensure that reliable and valid information exists to support Phases 2 and 3. Phase 2 examines the impact of HVTLs on farm costs and operations in Manitoba. Phase 3 examines the relationship between proximity to HVTLs and urban residential property values.

An HVTL carries voltages in excess of 115 KV and features large steel or wooden towers that require substantial rights-of-way. These lines differ from lower voltage distribution lines that deliver power to individual residential, commercial, and industrial end users. This study does not address the relationship between distribution lines and urban property values.

HVTLs may affect urban property values in two contexts:

1. They may affect the revenue or costs associated with land-using activities in agricultural, commercial, or industrial activities.
2. They may also influence residential owners' enjoyment of the property; it is this second context that is the subject of Phase 3.

Phase 3 method

This study used the following three methodological steps:

1. We undertook a systematic review of the literature that measured the relationship between HVTLs and property values. The review informed the data collection and statistical methodology we used and provided context for the statistical results we obtained. This ensures our approach uses state-of-the-art methods to measure the relationship between proximity to HVTLs and urban property values.

2. We defined the study area to meet the following criteria:
   a. Based on findings from the literature review and data availability, HVTLs must be within 100 metres of immediately adjacent properties in urban areas.
   b. Information on the attributes of the properties such as area, home amenities, and sales values had to be available for at least 10 years.

   We use Manitoba Hydro's Orientis system to identify candidate urban areas. The Provincial Municipal Assessor provided property data and PRA calculated proximity measures for each HVTL and for each property in the sample.

3. The sample used ex-urban developments outside Winnipeg. Winnipeg data were not available at the time this research was conducted. This study used assessment data for three residential developments in Selkirk, Oakbank, and East St. Paul. In most cases, the HVTLs we studied were constructed prior to residential development. This limits the findings of this

research to those specific circumstances. In one instance (East St. Paul), we were able to analyze the impact on sales values of adding a line to an existing right-of-way. Based on the data available from the Provincial Municipal Assessor, it is not possible to develop property value information prior to the construction of HVTLs constructed more than 15 years ago. Any new HVTL (under construction, announced, or in the planning stages) would offer Manitoba Hydro the opportunity to create a pre-post dataset of property values to analyse impacts more completely

4. The statistical modelling used multivariate regression to measure the relationship between proximity to the HVTL and property values.

Key findings

A key conclusion taken from the literature review is that the property value decline associated with proximity to HVTLs is situationally specific. It is difficult to develop a universal and precise rule about the extent of value adjustment associated with proximity to transmission lines, since these relationships are contingent on a host of site-specific variables.

The 30 years of studies we reviewed show wide variation in this value adjustment depending on context, the data available, and the specific statistical methodology. However, the more qualitatively robust studies (in the sense of having sufficient data and well-designed statistical tests) show that proximity to an HVTL is typically associated with a 5–10% reduction in property values for lots immediately adjacent to the right-of-way. This land value discount usually declines rapidly and properties in excess of 300 metres from the line usually show no value reduction.

The literature also suggests that the value reduction declines over time, as the rights-of-way become developed and as the landscaping on new properties matures. Also, because rights-of-way for HVTLs are wide, homeowners whose properties are adjacent to the lines may enjoy increased privacy from neighbours to one side. This creates property features that can counteract, and in some cases reverse, any value decline associated with proximity to the line.

The regression analysis used sales transactions after 1985. Our findings align with the literature although we find smaller value reductions, in the order of 3%. We also tested the impact of adding an additional line to the existing two lines that run along the boundary of East St. Paul. In this case, since the addition occurred after the construction of the residences, we are able to conduct a “natural experiment” and fairly assess any value change as an impact of the new line. We found no statistically significant negative impact of the additional line on property values.

Finally, we analyzed the current use of the three rights-of-way close to the three study regions. It is apparent that these areas are being used as greenspace, walking trails, gardens, and playgrounds. Over time, it is plausible that the land under the HVTL becomes a positive attribute that homeowners value, and a positive force on property prices. The report offers some qualitative evidence that HVTL rights of way can become a positive amenity to homeowners immediately adjacent to the line.

Since the findings of this research align closely with other studies, we believe that the same relationships between HVTLs and property values hold in other *urban residential* areas of

Manitoba and that these relationships will endure. The results of this research should not be imputed to non-residential land uses, residential land uses that feature multi-family units and condominium developments, and larger residential/recreation properties inside the perimeter of Winnipeg. The results would apply to developed residential properties in subdivisions outside the perimeter of Winnipeg, provided the line and rights-of-way were established prior to the development of the land and any sales.

Valid and invalid uses of the results in this report

Any statistical study of land values and their influences must be retrospective. Only by using a sufficient number of historical cases can one infer the relative importance of the multitudes of influences on value. This report uses econometric techniques that attempt to identify the independent effect of each measured influence on land values, of which the attributes of the HVTL (proximity of the residence to the line/tower) are but one factor.

In this study we use transactions made over an extended period from three residential subdivisions relatively close to Winnipeg. Data from Winnipeg residential properties were not available at the time of the research.

These methodological features define what can be stated about the relationship between HVTLs and proximate properties. In particular, it is important to keep in mind several caveats when interpreting results:

1. The statistical results apply only to the residential properties in the three subdivisions and for the time spanned by the data. It is not valid to transfer the results in this report to any other types of residential properties in Manitoba that are proximate to HVTLs. However, provided the nature of the homes and the layout of the subdivision are similar, the results should be broadly similar. The results in this report are generally consistent with the findings of other research that examined the impact of HVTLs on relatively dense subdivisions (smaller urban lots with three to four bedroom homes, and inside or within 15 to 30 minutes of the city boundary). As the nature of the properties diverge from this configuration, conclusions about the nature of the relationship between HVTLs and land values reached in this paper would not apply.

2. The fact that the land values of residential properties close to a transmission line can be lower than those of similar properties (e.g., similar style, lot size, subdivision) does not mean that owners of those properties have experienced a loss. The only group potentially experiencing a loss on these properties are those who owned the land at the time Manitoba Hydro announced plans for the lines. Typically, these "pre-development" owners are:
    a. farmers who wish to sell to a developer;
    b. developers who are holding land in anticipation of conversion to residential/commercial/industrial use; and
    c. owners of larger residential properties beyond the city limits, which are used either as residential/recreation properties or as investments on the chance that urban growth may make their properties attractive for denser development.

This research sheds no light on how HVTLs may affect the land values in these situations, largely because the provincial assessment records contain too few observations of sales before and after Manitoba Hydro constructed the line to support valid statistical analysis.

3. In mature neighbourhoods, HVTLs may have a positive influence on the value of properties close or even adjacent to the right-of-way. Increased separation and mixed use within the right-of-way can confer benefits to the owner. In addition, maturity often brings increased foliage density, obscuring the lines and towers. Given small sample sizes, we have no way to examine these associations statistically.

4. The majority of residential property owners whose land is close to existing lines (within 100 metres) is not affected in any way. These owners typically purchased after Manitoba Hydro either announced or constructed the lines; their purchase price would have been adjusted by the market to reflect any impact of the HVTL. Purchasers are assumed to make fully informed decisions when making offers for a home purchase, which reflect all attributes of the house, lot, and location, which includes proximity to the HVTLs. The 3% reduction we found (which is an average across time and all properties in the sample) aligns with the results from the literature on the relationship between HVTLs and land value. This reduction may or may not be perpetuated in subsequent property sales. Of course, buyers may not perform due diligence and sellers/brokers may not reveal the plans for an HVTL.

5. Most importantly, these results must not be transferred to larger rural undeveloped properties (usually an acre or more in size) that lie along a proposed HVTL. Such properties are usually diverse, as some owners having constructed residences, while others are holding the land or renting the land for agriculture. It is invalid to conclude that any or all of these larger properties will experience a 3% reduction in future sales value by virtue of a new transmission line. Any claim for compensation would be unique to each property and must include consideration of the situation's specific attributes: the situation of the residence on the property, the existence of trees, and other topographical factors. No statistical studies of how HVTLs have affected larger residential properties like these exist anywhere in North America. This is for three reasons. First, the property assessment data prepared for this research by Manitoba Assessment do not include the range of amenity factors (e.g., view, existence of ponds, wildlife) that affect price. This precludes statistical analysis. Second, unlike the residential properties included in the three subdivisions, the variation in properties of this type is very high. Third, the number of properties is small with few transactions; this, more than anything, has limited the statistical analysis of how HVTLs affect land values of rural residential properties.

1.0 Introduction

Manitoba Hydro contracted PRA Inc. to conduct a "detailed study conducted on the agronomic and land use effects of transmission line development on agricultural and other lands in Manitoba." The overall goal of this study is to use Manitoba information to statistically measure the relationship between high-voltage transmission lines (HVTLs) on the cost of agricultural operations and urban land values. This work is comprised of three phases. Phase 1 is an internal feasibility report intended to ensure that reliable and valid information exists to support Phases 2 and 3. Phase 2 examines the association of HVTLs on farm costs and operations in Manitoba. Phase 3 examines the relationship between proximity to HVTLs and urban residential property values.

An HVTL carries voltages in excess of 115 KV and features large steel or wood towers that require substantial rights-of-way. These lines differ from lower voltage distribution lines that deliver power to individual residential, commercial, and industrial end users. This study does not address the relationship between distribution lines and urban property values.

HVTLs may affect urban property values in two contexts:

1. They may affect the revenue or costs associated with land-using activities in agriculture, commercial, or industrial activities.
2. They may also influence residential owners' enjoyment of the property; it is this second context that is the subject of Phase 3.

Studying the relationship between HVTLs and residential property values offers Manitoba Hydro a Manitoba-based reference study to understand the probable impact of future lines on property values in similar residential settings.

It is important to understand that this study, like the vast majority of the research on this subject, cannot analyze the impact of an HVTL on the value of land. In most of the studies, including this research, the right-of-way existed prior to residential development. Therefore, it is incorrect to refer to the impact of an HVTL on residential property values, unless one can measure sales values before and after the identification of rights-of-way.

1.1 Organization of the report

This Phase 3 report is comprised of the following sections:

- Section 2.0 summarizes how property value is determined and how HVTLs affect those values.
- Section 3.0 presents the methodology used in this study.
- Section 4.0 presents an overview of the findings with interpretation and conclusions.
- Appendix A presents the detailed econometric analyses and Appendix B presents the literature review.
- Volume 2, bound separately, presents copies of the articles and materials cited.

2.0 How are land values determined?

All land values are the outcome of the intersection of supply and demand.

Supply: At the simplest level, the supply of land is fixed, except where natural processes (erosion, flooding, etc.) may expand or contract accessible properties. In North America, land is public or private. In Canada, government regulates the supply of total private land through its designation of national/provincial/municipal parks and Crown lands. Private land is also regulated through the provincially and municipally legislated planning processes that designate approved land use through zoning. Development plans and zoning bylaws prescribe the types of allowable land uses to comply with provincial land use policies to ensure land use compatibility and to manage external effects, such as noise and pollution, as well as to create efficiency in the delivery of services (e.g., transit, water). Thus, the supply of land for agricultural, industrial, commercial, and residential uses is also fixed in the short term.

Over time, the supply of land for a specific purpose adjusts by changed regulation (zoning). Designating a property as industrial through zoning, for example, increases the supply of land for that purpose. Urban expansion will often see purchases of farmland at the periphery of a city in anticipation of a change in zoning from agricultural to non-agricultural uses (e.g., industrial, commercial, residential). The change in zoning increases the supply of non-agricultural lands available for development.

Changes in development plans and, to a lesser extent, zoning, are usually longer-term processes; therefore, the supply of land in the long term expands slowly. The key point is that, in the short term, the supply of land tends to be fixed, and demand drives variations in property values.

Demand: Land is valued as input to a business or as input to social/economic welfare of a household. A business (industrial, commercial, or agricultural user) values land for its contribution to net income. A household values property (and the house) is valued for its ability to deliver a range of social, economic, and psychological benefits.

2.1 Demand for land

Industrial, commercial, and agricultural land is an input to the production process, where the value of land reflects its contribution to the net income of the business. Industrial land values reflect such things as proximity to transportation corridors (for incoming shipments of resources and outgoing shipments of product) and utility servicing. Commercial land values result from proximity to customer traffic and other businesses. Agricultural land values reflect, among other factors, soil type and condition, as well as proximity to transportation. Changes in the attributes of the property affect the net income for the business, and will be reflected (discounted) in changed property values.

> Income-producing assets, such as land, contribute to the stream of cash flows for a business. The value of the asset is determined as the discounted present value of the future cash flows according to this formula:
>
> $$P = \sum Fi/(1+r)^n$$
>
> This formula states that the value of the asset is the sum of future values (*Fi*), discounted by an interest rate factor (*r*) over *n* years. This basic relation between future income and the present value of the asset applies to land, businesses, and stocks — and, in fact, to any asset that contributes to income flows.

Residential land values reflect the role of the property (plus the house) to generate a stream of future utility values for the owner-resident. Location to various services (e.g., schools, employment, shopping), the nature of the property, and other factors all contribute to the "enjoyment" of the property, as experienced by the landowner, in what economists call the "hedonic" model of property valuation.

2.2 The hedonic model of residential land value determination

The hedonic model hypothesizes that buyers and sellers view the sales value of a residence as the result of the bundle of attributes that comprise the property. The most important determinants include location features (distance to schools, work, and shopping), property features (landscaping and size), and house features (number of rooms, existence of a finished basement, level of interior finish, etc.). Two common views are that the individual attributes add to produce value, or they interact and produce value together in a multiplicative model.

Attributes may contribute positively to value (proximity to shopping and work) or negatively (proximity to sources of noise and pollution). Unlike land used as a production input, where the value is the result of an accounting exercise, value for residential properties results both from objective factors, such as distance to important destinations (shopping and school) that translate into time costs, and subjective factors, such as view, landscaping, and house attributes.

Multivariate regression models estimate the marginal contribution of each attribute; in this way, it is possible to measure the relative importance of the distance to the transmission line as a factor in determining the market value of the property.

2.3 Efficient land markets

In an efficient market, all participants are fully informed about the products being transacted, and changes in price and product attributes are communicated quickly to all participants. Stock markets are the common example of highly efficient markets, but land markets are also efficient. Changes in attributes, such as opening a new road, will often see an appreciation in prices as buyers increase their willingness to pay for land that now involves lower commute times. Multiple listing services, the real estate brokerage industry, and a range of publications (real estate news) all work to increase the information flows in the land market.

Changes in the property attributes are quickly translated into price, which is a sensitive barometer of changes on the urban landscape. Negative changes, like the placement of a noisy bar close to a residence, will be discounted into the residence's price, and owners may incur a capital loss. A beneficial amenity may result in a capital appreciation for the owner. Typically, the effects on land prices weaken as distance from the attribute source increases.

The purpose of this research is to measure the relationship between the value of urban residential properties and their proximity to HVTLs. Residential development that occurs after the construction of the HVTLs will reflect any negative association of the towers and lines in the sales price of the property. Buyers would therefore pay a reduced price, if they collectively believe such a discount is warranted. If a single buyer sees no issue with the line, they would simply bid the market value as if the line did not exist. Developers/builders may also attempt to mitigate the effect of any assumed negative HVTLs effects. They factor these effects into the sales prices and into their calculation of the business case for building close to HVTLs.

In contrast, negative or positive attributes that occur *after* the residences have been constructed and sold may create a capital loss for owners. In North America, the instances where new HVTLs are routed close or through residential areas after urban development are comparatively rare.

2.4 Review of the literature

PRA conducted a systematic review of existing studies that examine the effect of transmission lines on property values. By identifying the state-of-the-art in econometric modelling of the relationship between HVTLs and residential land values, this review also provides context for the statistical analyses PRA conducted. Appendix A presents a systemic review of the literature and Volume 2 presents copies of most of the articles cited in the review.

The main findings from the review are as follows:

1. Properties used as an input to the production process, and with little prospect for conversion to any other use, may experience a reduction to net income due to an HVTL. Revenues may decrease and/or costs of production may increase, because the line impedes business operations. To reiterate, an HVTL is not the local distribution line needed to supply power to the business. Buyers and sellers in agricultural, industrial, and commercial markets are typically well informed of these associations; in this setting, the value of a property is closely related to changes in the net income stream, which will be discounted into the value of the property. Since these properties tend to sell infrequently, insufficient data exist to support statistical modelling. For this reason, few studies on the impact of HVTLs on business property values and/or net income exist.

2. Most of the qualitative research (opinion surveys and expert interviews) finds that both homeowners and assessors perceive negative effects of HVTLs. The early studies tended to focus on health hazards caused by electromagnetic fields (EMFs), but more recently research has shifted to the aesthetics of how HVTLs disrupt the visual field. When surveyed, real estate professionals tend to assess the impacts of HVTLs more negatively than homeowners/residents do.

3. The opinion survey-based studies have recently shifted to reframe the question, not as a method of measuring the impact of lines and towers on sales values, but of testing whether homeowners demonstrate a willingness to pay (WTP) to have existing lines removed or modified. A high willingness to pay to remove or modify lines suggests a perceived negative effect of these lines on property value. These recent studies are arcane and lack salience, since the hypothetical option of removing an HVTL is usually unrealistic. In most cases, homeowners would not find it credible that they could offer enough to bury or modify the location of a high-voltage system. However, the WTP to have a local distribution line buried is a more realistic proposition and there is literature on the WTP to have local distribution lines buried in older neighbourhoods. Most modern residential development in North America has buried its distribution lines for the past three decades and so this applies only to older neighbourhoods.

4. Assessment-based procedures that pair properties that abut an HVTL right-of-way with similar properties some distance removed find small negative impacts on property values. Such studies are methodologically weaker and less credible than statistical analysis for two reasons. First, considerable judgement goes into creating the property pairs, and second, samples tend to be small and therefore weaken any statistical test.

5. Statistical analyses of the HVTL association with on property values are more useful than qualitative studies, since they support a precise dollar value impact of structures and lines on property values. The results of the studies we reviewed are mixed. This research spans a period from the early seventies to the present. Some find quite large negative impacts on property values that abut HVTL rights-of-way. This effect declines rapidly with distance. Most research typically finds declines of 5–10% in value within 50 metres, but negligible effect once the property is more than 150 metres away. However, other equally sophisticated studies find little or no relationship.

6. The definition of distance to the line/tower is crucial. Early studies used the inverse of linear distance to the line and/or linear distance to the nearest tower structure (pylon). More recent studies create elaborate distance definitions based on whether the property abuts the line or whether a visual sightline to the tower from the most used rooms in the home exists.

7. While statistical studies are not conclusive, it is important that any current study carefully defines distance to the line in a variety of ways and uses state-of-the-art statistical testing. The literature review's Annex A (Appendix B to this report) discusses what constitutes good econometric practice in this area.

8. The following three methodological points are important:

   i. Most of the statistical studies are retrospective. Residential subdivisions generally emerged *after* the lines were constructed. Few studies measure the impact of HVTLs constructed after residential development has occurred. In the typical situation where lines existed prior to residential development, owners whose properties are close to a line rarely suffer a loss in property value; it is more likely that they paid a discounted (lower) price for that parcel. The developer may have adjusted the lot size and house orientation to compensate. If properties adjacent to the line are 3% lower in value, the purchaser would likely experience a discount on the price for their property. No "loss" occurs, since the purchaser freely assesses the price and the amenities offered by each particular property. Only owners of property at the time a new right-of-way and line are announced and prior to any development could possibly experience a loss in the value of their land.[1]

      We found no North American studies in which a high-voltage line was constructed close to established residential areas after residential development was completed.

      In Section 4.0, we examine the impact of an HVTL incremental addition to an already existing right-of-way, with two existing HVTLs in place.

[1] Purchasers of property close to existing HVTLs pay prices with full knowledge of the presence of the line. Only if they misjudge the impact of the line on their enjoyment of the property, would their valuation fall. But when they try to sell the house, all potential buyers would need to agree that the house was actually worth even less than the 3% discount.

ii. The variability in results across studies reflects two factors. First, methods are becoming more technically complex; researchers are using different specifications for the models and defining key variables, such as distance, in different ways. Second, the studies are situationally specific, and it is impossible to find a common set of independent variables across the sites used for these data. Regional variation in residential development, the many omitted variables that capture the unique features of a particular town/city, and the varying time frames of the study all impede general conclusions.

iii. Ideally, statistical methodologies should measure positive influences on the effects of HVTLs on land values if they occur. In principle, the rights-of-way can create a buffer between properties for which buyers may be prepared to pay a premium. Once vegetation has reduced the visual impact of the lines, buyers may see less intrusion. They may value the open space created by the line, especially if other uses, such as gardening and walking/cycling paths, are permitted. However, the data demands to measure this statistically are often onerous; too few sales have occurred in recent years when alternate uses have been developed and vegetation has matured. The literature appears not to address this issue; however, we do illustrate the potential for these positive influences using photographs of the lines associated with the residential areas included in this study.

9. Several of the qualitative and quantitative studies allude to rural-recreational-residential properties that are emerging as important uses of land. As cities grow and regional roads create access to agricultural land or woodlands not used for residences, their attraction as "accessible wilderness" grows. Some owners of these properties may place a high value on preserving the undeveloped state of their properties and will oppose any change to the landscape. On the other hand, other owners may be awaiting the right time to subdivide. While some studies suggest a negative association, the samples for these studies are very small and unreliable. We identified no valid statistical analysis of how HVTLs affect these types of properties.

10. The most important conclusion from the literature review is that the relationship between HVTLs and residential property values is situationally specific. It is difficult to develop a general rule about the extent of HVTL impacts on residential property values; they are contingent on a host of site-specific variables. There may be a negative correlation between proximity to the line and property values, but since the HVTLs have almost always been constructed before residential development, any property value reduction would reflect a buyer that had accepted the price and for whom the HVTL trade-off had been acceptable.

3.0 Methodology

Assessing the association between transmission lines and residential property values used the following steps:

1. selection of residential areas suitable for analysis
2. data extraction and processing
3. statistical estimation of relationships

We did not complete a paired property analysis, since as determined by the review of the literature, we concluded this technique is methodologically weak and produces unreliable results.

3.1 Selection of lines and properties

One of the important challenges facing studies of HVTL correlations and land values is the dependence on assessment data from municipalities, counties, states, and provinces. The information contained in the assessment studies typically defines the scope of analysis.

In this study, the initial focus was on urban properties within the City of Winnipeg, and residential subdivisions within a one-hour drive. PRA initially identified 10 subdivisions that qualified as urban developments with HVTLs traversing or running parallel to the "boundaries" of the subdivision. Seven of the candidate subdivisions are within the perimeter of the City of Winnipeg. Discussions with the City of Winnipeg Assessment Office revealed that, at the time of the intended data request (December 2014), a major information technology upgrade was concluding and that any data request would require some months to complete. On the other hand, data from the provincial assessor (outside the city limits of Winnipeg) were readily available; therefore, we elected to focus on the remaining three qualifying urban areas in Selkirk, Oakbank, and East St. Paul.

PRA selected a subsection of "homogeneous and contiguous" residential properties within each of these areas, comprising a swath of properties lying approximately within 500 metres of a nearby Manitoba Hydro HVTL. The literature regarding the association of transmission lines on property values suggests that if any relationship with property value exists, it is typically detectable within 200 metres of the line. By selecting residential properties lying within a defined residential subdivision, we reduce the variability introduced by different land uses, housing styles and quality, and property features. Since the data are defined by the contents of the assessment roll, controlling such variability improves the precision of the statistical modelling.

Figure 1 to Figure 6 below provide a street- and satellite-level view of the boundaries of properties selected for analysis in the three regions, along with the locations of the nearby Manitoba Hydro transmission line(s).

Figure 1: East St. Paul region Phase 3 properties

UTM XY coordinates: (640266.60, 5538840.66), zone 14 *Latitude/longitude coordinates*: (49.831952, -97.119559)

Figure 2: East St. Paul region Phase 3 properties (satellite view)

UTM XY coordinates: (640266.60, 5538840.66), zone 14 Latitude/longitude coordinates: (49.831952, -97.119559)

Figure 3: Oakbank region Phase 3 properties

UTM XY coordinates: (656771.90, 5533879.93), zone 14 *Latitude/longitude coordinates*: (49.936692, -96.815274)

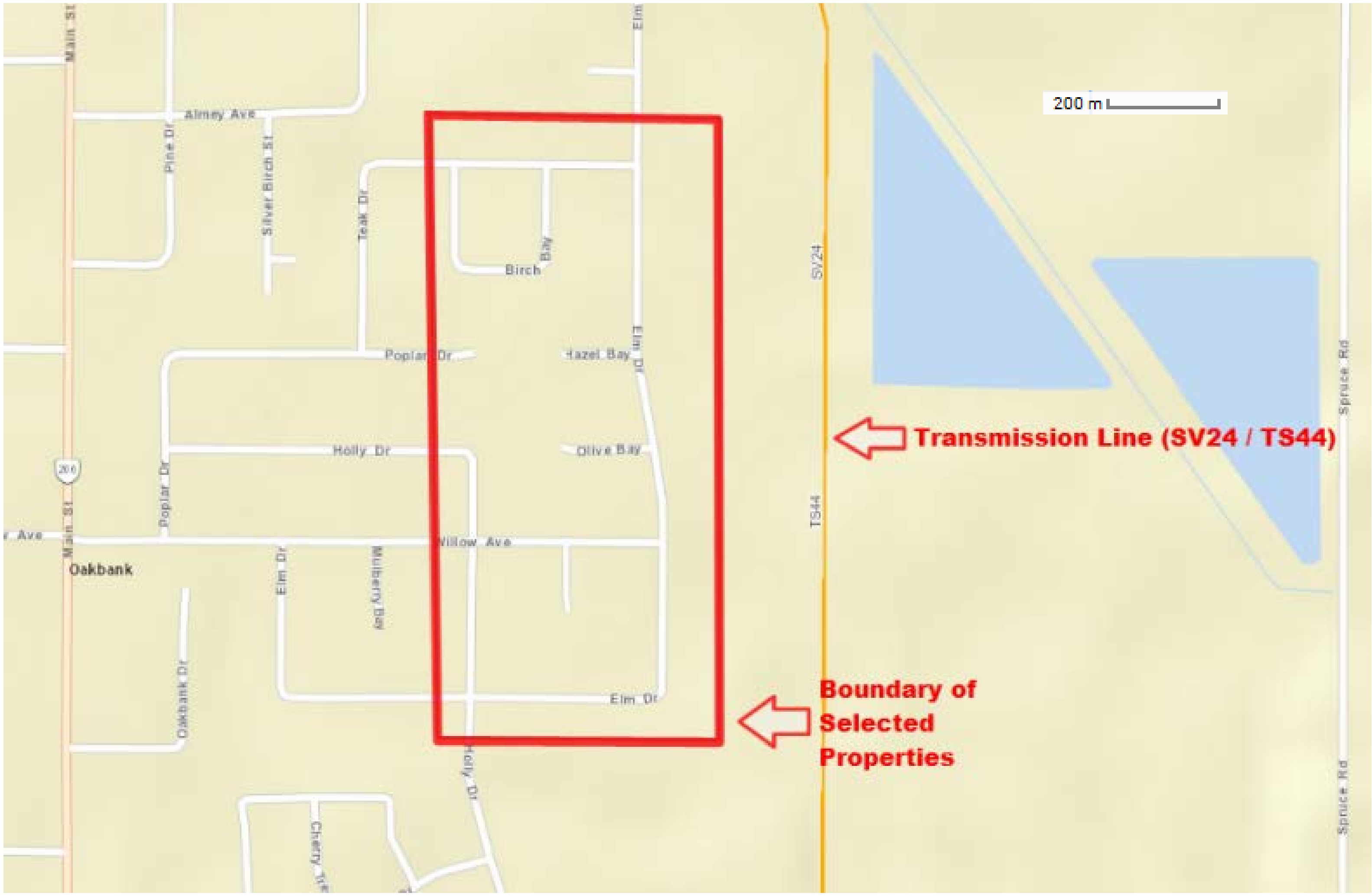


Figure 4: Oakbank region Phase 3 properties (satellite view)

UTM XY coordinates: (656771.90, 5533879.93), zone 14 *Latitude/longitude coordinates*: (49.936692, -96.815274)

Figure 5: Selkirk region Phase 3 properties

UTM XY coordinates: (651566.44, 5555488.42), zone 14 *Latitude/longitude coordinates*: (50.132249, -96.879222)

Figure 6: Selkirk region Phase 3 properties (satellite view)

UTM XY coordinates: (651566.44, 5555488.42), zone 14 *Latitude/longitude coordinates*: (50.132249, -96.879222)

Based on the literature review, the properties abutting the transmission line right-of-way would be expected to experience larger value changes compared to properties buffered by other residences.

Table 1 below describes the year of construction for each of the transmission lines. With the exception of the D72V transmission line in East St. Paul, all of the lines in the three regions were constructed well before the period of analysis of property sales (1985–2014). The D72V line is the closest to the selected properties of the three parallel lines in the East St. Paul region and distance measurements were adjusted accordingly for properties, depending on whether their year of sale occurred before or after the construction of this line.

The D72V line was constructed after the development of the adjoining residential area. It is incremental to two pre-existing lines in the right-of-way (R23R and D602F/D603M) and therefore allows us to perform a natural experiment on the impact on property values of an incremental line within the existing right-of-way adjacent to East St. Paul.

Table 1: Date of construction for Phase 3 transmission lines

Region	Line name	Line voltage	Year constructed
East St. Paul	D72V	230kV	2002
	R23R	230kV	1971
	D602F/D603M	500kV	1980
Oakbank	SV24/TS44	115kV	1960
Selkirk	SM26/SC25	115kV	1927

Notice that the properties closest to the lines in East St. Paul also lie close to a rail line. The three HVTLs exist on a Manitoba Hydro right-of-way that has been established for over four decades.

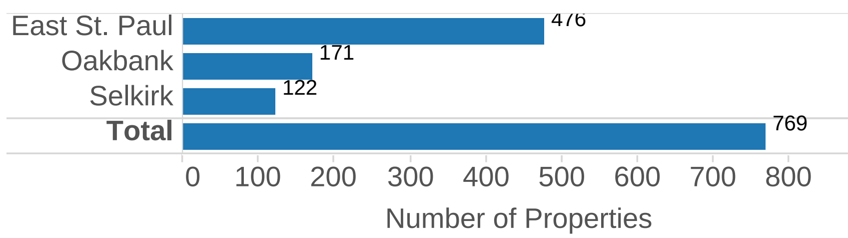
4.0 Findings

The three subdivisions are typical exurban developments, also known as "bedroom communities," where typically at least one household member commutes to Winnipeg for work.

4.1 Overview of properties in the three regions

The property characteristics data includes 813 properties in total across the three regions. The manual calculation of distance between the properties and the towers resulted in 28 properties being excluded, including schools, pathways, boulevards, fields, commercial buildings, and some properties outside of the specified region. There were also 16 properties that were described in the data but were not visible on satellite or parcel maps, as they are brand-new. As a result, there is a final sample of 769 properties included in the analysis.

Figure 7: Number of properties selected by region



As mentioned in Section 3.1, the literature indicates that a decline in value resulting from proximity of the property to transmission lines tend to occur within 200 metres, if a decline is observable at all. As a result, the analysis defines properties both within and beyond 200 metres to support a stronger comparison of effects. As indicated in Figure 8, the data include a wide spectrum of distances to transmission lines. Overall, the Selkirk properties were substantially closer to the lines than the other two regions, as a smaller number of properties were selected and the line crosses through the centre of the selected boundary, reducing the distance to the line (see Figure 6).

Figure 8: Average distance between properties and the nearest transmission towers (in metres)

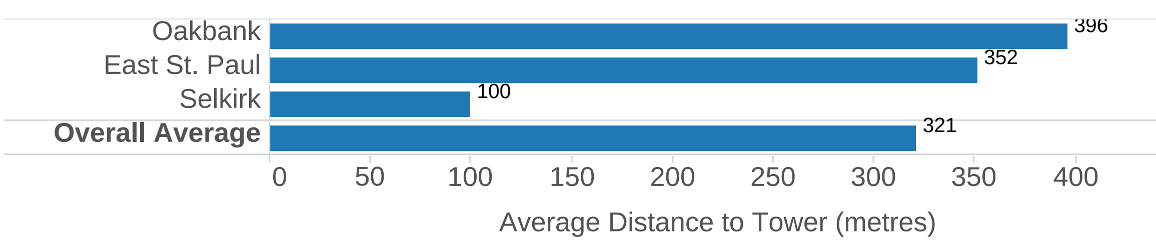
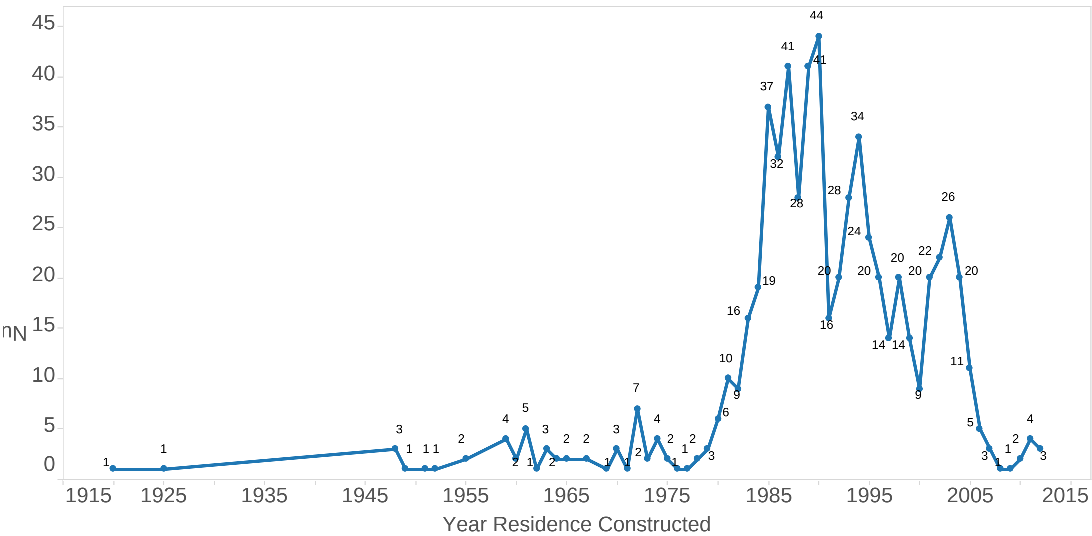


Figure 9 shows most of the properties were constructed between 1980 and 2000, with a large spike around 1990. Note that the data occasionally do not include information on the principal residence. As a result, this graph does not include all of the properties described above.

Figure 9: Year residence was constructed



The sales data provided include property sales from 1984 to 2014. In total, there are 1,312 sales corresponding to 660 unique properties within the three regions. Sales value is specified in the data by two variables: “consideration” (the amount of money changing hands) and “sworn value” (an estimate of the price in a competitive and open market). Since consideration and sworn value may not represent a true arms-length transaction (particularly if the two variables differ for a given sale), our econometric analysis defined the market value as sales where the consideration value is equal to the sworn value. We dropped the 255 sales observations where that did not occur. Figure 10 shows the number of sales by year, illustrating a consistent volume of sales across the time period (with the exception of a large number of sales in the East St. Paul region in the late 1980s).

Figure 10: Number of property sales by year and region

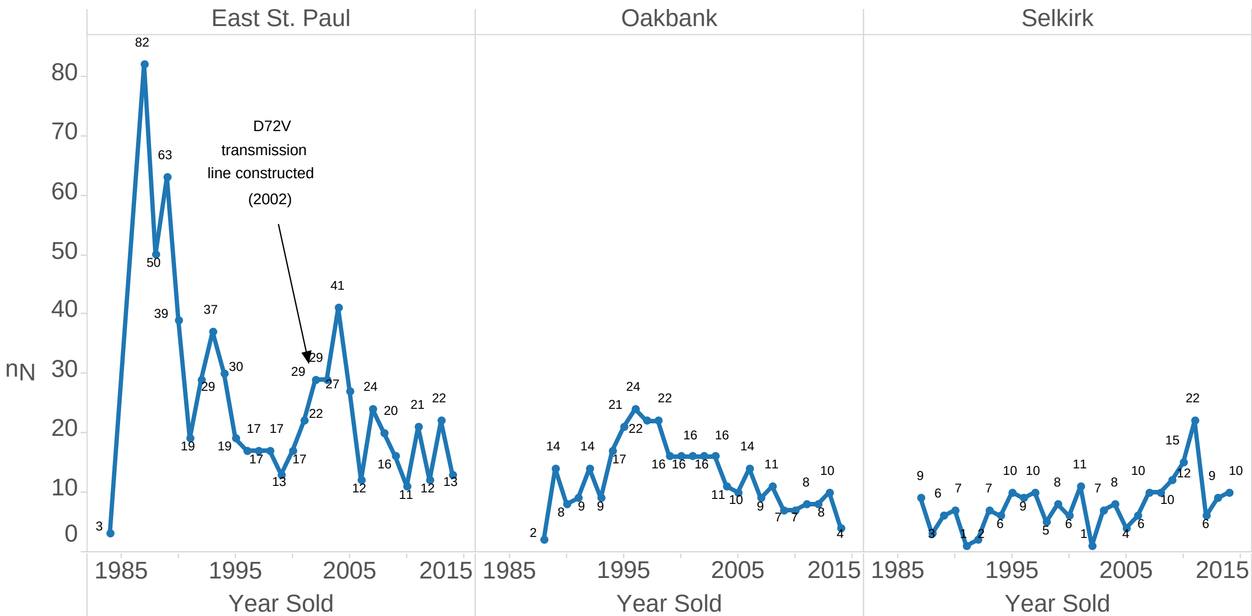
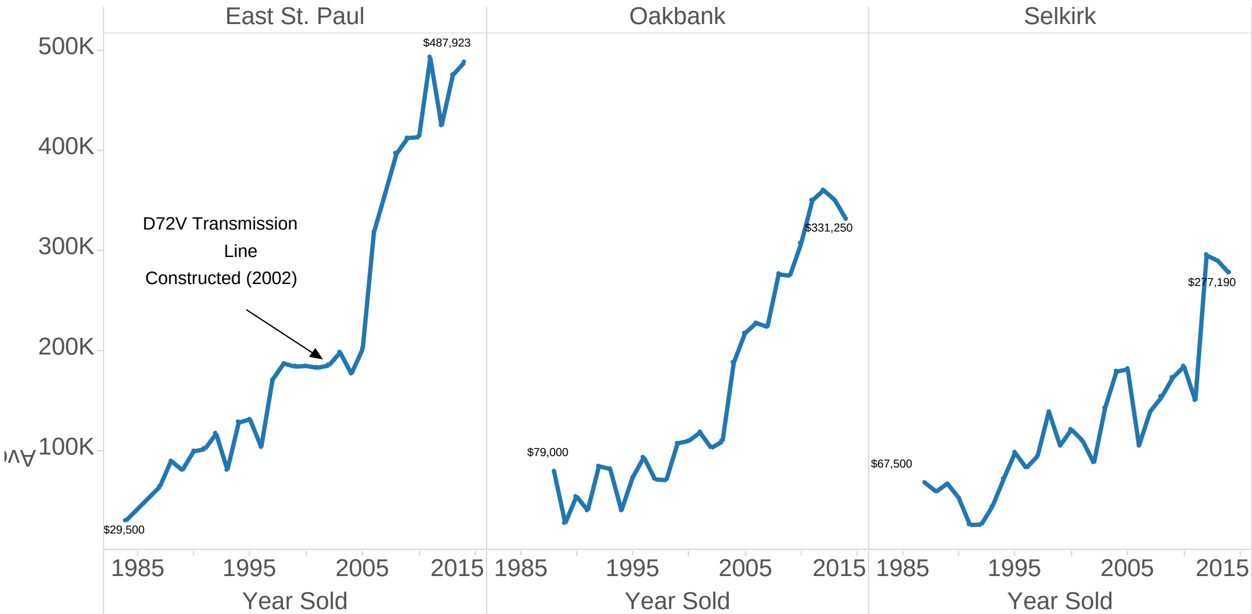


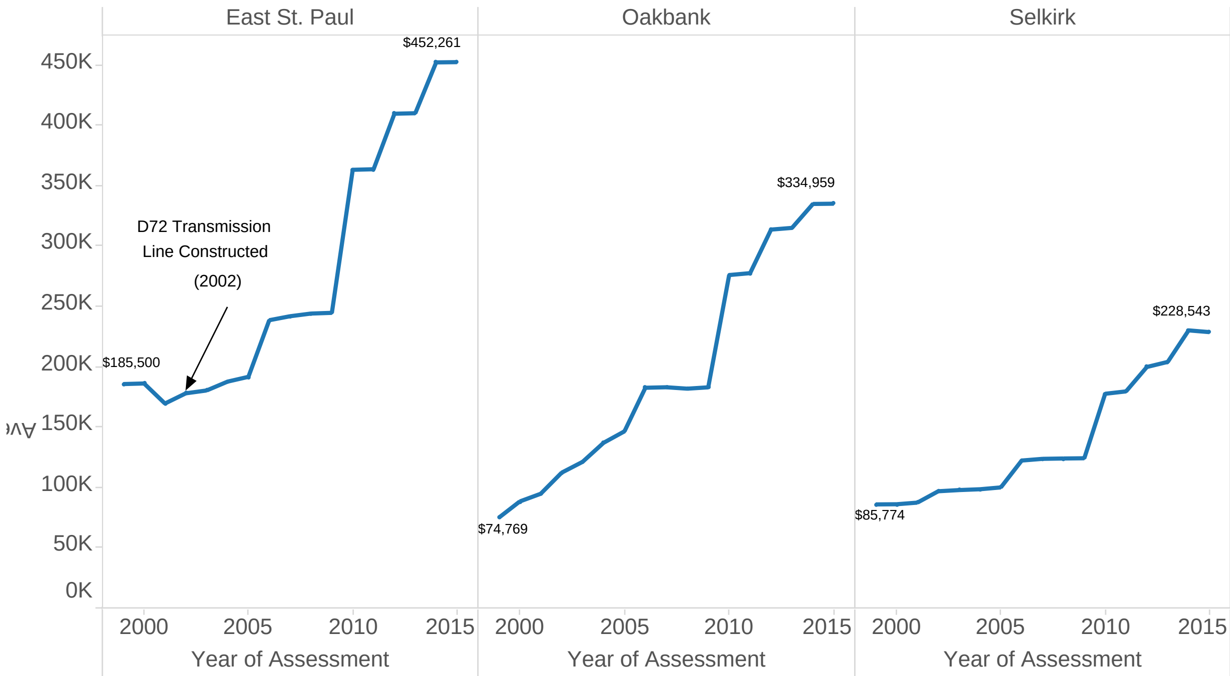
Figure 11 illustrates the trend of the property sales value over time for each of the three regions, showing a clear upward trend in sales value across all regions from 1987 to 2012. This underlines the importance of including a time trend variable in the regression model to account for price growth over time.

Figure 11: Average sale price by year and region



The assessment data provide assessed value over the period from 1999 to 2015. Figure 12 presents the average assessed value for properties over this time, illustrating a similar pattern to actual sale values described in Figure 11. By law, assessments must reflect market value. Calibration of assessed value to market value occurs every two years; previous to a change initiated in 2010, this calibration took place every four years. We used sales value as the measure of market value, since these tend to offer a more sensitive measure of market value than assessed value, as a comparison of Figure 11 and Figure 12 shows.

Figure 12: Average assessed value by year and region



4.2 The relationship between proximity to HVTLs and property values

We completed extensive econometric testing using both sales and assessed values as the dependent variables. Because changes in assessed values tend to lag changes in sales values, the models reported are for sales values only. A detailed discussion of econometric modelling, data management, and caveats appears in Appendix B. This section presents a synopsis of the findings.

The statistical measurement of the relationship between HVTLs typically uses a regression, which is a form of correlation between a dependent variable (the sales value of the property) and a set of independent or explanatory variables believed to affect sales values positively or negatively. It is important to stress that a regression model does not presume a causal relationship; it is unfortunate that the standard practice is the designation of a single variable as dependent on a set of other independent variables, which are said to explain the variation in the dependent variables. This terminology encourages the false idea that the HVTLs have caused a reduction in sales values. Since, in most cases, the lines pre-date residential development, any reduction in sales price would be enjoyed by the first-time buyers who presumably made a choice to accept the HVTLs in exchange for the lower price. Subsequent purchasers may continue to enjoy a price reduction, but as we show below, the transmission line right-of-way may evolve as a community benefit.

The regression models relied on data from the Manitoba Department of Municipal Government. These data include sales values, as well as property attributes. In addition, we calculated four distance measures from the centre of the property to the line. Table 2 shows the information used in the econometric models. Note that additional variables are available in the assessment data provided, but were not used because of missing/duplicated information. The data available from the provincial government do not include attributes that are available in some of the research we reviewed. Examples of variables not available to this research include the number of bedrooms, the number of bathrooms, and the developed area of the home.

Table 2: Names and descriptions of variables used in the Phase 3 econometric analysis

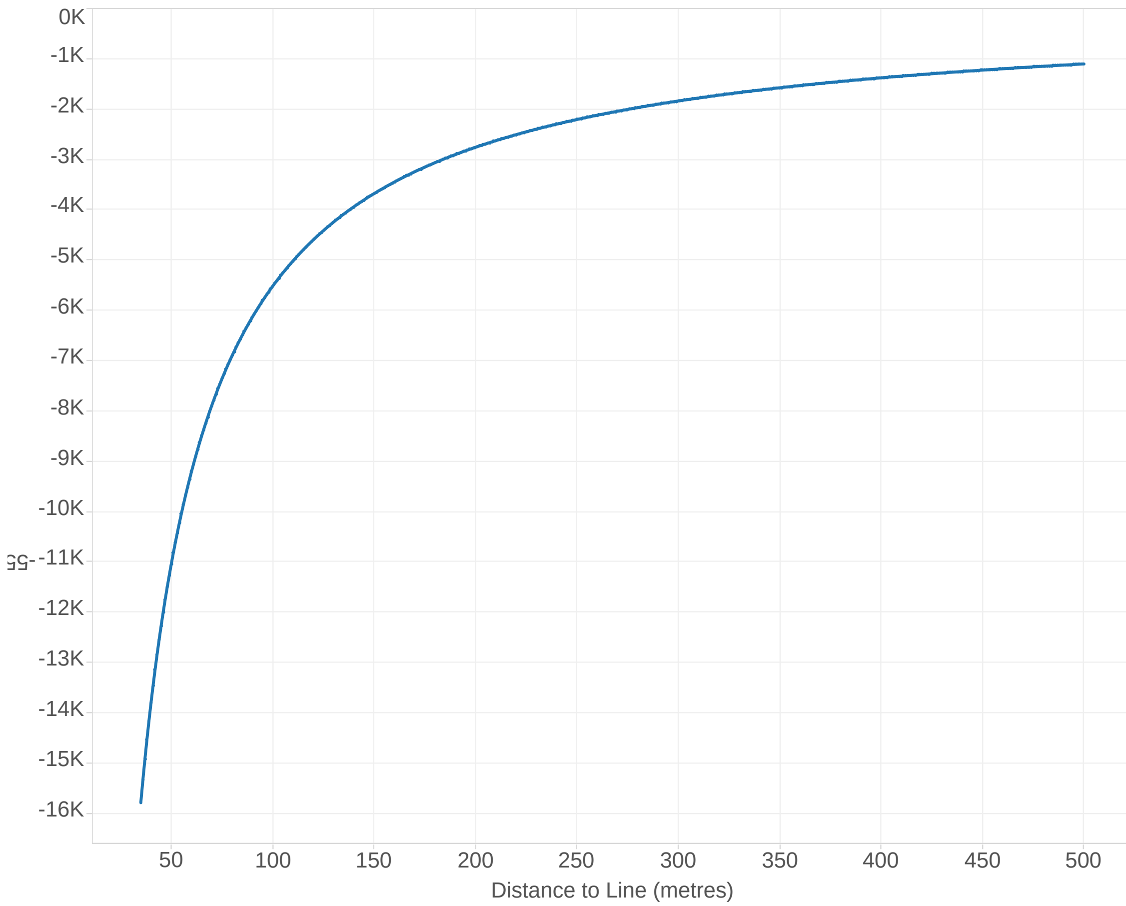
Variable	Description (as needed)
Dependent variables	
Sworn value of a property sale	Sale value of the property (dependent variable)
Independent variables	
Attached garage	Indicator for attached garage
Detached garage	Indicator for detached garage
Addition over garage	Indicators of an addition over garage (detached)
House below avg. quality	Indicator of house condition
House avg. quality	Indicator of house condition
House above avg. quality	Indicator of house condition
Number of floors of principal residence	
Above/in-ground pool	Indicators of a pool (above or below ground) (0=no; 1=yes)
Age of the principal residence	
Number of buildings	
Buildings area	
Lot size	
Addition with basement	Indicator for addition plus basement
Verandah	Indicator for verandah
Region (East St. Paul)	Indicator for East St. Paul properties
Region (Oakbank)	Indicator for Oakbank properties
Year sold	Year sold scaled so that 1985=1
Distance to HVTL measures	
Distance to line	The distance, in metres, from the centre of the principal residence on the property to the nearest transmission line
Inverse distance	1/Distance to the line
Distance to tower	The distance, in metres, from the centre of the principal residence on the property to the nearest transmission tower
Abuts the property	Indicator for whether the property abuts the line

The econometric model's returned values are entirely consistent with the research studies we reviewed. The most important findings are the effect of proximity to the line. The models we tested found HVTLs had a small negative impact on the sales values of properties. Most of the models showed statistically insignificant impacts, which means that the effects are essentially zero. Where models revealed a statistically significant impact, the effects were minor in the context of all the factors that influence property values. Further they decrease rapidly as the distance to the transmission line/tower increases. Figure 13 presents the relationship between distance and the impact on sale price. The closest homes are 36 metres from the line, but this is unusual. Most homes that are adjacent to the right-of-way are beyond 50 metres from the line. This suggests a price discount of about $11,000 or less for such homes. For example, the median distance from the line in Oakbank and East St. Paul is in excess of 350 metres, which implies that the lines have a negligible impact on home values. The median distance in Selkirk is 100 metres, which would equate to a discount of about $5,000. Since the average sales value of properties included over the study period was $163,934, a rough estimate of the percentage decrease in price for properties 100 metres away from the transmission lines is approximately 3% of the average selling price.

For properties abutting the line, the separation is clearly smaller. In Selkirk, the median distance for abutting properties is 51 metres, which represents about $12,000 in value; however, in Oakbank, abutting properties are a median distance of 230 metres, which represents little discount in value.

Some caution is needed when interpreting this relationship, since the regression coefficient used for the calculation is not statistically significant. Therefore, Figure 13 is a broadly indicative measure and not conclusive. It certainly aligns with the literature that shows that any effect becomes negligible more than 100–150 metres away from the line.[1]

Figure 13: Distance and sales price discount



[1] Distance to line means the distance to the line as viewed above from Google maps (not the ROW). In the case of St. Paul where there are multiple lines, we used the distance to the nearest line.

In 2002, line D202V was added to a Manitoba Hydro right-of-way, with two pre-existing lines and a pre-existing rail line. This offers an excellent opportunity to conduct a natural experiment, to assess the impact of this incremental HVTL on sales values. It is a natural experiment in that we are dealing with essentially the same pool of homes before and after the line construction.

This experiment used only East St. Paul data. Initially, we recorded the sales for each property prior to 2002 and after 2002 that were closest to the construction date. This resulted in a dataset that included sales much before 2002 and much after, so the analysis focussed on a narrower span of 1998–2006. Using a t-test (the average values before and after 2002, with sample sizes of 68 and 115 respectively) showed no statistically significant difference in prices. Tightening the range to span 2000–2004 reduced the sample (38 and 91 respectively), but it still failed to show a statistically significant difference in average sales price before and after the construction on the lines.

Therefore, we conclude that the addition of another line within an existing right-of-way had no measureable impact on the sales value of homes in East St. Paul.

4.3 Hydro rights-of-way as a positive effect in property values

Recent literature (in Appendix B) suggests that a transmission line right-of-way may offer a benefit to a community, especially for homes immediately adjacent. This is most apparent in Selkirk, where the right-of-way appears associated with green space and considerable separation at the rear of the abutting properties. Some photos illustrate the potential for the transmission corridor to add benefits.

Figure 14: Park and night lighting at the entrance to the Selkirk right-of-way

Note the lighting and the two sets of playground equipment.

Figure 15: Oakbank playground (line in the background on the horizon)

Figure 16: Entrance to the walking trail in the East St. Paul transmission line right-of-way

These photos illustrate how transmission line rights-of-way can be developed into green space and parks. One important advantage for homeowners living adjacent to these lines is that no further residential development will occur too near the property on the side exposed to the right-of -way. In effect, the line creates a separation of a few hundred metres to their closest neighbour at that side.

5.0 Conclusions

A key conclusion taken from the literature review is that the property value decline associated with proximity to HVTLs is situationally specific. It is difficult to develop a general rule about the extent of value reduction associated with proximity to transmission lines, since these relationships are contingent on a host of site-specific variables.

The 30 years of studies we reviewed show a wide variation in this value adjustment, depending on context, the data available, and the specific statistical methodology. However, the more qualitatively robust studies (in the sense of having sufficient data and well-designed statistical tests) show that proximity to an HVTL is typically associated with a 5–10% reduction in property values for lots immediately abutting the right-of-way. This land value discount usually declines rapidly and properties in excess of 300 metres usually show no value reduction.

The literature also suggests that the value reduction declines over time, as the rights-of-way become developed and as the landscaping on new properties matures. Also, because rights-of-way for HVTLs are wide, homeowners whose properties about the lines may enjoy increased privacy from neighbours to one side. This creates property features that can counteract, and in some cases reverse, any value decline associated by proximity to the line.

The regression analysis used sales transactions after 1985. Our findings align with the literature and we found similar value reductions. We also tested the impact of adding an additional line to the existing two lines that run along the boundary of East St. Paul. In this case, since the addition occurred after the construction of the residences, we are able to conduct a "natural experiment" and fairly assess any value change as an impact of the new line. We found no statistically significant negative impacts of the additional line on property values.

Finally, we analyzed the current use of the three rights-of-way close to the three study regions. It is apparent that these areas are being used as greenspace, walking trails, gardens, and playgrounds. Over time, the land under the HVTL becomes a positive factor that homeowners value and a positive force on sales prices.

Since the findings of this research align closely with other studies, we believe that the same relationships between proximity to HVTLs and property values hold in other established urban residential areas of Manitoba and that these relationships behave in a similar way. However, it is invalid to impute these to non-residential land uses or residential land uses that feature multi-family units and condominium developments. It is also incorrect to transfer the observation of a 3% reduction in values of residential properties that are close to HVTLs in the three subdivisions studied here to larger acreage, farm, or rural properties that lie well outside the perimeter of Winnipeg.

These results must not be applied to larger rural residential properties that lie along any proposed HVTL. It is invalid to conclude that any or all of these larger properties will experience a 3% reduction in future sales value by virtue of the new line. Any claim for compensation would be unique to each property, and must include the situation of the residence on the property, the existence of trees, and other topographical factors. No statistical studies of how HVTLs have affected such larger residential properties exist. This is for three reasons. First, the property assessment data prepared by Manitoba Assessment do not include the range of amenity factors (e.g., the view, existence of ponds, wildlife) that affect price. This precludes statistical analysis. Second, unlike the residential properties included in the three subdivisions, the variation in properties is very high. Third, the number of properties is small with few transactions; this, more than anything, has limited statistical analysis of how HVTLs affect land values of rural residential properties.

With the construction of additional HVTLs, such as Bipole III, an opportunity exists to develop property value data that pre-date the announcement of the routes. This would support more definitive pre-post research on the relationship between the construction of HVTLs and changes in property values.

Appendix A – The relationship between high-voltage transmission lines and property values:
A systematic review of the literature

1.0 Introduction to the literature review

This report serves as a background to the Phase 3 econometric analysis of the impact of Manitoba Hydro's transmission lines on three exurban residential developments: Selkirk, East St. Paul, and Oakbank. The review presents the evolving state-of-the-art in measuring the impact of high-voltage transmission lines (HVTLs) on property values and offers context for both the method and results.

This review has the following two sections:

1. It begins with a brief theoretical background on the determinants of property values in four land use contexts — agricultural, urban residential, exurban residential, and rural-recreational-residential (RRR). Establishing the key theoretical arguments about land value impacts in these three situations provides important context for understanding the methods used and interpreting results in the literature. Two central themes emerge: how land values are derived from a stream of financial and non-financial benefits; and how external factors or "disturbances," such as HVTLs, affect that stream of benefits, and therefore the value of land. Finally, this section also discusses the concept of an efficient market.

2. Next, we briefly review the methodologies that have been used to measure the incremental contribution of each attribute and the changes in benefits resulting from external factors or disturbances. Finally, we summarize the literature that has attempted to measure how high-voltage overhead transmission lines influence property values.

Copies of the literature cited are bound separately for reference and convenience.

2.0 Conceptual foundations of the determinants of property values

2.1 Value as the present value of future net benefits

Value results from the interaction of buyers and sellers, whose perceptions about how a specific property will fulfill needs create demand and supply. Land has value to an owner, based on the stream of benefits it yields, and in turn these depend on the attributes of a specific property. In agriculture, producers combine land with other inputs to yield annual revenues, and once costs are deducted, the sum of discounted net revenues becomes the foundation for the value of any given property.

Land used for agricultural, commercial, industrial, or residential rental derives value primarily from the future net revenues generated by the property and structures. Land that supports a revenue stream is usually easy to value for both buyer and seller, provided both parties understand and agree on the net revenue stream. Any change to the context in which the land is used or situated has the potential to alter its value, largely through the changes in net revenue as perceived by potential buyers and sellers.

Challenges emerge when land supports non-commercial activity, primarily land used for residential and recreational purposes. In these instances, the land becomes valued for a stream of services — economic, social, health, and psychological — as reflected in the amenities of the property. Economic benefits accrue to residential land owners through the proximity to services (schools, employment, retail, etc.), since being close to these services reduces time and travel costs. Social benefits include neighbourhood and communal effects arising from being situated with compatible co-residents. Health amenities include the absence of noise and pollution, while psychological benefits arise from the first three dimensions, but also include intangibles such as scenic views, privacy, and quiet.

2.1 Land value determination and efficient markets

Positive influences on land values include general economic growth, investments made by neighbours, and investments by the public sector. To take a specific example, an important impetus to the development of prairie agriculture was rural electrification that extended refrigeration to farms. The rural electrical system, as well as the construction of rural road systems, supported the development of agriculture and led to a general increase in agricultural land values over the past 100 years. In the last 10 years, the increased demand for grains and oilseeds has prompted a rapid appreciation in agricultural land values.

In general, population growth, agricultural price increases, increased farm efficiency, regional/urban growth, regional/urban investments in roads and other infrastructure, and finally, in the last decade, a low interest rate macro-economic policy have all supported rapid growth in rural (agricultural) and urban land values. This general and sustained land value appreciation presents an important barrier to the detection of specific disturbances to land values, such as HVTLs.

Negative influences on general land values include macro variable changes, such as interest rate increases and recession. In agricultural land, commodity price weakness or input cost inflation (energy prices) can compromise farm profitability, leading to value declines.

Land values are the expression of the collective opinion of buyers and sellers on the attributes of a specific property. When one says that agricultural land values are rising, this means that the collective impact of all property transactions reflects an increase in sales values on average. The sales value of any specific property reflects general (macro or economy wide) factors and micro influences reflecting the context of that particular parcel of land. Rapid land value increases usually reflect accelerating demand due to fundamental factors such as agricultural prices supporting increased farm revenues. This can feed speculative booms, especially in eras of very low interest rates.

An efficient market exists when buyers and sellers are fully informed about the goods and services being transacted and no impediment exists for any willing and qualified agency to participate in the transactions. Market efficiency implies that any change to a product or service, is instantly communicated to and understood by all market participants, sellers, and buyers equally. Stock markets are typically cited as examples of efficient markets. A change in the "fundamentals" of a company will result in a change in the price of its stock. For example, a pharmaceutical company that receives approval for a new drug will generally experience an appreciation in its stock value as investors seek to purchase more equity to gain the anticipated stream of higher dividends.

At the individual property level, specific changes (disturbances) can either enhance or erode value. Most common is a change in abutting land use or taking property for public use through eminent domain. Usually these disturbances are property/neighborhood/region specific. Some changes, such as citing a noxious industrial or commercial land use near residential areas, can reduce value for a large area, although this impact usually declines with distance.

The impact of a disturbance on land value can be complex and change over time. For example, the decision to allow a noisy late night restaurant to open next to a residential development will usually adversely affect the value of abutting homes. But as distance increases, property values may rise as buyers may value proximity to the restaurant without the noise.

An efficient market will incorporate (discount) the impact of disturbances into the value of the property. The process is similar to the discounting process for stocks where new information adjusts the expectations of buyers and sellers; the speed of adjustment depends on the numbers or market participants and is often used as a measure of efficiency.

HVTLs, as a "disturbance" to land use, illustrate how property values may adjust to these structures. Before examining the empirical literature that attempts to measure the impact of HVTLs, it is useful to consider how these impacts may play out in the three main types of non-industrial/commercial land use: agricultural, urban residential, and exurban residential. A final category of land use exists in the form of RRR properties.

2.1.1 Agricultural land value determination

Agricultural land is an input to a production process. Property values reflect the discounted present value of future net income in much the same way that an apartment building's value derives from future net income (gross rent less cost). Discounting cumulates future net incomes using declining weights the further in the future the income will be realized; the weights depend primarily on interest rates — as interest rises net incomes lying in the future are presently worthless.

Soil type, local climate, drainage, and other land features are micro or property-specific factors that materially affect farm profitability. Landowners may influence some factors, such as constructing drainage, but others, such as climate and HVTLs running across or adjacent to the property, are beyond the landowner's control. Any disturbance that affects farm profitability will affect property values through the market value determination process.

Changes to these property-specific attributes will alter net cash flow and may result in a changed value, given three important assumptions. First, the agricultural land market must be efficient, which means that all buyers and sellers are fully informed about all salient features that influence net revenues. Second, no institutional constraints exist to transactions, in the sense of barriers to who may participate in the land market. Third, no compensation exists for disturbances, such as the construction of HVTLs.

The compensation issue is important for understanding the dynamics of land value adjustments. Imagine a new HVTL was introduced by crossing a portion of agricultural land. Imagine also that the existing landowner received payments that covered just any operating losses caused by the line, leaving net income unaffected. One option might be that compensation could come in annual payments that could be paid to any farmer/owner who owned and farmed the land. In this case, land values would not change, since net revenues had not been altered. Alternatively, if the compensation were a lump sum that reflected the discounted present value of the net revenue reduction triggered by the line, then the current owner would receive compensation for the loss of sales value from future sales. The future buyer would receive no compensation, since under the assumption of an efficient market they pay a reduced price for the land. The price reduction should exactly equal the discounted present value of the difference in net income with and without the line.

Where land is productive in the sense of supporting revenue, and assuming that the net revenue impact of a disturbance, such as a HVTL, can be accurately calculated, then prospective buyers will be able to adjust their bids if no compensation is paid. If adequate and accurate compensation is received by the owner, and it is seen as accurate, then no adjustment to the bid price is needed. If compensation is inadequate, then there will be a reduction in bid prices; if the compensation is more than the net revenue reduction, bid prices will rise, since in this case the HVTL will be seen as generating overly generous compensation and creating positive increment to land values.

The assumption of efficient markets is probably accurate for agricultural markets, where buyers and sellers can expertly assess the potential for any property to generate income. This assumption may be less defensible.

2.1.2 Urban residential land value determination

When land does not generate revenue, the collection of all attributes offers a stream of physical, social, and psychological benefits to the owner/resident. A HVTL is just one of many factors that will affect the stream of benefits.

The impact of disturbances, such as the siting of a new HVTL, cannot be measured directly, but must be inferred indirectly from the changes in property value. Under the assumption that the urban real estate market is efficient (all buyers and sellers are fully informed and no constraints exist to transactions), land value changes will accurately reflect how buyers and sellers view the impacts of the disturbance in the context of all attributes. No accounting calculations of net revenue are possible, but assuming enough buyers and sellers are active in the land market, the selling price reflects the consensus on the collective impact on the stream of benefits of all attributes, including the HVTL.

2.1.3 Exurban residential land value determination

As regional road systems develop, there is an increase in the numbers of homeowners who elect to purchase large acreages (at least two acres) upon which to construct homes. Such development is an extension of the post-war explosion in the suburbs, triggered by the development of interstate and interprovincial highways, as well as widespread access to cars. Exurban development is marked by the discrete subdivisions of several hundred homes within a defined neighbourhood structure, typically separated some distance from a town or city. Owners in such subdivisions pay for a country lifestyle, but also wish to have access to employment, retail, education, and social amenities afforded by the proximity to urban areas. The set of attributes that contribute to or detract from such “accessible lifestyle” determine the willingness to pay (WTP) for these properties. HVTLs may exert a negative impact on values to a certain extent, or they may have no discernible effect. In most cases, HVTLs detract from views and other scenic attributes. Some purchasers may also have health concerns associated with the existence and maintenance of the lines.

Properties directly abutting the HVTL right-of-way may be priced lower than those set back and insulated from the line. Landscaping and house orientation may effectively mask an HVTL from a property that is close to it, in contrast to another property further away from it, but with an uninterrupted sightline. The measurement challenge is that many attributes interact to mitigate or reinforce the visual impact of an HVTL. Whether a systematic impact is detectable depends on the data available.

2.1.4 Rural-residential-recreational (non-farm)property value determination

The final class of property has few representative examples and it is not often formally identified in the land economic literature as a distinct class. Unlike exurban property owners who value the accessible country lifestyle, owners of RRR properties have diverse reasons for ownership. These are typically larger acreages (more than one acre and typically more than four). Some may have recently constructed residences, others may be vacant, with the owner may be interested in an uninterrupted enjoyment of a rural lifestyle as the most important attribute. Other motivations for ownership may be eventual retirement, creation of a legacy or estate, and even speculation in anticipation of eventual subdivision, pending regional road improvement.

One important feature of RRR properties is that their relative remoteness means that disturbances, such as HVTLs, are more likely to emerge after their purchase; this is in contrast to urban and exurban development, where development and the purchase of property occurs after the transmission lines and rights-of-way have been established. The timing of urban and exurban growth relative to transmission line construction is important since, as discussed in the next section, developers will take steps to mitigate the impact of towers and lines, and purchasers will pay a reduced price for properties that are adjacent to the HVTL right-of-way

Given the relatively few instances of these properties, the fact that the nature and degree of the intrusion by the HVTL will be site specific, and the diverse motivations for ownership, it is challenging to produce a general rule about the nature and degree of impact of HVTLs on these types of properties.

2.2 Summary

Efficient land markets imply that fully informed buyers and sellers come to a quick understanding of value, based on property attributes. Property markets are believed to be sufficiently efficient to ensure that buyers and sellers know and understand all the relevant property attributes that affect their business and personal enjoyment of any parcel being offered for sale. This is the working assumption of the literature reviewed in Section 3.0.

The relative contribution of a specific attribute or the impact of a disturbance on the use of a property, and therefore its value, is a matter of empirical analysis.

3.0 Methodological overview of HVTL impact studies

Academic/professional interest in the impact of HVTLs on property values started in the mid-50s, with the first rigorous studies appearing in the 1970s.

3.1 Overview of approaches

Several categories of methodology exist. One can identify the survey research of property owners and/or experts, statistical price analysis, and conceptual studies. Several useful reviews of the literature also exist, the most recent being by Jackson and Pitts (2010).

This review classifies empirical measures of HVTL impact on property values into two general study types:

- qualitative/opinion studies, which also include a few reviews and conceptual discussions
- quantitative/statistical studies, predominantly using assessment data

All studies are retrospective in the sense that the measurement of the effect of HVTLs on property values is studied after the transmission lines have been constructed. No studies prospective were discovered in the sense of a "before and after" analysis, where values are compared before and after a transmission line is constructed.

We identified sources using Google Scholar and EconLit and archived them using Zotero. Key words used in the search included *electric transmission lines*, *high-voltage overhead lines, property values*, and *land values.* Additional references identified in the bibliographies were searched and included as relevant. Google Scholar identifies technical reports issued by institutes and utilities when they are on websites, but unpublished material is generally not accessible. Manitoba Hydro made available various property value impact studies it obtained from other utilities, and these were also reviewed.

Most of the studies analyze the impact of HVTLs on urban and suburban residential properties. A few academic and professional studies examine their impact on residential-recreational properties, but the infrequency of sales has limited analysis.

Finally, this review adopts a chronological organization, revealing the evolution of academic and professional thinking on these issues.[3] More recent studies will typically incorporate prior studies in their methodology.

3.2 Qualitative/opinion studies of the impact of HVTLs on property values.

Table 3 presents the studies that used surveys or opinions of property owners and real estate professionals. The table identifies the type and numbers of respondents, the methodology (usually a mailed questionnaire), the findings, and a commentary that evaluates the study.

Kinnard (1967) marks the start of academic investigations into the impact of HVTLs on property values. This early study reported that homeowners were unconcerned about the impact of the lines and structures, but that professional appraisers were more inclined to see negative impacts. It is very important to place a study in context. This study is set in the early 1960s, when the degree of intrusion of HVTLs on residential areas was likely much less than that which exists now. It also predates the emergence of electromagnetic fields (EMF) as a health issue associated with HVTLs.

The qualitative literature remained dormant for some time. Morgan et. al (1985) explored the perceived EMF hazards associated with power lines in the context of a range of other harms households could encounter. They did not address the link between EMFs and property values. Kung and Seagle (1992) incorporated EMF concerns into a questionnaire about the impact of HVTLs on power lines, but their study is weakened by the introduction of potential health hazards prior to asking the respondents to assess the impact on property values. Other studies through the 1990s also incorporated health concerns into their analysis (Gallimore, Peter & Janyene, Michael Ross, 1999), but early in the millennium this issue had receded, with the last retrieved by Sims and Dent (2003).

Pre-2000 studies discovered that residents perceived towers as an eyesore and that they believed this affected property values. A tendency existed for professionals (appraisers and realtors), as opposed to residents, to see this impact as having a more negative impact. This might reflect the nature of the appraisal practice, where the value is computed as the sum of independent home attributes. The typical homeowner may not view their home in such a disaggregated way.

After 2000, the survey-based literature started to use more sophisticated techniques, specifically the introduction of contingent valuation to measure the WTP to move/alter the towers and lines. Contingent valuation is a stated choice technique that attempts to measure the impact of goods and services that are not directly traded. Widely applied to assess the WTP, at least three studies exist to assess WTP in relation to the removal or alteration of HVTLs.

3 Academic sources are usually university-based researchers, while professional sources are derived from the studies by appraisal and real estate professionals.

> **Stated choice vs. revealed preference**
>
> **Stated choice** techniques emerged in the 1990s and are now a common form of field experiment used in economics. These techniques attempt to mimic the market by asking respondents what they would be willing to pay (hypothetically) for various alternatives. These methods have been widely used in environment policy, and are now finding increased use in health and social policies. Market researchers have used these techniques to discover optimal pricing for product yet to be introduced to the market. Their application to the mitigation of the negative effects of HVTLs is recent and only a few studies exist.
>
> **Revealed preference** techniques use market data to infer consumer preferences. The market transactions reveal the preferences of consumers. The studies in the next section on statistical methods to measure the impact of HVTLs are all revealed preference.

Contingent valuation methods (CVM) are rooted in traditional welfare economics, where consumers state a price that they are willing to offer for a certain good (product or service) or a sum they are willing to accept to endure some negative outcome (also known as a “bad”). Many CVM studies use a form of discrete choice experiment, implemented in a survey setting, where respondents choose among several alternatives. In the context of HVTLs, researchers attempt to measure the WTP to mitigate the effects of the towers and lines through removal, burial, or alteration to the design. This WTP become a monetary economic measure of the negative perception of the line.

Callanan (2013) used a relatively large sample (n=887) and questionnaire using CVM to discover that residents see HVTLs as having a negative impact on property value. Some residents living very close to a line are prepared to pay something for their removal, but this is a minority, and furthermore the amounts are minimal.

Soini et al (2011) used a large sample questionnaire (n=2,172), sophisticated assessment questions, and advanced statistical techniques (latent class analysis) to assess the perceptions of non-farm rural residents about HVTLs and their impact on the landscape. These respondents viewed HVTLs as having a large negative impact on their enjoyment of their properties. However, the authors note that these types of residents, who may be representative of the RRR landowner in Manitoba, viewed any change to the landscape as impairing their enjoyment of their properties. By implication, this would have a negative influence on property values.

Atkinson et al (2004) represents a theoretical and complex experiment where respondents ranked six possible tower designs, one of which represented a configuration that the respondent experienced at his/her current residence. Respondents were then offered a menu of costs (to be added to their current bills) to shift from the design currently near their home to their most preferred option. Those who had a preferred design over their present exposure could value the move to a preferred option. For those whose current exposure to towers/lines was the preferred option, the researchers asked respondents to value the cost of actions (petitions, writing letters, etc.) to preserve their current configuration, under the scenario that the utility company was about to change the tower to the least preferred option. The cost of these “activist” options became a measure of the WTP to preserve their current option. The key finding is that residents are not willing to pay much to shift to an alternate, more preferred, tower or preserve the status quo if that is the preferred option.

Chalmers (2012) presents a case study of 49 land transactions in rural Montana. These sales all had HVTLs running through the property or close to it. Setting aside the limitations of case studies, this study also raises the issue of RRR properties being very sensitive to disturbances that detract from landscape factors, since the use of the property is to "get away from it all."

The qualitative literature finds that residents believe that HVTLs impair their enjoyment of their land, but the impacts are modest. The core problem with the qualitative literature is that factors that could explain why variation in response, most importantly distance to towers and lines, is not often included as part of the data. An important circularity also exists as noted by Gallimore et al (Gallimore, Peter & Janyne, Michael Ross, 1999). Homeowners who are close to a line would have discounted these effects into their willingness to purchase that home in the first place. Finally, the attempts to use stated choice methods, such as CVM, find that homeowners are not willing to pay much in order to directly mitigate the impact of the lines.

Table 3: Summary of survey-based studies and general reviews of the impact of HVTLs on residential property values

These studies used surveys of purchasers or professionals, such as real estate agents or appraisers, to gather perceptions of the impact of HVTLs on property values

Article	Respondent description	Number of respondents	Method	Findings	Assessment
Kinnard (1967)	Property owners (residential) in neighbourhoods with a HVTL, Hartford, CT	377 homeowner, 271 appraisers, real estate agents etc.	Mailed questionnaire (43%) with standard tabulations	Homeowners report not being too affected by the power lines. Trees and other screening tend to eliminate the impact of the lines in the view of the owners. Real estate professionals tend to view lines as having a more negative effect on property values and desirability.	Self-report opinion data are prone to bias, but this early study established important parameters to subsequent research cases.
Morgan, et al. (1985)	University alumni, Carnegie Mellon University	116	Mailed questionnaire (70%) with standard tabulations	This study focussed on the hazards of electric blankets or transmission lines (of 16 potential hazards). None were viewed as risky. The survey supplied information on EMFs for each of the hazards; transmission lines received a higher risk rating.	This must be interpreted in the context of understood EMF risks in the early 1980s. Furthermore, the relationship between perceived risk and property value is not clearly understood.
Solumn (1985)	Owners whose land has been encumbered by transmission line easements, as well as buyers and sellers of these properties	180	Mailed questionnaire (43%) with standard tabulations	Agricultural users perceived little impact, others who were using the land recreationally registered concern about future timber values, and residential owners were sensitive to the loss of aesthetics.	The sample is small, especially for sub-group analysis. The survey also asked about sales value and only one of the 23 encumbered was reported to have experienced a loss in value.
Delaney and Timmons (1992)	Professional appraisers	268	Mailed questionnaire (43%) with standard tabulations	Most (84%) of the respondents believed that transmission lines reduce property values due to visual impact. A minority believed that developers compensate for lines by home orientation and larger yards, which increases value.	Appraisers develop value by combining attributes of the property, some of which are perceived to have positive and others to have negative influences.
Kung and Seagle (1992)	Homeowners whose lands are adjacent to transmission lines	47	Interview (58.5%) with qualitative analysis and basic enumeration of responses	Half the respondents viewed the lines as visually intrusive, but of these most said this had not affected the purchase price. When primed with potential health effects, most (87%) stated they would have paid less for the property.	Visual impacts do not result in price impacts, but consumers stated that health effects would encourage them to lower their bids. This assumes that the effects are both real and believed. If transmission lines are widely believed to have health effects, then buyers will lower their bids. This is only a first round impact that occurs in two instances. If the line is constructed after property development has occurred, and if new medical data, that HVTLs do cause adverse health impact, becomes available and accepted, then this may lower bids and reduce values.

Table 3: Summary of survey-based studies and general reviews of the impact of HVTLs on residential property values

These studies used surveys of purchasers or professionals, such as real estate agents or appraisers, to gather perceptions of the impact of HVTLs on property values

Article	Respondent description	Number of respondents	Method	Findings	Assessment
Kroll and Priestly (1992)	NA	NA	Review of the literature; examined literature dealing with appraisal approaches to matched samples; attitudinal studies (owners and property professionals); and statistical analyzes correlating sales values with property attributes	Concludes that: - HVTLs have the potential to reduce the value of residential properties (typically in the range of 5–10%). - This increases in the case of specialized rural (recreational/residential) properties. - Other property attributes tend to dominate value. - Impacts tend to be highest on adjacent properties. - The impact of HVTLs may be mitigated by improvements, such as gardens. - Impacts tend to decline over time.	This is a comprehensive review reflecting the state-of-the-art and understanding in 1992.
Priestly and Evans (1996)	Residents living close to power lines in two neighbourhoods near San Francisco	256	Mailed questionnaire (60%) qualitative analysis and basic enumeration	Most respondents see transmission lines as having a negative impact on property values.	The question is about how lines affect attractiveness. This study shows that perception may not translate into changed property values, which is a common funding.
Gregory and Von Winterfeldt (1996)	NA	NA	Review of the literature and court cases; starts with an analysis of how EMFs from HVTLs could affect property values	This study concludes that the potential health effects of HVTLs will cause reductions in property values that require compensation and mitigation. The authors also raise concern over the long-term health effects of EMFs.	This study needs to be viewed in the context of 20 years ago when the prevailing belief was that HVTLs had significant health effects. This represents a dated scientific view.
Bond and Hopkins (1999)	Residents in a defined study area	462	Mailed questionnaires (note this study also included regression analysis on sales data)	Respondents registered a range of concerns, such as noise (crackling) and the potential for danger during earthquakes (EMFs not addressed). Proximity did not affect perceived rent or sales value unless the respondents were within 50 metres of a pylon.	Perceived impacts do not translate directly to changes in land value. The study confirms the non-linear impact — as the property lies closer to the lines, the negative perception accelerates.
Gallimore and Janyene (1999)	Homeowners and appraisers	45 homeowners, 35 appraisers	Survey ranked 19 common risks and HVTL was one; a scale of 1–19 (lowest to highest) was used to assess risk	Living near a HVTL was perceived as being in the upper end of the risks. There is some difference in perceived risks associated with living near a HVTL between owners and appraisers (appraisers tend to see slightly more risk), which has implications for assessment practice.	This study does not bear directly on whether HVTLs affect property values. The relevant idea is that at the time of the study concern with EMF in the UK and Europe was high and this probably affected many studies at the time.

Table 3: Summary of survey-based studies and general reviews of the impact of HVTLs on residential property values

These studies used surveys of purchasers or professionals, such as real estate agents or appraisers, to gather perceptions of the impact of HVTLs on property values

Article	Respondent description	Number of respondents	Method	Findings	Assessment
Sims and Dent (2003)	Residents and land surveyors (appraisers) in Midlands, UK	109 homeowners, 96 land surveyors	Mailed questionnaire to homeowners	This study treated HVTLs as a health hazard and asked respondents to rate lines above and below ground as potential contamination from the perspective of health, visual, and noise. Respondents rated both above and below ground lines as "contaminants." Substations were seen as posing similar health hazards. Land surveyors had similar views.	This study focusses on HVTLs and associated infrastructure from a health perspective (EMFs), but gathers perception of homeowners and appraisers. It offers no scientific basis for the existence of EMFs, but is trying to establish that a perception of these negative effects does occur and it can lead to property value impacts.
Atkinson et al. (2004)	Residents residing in 31 areas bordering existing HVTLs	800 residents	In-person interviews using maps and a sophisticated contingent valuation questionnaire comparing different tower designs	This study sought to compare the WTP for replacing an existing tower design with one that was less visually intrusive.	This study does not deal with property values, but asks respondents to offer a price to change the tower design. It shows that it is easy to overestimate the WTP for making changes to a tower design, as opposed to outright removal.
Soini, Katerina et al. (2010)	Residents in a rural area of Finland	2,172 residential households (not necessarily owners)	Mailed questionnaire with a final response rate	Confirmed that transmission lines are seen as negative elements of the landscape. This perception was counter-balanced by an acceptance that HVTLs are necessary for modern life. This study confirms that non-farmer residents in rural areas have a deep "antipathy" to any change in the landscape.	This is a sophisticated survey using state-of-the-art statistical techniques to analyze responses. It is relevant to the RRR properties in Manitoba.
Chalmers (2012)	Case study of transactions in rural Montana	49 individual transactions	Case studies of individual transactions to detect impact of HVTLs	These tend to be larger rural properties comprising agricultural, agricultural-recreational, and rural residential. The more "oriented" the property is to residential, the greater the impact of HVTLs on value.	This is a subjective analysis, which while suggestive, is not conclusive. It is important because it recognizes the importance of agricultural/recreational/residential lands which found to be sensitive to HVTLs.
Callanan (2015)	Residents in a suburb of Auckland,NZ where power lines are visible throughout the area	887	Mailed questionnaires and face-to-face interviews (note this study also included regression analysis on sales data)	Proximity to power lines has a negative but declining impact on WTP for the removal of lines. Most owners view lines as having a negative impact on value and that their removal would increase value. Most owners were reluctant to contribute to a pool to remove the lines. Those that were offered minimal amounts.	WTP to have lines removed is proxy measure of impact, as respondent may question the realism of the scenario. The CVM method is an improvement over perceptions of impact since it measures whether people are prepared to back up their perceptions with cash. In this case, few homeowners were willing to pay to remove line. This used the CVM methods that probed for WTP to have the lines removed.

3.3 Quantitative and statistical studies of the impact of HVTLs on property values

There are two approaches to quantitative/statistical analysis of the impact of HVTLs on property values:

The early work used paired property analysis, where the price patterns of properties abutting HVTLs are compared to comparable properties lying some distance from the line. This is a form of a natural experiment, where the crucial task is to match the properties abutting HVTLs with “identical twins” some distance away. Examples of this approach appear in Cowger, Bottemiller, and Cahill (1996) and Wolverton and Bottemiller (2003).

Statistical analysis of the relationship between HVTLs on property values rests on two concepts in micro-econometrics: revealed preference (as explained in Section 3.2) and the hedonic pricing model.[4] Sales are the result of market transactions, revealing the preferences of consumers. The preferences and the bid prices offered by consumers emerge from the component attributes of the property, comprised of positive effects (lot size, proximity to work and leisure, etc.), as well as negative factors, such as proximity to roads, industry and, of course, HVTLs.

Table 4 summarizes the studies discovered that use statistical techniques to measure the association between HVTLs on property values.

4 The hedonic pricing model views the price of any product as the result of its discrete attributes. This model has its origins with Lancaster’s theory of consumer demand (Lancaster, 1966). A simple explanation of its application to real estate appears in Monson (2009).

Table 4: Summary of statistical analysis of HVTLs of residential property value					
These studies used statistical analysis impact of HVTLs (lines and structures) property values					
Article	**Data description**	**Number of properties**	**Method**	**Findings**	**Assessment**
Colwell and Foley (1979)	Residential properties near Decatur, Illinois, with sales from 1968–78	164	Regression using a log-linear model; the distance to tower has a "shift variable" and becomes 1/(D+k), which assures that the selling price is positive when the distance is zero and removes any inflection point	A statistically significant and relatively large impact on selling price was discovered, but this impact falls rapidly as distance to the line rises.	This is an early study with a small sample, but it established a benchmark for following statistical analyses.
Rigdon (1991)	Recreational properties in Michigan	45 properties	Regression using base property attributes and inverse distance to the line and right-of-way	There was no relationship discovered between sales value and distance to the line.	This is a simple model based on a small sample. It is one of the few studies to consider HVTL impact on recreational properties.
Kinnard and Dickey (1995)	Review of four regression studies	247–1,816	Regression on a bare set of variables (year of sale and six coded zones measuring distance to the line)	The distance to the HVTL has no impact on sales values.	This study uses a minimalist approach to regression, focussing only on year of sale and six zones of distance. The models account for a good portion of the variation in sales (R^2 = .57 - .84). This is also a very frequently cited study.
Hamilton and Schwann (1996)	Properties in suburban Vancouver over1985–91	12,907	Several specifications (linear, log-linear, and Box-Cox transformations) used to measure impact of housing attribute, neighbourhood, and distance to HVTL	For homes adjacent to the HVTL, the reduction in selling price is 5.7%. The effect of being close to a pylon is also significant, and moving a property from being adjacent to being 100 m increases value by $6,400. Removing the visual impact of the line increases value by 1.1%. These results are all statistically significant.	This is a sophisticated econometric analysis with a large sample. It continues to be the benchmark study in this area.
Cowger, Bottemiller and Cahill (1996)	Paired properties in Seattle and Vancouver, WA comprising properties that abutted a HVTL and a "comparable property"	296 paired properties	The comparable properties were selected in the same way an appraiser would select a comparable property; sales values and delays (time required to sell) of the HVTL exposed properties were compared to sales values of the comparable within the study period	The impacts of HVTLs on the property values were found to be negligible.	Using paired properties matched by appraisal methods can still produce self-selection bias. Paired comparison studies have been largely abandoned in favour of statistical studies.
Desrosiers (1998)	Properties within a neighbourhood bisected by an HVTL, in Brossard, QC	507	Regression on a comprehensive set of lot, house, neighbourhood, and distance to HVTL variables	Being adjacent to the line and "exposed" to a pylon reduces property values significantly. However this effect decreases rapidly as a property is "insulated" by two or more lots.	This was a preliminary study to Desrosiers (2005) and it established the notion of measuring the impact of buffering properties in mitigating the impact of HVTLs.

Table 4: Summary of statistical analysis of HVTLs of residential property value

These studies used statistical analysis impact of HVTLs (lines and structures) property values

Article	Data description	Number of properties	Method	Findings	Assessment
Bond and Hopkins (1999)	Residential sales in a defined study area new Wellington, NZ (1983–93)	330 sales	Assessment data regressed sales against property attributes, location, time, and proximity to line (reciprocal of distance)	The distance to a pylon is statistically significant (20% of value within 15 metres) to essentially zero at 100 metres.	It seems likely that the term "pylon" reflects a distribution line and not the larger high-voltage structures. The easements and rights-of-way associated with the high-voltage towers in Manitoba would preclude it to such proximity as "15 metres."
Colwell (2001)	Re-analysis of Colwell and Foley (1979) with improved measures of distance from line	164	Log-linear model with a more complete specification of time of sale	The distance to the line was statistically significant, but the distance to tower was less so. The impact lessens with increased distance and over time.	The author notes that, over time, the impact of the line appears to fall, suggesting that as a subdivision matures, increased foliage obscures the line, reducing the impact.
Wolverton and Bottemiller (2003)	This is a re-analysis of Cowger et al. (1996) with enhanced data and methods	727	The distance to HVTL is measured as a dummy variable, signalling whether the property abuts the HVTL right-of-way	There is a statistically significant impact on property values for properties that abut the HVTL right-of-way.	The use of a single measure of distance to HVTL measured by an indicator variable serves to capture distance and visual factors in a single variable. It would be useful to assess the interaction of various measures of distance.
Desrosiers (2005)	Properties within a neighbourhood bisected by an HVTL, in Brossard, QC	596	This study included a range of variables that offer detail on the structure, the housing attributes, and sub-areas within the neighbourhood; many measures of distance from the line captured in the model, and standard regression modelling used, with highly statistically significant results (R^2 of over .95)	Regression on all variables showed that properties that are adjacent to a line and exposed to a pylon experience a much lower value. The average reduction is about 9%, but it increases to 21% when the home is within 50 ft. of the easement. Direct views of the line and pylon also negatively affect property values. However, the impact of HVTLs on values declines sharply for properties that are insulated or buffered by other lots.	This is a comprehensive study that gathered extensive information on the proximity to the lines, house and neighbourhood amenities, including tests for multicollinearity. However, it is possible that critical location and house attribute variables are correlated with proximity to the lines, especially when lines are constructed before the subdivisions are developed.
Chalmers and Voorvart (2009)	Four study areas in Massachusetts and Connecticut	1,654 sales coded for the four area	Regression on a large array of property, location, and distance to HVTLs; variables to rate "visibility" of lines (three levels highly, somewhat, and barely visible). HVTL variables include: - continuous distance - zones (0-75 and 75+ to 150 metres) - number of structures visible - weighted number of structures (cumulative impact measure) - degree of encumbrance portion property subjected to easement (in square ft)	After eliminating non-arms-length transactions, incomplete and missing data, and using regressions performed on 1,286 properties, no systematic impact of proximity to the lines on sales values was found.	This is a very compete study with care attention to proximity to line measures. There was no apparent testing for non-linearity, heteroscedasticity, or multicollinearity.

Table 4: Summary of statistical analysis of HVTLs of residential property value					
These studies used statistical analysis impact of HVTLs (lines and structures) property values					
Article	**Data description**	**Number of properties**	**Method**	**Findings**	**Assessment**
Callanan (2010)	Residential sales in a suburb and Auckland, NZ in 2000–06	860 sales	Regression of sales value against a vector of property features, location, year of sale, and various measures of location from HVTL, including: - distance to tower - distance to line - log of distance to tower - log of distance to line - reciprocal of distance to line - reciprocal of distance to tower	The distances to lines and towers were statistically significant. The price reduction was 20% for lines very close (proximate) to lines and towers, falling to 1% at 400 m.	The sales values were adjusted to a single year using the Consumer Price Index (CPI). This suppresses changes in the property that could affect values and also the CPI is two general an index for this.
Bond, Sims and Dent (eds) (2013)	Comprehensive review of the impact of HVTLs, wind turbines and cell towers on property values	Various studies (including most of those cited here)	Systematic review	The study notes that the literature development has slowed. The measurement of view intrusion, the size and structure of the pylons, and market conditions need to be included.	Chapter 6 ("A review of HOVTL studies in North America" by David Wyman and Elaine Worzala) arrives at essentially the same conclusions as this review. .
Studies of impact of HVTLs on agricultural, industrial, and commercial properties					
Thompson and Phillips (1985)	Sales of agricultural lands in Alberta	18 paired properties	Comparison of sales for properties encumbered by HVTL and those that are not	The existence of HVTLs was found to have an effect on sales prices.	This study had small samples and failed to control for other factors.
Jackson and Pitts (2010)	Sales of industrial properties in Milwaukee	129	Comparison of sales values of proximate and not-proximate (to HVTL) properties	Sales prices of proximate properties are higher (statistically significant) than properties further away.	The relatively small sample presents challenges to interpretation. Other factors, such as access and public infrastructure, may enhance property values in ways not captured in the data.

Most studies that find a statistically significant relationship between distances to the HVTL and property values confirm that properties closest to the HVTL right-of-way experience a reduction in property value, but this association weakens rapidly as distance from the tower/line decreases. What follows is a synopsis of the more notable studies.

The earliest study by Colwell and Foley (1979) established a form for the following statistical studies and found negligible relationships. The sales value of homes within an area that features HVTLs is the dependent variable to be explained by property attributes (features of the home, lots, and its location), sales year to accommodate trends in overall value, and various measures of distance to the towers and the lines. This article defined distance to the nearest towers as the inverse of linear distance. This created a very intuitive picture, as seen in Figure 17, that has endured up to the most recent research.

Subsequent studies have refined the analysis two ways: increasing sample size, including a wider array of property values and experimenting with alternate measures of proximity to towers and lines, and fitting more complex statistical models.

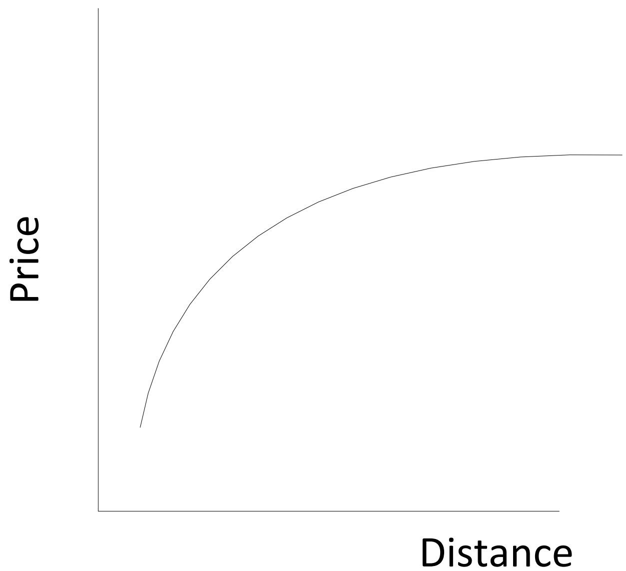


Figure 17: Illustration of property value and distance from HVTL

Hamilton and Schwann (1995), using a large sample, extended the property attributes and also explored alternative model specifications (linear regression, Cobb-Douglas, Box-Cox transformations and translog models). Variables included distance to centre of transmission line right-of-way, adjacent to right-of-way (dummy), within right-of-way or partially within right-of-way (dummy), numbers of towers visible from property (numbers of towers within 200 metres of property), transmission line visible (dummy), property characteristics that are commonly used to analyze real property prices (presence of garage, pool, sewer, curb, corner lot, number of fireplaces, basement rooms, bedrooms, full baths, partial baths, other rooms, and width and depth of lot). They also included dummy variables indicating the quarter of the date of sale.

This study represents an important milestone in the analysis of how HVTLs affect property values, and it makes three important contributions:

- The study tests whether the common measurement equations used by other authors (linear and log-linear variables) are accurate for estimating house prices. After exploring data using various regression forms, the study chose translog functional form. The authors emphasize that functional specification is crucial and overuse of linear and log-linear specifications can lead to incorrect results.
- They find the regression residuals have significant heteroscedasticity (which they test using the statistic proposed by Harvey 1974). This suggests that all studies need to incorporate this test and correct if discovered.
- Finally, they believe that a single type of equation is not likely common for properties at different distances from lines. They thus divide the sample into three groups and run three separate regressions for each distance zone: adjacent, mid-range, and far. Other authors include indicator variables denoting different distance gradients.

The main finding is that homes close to the HVTL will suffer a loss of 5.7% within 100 metres of the nearest tower. If the tower is out of the sightline of the home, value increases by 1.1%.

It is important to put this study in context. The authors were able to obtain detailed property attributes on over 12,000 properties in and around Vancouver. The assessment records included many housing and lot attributes, which allowed them to create a very complete model. Furthermore, these are urban properties.

Wolverton and Bottemiller (2003) used dummy variables, indicating whether a property abuts a transmission line, and a vector of concomitant covariates (temporal, site characteristics, location, building characteristics).

The study estimated four alternative models: two using the natural log of price as the dependent variable and two using the nominal price. Two models used abutting HVTL as the single variable of interest, while two disaggregate this variable of interest by geography. Estimating these models helps improve completeness and account for the possibility of results varying due to the functional form of the dependent.

The authors found no statistically significant relationship with sales values for properties that abut HVTLs. The authors were hesitant about this finding and caution that this conclusion cannot be extrapolated beyond the dataset used in the analysis. This underscores a core problem with all the research in this area — namely, that the results depend on the specific datasets being used. The studies can offer important clues and cautions for research, but comparing the results among different studies becomes very risky.

Des Rosiers (1998) and (2005) used standard and stepwise regression procedures applied to linear and log-linear functional forms, using a very broad array of housing and property attributes relating to physical, neighbourhood, environmental, access, fiscal, and sales time attributes. Power line distance variables included linear distance to the line of easement, dummy distance variables (50 and 100 metre increments), dummy variables to control for pylons' position relative to houses adjacent to the easement, and a series of interactive dummy descriptors to account for the combined extent of the view on the transmission lines and orientation of the property with respect to the right-of-way. They were tested through several transformations (logarithmic, square root, inverse, quadratic, gamma). The data derived from assessment information pertain to Brossard, Québec, a suburb of Montreal.

This is a very comprehensive study that includes so many property and neighbourhood attributes that the statistical models explain a very high proportion of variation in sales value. This study finds that, where a property abuts the right-of-way and a pylon is in view, the value decline averages 9.6%, but can be as much as 21% if the property is within 50 feet of the easement defining right-of-way. When the separation between property and the easement increases to 150 feet, the association between the lines/towers on sales vales becomes negligible. One important finding is that properties located some distance from the HVTL may enjoy a premium because the right-of-way implies less density and injects greenspace into the subdivision.

Chalmers and Voorvart (2009) examined the effect of 345-kV line, examining proximity, visibility, and the extent to which an adjoining property is actually encumbered by the transmission line right-of-way easement. It also examined whether higher-valued properties are more vulnerable to transmission line effects than lower-valued properties, whether properties are more vulnerable to transmission line effects in housing markets, and how to measure the incremental effect of the transmission line, given that it will take place in existing utility corridors.

The study used the following criteria for study area selection: the existing transmission corridor had to contain a 345-kV line, preferably on 130-foot steel poles (like the proposed line); the line had to have been built by 1997 (study examines sales data from 1998 to 2007); and development patterns along the corridor had to produce enough sales to make statistical analysis feasible.

Data gathered included Multiple Listings Service data on sale price, year, and other property characteristics. For each of these properties, the study used field workers (appraisers) to visit each property, record its location using a GPS device, verify data entry to the sales database, opine whether the sale appeared to be an arm's length transaction, record the extent to which the transmission line structures were visible from the property, and review assessor maps for all properties adjacent to the transmission line, to determine if each property was encumbered with an easement associated with the transmission line.

Variables related to the transmission line include continuous distance to property, whether the property is within 75 metres, whether the property is within 75–150 metres, the number of tower structures visible, weighted number of structures visible, and encumbrance (square feet of the lot encumbered by an easement). Their regression uses log of sale price as dependent variable, and uses log of liveable area, lot size, and basement area as explanatory variables to allow for a non-linear response of the sale price to increases in size.

This study found that HVTLs have no effect on the sales values of urban residential properties.

Few studies exist on the impact of HVTLs on agricultural, industrial, or commercial lands. The reason is simple. Buyers and sellers of these lands tend to be informed on the effect that HVTLs have on the economic returns for a parcel of land. Therefore, any increased costs are discounted quickly and fully into the value of the property. Chalmers (2012), cited in the previous section, noted that while agricultural lands may be owned for potential as recreational properties, and impact on sales value could exist, it is hard to measure the incremental benefits of recreation in the future. Thompson and Phillips (1985) attempted to measure the impact of transmission lines on farmland sales, but small samples and inadequate control variables hampered their study. Jackson and Pitts (2010) examined the impact of HVTLs on industrial and commercial properties and found no effect at all.

4.0 Summary

The following insights emerge from this systematic review of the literature:

Properties used as an input to the production process, and with little prospect for conversion to any other use, may experience a reduction to net income due to a HVTL. Revenues may be reduced and/or costs of production increased, because the line impedes business operations. To reiterate, an HVTL is not the local distribution line needed to supply power to businesses. Buyers and sellers in agricultural, industrial, and commercial markets are typically very well informed on these relationships, and the changed income stream will be discounted into the value of the property. The change in property value should reflect the change in net income. Since these properties tend to sell infrequently, insufficient data exist to support statistical modelling. For this reason, few studies on the relationship between HVTLs on business property values and/or net income exist.

Most of the qualitative research (opinion surveys and expert interviews) finds that both homeowners and assessors perceive negative effects of HVTLs on land values. The early studies tended to focus on health hazards caused by EMFs, but more recently research has shifted to the aesthetics of how HVTLs disrupt the visual field. When surveyed, real estate professionals tend to assess the impacts of HVTLs more negatively than homeowners/residents.

The opinion survey-based studies have recently shifted to reframe the question, not as measuring how lines and towers are related to sales values, but whether homeowners are willing to pay to have lines removed or modified. A high WTP to remove or modify lines suggests a negative impact of these lines on property value. These recent studies are arcane and lack salience, since the hypothetical option of removing an HVTL is seen as unrealistic. In most cases, homeowners would not find it credible that they could offer enough to bury or modify the location of a high-voltage system. However, the WTP to have a local distribution line buried is a more realistic proposition and there is literature on the WTP to have local distribution lines buried in older neighbourhoods. Most modern residential development in North America has buried its distribution lines for the past three decades and so this applies only to older neighbourhoods.

Assessment-based procedures that pair a “treatment” property that abuts an HVTL right-of-way, with a similar property some distance removed, find small negative relationships on property values. Such studies are methodologically weaker and less credible than statistical analysis for two reasons: first, considerable judgement goes into creating the property pairs, and second, samples tend to be small.

Statistical analyses of the relationship between HVTLs and property values are more useful than qualitative studies since they support a precise dollar value effect of structures and lines property values. The results of the studies dating from the early 1970s are mixed. Some find important negative relationships on properties that are adjacent to HVTL rights-of-way. This effect declines rapidly with distance. These studies typically find declines of 5–10% in value within 50 metres, but negligible impact once the property is more than 150 metres away. However, other equally sophisticated studies find little or no association.

The definition of distance to the line/tower is crucial. Early studies used the inverse of linear distance to the line and/or linear distance to the nearest tower structure (pylon). More studies that are recent create elaborate distance definitions based on whether the property abuts the line or whether a visual sightline to the tower exists from rooms used most in the home.

While statistical studies are not conclusive, it is important that any current study carefully defines distance to the line in a variety of ways and uses state-of-the-art statistical testing. Annex A of Appendix B discusses what constitutes good econometric practice in this area.

The following three methodological points are important:

1. The vast majority of the statistical studies reviewed for this research are retrospective. Residential subdivisions generally emerged *after* the lines were constructed. No studies we identified measured the impact of HVTLs on property values constructed after residential development had occurred. In this case, owners whose properties are close to a line did not suffer a loss in property value; it is more likely that they paid a discount for that parcel, and/or the developer may have made adjustments to the lot size and house orientation to compensate. We found no prospective North American studies where an HVTL was constructed close to existing residential areas after residential development was completed. Some European studies examine the effects of siting HVTLs after residential development, which is obviously a result of the higher urban densities in Europe.

   Note that Section 4.0 in the main report does measure the impact of an incremental addition of an HVTL line to an already existing right-of-way with two HVTLs in place.

   As an aside, literature is emerging on the property value impacts of cell towers, which must be positioned in the middle of existing urban areas after residential development has occurred. In this context, negative impacts on property values may exist and are a function of the size of the tower and proximity to the residence.

2. The variability in results across studies reflects two factors. First, methods are becoming more technically complex; researchers are using different specifications for the models and are defining key variables, such as distance, in different ways. Second, the studies are situationally specific, and it is impossible to find a common set of independent variables across the sites used for these data. Regional variation in residential development, the many omitted variables that capture the unique features of a particular town/city, and the varying time frames of the study all impede general conclusions.

3. In certain cases, HVTL rights-of-way can offer amenities. They can create a buffer between properties and once vegetation has reduced the visual impact, buyers may come to value the lines, especially if other uses are permitted, such as gardening and walking/cycling paths. Further, they increase the spacing between homes, and buyers may be prepared to pay a premium for properties that abut the

line if it increases the separation between houses. In this sense, HVTL may, over time, come to have a positive impact on residential property values. We illustrate this with the sample properties used in this study.

Several of the qualitative and quantitative studies allude to RRR properties that are emerging as an important land use. As cities grow and regional roads create access to agricultural or woodlands not used for any purpose, their attraction grows as "accessible wilderness." Some owners of these properties may place a high value on preserving the undeveloped state of their properties and will oppose any change to the landscape. On the other hand, other owners may be awaiting the development of a paved road before subdividing. While some studies suggest an impact, the samples are very small and we could identify no systemic analysis of how HVTLs affect these types of properties.

The most important conclusion from the literature review is that the relationship between HVTLs and residential properties is situationally specific. There is a negative correlation between proximity to the line and property values, but since the HVTLs are almost always constructed before residential development, any property value reduction would simply reflect a fair market trade-off between price and amenity.

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Appendix B – Econometric results

1.0 Introduction

This appendix presents the econometric results in some detail; however, it focusses on a description of the data preparation process.

2.0 Data extraction and processing

An econometric analysis of property values requires inclusion of as many relevant variables as possible that might have an influence on property value. This allows the model to isolate any effect of transmission lines, while holding all other influences on value constant. It is also the case that all econometric studies using administrative data (in this case, information from the Provincial Assessment Office) will encounter omitted variables and missing information.

Omitted variables are attributes of the property that were found important in the literature to explain the variation in land values, but are not available in the provincial assessment data. Missing values are individual data points that are not available. Omitted variables tend to increase the unexplained variance of the estimated equations (reduce the R^2), but nothing can be done to remedy this defect other than undertaking extensive and labour intensive manual inspection of each property. Most studies cited in Appendix A did not resort to that. Furthermore, some omitted variables may be "unobservable" in that they are not readily quantifiable and would therefore not easily be added to an analysis even using manual inspection (e.g., the "curb appeal" of a property or the "hipness" of a neighbourhood).

The most common example of missing information is sales values that often do not exist because a property was not sold in a particular year. Some properties in the sample were not ever included in the equations that related sales values to property attributes and distance to HVTLs because they were not sold within the sample period available from MMG (1985 – 2014).

The literature review determined that three main categories of data were necessary to conduct an effective analysis of the impact on property values: sales value of property, property characteristics (e.g., square footage, frontage, age of home, garage), and measures of distance between each property and the transmission line.

Gathering and processing the data involved the following steps:

1. ***Requesting existing data***: Manitoba Municipal Assessment Services provided data that included information on sales, assessment, and property characteristics. These three separate datasets link together through a common "roll number" field, which is a unique identifier for each of the properties that we include in the analysis.

2. ***Data cleaning and processing***: The sales and assessment tables were provided in a structured Excel file format and required little processing or data entry. However, the property characteristics data came in a semi-structured form not amenable for analysis. A programming script converted most of this semi-structured property characteristics data into a structured, flat-file format amenable for statistical analysis.

3. ***Measuring distance to the line and tower***: One important step was calculating the distance from properties to the nearby transmission line, which is a key variable in the econometric model. To gather this information, Google Maps was used together with overhead maps of the property parcels and their legal descriptions to determine the location of the relevant property in the data and calculate its distance to the transmission line and the transmission tower. The maps were also used to develop a variable indicating whether a property is directly abutting the transmission line.

   The image below illustrates the distance to tower calculation using an example property from the Selkirk region. Distance to tower was calculated in metres from the centre of the residence to the closest transmission tower and linear distance to the nearest tower.

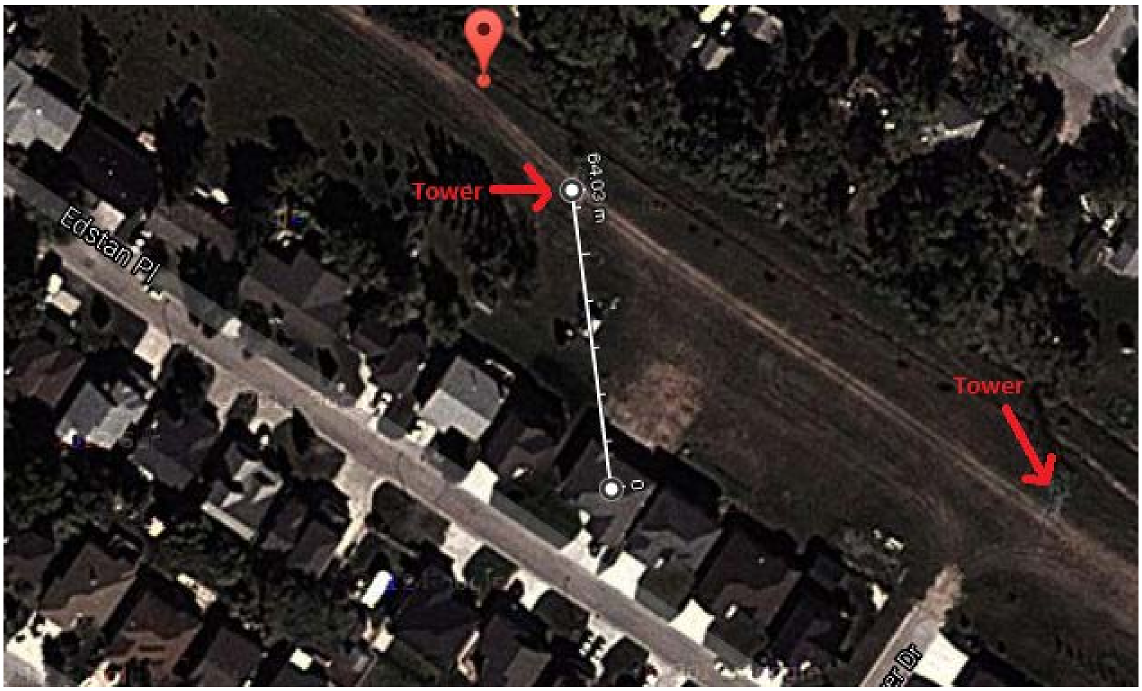

Figure 17: Measuring distance to the nearest tower

As indicated in the image below, the distance to *line* was calculated from the centre of the properties to the closest point of the line (i.e., the length of a line perpendicular to the transmission line).

Figure 18: Measuring distance to line

4. ***Manual data entry and checking***: After processing the data programmatically, manual data entry and checking was required for several components of the data. Manual data entry was also required for property characteristics data that could not be extracted via a programming script. After the data were extracted and manually entered, further processing using STATA statistical software was required to extract additional variables from the data, restructure the data, and conduct the econometric analysis.

Figure 20 provides a visual representation of the data cleaning and development process.

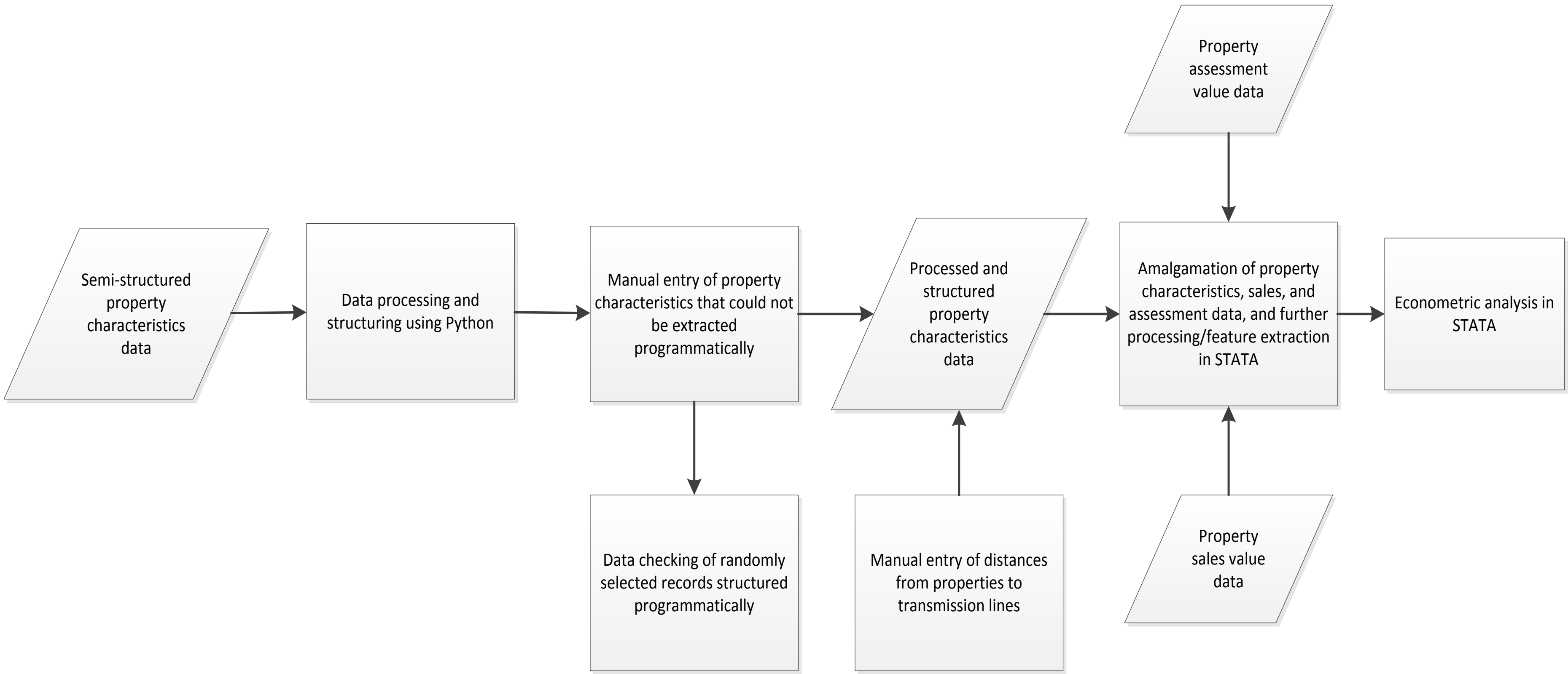

Figure 19: Flow chart of the data development process for Phase 3

3.0 Econometric estimation – main findings

3.1 Modelling strategy

To estimate impacts, PRA constructed and implemented econometric/statistical models on the property data to develop a quantitative estimate of the impact of transmission lines on property values. Most of the pre-existing econometric studies analyzed in the literature review take similar approaches with some varying technical details. Econometrics uses various statistical techniques, predominantly regression models, to explain variation in the outcome, effects, or *dependent* variable — in this case, the sales value of the property. The explanations of how sales value varies depend on movements of *independent* variables which may influence the dependent variable.

Specifically, the regression model uses the following variables:

1. Dependent variable:
   - ***Sale value***: The sale value of the property is the dependent (outcome) variable; the econometric analysis attempts to determine the impact of the property attributes and measures of distance to a transmission line distance on sales value.
2. Independent variables:
   - ***Property characteristics***: Independent variables include all other influences that affect sales value. It is also important to include the year of sale/assessment as an independent variable in the model, to account for time trends in property values. Most of the independent variables comprise characteristics of the property, and it is important to include as many of these variables as possible in the econometric models. For example, several studies in the literature review indicated lot size as a key factor, as it clearly contributes to property value.
   - ***Distance to transmission line/tower***: This is the most important independent variable, since a measure of proximity to transmission lines is necessary to estimate the impact of transmission lines on property values. Including this variable allows for comparison between “close” and “far” properties and thus allows for a comparison of value between the properties to see if there are systematic, statistically significant differences. We defined four distance variables — distance to the line in metres; distance to the nearest tower in metres; a dummy variable indicating whether a property abuts the line; and a dummy variable representing construction of the third line in East St. Paul.

See Table A1 in Section 3.3 for a detailed description of the variables used in the econometric analysis.

All of the econometric models in the current study test the null hypothesis that proximity to transmission lines has no effect on property sale price. If proximity to the transmission line is a statistically significant variable in the model and has a sufficiently large effect, then this suggests there is some impact of lines on property values. The concepts of “sufficiently large” and “statistically significant” are explained in more detail when we present the results in Section 3.2.

It is useful to understand that sales data reflect the values embodied in the property attributes or characteristics at the time of a sale. An improvement, such a new garage or deck, made after a sale would not be reflected in the sales value until the property came onto the market. The analysis accounts for these changing property characteristics by considering the year of construction for each building on the property. In particular, if a building (e.g., garage, pool, verandah) was constructed after the sale, that building is not included in that particular sales record.[5]

Most properties have periodic sales over the observation period (1984 – 2014 for sales), but for some properties no sales occurred during the observation period.

3.2 Qualifications and limitations

Although econometric analysis is generally considered the most accurate method of estimating the impact of transmission lines on residential property values, there are several important caveats to consider when interpreting the results described in Section 3.0.

1. ***Omitted variables influencing property values***: The study was ultimately able to acquire data on some of the most important variables expected to contribute to property values. However, an inherent challenge to conducting econometric analysis on observational data is that there are likely some unobserved characteristics of the properties themselves, or the surrounding environment, that contribute to property value (e.g., "curb appeal," or trends in consumer tastes at the time of sale). These omitted variables reduce the variation that is explained, particularly if they are also correlated with the distance of properties to the nearby transmission towers. For example, the literature review in Appendix A identified landscaping (trees) and important mitigation for the impact of an HVTL close to a property. Such an omitted variable can be added by using visual inspections of each property or sending homeowners a questionnaire. It is important to note that when such supplementary information is included, little impact occurs on the estimate of how distance to line/tower affects sales values. The value of such extra data collection is low.

2. ***Manual data entry***: Substantial manual data entry and programming was required, given the semi-structured nature of the property characteristics data and the need to manually measure and enter information on the distance from the centre of each property to the transmission towers. This increases the chance of data error, although we mitigated this risk by checking randomly-selected properties.

3. ***Data quality***: The data processing phase of the study revealed some missing data in the assessment records, such as properties with no buildings listed (while buildings were visible on an overhead satellite view of the parcel) or no land square footage listed. To mitigate the impact of missing data, the analysis imputed average values for these variables within the region. This provides an unbiased replacement value, given the uniformity of property characteristics within each of these three regions. This property

[5] For example, consider a property sold once in 1990 and once in 1995, and that the owner built a garage on the property in 1992. The data for analysis was constructed such that the 1990 sales observation would indicate the property did not have a garage (and building square feet would be lower) while the 1995 sales observation would indicate the property did have a garage at the time of sale.

uniformity is an important feature of exurban bedroom communities that allows us to reduce the impact of omitted variables and missing information.

3.3 Analysis of HVTLs and sales values

Table A1 presents the variables used in the analysis. More variables are available in the datasets provided by the Manitoba Municipal Government.

Table A1: Names and descriptions of variables used in the Phase 3 econometric analysis

Variable	Abbreviated variable name(s)	Description
Dependent Variables		
Sworn value of a property sale	sworn_value	Sale value of the property (dependent variable)
Independent Variables		
Attached garage	att_gar	Indicator for attached garage (0 = no 1 = yes)
Detached garage	det_gar	Indicator for detached garage(0 = no 1 = yes)
Addition over garage	add_over_gar	Indicators of an addition over garage (detached) (0 = no 1 = yes)
House below avg. quality	rq_below_avg	Indicator of house quality ("No rating" is the omitted category)
House avg. quality	rq_avg	Indicator of house quality
House above avg. quality	rq_above_avg	Indicator of house quality
Number of floors of principal residence	num_floor	Count of floors
Above/in-ground pool	pool_agg	Indicators of a pool (above or below ground) (0 = no 1 = yes)
Age of the principal residence	centered_res_age	Centred age of the residence of the property (value less the mean)
Number of buildings	n_buildings	The number of buildings with data reported for a property
Buildings area	centered_total_building_sf	Area of buildings
Lot size	centered_land_area_sf	Lot size
Addition with basement	add_w_bsmt	Indicator for addition plus basement (0 = no 1 = yes)
Verandah	verandah	Indicator for verandah (0 = no 1 = yes)
Region (East St. Paul)	st_paul	Indicator for East St. Paul properties (0 = no 1 = yes)
Region (Oakbank)	oakbank	Indicator for Oakbank properties (0 = no 1 = yes)
Year sold	scaled_year_sold	Year sold scaled so that 1985 = 1
Distance to HVTL measures		
Distance to line	dist_to_line / inv_dist_to_line	The distance, in metres, from the centre of the principal residence on the property to the nearest transmission line. inv_dist_to_line = 1/dist_to_line
Distance to tower	dist_to_tower	The distance, in metres, from the centre of the principal residence on the property to the nearest transmission tower
Abuts the property	new_adjacent_to_line	Indicator for whether the property abuts the line (0 = no 1 = yes)

Table A2 illustrates the basic sales regression results. As indicated in the table, the distance to the transmission line has a small, negative coefficient which is significant at the 1% level (p=0.002). This counter-intuitively indicates that increasing the distance from the property to the tower (i.e., decreasing proximity to the tower) appears to decrease the observed property sales value (in particular, a one-metre increase in distance to the line decreases property value by $54). This suggests that proximity to the transmission lines may actually have a small positive impact on property values. However, the effect is small and it is likely due to some unobservable characteristic of properties closer to the transmission line.

The following additional points may be made about this "complete" model:

1. An attached garage adds about $36,143 to the sales prices of a home.
2. Pools add $46,130 to the value, which seems high, but this is likely driven by the recent developments in East St. Paul, where lots are larger and homes are selling for at least $400,000.
3. An addition with a basement adds $25,204.
4. Compared to Selkirk, Oakbank properties are on average $59,068 more expensive and East St. Paul homes are $108,157 more expensive.

Table A2: Regression of property sales using linear model and only distance to line

Model statistics

R2	Adjusted R2	Prob > F	VIF	White test (Prob > chi2)	n
0.6875	0.6831	0.0000	3.57	0.0000	1312

Estimated coefficients

Variable	Coefficient value	Standard error	P-value
det_gar	9086	11015	0.410
att_gar	36143	13768	0.009
add_over_gar	1265	9571	0.895
rq_below_avg	-71472	17783	0.000
rq_avg	-14739	7613	0.053
rq_above_avg	97652	23718	0.000
num_floor	3368	5007	0.501
pool_agg	46130	11454	0.000
centered_res_age	2296	340	0.000
centered_land_area_sf	<1	<1	0.611
n_buildings	2787	4571	0.542
centered_total_building_sf	20	5	0.000
add_w_bsmt	25204	9153	0.006
verandah	-4334	8720	0.619
st_paul	108157	12699	0.000
oakbank	59068	11453	0.000
scaled_year_sold	10082	333	0.000
dist_to_line	**-54**	**17**	**0.002**
_cons	-88066	14779	0.000

Using distance to the tower rather than distance to the line produces very similar results as indicated in the table below.

Table A3: Regression of property sales using linear model using only distance to tower					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6872	0.6829	0.0000	3.61	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	9173	11019	0.405
att_gar	36325	13772	0.008
add_over_gar	1504	9577	0.875
rq_below_avg	-71425	17793	0.000
rq_avg	-14868	7615	0.051
rq_above_avg	97578	23727	0.000
num_floor	3462	5008	0.490
pool_agg	45894	11464	0.000
centered_res_age	2311	340	0.000
centered_land_area_sf	<1	<1	0.576
n_buildings	2802	4573	0.540
centered_total_building_sf	20	5	0.000
add_w_bsmt	24934	9156	0.007
verandah	-4326	8724	0.620
st_paul	108730	12914	0.000
oakbank	59463	11663	0.000
scaled_year_sold	10080	333	0.000
dist_to_tower	**-53**	**18**	**0.003**
_cons	-87784	14795	0.000

In contrast, when using the indicator of adjacency/abutting the line rather than distance to the line/tower, the coefficient for abutting the line suggests a negative impact on property values (abutting the line reduces property value by $8,832). However, this coefficient is not statistically significant (p=0.176).

Table A4: Regression of property sales using linear model using only adjacency/abutting line indicator

Model statistics

R2	Adjusted R2	Prob > F	VIF	White test (Prob > chi2)	n
0.6856	0.6812	0.0000	3.40	0.0000	1312

Estimated coefficients

Variable	Coefficient value	Standard error	P-value
det_gar	9914	11062	0.370
att_gar	37153	13808	0.007
add_over_gar	616	9598	0.949
rq_below_avg	-72499	17868	0.000
rq_avg	-17971	7630	0.019
rq_above_avg	96185	23809	0.000
num_floor	3955	5021	0.431
pool_agg	47769	11475	0.000
centered_res_age	2451	340	0.000
centered_land_area_sf	1	<1	0.276
n_buildings	3283	4586	0.474
centered_total_building_sf	20	5	0.000
add_w_bsmt	24290	9193	0.008
verandah	-3344	8740	0.702
st_paul	88081	11784	0.000
oakbank	40096	10215	0.000
scaled_year_sold	10010	333	0.000
new_adjacent_to_line	**-8832**	**6529**	**0.176**
_cons	-86840	15139	0.000

Using the inverse distance to the line as an explanatory variable is a common practice in the literature and likely represents the best model specification as it can capture the effects of declining line impacts as distance to the line increases. The model that specifies inverse distance to the line results in a statistically insignificant value (p=0.471).

Although not statistically significant, the coefficient estimate aligns closely with the literature, which often suggests negative impacts a small distance from the line and impacts that become negligible more than 100–150 metres away from the line. Figure 13 in the main section of the report provides a visual description of the hypothesized impacts at various distances, using the inverse distance coefficient described in Table A5 below. As illustrated in Figure 13 of the main report, the model hypothesizes that properties 50 metres from the line experience a price discount of about $11,000. In contrast, a property 100 metres away would see a discount of only $5,000 and properties over 300 metres away would experience a discount of under $2,000.

Table A5: Regression of property sales using linear model and only inverse distance to the line

Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6853	0.6809	0.0000	3.73	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	10531	11060	0.341
att_gar	37605	13809	0.007
add_over_gar	481	9604	0.960
rq_below_avg	-73194	17903	0.000
rq_avg	-17622	7645	0.021
rq_above_avg	96899	23816	0.000
num_floor	3930	5024	0.434
pool_agg	47935	11481	0.000
centered_res_age	2461	343	0.000
centered_land_area_sf	<1	<1	0.337
n_buildings	3211	4589	0.484
centered_total_building_sf	20	5	0.000
add_w_bsmt	24753	9189	0.007
verandah	-3168	8743	0.717
st_paul	86413	13427	0.000
oakbank	37084	12286	0.003
scaled_year_sold	10006	333	0.000
inv_dist_to_line	**-552379**	**766744**	**0.471**
_cons	-83943	17917	0.000

Multicollinearity refers to a situation where two or more of the independent variables in a regression are highly correlated. This can create problems for regression models, resulting in coefficients with lower precision and models that are highly sensitive to small changes in specifications. To illustrate the problems caused by multicollinearity, consider Table A5, which includes all three distance measurements (distance to line, distance to tower, and adjacency/abutting line indicator).

The three distance variables return very mixed results. Distance to the line reduces value by $228 and distance to the tower increases value by $153. These two estimates are not statistically significant. According to this specification, properties that abut a right-of-way are $23,694 less expensive, seemingly showing that proximity reduces value. However, these mixed findings are likely the result of high correlation between the three distance measurements, which creates multicollinearity and misleading results. Given these problems, only one of the distance measures should be included in any regression at a time.

The following additional points may be made about this "complete" model:

1. An attached garage adds about $33,221 to the sales prices of a home.

2. Pools add $45,962 to the value, which seems high, but again this is likely driven by the recent developments in East St. Paul, where lots are larger and homes are selling for at least $400,000.

3. An addition with a basement adds $24,301.

4. Compared to Selkirk, Oakbank properties are on average $58,264 more expensive and East St. Paul homes are $103,755 more expensive.

Table A6: Regression of property sales using linear model and all distance measurements					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6902	0.6854	0.0000	12.86	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	5062	11048	0.647
att_gar	33221	13746	0.016
add_over_gar	859	9560	0.928
rq_below_avg	-65369	17844	0.000
rq_avg	-16012	7595	0.035
rq_above_avg	94471	23657	0.000
num_floor	3236	4992	0.517
pool_agg	45962	11445	0.000
centered_res_age	2281	340	0.000
centered_land_area_sf	<1	<1	0.471
n_buildings	3127	4556	0.493
centered_total_building_sf	21	5	0.000
add_w_bsmt	24301	9151	0.008
verandah	-5201	8696	0.550
st_paul	103755	13204	0.000
oakbank	58624	11921	0.000
scaled_year_sold	10098	331	0.000
dist_to_line	-228	123	0.065
dist_to_tower	153	127	0.228
new_adjacent_to_line	**-23694**	**7324**	**0.001**
_cons	-75992	15312	0.000

The results corresponding to the log-linear models are similar, with the regional dummy variables and the year the property was sold as highly significant explanatory variables for sales value. The distance to the line and distance to the tower measures are statistically significant and show that for a 1% change in distance, there is typically a .10 % change in value. The log-linear specification usually produces this result, but represents the hedonic price formation in a very strong form — all property and house attributes are simultaneously interactive. It is for this reason that this model is less useful and not used in the assessment literature.

3.4 Incremental impact of a line within an existing right-of-way

In 2002, line D202V was added to a Manitoba Hydro right-of-way, with two pre-existing lines and a pre-existing rail line. This offers an excellent opportunity to conduct a “natural experiment” to assess the impact of this incremental HVTL on sales values. It is a natural experiment because we are dealing with the essentially the same pool of homes before and after the line construction.

This experiment used only East St. Paul data. Initially, we recorded the sales for each property prior to 2002 and after 2002 that were closest to the construction date. This resulted in a dataset that included sales much before 2002 and much after, so the analysis focussed on a narrower span of time, between 1986 and 2006. Using a t-test (the average values before and after 2002, with sample sizes of 77 and 132 respectively) showed no statistically significant difference in prices. Tightening the range to the span of 2000 – 2004 reduced the sample (44 and 103 respectively), and still failed to show a statistically significant difference in average sales price before and after the construction in the lines.

Therefore, we conclude that the addition of another line within an existing right-of-way had no measureable impact on sales values of homes in East St. Paul.

Annex A

Econometric issues in estimating the effects of HVTLs on property values

Regression and related statistical methodologies applied to administrative data (sales records, property tax information, and large samples) are the most widely used measures for estimating the impact of transmission lines, so this is the focus of the studies analyzed. Other common methods for evaluating transmission line impact on property values include matched pair studies, attitudinal studies, and appraisal studies, but these methods are generally seen as less rigorous.

Key challenges in econometric estimation include the following.

Data/overall approach

Almost all of the existing regression studies generally include the property sale prices as the dependent variable and the property/transmission line characteristics as the explanatory variables. They ultimately test the hypothesis that distance from the transmission line has an impact on sales price. Some studies, such as Colwell (1990), try to determine whether the price effects of transmission lines diminish over time.

In terms of data, most of the studies examine properties on or near a transmission line right-of-way. The only properties with data available on price and other characteristics are usually properties that have been sold. Some studies, such as Chalmers, Voorvart (2009), and Rigdon (1991), note the data focusses on "arms-length" transactions (or assumes arms-length transactions) for housing sales. The studies tend to focus on a small region and examine a particular type of property, most often single family homes. Studies that were undertaken to provide input into a new transmission line, such as Chalmers and Voorvaart (2009), attempt to examine the impact of transmission lines with close similarities to the proposed line, in a similar context (e.g., a line with a similar number of kVs, similar height, and from a recent time period).

Explanatory variables.

For almost all studies, explanatory variables can be divided into the following three categories:

1. ***Property characteristics***. These include any aspect of the property that might have an influence on value. Several studies indicate the most important of these factors is lot size, since developers tend to increase lot size in properties closer to transmission lines, thus increasing the value of those properties. Other characteristics used include, but are not limited to, the presence of a garage, pool, sewer, curb, or basement; whether the property is a corner lot; and number of fireplaces, basement rooms, bedrooms, full baths, partial baths, and other rooms. Almost all studies include a variable (or several dummy variables), indicating the month/date of sale, which helps account for time trends in property values. Studies also include a variable indicating the neighbourhood of sale to account for any neighbourhood price effects.

2. ***Transmission line characteristics***. Relevant variables here include kV level of transmission line, height of tower, and width/length of right-of-way. To adjust for these issues, many studies focus on analyzing data relating to one transmission line type (which has a fixed KV level/height/visual impact).

3. ***Variables describing the relationship between the transmission line and the property***. Obviously, the main variable in this category is some measure of proximity of the transmission line to the property. Some studies measure distance from the property to the transmission line as a continuous variable for each property, while others convert distance into a categorical variable (e.g., a categorical variable with two values: within 200 feet, +200 feet). Some studies, such as Colwell (1990), note that it is important to include a dummy variable indicating if the property is directly on the right-of-way (in addition to a distance variable); this can help account for value effects of transmission lines that derive only from the presence of an easement and its concomitant restriction of rights.

Functional form

Different studies use different functional forms for the regression. Hamilton and Schwann (1995) consider functional form the most carefully, using MacKinnon's J-test to test for various functional forms. The study ultimately chose the translog functional form. Des Rosiers (2002) uses both linear and log-linear functional forms, and power line distance variables are applied to several transformations (logarithmic, square root, inverse, quadratic, gamma). Most studies use a combination of log and linear variables, without explaining in great detail the reason for choosing that particular functional form.

Most studies use a linear regression where the dependent variable Y is regressed against independent variables measuring property attributes and description of HVTL. This model assumes that the effect of property attributes and HVTL measures has a linear and additive outcome on price. The double log-linear model is a transformation of Cobb-Douglas models; in contrast, the linear model assumes that sales values are the outcome of attributes that are multiplicative. The double log-linear model does present the results in terms of percentage change (elasticities), which can offer an alternative view of the impact of the HVTL.

Finally, the translog model represents a considerable increase in complexity and requires intricate assumptions to support the estimation. Of all the studies accessed, only Hamilton and Schwann select this approach, and that study is over 20 years old.

In this research the standard linear models are reported. Annex B in this Appendix presents all results for the linear additive and log-linear forms.

Heteroscedasticity

Heteroscedasticity is often an issue with property values, since the price of higher-value housing may be more volatile than low-value housing. Although the estimators will still be unbiased, this will hurt the confidence intervals for the estimates. As a result, the study may incorrectly assess variables to be insignificant.

Hamilton and Schwann (1995) find the regression residuals have significant heteroscedasticity (they test using the statistic proposed by Harvey 1974). They deal with it by estimating the model with endogenous multiplicative heteroscedasticity — the log of variance is linear in unit characteristics. Many studies also use the log of house sale price as the dependent variable, rather than just the sale price; this would reduce heteroscedasticity issues and perhaps this is the reason they use the log (although the studies never seem to state this explicitly). Another study mentions that using price per square foot, rather than price alone, can also potentially correct heteroscedasticity issues.

Multicollinearity

Several studies consider multicollinearity as a potential challenge. In the presence of multicollinearity, a model can potentially reduce independent variables without sacrificing model fit. Hamilton and Schwann (1995) use a Wald test to test for this. The authors were particularly concerned about multicollinearity because of their use of flexible functional forms, which often suffer from these problems. Wolverton and Bottemiller (2003) are also concerned about multicollinearity, as they use an ANCOVA model; multicollinearity is a key concern associated with these models. They examine Pearson correlation coefficients between the dummy variable of whether a property abuts a transmission line and the concomitant covariates. They also analyzed variance inflation factors and also ran alternative regression models entering interaction variables stepwise into the base ANCOVA model. Des Rosiers (2002) tests for multicollinearity via variance inflation factors (VIF) and does not find any.

In this study, multicollinearity among the various “distance to line” measures and between these measures and property/house attributes is a serious econometric issue that upsets the validity of the results. Depending on the degree of multicollinearity, such as with the models we tested, they can invalidate key indicators of interest. This is what occurs in these regressions with respect to the measurement of proximity to the line. We used the overall variance inflation factors (reported as VIF in results presented in Annex B), as well as the VIF on individual measures of distance. Regressions on the various permutations of distance measures appear in the annexes to Appendix B, illustrating the problem.

Spatial autocorrelation

Kroll and Priestly note that, with housing time series, one issue is serial correlation — that is, correlation between a variable and time (e.g., prices in 1989 may differ systematically from price levels in 1988). It is normally easy to detect/correct this issue in simple time series, but it is more complex with panel data that vary over space and time (which is what exists with studies on the impact of transmission lines). The authors refer to several studies as examples of how to adjust for this issue, including the use of a consumer price index to adjust for overall price inflation and other techniques.

The estimates completed for this study do not control for spatial autocorrelation because the three subdivisions are internally homogeneous. The interaction between the prices of adjacent properties is minimal.

Annex B

Summary statistics and econometric results

Summary statistics:

Table B1: Summary statistics of raw sales data (analyzed separately from property characteristics and distance measurements)

Variable	Number of sales	Mean	Min	Max	Variance	Median
sale_year	1564	1999.536	1984	2014	65.91102	1999
act_consid	1564	143560.8	1	850000	1.87E+10	107000
sworn_value	1564	166050.2	1	850000	1.84E+10	139265

Table B2: Summary statistics of raw property characteristics data (only for properties where a distance to the transmission line could be calculated)

Variable	Number of properties	Mean	Min	Max	Variance	Median
land_area_sf	749	15015.9	5005	25263	1.82E+07	15558.2
dist_to_line	769	297.379	36.16	570.18	24664.22	298.93
dist_to_tower	769	321.4046	36.16	598.33	24115.06	327.48
new_adjacent_to_line	769	0.140442	0	1	0.120875	0
land_area_sf	749	15015.9	5005	25263	1.82E+07	15558.2
year_constructed	658	1990.245	1920	2012	121.9811	1990

Table B3: Summary statistics of merged sales and characteristics data (n = 1312 sales)

Variable	Mean	Min	Max	Variance	Median	Sum
sworn_value	163934.4	9000	850000	1.82E+10	138641	2.15E+08
det_gar	0.070884	0	1	0.06591	0	93
att_gar	0.715701	0	1	0.203628	1	939
add_over_gar	0.072409	0	1	0.067217	0	95
rq_below_avg	0.026677	0	1	0.025985	0	35
rq_avg	0.641768	0	1	0.230077	1	842
rq_above_avg	0.009146	0	1	0.00907	0	12
num_floor	1.391029	1	4	0.240667	1.29291	1825.03
pool_agg	0.038872	0	1	0.037389	0	51
centered_res_age	2.21E-08	-9.70944	53.29055	101.8997	-1.04352	0.000029
centered_land_area_sf	0.000031	-9730.52	10527.48	1.81E+07	510.4775	0.040619
n_buildings	2.045732	0	6	1.804162	2	2684
centered_total_building_sf	5.28E-06	-1628.62	2547.381	1067961	278.3811	0.006928
add_w_bsmt	0.123476	0	1	0.108312	0	162
verandah	0.084604	0	1	0.077505	0	111
st_paul	0.572409	0	1	0.244944	1	751
oakbank	0.259909	0	1	0.192503	0	341
scaled_year_sold	15.94512	1	31	66.61178	15	20920
res_age	9.709444	0	63	101.8997	8.665929	12738.79
land_area_sf	14735.52	5005	25263	1.81E+07	15246	1.93E+07
total_building_sf	1628.619	0	4176	1067961	1907	2136748
dist_to_line	318.7399	36.16	595.5	26724.61	327.86	418186.8
dist_to_tower	339.535	36.16	626.43	26766.14	349.65	445470
new_adjacent_to_line	0.137195	0	1	0.118463	0	180

Table B4: Merged 2014 assessment data and characteristics data (n = 768 properties)						
Variable	**Mean**	**Min**	**Max**	**Variance**	**Median**	**Sum**
sumnet_class_totl_amt	390948.2	47700	906700	1.29E+10	391800	3.00E+08
det_gar	0.127604	0	1	0.111467	0	98
att_gar	0.890625	0	1	0.097539	1	684
add_over_gar	0.106771	0	1	0.095495	0	82
rq_below_avg	0.022135	0	1	0.021674	0	17
rq_avg	0.8125	0	1	0.152542	1	624
rq_above_avg	0.022135	0	1	0.021674	0	17
pool_agg	0.097656	0	1	0.088234	0	75
num_floor	1.392596	1	4	0.31645	1	1069.514
centered_res_age	5.013345	-15.8945	76.10552	112.9114	4.105525	3850.249
centered_land_area_sf	17.65768	-9989.28	10268.72	1.79E+07	550.5584	13561.1
n_buildings	2.721354	0	8	1.207783	3	2090
centered_total_building_sf	107.8024	-2027.05	3346.947	578560.7	149.9469	82792.23
add_w_bsmt	0.183594	0	1	0.150083	0	141
verandah	0.138021	0	1	0.119126	0	106
st_paul	0.619792	0	1	0.235957	1	476
oakbank	0.222656	0	1	0.173306	0	171
scaled_tax_year	16	16	16	0	16	12288
res_age	22.90782	2	94	112.9114	22	17593.21
land_area_sf	15011.94	5005	25263	1.79E+07	15544.84	1.15E+07
total_building_sf	2134.855	0	5374	578560.7	2177	1639569
dist_to_line	297.7076	36.16	570.18	24613.25	299.01	228639.4
dist_to_tower	321.7471	36.16	598.33	24056.15	327.875	247101.8
new_adjacent_to_line	0.140625	0	1	0.121007	0	108

Sales regression model results:

The following tables present the regression modelling used to support the conclusions in Appendix B and the main body of the report. Because assessed values are updated every two years in reference to recent sales values, we concluded that sales data are the most reliable and valid measure of property values for the purpose of this exercise.

All of the models provide valuable input into model selection and determinants of property values. However, the linear model using inverse distance to the transmission line as an explanatory variable (Table B8 below) is the preferred model that drives the results described in the main body of the report. Inverse line distance is a common model specification used by other transmission line impact studies. Furthermore, inverse distance captures changes in transmission line impacts as property distance changes. This is important, as the literature indicates impacts may be high at a short distance to the line, but decline rapidly as distance increases. Finally, this model only includes one distance measure to avoid harmful multicollinearity that results from using multiple distance measurements in the same regression.

Table B5: Regression of property sales using linear model and only distance to line					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6875	0.6831	0.0000	3.57	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	9086	11015	0.410
att_gar	36143	13768	0.009
add_over_gar	1265	9571	0.895
rq_below_avg	-71472	17783	0.000
rq_avg	-14739	7613	0.053
rq_above_avg	97652	23718	0.000
num_floor	3368	5007	0.501
pool_agg	46130	11454	0.000
centered_res_age	2296	340	0.000
centered_land_area_sf	<1	<1	0.611
n_buildings	2787	4571	0.542
centered_total_building_sf	20	5	0.000
add_w_bsmt	25204	9153	0.006
verandah	-4334	8720	0.619
st_paul	108157	12699	0.000
oakbank	59068	11453	0.000
scaled_year_sold	10082	333	0.000
dist_to_line	**-54**	**17**	**0.002**
_cons	-88066	14779	0.000

Table B6: Regression of property sales using linear model using only distance to tower					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6872	0.6829	0.0000	3.61	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	9173	11019	0.405
att_gar	36325	13772	0.008
add_over_gar	1504	9577	0.875
rq_below_avg	-71425	17793	0.000
rq_avg	-14868	7615	0.051
rq_above_avg	97578	23727	0.000
num_floor	3462	5008	0.490
pool_agg	45894	11464	0.000
centered_res_age	2311	340	0.000
centered_land_area_sf	<1	<1	0.576
n_buildings	2802	4573	0.540
centered_total_building_sf	20	5	0.000
add_w_bsmt	24934	9156	0.007
verandah	-4326	8724	0.620
st_paul	108730	12914	0.000
oakbank	59463	11663	0.000
scaled_year_sold	10080	333	0.000
dist_to_tower	**-53**	**18**	**0.003**
_cons	-87784	14795	0.000

Table B7: Regression of property sales using linear model using only adjacency to line					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6856	0.6812	0.0000	3.40	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	9914	11062	0.370
att_gar	37153	13808	0.007
add_over_gar	616	9598	0.949
rq_below_avg	-72499	17868	0.000
rq_avg	-17971	7630	0.019
rq_above_avg	96185	23809	0.000
num_floor	3955	5021	0.431
pool_agg	47769	11475	0.000
centered_res_age	2451	340	0.000
centered_land_area_sf	1	<1	0.276
n_buildings	3283	4586	0.474
centered_total_building_sf	20	5	0.000
add_w_bsmt	24290	9193	0.008
verandah	-3344	8740	0.702
st_paul	88081	11784	0.000
oakbank	40096	10215	0.000
scaled_year_sold	10010	333	0.000
new_adjacent_to_line	**-8832**	**6529**	**0.176**
_cons	-86840	15139	0.000

Table B8: Regression of property sales using linear model and only inverse distance to the line					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6853	0.6809	0.0000	3.73	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	10531	11060	0.341
att_gar	37605	13809	0.007
add_over_gar	481	9604	0.960
rq_below_avg	-73194	17903	0.000
rq_avg	-17622	7645	0.021
rq_above_avg	96899	23816	0.000
num_floor	3930	5024	0.434
pool_agg	47935	11481	0.000
centered_res_age	2461	343	0.000
centered_land_area_sf	<1	<1	0.337
n_buildings	3211	4589	0.484
centered_total_building_sf	20	5	0.000
add_w_bsmt	24753	9189	0.007
verandah	-3168	8743	0.717
st_paul	86413	13427	0.000
oakbank	37084	12286	0.003
scaled_year_sold	10006	333	0.000
inv_dist_to_line	**-552379**	**766744**	**0.471**
_cons	-83943	17917	0.000

Table B9: Regression of property sales using linear model and all distance measurements					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.6902	0.6854	0.0000	12.86	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	5062	11048	0.647
att_gar	33221	13746	0.016
add_over_gar	859	9560	0.928
rq_below_avg	-65369	17844	0.000
rq_avg	-16012	7595	0.035
rq_above_avg	94471	23657	0.000
num_floor	3236	4992	0.517
pool_agg	45962	11445	0.000
centered_res_age	2281	340	0.000
centered_land_area_sf	<1	<1	0.471
n_buildings	3127	4556	0.493
centered_total_building_sf	21	5	0.000
add_w_bsmt	24301	9151	0.008
verandah	-5201	8696	0.550
st_paul	103755	13204	0.000
oakbank	58624	11921	0.000
scaled_year_sold	10098	331	0.000
dist_to_line	-228	123	0.065
dist_to_tower	153	127	0.228
new_adjacent_to_line	**-23694**	**7324**	**0.001**
_cons	-75992	15312	0.000

Table B10: Log-linear regression of property sales using only distance to line					
Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.5880	0.5823	0.0000	3.98	0.0000	1312

Estimated coefficients			
Variable	**Coefficient value**	**Standard error**	**P-value**
det_gar	0.113099	0.086219	0.190
att_gar	0.47899	0.107982	0.000
add_over_gar	-0.0477	0.075147	0.526
rq_below_avg	-0.89424	0.140176	0.000
rq_avg	-0.08472	0.060926	0.165
rq_above_avg	0.288107	0.186427	0.122
pool_agg	0.120708	0.089797	0.179
log(num_floor)	0.023225	0.068567	0.735
centered_res_age	0.026367	0.002576	0.000
log(land_area_sf)	0.086465	0.102284	0.398
n_buildings	0.112175	0.036037	0.002
centered_total_building_sf	6.07E-06	4.32E-05	0.888
add_w_bsmt	-0.03463	0.073479	0.638
verandah	-0.07263	0.068343	0.288
st_paul	0.720552	0.115211	0.000
oakbank	0.321036	0.105618	0.002
log(scaled_year_sold)	0.678384	0.032922	0.000
log(dist_to_line)	**-0.11787**	**0.037454**	**0.002**
_cons	8.695806	0.954375	0.000

Table B11: Log-linear regression of property sales using only distance to tower

Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.5880	0.5823	0.0000	4.08	0.0000	1312

Variable	Coefficient value	Standard error	P-value
det_gar	0.112088	0.08629	0.194
att_gar	0.477341	0.108075	0.000
add_over_gar	-0.04813	0.075207	0.522
rq_below_avg	-0.88708	0.140324	0.000
rq_avg	-0.08612	0.060998	0.158
rq_above_avg	0.285684	0.186561	0.126
pool_agg	0.118938	0.089914	0.186
log(num_floor)	0.025695	0.068602	0.708
centered_res_age	0.026563	0.002574	0.000
log(land_area_sf)	0.092607	0.102294	0.365
n_buildings	0.112511	0.036065	0.002
centered_total_building_sf	7.36E-06	4.32E-05	0.865
add_w_bsmt	-0.03692	0.073521	0.616
verandah	-0.07373	0.068405	0.281
st_paul	0.727216	0.119061	0.000
oakbank	0.3254	0.109705	0.003
log(scaled_year_sold)	0.678256	0.032976	0.000
log(dist_to_tower)	**-0.12259**	**0.043524**	**0.005**
_cons	8.67051	0.95851	0.000

Table B12: Log-linear regression of property sales using only adjacency to line indicator

Model statistics					
R2	**Adjusted R2**	**Prob > F**	**VIF**	**White test (Prob > chi2)**	**n**
0.5861	0.5803	0.0000	3.68	0.0000	1312

Variable	Coefficient value	Standard error	P-value
det_gar	0.105662	0.086786	0.224
att_gar	0.475677	0.108436	0.000
add_over_gar	-0.05444	0.075352	0.470
rq_below_avg	-0.88284	0.140993	0.000
rq_avg	-0.11174	0.061001	0.067
rq_above_avg	0.27174	0.187081	0.147
pool_agg	0.131776	0.09	0.143
log(num_floor)	0.032226	0.068771	0.639
centered_res_age	0.027892	0.002556	0.000
log(land_area_sf)	0.109023	0.10258	0.288
n_buildings	0.117354	0.036148	0.001
centered_total_building_sf	1.44E-05	4.34E-05	0.741
add_w_bsmt	-0.04645	0.073797	0.529
verandah	-0.07135	0.068564	0.298
st_paul	0.545799	0.105025	0.000
oakbank	0.144953	0.092311	0.117
log(scaled_year_sold)	0.668541	0.03289	0.000
new_adjacent_to_line	**-0.06954**	**0.050826**	**0.171**
_cons	8.012829	0.934731	0.000