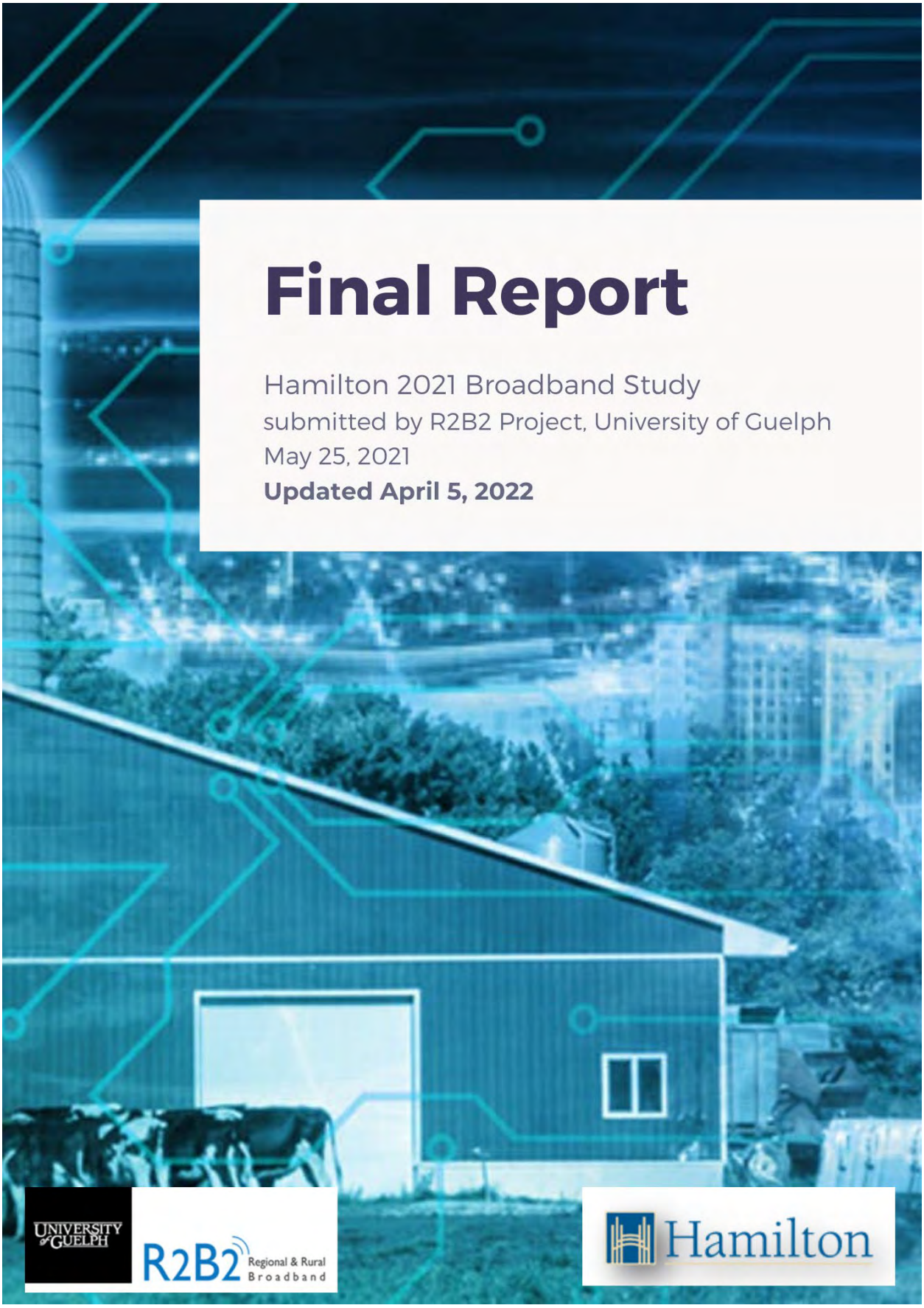

Final Report

Hamilton 2021 Broadband Study

submitted by R2B2 Project, University of Guelph

May 25, 2021

Updated April 5, 2022

UNIVERSITY of GUELPH

R2B2 Regional & Rural Broadband

Hamilton

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Disclaimer and Statement of Confidentiality

Analysts at the University of Guelph's Regional and Rural Broadband (R2B2) project prepared this report in collaboration with the City of Hamilton. The purpose of the overall study is to collect, analyze and present data about current Internet quality of service, user needs, demand and relevance of connectivity for residents and businesses in The City of Hamilton, Ontario, Canada.

We confirm that this report does not fulfil any requirement related to current or future broadband procurement processes. It does not realize or represent, in any site-specific manner, the goals and objectives of the City of Hamilton. This document is for descriptive and analytical purposes only. It is a report of 2020-2021 Internet use survey data compiled as of April 19th, 2021, under University of Guelph Research Contract #054683.

Subsequently, in March 2022, an update was made to the report following on additional collaboration between City of Hamilton and the R2B2 Project at University of Guelph which was funded separately by the Social Sciences and Humanities Research Council (SSHRC) of Canada entitled "Social Impact of Broadband Access In and Beyond the COVID-19 Pandemic." In March 2022, Annex 7 was added to the report based on the results of the SSHRC-funded study. An update of MLab data was produced by Frontier Insights and appended to this report.

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We acknowledge the use of data from publicly available sources such as the M-Lab datasets and data made available under the Data License Agreement (DLA) including The City of Hamilton Open Data.

This report would not be possible without the time spent by Hamilton residents and businesses to participate in the surveys. Thank you to the staff at the Region, individual municipalities and local organizations for their role in distributing information about the study.

We value the partnership between The City of Hamilton and the University of Guelph's R2B2 Project to enable economic and social benefits from improved broadband services for all residents and businesses within the municipality. The R2B2 Project assumes all responsibility for errors and omissions in this report. Where data is insufficient or unavailable, we acknowledge the limitations.

Helen Hambly, R2B2 Project Leader
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[1] Table 20 Residential User Willingness to Pay is redacted from this copy of the report.

Executive Summary

At no other point in time is the need for reliable, higher-speed residential Internet access apparent because during COVID-19 we must all keep working, studying, and staying healthy in the pandemic, and so much of our activity is online. For social well-being and economic prosperity, the City of Hamilton has been enabling digital services and efforts for improved broadband infrastructure.[2] Ensuring everyone in all City wards can access reliable, fast and affordable internet connections a broadband study was proposed by the "Local Rural Broadband Roundtable" held on December 2, 2019, at the Hamilton Technology Centre and convened by the Flamborough Chamber of Commerce and attended by a wide range of stakeholders including politicians, business owners, researchers and community leaders.

In collaboration with the University of Guelph's Regional and Rural Broadband (R2B2) Project, the study designed and supported the release of surveys on residential and business Internet use and needs. This report presents the analysis and mapping of data collected from May 25, 2020, to April 19, 2021 (Table 1, in blue) with all details in the report. The report was updated in March 2022 with data analysis conducted under the federal Social Sciences and Humanities Research Council (SSHRC) project "Social Impact of Broadband Access in and Beyond the COVID-19 Pandemic" in which the focus was on digital equity across Hamilton and specifically, a focus on "code red" neighborhoods (see Annex 7).

Internet Access	Indicator	Measurement
Availability & Quality of Service	*2020- April 2021 M-Lab Internet performance tests (median for sixteen months)	36/9 Mbps & 28 ms
	**All Hamilton residential survey Internet performance test results (median May 2020-2021)	30/8 Mbps & 19 ms
	**Urban Hamilton residential survey Internet performance test results (median May 2020-2021)	49/10 Mbps & 15 ms
	**Rural Hamilton residential survey Internet performance test results (median May 2020-2021)	7/1 Mbps & 33 ms
	Percent of residential premises without internet access	2%
	***Percent of residential premises with fixed broadband services below 5/1 Mbps	11%
	***Percent of residential premises with fixed broadband below 25/3 Mbps	29%

[2] See: https://www.hamilton.ca/city-initiatives/strategies-actions/hamilton-residential-rural-farm-and-business-broadband-surveys

Internet Access	Indicator	Measurement
	Percent of residential premises that meet BSO (50/10)	30%
	Percent of rural respondents that meet BSO (50/10)	9%
	Percent of residential premises with mobile wireless as primary connection type	1% (urban) 13% (rural)
	Percent of residential premises with fibre	9%
	Number of ISPs (M-Lab data, Annex 6)	107
Affordability	Percent of residential premises with data cap on primary connection	19%
	Percent of households with data caps having overage charges exceeding $100/month within past 12 months	66%
	Average cost of data overage for rural residents	$57 (low) - $125 (high)
	Highest monthly cost of data overages for rural residents	$600-$900
	Average monthly cost without & with data cap	$105 / $112
Social Equity	Percent of all household income levels below BSO 50/10 Mbps	70%
	Percent of lower income households below BSO 50/10 Mbps	73%
	Percent of households with seniors below BSO 50/10 Mbps	78%
	Percent of households with school-age children below BSO 50/10 Mbps	71%
Economic	Percent of home-based businesses with internet speeds below BSO 50/10 Mbps	84%
	Percent of farms below BSO 50/10 Mbps	96%
	Telecommuting surplus 1st telecommuter in household	$13,072
	Telecommuting surplus 2nd telecommuter in household	$9,334
Environmental	C02 emissions saved by telecommuting	2,113 kg of CO2/year for first telecommuter 1,407 kg of CO2/year for second telecommuter

**Approx. 600,000+ speed/latency tests; ** Includes mobile wireless when primary connection type; ***Fixed broadband services exclude mobile wireless*
All figures rounded to nearest whole number.

1.0 Introduction

1.1 Background

Arising from the Flamborough Chamber of Commerce "Local Rural Broadband Roundtable" on December 2, 2019, at the Hamilton Technology Centre, it was proposed that the City of Hamilton engage in data collection to assess Internet access across the city wards. This led to The City of Hamilton staff initiating discussions with the University of Guelph's Regional and Rural Broadband (R2B2) Project, which had conducted large-scale surveys and data analysis for other regions, including Durham Region, Halton Region, Niagara Region and the Western Ontario Warden's Caucus broadband program, Southwestern Integrated Fibre Technology (SWIFT). The City of Hamilton and the R2B2 Project therefore undertook a study in 2020 with deliverables including updated and site-specific Internet access data collection and analysis with mapping of broadband services for residents and businesses across the city wards. A preliminary analysis was presented on January 18, 2021, data downloads and analysis completed April 19, 2021, and a full and final draft report submitted to City of Hamilton on May 10, 2021. Subsequently, in March 2022, an update was made to the report following collaboration between City of Hamilton and R2B2 Project in the SSHRC-funded project entitled "Social Impact of Broadband Access in and Beyond the COVID-19 Pandemic."

1.2 Defining Broadband

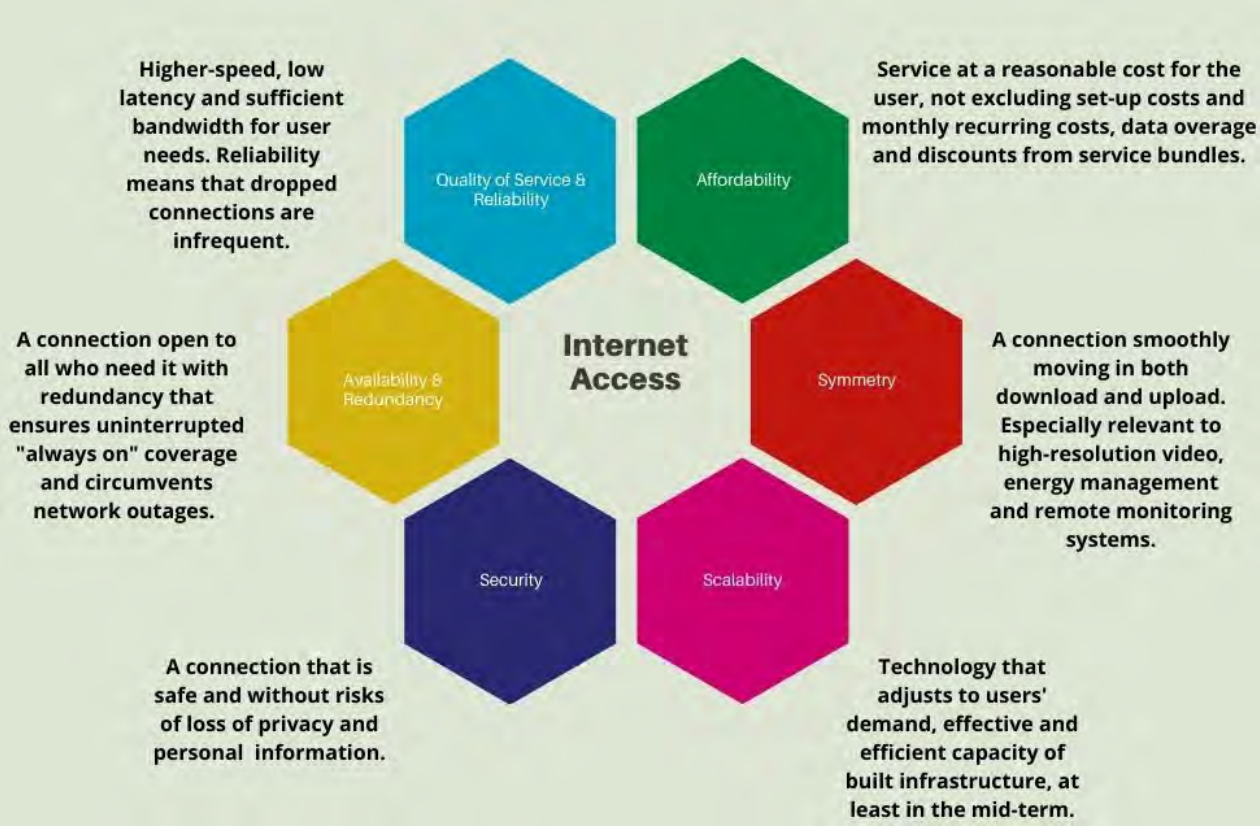
In simple terms, broadband is higher-speed Internet access. In the context of broadband investment policy and planning in Canada, the measurement of high-speed connectivity is directly obtained from the 2016 CRTC decision under the *Telecommunications Act* that defines "basic service" as 50 megabits per second (Mbps) download and 10 Mbps upload, with a latency of 50 milliseconds (ms).

As of May 2021, and certainly, under COVID-19 circumstances, most Canadians know that internet access is essential to their daily lives. Internet access is not, however, codified in Canadian law as "essential service" like water, electricity and other utilities or infrastructure. The Basic Service Objective (BSO) of 50/10 Mbps is an aspirational, universal service commitment. Internet speeds are defined as "best effort" retail service targets (i.e., "up to" x Mbps in speed, subject to varying network conditions). It is widely understood that the "guaranteed speeds" that Internet Service Providers (ISPs) advertise are lower (Hambly & Rajabiun, 2021).

Datasets such as the National Broadband Internet Service Availability Map do not necessarily match the actual Internet performance users experience at premise. Speeds and latency can be much slower. Typically, the terms 'underserved' define those premises below the BSO (50/10 Mbps).

Many factors account for quality of service measurements. Broadband is primarily private sector owned and operated infrastructure and there may be multiple and variable broadband wired and wireless, including mobile wireless connection types at a premise. ISPs (also referred to as Telecommunications Service Providers) vary in what they offer customers in terms of access to broadband through several types of wired (e.g., fibre, cable modem, DSL) or fixed wireless or mobile wireless connections and service plans. With currently available technology, optical fibre and data over cable service interface specification (DOCSIS) provide the fastest, most reliable, and secure Internet connections. DSL (digital subscriber line) over copper wire (as opposed to fibre) provides high-speed internet with "up to" speeds of 50 Mbps (download). Figure 1 summarizes some other key terms and factors associated with the measurement of broadband infrastructure.

Figure 1: Characteristics of Internet Access and Performance Measures



1.3 Context: Hamilton, Ontario

Hamilton is the ninth largest regional economy in Canada covering an area of 1,138 km^2, bordering the western tip of Lake Ontario, and lying southwest of the Greater Toronto-Hamilton Area (GTHA). Two-thirds (63.84%) of land use in Hamilton is agricultural and agriculture generates $1.26 billion annually for the local economy. Parks and open space are 12.48% and residential use accounts for 11.55% of the total land area.

Hamilton has just less than 540,000 residents with an average annual growth rate of 3.3% (16, 970) since 2011. The lower tier municipalities are Flamborough, Dundas, Ancaster, Hamilton,

Stoney Creek and Glanbrook.[3] Hamilton defines its area with 15 Wards, and the tremendous diversity of these communities detailed in Ward Profiles.[4] For general, descriptive purposes, Table 2 summarizes the ward profiles of Hamilton indicating population, number of occupied dwellings and as a proxy indicator of urban/rural premises, the area under agricultural land use.

Table 2: Population and Dwellings by Ward, Census Year 2016 and Existing Area under Agricultural Land Use (MPAC, 2018)

WARD	TOTAL_POP	OCC_PRIVATE_ DWELL	WARD_AREA_SQKM	TOTAL_POP_ DENSITY_ PPU	AREA AGRIC. LAND USE
1	29850	13575	15	1909	0
2	37070	20015	7	5369	0
3	37730	16055	15	2540	0
4	34505	15235	17	2082	0
5	37670	15440	21	1820	3
6	40395	16220	16	2505	24
7	60700	22330	18	3425	14
8	52155	18615	17	2924	26
9	30160	10855	19	1540	11979
10	24135	8955	12	1943	1545
11	45030	15780	274	164	37206
12	38375	12975	110	344	53179
13	24270	9915	26	918	42822
14	15970	5855	415	38	0
15	28915	9770	149	191	20197
total	536930	211590	1131		166905

Shading indicates a ward completely or predominantly within the urban boundary
Source: Census 2016, Statistics Canada and MPAC, 2018; data accessed from Open Hamilton Data.

2.0 Methodology

2.1 Survey Design and Distribution

The study created three surveys for City of Hamilton that collect data on Internet access. The residential and business surveys opened in May 2020. All surveys remain open until City of Hamilton determines otherwise. Data was downloaded on April 19, 2021, to present and report the findings presented in this report. Additional analyses of digital equity and connectivity metrics in Hamilton "code red" neighborhoods were conducted in 2021 and included in this updated report (Annex 7).

[3] See: Hamilton Profile: Our City: https://www.arcgis.com/apps/MapSeries/index.html?appid=8d7d72677d844bdd8a7acb641e3acd8a

[4] See: City of Hamilton Ward Profiles: https://open.hamilton.ca/pages/wardprofiles

Surveys were distributed as widely as possible with both electronic and hard copy formats available from a dedicated web page, including settings for the e-surveys that allowed English language translations through Google Translate. A list of FAQs (frequently asked questions) accompanied the surveys with additional instructions for accessibility, for example, tips on understanding and running the embedded Internet speed tests. [5] City of Hamilton staff in Digital Innovation Office and Communications were instrumental in creating marketing products such as banners for outlets such as the Feb. 5, 2021, youth initiatives group newsletter, 10 digital signs run by OutFront Media, a coms toolkit shared with three Chambers of Commerce, as well as all Councilors and a letter to the MP and MPPs from the Mayor's Office. Advertisements were placed in the Bay Observer and Hamilton Spectator, and two media interviews mentioning the Hamilton study by the R2B2 Project Leader, Dr. Helen Hambly.[6] Dozens of social media posts were pushed out by the Chambers of Commerce and R2B2 project including tagging McMaster University and Mohawk College as well as 50+ not-for-profit and educational programs operating in Hamilton. Hamilton Public Library (HPL) branches played a key role in outreach to the community distributing a post card in all grab bags to promote the surveys and offering printed hard copies of the surveys at all HPL branches and Municipal Service Centres.

2.2 Sample Size

The sample size (number of responses indicated by (n=) are as follows:
1) Residential, Farm and Home-Based Business Premise User Survey available online and in hard copy formats (n=2,941);
2) Business Premise User Survey (n= 49)
3) Measurement-Lab (M-Lab) Internet Performance Test data from 2020-2021.

This report concentrates on findings from the first dataset with relevant comparisons of results to the larger M-Lab dataset. Updated data analysis and visualization of additional M-Lab data as of March 2022 is summarized in Annex 5b.

Analysis of the data includes summary tables of descriptive statistics (frequencies), correlations and regressions. Data analysis was conducted using statistical software (STATA), ArcGIS for data mapping and NVIVO (v. 12) software for the coding of the open-ended comments and feedback

[5] Surveys and FAQs are available here: https://www.hamilton.ca/city-initiatives/strategies-actions/hamilton-residential-rural-farm-and-business-broadband-surveys

[6] See:https://bayobserver.ca/2021/02/15/help-hamilton-understand-the-communitys-broadband-needs/

provided by respondents to the residential and business surveys. Annex 1 explains the importance of reporting the median versus mean (average) for broadband analytics. Mapping of the premise-based data used base maps from the Open Hamilton data platform to aggregate results by area (municipality or ward). This method offers a more granular presentation of data compared to the federal government's generalized National Broadband Internet Service Availability Map.

2.3 Limitations

All research faces methodological limitations, and this work is no exception, particularly given the current context of the COVID-19 pandemic. Overall, the rate of response for the surveys demonstrates good regional distribution, but a lower-than-expected rate of participation. The total number of responses for the business survey is much lower than expected, compared to other regional broadband surveys (e.g., Durham Region, 2020). During COVID-19, many business premises were closed or operating under difficult circumstances. Results of the residential survey will speak to this situation to the extent that they implicate the 'work from home' orders during COVID-19, or the telecommuting and home-based business questions in the residential survey.

To ensure scientific rigor we intentionally used multiple datasets and strategies including:

a) use of and comparison of multiple datasets, including almost 600,000 M-Lab Internet Performance Test results (2020-2021)
b) marketing efforts and monitoring distribution of responses to recognize and limit data gaps
c) inclusion of a translatable and printed, hard copy survey format and engagement with youth groups and all branches of HPL and Municipal Service Office to support survey accessibility.

3.0 Findings

In this section of the report, we summarize the findings from the residential survey, general trends in the business survey and in Section 4 discuss the overall results of the study prior to presenting our recommendations.

The maps visualizing the data analysis are found in Annex 2, and where relevant, referred to in the text.

3.1 Residential Survey Findings

The survey has approximately 61 main questions with additional optional responses and a section for final comments. Table 3 summarizes the variables contained in the survey questionnaire and used in analysis.

Table 3: Residential Survey Variables

Type of Variable	Variable
Residential type and site of service	Site Name Site Address

Type of Variable	Variable
	Type of User Site (Household/ Farm/Home-Based Business)
Connectivity metrics	Internet Performance Test Data - Download and Upload Speeds (Mbps) and Latency (ms) Differences to Provider Guaranteed Speeds (Down/Up)
Connection type and cost of service	Type of Internet Connection (Transport Protocol) Service Provider One-Time Cost Monthly Recurring Charge Data Use / Overage (Data Caps)
Household use and needs	Frequency Preferred Applications Use Within Household Use for Telecommuting Use for Home-Based Business School-age children/education-related needs School grade level and board enrollment*
Willingness-to-pay	Willingness to pay for Internet service at defined price points
Additional comments/questions from residential users	Open-ended question at the end of the survey to allow final comments and feedback from survey respondents

Note: each record also includes the source of data and additional notes on some variables
*These survey questions were specifically requested by City of Hamilton given COVID-19 restrictions.

3.1.1 Residential Type and Site of Service

The total number of residential surveys included in analysis was 2,941 (as of May 10, 2021). Approximately 66% of the survey responses are from Hamilton's defined urban areas. See: Map R1: Distribution of Residential Survey Responses.

Overall, 85.24% of respondents indicate the premise is a home/primary residence only, 9.25% are both a residence with a (non-farm) home-based business (e.g., a storefront business at the residence), 4.33% are a residence and farm and 1.18% report as "other" premises (unoccupied residence; seasonal residence). As discussed in Section 2.1, the designation of a premise as "residential and business" during COVID-19 is problematic. According to the survey, about 27% of respondents currently operate at least one home-based business at the premise. See: Map R2: Residential Responses – Type of Premise.

3.1.2 Connectivity Metrics

The residential survey indicates that 29.94% of respondents speed tests achieve the federal Internet speed target (known as the Basic Service Objective or BSO) of 50 Mbps download and 10 Mbps upload and latency (data throughput) of 50 ms (CRTC 2016, 2018).

Table 4 summarizes the urban/rural breakdown of BSO attainment, indicating that only 9.4% of rural respondents (n=373) reported Internet performance tests at or above 50/10.

Table 4: Percentage of Residential Users at or Above Basic Service Objective

Basic Service Objective (BSO) 50/10 Mbps & 50 ms	% of responses at or above BSO
Total Hamilton (n=1,159)	29.94
Urban Hamilton (n=769)	40.57
Rural Hamilton (n=373)	9.38

Overall, 2.3% of respondents (n=41) do not have an Internet connection at their residential premise. Table 5 summarizes, this figure is higher for rural areas (6.3%). See: Map R3: Residential Premises with No Connection.

Table 5: Percentage of Residential Users Without an Internet Connection

	% of Respondents
Total Hamilton (n= 2,362)	2.29
Urban Hamilton (n= 1,532)	0.33
Rural Hamilton (n=781)	6.27

Table 6 summarizes the Internet performance test data collected in the survey and presents qualify of service by all Hamilton, rural and urban Hamilton. Overall, rural Hamilton is 6.8 Mbps download and 1.1 Mbps upload with latency of 33 ms. Rural Hamilton experiences download speeds more than five times slower, upload speeds eight times slower and latency more than twice as slow as urban Hamilton.

Table 6: Quality of Service Indicators

	Median Download speed (Mbps)	Median Upload speed (Mbps)	Median Latency (ms)
Total Hamilton	29.50 (n=1,349)	8.00 (n=1,333)	19 (n=1,169)
Urban Hamilton	49.00 (n=878)	10.00 (n=868)	15 (n=775)
Rural Hamilton	6.79 (n=450)	1.10 (n=443)	33 (n=376)

After running the Internet performance test contained in the survey, we asked respondents to compare the test results with their ISP's guaranteed Internet speed range as indicated within the user's subscribed service plan. Table 7 summarizes the findings. About half of the survey respondents, particularly in the rural areas, have test results that are less than providers' guaranteed speed range.

Table 7: ISP Guarantee Range of Speed

	% of responses
Total Hamilton – Download speed within guarantee	50.05 (n= 997)

	% of responses
Upload speed within guarantee	57.46 (n= 959)
Urban Hamilton – Download speed within guarantee	55.56 (n= 657)
Upload speed within guarantee	64.96 (n= 625)
Rural Hamilton – Download speed within guarantee	39.45 (n= 327)
Upload speed within guarantee	43.93 (n= 321)

See also:

Map R4: Download Speeds for Residential Respondents
Map R5: Upload Speeds for Residential Respondents
Map R6: Distribution of Latency for Residential Respondents
Map R7: Distribution of Residences that Meet the BSO (≥50/10)

3.1.3 Internet Service Providers and Primary Connection Types

Note (as of March 9, 2022), in this section of the report, we report only aggregate data which may still be attributed to a specific Internet Service Provider (ISP), but not premise-specific, "raw" or disaggregated ISP-specific data. Also, Section 3.1.5 "Residential User Willingness to Pay" and Table 20 is redacted from this copy of the report.

Table 8 summarizes the Internet Service Providers (ISPs) identified in the residential survey. In order of frequency, the most cited companies are Bell, Cogeco, Rogers, Xplornet, TekSavvy, Virgin, Silo, Detour, Fido and Primus. The notes to Table 8 refer to the "other" ISPs. In total, 107 ISPs were identified in the publicly available M-Lab dataset.

Table 8: Internet Service Providers

%	Bell	Cogeco	Detour	Execulink	Fido	Net Access	Primus	Rogers	Shaw	Silo	TekSavvy	Telus	Virgin	Xplornet	Other*
Total Hamilton (n= 2,122)	28	25	1	0	1	0	1	12	0	3	7	0	3	8	10
Urban Hamilton (n= 1,394)	26	30	0	0	1	0	1	15	1	1	10	0	5	1	11
Rural Hamilton (n=682)	31	16	1	0	0	1	0	8	0	7	2	0	0	24	9

*Refer to M-Lab ISP breakdown in Annex 6 for a full listing of identified ASN (autonomous system number) ISPs in Hamilton.

There is substantial variation among the various ISPs' areas of service. Several ISPs are small, local providers or wireless providers only. See: Map R8: Primary ISP for Residential Respondents.

Table 9 presents the data on the user's primary type of connection by ISP.

Table 9: Provider by User's Primary Type of Connection

	Bell (n=575)	Cogeco (n=525)	Detour (n=11)	Execulink (n=7)	Fido (n=12)	Net Access (n=8)	Primus (n=17)	Rogers (n=251)	Shaw (n=3)	Silo (n=55)	TekSavvy (n=158)	Telus (n=3)	Virgin (n=72)	Xplornet (n=169)	Other* (n=218)
Fibre	25	4	0	0	0	0	0	6	0	2	0	0	14	0	3
Mobile Wireless	9	0	0	0	8	13	0	10	0	7	0	33	1	1	2
Cable Modem	8	77	9	57	67	0	35	61	33	2	54	33	19	2	55
Satellite	4	0	45	0	0	0	0	2	33	31	1	0	0	56	3
Fixed Wireless	14	12	36	0	17	88	18	15	33	47	9	33	19	33	15
DSL	28	1	0	29	0	0	29	1	0	0	33	0	28	0	15
Dial Up	2	0	0	0	0	0	6	0	0	0	1	0	1	0	0

Note: Data on connection types, like all survey data, is self-reported and subject to inaccuracies when respondents are asked to assess their connection types. As such, low percentage types may be indicative of a lack of that connection type being offered by a particular ISP.

Approximately 66.3% Hamilton residents surveyed have access to a higher speed fixed broadband connection (e.g., fibre, cable modem, fixed wireless) for their primary use (Table 10). Rural Hamilton residential premises are approximately three times more likely to use mobile wireless for their primary Internet connection compared to urban Hamilton residential premises.

Table 10: Primary Type of Connection

	Cable Modem	Fixed Wireless	DSL	Fibre	Satellite	Mobile Wireless	Dial Up
Total Hamilton (n=2,088)	40.76%	16.33%	13.55%	9.20%	7.28%	4.50%	0.67%
Urban Hamilton (n=1,376)	52.25%	11.92%	13.74%	13.59%	0.51%	0.51%	0.22%

Rural Hamilton (n=670)	18.66%	25.37%	12.84%	0.60%	20.00%	12.84%	1.34%

For the geo-spatial distribution of primary type of connection reported by residential users in Hamilton see: Map R9: Primary Connection Type for Residences.

For the geographic distribution of higher speed fixed broadband connection types (e.g., fibre, cable modem and fixed wireless) for those residential premises which had reported speeds at or above 50/10 Mbps. See: Map R10: Estimated Distribution of Fibre, Cable Modem and Fixed Wireless Connections at 50/10 Mbps.

3.1.4 Cost of Service

The cost of residential Internet has four main variables. First is the cost of monthly Internet subscription, which is a recurring cost. The second cost is a cost to the subscriber if there is a data cap on the subscribed plan and the data limit is exceeded (referred to as overage cost). Third, there can be a one-time set-up cost for the residential Internet connection. Fourth, there can be a monthly cost reduction for Internet users who can "bundle" their telecommunications services with the provider. We examine each of these cost variables.

As Table 11 indicates, and on face value where no other costs are considered, the cost for the Internet compares favorably between Hamilton's urban and rural areas with a mean monthly cost per user of approximately $106.12. As shown in Table 5, however, the overall quality of service for rural residents is more than five times (download) and eight times (upload) slower than urban residents. While monthly average costs may be similar, the cost in relation to the quality of service received finds a distinct difference in affordability between rural and urban Hamilton respondents.

Table 11: Mean Monthly Cost of Internet Service

	Mean cost/month
Total Hamilton (n=1,980)	$106.12
Urban Hamilton (n=1,298)	$101.76
Rural Hamilton (n=641)	$114.43

As summarized in Table 12, about 19% of users have a data cap on their primary connection. The mean monthly cost for users with a data cap is $111.66 and this service is marginally more expensive than users without a data cap.

Table 12: Monthly Mean Cost for Users With and Without Data Caps

	Mean Monthly cost
Users with Data Cap	$111.66 (n=368)

	Mean Monthly cost
Users without Data Cap	$105.16 (n=1,522)

While unlimited data plans exist within the marketplace, data caps which could be generous or quite limited depending on user needs are present for all Internet connection types. Table 13 examines the type of connection for residential users' service plans with a data cap. Users whose primary access is satellite are most frequently associated with data caps, followed by fixed wireless and mobile wireless.

Table 13: Proportion of Data Caps by Connection Type

	Fibre	Mobile Wireless	Cable Modem	Satellite	Fixed Wireless	DSL	Dial Up
Data Cap (Yes=1) (n=381)	2.89%	18.90%	15.49%	23.62%	22.05%	9.97%	1.05%

The analysis of costs associated with data use considers that some users will exceed the volume of data in their subscription, but those users with a data cap are less likely to do so because they will incur overage costs. (Table 14).

Table 14: Data Use and Data Caps

Question	Response (Mean GB)
How much data do respondents with a data cap subscribe to? (n=373)	164.96 GB
How much data do respondents with a data cap use? (n=261)	151.40 GB
How much data do respondents without a data cap use? (n=917)	405.94 GB

The cost of Internet can disadvantage users who have no access to a so-called 'unlimited data' service plan. The cost of going over limited data plans can be substantial. Table 15 summarizes the findings on the percentage of all Hamilton users who have a data cap (19.3%) with 52% reporting that they have exceeded it, at least once in the past 12 months. Compared to urban Hamilton, rural Hamilton users are more than twice as likely to have a data cap but only marginally more likely to exceed it.

Table 15: Data Cap/Overages in Past 12 Months (Urban and Rural Areas)

Total Hamilton	% of responses
Has a data cap? (Yes=1) (n=2,007)	19.33
Has exceeded data cap in last 12 months? (Yes=1) (n=337)	51.63

Urban Hamilton	% of responses
Has a data cap? (Yes=1) (n=1,315)	7.76
Has exceeded data cap in last 12 months? (Yes=1) (n=80)	28.75
Rural Hamilton	**% of responses**
Has a data cap? (Yes=1) (n=650)	42.31
Has exceeded data cap in last 12 months? (Yes=1) (n=249)	58.63

Table 16 indicates that users who rely on mobile wireless for their primary residential Internet connection have higher data overage costs compared to other connection types. In contrast, the correlation between high data overage charges and cable modem and satellite connections is negative suggesting that exceeding data caps does not incur significant additional costs for these users.

Table 16: Correlation Matrix of Connection Type and Data Overage Charge

(n=213)	Fibre	Mobile Wireless	Cable Modem	Satellite	Fixed Wireless	DSL	Dial Up
Highest data overage charge in last 12 months	NS	0.3759	-0.1339	-0.1892	NS	NS	NS

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

The findings summarized in Table 17 examine the extra costs, added to the user's monthly bill, of going over the data allowance. Fewer urban Hamilton users have a data cap, but for those users who go over their data allowance they have overage costs, on average, at the high-end $57.33/month, and at the low end, $24.55/month. The average costs are higher for surveyed rural Hamilton users at $124.97 (high end) to $57.21 (low end). The maximum reported data overages occur in rural areas with ($900/month).

Table 17: Cost of Data Overage per Month (High/Low) in the Past Year (Urban and Rural Areas)

Total Hamilton	Mean	Min	Max
Highest Data Overage per Month in the Past Year (n=217)	$118.24	$0.00	$2,100.00*
Lowest Data Overage per Month in the Past Year (n=200)	$55.03	$0.00	$1,000.00*

Urban Hamilton	Mean	Min	Max
Highest Data Overage per Month in the Past Year (n=46)	$57.33	$0.00	$500.00
Lowest Data Overage per Month in the Past Year (n=40)	$24.55	$0.00	$300.00
Rural Hamilton	**Mean**	**Min**	**Max**
Highest Data Overage per Month in the Past Year (n=165)	$124.97	$0.00	$900.00
Lowest Data Overage per Month in the Past Year (n=155)	$57.21	$0.00	$600.00

Note: The largest overage charges reported in the dataset were provided by a respondent that did not provide sufficient address information to be classified as rural or urban which omits them from being classified under those rows in Table 17.

As indicated above, there is an additional cost to the residential users for a one-time, set up cost for the primary Internet connection. Table 18 indicates that rural users have higher one-time set-up costs.

Table 18: One-Time Set-up Costs (Urban and Rural Areas)

	Mean cost
Total Hamilton (n=1,349)	$104.40
Urban Hamilton (n=872)	$53.65
Rural Hamilton (n=453)	$195.37

A fourth cost associated with residential Internet access is a reduced cost opportunity (discount). Some ISPs can offer 'bundled service' savings for example for television, home phone and mobile wireless services, or any available combination with home internet service, where it is available. Generally, bundled services can save 10-15% off monthly costs, depending on the ISP and their available bundled services. Table 19 indicates that about 45% of Hamilton can access bundled services. This option is only available to about 33% of rural Hamilton users.

Table 19: Percentage of Users With Bundled Services (Urban and Rural Areas)

	% of responses
Total Hamilton (n=2,096)	44.51
Urban Hamilton (n=1,377)	50.25
Rural Hamilton (n=675)	33.33

Examining a sub-sample of respondents that report set up, monthly, and data overage costs in the top 75th percentile demonstrates how affordability can present a challenge for some respondents. For this sub-sample, average set up costs were $200, monthly costs were $150, and high data overage costs were $235. A respondent incurring this average set up cost, monthly cost, and these overage charges in just three months of the year (a quarter of their bills) could have an annual cost of over $2,705/year.

3.1.5 Residential User Willingness-to-Pay

Willingness-to-pay (WTP) analysis refers to an economic modeling technique that helps to assess the extent to which a consumer values a product, such as Internet services. WTP results can inform the likelihood (or not) of users adopting a faster, more reliable Internet service, if it was available. The definition of WTP is the maximum price at or below a customer will pay for a product, which in this case is Internet at different quality of service levels (50/10 Mbps, 100/50 Mbps or 500/500 Mbps). WTP data analysis identifies the trade-offs between price and download and upload bandwidth, and furthermore, we examined if there were different trade-offs for rural Hamilton and urban Hamilton households.

In the residential survey, three scenarios were presented to respondents based on different price points for three levels of bandwidth. We also analyzed the differences between rural and urban customers for the average price customers are willing to pay for download and upload bandwidth. The first scenario is the BSO level of service (50/10 Mbps), the second scenario is higher speed Internet service (100/50 Mbps) already available in some urban areas and the third scenario is even higher quality of service at a synchronous 500 Mbps connection which is more typical of advanced mobile wireless and fibre optic connections.

Table 20 summarizes the WTP findings. *[NOTE: THIS SECTION OF THE REPORT AND TABLE 20 ARE CONSIDERED PRIVILEGED INFORMATION AND IS REDACTED FROM THIS COPY OF THE REPORT]*

3.1.4 Household Use and Needs

Research on residential Internet access has emphasized the importance of considering access to Internet based on the needs of different households and what might influence user needs for better broadband. In this section of findings, we consider more closely how the use of and need for Internet varies at the household level, and specifically, according to the needs of the people residing at the premise and characteristics such as households with school-age children, seniors, farms or home-based businesses or telecommuters. In the final part of this section, we look at any preliminary trends or patterns of data use pre- and post-COVID 19.

Table 21 summarizes the average number of hours spent online by type of household. Households with a business at the primary residence spend more weekday and weekend hours online.

Table 21: Average Number of Online Hours per Day by Area

	Average consumption per day (hr online/day)	
	Weekdays	Weekends

	Average consumption per day (hr online/day)	
Total Hamilton	11.88 (n=1,335)	11.01 (n=1,324)
Urban Hamilton	12.85 (n=860)	12.11 (n=852)
Rural Hamilton	10.16 (n=452)	9.12 (n=449)

Researchers use different tools to examine if there is a statistically relevant relationship between variables. Table 22a correlates data to assess statistical significance on two sets of variables. One set of variables is quality of service measured by download and upload speeds and latency as reported in the Internet performance tests. The other set of variables are household characteristics. There was statistical significance found in the correlations of some household characteristics, but the correlations are small (the relationship between the two variables is not strong). Positive and statistically significant correlations were seen for the relationship between latency and the number of people in the household, the number of students, and the number of seniors in the household. Importantly, as latency increases the quality of service declines so these correlations suggest that the latency increases as the number of people, students, and/or seniors within the household increases. Negative correlations for download speed and upload speed and the number of students and seniors were also seen in the analysis. Again, these correlations were weak but significant. These results would suggest that download and upload speeds tend to be lower for households with more students and/or more seniors.

Table 22a: Correlation Matrix of Quality of Service by Household Characteristics

(n=931)	Number of people	Number of students	Number of seniors	Number of unemployed
Download speed (n=1,199)	NS	-0.0593	-0.1390	NS
Upload speed (n=1,189)	NS	-0.0606	-0.0913	NS
Latency (n=1,053)	0.0864	0.0754	0.0690	NS

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

Table 22b correlates data to assess statistical significance between quality of service metrics and the grade level enrollment of students. Most of the quality of service indicators have no statistically significant relationship with specific grade levels. There is a statistically significant, but weak, correlation between enrollment in the kindergarten to grade three category and higher download and upload speeds.

Table 22b: Correlation Matrix of Quality of Service by Education Enrollment

	K to Gr 3	Gr 4 - 6	Gr 7 - 8	Secondary	Post-Secondary	Multiple Grade Levels in Household
Download speed (n=645)	0.0723	NS	NS	NS	NS	NS
Upload speed (n=637)	0.0674	NS	NS	NS	NS	NS
Latency (n=567)	NS	NS	NS	NS	NS	NS

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

Table 22c: Correlation Matrix of Quality of Service by Education Enrollment

	Hamilton-Wentworth District School Board	Hamilton-Wentworth Catholic District School Board	Conseil scolaire catholique MonAvenir	Conseil scolaire Viamonde
Download speed (n=487)	-0.0811	NS	NS	0.1090
Upload speed (n=482)	-0.0864	0.1618	NS	0.0980
Latency (n=567)	NS	NS	NS	NS

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

Table 22c correlates data to assess statistical significance between quality of service metrics and the school board where students are enrolled. There is a statistically significant, but weak, correlation between enrollment in the Hamilton-Wentworth District School Board and lower download and upload speeds. There is a positive, but weak, correlation between upload speeds and enrollment in the Hamilton-Wentworth Catholic District School Board. There is no statistically significant relationship between enrollment in the Conseil scolaire catholique MonAvenir and quality of service. Lastly, there is a positive, but weak, correlation between download and upload speeds and enrollment in the Conseil scolaire Viamonde.

We considered if household income was influential in determining the type of primary Internet connection at premise. Table 23 summarizes the finding of the correlation of type of primary Internet connection by combined, total household income. The combined household income

variable is divided into three categories of high (more than $150,000/year), middle ($70 to 150,000/year), and low (less than $70,000/year). The results suggest that there are no strong correlations between income and connection type with most correlation estimates being either not statistically significant or a very weak correlation.

Table 23: Correlation Matrix of Connection Type by Combined Total Household Income

Household Income (n=1,236)	Fibre	Mobile Wireless	Cable Modem	Satellite	Fixed Wireless	DSL	Dial Up
High income (>150k)	NS	NS	NS	NS	NS	-0.0530	NS
Middle income (70-150k)	NS	NS	NS	NS	NS	NS	-0.0531
Low income (<70k)	NS	NS	-0.0678	-0.0659	NS	0.0746	0.0848

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

We also considered if household income was related to the cost of service. Analysis suggests that there are weak correlations between income and set up costs, monthly costs, and high data overage charges. More specifically, low income (less than $70,000 household income) respondents tend to have lower data overage charges and monthly costs, but both correlations are weak. Middle income ($70,000 to $150,000 household income) respondents tend to have lower monthly and set up costs but again, these correlations are weak. Lastly, high income households (more than $150,000 household income) tended to have higher monthly costs and higher set up costs with these correlations also being weak.

We found that the only statistically significant result is a correlation of primary connection types and number of people in the household (Table 24). To interpret this correlation, we can state that for all surveyed Hamilton households, a higher number of people in the household makes minimal difference to connection type, and what matters is the connection type available.

Table 24: Correlation Matrix of Connection Type by Number of People in Household

Responses (n=2,079)	**Fibre**	**Mobile Wireless**	**Cable Modem**	**Satellite**	**Fixed Wireless**	**DSL**	**Dial Up**
Number of people in hsld.	NS	NS	-0.0379	0.0534	0.0517	NS	NS

Note: Correlation measures the strength of the relationship between two variables in a range of -1 to 1. A correlation close to zero is a weak relationship while a correlation close to 1 is a strong positive relationship and a correlation close to -1 is a strong negative relationship. Only statistically significant correlations are presented. NS indicates no statistically significant result.

3.1.5 Working from Home

Internet needs for telecommuting (defined as working two or more days per week from home) featured strongly in the survey responses, not surprisingly, due to the current COVID-19 situation. Approximately 70% (n=1,915) of respondents have a job that allows for telecommuting. Two-thirds of respondents (64%) answering this question (n=1,330) indicated that their Internet connection at the premise enables telecommuting. That means too that 36% have a job that allows telecommuting, but they cannot telecommute due to a weak Internet connection.

Households may also have more than one telecommuter. For the first telecommuter 80% require (n=753) access to work through a VPN (a secure virtual private network connection). All, or all total respondents (n=475) answering the question "if you could telecommute, would you" indicated that they would telecommute to work. The finding was 98.4% in urban areas (n=193) and 99.6% (n=265) in rural areas.

Telecommuting has an economic value (net private benefit) referred to as the "telecommuter surplus" for each telecommuter in the household. Table 25 presents the telecommuter surplus for Hamilton.

Table 25: Telecommuter Surplus (urban/rural)

	Total Hamilton	Urban Hamilton	Rural Hamilton
First telecommuter in household	$13,072 (avg 4.47 days telecommuting)	$13,075 (avg 4.49 days telecommuting)	$12,925 (avg 4.34 days telecommuting)
Second telecommuter in household	$9,334 (avg 3.97 days telecommuting)	$9,359 (avg 4.09 days telecommuting)	$9,259 (avg 3.52 days telecommuting)

*Note (1): Telecommuter surplus is estimated with the following formula: (($0.52/km x commute distance) + ($22.02/hr * commute time)) x total number of days telecommuting per year - (annual service cost/number of telecommuters in the household). For more information refer to Hambly & Lee, 2019. Note (2): Telecommuting data 'outliers' were identified in the dataset and excluded from the values presented above. This means that for some households the benefit of being able to work from home because the distance to work is extremely far away, and the distance (kilometers for a return trip) is exceptionally high. In most cases, the distance travelled would not involve driving but air flights.*

Telecommuting has an environmental value in that removing vehicles from the road has a carbon offset value in terms of reduced carbon dioxide and carbon monoxide. Table 26 presents the telecommuter offset for CO_2 for Hamilton.

Table 26: CO_2 Off-Set of Telecommuting (urban/rural)

	Total Hamilton	Urban Hamilton	Rural Hamilton

First telecommuter in household	2,113 (avg 74 km/day commute)	2,055 (avg 75 km/day commute)	2,307 (avg 67 km/day commute)
Second telecommuter in household	1,407 (avg 60 km/day commute)	1,303 (avg 58 km/day commute)	1,734 (avg 69 km/day commute)

Note: Greenhouse gas mitigation is estimated using the following formula: (0.0834 L/km x commute distance (km) x 2.29 kg of CO2/L) x total number of days telecommuting per year (Natural Resources Canada 2014). Similarly, to the telecommuter analysis above, extreme outliers were removed from the dataset for greenhouse gas mitigation analysis.

Approximately 27% of surveyed residential premises in Hamilton have at least one home-based business. The types of businesses are primarily other than typical NAICS code (21%), professional, scientific, and technical services (12%) and information and communication technology (9%).

Among the residential users surveyed, 9.1% subscribe to an additional service plan for the home-based business at an average cost of $113.45 per month. Better Internet service will increase business opportunities, in the opinion of the surveyed users, with rural users more likely to answer affirmatively (Table 27). The geo-spatial distribution of results, however, indicate that some respondents in Hamilton (12.4%) may not know if better broadband will increase opportunities for home-based businesses and this should be taken into consideration by economic development planners and business associations.

Table 27: Responses to the Question: Will better Internet increase business opportunities?

	% Responses		
	Urban Hamilton (n=249)	Rural Hamilton (n=249)	Total Hamilton (n=510)
Yes	64.26	82.33	73.53
No	21.69	6.83	14.12
Other/I don't know	14.06	10.84	12.35

3.1.5 Overall Results

Regression analysis is a statistical analysis method that makes it possible to assess how several factors or 'explanatory' variables effect a particular variable of interest. Regression analysis is different from correlation analysis because it is possible to assess the relationship between the variable of interest and many explanatory variables simultaneously. In this way, regression analysis allows us to determine which factors matter most and which factors are not important. For example, we can assess how download speeds are affected by many variables such as location, income, household characteristics, and connection type. Two variables of interest were identified for regression, based on the overall findings reported above. The first area is the quality of service (download, upload, and latency variables) and the second is the WTP.

3.1.5.1 Quality of Service Regressions

Annex 3a summarizes the data regressions for connectivity metrics associated with quality of service. This approach used a log transformation of the independent variable (download speed, upload speed, or latency) to account for the right-skewed distribution seen in quality of service metrics (refer to Annex 1 for more information). Fibre connections were associated with the biggest increase in download speeds and cable modem connections resulted in a substantial increase.

Being urban was associated with the next largest increase in download speeds. Having higher weekday and weekend demand as well as being on a fixed wireless connection were associated with slightly higher download speeds in comparison to the average household.

Respondents located in urban areas, and on a fibre, cable modem, mobile wireless, or fixed wireless connection have higher upload speeds than the average respondent. Respondents with a data cap or that responded to the final question of the survey tend to have lower upload speeds. Higher numbers of students in the household does decrease reported upload speeds but the effect is small. Regression results for latency suggest that being in an urban area reduces latency while having a data cap, a fixed wireless, or satellite connection all lead to higher latency.

3.1.5.2 WTP Regressions

In Annex 3b (redacted), WTP regressions are estimated using the residential survey data. The results should be interpreted as the positive or negative effect of an explanatory variable (such as monthly cost) on the stated willingness to pay for a given level of broadband service. Three scenarios were presented to respondents representing a range of potential broadband services. These three scenarios were: 50/10, 100/50, and 500/500.

NOTE: As indicated in section 3.1.3, analysis of WTP regressions is redacted from this copy of the report.

3.2 Business Survey Findings

The business survey for the Hamilton 2021 Broadband Study was widely disseminated but not well subscribed, due to COVID-19 circumstances and difficulties faced by businesses. In total, we received 49 business user surveys as of April 19, 2021. For statistical analysis, we consider this number of responses insufficient to support conclusions. In this section, we will present exploratory results only and recommend continuation of the business data collection to obtain a larger sample size. To inform the reader, it is noted that the e-survey has approximately 30 questions including additional optional questions and a section for final comments. Table 29 summarizes the variables contained in the survey questionnaire and used in analysis. Section 4.6 makes recommendations regarding the business survey.

Table 29: Business Survey Variables

Type of Variable	Variable
Business type and site of service	Site Name Site Address Type of Business/NAICS sector

Type of Variable	Variable
Connectivity metrics	Internet Performance Test Data - Download and Upload Speeds (Mbps) and Latency (ms) Differences to Provider Guaranteed Speeds (Down/Up) Relevance and Reliability
Connection type and cost of service	Type of Internet Connection (Transport Protocol) Service Provider One-Time Cost Monthly Recurring Charge Data Use / Overage (Data Caps)
Willingness-to-pay	Willingness to pay for Internet service at defined price points
General comments (qualitative data)	Open-ended question at the end of the survey to allow final comments and feedback from survey respondents

3.4 Analysis of Other Available Datasets

The Hamilton 2021 Broadband Study also included analysis of other available and additional datasets. In this section, we summarize the findings from M-Lab's open access dataset, which includes Internet Performance Test data for 2020 - 2021. Additional data received from, mapped and submitted to the study is the wireless Internet access Environics (2020) study results. General comparisons are made to the Environics findings, see Map E1.

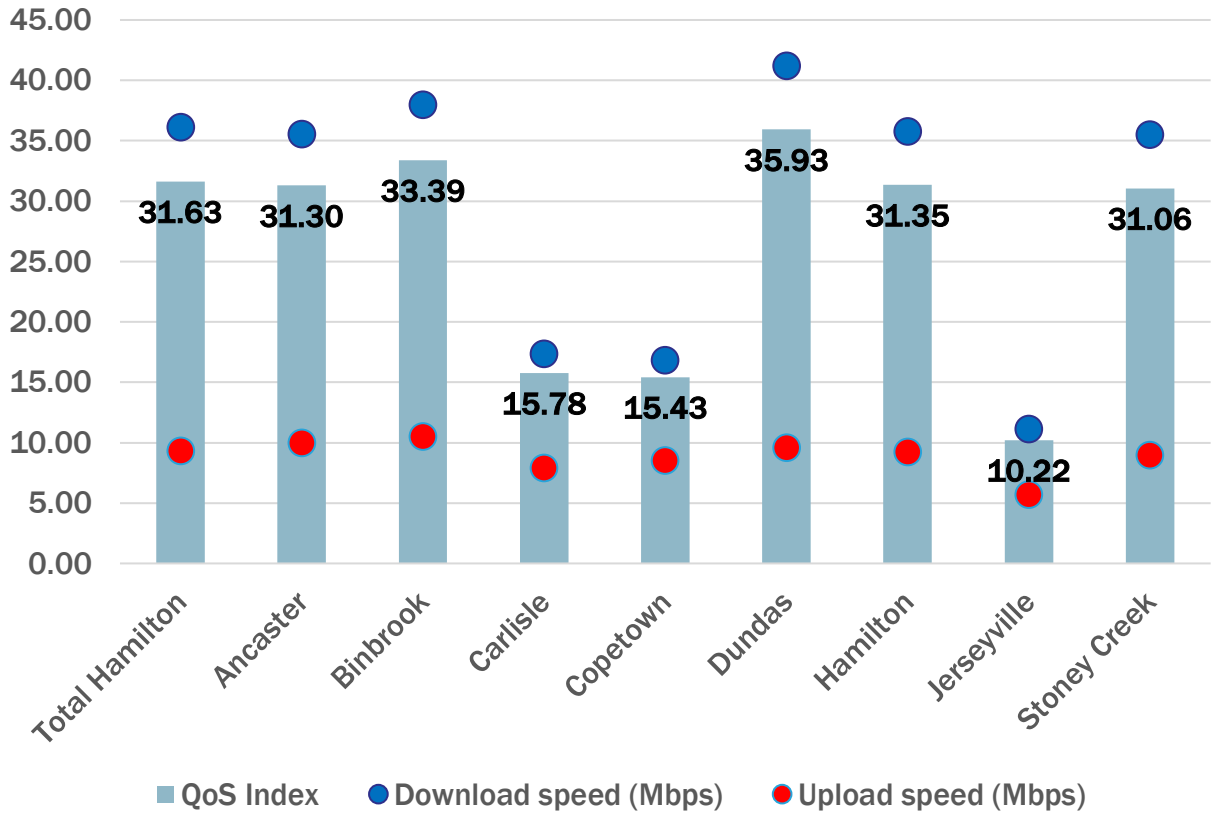
3.4.1 M-Lab Data

Annex 4 summarizes the M-Lab Internet Performance Test data for the January 2020 to April 2021 time period. To protect respondent privacy, M-Lab aggregates the data they collect at a more granular level, which is the users' nearest community and the first three digits of the postal code. Data were collected by postal codes within the Hamilton area and then filtered for named communities that are within the Hamilton boundary. M-Lab data is relevant given that M-Lab Network Diagnostics Tool is the only consistently used public data for Internet speed metrics. In Canada, the Canadian Internet Registration Authority (CIRA) also deploys M-Lab datasets.

Our findings indicate that from January 2020 to April 2021, almost 600,000 Internet speed tests were run from premises in Hamilton on the M-Lab network diagnostics platform. In M-Lab datasets for southern Ontario, we find that the number of tests run for download and upload speed and latency vary widely by community. Rural communities tend to have the fewest number of Internet performance test results.

Despite a lower number of speed tests for rural areas, the M-Lab data does allow for comparisons across the communities of: Ancaster, Binbrook, Carlisle, Copetown, Dundas, Hamilton, Jerseyville, and Stoney Creek. Figure 2 below provides an overview of the quality of service for each of these communities using M-Lab data.

Figure 2: M-Lab Quality of Service Index for Hamilton (January 2020 to April 2021)



Refer to Annex 4 for an overview of the data used to construct Figure 2.

[INSERT MARCH 2022 M-LAB DATA ANALYSIS/TIME SERIES DATA HERE]

4.0 Final Discussion, Conclusions and Recommendations

This section of the report discusses the overall results of the Hamilton 2021 Broadband Study, based on the data collected and analyzed as of May 10, 2021, and presents the study's conclusions. We concentrate on the data analysis for the residential survey. We compare the findings to historical M-Lab, where relevant.

To begin, we discuss Internet access in Hamilton in terms of three main characteristics: availability, quality of service and affordability. Given the relationship between availability and quality of service for high-speed connectivity we first determine the extent to which users have achieved the national BSO (50/10 Mbps). We also summarize the evidence of higher speed Internet access across Hamilton drawing on the analysis of connection types and connectivity metrics.

The discussion also presents comparative conclusions on Internet access in urban and rural Hamilton. We consider the extent to which broadband services vary across the 15 Wards. We discuss the relevance of the findings for economic opportunities across the region. Finally, we will consider the extent to which the findings can be used to inform recommendations for moving towards strategies for better broadband, recognizing areas for further data collection and analysis.

4.1 Broadband Availability and Quality of Service

A key indicator of high-speed connectivity attainment is the Basic Service Objective (50/10 Mbps and 50 ms) set by ISED/CRTC (CRTC, 2016, 2018). In this study, we found that a substantial percentage of respondents' experience Internet speeds and latency below and well below the BSO.

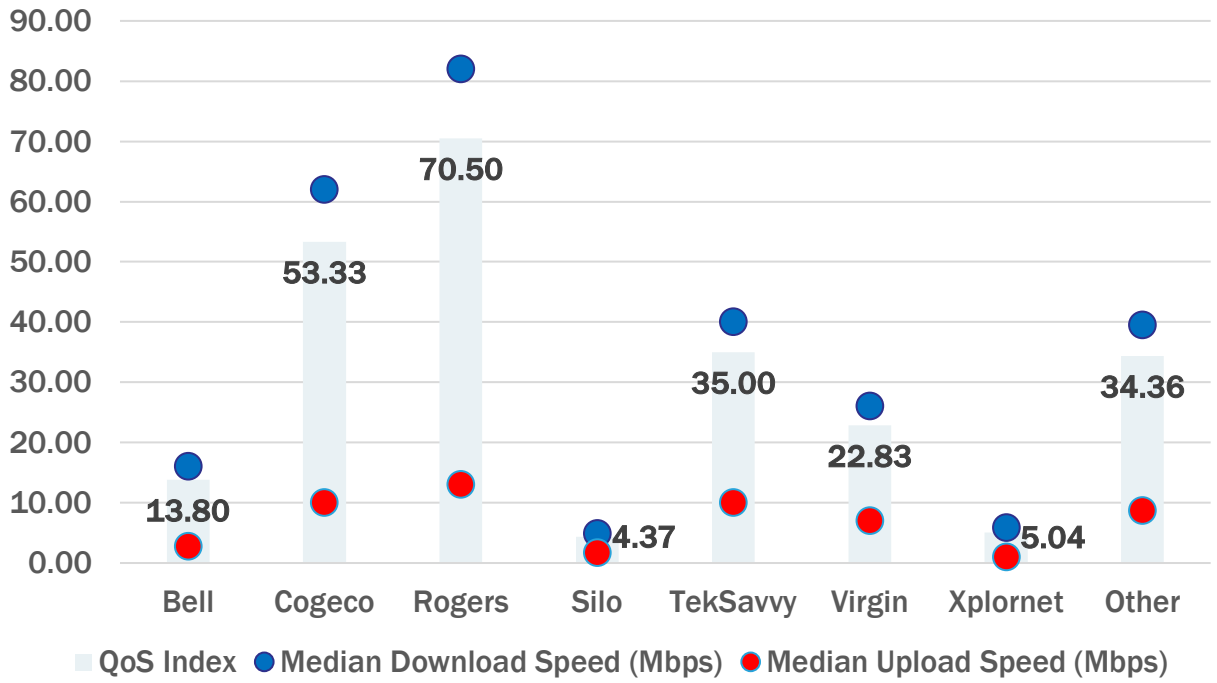
a) Less than a third of the respondents, effectively 29.9% of survey responses achieve 50/10 Mbps and 50 ms.
b) Visualized on Map D1 Distribution of Responses with/without 50/10 Mbps, there is low achievement of the BSO level of service in rural Hamilton with only 9.4% of responses at or above 50/10 Mbps.
c) With more than half a million M-Lab Internet performance test results (2020-April 2021) Hamilton's median download speed is 36.1 Mbps with a median upload speed of 9.30 Mbps and median latency of 28 ms
d) Our survey results find the following residential user results: 29.5 Mbps download, 8 Mbps upload and latency of 19. Only on the latency indicator is Hamilton above the BSO, and this is due to the influence of higher-speed connectivity in urban Hamilton.
e) We conclude that, based on the Hamilton 2021 Broadband Study results, about two-thirds of Internet users in Hamilton fall below 50/10 Mbps.
f) We also note that an Internet connection is not available at 2.3% of the surveyed residential premises. These are both urban and rural premises.

In total, there are 107 survey identified service providers identified in Hamilton using unique ASNs (autonomous system numbers) from the M-Lab data sources over the period of January 2020 to April 2021 (see Annex 6). Some ISPs are mobile wireless providers only. For all of Hamilton, half of the respondents indicate that Internet service falls short of the ISP guaranteed "best effort" performance. Download speeds were achieved at "best effort" service levels in 50% of responses, and upload speeds were higher, at 57%. There is a significant difference with achieving guaranteed speeds when we compare urban and rural responses. Urban respondents have download and upload speeds within "best effort" levels in 56% and 65% of responses, respectively. For rural respondents, these values are 39% and 44%, respectively. This result implicates that half of all respondents across Hamilton would agree that they are not receiving guaranteed, "best effort" broadband services and rural households fall well below even this level.

Approximately 50% of Hamilton residents surveyed potentially have access to higher broadband connection types such as fibre or cable modem. Based on data collected in the

study, connection types have a significant influence on quality of service. Using Internet performance test data reported in the residential surveys, even with the acknowledgement of errors in respondents' identification of connection type, cable modem services are widespread in Hamilton and have a higher quality of service as summarized in the index presented in Figure 3.

Figure 3: Quality of Service Index by ISP



Note: Only includes ISPs with more than 30 respondents. The QoS Index is created using a weighted average of median download and upload speeds for each respective ISP. This weighted average mirrors the CRTC basic service objective for download and upload speeds of 50/10 Mbps. Similarly, the QoS Index weighs download speed and upload speeds at a ratio of 5:1 or, more simply, that download speed is five times more influential for quality of service than upload speed.

We conclude that based on current residential survey results, users with DSL, satellite and fixed wireless are experiencing lower quality of service. Fixed wireless and satellite account for just under half (45.4%) of the primary connections for the surveyed rural Hamilton residents. It is noted that nearly 13% of rural Hamilton residents rely on mobile broadband for primary use, compared to 0.51% of urban residents.

4.2 Affordability of Broadband Services

Where there is available Internet access, the consumer considers affordability of the broadband services, particularly if there are high costs associated with set-up and data overage costs. As data collected in the study suggests, on face value, the monthly recurring cost for Internet compares favorably between Hamilton's urban and rural areas. Mean monthly cost for all Hamilton users is approximately $106 ($101/month for urban and $114/month for rural).

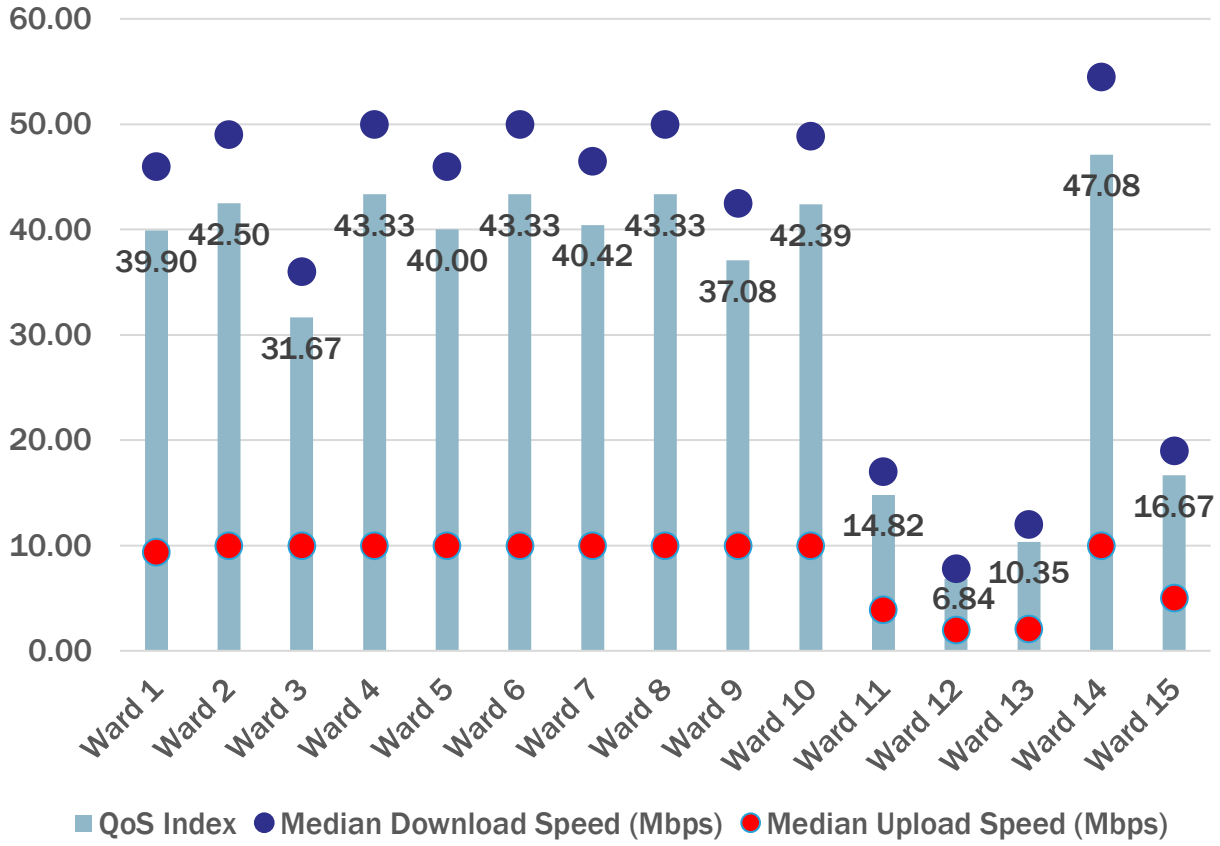
Approximately one-fifth (19%) of users surveyed have a data cap on their primary connection. Compared to other regions (e.g., Durham Region at 32%) this is lower. The mean monthly cost for users with a data cap is marginally more expensive, an additional $6.50/month, compared to users without a data cap. The costs are higher for users who go over their data allowance because they have overage costs, on average, at the high-end $118.24/month, and at the low end, $55.03/month. These costs can be twice to five times as high for rural users whose average costs are higher at $124.97 (high end) to $57.21 (low end). On this overage cost indicator Hamilton users are about $15-20 per month higher than other regions (e.g., Durham Region 2020 data comparisons). The findings suggest that rural users with a data cap and overages are paying, on average, the cost of another Internet subscription, because they have data caps and incur overage costs.

We conclude that rural Hamilton users are disadvantaged, compared to urban residents in terms of excessive costs for low quality of service. Mean monthly costs across Hamilton obscure the real household level cost of Internet services. Affordability of service should take into consideration the quality of service at an overall cost that includes data overages and set up costs, and the foregone benefits of bundled services.

4.3 Internet Access by Ward

Significant disparity exists when examining quality of service by the fifteen wards within Hamilton. More specifically, Wards 11, 12, 13, and 15 have a quality of service significantly lower than the remaining wards. In the most pronounced example of this disparity, Ward 14 has a quality of service index almost seven times higher than that of Ward 12. Unsurprisingly, the wards with the lowest quality of service indices are those with higher rural household percentages whereas the urban wards have higher index levels.

Figure 4: Quality of Service Index by Ward



Note: The QoS Index is created using a weighted average of median download and upload speeds for each respective municipality. This weighted average mirrors the CRTC basic service objective for download and upload speeds of 50/10 Mbps. Similarly, the QoS Index weighs download speed and upload speeds at a ratio of 5:1 or, more simply, that download speed is five times more influential for quality of service than upload speed.

We also examined the M-Lab dataset by community download speed, upload speed and latency (Figure 2 above). We conclude that this evidence suggests that there are rural-urban and intra-rural digital divides. While several wards have median service levels at 50/10 (43.33 on the QoS index) there are 11 wards that fall below this standard. Even within the rural wards significant disparities exist. For example, Wards 11 and 15 have a QoS index value more than double that of Ward 12.

See, Map F1: Ward Level - Download Speeds for Residential Respondents
Map F2: Ward Level - Upload Speeds for Residential Respondents
Map F3: Ward Level - Distribution of Latency for Residential Respondents
Map F4: Ward Level - Distribution of Residences that Meet the BSO (≥50/10)

Figure 5: Monthly Cost by Ward

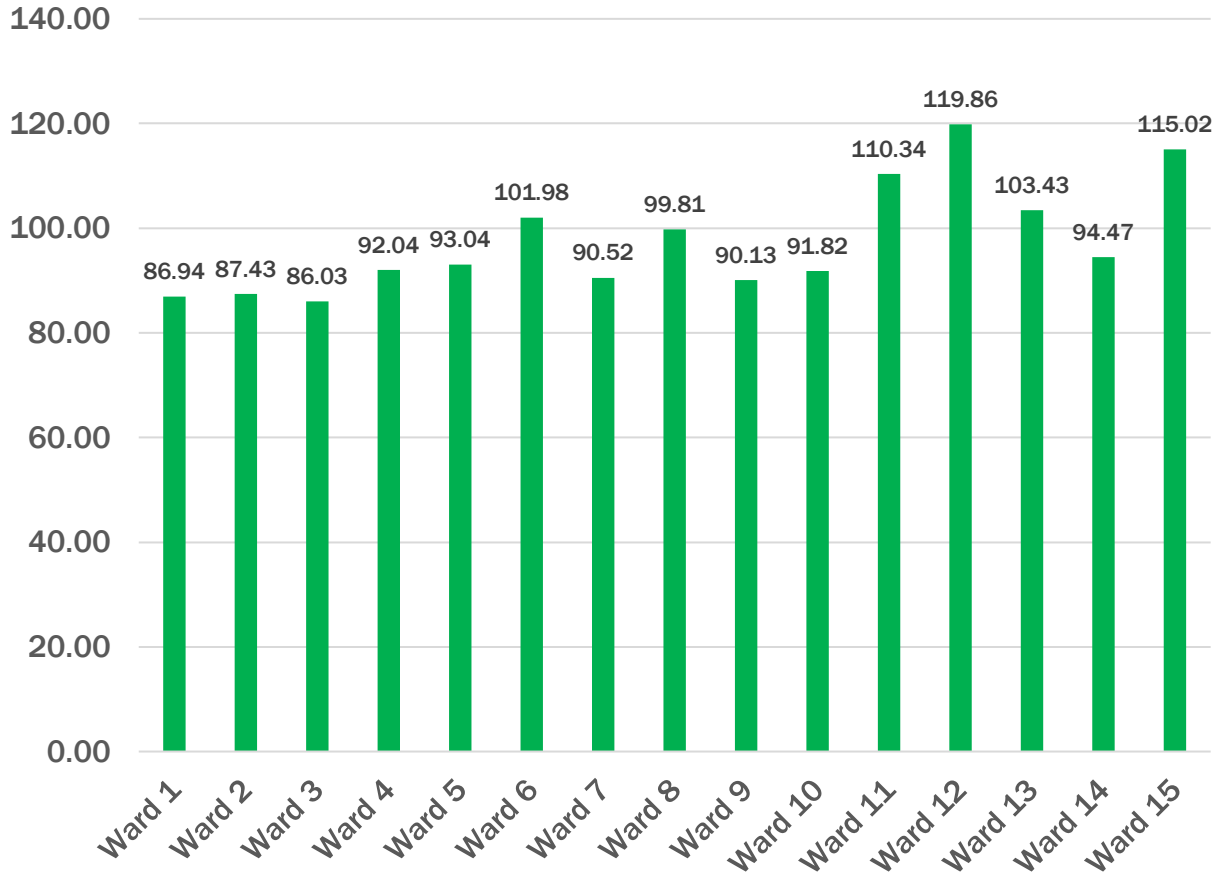


Figure 5 provides evidence of the disparity in monthly costs across wards. Importantly, the wards with the lowest quality of service (Wards 11, 12, 13, and 15) also tend to have the highest monthly costs. Monthly costs are also highly variable across the urban wards. This is of particular concern in reference to the "Code Red" areas of Hamilton. This will be assessed in the collaborative City of Hamilton and R2B2 Project, University of Guelph 2021 research project funded by SSHRC. We noted that there are 73 public wifi access points, most of which are in predominantly urban wards and within urban boundaries. Some "quick-build" solutions such as public wifi in more rural locations, including at designated parking/rest areas near public walking and bike trails may be considered.

4.4 Internet Access and Social and Economic Opportunities

The residential survey respondents reported that 27% of residential premises operate a home-based business. There was a lack of consistency in this finding given that 9% indicated that their residence has a home-based business and 4% indicated their residential premise was a farm. We can assume that COVID-19 complicates the respondents' understanding of the question.

We did find a notable telecommuting surplus in the Hamilton study. Hamilton has a recorded total telecommuter surplus of $22,406 per annum (first and second telecommuters), based on the specified average number of days telecommuted per week (see Table 25, above Using the telecommuting data, we also identified environmental benefits of telecommuting, and

specifically the carbon off-set. There are over 200,865 commuting workers in Hamilton, 74.4% drive to work and being able to work from home because there is fast, reliable Internet connections could generate a substantial environmental benefit. This area of results may warrant further study to report climate-smart transportation related outcomes in the region.

Our findings found that only a small number of home-based businesses reported a second connection for Internet access therefore, users rely on residential broadband access for business purposes, particularly during COVID-19 work from home. Further study may be needed to understand the longer-term management of work-related costs of data overages during and after COVID-19. This could be influential on workers' perspectives on "work from home" policies and residential connectivity willingness to pay scenarios that are of significant interest to the City's municipally owned infrastructure and ISPs willingness to invest.

Finally, based on the findings of this study there is one area of business, farming, that is highly underserved with faster and reliable broadband and cellular services. Such limited Internet access has potentially adverse economic (plus social and environmental) impact. We found that only one of the farms involved in the study (n=87) achieve service levels of 50/10 Mbps (see Map D1: Distribution of Farm with/without 50/10 Mbps). It was also noted (see Table 2, above) that some agricultural land use is located within or nearby urban boundaries of Hamilton. This is a finding that deserves further study, particularly in the context of Ward 9 and 10. Additional surveys from farms (ideally, a 25-40% regionally distributed rate of response to the survey) would help to assess connectivity constraints on economic activity at the farm level and evaluate impact in agri-food value chains. It is possible that Hamilton could secure agricultural research and innovation grants or co-funding for a digital agricultural land use strategy.

Furthermore, for this study, the current COVID-19 situation adversely affected the receipt of a sufficient number of surveys and attention to social equity concerns where Internet access is concerned. Open Hamilton data indicates there are 73 public wifi locations in Hamilton, most of which are in urban areas. The public wifi strategy should be considered and linked to social equity and we will address this issue in more detail with a collaborative research project between City of Hamilton and R2B2 Project, University of Guelph funded by SSHRC.

Finally, although we included a WTP model in the study, for both the residential and business surveys, more study is needed of household and business valuations of fast, reliable connectivity in Hamilton. Further data analysis may benefit from utilizing MPAC data to examine property values and connectivity variables.

4.5 Strategy Forward

In the short-term, and ongoing, City of Hamilton can aim to deliver on and strengthen its strategic decision-making in relation to "better broadband" with specific action plans to enhance broadband services across unserved and underserved areas of the region. The results of this study support the current activity within Hamilton to move ahead immediately on focused business planning that aims to improve Internet access in the Wards with the greatest digital divides, while achieving overall regional Internet access that respond to social equity and economic opportunities. This type of strategy would ensure inclusiveness for all residents and businesses, in all of Hamilton. As well, moving ahead requires tracking change over time **to use**

"better broadband" to achieve social, economic, and environmental impact. Table 47 provides an example of monitoring "better broadband" indicators that speak to different policy initiatives, and integrating broadband strategies with different policy and program initiatives.

Table 47: Social, Economic and Environmental Indicators for 'Better Broadband"

Indicator Theme	Measure	Indicator (April 19, 2021)
Social	Percent of residential premises without internet access	2%
	*Percent of residential premises with fixed broadband services below 5/1 Mbps	11%
	*Percent of residential premises with fixed broadband below 25/3 Mbps	29%
	Percent of all household levels of income below 50/10 Mbps	70%
	Percent of lower income households below 50/10 Mbps	73%
	Percent of households with seniors below 50/10 Mbps	78%
	Percent of households with school-age children below 50/10 Mbps	71%
Economic	Percent of home-based businesses with internet speeds below 50/10 Mbps	84%
	Telecommuting surplus 1st telecommuter in household	$13,072
	Telecommuting surplus 2nd telecommuter in household	$9,334
	Percent of households with data caps having overage charges exceeding $100/month within past 12 months	66%
	**Property values above $200,000 with residential fixed broadband services below 50/10 Mbps	Not yet assessed
Environmental	C02 emissions saved by telecommuting	2,113 kg of CO2/year for first telecommuter 1,407 kg of CO2/year for second telecommuter
	**Percent of residential premises within environmentally significant* areas below 50/10 Mbps	Not yet assessed

Note: *fixed broadband services refers to fibre, cable modem and DSL services. ** Indicator for further analysis.

4.6 Recommendations for Consideration

Based on the findings of this study, we present the following recommendations:

Recommendation 1: Expand broadband infrastructure in Hamilton's underserved areas, including consideration of municipally owned assets within rural areas.

Based on the responses received in the surveys, residents across Hamilton entirely grasp that broadband is an essential utility for everyday life and livelihoods. Based on the findings presented here, a lack of Internet access in terms of availability, quality of service and affordability is evident in some parts of the region, with considerable evidence of urban/rural digital divides.

Even within the urban areas, there is evidence of performance test levels below 50/10 Mbps. New investments are warranted. In some of these areas, the private sector has little incentive to close broadband gaps, particularly in terms of improved advanced fixed wireless, cable modem or fibre infrastructure. City of Hamilton, working closely with member Wards and lower-tier municipalities, is called upon to negotiate viable and location-specific business cases for broadband expansion. The vision is to achieve and sustain a viable Hamilton network with characteristics of network access such as affordability, quality of service (achieving speed guarantees reliability) with redundant, symmetrical, secure, and scalable infrastructure. Considerations of social equity and Internet access in Hamilton will be addressed in more detail in a separate report.

Recommendation 2: Data collection and analysis is an on-going role and responsibility of sustainable and equitable broadband networks, and yet broadband data is rarely co-financed or subject to sharing for municipal planning purposes under non-disclosure agreements and data licenses by ISPs. All data collected must address economic value and social equity access to the Internet across the region.

City of Hamilton should continue its residential surveys with a shorter "mini-survey" to crowdsource further data on Internet access. The business survey should be re-released post COVID-19. Regular updates of a summary datasheet and key maps are recommended, at least to 2026, which is the end date of current public funding programs. For the business survey, key partners in Hamilton BIAs, Chambers of Commerce, agricultural producers, and business groups within the region are needed to increase the number of residential and business survey responses. We recommend a continuation of City of Hamilton broadband database and engagement with stakeholders in support of "better broadband" and smart city initiatives. We also recommend Open Hamilton data platform include aggregate broadband datasets.

Recommendation 3: To be planning and funding application ready, continue to seek out provider data by issuing a RFI/pre-qualification to ISPs to compare the Hamilton 2021 Broadband Study and MLab user experience datasets and compare data to the National Broadband Internet Availability Maps, which are currently used in federal and provincial funding programs.

Concurrent attempts should be made to collect data from ISPs for at least two key reasons: 1) comparison to user experiences and ISP advertised speeds to actual user generated quality of service data; b) ensure a baseline for public and private sector return-on-investment including assessment of Net Present Value (NPV) of the cost to fill connectivity gaps in the region with scenarios for low, mid-range and high benefit/cost scenarios. In the past, some companies have not responded to a request to share proprietary, location-specific data on broadband services with municipalities without a RFI/Request for Proposal (RfP) process. Therefore, City of Hamilton should organize to source the data and use it for strategic decision-making on Recommendations 1 and 2 and funding applications.

Data also provides a baseline for evaluation of existing and prospective infrastructure development activities with ISPs across Hamilton, for example a determination of the current number of fibre-connected towers in the municipalities. With data collected at the regional level, a "ready to use" pipeline of information is available to location-specific grant applications, program development and government service delivery.[7]

Recommendation 4: City of Hamilton establishes "better broadband" milestones and benchmark change across relevant policy and program initiatives.

Moving ahead will use data to monitor and track change over time so that Hamilton has "better broadband" for achieving social, economic, and environmental impact. This report flagged the agricultural sector as a key stakeholder. Recreational facilities and tourism/leisure is another sector for consideration. Overall, in the Executive Summary and Table 47 there are examples of indicators for monitoring "better broadband" and integrating "better broadband" strategies in relevant City policy and program initiatives is strongly encouraged.

Recommendation 5: A "Part 2" Local Rural Broadband Roundtable be convened after the acceptance and distribution of this final report by City of Hamilton.

In efforts to follow-up and support broadband services for all Hamilton residents and businesses, there should be a follow up to the "Local Rural Broadband Roundtable" held on December 2, 2019, at the Hamilton Technology Centre and convened by the Flamborough Chamber of Commerce. Such a meeting would deliberate on the recommendations presented in this report and propose further actions. It could encourage further data collection to increase awareness about current Internet access constraints, particularly in Wards 11, 12, 13, and 15 where quality of service levels is significantly lower than the rest of Hamilton.

[7] On January 24, 2022 UBF funding was announced for rural areas in Flamborough and Limehouse see: https://www.canada.ca/en/innovation-science-economic-development/news/2022/01/adam-van-koeverden-member-of-parliament-for-milton-to-announce-high-speed-internet-projects-in-rural-areas-near-flamboro-and-limehouse-ontario.html

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ANNEXES

Annex 1: Explanation of Measures of Central Tendency (Mean and Median) for Quality of Service Metrics

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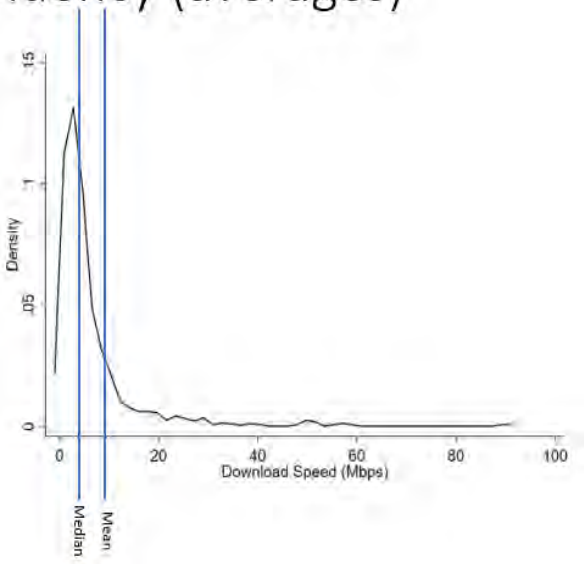
Annex 3: Regression Tables (annex 3b redacted)
Annex 4: M-Lab Quality of Service Data for The City of Hamilton (2020 to 2021)
Annex 4b: M-Lab Quality of Service Data for The City of Hamilton (2021 to 2022)
Annex 5: Final Survey Question - Feedback/Comments from the Residential Survey (Q91)
Annex 6: ISPs Identified in M-Lab Data (January 2020 to April 2021)
Annex 7: Digital Equity in Relation to Network Access: A Summary in Seven Questions

Annex 1: Explanation of Measures of Central Tendency (Mean and Median) for Quality of Service Metrics

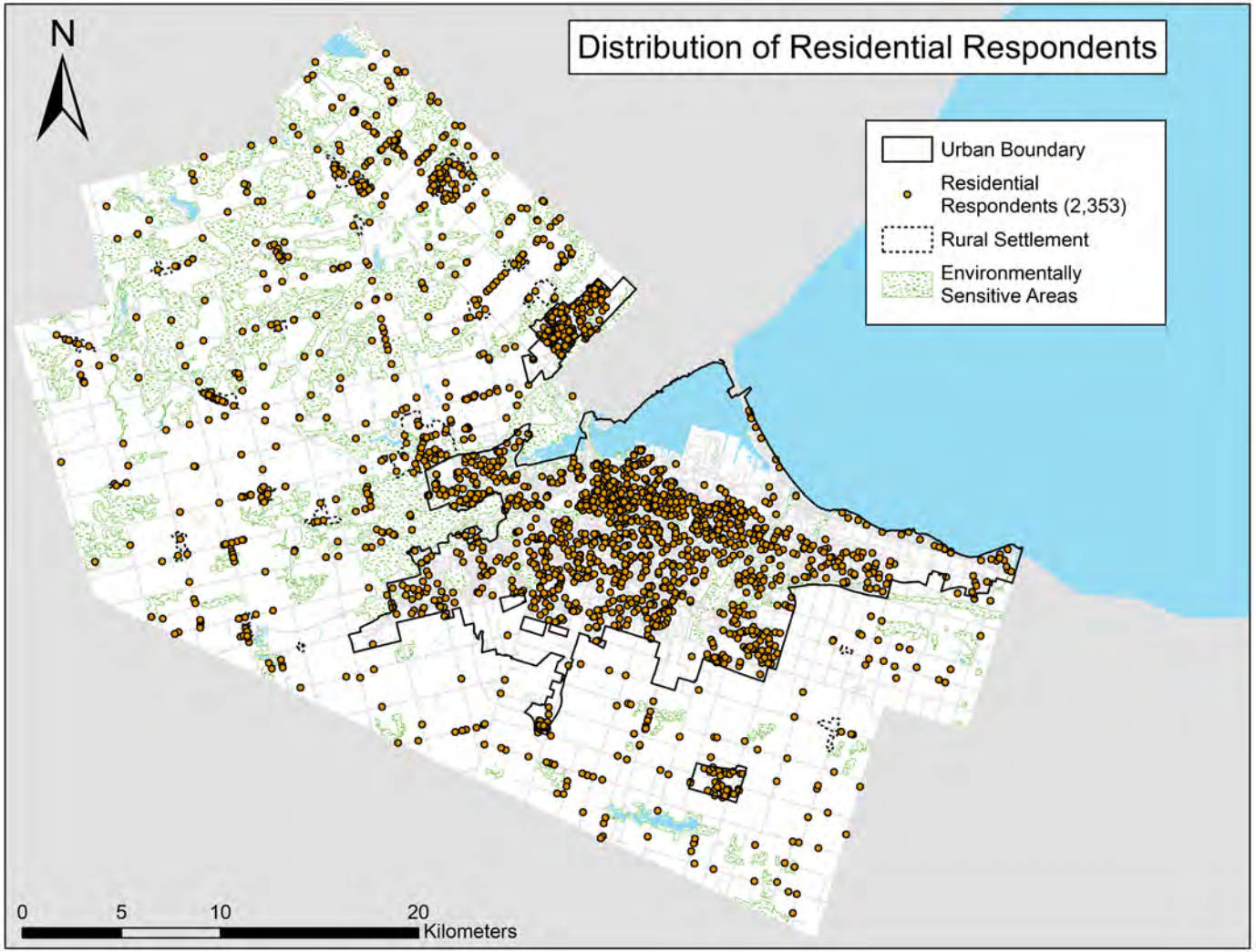
Measures of Central Tendency (averages)

- This report uses median as opposed to mean values where possible to estimate averages for Quality of Service (QoS) indicators and other metrics.
- With some residents having a very high quality of service, the mean value can 'hide' the QoS that the majority of respondents experience.
- The distribution of QoS indicators is said to be 'right-skewed' meaning that the mean exceeds the median.
- This right-skewed distribution means the majority of speed tests are clustered at a relatively lower quality of service while only a few tests have a very high quality of service.

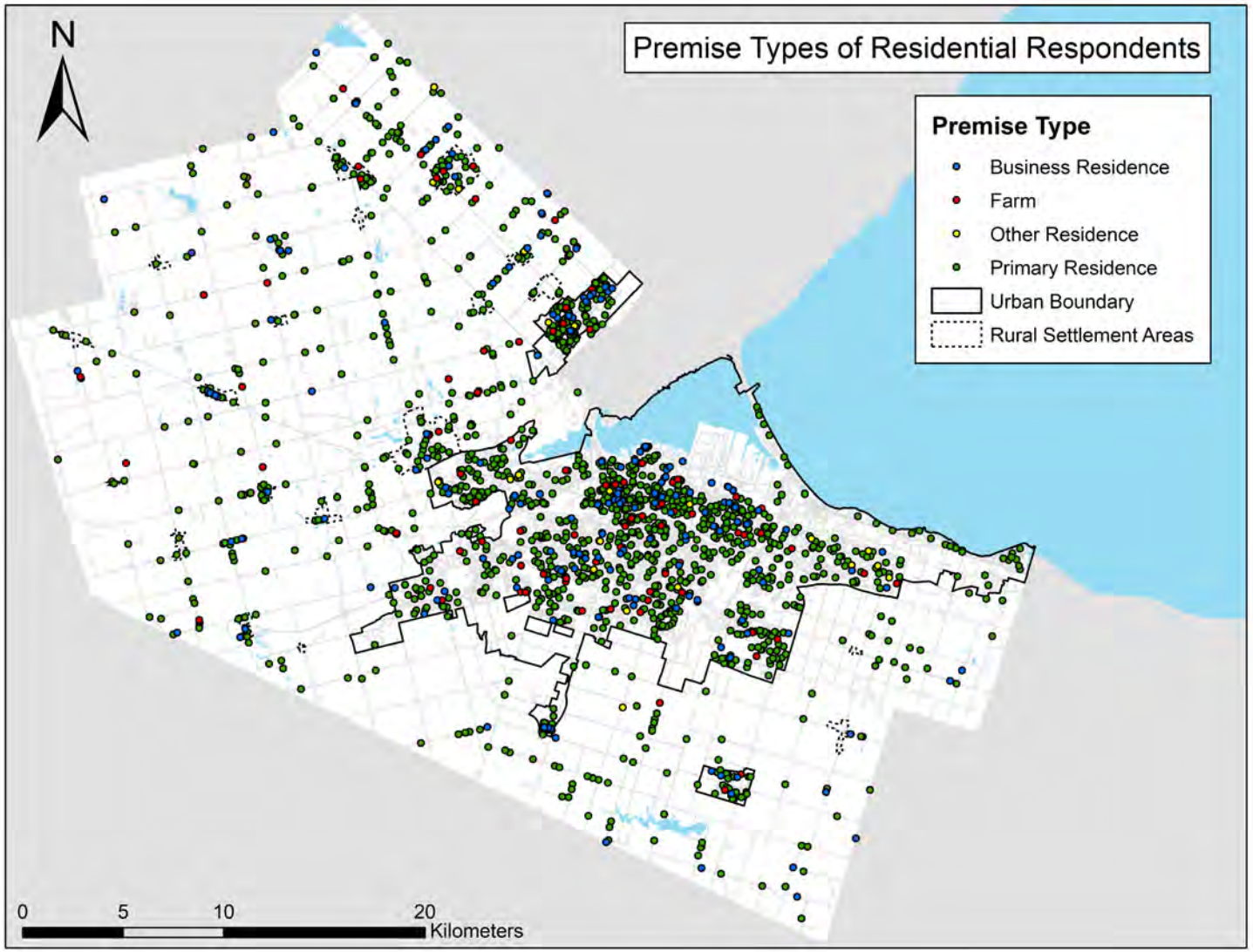


Annex 2: Maps

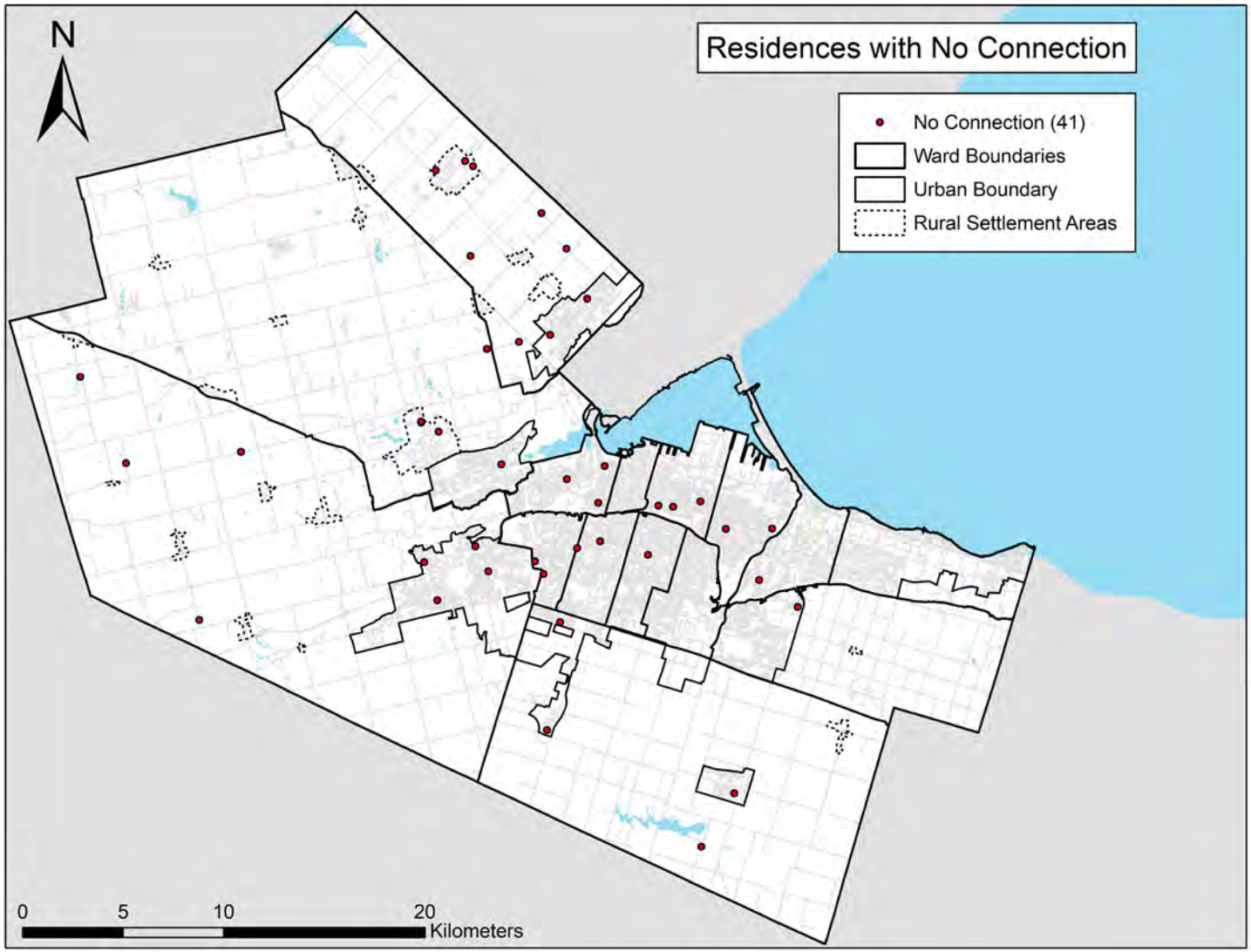
Map R1: Distribution of Residential Respondents



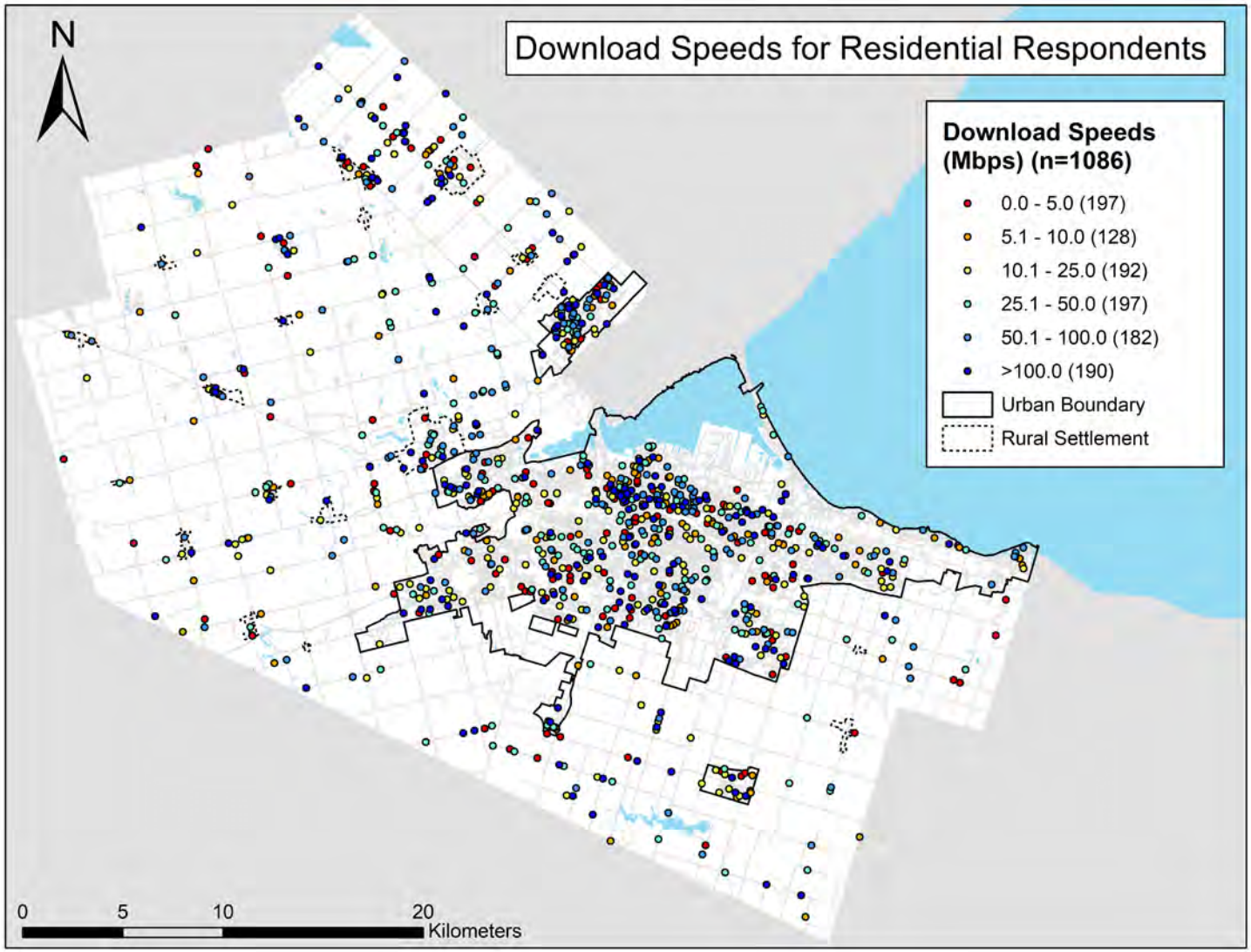
Map R2: Premise Types of Residential Respondents



Map R3: Residential Premises with No Connection



Map R4: Download Speeds for Residential Respondents



Map R5: Upload Speeds for Residential Respondents

Our findings suggest that there is no clear relationship between income level and the quality of service[1] expected by the user. The $60,000 to $125,000 income group has the lowest quality of service index with a value of 59.76 Mbps. The two lower income groups have the second and third lowest quality of service at 62.62 and 66.76 Mbps, respectively. The $125,000 to $250,000 group has an index value of 76.38 Mbps and the more than $250,000 income group has the highest quality of service with a weighted average of 87.12 Mbps (Fig. 4).

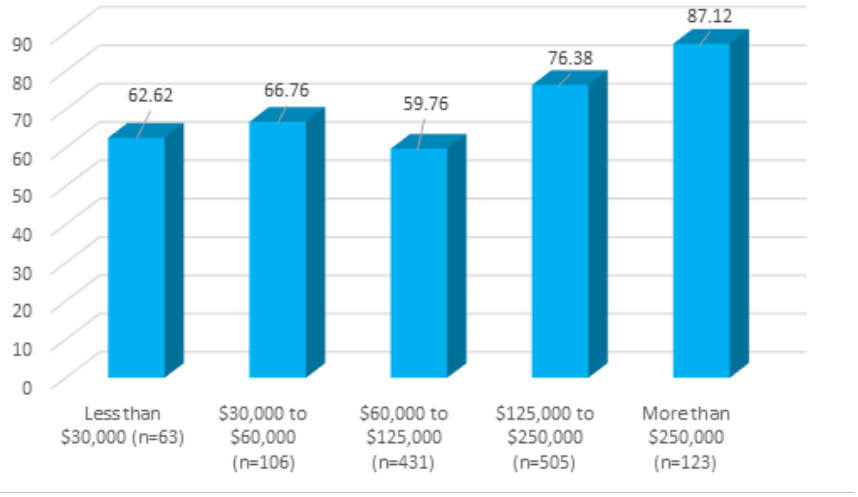


Figure 4: Quality of Service Index, by Income Groups

Conclusions and Recommendations as of March 2022 on Digital Equity

To conclude these seven questions, we could ask one last question based on all these questions: are there households in Hamilton facing digital vulnerability on the basis of where they live, what they can afford and their income level? The answer is affirmative.

We therefore update the main report with the following recommendations and examples of specific actions on digital equity:

- City of Hamilton is urged to continue to engage with all levels of government and MPs and MPPSs to promote and invest in infrastructure to address digital divides (urban/rural) and digital equity issues.
    - This may involve, for example, attention to broadband within wider infrastructure development involving new or upgraded investments in roads, energy systems and housing;
    - Including criteria for affordable broadband in the Canadian Mortgage and Housing Corporation (CMHC) programs;
    - Ensuring that new or upgraded public facilities are outfitted with public wi-fi access.
- City of Hamilton continue its engagement with the Federation of Canadian Municipalities and other coalitions/alliances on digital divides/digital equity.
    - This would include, for example, (i) putting forward to federal and provincial government, the acceleration of strategies for urban, rural and remote connectivity, including attention to farm level connectivity, (ii) municipal

strategies for ensuring digital equity that guarantee Internet access affordability and subsidized telecommunications retail rates at the individual and household levels, (iii) seeking out opportunities to join sector-specific alliances and coalitions organizing on digital equity in health care such as Health Promotion Ontario and the Alliance for Healthier Communities.

- City of Hamilton continue its efforts to collect data and analytics/mapping that informs digital strategies. City staff were successful at partnering with R2B2 project on the SSHRC funded research and similar opportunities may be explored with McMaster University and University of Guelph, in future.