

'Buried Beneath the Waves': Using GIS to Examine the Physical and Social Impact of a Historical Flood

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Introduction

There exists a complex and tenuous relationship between the natural and man-made environments in settlements along river courses. Such communities were sited to exploit the river (e.g. drawing water, generating power, and diverting waste). Rivers originally served as major transportation routes: they were the long-distance highways for the shipments of goods and people in the time before railways, highways, and airways. Rivers and their valleys are also picturesque locales and natural places for leisure-time activities, which are often implicated in the formation of a sense of place for the community. The river can, however, also tear at the town if it becomes unbridled. Rivers are naturally prone to flooding, with water levels breaking their banks and encroaching on low-lying areas.

The social fabric and built environment of river cities are thus linked to, and at the mercy of, their natural environments. Despite great feats of hydrological engineering, such as dams, levees, and spillways to control the natural ebb and flow of rivers, flooding will always be a threat to any river settlement. Great failures of engineering have also been the cause of much devastation; for example, the great Johnstown, Pennsylvania flood of 1889, probably the deadliest river flood in North American history, was caused when the South Fork Dam burst and emptied Lake Conemaugh into the river and town below, destroying 1,600 homes and killing 2,209 persons (McCullough). The Great Mississippi Flood of 1929 was perhaps the most physically destructive river flood in the history of North America: it took the lives of 246 people, displaced over 700,000 from their homes, and caused over four-hundred million dollars (US) in damages (Barry). The aftermath of that flood also profoundly changed race relations and society in the Mississippi Valley (Barry).

Canada has also experienced a number of major historical floods (e.g., Fraser River in 1894, 1948; Saguenay River in 1996; Saint John River in 1973, 2008; and the Red River in 1950, 1997, 2009), but they have not been as disastrous as the major floods in the US, where population and development densities are much higher. The Red River flood of 1997 is perhaps the most noteworthy flood in recent Canadian history; although there were no deaths as a direct result, property damages in Manitoba totalled eight-hundred million dollars. The impact of the 1997 flood was much worse South of the border, where damages exceeded three billion dollars (US). Manitoba fared better in this disaster due to massive investments in flood control after a 1950 disaster; the Red River Floodway was constructed (1962-1968) to divert potential flood waters of the Red around Winnipeg, the capital of the province and home to more than half its population (Brooks et al; Shelby). Even as this article was going to press (in April 2009), the Red River was again engulfing parts of North Dakota and Southern Manitoba; however, the city of Winnipeg appears to have again been spared disaster due to the Red River Floodway.

A major flood struck the Western suburb of London, Canada during the evening of 11 July 1883. Although flooding is most frequent during the spring thaw when excessive rains combine with melting snow to swell water levels, flooding can also occur during the typically dry months. On that historic evening in London, a deluge of rain fell on the upper watershed of the Thames River causing a freshet to race down the river (Ontario Department of Planning and Development 26; London Advertiser, 11 July 1883). Since Canadian summers are typically dry seasons, there was little warning or concern; the residents did not have flooding on their minds, having already escaped the annual spring melt. The flood struck at night, so many residents were at home resting or asleep, unaware of the torrent of water which was about to be unleashed on their community. The flood devastated the area of West London, causing seventeen deaths and rendering many others homeless (Armstrong 152; London Advertiser, 11 and 12 July 1883).

Despite its longstanding impact on the physical environment and urban development of London, very few details are known about this flood. In order to fill this gap in local historical knowledge, we have constructed a multi-layered, historical geographic information system (HGIS) to model the flood and examine where the flood struck, who was affected, and the social repercussions on the area. We begin this article by outlining the benefits and pitfalls of implementing HGIS for researching urban and environmental histories; we then describe our data sources and methodological procedures. Having built the HGIS, we then model water depth scenarios using the three-dimensional capabilities of the system, revealing the social and environmental impacts at each level. Our concluding discussion revolves around the utility of HGIS for recreating historical landscapes and events. We also discuss the repercussions of the flood and show how the community was resilient in the face of catastrophe.

1.0 Geographic Information Systems as a Multidisciplinary Research Tool

Geographic information systems are computer software programs used in the "handling, processing and analysing of geographic data" (Goodchild 301). They are essentially a combination of digital mapping, database management, and statistical analysis software programs that allow for capturing, managing, viewing, questioning, interpreting, and visualizing geographically referenced data in many different ways in order to reveal potential spatial relationships, patterns, and trends. In addition to spatial information, GIS software can also be tasked with temporally referenced data (Gregory and Ell 119). Working in two, three, and four dimensions adds much complexity to the software in comparison to standard database management programs. Implementing a GIS to study the added dimensions of a research question can thus be challenging; however, the pitfalls of using GIS are offset by the potential to enhance identification and analysis of important research questions.

Previous studies of floods have identified both the analytical and data management capabilities of GIS. Liu and De Smedt, for example, used GIS to create a model based on elevation, soil types, and land-uses in order to identify runoff routes through a watershed. Rodrigues and colleagues integrate GIS models of river topography with a regional emergency plan in a web-based system for managing flood events. Zerger and Wealands discuss how GIS should be integrated with other database systems in order to produce a framework for managing the hazards and repercussions of floods. Other researchers have used GIS modelling to complement flood models created with remotely-sensed imagery and sources of hydrological data (e.g. Overton). These examples of previous flood studies highlight how GIS offers researchers the ability to bring together and manage many disparate sources of geospatial data into a powerful tool for spatial analysis and decision-making.

Geographers argue that location and space are critical elements in the analysis of human behaviour (Goodchild and Janelle 4). As interest in spatial information has increased in fields outside of geography, the applications of GIS in research have expanded and diversified considerably; GIS is now being used by researchers across the social sciences, humanities, engineering, and the health sciences in order to reveal the importance of space to structuring the world. In political science, for example, GIS is commonly used to map and analyze voting patterns, such as the distribution of "red" versus "blue states," or the correlation between voter turnout and the distance to polling stations (Gimpel and Schuknecht). In the study of print cultures, MacDonald and Black (2000) have revealed the utility of GIS for examining the evolution of the printed word. Engineers have moved from CAD to GIS for their transportation and infrastructure studies, because it offers enhanced capabilities for dynamic modelling (Lang). Public health researchers have embraced the technology for not only mapping the distribution of diseases and "hot zone" detection, but also exploring the impacts of varying accessibility to health-promoting features of cities such as parks and grocery stores (Cromley and McLafferty; Larsen and Gilliland).

Historical researchers have implemented GIS to reconstruct past environments and study how space has impacted historical phenomena. In fact, an entire subfield of GIS analysis has evolved for historical research, typically referred to as Historical-GIS (HGIS). Historical geographer Anne Kelly Knowles has edited four influential volumes containing many examples of research that uses HGIS: special issues of the journals *Historical Geography* and *Social Science History* as well as the books *Past Time Past Place*, and *Placing History* (co-written with Hillier). These volumes, and numerous other individual papers, demonstrate how GIS facilitates new ways of seeing and explaining the past.

HGIS is often used to map records from nominal data sources containing information on past populations (e.g. censuses, city directories, and tax assessments). Historical censuses have been used as the basis of the National HGIS projects that have been constructed for Great Britain (Gregory et al.), the United States (McMaster and Noble), and China (Bol and Ge; Knowles). These national projects represent massive undertakings, with the transcribing of historical documents into digital format and subsequent geocoding (i.e. assigning spatial coordinates for mapping), and take an enormous amount of time and labour. As such, these projects have generally been constructed by multi-institutional and multi-disciplinary teams, with the goal of making the output available to a much wider group of researchers, in some cases through the internet (for example see <http://www.visionofbritain.org.uk>).

HGIS has also been implemented to study phenomena at the local level. A common starting point is to scan historical cartographic sources for individual cities into digital format and rectify them to modern spatial coordinates. This procedure allows the researcher to use a series of map layers to examine and display physical change over time (see Gilliland and Novak). Since urban areas have historically been more thoroughly mapped (with higher-quality, large-scale cartographic sources more widely available) than rural areas due to their greater density of populations, activities, and investment of capital, individual cities have been the focus of most of the HGIS work at a local level. Unlike the large national HGIS projects that typically use census data aggregated to the county, city, or census tract level, urban applications tend to maintain data on individuals in disaggregated format, therefore allowing for finer-grained spatial analyses. Among the more innovative urban applications of HGIS are those that integrate microdata on individual households from multiple nominal sources with detailed information on local environments. DeBats and Lethbridge (2005) use individual level data and spatial statistics within a GIS in order to study spatial patterns of political behaviour and ethnic residence in two small, pre-industrial cities: Alexandria, Virginia in 1859 and Newport, Kentucky in 1874; meanwhile, Gilliland and Olson (2009) have incorporated statistical analyses within GIS to examine residential segregation at multiple scales in late-nineteenth century Montreal. Other urban applications of HGIS include Hillier's digitization of residential security maps in order to explore racist home loan practices in Philadelphia. Similarly, Orford and his colleagues digitized Charles Booth's infamous maps of London in order to take a closer look at poverty and disease in the Victorian city.

Despite the fundamental limitations of the static, two-dimensional journal page, researchers have also exploited GIS for the representation and analysis of historical landscapes in three dimensions. Three-dimensional models are typically created in order to represent topography using point or contour elevation data, but they can also be used to visualize building heights, population densities, or land-value surfaces (Novak, Gilliland, and Paddle 8-10). In a particularly noteworthy historical application, Knowles and her colleagues created a Triangulated Irregular Network (TIN) of the Gettysburg battleground in order to study how topography influenced the outcome of this historic event.

Datasets in HGIS usually contain both a spatial and a temporal reference even though it is the spatial reference which the software is most adept at handling. Most desktop GIS programs do not handle time elegantly, but there are ways of dealing with these shortcomings (Gregory and Ell 124). Within GIS, the temporal dimension is typically managed by compiling a series of static snapshots at key time periods into a dynamic map series; the evolution or trajectories of certain features are then visualized and analyzed by juxtaposing and superimposing (overlying) successive time layers. When the constraints of the static page are not an issue, such as in an active demonstration, the dynamic map series can be represented as a digital animation. In the remainder of this article, we will examine the impact of the flood by both juxtaposing and superimposing data over different spans of time: that is, analyzing the water levels over one evening and examining the changing location of residents over one year.

2.0 Piecing together information to model the flood

As is often the case with historical research, our understanding of the 1883 flood in London West is hampered by a lack of available data. Records documenting the flood event, as well as the social and economic conditions and built environments of London West at the time of the flood, are especially sparse. As an autonomous suburb, the Town of London West had its own government structure, separate from the larger City of London. Unfortunately, when London West amalgamated with the larger City of London, many of the records of the smaller administrative body were apparently lost. Scholars have also speculated that the flood destroyed some of the community's record books.

Despite the flood's distinction as a major event in the city's history, there has been little study of the social and environmental impact of this flood episode, especially when compared to its political impact (Hives; Stott). This could be attributed to the fact that the record of the flood is so sparse; no one source sufficiently documents the event, and no map displaying the flood limits exists. In order to provide a fuller understanding of this flood event, we have created a Historical GIS that integrates historical and contemporary data sources (Figure 1). Using a contemporary source of data on elevations, we built a three-dimensional topographic model of the area of London West; with this model we raised water levels in the Thames River to several hypothetical heights. Using newspapers reports and photographs of the wreckage, we found that the water depths are validated. The social impact of the flood is also studied by showing who was affected, who left the area, and, if they remained in the city, where they resurfaced.

Contemporary elevation data was used to construct a triangulated irregular network (TIN) that represented the topography of the area at the time of the flood (figure 1). Elevation data was obtained as a GIS file representing contour lines from the City of London's Planning Department. Although no historical source of elevation data is available, it is nevertheless likely that the contemporary measures would be more accurate than historical measures due to improvements in equipment and measurement procedures. Based on contemporary field observations, there is little reason to believe that the topography of the area changed significantly following the flood; therefore, the contemporary elevation data is appropriate for use in this study. Many of the houses in the area today pre-date the flood, thus showing that the area was not raised with fill. The community did build a dyke to protect itself from future flooding (Stott 53). The dyke is present in the contemporary file, but would not change the elevations of the interior of the community in which we are interested. Many of the contour lines for the dyke were removed from the file before using it to create the TIN. This allows for the visualization of the area as it would have appeared at the time of the flood. Further validation of the contemporary file was obtained by comparing it with a 1926 geodetic survey of the area that contained generalized elevation data.

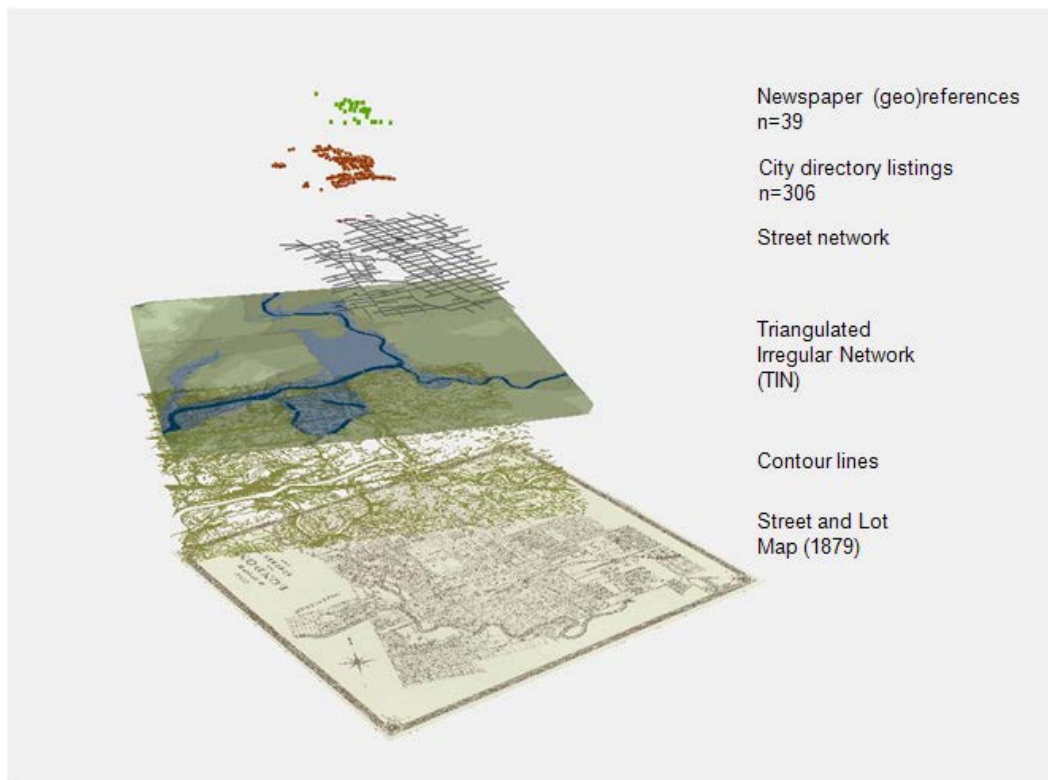


Figure 1. Various data sources are integrated into the GIS as layers of information united through a common spatial reference.

The TIN was created using the 3-D Analyst extension for ArcGIS 9.3 by ESRI. The software takes the elevation data from the contour lines and interpolates what the slopes would be in the missing areas based on changes in elevation and the distances between them. This model is navigable in three-dimensions using ESRI's ArcScene software.

With the TIN constructed it was possible to discern where the flood occurred in the community. In order to show what areas of London West would be submerged at increasing depths of water, we raised water levels at one metre increments. Those areas of the community at the same elevation were expected to be uniformly underwater since water succumbs to the forces of gravity.

The known locations where flood damage occurred were used to validate these water height scenarios. The locations of a series of photographs taken of the damage after the flood were mapped. The locations mentioned in the newspaper reports of the flood were also mapped. The newspaper listed streets that were underwater as well as specific people who were impacted, including those who lost their houses and/or their lives. In order to map individuals mentioned in the newspaper reports, city directories were used to discern the addresses of their dwellings. Since the flood occurred at night, we can expect that most of those who lost their lives did so while residing at home, and were not at work or socialising elsewhere. All the listings in the 1883 city directory were mapped for London West, showing the make-up of the community and allowing for the pinpointing of those mentioned in the newspaper articles.

Whereas the directory listings for those living in the main city contained complete street addresses, the suburb did not contain as complete information (civic numbers were usually missing), thereby confounding the geocoding process. The area, being small and rather disorganized, did not implement a detailed system of civic addressing; the directory listings for London West gave addresses to general position on streets. These locations were frequently identified to the intersection of two streets, such as *SW Cor Dundas and Centre*, or to the street segment, such as *Maple West of Wharncliffe*. Thus, we do not have exact locations for the people listed, but they are plotted within the general vicinity of their home, typically the same blockface. The names and locations of streets were identified from an 1879 map of the city that was scanned and geo-referenced in the HGIS (figure 1). Most of the plotted addresses were accurate to the blockface, or believed to be off by no more than one hundred metres; thus, the lack of civic address numbers did not significantly reduce the quality of the analysis. Of the 321 listings of household heads in the London West directory, 306 (95%) were successfully geocoded.

The social repercussions of the flood were also studied. Population changes in the suburb were traced using the city directories for the years before (1880/1, 1881/2, 1883) and after the flood (1884, 1886, 1887). No directory exists for 1885. Further analysis was done by tracking unique residents of the suburb from year to year in the city directories. This was done to determine if the flood forced people to move, and if so, identify the destination of their move.

With the construction of the GIS complete, including the creation of the three-dimensional model and the mapping of the community's inhabitants and the flood damage, we could begin to piece together the extent of the flood and its repercussions.

3.0 Recreating the flood and exploring the devastation in its wake

As an autonomous suburb of London, London West was both separate from the city proper and highly entwined with it. The suburb was physically isolated from the city by the Thames River, but connected by bridges spanning the river at Blackfriars and Dundas Streets (figure 2). The suburb had its own government, but its inhabitants were reliant upon the city for services and employment since London West had few shops and mills for industry (Stott 890-1). The area was originally two settlements, Kensington to the South and Petersville to the North, both of which were created out of the subdivision of the original farmsteads into building lots that were bought and built upon by a largely working class populous. Since the land was not in the city proper, it would have commanded lower sale prices, thereby attracting a predominantly lower to middle-class population that could not afford the higher land prices in the city (Stott 892).

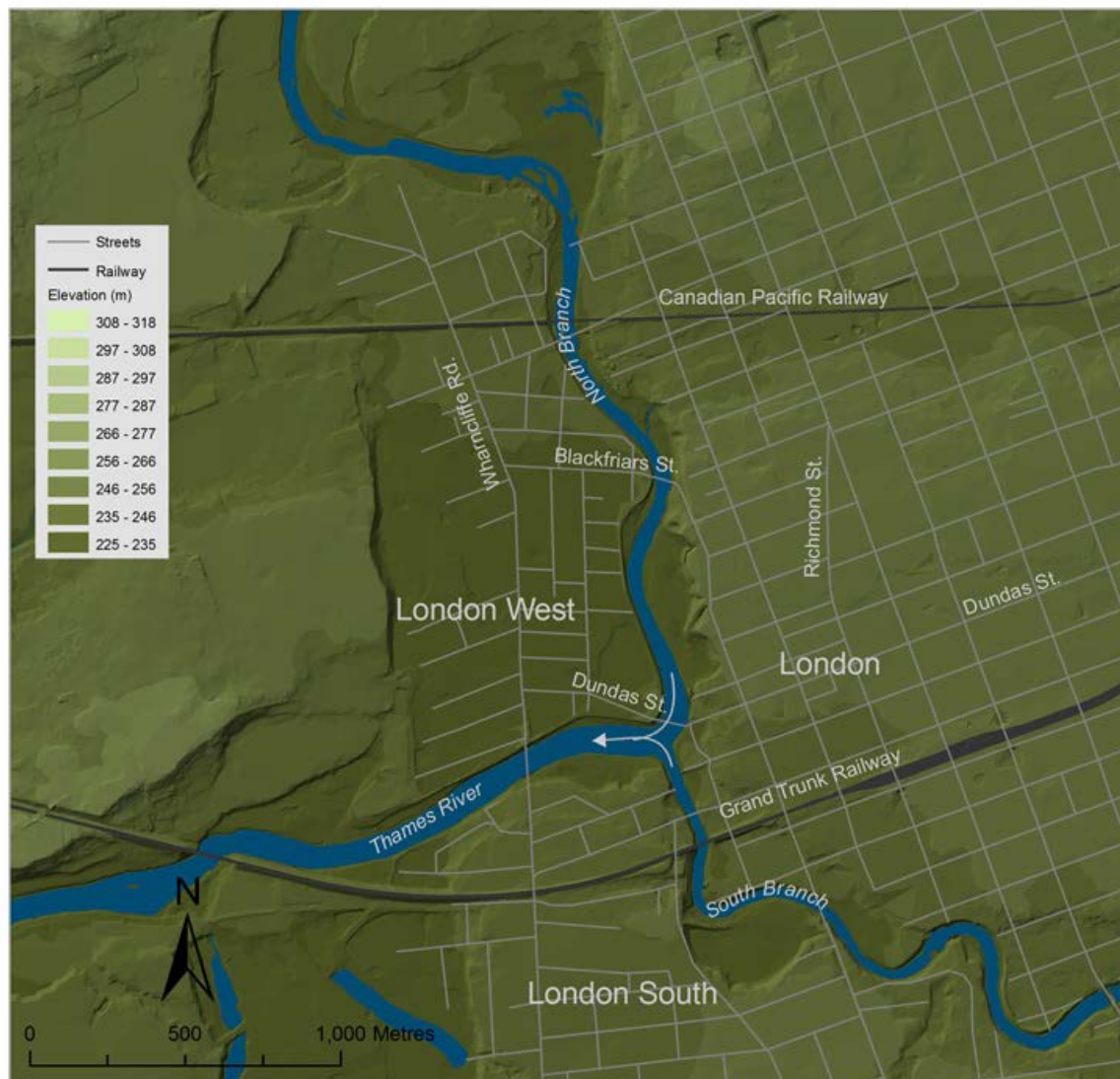


Figure 2. London West was situated on low-laying ground at The Forks of The Thames River, west of The City of London.

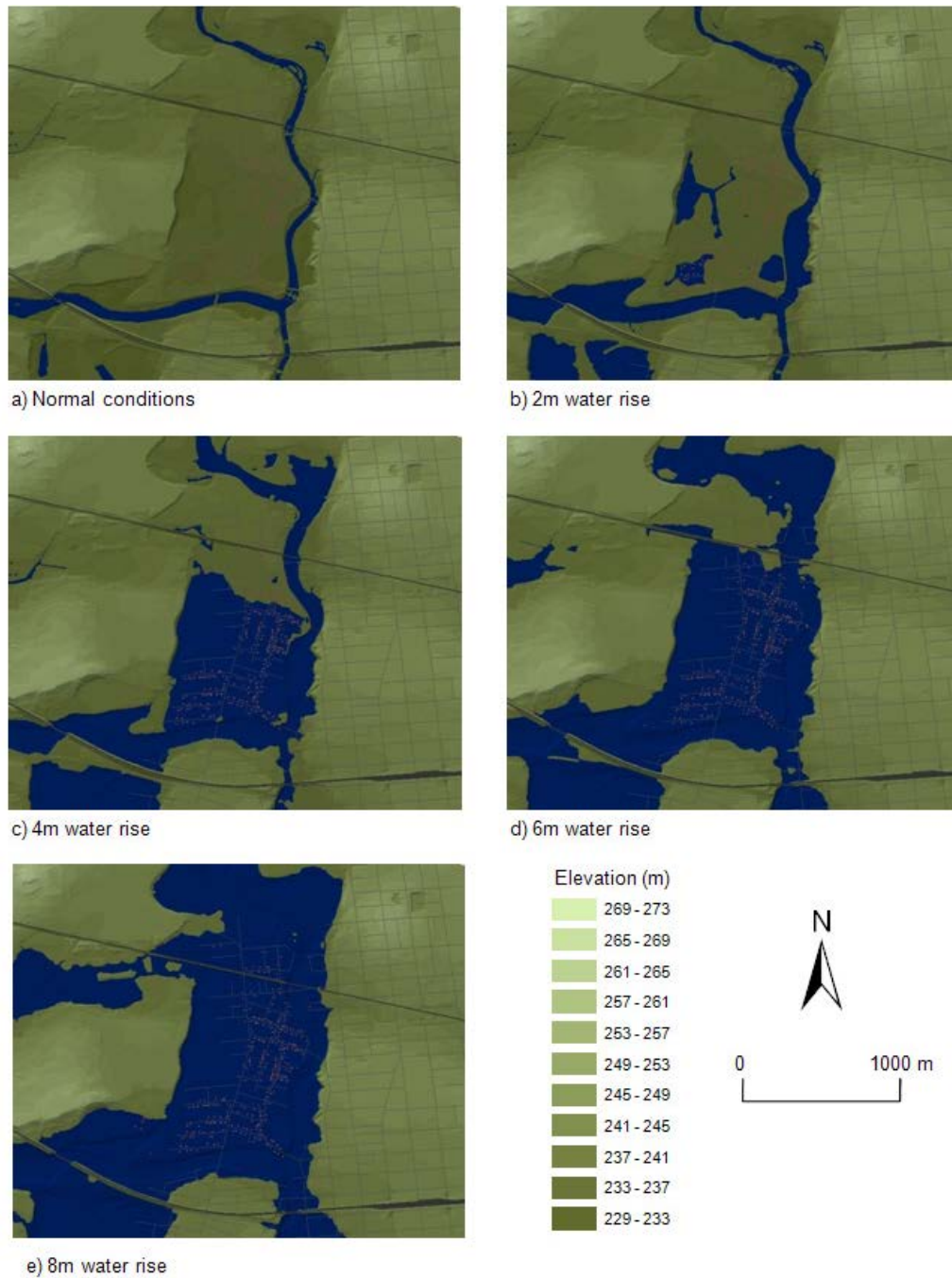
The land was not only inexpensive because of poorer accessibility (to the city centre and its jobs and shops), but also because it was prone to flooding. London West was built on a floodplain where the two branches (North and South) of the Thames River meet (figure 2). While the area offered excellent farmland due to the deposits of high-nutrient soil left by previous floods, it was also a poor site for a community due to its flood-prone, low-lying topography. Directly to the West of the settlement was a ridge that, although high enough not to flood, was also too far from the city centre to be conveniently inhabitable in the pedestrian era (the electric streetcar was introduced a decade after the flood) (figure 2). The city centre of London was spared from floods due to its higher elevation; its hotels would serve as shelter to those forced from their homes by the flood.

Given its unfavourable topography, the suburb had flooded before; however, the flood of 11 July 1883 was the most devastating to date (see Hives, pages 18-32, for a complete list of flood events). A deluge of rain soaked the areas north of the city that drain into the North Branch of the Thames River. This resulted in a freshet racing down the river toward the town. London West would become submerged during the evening, resulting in the area being "buried beneath the waves," as reported in the local newspaper (London Advertiser, 11 July 1883). Seventeen lives were lost in total, and the area suffered severe damage (figure 3).



Figure 3. Flood damage on Blackfriars Street looking west, near Wharncliffe Road. (Source: Archives and Regional Collections Centre, UWO)

Although no records remain of the flood's extent or subsequent damage, using alternate data sources and the analytical power of the Historical GIS we are able to model where the flood likely occurred, and who was impacted. Using the TIN model in ESRI's ArcScene 9.3 we were able to hypothetically raise the water levels, showing what parts of the suburb would be underwater at each level. With a two metre rise in the river level the area would have been relatively unscathed, as would be the result for a four meter rise (figures 4b, c). Were the flood waters to rise to six meters above the normal river level the area would be substantially hit (figure 4d), and if the waters were to rise to over eight meters above normal, more of the area to North would have been underwater (figure 4e).



Figures 4a-e. Rising flood waters were modeled using the TIN

In order to confirm the rise in water levels, we examined newspapers and photographs that indicated where damages occurred. A series of photographs taken after the flood waters receded show the extent to which the built form of the area was impacted by the flood (figure 5). The photographs show devastation along the length of Blackfriars Street, with houses moved from their foundations and even toppled onto their sides. Due to the poorer standing of inhabitants and likely less-stringent building codes than in the City proper, the area was built primarily using wood-frame construction. As such, local buildings were especially susceptible to the power of the flood waters. The flood also destroyed the Dundas Street Bridge, which spanned the river between London West and the City. Since these identified areas would have been underwater at levels of at least six metres, we can assume that the waters had raised at least this high.

Similar validation is provided by newspaper accounts of the catastrophe. The individuals mentioned in the articles were mapped using the city directory listings for 1883 (figure 5). These people were located throughout the community, indicating that the extent of the flood was vast. A cluster of articles related to locations along Blackfriars Street, the same area where photographs were taken, indicated that this area was especially hard hit. It is interesting to note, however, that inflicted people were scattered across the area. From this evidence, it appears that the flood waters caused devastation not just to this one area, but to nearly the entire suburb.

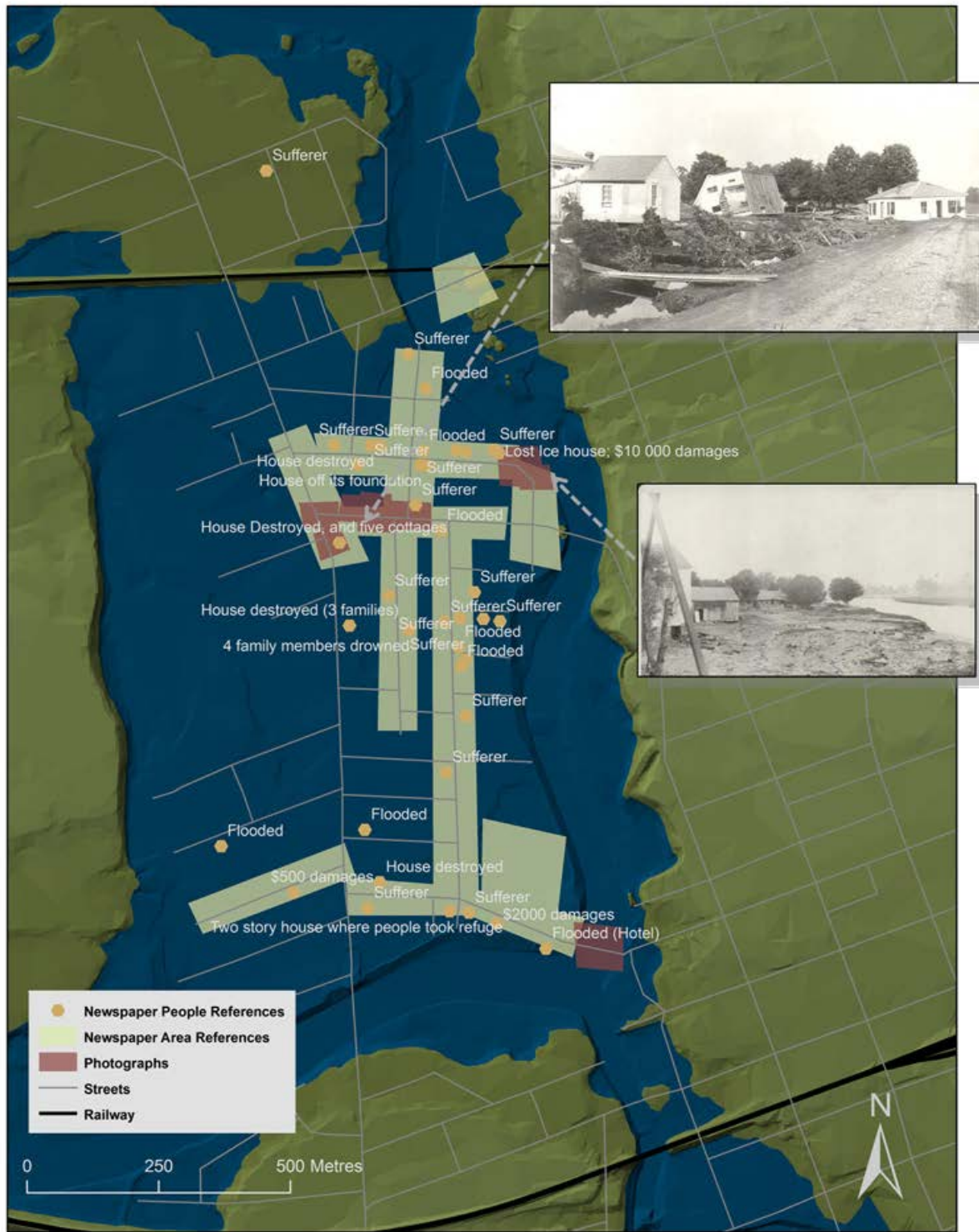


Figure 5 Georeferenced photographs and newspaper articles confirm which areas were flooded.
 Sources: J.J. Talman Regional Collection, University of Western Ontario; London Advertiser 1881.

Validated with historical photographs and newspaper accounts, our GIS model indicated that the river likely rose at least six metres, and possibly eight or more metres over normal heights during the flood. This would have left much of the suburb under water. If the waters had risen six metres, then 274 of the residents listed in the city directory, 90% of the community's inhabitants, would have been flooded. If the waters had risen eight metres, nearly all of the community would have been submerged.

After a flood or other catastrophe, the social fabric of a community is always disrupted. The seventeen lives that were lost would have touched nearly all those who lived in the closely knit community. Furthermore, many people were left homeless after the flood. The newspaper reports of the hotels across the city being filled with the refugees, some of whom were there for some time (London Advertiser, 13 July 1883: 1).

The capital investment would have been wiped out from these structures, causing significant financial strain to their owners. Flood insurance was not commonly used in America until the late 1890s (Manes 156). Thus, there was no ease to the financial strain placed on those people who suffered property loss. While the flood waters swept some buildings right off their foundations, it also caused serious problems to structures that remained standing. Water would have leached into

walls, destroying wood and plaster work. The dirty water left behind, full of refuse swept through the river, would have posed a major health risk. Especially worrisome was the contamination of the community's wells, which provided its drinking water. A sanitary committee was struck, lead by Peter Bryce from the Provincial Board of Health, in order to ensure that no epidemic occurred and lead the clean-up, making homes habitable after the flood (Hives 51).

Despite the flood covering much of the area, the year after the flood there was still an increase in the population of London West from the year before, as determined using the city directory listings (table 1). People were likely forced to leave the community in order to find shelter; however, they and/or others quickly moved back to the area. By 1886 the population was significantly larger than it was before the flood (table 1). This shows that, although the flood was damaging, the effects were only short-term.

Using the HGIS we were also able to trace inhabitants from year to year, in order to determine if they remained in the area after the flood. Compared to other years, the annual rate of household persistence at an address appeared to decrease due to the flood (table 1); therefore, the flood clearly caused many "forced moves" (Gilliland). The locations of those people who moved between 1883 and 1884 were mapped, revealing clusters of those who moved (figure 6). A total of 116 residents persisted in their original residence after the flood, 16 households moved to another location within London West, and 31 households moved elsewhere in the city. Finally, 143 households who were present in the 1883 directory did not reappear in the 1884 directory for London West, the city proper, or any of London's other suburbs. Some of these disappearances may have been the result of outmigration from the region or death, whether due to the flood or other causes. Furthermore, we assume that enumerators may have missed a large number of dispossessed individuals who were residing in temporary lodgings after the flood, whether hotel, boarding house, or "doubling up" in the homes of friends or relatives. Those households that we could identify as "movers" after the flood appeared to be clustered in the central-north area of the neighbourhood near Blackfriars Street, and another area in the south end. It did not appear that anyone from the most northern section of the neighbourhood – also the highest ground – was forced to move after the flood, suggesting that this area was not significantly damaged.

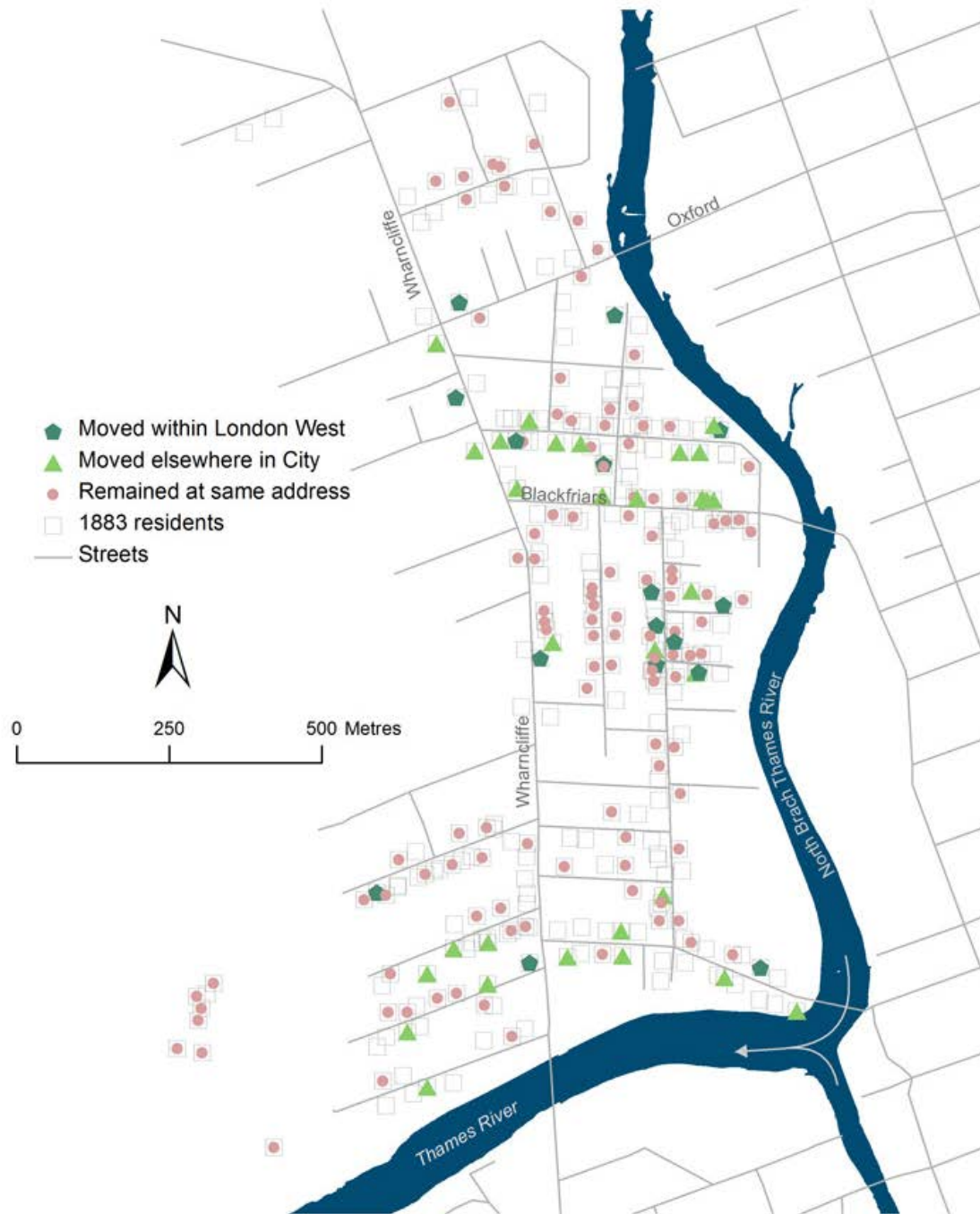


Figure 6. Persistence of London West residents between 1883 and 1884 was determined using the City Directories.

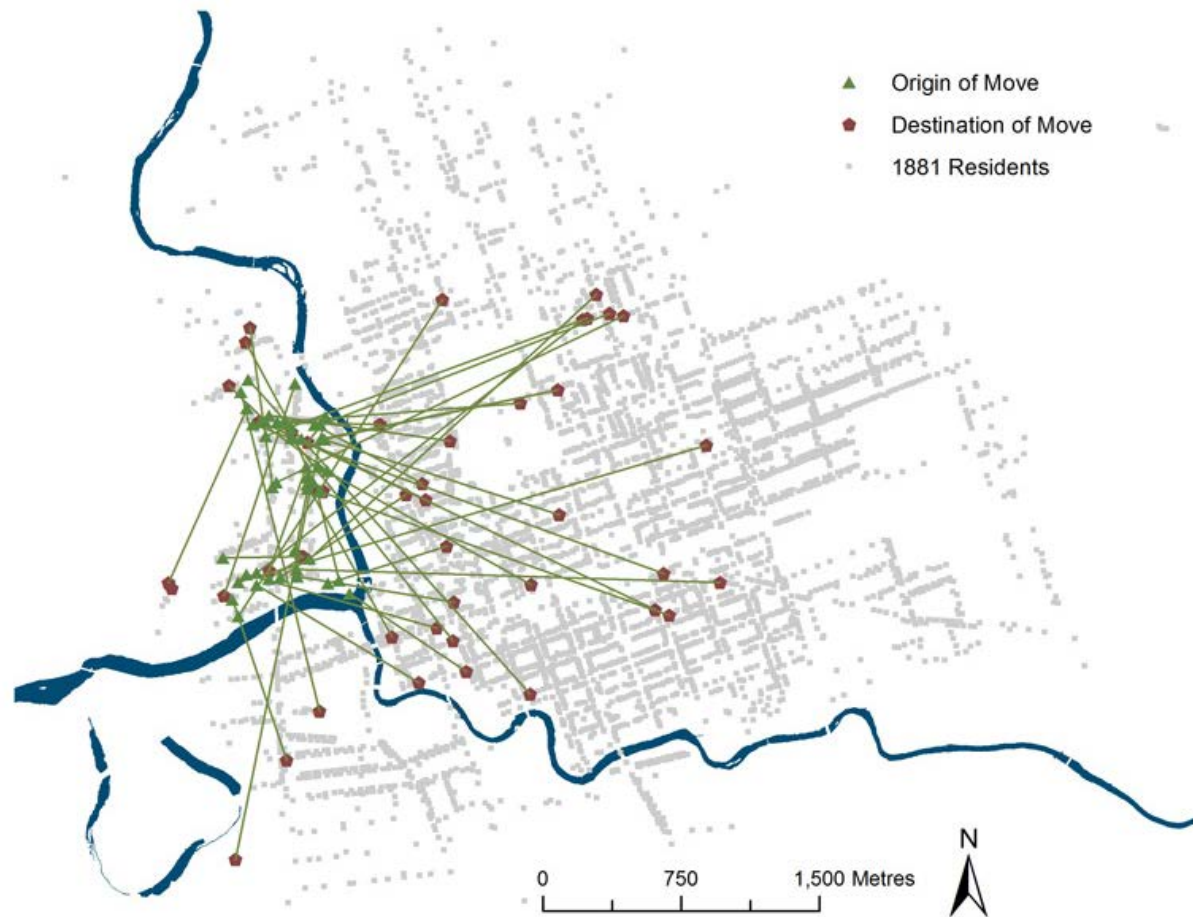


Figure 7. The movement of people following the flood indicated by lines from origin to destination. It is shown that most moves were close to their origin rather than randomly throughout the city.

Figure 7 maps where the movers from London West appeared in London after the flood (excluding those who disappeared from record). The majority of those who moved out of London West stayed within the western section of the city proper, still fairly close to the suburb. We had expected that a significant number of households may have moved to London East, another working-class suburb, due to its similar socio-economic status and housing stock as London West; however, this was not the case, and demonstrates the importance of 'proximity' to movers, likely for maintaining existing social networks. The average distance of the move was 1178 metres; whereas, the average distance to all other addresses in the city was 1748 metres. A comparison of these distance measures reveals that movers did not relocate randomly throughout the city, but chose to remain close to the community from which they originated.

4.0 Discussion and Conclusion

Key details of this historical flood event are missing from the popular histories of London; it is arguable that this omission is not due to lack of interest, but rather the limited nature of available data, and how existing data has previously been viewed. By implementing an HGIS we were able to piece together a number of historical documents in order to model the flood and examine its impact on London West.

Using a three-dimensional model we found that flood waters likely rose to at least six metres above their normal heights. This height was confirmed by photographs and newspaper articles that show that areas at this elevation were flooded. With waters reaching this height much of the suburb would have been under water, and over 90% of inhabitants would have been directly affected by the flood.

Community rebuilding was necessary after the flood waters receded; the built fabric and social fabric of the community both had to be patched. As construction materials act like wicks, sucking the flood waters and causing severe damage, many houses and shops needed to be dried out and repaired. Other structures were torn from their foundations. One intriguing newspaper story included a quote from Mr. McLean, who was standing along the riverbank near Dundas Street watching the flood: "Gracious Heavens! There's a woman in that house and she has a lamp in her hand" (London Advertiser, 11 July 1883: 4). Miss Wright's house was swept away in the torrent of water while she was still trapped inside. Also of critical concern in the aftermath of the flood was the availability of drinking water, since the wells from which the suburb drew its water were contaminated. Lye was used to try to reduce the contamination.

The flood actually had several positive benefits for the community. This flood pressed the community to erect a dyke, which still stands today, to protect the community against future flooding (Stott53). Stott argues that this massive construction project drove the suburb to secure amalgamation with the city in order to cover the costs that the small community could not afford.

In the aftermath of the flood, newspaper articles declared that it would take years for the suburb to get back on its feet (London Advertiser, 11 & 12 July 1883). The population figures and persistence rates for the area show otherwise. Within two years after the flood the population of the area was actually larger than before the flood. Residential persistence rates returned to a steady level following the spike in the year of the flood. Reports of the damage and long-term effects were sensationalized in the local press. Natural disasters have long been big news stories, whether they are floods, wildfires, hurricanes, tornadoes, or earthquakes. The predicted impact of the flood on the suburb was overstated, undoubtedly to generate interest and sell papers.

Using a Historical GIS to study the flood revealed a piece of the city's past which had largely been buried in the layers of time. The recreation of the extent of the flood depicts the magnitude of its damage; the visualizations of the flood waters rising and submerging most of the town are especially powerful. This research also demonstrates the utility of implementing a Historical GIS to study past urban conditions and events; it is an especially valuable tool for piecing fragmented data

sources together, thereby allowing gaps to be bridged in the historical record. By mapping the persistence of residents following the flood, this work also adds to the body of knowledge on residential mobility in the Victorian era; few historical studies have previously examined dynamics of forced moves. Finally, studying the flood reiterates the complex relationship between the built and natural environments.

The flood which struck London West in 1883 is but one example of the tenuous relationship between human developments and the natural world. The area on which the settlement of London West was built was prone to flooding, a fact known by its settlers; another flood had just struck the village of Kensington in March of the same year (Ontario Department of Planning and Development 25). It was only after this much more devastating flood that action was taken in order to attempt to control future damages by constructing a dyke to protect the village. By revealing the devastation that was wrought by one flood event, this study makes it clear that humans must be cognisant of the relationship between settlements and their environment.

Further work is proposed that looks at the impact of the flood on the social characteristics of the area. The changing composition of households in West London could be examined to see if the flood caused crowding or doubling up of families under one roof. Furthermore, it would be possible to study how the impact of the flood varied among households of different socioeconomic status, or household heads of different occupational rank. Unfortunately, the historical record of the built environment of London West is sparse. If this information were available, it would be interesting to examine the physical damage, and any morphological changes introduced during the rebuilding process.

Without GIS, our analysis of the flood would be much more limited. The software supported the creation of the TIN model, using existing contour lines, that were subsequently used to analyze and visualize water depths. The GIS was also used to manage the spatially referenced databases containing information about residents of the suburb and locations of newspaper stories. The visualization capabilities allowed the model to be viewed in three dimensions. The integrated databases on populations and the physical environment of the city also allowed us to perform analyses that revealed the distances residents moved and the number of individuals directly impacted by the flood. All these tools helped re-write the story of London's "great flood" of 1883; nevertheless, GIS does have a host of disadvantages. The software is generally expensive and has a steep learning curve. Furthermore, building a GIS, historical or otherwise, takes a large time and resource commitment. In contemplating the effort required to build an HGIS, we recommend that a researcher not begin the venture with only a single question in mind; rather, it is wise to share databases and effort amongst a larger team, in order to tackle several research questions which still remain unanswered.

Historical GIS is a powerful tool that can be applied to the study of urban history; it is also applicable to many other fields. Combining it with other novel analytical techniques can bring traditional historical studies into the digital era. It provides a platform on which spatial relationships can be viewed and analysed, and past landscapes can be virtually reconstructed. Using such a system allows a deeper comprehension and testing of established theories surrounding the development of the city. GIS also allows entirely new research questions to be posed, and answered, that would otherwise not be possible.

Year	Directory Listings	Persist Following Year	Persistence Rate (%)
1881/2	327	133	40.7
1883	321	131	40.8
1884	360	225	62.5
1886	513	253	49.3
1887	562		

Table 1: Directory Listings indicate the number of households in London West. They were also used to determine if the household remained in the community in the following year. Source: London West City Directory 1881/2 – 1887.

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