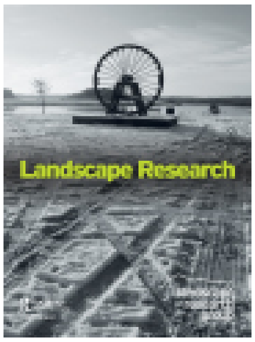

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Mind the gap: tools for a parcel-based storm water management approach

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ABSTRACT
In the Great Lakes Basin, a legacy of industrial use and localised depopulation has created a unique set of needs around storm water management and neighbourhood stabilisation. Vast quantities of vacant land present an opportunity for projects that can address either or both problems. Urban vacant land has its challenges: decision-making related to selecting project sites is complicated, and the structure and distribution of vacant land favour small projects that can work in aggregate. Here, we describe decision-making for two storm water management projects that utilise small, distributed vacant parcels in Great Lakes cities. The first showcases the collection of novel data that were standardised among sites and users. The second utilises a hierarchical approach to data analysis that exploits available data-sets and could be applied at increasingly finer spatial scales. Both projects prioritise components of site selection processes that could have broader applicability basin-wide.

KEYWORDS
Green infrastructure; storm water management; data collection; site selection; neighbourhood stabilisation; vacant land; Great Lakes; data analysis; tool development

Background

The Great Lakes of North America contain 21% of the world's fresh water (US Environmental Protection Agency [USEPA], 2012) and have been one of the region's most important industrial transportation routes for over two centuries, connecting inland ports with the eastern seaboard. From the late 1800s through the mid-twentieth century, population density in the Great Lakes Basin swelled with the rise of steel-related industries. More recently, competition in the global market has led to regional de-industrialisation, which has taken a serious toll on the social and economic conditions of the basin and its residents. Combined with the effects of residential desegregation in the United States (US) during the Civil Rights movement, urban centres began to lose population to suburban areas and other regions. This loss of industry and population has left many urban centres in the region with a dwindling tax base, high levels of poverty and unemployment, and several thousand hectares of vacant and abandoned urban land.[1] With this vacant land comes decreases in property values, visually blighted neighbourhoods, and the associated negative effects on crime and human health (Branas, Rubin, & Guo, 2012; Branas et al., 2011).

Concurrently, urbanisation and industrialisation of the region have negatively impacted the water quality of the Great Lakes. Because development within the region boomed at a time before separated sanitary and storm sewers, many cities contain combined sewer systems. To prevent backflow and flooding during high-volume storm water events—when storm water flow rates exceed water treatment

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capacity—untreated sewage and storm water from the combined system are released into adjacent water bodies. Of more than 700 combined sewer communities in the US, 182 are located within the Great Lakes watershed (USEPA, 2008). Combined US and Canadian annual combined sewer overflow (CSO) volume into the basin has been estimated at 70.8 million cubic metres (Lyandres & Welch, 2012) and 91 million cubic metres (MacDonald & Podolsky, 2009). Excessive CSO—judged by a combination of CSO volume, number of events, timing of events, and local conditions—are in violation of federal regulations (USEPA, 1994). Within the past decade, the USEPA has begun to use the 1972 Clean Water Act to force municipalities with excessive CSO to produce CSO mitigation plans, which are especially important given projections of increased storm water volume as a result of climate change (USEPA, 2008). This forced accountability has pushed cities within the basin to re-evaluate their storm water infrastructure and begin implementing billions of dollars in upgrades, retrofits, and new facilities (USEPA, 2001).

Initially, CSO compliance projects came in the form of large storage tunnels designed to hold peak event flow until volume fell within the capacity of water treatment facilities. Systems of this type are still being planned and constructed by several cities in the basin, including Akron, Cleveland, Detroit, Chicago, Fort Wayne, and Toledo. Great Lakes cities are also exploring the use of 'green' infrastructure to reduce the number or size of pipes (which in this context are referred to as 'grey' infrastructure); these cities include Milwaukee, Buffalo, and Gary, as well as cities that are concurrently building storage tunnels. *Green infrastructure* involves the use of natural systems—or engineered systems that mimic natural processes—to manage storm water, permitting more local infiltration and using plants and soil to clean, evapotranspire, or reduce water velocity and erosion. Because many of the techniques associated with green infrastructure are still considered to be experimental and unproven, it has been a challenge to argue that green infrastructure should 'count' for CSO mitigation compliance in a way similar to grey infrastructure. However, use of green infrastructure for CSO compliance has been facilitated by a growing body of evidence for the benefits of green infrastructure that extend beyond wastewater volume reductions to improvements in water quality and urban health (Jaffe et al., 2010). The goal of this paper is to showcase two ongoing projects by the authors and their colleagues in the Great Lakes Basin that attempt to link storm water management and vacant land mitigation through the process of strategic site selection.

Urban green infrastructure for storm water management and neighbourhood stabilisation

Urban storm water management necessitates the engagement of urban residents to ensure that the needs and concerns of sewer/storm water rate-payers, as both funders and service recipients, are adequately addressed. Increasingly, post-industrial cities in the Great Lakes Basin are looking for common solutions to vacant land and storm water management, with an understanding of the neighbourhood implications these projects could have. As a result, two approaches to green infrastructure as a method for urban vacant land reuse are emerging: projects that collect storm water from many parcels and route it to a single, large storm water management feature; or networks of distributed, disconnected projects that collect and manage storm water from immediately adjacent surfaces.

The first approach makes use of existing large commercial or industrial parcels, or aggregates of adjacent smaller, residential/commercial parcels. Aggregation of large tracts of residential and commercial land is difficult, as ownership varies among parcels (a problem that land banking has helped with enormously, but has not eliminated). These large parcels are also more likely to require expensive remediation compared to residential parcels because of past industrial or commercial land uses (however, elevated soil lead level is a consideration for any type of urban land). Regardless of the type of vacant land being used, large storm water installations necessitate significant infrastructure costs—such as those associated with localised sewer separation and pipes that discharge filtered storm water to waterways or back into the sewer system—and an increased expectation of permanence. If considering social engagement, larger projects can also be more spread out while still achieving the same storm water quantity controls, thus becoming destination locations that require considerable travel as opposed to being accessible to local communities.

As an example of a large built storm water project, the city of Cleveland, Ohio and the encompassing Northeast Ohio Regional Sewer District (NEORSD) are using green storm water infrastructure on vacant land to mitigate at least 170 000 cubic metres of annual CSO volume out of an overall goal of 20 million cubic metres annually (USEPA & The State of Ohio v. Northeast Ohio Regional Sewer District, 2011). The focus of their approach centres on large projects that often require the aggregation of numerous vacant parcels (NEORSD, 2012), with the goal of 'improv[ing] the overall health, welfare, and socioeconomic conditions' of these neighbourhoods through associated co-benefits (USEPA, 2013). The basin contains other examples such as the Menomonee River storm water park in Milwaukee, Wisconsin by William Wenk and Associates. This project incorporates pedestrian trails and waterfront access into a brownfield redevelopment site that treats storm water from a much larger basin. In Detroit, the development of scenarios that transform entire neighbourhoods of vacant land into lakes for storm water management have been formally proposed (Detroit Works Project, 2012). What these projects share in common is their attempt to address storm water mitigation with projects consisting of large singular parcels or aggregates of many smaller parcels.

In contrast, a distributed storm water management approach makes use of a type of vacancy that comprises the vast majority of urban vacant land—small, disconnected residential parcels. For example, in Cleveland, 85% of vacant land exists as one to three contiguous parcels, and less than 4% of vacant land aggregates are greater than 0.2 hectares in size (Figure 1). While residential parcels are least likely to require expensive remediation, aggregation of large numbers of parcels presents a logistical challenge regardless of adjacency. However, because a distributed approach manages storm water run-off closer to where it is generated and in smaller volumes, it does not require sewer separation, discharge, or associated infrastructure costs. In transitional urban environments where the future of land use is unknown, the smaller size and lower cost of construction associated with dispersed sites could make it easier to convert them from one function to another without tremendous financial losses. At present, this model of green infrastructure most commonly consists of medians or roadside green spaces in the right-of-way to collect run-off from streets and sidewalks; examples of this approach can be found in all cities that have experimented with green infrastructure but are common in Chicago and Milwaukee.

Another possible advantage to distributed green infrastructure is that these smaller, distributed projects offer a higher level of engagement with existing neighbourhoods, thus providing more opportunities for interaction with residents. A growing body of research from cities that have excess land vacancy due to population loss or urban sprawl indicates that certain types of urban greening projects that are tailored for storm water management may also have strong effects on *neighbourhood stabilisation*. For this project, we consider stabilisation to be the process of achieving quantifiable improvements, such as increased property values or decreased crime rates, to a neighbourhood that

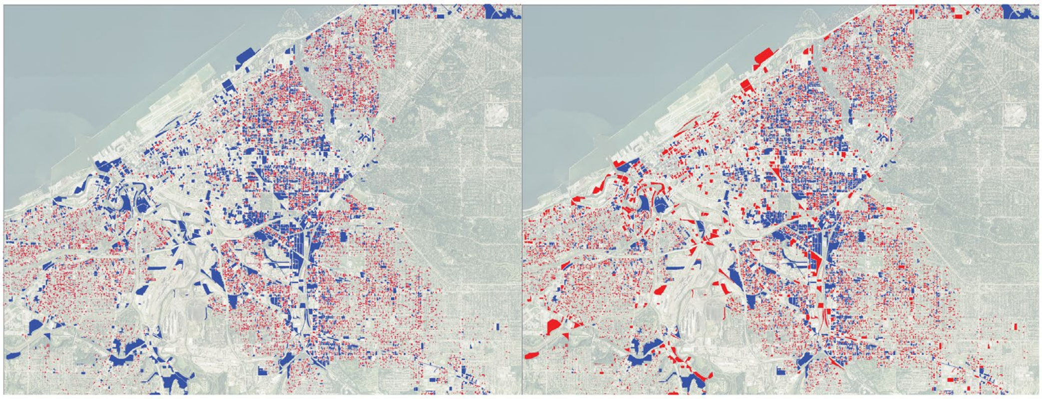


Figure 1. Comparison of aggregated vacant land of varying sizes in central Cleveland. Vacant land is highlighted based on size and number of parcels comprising aggregates. Left: red = <0.2 hectares; blue = all other vacant parcels. Right: red = <3 contiguous parcels; blue = all other vacant parcels (Aerial imagery © 2015 Google).

has undergone depopulation and/or economic hardship. In Philadelphia, vacant land that was 'greened' and managed in conjunction with the Philadelphia Green project was shown to decrease certain types of violent crime (Branas et al., 2011) and increase property values (Wachter, 2004). In Baltimore, research from the Baltimore Ecosystem Study points to a decrease in crime rates as tree canopy is increased (Troy, Grove, & O'Neil-Dunne, 2012). More recently, a study in Philadelphia showed reductions in public safety incidents up to one kilometre from green storm water infrastructure installations compared to untreated vacant parcels (Kondo, Low, Henning, & Branas, 2015).

One difficulty of a distributed storm water management approach is that selecting appropriate sites is complicated by the very large pool of potential locations—up to tens of thousands of vacant parcels—that are heterogeneous across multiple gradients and scales. While singular, distributed parcels are common within most cities, the pattern and distribution of these parcels vary considerably from city to city, making it difficult to generalise solutions that span scales (Burkholder, 2012). Storm water conditions within cities also vary considerably, with CSO volume spanning several orders of magnitude among watersheds (NEORSD, 2012). Several other studies have demonstrated considerable urban subsurface heterogeneity in cities including Baltimore (Pickett et al., 2008) and Cleveland (Shuster, Dadio, Drohan, Losco, & Shaffer, 2014). Such variability is due to wide-ranging conditions of topography, surface permeability, infrastructure location/condition, and soil characteristics that are further shaped by parcel-level land use histories. Site selection for any green infrastructure project is important, as each site is different and factors such as urban substrate, hydrology, land use, and community involvement all play large roles for potential success. The same is true for small, distributed green infrastructure projects in the urban environment, where a high level of variability in both distribution and physical conditions of sites require parcel-based assessments and interventions. In many cases, site selection is the most important factor for the success of green infrastructure projects. This paper will now look more specifically at two projects that prioritise site selection for parcel-based storm water management strategies.

Strategic project placement for a distributed storm water management approach on urban vacant land

The success of projects for storm water management and neighbourhood stabilisation depends on a number of social and environmental factors that operate at various spatial scales. Strategically locating small projects within a large urban region poses many challenges and, yet, is imperative to the effectiveness and long-term success of these projects. In the dynamic and productive history of the city, all sites are not created equal.

Here, we discuss data collection and analysis methodologies that were coordinated by the authors and their colleagues and utilise a variety of data to guide project placement on vacant land in urban areas of the Great Lakes Basin. The site selection methodologies presented here are novel (to the best of the authors' knowledge) and were formulated in response to the collection of known outcomes from distinct types of urban greening projects that were outlined previously (see 'Background'). By working backward from intended project outcomes to site features that have been associated with these outcomes, a collection of desired sites features was created. While, at present, the emergent social and environmental properties of distributed storm water management systems are poorly understood, measuring such outcomes is a longer term goal for both of the projects presented in this paper. Some aspects of these methodologies are project-specific; however, they are presented here as case studies that may prove useful for tool development and site selection for distributed storm water management more generally.

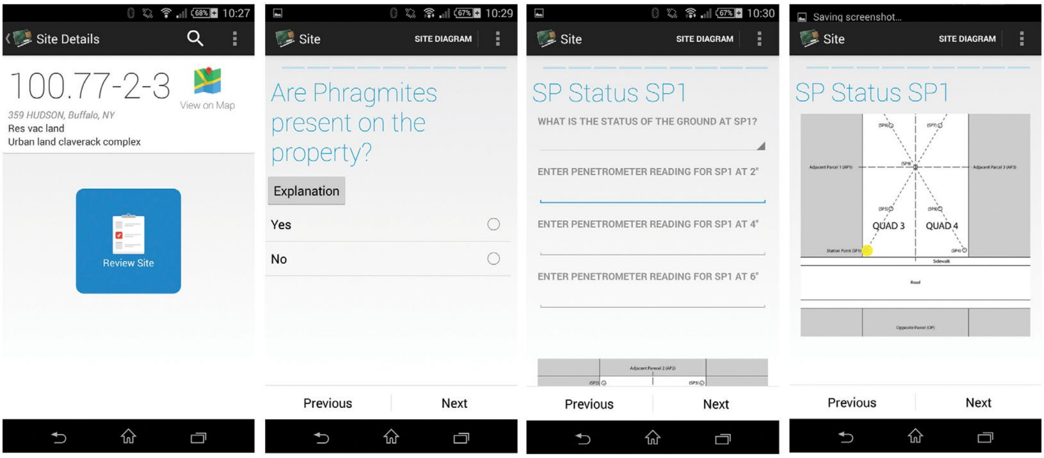
Buffalo vacant lot assessment project

Overview

To better understand lot-level variation in storm water management options, the city of Buffalo, New York received a technical assistance grant from USEPA in 2014 and teamed with the University at Buffalo to explore the possibilities for a web-based tablet application to aid in the assessment of existing site conditions of over 5 000 vacant parcels demolished between 2001 and 2013. This collection of parcels constituted more than 220 hectares of land and is believed to be one of the largest ground-truthed data-sets of vacant land ever generated. The team of collaborators included Tetra Tech Engineering, USEPA, Cyprus North Digital Marketing and Development, The City of Buffalo, and the University at Buffalo. The primary motivation behind this assessment was to generate a high fidelity data-set describing the storm water performance of post-demolition parcels. Buffalo is the first municipality in the United States where USEPA has approved the process of demolition as a method of CSO mitigation. The project data-set will be used to refine the city's storm water model. Under the current model, impervious surface area is based on land use type—prior field studies supported an assumption of 95% impervious surface area for streets and parking areas and 5% impervious surface area for vacant demolished properties (Buffalo Sewer Authority [BSA], 2014). Other land use assignments ranged between these two extremes. While acknowledging variability among different land uses, it treats parcels within each classification the same; thus all vacant land is assumed to have 5% impervious surface area. However, the permeability of vacant land within the urban environment is affected by site history, demolition technique, contractor, and soil types, among other variables, which all affect the generation of storm water run-off. Because of these factors, it was decided that a more fine-grained understanding of vacant parcels would improve storm water model estimates. An enhanced level of detail about vacant parcels will also allow for the establishment of site-specific baseline storm water performance standards that must be met when re-development occurs.

Methodology

The development of the Vacant Land Assessment Protocol tablet application was seen as essential in order to maintain the quality and comparability of data collected on a large number of sites, over a long period of time, by a changing list of assessors. The application utilises a streamlined set of choreographed instructions that were designed to maximise efficiency, thus limiting the time necessary on each site. The application also requires a pre-determined range of inputs, thus making the data collected less subjective (Figure 2). Sites were systematically sampled to capture the range of conditions found on vacant lots, from long-standing lawn to the footprint of the demolished structure. To accomplish this, a generalised site diagram and station point system was established. Two transects were run from corner to corner in an 'X' across the site. Station points were established at the ends of these lines, at the intersection, and midway from centre to corner along each transect, generating nine station points that were used throughout the sampling and assessment process. The transects also delineated four surficial



100.77-2-3

359 HUDSON, Buffalo, NY

Res vac land

Urban land claverack complex

Are Phragmites present on the property?

○ Yes

○ No

SP Status SP1

WHAT IS THE STATUS OF THE GROUND AT SP1?

ENTER PENETROMETER READING FOR SP1 AT 2"

ENTER PENETROMETER READING FOR SP1 AT 4"

ENTER PENETROMETER READING FOR SP1 AT 6"

Saving screenshot...

SP Status SP1

Figure 2. Screenshots from tablet application for Buffalo Vacant Lot Assessment during beta testing.

zones on the site that could be used to describe the locations of notable characteristics. In addition to this general set of inputs, there were also opportunities within the application to input more specific observations to provide clarity or to report dangerous conditions in need of immediate response by the city. To achieve a robust yet time-sensitive assessment of the storm water performance of individual lots, two types of assessments were developed: a detailed assessment that consisted of instrument-derived qualitative data, and a rapid assessment that consisted of a subset of the detailed assessment and focused primarily on qualitative, observable characteristics. These qualitative characteristics included:

- overall visual assessment of land cover;
- location of high and low points on each parcel, including areas of standing water;
- location and distribution of particular invasive, hydrophilic plant species; and
- specific land cover conditions at the nine station points;

The detailed assessment included the above characteristics as well as:

- elevation change from the centre of the property to corners, measured with a 2× magnification hand site level and a grade rod (accuracy to ± 3 centimetres);
- soil compaction at five[2] randomised sampling locations using a single-mass dynamic cone penetrometer, which quantifies compaction in both pounds per square inch (psi) and California bearing ratio (CBR);
- soil conductivity (K), measured using a Decagon mini disc infiltrometer; and
- soil texture, using the US Department of Agriculture (USDA) flow diagram for soil texture by feel (USDA, 2015).

Other data were pre-loaded into the application, such as recent rain events, site demolition date, and the demolition contractor. With this composite data-set, a range of valuable assessments were possible. Relating the data to geospatial information allows for pattern recognition opportunities and spatial relationship analysis. Some of these opportunities are straightforward, such as the relationship between groundcover and soil compaction, while others could be more speculative. For example, with the data collected, connections were made between demolition contractors and invasive species that are propagated through the fill soil they used on vacant parcels. However, even the most normative use of the data would allow a more accurate understanding of the storm water processes at the scale of the individual parcel, sewershed, neighbourhood, or city, thus allowing for further calibration of the storm water model for the city and better regulatory decisions.

Results

This project is still largely underway. To date, approximately 33% of 5 000 parcel assessments have been conducted, with 23% done as rapid assessments and 13% done as detailed assessments. While the total number of parcels in this study seems vast, it is only one-third of more than 1 300 hectares of total vacant land in Buffalo (BSA, 2014). Presently, the sample set is not yet large enough to generate any strong conclusions and no rigorous statistical analysis has been conducted on the sampled data to date, as the data collection process is still underway. However, the Buffalo assessment project builds on the assumptions inherent within this text—that individual discontiguous parcels have potential to quantifiably address storm water management issues present in many legacy cities and that a better understanding of the individual characteristics of these parcels will lead to more resilient and effective solutions.

Vacant to Vibrant project

Overview

The Vacant to Vibrant project centres around developing and monitoring a cluster of three distributed vacant lots in each of three US Great Lakes cities: Cleveland, Ohio, Gary, Indiana, and Buffalo, New York. At its inception, the project was notable for its utilisation of distributed vacant residential and commercial parcels for green storm water infrastructure, as well as its attempt to maximise and balance benefits in the areas of both storm water management and neighbourhood stabilisation. The project is still in progress; analysis of multiple environmental and social measures will attempt to describe the effects of small green infrastructure installations on ecologic and community factors.

Of relevance to this paper is the method for selecting project sites for Vacant to Vibrant, which has attempted to standardise selection factors among three disparate cities with varying existing conditions and data-sets. Goals for the site selection process included: identifying three treatment parcels, as well as three parcels that would remain vacant for comparison, out of a potential pool of up to 25 000 vacant parcels per city; identifying novel social and environmental data-sets for green storm water infrastructure; and creating methods for selection that could be applicable to other projects.

Methodology

The process of choosing sites for Vacant to Vibrant took into account three considerations: storm water management potential, recreational use potential, and ease of project installation and management. While site assessment occurred at a range of scales simultaneously, it could be generalised as a linear process beginning with the larger regional scale and working down to individual parcels (Figure 3). As the focus narrowed from regional to finer-scale site selection, datasets and characteristics of interest changed. Although quantitative data were factored into the analysis, examination of the data was mostly a qualitative process, described below, that attempted to maximise and balance storm water capture and neighbourhood stabilisation.

Regional

Initially, the larger urban region was analysed to establish the most impactful areas to locate green infrastructure. Sewersheds that had been targeted by a regional sewerage district for large grey or

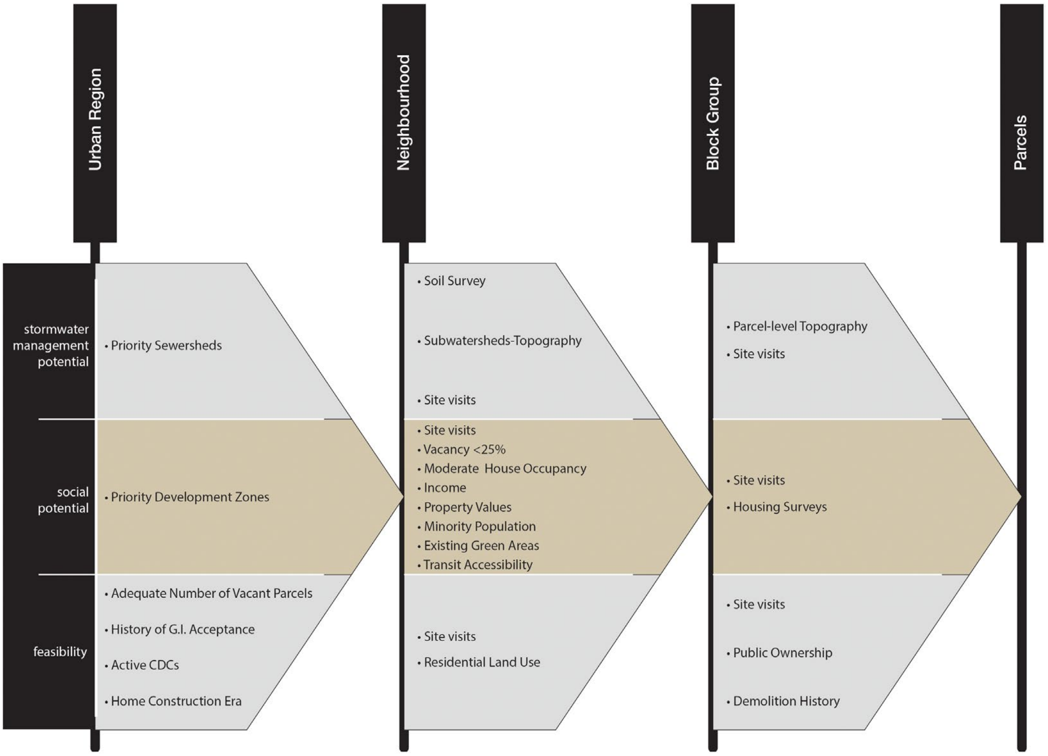


Figure 3. The generalised workflow of the site selection process of the Vacant to Vibrant project.

green infrastructure projects in the coming one to eight years were prioritised for the Vacant to Vibrant project. In each of the three cities, identification of target areas for grey/green infrastructure investment was based on engineered and natural landscape features that contributed to CSO volume and were conducive to storm water management, such as relatively smaller ratios of storm water run-off volume to resultant CSO volume (Cleveland), a high proportion of impervious surface (Cleveland/Buffalo), or naturally permeable soils (Gary) (BSA, 2014; NEORSD, 2012; USEPA, 2014). At this stage, long-term control plans and documentation related to consent decrees proved to be useful resources.

Neighbourhood

For neighbourhood-level analysis of green infrastructure potential, the Vacant to Vibrant project considered areas of investment overlap between development and storm water management. At this scale, the project team also looked for indicators that the neighbourhood would accept green land reuse strategies as part of near-term development plans—for example, existence of urban farms, or zoning for urban greening. Social indicators included identification of areas by city planning departments and local planning agencies as priority investment locations for development or stabilisation (Cleveland Planning Commission, 2011; PUSH Buffalo, 2012; The Times Media Company, 2013). In Buffalo, a community development corporation (CDC) was identified as a notable neighbourhood feature because of its capacity to utilise green infrastructure monies to increase capacity for 'high-road' jobs that would be available to a diverse employment pool (Magavern, Meyers, Kaminsky, & Maurer, 2014). In all three cities, neighbourhoods had been recipients of federal, state, and local monies allocated for targeted demolition to reduce the number of vacant structures, and so had adequate stores of existing vacant land from which to choose.

Neighbourhoods that had active CDCs to help coordinate localised development efforts and that were receptive to green infrastructure were qualitatively factored into our analysis. Only one city (Buffalo) had zoning ordinances that prohibited or controlled the location of green reuse projects. In the other two cities, informal factors, such as past or current involvement in non-traditional green land uses like urban farms, served as indicators that green infrastructure would be supported within specific neighbourhoods.

Block group

Within neighbourhoods, demographic data were evaluated to identify project areas with a diverse but manageable pool of vacant parcels from which to choose, and with enough residents that neighbourhood stabilisation efforts could still be effective. We also tried to keep neighbourhood composition consistent among the three cities so that findings could be more easily compared and generalised. Social and economic data from the 2010 decennial US census at block-group (ranging from 600 to 3 000 people) and census-tract (composed of at least one block group) geographical units described income, racial make-up, age, and property values of local residents (US Census Bureau, 2013). Pools of potential vacant parcels were narrowed by ownership to include only those that were held by city government (Cleveland and Gary) or by CDC (Buffalo), all of which had land access mechanisms in place that could be used for the project. Priority was given to block groups and census tracts that had proximity to neighbourhood amenities such as public transit stations, development projects, and public services (education, health care, religious institutions) that could further anchor stabilisation.

Geographic features were used to help identify localised storm water management potential. Sub-watershed boundaries for Gary and Cleveland that were based on fine-scale, LiDAR-derived topographic layers (US Geological Survey [USGS], 2014) were used to predict flow of storm water run-off on vacant parcels occurring near known boundaries, and to identify areas where run-off from streets or adjacent impervious surfaces could be diverted onto parcels. (Such files were not available for Buffalo at the necessary resolution.) The project team also used soil survey information to examine gross soil characteristics, such as soil texture, that relate to permeability (USDA, 2014).

Concurrent with this stage of site selection, the project team initiated community engagement via meetings, surveys, and targeted mailings to begin to educate residents about the justification and nature of upcoming work and to begin to collect feedback that could be incorporated into site design.

Parcel

At the final scale of parcel selection, site visits and publicly accessible data sets guided the selection of one cluster of six parcels per city—three designed and three controlled. Cities provided the project team with GIS shapefiles containing parcel attributes related to land use history and vacancy, which were used to perform calculations on individual parcel polygons and for 30-metre buffer polygons around each parcel. Using the same topographical data-sets from block group-level selection, the team calculated attributes such as slope, aspect, and curvature for parcels and buffer polygons to describe the ability of individual vacant parcels to capture storm water run-off that was generated on site and from adjacent impervious surfaces (Table 1). Additionally, because proximity to residents was important to maximise green infrastructure co-benefits, it was necessary to know the occupancy status of buildings within the area of interest. In Buffalo, current data relating to occupancy status of all neighbourhood parcels was available via the CDC. In Gary and Cleveland, the team surveyed all parcels within the block groups of interest to confirm occupancy; parcels were categorised as 'occupied structure', 'unoccupied structure', or 'vacant lot'. The number of parcels that intersected the 30-metre buffer polygon were tallied by category for each parcel. Finally, to evaluate parcels on other desirable features for green infrastructure and to ground-truth remotely sensed data, parcels that remained after quantitative screens were examined for 12 binary attributes, based on visual assessments from site visits and Street View in Google Maps (http://www.google.com/maps) (Table 2).

The list of potential parcels was then ranked based on the qualitative and quantitative attributes described above, producing a list of parcels within each city that would be suitable for both green infrastructure and neighbourhood stabilisation. Principal component analysis identified pairs of parcels that were statistically similar along quantitative and qualitative attributes. Given the small sample size, a paired approach was chosen to lend more statistical power to data analyses.

Results

One neighbourhood was chosen in each of the three cities, characterised by free-standing, one- and two-family, early twentieth-century homes with moderate levels of land vacancy (at least 25%) and house occupancy (61–77%). These three neighbourhoods—Aetna in Gary, Woodland Hills in Cleveland, and PUSH Buffalo's Green Development Zone on Buffalo's west side—were receiving ongoing assistance from the city (Gary) or were within the focal area of a local CDC (Cleveland, Buffalo). Neighbourhoods in Gary and Cleveland were part of a federal programme for demolition (US Department of the Treasury, 2012). Within each target neighbourhood, the project identified one to three block groups of interest, containing 7–36 vacant land bank- or CDC-owned parcels. Residents of these neighbourhoods were predominantly ethnic or racial minority (61–97%) with an average household median income of US$19 100. Six parcels per neighbourhood/city were selected for inclusion in the project, comprising three parcels that would be developed as green infrastructure and three parcels that would remain vacant for comparison (Figure 4).

In addition, three attributes that may have more general applicability, but that are not commonly used, emerged as being particularly useful for gauging potential for storm water capture and/or neighbourhood stabilisation for our project:

Table 1. Quantitative data attributes used in the selection of parcels in Cleveland.

Attribute[a]	Source	Inclusion value[c]
Parcel mean slope	1/9 arcsec slope raster map[b]	Less than median value (3.6)
Parcel standard deviation of slope	1/9 arcsec slope raster map[b]	Less than median value (1.6)
Parcel sum curvature	1/9 arcsec curvature raster map[b]	Less than median value (0.02)
Parcel mean aspect	1/9 arcsec aspect raster map[b]	Varied with orientation of street
# of occupied houses within buffer	County real estate GIS, field survey	Greater than median value (9)

[a] Calculated separately for parcel polygon and for parcel plus 30-m buffer (unless otherwise stated).
[b] Derived from 1/9 arcsec DEM raster map with GRASS GIS method r.slope.aspect (GRASS Development Team, 2011).
[c] Median values were calculated from all vacant lots in each neighbourhood. Numbers in parentheses represent median values for one neighbourhood (Woodland Hills) as examples.

Table 2. Binary criteria that comprised the qualitative suitability metric for parcel selection for Vacant to Vibrant.

Criterion	Justification
Parcel slopes away from street	Facilitates diversion of road run-off into green infrastructure. Relates to quantitative attribute *mean aspect*
Parcel is flat or convex	Facilitates storm water diversion and retention. Relates to quantitative attributes *mean slope* and *sum curvature*
Adjacent properties do not pose safety concern	Ensures lack of risk factors (dogs, dumping, obvious drug activity) that would pose a risk to site users
Street curb present	Facilitates curb cuts and discourages dumping on site without significant expenditure
Sidewalk in poor condition or absent	Increases positive change effected by project; reduces expenditures associated with demolishing existing sidewalk to divert street run-off and/or build new sidewalk
No remaining driveway apron	Driveway aprons that remain after house demolition facilitate driving, parking of cars, and illicit dumping on sites. Removal of apron is costly. Finding sites with no apron is a cost-saving measure
No large trees	Existing large trees within parcels could be costly to maintain/remove if not of good quality. Trees lining properties were considered neutral
Parcel surface is relatively even	A large depression in the location of the historic basement may indicate subsurface demolition debris (a feature of older demolitions) that would complicate installation. Other significant surface unevenness would increase costs associated with regrading. Relates to quantitative attribute *standard deviation of slope*
Fire hydrant present	Potential water source for plantings
No street-level storm sewer drain	Presence of a sewer drain inhibits diversion of street run-off into green infrastructure
Parcel is not being used/does not have potential as a side yard by an adjacent homeowner	Our target cities have programmes for qualifying homeowners to purchase adjacent vacant parcels for a small fee. Informal adoption of vacant parcels for use as side yards is also somewhat common. We wanted to avoid vacant parcels that had other potential uses in the community
Parcel has signs of existing informal use	Existing informal use of vacant parcels—as cut-throughs between blocks, play yards, or gathering places—indicates that site improvements might be desired and used by residents. Informal use could guide site design

(1) The number of occupied houses that intersected with a 30-metre buffer zone around each vacant parcel gave an indication of how closely installations would be positioned with respect to residents; parcels (6–9, depending on city) that had a higher than-median value were prioritised, as they tended to be within shorter walking distance for more residents.
(2) Demolition date was an important proxy for parcel-level variability in soil characteristics, such as flatness and permeability; as demolition demand increased in more recent years, procedures and ordinances changed, too, to improve the quality and consistency of fill, debris removal, contamination remediation, and grass cover. (Significant dates varied among the three cities but, generally, recent demolitions were better than older ones.)
(3) Lastly, variability of slope emerged as an indicator of the relative flatness of parcels (where zero variability indicates flatness), which was associated with better demolition quality and more favourable potential for storm water capture.

Parcel attributes that were not reported above did not factor into final parcel selection for our project. They were eliminated for one (or more) of three reasons: redundancy with other factors, lack of variability that was necessary to help narrowing down potential sites, or because other factors took priority over them. These factors may still prove useful for other urban greening or green storm water projects, however, our reasons for eliminating them were specific to project and local attributes that emerged during the process of selecting sites.

Discussion and conclusions

Due to the recent and ongoing nature of the two projects referenced above, it remains to be seen how a distributed approach to green storm water infrastructure compares to large, consolidated projects in terms of both social and economic factors that contribute to neighbourhood stabilisation, as well as environmental factors that effectively manage storm water. However, due to the prevalence of small,

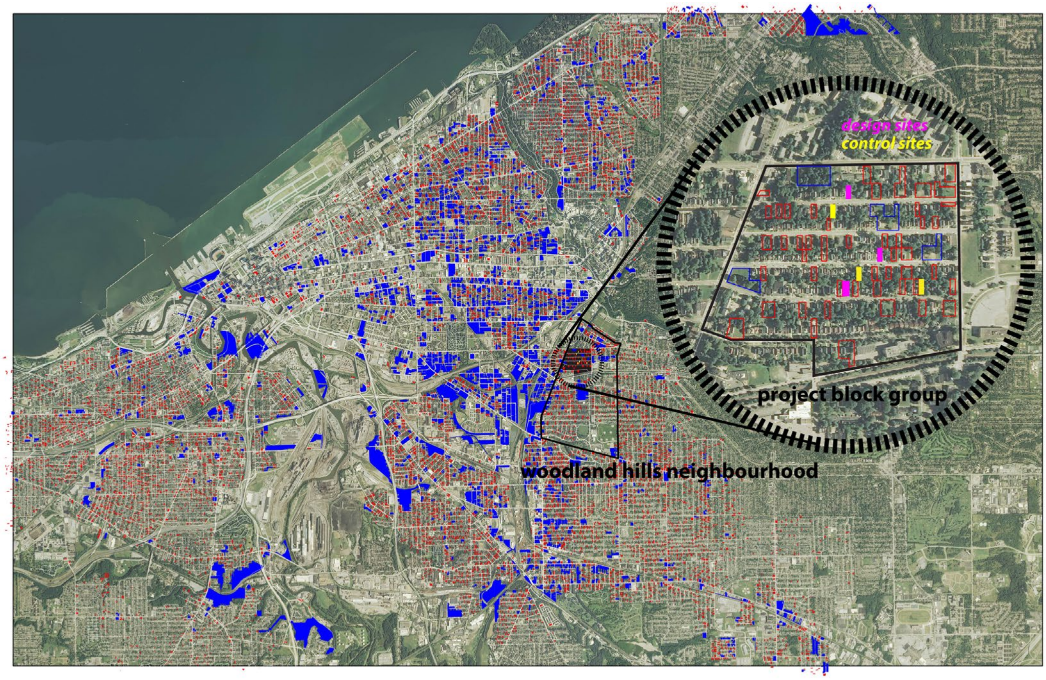


Figure 4. The locations of 3 vacant parcels that were redeveloped as green infrastructure ('design sites', solid, pink/dark) and 3 vacant parcels that remained unchanged for comparison ('control sites', solid, yellow/light) within the Woodland Hills neighbourhood of Cleveland. Potential sites <0.2 hectares AND <3 aggregated parcels are outlined in red; potential sites >0.2 hectares AND >3 aggregated parcels are outlined in blue (Aerial imagery © 2015 Google).

distributed parcels in most cities (shrinking or not) and the fact that they are seldom considered as assets for storm water management, this is a strong candidate for further study. This paper has referenced literature that suggests that both green infrastructure installations and vacant land that is maintained or cared for have positive social and economic impacts upon the surrounding neighbourhoods. Much prior work, however, has not given adequate consideration to project placement. A recent study by Eanes and Ventura (2015) documents a series of vacant land inventories—including their own in Madison, Wisconsin—for urban agriculture potential. They argue that, due to site heterogeneity, detailed site assessments are necessary for proper project placement.

Possible limitations of the case studies presented in this paper derive from the shared attributes of the study cities, such as geographic location, sewer infrastructure, and social history. While the locations within each city vary considerably, and cities worldwide possess the type of vacancy studied in this text, it remains to be seen how projects such as these might prove valuable in cities that have not undergone the loss of population that have been experienced by Cleveland and Buffalo. Further, there is the question of how relevant storm water management and neighbourhood stabilisation topics are to areas that currently have modern separate storm water systems and intact, healthy neighbourhoods, and how such relevance will be affected by climate change.

The processes presented here are intended as frameworks and case studies that illuminate several themes that relate to decision-making for urban vacant land. First is the need for standardised datasets that possess the level of detail necessary for parcel-scale analysis. A good deal of the work being conducted within the region is focused on demographics, hydrology, climate change, or transportation. The detail of this information seldom exceeds the census block; thus, finding information that is informative at the parcel scale has proven challenging. The Buffalo Vacant Lot Assessment Protocol is an example of a project aimed at the generation of this needed, highly detailed data. A standardised protocol for collection means that data can be referenced between sites, regardless of who collected it, and assessments can be completed rather quickly, at approximately 45 min per site. Objectivity and speed are of importance when considering the vast quantities of urban vacant land. It is assumed that, upon completion in Buffalo, the protocol will have a future assessing vacant property in other cities around the basin to aid in decisions around storm water management.

The parcel suitability method that was developed for Vacant to Vibrant has application to the more general problem of repurposing vacant land in urban areas. It can be expanded to include other types of data that relate to a variety of project goals. The use of multiple sites and cities buffers the project against variability that is inherent at the parcel scale, while use of commonly available remotely sensed data (typically acquired at the city or region scale) minimises investment needed for field surveying to determine parcel suitability.

By including objective assessments of the suitability of various parcels for green infrastructure treatment, community discussions can focus on criteria for identifying priority areas for treatment and the levels of parcel aggregation or dispersion needed to obtain quantifiable ecological, economic, and societal benefits. While the projects presented here have prioritised individual parcels, the process of site selection for research or development work of this type is of importance at all project scales. As data quality and gathering technologies improve, the potential for more specific and effective urban interventions will increase. Both the Buffalo Vacant Lot Assessment Protocol and Vacant to Vibrant attempt to envision a future where metropolitan-scale issues can be addressed in a highly precise and efficient manner. Projects of this sort hope to reduce the need for hulking, exclusive, non-responsive infrastructures within the existing urban fabric while exploring ways to synchronise their performance with the enhancement of the communities where they are located.

Notes

1. This is a highly abbreviated and generalised introduction to aspects of what has been called the ‘shrinking cities’ condition of the Great Lakes Basin. More detailed accounts of the causes and implications of this phenomenon have been published elsewhere (Oswalt, 2005; Pallagst et al., 2009; Wiechmann & Pallagst, 2012).
2. At project onset, compaction tests were conducted at each of the nine station points. However, unlike the sampling, these tests are quite loud and disruptive to neighbourhood residents. It was decided that we could reduce the number of tests to five as long as they included at least one sampling location at the front of the property, one at the rear of the property, one at the centre of the property, and then two of the bisected locations. The tablet randomised this process and gave indication where to conduct the tests.

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