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Multiobjective Optimization of Low Impact Development Stormwater Controls Under Climate Change Conditions

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By

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Abstract

A coupled optimization-simulation model was developed by linking the U.S. EPA Stormwater Management Model (SWMM) to the Borg Multiobjective Evolutionary Algorithm (Borg MOEA). The coupled model is capable of performing multiobjective optimization which use SWMM simulations as a tool to evaluate potential solutions to the optimization problem. For this research, the optimization-simulation tool was used to evaluate low impact development (LID) stormwater controls. LID is becoming increasingly prevalent as a climate change adaptation strategy. A SWMM model was developed, calibrated, and validated for a sewershed in Windsor, Ontario. LID stormwater controls were tested under both historical and climate change conditions. LID implementation strategies were optimized using the optimization-simulation model for 30 different scenarios with the objectives of minimizing peak flow in the stormsewers, reducing total runoff, and minimizing cost. The results of these simulations provided important information on the cost-effectiveness information for the LID controls.

Dedication

This thesis is dedicated to my family.

My family, who believe in me more than I do myself.

Your love and support has been such an important part of my life.

Because of all of you I never doubted that I could achieve this goal.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

BMP = Best management practice

BMPDSS = Best management practice decision support tool

BR = Bioretention

C = Clay, i.e., Brookston clay

CN = Curve number

CSO = Combined sewer overflow

EA = Evolutionary algorithm

EPA = United States Environmental Protection Agency

GA = Genetic algorithm

GIS = Global information system

IDF = Intensity-duration-frequency (related to IDF curves)

IPCC = Intergovernmental panel on climate change

IT = Infiltration trench

IUSM = Integrated urban stormwater management

IUWM = Integrated urban water management

L = Loam, i.e., Brookston clay loam

LID = Low impact development

LIUDD = Low impact urban design and development

MOEA = Multiobjective evolutionary algorithm

PP = Permeable pavement

RB = Rain barrel

RG = Rain garden

S = Sand, i.e., Berrien sand

SCS = Soil conservation society (related to curve number method)

SuDS = Sustainable drainage system

SWM = Stormwater management

SWMM = Stormwater management model (EPA model)

WQV = Water quality volume

WSUD = Water sensitive urban design

1 Introduction

1.1 Background

Urban stormwater management (SWM) has major ecological, economical and social importance. Methods for urban stormwater management must evolve to meet the increased demands resulting from urbanization, climate change and budgetary constraints

The traditional approach to urban stormwater management has been to use curbs, gutters, other grey infrastructure and sewers to convey the stormwater through a centralized system as rapidly and safely as possible. This approach, which looks to separate urban residents from the water management systems, generally does not contribute to sustainable urban development (Mitchell, 2006; van Roon, 2007; Wong and Eadie, 2000). Modern stormwater management objectives are evolving and now often include protecting water quality, maintaining the health of aquatic ecosystems and utilizing stormwater as a resource (Wong and Eadie, 2000). This is consistent with a desire for development which is ecologically, economically, and socially sustainable (van Roon, 2007). Visitacion et al. (2009) conducted interviews with 47 stormwater experts in the Puget Sound region of Washington, U.S. The aggregate ranking as to the opinion of the importance of stormwater impacts, in order of decreasing significance, was: water quality, effects on biota, effects on habitat, and flooding (Visitacion et al., 2009). The stresses of climate change and increasing urbanization make it even more difficult to manage the impacts listed by the authors.

Increased urbanization stresses urban stormwater management systems and consequently urban watersheds. "Urban and rural practices in New Zealand, the United States, Canada, and Australia over the past 40 years have radically changed the hydrology of catchments, streams and estuaries" (van Roon, 2005). For example, in Puget Sound watershed urbanization between 1972 and 1996 resulted in a 37% reduction in forest cover (van Roon, 2005). Urbanization is likely to impact urban streams by causing "increased frequency of high flows; redistribution of water from periods of base flow to periods of stormflow, and increased daily variation in streamflow" (Konrad and Booth, 2005). Development alters the water balance, decreasing infiltration and consequently groundwater recharge and increasing stormwater runoff (Wong, 2006). In fact, it is well understood that urbanization leads to decreased infiltration and base flow, and increased runoff and discharge from sewer outlets. Modelling with the forecasted land use changes to the Muskegon River watershed, located on the eastern coast of Lake Michigan, predicts watershed-wide runoff to increase by 12% relative to 1978 under an urban sprawl scenario (Tang et al.,2005). In Watford Connecticut a study was conducted on a 2.0 ha subdivision in a drainage basin contributing to a small estuary. The subdivision, built using traditional stormwater infrastructure, increased the impervious portion of the site from 1% to about 32%. This resulted in annual runoff increasing from 0.1 cm to over 50 cm and significant increases in nitrogen and phosphorus export occurred as well (Dietz and Clausen, 2008). The authors of this paper reasoned that the extreme response to development may have resulted from the small study area and these changes would likely be dampened (although still significant) in larger watersheds as has been reported in other studies including Jennings (2002).

The most significant impacts from accelerated stormwater runoff are generally associated with damage to aquatic ecosystems (Jennings et al., 2012). Ecosystems in urban streams will be altered and can only be restored with the reestablishment of pre-development hydrologic processes (Konrad and Booth, 2005). This damage can be caused by physical degradation, the transport and subsequent accumulation of toxic contaminants in receiving waters and organisms, and the transportation of nutrients which might lead to algae growth and eutrophication (Shuster et al., 2008; van Roon, 2007; Wong and Eadie, 2000). These concerns, as well as property damage from flooding, usually exceed the costs of stormwater management (Visitacion et al., 2009). Reports after 2007 floods in the United Kingdom suggested that upwards of two-thirds of the urban flooding resulted from the failings of urban drainage systems, especially during extreme storm events (Ellis and Viavattene, 2014). A U.S. Environmental Protection Agency study of

593,955 miles of streams and rivers in the U.S. (about 16% of the total length) found that 44% were impaired (USEPA, 2009). In this case impaired means that the stream or river could not support at least one of their designated uses. It was also reported that the urban runoff was a factor in the impairment of 22,559 miles, unspecified nonpoint source pollution in 34,556 miles, and municipal sewage discharges in 35,302 miles. Sewer overflows are relevant because in many cases, urbanization has led to problems with combined sewer overflows and/or basement and street flooding (Stovin et al., 2012). The Ontario (Canada) Ministry of the Environment estimated a total volume of 18 billion litres of CSOs in 2006 and 8 billion litres in 2007 making CSOs the largest single source of water pollution into Ontario water bodies (Ecojustice, 2009). CSOs continue to be a major problem today (Ecojustice, 2013). These problems worsen with increased urbanization, population growth, and climate change (Stovin et al., 2012; Visitacion et al., 2009).

IPCC (2007) showed widespread scientific consensus that the evidence shows "warming of the climate system is unequivocal." More recently the milestone of 400 ppm CO_2 was passed in Hawaii and experts believe significant warming is inevitable (Borenstein, 2013). Climate change is a topic of great concern for stormwater management. Many cities, New York, Toronto and London to name just a few, are utilizing green infrastructure as part of climate change adaptation strategies. EBNFLOW (2010) reports that future climate changes may significantly alter the water budget for Ontario, Canada and stress water infrastructure. In Windsor, Ontario, Canada a city climate change adaptation plan cited that climate change would pose a substantial risk to city operations by increasing demand in all areas due to an increase in severe storms and "an increased chance of flooding to basements, roads and other infrastructure" (The City of Windsor, 2012).

The concerns regarding hydrologic disturbance are consistent with observed and predicted climate change impacts. The IPCC reports varying precipitation changes but finds it likely (>66% probability of occurrence) that "heavy precipitation events (or the precipitation total from heavy falls) has increased in most areas" and very likely (>90% probability of occurrence) that heavy precipitation events will become more frequent (IPCC, 2007).

Climate change is expected to cause an intensification of the global water cycle. One result is that runoff is widely expected to increase through the 21st century (Huntington, 2006). For Toronto, Ontario, Cobbina (2007) studied climate change impacts on precipitation and runoff using time series analysis and found that an increased amount of small precipitation events would increase the runoff but no significant trend for extreme weather events. Franczyk and Chang (2009), while modelling the Rock Creek Basin in Oregon U.S., concluded that the combination of land-use change and climate change would amplify runoff even relative to what was found by studies examining only one of those factors. Semadeni-Davies et al. (2008) simulated (using the MOUSE urban drainage model) the impacts of several climate change and urban development scenarios on the combined sewer network of Helsingborg, Sweden. They found that both urbanization and climate change would increase combined sewer overflows (CSOs) with the worst case scenario (including both factors) seeing a 450% increase in the volume of CSOs and a 10-fold increase in the release of ammonia (Semadeni-Davies et al., 2008).

Denault et al. (2006) examined the impacts of changes to the precipitation patterns (becoming more intense for short storms) in the Mission/Wagg Creek watershed in British Columbia, Canada using regression analysis and the U.S. EPA Storm Water Management Model (SWMM). Their results indicated that with proper planning infrastructure could be adequately upgraded at a reasonable cost to account for urbanization and climate change. However, they also found that the increased runoff would likely damage stream health as increases in runoff might be similar to the effects of increasing the impervious or urbanized area (Denault et al., 2006), which is known to have a negative effect on stream health (Morley and Karr, 2002). The intensities of the rainfall in many parts of world are projected to be increasing. However, though the number of intense rainfall events appears to be increasing, the intensities do not seem to be increasing in Alpine regions (De Toffol et al, 2009). Overall, while climate change impacts will be spatially diverse, the literature does seem consistent in re-affirming that it will add additional stress to urban stormwater management challenges, especially with the additional factor of increased urbanization.

In their 2008 paper, Dietz and Clausen observed significant improvements in stormwater management with the application of low impact development (LID). Low impact development is an approach to stormwater management which is gaining popularity, especially as a climate change adaptation strategy. The LID philosophy incorporates various types of green infrastructure, natural features, and ecologically considerate development planning in order to improve hydrological systems impacted by urban stormwater. Low impact development is explained further in Chapter 2. Developing low knowledge on low impact development is a key component of this thesis.

1.2 Research Objectives

The first primary objective of this research was to develop an optimization-simulation model which can be used to generate important information about low impact development (LID). More specifically the model should be able to conduct multiobjective optimization so that cost-benefit curves can be easily generated. The model will also allow users to analyze the significance of various design parameters for LID controls. The optimization-simulation model is to be created by linking the stormwater management model (SWMM) to a genetic algorithm, the Borg Multi-Objective Evolutionary Algorithm (MOEA) (Hadka and Reed, 2013).

The second primary objective is to evaluate the use of LID stormwater controls as a climate change adaptation strategy. In order to do this, design storms must be created based off of both historical rainfall data and projected rainfall data under a future climate change scenario. Then, the performance of low impact development can be tested in each case and the results compared.

Another requirement for testing both LIDs and the optimization-simulation model is the development of a SWMM. This model is to be developed based on a sewershed in Windsor, Ontario. The model must also be calibrated and validated. The use of this model allows for the secondary objective of learning about the effectiveness of LID implementation in this area, information that is otherwise lacking.

1.3 Thesis Organization

The body of the thesis contains nine chapters. Chapters 1 and 2 provide an introduction to the stormwater management problems which necessitate this research, as well as an introduction to low impact development technologies. Chapter 2 includes the results of past research done on LIDs as well as information on the different methods used to study them. Chapter 3 provides information on the study area, a sewershed in Windsor, Ontario, that was used as the basis for the SWMM model. This information is used in Chapter 4 which discusses the development of the SWMM model. More specifically, Chapter 4 includes a discussion of the SWMM model, information on the development of the model used in this research, and a description of the calibration and validation of the model. Chapter 5 discusses the design of the LID stormwater controls that were used in the model. The end of the chapter includes the results of some sensitivity testing conducted in order to adjust some design parameters. Also included is a discussion of how the runoff from impervious surfaces is divided between the different LID types. Chapter 6 provides an introduction to multiobjective optimization, genetic algorithms, and the Borg MOEA. It also discusses how the Borg algorithm is linked with the SWMM model to create the optimization-simulation model and discusses the setup of the optimization component of the simulations conducted in this research. Chapter 7 discusses the development of the scenarios used in the simulations. That includes the development of a climate change scenario and the construction of design storms. LID control adoption and implementation is also discussed in this chapter. Chapter 8 presents the results of the optimization-simulation scenarios as well as the results of some additional tests. The results include cost benefit curves, cost breakdowns, LID sizing information, and hydrographs where various LID strategies are tested using one of the calibration events. All of these results are discussed at length and explanations for the results are provided. Chapter 9 summarizes the work completed and presents the conclusions drawn from the research.

Following the main body of the thesis is a set of appendices. Appendix A contains one the SWMM input file used for one of the scenarios. Appendix B contains the sewer maps used to design the routing network in the SWMM model. Appendix C contains the contents of the rainfall files used for each of the optimization-simulations scenarios. Appendix D contains additional information on the design of the LID controls discussed in Chapter 5. This includes some conceptual drawings for some of the LID controls. Appendix E contains the code for the Borg problem set-up from one of the scenarios. In this you can also see the cost functions for that scenario. Appendix F contains solutions produced in the simulations or used for further analysis. This includes the raw (sorted) results of each of the 30 optimization-simulation scenarios. Finally, Appendix F contains the IDF curves used in this research.

2 Literature Review

2.1 Introduction to Low Impact Development

2.1.1 Design Principles

The use of green infrastructure and infiltration techniques in urban development and stormwater management falls under the umbrella of "low impact development (LID)" in North America. Other philosophies similar in their treatment of stormwater management are low impact urban design and development (LIUDD, which is actually a more comprehensive philosophy) in New Zealand, water sensitive urban design (WSUD) in Australia, and sustainable urban drainage systems (SuDS) in Europe. These approaches might also include strategies such as integrated urban stormwater management (IUSM) and integrated urban water management (IUWM). Henceforth, in some cases, this paper may refer to any one of these approaches as low impact development or LID and is almost always referring to LID in the context of SWM. Fletcher et al. (2014) discuss the development and application of these and other terminology used in the urban drainage field. LID is designed to be more sustainable and look to address the issues discussed in proceeding sections along with some other negative ecological, economical and social impacts of traditional urban development (van Roon and Knight, 2004; van Roon, 2007; Wong and Eadie, 2000). At its most ambitious, LID aims to return developed watersheds to pre-development hydrological conditions (i.e. to mimic natural water cycles or achieve hydrologic neutrality) (Damodaram et al., 2010; Shuster et. al., 2008; van Roon, 2005; van Roon, 2007). LID is also often used as a retrofit designed to reduce the stress on urban stormwater systems and/or adapt to climate changes. LID relies heavily on infiltration and evapotranspiration to achieve these hydrologic objectives (van Roon, 2007). The resulting changes, or lack thereof for new sustainable development, in hydrologic patterns would allow streams to maintain flow characteristics and habitat conditions (Damodaram et al., 2010; Konrad and Booth, 2005).

"Water Sensitive Urban Design (WSUD) practices encompass the full spectrum of planning and engineering practices" (Wong and Eadie, 2000). To achieve sustainable urban environments, the complete urban water cycle (including stormwater, wastewater, and potable water) should be taken into consideration along with both anthropogenic and ecological needs (Mitchell, 2006; van Roon and Knight-Lenihan, 2004; van Roon, 2011). Within this system, the most sustainable solutions will come from considering the human environment as part of the natural environment rather than the reverse (van Roon, 2005). Both the ecological and economic value of land must be recognized in the designing of sustainable SWM systems (CVC, 2010). It is desirable to take a systemic approach which views all of the aforementioned components as part of a system which is also linked to the community and broader ecological systems (Mitchell, 2006). Considering the whole systems allows opportunities within the system to be maximized.

LID approaches to SWM often rely upon a variety of decentralized, source control solutions. The solutions are generally applied on small spatial scaled but can be part of broader LID strategies. Hydrologicaly, LID measures can be generally classified as either distributed source controls, more centralized on-site controls, and downstream conveyance controls (Zhou, 2014). Using LID approach can reduce urban runoff (Shuster et al., 2008), and reduce downstream flooding and damage to water quality (van Roon, 2011). Specific examples of solutions used as part of LID include green roofs, rain gardens (bioretention cells), soakaways, swales, permeable pavements, infiltration basins, ponds, rain barrels or cisterns, tree box filters, curbless roads with swales, downspout disconnection other green infrastructure and natural solutions and even community education (Debusk and Hunt, 2011; Shuster et al., 2008; Stovin et al., 2012).

In areas which are already heavily urbanized it might be most feasible simply to retrofit existing infrastructure such as parking lots, roads, sidewalks and buildings (Damodaram et al., 2010). In fact, it is very important to be able to retrofit in order to accommodate areas which are already built up (Charlesworth, 2010). Existing pervious areas such as parks, lawns, and gardens might provide additional capacity for infiltration in urban areas but this capacity might be limited depending on many factors which are spatially variable (Shuster et al., 2008). LID measures can usually be built into these public spaces without compromising their primary function (CVC, 2010). Another infiltration strategy is to direct runoff from impervious surfaces to pervious surfaces or retention facilities (Brander et al., 2004). Clustering development at a higher density in order to leave open more natural land, which might be used for infiltration and evapotranspiration, is considered an LID practice (van Roon, 2005; Williams and Wise, 2006). Interestingly, van Roon (2005) reported that some older urban development in New Zealand, which was built before curb and channel drainage systems were common practice, already has some LID characteristics. For example, grassed swales or ditches, which are considered to be a green infrastructure, are common in developments where there isn't a curb drainage system.

Treatment trains consisting of LID solutions in series or parallel can also be effective in managing runoff (Brown et al., 2012; CVC, 2010). A combination of LID and piped systems or best management practices (BMPs) can be very effective (Ashley et al., 2011; Damodaram et al., 2010; Damodaram and Zechman, 2013). Flood retarding basins might also be retrofitted with wetlands to improve water quality (Wong and Eadie, 2000). To clarify BMPs are usually measures such as detention ponds used to control runoff. They can be structural or non-structural and are sometimes considered to be included as LID measures or vice-versa. In any case, LID uses mechanisms such as infiltration and evapotranspiration and it is very important that specific LID solutions are carefully matched and scaled for a given application and location (Shuster et al., 2008). Evapotranspiration does not play a large role in stormwater management but is more significant in regards to some of the other benefits offered by LID technologies.

Although this review focuses on stormwater management, it is important to remember that one of the things that makes green infrastructure attractive is that it can offer many benefits. For example, the City of Toronto, Canada commissioned a study on the costs and benefits of green roofs prior to the adoption of their green roof policy. The study concluded that the benefits included reduced stormwater runoff, reduced energy consumption, reduced urban heat island effect, improved air quality and reduced emissions (Banting et al., 2005). Charlesworth (2010) and City of Portland Bureau of Environmental Services (2010) both reported similar benefits as well as improvements to community liveability and public health. Providing habitats for wildlife is another potential benefit (CVC, 2010; CNT, 2010). Green roofs and other green infrastructure might also provide social capital such as improved aesthetics, park space or citizen involvement in the community. Some suggested further reading in order to get a more complete view of the benefits of green infrastructure is CNT (2010), van Roon and van Roon (2009), Moore (2011), (CNT, 2010) and Ashley et al. (2011b). When taking a systemic approach to the design of the urban stormwater system, all of these factors should be considered. These additional benefits of green infrastructure might also help encourage the public to increase support for LID.

2.1.2 Adoption of LID

LID principles are widespread but not yet frequently utilized in most places. Climate change has been a major driver for LID strategies. Municipalities are planning for future climate changes and starting to see the effects of more intense storms which, in many places, have already increased in frequency. LIUDD was founded as a nationwide research and implementation programme in New Zealand (van Roon et al., 2006). In Australia, where water is in short supply, the focus has been largely on the recycling and reuse of stormwater and wastewater (van Roon, 2007). "Where resource scarcity or receiving water impacts are drivers for innovation, and this is combined with a willingness to work with, rather than against, natural processes, innovative design of greenfield developments follows" (van Roon, 2011, p.334). Mitchell (2006) also reviewed LID in Australia and found that the most common reason for adopting such practices was the reduction of negative environmental impacts, particularly related to water resources, and particularly when project constraints demanded innovative solutions.

van Roon (2007) concluded that there had been widespread use of LIUDD in demonstration projects, which were usually accompanied by guidelines from local government and developers, but there was not yet a larger, comprehensive approach to adopting LIUDD. A USEPA memorandum (USEPA, 2011) related to their release of a green infrastructure strategic agenda encourages communities to use green infrastructure and outlines their plans to partner with communities to assist them with this. The City of Lancaster, Pa., U.S., has cited this memorandum in their plans to use integrated green infrastructure to manage water issues. These issues include CSOs (about 45% of the city drains into a combined sewershed) and water pollution (Katzenmoyer et al., 2013).

Several major cities around the world are using LID solutions, often as strategies for climate change adaptation. One of the cities previously mentioned, Toronto, has a mandatory downspout disconnection (Toronto, 2007) and a by-law regarding mandatory implementation of green roofs (Toronto, 2009). USEPA (2010) provides a good overview of the development of green infrastructure across the U.S. They also cite changing regulatory frameworks as well as asset management decisions (using green infrastructure to reduce strain on grey infrastructure) as major drivers for the adoption of green infrastructure projects. Portland and Seattle are both leaders in LID largely because of strict stormwater regulations and rainfall profiles which are well suited for green infrastructure (Gallo et al., 2012). Portland has also developed tools which can be used to simplify the design of stormwater facilities.

Wise et al. (2010) reported that, in the U.S., Portland, Seattle, Philadelphia, Kansas City, New York, Washington, Louisville and more have included green infrastructure in their control plans for combined sewer overflows (one of the regulatory areas mentioned in the EPA report). Ashley et al. (2011) adds that in Melbourne, Australia retrofitting with SWMS "is seen as synonymous with greening and enhancing quality of life". The Environment Agency in the United Kingdom actively promotes LID (SuDS in their case) (Woods-Ballard et al., 2007). So it seems that more comprehensive strategies and policies related to LID are being developed. This is a positive because having an overarching vision is an important step to increased adoption of

LID practices (Binstock, 2011; CVC, 2010). The next section will discuss some of the challenges which must be overcome as LID continues to become more mainstream.

2.1.3 Improving Adoption of LID

2.1.3.1 Community Engagement

When using a decentralized, source control approach to stormwater management, community involvement becomes much more important. Montalto et al. (2013) developed an agent based model to represent the decision making of property owners and stochastically simulate LID adoption in a 175 ha neighbourhood in South Philadelphia. Their results highlighted the importance of stakeholder engagement and the importance of considering both the physical and social characteristics of an area targeted for LID adoption.

Shuster et al. (2008) suggested that decentralized stormwater management should be achieved through guided public participation and local partnerships which might also help to shift the public perception of stormwater towards valuing it as a resource rather than just viewing it as a nuisance or waste product. For example, measures, such as downspout disconnection, rain barrels, and rain gardens among others require widespread public participation in order to be impactful. This can be a challenge because it might take a great deal of education to get citizens to recognize the long-term effects stormwater can have on ecology, human health and quality of life (Visitacionet al., 2009). Jennings et al. (2012) considered that one might encourage the public to collect rooftop runoff with rain barrels by promoting them as a water source for urban gardening.

A common approach is financial incentive programs, such as rebates or fees; however, Roy et al. (2008) reported that these programs are most often flawed. This was not the case with a demonstration project in the Shepard Creek watershed of Cincinnati OH, where reverse auctions (paying people to take parcels, with people bidding down the amount they will receive as an incentive) were used to encourage residents to adopt LID measures such as rain barrels and rain gardens (Shuster et al., 2008). During a full reverse auction of 350 parcels there was a 25%

response rate with about 60% of the bids being for $0. The $0 bids would indicate that those citizens do value LID as they did not require the added incentive of being paid. Based on the results of this program (Shuster and Rhea, 2013) concluded that novel economic incentive programs could successfully initiate the adoption of distributed LID measures in suburban area.

One city previously mentioned, Melbourne, has been a leader in engaging organizations and the community around the adoption of LID (Roy et al., 2008). Lloyd et al. (2002) reported on a survey of 300 property owners and prospective home buyers from four LID site developments in Melbourne. More than 90% of respondents were in favour of landscaped and grassed bio-filtration systems for stormwater management and more than two-thirds thought they would improve neighborhood aesthetics (Lloyd et al., 2002). Overall the responses received still indicated a lack of understanding on the benefits of LID. Cote and Wolfe (2014) surveyed property owners in Kitchener, Ontario, Canada regarding the use of permeable surfaces. They found that the greatest barriers were awareness, cost, and technological acceptance. The characteristics commonly seen to drive adoption were a perceived need for improved stormwater management and the will to take ownership of said issue, as well as a willingness to seek out information and perform maintenance (Cote and Wolfe, 2014). Frame and Vale (2006) suggested that the largest barriers to sustainable development are of a social or political nature rather than technical challenges.

2.1.3.2 Municipal and Consulting Professionals

There are also significant barriers to LID becoming more accepted by professionals in risk adverse fields, such as engineering, utility operation and management, and public planning. Some of the common barriers which can lead to this risk (real or perceived) are a lack of familiarity with new practices, uncertainty about maintenance and who is responsible for maintenance, and liability issues (Binstock, 2011). Roy et al. (2008) also found problems with the distribution of responsibility and authority over water management within many watersheds. It can also be difficult to quantify some of the values additions offered by LID (Stovin et al., 2012). Similarly, one might implement LID for stormwater purposes without accounting for all of the other potential benefits. In Australia, many water utility managers were not confident enough in the long term benefits to their systems to adjust existing systems in order to take full advantage of the benefits of LID (Mitchell, 2006). Visitacion et al. (2009) found that most managers of stormwater programs lack the cost and benefit information they need to make rational funding decisions. To progress towards resolving these issues there should be a commonly agreed upon method or framework for examining the potential environmental, social, and economic costs and benefits of water system alternatives over multiple time frames (Mitchell, 2006). It is also important for contractors working on low impact development projects to have knowledge and experience (Line et al., 2012; Roy et al., 2008; van Roon, 2007).

Lloyd et al. (2002) surveyed stormwater professionals as to what barriers to WSUD (LID) ranked 'high' or 'very high' in terms of importance. The response showed a lack of an effective regulatory and operating environment (76% ranked high or very high importance) as the most important followed by limited quantitative data on long-term performance and best practices (75%), insufficient information on operation and maintenance and structural best practices (70%), institutional fragmentation of responsibilities (67%), lacking culture and technical skills within local governments and water corporations (52%), lack of ability to factor externality costs into life cycle cost analysis (52%), lack of information of market acceptance of residential properties with WSUD (52%), and poor construction management leading to reduced effectiveness (39%) (Lloyd et al., 2002, p.25). One example of sharing LID information between professionals is the International Stormwater BMP Database http://www.bmpdatabase.org/. This is an open access Microsoft Access database which contains details from over 500 BMP studies.

Binstock (2011) suggested that funding from higher levels of government would be one effective method by which to reduce the risk for municipalities experimenting with LID. In England LID is still not incentivized over traditional grey infrastructure solutions (Stovin et al., 2012). Roy et al. (2008) noted a lack of strict regulatory mandates regarding LID. In the U.S., Washington and Maryland have requirements for LID use; however, regulations regarding LID use should be flexible (Binstock, 2011). Sometimes engineering standards and guidelines can prevent the adoption of LID (Roy et al., 2008). For example, in some locations roads might be required to have continuous curbs, stormwater detention basins might be required, and any ponding might be discouraged.

Roy et al. (2008) suggested that LID policies might be easier to implement in response to downstream water goals. The previously mentioned case of green infrastructure use in Lancaster, Pa. (Katzenmoyer et al., 2013) was initiated largely by regulatory requirements that were put in place to protect downstream water quality. Smullen et al. (2008) also suggested that a key barrier would be adopting a set of practical targets for CSO and stormwater regulations. In any case successful implementation of LID practices will require a multidisciplinary approach and successful coordination between different government agencies (likely at multiple levels of government), community groups, and the private sector (Brown, 2005; Roy et al., 2008; Wong and Eadie, 2000). van Roon (2011) suggested "champions of the approach" would be required to provide leadership and move LID practice forward.

2.1.4 Location Dependencies of LID

LID solutions for SWM can be very location dependant. Since LID measures generally rely on infiltration and evapotranspiration, their effectiveness will be impacted by such things as soil type/conditions, what types of plants will grow, the amount of sunlight, rainfall patterns and other meteorological and hydrological properties. Simulation results from Xiao et al. (2007) found that the physical properties and effective depth of soil were particularly impactful on infiltration and surface runoff processes. Brander et al. (2004, p.961), when talking about infiltration basins in New York City, commented that site selection is "complicated by the need for favorable underlying soils and sufficient depths to groundwater." For these reasons professionals often require successful demonstration projects in their own community before they are comfortable using LID practices (Ewing and Grayson, 2000). More localized data, which could be obtained from pilot projects, is still lacking (Binstock, 2011). A study into the costs of LID projects by the U.S. EPA (2007) found that site-specific factors influenced the outcomes. CVC (2010) includes guidelines for LID design based on site-specific parameters.

Gilroy and McCuen (2009) developed a model in the Matlab language to simulate rainfall and runoff processes from lot-sized microwatersheds and test various combinations of cisterns and bioretention cells (LID measures). They found that the location of the cisterns and bioretention cells was critical. They provided many suggestions based on their findings including placing bioretention facilities in areas that drain impervious surfaces, for small more frequent storms the bioretention pits and cisterns can be independent but they might need to be in series for larger storms, peak discharge depends heavily on portions of the watershed not controlled by the LID measures, and total runoff volumes and peak rates do not seem to depend on the spatial separation of LID measures (Gilroy and McCuen, 2009, p.235). Rainfall patterns also impact the effectiveness of LID solutions and the size designs which will need to be implemented (Gallo et al., 2012; Jennings et al., 2012). Qin et al. (2013) modelled the effects rainfall patterns on LID measures in an urbanizing catchment in Shenzhen, China using SWMM. Rainfall volume, duration, and the time-to-peak ratio all impacted the performance of grassed swales, green roofs and permeable pavement. For example swales performed best when the peak intensity was early whereas permeable pavement performed best with a time-to-peak ratio of 0.5 and green roofs performed best with an even slightly later peak.

2.2 Evaluation of Low Impact Development

2.2.1 LID Case Studies

2.2.1.1 Overview

This section describes some of the research done in monitoring and analysis on actual LID projects. In order to get further information and summaries of results the Credit Valley Conservation report (CVC, 2010) and the review paper done by Ahiablame et al. (2012) are both valuable resources. Brown et al. (2012) also reports on the performance of several LID projects.

Another way to find additional case studies would be to search for research regarding specific LID solutions rather than the topic of LID itself. Summary tables of the results of reviewed papers are provided in the following sections.

2.2.1.2 Hydrology

Some of the primary goals of LID are to reduce stormwater runoff, reduce peak flows and to mimic pre-development hydrological conditions in watersheds. Debusk and Hunt (2011) compared streamflow from three small, undeveloped watershed to bioretention outflow from four cells, all in the Piedmont region of North Carolina. Their comparison showed very similar patterns of flow rates and volumes between the shallow interflow-produced streamflow of natural watersheds and the outflow from the bioretention cells. That result is significant because one of the main principles of LID is mimicking natural hydrological patterns.

Another demonstration project in which the timing of flows were considered is in Lynbrook Estate, Melbourne, and studied by Lloyd et al. (2002). The project incorporated 32 hectares consisting of 271 medium density allotments and parklands. Roof and road runoff systems were collected by grassed and landscaped swales with underlying gravel filled trenches with the system eventually feeding into wetlands. A paired catchment storm event monitoring program was established in adjacent sub-catchments to compare the conventional (piped) and LID (bio-filtration) systems. It was found that runoff from the LID catchment was between 51% and 100% less than the conventional system, peak discharges from the LID system were consistently lower, stormwater was delayed by an average of 10 minutes compared to the conventional system, and the LID system consistently had a shorter duration stormwater discharge (Lloyd et al., 2002, p.22).

For the case of Watford, Connecticut, previously discussed in section 1.1, a LID subdivision was compared to the one with traditional stormwater management. The LID measures included replacing asphalt roads and gutters with Ecostone® paver road (permeable) and grass swales, some driveways used Ecostone® or crushed rock, a bioretention cul-de-sac was added, rain gardens were used, and houses were constructed in a clustered layout. Monitoring and analysis of this site revealed that, due to the LID measures, the runoff did not increase even as the impervious area increased from zero to 21% (Dietz and Clausen, 2008). Mayer et al. (2012) ran an extensive six year before and after study (three years before, three after) of 1.8 km^2 Shepherd Creek watershed near Cincinnati, Ohio. They monitored hydrological and ecological indicators in the watershed in which they ran a program which saw the installation of 83 rain gardens and 176 rain barrels onto what amounted to over 30% of the properties (the reverse auction that was a component of this study was mentioned in section 2.1.3.1). They found the LID measures had a "small but statistically significant effect of decreasing stormwater quantity at the sub-watershed scale" (Mayer et al., 2012, p.65). This result assumes significance as most of the studies conducted are on a smaller scale and the cumulative impacts of LID on a watershed have not been as frequently evaluated. As a part of the same study Shuster and Rhea (2013) also found that LID practices made a difference as the distributed stormwater controls added detention capacity to the system. They also highlighted the importance of transportation surfaces as a focus point to maximize the efficiency of further retrofits and that swales may be a good method for said retrofit (Shuster et al., 2010; Shuster and Rhea, 2013).

Line et al. (2012) conducted a comparison between three commercial sites, one with no stormwater control measures, one with a wet detention basin and one with LID measures (including eight bioretention cells, 0.53 ha of pervious concrete and two constructed stormwater wetlands) in the Piedmont and Coastal Plain regions of central North Carolina. The LID measures throughout the whole site did have a positive impact; however, there were problems with the LID stormwater controls. These included the lack of a drawdown orifice in the stormwater wetland and undersized and clogged bioretention cells. These problems reduced the ability of the LID measures to reduce runoff (Line et al., 2012). Bergman et al. (2010) evaluated two infiltration trenches in Copenhagen over 15 years and observed a significant decrease in the infiltration rate which was likely due largely to clogging by fine particles. They also developed a model to simulate clogging and infiltration. The model predicted that infiltration rates will decay at a rate inversely proportional to time (Bergman et al., 2010). LID may also become less effective for large precipitation events. Hunt et al. (2008) studied a bioretention cell, sited in an area with a steep hydraulic gradient, connected to a 0.37 ha asphalt parking lot in Charlotte, N.C. The bioretention cell was able to reduce the peak flows of precipitation events of 40 mm or less by at least 96% (comparing the inflow and outflow rates of the bioretention cell) but would be much less effective for larger events.

A treatment chain might be more effective than single LID measures. Brown et al. (2012) compared a treatment train with 0.53 ha of pervious concrete and a 0.05 ha bioretention cell to using only the bioretention cell. The treatment train was effective in reducing the runoff volume, peak flow and duration of elevated outflow rates. The treatment train significantly outperformed using only the bioretention cell reducing the outflow by around 50% and reducing the overflow from about 11-12% of annual runoff to only 1% (Brown et al., 2012). Outflow was also reduced when there were extended dry periods before a rainfall event. Lenhart and Hunt (2011) found that a 0.14 ha stormwater treatment wetland in River Bend, North Carolina, reduced peak flows and runoff volumes by 80% and 54%, respectively and they suggested that stormwater wetlands should be considered a viable LID option, especially where there are sandy soils. The results of these studies are summarized in Table 2-1

Table 2-1 Water quantity and hydraulics from field studies

Reference	Study Area	LID Information	Runoff/Outflow Reduction	Peak Flow Reduction	Other/Notes
Lloyd et al. (2002)	Lynbrook Estates, Melbourne, Australia. 32 ha site with 271 medium density allotments and parklands.	Grass swales with underlying gravel trenches were used to collect roof and road runoff and transport it to wetlands.	51% to 100%	Consistently lower	Shorter duration for discharge, average delay of 10 minutes
Dietz and Clausen (2008)	Watford, Connecticut, USA One subdivision.	Replacing asphalt roads and gutters with Ecostone® paver road and swales. Some driveways used permeable surfaces. A bioretention cul-de-sac and rain gardens were also used. Houses were clustered.	No increase while impervious area increased from 0% to 21%	N/A	N/A
Mayer et al., (2012)	Shepherd Creek watershed near Cincinnati, Ohio, USA	83 rain gardens and 176 rain barrels which included over 30% of the properties.	Small decrease in stormwater quantity at the sub-watershed scale	N/A	N/A
Line et al., (2012)	Piedmont and Coastal Plain regions of North Carolina, USA. 3 commercial sites.	8 bioretention cells, 2 stormwater wetlands, and some pervious concrete.	34.8% reduction in rainfall/runoff ratio	N/A	Detention basin was more effective
Lenhart and Hunt, (2011)	River Bend, North Carolina, USA	0.14 ha stormwater treatment wetland	54% (wetland outflow vs. inflow)	80% (wetland outflow vs. inflow)	N/A
Hunt et al. (2008)	Charlotte, North Carolina, USA. 0.37 ha asphalt parking lot.	Bioretention cell in area with steep hydraulic gradient.	N/A	96.5% for precipitation events under 40 mm (outflow vs. inflow)	N/A
Brown et al. (2012)	Nashville, North Carolina, USA. 0.89 ha parking lot.	0.53 ha pervious concrete in series with 0.05 ha bioretention cell (0.5 m media)	69% (annual); 35% with just bioretention with 0.6 m media and 45% with 0.9 m media	N/A	Annual untreated runoff was 1% for the treatment train and 12%, or 11% for just bioretention

2.2.1.3 Water Quality

One of the major ecological benefits claimed of LID is the ability to reduce water pollution thereby assisting with the regulation of biogeochemical cycles. Nutrient export was studied for the Watford CT case presented in the previous section. Dietz and Clausen (2008) found that, for the traditional development case, NO_3-N export increased logarithmically as impervious area increased which was also the case for NH_3-N, TN, and TP. For the LID development NO_3-N export did not change, NH_3-N export actually significantly decreased and both TN and TP remained very low. Field studies on water quality were also conducted on the LID demonstration project in Lynwood Estates, Melbourne. Lloyd et al. (2002) found that the system reduced the total suspended solids (TSS) with a positive relationship between dose and removal. More results can be found in Table 2-2. The pollutant load reductions achieved by the whole LID system in the subdivision exceeded the efficiencies of single LID controls (Lloyd et al., 2002).

LID measures can also be used to reduce concentrations of metals (Hunt et al., 2008) and bacteria (Hathaway et al., 2009; Hunt et al., 2008). A bioretention cell was able to reduce Zn, Cu, and PB effluent concentrations; however, Fe increased by 330%, likely because of high Fe concentrations in the soil (Hunt et al., 2008). Bioretention cells are also capable of reducing fecal coliform and *E. Coli* bacteria (Hathaway et al., 2009; Hunt et al., 2008). Wetlands, particularly one which was shallow (15-45 cm) and had low vegetative cover, were also effective at reducing the effluent concentrations of indicator bacteria; however, the environmental conditions found in some LID projects can also breed bacteria (Hathaway et al., 2009). Both Hathaway et al. (2009) and Hunt et al. (2008) cautioned about generalizing their results as the studies are limited in scope and there are not a great deal of other studies testing the bacterial removal properties of LID measures.

Another example of the need to be careful in interpreting results comes from Lenhart and Hunt (2011). They found that a 0.14 ha stormwater treatment wetland in River Bend, North

Carolina, significantly decreased pollutant loadings; however, the mean concentrations of many pollutants actually increased. The increase in concentration demonstrates that the performance of LID measures may appear different depending on which metrics you are being used to evaluate them. In this case the stormwater wetland may have increased the concentrations due to problems with the establishment of vegetation and then the flushing of large algal mats (Lenhart and Hunt, 2011).

As mentioned when discussing location dependency, many factors can affect the performance of LID controls. Hunt et al. (2008) found reductions in TP but suggested that the fill soil's low cation exchange capacity would limit long-term TP reductions. Despite the success of bioretention cells in reducing pollutant loading, when located on a seasonally high water table areas, only total ammoniacal nitrogen and TSS concentrations were significantly reduced while $NO_{2\text{-}3}$-N and TN were increased two to four times because of contributions from baseflow (Brown et al., 2012). The authors advised against draining groundwater through a bioretention cell, remarking that it can also damage local hydrology. Again, it may be difficult to determine the downstream effects of LID measures. A summary of the results reported for some water quality experiments are listed in Table 2-2.

Table 2-2 Percent reductions in pollutant loading observed in field studies of LIDs

# Source	*E. Coli*	Fecal coliform	TN	TKN	Soluble N	NO_x-N	NH_3-N	TP	Soluble P	Ortho-P	TSS	Metals
Lloyd et al. (2002)	N/A	N/A	0[a], 70	N/A	29	N/A	N/A	47[a], 77	66	N/A	60[a], 73	N/A
Dietz and Clausen (2008)	N/A	N/A	No change[b]	N/A	N/A	No change[b]	Significant decrease[b]	No change[b]	N/A	N/A	N/A	N/A
Line et al. (2012)	N/A	N/A	42 (57)[c,e]	74 (53)[c,e]	N/A	-68 (70)[c,e]	87 (77)[c,e]	54 (45)[c,e]	N/A	0	97 (65)[c,e]	N/A
Lenhart and Hunt (2011)	N/A	N/A	35.7	34.9	N/A	40.7	41.6 (NH_4-N)	47.2	N/A	60.9	49.2	N/A
Hunt et al. (2008)	71[a]	69[a]	32[a]	44[a]	N/A	limited	73 (NH_4-N)	31[a,d]	N/A	N/A	60[a]	Zn:77[a] Cu:54[a] PB:31[a] Fe: -330[a]
Hathaway et al. (2009)**:** dry detention 1,2	-22, 0[a]	-45, -20[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
: wet pond	46[a]	70[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
: wetland 1,2	96, 33[a]	98, 56[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
: bioretention	92[a]	89[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
: proprietary 1,2,3	-2[a], -269, -7	59[a], -57, -62	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Brown et al., (2012)	N/A	N/A	-64[e]	57[e]	N/A	-471[e]	88[e]	30[e]	N/A	-60[e]	87	N/A

Table displays reductions in pollutant loadings in %. a Removal efficiency of LID control, b Trend while imperviousness is increasing; no change might mean no relationship with increasing imperviousness. c Number in brackets is for the traditional detention basin. d Limited long-term potential. e Arithmetic reduction. TSS = Total Suspended Solids, TN = Total Nitrogen, TP = Total Phosphorus, TKN = Total Kjeldahl Nitrogen, NH_3-N = Ammonia Nitrogen, NH_4-N = Ammonium Nitrogen, NO_x-N = Nitrate + Nitrite Nitrogen, Ortho-P = Orthophosphorus

2.2.2 Computer Modeling of LID

2.2.2.1 Overview

Computer modelling is the most effective tool for the design and optimization of sewer systems and wastewater treatment plants (Freni et al., 2010). The following sections present some of the results found via modelling LIDs as well as looking at how some of the models are used and the ways in which they represent LID controls.

There are other useful reviews on modelling for the purposes of evaluating LID measures. An older review was conducted by (Elliott and Trowsdale, 2007). They found that available models did not incorporate a sufficient amount of contaminants relating to water quality. They also found that it was difficult to link hydrologic models to outside processes such as toxicity and habitat models as well as procedures for automated calibration and evaluating prediction uncertainty (Elliott and Trowsdale, 2007). In general, water quality is modelled less frequently than quantity. One factor likely contributing to this is that water quality data, with which to calibrate a model, is less often available than the quantity data. Modelling water quality is relatively more difficult than modelling hydrology (Imteaz et al., 2013). Obropta and Kardos (2007) did review urban stormwater quality models. Comparing between deterministic, stochastic, and hybrid approaches to modelling, the authors suggested that hybrid approaches might reduce prediction error and uncertainty.

The thesis of Bosley (2008) contains an in depth review of the models ANSWERS, CASC2D, DR3M, HEC-HMS, HSPF, KINEROS2, and SWMM. More recently, Zhou (2014) included a section on modelling in their LID literature review. They found that open source models can be difficult to use and are often lacking in user support while proprietary models offer greater support but are often too expensive for many potential users. Viavattene et al. (2008) and Viavattene et al. (2010) discussed the development of a GIS decision making tool. GIS integration would reduce amount of work required in the processing data to input into the models. Some proprietary software such as PCSWMM (CHI Water, 2011) offer both GIS integration and

LID modelling. A GIS interface might also help users who are familiar with GIS overcome some of the technical complexity of many current models. Ellis and Viavattene (2014) also used GIS tools in a study. Some non-proprietary models such as HEC-HMS (Scharffenberg, 2013) and L-THIA (Park et al., 2013) now offer GIS extensions.

Ahiablame et al. (2013) found little literature where the impacts of LID had been quantified at a watershed scale. This is an important area for the use of models where results can be simulated from a lot scale to a watershed scale across many temporal scales (Ahiablame et al., 2012). Although small scale field studies are important to understanding the processes involved in LID projects, the site specific properties make it impractical to scale these results (Ahiablame et al., 2012).

Sharma et al. (2008) used three models to evaluate the impact of stormwater management options in Canberra, Australia. They used Aquacycle for the urban water balance; MUSIC for the stormwater flows, contaminants, and treatment options; and PURRS for peak stormwater flows from allotments. Another example of multiple model use was a study on the campus of Texas A&M University in College Station, Texas by (Damodaram et al., 2010). In this case HEC-HMS was used as a hydrological model with hydraulic routing computed using SWMM. SWMM was also used in LID studies by (Bosley, 2008; Damodaram et al., 2010; Elliott and Trowsdale, 2007; Karamouz and Nazif, 2013; Maharjan et al., 2009; McGarity, 2010; Qin et al., 2013; Zahmatkesh et al., 2015; Zhang, 2009). Some newer proprietary, integrated models such as MIKE URBAN (DHI, 2014) can be used to model all urban water networks as an integrated system. For studying LIDs Yazdi and Neyshabouri (2014) used HEC-HMS as a hydrological model and MIKE11 as a hydraulic model.

Another model, not included in, is the Cooperative Research Centre for Catchment Hydrology developed the Model for Urban Stormwater Improvement Conceptualisation which was used by (Lloyd et al., 2002). There has also been work done on developing methods and metrics by which to evaluate the performance in a way which is more meaningful in regards to the ecological benefits claimed of LID (Giacomoni et al., 2012; Reichold et al., 2009). A different approach is for researchers to develop their own model. McGarity (2011) developed the StormWise model as a screening strategy to be used to find optimal strategies to maximize improvements to water quality. Finally, Engel et al. (2007) put forward a standard procedure for the application of hydrologic and water quality models.

2.2.2.2 LID Representation in Models

There are multiple ways in which models represent LID stormwater controls. For example, LID measures might be considered by using aggregate properties such as a curve number (CN) or by representing the physical processes within the LID object (Ahiablame et al., 2012). It is also possible for users to develop their own models for LID objects and incorporate them into open-source models such as was done by Damodaram et al. (2010) who used curve numbers (based on the Soil Conservation Service curve number method) and Zhang (2009) who developed physically based algorithms to represent bioretention, green roofs, and porous pavement in SWMM (SWMM now has a built in LID toolbox). A more in depth description of the simulation of LID measures in SWMM can be found in section 4.1.4 and in Chapter 5. Table 2-3 gives some examples of commonly used models and their method of representing LID objects. Results found with these models as well as others will be presented in the following sections. The representation of the LID both in modelling and physical design is important. Zhou (2014) found that underestimating the complexity of LID functionality often lead to the performance of LID measures failing to meet expectations.

Table 2-3 LID representation in modelling

Model	Name	Developer (Info)	Availability	LID Simulation
SWMM	Stormwater Management Model	USEPA (Rossman, 2010)	Open Source	Process, physically based LID toolbox. LIDs within sub-catchments will be in parallel and LID simulation for water quality is not yet available.
MUSIC	Model for Urban Stormwater Improvement Conceptualization	eWater (Wong et al., 2002), (eWater, 2014)	Open Source with membership	Stochastic, LIDs have individual properties. Used for water quality.
HEC-HMS	The Hydrologic Modelling System	US Army Corps of Engineers (Scharffenberg, 2013)	Free	Aggregate simulation by altering properties.
PCSWMM	PCSWMM	CHI Software (CHI Water, 2011)	Commercial	Based on SWMM, process driven. Contains LID toolbox for both quality and quantity.
L-THIA-LID	L-THIA Low Impact Development	Purdue University (Fletcher et al., 2014; U.S. Army Corps of Engineers, 2014)	Free	LID screening tool which uses curve number analysis (aggregates properties).

2.2.2.3 Hydrology

This section describes the findings of studies which used computer models to simulate LID controls. Some of the results are summarized in Table 2-4. Xiao et al. (2007) studies some lot level controls using a model they developed themselves. They found that tree planting resulted in a runoff reduction after 15 years, and reduced runoff by 26% by year 30. They also reported that increased percolation to groundwater played a larger role than evapotranspiration (Xiao et al., 2007). This could help with groundwater recharge; however, care should be taken not to contaminate groundwater when runoff is being collected from paved surfaces in areas with highly permeable soil. Gilroy and McCuen (2009) developed a model in the Matlab language in order to simulate temporal and spatial features of rainfall and runoff on lot-sized watersheds and study the effectiveness of cisterns and bioretention cells. The LID measures considered did a much better job at reducing runoff and peak flows for a 1-year storm than a 2-year storm; however, the available storage for these events could be increased by placing LID controls in series (sited along the same flow path). It is also of note that the LID design impacts runoff volume and peak flow rates differently and both runoff volume and timing must be considered in the design. Additionally, there are vastly diminished returns when adding excessive LID measures which adds to the importance of properly locating LID measures (Gilroy and McCuen, 2009).

Damodaram et al. (2010) compared LIDs (permeable pavement, rainwater harvesting, and green roofs) to a traditional BMP (detention pond) and a hybrid scenario for a watershed on the campus of Texas A&M University. They reported that infiltration based LID measures were more effective than storage based BMPs for smaller storms (18 mm, 45 mm) but the BMPs were more effective for larger storms (114 mm, 185 mm, 279 mm). For two year design storms (114 mm) the LID measures may be better at creating flow timings similar to pre-development conditions (Damodaram et al., 2010). The hybrid scenario performed the best in for each case and still achieved around 50% reductions in peak flow for the 10-yr (185 mm) and 100-yr (279 mm) events; however, almost all the reduction for large events is attributable to the detention pond.

Damodaram and Zechman (2013) expanded on the previous method by using a genetic algorithm in order to optimize placement of LID measures (permeable pavement and rainwater harvesting) and BMP measures (detention ponds) in order to reduce impacts to peak flow by a range of design storms while constrained by a budget. They found that LID/BMP hybrids performed the best but that the peak flow metrics might not be the best for judging sustainability. The authors also reported the least amount of possible solution choices for the LID/BMP combination for a two year storm and the most flexibility for low level LID measures. Optimization will be discussed further in section 2.2.2.5 and Chapter 6. Karamouz and Nazif (2013) also used a genetic algorithm as well as climate change data. They found that BMPs could effectively reduce expected flooding volumes by 20 to 95%. The reduction of flood volumes could depend on the LID configuration. Qin et al. (2013) found that swales were not effective at reducing flood volumes because they received runoff from too large of an area and quickly overflowed. They did find that permeable pavement and green roofs were effective at reducing flood volumes for precipitation events between 70 and 140 mm (Qin et al., 2013).

Brander et al. (2004) compared conventional curvilinear, urban cluster, coving, and new urbanism development methods, with and without infiltration based LID measures, using a model they developed. The model, Infiltration Patch, is a spreadsheet based model which expands on the National Resources Conservation Service SCS CN m. Once again, the LID measures proved most effective for smaller storms. The cluster development, which leaves room for undeveloped space, was the most effective for reducing runoff (Brander et al., 2004). Williams and Wise (2006) found cluster development to reduce runoff volume and peak flows, and LID measures to help preserve natural hydrological patterns. Bosley (2008), using SWMM, found that LID stormwater management performed similarly to a forested area. Another study noted importance of evapotranspiration and groundwater in the hydrological systems (Trinh and Chui, 2013). With proper planning and design, distributed LID measures could be used to reshape a outlet hydrograph (Trinh and Chui, 2013).

Modelling the Helsingborg, Sweden, combined sewer system using the commercial Danish Hydrological Institute MOUSE (MOdel of Urban SEwers) Semadeni-Davies et al. (2008) found that using LID measures as well as disconnecting stormwater from combined sewers could limit or eliminate CSOs under future climate scenarios. Freni et al. (2010) developed a model in order to compare the effectiveness of decentralized LID measures to centralized, more traditional stormwater measures and to explore ways to improve stormwater management practices. The 12.8 ha urban catchment The Parco d'Orlèans at the University of Palermo, Italy, was used as a case study. They found that storage tanks connected to centralized systems were actually more effective at reducing CSO volume and pollutant loads. Storage tanks can also be more efficient because they can act directly on would-be CSO volume. For high infiltration soils, distributed infiltration techniques can be more effective; however, over the long term clogging can have a significant effect on efficiency and may require maintenance. Overall, a combination of centralized and distributed SWM measures can be feasible and effective (Freni et al., 2010).

Stovin et al. (2012) developed a GIS-based tool to model and evaluate retrofit LID measures. These were measured as disconnect sewers, disconnecting areas of catchments from the sewer system by creating pervious area or routing to pervious area (rather than modelling individual LID projects). They selected three well-suited catchments within the London Tideway Improvements area to test. Modelling global disconnect scenarios probed to be an efficient way to determine the potential of LID implementation (disconnection). Overall, they found large-scale disconnection to be costly and difficult to implement and suggested that the LID measures might serve best as a tool to be used alongside centralized sewer systems (Stovin et al., 2012).

2.2.2.4 Water Quality

As discussed in the overview, water quality as it relates to LID is not modeled as often as hydrology and it is studied more often through experimentation (see section 2.2.1.3). Ahiablame et al. (2012) found that more research was required on the characterization of runoff water quality from different types of land uses. Some results on studies which have used computer models to study stormwater quality are presented in Table 2-5.

Table 2-4 Hydrologic and hydraulic performance of LIDs in simulation

Source	Study Area and Model	LID Info	Runoff/Outflow Reduction	Peak Flow Reduction	Other/Notes
Jia et al. (2012)	Beijing Olympic Village, China; SWMM, BMPDSS	Decrease impervious area, rain barrels, routing to pervious, bioretention cells, increased storage.	27%	21%	Optimization completed on BMP sizes.
Ellis and Viavattene (2014)	Birmingham, U.K., industrial area; SUDSLOC, STORM	Permeable pavement, green roofs	57% (30 y storm) 30% (200 y storm)	N/A	Developed the SUDSLOC as a decision support tool.
Ellis and Viavattene (2014)	Coventry, U.K., residential area; SUDSLOC, STORM	Infiltration basins to disconnect impervious areas	95% (30 y storm) 55% (200 y storm)	N/A	STORM is hydrological model.
Pyke et al. (2011)	South Weymouth Naval Air Station, U.S.; SGWATER	Differences in development density and impervious area.	20% to 38%	N/A	10% increase in precipitation and 5% increase in intensity could be offset by a 4% decrease in impervious cover.
Zahmatkesh et al. (2015)	Bronx River Watershed, U.S.; SWMM	Rainwater harvesting, permeable pavement and bioretention.	28% (2 y storm) 14% (50 y storm)	8% to 13%	Considered climate change. Designed LIDs based on guides.
Bosley (2008)	Village at Tom's Creek, U.S.; SWMM	Dry swales, bioretention, rain barrels, and green roofs.	59.1% (unfavourable conditions for both LID and conventional) 83.5% (favourable)	LID outperformed conventional for up to 100 y storms. Detention pond was best.	Used both continuous simulation and event modeling.
Trinh and Chui (2013)	Singapore Marina Watershed; Mike SHE (System Hydrologique European)	Green roofs (14% of area), bioretention (5% of area)	30% to 50% (green roofs) 10% increase in infiltration	Delay of 2 hours (green roofs)	Combining the LID measures preserved the benefits of each.
Imteaz et al. (2013)	Melbourne, Brisbane, Auckland, Scotland; MUSIC	Bioretention (Mel and Bris), permeable pavement (Auk, Scot)	59.5% (Melbourne) 30.4% (Brisbane) 92.9% (Auckland) 100% (Scotland)	N/A	Compared to experimental results the model usually estimated flow effectively.
Ahiablame et al. (2013)	Urbanized watershed, Indianapolis, U.S.; L-THIA-LID	Rain barrels and porous pavement	3% to 11% (watershed-wide reduction)	N/A	50% adoption of rain barrels or cisterns was the most effective scenario

Table 2-5 Percent reductions in pollutant loading from simulated LIDs

Source	Study Area and Model	LID Info	TSS Reduction	TN Reduction	TP Reduction	Other/Notes
Imteaz et al. (2013)	Melbourne, Australia (3 experiments); MUSIC	Bioretention	Model: 91.6% Experiments: (90%)	87.0% (-162%)	82.6% (-12%)	1, 2
Imteaz et al. (2013)	Brisbane, Australia (1 experiment); MUSIC	Bioretention	91.9% (89%)	85.2% (83%)	76.2% (19%)	1, 2
Imteaz et al. (2013)	Brisbane, Australia(3 experiments); MUSIC	Swale	52.4% (83.1%)	44.0% (63.3%)	35.8% (53.1%)	1, 2
Imteaz et al. (2013)	Sweden (1 experiment); MUSIC	Swale	38.0% (-20%)	26.9% (N/A)	35.0% (N/A)	1, 2
Imteaz et al. (2013)	Auckland, New Zealand (2 experiments); MUSIC	Permeable pavement	99.8% (85.9%)	99.5% (N/A)	99.7% (N/A)	1, 2
Imteaz et al. (2013)	Scotland (1 experiment); MUSIC	Permeable pavement	100% (99.0%)	100% (82.7%)	100% (52.3%)	1, 2
Pyke et al. (2011)	South Weymouth Naval Air Station, U.S.; SGWATER	Differences in development density and impervious area.	18% to 26%	17% to 25%	24% to 34%	Water quality is more sensitive to land-use changes where there is less existing development.
Ahiablame et al. (2013)	Urbanized watershed, Indianapolis, U.S.; L-THIA-LID	Rain barrels and porous pavement	N/A	-1% to 0% (baseflow) 3% to 12% (runoff) 1% to 6% (streamflow)	-1% to 0% (baseflow) 2% to 11% (runoff) 2% to 9% (streamflow)	Reductions are given as the reductions in the flows in brackets.

1, When multiple there are multiple tests conducted, the mean results is displayed. 2, The experimental results are shown in brackets, with the simulation results not being in brackts. TSS = Total Suspended Solids, TN = Total Nitrogen, TP = Total Phosphorus

2.2.2.5 Optimization

This section will provide some examples and discussion of optimization in water resource problems and low impact development. For additional background information on optimization and a description of multiobjective optimization and genetic algorithms see Chapter 6. Among the most common methods of optimization in water resources is the use of genetic algorithms. These algorithms can be linked with simulation models and can optimize multiple objectives. Kaini et al. (2008) developed an optimal control model by linking a genetic algorithm with the Soil and Water Assessment Tool (Neitsch et al., 2011). Jia et al. (2012) used an optimization tool called Best Management Practice Decision Support System (BMPDSS) which assists in the design and placement of BMPs and requires the user to specify decision variables, assessment points and evaluation factors, management targets, and cost functions. BMPDSS uses a metaheuristic and more information is provided in Cheng et al. (2009). Another similar tool which uses a genetic algorithm, GIS integration, and some of the SWMM computational methods is SUSTAIN or the System for Urban Stormwater Treatment and Analysis Integration Model (Lai et al., 2007). A case study using SUSTAIN was conducted by Lee et al. (2012); however, SUSTAIN only runs on ArcGIS 9.x and Windows XP and is no longer supported by the EPA. Another GIS-integrated decision support system called SUDSLOC was developed by Ellis and Viavattene (2014). McGarity (2011) developed an optimization model to help determine investment in LIDs to improve water quality in a watershed.

A popular genetic algorithm is NSGA-II (Deb et al., 2000). This algorithm, and variations of it are used in many studies including SUSTAIN model. Karamouz and Nazif (2013) used NSGA-II with data envelopment analysis to optimize stormwater management for flood control under climate change conditions in an urban watershed in Tehran, Iran. They optimized based on a reliability criteria related to flood reduction as well as cost reduction (Karamouz and Nazif, 2013). An elitist version of NSGA-II, ε-NSGA-II was used by Zhang (2009) for the cost effectiveness optimization of several LID measures using SWMM. Maharjan et al. (2009) also combined a genetic algorithm with SWMM to optimize intervention times and strategies to respond to changes in climate and land use over time. Damodaram and Zechman (2013) used a genetic algorithm to optimize an LID system for the control of peak flows. In the development of cost-benefit information relating to LID use Yazdi and Neyshabouri (2014) used NSGA-II as well as multi-criteria selection, an artificial neural network, and fuzzy set theorem.

A study on stormwater management and non-point source pollution found that linear and dynamic programming could be as effective at finding optimal solutions as a genetic algorithm and could do so in less time (Limbrunner et al., 2013). Another approach was taken by Zhen et al. (2004) who used a scatter search in a single-objective constrained optimization. When single objective optimization is used additional objectives which might otherwise be optimized are often instead simply constrained to a target range. Further discussion on this topic can be found in Chapter 6.

2.2.3 Cost of LID

Stormwater management can incur significant costs. It was estimated that the cost of stormwater management in the Puget Sound region is $100/capita, negating damage created by very large storms. The most significant costs are associated with efforts to reduce flooding and improve drainage (Visitacion et al., 2009). If LID can reduce the burden on the conveyance network there would be significant cost savings (Roy et al., 2008). Upgrading existing subterranean stormwater management infrastructure in densely populated urban areas can be difficult, disruptive, and costly (Ashley et al., 2011). LID might reduce the cost of regulatory compliance for areas such as CSOs for communities served by combined sewer systems (Smullen et al., 2008). Despite the economic significance, few jurisdictions have actually conducted substantive economic analysis of their LID programs (USEPA, 2013). The USEPA (2013) report studied the economic analysis done in 13 case studies in the United States. One case where substantive analysis was done, including triple bottom line analysis, was that of Philadelphia.

Philadelphia Water Department (2009) completed a comprehensive study of potential cost savings from LID implementation in Philadelphia.

The U.S. EPA also studied 17 LID projects across North America and consistently found significant savings (USEPA, 2007). They found that, in general, the initial costs might be higher due to the "cost of green roofs, increased site preparation costs, or more expensive landscaping and plant species. However, in the vast majority of cases, significant savings were realized during the development and construction phases of the projects due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping" (USEPA, 2007, p.27). The capital cost savings were between 15% and 80% and which also has the added benefit of making systems more adaptable (easier to replace than large infrastructure). Swan and Stovin (2007) determined costs of LID measures and found that they ranked, from the least to the most expensive, infiltration basins, soakaways, ponds, infiltration trenches and porous pavement (some factors such as land acquisition were not considered).

After the closure of the Oslo Airport at Fornebu in 1998 development plans were made including LID measures. It was estimated that the construction of an open drainage system (LID alternative) would be 30% cheaper than a traditional piped system, the operations and maintenance costs should be similar (AAstebøl et al., 2004). LID also incurs additional costs when education and outreach is required in order to change the normative culture to get multiple stakeholder groups on board with sustainable stormwater management (Ashley et al., 2011). In Lancaster, Pa., the city developed a green infrastructure calculator to estimate costs and benefits of LID implementation. They calculated that, in 2010 dollars, their program would cost $141 million, $77 million of which would be the increased cost from incorporating LID initiatives into infrastructure and development projects. This works out to a marginal cost of $0.03/L of stormwater which is much cheaper than what was estimated for the preliminary costs of building grey infrastructure to remediate CSO and water pollution issues (Katzenmoyer et al., 2013). For CSO reduction they estimated the cumulative cost would be $0.05/L for green infrastructure and

$0.06/L for a large storage tank. Brown, et al. (2012) found that adding a 0.53 ha of pervious concrete to create a treatment train with a 0.05 ha bioretention cell increased the cost of the LID project to five times the cost of using only the bioretention cell.

Property values have increased in areas recognized for their LID practices (van Roon, 2005). There is a drawback that property owners or stormwater managers maybe be concerned about lost opportunity costs (losing potential other uses of property) due to designating land for green infrastructure projects (Roy et al., 2008). Another variable which impacts the cost is how effectively LID measures are implemented, especially in terms of location and quantity (Gilroy and McCuen, 2009). Reduced lot size from the implementation of open space and swales reduced sale prices but resulted in lower construction costs (Williams and Wise, 2009). The ratio of sale price to construction cost was better with LIDs for part of the study period and worse for part of the study period. Clustered development consistently outperformed traditional development (Williams and Wise, 2009).

A few conclusions on LIDs and costs have been drawn based on studies which included optimization. Karamouz and Nazif (2013) found that the cost of BMPs was a critical factor in the reliability of flood control systems. One study found that the LIDs, optimized for cost effectiveness in runoff reduction, usually had smaller dimensions than design recommendation provided in plans (Jia et al., 2012). Finally, Maharjan et al. (2009) found that optimization for stormwater system intervention over time allowed for cost savings.

As was discussed in section 2.1.3.2, it can be difficult to quantify some of the benefits of LID thus would also be difficult to associate monetary values. For LID, a significant portion of the infrastructure costs occur early in the implementation projects; however, the full environmental benefits might not be apparent for years (van Roon, 2011). For this reason, improved life-cycle cost benefit analysis might allow a more accurate comparison with traditional SWM methods (Wise et al., 2010). The USEPA (2007) suggests that further research should be done to quantify and monetize some social and environmental benefits such as improved downstream environmental protection, flooding damage, aesthetics and recreation and other factors that might create cost savings over the life of LID projects. Among work that has been done, Houdeshel et al. (2011) created a tool with which to calculate the capital costs, operation and maintenance costs, and life-cycle net present value of some common LID projects. For looking simply at the costs, Moeller and Pomeroy (2009) developed a set of spreadsheet tools to help users conduct life-cycle cost analysis for several LID stormwater controls. Sample et al. (2003) developed a costing approach based on land parcels and noted the importance of accurate unit cost data. Another source for LID cost information is the international BMP database (bmpdatabase.org, 2014; Wright Water Engineers Inc. and Geosyntec Consultants, 2010) where the costs of many LID projects have been logged.

2.2.4 Monitoring and Evaluation and Research Gaps

Monitoring and evaluation of LID projects is extremely important. One of the greatest barriers to the adoption of LID stormwater management techniques is a lack of data regarding their performance in various situations (Roy et al., 2008). There is not sufficient long-term data to support meaningful conclusions regarding the claimed benefits of LID (Clary et al., 2010; Shuster et al., 2008). Reviewing LID adoption in Australia, Mitchell (2006) found that monitoring was normally limited to what was required for operation as dictated by regulations. Mayer et al. (2012) who ran a six year study on the ecological impacts of distributed LID measures, suggested that even six years might be too little time to observe ecological impacts of such measures. They also highlighted the importance of quantifying environmental benefits and ecosystem services.

Systemic performance monitoring was lacking aside from a few research projects and there was generally a lack of long term monitoring and evaluation of projects, possibly due to limited resources (Mitchell, 2006). More specifically resources on demonstration projects might be used for gathering data but the same projects might lack proper scientific oversight, negatively impacting the quality of monitoring and evaluation (Shuster et al., 2008). The short time period associated with most demonstration projects might not allow sufficient time to run meaningful before and after statistical comparisons (Shuster et al., 2008). Since the goal of LID is often to reproduce predevelopment hydrological conditions, before and after studies might be appropriate to gauge performance (Clary et al., 2010). Traditionally, reference or parallel watershed studies have been more common. Visitacion et al. (2009) agreed that monitoring and evaluation of stormwater projects was lacking such that it is difficult to accurately determine costs, benefits, and risks. On the modelling side, sewershed level performance data on LID measures would be helpful to calibrate the performance of LID measures included in models.

Location dependence, discussed in section 2.1.4, means that it is important to understand unique physiographic characteristics and operating conditions as part of the monitoring process (Shuster et al., 2008). One major challenge in monitoring and evaluation measures is that in large urban areas it can be extremely difficult to detect the impacts of LID measures in the receiving waters (Walsh and Fletcher, 2006). It might even be difficult to model LID performance at larger scales such as large sites, regions or watersheds (as opposed to individual LID solutions) (Clary et al., 2010; Wise et al., 2010). Freni et al. (2010) also suggested research into the impacts of SWM measures on wastewater treatment plants, where there are combined sewer systems, in order to determine potential effects on pollutant loading to the plant and receiving waters.

Further research is required to evaluate the risk (e.g. public health, environmental health, financial risk) associated with LID. This research into risk would be well suited to be done in coordination with the long term monitoring and evaluation of demonstration projects (Mitchell, 2006). Further research on quantifying the environmental benefits and ecosystem services from decentralized LID projects is also required (Mayer et al., 2012). Identifying appropriate curve number values for LID practices could allow them to be integrated into many hydrological models (Damodaram et al., 2010). There is a need for further research on the location and spacing of stormwater solutions (Gilroy and McCuen, 2009). It is also important for additional research to be conducted into the quantity of SWM solutions, especially to determine if there are diminishing returns (Gilroy and McCuen, 2009). Similarly, Brown et al. (2012) proposed that it is important to find out how big LID projects should be, relative to their drainage area, in order to effectively reduce runoff. Goonrey et al. (2009) suggest that as more information on LID is obtained it should be incorporated into decision making frameworks, and the authors of the paper went as far as to develop a decision making framework of their own.

Some cost-benefit analysis has been conducted; however, further such analysis would be beneficial in order to see how cost effective various combinations of LIDs can be in different areas. There is also room for additional research on whether LIDs are an effective climate change adaptation strategy and how the performance of LID measures might be impacted by climate change.

2.3 Conclusions

The conclusions of several research studies are presented throughout this review. Taking these all into consideration, some conclusions may be drawn about using low impact development for sustainable stormwater management and the state of research on those topics.

First of all, there are several drivers for finding new approaches to stormwater management, among them climate change, urbanization, and changing regulatory environments. These seem to be driving the adoption of design philosophies such as low impact development. Many major cities, around the world have been incorporating LID measures into their stormwater management plans and regulatory bodies, such as the EPA in the U.S., are encouraging the use of green infrastructure.

The balance of the research reviewed suggests that the benefits attributed to LID, in short mimicking pre-development hydrological patterns and improving water quality, are real qualities; however, the extent of the benefits depends of many factors including many location dependent properties. It seems that, in most cases, LID practices would best serve as a tool to be used in coordination with more traditional SWM practices. Further research on many aspects of LID is still required before those who would use LID can make fully informed decisions while optimizing the design of SWM systems.

3 Study Area Description

3.1 Introduction

A 77 ha suburban sewershed in Windsor, Ontario, Canada was selected for this study. This sewershed (the study area) is modelled using the U.S. Environmental Protection Agency's Stormwater Management Model version 5 (SWMM). The model is then used to evaluate low impact development practices under climate change conditions. This chapter describes the relevant properties of the study area.

3.2 Stormwater Challenges

Some areas of Windsor, Ontario have experienced challenges related to street and basement flooding as well as combined sewer overflows. The later has lead the city to spend $186 million dollars in infrastructure upgrades in recent years (Stantec Consulting, 2012). There are also problems with street and basement flooding. There have been significant flooding events in 2007, 2010, and 2011 (The City of Windsor, 2012). In an event in June 2010, about 90 mm of rain fell in four hours. This led to the City of Windsor receiving 2,281 flooded basement calls (The City of Windsor, 2013). The City of Windsor climate change adaptation plan (The City of Windsor, 2012) expects such extreme rainfall events to become more frequent and more intense in the future. The effect of urbanization and climate change on stormwater was discussed further in Chapter 2.

3.3 Location and Land Cover

The sewershed in question is represented by the shaded area Figure 3-1corresponding to flow monitor ST 1200. The map was shared by The City of Windsor and shows the locations of recently installed flow monitors in storm sewers throughout the city. The selected sewershed was chosen because it is an urbanizing area where there is room for LID measures and because it is of manageable size (77.02 ha) for this study. The development of the study area can be viewed in Figure 3-2 and Figure 3-3 on a following page. Those figures show satellite photos of the study area obtained from Google Earth. An approximate outline of the sewershed based on the outline in Figure 3-1 is shaded blue. The photograph in Figure 3-2 was taken in 2007 while the photograph in Figure 3-3 is from 2009. Additional development has taken place since then and continues today. The sewershed is a residential area with varied styles of home. The lot sizes are mostly in the range of 0.05 to 0.15 ha. There are no large parking lots or similar paved areas in within the drainage boundaries of the sewershed; however, there are wooded areas. Some of the wooded areas have been developed with additional residential growth in recent years. There are no rivers or streams running through the sewershed. Using Google Earth, the various land use types were delineated and imported into ESRI's ArcMap 10 global information system program. In this process, the delineation of newly developed areas which did not show development in the 2009 satellite photograph were estimated based on visual inspection. The land use map developed is displayed as shown in Figure 3-4. Analysis of the land use types in ArcMap showed that among the developed areas (excluding the undeveloped pervious area) the sewershed imperviousness was about 48%. Approximately 12% of the sewershed is still covered by woodland meaning the overall percentage of impervious area is about 43%.

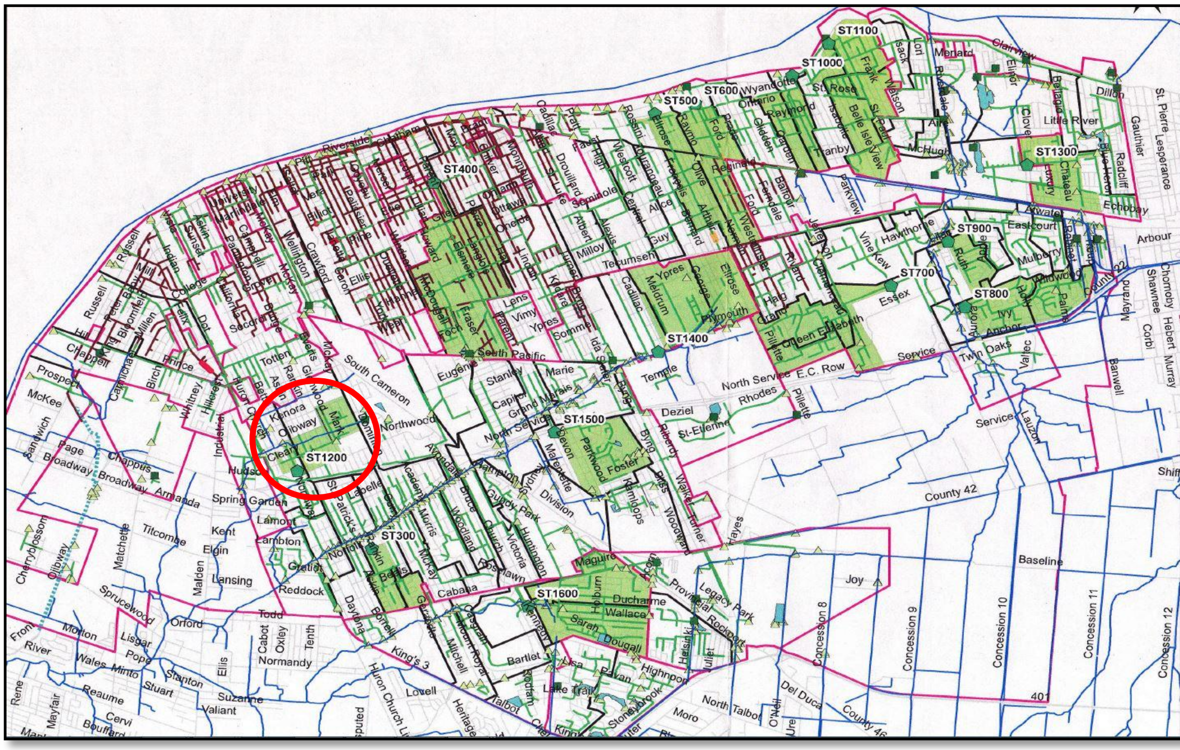


Figure 3-1 Study area location

Figure 3-2 Google Earth image of study area, 2007

Figure 3-3 Google Earth image of study area, 2009

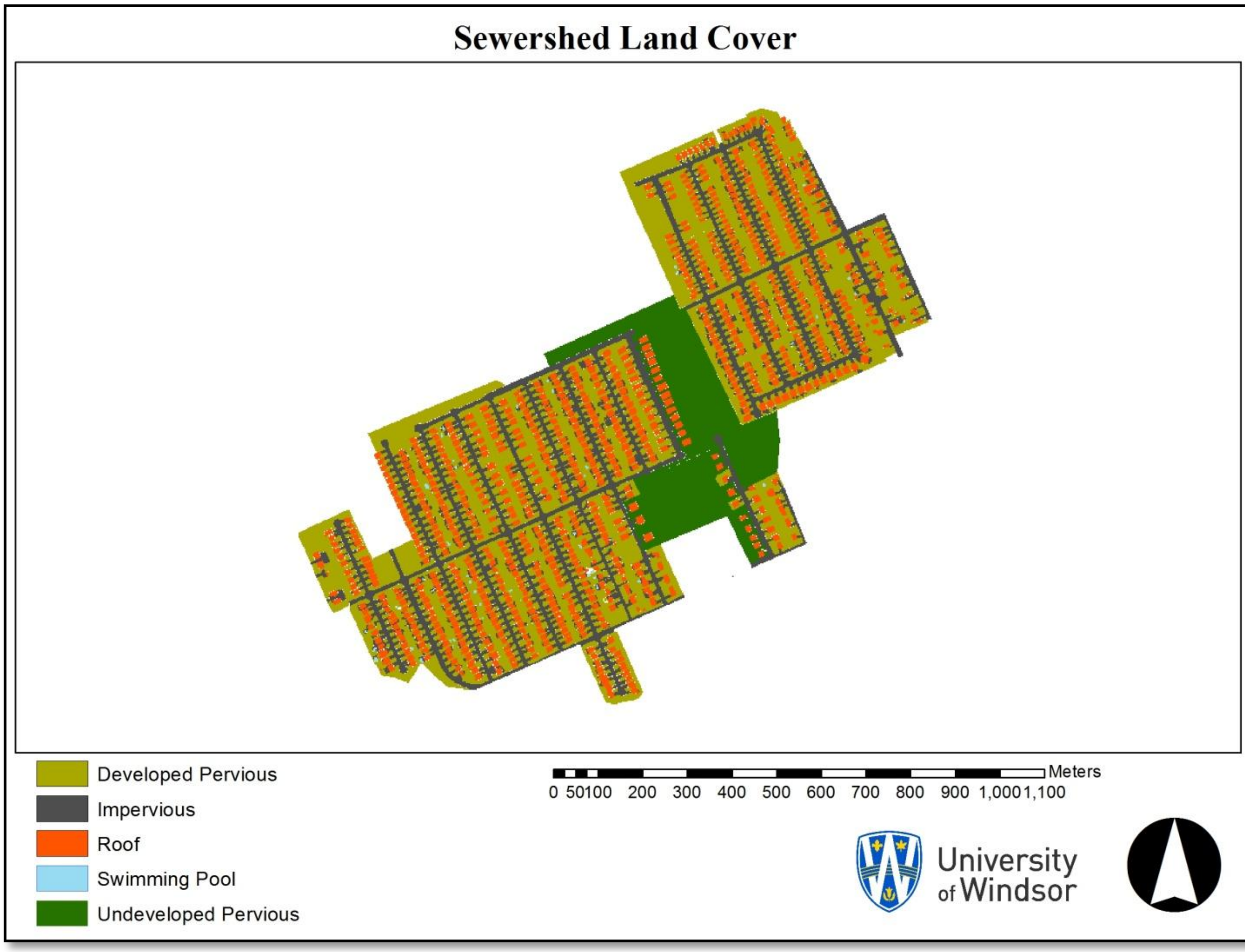


Figure 3-4 ArcGIS map of study area land cover

3.4 Sewer Network

The study area sewershed has a fully separated sewer system and this study limits itself to the stormsewers. The runoff is directed into the stormsewers almost exclusively through a curb and channel drainage system. There is a single side-street which has grassed ditches leading into the sewer system. There are no other apparent features which would be classified as low impact development measures. Some of the downspouts are directly connected to the sewer system while some drain onto the driveways or lawns. The prevalence of directly connected downspouts varies from street to street. The direct connection of downspouts to the sewer systems has been banned by The City of Windsor in some area, but not within the sewershed studied. Figure 3-5 is a map of the sewer network in the area obtained from Mapmycity.ca. The location of the flow monitor (where the outfall of the SWMM model is placed) is marked with a star. The blue lines represent the stormsewers with the nodes being the manhole locations. This was the image which was used as the backdrop for the graphical interface version of the SWMM model. More detailed sewer maps from the city's sewer atlas can be found in Appendix B.

Figure 3-5 Sewer map of study area

3.5 Soils and Slopes

Like most of Windsor and Essex County, the underlying soils in the sewershed in question are primarily clayey in nature and have poor hydrological properties. The soils present in the sewershed are Berrien Sand (hydrological soil group C), Brookston Clay (group D), and Brookston Clay Loam (group D). Table 3-1and Table 3-1, published by Rahman (2007), provide information on the clay soils. Additional information on the soils can be found in Richards et al. (1949). In the hydrological modelling used in this study (see chapter 4), the soil parameters are lumped into the curve number property. Some individual soil properties are also utilized for the setting of parameters for LID controls in chapter 5.

Table 3-1 Brookston Clay properties (Rahman, 2007)

Brookston Clay (D)					
Depth from soil surface to bottom of layer (mm)	178	330	787	965	-
Soil texture	Clay	Clay	Clay	Clay	Heavy Clay
Moist bulk density (gm/cm3)	1.21	1.33	1.39	1.43	1.44
Available water capacity of soil layer (mm/mm)	0.14	0.13	0.13	0.13	0.13
Saturated hydraulic conductivity (mm/hr)	8.22	3.67	2.27	1.64	1.44
Organic carbon content (%)	4.61	2.31	1.15	0.58	0.29
Clay content (%)	39	39	39	39	59
Silt content (%)	31	31	31	31	24
Sand Content (%)	30	30	30	30	17
Rock fragment content (%)	2	2	2	2	2
Moist soil albedo	0.12	0.15	0.15	0.14	0.14
USLE equation soil erodibility (k) factor	0.21	0.21	0.24	0.24	0.19

Table 3-2 Brookston Clay Loam properties (Rahman, 2007)

Brookston Clay Loam (D)					
Depth from soil surface to bottom of layer (mm)	178	330	787	965	-
Soil texture	Clay	Clay	Clay	Clay	Heavy Clay
Moist bulk density (gm/cm3)	1.14	1.34	1.4	1.43	1.24
Available water capacity of soil layer (mm/mm)	0.16	0.15	0.13	0.13	0.12
Saturated hydraulic conductivity (mm/hr)	21.25	9.85	2.21	1.67	0.56
Organic carbon content (%)	4.09	2.04	1.02	0.51	0.26
Clay content (%)	29	39	39	39	59
Silt content (%)	24	31	31	31	24
Sand content (%)	32	30	30	30	17
Rock fragment content (%)	2	2	2	2	2
Moist soil albedo	0.12	0.15	0.15	0.14	0.14
USLE equation soil erodibility (k) factor	0.28	0.21	0.24	0.24	0.19

Figure 3-6 shows the underlying soils in relation to the outline of the sewershed. As is apparent, the majority of the sewershed built upon clay soils classified in hydrological soil group D. The Berrien Sand is classified in hydrological soil group C. It also may become heavy calcareous clay at a depth of about 1 to 2 m (Richards et al., 1949). It is unclear whether disturbance from development impacted these soil characteristics in any meaningful way. Figure 3-6 and Figure 3-7 were created in ESRI ArcMap from larger shapefiles obtained from University of Western Ontario Data Delivery System (soil data) and Scholars GeoPortal (DEM used to calculate slope). Figure 3-7 presents the underlying slopes in the sewershed as calculated in ArcMap from a digital elevation model. The slopes in the sewershed are generally very low, although the development of the land will have altered some of the slopes. The digital elevation model itself is displayed in Figure 3-8.

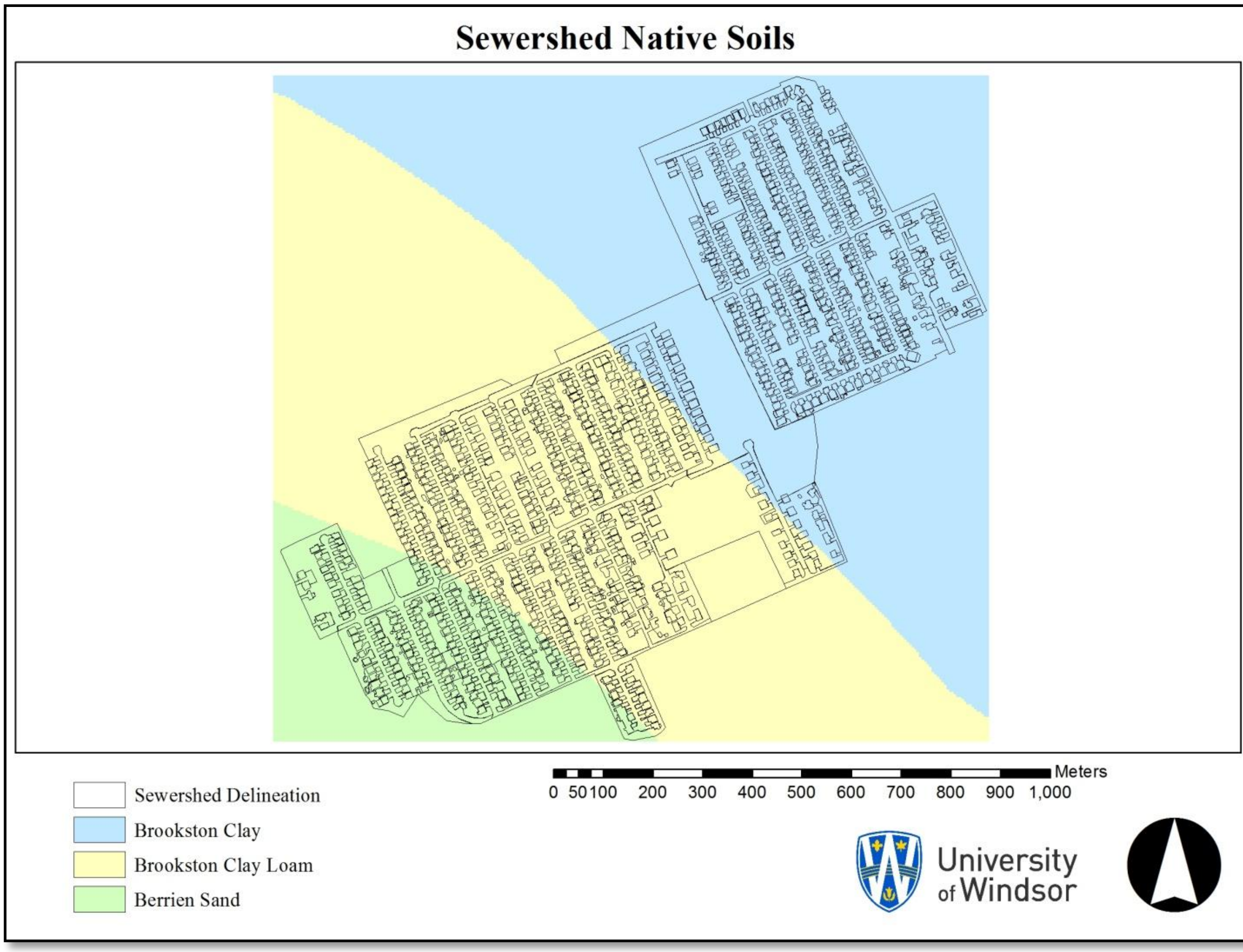


Figure 3-6 ArcGIS map of study area soils

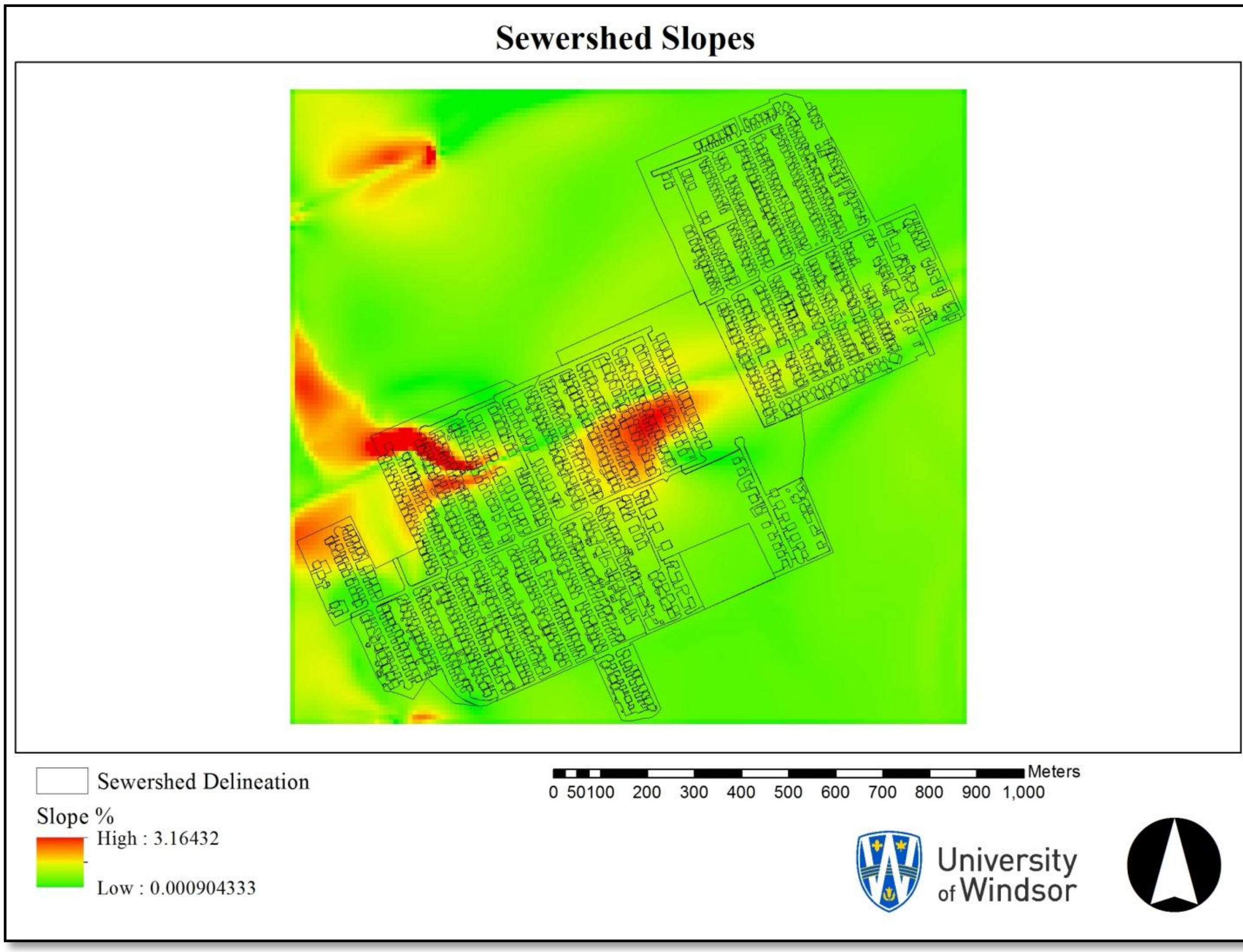


Figure 3-7 ArcGIS map of study area slopes

Another consideration for the infiltration behavior of the soil would be the initial moisture conditions. Part of this will be determined by the depth to the water table. In the case of this sewershed, the water table is very shallow, with a high level of 0 to 2 m (Essex Region Source Protection Area, 2014). This is likely to lead to more issues with runoff as saturated soils will reduce infiltration rates. Additionally, LIDs may be less effective and may require underdrains (this will be further discussed in chapter 5).

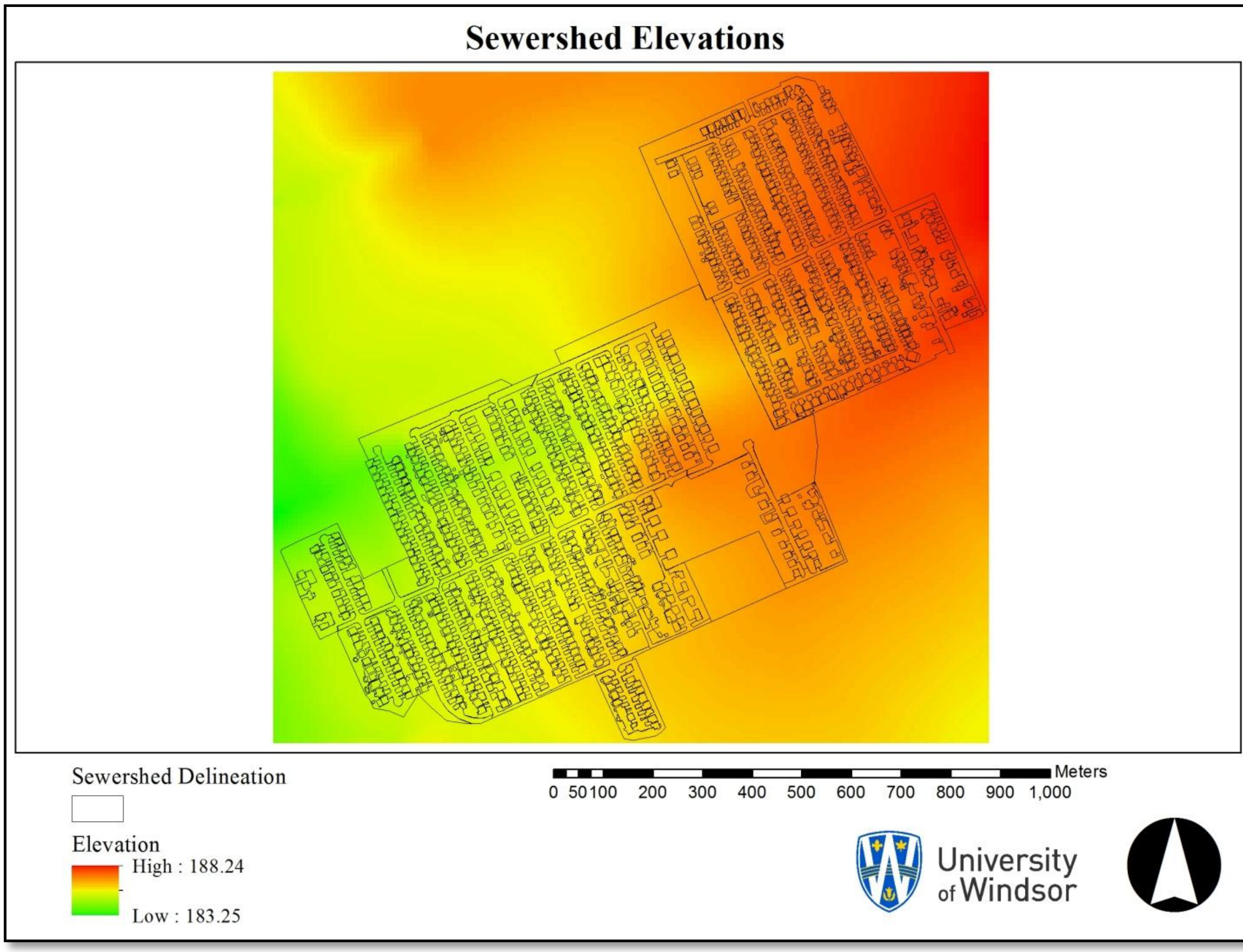


Figure 3-8 ArcGIS digital elevation map

3.6 Climate

Windsor, Ontario is located at the southwestern tip of Ontario at 42°17 N, 83°00 W. It is bordered by Lake St. Clair in the north, Lake Erie in the south, and the Detroit River in the west and north-west. The city has an elevation of around 190 m above sea level. According to the Canadian climate normals for the Windsor Airport Station from 1981 to 2010 there were three months, December, January and February, with temperatures below 0 °C. The summer months are characterized by heat and humidity (the highest recorded humidex in this period was 52.1 °C. June, July, August and September are the hottest months (July is the hottest) and also experience some of the most intense rainfall events. June, July and September experienced the most days with greater than 25 mm of rain between 1981 and 2010 (Canadian climate normals). During the summer months, particularly June, July, and August much of this rain can come in the form of thunderstorms which often produce high intensity rainfall over short periods of time. Farnsworth and Thompson (1983) provide pan evaporation values for Dearborn, Michigan, United States which is close to Windsor. Dearborn is located at 42° 18'N, 83° 14'W. The pan evaporation values can be found in Table 3-3.

Table 3-3 Monthly pan evaporation (mm)

APR	MAY	JUN	JUL	AUG	SEP	OCT
98.6	148.8	175.5	186.7	157.0	78.7	76.0

Further discussion on the localized rainfall and available gages can be found in section 4.2.1. Expected future climate changes are analyzed in section 7.2.1.

4 Hydrological Model

4.1 Stormwater Management Model

4.1.1 Overview

The Storm Water Management Model (SWMM) is an open source model created and updated by the United States Environmental Protection Agency (EPA). SWMM is commonly used for the design, planning, and analysis of urban water systems (Rossman, 2010). More specifically, it is often used for simulation involving urban stormwater runoff, combined sewers (it's original purpose), sanitary sewers, and the implementation of BMPs. SWMM can be used for the evaluation of both stormwater hydrology and water quality; however, the tools for the former are more developed. As was noted in the literature review, SWMM has been used for the evaluation of urban climate change impacts (Denault et al., 2006), and low impact development (Bosley, 2008; Damodaram et al., 2010; Elliott and Trowsdale, 2007; Maharjan et al., 2009; McGarity, 2010; Qin et al., 2013; Zahmatkesh et al., 2015). SWMM has also been linked with genetic algorithms in order to optimize LIDs or BMPs as was the case in Zhang (2009) and Karamouz and Nazif (2013). SWMM can be used from a Windows based graphical user interface or as a command line version which can interface or link with other programs, such as a genetic algorithm. Examples of SWMM applications can be found in the SWMM Applications Manual (Gironás et al., 2009).

SWMM is a physically based distributed model. This means that the objects in SWMM, whose parameters are used by the process equations, have a spatial representation. The parameters of various objects can be altered independently of other objects. In SWMM these objects are subcatchments, nodes, and conduits, which will all be discussed in subsequent sections. The process equations are generally derived from conservations of mass, energy, and momentum (Rossman, 2010). The physical process represented include surface runoff, groundwater, flow routing, water quality routing, infiltration, snowmelt, and surface ponding

(Rossman, 2010). For this case groundwater, water quality routing, and snowmelt were not employed; runoff and routing will be discussed in the following sections.

SWMM simulates in discrete-time and has variable wet-weather, dry-weather, and routing time-steps (Rossman, 2010). Simulations can be run as single event or continuous; however, they are treated in the same manner so that essentially a continuous simulation is like a single event simulation that last much longer (and likely includes several events). This study employs both single event and continuous simulation. The study area map for the SWMM model is displayed in Figure 4-1 with a star on the outfall (the section of the stormsewer network where the entire modeled network flows to).

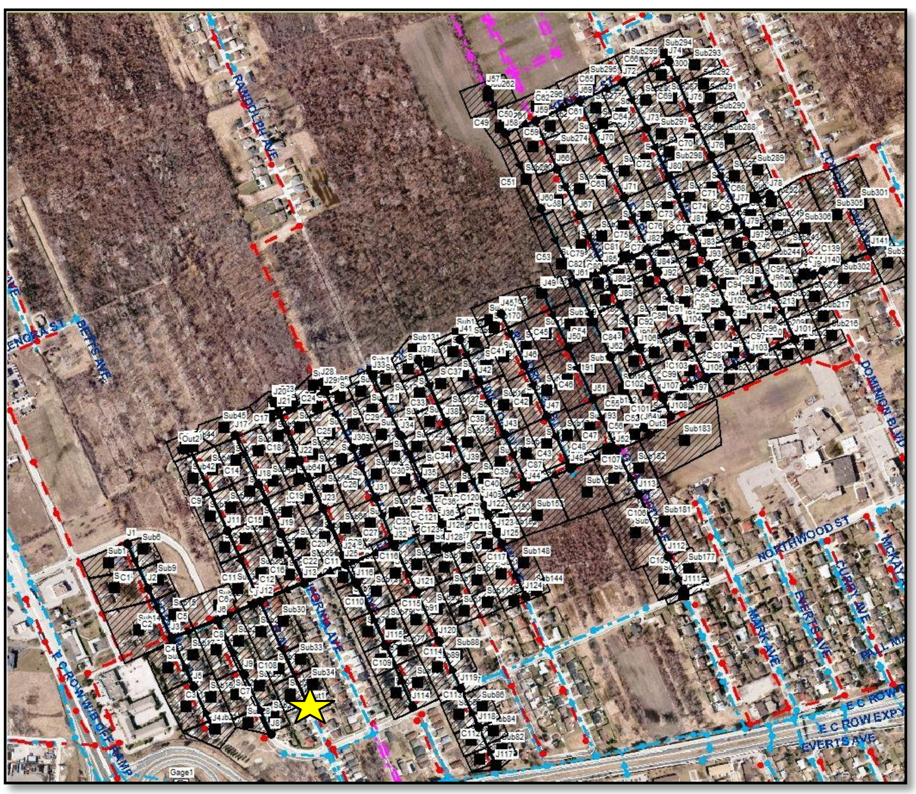


Figure 4-1 Screenshot of SWMM model

4.1.2 Infiltration and Runoff

4.1.2.1 Overview

The generation of runoff is a key hydrologic process in the SWMM model. SWMM treats subcatchments as nonlinear reservoirs (Rossman, 2010). The input is precipitation, run-on or snowmelt which is then either stored in surface depressions, evaporated, infiltrated, or it becomes runoff. This is depicted in Figure 4-2. There are three methods available to be used in the calculation of infiltration, a key consideration in the generation of runoff. These are described in sections 4.1.2.2 to 4.1.2.4. The surface ponding is set as a subcatchment parameter and evaporation can be calculated either using climate files, or an evaporation rate time series. Not depicted in the figure is the possibility of a given subcatchment receiving run-on from another subcatchment. After the runoff is calculated (the outflow from the nonlinear reservoir) its flow is determined using Manning's equation (Rossman, 2010).

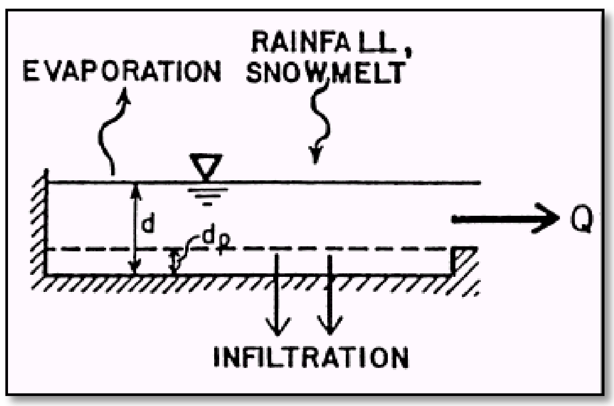


Figure 4-2 SWMM infiltration scheme (Rossman, 2010, p.56)

4.1.2.2 Green-Ampt

The Green-Ampt method is derived from Richard's equation and represents a relationship between moisture content and soil depth (Bedien et al., 2008). The Green-Ampt method considers a sharp wetting front that separates the top of the soil column from the initial moisture at the base (Bedient et al., 2008). The inputs required for Green-Ampt calculations are the initial moisture deficit of the soil, the hydraulic conductivity of the soil, and the suction head along the wetting front (Rossman, 2010).

4.1.2.3 Horton's Equation

Horton's method calculates infiltration using an exponential equation in which the infiltration decreases from a maximum rate to a minimum rate as rainfall continues (Bedient et al., 2008). Horton's method requires the definition of the maximum, and minimum infiltration rates, a decay constant related to the exponential function, and the time it takes for saturated soil to dry (Rossman, 2010).

4.1.2.4 Curve Number Method

The curve number method will be discussed in greater detail than the previous sections as it was the method used in this study. The curve number method has previously been used in a study of an urban stormwater system which used a genetic algorithm and considered climate change (Maharjan et al., 2009). The curve number method, known as the SCS curve number method, was developed by the U.S. Soil Conservation Society in 1964. The curve number method determines runoff primarily based on a curve number. The curve number is a value assigned to a land parcel and is based on land cover, hydrologic soil type, and the antecedent soil moisture conditions. The curve number method is outlined in equation 4-1 from (Cronshey, 1986). Equation 4-1 becomes equation 4-3 when metric units (mm) are used.

(4-1)

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where Q = runoff (in)

P = rainfall (in)

S = potential maximum retention after runoff begins (in)

I_a = initial abstraction (in)

(4-2)

$$S = \frac{1000}{CN} - 10$$

where CN = curve number (between 0 and 100)

$$S = \frac{25400}{CN} - 254 \quad (4\text{-}3)$$

Ponce and Hawkins (1996) list the perceived advantages of the SCS curve number method as its "simplicity, predictability, stability, reliance on one parameter, and responsiveness to major runoff-producing watershed properties." The perceived disadvantages are "its sensitivity to choice of curve number, uncertainty on how to vary antecedent moisture conditions, varying accuracy for different biomes, the absence of a specific provision for spatial scale effects, and the fixing of the initial abstraction ratio" (Ponce and Hawkins, 1996). In the case of SWMM some of these disadvantages are mitigated. This is because the initial abstraction is set by the depression storage of the subcatchments rather than a fixed ratio. The antecedent moisture conditions are updated as the SWMM simulation continues. During dry times this is governed by the soil recovery rate parameter. SWMM may also add evaporation losses before runoff unless the option to only evaporate during dry periods is selected.

The SCS curve number method was selected because the available data on which the model parameter can be set (as seen in section 3) are those which are required for the determination of curve numbers. The fact reliance on the curve number parameter also allows for greater ease in calibrating the model since the calibration of the infiltration is dependent on one parameter rather than, for example, the three which would be required for the Green-Ampt method. Finally, the SCS curve number method was developed to calculate the runoff in small urban watersheds which is the focus of this study.

4.1.3 Routing

The flexibility in designing the routing networks for urban water systems is one of the benefits of the SWMM model. There is the option to include conduits of many shapes, including open channels and culverts, as well as manholes and other non-conduit structures which serve as nodes in the routing network. Water flows into the routing network where runoff from subcatchments is directed into a node. The water then travels through the conduits in the network. The flow through the routing networks can be governed by one of three routing systems. These are steady flow routing, kinematic wave routing, and dynamic wave routing. All three methods use Manning's equation to connect flow rate to flow depth but one of the Hazen-Williams or Darcy-Weisbach equations are used when considering force mains under pressure (Rossman, 2010).

The most complex and complete routing method available is dynamic wave routing. This method solves the one-dimensional Saint Venant equations (Rossman, 2010). This uses a complete form of the momentum equation and the continuity equation (Nix, 1994; Rossman, 2010). Unlike the other methods, the dynamic wave routing method can account for channel storage, backwater effects, entrance/exit losses, flow reversal, and pressurized flow (Rossman, 2010). For this reason the dynamic wave routing method was selected. For example, there was one location in the routing network where flow left a node (manhole) through two stormsewers flowing in opposite directions. Only dynamic wave routing could properly handle this. The information on the routing network was developed from detailed sewer maps which can be found in Appendix B.

4.1.4 LID Representation

The evaluation of LID measures using SWMM has become less difficult as newer versions of SWMM (5, 5.1) include an LID toolbox which allows users to implement LID strategies. Predating this, a discussion of how LIDs might be represented in SWMM can be found in (Huber et al., 2004). The LID toolbox in SWMM 5.1 includes the ability to define bio-retention cells, rain gardens, green roofs, infiltration trenches, permeable pavements, rain barrels, and vegetative swales. All of these LID controls except for green roofs will be included in this study

The LIDs are represented through the parameterization of several layers (not all the LIDs have all the layers). The LID representation is illustrated in Figure 4-3. A discussion the design and parameterization of the LIDs included in this study can be found in chapter 5.

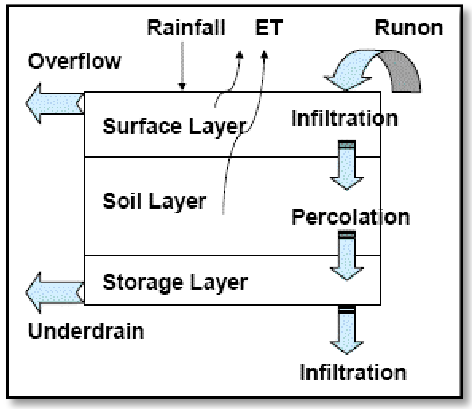


Figure 4-3 SWMM LID processes (Rossman, 2010, p.60)

The run-on is directed to the LID measures from within a subcatchment as seen in Figure 4-4. The amount of the impervious area which routes to each LID type is a parameter defined for each subcatchment. LIDs themselves can be added to existing subcatchments, or new subcatchments can be created specifically for LIDs. In the later case one could create a subcatchment simply for one LID and route from existing subcatchments to the LID subcatchment as run-on, or even to other LID subcatchments in order to create a treatment train. The creation of treatment trains is not otherwise currently possible in SWMM as runoff from impervious areas will be divided amongst the LIDs measures and then runoff to the subcatchment outlet or the pervious area, there is no option to route to other LID measures within a subcatchment. SWMM also provides the option of providing reports on LID measures to see how a specific LID measure performs during simulations.

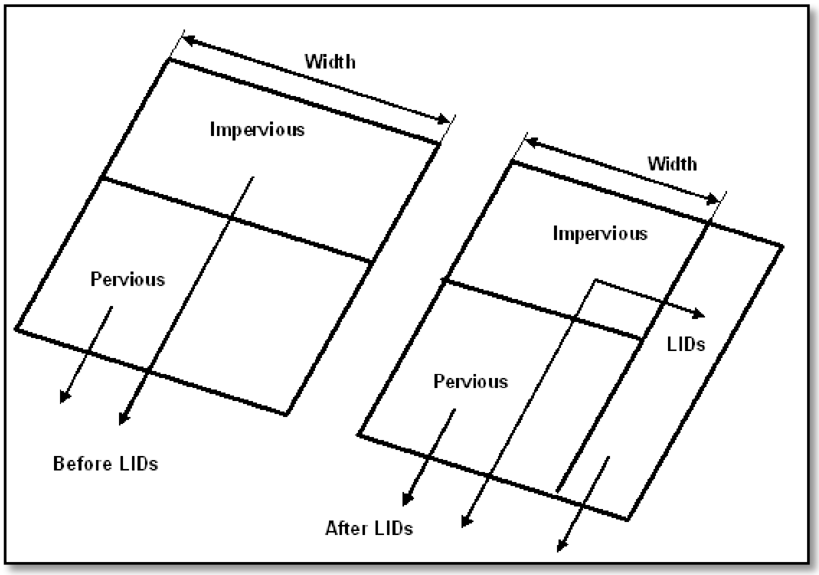


Figure 4-4 SWMM LID routing scheme (Rossman, 2010, p.55)

4.1.5 Objectives of Model Development

The primary objective in developing the model is to create a representation of the hydrologic conditions of sewershed in Windsor, Ontario described in Chapter 3. The sewershed will be model will be calibrated against flow monitor data from the outlet of this section of the sewer network. This allows performance of LIDs, the optimal combinations, and there cost-benefit relationships to all be evaluated for this area. The calibration will be conducted based on historical precipitation events. The model will then be verified against additional historical events.

4.2 Data

4.2.1 Precipitation Data

With precipitation being the primary input of the urban hydrologic system and the SWMM model, the precipitation data has a significant impact on the performance of the model.

4.2.1.1 Available Data

Rainfall data was provided by the City of Windsor. The rainfall data is available in either 1-minute or 15-minute intervals. At the time the data was received, the 1- minute interval precipitation data was available from October 10th, 2012 to January 15th, 2014. The 1-minute interval precipitation data was available from September 27th, 2013 to December 9th, 2013. Figure 4-5 shows the locations of the rain gauges. Data from gauges 7 and 13 is only available for a shorter period and data from gauges 4 and 5 is not available at all. The star represents in the figure represents the location of the sewershed which was modeled. It is important to notice that there are no rain gauges directly within the sewershed. For some scale, at its widest (not diagonally) the shaded grey region is about 22 km wide.

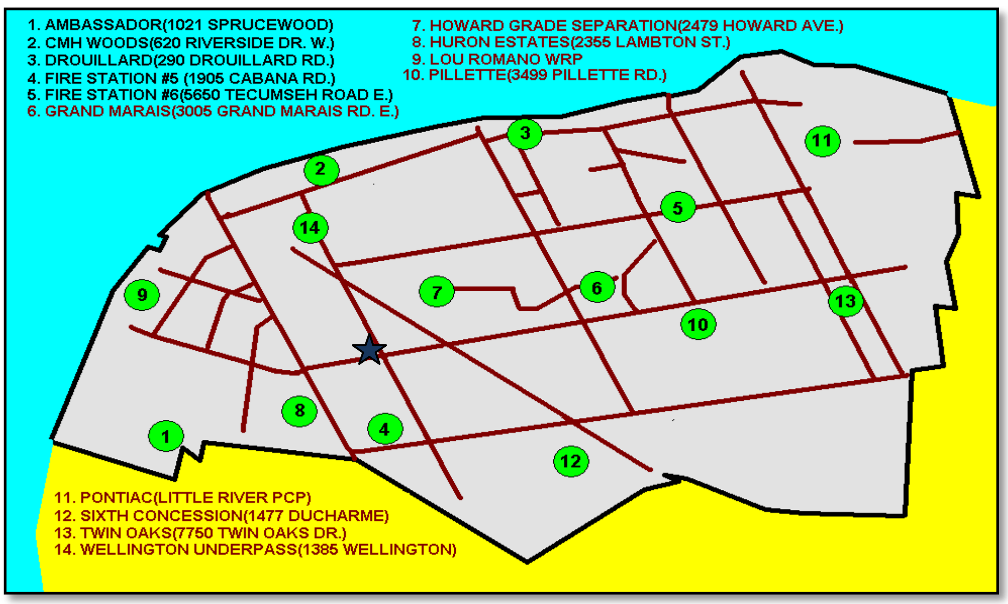


Figure 4-5 Rain gauge locations (Provided by the City of Windsor, 2014)

4.2.1.2 Selection of Events

The selection of events was limited by the time period in which the flow monitor data was available. When the data was provided, reliable flow monitor data was only available from July 11th, 2013 to mid November of the same year. For this reason, all the significant events in this time period were selected for calibration and validation. Events which occurred in close proximity to each other were simulated as one continuous simulation so that the model could be tested against consecutive series of events where initial saturation conditions would be changing. The most significant rainfall events that were captured in the simulation periods are listed in Table 4-1. How they are grouped together as simulations can be seen in the model outputs which will be presented in the following sections. Considering the difference between 1-minute interval rainfall and 15-minute interval rainfall, the comparisons conducted by Bosley (2008) are useful. He compared the response of the SWMM model to 5 and 15 minute rainfall intervals for the same events. There were very similar results for runoff, peak flow, infiltration and time to peak; however, there was one instance of a 15 minute difference in time to peak (Bosley, 2008). The input climate files in which the precipitation time series are stored can be found in Appendix B.

Table 4-1 Recorded rain events

Storm Event	Start Time	Recording Interval (min)	Peak Interval Intensity (mm/h)	Duration (min)	Total Volume (mm)	Return Period (yrs)
July #1	7/15/13 20:22	15	22.6	300	31.8	< 2
July #2	7/16/13 14:52	15	16.8	60	7.5	< 2
July #3	7/18/13 13:07	15	30.6	45	9	< 2
July #4	7/19/13 20:22	15	18.8	105	11.2	< 2
July #5	7/20/13 0:52	15	9.6	195	8.1	< 2
July #6	7/23/13 9:04	15	24.2	75	11.25	< 2
July #7	7/23/13 15:24	15	39.8	60	13.7	< 2
August #1	8/27/13 7:07	15	4.7	180	4.87	< 2
August #2	8/27/13 20:07	15	3.87	285	6.87	< 2
August #3	8/30/13 22:37	15	31.9	135	24.9	2
October #1	10/5/13 6:53	1	28	49	5.9	< 2
October #2	10/6/13 6:22	1	4	45	1.3	< 2
October #3	10/6/13 17:42	1	30	54	7.1	< 2
October #4	10/6/13 23:02	1	4	80	1	< 2
October #5	10/31/13 0:15	1	32	299	17.5	< 2
October #6	10/31/13 10:48	1	32	471	17.7	< 2
October #7	10/31/13 20:21	1	10	196	6.8	< 2

In regards to Table 4-1, the return periods were calculated using an IDF curve for the Windsor airport (Environment Canada, 2012). There are so many values of < 2 because 2 years is the lowest return period displayed on the IDF curve and only one event came close to or reached that return period. The return period was estimated using the average rainfall intensity over the total duration of the events. It is a drawback to the available data (but not the people who live in this area) that there were no events of a larger return period recorded in the available data.

4.2.1.3 Selection of Rain Gauges

The selection of rain gauges is very important because rainfall is subject to significant spatial variation and, as seen in Figure 4-5, none of the rain gauges are directly located in the modeled sewershed. In order to evaluate which time series provided the model results which most closely matched the observed data (in terms of flow rate into the sewershed outfall) the model runs using various time series were compared for one of the calibration series of events. The precipitation time series which were compared were gauge 8 (the closest to the subcatchment), the mean of gauges 8, 9, and 14, and an adjusted average time series. The adjusted average was created by looking at radar data from the National Oceanic and Atmospheric Administration's National Climate Data Center radar maps (NOAA, 2014). Radar data was compared to rain gauge data and the precipitation values for the subcatchment were adjusted accordingly. The results of the simulation are shown in Figure 4-6. It was determined that the mean rainfall values performed the best so they were used for calibration. It is the mean rain series that is displayed in the calibration and validation figures.

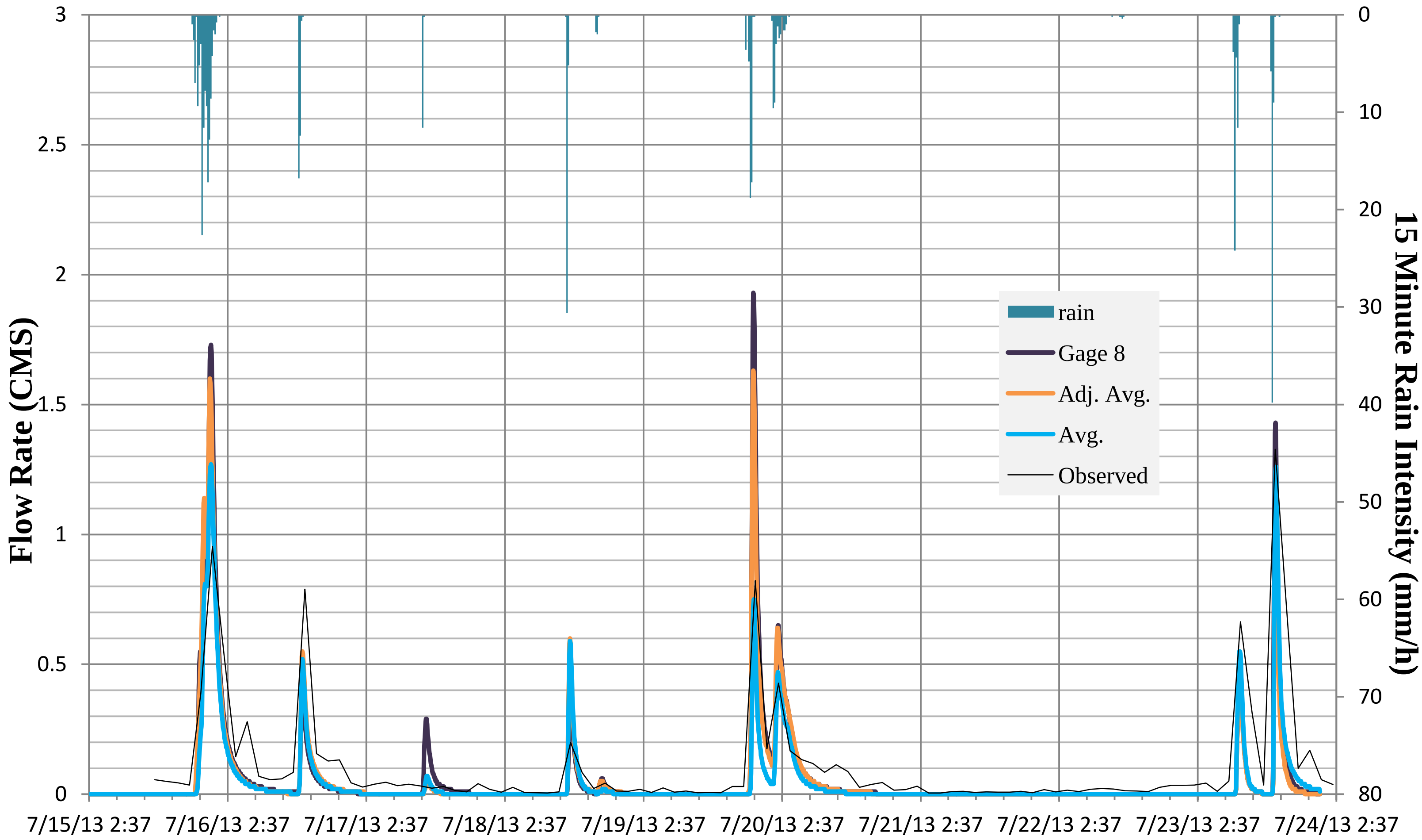


Figure 4-6 Comparison of rain gauges for the July 15th event

4.2.2 Flow Monitoring Data

Flow monitor data were provided by the City of Windsor. When the data was provided in 2014, there was reliable data provided from July 11th, 2013 to mid November of the same year. The location of the flow monitor and other flow monitors in the City of Windsor can be seen in Figure 3-1 where the flow monitor for the sewershed in question is ST1200. It should also be noted that the flow monitors catch large areas of sewer networks and are quite dispersed. This means that we can only calibrate to the flow leaving the entire sewershed at the point where the flow monitor is installed. The flow monitor data includes flow depth, velocity, and rate. The data is recorded at two hour intervals. This long interval makes calibration more challenging. As was previously mentioned, the short time period during which flow monitor data was available limits the number of precipitation events which can be used to compare the observed data from the flow monitor to the SWMM model output. The flow monitor reporting times appeared to be shifted by 2 or 4 hours so these errors were corrected. The timing of the rainfall data was verified using the radar data and alterations in SWMM parameters would not create a timing difference of 2 or 4 hours. This means that it is very likely that an error in the recording time of the flow monitor was creating this problem.

4.3 Model Development

4.3.1 Subcatchments

There are 292 subcatchments in the model. This number is high for a 77 ha sewershed. The number of subcatchments was implemented so that there could be inflow at each node (manhole) described in the sewer maps which were used to set up the routing network. This was so that the timing of the flows through the sewershed could be as accurate as possible. Drainage maps were not available, so it was assumed that each lot would drain to the nearest curb and then to the nearest downstream node and subcatchments were simply divided into blocks of lots around each node. However, using this many subcatchments created some challenges in setting up scenarios for LID optimization.

The main parameters for subcatchments are area, percent impervious area, width, slope, infiltration parameters, Manning's n values for overland flow for pervious and impervious surfaces, depression storage depth for pervious and impervious surfaces, percent zero, and internal routing parameters. The area of the subcatchments was calculated using the auto-length feature by setting the map in Figure 3-5 as the back drop and scaling the distances. The accuracy of the distances between manholes on the same map, when compared to the detailed sewer atlas maps, confirmed that the scale is accurate. The percent impervious area and slope were determined using GIS, Google Earth. The width was set as the distance from the back of the subcatchment to the street, as suggested in Gironás et al. (2009) and then altered in calibration (as were some of the other parameters. The function of the width is essentially to determine the overland flow distance which runoff must travel before becoming channelized; this is depicted in Figure 4-7. The infiltration parameters, mainly the curve number, were determined using the sewershed information (see chapter 3) and the tables in the appendices of the SWMM manual (Rossman, 2010). Manning's n values and storage depths were set based on sewershed information and information from the SWMM manual (Rossman, 2010). These values were later calibrated. The internal routing parameters are if runoff from impervious areas is routed to pervious areas before the subcatchment outlet and if so what percentage of the runoff from impervious area. These were set largely based on inspection of the sewershed, primarily to where downspouts were routing roof water. The percent zero is the percent of the impervious area on which there is no surface storage (primarily roofs). This value was calibrated to 30% which lies in the typical range reported in Zhang (2009). For a complete list of parameters and their determined values, see Appendix A.

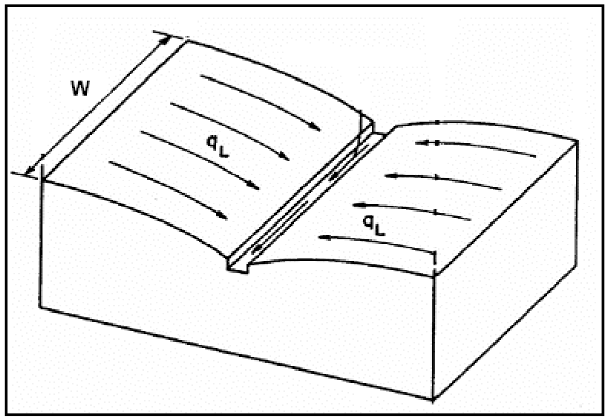


Figure 4-7 SWMM subcatchment width (Gironás et al., 2009, p.17)

4.3.2 Conduits

The conduits in the SWMM model were designed exactly as specified in the in the sewer maps (Appendix A). Other properties, such Manning's n and loss coefficients were determined from the SWMM manual (Rossman, 2010) and Vano Engineering (2012). For a complete list of parameters and their determined values, see Appendix A.

4.3.3 Nodes

Like the conduits, the nodes were taken from the sewer atlas maps (Appendix A). In cases where the invert elevation and/or maximum depth was not available from the sewer map, it was estimated by the inverts of connecting sewers or other nodes in the area. The initial depth and surcharge depth were both set at 0. The ponding area (the surface area of a puddle above the node when it becomes backed up) varies between 0 and 10 m^2.

4.3.4 Other Properties

There are a few additional input parameters. The evaporation was set to only occur during dry periods and based on Table 3-3. Because these evaporation rates were used and snowmelt is not considered there is no need for a climate file with temperatures. The equation selected for force main was the Darcy-Weisbach equation. The start and end times were selected to include the entire precipitation events and some time before and after where there is no precipitation. As for the time controls, the reporting interval was set to 5 minutes, the wet calculation time step was set to 20 seconds while the dry step was set to 40 seconds. The routing time step was set to 3 seconds because a very short time step is required for dynamic wave routing. With these parameters, the calculation error was consistently very low. For a complete list of parameters and their determined values, see Appendix A.

4.3.5 Sensitivity Testing

Before the model was calibrated, a simple sensitivity test was conducted to get a feel for how the model responded to changes in the parameters under consideration for calibration. Previous studies have also conducted sensitivity analyses on SWMM. Bosley (2008) found that peak flows and time to peak were influenced more by flow length than soil moisture content. Therefore, the subcatchment width is very important for time to peak. They also found that SWMM was more sensitive to slopes in the low range (Bosley, 2008). Although the slopes in the sewershed under consideration for this study are low, slope was not a calibration parameter. Zhang (2009) reported similar results to what is shown in Figure 4-8 to Figure 4-11. He also reported that increasing the depression storage depth delays flow after the beginning of precipitation events, reduces peak flows, and reduces total runoff. It was also reported that increasing Manning's n will reduce the runoff rate and lengthen the duration of the flow (Bosley, 2008; Zhang, 2009). Baffaut and Delleur (1989) found that the subcatchment percent imperviousness was the most sensitive parameter to runoff volumes. Similarly, Warwick and Tadepalli (1991) found that using percent imperviousness as more successful for calibration than pervious depression storage. The findings of the sensitivity testing and discussion are presented below. It should be noted that, while the figures display the results for July, similar testing was conducted for the August event.

The largest impact of reducing the percent zero, the percent of the impervious area where there is no depression storage, is reducing the peak flows. The reduction of subcatchment percent imperviousness has a much larger impact on the reduction of runoff than the percent zero. As the peak flows are reduced the total runoff and outflow volumes in each event also decreases and the response times seem delayed. The changes in curve number have a significant effect on the results, similar to the effect of the percent imperviousness. In this case there is a narrow range of values that would be reasonable for the curve numbers; therefore, amount by which the curve number is being changes is not very high. Similar to the other properties under consideration, decreasing the subcatchment width decreases the peak flows. Decreasing the width also increases the trailing arm of the hydrograph, making the peaks slightly less abrupt.

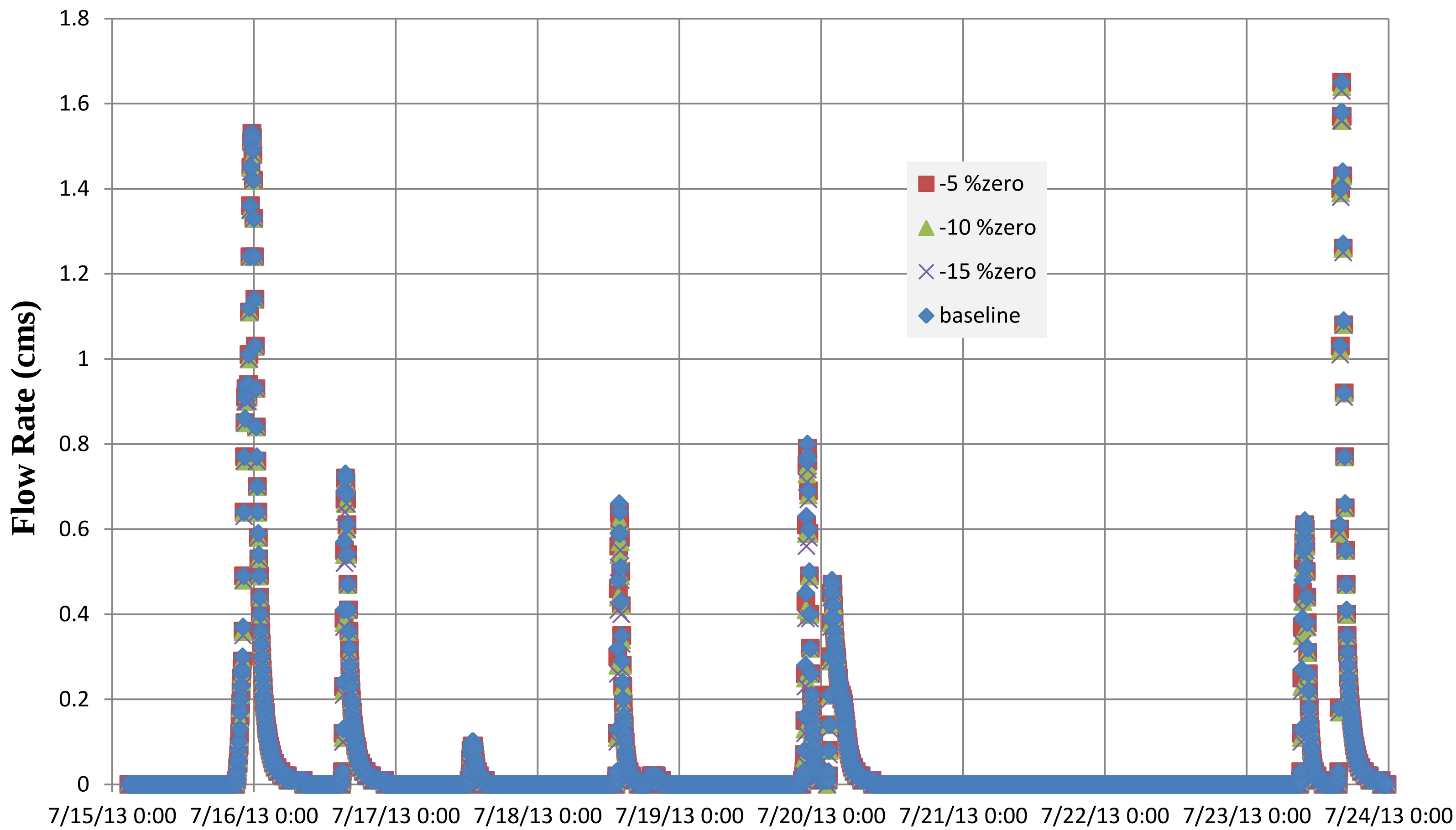


Figure 4-8 Sensitivity of the model hydrograph to subcatchment % zero

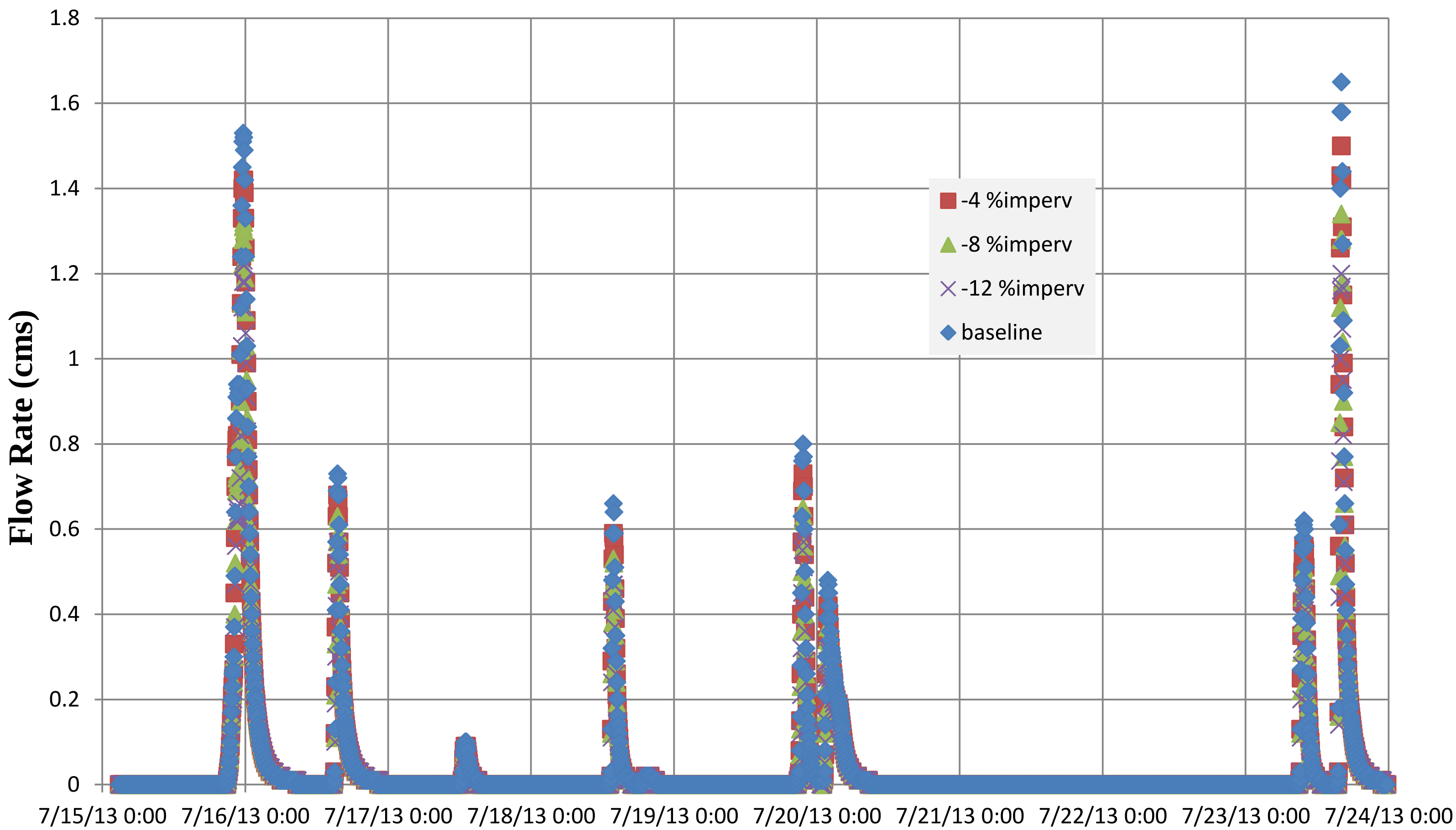


Figure 4-9 Sensitivity of the model hydrograph to subcatchment % imperviousness

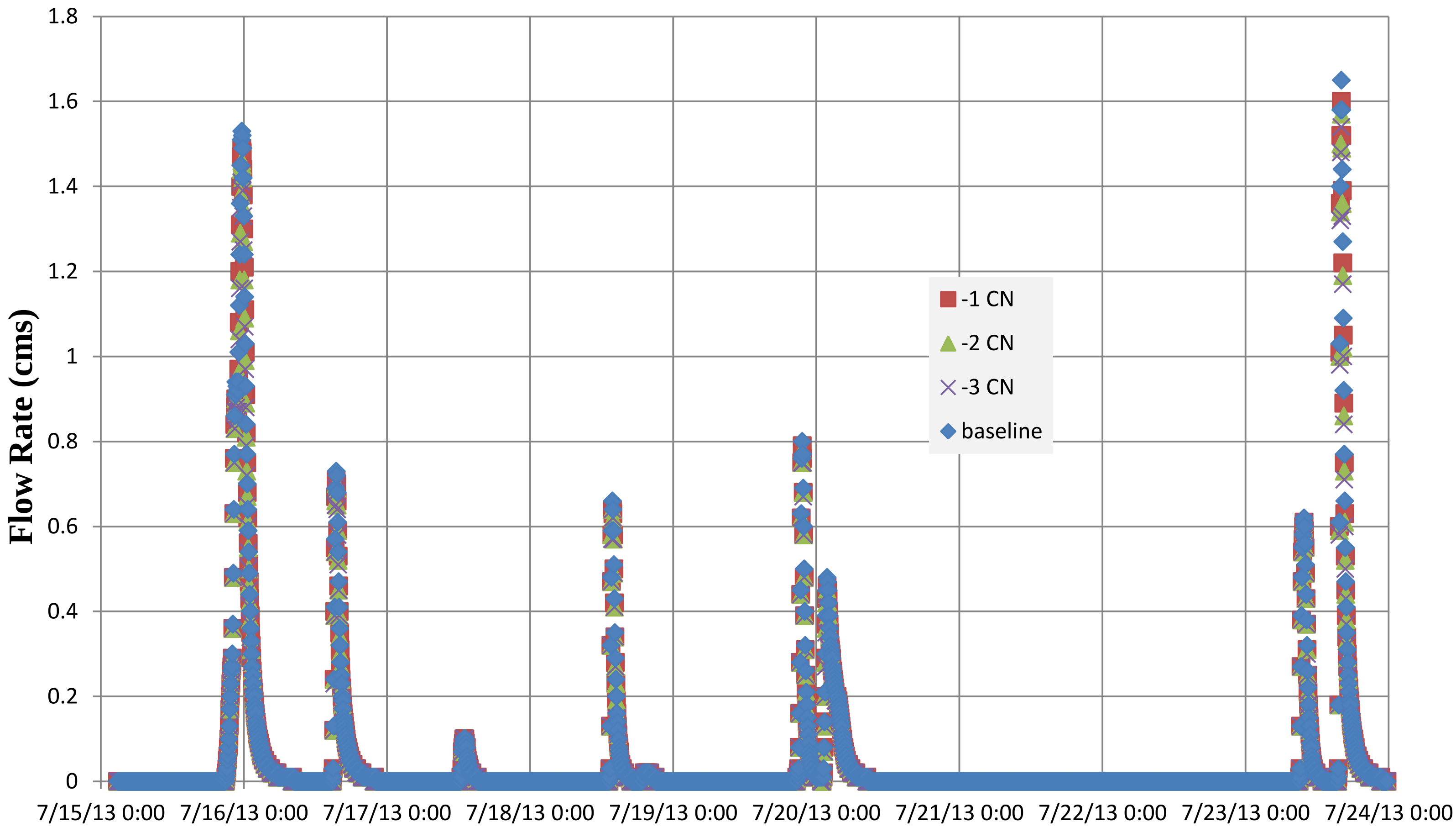


Figure 4-10 Sensitivity of the model hydrograph to subcatchment curve number

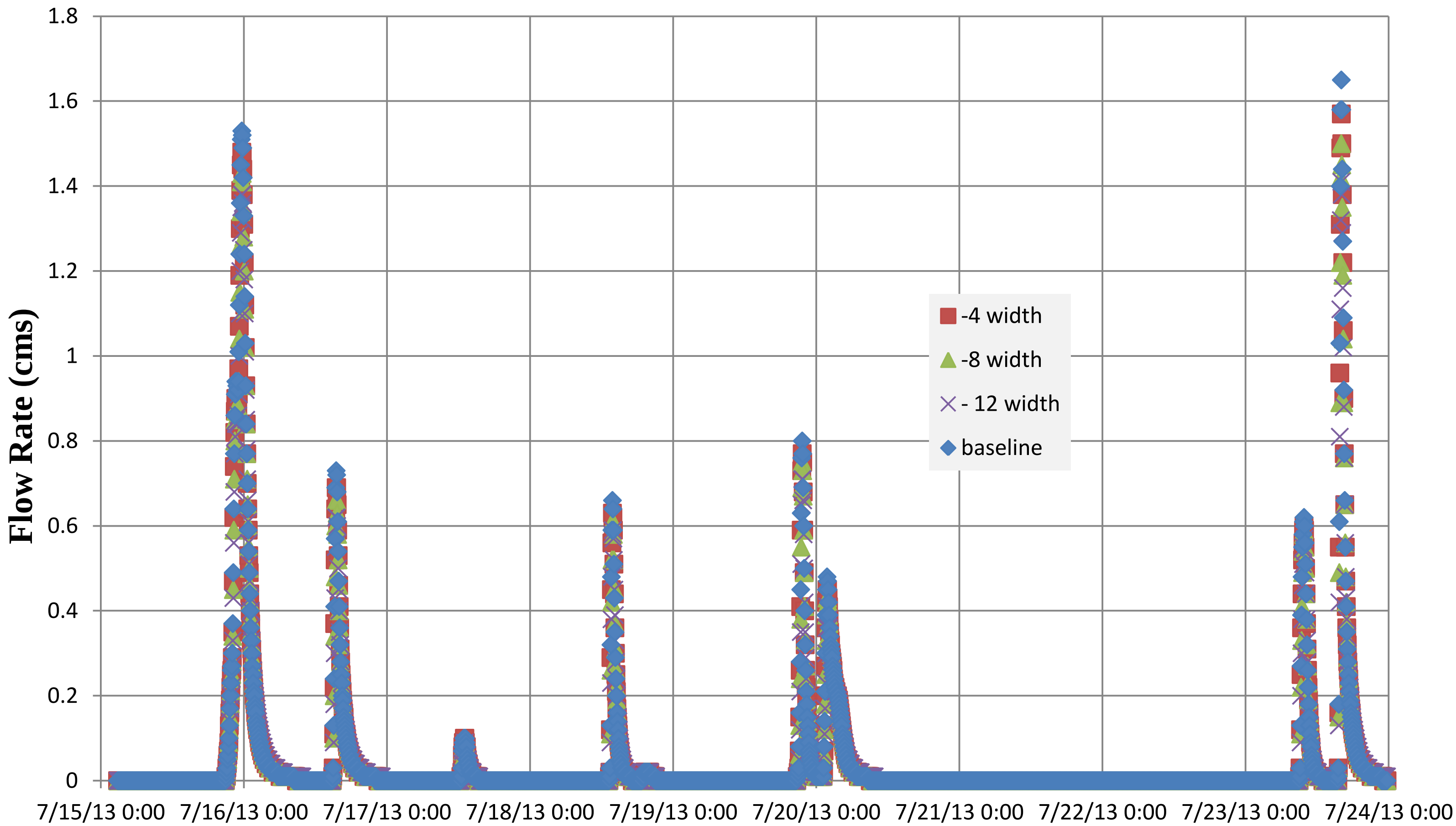


Figure 4-11 Sensitivity of the model hydrograph to subcatchment width

4.3.6 Calibration and Validation of the SWMM Model

The calibration of the SWMM model involves adjusting model parameters to better fit the observed data. The assumption here is that if the model more accurately reproduces the flow rates recorded by the flow meter then this indicates that the model is more accurately representing the actual sewershed.

For this study, the model parameters were adjusted to attempt to adjust the hydrographs to better fit the observed data. The calibration was done comparing the outfall hydrograph to the observed flow monitor data for two series of events (continuous simulations which each contained multiple precipitation events). Validation was then conducted by evaluating the goodness of fit for two additional series of events. In both calibration and validation the goodness of fit was evaluated both visually on graphs, and by calculating the Nash-Sutcliffe efficiency (equation 4-4, Nash and Sutcliffe, 1970).

$$E = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)^2} \tag{4-4}$$

Where O is the observed flow and P is the predicted or simulated flow.

The Nash-Sutcliffe efficiency values can fall between - ∞ and 1, where 1 is a perfect fit. If E falls below zero, then this indicates that the mean value of the observed series of data would be better predictor than the flow series estimated by the model. A drawback of Nash-Sutcliffe is that the differences are calculated as squared values which leads to overestimating the goodness of fit during peak flows and underestimating it during low flows (Krause et al., 2005). To expand this point Krause et al. (2005) reported that the Nash-Sutcliffe method was sensitive to peak flows which leads to poorer performance during low flows. In our case the predictions of the peak flows is the most important component. In addition to the Nash-Sutcliffe calculations, peak flow rates, and time to peaks were compared in order to further evaluate model dynamics and quantity simulation. This comparison can be seen in section 4.4. Ahiablame et al. (2013) used Nash-Sutcliffe efficiency to measure the performance of their watershed models in L-THIA-LID. They calculated Nash-Sutcliffe values for the calibration of runoff, baseflow, and streamflow and got values from 0.50 to 0.67, 0.32 to 0.60, and 0.57 to 0.79, respectively (Ahiablame et al., 2013). These values were calculated from ten year continuous simulations. Baffaut and Delleur (1989) suggested that an equal number of events over and under-predicted as a positive sign for calibration. They also reported % imperviousness as the most influential parameter on runoff volumes. After calibration the model percent imperviousness, considering the developed subcatchments, is 46.7%. This is very close to the 48% imperviousness estimated for the same area using Google Earth and ArcGIS.

The main parameters altered in order to calibrate the model are the ones discussed in section 4.3.5. They are subcatchment width, percent imperviousness, curve number, and percent zero storage. In addition to those parameters, the depression storage depth and Manning's numbers for overland flow were also used to a lesser extent for calibration. Table 4-2 shows the parameters and number of events selected in other studies.

Table 4-2 SWMM calibration parameters used in previous studies

Source	# of Calibration Events	Calibration Parameters Considered.
Liong et al.(1991)	5	Manning's n, depression storage, infiltration parameters, sub width, sub % imperv, sub slope, sub %0 imperv, channel n values
Warwick and Tadepalli (1991)	3	sub % imperv, sub impervious depression storage
Zhang (2009)	8	sub d storage, curve number, Manning's n, sub %0 imperv

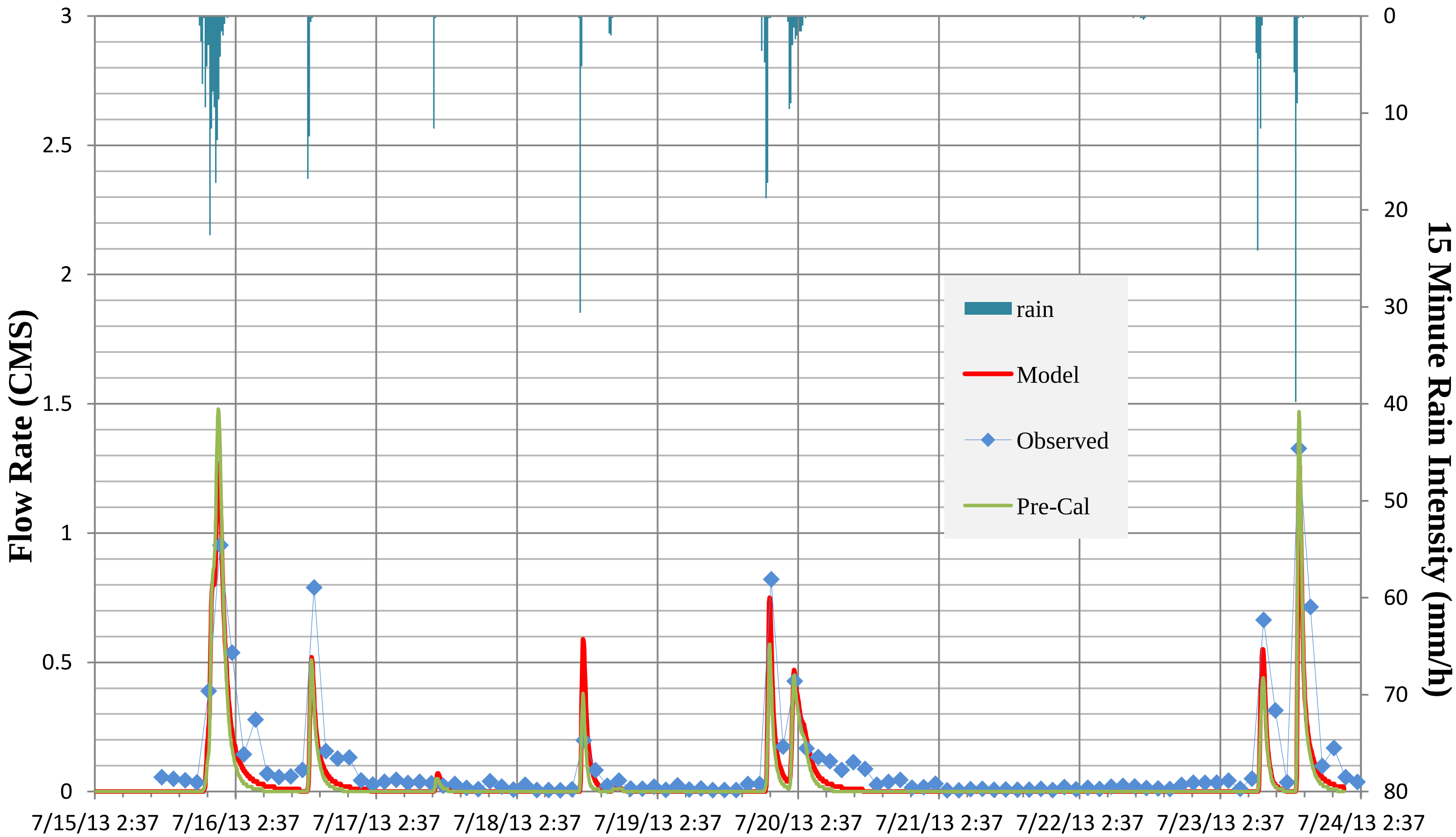
4.4 Results and Discussion

This section contains the results of the SWMM model calibration and validation including conclusions on the performance of the SWMM model and its utility in this study.

4.4.1 Calibration Events

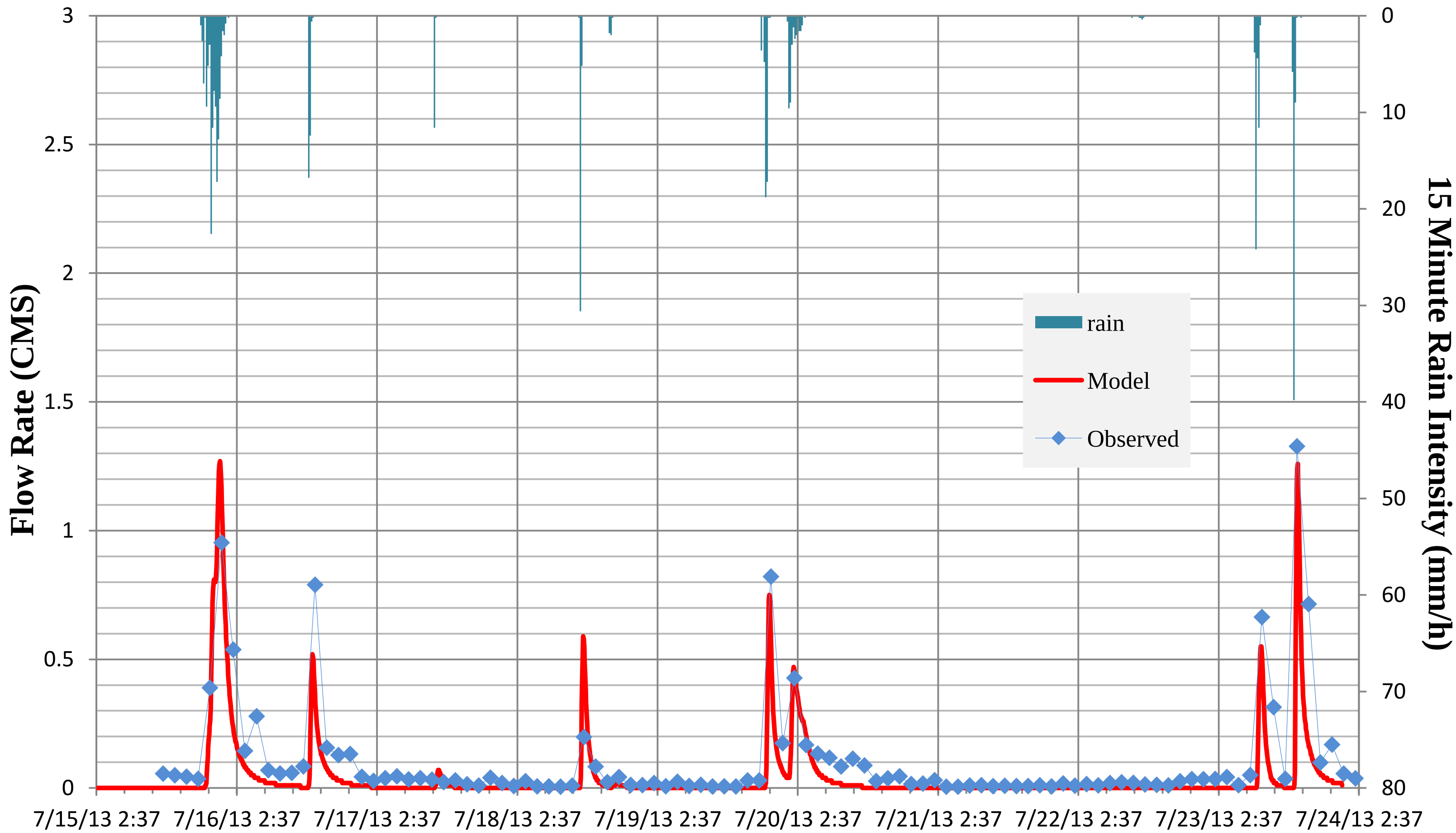
4.4.1.1 Calibration for the events from 7/15/13 to 7/23/13

The first series of events, presented in Figure 4-13 and Figure 4-14, were used for calibration. The first graph shows both the results of the calibrated and uncalibrated models. The main objectives during the optimization process, in order to improve the goodness of fit, were to decrease some of the overestimated peaks and increase the length of time the model was producing flow for each event. One important point to note is that there is a reason that the SWMM model did not capture the secondary, smaller spikes in the flow following the main events. These secondary spikes were caused by an additional area which would drain into the stormsewer system of the study area. The additional area, not included in the model, stores stormwater in a pond and ditch and then pumps it into the stormsewer system after the event has concluded. The specific details regarding this pumping were not available but the existence of this procedure was confirmed. For this reason, these specific data points were not included in the calculating of the Nash-Sutcliffe efficiency. A few points were excluded from the two 15-minute interval precipitation series but not the 1-minute interval series as it was not clear whether or not the same pumping occurred. The model values selected for the Nash-Sutcliffe calculation was those that were closest (usually within 1 minute) of the closest observed data point. The Nash-Sutcliffe efficiency was calculated twice, once including all the values except those previously mentioned (presented in Table 4-3), and once using only the values where the model was not producing zero flow (i.e. only during events; presented in Table 4-4). For the removal of zeroes, a model reading of zero was not removed where the observed reading was significantly above zero, in order to preserve the integrity of the metric. The Nash-Sutcliffe efficiencies improved with calibration.   Overall the Nash-Sutcliff efficiencies are good and the model seems to be effectively simulating the sewershed dynamics in this time series.



The pre-cal line represents the model output at an earlier stage of calibration.

Figure 4-12 Calibration of the SWMM model for the events from July 15th to 24th, 2013



The same model results as Figure 4-13 are presented without the pre-calibration results.

Figure 4-13 Modeled and observed hydrographs for the events from July 15th to 24th, 2013

Table 4-3 Calibration statistics for the events from July 15th to 24th

	Nash-Sutcliffe
Pre-Cal	0.73
Post-Cal	0.79

Table 4-4 Calibration statistics without zeros for the events from July 15th to 24th

Without zeros	
	Nash-Sutcliffe
Pre-Cal	0.54
Post-Cal	0.64

4.4.1.2 Calibration for the events from 10/4/13 to 10/7/13

The fit is not as good for this 1-minute interval series as it was for the 15-minute rain recording interval calibration series (discussed in the previous section). The calibration did improve the Nash-Sutcliffe efficiencies as can be seen in Table 4-5 and Table 4-6; however, the values themselves indicate poor performance. In fact, without including the zero flow data points the model is only slightly better than simply using the mean of the observed values. The model dynamics appear to be functioning well, besides the time to peak for the second event. For this study, this error may or may not be due to the model construction but could also be due to the long recording time for the flow monitor data and the spatially variable rainfall data.

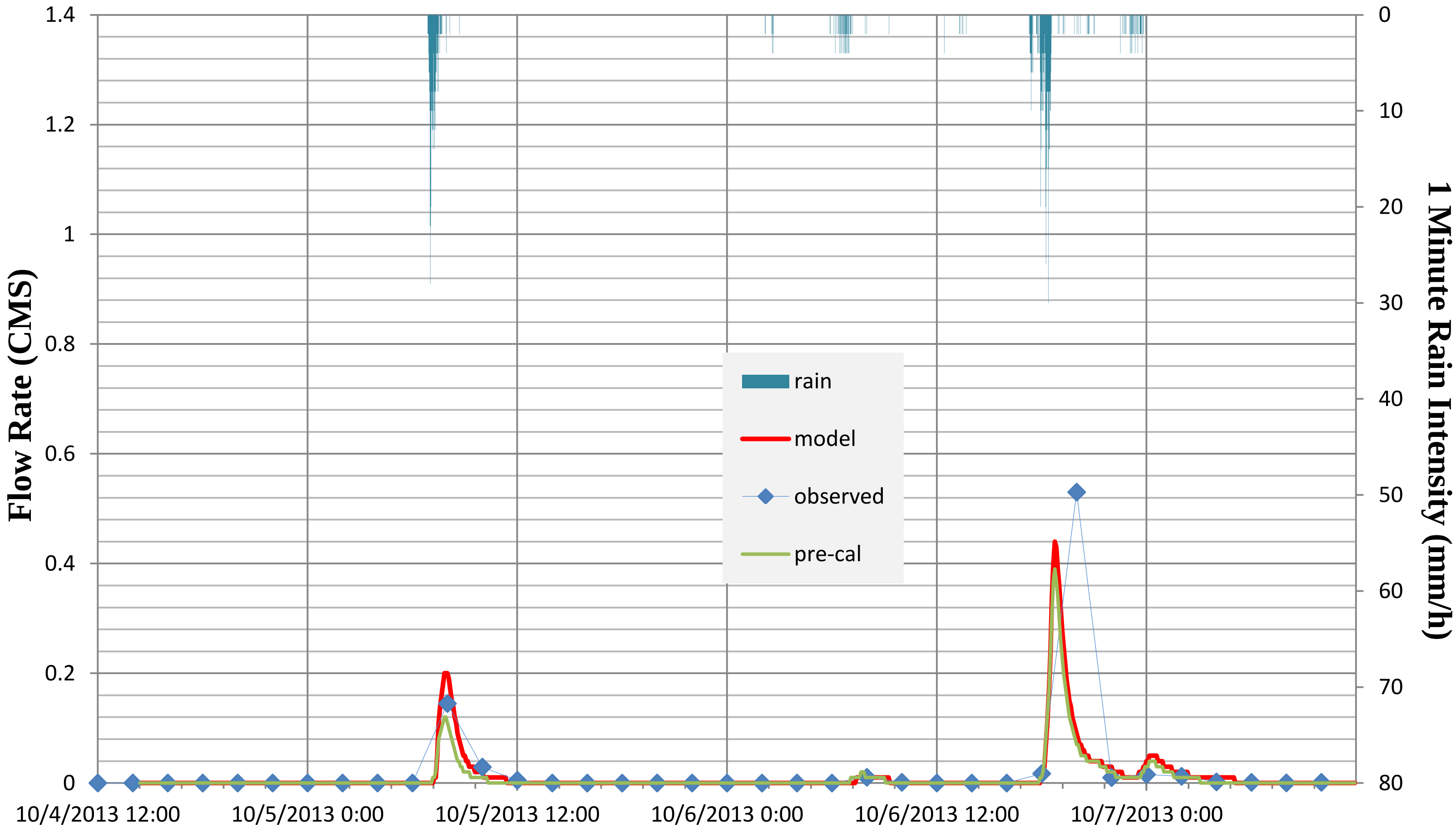
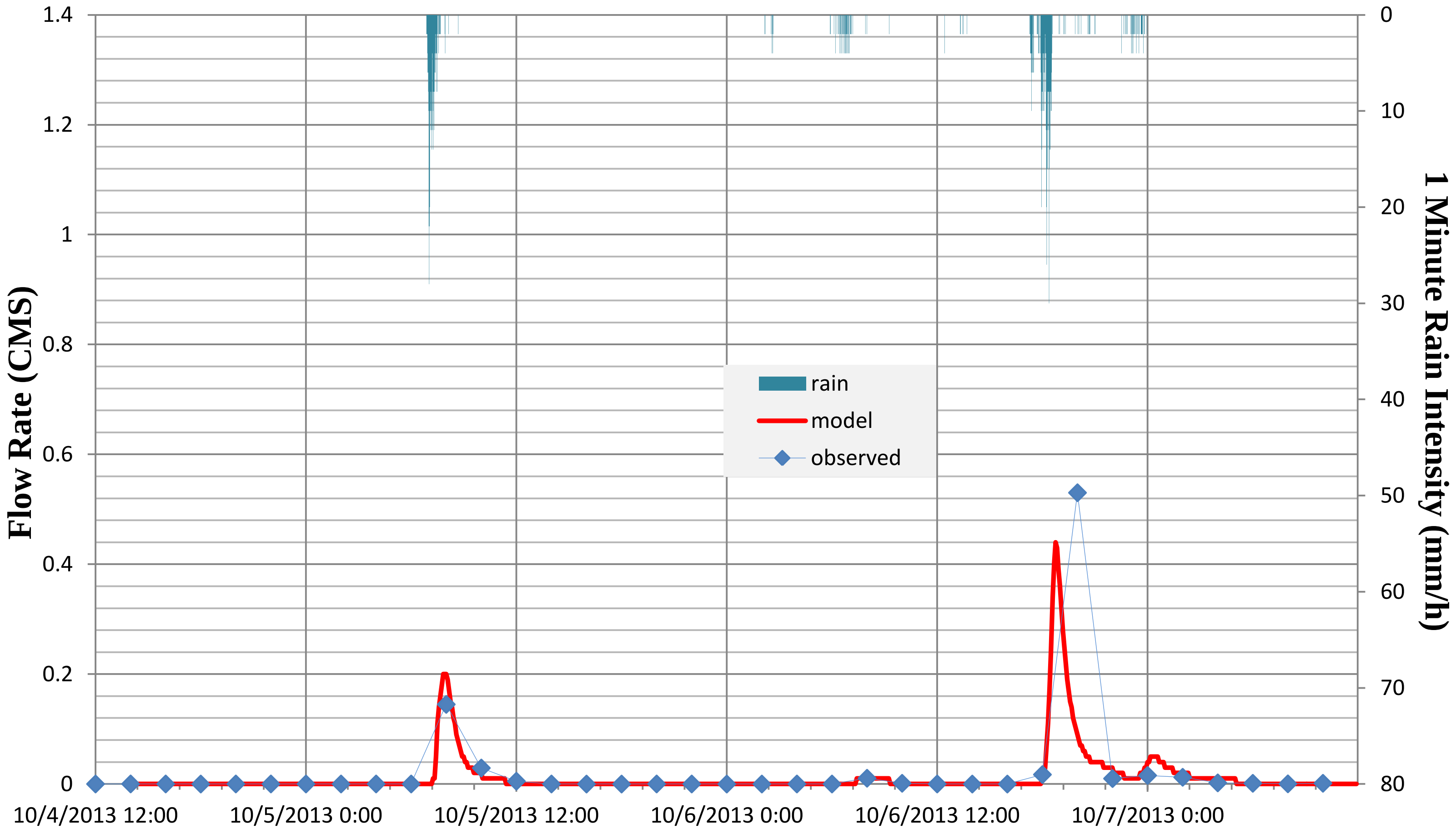


Figure 4-14 Calibration of the SWMM model for the events from October 4th to 7th, 2013



The graph without the pre-calibration model output is shown for clarity

Figure 4-15 Modeled and observed hydrographs for the events from October 4th to 7th, 2013

Table 4-5 Calibration statistics for the events from October 4th to 7th

	Nash-Sutcliffe
Pre-Cal	0.25
Post-Cal	0.31

Table 4-6 Calibration statistics without zeros for the events from October 4th to 7th

Without Zeros	
	Nash-Sutcliffe
Pre-Cal	0.1
Post-Cal	0.17

4.4.2 Validation Events

The first validation event, shown in Figure 4-16 is an event using the 15-minute rain recording interval. The Nash-Sutcliffe (E) efficiency is 0.93 or 0.91 without zeros. This fit is extremely good as the model was a very close match in this case. The second validation event uses a 1-minute rain recording interval and is displayed as Figure 4-17. The E values are 0.51 or 0.42 without zeros. The primary cause of error in this series would seem to be an over prediction of the amount of rainfall which contributes to the middle peak.

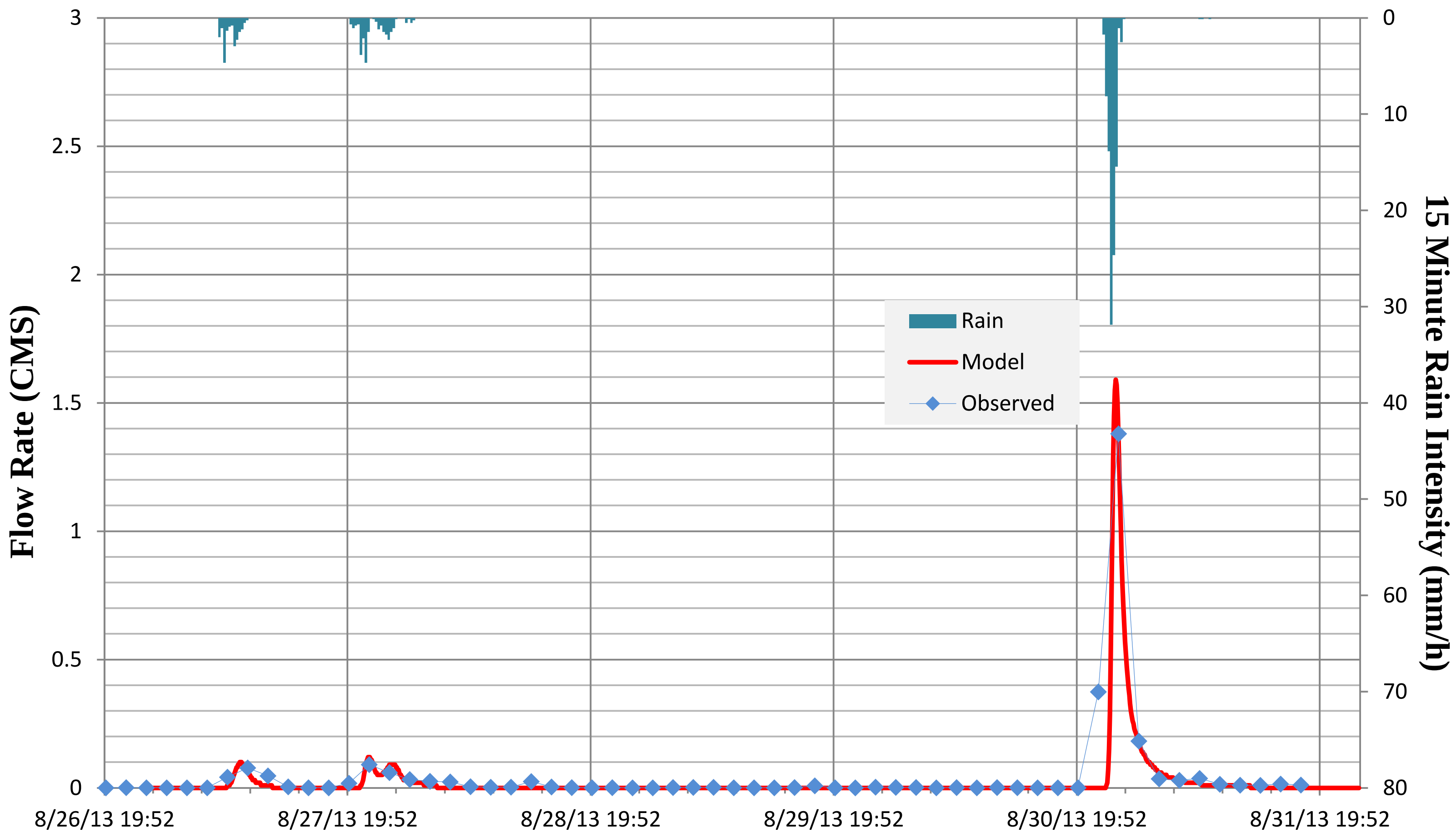


Figure 4-16 Modeled and observed hydrographs for the events from Augusts 26th to 31st, 2013

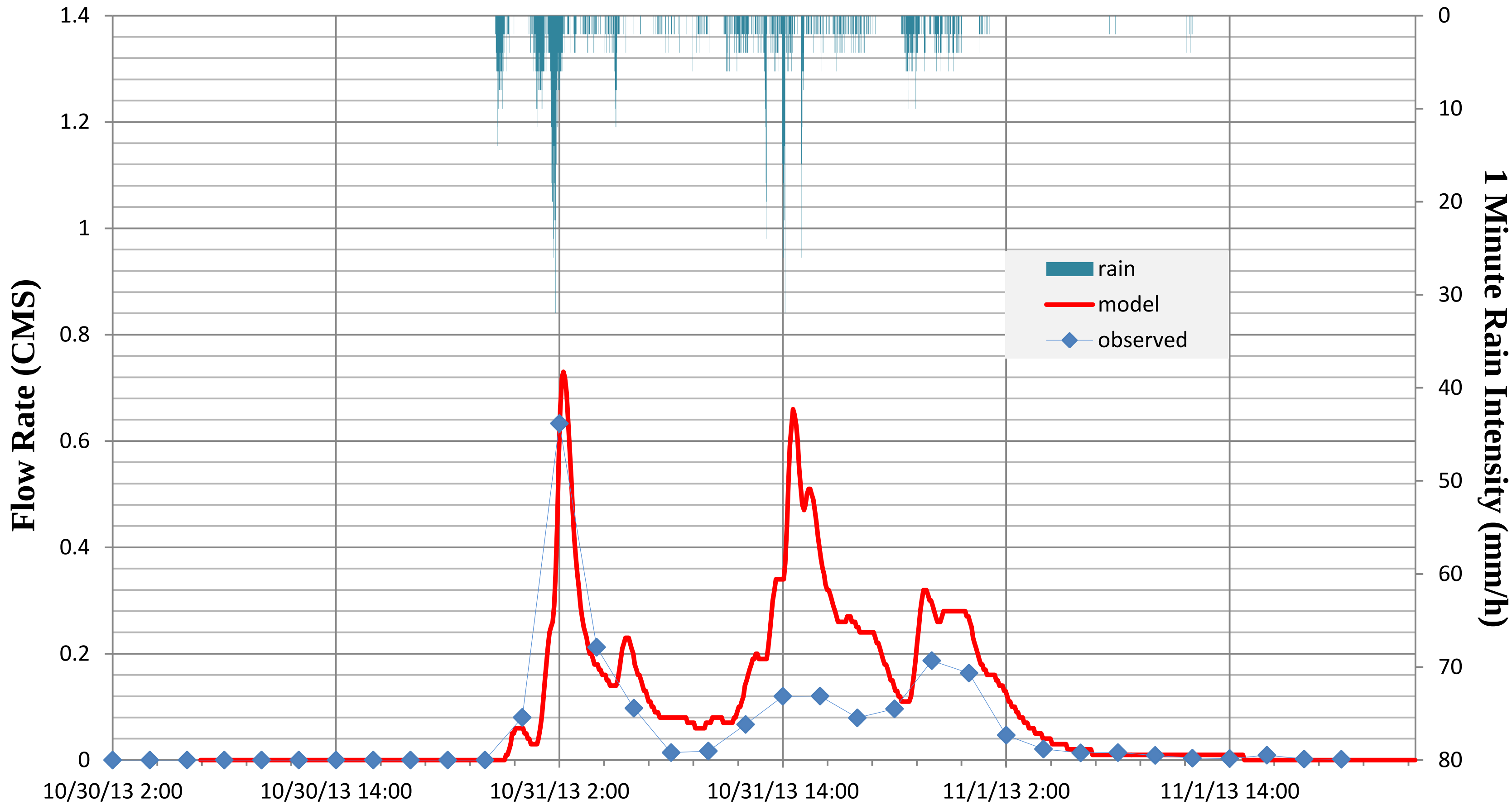


Figure 4-17 Modeled and observed hydrographs for the events from October 30th to November 1st, 2013

4.4.3 Comparison of Peak Flows

Table 4-7 presents the peak flows and time to peak values related to all the events listed in Table 4-1, these are also the events displayed in the hydrographs in the preceding sections. There is a wide range in the accuracy of the peak flow predictions and no clear bias. Some peak flows are over-predicted and some are under-predicted, although over-prediction occurs more often. The performance of the model in predicting time to peak values appears to be quite poor; however, there are many possible explanations for this and errors in model calibration is probably not even the most likely explanation. Differences of greater than 20 minutes in time to peak would be difficult to create through differences in parameter values for a small urban sewershed such as the one in our study. Also, as already mentioned, the overall percent imperviousness after calibration was very close to the calculated actual value for the sewershed. Large discrepancies in timing likely mean that there is some inconsistency in the timing or the rainfall and flow monitor data. For one, the two hour reporting interval for the flow monitors makes it very unlikely that the actual observed peak is captured; therefore, there is uncertainty regarding the time to peak. There is also uncertainty in the amount of rainfall being received by the subcatchments due to the locations of the rain gauges being outside the modeled sewershed.

Table 4-7 Comparison of peak flows and times to peak

Storm Event	Observed Peak (cms)	Model Peak (cms)	Difference (cms)	Difference (%)	Flow at Time Closest to Observed Peak (cms)	Difference' (cms)	Difference' (%)	Observed Time to Peak (h:min)	Model Time to Peak (h:min)	Observed Time to Peak, Peak Rain (h:min)	Model Time to Peak, Peak Rain (h:min)	Absolute Difference
July #1	0.95	1.26	0.31	32.2	1.17	0.22	22.7	3:38	3:17	1:53	1:32	0:21
July #2	0.79	0.52	-0.27	-34.2	0.37	-0.42	-53.1	1:08	0:42	1:08	0:42	0:26
July #3	0.20	0.59	0.39	197.7	0.58	0.38	192.6	0:53	0:47	0:38	0:32	0:06
July #4	0.82	0.75	-0.07	-8.7	0.60	-0.22	-27.0	1:38	1:22	0:53	0:37	0:16
July #5	0.43	0.47	0.04	9.9	0.46	0.03	7.6	1:08	1:02	0:38	0:32	0:06
July #6	0.66	0.55	-0.11	-17.2	0.54	-0.12	-18.7	0:56	0:50	0:16	0:10	0:06
July #7	1.33	1.26	-0.07	-5.1	1.16	-0.17	-12.6	0:36	0:45	0:01	0:10	0:09
August #1	0.08	0.10	0.02	28.7	0.06	-0.02	-22.8	2:53	2:12	2:23	1:42	0:41
August #2	0.09	0.12	0.03	32.6	0.12	0.03	32.6	1:53	1:52	0:23	0:22	0:01
August #3	1.38	1.59	0.21	15.3	1.38	0.00	0.0	1:23	1:07	0:38	0:22	0:16
October #1	0.14	0.20	0.06	37.9	0.20	0.06	37.9	1:07	1:02	0:58	0:53	0:05
October #2	0.01	0.01	0.00	-5.7	0.01	0.00	-5.7	1:38	1:58	1:12	1:32	0:20
October #3	0.53	0.44	-0.09	-17.0	0.09	-0.44	-83.0	2:18	1:03	1:45	0:30	1:15
October #4	0.01	0.05	0.03	220.5	0.04	0.02	156.4	0:58	1:18	0:49	1:09	0:20
October #5	0.63	0.73	0.10	15.3	0.57	-0.06	-9.9	1:45	1:58	0:13	0:26	0:13
October #6	0.12	0.66	0.54	448.6	0.34	0.22	182.6	3:12	3:45	Negative	0:26	0:33
October #7	0.19	0.32	0.13	71.1	0.28	0.09	49.7	1:39	1:17	1:14	0:52	0:22

4.5 Summary and Conclusions

SWMM was selected for this study because of its proficiency in simulating urban stormwater networks, the inclusion of an LID toolbox, and because the source code is available so that it can be linked with an external optimization engine. The model was both calibrated and validated using corresponding rainfall and flow monitor data provided by the City of Windsor. The performance of the model in replicating the observed flow rates through the outfall of the sewershed varied from event to event from very good to poor. With better rainfall and flow monitoring data the calibration of the model could be improved and uncertainty could be reduced. The closeness to the real sewershed in important physical such as the percent imperviousness is important. Overall, the hydrological model may not be a perfect representation of the study area sewershed; however, it is accurate enough to be useful in determining the effectiveness of low impact development measures in this area.

5 Design of LID Controls

5.1 Overview

The present chapter describes the design and implementation of low impact development stormwater controls in the design-optimization model. The representation of LID controls in SWMM is described in section 4.1.4. This section describes the design of LID controls including their size, placement, and other physical characteristics which are parameterized in SWMM. The sources used to select the parameter values are listed in the design tables. There is also a discussion regarding how different the values runoff in a given subcatchment is divided between the different LID types. Finally, the price breakdown and costing strategy for each LID type is described in this section; to see the cost functions themselves please see Appendix D.

5.2 LID Design Strategy

For LID parameters being optimized the constraints had to be determined. The majority of the parameters defining the LID controls in SWMM were not selected for optimization; therefore, they had to be set according to design standards. Several LID design guidelines were consulted in order to find appropriate values for the parameters required by SWMM. Several design guidelines were required primarily because the design principles for any given LID guide are not completely aligned with how LIDs are classified and parameterized in SWMM. One common design principle that was not utilized is the use of a water quality volume (WQV) in sizing LID controls. WQV was not utilized for one, because water quality was not a consideration for this study, and also because of the requirement to come up with general designs for LIDs that would be placed in varying numbers into subcatchments of varying size. Also considered in the design of the LID controls were the sewershed properties. For example, because the soils have extremely poor hydrological properties, and there is a high water table, most of the LID controls were designed with underdrains.

5.3 Rain Barrels

5.3.1 Design

There are several available sizes of rain barrels. A common size offered by the City of Windsor and commercial retailers is about 200 L. A rain barrel requires a spigot (although many come with one) and downspout adapter to direct flow into the rain barrel. Additional options include an overflow pipe to direct overflow, a soaker hose if the rain barrel is to be used for watering gardens or lawns, and a filter to prevent debris or mosquitoes from entering the rain barrel. The height of the rain barrel, see Table 5-1, was for a 200 L (50 gal) rain barrel.

Table 5-1 Rain barrel storage layer parameters

Parameter	Description	Value Selected	Source
Height (mm)	The height of the rain barrel	864	City of Windsor and online retailers

The design of the underdrain is essentially the design of the rain barrel outflow. All of the LID underdrains in SWMM are represented the same way. Equation 5-1 governs the flow from underdrains in the SWMM model. The underdrain properties are displayed in Table 5-2.

$$q = C(h - H_d)^n \tag{5-1}$$

where q is the outflow velocity through the underdrain (mm/hr), h is the height of stored water (mm) in the layer(s) being drained (simply the rain barrel in this case), and H_d is the drain height (mm) using the same zero as the water height (Rossman, 2010). C and n are parameters which can be adjusted and determine the flow rate. The SWMM manual states that a typical value for n would be 0.5 and that using 0.5 would lead the underdrain outflow to behave like an orifice. In the case of a rain barrel, the underdrain is an orifice.

The underdrain coefficient was found using Torricelli's law (equation 5-2), which itself is a specific case the Bernoulli principle related to fluid exiting a tank or reservoir.

(5-2)

$$v = (2gh)^{\frac{1}{2}}$$

where v is the flow velocity through the exit orifice, h is the depth of water in the tank, and g is the gravitational constant. The flow through the orifice, Q, can then be found by multiplying v by the area of the orifice. Q may also be found by multiplying q from equation 5-2 by the area of the tank. This leads to equation 5-3.

(5-3)

$$Q = qA_{tank} = A_{orifice}\,(2gh)^{\frac{1}{2}}$$

where the areas are the cross-sectional areas. Equation 5-3 may now be rearranged to fit the form of equation 5-1 (when n = 0.5) by rearranging it as seen in equation 5-4 and considering equation 5-5 and that in the case of equations 5-3 and 5-4 h is equivalent to the term $h - H_d$.

(5-4)

$$q = \frac{A_{orifice}}{A_{tank}}(2gh)^{\frac{1}{2}}$$

(5-5)

$$C = \frac{A_{orifice}}{A_{tank}}(2g)^{\frac{1}{2}}$$

Using equation 5-5 with an orifice area of 0.045 m^2, C was found to be 4407; however, as this value is quite high and does not include head losses in outflow pipes, or due to clogging it was reduced by a factor of 2 to 2204. The drain delay was set to 24 hours based on the assumption that, on average, a homeowner would be unlikely to regularly drain their rain barrel sooner than 24 hours after a precipitation event.

Table 5-2 Rain barrel underdrain parameters

Parameter	Description	Value Selected	Source
Drain coefficient (C)	See equation 5-1	2204	Equation 5-5
Drain exponent (n)	See equation 5-1	0.5	Rossman (2010)
Drain offset height (mm)	H_d, the height of the drain above the bottom of the storage layer	0	Design choice
Drain delay (hours)	The length of a dry period required for the normal rain barrel outflow to be opened	24	Estimate

Table 5-3 describes the parameters relating to the implementation of the LID control in each individual subcatchment. The number of the units per house is the optimized parameter (see section 6.6.4). The number of replica units in each subcatchment is then found by multiplying the number of rain barrels per house by the number of adopting houses in a given subcatchment.

Table 5-3 Rain barrel subcatchment parameters

Parameter	Description	Value Selected	Source
# of replica units	Number of units in a given subcatchment	# of units per house optimized	N/A
Area of each unit (m^2)	The total surface area of each unit	0.232	Volume divided by height
% Impervious area treated	The percentage of the impervious area in a given subcatchment which is directed to this LID type	Depends on LID combinations	Section 5.10
% Initially saturated	% of rain barrel filled at the beginning of a simulation	0	N/A
Top width of each unit (m)	The width of the side of the LID from which outflow will be directed	N/A	N/A
Overflow routed to pervious (Y/N)	If outflow is routed to the subcatchment pervious area (Y), or to the outlet (N)	Y	Design choice

5.3.2 Costing

Table 5-4 displays the costs used for rain barrels in the cost function for the cost objective. Since only one size of rain barrel is used the cost is simply totaled as a cost per unit. The installation price is a conservative estimate based on the cost for the City of Windsor to disconnect a downspout. "Online vendors" as a source implies that the cost was an estimate used after checking several websites which sell rain barrels, or similar rain barrel parts. The costing for the rain barrels could be considered to be very conservative.

Table 5-4 Rain barrel costing

Item	Description	Unit Price	Source
Rain barrel	200 L rain barrel	$60/unit	City of Windsor
Spigot	Brass spigot with washer and nut	$15/unit	Online vendors
Downspout adapter	Divert downspout through filter to barrel	$50	Online vendors
Installation	Cost to disconnect downspout	$75/unit	City of Windsor
Soaker hose	15 m hose designed for rain barrel use	$30/unit	Online vendors
Overflow pipe	Used to direct overflows through an outlet	$22.50/unit	Online vendors
TOTALS		**$252.50/unit**	

5.4 Rain Gardens and Bioretention Units

5.4.1 Design

One of rain gardens or bioretention units was considered depending on the scenario. The bioretention design includes a storage layer and underdrain, whereas, the rain garden does not. The bioretention is the design suggested in the Credit Valley Conservation LID Planning and Design Guide (2010); however, the design and construction of this is more complex than a simple rain garden and therefore it was assumed that a homeowner would be very unlikely to adopt this as a retrofit. For this reason, the engineered bioretention units were only considered for a new development scenario, where they could be implemented at the time of home construction. The retrofit scenarios only considered a more simple rain garden design. This model was created before the latest version of SWMM 5.1 which made a distinction between rain gardens and bioretention. For this study, the rain garden is a bioretention unit whose storage layer has a depth of zero and for which the conductivity of the underlying soils is set to the infiltration rate which would be set for the depth found at the bottom of the soil layer. The underdrain is turned off for the rain garden by setting the underdrain coefficient, C, to zero. The underdrain is included in the bioretention unit because underdrains are recommended for most LID types when the soil infiltration rates are as they are in the sewershed studied here. Rough sketches of the designs of these LID controls can be found in Appendix D.

Table 5-5 lists the parameters related to the surface layers of the rain gardens and bioretention units. The depression storage for the rain garden is higher than it would be for a normal surface because it is landscaped such that runoff will flow into it. Therefore, rain gardens are often slightly depressed relative to the surrounding surfaces, adding to the surface storage. It was assumed that the landscaping in the simple rain garden used in the retrofit scenario would likely be less effective, thus the lesser surface storage. The roughness was selected from tables in the SWMM manual (Rossman, 2010) based on the type of ground cover which would be found in a rain garden. The slope and roughness can be set to zero for rain gardens or bioretention because they are not used to transmit overland flow; however, when included these values will, according to discussion on a SWMM info page (Dickinson, 2012), be used in the flux calculations for the outflow of the bioretention cell once there is surface ponding.

Table 5-5 Rain garden and bioretention surface layer parameters

Parameter	Description	Value Selected for Rain Garden	Value Selected for Bioretention	Source
Storage depth (mm)	The height of the surface depression storage	150	200	CVC (2010)
Vegetation volume (fraction)	The fraction of the volume within the storage depth which is occupied by vegetation	0.1	0.1	CHI Support (2015)
Surface roughness (Manning's n)	Roughness for overland flow on the surface of the LID	0.03	0.03	Rossman (2010)
Surface slope (%)	Slope of the LID surface	2.5	2.5	CVC (2010)

Referring to Table 5-6, the values are the same for both cases because in either case soil should be imported in both cases. The soil imported for the rain gardens should have good hydraulic properties. Most of the parameters were selected from the SWMM Manual (Rossman, 2010).

Table 5-6 Rain garden and bioretention soil layer parameters

Parameter	Description	Value Selected for Rain Garden	Value Selected for Bioretention	Source
Thickness (mm)	Height of soil layer	Optimized	Optimized	CVC (2010)
Porosity (volume fraction)	The volume of pore space divided by the total volume	0.4	0.4	Rossman (2010)
Field capacity (volume fraction)	The volume of water remaining in the pores after the soil has had time to drain	0.25	0.25	Rossman (2010)
Wilting point (volume fraction)	The minimum volume of pore water after drainage, relative to the total soil volume, required to prevent vegetation from wilting	0.15	0.15	Rossman (2010)
Conductivity (mm/hr)	Saturated hydraulic conductivity within the soil layer	40	40	Estimate
Conductivity slope	Slope of the curve of the log graph of conductivity versus the soil moisture content	6	6	Rossman (2010)
Suction head (mm)	Mean soil capillary suction along the wetting front	75	75	Rossman (2010)

The conductivity of the soils underlying the storage layer listed in Table 5-7 is grouped by soil type; however, the groups are different depending on the scenario. This is because of which soil types have similar infiltration rates differs between the depth at the bottom of the rain garden and the depth at the bottom of the infiltration trench. Clogging factors are not considered because they would be insignificant over the length of time of any simulation in this study.

Table 5-7 Rain garden and bioretention storage layer parameters

Parameter	Description	Value Selected for Rain Garden	Value Selected for Bioretention	Source
Height (mm)	Height of the storage layer	0	300	CVC
Void ratio (V voids/V solids)	Related to materials used	0.4	0.4	Estimate
Conductivity of underlying soils (mm/hr)	Saturated hydraulic conductivity	2.21 (Clay or Clay Loam) 15.0 (Sand)	1.44 (Clay and Sand) 0.56 (Loam)	Rahman (2007); Richards et al. (1949)
Clogging factor	The number of times a volume of stormwater equivalent to the pore volume has to pass through this LID before it clogs the bottom layer	0	0	Based on scenario

The underdrain parameters for the rain gardens and bioretention units are listed in Table 5-8. For the case of the bioretention unit, equation 5-5 cannot be used to find the outflow coefficient. This is because Torricelli's law cannot be applied in this case because the water is draining through soil and aggregate. Therefore, some equations from a study on flow through perforated pipe surrounded by aggregate (Murphy, 2013) were used. Later, sensitivity testing was conducted on the underdrains coefficients and they were adjusted; however, the coefficient for the bioretention units remained unchanged.

Equation 5-6 was developed based on a dimensional analysis that found that head loss due to the aggregate made up less than 0.5% of the total head loss (Murphy, 2013).

(5-6)

$$Q_{sat} = A_{pipe}\sqrt{\left(\frac{2gH}{N}\right)}$$

where Q_{sat} is the flow out of the underdrain under saturated conditions, A_{pipe} is the cross-sectional area of the pipe (used a diameter of 0.102 m), and H is the water surface elevation (used 0.35 m).

(5-7)

$$N = 1 + \frac{fL}{D} + C_L \frac{A_{pipe}^2}{\left(A_{inlet}^2 Ø_{agg}^2\right)}$$

where D is the pipe diameter, L is the length of the pipe (used 11 m), $Ø_{agg}$ is the porosity of the aggregate (used 0.29) , and A_{inlet} is the area of the inlets holes into the perforated pipe (used 0.095 m^2).

(5-8)

$$f = \left(\frac{2gn^2}{R_h^{2/3}}\right)$$

where f is the friction factor, R_h is the hydraulic radius which is equivalent to $R/2$ when the pipe is flowing full, and n is Manning's n (0.012 was used).

(5-9)

$$C_L = \left(\frac{1 - C_d^2}{C_d^2}\right)$$

where C_d is the orifice coefficient of contractions (0.47 was used). Equation 5-6, the flow out of the underdrain can be set equal to the reduction of the volume of water in the LID as shown by equation 5-10.

(5-10)

$$Q = A_{pipe}\left(\frac{2gH}{N}\right)^{1/2} = -A_{surface}\frac{dH}{dt}$$

where $A_{surface}$ is the surface area of the LID unit (in this case it should be adjusted by the porosity since the area is mostly occupied by the aggregate). Through the separation of and integration (equation 5-11) equation 5-10 can be solved for the time it takes to drain a water of a given depth. The resulting equation is presented as equation 5-12.

$$\int_0^t \left(\frac{2g}{N}\right)^{0.5} dt = \int_H^0 - \left(\frac{A_{surface}}{H^{1/2}}\right) dH \tag{5-11}$$

$$t = \frac{2A_{surface}\, H^{1/2}}{A_{pipe}\left(\frac{2g}{N}\right)^{1/2}} \tag{5-12}$$

The SWMM manual (Rossman, 2010) states that an estimate for the outflow coefficient can be found when the time to drain a given depth of water is known. This is done by using equation 5-13.

$$C = \frac{2D^{1/2}}{T} \tag{5-13}$$

Table 5-8 Rain garden and bioretention underdrain parameters

Parameter	Description	Value Selected for Rain Garden	Value Selected for Bioretention	Source
Drain coefficient (C)	See equation 5-1, value found using equations 5-6 to 5-13	0	15.8	Murphy (2013; Rossman (2010)
Drain exponent (n)	See equation 5-1	0	0.5	Rossman (2010)
Drain offset height (mm)	See Table 5-3	0	50	Design choice

The initial saturation listed in Table 5-9 is estimated based on having soils with good hydrological performance (soils important for the rain gardens/bioretention units). The saturation is lower in the bioretention unit because the soil is on top of drain rock with an underdrain rather than the native clay soils underlying the rain gardens (i.e. the soil layer of the bioretention unit should drain more rapidly). The width of each unit is based on the average space available for rain gardens to meet the requirement of being greater than 4 m from building foundations but within 10 m of the areas directing runoff to the rain garden (Center for Watershed Protection, 2010; CVC, 2010).

Table 5-9 Rain garden and bioretention subcatchment parameters

Parameter	Description	Value Selected for Rain Garden	Value Selected for Bioretention	Source
# of replica units	See Table 5-3	Optimized	Optimized	N/A
Area of each unit (m^2)	See Table 5-3	Optimized	Optimized	N/A
% Impervious area treated	See Table 5-3	Depends on LID combinations	Depends of LID combinations	Section 5.10
% Initially saturated	Saturation of the soil layer at the beginning of a simulation	50	20	Estimate
Top width of each unit (m)	See Table 5-3	4	4	Design choice
Overflow routed to pervious (Y/N)	See Table 5-3	N	N	Design choice

5.4.2 Costing

The costs used for rain gardens and bioretention are displayed in Table 5-10. The items listed as personal communication were based on estimates from a professional with a consulting engineering company that has done work on municipal infrastructure project. The estimates are based on the other prices observed as well as consultation with a professional in the home construction industry.

Table 5-10 Bioretention and rain garden costing

Item	Description	Unit Price (New)	Unit Price (Retrofit)	Source
Excavation	Excavate storage layer and remove and dispose of excess materials	$\$25/m^3$ (total volume)	$\$40/m^3$, price increase over new estimated	Personal communication
Dewatering	Removing water from ground during construction	$\$3.50/m^2$	N/A	Estimate based on Pinellas site report
Placement and grading of drain rock	Labour. Scale to the depth	$\$1/m^2$ (estimate)	N/A	Personal communication
Landscaping, mulch, soil, and plants	The soil layer and garden. Scale to depth for soil cost	$\$107/m^2$	$\$107/m^2$	Garlatti Landscaping Inc.
Geotextile fabric	LM310 Non-woven	$\$0.60/m^2$ of fabric	N/A	L&M Supply
Underdrain pipe, installation, and connection to catch basin. Includes pipe bedding	HDPE perforated underdrain pipe	$\$3.75/m^2$	N/A	Personal communication
Outflow structure	Flow out of rain garden to lawn, curb or swale	$50/unit	$50/unit	Estimate
Drain rock	50 mm clear crushed aggregate for storage layer	$\$22/m^3$ (storage layer)	$\$22/m^3$	Basic Rock Products
Total	**$\$25/m^3$ (total), $\$22/m^3$ (storage) $\$111.75/m^2$ (scaled to depth) $\$0.60/m^2$ (fabric) $50/unit**		**$\$40/m^3$ (total) $\$107/m^2$ (scaled to depth) $\$0.60/m^2$ (fabric) $50/unit**	

5.5 Infiltration Trenches

5.5.1 Design

Infiltration trenches are not open trenches, but buried storage units filled with drain rock (CVC, 2010). As a result of offering a significant amount of underground storage, infiltration trenches can be useful where space is limited (CVC, 2010). An infiltration trench should be set back from houses by at least 4 m. Infiltration trenches can be effectively implemented in areas with compact housing where several lots can drain into a single infiltration trench (MOE, 2003). Taking these factors into consideration the proposed location for the infiltration trenches is in the shared backyard space between rows of houses. This is depicted in Figure D 1 and Figure D 3 in Appendix D. Infiltration trenches can be placed where the infiltration rates of the underlying soils are low but will require underdrains (CVC, 2010). The infiltration trench should accept sheet flow from the houses evenly distributed along its length (MOE). A conceptual section view sketch for the design of the infiltration trench is depicted in Figure D 2. Tables 5-11 to 5-14 list the design parameters used to implement infiltration trenches in the SWMM model.

Table 5-11 contains the parameters defining the infiltration trench surface layer. The surface storage was provided as the surface storage from a design in the MOE (2003) design manual with the addition of normal surface storage.

Table 5-11 Infiltration trench surface layer parameters

Parameter	Description	Value Selected	Source
Storage depth (mm)	See Table 5-5	64	MOE (2010); Rossman (2010)
Vegetation volume (fraction)	See Table 5-5	0	Rossman (2010); Gironás et al. (2009)
Surface roughness (Manning's n)	See Table 5-5	0.11	Chow (1959)
Surface slope (%)	See Table 5-5	0.5	Estimated

The parameters in Table 5-12 describe the storage layer for the infiltration trenches. The depth of the infiltration trench was selected based on designs in the two LID design guidebooks listed as sources. The underdrain is located 100 mm above the bottom of the infiltration trench. This satisfies design guidelines and helps to drain water more rapidly in order to prevent flooding. With the extremely low infiltration rates, the deep underdrain will have little impact on the amount of water which will be infiltrated.

Table 5-12 Infiltration trench storage layer parameters

Parameter	Description	Value Selected	Source
Height (mm)	Height of the storage layer	1500	CVC (2010); Woods-Ballard et al. (2007)
Void ratio (V voids/V solids)	Related to materials used	0.4	Estimate
Conductivity of underlying soils (mm/hr)	Saturated hydraulic conductivity	1.44 (Clay and Sand) 0.56 (Loam)	Rahman (2007); Richards et al. (1949)
Clogging factor	See Table 5-7	0	Based on scenario

Table 5-13 shows the underdrain properties for the infiltration trenches implemented in the simulations. The underdrain design plays a significant factor in the performance of the LID controls. This is discussed in section 5.8 and in Chapter 8. Equations 5-7 to 5-13 were used to come up with an estimate of the underdrain coefficient. The calculated value was 27.4. After the sensitivity testing conducted in section 5.8 the underdrain coefficient was reduced to 1.

Table 5-13 Infiltration trench underdrain parameters

Parameter	Description	Value Selected	Source
Drain coefficient (C)	See equation 5-1	1	Equation 5-5
Drain exponent (n)	See equation 5-1	0.5	Rossman (2010)
Drain offset height (mm)	H_d, the height of the drain above the bottom of the storage layer	100	Design choice

Table 5-14 describes the subcatchment properties that define the implementation of the infiltration trenches within subcatchments. Infiltration trenches have two optimized parameters. That is the number of replica units and the area of each unit. The number of replica units is zero or one because there is only one infiltration trench per subcatchment. The infiltration trench will receive the allotted runoff from all of the lots in that subcatchment. The infiltration trench area is also optimized. The range for the areas, 10 m^2 to 300 m^2 is based loosely on the guideline in Young (2011) which states that the infiltration trench area should be between 1/5 and 1/20 of the treated impervious area. The width selected was 2 m. This is divided in half because of the way the subcatchments are delineated. The backyard area where the infiltration trench is to be located usually receives runoff from two different sets of houses. Since the infiltration trench will only be receiving runoff from one of those sets (the houses in the same subcatchment) the width is divided by two for the SWMM implementation. A 2 m wide infiltration trench is being represented as two 1 m wide infiltration trenches, each in a different subcatchment. One flaw in this system is that, for back to back subcatchments, it is possible for a solution to select to implement an infiltration trench in only one of them.

Table 5-14 Infiltration trench subcatchment parameters

Parameter	Description	Value Selected for Bioretention	Source
# of replica units	See Table 5-3	Optimized	N/A
Area of each unit (m^2)	See Table 5-3	Optimized	N/A
% Impervious area treated	See Table 5-3	Depends of LID combinations	Section 5.10
% Initially saturated	Saturation of the soil layer at the beginning of a simulation	10	Estimate
Top width of each unit (m)	See Table 5-3	1	CVC (2010); Rossman (2010)
Overflow routed to pervious (Y/N)	See Table 5-3	N	Design choice

5.5.2 Costing

The cost estimates for the infiltration trenches are presented in Table 5-15. Some of the significantly increased costs in the retrofit scenario are because it would be difficult, and therefore costly, to navigate in between houses and back patios to build infiltration trenches. The costs, and in particular the marginal costs, would be much lower in the case of new development. For the price that was estimated from old unit cost data, the prices were inflated according to changes in construction costs since the time when the figure was originally published.

Table 5-15 Infiltration trench costing

Item	Description	Unit Price (New)	Unit Price (Retrofit)	Source
Excavation	Digging of infiltration trench	$25/m^3$	$50/m^3$ (price increase over new estimated)	Estimate based off of old RSMeans unit cost data for trenching
Removal	Removal of excavated materials	$12.50/m^3$	$20/m^3$	Estimate
Dewatering	Removing water from ground during construction	$3.50/m^2$	$3.50/m^2$	Estimate based on Pinellas site report
Grading	Grading trench as it is filled and other labour	$5/m^2$	$7.50/m^2$	Estimates
Geotextile fabric	LM310 Non-woven geotextile fabric	$0.60/m^2$	$0.60/m^2$	L&M Supply
Underdrain pipe, installation, and connection to catch basin. Includes pipe bedding	HDPE perforated underdrain pipe	$15/m	$30/m (price increase from new estimated)	Personal communication
Roof leaders	Direct downspouts to infiltration trench	3200/trench	$300/trench	Estimate
Instillation of new connection to storm drain	Includes backfill	$250/trench	$250/trench	Personal communication
Drain rock	50 mm clear crushed aggregate for storage layer	$22/m^3$	$22/m^3$	Basic Rock Products
Totals	**$59.50/m^3$ $550/trench $8.50/m^2$, $0.60/m^2$ (fabric) $15/m**		**$92/m^3$ $550/trench $11.00/m^2$, $0.60/m^2$ (fabric) $30/m**	

5.6 Permeable Pavement

5.6.1 Design

In the scenarios tested in this study, permeable pavement is implemented via the installation of permeable pavement driveways. The parameters used to represent the permeable pavement driveways in SWMM are listed in Tables 5-16 to 5-20. The first table, 5-16 lists the surface layer parameters. Another feature included in the implementation of the permeable pavement driveways is a reduction in the size of the driveways. Using Google Earth, it was estimated that the mean size of the driveways in the study area was about 73 m^2, which is quite large. During testing it was determined that replacing a 73 m^2 driveway with a 50 m^2 permeable pavement driveway, and converting the remaining area to pervious cover, resulted in a greater reduction in peak flow than installing a 73 m^2 permeable pavement driveway. Reducing peak flow is the most important objective for this study area so the design with an area of 50 m^2 was retained.

Table 5-16 Permeable pavement surface layer parameters

Parameter	Description	Value Selected	Source
Storage depth (mm)	See Table 5-5	4	Rossman (2010)
Vegetation volume (fraction)	See Table 5-5	0	Design choice
Surface roughness (Manning's n)	See Table 5-5	0.014	Rossman (2010)
Surface slope (%)	See Table 5-5	2.5	CVC (2011)

Permeable pavement has an additional layer of parameters, the pavement layer, that define its implementation in SWMM. These parameters are listed in Table 5-17. The thickness selected for the permeable pavement layer (interlocking concrete paving stones were selected for this design) is 80 mm. The infiltration rate listed is only applicable to the space between the paving stones, which will be filled with a small aggregate. There is a clogging factor listed; however, clogging will still not play a significant role in the simulations conducted in this study.

Table 5-17 Pavement layer parameters

Parameter	Description	Value Selected	Source
Thickness (mm)	Thickness of the permeable pavement surface	80	CVC (2010); Woods-Ballard et al. (2007)
Void ratio (V voids/V solids)	Related to materials used	0.4	Estimate
Impervious surface fraction	The fraction of the area of the permeable pavement that is impervious	0.9	Center for Watershed Protection (2010)
Permeability (mm/hr)	Permeability through the paving joints	4000	Woods-Ballard et al. (2007)
Clogging factor	See Table 5-7	100	Based on scenario

The height (or depth) of the storage layer (described in Table 5-18) is composed of 400 mm of aggregate specifically for storage and additional 50 mm to provide bedding for the driveway. The clogging factor is zero because the time periods encompassed by the simulations are not lengthy enough for clogging to become a significant factor. The infiltration rate selected was the lowest infiltration rate of any of the soils at the depth at which the permeable pavement units will be implemented.

Table 5-18 Permeable pavement storage layer parameters

Parameter	Description	Value Selected	Source
Height (mm)	Height of the storage layer	450	CVC (2010)
Void ratio (V voids/V solids)	Related to materials used	0.4	Estimate
Conductivity of underlying soils (mm/hr)	Saturated hydraulic conductivity	2.21	Rahman (2007); Richards et al. (1949)
Clogging factor	See Table 5-7	0	Based on scenario

The underdrain parameters for the permeable pavement units are listed in Table 5-19. Equations 5-7 to 5-13 were used to come up with an estimate of the underdrain coefficient. The calculated value was 28.2. This value was lowered to 10, as discussed in section 5.8, but not as low as the infiltration trench. This is because, compared to the infiltration trenches, it is more important for the permeable pavement driveways to be able to drain rapidly.

Table 5-19 Permeable pavement underdrain parameters

Parameter	Description	Value Selected	Source
Drain coefficient (C)	See equation 5-1	10	Equation 5-5
Drain exponent (n)	See equation 5-1	0.5	Rossman (2010)
Drain offset height (mm)	H_d, the height of the drain above the bottom of the storage layer	50	Design choice

Table 5-20 lists the subcatchment parameters for the permeable pavement driveways. The number of permeable pavement units implemented in a subcatchment, given that a solution includes the implementation of permeable pavement in that subcatchment, is equal to the number of adopting houses in that subcatchment. The low initial saturation rate was selected because an underdrain is able to drain the drain-rock storage layer quickly; therefore, there will not often be a large amount of water stored for any significant length of time.

Table 5-20 Permeable pavement subcatchment parameters

Parameter	Description	Value Selected for Bioretention	Source
# of replica units	See Table 5-3	Optimized	N/A
Area of each unit (m^2)	See Table 5-3	50	Design choice
% Impervious area treated	See Table 5-3	Depends of LID combinations	Section 5.10
% Initially saturated	Saturation of the soil layer at the beginning of a simulation	10	Estimate
Top width of each unit (m)	See Table 5-3	6	Estimate based on Google Earth
Overflow routed to pervious (Y/N)	See Table 5-3	N	Design choice

5.6.2 Costing

Table 5-21 lists the costs associated with the construction of permeable pavement driveways. Permeable pavement is very expensive relative to the other types of LID controls considered because of the significant cost associated with the purchase and installation of paving stones. Retrofitting is expected to be slightly more expensive because of the additional cost of removing an existing driveway as well as the increase in work efficiency expected for new development. Personal communication refers to estimates for similar work obtained from a contact at a consulting engineering company.

Table 5-21 Permeable pavement costing

Item	Description	Unit Price (New)	Unit Price (Retrofit)	Source
Excavation and removal	Excavate storage layer and remove and dispose of excess materials	$723/driveway ($25/m^3)	$1156/driveway ($40/m^3, price increase over new estimated)	Personal communication
Dewatering	Removing water from ground during construction	$250/driveway	$250/driveway	Estimate based on engineering site report
Removal of existing driveway	Break, remove and dispose existing materials	N/A	$365/driveway ($5/m^2)	Personal communication
Geotextile fabric	LM310 Non-woven geotextile fabric	$90/driveway ($0.60/m^2)	$90/driveway ($0.60/m^2)	L&M Supply
Underdrain pipe, installation, and connection to catch basin. Includes pipe bedding	HDPE perforated underdrain pipe	$165/driveway	$190/driveway (price increase over new estimated)	Personal communication
Drain rock for storage layer	50 mm clear crushed aggregate	$49/driveway ($13.00/ton)	$49/driveway ($13.00/ton)	Basic Rock Products
Placement and grading of drain rock	Labour	$70/driveway (estimate)	$100/driveway (estimate)	Personal communication
Instillation, seam fill, and edge constraints.	Some discount in the new scenario with many units being installed	$2300/driveway (discount on retrofit is estimated)	$2692/driveway	TLC Landscaping
Interlocking permeable pavement	Medium priced pavement stones	$5502/driveway	$5502/driveway	TLC Landscaping (provided a price range)
Total		**$9149/driveway**	**$10394/driveway**	

5.7 Grassed Swales

Swales were originally intended to be included in the optimization-simulation tests; however, due to uncertainty in the performance of swales they were not included. Tests were still run on the performance of grassed swales alone and the results of those tests in available in Chapter 8.

5.7.1 Implementation in SWMM

The swale implementation in SWMM is different than that of the other LID types. Rather than being placed in a subcatchment, additional subcatchments were created which are entirely occupied by the swales. This method was one of the methods for LID representation discussed in (Rossman, 2010). Swales were implemented as such so that they could collect all of the runoff generated within the existing subcatchments, including outflow from other LID types. As a consequence of the SWMM LID system not allowing routing from one LID to another, the additional subcatchments were required to achieve this.

The area of the new subcatchments is equivalent to the area of the swales. An area equivalent to the area of the subcatchments added was removed from some other subcatchments in order to compensate.

The swales were implemented in place of stormsewers on all side streets. This means that some stormsewers were removed from the SWMM model and replaced with swales. Subcatchments were then routed to swales instead of stormsewer nodes. Swales were routed to downstream swales or, when reaching a "main" street, routed into a stormsewer node. Each swale subcatchment that was added contained two swales in order to represent one swale being placed on each side of a street.

As swales are running beside streets, culverts under driveways would be required. The design of the culverts implemented was based on the culvert shown in Figure D 6 and the existing pipe sizes. SWMM only allows for culverts to be implemented within the routing network so culverts could not route into swales. For this reasons the total length of culverts required on a street would be summed and added as a single culvert for the water to flow through travelling between the final swale and the node through which it enters the stormsewer system. This method of simulating culverts will add some inaccuracy because in reality water flows into swales along their length so all of the water does not flow through all of the culverts. This will likely lead to a reduction in the predicted performance as the water will flow more rapidly through the culverts when the flow volume is greater. The length of the road segments where culverts would be required was subtracted from the length of the swales, which were otherwise equivalent to the lengths of the streets along which they would be running.

5.7.2 Design

The process used to design the enhanced grassed swales will be discussed in this section. Each length of swale was individually designed, instead of generalizing designs as was done for the other LID types. Several general designs for the swale surface parameters were used but the subcatchment properties were unique to each swale. The steps taken in the design will now be described. The design tables for two of the swales (corresponding to one street) can be found in Appendix D (Table D 1). The volume of runoff entering the swales was calculated using the rational method (equation 5-14).

$$Q = CiA \tag{5-14}$$

where Q is the flow in m^3/s, C is the runoff coefficient (0.5 was used), i is the rainfall intensity in mm/hr, and A is the contributing area in hectares (usually the entire subcatchments, the runoff coefficient accounts for pervious area). The rainfall intensity was obtained from an Environment Canada IDF curve (Figure G 1). The time used to find the correct rainfall intensity from the IDF curve was the time of concentration. The ten year return period intensities were selected. The time of concentration was calculated by adding the overland flow time to the swale flow time. For a given subcatchment, the swale flow time was calculated using an estimated flow velocity.

The calculated time of concentration would not significantly change after the correct swale flow velocity was calculated (the overland flow is a larger factor and the estimated velocities were close to the calculated values) so an iterative process was not used for the time of concentration. For swales receiving flow from upstream subcatchments through another swale, the time of concentration was the maximum of any flow path to the end of the swale under consideration. The contributing area includes upstream subcatchments. The overland flow time was calculated using the Federal Aviation Agency method of estimating the time of concentration (equation 5-15).

(5-15)

$$t_c = 0.0543\left[(1.1 - C) * \frac{L^{1/2}}{S^{1/3}}\right] * 60$$

where t_c is the time of concentration in minutes (used as overland flow time), C is a cover coefficient, L is the path length (used as the distance from the back of a subcatchment to the street), and S is the surface slope (the subcatchment slope was used). After computing the maximum flow through the swales, the actual swale flow velocity, depth, and area was calculated. The velocity was calculated by using equation 5-17, which is a rearranged version of Manning's equation for flow in a channel (equation 5-16). Values for the base width and side slope of the swale would be selected before equation 5-17 was solved with Excel's solver tool changing the swale depth (which is incorporated into both sides of equation 5-17). With the depth solved, top width, surface area, and flow velocity (using equation 5-16) could all be calculated. If the flow depth, velocity, or the top width of the swale was unacceptable, the process would be repeated with new values for the base width and side slope. The swales were designed to keep the flow velocity below 1 m/s, the depth below 400 mm (Woods-Ballard et al. (2007) recommends a maximum depth of 400 to 600 mm) and the width as narrow as possible while meeting the other two objectives. The flow velocity, V, in m/s is calculated using equation 5-16.

(5-16)

$$V = \frac{1}{n} {R_h}^{2/3} S^{1/2}$$

where n is manning's n, R_h is the hydraulic radius and S is the slope.

(5-17)

$$\frac{Q * n}{S^{1/2}} = A * R^{2/3}$$

where A is the cross-sectional area of the channel.

5.7.3 Performance of Swales

It was previously mentioned that swales were not included in the optimization-simulation scenarios because of their poor performance. It is possible that this poor performance is not completely due to a misrepresentation of swales in the model. One factor that might hinder the performance of the swales during the design storms is that the peak intensity of the design storms (SCS type II events) comes in the middle of the events. Qin et al. (2013) found that swales performed best during storms with early peaks. The amount of precipitation occurring during the design storms could also be a factor. In section 8.2 swales are tested for the July 15th calibration events, which are of a much lower intensity, and they offer some reduction in peak flow. It is also possible that the swales are too small for the areas of land they receive runoff from. Young (2011) suggests that the area of swales should be between 10% and 20% of the treated impervious area while CVC (2010) suggests 5% to 15%. The swales, as designed, have an area much smaller than suggested. MOE (2010) states that grassed swales are most effective when the depth of flow is minimized and the bottom width is maximized. Designing swales as such requires lots of space and might make it difficult to effectively use grassed swales in some areas. Even with the poor performance, swales might still be useful. Their performance was slightly better than the full stormsewer network for small events and slightly worse for larger events. The swales also likely cost less than the stormsewers they are replacing and would be easier to modify.

5.8 LID Underdrain Coefficients

While running test simulations it became apparent that some LID scenarios actually increased peak flow rates. It was determined that the flow rate through the underdrains contributed to the problem (this is discussed further in section 8.4.1). As the objective is to decrease peak flow, different values were tested for the underdrain coefficients. The underdrain coefficient is used in equation 5-1 and controls the flow rate out of an underdrain.

When designing an underdrain it would be possible to restrict the flow rate out of the underdrain pipe if necessary. The LID controls should be able to retain water for long enough to restrict peak flow and allow for some infiltration. The underdrains should not be so restricted so as to cause flooding.

Tests were run using the historical 100 year return period storm in order to test the impact of changing the underdrain coefficients. For these tests, only one LID control is implemented and that control is implemented in every subcatchment which might receive LIDs. Tables 5-22 to 5-24 list the results of these tests. Although some LID controls are designed to have surface outflow, the number of subcatchments in which the LID control had surface outflow, and the number that had surface outflow exceeding 100 mm were included as a proxy for flooding. The highlighted cells are the values that were used in the final designs.

Table 5-22 Infiltration trench underdrain coefficient

Underdrain Coefficient	**27.4**	**15**	**10**	**5**	**2**	**1**	**0.75**	**0.5**
R_t (ha.m)	6.32	6.32	6.32	6.32	6.31	6.20	6.04	5.78
Q_P (cms)	7.86	7.50	7.14	6.52	5.99	5.76	5.70	5.63
Infiltration Loss (ha.m)	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Initial LID Storage (ha.m)	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Surface Outflow # of Subs	0	0	0	0	0	0	1	1
Surface Outflow # of Subcatchments over 100mm	0	0	0	0	0	0	0	0

Table 5-23 Bioretention underdrain coefficient

Underdrain Coefficient	25	20	15.8	10
R_t (ha.m)	6.35	6.33	6.32	6.32
Q_P (cms)	6.14	6.14	6.14	6.14
Infiltration Loss (ha.m)	1.33	1.34	1.35	1.35
Initial LID Storage (ha.m)	0.52	0.52	0.52	0.52
Surface Outflow # of Subs	66	67	68	68
Surface Outflow # of Subcatchments over 100mm	16	16	17	17

Table 5-24 Permeable pavement underdrain coefficient

Underdrain Coefficient	36	33.2	28.2	25	20	15	10
R_t (ha.m)	6.06	6.06	6.06	6.06	6.06	6.06	6.06
Q_P (cms)	6.60	6.61	6.61	6.61	6.59	6.51	6.35
Infiltration Loss (ha.m)	1.69	1.69	1.69	1.69	1.69	1.69	1.69
Initial LID Storage (ha.m)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Surface Outflow # of Subs	3	3	3	3	3	3	3
Surface Outflow # of Subcatchments over 100mm	0	0	0	0	0	0	0

No lower values are listed for the permeable pavement. This is because the permeable pavement drains the driveway and comes close to the houses. As such, it was decided that the underdrain coefficient for the permeable pavement driveways should not be lowered any further in order to minimize the risk of flooding.

5.9 Initial Saturation Testing

Another property tested was the initial saturation values for the LID controls. Tests were run using the historical 100 year return period storm in order to test the impact of changing the underdrain coefficients. For these tests, only one LID control is implemented and that control is implemented in every subcatchment which might receive LIDs. The results for those tests are presented in Tables 5-25 to 5-28. There were no changes made to the values discussed in the LID design sections; however, the selected values are still highlighted. The initial LID storage values are representative of the total volume of water contained in the LIDs due to saturation. For the LIDs with underdrains, the water stored in the LIDs also accounts for most of the changes in runoff.

The effect of the initial saturation on peak flows is very small for every LID control besides the rain gardens. That is because for the other LIDs, the underdrain helps to drain water, stored due to initial saturation, before the arrival of the most intense part of the storm (the time when the peak flow would be generated). The initial saturation does not make a good proxy for a high water table. If the water table was close to the surface then the LIDs would be continuously receiving additional inflow from surrounding soil. The outflow from the rain garden is not a concern because rain gardens can be designed to accommodate surface outflow.

Table 5-25 Rain garden saturation test

Initial Saturation %	**100**	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**
R_t (ha.m)	6.06	6.03	6.00	6.00	5.93	5.91	5.88	5.87	5.85	5.83
Q_P (cms)	7.19	7.14	7.05	6.93	6.79	6.63	6.52	6.47	6.38	6.28
Infiltration Loss (ha.m)	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.43	1.42	1.41
Initial LID Storage (ha.m)	0.48	0.45	0.42	0.39	0.36	0.33	0.3	0.27	0.24	0.21
Surface Outflow (subs)	All	All	All	All	All	All	All	All	All	All
Surface Outflow # of Subs over 100mm	All	All except for 1	All except for 2	All except for 8	All except for 13	All except for 19	All except for 26	All except for 31	All except for 41	All except for 46

Table 5-26 Bioretention saturation test

Initial Saturation %	100	90	80	70	60	50	40	30	20	10
R_t (ha.m)	6.95	6.87	6.80	6.72	6.64	6.56	6.49	6.41	6.32	6.25
Q_P (cms)	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.14	6.13
Infiltration Loss (ha.m)	1.37	1.37	1.36	1.36	1.36	1.35	1.35	1.35	1.35	1.35
Initial LID Storage (ha.m)	1.16	1.08	1.00	0.92	0.84	0.76	0.68	0.60	0.52	0.44
Surface Outflow (subs)	68	68	68	68	68	68	68	68	68	68
Surface Outflow # of Subs over 100mm	17	17	17	17	17	17	17	17	17	17

Table 5-27 Infiltration trench saturation trench

Initial Saturation %	100	90	80	70	60	50	40	30	20	10
R_t (ha.m)	7.99	7.80	7.61	7.41	7.21	7.02	6.89	6.61	6.41	6.20
Q_P (cms)	5.85	5.83	5.82	5.81	5.80	5.80	5.78	5.78	5.78	5.76
Infiltration Loss (ha.m)	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Initial LID Storage (ha.m)	2.05	1.85	1.64	1.44	1.23	1.03	0.83	0.62	0.42	0.21
Surface Outflow (subs)	2	1	1	1	1	1	1	0	0	0
Surface Outflow # of Subs over 100mm	0	0	0	0	0	0	0	0	0	0

Table 5-28 Permeable pavement saturation trench

Initial Saturation %	100	90	80	70	60	50	40	30	20	10
R_t (ha.m)	6.56	6.51	6.45	6.40	6.34	6.29	6.23	6.18	6.12	6.07
Q_P (cms)	6.36	6.36	6.36	6.36	6.35	6.35	6.35	6.35	6.35	6.35
Infiltration Loss (ha.m)	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.70	1.69
Initial LID Storage (ha.m)	0.55	0.50	0.44	0.38	0.33	0.28	0.22	0.17	0.11	0.05
Surface Outflow (subs)	4	4	4	4	4	3	3	3	3	3
Surface Outflow # of Subs over 100mm	1	1	1	1	1	1	1	0	0	0

5.10 LID Combinations

Table 5-29, found on the following page, has a breakdown of the routing from impervious surfaces to each LID type depending on the combinations present. The inflow to the LID units is the precipitation falling on them as well as run-on. The run-on is the runoff from the impervious areas in the subcatchment. The percentage of the runoff from impervious areas in the same subcatchment, which the LID controls receive, is a parameter defined in SWMM. The LID controls can direct their own overflow to the subcatchment pervious area, or to the subcatchment outlet, but not to other LIDs (no treatment trains within subcatchments). The LID simulation method is depicted in Figure 4-3 and Figure 4-4.

In order to determine how much runoff each LID would receive, the normal breakdown of impervious surfaces within a subcatchment was estimated using Google Earth. Estimates about which LID unit each impervious surface could drain to were then made using the conceptual layout depicted in Figure D 1. These estimates were made for all of the possible combinations of LID controls and are listed in Table 5-21. The reason that none of the totals sum to 100% is because, as designed, none of the LID controls are going to capture runoff from the streets. Even with the runoff that can be captured, it is unlikely that the landscaping would be so perfect that all of it would enter the LID controls.

Within the optimization-simulation model, the values in Table 5-21 were stored in arrays. Code was added to test which LIDs were present within a given subcatchment and the appropriate runoff percentages were extracted from the arrays. These values would then be ammended to account for LID adoption rates (this is discussed in section 7.3).

Table 5-29 Routing schemes for runoff from impervious surfaces to LID controls

	Maximum % Impervious Area Treated					Notes
Combination	RB	PP	BR	IT	Sum	
RB	47	0	0	0	47	Rain barrels capturing entire roof
PP	0	15	0	0	15	Permeable driveway capturing 1/4 of roof (less other imp. Area because of PP) + a little (e.g. walkway around the door)
BR	0	0	28.3	0	28.3	Captures 1/4 of driveway + 1/2 of roof
IT	0	0	0	34.3	34.3	From Google earth calculations
RB + PP	58	2	0	0	60	Roof represents higher % of total with PP. Also, PP captures very little outside its own surface with the roof accounted for.
RB + BR	35.25	0	16.51	0	51.76	Bioretention takes 1/4 of roof runoff and 1/4 of driveway runoff. Rain barrels routed to pervious to simulate routing to rain garden.
RB + IT	23.5	0	0	25	48.5	Infiltration trench captures back roofs and a little more.
IT + BR	0	0	28.3	34.3	62.56	Infiltration trench captures back half of roof plus a little more; bioretention captures up to 1/2 roof plus 1/4 driveway
IT + PP	0	15	0	34.3	49.3	Solutions do not interfere with each other. Roof proportion increases because of the driveways being replaced with PP.
PP + BR	0	2	29	0	31	Bioretention takes 1/2 of roof runoff since permeable pavement is not designed to take much flow from other areas and doesn't off infiltration in this case.
RB + PP + BR	43.5	2	14.5	0	60.5	Bioretention takes a little more than 1/4 of the roof.
RB + PP + IT	29	2	0	31	62	Rear portion of the roof directed to the infiltration trench.
RB + BR + IT	11.75	0	20	26	57.75	Rain barrel and bioretention only get 1/4 of roof while infiltration trench gets 1/2 and a little more (e.g. back porch). Bioretention can take some additional runoff.
IT + BR + PP	0	2	29	34.3	65.3	Infiltration trench and bioretention each can receive up to half of the roof runoff, infiltration trench can receive a little more.
RB + PP + BR + IT	29	2	18	22	71	Roof runoff split between rain barrels, bioretention and infiltration trench. Bioretention and infiltration trench receive a little extra runoff from other surfaces.

*BR = Bioretention (the same values apply for rain gardens); IT = Infiltration trench; PP = Permeable pavement; RB = Rain barrel

6 Optimization

6.1 Objectives of Optimization

There are many possible combinations of low impact development controls which might be implemented in an urban or sub-urban area. In addition to determining which LID stormwater controls are selected, there are also considerations of how many will be implemented, how large they will be, and where they will be placed. The literature (see section 2.1.4) suggests that LIDs perform differently in different locations and different combinations. Therefore, a primary objective of the optimization process is to find combinations of LIDs that will optimally reduce sewershed-wide runoff and peak flow into the stormsewers. The other primary objective is directly related to the first. When implementing stormwater controls it is ideal to get the maximum performance (reduction) at the lowest cost. Therefore, the other primary objective of the optimization process is to find the least cost solutions. Overall, the objective of the optimization process is to find the most effective combinations of LID controls at various cost levels. In other words, a primary goal of the optimization process is the generation of cost-benefit curves.

6.2 Single Objective Optimization

In single objective optimization, the goal is to find an optimal solution or optimal solutions which provide the maximum or minimum values (depending on the problem formulation) of the single objective. Which solutions are optimal is based on the single objective; however, there can be one or many decision parameters. Some single objective optimization techniques include stochastic hill climbing, linear programming, and gradient searches (Sivanandam and Deepa, 2007; Zhang, 2009). Some single objective techniques for optimizing stormwater controls are discussed in (USEPA, 2006). More recently, Loáiciga et al. (2015) used single objective optimization to find the optimal sizing and location (separate tests) of stormwater best management practices. They used linear programming or binary linear programming to minimize the cost while altering size or placement. Other parameters were taken care of by constrains on things such as budget, water balance, and limits on stormwater volume and quality (Loáiciga et al., 2015).

6.3 Multiobjective Optimization

6.3.1 Overview

Multi objective optimization refers to the maximizing, or more often, minimizing multiple objectives $F(x) = [f_1(x), f_2(x),..., f_n(x)]$ where $x = x_1, x_2,...,x_n$ represent the decision variables. The decision variables make up the decision space where the feasible region is the set of solutions in the decision space which satisfy constraints placed on the decision variables. A single solution is a set of n values corresponding to a feasible value for each decision variable. For example, for the design and placement of rain barrels (a common LID control) the decision variables might be the number of rain barrels per house constrained between 0 and 4, as well as the size of rain barrels constrained to one of the commonly available sizes. The objectives in this example could be to minimize cost and stormwater runoff. For multiobjective optimization a unique mapping exists between the decision space, composed of possible combinations of decision variables, and the objective space, the space containing the possible combinations of objective values (Deb, 2001).

6.3.2 Benefits of Using Multiobjective Optimization

In order to see the benefits of using multiobjective optimization, first consider how the problem might be formulated as a single objective one. One way to eliminate one of the objectives from the optimization procedure would be to use prior knowledge to set the values of one of the objectives using constraints. This method is similar to what Loáiciga et al. (2015) did in their study. Returning to the rain barrel example from section 6.3.1, we could focus on the objective of cost reduction and constrain the runoff within a range of acceptable values. More specifically, the objective would be to minimize the cost but a penalty could be applied to the objective function if the runoff exceeded allowable levels. Conversely, we could focus on the objective of minimizing the runoff, but penalize a solution if its cost exceeded allowable levels.

Another method of using a single objective approach would be to weight multiple objectives according to preference. However, it is difficult and subjective to weigh objectives prior to optimization in order to transform a multi-objective problem to fit single-objective optimization. This requires developing a quantitative preference vector prior to optimization, when one is unlikely to know what the trade-offs between solutions will look like (Deb, 2001). The problem of weighing objectives is amplified when the multiple objectives are directly conflicting and therefore signals from the decision space will have opposite effects on the objectives. A relevant example is stormwater control. Adding additional stormwater controls (LIDs or other BMPs) will reduce runoff and flow in the stormsewers; however, they will add cost. Using fewer stormwater controls will reduce cost but be less effective in reducing wet weather flows.

Before the study is conducted we do not know how effective LID measures will be in our study area, we are trying to find out. Rather than trying to design stormwater controls based on a priori knowledge and constraints, we are simply trying to develop that knowledge so that a future designer could more effectively design stormwater controls. Finding trade-off solutions which are optimal in many objectives will give a future designer access to a catalogue of solutions, at various cost levels, from which to choose. For this study the set of trade-off solutions would together create cost-benefit curves.

Developing knowledge of trade-off solutions is important for LID stormwater controls for several reasons. As discussed in section 2.1.3.2, professionals may be wary of using LID methods in the absence of local knowledge. Also, LID often requires public participation, and will also have other environmental and social benefits. Finally, the development of trade-off solutions is important in the context of developing local LID knowledge because of how heavily local environmental factors can impact the performance of LIDs and how much construction costs can also change from location to location. Deb (2001) describes the ideal multiobjective optimization procedure as one in which a multiobjective optimizer finds multiple trade-off solutions to a multiobjective problem, after which higher level information can be applied to select the preferred solutions.

There are additional reasons why multi-objective optimization is the correct approach for this study. State-of-the-art multiobjective evolutionary solvers such as genetic algorithms, tabu search, and simulated annealing allow the simulation to be detached from the optimization (USEPA, 2006). This eliminates some mathematical constraints that have traditionally faced optimization problems. Therefore, we can utilize independent runs of a hydrological model, in this case SWMM, in the optimization process.

Finally, using a multiobjective approach makes it easier for the work of this study to be expanded in the future. If we were to add an additional objective, water quality being a possibility, this objective could be added independently without having to work it into a pre-existing weighting scheme.

6.3.3 Pareto Dominance

In the previous section multiple trade-off solutions were described as comprising a cost-benefit curve. A cost benefit curve is actually one example of a pareto front. In order to describe a pareto front we must first discuss the concept of pareto dominance, a key concept in multiobjective optimization.

6.3.3.1 Dominance and Non-Dominated

A vector $u = (u_1, u_2, ..., u_n)$ "pareto dominates" another vector $v = (v_1, v_2, ..., v_n)$ iff $\forall\, i \in \{1, 2, ..., M\}$, $u_i \leq v_i$ and $\exists\, j \in \{1, 2, ..., M\}$, $u_j < v_j$ (Hadka and Reed, 2013). In other words, given any component u_i of vector u is less than or equal to the corresponding component v_i of the vector v and there exists at least one component of the vector u which is strictly less than the corresponding component in v. The components would be the values, or fitness of the solutions for each given objective. Solutions with lower values are considered dominant because the objectives are being minimized. A solution can be "non-dominated" without dominating all other solutions.

6.3.3.2 Pareto-Optimal Set

For a given multi-objective problem, the pareto-optimal set is defined by: $P^* = \{x \in \Lambda \mid \neg \exists x' \in \Lambda$, where $F(x')$ pareto dominates $F(x)\}$ (Hadka and Reed, 2013). This means that solutions “x” are a member of the pareto-optimal set when they belong to the set of feasible solutions, and there does not exist any solutions in the set of feasible solutions which would dominate them. Essentially the pareto-optimal set is the set of optimal trade-off solutions.

6.3.3.3 Pareto Front

For a multiobjective problem, the solutions belonging to the pareto-optimal set will define a pareto front. Consider the rain barrel example taken as a multiobjective problem. The cost-benefit curve representing all of the optimal trade-off solutions between cost and runoff reduction would represent a pareto front. Figure 6-1 provides an example of a pareto-optimal front for a multiobjective optimization problem where one objective is minimized and one is maximized. The edge of the objective space that is shaded black represents the set of non-dominated solutions, i.e., the pareto-optimal front.

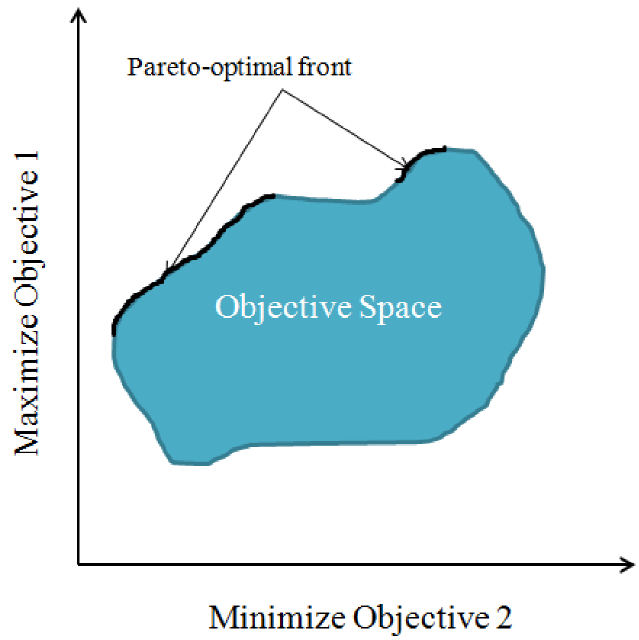


Figure 6-1 Example of a pareto-optimal front

6.4 Genetic Algorithms

6.4.1 Overview

Modern multiobjective optimization techniques include genetic (or evolutionary) algorithms, tabu searches, scatter searches, and simulated annealing. Of these techniques, genetic algorithms (GAs) offer many advantages and are the most commonly used multiobjective optimization tool for water resource problems (Sivanandam and Deepa, 2007; USEPA, 2006; Zhen et al., 2004). When the U.S. EPA decided to develop a tool for the optimization of the design and placement of stormwater best management practices they used a GA for the optimization engine (Lai et al., 2007). For the purpose of solving multiobjective problems, GAs are more effective than the traditional techniques such as linear programming and gradient searches (Fonseca and Fleming, 1995). It should be noted that this report uses genetic algorithm (GA) and evolutionary algorithm (EA) synonymously unless otherwise specified. A genetic algorithm is a common type of evolutionary algorithm.

Genetic algorithms are a stochastic global search technique which relies on concepts borrowed from biological evolution such as fitness and the passing on of genes. When considering a GA, the population refers to the group of solutions currently being evaluated and used to generate new solutions. A new solution typically must be non-dominated by members of the population in order to be added to it. If a new solution dominates some members of the population those dominated solutions are typically removed. Some GAs have an archive of elite solutions which may have more strict dominance criteria than the population and is preserved even when the population is regenerated. The dominance of solutions is based on their fitness, which is determined by the objective values. The objective values are produced through fitness functions.

GAs create new solutions using the genes from successful previous solutions, i.e., solutions from the population or elite archive. In this case a "gene" refers to a value for one of the decision variables. New solutions are created through a variety of techniques, for example gene-crossover and mutation, to produce new solutions from parents in the population or archive which have high fitness (express dominance in the objective space). The goal of GAs is to both find optimal solutions (i.e., solutions that are on or very close to the actual pareto-front) as well as to maintain diversity (i.e., discover as much of the objective space and pareto-front as possible). Figure 6-2 shows a general outline of a genetic algorithm. A more detailed explanation of genetic algorithms is available in literature (e.g. Deb, 2001; Sivanandam and Deepa, 2007).

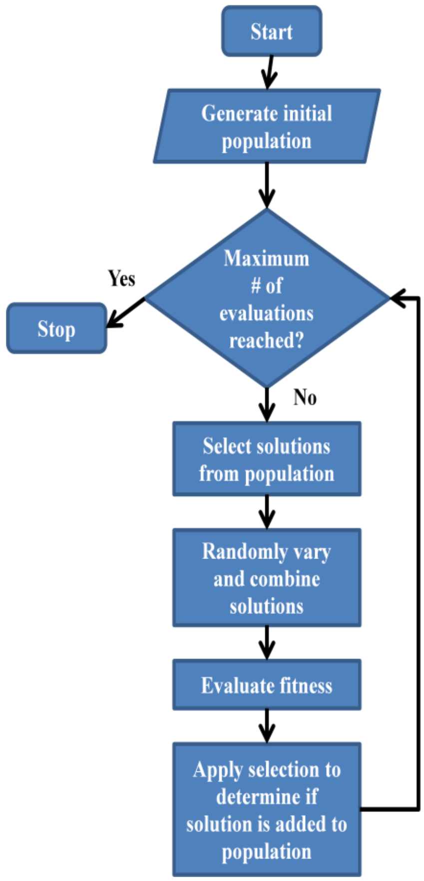


Figure 6-2 General GA Scheme

6.4.2 Weaknesses of GAs

There are some weaknesses to the use of genetic algorithms. One drawback is that it can be difficult to develop fitness functions (Sivanandam and Deepa, 2007). Choosing configuration parameters for the algorithm can also be difficult. Some examples of parameters would be determining how large of a difference between objective function values would be required for a new solution to be considered dominant over a previous solution (such a parameter is used in some GAs). Another example would be simply how many iterations should be run. Genetic algorithms generally use a preset number of iterations to trigger termination and it might be difficult to determine how many iterations would be required for the algorithm to effectively find the pareto front. Further drawbacks to genetic algorithms would be that they are not good at identifying local optima which are not a part of the pareto-optimal set and are not guaranteed to find an exact global optimum (Sivanandam and Deepa, 2007).

6.4.3 Advantages of GAs

Although genetic algorithms have some weaknesses they have many strengths. One unique benefit of GAs is their ability to find multiple optimal solutions in a single run (Deb, 2001). Furthermore, GAs allow for a more evenly distributed pareto-optimal set than you may get by running several runs of a single optimization problem and altering the weights a-priori (Deb, 2001). GAs are very adaptable and can be applied to a wide variety of problem types and scales (Sivanandam and Deepa, 2007). The fitness functions used are also very adaptable. For example, a fitness function might be a simple mathematical formula which uses the decision variable values to produce objective function values, or it could be a hydrological model which uses the decision variables as some of its input parameters and produces outputs which are used as objective values. One thing that can make it easier to use a GA is that they require no prior knowledge of the response surface or gradients (Sivanandam and Deepa, 2007). One final benefit of GAs relevant to this study is that they are specifically designed to discover pareto-optimal fronts (Sivanandam and Deepa, 2007).

6.5 Borg MOEA

6.5.1 Overview

There are several genetic algorithms available to be used in multiobjective optimization and several improvements have been made over time. For this study the genetic algorithm of choice is the Borg Multi-Objective Evolutionary Algorithm (MOEA) (Hadka and Reed, 2013). Borg MOEA combines and enhances several processes used successfully in previous GAs. It has been used for water resource problems, for example d' Ervau (2013), however it has not yet been widely used as it is still new. Tested against 6 state-of-the-art MOEAs on several test problems, Borg met or exceeded the performance of the other MOEAs on most of the tests (Hadka and Reed, 2012). Some important components of the Borg MOEA will be described in the following sections; however, a complete description can be found in Hadka and Reed (2013). Borg is freely available for research purposes from borgmoea.org.

6.5.2 Dominance, Population, and Archive

Borg MOEA is an elitist genetic algorithm. This means that, in addition to the population, Borg also stores an elite archive of solutions. This archive has more stringent acceptance criteria than the population and is stored throughout a run of Borg. In fact, the output of a Borg run is the elite archive. A new solution is added to the population if it dominates at least one member of the population. The dominated member of the population is replaced and if more than one member of the population are dominated by the new solution then one of the dominated solutions is removed at random (Hadka and Reed, 2013). The size of the population is set to be within a certain multiple of the archive. The population also has a minimum initial size (a parameter which can be set) which is generated at the start of a run. There are also times, when Borg's progress has stalled, when the population will be regenerated from archive solutions and their mutations (randomly changed genes) (Hadka and Reed, 2013).

The criteria for a new solution to be added to the elite archive are more demanding. That is that a new solution must ε-box dominate at least one solution in the elite archive and all solutions in the elite archive which are ε-box dominated are removed. The ε-box dominance is a system presented in Hadka and Reed (2013). Essentially, it is adding a minimum resolution for improvement, ε, so that the solutions which are improvements but still very close to existing solutions in objective space will not be added. For a given $\varepsilon < 0$, $u = (u_1, u_2, \ldots, u_n)$ ε-box dominates another vector $v = (v_1, v_2, \ldots, v_n)$ iff $\left\lfloor \frac{u}{\varepsilon} \right\rfloor$ pareto dominates $\left\lfloor \frac{v}{\varepsilon} \right\rfloor$, or $\left\lfloor \frac{u}{\varepsilon} \right\rfloor = \left\lfloor \frac{v}{\varepsilon} \right\rfloor$ and $\left\| u - \varepsilon \left\lfloor \frac{u}{\varepsilon} \right\rfloor \right\| < \left\| v - \varepsilon \left\lfloor \frac{v}{\varepsilon} \right\rfloor \right\|$ (Hadka and Reed, 2013).

6.5.3 Generating New Solutions

New solutions are generated from two parent solutions. One of the parent solutions is taken from the elite archive and the other parent is chosen from the population via tournament selection. Tournament selection provides selection pressure by holding a competition among individuals from the population. The winner of the tournament is the one with the highest fitness (Sivanandam and Deepa, 2007). The fitness is measured by the objective function. In this case, it would be determined by dominance. If a solution in the competition dominates the other it moves on, if they are both non-dominated then one will be selected at random (Deb et al., 2003). In Borg, the size of the tournament (the number of solutions selected from the population to be considered as a parent in each iteration) is adaptive. Borg uses adaptive tournament sizing to maintain selection pressure. By changing the tournament size as the population grows, the chance that a non-dominated solution from the population will be selected to participate in the tournament will not drop as it otherwise would (Hadka and Reed, 2013).

Once the parent solutions are determined their genes are combined to form a new solution. The Borg algorithm incorporates an adaptive multi-operator recombination process called similar to AMALGAM (Vrugt and Robinson, 2007). This establishes a feedback process in order to utilize to a greater extent the recombination operators which generate more successful solutions (Hadka and Reed, 2013). There are six operators which can be used to recombine the parent genes to create a new solution. Over the course of the run the probability of any recombination operator being selected is updated based on how many solutions created using each operator have been added to the elite archive (Hadka and Reed, 2013).

6.6 Optimization Methodology

6.6.1 Overview

The goal of the optimization is to find the pareto-optimal front for the objectives of reducing stormsewer peak flow and total runoff in the study area while also minimizing the cost. Such a procedure may be represented as the development of cost-benefit curves. The decision variables are various LID design parameters related to their definition in the SWMM input file. The fitness functions which evaluate the solutions (taking the decision variables and returning objective values) are the SWMM model itself as well as cost functions. This whole system is created by linking the SWMM model to the Borg algorithm so that there can be a feedback process where Borg alters some SWMM input parameters and receives outputs from the SWMM model. The construction of this system and the scenarios it used to evaluate will be discussed further in Chapter 7.

6.6.2 Layout of Optimization System

Flow charts of the optimization scheme, including how SWMM and Borg are linked are presented in this section (Figure 6-3 and Figure 6-4). In terms of the actual coding, the Borg algorithm was built into the SWMM code. SWMM essentially serves as a fitness function for the Borg algorithm.

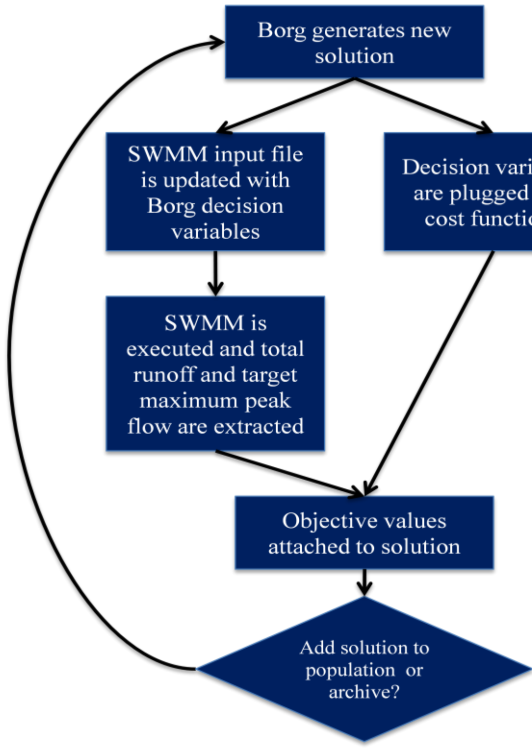


Figure 6-3 Coupled optimization-simulation model framework

Figure 6-3 shows the essential data flow between SWMM and Borg while Figure 6-4 is expanded to include more of the procedures occurring within Borg. The updates to the SWMM input file was done using read-write functions that parse the input file and make changes to the targeted portions of the input file. The parsing functions used the Borg decision variables, arrays of subcatchment properties, and arrays of unaltered subcatchment parameters in order to calculate the correct values to write into each targeted string of the SWMM input file.

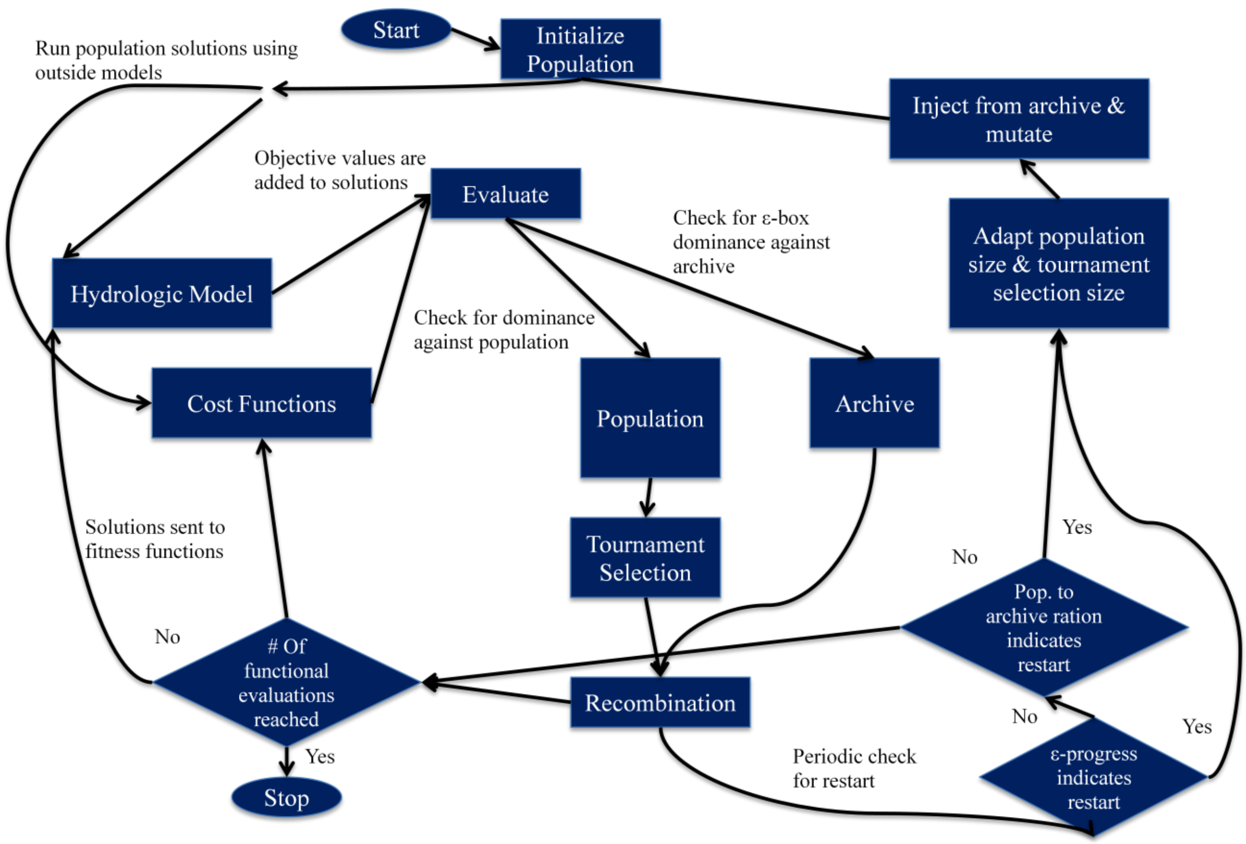


Figure 6-4 Overview of optimization-simulation scheme

6.6.3 Objective Functions

Equations 6-1, 6-2, and 6-3 represent the three objectives for optimization by the Borg algorithm. It should be noted that Borg minimizes all objectives.

$$min \sum_{i=1}^{m} \sum_{j=1}^{n} C_i^j \, (S, N) \qquad \textbf{(6-1)}$$

where C_i^j denotes the cost of LID type j in subcatchment i, the cost being a function of the LID type j, the size S, and the number of units of that LID in a given subcatchment. The cost of each LID type is calculated according to the costing principles discussed in Chapter 5. The costs for location are aggregated in groups as discussed in Chapter 7.

(6-2)

$$min(Q_P)$$

(6-3)

$$min \sum_{t=0}^{k} \sum_{i=1}^{n} R_i^t$$

Where Q_P is the maximum flow rate through the point of interest in the stormsewer during the duration of the simulation. R_i^t denotes the runoff from subcatchment i at time t (where k is simply the end point of the simulation). The minimization of the runoff and peak flow are closely linked; however, they were kept as separate objectives so that the results would be more easily interpretable. Combining these two objectives would require their normalization and weighting making the objective values in the output less intuitive. The results of the final simulations would eventually show the importance of timing in peak flow and confirm that keeping these objectives separate was the correct decision.

6.6.4 Decision Variables

For this study 24 decision variables were selected. Selecting the decision variables required the balancing of a few factors. A greater number of decision variables can potentially provide more information as more parameters are being optimized. The downside of adding more variables is that it adds complexity to the coding linking Borg to SWMM and also makes it more difficult for Borg to converge on the pareto-optimal front. In this study the number of decision variables was reduced from 36 to 24 in order to increase the likeliness that Borg would adequately explore the solution space and converge on the pareto-optimal front in a reasonable amount of time. The decision variables selected focus on the types of LIDs selected and also, but to a lesser extent, the sizing and location of the LIDs. The LIDs are interdependent in that which combinations of LIDs are present in a given subcatchment influences the percent of the impervious area in each subcatchment which routes runoff to each LID. The decision variables are listed in Table 6-1. Note that the first decision variable is numbered "0" for consistency with the C programming used where the first member of an array is called with a 0.

The placement of LIDs was optimized by dividing LIDs into groups based on runoff zones and soil types. Runoff zones are three groupings that were created based on the runoff coefficient of each subcatchment where LIDs might be placed. Note that this is related to the implementation of decision variables, and not a division between scenarios. This was done based on the results of a test run of the hydrological model without any LID controls. Runoff group 1 consists of all the subcatchments with runoff coefficients of at least one standard deviation below the mean value, group 2 was all the subcatchments within 1 standard deviation from the mean, and group 3 subcatchments are at least one standard deviation above the mean. Runoff group 1 contains 30 subcatchments with a total of 133 houses, group 2 contains 172 subcatchments with a total of 624 houses, and runoff group 3 contains 40 subcatchments with a total of 99 houses. The total number of subcatchments listed is fewer than the total in the model because not all of the subcatchments were deemed appropriate for LID controls. Although there are far more subcatchments and houses in group 2 the number in the other groups should be sufficient to determine if there is, for example, a cost efficiency benefit to investing in high runoff areas. Gaining this information is the purpose of dividing the subcatchments into different groups which can be individually optimized. The LIDs were not optimized by individual subcatchments because of the high number of subcatchments included in the model. Increasing the number of groupings would be one way to increase the focus on the placement of LIDs.

The other spatial division of LID controls in the decision variables concerns the soil types. The different underlying soil types have different infiltration rates at the depths which coincide with the depths of the bottoms of the LID controls. Therefore, the decision variables relating to the sizing of some LIDs were divided by soil type. Infiltration trenches and bioretention units were divided into those placed onto Berrien Sand or Brookston Clay and those placed onto Brookston Clay Loam. Rain gardens divided into those being placed on Berrien

Sand, or those being placed on Brookston Clay or Brookston Clay Loam. The soil types are described in section 3.5. More details on the scenarios can be found in Chapter 7.

Table 6-1 Decision variables

Decision Variable	Explanation	Range	Change by
0, 1, 2	Number of rain barrels per house for subcatchments in runoff zones 1, 2, and 3.	0 to 4	1
3, 4, 5	The placement of an infiltration trench in runoff groups 1, 2, and 3, all soil types included.	0 or 1	1
6, 7, 8	The placement of permeable pavement driveways in runoff groups 1, 2, and 3.	0 or 1	1
9, 10, 11	The placement of rain gardens (or bioretention units for the new development scenarios) in runoff zones 1, 2, and 3, all soil types included.	0 or 1	1
12, 13, 14	Surface area (m^2) of infiltration trenches in zones 1, 2, and 3 with underlying sand or clay.	20 to 300	10
15, 16, 17	Surface area (m^2) of infiltration trenches in zones 1, 2, and 3 with underlying clay loam.	20 to 300	10
18, 19, 20	Surface area (m^2) of rain gardens in zones 1, 2, and 3 with underlying sand or (for the new development scenarios) the area of bioretention units in zones 1, 2, and 3 with underlying clay loam.	4 to 28	4
21, 22, 23	Surface area (m^2) of rain gardens in zones 1, 2, and 3 with underlying clay or clay loam or (for the new development scenarios) the area of bioretention units in zones 1, 2, and 3 with underlying clay or sand.	4 to 28	4

The decision variables are set to whole numbers by acting on them with the floor function. The margin by which the variables change by is determined while setting the constraints. The constraints are divided by that number, but then the decision variable is multiplied by that number when it is written into the input file or used in the cost function. For example, the constraints for decision variable 23 are set as 1 to 7.1 (7.1 so that the floor function sets it as 7) but this value is multiplied by 4 at points where it is written into the SWMM input file.

6.6.5 Verification of Optimization

The functioning of the optimization system was verified in a few ways. First, the Borg algorithm was tested using the dtlz2 optimization problem that is included as an example when downloading Borg. Second, when the system was linked the SWMM input files were checked during trial runs to ensure that they were being correctly updated with the Borg decision variables. Additionally, some of the optimal solutions from the elite archive output at the end of a test run were cross-checked. The decision variable values were used in a single run of SWMM in order to ensure that the peak flow and total runoff values presented in the output were correct. Finally, a run was conducted using only the decision variable of the number or rain barrels per house in the study area (constrained between 0 and 4). In this case, each possible value of the discrete decision variable belongs to the pareto-optimal front; therefore, the optimization system should produce an output that includes each possible value of the decision variable.

6.6.6 Borg Parameters

Borg has several parameters which govern the operation of its many components. The properties are set to defaults; however, the user can alter them if they choose. Some of the Borg properties were altered in order to attempt to get the algorithm to perform as desired for this study. The primary parameters which the users set in defining the problem are the ε (epsilon) values for each objective as well as the maximum number of functional evaluations.

The epsilon values determine the resolution at which the objective values will be evaluated. The larger the epsilon, the coarser the resolution, meaning the output solutions are separated by a greater distance in the objective space. The Borg manual (Hadka and Reed, 2014) highlights the importance of the epsilon values. They are used in the proof of convergence and they are also used by the algorithm in its method of tracking progress (Hadka and Reed, 2014). If a given number of evaluations are completed without a new solution being added to the elite archive, which relies on the ε-box dominance criteria, then restart mechanisms are triggered to try to allow Borg to become unstuck (Hadka and Reed, 2013).

Tests were conducted in order to determine the number of functional evaluations required for convergence. The results of these tests can be seen in Figure 6-5 and Figure 6-6, where the objective values are graphed. Some solutions may appear dominated; however, those solutions are non-dominated in the objective not displayed. The numbers in the chart legends indicate the

the number of functional evaluations completed for each run of the optimizaiton-simulation model. The optimization algorithm functions in a stochastic manner. The runs displayed in the figures were independent, meaning that a 4000 evaluation run might not have the same solution set after 2,000 runs as the 2,000 run test unless the algorithm has already identified the pareto front at that point. When the solutions overlap it means that two independent runs have arrived at the same solutions.

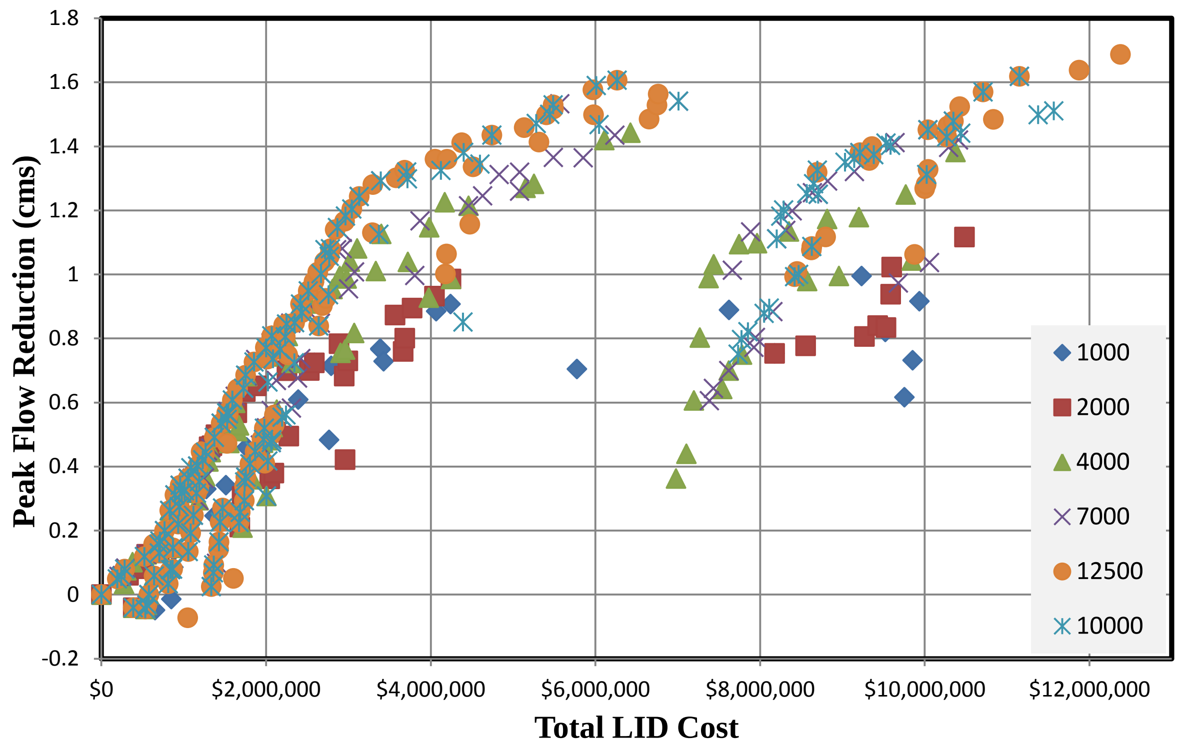


Figure 6-5 Convergence test with peak flow reduction displayed

The two main goals of the optimization are to obtain solutions as close to the pareto-optimal front as possible, as well as identifying the solutions from all regions of the front (i.e., having a good diversity of solutions). In both figures (each displays the same tests), it appears that there is a large improvement in the quality of the results up until 4000 functional evaluations. The solution sets seem to converge between 10,000 and 12,500 functional evaluations based on the observation that most of the solutions for those two tests are exactly the same. This indicates that better solutions are no longer being identified by increasing the number of functional evaluations. For reference, in his research Zhang (2009) used 10,000 evaluations. The number used for the simulations in this study was 12,500.

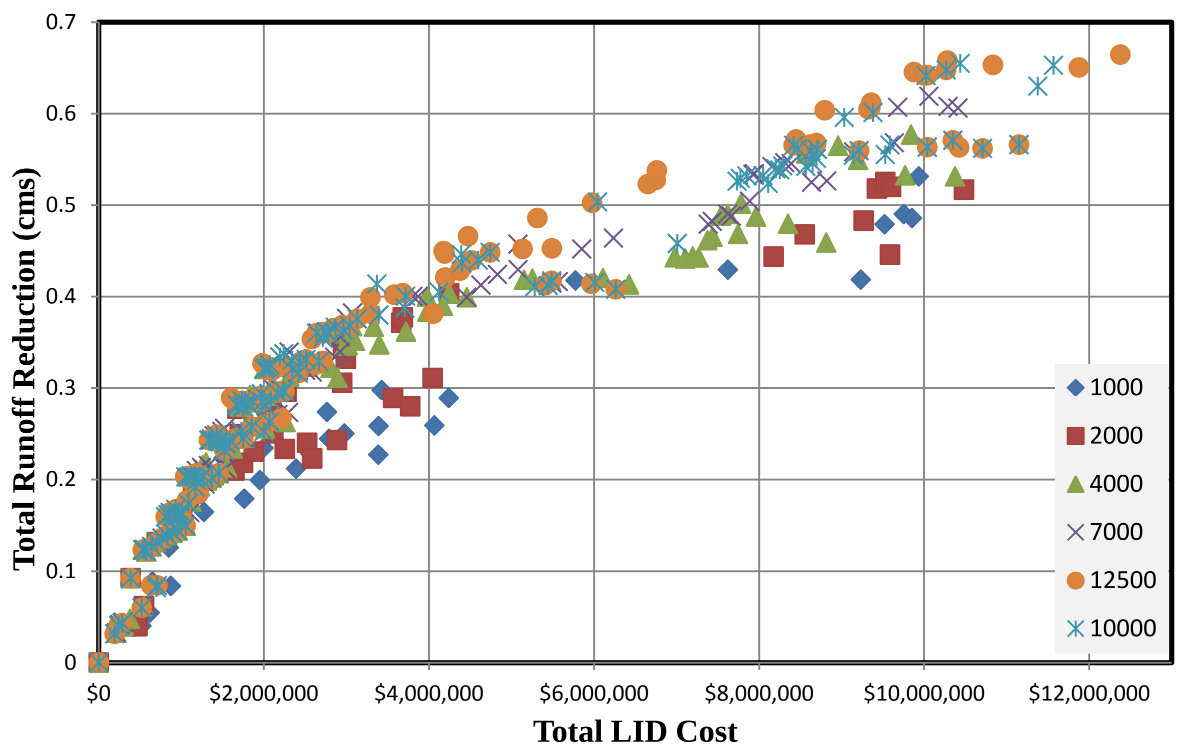


Figure 6-6 Convergence test with total runoff reduction displayed

Prior to testing for convergence or running the final simulations, several test runs were conducted with Borg to try to determine which values should be used for the operating parameters in order to find good solutions in a reasonable amount of time.

The final epsilon values selected are displayed in Table 6-2. They were kept low in order to increase the diversity of the solutions explored and to ensure that the signals created by changing each variable was impactful. For example, 0.01 m^3/s has a low level of significance when the peak flow exceeds 4 m^3/s; however, adding, for example, ten rain barrels likely won't have a large impact on the peak flow for the sewer collecting water from the entire sewershed. This is especially the case in the retrofit, low adoption scenario where the maximum number of

LID controls that may be implemented is relatively low. The opposite is the case for the unrestricted scenario. In this case the number of LID controls being added or altered by a change in a decision variable is larger; therefore, the resolution required to account for the impacts of those changes need not be as small.

Table 6-2 Epsilon values used for optimization

Epsilon Values (Q_p, R_T, $)	**Retrofit**	**New-Development**
Low Adoption	(0.01, 0.01, 1000)	(0.02, 0.02, 2000)
High Adoption	(0.01, 0.01, 2000)	(0.02, 0.02, 2000)
Unrestricted	N/A	(0.05, 0.05, 5000)

The other Borg parameters altered for the final simulations are presented in Table 6-3. These same parameters were used for each scenario. Changing any of these parameters is essentially simply part of a trial and error procedure with the goals of converging on the pareto-optimal front while maintaining a diversity of solutions. Some of the parameters that were changed so that Borg would update more frequently, were changed as such because the number of functional evaluations was being changed from the default value of 1,000,000 to 12,500. For example, it is fine if Borg only checks for progress every 20,000 evaluations if it is running 1,000,000 evaluations; however, progress should be checked more frequently if the number of functional evaluations is lower.

Table 6-3 Changes to Borg operation parameters

Parameter	Notes	Default Value	New Value
Tournament Size	Minimum tournament size. The tournament size adapts throughout the run.	2	4
Window Size	The minimum number of evaluations between epsilon-progress checks.	50	100
Maximum Window Size	The maximum number of evaluations between epsilon-progress checks.	20,000	200
Initial Population	Number of solutions in the initial population.	100	1,500
Minimum Population	Minimum size of the population. The population size is normally governed by the population to archive ratio. Remained unchanged.	100	100
Maximum Population	The maximum number of solutions allowed in the population. Remained unchanged.	10,000	10,000
Population Ratio	Sets the population to archive ratio.	4	5
Selection Ratio	Remained unchanged.	0.02	0.02
Update Interval	Determines how frequently some properties, such as the operator selection probability, are updated.	100	50

7 Development of Scenarios

7.1 Overview

This chapter outlines the scenarios which will define the different runs of the optimization-simulation model. Using different scenarios allows one to make observations on how LID stormwater controls will perform under various conditions. Comparisons between scenarios help to improve understanding of how the factors being changed between the scenarios impact LID design and performance.

For this study there are a total of 30 different scenarios for which the optimization-simulation model will be run. These 30 scenarios are composed of five different LID implementation scenarios, each being tested for six different design storms. The six design storms are 5 year, 25 year, and 100 year return period storms based off of historical data or future climate change projections. The development of these scenarios and the reason for their selection is described in this chapter.

7.2 Climate Change and Design Storms

7.2.1 Climate Change Scenario

As discussed in the literature review, a significant driving force behind the increased interest in LID stormwater controls is climate change adaptation. Cities of all sizes are creating climate change adaptation plans that have to deal with the reality of an increase in the frequency of high intensity precipitation events. Windsor, Ontario, the location of the study site, includes low impact development as a stormwater management strategy in their climate change adaptation plan (The City of Windsor, 2012).

The climate change component of this research is based on the use of an intensity-duration-frequency (IDF) curve which has been updated to include climate change data. IDF curves play a critical role in the design of stormwater management systems. Fortunately, a tool was developed by researchers at the University of Western Ontario. The IDF Climate Change Tool allows users to select climate stations in Canada, select data from climate models, and generate new IDF curves (Srivastav et al., 2015). For this study, the Windsor Airport station was selected. This station had 60 years of historical data which could be used to generate the historical IDF curves. The climate change data from an ensemble of 22 climate models were used to create the future climate change scenario IDF curves. The climate change data is for the period between 2006 and 2100. The RCP 2.6, 4.5, and 8.5 emissions scenarios were considered. For the simulations included in this research RCP 8.5, the highest emissions scenario, was selected as it provides the greatest contrast with the historical data and then the LID controls can be tested under the worst case scenario. The IDF curves used in this research are located in Appendix G.

7.2.2 Development of Design Storms

The design storms used by the SWMM model in each scenario were developed from IDF curves and a SCS Type II rainfall distribution. Precipitation values for a 24 hour events were obtained from the IDF curves (see Appendix G) for 5, 25, and 100 year return periods for both the climate change (RCP 8.5) and historical scenarios. The total rainfall for the each 24 hour event was then plugged into the SCS Type II distribution which determined the fraction of the total rainfall falling in each 12-minute time block. This results in the rainfall intensity for each 12 minute period. The precipitation files can be found in Appendix C. The cumulative rainfalls are depicted in Figure 7-1. From this it is clear that a 100 year return period historical precipitation event will become a 25 year event under the RCP 8.5 climate change scenario. The 25 year historical event becomes about a one in 5 year event under this climate change scenario.

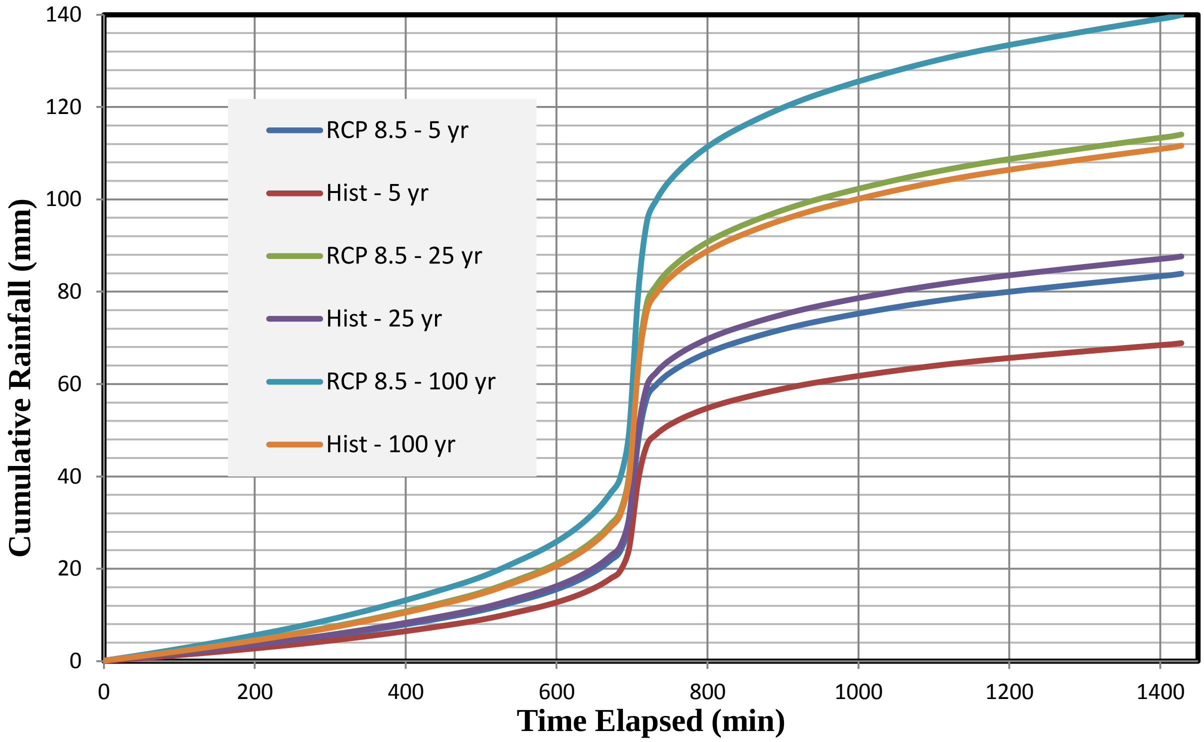


Figure 7-1 Cumulative rainfall for each storm scenario

7.3 LID Adoption Scenarios

There are five different LID adoption scenarios. They include retrofit low and high LID adoption, and new development low, high and unrestricted adoption. The retrofit scenarios represent the addition of LID stormwater controls to the sewershed as it currently exists. The new development scenarios consider the implementation of LID controls in the development of the sewershed. The new development scenarios do not represent comprehensive LID designs as they still only supplement the existing style of development. A true comprehensive approach to low impact development would include concerns regarding water and ecology throughout the planning process. In addition to the LIDs included in the new development scenarios in this study, a more comprehensive approach to LID might also implement shared green spaces which can also assist in stormwater control, cluster development to leave more space untouched, and take advantage of natural waterways and flow paths.

The new development scenarios in this study do have the advantage of some reduced construction costs where construction is more efficient, as well as increased adoption rates. Increased adoption rates are possible because a new development can be built to include permeable pavement or infiltration trenches. A developer could choose to implement LID strategies or the LID strategies could be mandated for new development (e.g. Toronto's green roof policy). People are also more likely to use a rain barrel or rain garden if it can come installed in their home and they do not have to expend any effort to implement them. Some LID adoption rates reported in the literature are listed in Table 7-1.

Table 7-1 Typical public adoption rates of LID controls

LID Type	Adoption Rate	Further Information	Source
Rain barrels and Rain gardens	30% of properties	83 rain gardens and 176 rain barrels	Mayer et al., (2012)
Rain barrels	25% of 350 parcels	40% of the parcels had to be incentivized to take the rain barrels	Shuster et al. (2008)
Landscaped and grassed bio-filtration systems	90% of 300 property owners in favour	60% thought aesthetics would be improved by the LIDs suggested	Lloyd et al. (2002)
Rain barrels (retrofit)	2% to 8%	Based on the current rates of downspout disconnection	Personal communication*
Rain barrels (new)	10% to 25%	Easier if downspouts do not have to be disconnected	"
Permeable pavement driveways (retrofit)	1% to 2%	Too expensive to retrofit	"
Rain gardens (retrofit)	1% to 5%	N/A	"
Rain gardens (new)	3% to 10%	Based on them being abandoned over time	"

*The personal communication was rough estimates provided by the City of Windsor Supervisor for Environmental Sustainability and Climate Change based off her experience.

Table 7-2 lists the maximum LID adoption percentages used for the five LID implementation scenarios. The adoption rates are selected in order to be close to what might be achieved in reality while also being able to study the benefit of LIDs at various adoption rates. Adoption rates as low as 1% were not used because this would mean that changes to decision variables would result in very minute feedback from the simulation model. The unrestricted scenario was included in order to study the maximum benefit LIDs could achieve. The adoption of infiltration trenches rises more quickly between the scenarios because it is a centralized LID that does not rely on public adoption, assuming the land on which to locate it is available.

Table 7-2 Maximum adoption rates of each LID control by percent of houses or subcatchments

(%)	Retrofit		New Development		
LID Control	**Low**	**High**	**Low**	**High**	**Unrestricted**
Rain barrel	5	10	10	25	100
Rain garden/ bioretention	5	10	10	25	100
Permeable pavement	2	5	10	100	100
Infiltration trench	5	25	25	100	100

The LID adoption rates listed are the maximum possible adoption rates for each scenario. That means that if some LIDs are not activated the implementation rates will actually be lower. The adoption rates are applied differently depending on the LID. The infiltration trenches, for which there is only one per eligible subcatchment, the number of eligible subcatchments was reduced accordingly. The subcatchments which remained eligible for infiltration trenches were those which remained eligible for other LID types in the given scenario. This was done to preserve the routing dynamics which help to inform the user, of the optimization-simulation model, about which LID combinations are effective. Following this, if more subcatchments had to be made eligible for LID implementation in order to reach the specified adoption percentage, subcatchments were made eligible for LID implementation at random until the specified adoption rate was met.

For permeable paving driveways (0 to 1 unit per house), rain gardens or bioretention (0 to 1 unit per house) and rain barrels (0 to 4 units per house) the LID adoption was limited by limiting the number of adopting houses. The number of units or each LID type in each subcatchment are written into the SWMM input file (see Appendix A for an example of an input file) by first multiplying the number of units per house (the decision variable value) by the number of houses in that subcatchment. This is done by retrieving values from an array which contains the number of houses in each subcatchment. In order to limit LID adoption, additional arrays were constructed with reduced number of houses in order to align with the desired LID adoption rates. Which houses remained eligible for LID adoption was determined partially at random while attempting to spread the LID adopting houses between different subcatchments. At this point it is important to note how routing is handled. The routing from impervious surfaces to each lot-level LID type is multiplied by the number of adopting houses in a given subcatchment over the total number of houses in the subcatchment. This represents reality, in the sense that a rain garden at one house is unlikely to receive runoff from several other houses, and prevents LIDs from becoming overloaded sooner than they would be while receiving runoff only from a single lot. Similar methods were used to adjust the changes in subcatchment percent imperviousness, and the changes in internal routing caused by the implementation of LIDs.

The maximum total number of units of each LID type which can be implemented at each applicable adoption level are listed in Tables 7-4 to 7-7. Table 7-3 should be helpful in interpreting those tables. One additional comment on Table 7-3 is that if two soil type acronyms are used together it means that the same LID type is being implemented on each soil type. For example, ITSC2 refers to the infiltration trenches in subcatchments which are a part of runoff zone 2 and have either sand (Berrien sand) or clay (Brookston clay) as an underlying soil type.

Table 7-3 LID acronyms

Acronym	Description
RB	Rain barrel
IT	Infiltration trench
RG	Rain garden
BR	Bioretention unit
PP	Permeable pavement
S	Berrien sand
C	Brookston clay
L	Brookston clay loam
1	Runoff zone 1 (low runoff coefficient)
2	Runoff zone 2 (middle runoff coefficient)
3	Runoff zone 3 (high runoff coefficient)

Table 7-4 Number of units for infiltration trench in each adoption scenario

LID Adoption	ITSC1	ITSC2	ITSC3	ITL1	ITL2	ITL3
5%	1	5	1	0	4	1
25%	6	24	4	1	19	6
100%	25	97	16	5	74	24

Table 7-5 Number of units for rain garden in each adoption scenario

LID Adoption	RGS1	RGS2	RGS3	RGCL1	RGCL2	RGCL3
5%	2	8	1	5	23	4
10%	4	12	1	9	50	9
25%	6	17	1	27	139	24
100%	31	105	5	102	519	94

Table 7-6 Number of units for bioretention in each adoption scenario

LID Adoption	BRL1	BRL2	BRL3	BRCS1	BRCS2	BRCS3
5%	0	16	1	7	15	4
10%	2	36	3	11	26	7
25%	4	70	13	29	86	12
100%	16	262	51	117	362	48

Table 7-7 Number of adopting houses for rain barrels and permeable pavement in each adoption scenario

LID Adoption	RB1	RB2	RB3	PP1	PP2	PP3
2%	N/A	N/A	N/A	3	13	2
5%	7	31	5	7	31	5
10%	13	62	10	13	62	10
25%	33	156	25	N/A	N/A	N/A
100%	133	624	99	133	624	99

*The maximum total number of rain barrels would be four rain barrels per house multiplied by the number of eligible houses.

7.4 Summary of Scenarios

In summary, there are 30 total optimization scenarios. 30 results from running six different design storms for each of five LID implementation scenarios. These divisions allow for observations on the usefulness and cost-effectiveness of LID stormwater controls at various LID adoption levels as well as observations on how the performance of LID solutions, of varying adoption rates, perform during storms of various intensities. These the results from each scenario are discussed in chapter 8.

8 Results and Discussion

8.1 Overview

The results of all the tests and simulations are presented and discussed in this chapter. Table 7-3 will be helpful for understanding acronyms used in some of the tables and figures. The first results presented are tests of adding a single LID control type at 100% adoption. Following this, the performance of LIDs is evaluated for all six design storms for each of the five LID implementation scenarios. It is important to note that there is a reason that it appears that some solutions are dominated in the figures. That is because the results are three dimensional but graphed in two dimensions. Essentially, if a solution on a peak flow graph appears dominated, this probably means that it is actually non-dominated for runoff reduction and vice versa. For this reason, additional graphs were created that only show the solutions non-dominated in each of those two reduction objectives and cost. Finally, some of the solutions from the optimization process are further analyzed. The cost breakdown and LID sizes are presented and discussed. These are a selection of some of the more cost effective solutions (represented in some of the other figures by triangle markers). There are also comparisons of cost-benefit curves from each LID implementation scenario and finally some cost-effective solutions are tested for the July 15th calibration event. The raw results from the optimization runs, as well as number of each LID type implemented in some of the most cost-efficient solutions are included in Appendix F. It should be restated that the cost values presented are estimates for the capital costs associated with the construction of the LID stormwater controls. Design, engineering, maintenance, and land acquisition costs are not considered.

There are limitations to the simulations which could impact the performance of the LID stormwater controls. One aspect of the simulation which will certainly reduce the predicted performance of the LID performance is the fact that the LID designs are widely generalized. Since the subcatchment sizes and properties are not uniform, the generalization of LID designs means that a certain type of LID might be designed to be too small for some subcatchments resulting in reduced performance but also over-designed for other subcatchments resulting in increased cost. Another factor which might limit the performance of LIDs in the simulation are discussed in chapter 7. Due to the fact that even the new development scenario does not really represent a comprehensive LID design. Finally, the limitations of LID routing in SWMM (discussed in section 5.10), which prevent routing from one LID to another, might limit the performance of the LID controls. There is also a factor, not considered in this model which could reduce the performance of the LIDs in reality. This is the flow from groundwater into the LIDs, such as could be the case if the water table were high. However, if high-water tables were a factor, it would be possible to add impervious liners to the LID units to preserve the peak flow reduction benefits.

8.2 Individual LID Testing

Individual LID types were tested in order to see how effective each type could be on their own relative to other LID types. These tests also provide information which will be helpful in interpreting the results of the optimization-simulation runs. Individual tests were conducted using the 24 hour, historical 100 year storm used for the optimization runs as well as the July 15th-23rd event used to calibrate the SWMM model.

8.2.1 Peak Flow and Total Runoff

Table 8-1 presents the results of individual LID controls tested for the 100 year precipitation event. The null case indicates a run where no LID controls were implemented and full indicates all of the LIDs implemented along the lines of the new development, unrestricted scenario. The maximum runoff reduction achieved, about 9% for full implementation, was less than most of the results reviewed in the literature. Among the closest values reported in a study conducted with computer simulation (also SWMM) was a 14% reduction for a 50 year precipitation event reported by Zahmatkesh et al. (2015). Their study used a similar combination of LIDs. Another difference between this study and the results reported by Zahmatkesh (2015) is that they report runoff reductions greater than the peak flows; whereas, the results of this study show greater reductions (by percentage) in peak flow. Another similar result was from Ahiablame et al. (2013) who reported a 3% to 11% reduction in runoff for an urbanized watershed in Indianapolis.

Comparing between the different LID measures, rain barrel has the least significant impact. This is because four 200 L rain barrels at each of the 856 houses is only a volume of 0.0685 ha.m. Additionally, the available storage volume will be filled before the portion of the storm which causes the highest peak flows. Swales perform poorly in terms of both peak flow and runoff for the historical 100 year event. It is not clear whether this is because the manner in which the swales are represented is flawed or rather that they would actually perform as the model predicts for such an intense precipitation event. The poor runoff reduction is discussed further in the following section. The infiltration trench performs the best for peak flow; a result that will be repeated several times in the optimization run. Permeable pavement performs better than every other individual LID control, besides rain gardens, for reducing runoff. This can be attributed to the fact that permeable pavement is reducing the percent imperviousness of the subcatchments by virtue of replacing impervious area (the other LID types are mostly placed in already pervious areas).

Table 8-1 Performance summary of individual LID types fully adopted

	Null	SW	BR	IT	RG	RB	PP	Full
R_t (ha.m)	6.41	6.56	6.32	6.20	5.91	6.35	6.07	5.84
Q_P (cms)	6.88	7.26	6.14	5.76	6.63	6.87	6.35	5.43
Infiltration Loss (ha.m)	1.37	1.42	1.35	1.36	1.45	1.37	1.69	1.66
Initial LID Storage (ha.m)	0	0	0.52	0.21	0.33	0	0.05	0.78

8.2.2 Extended Duration Tests (July 15th event)

The extended simulations represent the results of adding LIDs to the model and running the July 15th calibration event. The calibration event is the same event as is displayed in Figure 4-13 and Figure 4-14. It is a continuous simulation over about nine days. The precipitation events within this time series are much smaller than any of the design storms used in the optimization runs. For these smaller events the LIDs appear to be much more effective at reducing peak flows, at least in terms of reduction percentages. The full LID adoption scenario reduces peak flow by a high of 79% for the peak at 21:49 on July 19th. The lowest peak flow reduction percentage occurs during largest peak. From Figure 8-1 it may be observed that rain barrels offer some benefit, but much less than other LID measures. These small benefits offered by the rain barrels are also occurring in a scenario where all of the houses in the sewershed have four rain barrels, which far exceeds what could be expected in reality. The swales (see Figure 8-3) perform even more poorly than the rain-barrels (see the discussion on swales in section 5.7) as this may not be an accurate prediction of their performance. Looking at both Figure 8-1 and Figure 8-2 it seems that for these events infiltration trenches, rain gardens, permeable pavement and bioretention are able to provide similar or better amounts of peak flow reduction. Although it is difficult to see in Figure 8-2, the infiltration trenches slightly outperform the bioretention units. Permeable pavement outperforms those two LIDs except during the highest peak flow event when it is clearly worse. One other thing to note is that the additional peak at the beginning of the time series for some of the LID scenarios represents some of the water volume initially stored in LID controls (due to the initial saturation) entering the stormsewer via their underdrains.

The total runoff generated in the simulations is reported in Table 8-2. This table should not be compared to the values in Table 8-1 because these runoff values are not for a specific event but for all the events contained in the July 15th time series. The reason that the runoff increases in the case of swales is certainly because of how they were simulated. As previously discussed, the swales were added as additional subcatchments which they completely occupied. The added area was subtracted from other subcatchments; however, the swale area would generate more runoff because it receives all the runoffs from the subcatchments and therefore the swales would quickly become saturated likely generate more runoff than the subcatchments from which area was subtracted. As for the other single LID controls, permeable pavement once again offered the most runoff reduction. The rain gardens outperform the bioretention units for runoff reduction because they are modeled with higher saturated soil conductivity.

Table 8-2 Total runoff for single LID controls during the July 15th series of events

	Null	SW	BR	IT	RG	RB	PP	All
R_t (ha.m)	2.22	2.31	1.93	1.79	1.87	2.14	1.73	1.34

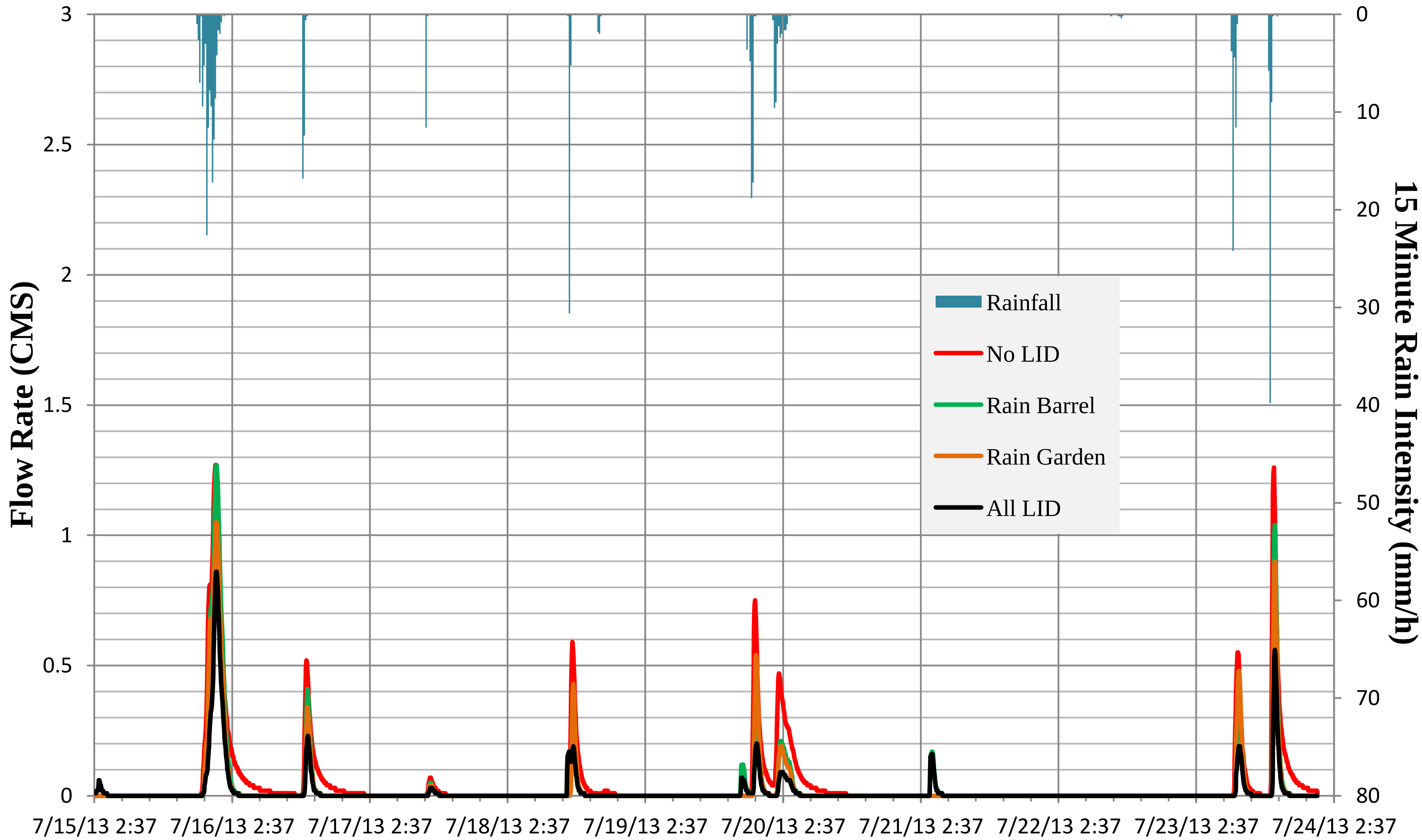


Figure 8-1 Hydrographs for the implementation of single LID types during the July 15th series of events (1st set)

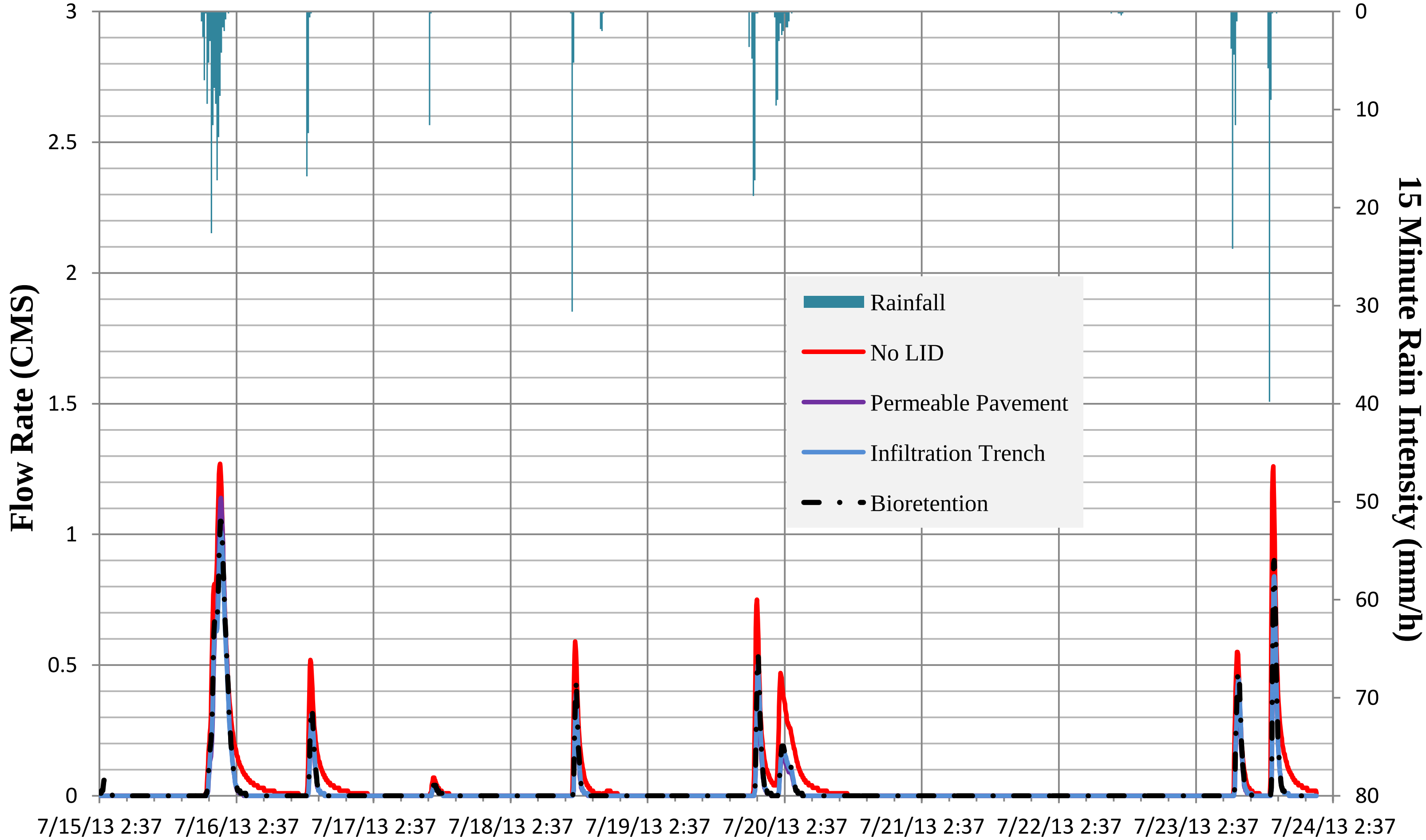


Figure 8-2 Hydrographs for the implementation of single LID types during the July 15th series of events (2nd set)

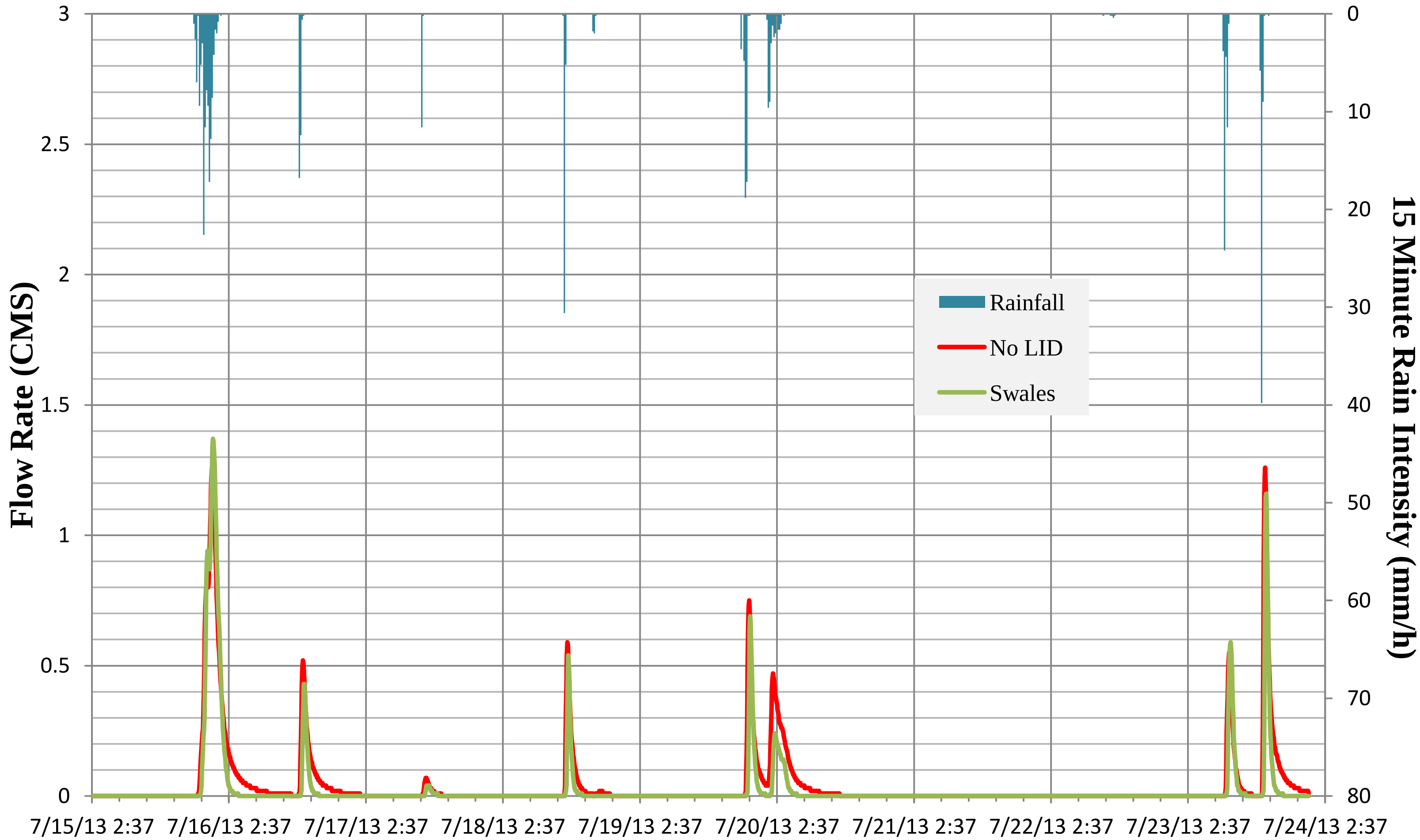


Figure 8-3 Hydrograph for the implementation of swales during the July 15th series of events

8.3 Retrofit, Low LID Adoption

8.3.1 All Solutions

The raw results for the retrofit, low LID adoption scenario are presented in Figure 8-4 and Figure 8-5. The data series in each figure are the objective values of the solutions stored in Borg's elite archive during the optimization-simulation runs for each design storm. These figures might not seem easy to interpret. This is because at an LID adoption level this low, the changes in the decision variables result in very small changes in runoff and peak flow causing the solutions to become crowded together. The results also do not look like a pareto front. This is because there are three objectives, so in order to observe a clear pareto front the results would have to be graphed in three dimensions (which would make it more difficult interpret the results). The different performance of some solutions between peak flow reduction and total runoff reduction confirms the importance of flow timing in peak flow levels. The runoff volumes would be the other large contributing factor but peak flow reduction significantly exceeds runoff reduction. In order to make the results easier to interpret, additional graphs are created for each scenario which have been filtered to only include the solutions which are non-dominated for peak flow reduction or total runoff reduction. For this scenario these are Figure 8-6 and Figure 8-8. This section also includes labelled graphs which assist in describing the trends seen in Figure 8-6 and Figure 8-8. These extra graphs are Figure 8-7 and Figure 8-9.

Returning to Figure 8-4 and Figure 8-5, there are important observations that can be made from these figures. The overall reduction capacity is very low for both peak flow reduction and total runoff reduction. As is the case for every scenario, the percentage by which the peak flow can be reduced by LID controls is less than the percentage by which the runoff can be reduced. For this scenario the costs are also low. This leads to cost-effectiveness (reduction per money spent) which is similar to the other scenarios. Even with similar cost-effectiveness to the other scenarios, these results cast doubt on to whether this level of LID adoption would be useful for limiting peak flow or runoff for the large precipitation events studied. One final observation is that the reduction percentage is quite clearly the worst for the most intense rainfall event, the climate change 100 year storm.

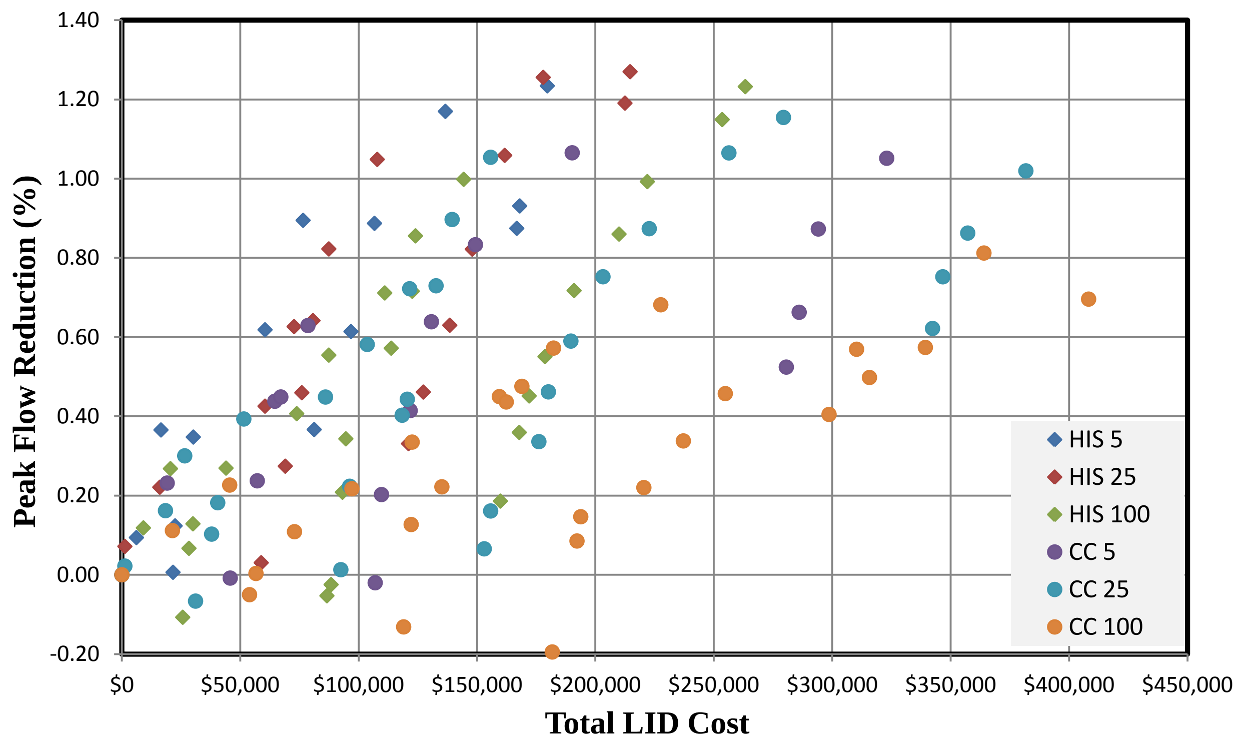


Figure 8-4 Peak flow reduction, by percentage, for the retrofit-low scenario

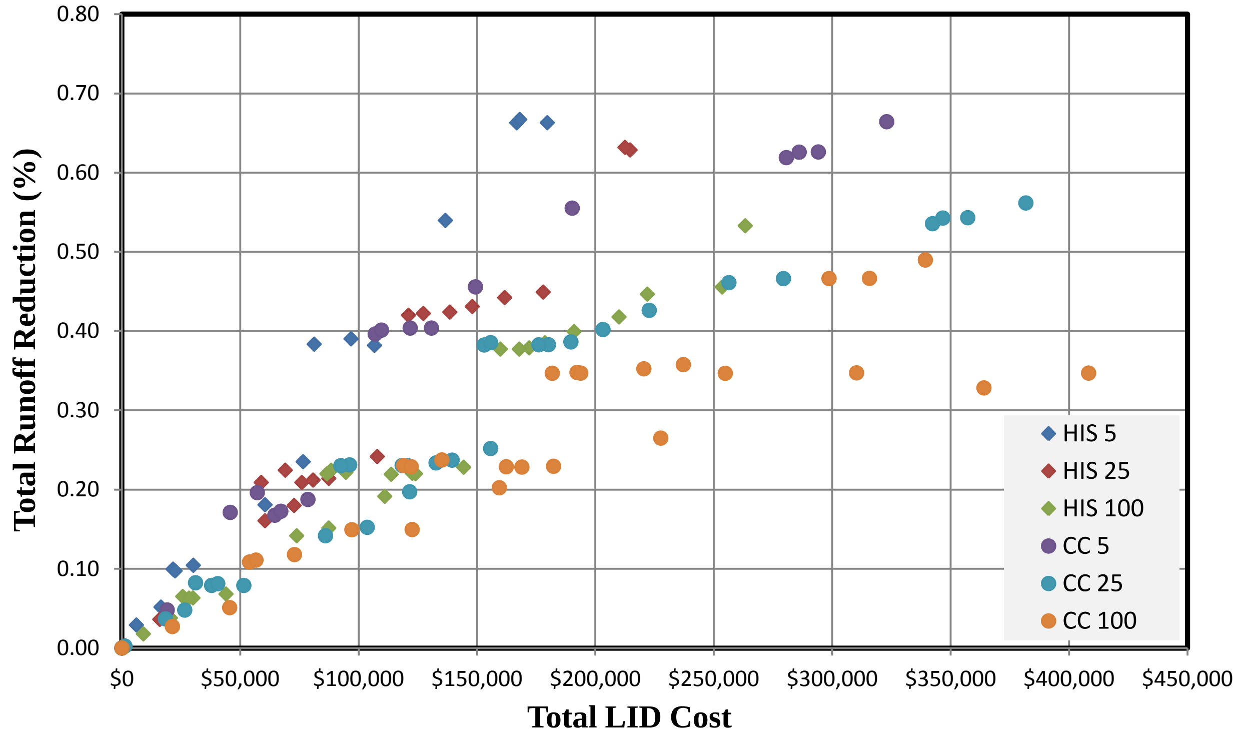


Figure 8-5 Total runoff reduction, by percentage, for the retrofit-low scenario

8.3.2 Non-dominated Peak Flow Solutions

Figure 8-6 shows the solutions for each of the design storms filtered such that only the solutions which are non-dominated in the objectives of peak flow reduction and cost minimization are included. Non-dominated means that no other solution performs better in both objectives considered. As previously stated, the markers which have been changed to triangles are some of the more cost-efficient solutions which are used for further analysis in section 8.9. More specifically, in section 8.9, there are cost breakdowns and tables of LID areas for those solutions. Even considering that Figure 8-6 presents the peak flow reduction as a quantity rather than a percentage, the reductions offered by LIDs for the 100 year climate change event still appears as the lowest of all the design storms. LIDs offer the highest total reduction, if not percentage reduction, for the 25 year climate change event and the historical 100 year storm. This indicates that at some level of rainfall intensity between those two events and the 100 year climate change event the LID performance drops off significantly. Possible reasons for this are discussed further in section 8.4.1.

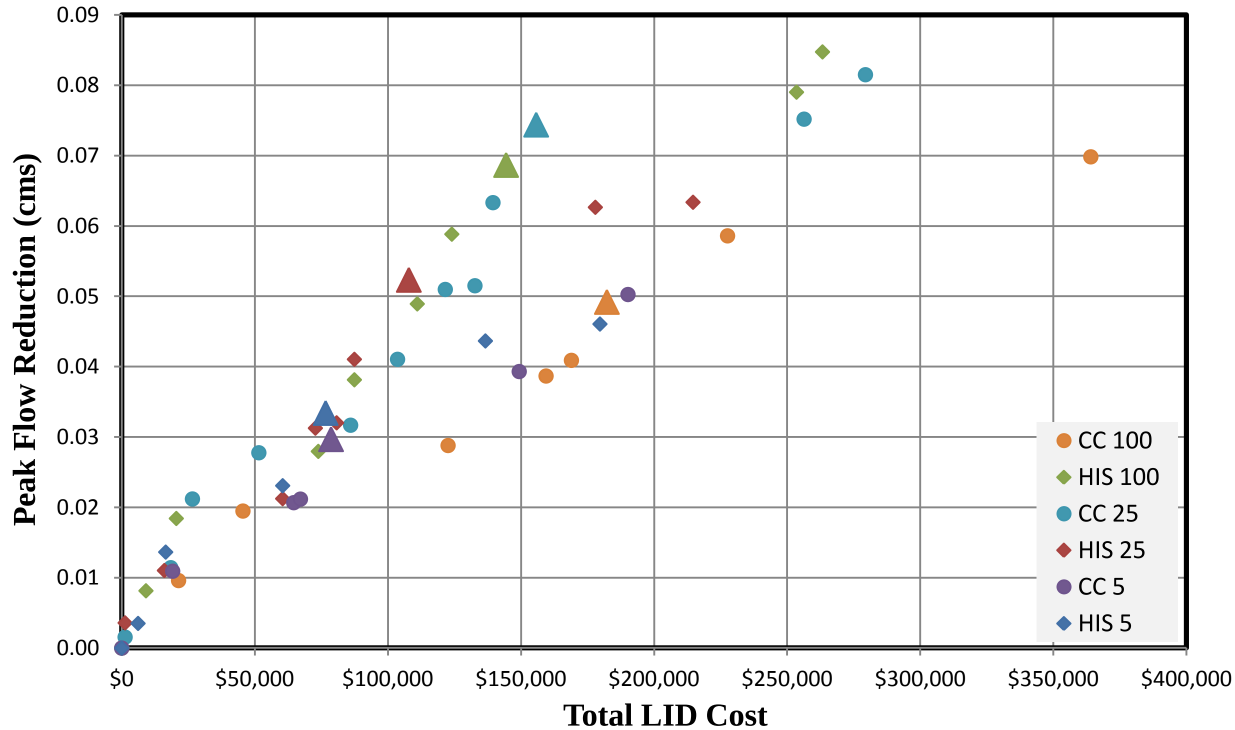


Figure 8-6 Solutions non-dominated in peak flow reduction or cost for the retrofit-low scenario

The slope of the series in the graph is not uniform. This is because the efficiency of improvements differs depending on whether the changes are due to changes in the sizing of rain gardens and/or infiltration trenches, changes in the numbers of a given LID, or changes in the combinations of LIDs present in any solution. All of these changes are described in Figure 8-7. Along these lines, the diminishing returns in investment occur once the adoption of a better performing LID has been completed and further increases in peak flow reduction can only be achieved by investing in less efficient LIDs. Therefore, the amount of peak flow reduction that can be achieved, before a significant point of diminishing returns is reached, depends on the constraints on the adoption of the most efficient LID types in each scenario. Figure 8-7 makes it clear that the most efficient LID type for this scenario is the infiltration trenches. Additional reduction can be achieved by adding rain gardens. Rain barrels are also present in some solutions but are not a significant factor. The cost estimate for the rain barrels could be considered to be very conservative. If a cheaper price were used rain barrels might play a more significant role in the extremely low cost solutions. One reason the rain barrels are less effective for peak flow reduction than they are for total runoff reduction is that they fill up before the most intense portion of the precipitation events and therefore cannot contribute during the times at which the highest peak flows are generated. There is an additional factor that can prevent the rain barrels from being included in more solutions. That is, once the rain barrel is full the outflow can be directed to pervious areas but not to other LID controls (due to the SWMM routing scheme). This means that whatever runoff from impervious surfaces is routed to the rain barrels (which can be significant portions of roof runoff) is prevented from being routed to more efficient LID controls. This is a factor for more than just rain barrels. Routing as much runoff as is feasible to the most efficient LIDs should be an objective real LID design.

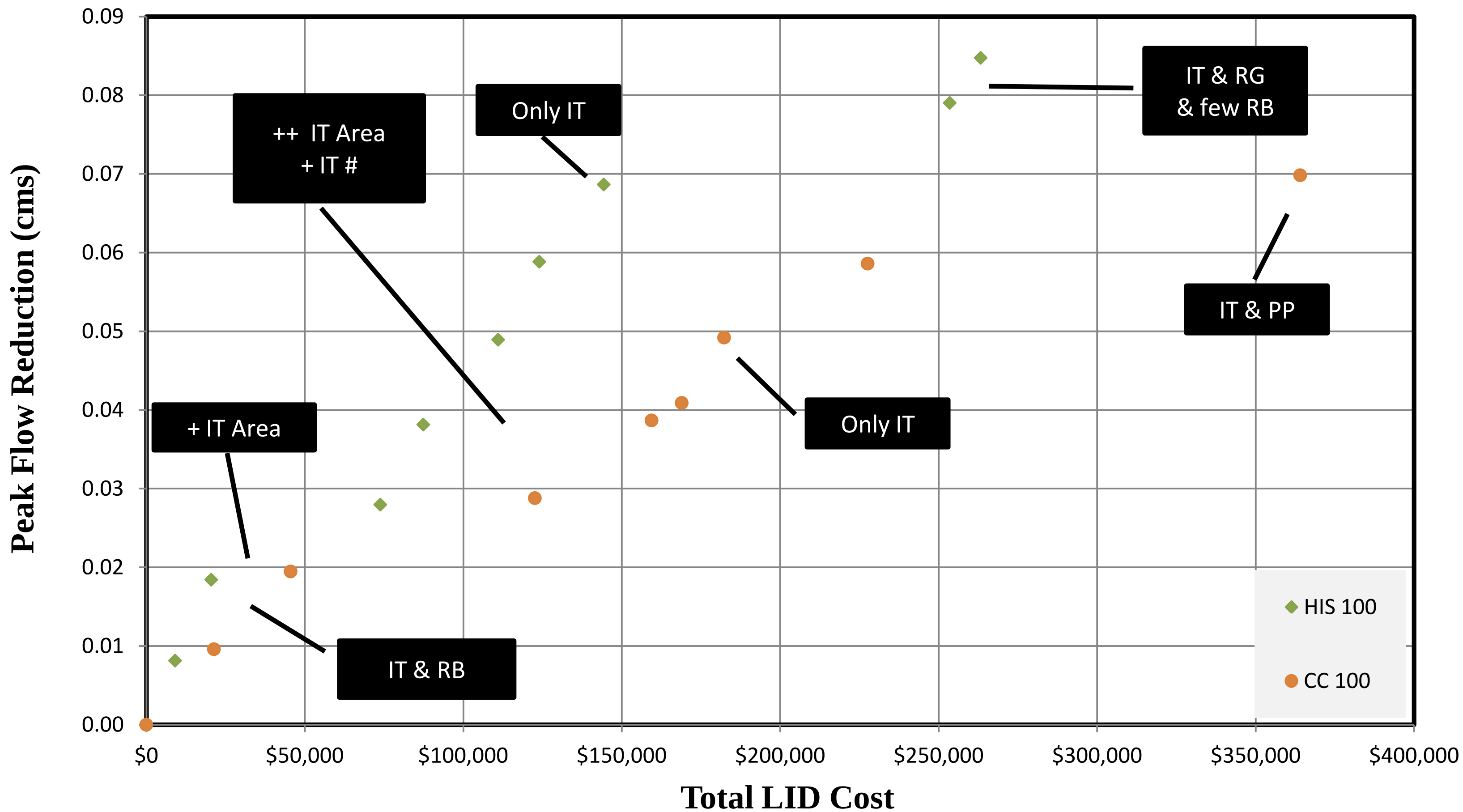


Figure 8-7 Explanation for the changes in peak flow reduction performance in the retrofit-low scenario

Figure 8-7 only presents two data series for clarity. The plus signs in this case indicate a property that is increasing in the region indicated. For example, the top-left label indicates that the increases in peak flow reduction in the labeled region occurs as the number of infiltration trenches increases, and the total area of the infiltration trenches greatly increases (partly due to the increased number).

8.3.3 Non-dominated Runoff Solutions

The cost-benefit curves for total runoff reduction show different patterns than those for peak-flow reduction. Comparing Figure 8-8 to Figure 8-6, observe that the increases in reduction are steadier than the increases in peak flow reduction with no obvious point of diminishing returns. Another significant difference in this case is that the LIDs are able to achieve the highest total reduction, if not percentage reduction, for the climate change 100 year storm. This indicates that the ability of the LIDs to reduce runoff does not decline as sharply as their ability to reduce peak flows. From Figure 8-9 we can see that infiltration trenches are also represented in the most cost-effective solution for total runoff reduction; however, compared to the non-dominated solutions for peak flow reduction, rain gardens and rain barrels are both more often present in the dominant solutions. The labels in Figure 8-9 provide a more detailed explanation of what is happening with LID designs and implementation.

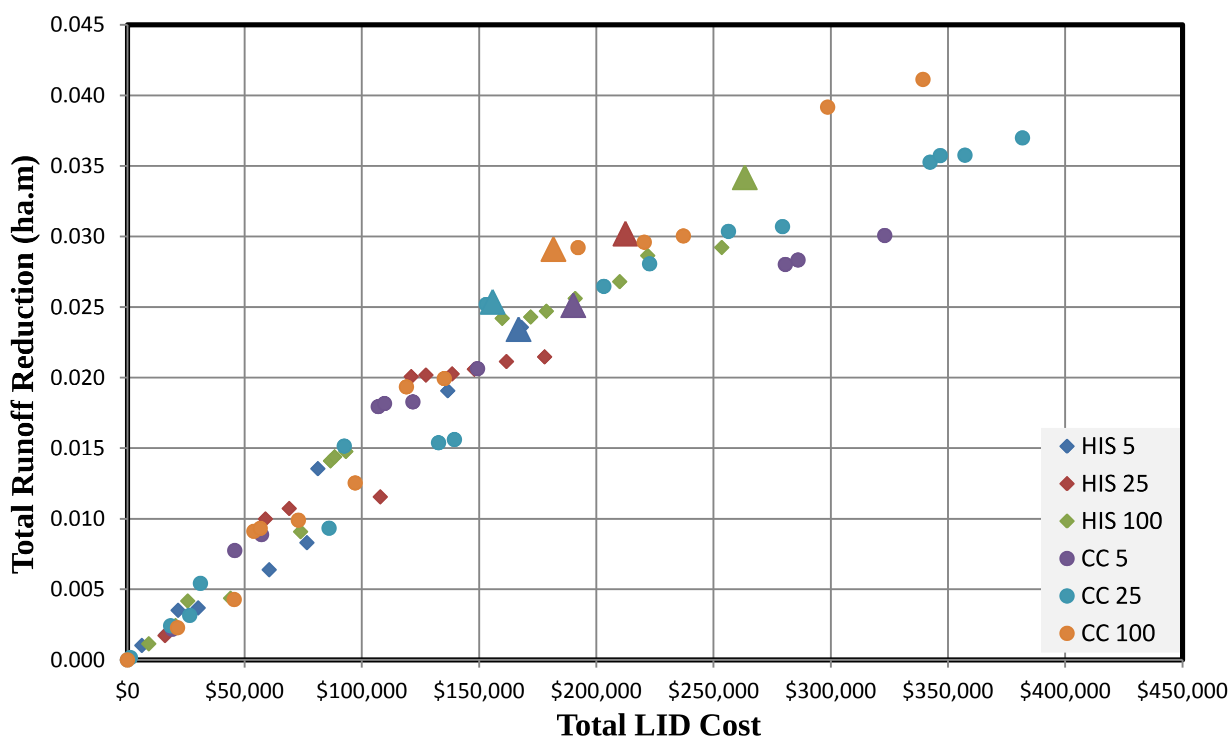


Figure 8-8 Solutions non-dominated in total runoff reduction or cost for the retrofit-low scenario

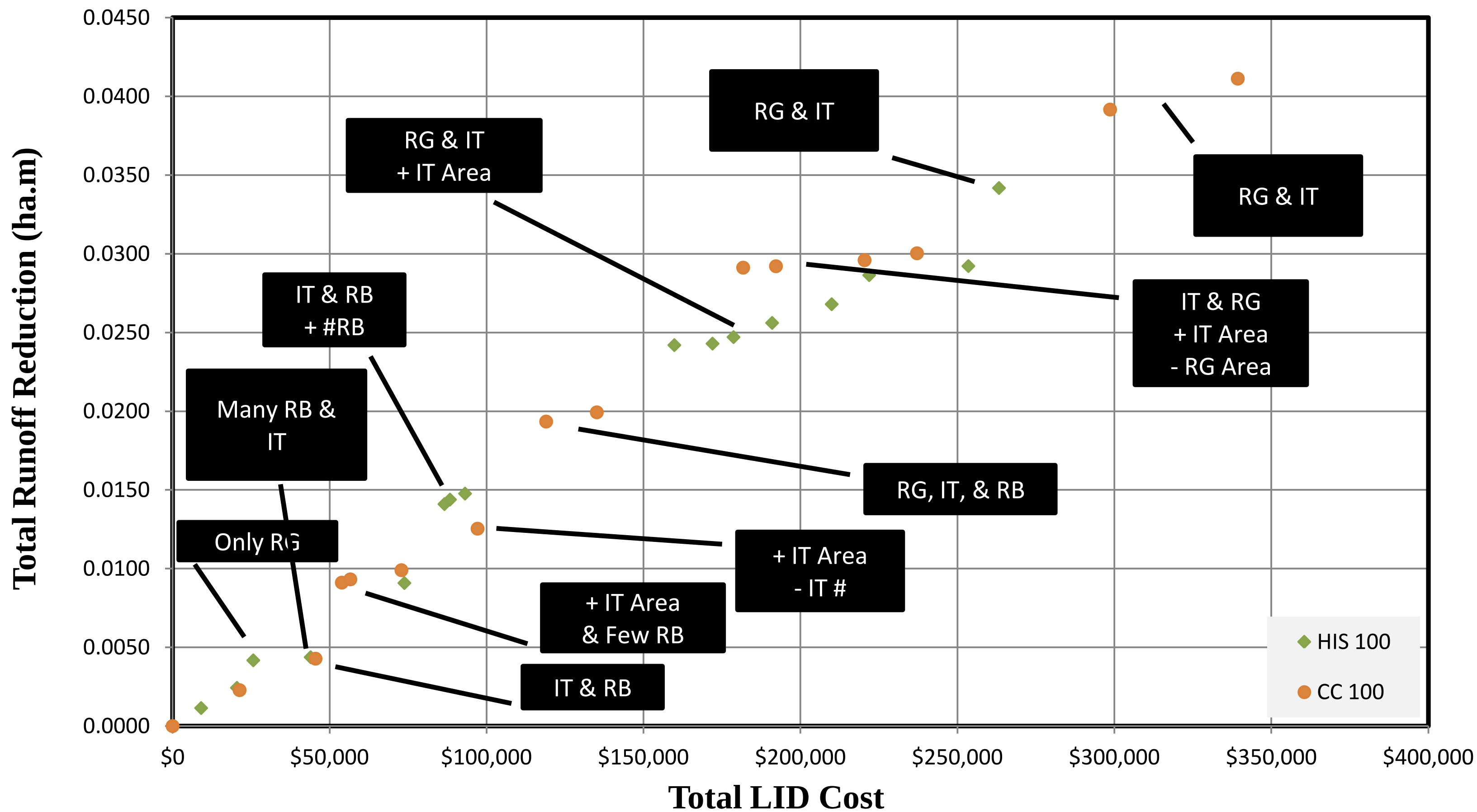


Figure 8-9 Explanation for changes in total runoff reduction in the retrofit-low scenario

The notation for Figure 8-9 is similar to what was described for Figure 8-8. Minus signs indicate a decrease in a given property, and/or that the property is decreasing. Some labels refer to specific solutions while some refer to series of solutions.

8.4 Retrofit, High LID Adoption

8.4.1 All Solutions

The raw results for each storm in the retrofit, high LID adoption scenario are presented in Figure 8-10 and Figure 8-11. Compared to the retrofit, low LID adoption, scenario the maximum reduction that the LIDs can achieve is significantly greater for both peak flow and total runoff. The factor by which the reduction percentage increased between scenarios was greater for peak flow reduction. In addition to increases in reduction percentages, the efficiency of that reduction increased. The increase in efficiency could be attributed to the decrease in the restrictions on infiltration trenches. The number of subcatchments at which an infiltration trench may be installed is increased from 5% of feasible subcatchments in the retrofit, low adoption scenario to 25% in the retrofit, high adoption scenario. This increase is greater than the increase for other LID types. Infiltration trenches are once again the dominant LID type expressed in the solutions, especially for peak flow reduction. One possible explanation for the good performance of infiltration trenches is related to the relationship between peak flows and flow timing which is discussed further below.

The most likely cause of the poor peak flow performance of some solutions is due to the flow timing. This was already touched upon in the discussion of the underdrain calibration in section 5.8. Once the depth of water stored in some LIDs reaches a certain point, the rate of flow through the underdrains can be great enough that the water will reach the storm-sewer faster by flowing through the LID and the underdrain than it would by travelling overland to the outlet node for the subcatchment. Essentially, it seems as though the LIDs can cause a short circuit in the flow routing which can lead to increases in peak flow even with a reduction in total runoff. Besides what was determined by changing the underdrain parameters another test was run to help confirm this explanation. The subcatchment widths were increased by a factor of four and both a no-LID scenario and one of the solutions which had produced a runoff increase were tested. Both scenarios experienced significant increases in peak flow over their previous levels; however, the solution which had increased peak flow over the no-LID solution now caused a decrease in peak flow. The subcatchment width (Figure 4-7) determines the distance runoff must flow overland. Decreasing the widths increases the time it will take for runoff to reach the stormsewers but does not impact how long it will take for water to reach the stormsewers through an LID underdrain. The widths were decreased as a part of the calibration process. The infiltration trenches are not as likely to short circuit because they are longer (the water has farther to travel through the infiltration trenches) and the underdrain coefficient is lower than for the other LID types.

Returning to Figure 8-10 and Figure 8-11, it can be observed that the percentage reduction for both peak flow reduction and total runoff reduction consistently decrease as the intensity of the design storms increases. Again, the reason why there are sometimes series of solutions with gaps between the solutions is that there are different factors changing. A series of solutions generally indicates one combination of LID controls with changes to the areas of the given LIDs (assuming rain gardens/bioretention units or infiltration trenches are included as only these LIDs have variable area) or changes to the numbers of LIDs (due to different zones being turned off or on). The jumps in the series are most often due to changes in which LID combinations are present.

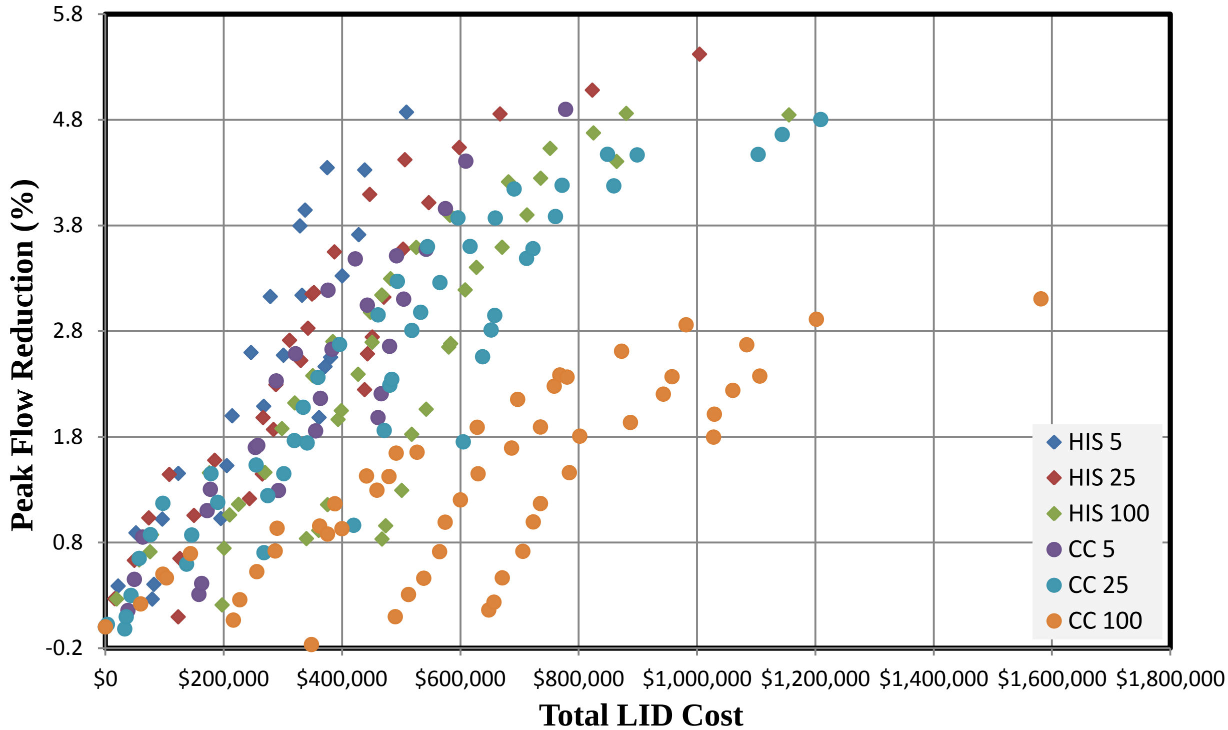


Figure 8-10 Peak flow reduction, by percentage, for the retrofit-high scenario

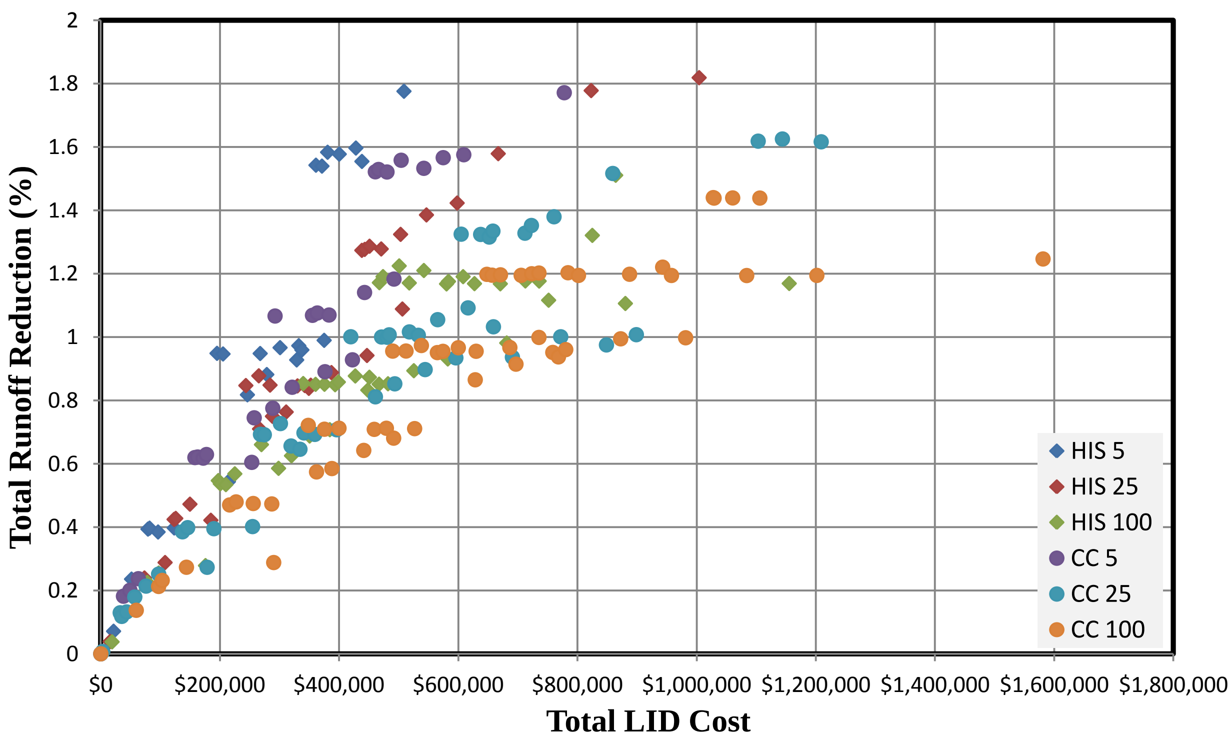


Figure 8-11 Total runoff reduction, by percentage, for the retrofit-high scenario

8.4.2 Non-dominated Peak Flow Solutions

The relationship between the intensity of the design storms and the total runoff reduction achieved is similar to what was found in the retrofit, low LID adoption, scenario. Once again the LID performance drops off significantly for the climate change 100 year storm. In Figure 8-12 it appears that there is a point of diminishing returns, where the slope of the cost benefit curve begins to significantly decrease, and this occurs between a 0.2 m^3/s and 0.3 m^3/s depending on the scenario. This point is higher for the scenarios where the constraints on LID adoption are decreased because there is more opportunity to implement the most efficient LIDs. The cost at which the most efficient solutions occur depends on the design storm under consideration.

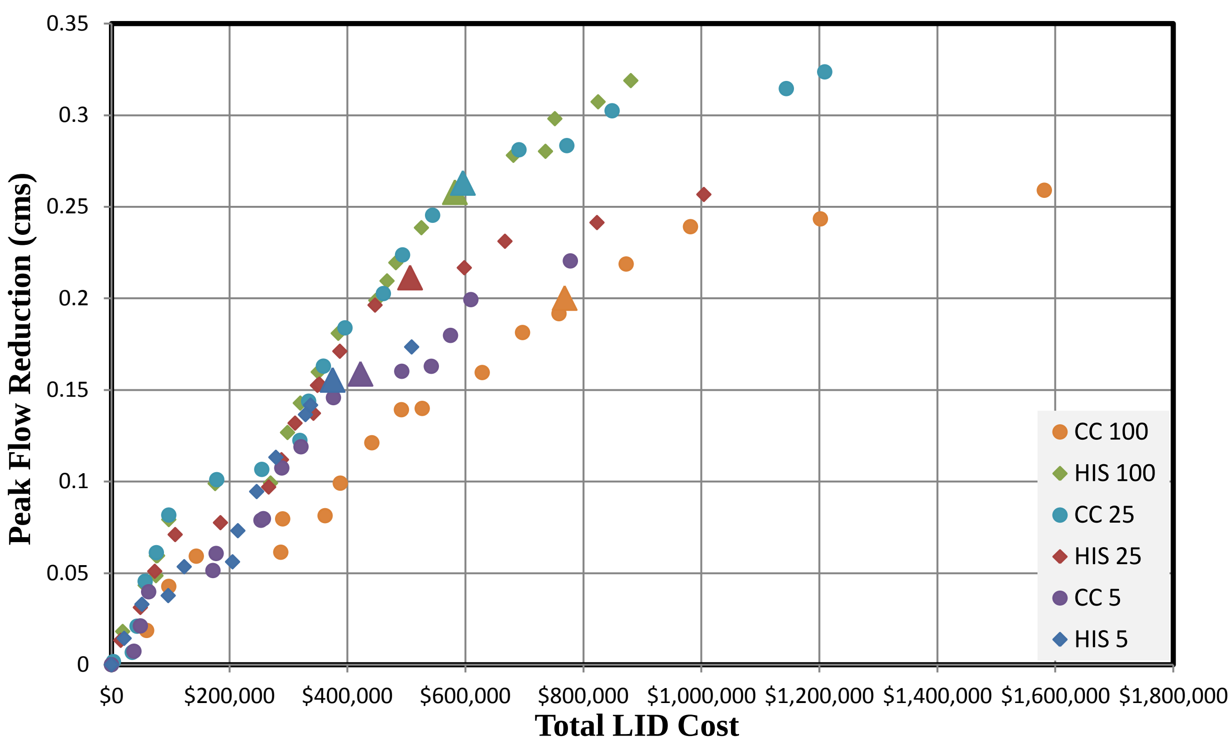


Figure 8-12 Solutions non-dominated in peak flow reduction or cost for the retrofit-high scenario

8.4.3 Non-dominated Runoff Solutions

Figure 8-13 presents the solutions for the retrofit, high LID adoption scenario which have been filtered, such that only the solutions which are non-dominated in total runoff reduction or cost minimization are included. As in the retrofit, low adoption scenario, the increase in total runoff reduction is steadier than the peak flow reduction. Also, the ability of LIDs to reduce total runoff does not decline as sharply with increasing storm intensity as does the ability of LIDs to reduce peak flow. A final observation is that the spread of the series of solutions fall closer together than do the series of peak flow non-dominated solutions presented in Figure 8-12.

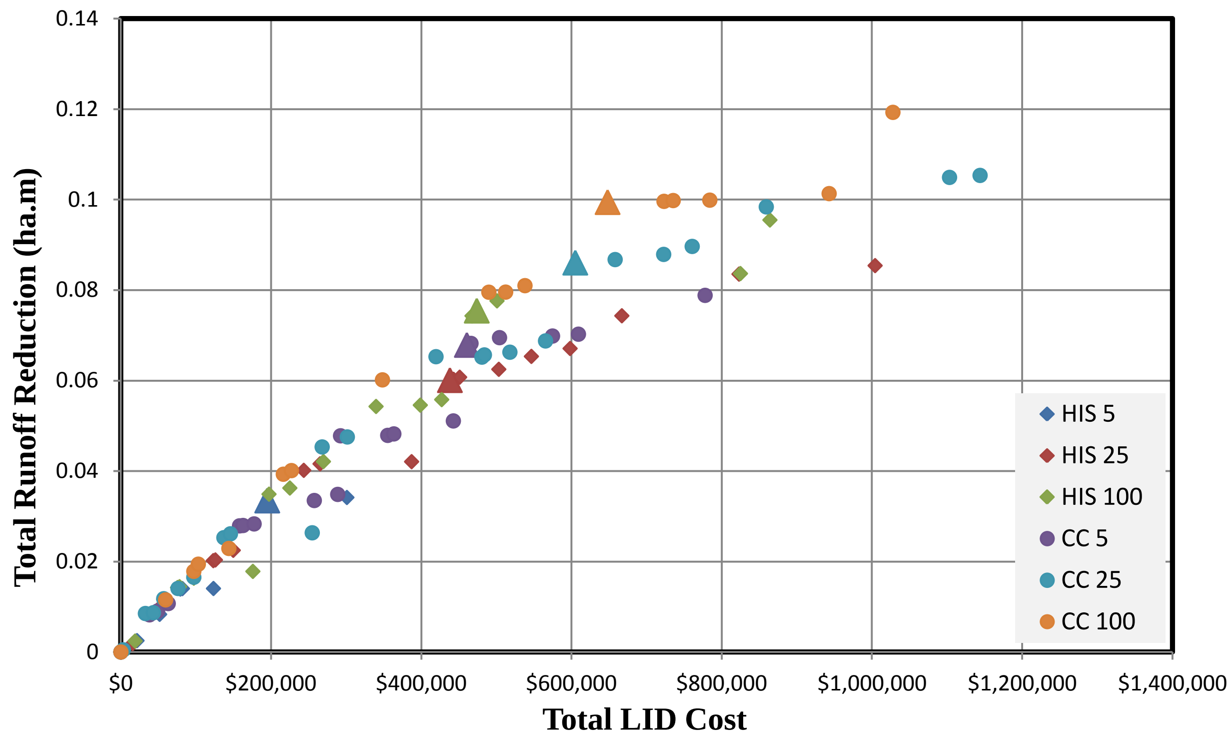


Figure 8-13 Solutions non-dominated in total runoff reduction or cost for the retrofit-high scenario

8.5 New Development, Low LID Adoption

8.5.1 All Solutions

The cost-benefit curves for the new development, low LID adoption scenario are very similar to the retrofit, high LID adoption scenario. Once again the reduction percentage for peak flow is significantly better than the reduction percentage for total runoff. A likely explanation for this is the low infiltration rates of the underlying soils limiting the capacity of the LIDs to reduce runoff. This new development scenario is slightly more cost-effective for peak flow reduction and slightly less cost-effective for runoff reduction. The reasons for this can be found by looking at the changes between the scenarios. One is a reduction in the cost of constructing infiltration trenches. Although infiltration trenches are again the dominant LID type in the solutions for both peak flow reduction and runoff reduction they are more important for peak flow reduction. Another change is the change from simple rain gardens to more complex bioretention units. The bioretention units are better for peak flow reduction (except perhaps for the 100 year climate change event) because they offer more storage space where water can be detained; however, they perform worse for runoff reduction as they infiltrate less water. Another change from the retrofit, high LID adoption scenario is that an increase in the maximum possible adoption level for permeable pavement; however, this is not a significant factor as permeable pavement does not prove to be a cost-effective solution. The implementation of permeable pavement can offer improvements; however, it is very expensive. This can be observed in the historical 5 year storm, and historical 25 year storm time series in Figure 8-14 and Figure 8-15. The large jumps in cost before the final clusters of solutions represent the addition of permeable pavement.

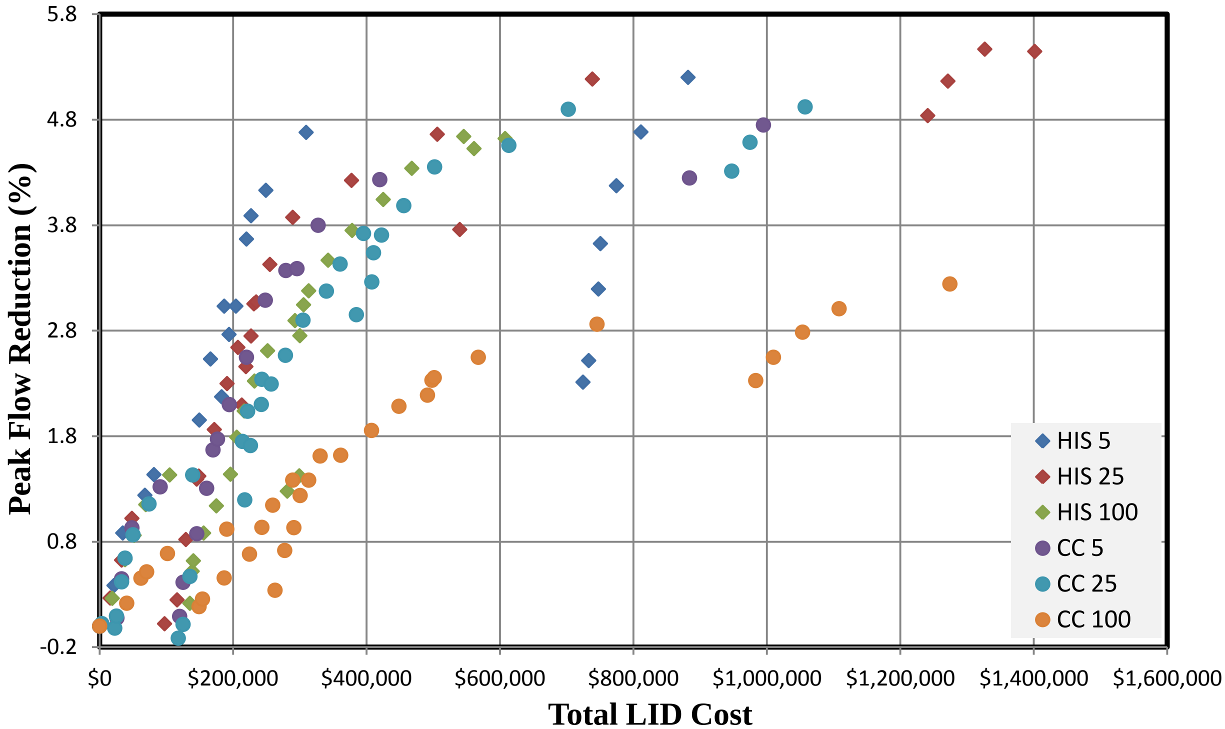


Figure 8-14 Peak flow reduction, by percentage, for the new development-low scenario

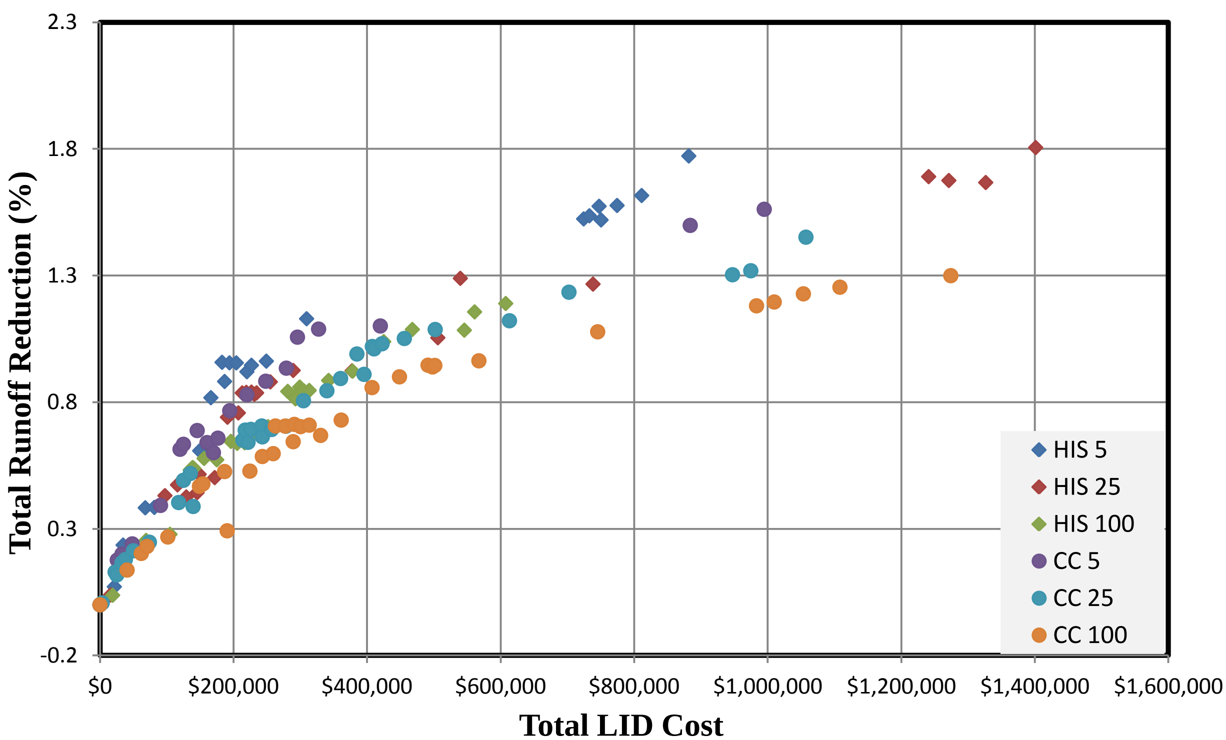


Figure 8-15 Total runoff reduction, by percentage, for the new development-low scenario

8.5.2 Non-dominated Peak Flow Solutions

The cost-benefit curves in Figure 8-16 follows a familiar pattern of the LIDs offering the highest peak flow reduction historical 100 year storm and climate change 25 year storm. Once again the lowest peak flow reduction is experienced for the climate change 100 year storm. The point at which the peak flow reduction return on investment begins to sharply decrease for the new development, low LID adoption scenario, around 0.3 m^3/s for the aforementioned series, is very close to the same reduction level as for the retrofit, high LID adoption scenario but comes at a slightly lower cost.

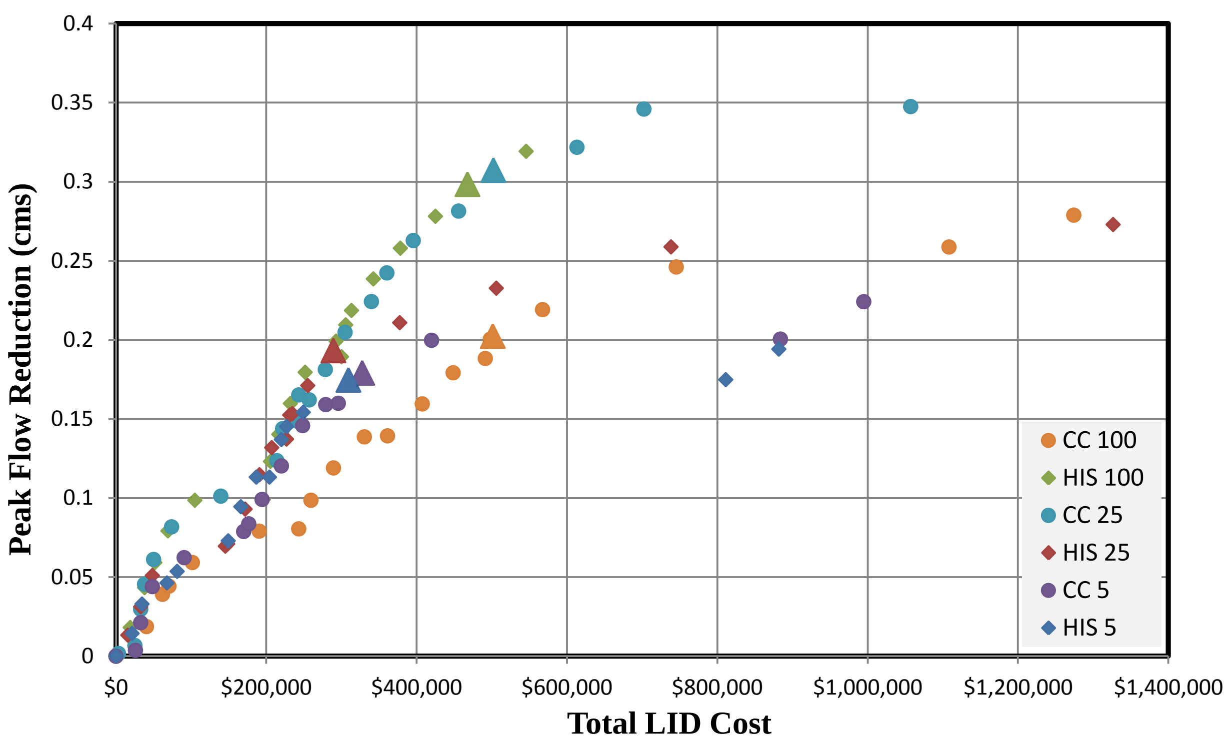


Figure 8-16 Solutions non-dominated in peak flow reduction or cost for the new development-low scenario

8.5.3 Non-dominated Runoff Solutions

The new development, low LID adoption scenario also follows a similar pattern to previous scenarios when it comes to total runoff reduction. One difference is that some of the jumps in cost between clusters of solutions are larger because of the greater presence of permeable pavement in a few of the solutions. The point of diminishing returns for total runoff reduction also occurs at a slightly lower level, just below 0.08 ha.m for the events which result in the greatest reduction, then for the retrofit, high LID adoption scenario where it occurs just below 0.1 ha.m.

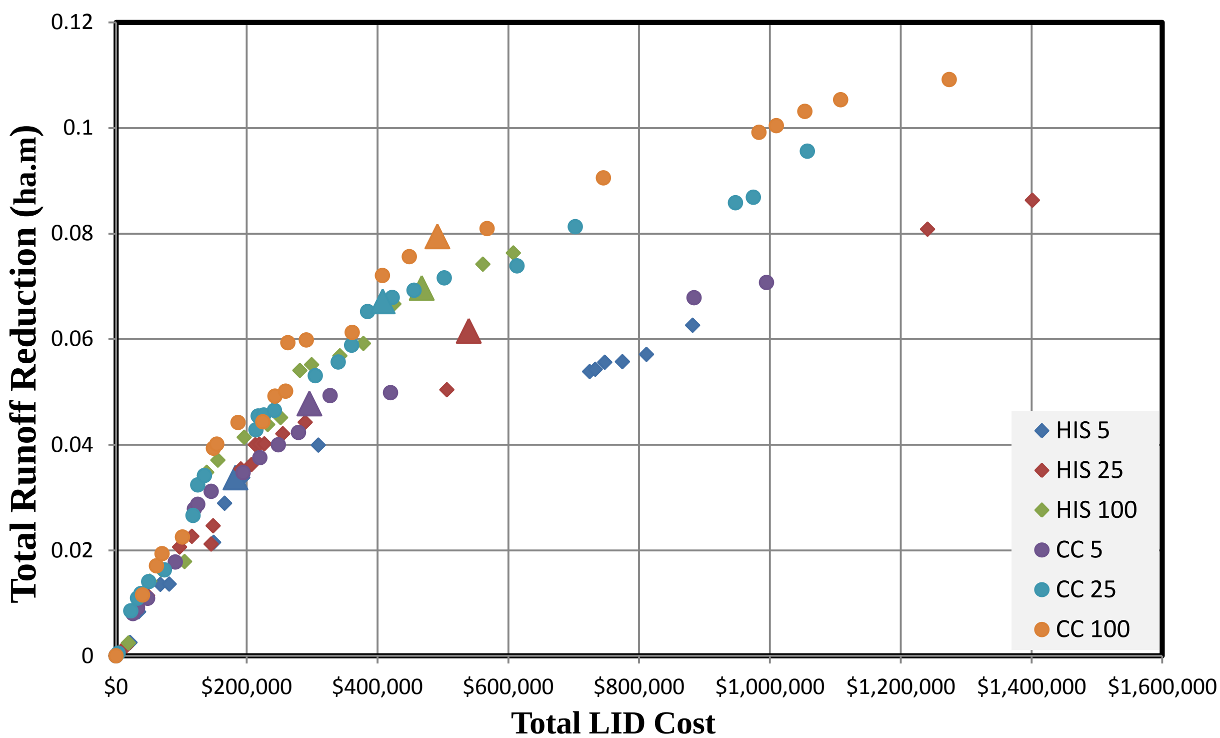


Figure 8-17 Solutions non-dominated in total runoff reduction or cost for the new development-low scenario

8.6 New Development, High LID Adoption

8.6.1 All Solutions

In the new development, high LID adoption scenario, the maximum adoption of some of the LIDs significantly increases. For this scenario, permeable pavement driveways can now be placed at all the houses in the sewershed, and infiltration trenches can be placed in any subcatchment eligible for LIDs. The results, as can be observed in Figure 8-18 and Figure 8-19 is a large spike in the reduction percentages for both peak flow reduction (reduction exceeding 21% is possible) and total runoff reduction (reduction exceeding 12% is possible). This reduction does come at a higher cost but the cost-effectiveness is no less than for previously discussed scenarios. The relationship between the reduction percentages achieved by the LID stormwater controls and the intensity of the precipitation events follows the same pattern seen in the other scenarios. That is, as the intensity of the storms increases, the reduction percentages decrease as well. This is the case for both peak flow reduction and total runoff reduction although the drop-off is greater for peak flow. The types of LIDs present in the solutions will be discussed in the following sections where labeled graphs are provided (Figure 8-21 and Figure 8-23). There is another common thread between the scenarios that has not yet been mentioned. That is the LID units are often added to the highest runoff zone (zone 3) first and then the middle runoff zone second. This could indicate that it is, as would be expected, more cost-effective to invest in installing LID controls in high runoff areas. One caveat is that this might not be the case when installing the LID controls in high runoff areas might cause them to become overloaded more rapidly.

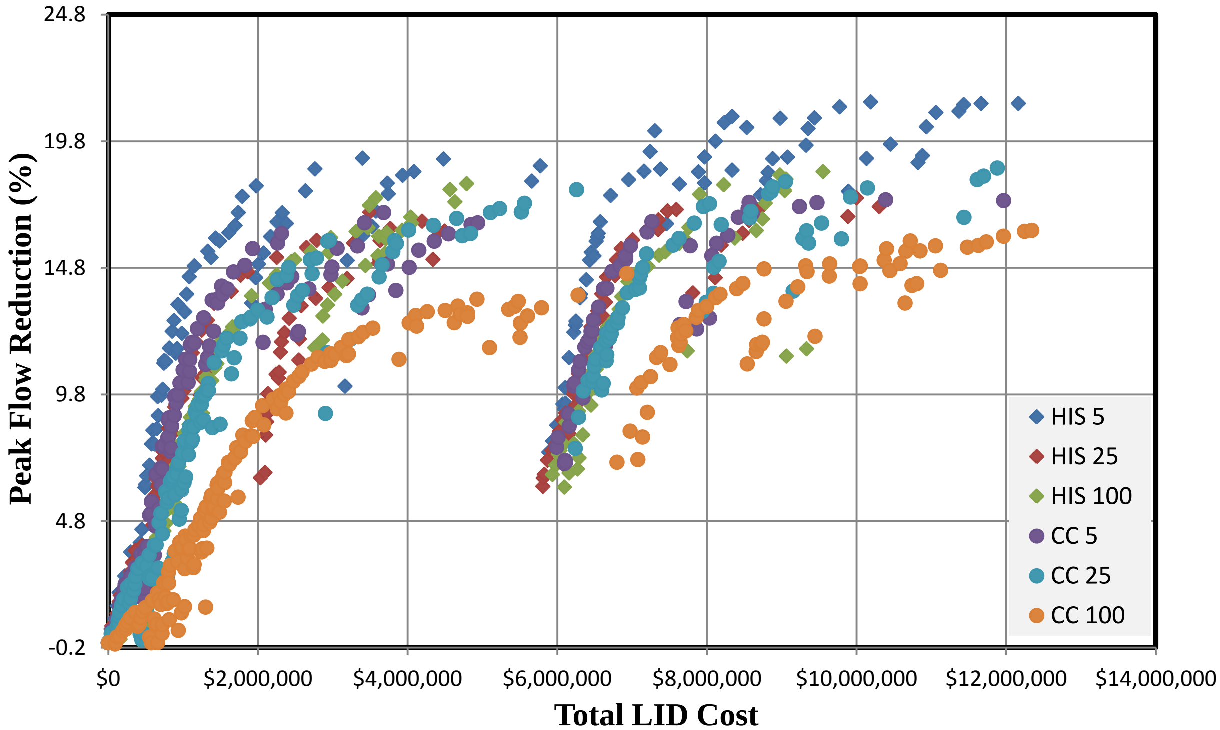


Figure 8-18 Peak flow reduction, by percentage, for the new development-high scenario

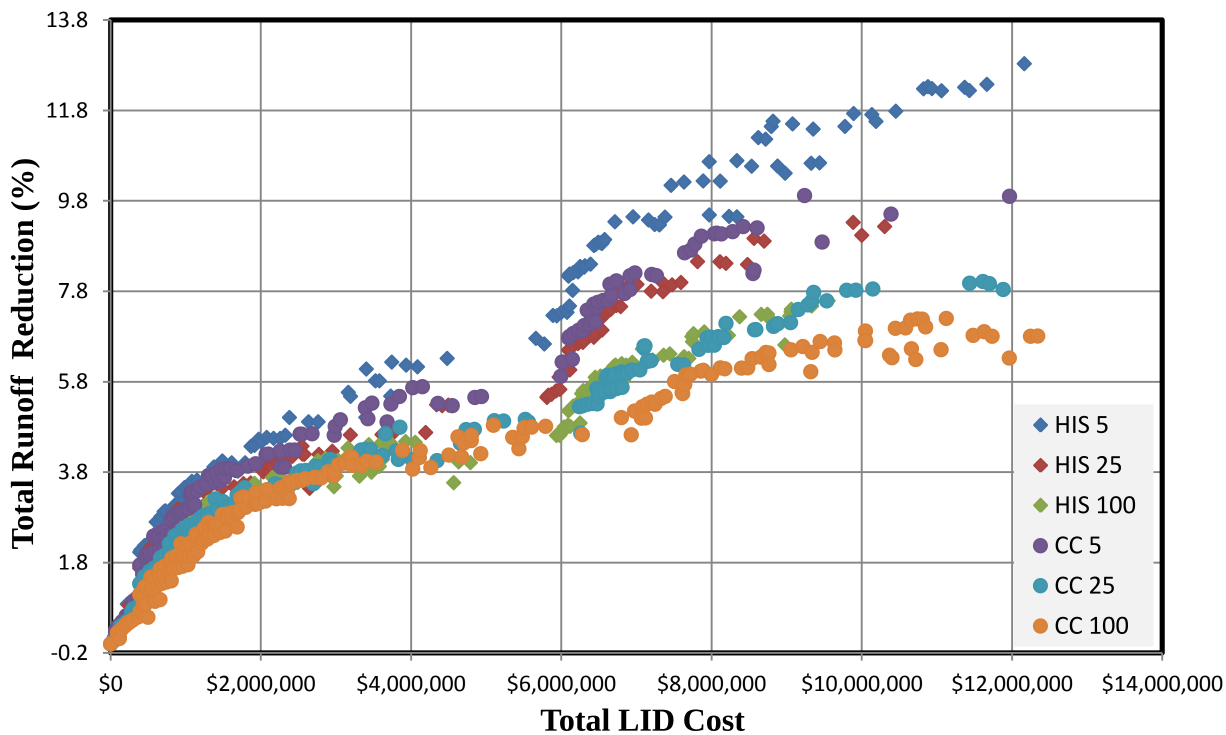


Figure 8-19 Total runoff reduction, by percentage, for the new development-high scenario

8.6.2 Non-dominated Peak Flow Solutions

Figure 8-20 presents the results for the new development, high LID adoption scenario which have been filtered to only include solutions which are non-dominated in terms of peak flow reduction and cost minimization. Figure 8-21 supplements Figure 8-20 by labelling the changes in LID design which determine the cost-benefit relationship. For peak flow reduction the most efficient solutions are once again dominated by infiltration trenches and the reduction efficiency starts to drop-off once other LID types have to be relied upon for additional improvement. Some of the high performing solutions selected for further analysis also include bioretention units. The cost-benefit curve levels out more quickly for this scenario than for the unrestricted scenario (Figure 8-27). This is likely because the adoption rates for bioretention units (the second most cost-effective LID for peak flow reduction) is still restricted to 25% for this scenario.

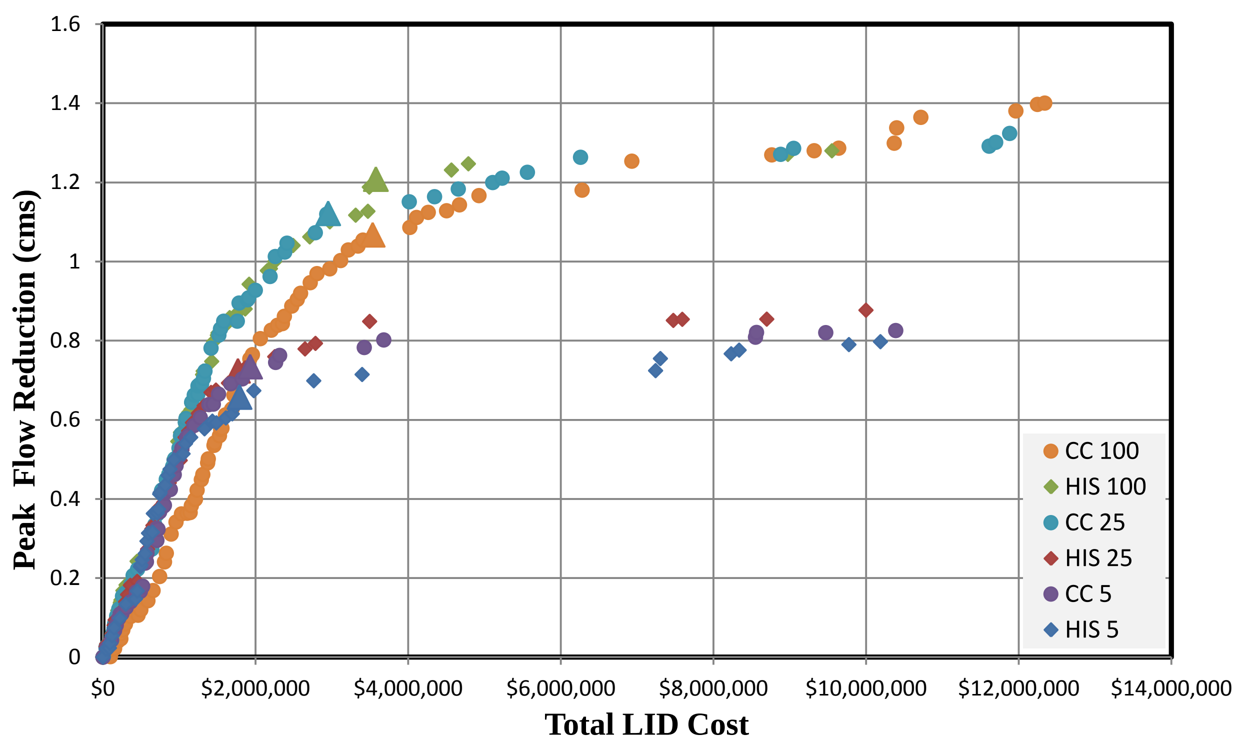


Figure 8-20 Solutions non-dominated in peak flow reduction or cost for the new development-high scenario

One noticeable difference from previously discussed scenarios is that, although still the worst by reduction percentage, the total runoff reduction offered by the LIDs is not the worst for the climate change 100 year storm. This change is somewhat present in the retrofit, low LID adoption scenario but presents more clearly here. There are a few reasons for this, and Figure 8-21 is helpful for these explanations. The performance of the LIDs during the climate change 100 year storm is in fact still the worst at the low reduction levels; however, the reduction levels can exceed those of the smaller storms. This is because the performance of the infiltration trenches does not fall off as sharply (explained in section 8.4.1). The total reduction that can be achieved by infiltration trenches in the climate change 100 year storm is greater than that of the smaller events simply because the total volume of water being processes is that much larger. Therefore, the solutions for the smaller events begin to include less cost-effective LIDs at reduction levels that are achieved with only infiltration trenches for the climate change 100 year storm. Additionally, it can be observed that combinations of permeable pavement and infiltration trenches can achieve very similar peak flow reduction quantities for climate change 100 year, and 25 year storms as well as the historical 100 year storm. In any case, the reduction percentages are still the lowest for the 100 year storm.

Making a final observation from Figure 8-21, it appears that, for this scenario, permeable pavement and infiltration trenches can achieve greater peak flow reduction than the combination of bioretention units and infiltration trenches for each of the 25 year events.

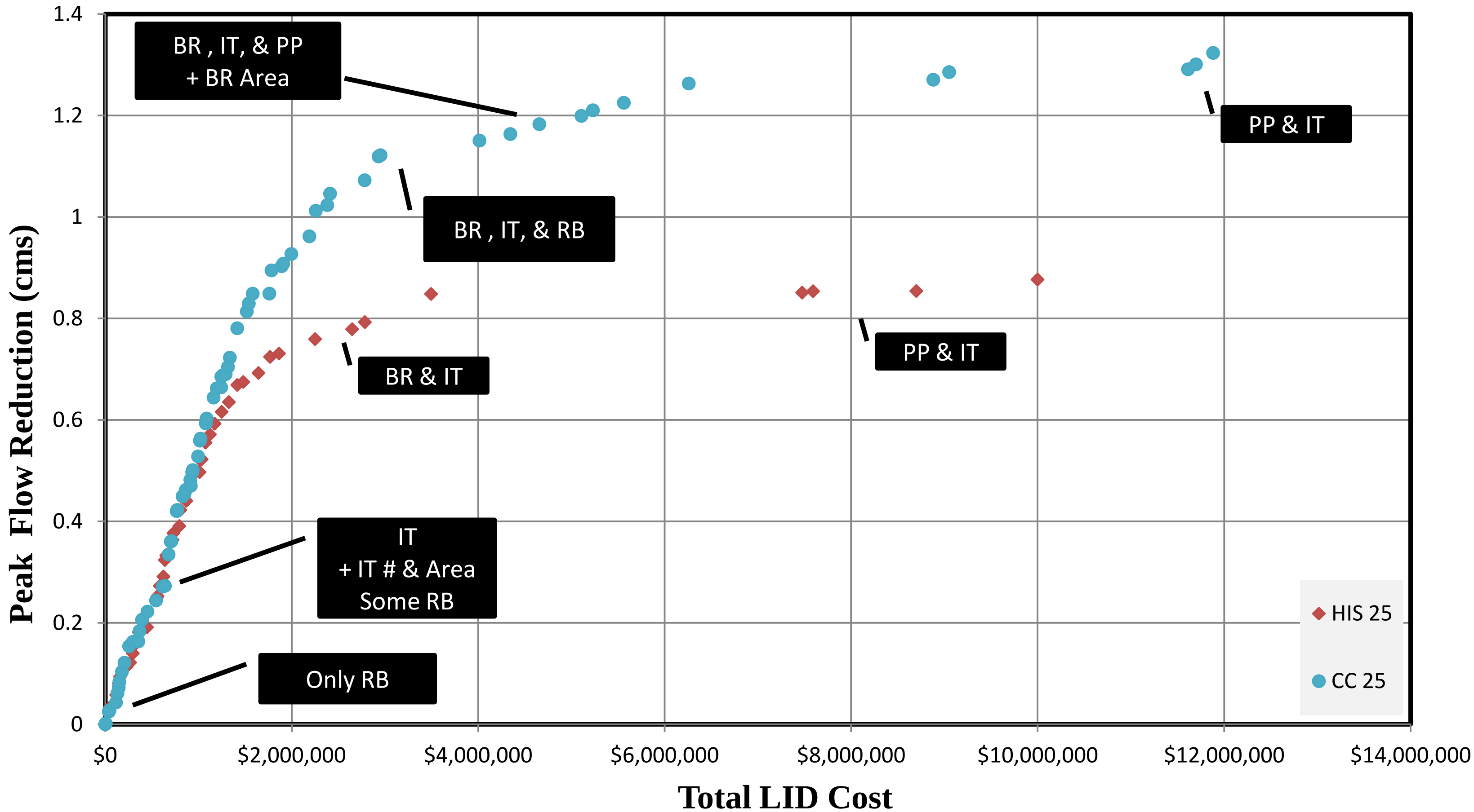


Figure 8-21 Explanation of changes in peak flow reduction for the new development-high scenario

8.6.3 Non-dominated Runoff Solutions

Figure 8-22 depicts the solutions generated by the optimization simulation runs for the new development, high LID adoption scenario. The solutions in Figure 8-22 are the ones which are non-dominated for the objectives of total runoff reduction and cost minimization. The series for each storm event, when total runoff reduction is presented in ha.m is the opposite order as when it is presented as a reduction percentage. Even though the reduction percentages are lower for the higher events, the total runoff reduction volumes are greater because of the greater amount of precipitation. Once again for this scenario, there are diminishing returns once LIDs other than infiltration trenches become more heavily relied upon. For example, a reduction of 0.3 ha.m in total runoff for the climate change 100 year storm can be achieved for a cost of $2,375,000 whereas the estimated LID price for a reduction of 0.6 ha.m is estimated to be about $10,600,000.

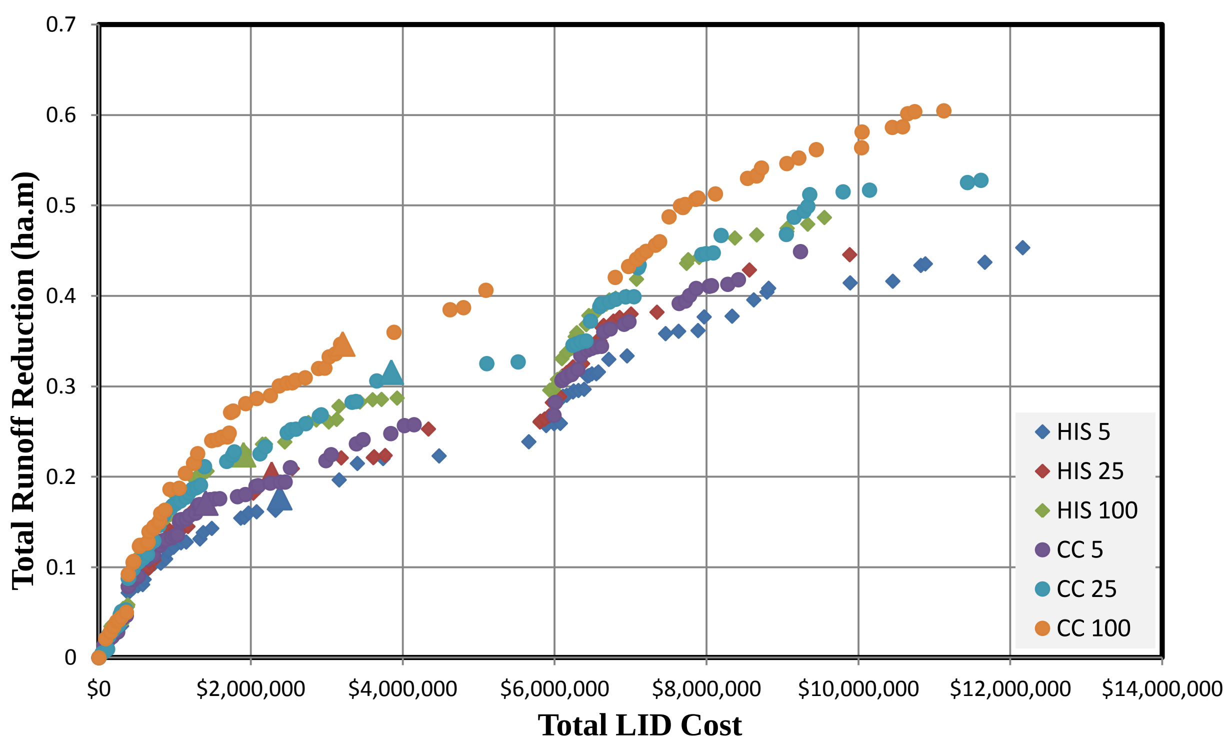


Figure 8-22 Solutions non-dominated in total runoff reduction or cost for the new development-high scenario

Figure 8-23 describes the changes in LID designs which lead to the results presented in Figure 8-22. The runoff reduction is the same for each event for the beginning portion of the data series because the first few solutions only include rain barrels. Regardless of the peak intensities of each event the rain barrels will fill up to the same volume (200 L each) after which they will no longer provide any benefits. For the most cost-effective solutions, infiltration trenches are once again the dominant LID type. For some of the higher reduction, but less cost effective, solutions all of the LID types are mixed in. Bioretention is more present in the lower cost ranges and permeable pavement is more present in the higher cost ranges. This time solutions offering the highest runoff reduction for each series include three different LID types.

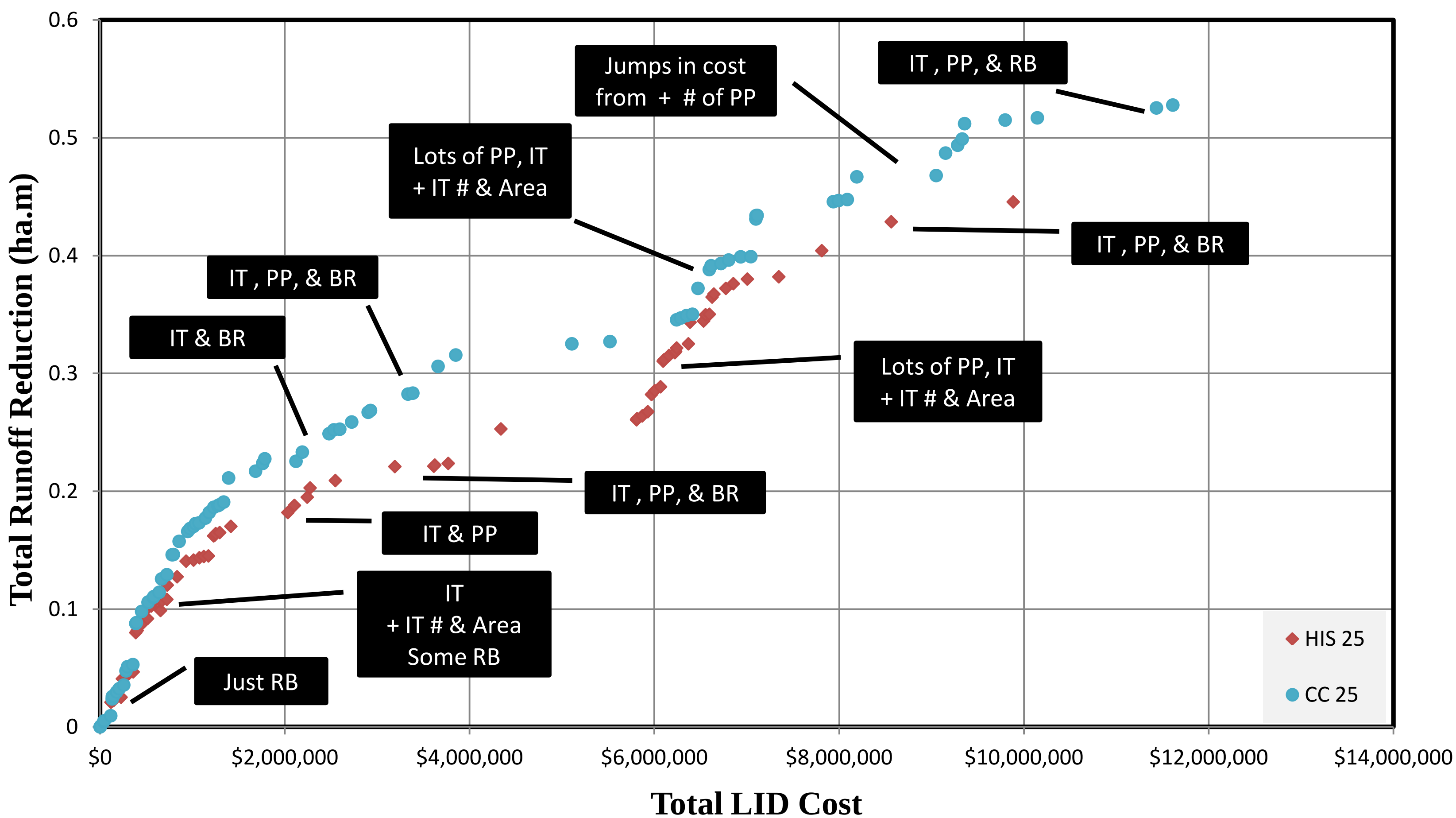


Figure 8-23 Explanation of changes in total runoff reduction for the new development-high scenario

8.7 New Development, Unrestricted LID Adoption

8.7.1 All Solutions

The final scenario for which the solutions are to be discussed is the new development, unrestricted LID adoption scenario. The results of the simulations are presented in Figure 8-24 and Figure 8-25. The patterns familiar from the previously discussed scenarios are present. The reduction percentages for both peak flow reduction and total runoff reduction decrease as the intensity of the design storms increases with a slight caveat. The maximum peak flow reduction percentage is not the highest for the least intense event (the 5 year historical storm) but the LIDs retain the highest cost-effectiveness for that event. The maximum percentage reduction in peak flow (29.34% during a historical 100 year storm) is much higher than the maximum percentage reduction achievable for total runoff (12.84% for a historical 5 year storm). The maximum percent reduction in peak flow for each storm event also comes at a much lower cost than the maximum runoff percent reduction in total runoff for the same events.

The peak flow reduction data series for the historical 5 and 100 year storms are further analyzed, with labels applied in Figure 8-26. Diverging from the other figures to which labels have been applied, Figure 8-26 includes solutions which are dominated in the objectives of peak flow reduction and cost minimization so that observations can be made about what causes drop-offs in peak flow reduction. Some of the poor performing solutions in the low cost section of the figure are those that include bioretention units with very small areas. Bioretention units, with small surface areas, and which are receiving a large portion of the runoff from impervious surfaces may be overloaded leading to the short-circuiting phenomena hypothesized earlier in the chapter. Other drops are attributable to when the number or area of infiltration trenches, and to a lesser extent bioretention units are reduced, while permeable pavement is added. These changes might result in an increase in runoff because permeable pavement can be effective at reducing runoff; however, the changes also lessen peak flow reduction.

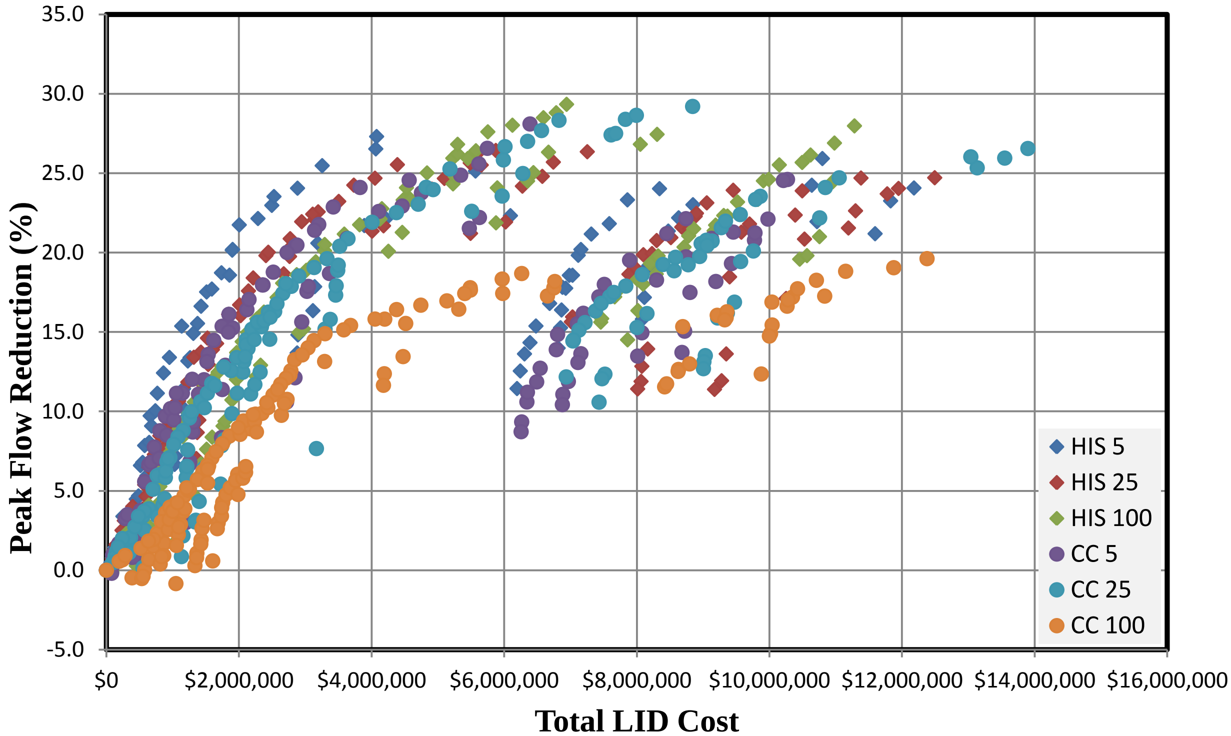


Figure 8-24 Peak flow reduction, by percentage, for the new development-unrestricted scenario

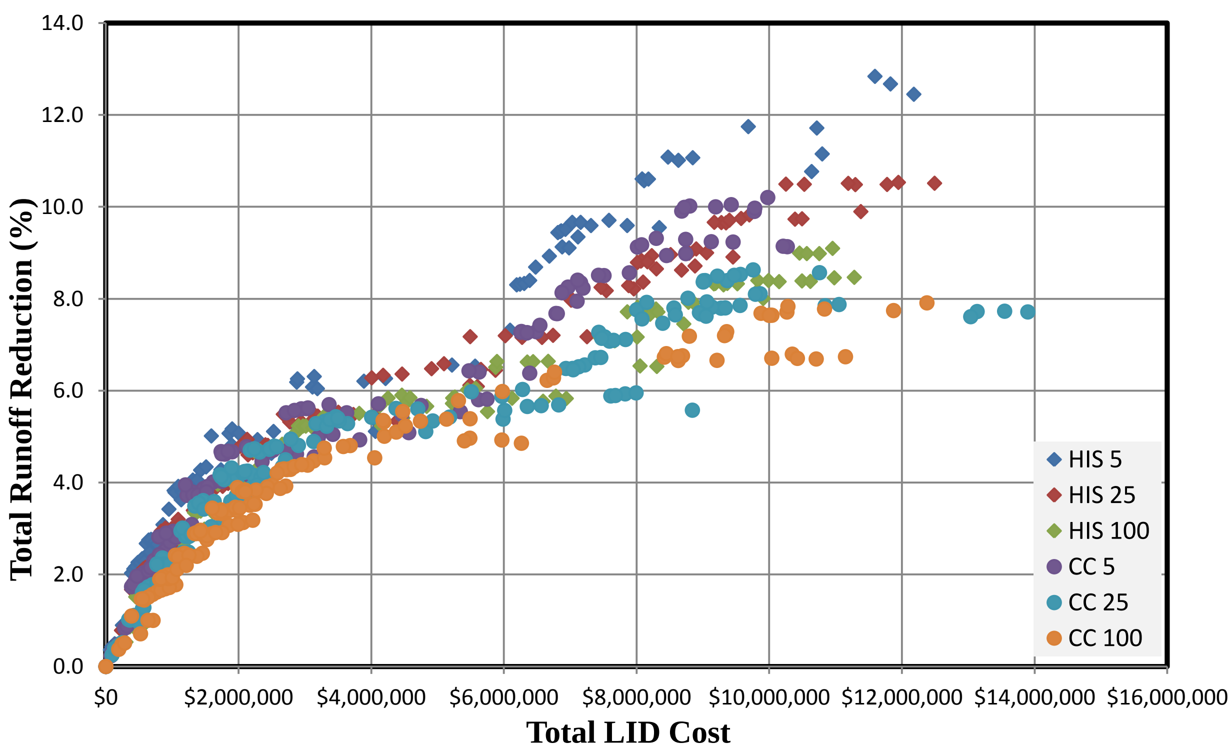


Figure 8-25 Total runoff reduction, by percentage, for the new development-unrestricted scenario

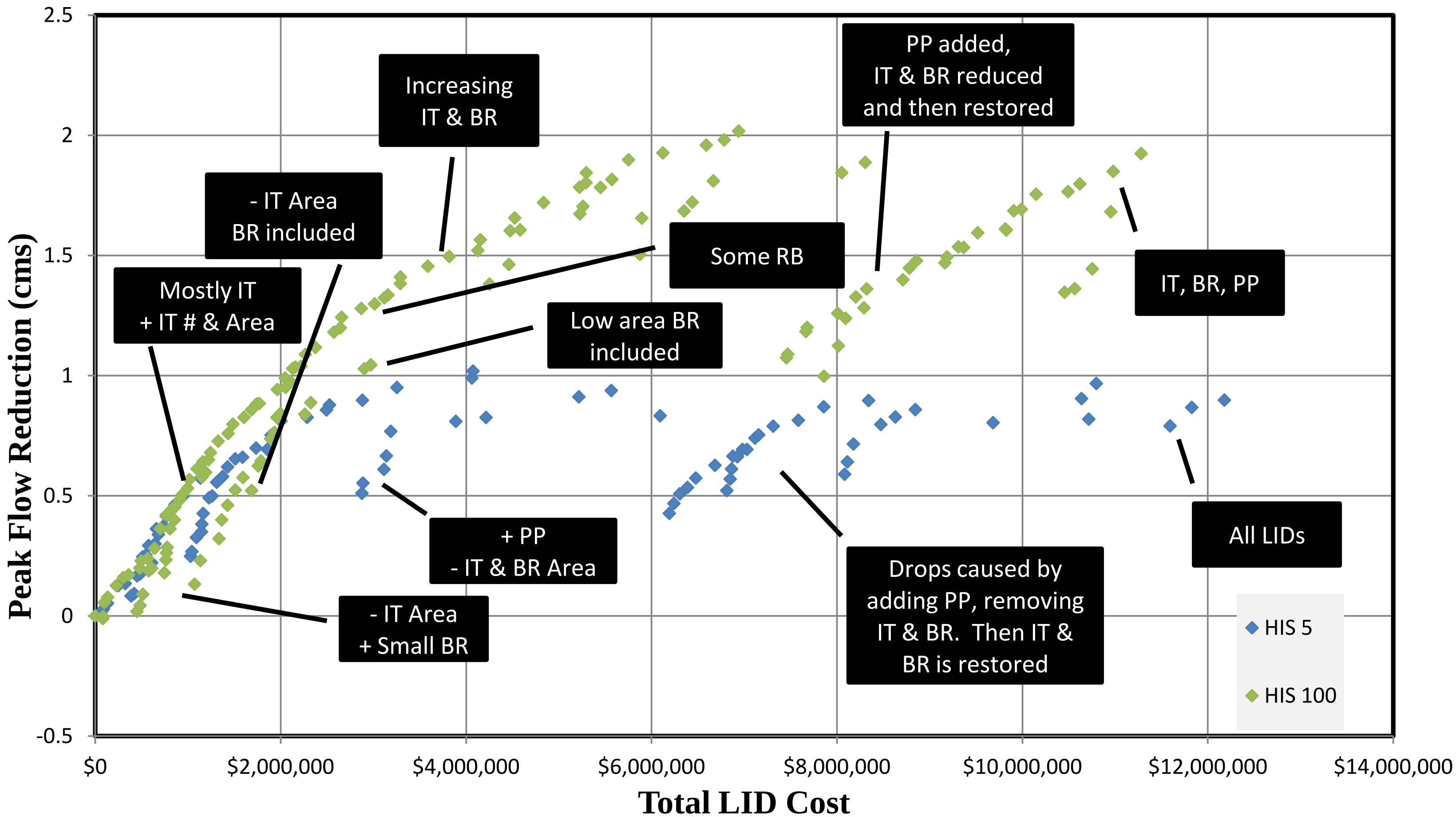


Figure 8-26 Explanation of raw results for peak flow reduction in the new development-unrestricted scenario

8.7.2 Non-dominated Peak Flow Solutions

Figure 8-27 presents the results the solutions depicted in Figure 8-24 but with the solutions which are dominated in the objectives of peak flow reduction and cost minimization removed. The patterns in the solutions presented are similar to those discussed in reference to Figure 8-20 and Figure 8-21. The differences for the case of unrestricted LID adoption are that a higher peak flow reduction is achieved and the cost-effectiveness levels off more gradually. The more gradual levelling off in cost-effectiveness is because the restrictions on the adoption levels for bioretention units (which are cost-effective relative to permeable pavement) are removed. The reason that the LID performance during the climate change 100 year storm loses efficiency more rapidly is because the bioretention units become overloaded during a storm of such intensity. The solutions before the reduction in cost-effectiveness are dominated by infiltration trenches.

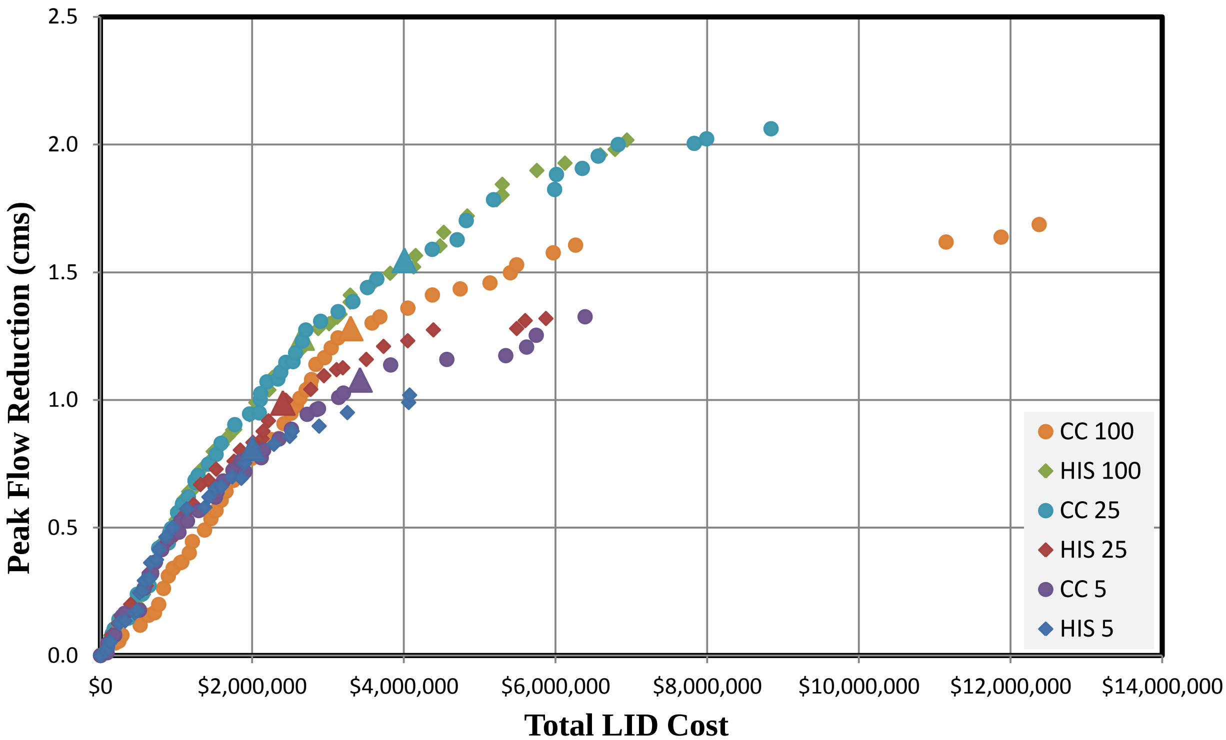


Figure 8-27 Solutions non-dominated in peak flow reduction or cost for the new development-unrestricted scenario

8.7.3 Non-dominated Runoff Solutions

Figure 8-28 presents the results the solutions depicted in Figure 8-25 but with the solutions which are dominated in the objectives of total runoff reduction and cost minimization removed. The patterns in the solutions presented are very similar to those discussed in reference to Figure 8-22 and Figure 8-23. Even the total runoff reduction achievable through the implementation of LIDs has increased by less than 0.07 ha.m over what is achievable in the new development, high LID adoption scenario. The reason that the maximum runoff reduction did not increase as much as the maximum peak flow reduction over the previous scenario is because the maximum adoption rate of infiltration trenches and permeable pavement does not change between the two scenarios. Although the maximum adoption of bioretention units increases, bioretention units are not as significant a factor for total runoff reduction as they are for peak flow reduction.

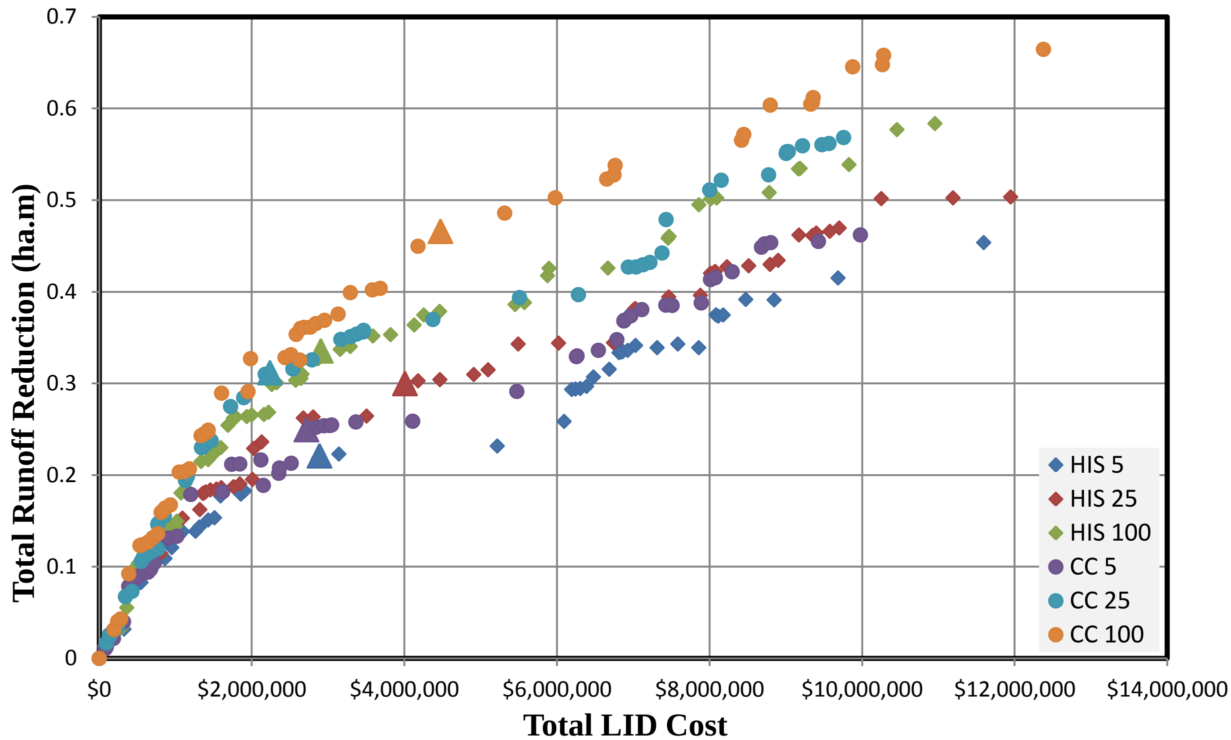


Figure 8-28 Solutions non-dominated in total runoff reduction or cost for the new development-unrestricted scenario

8.8 Comparisons of Scenarios

Many comparisons between the different LID scenarios have already been drawn in sections 8.3 to 8.7; however, seeing the results of each scenario on the same graphs can add clarity and provide opportunity for further analysis. Figure 8-29 includes the historical 100 year storm series, from the results of each LID adoption scenario filtered to include only the solutions which are non-dominated in the objectives of peak flow reduction and cost minimization. Figure 8-30 includes the historical 100 year storm series, from the results of each LID adoption scenario filtered to include only the solutions which are non-dominated in the objectives of total runoff reduction and cost minimization. Again, whereas the different series on the previous graphs represented the performance of LIDs during different design storms, the lines in Figure 8-29 and Figure 8-30 represent the different LID adoption scenarios. The cost effectiveness achieved in all the scenarios is quite similar for most of the low cost solutions; however, the amount of reduction (both of peak flow and total runoff) that can be achieved in the new development, high LID adoption and new development, unrestricted LID adoption scenarios is much greater. The reduction observed for those two scenarios is achievable in reality. Most of that reduction for peak flow, and smaller majority for runoff reduction, is provided by infiltration trenches and bioretention units. When planning a new development both of these LID practices could possibly be incorporated into shared spaces such that they did not require each member of the community to individually adopt them. The divergence between the "New-Unrestricted" and "New-High" scenarios in Figure 8-29 results from the increase in the number of bioretention units in the "New-Unrestricted" scenario. The more expensive solution, which includes permeable pavement, is not included in the unrestricted scenario because the unrestricted scenario allows for more bioretention units to be installed. The solutions with those extra bioretention units achieve greater peak flow reduction and are less expensive than the solutions which feature permeable pavement. This was previously discussed in section 8.7.2.

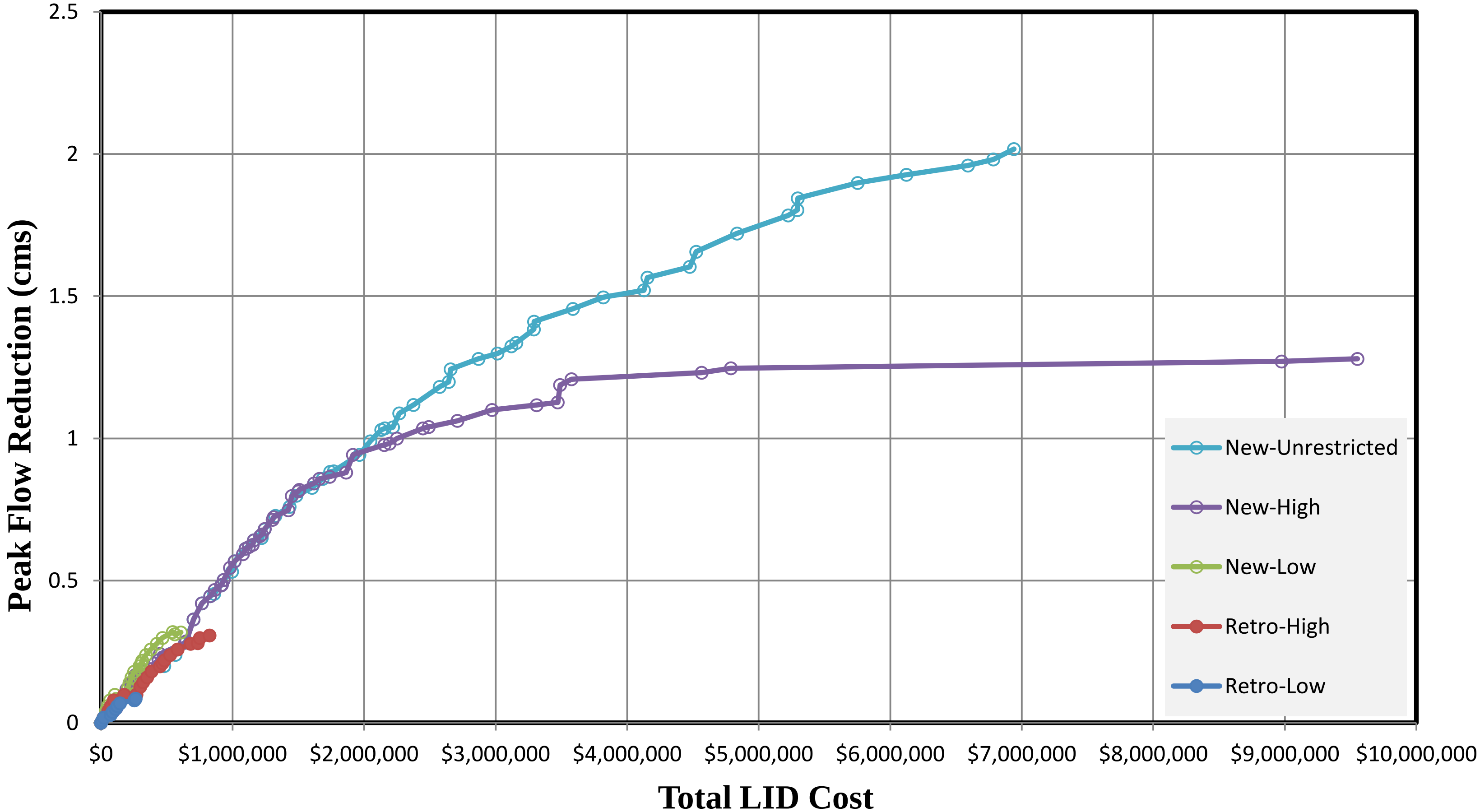


Figure 8-29 Non-dominated peak flow reduction, for each LID implementation scenario, during the historical 100 year storm

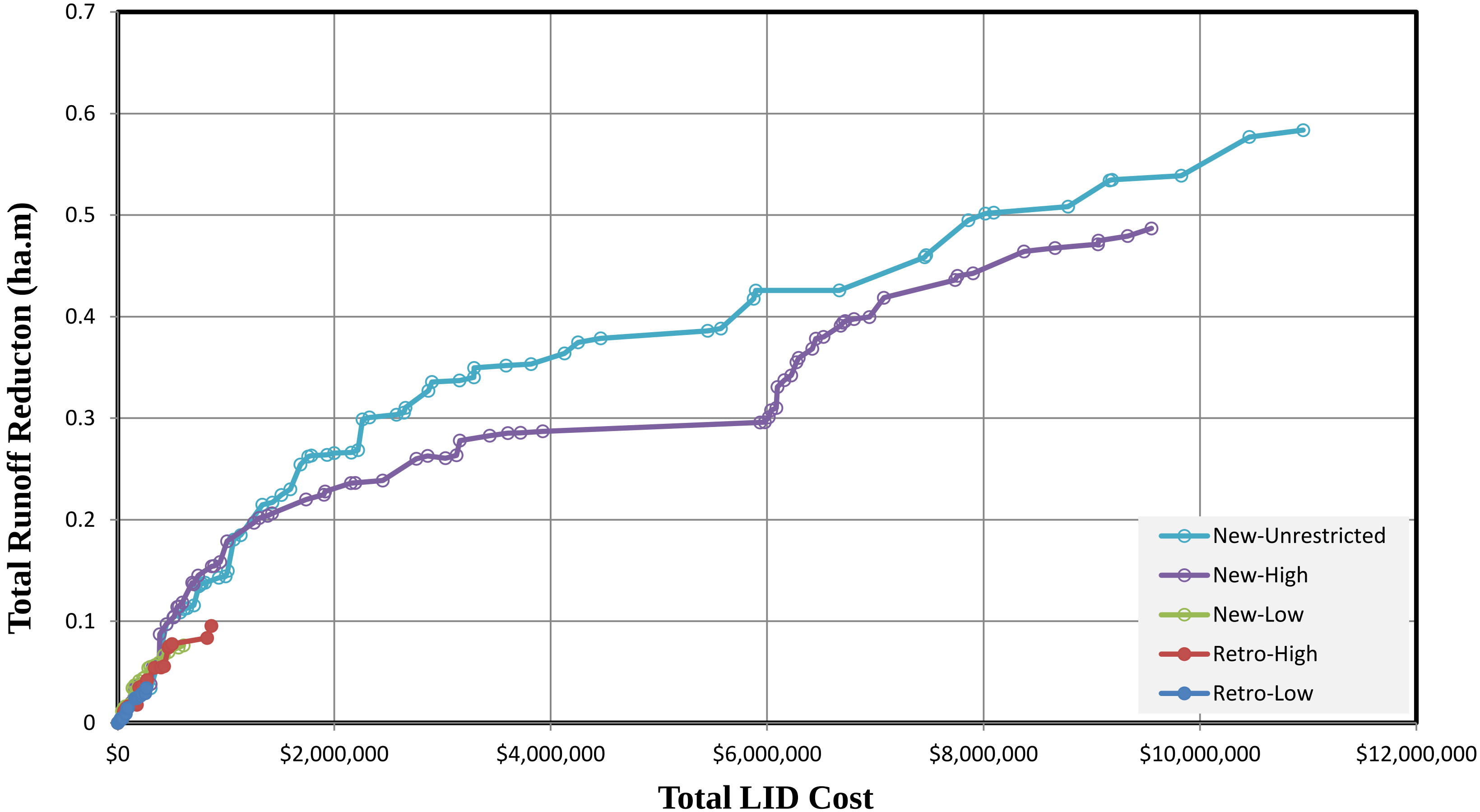


Figure 8-30 Non-dominated total runoff reduction, for each LID implementation scenario, during the historical 100 year storm

8.9 Cost and Sizing

This section presents the decision variables values that determine the areas of the rain gardens or bioretention units and infiltration trenches for the cost-effective solutions which were selected from the datasets presented earlier in the chapter. The high cost-effectiveness of the selected solutions is based on comparison to the other solutions; they were not compared to non-LID stormwater controls. The mean costs (average of the costs for each LID type for each design storm in a given scenario) of each LID type for those solutions are also presented in this section. The number of units for each LID type as well as the performance for each solution analyzed in this section can be found in Appendix F.

8.9.1 Peak Flow Cost-Effective Solutions

The solutions presented in this section represent the cost-effective solutions that were selected from the datasets which had been filtered to only include the solutions that are non-dominated for the objectives of peak flow reduction and cost-minimization. As the notes below the tables indicate, the values in the tables presented in this section are the decision variables for LID sizing. The cells are shaded if the LID, whose size is determined by the value in that cell is implemented in that solution.

8.9.1.1 Retrofit, Low LID Adoption

Several relevant observations can be made from Table 8-3. Rain gardens are only present in one of the solutions, and the same can be said for infiltration trenches in the low runoff zone (zone 1). The size of the LIDs consistently increases corresponding to increases in the intensity of the storm events. Finally, none of the LID sizes come close to their maximum allowed sizes (300 m^2 for infiltration trenches and 28 m^2 for the rain gardens). The LID cost for these solutions is almost entirely from infiltration trenches as can be seen in Figure 8-31.

Table 8-3 Sizing decision variable values for the peak flow reduction, cost-effective solutions from the retrofit-low scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	RG S 1	RG S 2	RG S 3	RG CL 1	RG CL 2	RG CL 3
HIS 5	9	5	2	17	5	5	2	5	2	2	1	2
HIS 25	15	7	3	21	7	7	6	3	1	1	6	1
HIS 100	3	9	5	2	11	8	4	5	4	7	6	4
CC 5	17	5	14	8	7	5	3	2	3	3	3	5
CC 25	11	9	7	4	9	11	1	1	5	1	7	1
CC 100	3	12	12	29	11	14	5	6	3	6	5	1

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the rain gardens they represent the area in m^2 divided by 4.
**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

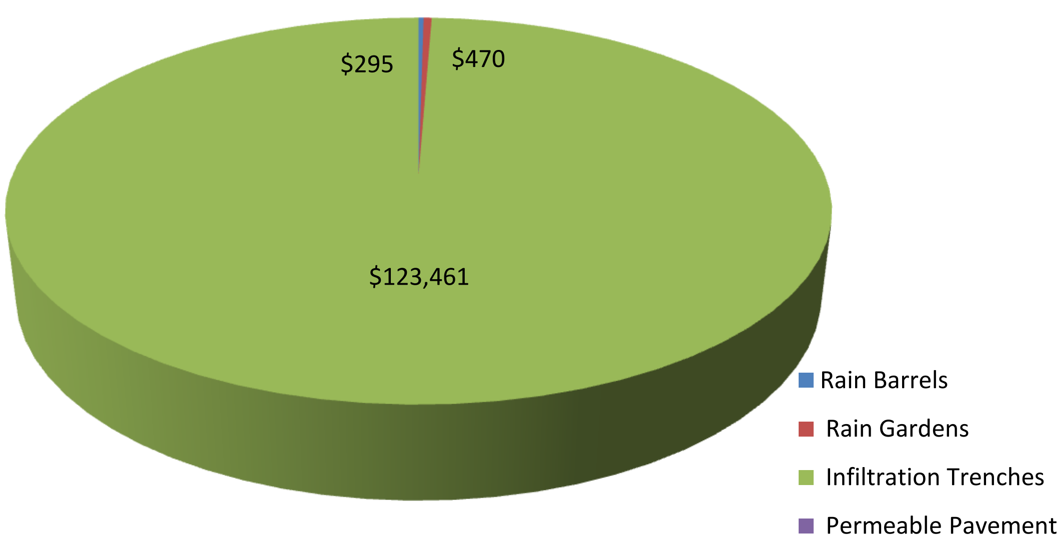


Figure 8-31 Mean cost breakdown of the peak flow reduction, cost-effective solutions from the retrofit-low scenario

8.9.1.2 Retrofit, High LID Adoption

In the solutions selected for this scenario, infiltration trenches are the only LID type present, as is evident by Figure 8-32. Infiltration trenches are only used in runoff zone one for a single solution (see Table 8-4). As would be expected, running the optimization process for more intense precipitation events results in the optimization process selecting larger LID areas. And additional result similar to the previous section is that the areas for the infiltration trenches are all far below their maximum allowable areas.

Table 8-4 Sizing decision variable values for the peak flow reduction, cost-effective solutions from the retrofit-high scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	RG S 1	RG S 2	RG S 3	RG CL 1	RG CL 2	RG CL 3
HIS 5	15	5	4	2	5	4	1	4	1	3	3	2
HIS 25	6	6	5	5	6	5	1	2	4	1	3	1
HIS 100	9	8	7	4	8	6	1	6	1	1	1	1
CC 5	18	5	5	9	6	6	2	6	1	7	5	4
CC 25	2	8	8	11	8	7	5	5	1	5	3	1
CC 100	12	10	6	7	11	12	3	4	3	1	4	3

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the rain gardens they represent the area in m^2 divided by 4.
**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

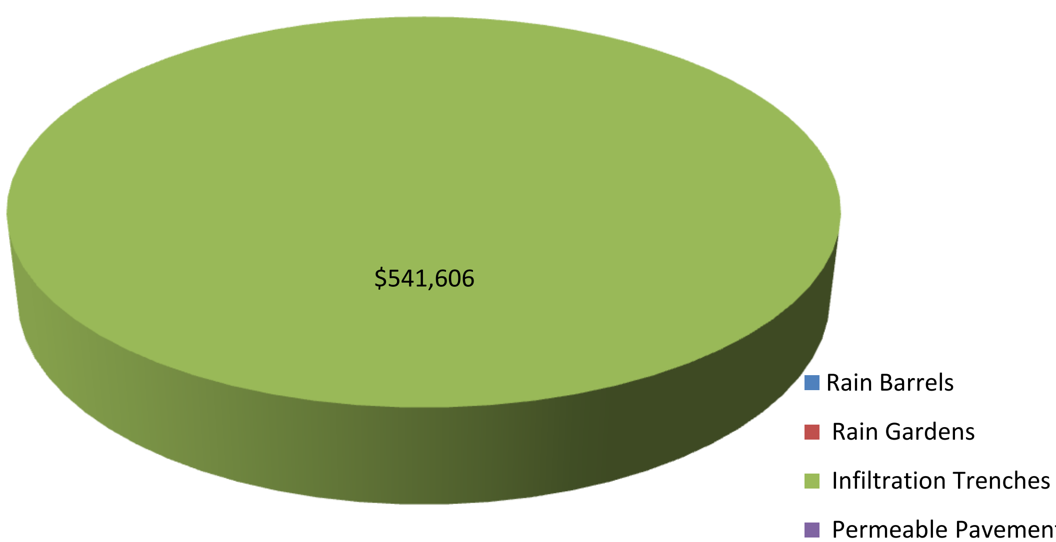


Figure 8-32 Mean cost breakdown of the peak flow reduction, cost-effective solutions from the retrofit-high scenario

8.9.1.3 New Development, Low LID Adoption

This scenario has a couple of differences from the retrofit, high LID adoption scenario. Table 8-5 shows that infiltration trenches are present in four out of the six solutions. Inferring from Figure 8-33, there are rain barrels included in one of the solutions. All the other observations from the previous scenario are also applicable here. One interesting note on the first three scenarios analyzed is that there doesn't seem to be any clear pattern (like LID sizing increasing for the larger storms) for LID sizing between different runoff zones similar to the.

Table 8-5 Sizing decision variable values for the peak flow reduction, cost-effective solutions from the new development-low scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	5	6	3	6	5	6	1	1	4	1	4	1
HIS 25	18	6	4	28	6	5	4	1	1	1	1	3
HIS 100	12	8	7	9	9	6	1	1	2	5	6	1
CC 5	5	6	6	2	6	5	1	2	1	1	1	4
CC 25	11	9	8	16	8	11	1	4	1	1	4	1
CC 100	21	11	6	14	10	11	1	5	1	1	1	4

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.
**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

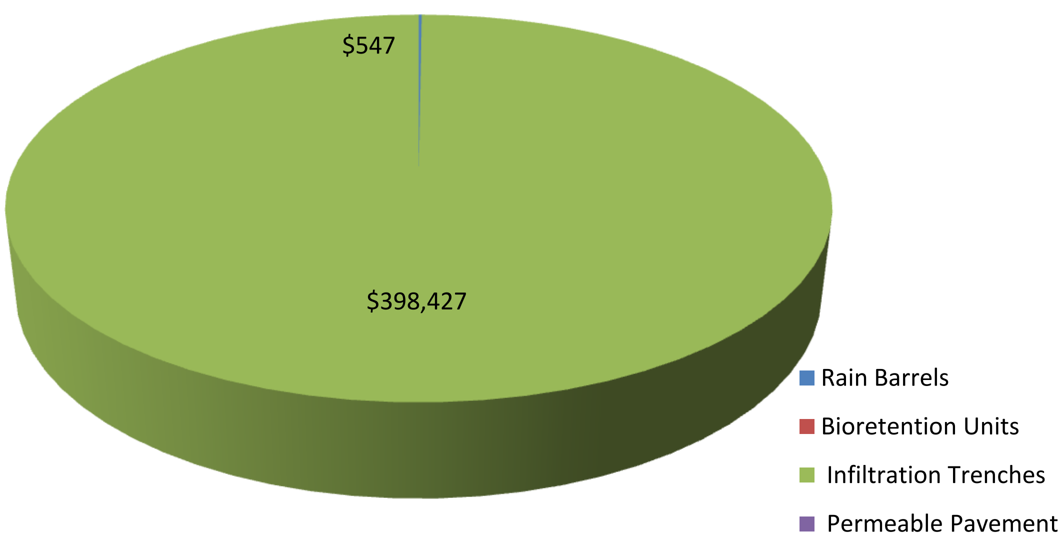


Figure 8-33 Mean cost breakdown for the peak flow reduction, cost-effective solutions from the new development-low scenario

8.9.1.4 New Development, High LID Adoption

The differences between the new development, high LID adoption and the previous scenarios are reflective of the differences discussed in sections 8.6.2 and 8.7.2. That is decreases in the restrictions on the adoption of infiltration trenches and bioretention units allow for a greater peak flow reduction to be achieved at a relatively high level of cost-effectiveness. This results in solutions farther along the cost benefit curves were selected. As can be seen in Figure 8-34 this results in solutions with a higher overall cost as well as a higher percentage of that cost being invested in LIDs other than infiltration trenches but infiltration trenches being applied to every runoff zone. Some areas now approach the maximum allowed.

Table 8-6 Sizing decision variable values for the peak flow reduction, cost-effective solutions from the new development-high scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	5	8	6	15	5	7	1	4	1	1	1	1
HIS 25	6	7	5	10	8	15	1	4	3	3	4	1
HIS 100	24	9	6	12	11	26	1	7	6	1	7	4
CC 5	9	6	9	4	7	5	1	3	6	1	4	1
CC 25	13	13	8	8	11	7	6	5	4	1	3	1
CC 100	8	11	29	4	13	15	6	7	4	1	6	5

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.

**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

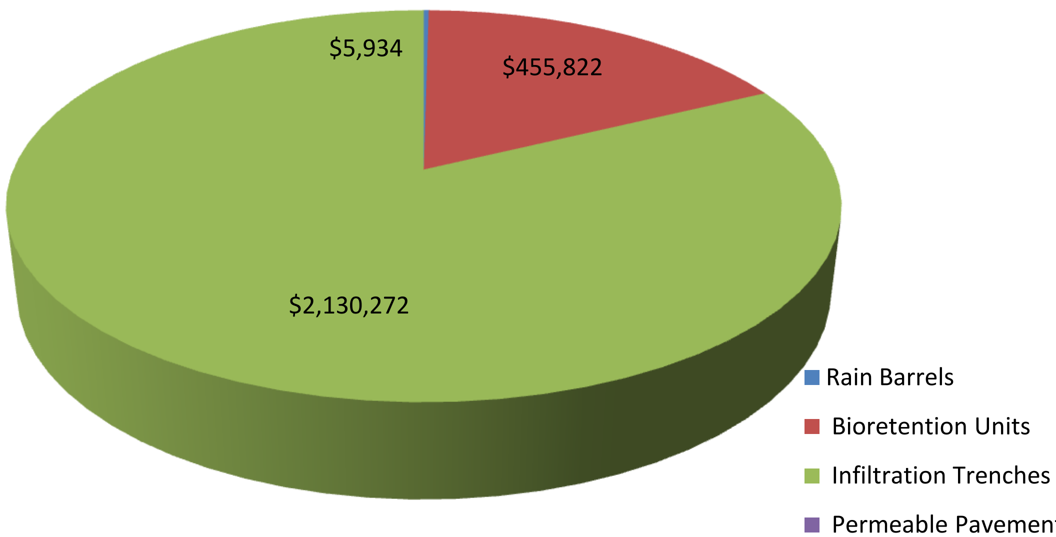


Figure 8-34 Mean cost breakdown for the peak flow reduction, cost-effective solutions from the new development-high scenario

8.9.1.5 New Development, Unrestricted LID Adoption

The solutions selected for the unrestricted scenario have, on average, a higher total cost as well as a higher proportion of that cost invested in bioretention rather than infiltration trenches. Infiltration trenches still receive the greatest investment. The costs can be seen in Figure 8-35 and the reduction in the infiltration trenches can also be seen by comparing Table 8-7 to Table 8-6. Infiltration trenches are no longer present in runoff zone one for some solutions. One difference between this scenario and previous scenarios is that the solution selected for the climate change 100 year storm does not have the largest LID areas.

Table 8-7 Sizing decision variable values for the peak flow reduction, cost-effective solutions from the new development-unrestricted scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	9	5	4	5	6	9	1	4	4	3	1	1
HIS 25	9	7	10	2	8	4	6	6	6	1	1	1
HIS 100	10	6	9	2	9	11	1	6	1	3	1	6
CC 5	11	6	8	7	9	13	3	5	4	1	3	1
CC 25	21	8	13	12	12	16	5	7	5	1	2	1
CC 100	2	11	8	6	14	15	1	7	3	1	1	2

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.

**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

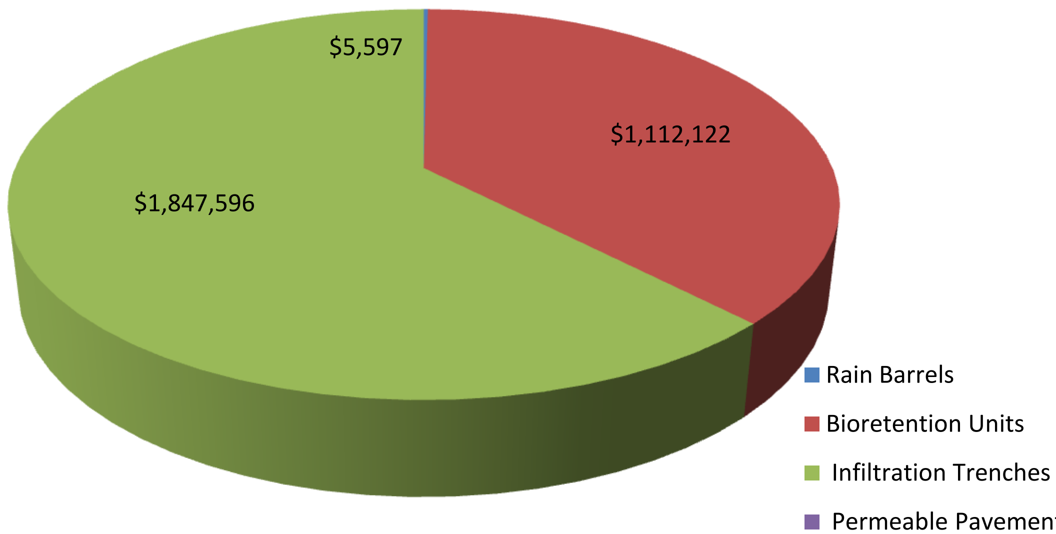


Figure 8-35 Mean cost breakdown for the peak flow reduction, cost-effective solutions from the new development-unrestricted scenario

8.9.2 Total Runoff Cost-Effective Solutions

8.9.2.1 Retrofit, Low LID Adoption

Overall, the solutions selected as cost-effective solutions from the total runoff non-dominated series ended up having more diverse investment in LIDs than the peak flow non-dominated solutions. The retrofit, low LID adoption scenario is the only one where investment in another LID (rain gardens) exceeded investment in infiltration trenches (see Figure 8-36 on the following page). Rain gardens can be effective at reducing runoff because they are relatively cheap and infiltrate more water than the other LID types. As for the LID sizes (Table 8-8), they still mostly increase as the storm intensities increase. It is also noteworthy that the areas of the rain gardens range, except for one instance, are between 20 m^2 and 30 m^2 (the maximum allowed).

Table 8-8 Sizing decision variable values for the total runoff reduction, cost-effective solutions from the retrofit-low scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	RG S 1	RG S 2	RG S 3	RG CL 1	RG CL 2	RG CL 3
HIS 5	2	6	5	12	3	23	3	5	5	1	7	4
HIS 25	9	7	2	20	6	5	6	5	3	1	7	5
HIS 100	17	10	5	3	9	14	4	7	1	7	7	6
CC 5	14	8	2	2	7	3	1	5	1	1	6	5
CC 25	14	2	2	11	2	7	1	7	6	3	7	4
CC 100	4	7	2	28	3	11	5	7	4	1	7	1

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the rain gardens they represent the area in m^2 divided by 4.

**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

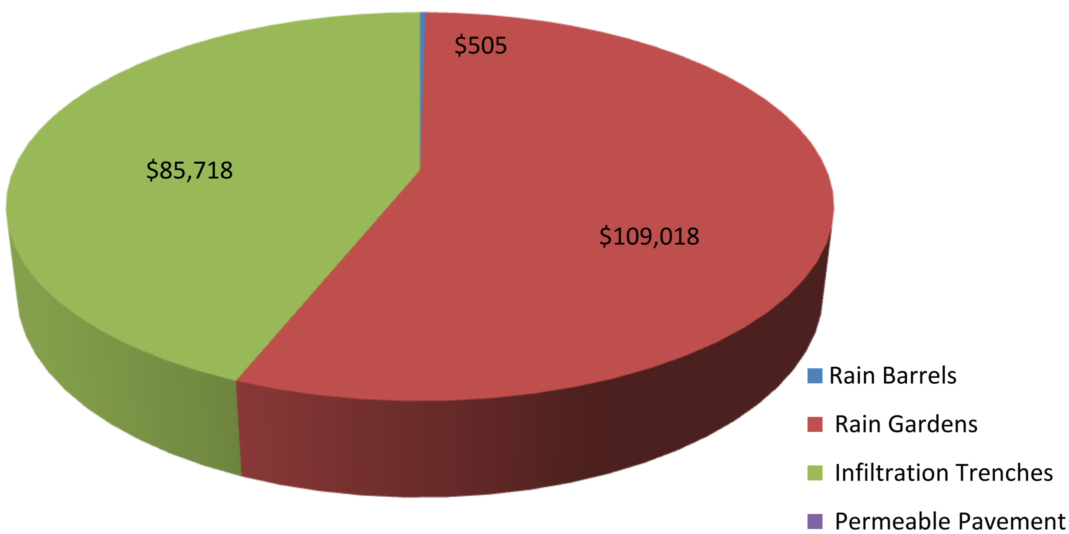


Figure 8-36 Mean cost breakdown of the total runoff reduction, cost-effective solutions from the retrofit-low scenario

8.9.2.2 Retrofit, High LID Adoption

For this scenario, infiltration trenches receive the highest investment; however, rain gardens are still a significant factor (Figure 8-37). The areas of the rain gardens in zone 2 (the only zone that has rain gardens other than for the solution selected from the climate change 100 year storms series) are almost all in the high end of the allowable range (see Table 8-9). The areas of the infiltration trenches are all in the low end of the allowable range. For the second consecutive scenario the cost-efficient solutions selected did not include any infiltration trenches in runoff zone 1.

Table 8-9 Sizing decision variable values for the total runoff reduction, cost-effective solutions from the retrofit-high scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	RG S 1	RG S 2	RG S 3	RG CL 1	RG CL 2	RG CL 3
HIS 5	2	3	2	3	20	2	1	5	1	3	5	2
HIS 25	6	5	3	6	2	5	1	1	1	1	5	1
HIS 100	8	4	4	3	2	5	3	7	1	3	6	3
CC 5	7	3	4	5	3	5	5	6	1	6	6	6
CC 25	3	6	8	6	3	6	6	4	1	4	7	2
CC 100	17	4	11	2	4	9	2	7	6	4	7	1

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the rain gardens they represent the area in m^2 divided by 4.

**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

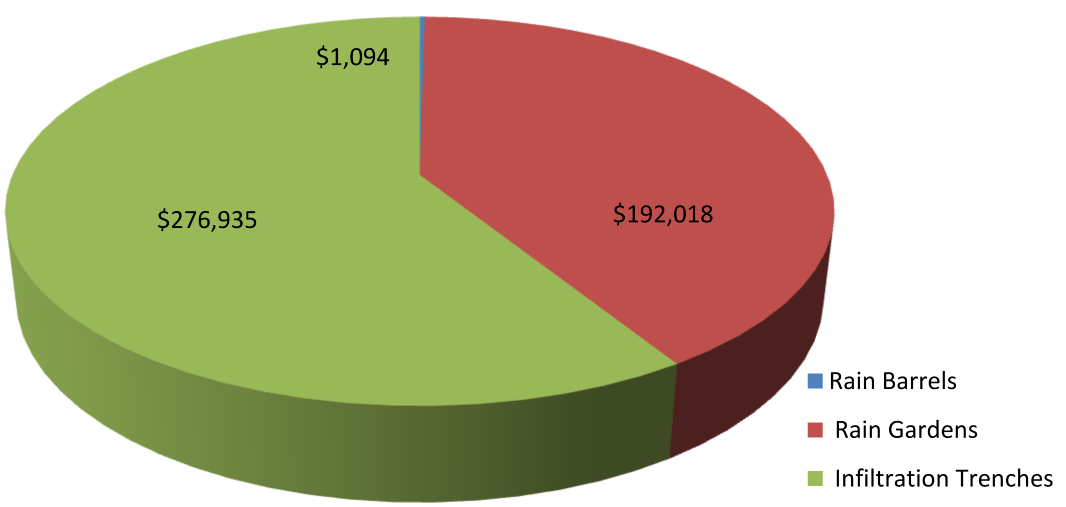


Figure 8-37 Mean cost breakdown of the total runoff reduction, cost-effective solutions from the retrofit-high scenario

8.9.2.3 New Development, Low LID Adoption

The LID investment for this scenario is almost entirely in infiltration trenches, as is depicted in Figure 8-38. This departure from the previous two scenarios is likely because the change from retrofit to new development means a change from rain gardens to bioretention units, which are less effective at reducing runoff. Permeable pavement can be effective, but is not as cost-effective because of how expensive it is. In Table 8-10 we see that the area of the infiltration trenches is small compared to the maximum allowable areas and generally tends to increase as the intensity of the precipitation events increases.

Table 8-10 Sizing decision variable values for the total runoff reduction, cost-effective solutions from the new development-low scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	3	3	2	2	3	3	1	1	5	1	3	1
HIS 25	10	5	8	8	5	3	1	3	1	1	1	1
HIS 100	12	8	7	9	9	6	1	1	2	5	6	1
CC 5	6	5	6	2	5	5	1	1	1	1	1	1
CC 25	8	7	10	2	6	11	1	1	1	1	1	1
CC 100	21	10	14	14	10	9	1	1	1	1	1	1

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.
**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

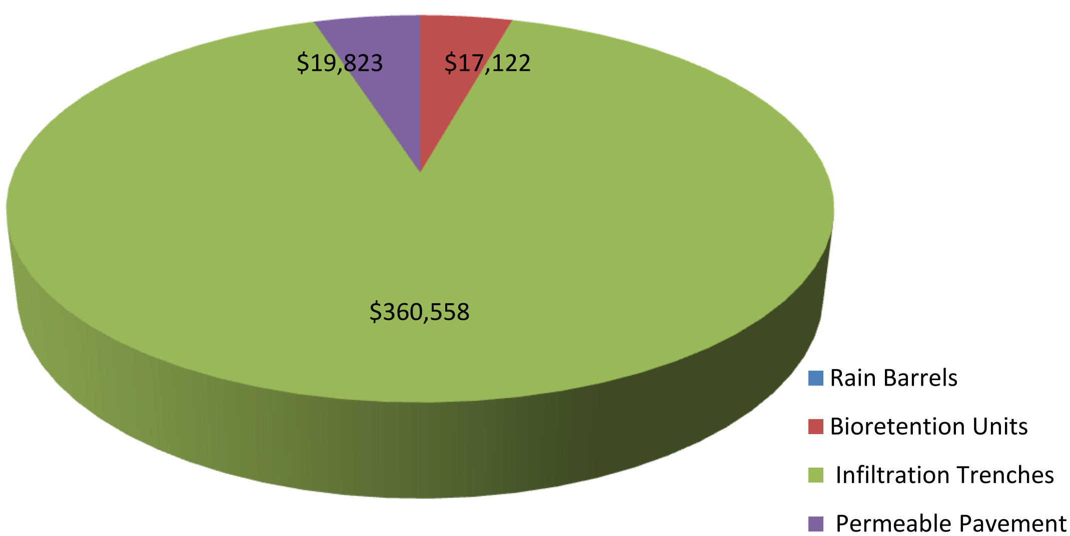


Figure 8-38 Mean cost breakdown of the total runoff reduction, cost-effective solutions from the new development-low scenario

8.9.2.4 New Development, High LID Adoption

The cost-efficient solution selected for this scenario include, on average, more permeable pavement than any previous scenarios as can be seen in Figure 8-39. All of the infiltration trench cells being shaded in Table 8-11 indicate that infiltration trenches are implemented in every runoff zone for every solution selected. This time there are more infiltration trenches with high areas (up to 290 m^2) which is probably the result of more expensive (but still relatively efficient) solutions being selected.

Table 8-11 Sizing decision variable values for the total runoff reduction, cost-effective solutions from the new development-high scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	4	4	21	7	5	3	1	3	1	4	1	1
HIS 25	5	4	2	9	5	5	1	5	2	1	6	5
HIS 100	10	11	2	2	8	5	3	1	6	1	4	1
CC 5	8	4	3	2	6	5	1	2	1	1	2	1
CC 25	10	11	16	10	10	6	1	3	1	3	3	4
CC 100	17	12	19	26	11	10	1	5	5	1	1	7

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.

**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

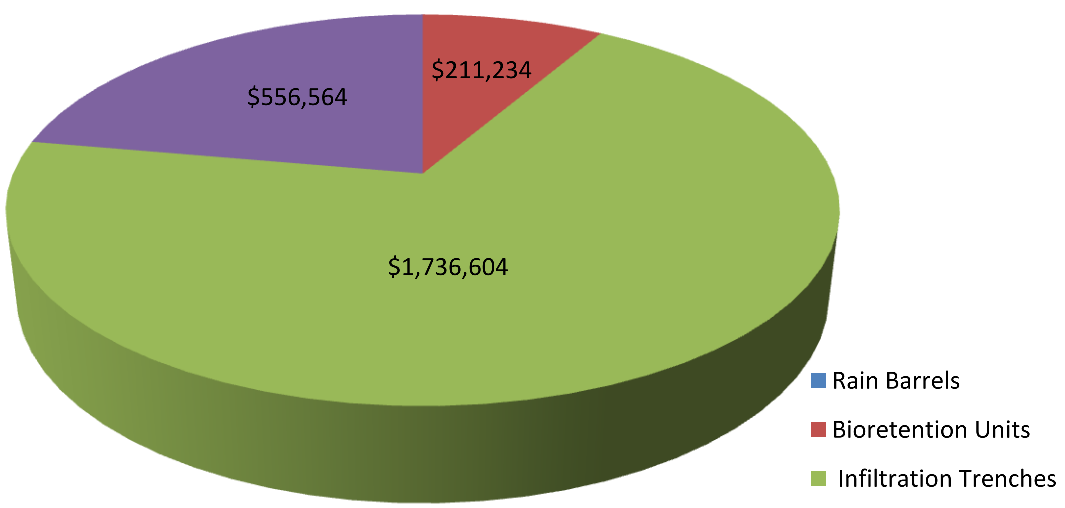


Figure 8-39 Mean cost breakdown of total runoff reduction, cost-effective solutions from the new development-high scenario

8.9.2.5 New Development, Unrestricted LID Adoption

The solutions selected for the new development unrestricted scenario have the highest mean costs of any of the scenarios. Infiltration trenches, bioretention units, permeable pavement, and rain barrels are all included (Figure 8-40). Although there is relatively high investment in bioretention units, Table 8-12 shows no bioretention units being placed in runoff zone 1. This could be because there is the least benefit to be had from investing in the lowest runoff subcatchments. It also appears that the bioretention units being placed in the areas with Berrien sand, or Brookston clay have lower areas than the bioretention units being placed in the areas with Brookston clay loam.

Table 8-12 Sizing decision variable values for the total runoff reduction, cost-effective solutions from the new development-unrestricted scenario

	IT SC 1	IT SC 2	IT SC 3	IT L 1	IT L 2	IT L 3	BR L 1	BR L 2	BR L 3	BR SC 1	BR SC 2	BR SC 3
HIS 5	23	3	5	29	4	14	7	2	4	1	1	1
HIS 25	7	9	2	7	8	7	5	7	4	1	1	1
HIS 100	17	7	12	3	9	13	1	3	4	2	1	2
CC 5	9	5	7	14	5	3	5	1	1	1	1	1
CC 25	7	6	5	27	9	6	1	1	3	1	1	1
CC 100	11	10	5	7	9	17	1	7	1	1	1	1

*The values represented in the table are the decision variable values. For infiltration trenches they represent the area in m^2 divided by 10 and for the bioretention units they represent the area in m^2 divided by 4.
**The shaded cells are those for which the LID corresponding to that area is turned on for the solution in question.

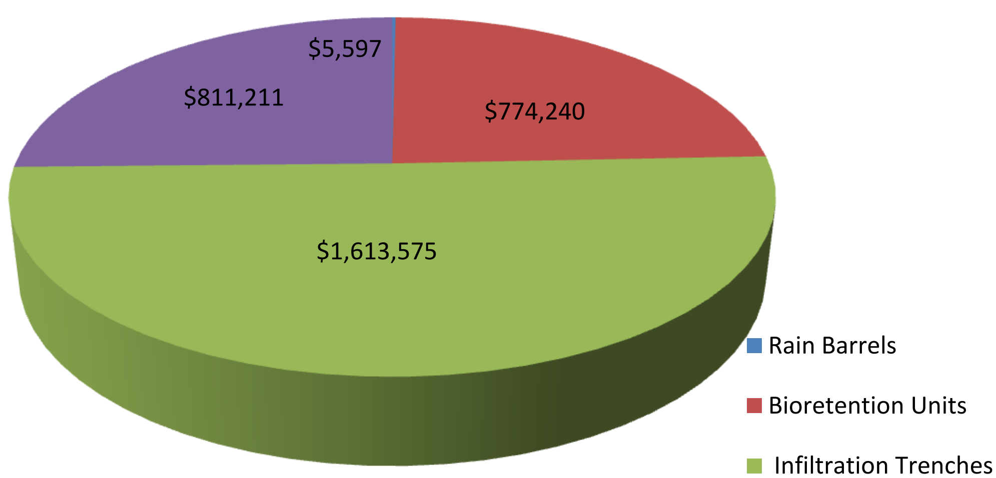


Figure 8-40 Mean cost breakdown of the total runoff reduction, cost-effective solutions from the new development-unrestricted scenario

8.10 Extended Duration Tests (July15th event)

From the cost effective solutions selected for analysis in the preceding sections, one solution was generated for each LID adoption scenario. These solutions have the most frequently observed LID characteristics of the cost-effective solutions for each respective scenario. Therefore, five solutions were generated from the cost-effective solutions selected from the peak flow non-dominated solutions and five solutions were generated from the cost-effective solutions selected from the total runoff non-dominated solutions. These solutions are included in Appendix F.

These solutions were tested using the July 15th calibration events to test how they would perform over a longer continuous simulation which included several lower intensity storms. The results of these tests are displayed in Figure 8-41 for the solutions generated from the peak flow reduction non-dominated solutions and in Figure 8-42 for the solutions generated from the total runoff reduction non-dominated solutions. Based on the hydrographs, the performance of each set of solutions appears to be very similar. As would be expected the scenarios with greater LID adoption perform better. The peak flow reductions for all the scenarios appear to be greater, as a percentage of the peak flow, than the reductions achieved for the design storms. This would follow the pattern of the reduction efficiency of the LIDs decreasing with increasing precipitation intensity. None of the LID combinations achieves the reduction of the all LIDs scenario presented in Figure 8-1; however, these solutions are much more cost-effective.

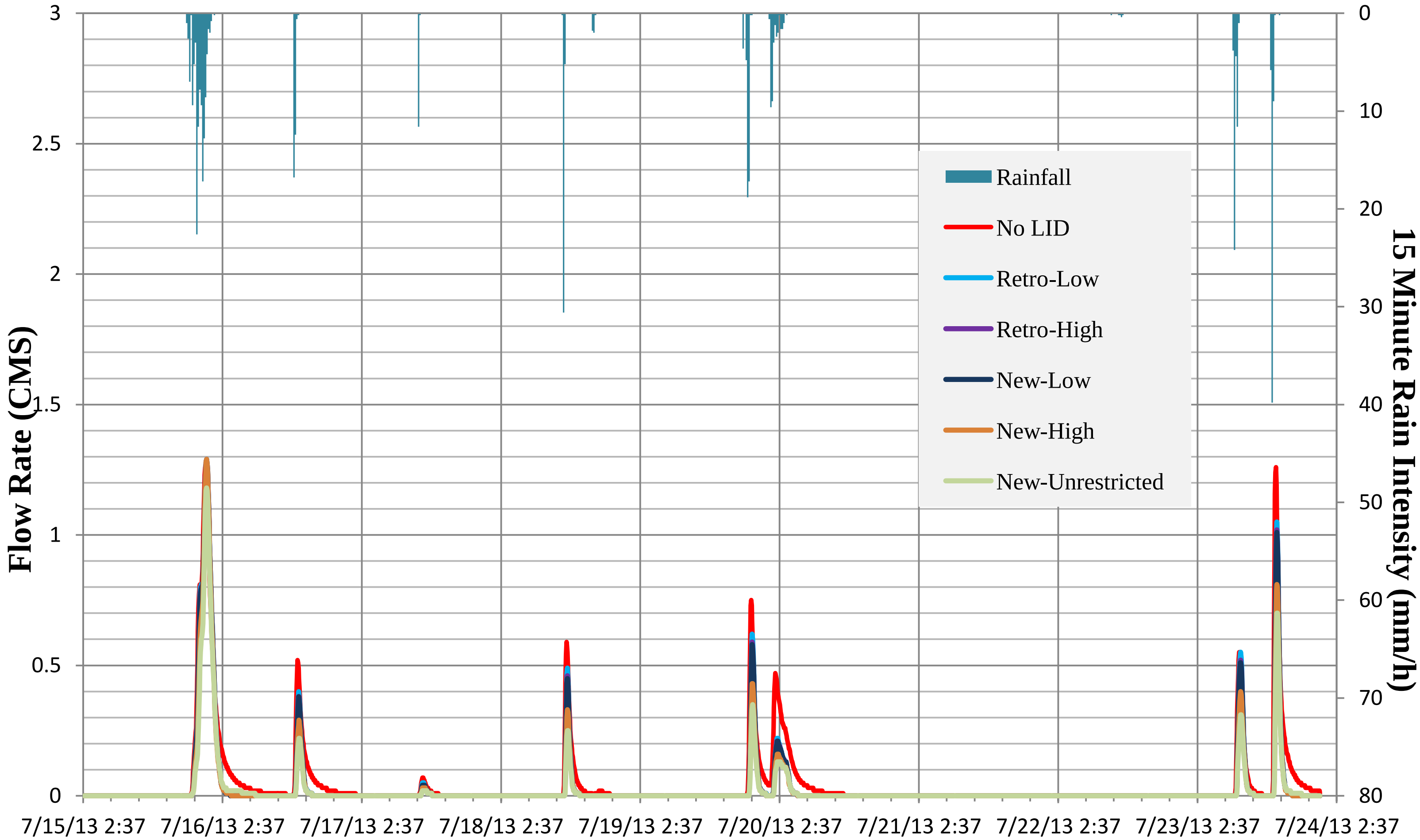


Figure 8-41 Hydrographs of typical peak flow reduction, cost-effective solutions tested during the July 15th series of events

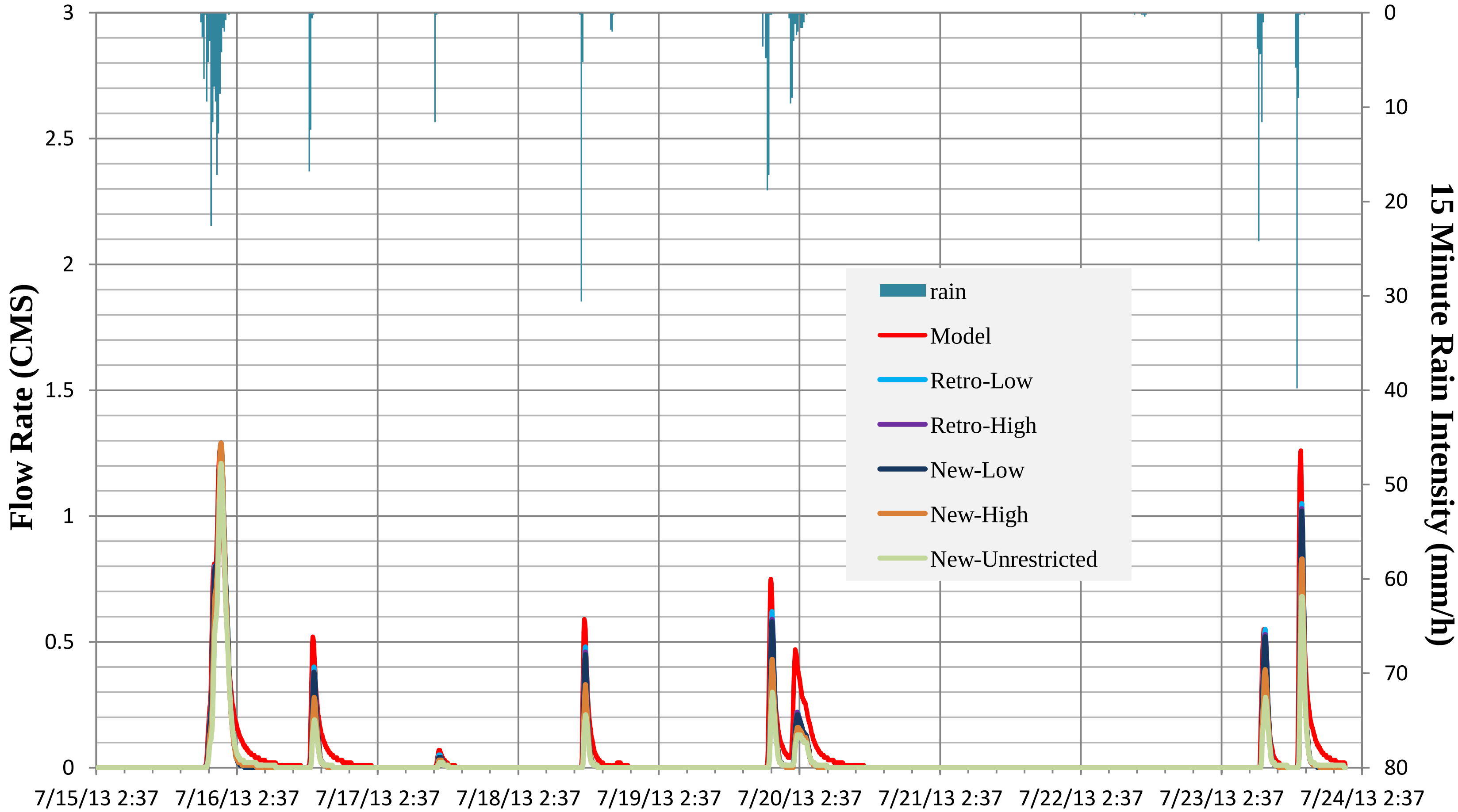


Figure 8-42 Hydrographs of typical total runoff reduction, cost-effective solutions tested during the July 15th series of events

Table 8-13 shows the total runoff generated during these simulations. The results for the two sets of solutions are once again very similar. This is mostly because the typical cost-effective solutions for runoff and peak flow were very similar. Also, the differences might not be as apparent for these smaller storm events.

Table 8-13 Total Runoff for typical, cost-effective solutions from July 15 to 24

	Q_P Dominant	R_t Dominant
LID Adoption Scenario	**Total Runoff (ha.m)**	
No LIDs	2.22	2.22
Retrofit-Low	2.20	2.20
Retrofit-High	2.15	2.15
New Development-Low	2.14	2.15
New Development-High	1.85	1.87
New Development-Unrestricted	1.67	1.65

8.11 Summary

All of the results of the 30 optimization-simulation runs are presented in chapter 8. Although it took some work to interpret the results, the simulations provided some valuable information. The frequency with which similar results and patterns were present between the various scenarios allows some conclusions to be drawn from these observations. These conclusions are discussed at length in Chapter 8 and summarized in chapter 9.

9 Conclusions

A major portion of this study was dedicated to the construction of an optimization-simulation model which could be used to generate cost-benefit information for low impact development stormwater controls. This was achieved by coupling the stormwater management model (SWMM) with Borg multiobjective evolutionary algorithm (MOEA). SWMM is able to evaluate solutions passed to it by Borg and return the outputs of simulations to Borg so that Borg can determine the effectiveness of those solutions. Solutions consist of the decision variables in the optimization process which can be set to any parameter found in the SWMM input file. This study evaluated low impact development measures; therefore, the decision variables were set to control the implementation of LID controls in the model. Parsing functions were developed to change all the parameters in the SWMM input file necessary to accurately reflect changes being made to LID controls.

LID controls could be evaluated for any SWMM model with minor adjustments to the parsing functions and variables related to subcatchment properties (such as the number of houses in each subcatchment). The SWMM model developed for this study was of a 77 ha suburban sewershed in Windsor, Ontario. The sewershed included 856 houses and the SWMM model has 292 subcatchments. The characteristics of this sewershed, particularly the poor soil infiltration, should reduce the effectiveness of LID controls. Using the optimization-simulation model, the effectiveness of the LID controls at the sewershed level can be tested.

The LID controls selected for evaluation include infiltration trenches, permeable pavement, rain barrels, and bioretention cells (or rain gardens for the retrofit scenarios). The LID controls were evaluated over 30 scenarios. These scenarios include five different LID implementation scenarios. Each scenario has different adoption levels for each type of LID. There are two retrofit scenarios; low LID adoption and high LID adoption. The retrofit scenarios represent retrofitting the sewershed, in its current state, with LID controls. There are three new development scenarios; low LID adoption, high LID adoption, and unrestricted LID adoption. The new development scenarios imagine that the sewershed is developed in a similar manner, but with the LID controls included at the time of construction. Each LID adoption scenario is run with six different precipitation events. The precipitation events considered were 5, 25, and 100 year return period events based on historical data, or predicted future climate change conditions.

The optimization problem was set up with 24 decision variables; however, the user can alter this very easily. Twelve decision variables control the number of each LID type implemented in each subcatchment for three different zones. The other twelve decision variables control the surface area of the infiltration trenches and bioretention cells or rain gardens. There are three objectives that define the multiobjective problem. They are the reduction of the peak flow in the stormsewer at the point where the flow monitor is located, total runoff reduction, and cost minimization. Each simulation was run for 12,500 functional evaluations.

The results of the simulations provide many interesting conclusions. Many of the conclusions are related to flow routing and timing. For many solutions (a solution contains a value for each decision variable, i.e., a specific LID implementation), there was a significant departure between that LID set's ability to reduce runoff and its ability to reduce peak flow. It was possible for a solution B to improve runoff reduction compared to solution A, but at the same time greatly decrease peak flow reduction from what solution A was able to achieve. This is because of timing differences. For example, adding 200 bioretention cells, each with a surface area of 4 m^2 (solution B) would reduce runoff to a greater extent than adding 50 bioretention cells with a surface area of 10 m^2 (solution A). However, solution A could perform better than solution B for peak flow reduction. This is because the 4 m^2 will fill up more quickly and, as the depth of the water in their storage layer will be greater, transmit flow through their underdrains more rapidly. Therefore, the bioretention cells in solution B will have a reduced capacity to delay flow from entering the storm sewers and therefore perform poorly in regards to peak flow reduction.

A few of the solutions generated in the optimization process even increased the peak flow. This is because for certain LID configurations water is able to reach the stormsewers more rapidly by traveling through the LIDs and their underdrains than by flowing on the surface. Essentially, some LID configurations short circuit the flow routing. This is a consequence of both the LID designs and the factors influencing the surface travel times, such as subcatchment width. Whether or not this phenomenon would occur in reality is dependent on these same factors.

One reason why the importance of flow timing acquires such significance in controlling peak flows is because the ability of the LID controls to reduce runoff is limited due to the low infiltration rates allowed by the underlying soils. The maximum peak flow reduction percentage exceeds the maximum runoff reduction percentage for every scenario tested.

As the intensity of the storms increases, both the peak flow reduction percentage and runoff reduction percentage decrease; therefore, the performance of the LID measures tested can be expected to decrease with climate change. For the most part the decrease was gradual, except for peak flow reduction during the 100 year return period climate change storm. For this event, not only was the reduction percentage the lowest in each of the tested scenarios, but the reduction quantity was also the lowest in several of the tested scenarios. For the other events, the reduction quantities increased even as the percentage reduction decreased; however, for the climate change 100 year storm this was not the case. That event is significantly more intense than any other event and causes more of the LIDs to become overwhelmed and short circuit.

Comparisons between the different LIDs were also made. For runoff reduction, rain gardens were the most cost-efficient because of their simple design and the fact that they were designed with higher infiltration rates. Permeable pavement driveways were the second best at reducing runoff; however, infiltration trenches are more cost effective. Infiltration trenches also were the dominant LID type for peak flow reduction. Bioretention cells were also beneficial for peak flow reduction, but they could become overloaded more easily than infiltration trenches.

Infiltration trenches and bioretention units together were an effective combination for peak flow reduction. The LID combinations are important and play a role in the cost effectiveness of the LID controls because the LID combinations control how much runoff from impervious surfaces is routed to each LID type.

Other trends in LID implementation were apparent in the results. For one, the surface area of the infiltration trenches and bioretention units had to increase as the intensity of the rainfall events increased, especially for peak flow reduction. Also, it generally proved to be the most cost-effective to implement LID controls in the high runoff subcatchments first. An exception to this rule would be for some peak flow reduction in cases where the LIDs would be overloaded more quickly in the high-runoff subcatchments.

In conclusion, the results show that the performance of LID stormwater controls was limited by the sewershed conditions. Even so, LID controls were able to provide some benefits. The maximum reductions were: in the retrofit, low LID adoption, scenario 0.08 m^3/s of peak flow and 0.04 ha.m of runoff; in the retrofit, high LID adoption, scenario 0.32 m^3/s of peak flow and 0.12 ha.m of runoff; in the new development, low LID adoption, scenario 0.35 m^3/s of peak flow and 0.11 ha.m of runoff; in the new development, high LID adoption, scenario 1.4 m^3/s of peak flow and 0.6 ha.m of runoff; and finally for the new development, unrestricted LID adoption, scenario 2.06 m^3/s of peak flow and 0.66 ha.m of runoff. Whether or not LID implementation would be cost effective would also depend on the costs of alternatives and the overall stormwater management objectives. In any case, all of the information obtained from the simulations would be useful both for deciding whether or not to implement LIDs and for the planning and design of an LID implementation strategy. This is the power of using multiobjective optimization with the optimization-simulation system. Low impact development technologies are one tool available for stormwater management. The optimization-simulation system is able to produce information vital to understanding that tool.

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Appendix A: SWMM Input File

The following is the input file for the retrofit low adoption scenario. By copying this text into a text file and then changing the extension to ".inp" the file could be opened in SWMM.

```
[TITLE]
;;Project Title/Notes

[OPTIONS]
;;Option            Value
FLOW_UNITS          CMS
INFILTRATION        CURVE_NUMBER
FLOW_ROUTING                DYNWAVE
LINK_OFFSETS                ELEVATION
MIN_SLOPE           0
ALLOW_PONDING               YES
SKIP_STEADY_STATE           NO

START_DATE          07/15/2013
START_TIME          17:12:00
REPORT_START_DATE           07/15/2013
REPORT_START_TIME           17:12:00
END_DATE            07/16/2013
END_TIME            17:12:00
SWEEP_START                 01/01
SWEEP_END           12/31
DRY_DAYS            5
REPORT_STEP         00:05:00
WET_STEP            00:00:45
DRY_STEP            00:02:00
ROUTING_STEP                0:00:10

INERTIAL_DAMPING            PARTIAL
NORMAL_FLOW_LIMITED         BOTH
FORCE_MAIN_EQUATION         D-W
VARIABLE_STEP               0.40
LENGTHENING_STEP            0
MIN_SURFAREA                1.14
MAX_TRIALS          8
HEAD_TOLERANCE              0.0015
SYS_FLOW_TOL                5
LAT_FLOW_TOL                5

[EVAPORATION]
;;Evap Data         Parameters
;;--------------    ----------------
MONTHLY             15      25      55      79.95   148.84  175.51  186.69  156.97  78.74   75.95
            60      50
RECOVERY            Estimate
DRY_ONLY            YES

[TEMPERATURE]
;;Temp/Wind/Snow    Source/Data
FILE                "Windsor_Daily_2013.txt"
WINDSPEED           MONTHLY         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            0.0     0.0     0.0     0.0
SNOWMELT            34      0.5     0.6     0.0     42.28   0.0
ADC IMPERVIOUS              1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0
            1.0
```

ADC PERVIOUS	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[RAINGAGES]

;;Gage	Format	Interval	SCF	Source				
;;--------------	---------	------	------	----------				
Gage1	VOLUME		0:12	1.0	FILE	"RCP85_100.txt"	STA1	MM

[SUBCATCHMENTS]

;;Subcatchment	Rain Gage	Outlet	Area	%Imperv	Width	%Slope	CurbLen	Snow Pack
;;-------------- ---	----------------	----------------	--------	--------	--------	--------	--------	-------------
Sub1	Gage1	J1	0.37	51.00	55	1.500	0	
Sub6	Gage1	J1	0.21	56.00	11	1.500	0	
Sub8	Gage1	J2	0.55	49.00	63	1.125	0	
Sub9	Gage1	J2	0.25	56.00	11	1.125	0	
Sub14	Gage1	J3	0.81	41.00	15	0.3000	0	
Sub15	Gage1	J3	0.3	56.00	11	0.3000	0	
Sub16	Gage1	J3	0.4	36.00	25	0.3750	0	
Sub17	Gage1	J3	0.33	51.00	11	0.3750	0	
Sub18	Gage1	J5	0.4	41.00	23	0.3000	0	
Sub19	Gage1	J5	0.3	51.00	11	0.3000	0	
Sub21	Gage1	J4	0.29	36.00	15	0.7500	0	
Sub22	Gage1	J6	0.13	30.00	5	0.2250	0	
Sub23	Gage1	J6	0.41	51.00	15	0.3750	0	
Sub24	Gage1	J6	0.42	51.00	15	0.3750	0	
Sub25	Gage1	J9	0.34	51.00	13	0.3750	0	
Sub26	Gage1	J9	0.31	51.00	11	0.3750	0	
Sub27	Gage1	J8	0.2	51.00	11	0.3750	0	
Sub28	Gage1	J8	0.15	32.00	15	0.3750	0	
Sub29	Gage1	J12	0.42	46.00	13	0.3750	0	
Sub30	Gage1	J12	0.43	51.00	13	0.3750	0	
Sub31	Gage1	Out1	0.19	46.00	11	0.3750	0	
Sub32	Gage1	Out1	0.22	46.00	11	0.3750	0	
Sub33	Gage1	Out1	0.19	51.00	12	0.3750	0	
Sub34	Gage1	Out1	0.22	51.00	12	0.3750	0	
Sub35	Gage1	J12	0.34	56.00	7	0.3750	0	
Sub36	Gage1	J12	0.37	46.00	13	0.3750	0	
Sub37	Gage1	J11	0.17	56.00	8	1.350	0	
Sub38	Gage1	J11	0.19	46.00	14	1.350	0	
Sub39	Gage1	J11	0.27	46.00	8	1.350	0	
Sub40	Gage1	J11	0.3	46.00	13	1.350	0	
Sub41	Gage1	J10	0.3	46.00	13	1.350	0	
Sub42	Gage1	J10	0.27	56.00	8	1.350	0	
Sub43	Gage1	Out2	0.15	17.00	7	3.000	0	
Sub44	Gage1	J10	0.09	32.00	5	3.000	0	
Sub45	Gage1	J17	0.42	11.00	18	2.250	0	
Sub46	Gage1	J18	0.33	46.00	16	1.350	0	
Sub47	Gage1	J18	0.31	46.00	16	1.350	0	
Sub48	Gage1	J18	0.2	46.00	16	1.350	0	
Sub49	Gage1	J18	0.2	46.00	16	1.350	0	
Sub50	Gage1	J19	0.31	46.00	16	1.350	0	
Sub51	Gage1	J19	0.32	46.00	15	1.350	0	
Sub52	Gage1	J13	0.19	46.00	16	0.3750	0	
Sub53	Gage1	J13	0.2	46.00	16	0.3750	0	
Sub54	Gage1	J13	0.17	46.00	16	0.3750	0	
Sub55	Gage1	J13	0.17	46.00	16	0.3750	0	
Sub56	Gage1	J20	0.21	11.00	5	0.4500	0	
Sub57	Gage1	J21	0.06	97.00	5	0.2250	0	
Sub58	Gage1	J21	0.06	86.00	5	0.2250	0	
Sub59	Gage1	J22	0.25	55.00	9	0.3000	0	
Sub60	Gage1	J22	0.25	51.00	12	0.4500	0	

Sub61	Gage1	J22	0.18	51.00	9	0.3000	0
Sub62	Gage1	J22	0.17	51.00	12	0.4500	0
Sub63	Gage1	J23	0.07	22.00	12	0.3000	0
Sub64	Gage1	J23	0.07	51.00	9	0.4500	0
Sub65	Gage1	J23	0.24	51.00	9	0.3000	0
Sub66	Gage1	J23	0.23	51.00	12	0.4500	0
Sub67	Gage1	J24	0.36	51.00	9	0.4500	0
Sub68	Gage1	J24	0.34	51.00	12	0.4500	0
Sub69	Gage1	J25	0.15	96.00	5	3.750	0
Sub70	Gage1	J116	0.12	46.00	15	1.125	0
Sub71	Gage1	J116	0.13	46.00	15	1.125	0
Sub72	Gage1	J116	0.25	46.00	12	0.3750	0
Sub73	Gage1	J116	0.27	46.00	12	0.3750	0
Sub74	Gage1	J114	0.35	56.00	12	0.3750	0
Sub75	Gage1	J114	0.37	61.00	13	0.3750	0
Sub76	Gage1	J115	0.2	56.00	12	0.3750	0
Sub77	Gage1	J115	0.17	61.00	13	0.3750	0
Sub78	Gage1	J115	0.25	46.00	13	0.3750	0
Sub79	Gage1	J115	0.27	41.00	14	0.3750	0
Sub80	Gage1	J117	0.06	22.00	5	0.3750	0
Sub81	Gage1	J117	0.14	41.00	15	0.3750	0
Sub82	Gage1	J117	0.15	46.00	13	0.3750	0
Sub83	Gage1	J118	0.2	46.00	15	0.3750	0
Sub84	Gage1	J118	0.13	51.00	13	0.3750	0
Sub85	Gage1	J119	0.26	46.00	15	0.3750	0
Sub86	Gage1	J119	0.25	51.00	13	0.3750	0
Sub87	Gage1	J119	0.11	91.00	5	3.750	0
Sub88	Gage1	J120	0.37	51.00	11	0.3750	0
Sub89	Gage1	J120	0.4	51.00	13	0.3750	0
Sub90	Gage1	J121	0.32	51.00	11	0.3750	0
Sub91	Gage1	J121	0.37	56.00	13	0.3750	0
Sub92	Gage1	J32	0.39	41.00	13	0.3750	0
Sub93	Gage1	J32	0.38	56.00	11	0.3750	0
Sub94	Gage1	J28	0.21	11.00	7	0.1800	0
Sub95	Gage1	J29	0.12	97.00	5	0.1800	0
Sub96	Gage1	J29	0.1	51.00	14	0.6000	0
Sub97	Gage1	J29	0.09	51.00	11	0.6000	0
Sub98	Gage1	J30	0.38	46.00	16	0.4500	0
Sub99	Gage1	J30	0.32	56.00	8	0.6000	0
Sub100	Gage1	J30	0.09	24.00	17	1.125	0
Sub101	Gage1	J30	0.08	51.00	11	0.7500	0
Sub102	Gage1	J31	0.37	46.00	18	1.350	0
Sub103	Gage1	J31	0.3	56.00	11	1.350	0
Sub104	Gage1	J32	0.35	46.00	18	0.6000	0
Sub105	Gage1	J32	0.3	56.00	11	1.350	0
Sub106	Gage1	J32	0.13	91.00	5	3.750	0
Sub107	Gage1	J36	0.07	46.00	13	0.7500	0
Sub108	Gage1	J36	0.07	51.00	12	0.7500	0
Sub109	Gage1	J126	0.13	46.00	13	0.7500	0
Sub110	Gage1	J126	0.12	51.00	12	0.7500	0
Sub111	Gage1	J128	0.19	48.00	15	0.3750	0
Sub112	Gage1	J127	0.18	48.00	13	0.3750	0
Sub113	Gage1	Sub111	0.19	51.00	13	0.3750	0
Sub114	Gage1	Sub112	0.18	51.00	11	0.3750	0
Sub115	Gage1	Sub113	0.17	51.00	11	0.3750	0
Sub116	Gage1	Sub114	0.17	51.00	14	0.3750	0
Sub117	Gage1	J33	0.1	96.00	5	0.2250	0
Sub118	Gage1	J33	0.14	51.00	15	0.4500	0
Sub119	Gage1	J33	0.15	51.00	15	0.6000	0
Sub120	Gage1	J34	0.21	51.00	15	1.125	0
Sub121	Gage1	J34	0.2	51.00	15	1.125	0

Sub122	Gage1	J34	0.2	51.00	15	0.7500	0
Sub123	Gage1	J34	0.2	51.00	15	0.7500	0
Sub124	Gage1	J35	0.19	51.00	15	1.125	0
Sub125	Gage1	J35	0.19	51.00	15	1.125	0
Sub126	Gage1	J35	0.19	46.00	15	1.350	0
Sub127	Gage1	J35	0.2	46.00	15	1.350	0
Sub128	Gage1	J36	0.28	46.00	15	1.350	0
Sub129	Gage1	J36	0.26	46.00	15	1.350	0
Sub130	Gage1	J36	0.1	96.00	5	3.750	0
Sub131	Gage1	J37	0.1	42.00	8	0.2250	0
Sub132	Gage1	J37	0.14	56.00	12	0.6000	0
Sub133	Gage1	J37	0.14	46.00	13	0.6000	0
Sub134	Gage1	J38	0.24	56.00	11	0.9000	0
Sub135	Gage1	J38	0.24	51.00	12	0.9000	0
Sub136	Gage1	J38	0.18	51.00	11	0.6000	0
Sub137	Gage1	J38	0.18	51.00	10	1.125	0
Sub138	Gage1	J39	0.33	46.00	11	1.125	0
Sub139	Gage1	J39	0.3	56.00	10	1.125	0
Sub140	Gage1	J40	0.26	51.00	11	1.125	0
Sub141	Gage1	J40	0.25	51.00	10	1.125	0
Sub142	Gage1	J40	0.1	86.00	15	3.750	0
Sub143	Gage1	J124	0.08	56.00	15	0.3750	0
Sub144	Gage1	J124	0.1	41.00	20	0.2250	0
Sub145	Gage1	J40	0.09	46.00	18	0.7500	0
Sub146	Gage1	J40	0.08	46.00	12	0.7500	0
Sub147	Gage1	J125	0.39	11.00	23	0.3750	0
Sub148	Gage1	J125	0.35	29.00	20	0.2250	0
Sub149	Gage1	J122	0.14	46.00	18	0.7500	0
Sub150	Gage1	J122	0.12	51.00	12	0.7500	0
Sub151	Gage1	J123	0.14	46.00	16	1.125	0
Sub152	Gage1	J123	0.12	41.00	20	0.2250	0
Sub153	Gage1	J44	1.53	8.000	27	0.2250	0
Sub154	Gage1	J44	0.11	91.00	5	3.750	0
Sub155	Gage1	J41	0.09	51.00	15	3.750	0
Sub156	Gage1	J41	0.15	66.00	13	0.6000	0
Sub157	Gage1	J41	0.16	56.00	14	0.6000	0
Sub158	Gage1	J42	0.23	56.00	13	0.9000	0
Sub159	Gage1	J42	0.23	51.00	15	0.9000	0
Sub160	Gage1	J43	0.43	51.00	14	1.125	0
Sub161	Gage1	J43	0.44	51.00	14	0.9000	0
Sub162	Gage1	J44	0.37	51.00	14	1.125	0
Sub163	Gage1	J44	0.35	51.00	13	0.7500	0
Sub164	Gage1	J48	0.7	9.000	22	0.1125	0
Sub165	Gage1	J48	0.12	91.00	5	3.750	0
Sub166	Gage1	J45	0.35	17.00	7	0.2250	0
Sub167	Gage1	J45	0.05	96.00	5	0.4500	0
Sub168	Gage1	J46	0.34	51.00	13	0.9000	0
Sub169	Gage1	J46	0.28	51.00	8	0.9000	0
Sub170	Gage1	J45	0.08	43.00	12	7.500	0
Sub171	Gage1	J47	0.33	51.00	13	1.125	0
Sub172	Gage1	J47	0.3	51.00	8	0.5250	0
Sub173	Gage1	J48	0.35	51.00	13	0.7500	0
Sub174	Gage1	J48	0.31	51.00	8	0.4500	0
Sub175	Gage1	J111	0.08	96.00	5	3.750	0
Sub176	Gage1	J112	0.32	41.00	19	0.2250	0
Sub177	Gage1	J112	0.3	46.00	17	0.3000	0
Sub178	Gage1	J113	1.56	13.00	24	0.2250	0
Sub179	Gage1	J52	0.39	46.00	13	0.2250	0
Sub180	Gage1	J52	0.07	96.00	5	0.2250	0
Sub181	Gage1	J113	0.49	51.00	11	0.2250	0
Sub182	Gage1	J52	0.36	46.00	10	0.2250	0

Sub183	Gage1	Out3	1.06	9.000	15	0.3000	0
Sub184	Gage1	J64	0.22	17.00	5	0.4500	0
Sub185	Gage1	J64	0.45	8.000	5	0.2700	0
Sub186	Gage1	J62	0.52	8.000	5	0.5250	0
Sub187	Gage1	J49	0.39	8.000	13	0.2700	0
Sub188	Gage1	J50	0.36	9.500	21	0.3000	0
Sub189	Gage1	J50	0.29	9.500	11	0.3000	0
Sub190	Gage1	J51	0.39	9.500	10	0.6000	0
Sub191	Gage1	J51	0.51	9.500	20	0.6000	0
Sub192	Gage1	J52	0.23	8.000	10	0.3750	0
Sub193	Gage1	J52	0.41	8.000	21	0.3750	0
Sub194	Gage1	J108	0.15	61.00	7	0.3000	0
Sub195	Gage1	J107	0.26	61.00	8	0.7500	0
Sub196	Gage1	J106	0.14	61.00	9	0.7500	0
Sub197	Gage1	J107	0.32	51.00	10	1.125	0
Sub198	Gage1	J107	0.24	41.00	15	0.7500	0
Sub199	Gage1	J106	0.17	41.00	12	0.7500	0
Sub200	Gage1	J105	0.18	41.00	13	0.7500	0
Sub201	Gage1	J105	0.29	61.00	10	0.7500	0
Sub202	Gage1	J105	0.16	41.00	11	0.7500	0
Sub203	Gage1	J104	0.23	41.00	13	0.7500	0
Sub204	Gage1	J104	0.21	41.00	11	0.7500	0
Sub205	Gage1	J103	0.21	61.00	10	0.7500	0
Sub206	Gage1	J101	0.15	61.00	10	0.7500	0
Sub207	Gage1	J101	0.18	36.00	15	0.7500	0
Sub208	Gage1	J101	0.15	46.00	14	0.7500	0
Sub209	Gage1	J101	0.16	51.00	14	0.7500	0
Sub210	Gage1	J103	0.15	46.00	11	0.7500	0
Sub211	Gage1	J103	0.18	46.00	13	0.7500	0
Sub212	Gage1	J100	0.18	41.00	15	0.7500	0
Sub213	Gage1	J100	0.22	51.00	14	0.7500	0
Sub214	Gage1	J102	0.25	46.00	11	0.7500	0
Sub215	Gage1	J102	0.25	46.00	13	0.7500	0
Sub216	Gage1	Sub207	0.15	46.00	15	0.7500	0
Sub217	Gage1	Sub208	0.13	46.00	15	0.7500	0
Sub218	Gage1	Sub212	0.15	46.00	15	0.7500	0
Sub219	Gage1	J90	0.31	61.00	9	0.5250	0
Sub220	Gage1	J89	0.36	51.00	14	0.5250	0
Sub221	Gage1	J86	0.12	61.00	10	0.5250	0
Sub223	Gage1	J86	0.12	51.00	15	0.5250	0
Sub224	Gage1	J85	0.12	56.00	11	0.5250	0
Sub225	Gage1	J85	0.14	46.00	11	0.5250	0
Sub226	Gage1	J91	0.36	46.00	13	0.5250	0
Sub227	Gage1	J84	0.12	46.00	15	0.5250	0
Sub228	Gage1	J82	0.15	46.00	16	0.5250	0
Sub229	Gage1	J92	0.36	51.00	13	0.5250	0
Sub230	Gage1	J84	0.12	51.00	12	0.5250	0
Sub231	Gage1	J82	0.15	51.00	12	0.5250	0
Sub232	Gage1	J95	0.15	46.00	15	1.125	0
Sub233	Gage1	J93	0.21	51.00	14	0.5250	0
Sub234	Gage1	J94	0.36	46.00	12	0.5250	0
Sub235	Gage1	J83	0.12	46.00	15	0.5250	0
Sub236	Gage1	J83	0.11	46.00	15	0.5250	0
Sub237	Gage1	J81	0.17	46.00	16	0.5250	0
Sub238	Gage1	J81	0.17	46.00	14	0.5250	0
Sub239	Gage1	J98	0.29	46.00	13	0.5250	0
Sub240	Gage1	J98	0.19	46.00	14	0.5250	0
Sub242	Gage1	J99	0.18	36.00	10	0.5250	0
Sub243	Gage1	J99	0.21	56.00	9	0.5250	0
Sub244	Gage1	J98	0.13	51.00	13	0.5250	0
Sub245	Gage1	J97	0.19	11.00	12	0.5250	0

Sub246	Gage1	J97	0.12	46.00	12	0.5250	0
Sub247	Gage1	J79	0.12	51.00	13	0.5250	0
Sub248	Gage1	J79	0.05	46.00	9	0.5250	0
Sub249	Gage1	Sub245	0.19	51.00	12	0.5250	0
Sub250	Gage1	J77	0.18	51.00	15	0.5250	0
Sub251	Gage1	J77	0.17	51.00	10	0.5250	0
Sub252	Gage1	J78	0.13	46.00	11	0.5250	0
Sub254	Gage1	J61	0.08	96.00	5	3.750	0
Sub255	Gage1	J85	0.11	96.00	5	3.750	0
Sub256	Gage1	J82	0.1	96.00	5	3.750	0
Sub257	Gage1	J81	0.08	96.00	5	3.750	0
Sub258	Gage1	J77	0.07	96.00	5	3.750	0
Sub259	Gage1	J61	0.76	9.000	5	0.2250	0
Sub260	Gage1	J60	0.81	9.000	5	0.3750	0
Sub261	Gage1	J58	0.4	9.000	5	0.3000	0
Sub262	Gage1	J57	0.44	16.00	7	0.3000	0
Sub263	Gage1	J85	0.32	61.00	7	0.4500	0
Sub264	Gage1	J85	0.36	51.00	11	0.4500	0
Sub265	Gage1	J67	0.37	37.00	9	0.3750	0
Sub266	Gage1	J67	0.38	51.00	10	0.3750	0
Sub267	Gage1	J59	0.34	37.00	9	0.3000	0
Sub268	Gage1	J59	0.15	51.00	11	0.3000	0
Sub269	Gage1	J82	0.38	46.00	14	0.4500	0
Sub270	Gage1	J82	0.37	51.00	13	0.4500	0
Sub271	Gage1	J71	0.4	46.00	14	0.3750	0
Sub272	Gage1	J71	0.39	51.00	15	0.3750	0
Sub273	Gage1	J69	0.46	46.00	15	0.3000	0
Sub274	Gage1	J66	0.22	22.00	12	0.3000	0
Sub275	Gage1	J70	0.16	51.00	11	0.3000	0
Sub276	Gage1	J69	0.05	22.00	15	0.3000	0
Sub277	Gage1	J69	0.2	51.00	12	0.3000	0
Sub278	Gage1	J81	0.37	51.00	15	0.4500	0
Sub279	Gage1	J81	0.35	51.00	12	0.4500	0
Sub280	Gage1	J80	0.44	56.00	14	0.3750	0
Sub281	Gage1	J80	0.12	46.00	13	0.3750	0
Sub282	Gage1	J72	0.4	51.00	14	0.3000	0
Sub283	Gage1	J72	0.38	41.00	13	0.3000	0
Sub284	Gage1	J77	0.37	51.00	14	0.4500	0
Sub285	Gage1	J76	0.45	51.00	13	0.3750	0
Sub286	Gage1	J77	0.38	46.00	12	0.4500	0
Sub287	Gage1	J75	0.24	46.00	12	0.3000	0
Sub288	Gage1	J76	0.33	46.00	48	0.3750	0
Sub289	Gage1	J78	0.33	51.00	48	0.4500	0
Sub290	Gage1	J76	0.36	46.00	48	0.3750	0
Sub291	Gage1	J75	0.24	41.00	48	1.125	0
Sub292	Gage1	J75	0.22	41.00	48	0.3000	0
Sub293	Gage1	J74	0.34	41.00	48	0.3000	0
Sub294	Gage1	J74	0.39	46.00	23	0.3000	0
Sub295	Gage1	J69	0.53	46.00	14	0.3000	0
Sub296	Gage1	J59	0.43	51.00	15	0.3000	0
Sub297	Gage1	J73	0.16	41.00	12	0.3750	0
Sub298	Gage1	J80	0.13	51.00	12	0.3750	0
Sub299	Gage1	J72	0.2	46.00	15	0.3000	0
Sub300	Gage1	J74	0.14	51.00	12	0.3000	0
Sub301	Gage1	J141	0.73	47.00	9	0.5250	0
Sub302	Gage1	J140	0.55	42.00	11	0.7500	0
Sub305	Gage1	J141	0.79	47.00	9	0.5250	0
Sub306	Gage1	J140	0.86	47.00	11	0.5250	0
Sub322	Gage1	J141	0.31	42.00	9	0.7500	0

[SUBAREAS]

;;Subcatchment	N-Imperv	N-Perv	S-Imperv	S-Perv	PctZero	RouteTo	PctRouted
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Sub1	0.0200	0.2500	1.690	3.930	30	PERVIOUS	50
Sub6	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub8	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub9	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub14	0.0200	0.2500	1.690	3.930	30	PERVIOUS	50
Sub15	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub16	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub17	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub18	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub19	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub21	0.0200	0.2500	1.690	3.930	30	PERVIOUS	20
Sub22	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub23	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub24	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub25	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub26	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub27	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub28	0.0200	0.2500	1.690	3.930	30	PERVIOUS	15
Sub29	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub30	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub31	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub32	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub33	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub34	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub35	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub36	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub37	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub38	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub39	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub40	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub41	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub42	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub43	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub44	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub45	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub46	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub47	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub48	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub49	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub50	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub51	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub52	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub53	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub54	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub55	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub56	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub57	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub58	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub59	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub60	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub61	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub62	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub63	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub64	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub65	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub66	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub67	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub68	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub69	0.0200	0.2500	1.690	3.930	30	OUTLET	

Sub70	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub71	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub72	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub73	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub74	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub75	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub76	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub77	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub78	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub79	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub80	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub81	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub82	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub83	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub84	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub85	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub86	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub87	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub88	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub89	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub90	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub91	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub92	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub93	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub94	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub95	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub96	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub97	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub98	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub99	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub100	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub101	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub102	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub103	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub104	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub105	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub106	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub107	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub108	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub109	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub110	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub111	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub112	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub113	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub114	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub115	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub116	0.0200	0.2500	1.690	3.930	30	PERVIOUS	75
Sub117	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub118	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub119	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub120	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub121	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub122	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub123	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub124	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub125	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub126	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub127	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub128	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub129	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub130	0.0200	0.2500	1.690	3.930	30	OUTLET	

Sub131	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub132	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub133	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub134	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub135	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub136	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub137	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub138	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub139	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub140	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub141	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub142	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub143	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub144	0.0200	0.3500	1.690	3.930	30	PERVIOUS	35
Sub145	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub146	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub147	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub148	0.0200	0.8000	1.690	3.930	30	OUTLET	
Sub149	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub150	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub151	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub152	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub153	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub154	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub155	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub156	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub157	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub158	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub159	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub160	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub161	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub162	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub163	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub164	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub165	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub166	0.0200	0.8000	1.690	3.930	30	OUTLET	
Sub167	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub168	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub169	0.0200	0.8000	1.690	3.930	30	PERVIOUS	25
Sub170	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub171	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub172	0.0200	0.8000	1.690	3.930	30	PERVIOUS	25
Sub173	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub174	0.0200	0.8000	1.690	3.930	30	PERVIOUS	25
Sub175	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub176	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub177	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub178	0.0200	0.3500	1.690	6.350	30	PERVIOUS	25
Sub179	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub180	0.0200	0.2500	1.690	2.580	30	OUTLET	
Sub181	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub182	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub183	0.0200	0.3500	1.690	4.080	30	OUTLET	
Sub184	0.0200	0.2500	1.690	6.000	30	OUTLET	
Sub185	0.0200	0.6000	1.690	2.580	30	OUTLET	
Sub186	0.0200	0.6000	1.690	6.000	30	OUTLET	
Sub187	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub188	0.0200	0.2500	1.690	6.000	30	OUTLET	
Sub189	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub190	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub191	0.0200	0.8000	1.690	6.000	30	OUTLET	

Sub192	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub193	0.0200	0.8000	1.690	6.000	30	OUTLET	
Sub194	0.0200	0.2500	1.690	3.930	30	PERVIOUS	15
Sub195	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub196	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub197	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub198	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub199	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub200	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub201	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub202	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub203	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub204	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub205	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub206	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub207	0.0200	0.2500	1.690	3.930	30	PERVIOUS	20
Sub208	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub209	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub210	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub211	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub212	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub213	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub214	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub215	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub216	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub217	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub218	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub219	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub220	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub221	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub223	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub224	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub225	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub226	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub227	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub228	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub229	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub230	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub231	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub232	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub233	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub234	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub235	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub236	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub237	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub238	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub239	0.0200	0.2500	1.690	3.930	30	PERVIOUS	50
Sub240	0.0200	0.2500	1.690	3.930	30	PERVIOUS	50
Sub242	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub243	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub244	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub245	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub246	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub247	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub248	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub249	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub250	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub251	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub252	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub254	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub255	0.0200	0.2500	1.690	3.930	30	OUTLET	

Sub256	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub257	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub258	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub259	0.0200	0.6000	1.690	6.000	30	OUTLET	
Sub260	0.0200	0.6000	1.690	5.500	30	OUTLET	
Sub261	0.0200	0.2500	1.690	4.080	30	OUTLET	
Sub262	0.0200	0.2500	1.690	2.580	30	OUTLET	
Sub263	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub264	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub265	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub266	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub267	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub268	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub269	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub270	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub271	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub272	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub273	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub274	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub275	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub276	0.0200	0.2500	1.690	3.930	30	OUTLET	
Sub277	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub278	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub279	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub280	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub281	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub282	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub283	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub284	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub285	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub286	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub287	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub288	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub289	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub290	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub291	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub292	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub293	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40
Sub294	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub295	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub296	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub297	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub298	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub299	0.0200	0.2500	1.690	2.580	30	PERVIOUS	25
Sub300	0.0200	0.2500	1.690	3.930	30	PERVIOUS	30
Sub301	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub302	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub305	0.0200	0.2500	1.690	3.930	30	PERVIOUS	35
Sub306	0.0200	0.2500	1.690	3.930	30	PERVIOUS	25
Sub322	0.0200	0.2500	1.690	3.930	30	PERVIOUS	40

[INFILTRATION]

;;Subcatchment	CurveNum		HydCon	DryTime
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Sub1	85.50	0.5	10	
Sub6	83.50	0.5	10	
Sub8	84.50	0.5	10	
Sub9	85.50	0.5	10	
Sub14	82.50	0.5	10	
Sub15	85.50	0.5	10	
Sub16	81.50	0.5	10	

Sub17	85.50	0.5	10
Sub18	81.50	0.5	10
Sub19	85.50	0.5	10
Sub21	80.50	0.5	10
Sub22	82.50	0.5	10
Sub23	85.50	0.5	10
Sub24	85.50	0.5	10
Sub25	85.50	0.5	10
Sub26	85.50	0.5	10
Sub27	85.50	0.5	10
Sub28	83.50	0.5	10
Sub29	89.50	0.5	10
Sub30	89.50	0.5	10
Sub31	89.50	0.5	10
Sub32	89.50	0.5	10
Sub33	89.50	0.5	10
Sub34	89.50	0.5	10
Sub35	89.50	0.5	10
Sub36	89.50	0.5	10
Sub37	89.50	0.5	10
Sub38	89.50	0.5	10
Sub39	89.50	0.5	10
Sub40	89.50	0.5	10
Sub41	89.50	0.5	10
Sub42	89.50	0.5	10
Sub43	80.50	0.5	10
Sub44	85.50	0.5	10
Sub45	80.50	0.5	10
Sub46	89.50	0.5	10
Sub47	89.50	0.5	10
Sub48	89.50	0.5	10
Sub49	89.50	0.5	10
Sub50	89.50	0.5	10
Sub51	89.50	0.5	10
Sub52	89.50	0.5	10
Sub53	89.50	0.5	10
Sub54	89.50	0.5	10
Sub55	89.50	0.5	10
Sub56	83.50	0.5	10
Sub57	95.50	0.5	10
Sub58	95.50	0.5	10
Sub59	90.50	0.5	10
Sub60	89.50	0.5	10
Sub61	89.50	0.5	10
Sub62	89.50	0.5	10
Sub63	85.50	0.5	10
Sub64	89.50	0.5	10
Sub65	89.50	0.5	10
Sub66	89.50	0.5	10
Sub67	89.50	0.5	10
Sub68	89.50	0.5	10
Sub69	97.50	0.5	10
Sub70	89.50	0.5	10
Sub71	89.50	0.5	10
Sub72	89.50	0.5	10
Sub73	89.50	0.5	10
Sub74	89.50	0.5	10
Sub75	89.50	0.5	10
Sub76	89.50	0.5	10
Sub77	89.50	0.5	10
Sub78	87.50	0.5	10

Sub79	86.50	0.5	10
Sub80	83.50	0.5	10
Sub81	85.50	0.5	10
Sub82	87.50	0.5	10
Sub83	87.50	0.5	10
Sub84	87.50	0.5	10
Sub85	85.50	0.5	10
Sub86	85.50	0.5	10
Sub87	97.50	0.5	10
Sub88	89.50	0.5	10
Sub89	89.50	0.5	10
Sub90	89.50	0.5	10
Sub91	89.50	0.5	10
Sub92	85.50	0.5	10
Sub93	89.50	0.5	10
Sub94	83.50	0.5	10
Sub95	95.50	0.5	10
Sub96	89.50	0.5	10
Sub97	89.50	0.5	10
Sub98	87.50	0.5	10
Sub99	90.50	0.5	10
Sub100	85.50	0.5	10
Sub101	89.50	0.5	10
Sub102	89.50	0.5	10
Sub103	89.50	0.5	10
Sub104	89.50	0.5	10
Sub105	89.50	0.5	10
Sub106	89.50	0.5	10
Sub107	88.50	0.5	10
Sub108	88.50	0.5	10
Sub109	87.50	0.5	10
Sub110	87.50	0.5	10
Sub111	86.50	0.5	10
Sub112	86.50	0.5	10
Sub113	86.50	0.5	10
Sub114	86.50	0.5	10
Sub115	86.50	0.5	10
Sub116	86.50	0.5	10
Sub117	97.50	0.5	10
Sub118	89.50	0.5	10
Sub119	89.50	0.5	10
Sub120	89.50	0.5	10
Sub121	89.50	0.5	10
Sub122	89.50	0.5	10
Sub123	89.50	0.5	10
Sub124	89.50	0.5	10
Sub125	89.50	0.5	10
Sub126	88.50	0.5	10
Sub127	88.50	0.5	10
Sub128	88.50	0.5	10
Sub129	88.50	0.5	10
Sub130	97.50	0.5	10
Sub131	86.50	0.5	10
Sub132	89.50	0.5	10
Sub133	86.50	0.5	10
Sub134	88.50	0.5	10
Sub135	86.50	0.5	10
Sub136	86.50	0.5	10
Sub137	86.50	0.5	10
Sub138	86.50	0.5	10
Sub139	88.50	0.5	10

Sub140	86.50	0.5	10
Sub141	86.50	0.5	10
Sub142	94.50	0.5	10
Sub143	87.50	0.5	10
Sub144	84.50	0.5	10
Sub145	86.50	0.5	10
Sub146	86.50	0.5	10
Sub147	81.50	0.5	10
Sub148	80.50	0.5	10
Sub149	85.50	0.5	10
Sub150	85.50	0.5	10
Sub151	85.50	0.5	10
Sub152	85.50	0.5	10
Sub153	79.50	0.5	10
Sub154	97.50	0.5	10
Sub155	86.50	0.5	10
Sub156	89.50	0.5	10
Sub157	87.50	0.5	10
Sub158	88.50	0.5	10
Sub159	87.50	0.5	10
Sub160	86.50	0.5	10
Sub161	86.50	0.5	10
Sub162	86.50	0.5	10
Sub163	86.50	0.5	10
Sub164	79.50	0.5	10
Sub165	95.50	0.5	10
Sub166	94.50	0.5	10
Sub167	97.50	0.5	10
Sub168	86.50	0.5	10
Sub169	86.50	0.5	10
Sub170	86.50	0.5	10
Sub171	86.50	0.5	10
Sub172	86.50	0.5	10
Sub173	86.50	0.5	10
Sub174	86.50	0.5	10
Sub175	97.50	0.5	10
Sub176	83.50	0.5	10
Sub177	85.50	0.5	10
Sub178	80.50	0.5	10
Sub179	85.50	0.5	10
Sub180	97.50	0.5	10
Sub181	86.50	0.5	10
Sub182	85.50	0.5	10
Sub183	78.50	0.5	10
Sub184	81.50	0.5	10
Sub185	78.50	0.5	10
Sub186	78.50	0.5	10
Sub187	73.50	0.5	10
Sub188	71.50	0.5	10
Sub189	71.50	0.5	10
Sub190	71.50	0.5	10
Sub191	71.50	0.5	10
Sub192	71.50	0.5	10
Sub193	72.50	0.5	10
Sub194	90.50	0.5	10
Sub195	91.50	0.5	10
Sub196	91.50	0.5	10
Sub197	88.50	0.5	10
Sub198	87.50	0.5	10
Sub199	86.50	0.5	10
Sub200	86.50	0.5	10

Sub201	91.50	0.5	10
Sub202	86.50	0.5	10
Sub203	86.50	0.5	10
Sub204	86.50	0.5	10
Sub205	91.50	0.5	10
Sub206	91.50	0.5	10
Sub207	86.50	0.5	10
Sub208	87.50	0.5	10
Sub209	88.50	0.5	10
Sub210	87.50	0.5	10
Sub211	87.50	0.5	10
Sub212	87.50	0.5	10
Sub213	88.50	0.5	10
Sub214	87.50	0.5	10
Sub215	87.50	0.5	10
Sub216	85.50	0.5	10
Sub217	87.50	0.5	10
Sub218	87.50	0.5	10
Sub219	91.50	0.5	10
Sub220	88.50	0.5	10
Sub221	91.50	0.5	10
Sub223	88.50	0.5	10
Sub224	89.50	0.5	10
Sub225	87.50	0.5	10
Sub226	87.50	0.5	10
Sub227	87.50	0.5	10
Sub228	87.50	0.5	10
Sub229	88.50	0.5	10
Sub230	88.50	0.5	10
Sub231	88.50	0.5	10
Sub232	87.50	0.5	10
Sub233	88.50	0.5	10
Sub234	87.50	0.5	10
Sub235	87.50	0.5	10
Sub236	87.50	0.5	10
Sub237	87.50	0.5	10
Sub238	87.50	0.5	10
Sub239	87.50	0.5	10
Sub240	87.50	0.5	10
Sub242	86.50	0.5	10
Sub243	89.50	0.5	10
Sub244	88.50	0.5	10
Sub245	83.50	0.5	10
Sub246	87.50	0.5	10
Sub247	88.50	0.5	10
Sub248	89.50	0.5	10
Sub249	88.50	0.5	10
Sub250	88.50	0.5	10
Sub251	88.50	0.5	10
Sub252	87.50	0.5	10
Sub254	99.50	0.5	10
Sub255	99.50	0.5	10
Sub256	99.50	0.5	10
Sub257	99.50	0.5	10
Sub258	99.50	0.5	10
Sub259	79.50	0.5	10
Sub260	79.50	0.5	10
Sub261	80.50	0.5	10
Sub262	79.50	0.5	10
Sub263	91.50	0.5	10
Sub264	88.50	0.5	10

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Sub265          86.50   0.5     10
Sub266          88.50   0.5     10
Sub267          85.50   0.5     10
Sub268          88.50   0.5     10
Sub269          87.50   0.5     10
Sub270          88.50   0.5     10
Sub271          87.50   0.5     10
Sub272          88.50   0.5     10
Sub273          87.50   0.5     10
Sub274          84.50   0.5     10
Sub275          88.50   0.5     10
Sub276          85.50   0.5     10
Sub277          88.50   0.5     10
Sub278          88.50   0.5     10
Sub279          88.50   0.5     10
Sub280          89.50   0.5     10
Sub281          87.50   0.5     10
Sub282          88.50   0.5     10
Sub283          85.50   0.5     10
Sub284          88.50   0.5     10
Sub285          88.50   0.5     10
Sub286          87.50   0.5     10
Sub287          87.50   0.5     10
Sub288          87.50   0.5     10
Sub289          87.50   0.5     10
Sub290          87.50   0.5     10
Sub291          85.50   0.5     10
Sub292          85.50   0.5     10
Sub293          85.50   0.5     10
Sub294          87.50   0.5     10
Sub295          87.50   0.5     10
Sub296          88.50   0.5     10
Sub297          85.50   0.5     10
Sub298          88.50   0.5     10
Sub299          87.50   0.5     10
Sub300          88.50   0.5     10
Sub301          88.50   0.5     10
Sub302          86.50   0.5     10
Sub305          88.50   0.5     10
Sub306          88.50   0.5     10
Sub322          86.50   0.5     10

[LID_CONTROLS]
;;      Type/Layer      Parameters
;;--------------        ----------      ----------
Ditch           VS
Ditch           SURFACE         1000    0.1     0.1     5       2

ITLoam1         IT
ITLoam1         SURFACE         64      0       0.11    0.5     5
ITLoam1         STORAGE         1000    0.4     .56     0
ITLoam1         DRAIN           1.0     0.5     200     6

ITLoam2         IT
ITLoam2         SURFACE         64      0       0.11    0.5     5
ITLoam2         STORAGE         1000    0.4     .56     0
ITLoam2         DRAIN           1.0     0.5     200     6

ITLoam3         IT
ITLoam3         SURFACE         64      0       0.11    0.5     5
ITLoam3         STORAGE         1000    0.4     .56     0
```

ITLoam3	DRAIN	1.0	0.5	200	6			
ITSand&Clay1	IT							
ITSand&Clay1	SURFACE	64	0.0	0.11	0.5	5		
ITSand&Clay1	STORAGE	1000	0.4	1.44	0			
ITSand&Clay1	DRAIN	1.0	0.5	200	6			
ITSand&Clay2	IT							
ITSand&Clay2	SURFACE	64	0.0	0.11	0.5	5		
ITSand&Clay2	STORAGE	1000	0.4	1.44	0			
ITSand&Clay2	DRAIN	1.0	0.5	200	6			
ITSand&Clay3	IT							
ITSand&Clay3	SURFACE	64	0.0	0.11	0.5	5		
ITSand&Clay3	STORAGE	1000	0.4	1.44	0			
ITSand&Clay3	DRAIN	1.0	0.5	200	6			
PermeablePavement1	PP							
PermeablePavement1	SURFACE	4	0.0	0.014	2.5	5		
PermeablePavement1	PAVEMENT	80	.67	0.9	4000	100		
PermeablePavement1	STORAGE	450	.4	2.21	0			
PermeablePavement1	DRAIN	10.0	0.5	50	6			
PermeablePavement2	PP							
PermeablePavement2	SURFACE	4	0.0	0.014	2.5	5		
PermeablePavement2	PAVEMENT	80	.67	0.9	4000	100		
PermeablePavement2	STORAGE	450	.4	2.21	0			
PermeablePavement2	DRAIN	10.0	0.5	50	6			
PermeablePavement3	PP							
PermeablePavement3	SURFACE	4	0.0	0.014	2.5	5		
PermeablePavement3	PAVEMENT	80	.67	0.9	4000	100		
PermeablePavement3	STORAGE	450	.4	2.21	0			
PermeablePavement3	DRAIN	10.0	0.5	50	6			
RainBarrel1	RB							
RainBarrel1	STORAGE	863.6	0.75	10	0			
RainBarrel1	DRAIN	2204	0.5	0	24			
RainBarrel2	RB							
RainBarrel2	STORAGE	863.6	0.75	10	0			
RainBarrel2	DRAIN	2204	0.5	0	24			
RainBarrel3	RB							
RainBarrel3	STORAGE	863.6	0.75	10	0			
RainBarrel3	DRAIN	2204	0.5	0	24			
RainGardenSand1	BC							
RainGardenSand1	SURFACE	150	0.1	0.03	2.5	5		
RainGardenSand1	SOIL 500	0.4	0.25	0.15	40	6	75	
RainGardenSand1	STORAGE	0	0.75	4	0			
RainGardenSand1	DRAIN	0	0.5	0	6			
RainGardenSand2	BC							
RainGardenSand2	SURFACE	150	0.1	0.03	2.5	5		
RainGardenSand2	SOIL	500	0.4	0.25	0.15	40	6	75
RainGardenSand2	STORAGE	0	0.75	4	0			
RainGardenSand2	DRAIN	0	0.5	0	6			
RainGardenSand3	BC							
RainGardenSand3	SURFACE	150	0.1	0.03	2.5	5		

RainGardenSand3	SOIL	500	0.4	0.25	0.15	40	6	75
RainGardenSand3	STORAGE	0	0.75	4	0			
RainGardenSand3	DRAIN	0	0.5	0	6			
BioreLoam1	BC							
BioreLoam1	SURFACE	200	0.1	.03	2.5	5		
BioreLoam1	SOIL	1000	0.4	0.25	0.15	40	6.0	75
BioreLoam1	STORAGE	300	0.4	0.56	0			
BioreLoam1	DRAIN	15.8	0.5	50	6			
BioreLoam2	BC							
BioreLoam2	SURFACE	200	0.1	.03	2.5	5		
BioreLoam2	SOIL	1000	0.4	0.25	0.15	40	6.0	75
BioreLoam2	STORAGE	300	0.4	0.56	0			
BioreLoam2	DRAIN	15.8	0.5	50	6			
BioreLoam3	BC							
BioreLoam3	SURFACE	200	0.1	.03	2.5	5		
BioreLoam3	SOIL	1000	0.4	0.25	0.15	40	6.0	75
BioreLoam3	STORAGE	300	0.4	0.56	0			
BioreLoam3	DRAIN	15.8	0.5	50	6			
RainGardenClay&Loam1	BC							
RainGardenClay&Loam1	SURFACE	150	0.1	0.03	2.5	5		
RainGardenClay&Loam1	SOIL	500	0.4	0.25	0.15	40	6	75
RainGardenClay&Loam1	STORAGE	0	0.75	2.21	0			
RainGardenClay&Loam1	DRAIN	0	0.5	0	6			
RainGardenClay&Loam2	BC							
RainGardenClay&Loam2	SURFACE	150	0.1	0.03	2.5	5		
RainGardenClay&Loam2	SOIL	500	0.4	0.25	0.15	40	6	75
RainGardenClay&Loam2	STORAGE	0	0.75	2.21	0			
RainGardenClay&Loam2	DRAIN	0	0.5	0	6			
RainGardenClay&Loam3	BC							
RainGardenClay&Loam3	SURFACE	150	0.1	0.03	2.5	5		
RainGardenClay&Loam3	SOIL	500	0.4	0.25	0.15	40	6	75
RainGardenClay&Loam3	STORAGE	0	0.75	2.21	0			
RainGardenClay&Loam3	DRAIN	0	0.5	0	6			
BioretentionClay&Sand1	BC							
BioretentionClay&Sand1	SURFACE	200	0.1	0.03	2.5	5		
BioretentionClay&Sand1	SOIL	1000	0.4	0.25	0.15	40	6	75
BioretentionClay&Sand1	STORAGE	300	0.4	1.44	0			
BioretentionClay&Sand1	DRAIN	15.8	0.5	0	6			
BioretentionClay&Sand2	BC							
BioretentionClay&Sand2	SURFACE	200	0.1	0.03	2.5	5		
BioretentionClay&Sand2	SOIL	1000	0.4	0.25	0.15	40	6	75
BioretentionClay&Sand2	STORAGE	300	0.4	1.44	0			
BioretentionClay&Sand2	DRAIN	15.8	0.5	0	6			
BioretentionClay&Sand3	BC							
BioretentionClay&Sand3	SURFACE	200	0.1	0.03	2.5	5		
BioretentionClay&Sand3	SOIL	1000	0.4	0.25	0.15	40	6	75
BioretentionClay&Sand3	STORAGE	300	0.4	1.44	0			
BioretentionClay&Sand3	DRAIN	15.8	0.5	0	6			
SingleSubSwale	VS							
SingleSubSwale	SURFACE	300	.1	0.035	.6	2.5		

[LID_USAGE]

;;Subcatchment	LID Process	Number	Area	Width	InitSatur	FromImprv	ToPerv
;;--------------	----------------	-------	----------	----------	----------	----------	----------
Sub1	RainBarrel3	1	0.232	0	0	29	1
Sub1	PermeablePavement3	1	50	6	10	2	0
Sub1	RainGardenSand3	1	10	4	50	18	0
Sub6	RainBarrel2	1	0.232	0	0	29	1
Sub6	PermeablePavement2	1	50	6	10	2	0
Sub6	RainGardenSand2	1	10	4	50	18	0
Sub8	RainBarrel2	1	0.232	0	0	29	1
Sub8	PermeablePavement2	1	50	6	10	2	0
Sub8	RainGardenSand2	1	10	4	50	18	0
Sub9	RainBarrel2	1	0.232	0	0	29	1
Sub9	PermeablePavement2	1	50	6	10	2	0
Sub9	RainGardenSand2	1	10	4	50	18	0
Sub14	RainBarrel1	1	0.232	0	0	29	1
Sub14	PermeablePavement1	1	50	6	10	2	0
Sub14	RainGardenSand1	1	10	4	50	18	0
Sub14	ITSand&Clay1	1	100	1	10	22	0
Sub15	RainBarrel2	1	0.232	0	0	29	1
Sub15	PermeablePavement2	1	50	6	10	2	0
Sub15	RainGardenSand2	1	10	4	50	18	0
Sub16	RainBarrel1	1	0.232	0	0	29	1
Sub16	PermeablePavement1	1	50	6	10	2	0
Sub16	RainGardenSand1	1	10	4	50	18	0
Sub17	RainBarrel2	1	0.232	0	0	29	1
Sub17	PermeablePavement2	1	50	6	10	2	0
Sub17	RainGardenSand2	1	10	4	50	18	0
Sub18	RainBarrel1	1	0.232	0	0	29	1
Sub18	PermeablePavement1	1	50	6	10	2	0
Sub18	RainGardenSand1	1	10	4	50	18	0
Sub19	RainBarrel2	1	0.232	0	0	29	1
Sub19	PermeablePavement2	1	50	6	10	2	0
Sub19	RainGardenSand2	1	10	4	50	18	0
Sub21	RainBarrel1	1	0.232	0	0	29	1
Sub21	PermeablePavement1	1	50	6	10	2	0
Sub21	RainGardenSand1	1	10	4	50	18	0
Sub23	RainBarrel2	1	0.232	0	0	29	1
Sub23	PermeablePavement2	1	50	6	10	2	0
Sub23	RainGardenSand2	1	10	4	50	18	0
Sub24	RainBarrel2	1	0.232	0	0	29	1
Sub24	PermeablePavement2	1	50	6	10	2	0
Sub24	RainGardenSand2	1	10	4	50	18	0
Sub25	RainBarrel2	1	0.232	0	0	29	1
Sub25	PermeablePavement2	1	50	6	10	2	0
Sub25	RainGardenSand2	1	10	4	50	18	0
Sub26	RainBarrel2	1	0.232	0	0	29	1
Sub26	PermeablePavement2	1	50	6	10	2	0
Sub26	RainGardenSand2	1	10	4	50	18	0
Sub27	RainBarrel2	1	0.232	0	0	29	1
Sub27	PermeablePavement2	1	50	6	10	2	0
Sub27	RainGardenSand2	1	10	4	50	18	0
Sub28	RainBarrel1	1	0.232	0	0	29	1
Sub28	PermeablePavement1	1	50	6	10	2	0
Sub28	RainGardenSand1	1	10	4	50	18	0
Sub29	RainBarrel1	1	0.232	0	0	29	1
Sub29	PermeablePavement1	1	50	6	10	2	0
Sub29	RainGardenSand1	1	10	4	50	18	0
Sub30	RainBarrel2	1	0.232	0	0	29	1
Sub30	PermeablePavement2	1	50	6	10	2	0
Sub30	RainGardenSand2	1	10	4	50	18	0

Sub30	ITSand&Clay2	1	100	1	10	22	0	
Sub31	RainBarrel2	1	0.232	0	0	29	1	
Sub31	PermeablePavement2	1	50	6	10	2	0	
Sub31	RainGardenSand2	1	10	4	50	18	0	
Sub32	RainBarrel2	1	0.232	0	0	29	1	
Sub32	PermeablePavement2	1	50	6	10	2	0	
Sub32	RainGardenSand2	1	10	4	50	18	0	
Sub33	RainBarrel2	1	0.232	0	0	29	1	
Sub33	PermeablePavement2	1	50	6	10	2	0	
Sub33	RainGardenSand2	1	10	4	50	18	0	
Sub34	RainBarrel2	1	0.232	0	0	29	1	
Sub34	PermeablePavement2	1	50	6	10	2	0	
Sub34	RainGardenSand2	1	10	4	50	18	0	
Sub35	RainBarrel2	1	0.232	0	0	29	1	
Sub35	PermeablePavement2	1	50	6	10	2	0	
Sub35	RainGardenSand2	1	10	4	50	18	0	
Sub36	RainBarrel2	1	0.232	0	0	29	1	
Sub36	PermeablePavement2	1	50	6	10	2	0	
Sub36	RainGardenSand2	1	10	4	50	18	0	
Sub37	RainBarrel3	1	0.232	0	0	29	1	
Sub37	PermeablePavement3	1	50	6	10	2	0	
Sub37	RainGardenClay&Loam3		1	10	4	50	18	0
Sub38	RainBarrel3	1	0.232	0	0	29	1	
Sub38	PermeablePavement3	1	50	6	10	2	0	
Sub38	RainGardenClay&Loam3		1	10	4	50	18	0
Sub39	RainBarrel2	1	0.232	0	0	29	1	
Sub39	PermeablePavement2	1	50	6	10	2	0	
Sub39	RainGardenClay&Loam2		1	10	4	50	18	0
Sub40	RainBarrel2	1	0.232	0	0	29	1	
Sub40	PermeablePavement2	1	50	6	10	2	0	
Sub40	RainGardenClay&Loam2		1	10	4	50	18	0
Sub41	RainBarrel2	1	0.232	0	0	29	1	
Sub41	PermeablePavement2	1	50	6	10	2	0	
Sub41	RainGardenClay&Loam2		1	10	4	50	18	0
Sub42	RainBarrel2	1	0.232	0	0	29	1	
Sub42	PermeablePavement2	1	50	6	10	2	0	
Sub42	RainGardenClay&Loam2		1	10	4	50	18	0
Sub46	RainBarrel2	1	0.232	0	0	29	1	
Sub46	PermeablePavement2	1	50	6	10	2	0	
Sub46	RainGardenClay&Loam2		1	10	4	50	18	0
Sub47	RainBarrel2	1	0.232	0	0	29	1	
Sub47	PermeablePavement2	1	50	6	10	2	0	
Sub47	RainGardenClay&Loam2		1	10	4	50	18	0
Sub48	RainBarrel2	1	0.232	0	0	29	1	
Sub48	PermeablePavement2	1	50	6	10	2	0	
Sub48	RainGardenClay&Loam2		1	10	4	50	18	0
Sub49	RainBarrel2	1	0.232	0	0	29	1	
Sub49	PermeablePavement2	1	50	6	10	2	0	
Sub49	RainGardenClay&Loam2		1	10	4	50	18	0
Sub50	RainBarrel2	1	0.232	0	0	29	1	
Sub50	PermeablePavement2	1	50	6	10	2	0	
Sub50	RainGardenClay&Loam2		1	10	4	50	18	0
Sub51	RainBarrel2	1	0.232	0	0	29	1	
Sub51	PermeablePavement2	1	50	6	10	2	0	
Sub51	RainGardenClay&Loam2		1	10	4	50	18	0
Sub52	RainBarrel2	1	0.232	0	0	29	1	
Sub52	PermeablePavement2	1	50	6	10	2	0	
Sub52	RainGardenClay&Loam2		1	10	4	50	18	0
Sub53	RainBarrel2	1	0.232	0	0	29	1	
Sub53	PermeablePavement2	1	50	6	10	2	0	
Sub53	RainGardenClay&Loam2		1	10	4	50	18	0

Sub54	RainBarrel2	1	0.232	0	0	29	1	
Sub54	PermeablePavement2	1	50	6	10	2	0	
Sub54	RainGardenClay&Loam2		1	10	4	50	18	0
Sub55	RainBarrel2	1	0.232	0	0	29	1	
Sub55	PermeablePavement2	1	50	6	10	2	0	
Sub55	RainGardenClay&Loam2		1	10	4	50	18	0
Sub59	RainBarrel2	1	0.232	0	0	29	1	
Sub59	PermeablePavement2	1	50	6	10	2	0	
Sub59	RainGardenClay&Loam2		1	10	4	50	18	0
Sub60	RainBarrel2	1	0.232	0	0	29	1	
Sub60	PermeablePavement2	1	50	6	10	2	0	
Sub60	RainGardenClay&Loam2		1	10	4	50	18	0
Sub60	ITLoam2	1	100	1	10	22	0	
Sub61	RainBarrel2	1	0.232	0	0	29	1	
Sub61	PermeablePavement2	1	50	6	10	2	0	
Sub61	RainGardenClay&Loam2		1	10	4	50	18	0
Sub62	RainBarrel2	1	0.232	0	0	29	1	
Sub62	PermeablePavement2	1	50	6	10	2	0	
Sub62	RainGardenClay&Loam2		1	10	4	50	18	0
Sub64	RainBarrel3	1	0.232	0	0	29	1	
Sub64	PermeablePavement3	1	50	6	10	2	0	
Sub64	RainGardenClay&Loam3		1	10	4	50	18	0
Sub65	RainBarrel2	1	0.232	0	0	29	1	
Sub65	PermeablePavement2	1	50	6	10	2	0	
Sub65	RainGardenClay&Loam2		1	10	4	50	18	0
Sub66	RainBarrel2	1	0.232	0	0	29	1	
Sub66	PermeablePavement2	1	50	6	10	2	0	
Sub66	RainGardenClay&Loam2		1	10	4	50	18	0
Sub67	RainBarrel2	1	0.232	0	0	29	1	
Sub67	PermeablePavement2	1	50	6	10	2	0	
Sub67	RainGardenClay&Loam2		1	10	4	50	18	0
Sub67	ITLoam2	1	100	1	10	22	0	
Sub68	RainBarrel2	1	0.232	0	0	29	1	
Sub68	PermeablePavement2	1	50	6	10	2	0	
Sub68	RainGardenClay&Loam2		1	10	4	50	18	0
Sub70	RainBarrel2	1	0.232	0	0	29	1	
Sub70	PermeablePavement2	1	50	6	10	2	0	
Sub70	RainGardenClay&Loam2		1	10	4	50	18	0
Sub71	RainBarrel2	1	0.232	0	0	29	1	
Sub71	PermeablePavement2	1	50	6	10	2	0	
Sub71	RainGardenClay&Loam2		1	10	4	50	18	0
Sub72	RainBarrel2	1	0.232	0	0	29	1	
Sub72	PermeablePavement2	1	50	6	10	2	0	
Sub72	RainGardenClay&Loam2		1	10	4	50	18	0
Sub73	RainBarrel2	1	0.232	0	0	29	1	
Sub73	PermeablePavement2	1	50	6	10	2	0	
Sub73	RainGardenClay&Loam2		1	10	4	50	18	0
Sub74	RainBarrel2	1	0.232	0	0	29	1	
Sub74	PermeablePavement2	1	50	6	10	2	0	
Sub74	RainGardenSand2	1	10	4	50	18	0	
Sub75	RainBarrel2	1	0.232	0	0	29	1	
Sub75	PermeablePavement2	1	50	6	10	2	0	
Sub75	RainGardenSand2	1	10	4	50	18	0	
Sub75	ITSand&Clay2	1	100	1	10	22	0	
Sub76	RainBarrel2	1	0.232	0	0	29	1	
Sub76	PermeablePavement2	1	50	6	10	2	0	
Sub76	RainGardenSand2	1	10	4	50	18	0	
Sub77	RainBarrel3	1	0.232	0	0	29	1	
Sub77	PermeablePavement3	1	50	6	10	2	0	
Sub77	RainGardenSand3	1	10	4	50	18	0	
Sub77	ITSand&Clay3	1	100	1	10	22	0	

Sub78	RainBarrel2	1	0.232	0	0	29	1	
Sub78	PermeablePavement2	1	50	6	10	2	0	
Sub78	RainGardenSand2	1	10	4	50	18	0	
Sub79	RainBarrel1	1	0.232	0	0	29	1	
Sub79	PermeablePavement1	1	50	6	10	2	0	
Sub79	RainGardenSand1	1	10	4	50	18	0	
Sub81	RainBarrel2	1	0.232	0	0	29	1	
Sub81	PermeablePavement2	1	50	6	10	2	0	
Sub81	RainGardenSand2	1	10	4	50	18	0	
Sub82	RainBarrel2	1	0.232	0	0	29	1	
Sub82	PermeablePavement2	1	50	6	10	2	0	
Sub82	RainGardenClay&Loam2		1	10	4	50	18	0
Sub83	RainBarrel2	1	0.232	0	0	29	1	
Sub83	PermeablePavement2	1	50	6	10	2	0	
Sub83	RainGardenSand2	1	10	4	50	18	0	
Sub84	RainBarrel2	1	0.232	0	0	29	1	
Sub84	PermeablePavement2	1	50	6	10	2	0	
Sub84	RainGardenClay&Loam2		1	10	4	50	18	0
Sub85	RainBarrel2	1	0.232	0	0	29	1	
Sub85	PermeablePavement2	1	50	6	10	2	0	
Sub85	RainGardenClay&Loam2		1	10	4	50	18	0
Sub86	RainBarrel2	1	0.232	0	0	29	1	
Sub86	PermeablePavement2	1	50	6	10	2	0	
Sub86	RainGardenClay&Loam2		1	10	4	50	18	0
Sub88	RainBarrel2	1	0.232	0	0	29	1	
Sub88	PermeablePavement2	1	50	6	10	2	0	
Sub88	RainGardenClay&Loam2		1	10	4	50	18	0
Sub89	RainBarrel2	1	0.232	0	0	29	1	
Sub89	PermeablePavement2	1	50	6	10	2	0	
Sub89	RainGardenClay&Loam2		1	10	4	50	18	0
Sub90	RainBarrel2	1	0.232	0	0	29	1	
Sub90	PermeablePavement2	1	50	6	10	2	0	
Sub90	RainGardenClay&Loam2		1	10	4	50	18	0
Sub91	RainBarrel2	1	0.232	0	0	29	1	
Sub91	PermeablePavement2	1	50	6	10	2	0	
Sub91	RainGardenClay&Loam2		1	10	4	50	18	0
Sub92	RainBarrel1	1	0.232	0	0	29	1	
Sub92	PermeablePavement1	1	50	6	10	2	0	
Sub92	RainGardenClay&Loam1		1	10	4	50	18	0
Sub93	RainBarrel2	1	0.232	0	0	29	1	
Sub93	PermeablePavement2	1	50	6	10	2	0	
Sub93	RainGardenClay&Loam2		1	10	4	50	18	0
Sub96	RainBarrel3	1	0.232	0	0	29	1	
Sub96	PermeablePavement3	1	50	6	10	2	0	
Sub96	RainGardenClay&Loam3		1	10	4	50	18	0
Sub97	RainBarrel3	1	0.232	0	0	29	1	
Sub97	PermeablePavement3	1	50	6	10	2	0	
Sub97	RainGardenClay&Loam3		1	10	4	50	18	0
Sub98	RainBarrel2	1	0.232	0	0	29	1	
Sub98	PermeablePavement2	1	50	6	10	2	0	
Sub98	RainGardenClay&Loam2		1	10	4	50	18	0
Sub99	RainBarrel2	1	0.232	0	0	29	1	
Sub99	PermeablePavement2	1	50	6	10	2	0	
Sub99	RainGardenClay&Loam2		1	10	4	50	18	0
Sub100	RainBarrel1	1	0.232	0	0	29	1	
Sub100	PermeablePavement1	1	50	6	10	2	0	
Sub100	RainGardenClay&Loam1		1	10	4	50	18	0
Sub101	RainBarrel3	1	0.232	0	0	29	1	
Sub101	PermeablePavement3	1	50	6	10	2	0	
Sub101	RainGardenClay&Loam3		1	10	4	50	18	0
Sub102	RainBarrel2	1	0.232	0	0	29	1	

Sub102	PermeablePavement2	1	50	6	10	2	0	
Sub102	RainGardenClay&Loam2		1	10	4	50	18	0
Sub103	RainBarrel3	1	0.232	0	0	29	1	
Sub103	PermeablePavement3	1	50	6	10	2	0	
Sub103	RainGardenClay&Loam3		1	10	4	50	18	0
Sub104	RainBarrel2	1	0.232	0	0	29	1	
Sub104	PermeablePavement2	1	50	6	10	2	0	
Sub104	RainGardenClay&Loam2		1	10	4	50	18	0
Sub105	RainBarrel3	1	0.232	0	0	29	1	
Sub105	PermeablePavement3	1	50	6	10	2	0	
Sub105	RainGardenClay&Loam3		1	10	4	50	18	0
Sub105	ITLoam3	1	100	1	10	22	0	
Sub107	RainBarrel2	1	0.232	0	0	29	1	
Sub107	PermeablePavement2	1	50	6	10	2	0	
Sub107	RainGardenClay&Loam2		1	10	4	50	18	0
Sub108	RainBarrel3	1	0.232	0	0	29	1	
Sub108	PermeablePavement3	1	50	6	10	2	0	
Sub108	RainGardenClay&Loam3		1	10	4	50	18	0
Sub109	RainBarrel2	1	0.232	0	0	29	1	
Sub109	PermeablePavement2	1	50	6	10	2	0	
Sub109	RainGardenClay&Loam2		1	10	4	50	18	0
Sub110	RainBarrel2	1	0.232	0	0	29	1	
Sub110	PermeablePavement2	1	50	6	10	2	0	
Sub110	RainGardenClay&Loam2		1	10	4	50	18	0
Sub111	RainBarrel3	1	0.232	0	0	29	1	
Sub111	PermeablePavement3	1	50	6	10	2	0	
Sub111	RainGardenClay&Loam3		1	10	4	50	18	0
Sub112	RainBarrel3	1	0.232	0	0	29	1	
Sub112	PermeablePavement3	1	50	6	10	2	0	
Sub112	RainGardenClay&Loam3		1	10	4	50	18	0
Sub113	RainBarrel3	1	0.232	0	0	29	1	
Sub113	PermeablePavement3	1	50	6	10	2	0	
Sub113	RainGardenClay&Loam3		1	10	4	50	18	0
Sub113	Ditch	1	60	4	10	29	0	
Sub114	RainBarrel3	1	0.232	0	0	29	1	
Sub114	PermeablePavement3	1	50	6	10	2	0	
Sub114	RainGardenClay&Loam3		1	10	4	50	18	0
Sub114	Ditch	1	60	4	10	29	0	
Sub115	RainBarrel2	1	0.232	0	0	29	1	
Sub115	PermeablePavement2	1	50	6	10	2	0	
Sub115	RainGardenClay&Loam2		1	10	4	50	18	0
Sub115	Ditch	1	60	4	10	29	0	
Sub116	RainBarrel2	1	0.232	0	0	29	1	
Sub116	PermeablePavement2	1	50	6	10	2	0	
Sub116	RainGardenClay&Loam2		1	10	4	50	18	0
Sub116	ITLoam2	1	100	1	10	22	0	
Sub116	Ditch	1	60	4	10	29	0	
Sub118	RainBarrel3	1	0.232	0	0	29	1	
Sub118	PermeablePavement3	1	50	6	10	2	0	
Sub118	RainGardenClay&Loam3		1	10	4	50	18	0
Sub119	RainBarrel3	1	0.232	0	0	29	1	
Sub119	PermeablePavement3	1	50	6	10	2	0	
Sub119	RainGardenClay&Loam3		1	10	4	50	18	0
Sub120	RainBarrel3	1	0.232	0	0	29	1	
Sub120	PermeablePavement3	1	50	6	10	2	0	
Sub120	RainGardenClay&Loam3		1	10	4	50	18	0
Sub121	RainBarrel3	1	0.232	0	0	29	1	
Sub121	PermeablePavement3	1	50	6	10	2	0	
Sub121	RainGardenClay&Loam3		1	10	4	50	18	0
Sub122	RainBarrel2	1	0.232	0	0	29	1	
Sub122	PermeablePavement2	1	50	6	10	2	0	

Sub122	RainGardenClay&Loam2	1	10	4	50	18	0
Sub123	RainBarrel2	1	0.232	0	0	29	1
Sub123	PermeablePavement2	1	50	6	10	2	0
Sub123	RainGardenClay&Loam2	1	10	4	50	18	0
Sub124	RainBarrel3	1	0.232	0	0	29	1
Sub124	PermeablePavement3	1	50	6	10	2	0
Sub124	RainGardenClay&Loam3	1	10	4	50	18	0
Sub125	RainBarrel3	1	0.232	0	0	29	1
Sub125	PermeablePavement3	1	50	6	10	2	0
Sub125	RainGardenClay&Loam3	1	10	4	50	18	0
Sub126	RainBarrel2	1	0.232	0	0	29	1
Sub126	PermeablePavement2	1	50	6	10	2	0
Sub126	RainGardenClay&Loam2	1	10	4	50	18	0
Sub127	RainBarrel2	1	0.232	0	0	29	1
Sub127	PermeablePavement2	1	50	6	10	2	0
Sub127	RainGardenClay&Loam2	1	10	4	50	18	0
Sub128	RainBarrel2	1	0.232	0	0	29	1
Sub128	PermeablePavement2	1	50	6	10	2	0
Sub128	RainGardenClay&Loam2	1	10	4	50	18	0
Sub129	RainBarrel2	1	0.232	0	0	29	1
Sub129	PermeablePavement2	1	50	6	10	2	0
Sub129	RainGardenClay&Loam2	1	10	4	50	18	0
Sub132	RainBarrel3	1	0.232	0	0	29	1
Sub132	PermeablePavement3	1	50	6	10	2	0
Sub132	RainGardenClay&Loam3	1	10	4	50	18	0
Sub133	RainBarrel2	1	0.232	0	0	29	1
Sub133	PermeablePavement2	1	50	6	10	2	0
Sub133	RainGardenClay&Loam2	1	10	4	50	18	0
Sub134	RainBarrel2	1	0.232	0	0	29	1
Sub134	PermeablePavement2	1	50	6	10	2	0
Sub134	RainGardenClay&Loam2	1	10	4	50	18	0
Sub135	RainBarrel2	1	0.232	0	0	29	1
Sub135	PermeablePavement2	1	50	6	10	2	0
Sub135	RainGardenClay&Loam2	1	10	4	50	18	0
Sub136	RainBarrel2	1	0.232	0	0	29	1
Sub136	PermeablePavement2	1	50	6	10	2	0
Sub136	RainGardenClay&Loam2	1	10	4	50	18	0
Sub137	RainBarrel2	1	0.232	0	0	29	1
Sub137	PermeablePavement2	1	50	6	10	2	0
Sub137	RainGardenClay&Loam2	1	10	4	50	18	0
Sub138	RainBarrel2	1	0.232	0	0	29	1
Sub138	PermeablePavement2	1	50	6	10	2	0
Sub138	RainGardenClay&Loam2	1	10	4	50	18	0
Sub139	RainBarrel2	1	0.232	0	0	29	1
Sub139	PermeablePavement2	1	50	6	10	2	0
Sub139	RainGardenClay&Loam2	1	10	4	50	18	0
Sub140	RainBarrel2	1	0.232	0	0	29	1
Sub140	PermeablePavement2	1	50	6	10	2	0
Sub140	RainGardenClay&Loam2	1	10	4	50	18	0
Sub141	RainBarrel2	1	0.232	0	0	29	1
Sub141	PermeablePavement2	1	50	6	10	2	0
Sub141	RainGardenClay&Loam2	1	10	4	50	18	0
Sub143	RainBarrel3	1	0.232	0	0	29	1
Sub143	PermeablePavement3	1	50	6	10	2	0
Sub143	RainGardenClay&Loam3	1	10	4	50	18	0
Sub144	RainBarrel2	1	0.232	0	0	29	1
Sub144	PermeablePavement2	1	50	6	10	2	0
Sub144	RainGardenClay&Loam2	1	10	4	50	18	0
Sub145	RainBarrel2	1	0.232	0	0	29	1
Sub145	PermeablePavement2	1	50	6	10	2	0
Sub145	RainGardenClay&Loam2	1	10	4	50	18	0

Sub146	RainBarrel3	1	0.232	0	0	29	1	
Sub146	PermeablePavement3	1	50	6	10	2	0	
Sub146	RainGardenClay&Loam3		1	10	4	50	18	0
Sub147	RainBarrel1	1	0.232	0	0	29	1	
Sub147	PermeablePavement1	1	50	6	10	2	0	
Sub147	RainGardenClay&Loam1		1	10	4	50	18	0
Sub148	RainBarrel1	1	0.232	0	0	29	1	
Sub148	PermeablePavement1	1	50	6	10	2	0	
Sub148	RainGardenClay&Loam1		1	10	4	50	18	0
Sub149	RainBarrel2	1	0.232	0	0	29	1	
Sub149	PermeablePavement2	1	50	6	10	2	0	
Sub149	RainGardenClay&Loam2		1	10	4	50	18	0
Sub150	RainBarrel2	1	0.232	0	0	29	1	
Sub150	PermeablePavement2	1	50	6	10	2	0	
Sub150	RainGardenClay&Loam2		1	10	4	50	18	0
Sub151	RainBarrel2	1	0.232	0	0	29	1	
Sub151	PermeablePavement2	1	50	6	10	2	0	
Sub151	RainGardenClay&Loam2		1	10	4	50	18	0
Sub152	RainBarrel2	1	0.232	0	0	29	1	
Sub152	PermeablePavement2	1	50	6	10	2	0	
Sub152	RainGardenClay&Loam2		1	10	4	50	18	0
Sub156	RainBarrel3	1	0.232	0	0	29	1	
Sub156	PermeablePavement3	1	50	6	10	2	0	
Sub156	RainGardenClay&Loam3		1	10	4	50	18	0
Sub157	RainBarrel3	1	0.232	0	0	29	1	
Sub157	PermeablePavement3	1	50	6	10	2	0	
Sub157	RainGardenClay&Loam3		1	10	4	50	18	0
Sub158	RainBarrel3	1	0.232	0	0	29	1	
Sub158	PermeablePavement3	1	50	6	10	2	0	
Sub158	RainGardenClay&Loam3		1	10	4	50	18	0
Sub159	RainBarrel2	1	0.232	0	0	29	1	
Sub159	PermeablePavement2	1	50	6	10	2	0	
Sub159	RainGardenClay&Loam2		1	10	4	50	18	0
Sub160	RainBarrel2	1	0.232	0	0	29	1	
Sub160	PermeablePavement2	1	50	6	10	2	0	
Sub160	RainGardenClay&Loam2		1	10	4	50	18	0
Sub161	ITLoam2	1	100	1	10	22	0	
Sub161	RainBarrel2	1	0.232	0	0	29	1	
Sub161	PermeablePavement2	1	50	6	10	2	0	
Sub161	RainGardenClay&Loam2		1	10	4	50	18	0
Sub162	RainBarrel2	1	0.232	0	0	29	1	
Sub162	PermeablePavement2	1	50	6	10	2	0	
Sub162	RainGardenClay&Loam2		1	10	4	50	18	0
Sub163	RainBarrel2	1	0.232	0	0	29	1	
Sub163	PermeablePavement2	1	50	6	10	2	0	
Sub163	RainGardenClay&Loam2		1	10	4	50	18	0
Sub168	RainBarrel2	1	0.232	0	0	29	1	
Sub168	PermeablePavement2	1	50	6	10	2	0	
Sub168	RainGardenClay&Loam2		1	10	4	50	18	0
Sub169	RainBarrel2	1	0.232	0	0	29	1	
Sub169	PermeablePavement2	1	50	6	10	2	0	
Sub169	RainGardenClay&Loam2		1	10	4	50	18	0
Sub170	RainBarrel2	1	0.232	0	0	29	1	
Sub170	PermeablePavement2	1	50	6	10	2	0	
Sub170	RainGardenClay&Loam2		1	10	4	50	18	0
Sub171	RainBarrel2	1	0.232	0	0	29	1	
Sub171	PermeablePavement2	1	50	6	10	2	0	
Sub171	RainGardenClay&Loam2		1	10	4	50	18	0
Sub172	RainBarrel2	1	0.232	0	0	29	1	
Sub172	PermeablePavement2	1	50	6	10	2	0	
Sub172	RainGardenClay&Loam2		1	10	4	50	18	0

Sub173	RainBarrel2	1	0.232	0	0	29	1	
Sub173	PermeablePavement2	1	50	6	10	2	0	
Sub173	RainGardenClay&Loam2		1	10	4	50	18	0
Sub174	RainBarrel2	1	0.232	0	0	29	1	
Sub174	PermeablePavement2	1	50	6	10	2	0	
Sub174	RainGardenClay&Loam2		1	10	4	50	18	0
Sub176	RainBarrel2	1	0.232	0	0	29	1	
Sub176	PermeablePavement2	1	50	6	10	2	0	
Sub176	RainGardenClay&Loam2		1	10	4	50	18	0
Sub177	RainBarrel2	1	0.232	0	0	29	1	
Sub177	PermeablePavement2	1	50	6	10	2	0	
Sub177	RainGardenClay&Loam2		1	10	4	50	18	0
Sub178	RainBarrel1	1	0.232	0	0	29	1	
Sub178	PermeablePavement1	1	50	6	10	2	0	
Sub178	RainGardenClay&Loam1		1	10	4	50	18	0
Sub179	RainBarrel2	1	0.232	0	0	29	1	
Sub179	PermeablePavement2	1	50	6	10	2	0	
Sub179	RainGardenClay&Loam2		1	10	4	50	18	0
Sub181	RainBarrel2	1	0.232	0	0	29	1	
Sub181	PermeablePavement2	1	50	6	10	2	0	
Sub181	RainGardenClay&Loam2		1	10	4	50	18	0
Sub194	RainBarrel3	1	0.232	0	0	29	1	
Sub194	PermeablePavement3	1	50	6	10	2	0	
Sub194	RainGardenClay&Loam3		1	10	4	50	18	0
Sub195	RainBarrel3	1	0.232	0	0	29	1	
Sub195	PermeablePavement3	1	50	6	10	2	0	
Sub195	RainGardenClay&Loam3		1	10	4	50	18	0
Sub196	RainBarrel3	1	0.232	0	0	29	1	
Sub196	PermeablePavement3	1	50	6	10	2	0	
Sub196	RainGardenClay&Loam3		1	10	4	50	18	0
Sub197	RainBarrel2	1	0.232	0	0	29	1	
Sub197	PermeablePavement2	1	50	6	10	2	0	
Sub197	RainGardenClay&Loam2		1	10	4	50	18	0
Sub198	RainBarrel2	1	0.232	0	0	29	1	
Sub198	PermeablePavement2	1	50	6	10	2	0	
Sub198	RainGardenClay&Loam2		1	10	4	50	18	0
Sub199	RainBarrel2	1	0.232	0	0	29	1	
Sub199	PermeablePavement2	1	50	6	10	2	0	
Sub199	RainGardenClay&Loam2		1	10	4	50	18	0
Sub200	RainBarrel2	1	0.232	0	0	29	1	
Sub200	PermeablePavement2	1	50	6	10	2	0	
Sub200	RainGardenClay&Loam2		1	10	4	50	18	0
Sub201	RainBarrel3	1	0.232	0	0	29	1	
Sub201	PermeablePavement3	1	50	6	10	2	0	
Sub201	RainGardenClay&Loam3		1	10	4	50	18	0
Sub202	RainBarrel2	1	0.232	0	0	29	1	
Sub202	PermeablePavement2	1	50	6	10	2	0	
Sub202	RainGardenClay&Loam2		1	10	4	50	18	0
Sub203	RainBarrel1	1	0.232	0	0	29	1	
Sub203	PermeablePavement1	1	50	6	10	2	0	
Sub203	RainGardenClay&Loam1		1	10	4	50	18	0
Sub204	RainBarrel1	1	0.232	0	0	29	1	
Sub204	PermeablePavement1	1	50	6	10	2	0	
Sub204	RainGardenClay&Loam1		1	10	4	50	18	0
Sub205	RainBarrel3	1	0.232	0	0	29	1	
Sub205	PermeablePavement3	1	50	6	10	2	0	
Sub205	RainGardenClay&Loam3		1	10	4	50	18	0
Sub206	RainBarrel3	1	0.232	0	0	29	1	
Sub206	PermeablePavement3	1	50	6	10	2	0	
Sub206	RainGardenClay&Loam3		1	10	4	50	18	0
Sub207	RainBarrel2	1	0.232	0	0	29	1	

Sub207	PermeablePavement2	1	50	6	10	2	0	
Sub207	RainGardenClay&Loam2		1	10	4	50	18	0
Sub208	RainBarrel3	1	0.232	0	0	29	1	
Sub208	PermeablePavement3	1	50	6	10	2	0	
Sub208	RainGardenClay&Loam3		1	10	4	50	18	0
Sub209	RainBarrel3	1	0.232	0	0	29	1	
Sub209	PermeablePavement3	1	50	6	10	2	0	
Sub209	RainGardenClay&Loam3		1	10	4	50	18	0
Sub210	RainBarrel2	1	0.232	0	0	29	1	
Sub210	PermeablePavement2	1	50	6	10	2	0	
Sub210	RainGardenClay&Loam2		1	10	4	50	18	0
Sub211	RainBarrel2	1	0.232	0	0	29	1	
Sub211	PermeablePavement2	1	50	6	10	2	0	
Sub211	RainGardenClay&Loam2		1	10	4	50	18	0
Sub212	RainBarrel2	1	0.232	0	0	29	1	
Sub212	PermeablePavement2	1	50	6	10	2	0	
Sub212	RainGardenClay&Loam2		1	10	4	50	18	0
Sub213	RainBarrel2	1	0.232	0	0	29	1	
Sub213	PermeablePavement2	1	50	6	10	2	0	
Sub213	RainGardenClay&Loam2		1	10	4	50	18	0
Sub214	RainBarrel2	1	0.232	0	0	29	1	
Sub214	PermeablePavement2	1	50	6	10	2	0	
Sub214	RainGardenClay&Loam2		1	10	4	50	18	0
Sub215	RainBarrel2	1	0.232	0	0	29	1	
Sub215	PermeablePavement2	1	50	6	10	2	0	
Sub215	RainGardenClay&Loam2		1	10	4	50	18	0
Sub216	RainBarrel2	1	0.232	0	0	29	1	
Sub216	PermeablePavement2	1	50	6	10	2	0	
Sub216	RainGardenClay&Loam2		1	10	4	50	18	0
Sub217	RainBarrel2	1	0.232	0	0	29	1	
Sub217	PermeablePavement2	1	50	6	10	2	0	
Sub217	RainGardenClay&Loam2		1	10	4	50	18	0
Sub218	RainBarrel2	1	0.232	0	0	29	1	
Sub218	PermeablePavement2	1	50	6	10	2	0	
Sub218	RainGardenClay&Loam2		1	10	4	50	18	0
Sub219	RainBarrel3	1	0.232	0	0	29	1	
Sub219	PermeablePavement3	1	50	6	10	2	0	
Sub219	RainGardenClay&Loam3		1	10	4	50	18	0
Sub220	RainBarrel2	1	0.232	0	0	29	1	
Sub220	PermeablePavement2	1	50	6	10	2	0	
Sub220	RainGardenClay&Loam2		1	10	4	50	18	0
Sub221	RainBarrel3	1	0.232	0	0	29	1	
Sub221	PermeablePavement3	1	50	6	10	2	0	
Sub221	RainGardenClay&Loam3		1	10	4	50	18	0
Sub223	RainBarrel3	1	0.232	0	0	29	1	
Sub223	PermeablePavement3	1	50	6	10	2	0	
Sub223	RainGardenClay&Loam3		1	10	4	50	18	0
Sub224	RainBarrel3	1	0.232	0	0	29	1	
Sub224	PermeablePavement3	1	50	6	10	2	0	
Sub224	RainGardenClay&Loam3		1	10	4	50	18	0
Sub225	RainBarrel2	1	0.232	0	0	29	1	
Sub225	PermeablePavement2	1	50	6	10	2	0	
Sub225	RainGardenClay&Loam2		1	10	4	50	18	0
Sub226	RainBarrel2	1	0.232	0	0	29	1	
Sub226	PermeablePavement2	1	50	6	10	2	0	
Sub226	RainGardenClay&Loam2		1	10	4	50	18	0
Sub226	ITSand&Clay2	1	100	1	10	22	0	
Sub227	RainBarrel2	1	0.232	0	0	29	1	
Sub227	PermeablePavement2	1	50	6	10	2	0	
Sub227	RainGardenClay&Loam2		1	10	4	50	18	0
Sub228	RainBarrel2	1	0.232	0	0	29	1	

Sub228	PermeablePavement2	1	50	6	10	2	0
Sub228	RainGardenClay&Loam2	1	10	4	50	18	0
Sub229	RainBarrel2	1	0.232	0	0	29	1
Sub229	PermeablePavement2	1	50	6	10	2	0
Sub229	RainGardenClay&Loam2	1	10	4	50	18	0
Sub230	RainBarrel2	1	0.232	0	0	29	1
Sub230	PermeablePavement2	1	50	6	10	2	0
Sub230	RainGardenClay&Loam2	1	10	4	50	18	0
Sub231	RainBarrel2	1	0.232	0	0	29	1
Sub231	PermeablePavement2	1	50	6	10	2	0
Sub231	RainGardenClay&Loam2	1	10	4	50	18	0
Sub232	RainBarrel2	1	0.232	0	0	29	1
Sub232	PermeablePavement2	1	50	6	10	2	0
Sub232	RainGardenClay&Loam2	1	10	4	50	18	0
Sub233	RainBarrel2	1	0.232	0	0	29	1
Sub233	PermeablePavement2	1	50	6	10	2	0
Sub233	RainGardenClay&Loam2	1	10	4	50	18	0
Sub234	RainBarrel1	1	0.232	0	0	29	1
Sub234	PermeablePavement1	1	50	6	10	2	0
Sub234	RainGardenClay&Loam1	1	10	4	50	18	0
Sub235	RainBarrel2	1	0.232	0	0	29	1
Sub235	PermeablePavement2	1	50	6	10	2	0
Sub235	RainGardenClay&Loam2	1	10	4	50	18	0
Sub236	RainBarrel2	1	0.232	0	0	29	1
Sub236	PermeablePavement2	1	50	6	10	2	0
Sub236	RainGardenClay&Loam2	1	10	4	50	18	0
Sub237	RainBarrel2	1	0.232	0	0	29	1
Sub237	PermeablePavement2	1	50	6	10	2	0
Sub237	RainGardenClay&Loam2	1	10	4	50	18	0
Sub238	RainBarrel2	1	0.232	0	0	29	1
Sub238	PermeablePavement2	1	50	6	10	2	0
Sub238	RainGardenClay&Loam2	1	10	4	50	18	0
Sub239	RainBarrel1	1	0.232	0	0	29	1
Sub239	PermeablePavement1	1	50	6	10	2	0
Sub239	RainGardenClay&Loam1	1	10	4	50	18	0
Sub240	RainBarrel2	1	0.232	0	0	29	1
Sub240	PermeablePavement2	1	50	6	10	2	0
Sub240	RainGardenClay&Loam2	1	10	4	50	18	0
Sub242	RainBarrel1	1	0.232	0	0	29	1
Sub242	PermeablePavement1	1	50	6	10	2	0
Sub242	RainGardenClay&Loam1	1	10	4	50	18	0
Sub243	RainBarrel2	1	0.232	0	0	29	1
Sub243	PermeablePavement2	1	50	6	10	2	0
Sub243	RainGardenClay&Loam2	1	10	4	50	18	0
Sub244	RainBarrel2	1	0.232	0	0	29	1
Sub244	PermeablePavement2	1	50	6	10	2	0
Sub244	RainGardenClay&Loam2	1	10	4	50	18	0
Sub246	RainBarrel2	1	0.232	0	0	29	1
Sub246	PermeablePavement2	1	50	6	10	2	0
Sub246	RainGardenClay&Loam2	1	10	4	50	18	0
Sub247	RainBarrel2	1	0.232	0	0	29	1
Sub247	PermeablePavement2	1	50	6	10	2	0
Sub247	RainGardenClay&Loam2	1	10	4	50	18	0
Sub248	RainBarrel2	1	0.232	0	0	29	1
Sub248	PermeablePavement2	1	50	6	10	2	0
Sub248	RainGardenClay&Loam2	1	10	4	50	18	0
Sub249	RainBarrel2	1	0.232	0	0	29	1
Sub249	PermeablePavement2	1	50	6	10	2	0
Sub249	RainGardenClay&Loam2	1	10	4	50	18	0
Sub250	RainBarrel2	1	0.232	0	0	29	1
Sub250	PermeablePavement2	1	50	6	10	2	0

Sub250	RainGardenClay&Loam2	1	10	4	50	18	0
Sub251	RainBarrel2	1	0.232	0	0	29	1
Sub251	PermeablePavement2	1	50	6	10	2	0
Sub251	RainGardenClay&Loam2	1	10	4	50	18	0
Sub252	RainBarrel2	1	0.232	0	0	29	1
Sub252	PermeablePavement2	1	50	6	10	2	0
Sub252	RainGardenClay&Loam2	1	10	4	50	18	0
Sub263	RainBarrel2	1	0.232	0	0	29	1
Sub263	PermeablePavement2	1	50	6	10	2	0
Sub263	RainGardenClay&Loam2	1	10	4	50	18	0
Sub263	ITSand&Clay2	1	100	1	10	22	0
Sub264	RainBarrel2	1	0.232	0	0	29	1
Sub264	PermeablePavement2	1	50	6	10	2	0
Sub264	RainGardenClay&Loam2	1	10	4	50	18	0
Sub265	RainBarrel1	1	0.232	0	0	29	1
Sub265	PermeablePavement1	1	50	6	10	2	0
Sub265	RainGardenClay&Loam1	1	10	4	50	18	0
Sub266	RainBarrel2	1	0.232	0	0	29	1
Sub266	PermeablePavement2	1	50	6	10	2	0
Sub266	RainGardenClay&Loam2	1	10	4	50	18	0
Sub267	RainBarrel1	1	0.232	0	0	29	1
Sub267	PermeablePavement1	1	50	6	10	2	0
Sub267	RainGardenClay&Loam1	1	10	4	50	18	0
Sub268	RainBarrel2	1	0.232	0	0	29	1
Sub268	PermeablePavement2	1	50	6	10	2	0
Sub268	RainGardenClay&Loam2	1	10	4	50	18	0
Sub269	RainBarrel2	1	0.232	0	0	29	1
Sub269	PermeablePavement2	1	50	6	10	2	0
Sub269	RainGardenClay&Loam2	1	10	4	50	18	0
Sub270	RainBarrel2	1	0.232	0	0	29	1
Sub270	PermeablePavement2	1	50	6	10	2	0
Sub270	RainGardenClay&Loam2	1	10	4	50	18	0
Sub271	RainBarrel2	1	0.232	0	0	29	1
Sub271	PermeablePavement2	1	50	6	10	2	0
Sub271	RainGardenClay&Loam2	1	10	4	50	18	0
Sub272	RainBarrel3	1	0.232	0	0	29	1
Sub272	PermeablePavement3	1	50	6	10	2	0
Sub272	RainGardenClay&Loam3	1	10	4	50	18	0
Sub273	RainBarrel1	1	0.232	0	0	29	1
Sub273	PermeablePavement1	1	50	6	10	2	0
Sub273	RainGardenClay&Loam1	1	10	4	50	18	0
Sub274	RainBarrel1	1	0.232	0	0	29	1
Sub274	PermeablePavement1	1	50	6	10	2	0
Sub274	RainGardenClay&Loam1	1	10	4	50	18	0
Sub275	RainBarrel2	1	0.232	0	0	29	1
Sub275	PermeablePavement2	1	50	6	10	2	0
Sub275	RainGardenClay&Loam2	1	10	4	50	18	0
Sub277	RainBarrel2	1	0.232	0	0	29	1
Sub277	PermeablePavement2	1	50	6	10	2	0
Sub277	RainGardenClay&Loam2	1	10	4	50	18	0
Sub278	RainBarrel2	1	0.232	0	0	29	1
Sub278	PermeablePavement2	1	50	6	10	2	0
Sub278	RainGardenClay&Loam2	1	10	4	50	18	0
Sub279	RainBarrel2	1	0.232	0	0	29	1
Sub279	PermeablePavement2	1	50	6	10	2	0
Sub279	RainGardenClay&Loam2	1	10	4	50	18	0
Sub280	RainBarrel2	1	0.232	0	0	29	1
Sub280	PermeablePavement2	1	50	6	10	2	0
Sub280	RainGardenClay&Loam2	1	10	4	50	18	0
Sub280	ITSand&Clay2	1	100	1	10	22	0
Sub281	RainBarrel2	1	0.232	0	0	29	1

Sub281	PermeablePavement2	1	50	6	10	2	0	
Sub281	RainGardenClay&Loam2		1	10	4	50	18	0
Sub282	RainBarrel2	1	0.232	0	0	29	1	
Sub282	PermeablePavement2	1	50	6	10	2	0	
Sub282	RainGardenClay&Loam2		1	10	4	50	18	0
Sub283	RainBarrel1	1	0.232	0	0	29	1	
Sub283	PermeablePavement1	1	50	6	10	2	0	
Sub283	RainGardenClay&Loam1		1	10	4	50	18	0
Sub284	RainBarrel2	1	0.232	0	0	29	1	
Sub284	PermeablePavement2	1	50	6	10	2	0	
Sub284	RainGardenClay&Loam2		1	10	4	50	18	0
Sub285	RainBarrel2	1	0.232	0	0	29	1	
Sub285	PermeablePavement2	1	50	6	10	2	0	
Sub285	RainGardenClay&Loam2		1	10	4	50	18	0
Sub286	RainBarrel1	1	0.232	0	0	29	1	
Sub286	PermeablePavement1	1	50	6	10	2	0	
Sub286	RainGardenClay&Loam1		1	10	4	50	18	0
Sub287	RainBarrel2	1	0.232	0	0	29	1	
Sub287	PermeablePavement2	1	50	6	10	2	0	
Sub287	RainGardenClay&Loam2		1	10	4	50	18	0
Sub288	RainBarrel2	1	0.232	0	0	29	1	
Sub288	PermeablePavement2	1	50	6	10	2	0	
Sub288	RainGardenClay&Loam2		1	10	4	50	18	0
Sub289	RainBarrel2	1	0.232	0	0	29	1	
Sub289	PermeablePavement2	1	50	6	10	2	0	
Sub289	RainGardenClay&Loam2		1	10	4	50	18	0
Sub290	RainBarrel2	1	0.232	0	0	29	1	
Sub290	PermeablePavement2	1	50	6	10	2	0	
Sub290	RainGardenClay&Loam2		1	10	4	50	18	0
Sub291	RainBarrel2	1	0.232	0	0	29	1	
Sub291	PermeablePavement2	1	50	6	10	2	0	
Sub291	RainGardenClay&Loam2		1	10	4	50	18	0
Sub292	RainBarrel2	1	0.232	0	0	29	1	
Sub292	PermeablePavement2	1	50	6	10	2	0	
Sub292	RainGardenClay&Loam2		1	10	4	50	18	0
Sub293	RainBarrel1	1	0.232	0	0	29	1	
Sub293	PermeablePavement1	1	50	6	10	2	0	
Sub293	RainGardenClay&Loam1		1	10	4	50	18	0
Sub294	RainBarrel2	1	0.232	0	0	29	1	
Sub294	PermeablePavement2	1	50	6	10	2	0	
Sub294	RainGardenClay&Loam2		1	10	4	50	18	0
Sub295	RainBarrel2	1	0.232	0	0	29	1	
Sub295	PermeablePavement2	1	50	6	10	2	0	
Sub295	RainGardenClay&Loam2		1	10	4	50	18	0
Sub297	RainBarrel1	1	0.232	0	0	29	1	
Sub297	PermeablePavement1	1	50	6	10	2	0	
Sub297	RainGardenClay&Loam1		1	10	4	50	18	0
Sub298	RainBarrel2	1	0.232	0	0	29	1	
Sub298	PermeablePavement2	1	50	6	10	2	0	
Sub298	RainGardenClay&Loam2		1	10	4	50	18	0
Sub299	RainBarrel2	1	0.232	0	0	29	1	
Sub299	PermeablePavement2	1	50	6	10	2	0	
Sub299	RainGardenClay&Loam2		1	10	4	50	18	0
Sub300	RainBarrel2	1	0.232	0	0	29	1	
Sub300	PermeablePavement2	1	50	6	10	2	0	
Sub300	RainGardenClay&Loam2		1	10	4	50	18	0
Sub301	RainBarrel1	1	0.232	0	0	29	1	
Sub301	PermeablePavement1	1	50	6	10	2	0	
Sub301	RainGardenClay&Loam1		1	10	4	50	18	0
Sub302	RainBarrel1	1	0.232	0	0	29	1	
Sub302	PermeablePavement1	1	50	6	10	2	0	

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Sub302          RainGardenClay&Loam1     1        10       4        50       18       0
Sub305          RainBarrel1        1        0.232    0        0        29       1
Sub305          PermeablePavement1 1        50       6        10       2        0
Sub305          RainGardenClay&Loam1     1        10       4        50       18       0
Sub306          RainBarrel1        1        0.232    0        0        29       1
Sub306          PermeablePavement1 1        50       6        10       2        0
Sub306          RainGardenClay&Loam1     1        10       4        50       18       0
Sub322          RainBarrel1        1        0.232    0        0        29       1
Sub322          PermeablePavement1 1        50       6        10       2        0
Sub322          RainGardenClay&Loam1     1        10       4        50       18       0

[JUNCTIONS]
;;Junction      Invert     MaxDepth              InitDepth  SurDepth   Aponded
;;--------------  ---------- ---------- ---------- ---------- ----------
;Depth is estimated from manhole drawings and elevation.
;Invert elevation is estimated from lowest offset -0.45m.
;Ponded area is estimated.
J1       180.49     2          0          0          9
J2       180.26     2          0          0          4
J3       180.13     2.57       0          0          4
J4       180.737    2.03       0          0          9
J5       180.381    2.42       0          0          4
J6       179.363    3.64       0          0          4
J7       179.36     2.84       0          0          4
J8       180.26     2.14       0          0          4
J9       179.915    2.285      0          0          4
J10             178.406    3.704      0          0          9
J11             178.365    4.245      0          0          4
J12             178.27     4.88       0          0          4
J13             178.37     4.98       0          0          4
J17             179.88     2.35       0          0          9
J18             179.61     2.99       0          0          4
J19             179.35     3.35       0          0          4
;Entrance for culvert.  Depth estimated.
J20             180.635    2          0          0          9
;Depth estimated as surface elevation not given.
J21             180.179    2.12       0          0          4
;Depth estimated, based on surrounding surface elevation, as the node surface elevation is not given.
J22             179.994    2.81       0          0          4
J23             179.643    3.607      0          0          4
J24             179.353    3.697      0          0          3
;Depth estimated.
J25             178.415    5.0        0          0          4
;Entrance to culvert.  Values estimated.
J28             179.535    3.655      0          0          9
;Depth estimated.
J29             179.08     4.27       0          0          4
;Depth estimated.
J30             178.988    4.512      0          0          4
J31             178.917    4.453      0          0          4
;Depth estimated.
;As with others, the EI is estimated as the min offset -0.45m
J32             178.482    4.39       0          0          4
;On sidewalk so no ponded area.
J33             180.728    2.852      0          0          0
J34             180.456    2.94       0          0          0
;Depth estimated.
J35             180.247    3.25       0          0          0
;Depth estimated.
J36             177.955    5.80       0          0          4
;Depth estimated.
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J37	180.82	2.75	0	0	4
;Depth estimated.					
J38	180.496	3	0	0	4
;Depth estimated.					
J39	180.29	3.25	0	0	4
J40	179.13	4.37	0	0	4
J41	179.84	3.36	0	0	4
J42	180.82	2.43	0	0	4
J43	180.29	3.01	0	0	4
J44	179.22	4.38	0	0	4
J45	180.674	2.596	0	0	9
J46	180.442	2.838	0	0	4
J47	180.095	3.248	0	0	4
J48	179.378	4.182	0	0	4
J49	180.820	2.83	0	0	9
J50	180.550	3.13	0	0	4
J51	180.290	3.380	0	0	4
J52	179.430	4.14	0	0	4
;Entrance to culvert?? Depth estimated.					
J57	180.669	2	0	0	9
J58	180.650	3.35	0	0	9
J59	181.625	2.375	0	0	4
J60	179.560	3.80	0	0	4
;Depth estimated.					
J61	180.397	3	0	0	4
;Depth estimated.					
J62	180.225	3	0	0	4
;Depth estimated.					
;One intermediate node near this one was excluded due to a lack of data.					
J64	179.490	3.5	0	0	4
;Depth estimated.					
J66	182.005	3	0	0	2
;Depth estimated.					
J67	181.770	2	0	0	2
;Depth estimated.					
J69	181.870	2.5	0	0	4
;Depth estimated.					
J70	182.150	2	0	0	2
;Depth estimated.					
J71	181.790	2	0	0	4
;Depth estimated.					
J72	181.990	2.5	0	0	4
;Depth estimated.					
J73	181.797	2.5	0	0	2
;Depth estimated.					
J74	182.185	2.5	0	0	9
;Depth estimated.					
J75	182.185	2.5	0	0	4
;Depth estimated.					
J76	182.070	2.5	0	0	2
;Depth estimated.					
J77	181.617	3	0	0	4
;Depth estimated.					
J78	182.247	2.5	0	0	9
;Depth estimated.					
J79	182.250	2.5	0	0	4
;Depth estimated.					
J80	181.660	3	0	0	2
;Depth estimated.					
J81	181.507	3	0	0	4
;Depth added.					

J82	181.267	3	0	0	4
;Depth estimated					
J83	182.25	2.5	0	0	2
;Depth estimated.					
J84	182.010	2.5	0	0	2
;Depth estimated.					
J85	181.037	3	0	0	4
;Depth estimated.					
J86	182.065	2.5	0	0	2
;Depth estimated.					
J89	181.60	2	0	0	2
J90	181.03	2.87	0	0	4
;Depth estimated.					
J91	181.250	2.75	0	0	4
;Depth estimated					
J92	181.705	2	0	0	2
;Depth estimated					
J93	181.725	2.5	0	0	2
;Depth estimated					
J94	181.440	3	0	0	4
;Depth estimated.					
J95	181.370	2.5	0	0	2
;Depth estimated.					
J96	181.340	2.5	0	0	2
;Depth estimated.					
J97	181.865	2.5	0	0	2
;Depth estimated.					
J98	181.575	2.5	0	0	4
;Depth estimated.					
J99	181.710	3	0	0	2
;Depth estimated.					
J100	182.094	2.5	0	0	2
;Depth estimated.					
J101	181.844	2.5	0	0	9
;Depth estimated.					
J102	182.034	2.5	0	0	2
;Depth estimated.					
J103	181.664	2.5	0	0	4
;Depth estimated.					
J104	182.030	2.5	0	0	2
;Depth Estimated.					
J105	181.519	2.5	0	0	4
J106	182.029	2.5	0	0	2
;Depth estimated.					
J107	181.389	2.5	0	0	4
;Depth estimated.					
J108	181.344	3	0	0	9
;Depth estimated.					
J111	181.359	2.5	0	0	4
;Depth estimated.					
J112	181.050	2.5	0	0	4
J113	0	0	0	0	0
;Depth estimated.					
J114	180.537	2.5	0	0	4
;Depth estimated.					
J115	180.149	2.5	0	0	2
;Depth estimated.					
J116	179.987	2.5	0	0	4
J117	180.441	2.459	0	0	9
;Depth estimated.					
J118	180.088	2.5	0	0	4

```
;Depth estimated.
J119             179.686    3        0         0        4
;Depth estimated.
J120             178.680    3        0         0        4
J121             179.185    3.815    0         0        2
;Depth estimated.
J122             180.315    3        0         0        4
;Depth estimated.
J123             180.315    3        0         0        4
;Depth estimated.
J124             180.632    3        0         0        4
;Depth estimated.
J125             180.347    3        0         0        4
;Culvert entrance, values estimated
Out2             179        3.5      0         0        15
;Depth and invert estimated.
;Culvert entrance?
Out3             180        3.5      0         0        9
;JUNCTION
;Values estimated
J126             180.533    1.5      0         0        0
;Entrance outfall
;Values estimated.
J127             183        1        0         0        0
;Entance inflow.  Values estimated.
J128             183        1        0         0        0
J140             182.197    2        0         0        4
J141             182.31     2        0         0        4

[OUTFALLS]
;;Outfall        Invert     Type       Stage Data         Gated
;;-------------- ---------- ---------- ----------------   --------
Out1             178.150    FREE                 NO

[CONDUITS]
;;Conduit        From Node        To Node          Length     Roughness             InOffset   OutOffset  InitFlow
          MaxFlow
;;-------------- ---------------- ---------------- ---------- ---------- ---------- ---------- ---------- ----------
C1               J1         J2    89         0.013    180.940    180.720    0          0
C2               J2         J3    98.4       0.013    180.71     180.693    0          0
C3               J4         J5    80.7       0.013    181.187    180.869    0          0
C4               J5         J3    93.2       0.013    180.831    180.693    0          0
C5               J3         J6    89.73      0.013    180.580    179.815    0          0
C6               J6         J7    70.15      0.013    179.815    179.810    0          0
C7               J8         J9    116.4      0.013    180.71     180.435    0          0
C8               J9         J6    109.4      0.013    180.365    180.157    0          0
C9               J10              J11                 163.016    0.013      178.856    178.815    0          0
C10              J7         J12              10       0.013      179.810    178.72     0          0
C11              J11              J12                 138.33     0.013      178.815    178.78     0          0
C12              J13              J12                 82         0.013      178.82     178.72     0          0
C13              Out2             J10                 15         0.013      179        178.871    0          0
C14              J17              J18                 96.4       0.013      180.33     180.12     0          0
C15              J18              J19                 96.4       0.013      180.06     179.86     0          0
C16              J19              J13                 96.4       0.013      179.80     179.67     0          0
;Culvert
C17              J20              J21                 18.1       0.013      180.635    180.629    0          0
C18              J21              J22                 97.2       0.013      180.729    180.455    0          0
C19              J22              J23                 91.7       0.013      180.444    180.103    0          0
C20              J23              J24                 99.7       0.013      180.093    179.803    0          0
;PVC Pipe
C21              J24              J25                 16.76      0.012      179.520    179.198    0          0
```

C22	J25	J13	82.13	0.013	178.866	178.82	0	0
C23	J21	J29	88.6	0.013	180.629	180.226	0	0
C24	J28	J29	18.65	0.013	179.535	179.530	0	0
C25	J29	J30	110.8	0.013	180.324	179.444	0	0
C26	J30	J31	101.0	0.013	179.438	179.387	0	0
;Outlet offset estimated.								
C27	J31	J32	91.2	0.013	179.367	179.300	0	0
C28	J32	J25	89.61	0.013	178.932	178.866	0	0
;PVC pipe. Exit offset estimated by interpolation.								
C29	J33	J34	120.39	0.012	181.179	180.906	0	0
C30	J34	J35	92.04	0.013	180.906	180.697	0	0
C31	J35	J36	80.46	0.013	180.697	180.514	0	0
C32	J36	J32	79.86	0.013	179.58	179.405	0	0
;PVC								
C33	J37	J38	119.48	0.012	181.270	180.985	0	0
C34	J38	J39	90.22	0.013	180.946	180.756	0	0
C35	J39	J40	74.67	0.013	180.741	180.60	0	0
C36	J40	J36	79.86	0.013	179.58	179.405	0	0
;PVC Pipe								
C37	J41	J42	80	0.012	181.39	181.29	0	0
;PVC Pipe								
C38	J42	J43	105	0.012	181.27	180.75	0	0
;PCP Pipe?? Assumed to be RCP.								
C39	J43	J44	105	0.013	180.74	180.35	0	0
;PC Pipe?? Assumed to be RCP								
C40	J44	J40	83.0	0.013	179.67	179.58	0	0
C41	J45	J46	103.0	0.012	181.124	180.895	0	0
C42	J46	J47	98.0	0.013	180.892	180.640	0	0
C43	J47	J48	102.0	0.013	180.640	179.871	0	0
;PVC								
C45	J49	J50	103.0	0.012	181.270	181.030	0	0
C46	J50	J51	100.0	0.013	181.000	180.770	0	0
C47	J51	J52	100.0	.013	180.740	180.520	0	0
C48	J52	J48	83.0	0.013	179.880	179.871	0	0
C49	J57	J58	47.0	0.013	181.119	181.100	0	0
C50	J59	J58	51.0	0.012	182.075	181.911	0	0
C51	J58	J60	148.0	0.013	181.085	180.010	0	0
C52	Out3	J64	10	0.012	181.1	179.989	0	0
C53	J60	J61	149.0	0.013	180.995	180.855	0	0
C54	J61	J62	141.5	0.013	180.847	180.680	0	0
;Includes the short connecter of the node that was not included.								
;Outlet offset estimated.								
C55	J62	J64	137.5	0.013	180.675	180	0	0
C56	J64	J52	60.4	0.013	179.989	179.880	0	0
;PVC Pipe, does flow north								
C59	J66	J59	94.5	0.012	182.455	182.125	0	0
;PVC Pipe								
C61	J70	J69	93.5	0.012	182.600	182.345	0	0
;PVC Pipe								
C62	J69	J59	86.0	0.012	182.320	182.085	0	0
;PVC Pipe								
C63	J70	J71	94.0	0.012	182.630	182.300	0	0
;PVC Pipe								
C64	J72	J73	92.5	0.012	182.435	182.247	0	0
;PVC Pipe								
;Other offset was used to avoid slope contrary to flow.								
C65	J72	J69	83	0.012	182.440	182.320	0	0
;PVC Pipe								
C66	J74	J72	86	0.012	182.695	182.440	0	0
;PVC Pipe								
C67	J79	J77	45.0	0.012	182.700	182.567	0	0

;PVC Pipe								
C68	J78	J77	66.5	0.012	182.697	182.500	0	0
;PVC Pipe								
C69	J74	J75	91	0.012	182.635	182.417	0	0
;CP (concrete pipe?)								
C70	J75	J76	94.0	0.013	182.417	182.257	0	0
C71	J76	J77	103.5	0.013	182.250	182.097	0	0
C72	J73	J80	93.5	0.013	182.247	182.117	0	0
C73	J80	J81	103.5	0.013	182.110	181.977	0	0
C74	J77	J81	84	0.013	182.067	181.967	0	0
C75	J71	J82	103.5	0.013	182.240	182.020	0	0
C76	J81	J82	86.0	0.013	181.957	181.727	0	0
;PVC Pipe								
C77	J83	J81	46.0	0.012	182.700	182.567	0	0
;PVC Pipe.								
C78	J84	J82	44.5	0.012	182.460	182.325	0	0
C79	J67	J85	105.5	0.013	182.220	182.020	0	0
;PVC Pipe								
C80	J86	J85	39.5	0.012	182.515	182.395	0	0
C81	J82	J85	85.0	0.013	181.717	181.497	0	0
C82	J85	J61	55.0	0.013	181.487	181.407	0	0
;PVC Pipe								
C83	J89	J90	78.6	0.012	182.095	181.925	0	0
;HDPE								
C84	J90	J62	53	0.012	181.480	181.29	0	0
;PVC								
C86	J92	J91	80.1	0.012	182.155	181.750	0	0
;The sewer map shows this sewer running								
;in the other direction; however, the slope								
;should have it running the other way								
;and it can only run as shown if there is an								
;outlet into the neighboring woodland.								
C87	J48	J44	81	0.013	179.828	179.69	0	0
;PVC								
C88	J93	J94	79.2	0.012	182.175	182.020	0	0
;HDPE								
C89	J94	J95	31	0.012	181.890	181.820	0	0
;HDPE								
C90	J95	J96	16.3	0.012	181.820	181.790	0	0
;HDPE								
C91	J96	J91	30.6	0.012	181.720	181.700	0	0
;HDPE								
C92	J91	J90	85.5	0.012	181.700	181.300	0	0
;PVC								
C93	J97	J98	86.2	0.012	182.315	182.090	0	0
;PE								
C94	J98	J94	84.1	0.012	182.025	181.890	0	0
;PE								
C95	J99	J98	79.3	0.012	182.160	182.025	0	0
;CP								
C96	J100	J101	84.5	0.013	182.544	182.344	0	0
C97	J101	J103	84.5	0.013	182.294	182.129	0	0
C98	J103	J105	85.2	0.013	182.114	182.009	0	0
C99	J105	J107	84.5	0.013	181.969	181.859	0	0
C100	J107	J108	38	0.013	181.839	181.794	0	0
C101	J108	J64	51.9	0.013	181.729	181.699	0	0
;PVC								
C102	J106	J107	93.1	0.012	182.479	182.257	0	0
;PVC								
C103	J104	J105	93.1	0.012	182.480	182.246	0	0
;CP								

C104	J102	J103	91.3	0.013	182.484	182.279	0	0
C105	J111	J112	64.62	0.013	181.809	181.610	0	0
C106	J112	J113	121.47	0.013	181.500	181.276	0	0
C107	J113	J52	92.19	0.013	181.151	181.005	0	0
C108	J12	Out1	205.1	0.013	178.72	178.600	0	0
C109	J114	J115	120	0.013	180.987	180.712	0	0
C110	J115	J116	181.5	0.013	180.599	180.439	0	0
C111	J116	J25	40	0.013	180.437	180.372	0	0
C112	J117	J118	73.81	0.013	180.891	180.538	0	0
C113	J118	J119	76.46	0.013	180.568	180.237	0	0
C114	J119	J120	92.62	0.013	180.136	179.943	0	0
C115	J120	J121	94.12	0.013	179.913	179.727	0	0
C116	J121	J32	91.49	0.013	179.635	178.932	0	0
;PVC								
C117	J124	J125	104.102	0.012	181.082	180.807	0	0
C118	J125	J123	21.216	0.013	180.797	180.765	0	0
C119	J123	J122	38.0	0.013	180.765	180.765	0	0
C120	J122	J40	15	.013	180.765	180.60	0	0
;Direction of flow uncertain.								
C121	J126	J36	22.87	0.013	180.983	180.533	0	0
;Direction of flow uncertain. PVC								
C122	J127	J126	7.62	0.012	183	180.983	0	0
;Direction of flow uncertain. PVC								
C123	J128	J126	13.72	0.012	183	180.983	0	0
;PVC, Flows south								
C58	J66	J67	95.0	.012	182.460	182.235	0	0
C139	J141	J140	92.66	0.013	182.760	182.647	0	0
C140	J140	J99	18	0.013	182.647	182.625	0	0

[XSECTIONS]

;;Link	Shape	Geom1		Geom2	Geom3	Geom4	Barrels		
;;--------------	------------	----------------		----------	----------	----------	----------		
C1	CIRCULAR		0.45		0	0	0	1	
C2	CIRCULAR		0.525		0	0	0	1	
C3	CIRCULAR		0.375		0	0	0	1	
C4	CIRCULAR		0.525		0	0	0	1	
C5	CIRCULAR		.75		0	0	0	1	
C6	CIRCULAR		1.050		0	0	0	1	
C7	CIRCULAR		.375		0	0	0	1	
C8	CIRCULAR		.525		0	0	0	1	
C9	CIRCULAR		1.950		0	0	0	1	
C10	CIRCULAR		.6	0	0	0	1		
C11	CIRCULAR		1.950		0	0	0	1	
C12	CIRCULAR		2.250		0	0	0	1	
C13	CIRCULAR		1.5		0	0	0	1	3
C14	CIRCULAR		.45		0	0	0	1	
C15	CIRCULAR		.525		0	0	0	1	
C16	CIRCULAR		.6	0	0	0	1		
C17	CIRCULAR		.45		0	0	0	1	3
C18	CIRCULAR		.3	0	0	0	1		
C19	CIRCULAR		.375		0	0	0	1	
C20	CIRCULAR		.450		0	0	0	1	
C21	CIRCULAR		.45		0	0	0	1	
C22	CIRCULAR		2.275		0	0	0	1	
C23	CIRCULAR		.45		0	0	0	1	
C24	CIRCULAR		1.5		0	0	0	1	3
C25	CIRCULAR		1.650		0	0	0	1	
C26	CIRCULAR		1.650		0	0	0	1	
C27	CIRCULAR		1.650		0	0	0	1	
C28	CIRCULAR		2.275		0	0	0	1	
C29	CIRCULAR		1	0	0	0	1		

C30	CIRCULAR	.525		0	0	0	1	
C31	CIRCULAR	.600		0	0	0	1	
C32	CIRCULAR	1.650		0	0	0	1	
C33	CIRCULAR	.375		0	0	0	1	
C34	CIRCULAR	.450		0	0	0	1	
C35	CIRCULAR	.525		0	0	0	1	
C36	CIRCULAR	1.650		0	0	0	1	
C37	CIRCULAR	.300		0	0	0	1	
C38	CIRCULAR	.375		0	0	0	1	
C39	CIRCULAR	.450		0	0	0	1	
C40	CIRCULAR	1.650		0	0	0	1	
C41	CIRCULAR	.375		0	0	0	1	
C42	CIRCULAR	.450		0	0	0	1	
C43	CIRCULAR	.525		0	0	0	1	
C45	CIRCULAR	.375		0	0	0	1	
C46	CIRCULAR	.450		0	0	0	1	
C47	CIRCULAR	.525		0	0	0	1	
C48	CIRCULAR	1.650		0	0	0	1	
C49	CIRCULAR	1.500		0	0	0	1	3
C50	CIRCULAR	.450		0	0	0	1	
C51	CIRCULAR	1.650		0	0	0	1	
C52	CIRCULAR	.250		0	0	0	1	3
C53	CIRCULAR	1.650		0	0	0	1	
C54	CIRCULAR	1.650		0	0	0	1	
C55	CIRCULAR	1.650		0	0	0	1	
C56	CIRCULAR	1.650		0	0	0	1	
C59	CIRCULAR	.300		0	0	0	1	
C61	CIRCULAR	.300		0	0	0	1	
C62	CIRCULAR	.375		0	0	0	1	
C63	CIRCULAR	.300		0	0	0	1	
C64	CIRCULAR	.450		0	0	0	1	
C65	CIRCULAR	.300		0	0	0	1	
C66	CIRCULAR	.300		0	0	0	1	
C67	CIRCULAR	.300		0	0	0	1	
C68	CIRCULAR	.300		0	0	0	1	
C69	CIRCULAR	.375		0	0	0	1	
C70	CIRCULAR	.450		0	0	0	1	
C71	CIRCULAR	.525		0	0	0	1	
C72	CIRCULAR	.525		0	0	0	1	
C73	CIRCULAR	.600		0	0	0	1	
C74	CIRCULAR	.600		0	0	0	1	
C75	CIRCULAR	.450		0	0	0	1	
C76	CIRCULAR	.675		0	0	0	1	
C77	CIRCULAR	.300		0	0	0	1	
C78	CIRCULAR	.300		0	0	0	1	
C79	CIRCULAR	.450		0	0	0	1	
C80	CIRCULAR	.300		0	0	0	1	
C81	CIRCULAR	.750		0	0	0	1	
C82	CIRCULAR	.900		0	0	0	1	
C83	CIRCULAR	.375		0	0	0	1	
C84	CIRCULAR	.900		0	0	0	1	
C86	CIRCULAR	.375		0	0	0	1	
C87	CIRCULAR	1	0	0	0	1		
C88	CIRCULAR	.375		0	0	0	1	
C89	CIRCULAR	.900		0	0	0	1	
C90	CIRCULAR	.900		0	0	0	1	
C91	CIRCULAR	.900		0	0	0	1	
C92	CIRCULAR	.900		0	0	0	1	
C93	CIRCULAR	.375		0	0	0	1	
C94	CIRCULAR	.900		0	0	0	1	
C95	CIRCULAR	.900		0	0	0	1	

C96	CIRCULAR	.375		0	0	0	1
C97	CIRCULAR	.450		0	0	0	1
C98	CIRCULAR	.600		0	0	0	1
C99	CIRCULAR	.675		0	0	0	1
C100	CIRCULAR	.750		0	0	0	1
C101	CIRCULAR	.750		0	0	0	1
C102	CIRCULAR	.375		0	0	0	1
C103	CIRCULAR	.375		0	0	0	1
C104	CIRCULAR	.375		0	0	0	1
C105	CIRCULAR	.300		0	0	0	1
C106	CIRCULAR	.450		0	0	0	1
C107	CIRCULAR	.525		0	0	0	1
C108	HORIZ_ELLIPSE	2.100		3.000	0	0	1
C109	CIRCULAR	.450		0	0	0	1
C110	CIRCULAR	.525		0	0	0	1
C111	CIRCULAR	.600		0	0	0	1
C112	CIRCULAR	.300		0	0	0	1
C113	CIRCULAR	.375		0	0	0	1
C114	CIRCULAR	.450		0	0	0	1
C115	CIRCULAR	.525		0	0	0	1
C116	CIRCULAR	.600		0	0	0	1
C117	CIRCULAR	.375		0	0	0	1
C118	CIRCULAR	.525		0	0	0	1
C119	CIRCULAR	.525		0	0	0	1
C120	CIRCULAR	.525		0	0	0	1
C121	CIRCULAR	.525		0	0	0	1
C122	CIRCULAR	.450		0	0	0	1
C123	CIRCULAR	1	0	0	0	1	
C58	CIRCULAR	.375		0	0	0	1
C139	CIRCULAR	.9	0	0	0	1	
C140	CIRCULAR	.9	0	0	0	1	

[LOSSES]

;;Link	Kinlet	Koutlet	Kavg	Flap Gate	SeepRate
;;--------------	----------	----------	----------	----------	----------
C1	.5	.5	0.1	NO	0
C2	.5	.8	0.1	NO	0
C3	.5	.5	0.1	NO	0
C4	.5	.8	0.1	NO	0
C5	.8	.6	0.1	NO	0
C6	.6	.5	0.1	NO	0
C7	.5	.5	0.1	NO	0
C8	.5	.8	0.1	NO	0
C9	.5	.5	0.1	NO	0
C10	.5	1	0.1	NO	0
C11	.5	1	0.1	NO	0
C12	.6	1	0.1	NO	0
C13	.5	.5	0.1	NO	0
C14	.5	.5	0.1	NO	0
C15	.5	.5	0.1	NO	0
C16	.5	.8	0.1	NO	0
C17	.5	.6	0.1	NO	0
C18	.6	.5	0.1	NO	0
C19	.5	.5	0.1	NO	0
C20	.5	.5	0.1	NO	0
C21	.5	1	0.1	NO	0
C22	1	.6	0.1	NO	0
C23	.8	.8	0.1	NO	0
C24	.5	.5	0.1	NO	0
C25	.8	.5	0.1	NO	0
C26	.5	.5	0.1	NO	0

C27	.5	1	0.1	NO	0
C28	1	1	0.1	NO	0
C29	.5	.5	0.1	NO	0
C30	.5	.5	0.1	NO	0
C31	.5	1	0.1	NO	0
C32	1	1	0.1	NO	0
C33	.5	.5	0.1	NO	0
C34	.5	.5	0.1	NO	0
C35	.5	1	0.1	NO	0
C36	1	1	0.1	NO	0
C37	.5	.5	0.1	NO	0
C38	.5	.5	0.1	NO	0
C39	.5	1	0.1	NO	0
C40	1	1	0.1	NO	0
C41	.5	.5	0.1	NO	0
C42	.5	.5	0.1	NO	0
C43	.5	.8	0.1	NO	0
C45	.5	.5	0.1	NO	0
C46	.5	.5	0.1	NO	0
C47	.5	1	0.1	NO	0
C48	1	.6	0.1	NO	0
C49	.5	.6	0.1	NO	0
C50	.6	.8	0.1	NO	0
C51	.6	.5	0.1	NO	0
C52	.5	1	0.1	NO	0
C53	.5	.6	0.1	NO	0
C54	.6	.6	0.1	NO	0
C55	.5	1	0.1	NO	0
C56	1	1	0.1	NO	0
C59	.5	.6	0.1	NO	0
C61	.5	.6	0.1	NO	0
C62	.6	.6	0.1	NO	0
C63	.5	.5	0.1	NO	0
C64	.8	.5	0.1	NO	0
C65	.6	.6	0.1	NO	0
C66	.8	.6	0.1	NO	0
C67	.5	1	0.1	NO	0
C68	.5	1	0.1	NO	0
C69	.5	.5	0.1	NO	0
C70	.5	.5	0.1	NO	0
C71	.5	1	0.1	NO	0
C72	.5	.5	0.1	NO	0
C73	.5	1	0.1	NO	0
C74	1	1	0.1	NO	0
C75	.5	1	0.1	NO	0
C76	1	1	0.1	NO	0
C77	.5	1	0.1	NO	0
C78	.5	1	0.1	NO	0
C79	.5	1	0.1	NO	0
C80	.5	1	0.1	NO	0
C81	1	1	0.1	NO	0
C82	1	.8	0.1	NO	0
C83	.5	.8	0.1	NO	0
C84	.6	.8	0.1	NO	0
C86	.5	.8	0.1	NO	0
C87	.6	1	0.1	NO	0
C88	.5	.8	0.1	NO	0
C89	.6	.5	0.1	NO	0
C90	.5	.5	0.1	NO	0
C91	.5	.6	0.1	NO	0
C92	.6	.6	0.1	NO	0

```
C93        .5    .8    0.1   NO    0
C94        .6    .6    0.1   NO    0
C95        .5    .6    0.1   NO    0
C96        .5    .8    0.1   NO    0
C97        .5    .6    0.1   NO    0
C98        .6    .6    0.1   NO    0
C99        .6    .8    0.1   NO    0
C100       .6    .8    0.1   NO    0
C101       .5    1     0.1   NO    0
C102       .5    .6    0.1   NO    0
C103       .5    .8    0.1   NO    0
C104       .5    .8    0.1   NO    0
C105       .5    .5    0.1   NO    0
C106       .5    .5    0.1   NO    0
C107       .5    1     0.1   NO    0
C108       1     .5    0.1   NO    0
C109       .5    .5    0.1   NO    0
C110       .5    .5    0.1   NO    0
C111       .5    1     0.1   NO    0
C112       .5    .5    0.1   NO    0
C113       .5    .5    0.1   NO    0
C114       .5    .5    0.1   NO    0
C115       .5    .5    0.1   NO    0
C116       .5    1     0.1   NO    0
C117       .5    .5    0.1   NO    0
C118       .5    .5    0.1   NO    0
C119       .5    .5    0.1   NO    0
C120       .5    1     0.1   NO    0
C121       .5    .5    0.1   NO    0
C122       .5    .6    0.1   NO    0
C123       .5    .6    0.1   NO    0
C58        .5    .5    0.1   NO    0
C139       .5    .5    .1    NO    0
C140       .5    .5    .1    NO    0

[PATTERNS]
;;Pattern      Type        Multipliers
;;-------------- ----------  -----------
Estimate       MONTHLY           .35   .35   .6    .75   1.13  1.33
Estimate                   1.42  1.19  .6    .58   .5    .4

[REPORT]
;;Reporting Options
INPUT     YES
CONTROLS       NO
SUBCATCHMENTS ALL
NODES     ALL
LINKS     ALL

[TAGS]
Node      J1        J1

[MAP]
DIMENSIONS     0.000     0.000     1750.000  1390.000
Units     Meters

[COORDINATES]
;;Node         X-Coord             Y-Coord
;;-------------- ------------------  ------------------
J1        212.201             448.096
J2        249.287             368.515
```

J3	290.237		281.980	
J4	362.864		120.500	
J5	329.641		195.446	
J6	372.436		313.358	
J7	435.791		341.173	
J8	467.469		110.929	
J9	419.566		216.779	
J10		321.442		617.775
J11		389.433		471.748
J12		446.608		345.809
J13		525.417		379.032
J17		403.341		640.181
J18		443.518		553.647
J19		483.695		467.112
J20		471.332		698.129
J21		479.059		681.904
J22		517.690		595.369
J23		557.867		511.152
J24		595.726		425.390
J25		598.817		411.483
J28		555.549		733.670
J29		560.958		718.990
J30		611.179		617.775
J31		651.356		528.922
J32		685.351		446.251
J33		647.492		746.805
J34		697.713		639.409
J35		737.118		555.192
J36		769.568		483.337
J37		727.846		773.074
J38		777.294		664.133
J39		813.608		582.234
J40		845.286		515.015
J41		801.246		810.933
J42		835.242		737.533
J43		880.054		641.727
J44		921.004		549.011
J45		873.873		855.746
J46		914.823		764.575
J47		955.772		674.177
J48		998.267		581.461
J49		948.819		890.514
J50		992.859		797.026
J51		1036.899		704.310
J52		1079.393		615.457
J57		849.149		1252.106
J58		882.372		1175.615
J59		934.911		1198.021
J60		944.183		1042.722
J61		1007.539		909.057
J62		1067.804		779.255
J64		1127.297		654.861
J66		973.543		1113.032
J67		1013.720		1029.588
J69		1013.720		1232.790
J70		1051.579		1148.573
J71		1091.755		1062.038
J72		1090.983		1266.786
J73		1131.932		1183.341
J74		1171.337		1302.327
J75		1208.423		1220.428

J76	1246.282	1135.438
J77	1291.094	1041.950
J78	1350.587	1068.219
J79	1309.638	1001.000
J80	1171.337	1098.352
J81	1213.059	1005.636
J82	1134.250	970.095
J83	1230.829	964.687
J84	1152.021	929.146
J85	1057.760	933.781
J86	1073.985	899.013
J89	1084.802	873.516
J90	1117.252	802.434
J91	1197.606	835.657
J92	1162.065	909.057
J93	1241.646	943.053
J94	1273.324	870.426
J95	1238.555	858.063
J96	1222.330	848.792
J97	1318.137	977.049
J98	1353.678	899.786
J99	1427.078	924.510
J100	1359.086	888.196
J101	1393.854	810.933
J102	1277.960	861.154
J103	1317.364	776.165
J104	1199.924	827.158
J105	1237.783	742.169
J106	1120.343	793.935
J107	1158.974	708.946
J108	1175.200	674.950
J111	1198.379	367.443
J112	1169.791	425.390
J113	1118.798	535.104
J114	717.802	159.605
J115	669.126	268.546
J116	617.245	378.343
J117	865.260	56.929
J118	835.127	124.148
J119	801.904	192.912
J120	764.045	276.356
J121	724.641	362.891
J122	850.811	501.080
J123	867.036	466.311
J124	917.257	355.052
J125	875.535	449.313
Out2	309.080	614.685
Out3	1136.568	641.727
J126	778.943	462.490
J127	788.214	444.720
J128	776.625	440.857
J140	1444.340	932.409
J141	1530.570	966.312
Out1	533.143	160.377

[VERTICES]

;;Link	X-Coord	Y-Coord
;;--------------	------------------	------------------

[Polygons]

;;Subcatchment	X-Coord	Y-Coord

;;--------------	------------------	------------------
Sub1	230.395	404.178
Sub1	143.138	386.804
Sub1	129.239	418.463
Sub1	208.388	451.667
Sub6	232.712	404.950
Sub6	273.251	421.552
Sub6	253.947	459.775
Sub6	229.623	457.844
Sub6	211.090	451.667
Sub8	142.752	385.645
Sub8	168.700	327.230
Sub8	257.501	349.238
Sub8	231.167	403.405
Sub8	148.158	387.190
Sub9	260.204	350.010
Sub9	298.040	366.226
Sub9	273.717	420.278
Sub9	233.177	403.290
Sub14	207.695	236.885
Sub14	291.863	275.494
Sub14	257.887	348.465
Sub14	168.700	326.072
Sub15	289.933	283.216
Sub15	328.156	297.888
Sub15	298.427	365.453
Sub15	260.204	348.465
Sub16	275.261	183.605
Sub16	323.909	206.770
Sub16	292.249	274.336
Sub16	243.602	251.943
Sub17	325.839	206.384
Sub17	363.290	221.055
Sub17	330.472	295.957
Sub17	292.249	280.900
Sub18	309.237	115.653
Sub18	355.954	134.957
Sub18	324.295	205.226
Sub18	275.261	182.446
Sub19	357.885	135.343
Sub19	393.019	148.084
Sub19	362.904	219.511
Sub19	326.225	204.840
Sub21	374.873	84.765
Sub21	403.829	122.602
Sub21	393.791	146.926
Sub21	355.954	133.413
Sub21	309.623	114.494
Sub22	307.133	346.153
Sub22	391.638	377.987
Sub22	404.757	347.504
Sub22	399.548	345.381
Sub22	406.300	330.140
Sub22	329.717	298.676
Sub23	330.875	298.290
Sub23	367.725	313.532
Sub23	408.820	224.589
Sub23	368.883	207.032
Sub24	410.798	222.259
Sub24	450.349	238.851
Sub24	406.167	329.530

Sub24	368.545	313.323
Sub25	398.257	138.719
Sub25	441.281	155.504
Sub25	409.061	223.995
Sub25	369.124	206.245
Sub26	410.798	221.487
Sub26	451.507	238.658
Sub26	480.254	172.096
Sub26	441.667	155.890
Sub27	462.118	112.480
Sub27	500.512	128.107
Sub27	480.832	171.517
Sub27	442.439	155.118
Sub28	398.064	137.947
Sub28	441.667	154.346
Sub28	461.539	112.094
Sub28	404.238	122.898
Sub29	450.793	239.926
Sub29	488.415	256.518
Sub29	446.831	347.328
Sub29	407.190	330.990
Sub30	447.603	347.906
Sub30	487.540	365.656
Sub30	527.863	274.399
Sub30	489.084	256.070
Sub31	469.983	198.576
Sub31	508.570	215.940
Sub31	489.663	256.070
Sub31	451.462	239.478
Sub32	491.785	149.571
Sub32	530.564	167.128
Sub32	508.570	214.976
Sub32	470.176	197.419
Sub33	509.149	215.940
Sub33	548.121	233.497
Sub33	527.863	273.627
Sub33	490.627	255.684
Sub34	531.336	167.321
Sub34	569.344	184.299
Sub34	548.121	232.147
Sub34	509.921	214.783
Sub35	400.268	344.975
Sub35	406.442	330.891
Sub35	446.765	348.255
Sub35	410.879	427.358
Sub35	376.730	412.502
Sub35	405.477	347.098
Sub36	447.344	348.834
Sub36	487.281	366.005
Sub36	450.816	445.108
Sub36	411.651	427.744
Sub37	358.209	455.719
Sub37	391.779	470.961
Sub37	410.300	428.130
Sub37	376.151	413.274
Sub38	392.358	470.768
Sub38	432.026	486.029
Sub38	450.045	445.879
Sub38	411.072	428.130
Sub39	357.260	456.379
Sub39	326.299	523.844

Sub39	361.220	537.157
Sub39	390.932	471.173
Sub40	361.799	537.543
Sub40	398.290	552.884
Sub40	430.869	486.222
Sub40	391.236	471.436
Sub41	397.684	553.942
Sub41	366.917	620.690
Sub41	329.000	605.455
Sub41	361.027	538.314
Sub42	328.228	605.069
Sub42	295.816	593.300
Sub42	325.913	524.423
Sub42	360.448	537.928
Sub43	316.074	609.507
Sub43	311.636	620.311
Sub43	318.389	624.362
Sub43	328.035	625.327
Sub43	336.139	651.180
Sub43	280.188	628.221
Sub43	295.044	593.686
Sub43	323.019	603.526
Sub44	364.886	620.890
Sub44	334.402	643.463
Sub44	328.228	624.555
Sub44	318.196	623.398
Sub44	313.951	617.996
Sub44	317.231	609.507
Sub44	324.370	604.297
Sub45	428.848	691.304
Sub45	338.556	659.277
Sub45	334.697	644.035
Sub45	365.566	621.269
Sub45	448.142	656.190
Sub46	398.558	553.936
Sub46	440.231	572.264
Sub46	408.205	638.440
Sub46	367.303	621.462
Sub47	440.810	572.457
Sub47	480.169	589.242
Sub47	447.756	655.418
Sub47	408.590	638.826
Sub48	418.044	513.420
Sub48	458.560	529.240
Sub48	440.231	571.685
Sub48	398.944	553.164
Sub49	440.810	571.492
Sub49	480.169	588.664
Sub49	499.459	547.930
Sub49	459.139	529.626
Sub50	450.920	445.868
Sub50	488.735	462.268
Sub50	459.023	528.637
Sub50	418.121	512.816
Sub51	489.121	462.461
Sub51	529.444	479.632
Sub51	499.539	547.544
Sub51	459.409	529.023
Sub52	470.213	404.002
Sub52	508.221	420.594
Sub52	488.928	461.689

Sub52	451.306	445.290
Sub53	508.607	420.787
Sub53	549.123	435.450
Sub53	529.444	479.053
Sub53	489.506	462.075
Sub54	470.213	403.423
Sub54	508.607	419.822
Sub54	525.971	383.165
Sub54	487.770	366.187
Sub55	526.357	383.358
Sub55	566.680	400.336
Sub55	549.702	435.064
Sub55	508.993	420.015
Sub56	439.537	672.758
Sub56	512.080	703.434
Sub56	505.520	719.448
Sub56	461.145	717.133
Sub56	429.118	692.437
Sub57	485.887	675.007
Sub57	480.485	688.898
Sub57	439.583	671.920
Sub57	446.529	659.958
Sub58	524.281	692.950
Sub58	518.493	705.490
Sub58	480.678	689.477
Sub58	486.273	675.200
Sub59	473.346	604.779
Sub59	511.161	619.442
Sub59	486.273	674.428
Sub59	446.722	659.379
Sub60	511.933	619.635
Sub60	549.748	634.684
Sub60	523.702	691.792
Sub60	486.466	674.814
Sub61	492.640	563.299
Sub61	529.876	579.505
Sub61	511.547	619.056
Sub61	473.539	604.201
Sub62	530.262	579.505
Sub62	566.919	593.975
Sub62	549.555	633.912
Sub62	511.933	619.056
Sub63	537.927	563.548
Sub63	574.370	578.974
Sub63	567.090	593.680
Sub63	530.261	579.122
Sub64	537.638	563.548
Sub64	529.829	579.167
Sub64	492.711	562.873
Sub64	499.845	547.833
Sub65	524.126	493.141
Sub65	560.783	508.961
Sub65	537.824	562.983
Sub65	500.202	547.355
Sub66	561.169	509.347
Sub66	597.054	524.010
Sub66	574.288	578.417
Sub66	538.210	563.175
Sub67	561.932	411.236
Sub67	599.249	428.726
Sub67	560.998	508.607

Sub67	523.976	492.699
Sub68	561.354	508.958
Sub68	597.122	523.709
Sub68	635.135	443.389
Sub68	599.635	428.919
Sub69	649.360	431.149
Sub69	642.797	445.048
Sub69	599.941	428.446
Sub69	563.262	410.686
Sub69	569.826	394.856
Sub70	581.408	367.058
Sub70	618.859	383.660
Sub70	607.046	411.311
Sub70	569.616	394.526
Sub71	619.153	383.572
Sub71	659.669	400.550
Sub71	645.971	428.911
Sub71	607.384	411.547
Sub72	606.420	312.187
Sub72	645.439	328.543
Sub72	618.811	383.414
Sub72	581.338	366.594
Sub73	645.825	328.736
Sub73	686.727	344.363
Sub73	659.909	400.121
Sub73	619.393	383.143
Sub74	724.349	155.675
Sub74	690.586	229.954
Sub74	651.999	213.748
Sub74	685.376	137.732
Sub75	724.735	155.675
Sub75	764.865	173.425
Sub75	728.401	249.633
Sub75	689.428	233.427
Sub76	651.613	214.133
Sub76	690.200	230.340
Sub76	669.556	273.364
Sub76	631.934	256.193
Sub77	672.064	269.119
Sub77	711.229	286.291
Sub77	728.208	250.212
Sub77	689.042	233.620
Sub78	631.934	256.579
Sub78	669.556	273.557
Sub78	645.632	328.157
Sub78	606.467	311.565
Sub79	646.018	328.350
Sub79	686.920	343.785
Sub79	710.651	286.483
Sub79	672.064	269.698
Sub80	869.766	48.166
Sub80	902.584	75.578
Sub80	822.663	43.919
Sub81	821.891	44.305
Sub81	863.879	60.635
Sub81	850.760	88.610
Sub81	809.536	72.103
Sub82	849.216	93.433
Sub82	887.031	109.447
Sub82	902.080	75.683
Sub82	864.265	60.828

Sub83	791.143	111.955
Sub83	833.396	129.126
Sub83	850.181	88.803
Sub83	809.279	72.211
Sub84	835.904	124.303
Sub84	873.719	139.544
Sub84	886.452	109.640
Sub84	848.637	93.819
Sub85	766.689	164.577
Sub85	807.977	181.170
Sub85	832.865	129.463
Sub85	790.806	112.292
Sub86	808.363	181.170
Sub86	846.949	196.411
Sub86	873.381	139.882
Sub86	836.145	124.833
Sub87	762.722	178.542
Sub87	830.449	206.944
Sub87	837.826	193.293
Sub87	769.096	166.042
Sub88	759.497	287.735
Sub88	795.190	303.170
Sub88	831.076	226.382
Sub88	800.978	194.741
Sub89	721.297	265.741
Sub89	760.655	282.526
Sub89	800.399	194.934
Sub89	762.777	179.114
Sub90	725.927	362.207
Sub90	763.163	377.063
Sub90	794.805	303.471
Sub90	758.941	287.853
Sub91	686.569	346.001
Sub91	725.541	362.014
Sub91	760.269	282.719
Sub91	721.297	266.512
Sub92	646.439	429.155
Sub92	686.569	446.519
Sub92	724.769	362.400
Sub92	686.376	346.773
Sub93	725.734	362.593
Sub93	762.970	377.256
Sub93	724.384	463.111
Sub93	686.762	446.519
Sub94	506.003	719.541
Sub94	544.396	754.076
Sub94	604.206	742.693
Sub94	512.562	703.721
Sub95	610.186	730.732
Sub95	604.784	742.308
Sub95	518.929	705.843
Sub95	524.717	693.303
Sub96	533.061	672.610
Sub96	574.687	690.601
Sub96	565.096	710.524
Sub96	524.025	692.399
Sub97	565.481	710.813
Sub97	601.635	726.431
Sub97	611.923	705.843
Sub97	575.458	690.987
Sub98	565.860	596.981

Sub98	609.996	617.002
Sub98	574.716	690.154
Sub98	534.223	672.607
Sub99	610.382	617.388
Sub99	647.425	632.437
Sub99	611.921	705.367
Sub99	575.847	690.510
Sub100	609.562	616.377
Sub100	618.239	598.445
Sub100	574.882	579.187
Sub100	566.393	596.551
Sub101	655.936	614.834
Sub101	647.645	632.188
Sub101	610.044	616.473
Sub101	618.625	598.445
Sub102	604.883	509.828
Sub102	650.609	529.314
Sub102	618.196	597.612
Sub102	574.786	578.705
Sub103	651.380	529.507
Sub103	687.266	544.556
Sub103	655.818	614.011
Sub103	618.775	597.805
Sub104	678.391	461.787
Sub104	650.416	528.735
Sub104	604.498	508.863
Sub104	636.139	442.880
Sub105	651.380	529.314
Sub105	687.845	544.170
Sub105	718.714	479.923
Sub105	679.356	462.173
Sub106	724.193	463.427
Sub106	718.794	479.431
Sub106	643.111	445.495
Sub106	649.860	430.937
Sub107	724.564	463.163
Sub107	763.747	480.422
Sub107	771.078	464.601
Sub107	731.527	447.430
Sub108	808.293	481.024
Sub108	800.576	497.616
Sub108	764.304	480.638
Sub108	771.636	464.818
Sub109	732.278	447.068
Sub109	771.443	464.239
Sub109	783.984	435.492
Sub109	744.625	419.671
Sub110	783.791	436.649
Sub110	821.220	452.663
Sub110	808.486	480.445
Sub110	772.022	464.432
Sub111	762.960	377.899
Sub111	802.752	395.407
Sub111	784.182	435.200
Sub111	744.631	418.994
Sub112	803.331	395.793
Sub112	840.953	412.386
Sub112	821.467	452.130
Sub112	784.038	436.309
Sub113	780.758	337.142
Sub113	821.467	356.242

Sub113	802.752	395.215
Sub113	763.394	377.465
Sub114	821.897	356.208
Sub114	859.786	373.754
Sub114	840.953	412.000
Sub114	803.000	395.350
Sub115	795.748	303.105
Sub115	837.808	320.469
Sub115	821.620	355.626
Sub115	780.911	336.526
Sub116	839.544	317.768
Sub116	877.359	334.939
Sub116	859.821	373.376
Sub116	822.006	355.626
Sub117	683.898	765.047
Sub117	679.702	775.553
Sub117	605.037	742.947
Sub117	610.632	730.985
Sub118	615.202	699.426
Sub118	655.911	715.825
Sub118	641.248	744.572
Sub118	602.083	726.629
Sub118	612.308	705.792
Sub119	656.104	716.211
Sub119	697.006	735.890
Sub119	683.887	764.637
Sub119	641.634	744.765
Sub120	675.783	675.695
Sub120	716.878	692.480
Sub120	697.392	735.504
Sub120	656.490	715.825
Sub121	635.846	657.366
Sub121	675.398	675.116
Sub121	656.104	715.246
Sub121	615.202	699.040
Sub122	695.848	633.056
Sub122	735.786	650.999
Sub122	717.013	692.134
Sub122	676.039	675.359
Sub123	648.242	632.429
Sub123	655.574	616.030
Sub123	695.547	632.784
Sub123	675.782	674.915
Sub123	635.869	656.886
Sub124	656.394	615.403
Sub124	673.372	576.238
Sub124	713.502	592.830
Sub124	695.752	632.381
Sub125	696.089	632.720
Sub125	735.811	650.653
Sub125	754.418	609.196
Sub125	713.888	593.023
Sub126	692.713	534.902
Sub126	731.300	551.108
Sub126	713.743	592.396
Sub126	673.613	575.803
Sub127	713.936	592.589
Sub127	754.483	608.832
Sub127	773.359	569.051
Sub127	731.686	551.108
Sub128	759.517	492.601

Sub128	798.682	510.544
Sub128	773.408	568.424
Sub128	731.734	550.481
Sub129	719.194	480.446
Sub129	719.965	476.588
Sub129	759.131	492.215
Sub129	730.962	550.481
Sub129	692.955	534.468
Sub130	763.367	481.191
Sub130	802.726	498.940
Sub130	798.674	509.938
Sub130	759.702	491.995
Sub130	720.536	475.981
Sub130	724.395	463.634
Sub131	761.942	799.000
Sub131	756.540	809.099
Sub131	712.165	816.238
Sub131	680.331	775.655
Sub131	684.383	765.044
Sub132	698.081	734.946
Sub132	735.509	750.679
Sub132	722.398	781.338
Sub132	684.383	764.465
Sub133	735.896	750.767
Sub133	774.868	768.517
Sub133	761.829	798.499
Sub133	722.783	781.434
Sub133	735.896	750.960
Sub134	722.728	680.201
Sub134	759.964	696.408
Sub134	736.426	750.429
Sub134	698.226	734.608
Sub135	760.350	696.601
Sub135	797.972	712.807
Sub135	774.820	767.793
Sub135	736.812	750.429
Sub136	736.475	651.213
Sub136	740.719	640.795
Sub136	779.692	656.229
Sub136	759.965	696.022
Sub136	722.969	679.574
Sub137	780.078	656.422
Sub137	815.963	671.471
Sub137	798.020	712.180
Sub137	760.351	696.215
Sub138	773.566	568.975
Sub138	811.960	585.568
Sub138	779.933	655.602
Sub138	740.767	640.168
Sub139	812.732	585.760
Sub139	849.003	601.774
Sub139	816.204	671.037
Sub139	780.319	655.602
Sub140	799.226	510.324
Sub140	837.427	527.302
Sub140	812.153	585.182
Sub140	773.759	568.589
Sub141	837.620	527.302
Sub141	875.097	545.003
Sub141	849.196	601.388
Sub141	813.117	585.375

Sub142	880.876	533.584
Sub142	875.188	544.671
Sub142	837.781	527.125
Sub142	799.024	509.964
Sub142	803.073	499.166
Sub143	872.149	346.961
Sub143	913.011	364.001
Sub143	920.451	347.539
Sub143	879.862	330.089
Sub144	910.826	368.858
Sub144	951.649	384.903
Sub144	961.599	364.267
Sub144	921.051	347.636
Sub145	808.846	480.778
Sub145	852.298	498.805
Sub145	843.815	516.905
Sub145	801.128	497.757
Sub146	844.393	517.098
Sub146	881.581	533.256
Sub146	890.620	514.859
Sub146	852.634	498.854
Sub147	872.266	347.449
Sub147	912.396	364.234
Sub147	877.089	444.880
Sub147	834.644	426.166
Sub148	910.613	369.204
Sub148	950.912	385.272
Sub148	916.641	461.184
Sub148	878.054	445.073
Sub149	821.397	452.867
Sub149	864.589	472.631
Sub149	852.634	498.372
Sub149	808.864	480.344
Sub150	864.878	472.824
Sub150	904.089	487.926
Sub150	890.977	514.535
Sub150	852.923	498.662
Sub151	877.412	445.347
Sub151	864.685	472.245
Sub151	821.494	452.481
Sub151	834.316	426.354
Sub152	915.904	461.552
Sub152	904.480	487.348
Sub152	864.975	472.245
Sub152	877.894	445.250
Sub153	904.155	488.556
Sub153	917.500	461.888
Sub153	934.488	468.065
Sub153	979.660	484.281
Sub153	993.644	490.514
Sub153	960.427	566.081
Sub153	882.096	534.054
Sub154	959.655	566.274
Sub154	954.094	578.369
Sub154	875.616	544.914
Sub154	881.111	534.020
Sub155	761.947	799.096
Sub155	835.455	831.509
Sub155	830.824	841.928
Sub155	757.124	809.322
Sub156	777.741	763.334

Sub156	814.977	780.505
Sub156	799.157	814.654
Sub156	762.306	798.448
Sub157	815.749	780.891
Sub157	854.335	797.290
Sub157	838.708	832.404
Sub157	799.735	814.847
Sub158	798.489	712.431
Sub158	838.114	730.557
Sub158	815.168	780.208
Sub158	777.279	762.565
Sub159	815.554	780.304
Sub159	854.646	797.126
Sub159	878.221	748.778
Sub159	838.403	730.749
Sub160	816.519	671.602
Sub160	840.057	621.825
Sub160	879.415	639.961
Sub160	837.935	729.868
Sub160	798.769	711.732
Sub161	838.127	730.061
Sub161	878.451	748.003
Sub161	920.317	656.553
Sub161	879.801	639.961
Sub162	849.559	602.098
Sub162	875.219	545.568
Sub162	915.542	562.160
Sub162	880.235	639.527
Sub162	840.298	621.005
Sub163	915.928	562.353
Sub163	953.936	578.560
Sub163	920.365	655.926
Sub163	881.200	639.527
Sub164	1038.013	597.895
Sub164	1055.720	560.727
Sub164	1076.183	519.801
Sub164	1037.960	505.516
Sub164	995.104	490.072
Sub164	960.990	565.842
Sub165	954.167	578.500
Sub165	1035.463	611.375
Sub165	1041.058	599.992
Sub165	960.026	566.035
Sub166	872.150	859.672
Sub166	831.441	841.922
Sub166	820.830	865.802
Sub166	901.164	898.230
Sub166	922.679	847.557
Sub166	885.583	830.817
Sub166	874.773	853.210
Sub167	876.587	848.675
Sub167	871.764	858.900
Sub167	831.634	841.536
Sub167	835.878	831.504
Sub168	854.574	797.973
Sub168	878.498	749.932
Sub168	884.822	734.941
Sub168	920.171	752.441
Sub168	884.672	830.193
Sub168	847.436	813.986
Sub169	920.750	752.633

Sub169	951.874	767.517
Sub169	915.217	843.726
Sub169	885.829	830.386
Sub170	884.865	830.386
Sub170	876.568	848.328
Sub170	839.139	832.315
Sub170	847.050	813.986
Sub171	920.171	657.903
Sub171	956.057	673.724
Sub171	920.171	751.862
Sub171	884.865	734.691
Sub172	956.636	673.724
Sub172	988.724	688.607
Sub172	951.874	767.131
Sub172	920.943	752.248
Sub173	953.935	578.801
Sub173	992.328	594.428
Sub173	956.057	673.145
Sub173	920.364	657.517
Sub174	992.907	594.621
Sub174	1025.768	607.961
Sub174	988.724	688.222
Sub174	956.829	673.338
Sub175	1225.058	376.825
Sub175	1229.927	365.992
Sub175	1170.729	339.916
Sub175	1165.543	351.469
Sub176	1153.903	347.228
Sub176	1125.714	407.483
Sub176	1169.760	425.101
Sub176	1198.302	366.256
Sub177	1170.465	425.101
Sub177	1213.453	442.367
Sub177	1241.422	384.271
Sub177	1199.711	366.256
Sub178	1118.798	535.085
Sub178	1053.404	510.149
Sub178	1105.912	400.885
Sub178	1169.891	425.498
Sub179	1060.393	552.968
Sub179	1038.172	597.975
Sub179	1079.773	614.984
Sub179	1118.181	535.349
Sub179	1077.306	520.550
Sub180	1036.079	611.461
Sub180	1086.886	631.262
Sub180	1091.401	620.622
Sub180	1041.717	599.832
Sub181	1119.591	535.701
Sub181	1156.942	550.501
Sub181	1207.683	440.914
Sub181	1170.332	425.763
Sub182	1119.591	535.701
Sub182	1156.589	550.853
Sub182	1119.238	630.841
Sub182	1080.478	615.337
Sub183	1256.339	705.305
Sub183	1264.838	624.179
Sub183	1152.806	563.913
Sub183	1119.943	630.841
Sub184	1119.221	630.984

Sub184	1136.778	642.367
Sub184	1176.715	668.413
Sub184	1130.218	648.734
Sub184	1119.800	670.149
Sub184	1065.007	646.804
Sub184	1073.882	626.546
Sub184	1087.194	631.563
Sub184	1092.017	620.179
Sub185	1049.093	770.593
Sub185	1083.455	786.036
Sub185	1133.647	676.772
Sub185	1099.285	662.487
Sub186	989.249	900.319
Sub186	1021.680	915.377
Sub186	1082.683	787.194
Sub186	1048.707	771.365
Sub187	901.901	898.599
Sub187	928.065	904.126
Sub187	944.695	907.079
Sub187	979.210	921.940
Sub187	997.743	880.242
Sub187	923.227	847.811
Sub188	947.165	778.700
Sub188	992.724	796.847
Sub188	961.064	863.640
Sub188	915.892	843.178
Sub189	993.882	796.847
Sub189	1029.402	811.904
Sub189	998.129	879.470
Sub189	962.222	864.027
Sub190	1037.221	703.316
Sub190	1073.127	717.988
Sub190	1029.499	811.035
Sub190	994.365	795.978
Sub191	992.048	682.853
Sub191	1036.835	703.702
Sub191	992.142	796.071
Sub191	947.188	778.128
Sub192	1064.344	647.622
Sub192	1098.992	661.620
Sub192	1073.139	717.570
Sub192	1038.476	702.833
Sub193	1026.217	608.531
Sub193	1072.934	627.063
Sub193	1037.028	702.737
Sub193	992.241	682.274
Sub194	1133.950	676.674
Sub194	1119.737	670.893
Sub194	1130.336	648.973
Sub194	1181.355	670.485
Sub194	1169.779	694.409
Sub194	1132.553	679.710
Sub195	1132.535	679.819
Sub195	1165.520	693.224
Sub195	1134.807	760.415
Sub195	1102.008	746.717
Sub196	1085.100	783.043
Sub196	1118.059	797.408
Sub196	1134.614	760.801
Sub196	1101.622	747.103
Sub197	1169.765	694.960

Sub197	1165.906	693.224
Sub197	1157.996	710.202
Sub197	1236.509	743.220
Sub197	1253.112	708.080
Sub197	1179.026	676.631
Sub198	1174.937	777.586
Sub198	1198.174	727.325
Sub198	1157.658	710.925
Sub198	1135.000	760.415
Sub199	1118.408	797.458
Sub199	1157.766	814.244
Sub199	1174.358	777.972
Sub199	1134.807	760.801
Sub200	1237.597	744.198
Sub200	1220.016	781.942
Sub200	1180.488	766.579
Sub200	1198.431	727.799
Sub201	1253.610	708.120
Sub201	1322.294	737.639
Sub201	1304.714	772.103
Sub201	1236.632	743.619
Sub202	1237.766	744.513
Sub202	1273.844	759.562
Sub202	1257.638	797.956
Sub202	1220.595	782.135
Sub203	1219.871	782.280
Sub203	1198.263	830.513
Sub203	1158.133	814.500
Sub203	1180.127	766.845
Sub204	1220.450	782.473
Sub204	1257.300	797.907
Sub204	1236.126	845.707
Sub204	1198.649	830.513
Sub205	1355.339	794.821
Sub205	1372.124	759.128
Sub205	1322.734	737.906
Sub205	1305.370	772.248
Sub206	1407.624	773.984
Sub206	1391.418	810.449
Sub206	1355.725	795.014
Sub206	1372.510	759.321
Sub207	1391.997	810.642
Sub207	1434.268	828.235
Sub207	1449.124	792.157
Sub207	1408.010	774.370
Sub208	1393.347	811.992
Sub208	1433.882	828.621
Sub208	1419.798	860.648
Sub208	1378.877	844.019
Sub209	1392.961	811.413
Sub209	1351.866	793.856
Sub209	1337.975	826.848
Sub209	1378.684	843.633
Sub210	1299.582	810.063
Sub210	1337.589	826.848
Sub210	1351.288	793.664
Sub210	1314.244	776.685
Sub211	1274.307	759.707
Sub211	1314.052	776.685
Sub211	1297.266	814.307
Sub211	1257.715	798.101

Sub212	1419.605	861.034
Sub212	1404.363	899.042
Sub212	1361.706	882.606
Sub212	1379.070	844.598
Sub213	1337.589	827.234
Sub213	1378.877	843.633
Sub213	1358.619	888.201
Sub213	1318.296	873.152
Sub214	1299.389	810.256
Sub214	1337.011	827.234
Sub214	1313.797	882.016
Sub214	1274.886	867.171
Sub215	1297.266	814.693
Sub215	1274.307	866.978
Sub215	1245.753	856.946
Sub215	1236.492	846.141
Sub215	1257.522	798.294
Sub216	1434.461	828.042
Sub216	1470.539	842.320
Sub216	1486.553	807.592
Sub216	1449.510	792.350
Sub217	1420.184	860.648
Sub217	1456.262	874.732
Sub217	1470.154	842.512
Sub217	1434.461	828.621
Sub218	1404.749	899.042
Sub218	1440.442	911.583
Sub218	1455.876	875.118
Sub218	1419.991	860.841
Sub219	1082.636	788.393
Sub219	1085.029	783.422
Sub219	1117.982	797.966
Sub219	1083.142	873.824
Sub219	1048.717	859.281
Sub220	1118.166	797.782
Sub220	1157.378	814.350
Sub220	1121.986	890.208
Sub220	1082.590	875.665
Sub221	1035.094	887.723
Sub221	1070.440	902.174
Sub221	1083.050	874.008
Sub221	1048.532	859.787
Sub223	1082.406	875.849
Sub223	1121.894	890.300
Sub223	1109.652	917.546
Sub223	1070.808	902.174
Sub224	1021.931	915.337
Sub224	1058.197	932.826
Sub224	1070.164	902.359
Sub224	1034.909	887.907
Sub225	1058.474	932.642
Sub225	1095.200	949.763
Sub225	1109.376	917.638
Sub225	1070.348	902.359
Sub226	1122.170	890.116
Sub226	1160.830	907.789
Sub226	1196.820	830.309
Sub226	1157.700	814.569
Sub227	1109.928	917.707
Sub227	1148.588	933.954
Sub227	1160.738	908.181

Sub227	1122.078	890.508
Sub228	1095.569	949.602
Sub228	1134.781	967.459
Sub228	1148.127	934.000
Sub228	1109.560	917.799
Sub229	1161.290	907.766
Sub229	1199.766	923.967
Sub229	1235.848	846.095
Sub229	1197.189	830.079
Sub230	1148.956	933.862
Sub230	1187.432	949.924
Sub230	1199.214	924.059
Sub230	1161.014	907.904
Sub231	1135.149	967.505
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Sub231	1187.432	950.476
Sub231	1148.404	933.908
Sub232	1218.815	883.168
Sub232	1259.166	899.750
Sub232	1273.722	867.506
Sub232	1245.347	857.188
Sub232	1235.950	846.502
Sub233	1259.719	900.441
Sub233	1240.557	942.267
Sub233	1198.731	927.527
Sub233	1218.631	883.674
Sub234	1260.640	900.257
Sub234	1259.719	899.152
Sub234	1274.275	867.460
Sub234	1313.705	882.385
Sub234	1278.697	959.771
Sub234	1239.359	945.537
Sub235	1186.755	952.907
Sub235	1228.580	968.200
Sub235	1240.465	942.543
Sub235	1197.902	927.619
Sub236	1278.605	960.093
Sub236	1268.102	984.875
Sub236	1227.659	970.734
Sub236	1239.267	945.860
Sub237	1171.370	985.474
Sub237	1212.642	1005.834
Sub237	1228.304	968.523
Sub237	1186.479	953.322
Sub238	1213.380	1005.972
Sub238	1250.506	1023.476
Sub238	1267.826	985.151
Sub238	1227.751	971.148
Sub239	1290.858	934.252
Sub239	1331.025	949.913
Sub239	1358.939	888.695
Sub239	1317.943	873.218
Sub240	1402.330	898.553
Sub240	1384.642	937.983
Sub240	1343.738	922.874
Sub240	1361.795	882.891
Sub242	1440.194	911.773
Sub242	1420.203	952.907
Sub242	1383.537	941.115
Sub242	1402.515	898.599
Sub243	1419.834	953.045

Sub243	1399.709	1001.266
Sub243	1360.689	987.316
Sub243	1383.352	941.253
Sub244	1384.274	938.121
Sub244	1369.718	967.970
Sub244	1331.393	950.097
Sub244	1343.554	923.012
Sub245	1312.599	990.955
Sub245	1350.187	1007.907
Sub245	1369.718	968.292
Sub245	1330.103	950.051
Sub246	1290.489	934.390
Sub246	1330.011	949.821
Sub246	1318.127	976.538
Sub246	1278.328	961.337
Sub247	1267.826	985.981
Sub247	1307.532	1002.379
Sub247	1318.311	976.952
Sub247	1278.236	961.567
Sub248	1307.625	1002.655
Sub248	1344.475	1019.238
Sub248	1349.450	1008.183
Sub248	1312.599	991.416
Sub249	1399.567	1001.550
Sub249	1379.483	1043.375
Sub249	1340.422	1028.267
Sub249	1349.818	1008.183
Sub249	1350.371	1008.367
Sub249	1360.505	987.731
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Sub250	1250.598	1023.660
Sub250	1289.752	1042.454
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Sub251	1289.936	1042.638
Sub251	1327.155	1058.300
Sub251	1344.014	1019.468
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Sub252	1362.992	1071.612
Sub252	1379.299	1043.606
Sub252	1340.237	1028.497
Sub254	1057.410	932.709
Sub254	1052.159	944.777
Sub254	994.396	917.393
Sub254	998.818	905.232
Sub255	1134.059	967.624
Sub255	1128.900	979.670
Sub255	1052.251	945.054
Sub255	1057.686	932.524
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Sub256	1208.220	1015.622
Sub256	1129.084	979.693
Sub256	1134.519	967.624
Sub257	1289.752	1042.615
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Sub257	1208.405	1015.645
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Sub258	1352.214	1080.755
Sub258	1285.699	1051.068

Sub258	1289.844	1042.684
Sub259	979.443	922.908
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Sub259	926.380	1022.878
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Sub259	989.190	900.534
Sub260	870.783	1148.744
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Sub260	966.435	1037.849
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Sub261	829.857	1204.727
Sub261	882.739	1225.739
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Sub261	870.010	1149.130
Sub262	800.281	1249.780
Sub262	880.435	1280.232
Sub262	901.440	1233.432
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Sub263	1051.237	944.731
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Sub267	937.738	1100.977
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Sub275	1037.827	1179.942
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Sub280	1172.193	1093.343
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Sub280	1131.658	1076.576
Sub281	1147.509	1148.906
Sub281	1185.465	1163.462
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Sub282	1092.412	1267.093
Sub282	1051.877	1250.879
Sub282	1071.960	1205.369
Sub282	1076.935	1195.235
Sub282	1089.372	1168.380
Sub283	1167.863	1201.177
Sub283	1131.848	1285.345
Sub283	1092.688	1267.370
Sub283	1130.644	1186.252
Sub284	1244.420	1032.724
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Sub285	1249.948	1127.384
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Sub285	1167.034	1204.401
Sub285	1209.965	1110.064
Sub286	1248.848	1130.849
Sub286	1288.462	1148.353
Sub286	1325.313	1069.124
Sub286	1285.699	1051.436

Sub287	1145.237	1255.166
Sub287	1185.220	1271.012
Sub287	1208.059	1220.701
Sub287	1166.487	1204.504
Sub288	1232.381	1167.083
Sub288	1308.293	1200.249
Sub288	1324.138	1164.320
Sub288	1248.779	1131.154
Sub289	1325.059	1069.061
Sub289	1354.949	1082.276
Sub289	1355.093	1094.119
Sub289	1324.138	1163.951
Sub289	1288.578	1148.105
Sub290	1214.364	1208.397
Sub290	1289.355	1240.088
Sub290	1307.596	1200.474
Sub290	1232.421	1167.493
Sub291	1288.802	1240.088
Sub291	1276.826	1266.621
Sub291	1202.019	1235.851
Sub291	1214.180	1208.765
Sub292	1276.273	1266.805
Sub292	1264.481	1291.679
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Sub292	1201.651	1236.219
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Sub297	1146.896	1149.106
Sub297	1185.036	1163.661
Sub297	1168.085	1200.880
Sub297	1130.866	1185.772
Sub298	1159.240	1122.412
Sub298	1197.243	1137.636
Sub298	1209.956	1109.676
Sub298	1172.507	1093.484
Sub299	1095.812	1269.284
Sub299	1133.215	1286.351
Sub299	1115.342	1330.709
Sub299	1075.360	1312.031
Sub300	1185.036	1271.426
Sub300	1170.940	1302.473
Sub300	1132.063	1285.522
Sub300	1144.869	1255.350
Sub301	1564.288	989.620

Sub301	1504.406	1132.599
Sub301	1460.923	1111.963
Sub301	1525.964	965.667
Sub302	1440.839	911.957
Sub302	1433.469	926.513
Sub302	1525.779	964.101
Sub302	1548.995	914.537
Sub302	1456.316	875.291
Sub305	1481.559	947.794
Sub305	1525.595	965.390
Sub305	1460.370	1112.055
Sub305	1412.280	1100.355
Sub306	1480.638	947.886
Sub306	1433.100	927.619
Sub306	1420.756	952.677
Sub306	1400.672	1000.951
Sub306	1380.036	1043.513
Sub306	1363.453	1071.888
Sub306	1411.911	1100.079
Sub322	1552.865	907.397
Sub322	1595.427	925.269
Sub322	1564.841	989.389
Sub322	1525.964	964.515

[SYMBOLS]
;;Gage X-Coord Y-Coord
;;-------------- ------------------ ------------------
Gage1 308.977 16.214

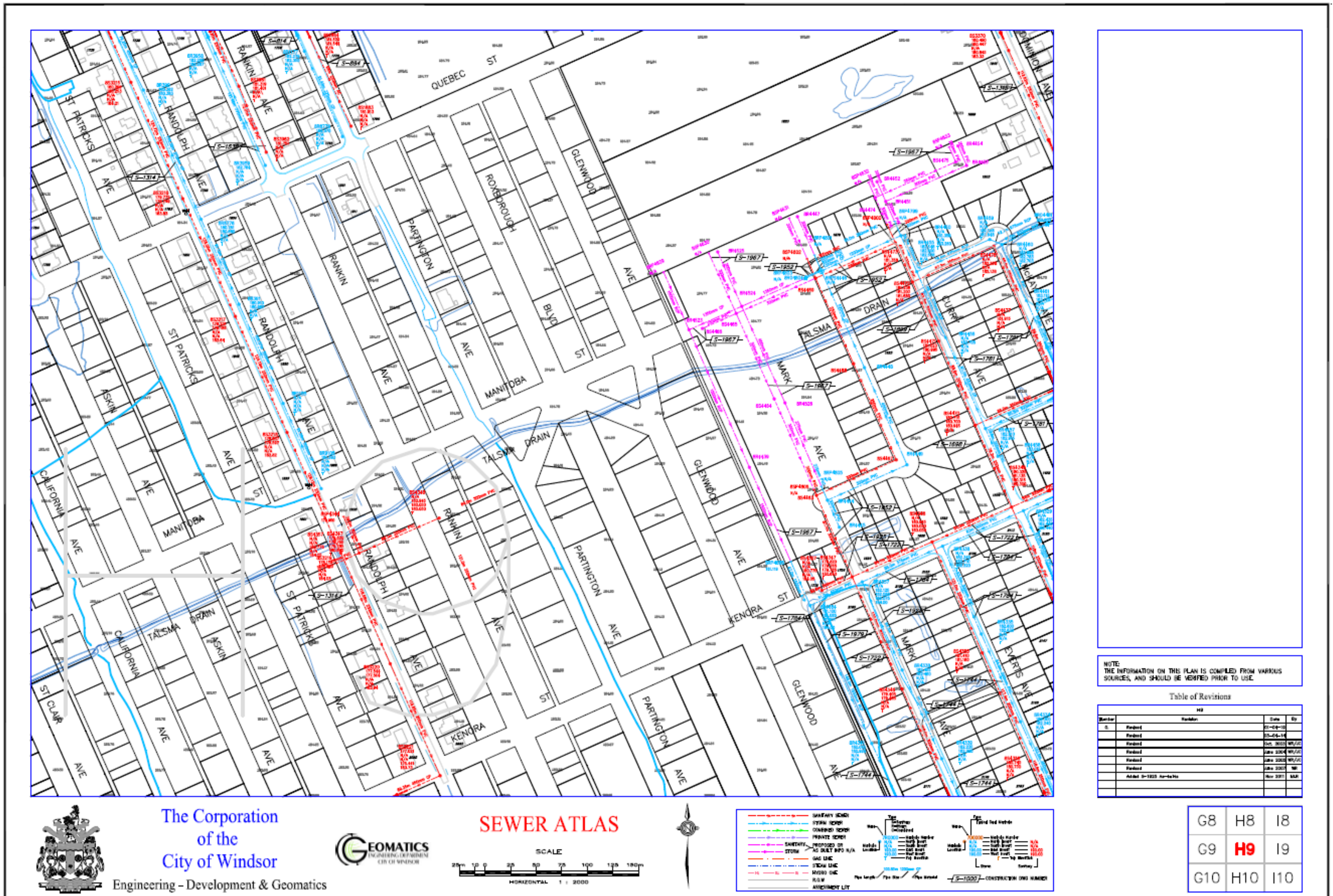
[LABELS]
;;X-Coord Y-Coord Label
733.526 1323.515 "This area is now somewhat developed" "" "Arial" 10 0
0

[BACKDROP]
FILE "C:\Users\Kyle Eckart\Desktop\FM1200.jpg"
DIMENSIONS 0.000 0.000 1750.000 1390.000

Appendix B: Sewer Maps

This appendix contains the sewer maps which were used to design the routing network in the SWMM model. Most of the maps were obtained from Windsor's sewer atlas. The final two maps were obtained via personal communication with a city employee. Sewer maps from the City of Windsor can be found in the sewer atlas at the following web address:

http://www.citywindsor.ca/visitors/Maps/Pages/MAPS-For-Residents.aspx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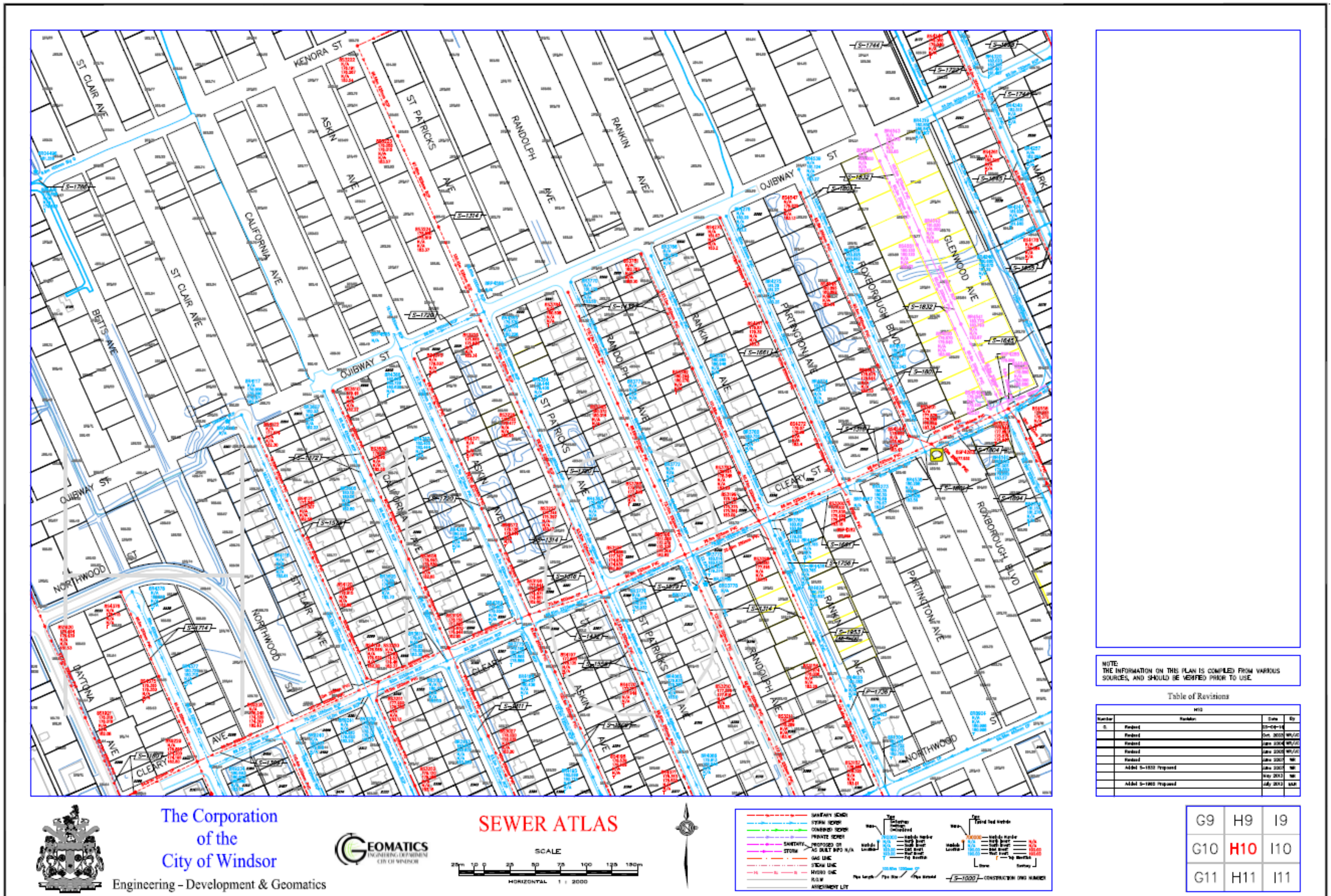
ST PATRICKS AVE
RANDOLPH AVE
RANKIN AVE
PARTINGTON AVE
ROXBOROUGH BLVD
GLENWOOD AVE
MANITOBA ST
TALSMA DRAIN
ASKIN AVE
CALIFORNIA AVE
ST CLAIR AVE
KENORA ST
MARK AVE
CURRY AVE
EVERTS AVE
MCKAY AVE
DOMINION AVE
NOTE: THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.
Table of Revisions
The Corporation of the City of Windsor
Engineering - Development & Geomatics
GEOMATICS
SEWER ATLAS
SCALE
HORIZONTAL 1 : 2000
G8
H8
I8
G9
H9
I9
G10
H10
I10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ST CLAIR AVE
ASKIN AVE
ST PATRICKS AVE
RANDOLPH AVE
RANKIN AVE
OJIBWAY ST
CALIFORNIA AVE
BETTS AVE
ROXBOROUGH BLVD
GLENWOOD AVE
PARTINGTON AVE
CLEARY ST
NORTHWOOD ST
DAYTONA AVE
NOTE: THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.
Table of Revisions
The Corporation of the City of Windsor
Engineering - Development & Geomatics
GEOMATICS
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SCALE
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G10
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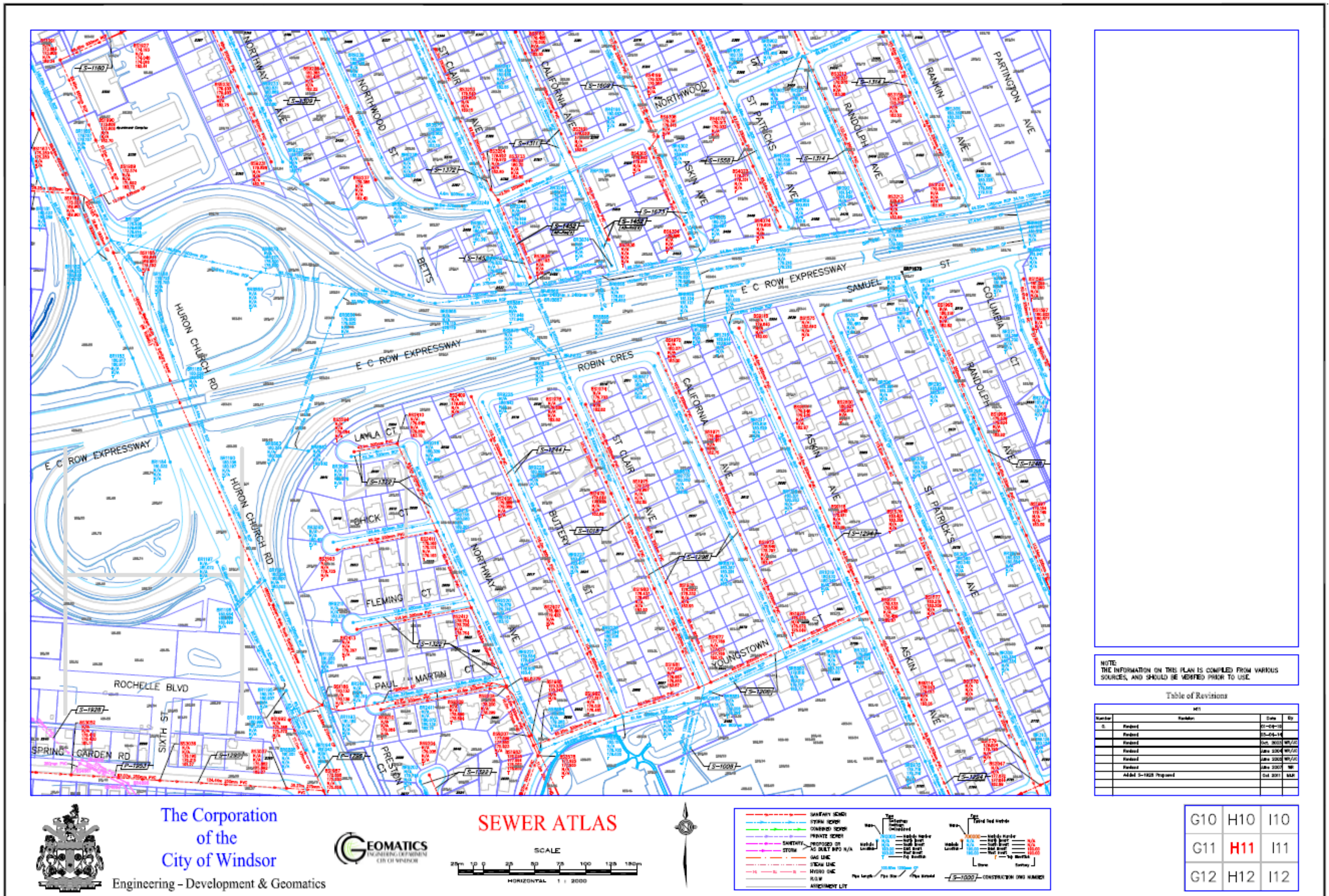
I11



NORTHWAY AVE
NORTHWOOD ST
ST CLAIR AVE
CALIFORNIA AVE
NORTHWOOD
ST PATRICKS AVE
ASKIN AVE
RANDOLPH AVE
RANKIN AVE
PARTINGTON AVE
BETTS
HURON CHURCH RD
E C ROW EXPRESSWAY
SAMUEL ST
COLUMBIA CT
ROBIN CRES
LAYLA CT
CHICK CT
FLEMING CT
PAUL MARTIN CT
PRESTON CT
BUTTERY ST
YOUNGSTOWN ST
ROCHELLE BLVD
SIXTH ST
SPRING GARDEN RD
NOTE: THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.
Table of Revisions
The Corporation of the City of Windsor
Engineering - Development & Geomatics
GEOMATICS
SEWER ATLAS
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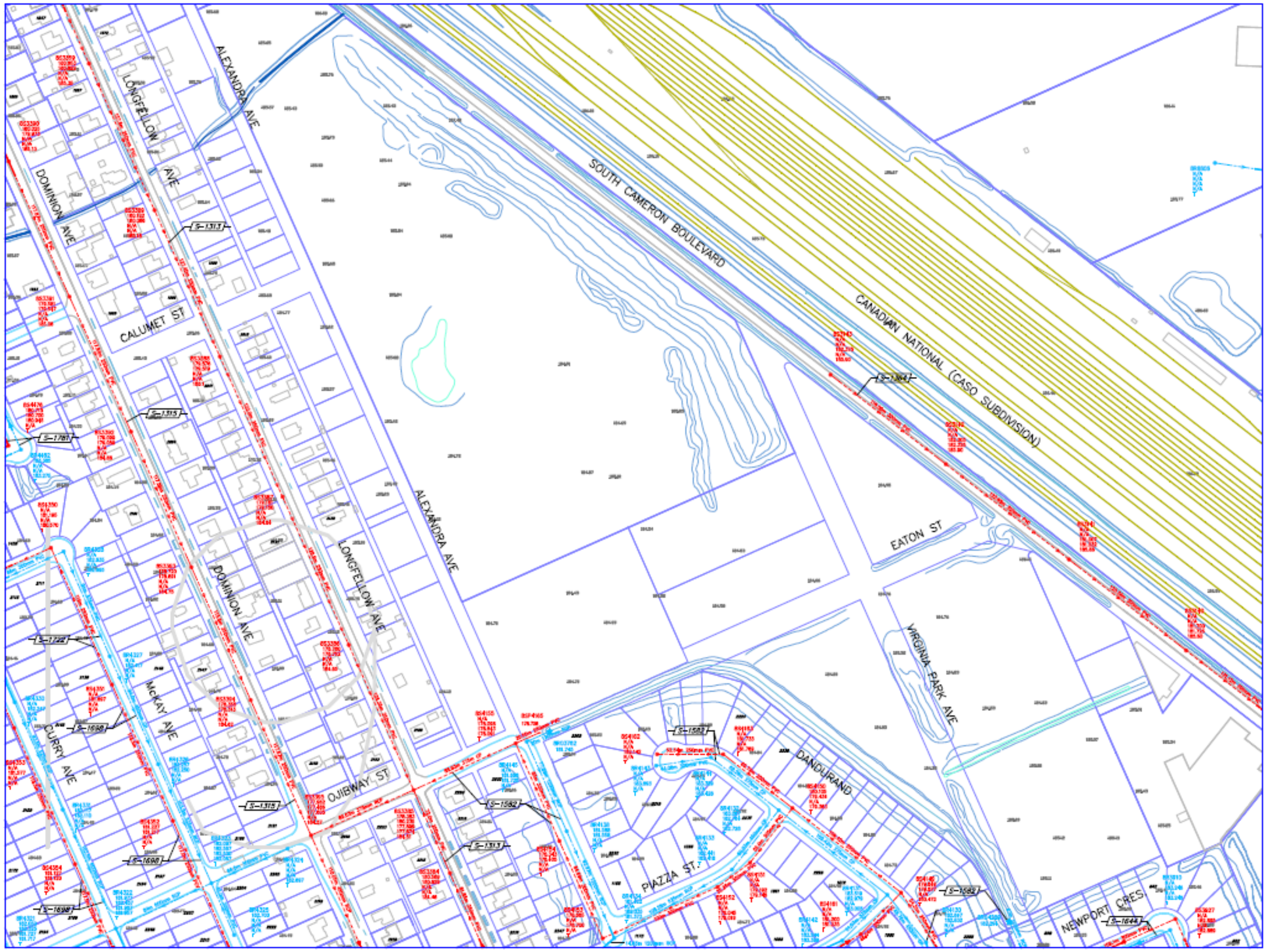
G12 H12 I12



NOTE:
THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.

Table of Revisions

The Corporation of the City of Windsor

Engineering - Development & Geomatics

GEOMATICS

SEWER ATLAS

SCALE

HORIZONTAL 1 : 2000

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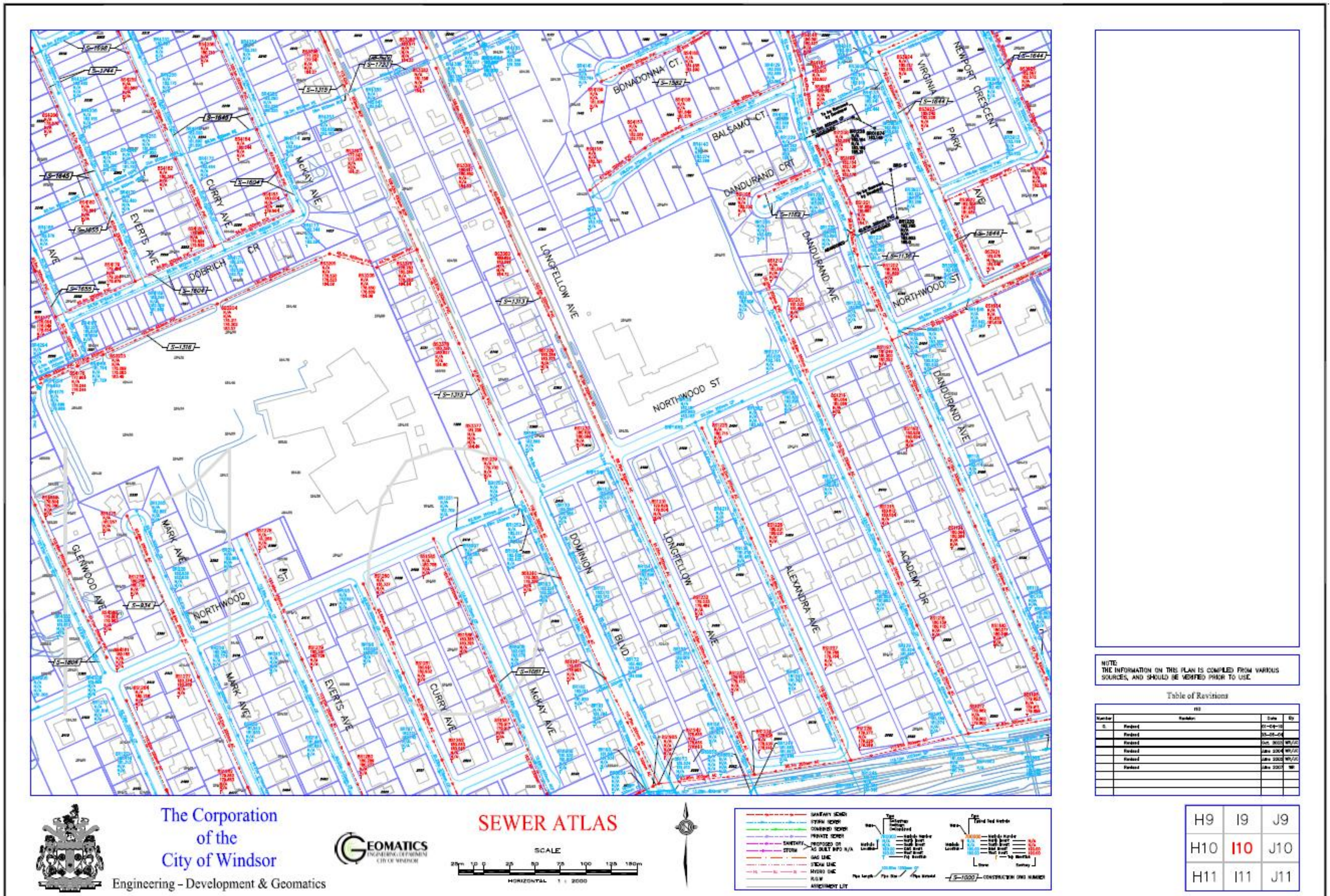
H10	I10	J10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BALSAMO CT
DANDURAND CRT
DANDURAND AVE
VIRGINIA PARK AVE
NEWPORT CRESCENT
NORTHWOOD ST
LONGFELLOW AVE
McKAY AVE
CURRY AVE
EVERTS AVE
DOBRICH CR
MARK AVE
GLENWOOD AVE
NORTHWOOD
DOMINION BLVD
LONGFELLOW AVE
ALEXANDRA AVE
ACADEMY DR
The Corporation
of the
City of Windsor
Engineering – Development & Geomatics
GEOMATICS
SEWER ATLAS
SCALE
HORIZONTAL 1 : 2000
NOTE:
THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.
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J9
H10
I10
J10
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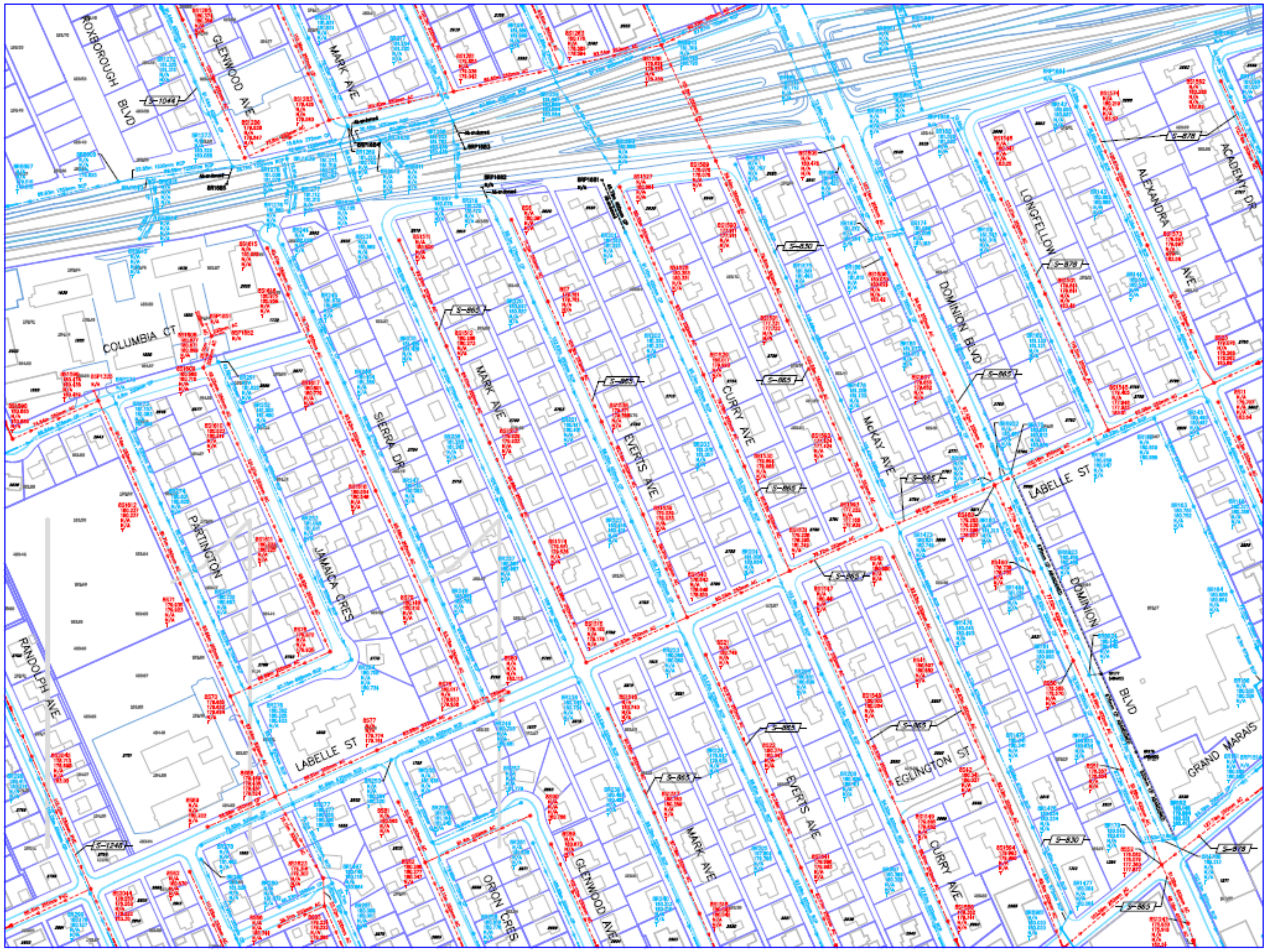
I11
J11



NOTE:
THE INFORMATION ON THIS PLAN IS COMPILED FROM VARIOUS SOURCES, AND SHOULD BE VERIFIED PRIOR TO USE.

Table of Revisions

The Corporation of the City of Windsor

Engineering – Development & Geomatics

GEOMATICS

SEWER ATLAS

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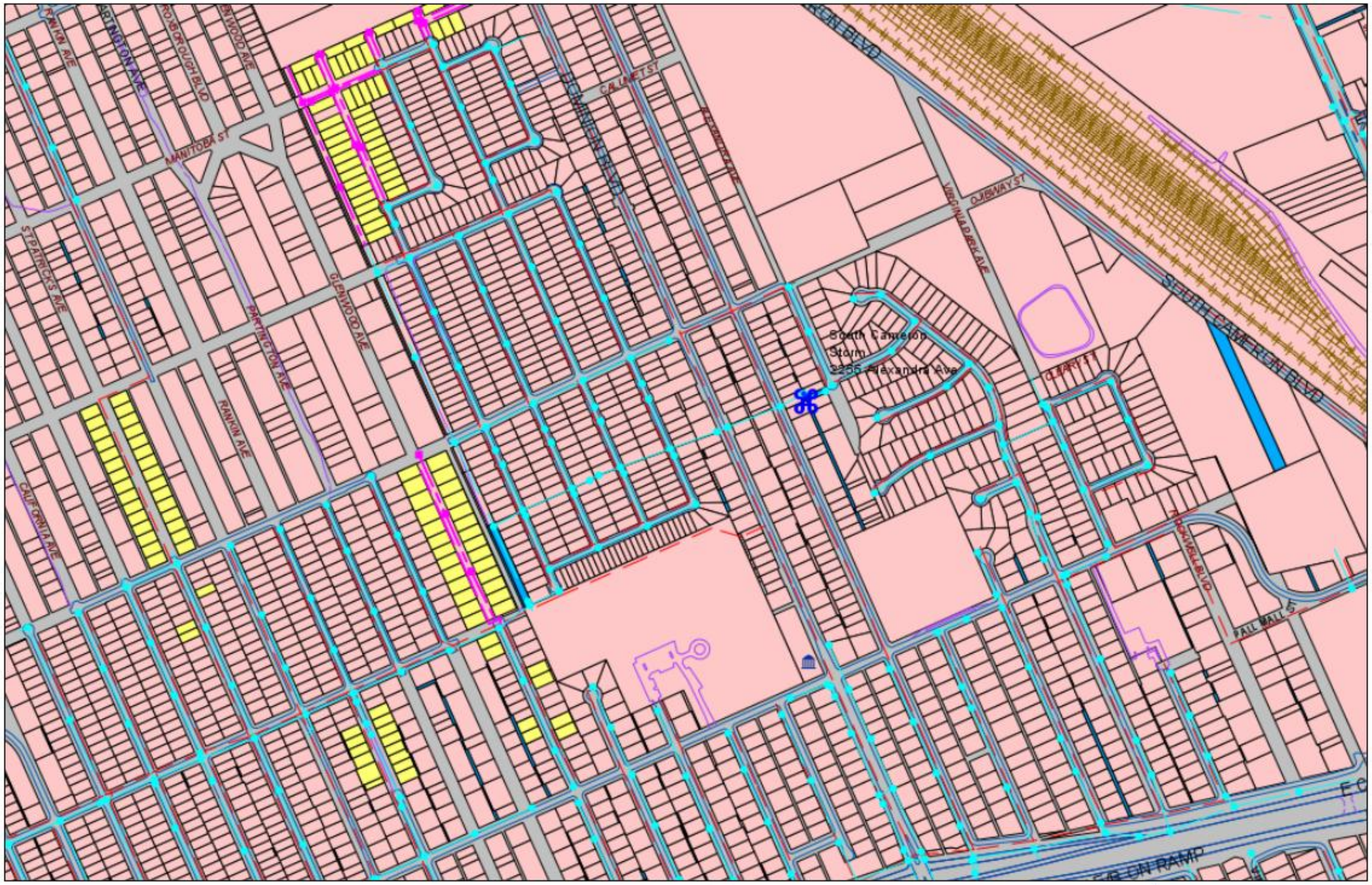
Apr 8, 2014



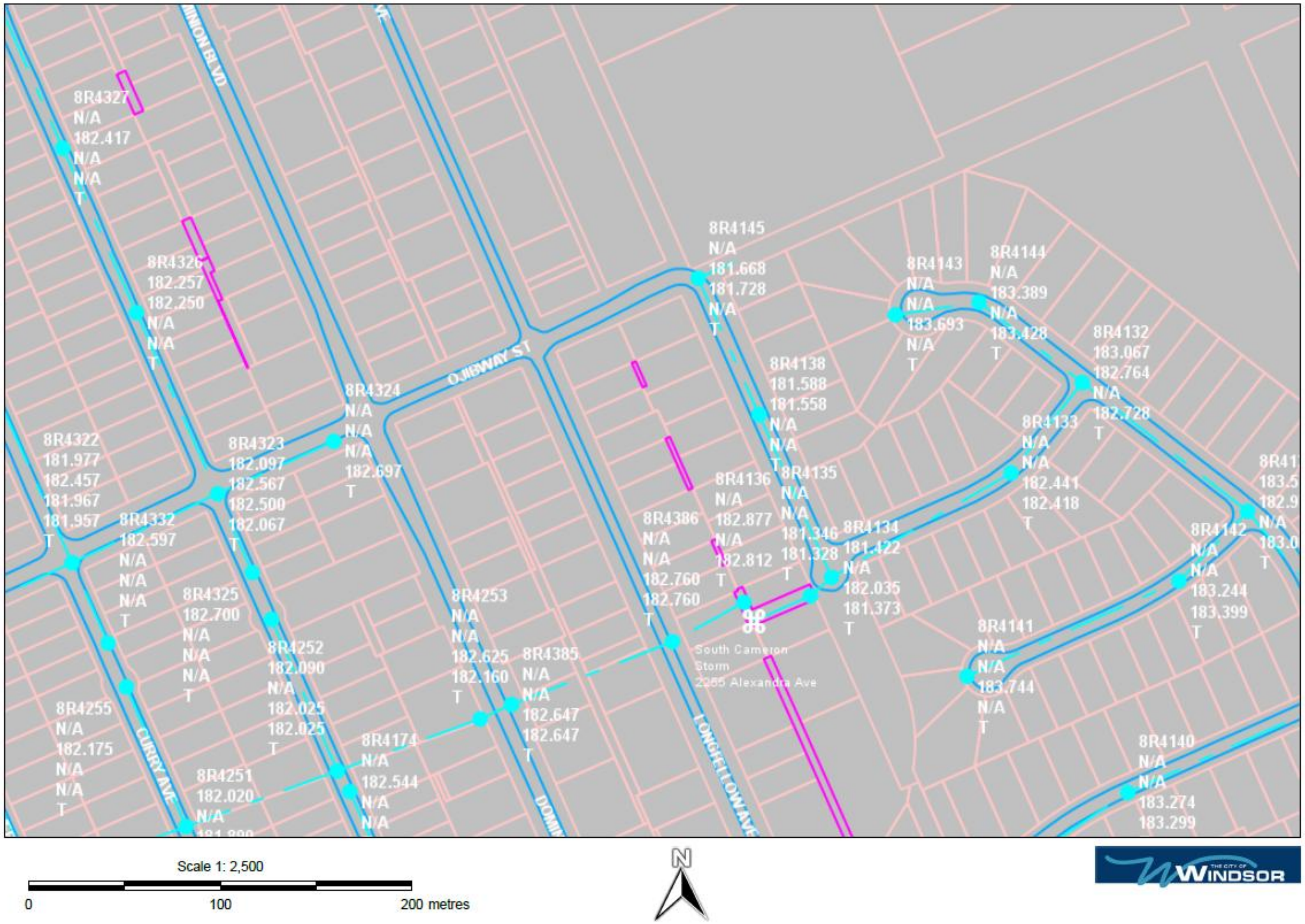
Scale 1: 8,000

0 400 800 metres

N

THE CITY OF WINDSOR

Apr 8, 2014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N/A
T
8R4326
182.257
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N/A
N/A
T
OJIBWAY ST
8R4324
N/A
N/A
N/A
182.697
T
8R4322
181.977
182.457
181.967
181.957
T
8R4323
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182.567
182.500
182.067
T
8R4332
182.597
N/A
N/A
N/A
T
8R4325
182.700
N/A
N/A
N/A
T
8R4252
182.090
N/A
182.025
182.025
T
8R4255
N/A
182.175
N/A
N/A
T
CURRY AVE
8R4251
182.020
N/A
8R4174
N/A
182.544
N/A
N/A
8R4253
N/A
N/A
182.625
182.160
T
8R4385
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N/A
182.760
182.760
T
8R4134
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N/A
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181.373
T
South Cameron
Storm
2255 Alexandra Ave
LONGFELLOW AVE
8R4143
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N/A
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8R4144
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8R4142
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N/A
183.244
183.399
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8R4141
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N/A
183.744
N/A
T
8R4140
N/A
N/A
183.274
183.299
Scale 1: 2,500
0
100
200 metres
N
THE CITY OF WINDSOR

Appendix C: Rainfall Files

Historical 5 year storm

[Station][Year][Month][Day][Hour][Minute]

[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.0695
STA1	2013	7	15	17	24	0.1405
STA1	2013	7	15	17	36	0.1432
STA1	2013	7	15	17	48	0.1460
STA1	2013	7	15	18	0	0.1487
STA1	2013	7	15	18	12	0.1515
STA1	2013	7	15	18	24	0.1542
STA1	2013	7	15	18	36	0.1570
STA1	2013	7	15	18	48	0.1597
STA1	2013	7	15	19	0	0.1625
STA1	2013	7	15	19	12	0.1652
STA1	2013	7	15	19	24	0.1680
STA1	2013	7	15	19	36	0.1707
STA1	2013	7	15	19	48	0.1735
STA1	2013	7	15	20	0	0.1763
STA1	2013	7	15	20	12	0.1790
STA1	2013	7	15	20	24	0.1818
STA1	2013	7	15	20	36	0.1845
STA1	2013	7	15	20	48	0.1873
STA1	2013	7	15	21	0	0.1900
STA1	2013	7	15	21	12	0.1928
STA1	2013	7	15	21	24	0.1983
STA1	2013	7	15	21	36	0.2038
STA1	2013	7	15	21	48	0.2093
STA1	2013	7	15	22	0	0.2148
STA1	2013	7	15	22	12	0.2203
STA1	2013	7	15	22	24	0.2258
STA1	2013	7	15	22	36	0.2313
STA1	2013	7	15	22	48	0.2368
STA1	2013	7	15	23	0	0.2424
STA1	2013	7	15	23	12	0.2479
STA1	2013	7	15	23	24	0.2534
STA1	2013	7	15	23	36	0.2589
STA1	2013	7	15	23	48	0.2644
STA1	2013	7	16	0	0	0.2699
STA1	2013	7	16	0	12	0.2754
STA1	2013	7	16	0	24	0.2809
STA1	2013	7	16	0	36	0.2864
STA1	2013	7	16	0	48	0.2919
STA1	2013	7	16	1	0	0.2974
STA1	2013	7	16	1	12	0.3057
STA1	2013	7	16	1	24	0.3305
STA1	2013	7	16	1	36	0.3580
STA1	2013	7	16	1	48	0.3856
STA1	2013	7	16	2	0	0.4131
STA1	2013	7	16	2	12	0.4372
STA1	2013	7	16	2	24	0.4406
STA1	2013	7	16	2	36	0.4406
STA1	2013	7	16	2	48	0.4627
STA1	2013	7	16	3	0	0.5067
STA1	2013	7	16	3	12	0.5536
STA1	2013	7	16	3	24	0.6169
STA1	2013	7	16	3	36	0.6830
STA1	2013	7	16	3	48	0.7711
STA1	2013	7	16	4	0	0.8813
STA1	2013	7	16	4	12	1.0107
STA1	2013	7	16	4	24	1.2558

STA1	2013	7	16	4	36	1.5202
STA1	2013	7	16	4	48	4.9131
STA1	2013	7	16	5	0	14.6995
STA1	2013	7	16	5	12	7.8558
STA1	2013	7	16	5	24	2.1399
STA1	2013	7	16	5	36	1.5119
STA1	2013	7	16	5	48	1.1264
STA1	2013	7	16	6	0	0.9832
STA1	2013	7	16	6	12	0.8482
STA1	2013	7	16	6	24	0.7629
STA1	2013	7	16	6	36	0.6857
STA1	2013	7	16	6	48	0.6197
STA1	2013	7	16	7	0	0.5646
STA1	2013	7	16	7	12	0.5143
STA1	2013	7	16	7	24	0.4902
STA1	2013	7	16	7	36	0.4709
STA1	2013	7	16	7	48	0.4517
STA1	2013	7	16	8	0	0.4324
STA1	2013	7	16	8	12	0.4131
STA1	2013	7	16	8	24	0.3938
STA1	2013	7	16	8	36	0.3745
STA1	2013	7	16	8	48	0.3553
STA1	2013	7	16	9	0	0.3360
STA1	2013	7	16	9	12	0.3181
STA1	2013	7	16	9	24	0.3098
STA1	2013	7	16	9	36	0.3029
STA1	2013	7	16	9	48	0.2961
STA1	2013	7	16	10	0	0.2892
STA1	2013	7	16	10	12	0.2823
STA1	2013	7	16	10	24	0.2754
STA1	2013	7	16	10	36	0.2685
STA1	2013	7	16	10	48	0.2616
STA1	2013	7	16	11	0	0.2547
STA1	2013	7	16	11	12	0.2479
STA1	2013	7	16	11	24	0.2410
STA1	2013	7	16	11	36	0.2341
STA1	2013	7	16	11	48	0.2272
STA1	2013	7	16	12	0	0.2203
STA1	2013	7	16	12	12	0.2134
STA1	2013	7	16	12	24	0.2066
STA1	2013	7	16	12	36	0.1997
STA1	2013	7	16	12	48	0.1928
STA1	2013	7	16	13	0	0.1859
STA1	2013	7	16	13	12	0.1797
STA1	2013	7	16	13	24	0.1776
STA1	2013	7	16	13	36	0.1763
STA1	2013	7	16	13	48	0.1749
STA1	2013	7	16	14	0	0.1735
STA1	2013	7	16	14	12	0.1721
STA1	2013	7	16	14	24	0.1707
STA1	2013	7	16	14	36	0.1694
STA1	2013	7	16	14	48	0.1680
STA1	2013	7	16	15	0	0.1666
STA1	2013	7	16	15	12	0.1652
STA1	2013	7	16	15	24	0.1639
STA1	2013	7	16	15	36	0.1625
STA1	2013	7	16	15	48	0.1611
STA1	2013	7	16	16	0	0.1597
STA1	2013	7	16	16	12	0.1584
STA1	2013	7	16	16	24	0.1570

STA1	2013	7	16	16	36	0.1556
STA1	2013	7	16	16	48	0.1542
STA1	2013	7	16	17	0	0.2286

Historical 25 year storm

[Station][Year][Month][Day][Hour][Minute
]

[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.0885
STA1	2013	7	15	17	24	0.1788
STA1	2013	7	15	17	36	0.1824
STA1	2013	7	15	17	48	0.1859
STA1	2013	7	15	18	0	0.1894
STA1	2013	7	15	18	12	0.1929
STA1	2013	7	15	18	24	0.1964
STA1	2013	7	15	18	36	0.1999
STA1	2013	7	15	18	48	0.2034
STA1	2013	7	15	19	0	0.2069
STA1	2013	7	15	19	12	0.2104
STA1	2013	7	15	19	24	0.2139
STA1	2013	7	15	19	36	0.2174
STA1	2013	7	15	19	48	0.2209
STA1	2013	7	15	20	0	0.2244
STA1	2013	7	15	20	12	0.2279
STA1	2013	7	15	20	24	0.2314
STA1	2013	7	15	20	36	0.2350
STA1	2013	7	15	20	48	0.2385
STA1	2013	7	15	21	0	0.2420
STA1	2013	7	15	21	12	0.2455
STA1	2013	7	15	21	24	0.2525
STA1	2013	7	15	21	36	0.2595
STA1	2013	7	15	21	48	0.2665
STA1	2013	7	15	22	0	0.2735
STA1	2013	7	15	22	12	0.2805
STA1	2013	7	15	22	24	0.2876
STA1	2013	7	15	22	36	0.2946
STA1	2013	7	15	22	48	0.3016
STA1	2013	7	15	23	0	0.3086
STA1	2013	7	15	23	12	0.3156
STA1	2013	7	15	23	24	0.3226
STA1	2013	7	15	23	36	0.3296
STA1	2013	7	15	23	48	0.3367
STA1	2013	7	16	0	0	0.3437
STA1	2013	7	16	0	12	0.3507
STA1	2013	7	16	0	24	0.3577
STA1	2013	7	16	0	36	0.3647
STA1	2013	7	16	0	48	0.3717
STA1	2013	7	16	1	0	0.3787
STA1	2013	7	16	1	12	0.3893
STA1	2013	7	16	1	24	0.4208
STA1	2013	7	16	1	36	0.4559
STA1	2013	7	16	1	48	0.4910
STA1	2013	7	16	2	0	0.5260
STA1	2013	7	16	2	12	0.5567
STA1	2013	7	16	2	24	0.5611
STA1	2013	7	16	2	36	0.5611
STA1	2013	7	16	2	48	0.5891
STA1	2013	7	16	3	0	0.6453
STA1	2013	7	16	3	12	0.7049
STA1	2013	7	16	3	24	0.7855
STA1	2013	7	16	3	36	0.8697
STA1	2013	7	16	3	48	0.9819

STA1	2013	7	16	4	0	1.1222
STA1	2013	7	16	4	12	1.2870
STA1	2013	7	16	4	24	1.5991
STA1	2013	7	16	4	36	1.9358
STA1	2013	7	16	4	48	6.2561
STA1	2013	7	16	5	0	18.7175
STA1	2013	7	16	5	12	10.0031
STA1	2013	7	16	5	24	2.7248
STA1	2013	7	16	5	36	1.9252
STA1	2013	7	16	5	48	1.4343
STA1	2013	7	16	6	0	1.2519
STA1	2013	7	16	6	12	1.0801
STA1	2013	7	16	6	24	0.9714
STA1	2013	7	16	6	36	0.8732
STA1	2013	7	16	6	48	0.7890
STA1	2013	7	16	7	0	0.7189
STA1	2013	7	16	7	12	0.6549
STA1	2013	7	16	7	24	0.6242
STA1	2013	7	16	7	36	0.5997
STA1	2013	7	16	7	48	0.5751
STA1	2013	7	16	8	0	0.5506
STA1	2013	7	16	8	12	0.5260
STA1	2013	7	16	8	24	0.5015
STA1	2013	7	16	8	36	0.4769
STA1	2013	7	16	8	48	0.4524
STA1	2013	7	16	9	0	0.4278
STA1	2013	7	16	9	12	0.4050
STA1	2013	7	16	9	24	0.3945
STA1	2013	7	16	9	36	0.3857
STA1	2013	7	16	9	48	0.3770
STA1	2013	7	16	10	0	0.3682
STA1	2013	7	16	10	12	0.3594
STA1	2013	7	16	10	24	0.3507
STA1	2013	7	16	10	36	0.3419
STA1	2013	7	16	10	48	0.3331
STA1	2013	7	16	11	0	0.3244
STA1	2013	7	16	11	12	0.3156
STA1	2013	7	16	11	24	0.3068
STA1	2013	7	16	11	36	0.2981
STA1	2013	7	16	11	48	0.2893
STA1	2013	7	16	12	0	0.2805
STA1	2013	7	16	12	12	0.2718
STA1	2013	7	16	12	24	0.2630
STA1	2013	7	16	12	36	0.2542
STA1	2013	7	16	12	48	0.2455
STA1	2013	7	16	13	0	0.2367
STA1	2013	7	16	13	12	0.2288
STA1	2013	7	16	13	24	0.2262
STA1	2013	7	16	13	36	0.2244
STA1	2013	7	16	13	48	0.2227
STA1	2013	7	16	14	0	0.2209
STA1	2013	7	16	14	12	0.2192
STA1	2013	7	16	14	24	0.2174
STA1	2013	7	16	14	36	0.2157
STA1	2013	7	16	14	48	0.2139
STA1	2013	7	16	15	0	0.2122
STA1	2013	7	16	15	12	0.2104
STA1	2013	7	16	15	24	0.2087
STA1	2013	7	16	15	36	0.2069
STA1	2013	7	16	15	48	0.2051

STA1	2013	7	16	16	0	0.2034
STA1	2013	7	16	16	12	0.2016
STA1	2013	7	16	16	24	0.1999
STA1	2013	7	16	16	36	0.1981
STA1	2013	7	16	16	48	0.1964
STA1	2013	7	16	17	0	0.2911

Historical 100 year storm

[Station][Year][Month][Day][Hour][Minute]

[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.1127
STA1	2013	7	15	17	24	0.2276
STA1	2013	7	15	17	36	0.2321
STA1	2013	7	15	17	48	0.2366
STA1	2013	7	15	18	0	0.2410
STA1	2013	7	15	18	12	0.2455
STA1	2013	7	15	18	24	0.2500
STA1	2013	7	15	18	36	0.2544
STA1	2013	7	15	18	48	0.2589
STA1	2013	7	15	19	0	0.2634
STA1	2013	7	15	19	12	0.2678
STA1	2013	7	15	19	24	0.2723
STA1	2013	7	15	19	36	0.2767
STA1	2013	7	15	19	48	0.2812
STA1	2013	7	15	20	0	0.2857
STA1	2013	7	15	20	12	0.2901
STA1	2013	7	15	20	24	0.2946
STA1	2013	7	15	20	36	0.2991
STA1	2013	7	15	20	48	0.3035
STA1	2013	7	15	21	0	0.3080
STA1	2013	7	15	21	12	0.3125
STA1	2013	7	15	21	24	0.3214
STA1	2013	7	15	21	36	0.3303
STA1	2013	7	15	21	48	0.3392
STA1	2013	7	15	22	0	0.3482
STA1	2013	7	15	22	12	0.3571
STA1	2013	7	15	22	24	0.3660
STA1	2013	7	15	22	36	0.3749
STA1	2013	7	15	22	48	0.3839
STA1	2013	7	15	23	0	0.3928
STA1	2013	7	15	23	12	0.4017
STA1	2013	7	15	23	24	0.4107
STA1	2013	7	15	23	36	0.4196
STA1	2013	7	15	23	48	0.4285
STA1	2013	7	16	0	0	0.4374
STA1	2013	7	16	0	12	0.4464
STA1	2013	7	16	0	24	0.4553
STA1	2013	7	16	0	36	0.4642
STA1	2013	7	16	0	48	0.4731
STA1	2013	7	16	1	0	0.4821
STA1	2013	7	16	1	12	0.4955
STA1	2013	7	16	1	24	0.5356
STA1	2013	7	16	1	36	0.5803
STA1	2013	7	16	1	48	0.6249
STA1	2013	7	16	2	0	0.6695
STA1	2013	7	16	2	12	0.7086
STA1	2013	7	16	2	24	0.7142
STA1	2013	7	16	2	36	0.7142
STA1	2013	7	16	2	48	0.7499
STA1	2013	7	16	3	0	0.8213
STA1	2013	7	16	3	12	0.8972

STA1	2013	7	16	3	24	0.9998
STA1	2013	7	16	3	36	1.1070
STA1	2013	7	16	3	48	1.2498
STA1	2013	7	16	4	0	1.4284
STA1	2013	7	16	4	12	1.6381
STA1	2013	7	16	4	24	2.0354
STA1	2013	7	16	4	36	2.4639
STA1	2013	7	16	4	48	7.9631
STA1	2013	7	16	5	0	23.8245
STA1	2013	7	16	5	12	12.7324
STA1	2013	7	16	5	24	3.4682
STA1	2013	7	16	5	36	2.4505
STA1	2013	7	16	5	48	1.8256
STA1	2013	7	16	6	0	1.5935
STA1	2013	7	16	6	12	1.3748
STA1	2013	7	16	6	24	1.2364
STA1	2013	7	16	6	36	1.1114
STA1	2013	7	16	6	48	1.0043
STA1	2013	7	16	7	0	0.9150
STA1	2013	7	16	7	12	0.8336
STA1	2013	7	16	7	24	0.7945
STA1	2013	7	16	7	36	0.7633
STA1	2013	7	16	7	48	0.7320
STA1	2013	7	16	8	0	0.7008
STA1	2013	7	16	8	12	0.6695
STA1	2013	7	16	8	24	0.6383
STA1	2013	7	16	8	36	0.6070
STA1	2013	7	16	8	48	0.5758
STA1	2013	7	16	9	0	0.5446
STA1	2013	7	16	9	12	0.5155
STA1	2013	7	16	9	24	0.5022
STA1	2013	7	16	9	36	0.4910
STA1	2013	7	16	9	48	0.4798
STA1	2013	7	16	10	0	0.4687
STA1	2013	7	16	10	12	0.4575
STA1	2013	7	16	10	24	0.4464
STA1	2013	7	16	10	36	0.4352
STA1	2013	7	16	10	48	0.4240
STA1	2013	7	16	11	0	0.4129
STA1	2013	7	16	11	12	0.4017
STA1	2013	7	16	11	24	0.3906
STA1	2013	7	16	11	36	0.3794
STA1	2013	7	16	11	48	0.3682
STA1	2013	7	16	12	0	0.3571
STA1	2013	7	16	12	12	0.3459
STA1	2013	7	16	12	24	0.3348
STA1	2013	7	16	12	36	0.3236
STA1	2013	7	16	12	48	0.3125
STA1	2013	7	16	13	0	0.3013
STA1	2013	7	16	13	12	0.2912
STA1	2013	7	16	13	24	0.2879
STA1	2013	7	16	13	36	0.2857
STA1	2013	7	16	13	48	0.2834
STA1	2013	7	16	14	0	0.2812
STA1	2013	7	16	14	12	0.2790
STA1	2013	7	16	14	24	0.2767
STA1	2013	7	16	14	36	0.2745
STA1	2013	7	16	14	48	0.2723
STA1	2013	7	16	15	0	0.2700
STA1	2013	7	16	15	12	0.2678

STA1	2013	7	16	15	24	0.2656
STA1	2013	7	16	15	36	0.2634
STA1	2013	7	16	15	48	0.2611
STA1	2013	7	16	16	0	0.2589
STA1	2013	7	16	16	12	0.2567
STA1	2013	7	16	16	24	0.2544
STA1	2013	7	16	16	36	0.2522
STA1	2013	7	16	16	48	0.2500
STA1	2013	7	16	17	0	0.3705

Climate Change 5 year storm

[Station][Year][Month][Day][Hour][Minute
]
[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.0847
STA1	2013	7	15	17	24	0.1712
STA1	2013	7	15	17	36	0.1745
STA1	2013	7	15	17	48	0.1779
STA1	2013	7	15	18	0	0.1812
STA1	2013	7	15	18	12	0.1846
STA1	2013	7	15	18	24	0.1880
STA1	2013	7	15	18	36	0.1913
STA1	2013	7	15	18	48	0.1947
STA1	2013	7	15	19	0	0.1980
STA1	2013	7	15	19	12	0.2014
STA1	2013	7	15	19	24	0.2047
STA1	2013	7	15	19	36	0.2081
STA1	2013	7	15	19	48	0.2115
STA1	2013	7	15	20	0	0.2148
STA1	2013	7	15	20	12	0.2182
STA1	2013	7	15	20	24	0.2215
STA1	2013	7	15	20	36	0.2249
STA1	2013	7	15	20	48	0.2282
STA1	2013	7	15	21	0	0.2316
STA1	2013	7	15	21	12	0.2349
STA1	2013	7	15	21	24	0.2417
STA1	2013	7	15	21	36	0.2484
STA1	2013	7	15	21	48	0.2551
STA1	2013	7	15	22	0	0.2618
STA1	2013	7	15	22	12	0.2685
STA1	2013	7	15	22	24	0.2752
STA1	2013	7	15	22	36	0.2819
STA1	2013	7	15	22	48	0.2887
STA1	2013	7	15	23	0	0.2954
STA1	2013	7	15	23	12	0.3021
STA1	2013	7	15	23	24	0.3088
STA1	2013	7	15	23	36	0.3155
STA1	2013	7	15	23	48	0.3222
STA1	2013	7	16	0	0	0.3289
STA1	2013	7	16	0	12	0.3356
STA1	2013	7	16	0	24	0.3424
STA1	2013	7	16	0	36	0.3491
STA1	2013	7	16	0	48	0.3558
STA1	2013	7	16	1	0	0.3625
STA1	2013	7	16	1	12	0.3726
STA1	2013	7	16	1	24	0.4028
STA1	2013	7	16	1	36	0.4363
STA1	2013	7	16	1	48	0.4699
STA1	2013	7	16	2	0	0.5035
STA1	2013	7	16	2	12	0.5328
STA1	2013	7	16	2	24	0.5370
STA1	2013	7	16	2	36	0.5370

STA1	2013	7	16	2	48	0.5639
STA1	2013	7	16	3	0	0.6176
STA1	2013	7	16	3	12	0.6746
STA1	2013	7	16	3	24	0.7518
STA1	2013	7	16	3	36	0.8324
STA1	2013	7	16	3	48	0.9398
STA1	2013	7	16	4	0	1.0740
STA1	2013	7	16	4	12	1.2318
STA1	2013	7	16	4	24	1.5305
STA1	2013	7	16	4	36	1.8527
STA1	2013	7	16	4	48	5.9878
STA1	2013	7	16	5	0	17.9148
STA1	2013	7	16	5	12	9.5741
STA1	2013	7	16	5	24	2.6079
STA1	2013	7	16	5	36	1.8427
STA1	2013	7	16	5	48	1.3728
STA1	2013	7	16	6	0	1.1982
STA1	2013	7	16	6	12	1.0338
STA1	2013	7	16	6	24	0.9297
STA1	2013	7	16	6	36	0.8357
STA1	2013	7	16	6	48	0.7552
STA1	2013	7	16	7	0	0.6881
STA1	2013	7	16	7	12	0.6268
STA1	2013	7	16	7	24	0.5974
STA1	2013	7	16	7	36	0.5739
STA1	2013	7	16	7	48	0.5504
STA1	2013	7	16	8	0	0.5270
STA1	2013	7	16	8	12	0.5035
STA1	2013	7	16	8	24	0.4800
STA1	2013	7	16	8	36	0.4565
STA1	2013	7	16	8	48	0.4330
STA1	2013	7	16	9	0	0.4095
STA1	2013	7	16	9	12	0.3877
STA1	2013	7	16	9	24	0.3776
STA1	2013	7	16	9	36	0.3692
STA1	2013	7	16	9	48	0.3608
STA1	2013	7	16	10	0	0.3524
STA1	2013	7	16	10	12	0.3440
STA1	2013	7	16	10	24	0.3356
STA1	2013	7	16	10	36	0.3272
STA1	2013	7	16	10	48	0.3189
STA1	2013	7	16	11	0	0.3105
STA1	2013	7	16	11	12	0.3021
STA1	2013	7	16	11	24	0.2937
STA1	2013	7	16	11	36	0.2853
STA1	2013	7	16	11	48	0.2769
STA1	2013	7	16	12	0	0.2685
STA1	2013	7	16	12	12	0.2601
STA1	2013	7	16	12	24	0.2517
STA1	2013	7	16	12	36	0.2433
STA1	2013	7	16	12	48	0.2349
STA1	2013	7	16	13	0	0.2266
STA1	2013	7	16	13	12	0.2190
STA1	2013	7	16	13	24	0.2165
STA1	2013	7	16	13	36	0.2148
STA1	2013	7	16	13	48	0.2131
STA1	2013	7	16	14	0	0.2115
STA1	2013	7	16	14	12	0.2098
STA1	2013	7	16	14	24	0.2081
STA1	2013	7	16	14	36	0.2064

STA1	2013	7	16	14	48	0.2047
STA1	2013	7	16	15	0	0.2031
STA1	2013	7	16	15	12	0.2014
STA1	2013	7	16	15	24	0.1997
STA1	2013	7	16	15	36	0.1980
STA1	2013	7	16	15	48	0.1963
STA1	2013	7	16	16	0	0.1947
STA1	2013	7	16	16	12	0.1930
STA1	2013	7	16	16	24	0.1913
STA1	2013	7	16	16	36	0.1896
STA1	2013	7	16	16	48	0.1880
STA1	2013	7	16	17	0	0.2786

Climate Change 25 year storm

[Station][Year][Month][Day][Hour][Minute
]

[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.1152
STA1	2013	7	15	17	24	0.2327
STA1	2013	7	15	17	36	0.2372
STA1	2013	7	15	17	48	0.2418
STA1	2013	7	15	18	0	0.2464
STA1	2013	7	15	18	12	0.2509
STA1	2013	7	15	18	24	0.2555
STA1	2013	7	15	18	36	0.2601
STA1	2013	7	15	18	48	0.2646
STA1	2013	7	15	19	0	0.2692
STA1	2013	7	15	19	12	0.2737
STA1	2013	7	15	19	24	0.2783
STA1	2013	7	15	19	36	0.2829
STA1	2013	7	15	19	48	0.2874
STA1	2013	7	15	20	0	0.2920
STA1	2013	7	15	20	12	0.2966
STA1	2013	7	15	20	24	0.3011
STA1	2013	7	15	20	36	0.3057
STA1	2013	7	15	20	48	0.3102
STA1	2013	7	15	21	0	0.3148
STA1	2013	7	15	21	12	0.3194
STA1	2013	7	15	21	24	0.3285
STA1	2013	7	15	21	36	0.3376
STA1	2013	7	15	21	48	0.3467
STA1	2013	7	15	22	0	0.3559
STA1	2013	7	15	22	12	0.3650
STA1	2013	7	15	22	24	0.3741
STA1	2013	7	15	22	36	0.3832
STA1	2013	7	15	22	48	0.3924
STA1	2013	7	15	23	0	0.4015
STA1	2013	7	15	23	12	0.4106
STA1	2013	7	15	23	24	0.4197
STA1	2013	7	15	23	36	0.4289
STA1	2013	7	15	23	48	0.4380
STA1	2013	7	16	0	0	0.4471
STA1	2013	7	16	0	12	0.4562
STA1	2013	7	16	0	24	0.4654
STA1	2013	7	16	0	36	0.4745
STA1	2013	7	16	0	48	0.4836
STA1	2013	7	16	1	0	0.4927
STA1	2013	7	16	1	12	0.5064
STA1	2013	7	16	1	24	0.5475
STA1	2013	7	16	1	36	0.5931
STA1	2013	7	16	1	48	0.6387
STA1	2013	7	16	2	0	0.6844

STA1	2013	7	16	2	12	0.7243
STA1	2013	7	16	2	24	0.7300
STA1	2013	7	16	2	36	0.7300
STA1	2013	7	16	2	48	0.7665
STA1	2013	7	16	3	0	0.8395
STA1	2013	7	16	3	12	0.9170
STA1	2013	7	16	3	24	1.0220
STA1	2013	7	16	3	36	1.1315
STA1	2013	7	16	3	48	1.2775
STA1	2013	7	16	4	0	1.4600
STA1	2013	7	16	4	12	1.6744
STA1	2013	7	16	4	24	2.0805
STA1	2013	7	16	4	36	2.5184
STA1	2013	7	16	4	48	8.1393
STA1	2013	7	16	5	0	24.3518
STA1	2013	7	16	5	12	13.0142
STA1	2013	7	16	5	24	3.5450
STA1	2013	7	16	5	36	2.5048
STA1	2013	7	16	5	48	1.8660
STA1	2013	7	16	6	0	1.6288
STA1	2013	7	16	6	12	1.4052
STA1	2013	7	16	6	24	1.2638
STA1	2013	7	16	6	36	1.1360
STA1	2013	7	16	6	48	1.0265
STA1	2013	7	16	7	0	0.9353
STA1	2013	7	16	7	12	0.8520
STA1	2013	7	16	7	24	0.8121
STA1	2013	7	16	7	36	0.7802
STA1	2013	7	16	7	48	0.7482
STA1	2013	7	16	8	0	0.7163
STA1	2013	7	16	8	12	0.6844
STA1	2013	7	16	8	24	0.6524
STA1	2013	7	16	8	36	0.6205
STA1	2013	7	16	8	48	0.5885
STA1	2013	7	16	9	0	0.5566
STA1	2013	7	16	9	12	0.5270
STA1	2013	7	16	9	24	0.5133
STA1	2013	7	16	9	36	0.5019
STA1	2013	7	16	9	48	0.4905
STA1	2013	7	16	10	0	0.4791
STA1	2013	7	16	10	12	0.4676
STA1	2013	7	16	10	24	0.4562
STA1	2013	7	16	10	36	0.4448
STA1	2013	7	16	10	48	0.4334
STA1	2013	7	16	11	0	0.4220
STA1	2013	7	16	11	12	0.4106
STA1	2013	7	16	11	24	0.3992
STA1	2013	7	16	11	36	0.3878
STA1	2013	7	16	11	48	0.3764
STA1	2013	7	16	12	0	0.3650
STA1	2013	7	16	12	12	0.3536
STA1	2013	7	16	12	24	0.3422
STA1	2013	7	16	12	36	0.3308
STA1	2013	7	16	12	48	0.3194
STA1	2013	7	16	13	0	0.3080
STA1	2013	7	16	13	12	0.2977
STA1	2013	7	16	13	24	0.2943
STA1	2013	7	16	13	36	0.2920
STA1	2013	7	16	13	48	0.2897
STA1	2013	7	16	14	0	0.2874

STA1	2013	7	16	14	12	0.2851
STA1	2013	7	16	14	24	0.2829
STA1	2013	7	16	14	36	0.2806
STA1	2013	7	16	14	48	0.2783
STA1	2013	7	16	15	0	0.2760
STA1	2013	7	16	15	12	0.2737
STA1	2013	7	16	15	24	0.2715
STA1	2013	7	16	15	36	0.2692
STA1	2013	7	16	15	48	0.2669
STA1	2013	7	16	16	0	0.2646
STA1	2013	7	16	16	12	0.2623
STA1	2013	7	16	16	24	0.2601
STA1	2013	7	16	16	36	0.2578
STA1	2013	7	16	16	48	0.2555
STA1	2013	7	16	17	0	0.3787

Climate Change 100 year storm

[Station][Year][Month][Day][Hour][Minute
]

[Rain, mm, 12min interval]

STA1	2013	7	15	17	12	0.1413
STA1	2013	7	15	17	24	0.2855
STA1	2013	7	15	17	36	0.2911
STA1	2013	7	15	17	48	0.2967
STA1	2013	7	15	18	0	0.3023
STA1	2013	7	15	18	12	0.3079
STA1	2013	7	15	18	24	0.3135
STA1	2013	7	15	18	36	0.3191
STA1	2013	7	15	18	48	0.3247
STA1	2013	7	15	19	0	0.3303
STA1	2013	7	15	19	12	0.3359
STA1	2013	7	15	19	24	0.3415
STA1	2013	7	15	19	36	0.3471
STA1	2013	7	15	19	48	0.3527
STA1	2013	7	15	20	0	0.3583
STA1	2013	7	15	20	12	0.3639
STA1	2013	7	15	20	24	0.3695
STA1	2013	7	15	20	36	0.3751
STA1	2013	7	15	20	48	0.3807
STA1	2013	7	15	21	0	0.3863
STA1	2013	7	15	21	12	0.3919
STA1	2013	7	15	21	24	0.4031
STA1	2013	7	15	21	36	0.4143
STA1	2013	7	15	21	48	0.4254
STA1	2013	7	15	22	0	0.4366
STA1	2013	7	15	22	12	0.4478
STA1	2013	7	15	22	24	0.4590
STA1	2013	7	15	22	36	0.4702
STA1	2013	7	15	22	48	0.4814
STA1	2013	7	15	23	0	0.4926
STA1	2013	7	15	23	12	0.5038
STA1	2013	7	15	23	24	0.5150
STA1	2013	7	15	23	36	0.5262
STA1	2013	7	15	23	48	0.5374
STA1	2013	7	16	0	0	0.5486
STA1	2013	7	16	0	12	0.5598
STA1	2013	7	16	0	24	0.5710
STA1	2013	7	16	0	36	0.5822
STA1	2013	7	16	0	48	0.5934
STA1	2013	7	16	1	0	0.6046
STA1	2013	7	16	1	12	0.6214
STA1	2013	7	16	1	24	0.6718

STA1	2013	7	16	1	36	0.7277
STA1	2013	7	16	1	48	0.7837
STA1	2013	7	16	2	0	0.8397
STA1	2013	7	16	2	12	0.8887
STA1	2013	7	16	2	24	0.8957
STA1	2013	7	16	2	36	0.8957
STA1	2013	7	16	2	48	0.9405
STA1	2013	7	16	3	0	1.0300
STA1	2013	7	16	3	12	1.1252
STA1	2013	7	16	3	24	1.2540
STA1	2013	7	16	3	36	1.3883
STA1	2013	7	16	3	48	1.5674
STA1	2013	7	16	4	0	1.7914
STA1	2013	7	16	4	12	2.0545
STA1	2013	7	16	4	24	2.5527
STA1	2013	7	16	4	36	3.0901
STA1	2013	7	16	4	48	9.9868
STA1	2013	7	16	5	0	29.8793
STA1	2013	7	16	5	12	15.9683
STA1	2013	7	16	5	24	4.3496
STA1	2013	7	16	5	36	3.0733
STA1	2013	7	16	5	48	2.2896
STA1	2013	7	16	6	0	1.9985
STA1	2013	7	16	6	12	1.7242
STA1	2013	7	16	6	24	1.5506
STA1	2013	7	16	6	36	1.3939
STA1	2013	7	16	6	48	1.2596
STA1	2013	7	16	7	0	1.1476
STA1	2013	7	16	7	12	1.0454
STA1	2013	7	16	7	24	0.9964
STA1	2013	7	16	7	36	0.9573
STA1	2013	7	16	7	48	0.9181
STA1	2013	7	16	8	0	0.8789
STA1	2013	7	16	8	12	0.8397
STA1	2013	7	16	8	24	0.8005
STA1	2013	7	16	8	36	0.7613
STA1	2013	7	16	8	48	0.7221
STA1	2013	7	16	9	0	0.6830
STA1	2013	7	16	9	12	0.6466
STA1	2013	7	16	9	24	0.6298
STA1	2013	7	16	9	36	0.6158
STA1	2013	7	16	9	48	0.6018
STA1	2013	7	16	10	0	0.5878
STA1	2013	7	16	10	12	0.5738
STA1	2013	7	16	10	24	0.5598
STA1	2013	7	16	10	36	0.5458
STA1	2013	7	16	10	48	0.5318
STA1	2013	7	16	11	0	0.5178
STA1	2013	7	16	11	12	0.5038
STA1	2013	7	16	11	24	0.4898
STA1	2013	7	16	11	36	0.4758
STA1	2013	7	16	11	48	0.4618
STA1	2013	7	16	12	0	0.4478
STA1	2013	7	16	12	12	0.4338
STA1	2013	7	16	12	24	0.4199
STA1	2013	7	16	12	36	0.4059
STA1	2013	7	16	12	48	0.3919
STA1	2013	7	16	13	0	0.3779
STA1	2013	7	16	13	12	0.3653
STA1	2013	7	16	13	24	0.3611

STA1	2013	7	16	13	36	0.3583
STA1	2013	7	16	13	48	0.3555
STA1	2013	7	16	14	0	0.3527
STA1	2013	7	16	14	12	0.3499
STA1	2013	7	16	14	24	0.3471
STA1	2013	7	16	14	36	0.3443
STA1	2013	7	16	14	48	0.3415
STA1	2013	7	16	15	0	0.3387
STA1	2013	7	16	15	12	0.3359
STA1	2013	7	16	15	24	0.3331
STA1	2013	7	16	15	36	0.3303
STA1	2013	7	16	15	48	0.3275
STA1	2013	7	16	16	0	0.3247
STA1	2013	7	16	16	12	0.3219
STA1	2013	7	16	16	24	0.3191
STA1	2013	7	16	16	36	0.3163
STA1	2013	7	16	16	48	0.3135
STA1	2013	7	16	17	0	0.4646

Appendix D: Additional LID Design Information

This appendix contains figures and a table which supplement the LID design information presented in Chapter 5. Figure D 1is important as it shows the conceptual layout of the LID controls considered for this study.

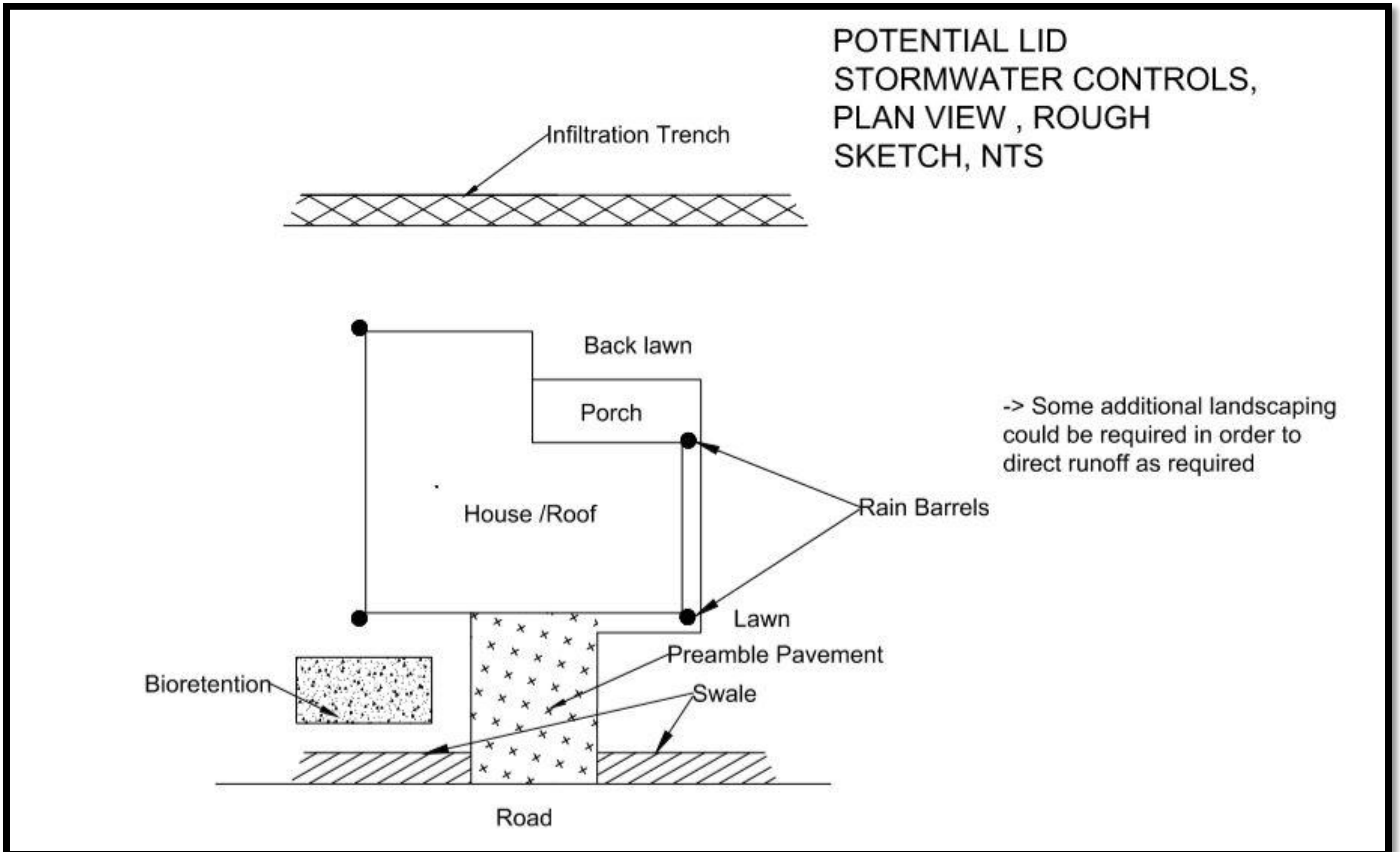

Figure D 1 Conceptual LID layout for a single lot

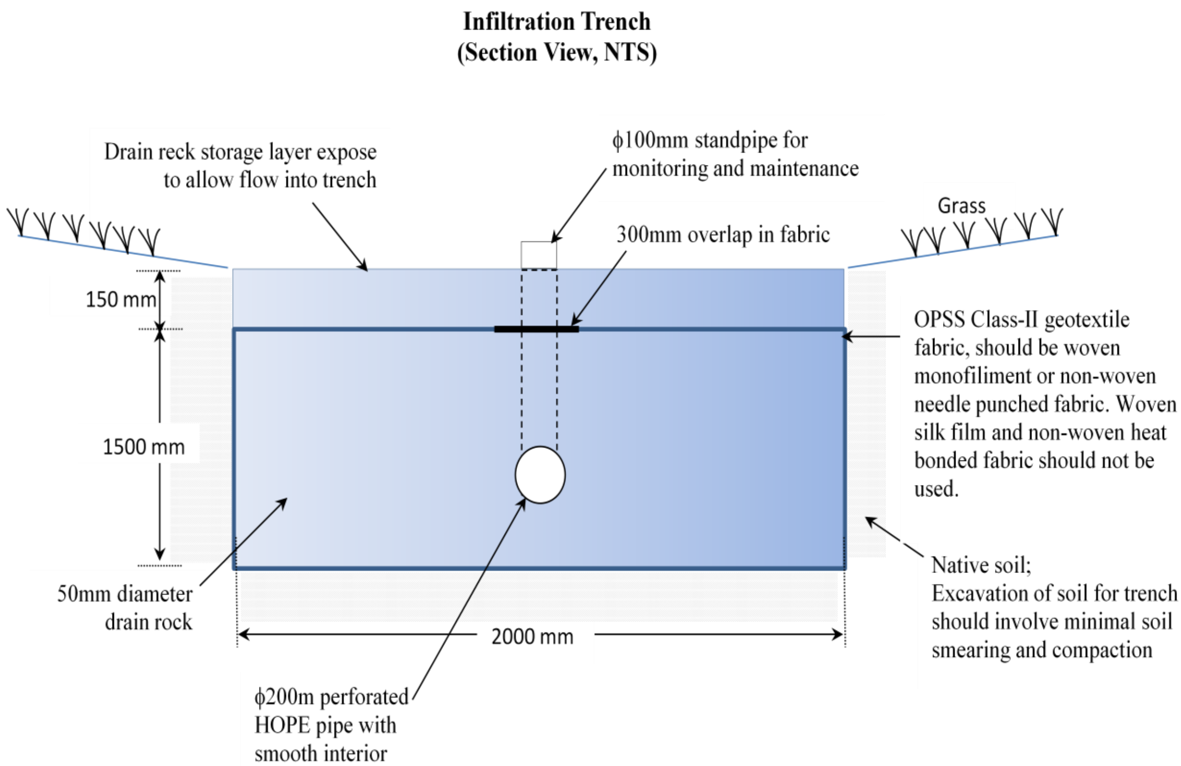

Figure D 2 Section view sketch of infiltration trench

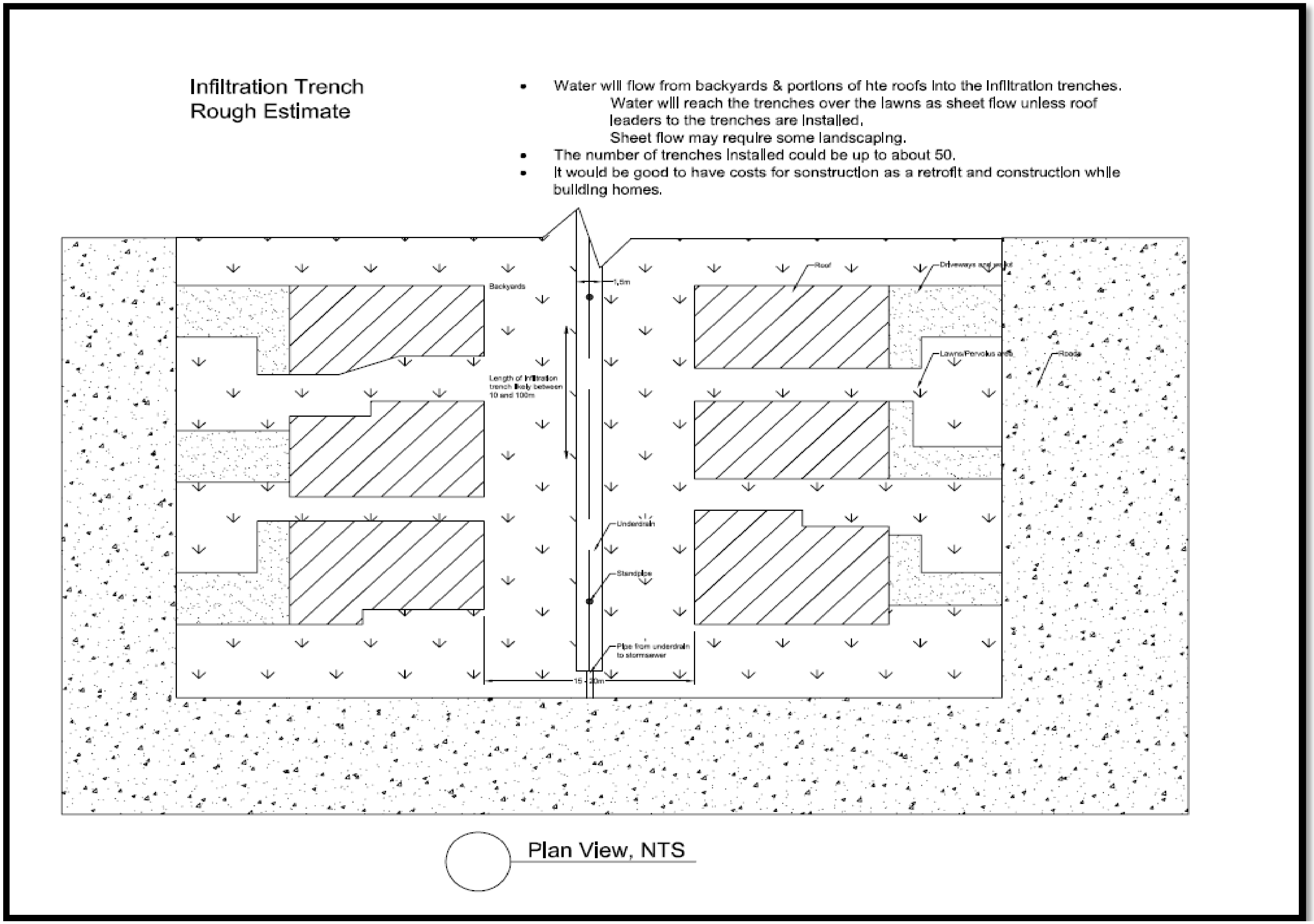

Figure D 3 Conceptual infiltration trench plan view sketch

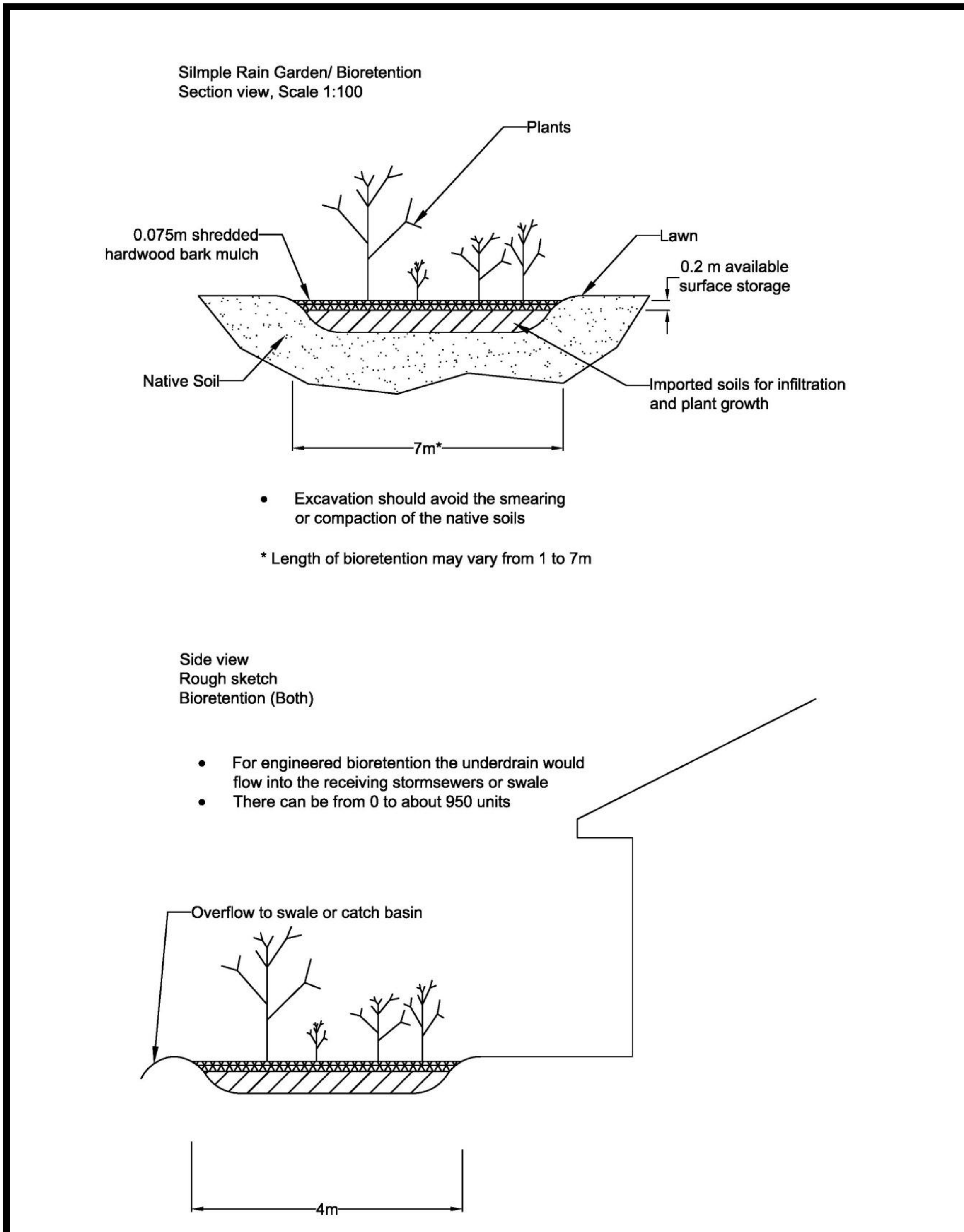

Figure D 4 Conceptual rain garden design

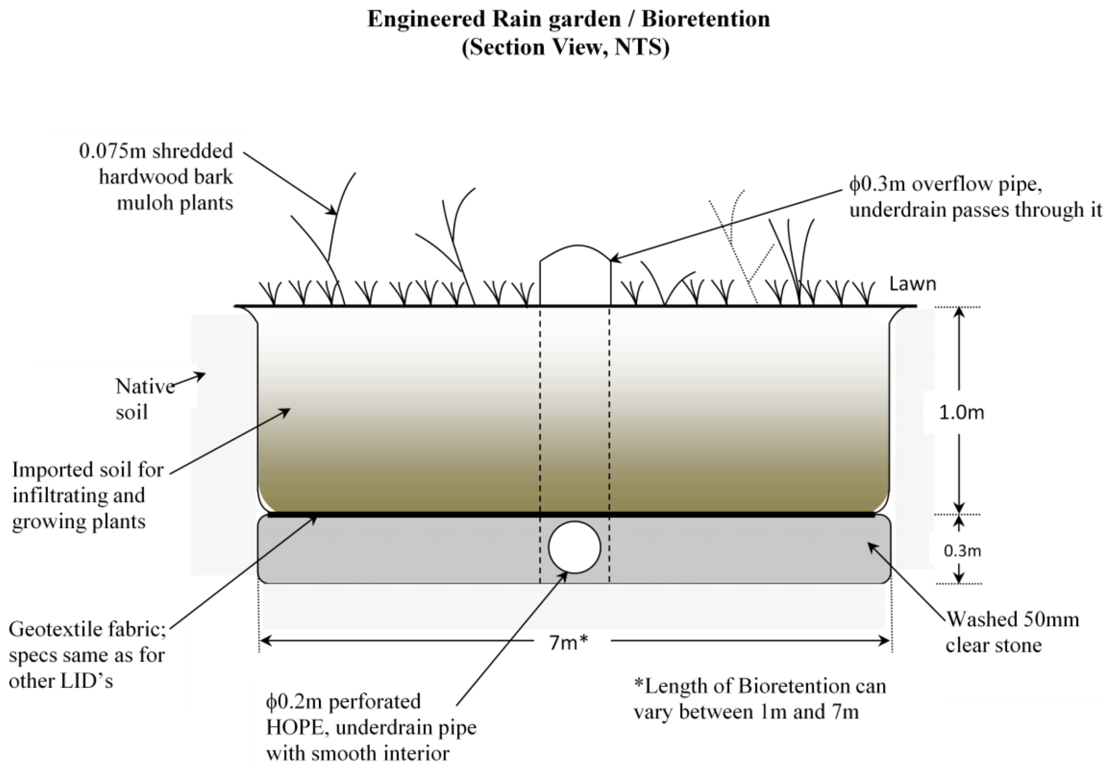

Figure D 5 Conceptual bioretention unit design

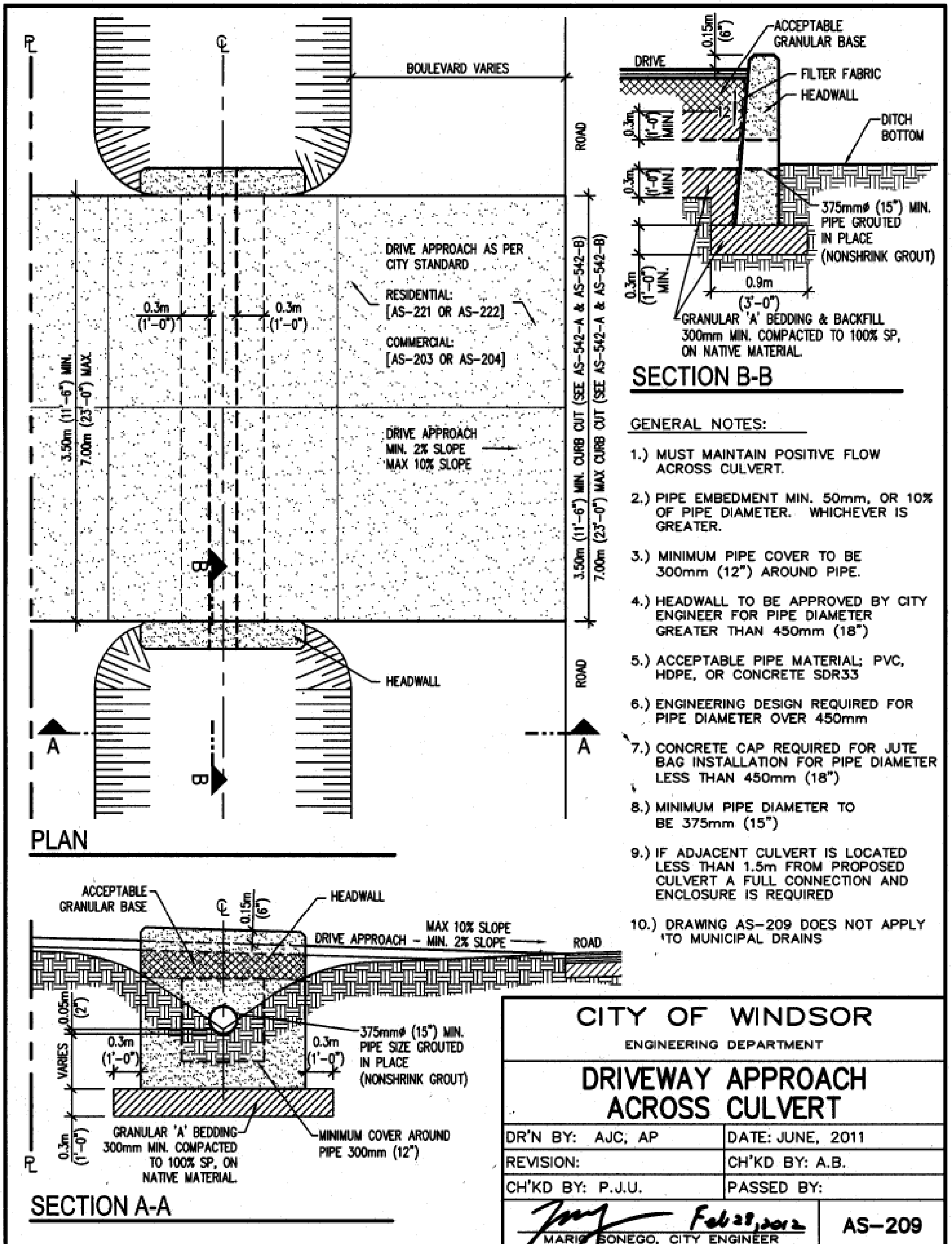

Figure D 6 City of Windsor driveway culvert design

Table D 1 Swale design table

Swale Sub#/Swale LID #	Sub331/1	Sub332/6
Longitudinal Slope	0.01	0.01
Side Slope (rise/run)	2.5	2.5
Base Width (m)	0.6	1
Manning's Roughness in Swale	0.035	0.035
Swale Segment Length (m)	90	70
Top Width (m)	2.48	2.58
Area of 1 Swale (ha)	0.02	0.02
Area of 2 Swales (ha)	0.04	0.04
Subcatchment Slope %	0.5	0.5
Maximum Path Length to Swale (m)	45	45
Swale Travel Time (min)	1.92	1.31
Total Swale Travel Time (min)	1.92	3.23
Overland Travel Time (min)	16.48	16.48
Sub TOC (min)	18.40	17.80
TOC From Upstream (min)	N/A	19.71
Time of Concentration (min)	18.40	19.71
Runoff Coefficient	0.5	0.5
Rainfall Intensity Local IDF (10 year) (mm)	91	83
Upstream Area (ha)	0	1.38
Subcatchment Area (ha)	1.38	1.21
Total Area (ha)	1.38	2.59
% Treated	70.00	70.00
Contributing Area Per Swale (ha)	0.97	1.81
Q (cms)	0.12	0.21
XArea of Swale (m^2)	0.16	0.24
Q*n/(S^1/2)	0.04	0.07
A*R^(2/3)	0.04	0.07
Difference	0.00	0.00
Depth (m)	0.23	0.17
Wetted Perimeter (m)	1.09	1.36
Hydraulic Radius	0.14	0.17
Manning's Velocity (m/s)	0.78	0.89
Swale Depth (mm)	375.84	316.25
# Houses Requiring Culvert	12	12

Appendix E: Borg Problem Setup

Borg problem setup for the retrofit, low LID adoption scenario

```
int nvars = 24;
int nobjs = 3;
void borg_fitness(double* vars, double* objs, double* constrs) {

//making the decision variables discrete
        vars[0] = (int)floor(vars[0]) ;
        vars[1] = (int)floor(vars[1]) ;
        vars[2] = (int)floor(vars[2]) ;
        vars[3] = (int)floor(vars[3]) ;
        vars[4] = (int)floor(vars[4]) ;
        vars[5] = (int)floor(vars[5]) ;
        vars[6] = (int)floor(vars[6]) ;
        vars[7] = (int)floor(vars[7]) ;
        vars[8] = (int)floor(vars[8]) ;
        vars[9] = (int)floor(vars[9]) ;
        vars[10] = (int)floor(vars[10]) ;
        vars[11] = (int)floor(vars[11]) ;
        vars[12] = (int)floor(vars[12]) ;
        vars[13] = (int)floor(vars[13]) ;
        vars[14] = (int)floor(vars[14]) ;
        vars[15] = (int)floor(vars[15]) ;
        vars[16] = (int)floor(vars[16]) ;
        vars[17] = (int)floor(vars[17]) ;
        vars[18] = (int)floor(vars[18]) ;
        vars[19] = (int)floor(vars[19]) ;
        vars[20] = (int)floor(vars[20]) ;
        vars[21] = (int)floor(vars[21]) ;
        vars[22] = (int)floor(vars[22]) ;
        vars[23] = (int)floor(vars[23]) ;


swmm_fitness("scenario1.inp",vars,output);

        objs[0] = output[0]; //peak flow
        objs[1] = output[1]; //total runoff
```

```
//cost function
        objs[2] = 252.5*(vars[0]*7 +vars[1]*31 + vars[2]*5)

        + 10394*(vars[6]*3 + vars[7]*13 + vars[8]*2)

        + (vars[3]*1)*(92*vars[12]*10 + 550 + 410*vars[12] + 6*(2.3*vars[12]+2*vars[12]))
        + (vars[4]*5)*(92*vars[13]*10 + 550 + 410*vars[13] + 6*(2.3*vars[13]+2*vars[13]))
        + (vars[5]*1)*(92*vars[14]*10 + 550 + 410*vars[14] + 6*(2.3*vars[14]+2*vars[14]))
        + (vars[3]*0)*(92*vars[15]*10 + 550 + 410*vars[15] + 6*(2.3*vars[15]+2*vars[15]))
        + (vars[4]*4)*(92*vars[16]*10 + 550 + 410*vars[16] + 6*(2.3*vars[16]+2*vars[16]))
        + (vars[5]*1)*(92*vars[17]*10 + 550 + 410*vars[17] + 6*(2.3*vars[17]+2*vars[17]))

        + (vars[9]*2)*(40*vars[18]*(5*4/10) + 50 + 107*vars[18]*4*(0.7 + (0.3*5/5)) + 1.5*vars[18]*4)
        + (vars[10]*8)*(40*vars[19]*(5*4/10) + 50 + 107*vars[19]*4*(0.7 + (0.3*5/5)) + 1.5*vars[19]*4)
        + (vars[11]*1)*(40*vars[20]*(5*4/10) + 50 + 107*vars[20]*4*(0.7 + (0.3*5/5)) + 1.5*vars[20]*4)
        + (vars[9]*5)*(40*vars[21]*(5*4/10) + 50 + 107*vars[21]*4*(0.7 + (0.3*5/5)) + 1.5*vars[21]*4)
        + (vars[10]*23)*(40*vars[22]*(5*4/10) + 50 + 107*vars[22]*4*(0.7 + (0.3*5/5)) + 1.5*vars[22]*4)
        + (vars[11]*4)*(40*vars[23]*(5*4/10) + 50 + 107*vars[23]*4*(0.7 + (0.3*5/5)) + 1.5*vars[23]*4);



                //constrs[0] = objs[0] >= 0.0?0.0:10; //constraint if required
                //constrs[1] = objs[1] >= 0.0?0.0:10; //constraint if required

         }


        problem = BORG_Problem_create(nvars, nobjs, 0, borg_fitness);
```

```
//The variables 0-2 & 6-11 will also be multiplied by the number of houses in each subcatchmemnt before writing to the LID //usage section.
	BORG_Problem_set_bounds(problem, 0, 0.0, 4.1);
	BORG_Problem_set_bounds(problem, 1, 0.0, 4.1);
	BORG_Problem_set_bounds(problem, 2, 0.0, 4.1);
	BORG_Problem_set_bounds(problem, 3, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 4, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 5, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 6, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 7, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 8, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 9, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 10, 0.0, 1.1);
	BORG_Problem_set_bounds(problem, 11, 0.0, 1.1);

	BORG_Problem_set_bounds(problem, 12, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 13, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 14, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 15, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 16, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 17, 2, 30.1); //x10
	BORG_Problem_set_bounds(problem, 18, 1, 7.1); //x4
	BORG_Problem_set_bounds(problem, 19, 1, 7.1); //x4
	BORG_Problem_set_bounds(problem, 20, 1, 7.1); //x4
	BORG_Problem_set_bounds(problem, 21, 1, 7.1); //x4
	BORG_Problem_set_bounds(problem, 22, 1, 7.1); //x4
	BORG_Problem_set_bounds(problem, 23, 1, 7.1); //x4



	BORG_Problem_set_epsilon(problem, 0, 0.01);
	BORG_Problem_set_epsilon(problem, 1, 0.01);
	BORG_Problem_set_epsilon(problem, 2, 1000);
	result = BORG_Algorithm_run(problem, 12500);
	BORG_Archive_print(result, stdout);
	BORG_Archive_destroy(result);
	BORG_Problem_destroy(problem);
```

Appendix F: Tables of Solutions

This appendix contains three sets of solutions. The first set, Tables F 1-10, are the cost-effective solutions that were analyzed in section 8.9. These tables present the number of each LID unit for each scenario, rather than the actual decision variable values. The decision variables related to LID size are not included in these tables as they are included in Table 8-3 to Table 8-12. Table F 11 and Table F 12 are the created "typical" solutions which were analyzed in section 8.10. These contain both the decision variables (labeled "v") and objective function values (labeled "o") .

Table F 1 Number of LID controls in cost effective solutions

Q_P Retro-Low	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	0	9	2	0	0	0	0	0	0	76,552	0.23	0.01
HIS 25	0	0	0	0	9	2	0	0	0	0	0	5	107,843	0.22	0.01
HIS 100	0	0	0	0	9	2	0	0	0	0	0	0	144,342	0.23	0.01
CC 5	7	0	0	0	9	0	0	0	0	0	0	0	78,575	0.18	0.01
CC 25	0	0	0	1	9	2	0	0	0	0	0	0	155,738	0.25	0.017
CC 100	0	0	0	0	9	2	0	0	0	0	0	0	182,304	0.23	0.019

Table F 2 Number of LID controls in cost effective solutions

Q_P Retro-High	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# RG Zone 1	# RG Zone 2	# RG Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	0	43	10	0	0	0	0	0	0	374,879	0.15	0.03
HIS 25	0	0	0	7	43	10	0	0	0	0	0	0	506,174	0.21	0.05
HIS 100	0	0	0	0	43	10	0	0	0	0	0	0	582,316	0.26	0.06
CC 5	0	0	0	0	43	10	0	0	0	0	0	0	422,332	0.16	0.04
CC 25	0	0	0	0	43	10	0	0	0	0	0	0	595,874	0.26	0.06
CC 100	0	0	0	0	43	10	0	0	0	0	0	0	768,061	0.20	0.08

Table F 3 Number of LID controls in cost effective solutions

Q_P New-Low	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	7	43	10	0	0	0	0	0	0	309,423	0.17	0.04
HIS 25	0	0	0	0	43	10	0	0	0	0	0	0	289,313	0.19	0.04
HIS 100	0	0	0	7	43	10	0	0	0	0	0	0	467,746	0.30	0.07
CC 5	0	0	0	7	43	10	0	0	0	0	0	0	327,395	0.18	0.05
CC 25	0	0	0	7	43	10	0	0	0	0	0	0	501,978	0.31	0.07
CC 100	13	0	0	0	43	10	0	0	0	0	0	0	497,988	0.20	0.08

Table F 4 Number of LID controls in cost effective solutions

Q_P New-High	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	30	171	40	0	0	0	0	156	0	1,790,309	0.66	0.14
HIS 25	0	0	0	30	171	40	0	0	0	0	0	0	1,767,984	0.72	0.17
HIS 100	0	0	0	30	171	40	0	0	0	0	156	0	3,576,991	1.21	0.25
CC 5	0	0	0	30	171	40	0	0	0	0	156	0	1,929,231	0.73	0.18
CC 25	0	0	75	30	171	40	0	0	0	0	156	0	2,952,804	1.12	0.26
CC 100	66	0	0	30	171	40	0	0	0	0	156	0	3,534,849	1.07	0.34

Table F 5 Number of LID controls in cost effective solutions

Q_P New-Unrestricted	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	133	0	0	0	171	40	0	0	0	0	624	99	2,003,350	0.81	0.18
HIS 25	0	0	0	0	171	40	0	0	0	0	624	99	2,405,482	0.99	0.23
HIS 100	0	0	0	30	171	40	0	0	0	0	624	0	2,657,744	1.24	0.31
CC 5	0	0	0	30	171	40	0	0	0	0	624	0	3,421,605	1.08	0.23
CC 25	0	0	0	30	171	40	0	0	0	0	624	99	4,006,730	1.55	0.36
CC 100	0	0	0	0	171	40	0	0	0	0	624	0	3,296,977	1.28	0.38

Table F 6 Number of LID controls in cost effective solutions

R_T Retro-Low	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# RG Zone 1	# RG Zone 2	# RG Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	5	0	9	0	0	0	0	0	31	0	168,020	0.03	0.02
HIS 25	0	0	0	0	9	2	0	0	0	0	31	5	212,469	0.06	0.03
HIS 100	7	0	0	0	9	2	0	0	0	0	31	0	263,265	0.08	0.03
CC 5	0	0	0	0	9	0	0	0	0	0	31	0	190,186	0.05	0.02
CC 25	0	0	0	0	9	2	0	0	0	0	31	0	155,745	0.01	0.02
CC 100	0	0	0	0	9	0	0	0	0	0	31	0	181,761	-0.02	0.03

Table F 7 Number of LID controls in cost effective solutions

R_T Retro-High	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# RG Zone 1	# RG Zone 2	# RG Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	0	0	10	0	0	0	0	62	0	195,056	0.04	0.03
HIS 25	0	0	0	0	43	10	0	0	0	0	62	0	438,078	0.11	0.06
HIS 100	0	0	0	0	43	10	0	0	0	0	62	0	473,670	0.06	0.07
CC 5	0	0	0	0	43	10	0	0	0	0	62	0	460,723	0.09	0.07
CC 25	13	0	0	0	43	10	0	0	0	0	62	0	604,815	0.12	0.09
CC 100	13	0	0	0	43	10	0	0	0	13	62	0	647,941	0.01	0.10

Table F 8 Number of LID controls in cost effective solutions

R_T New-Low	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	7	43	10	0	0	0	0	0	0	182,765	0.08	0.03
HIS 25	0	0	0	7	43	10	13	0	0	0	62	0	539,647	0.19	0.06
HIS 100	0	0	0	7	43	10	0	0	0	0	0	0	467,746	0.30	0.07
CC 5	0	0	0	7	43	10	0	0	0	0	0	0	295,731	0.16	0.05
CC 25	0	0	0	7	43	10	0	0	0	0	0	0	407,840	0.23	0.07
CC 100	0	0	0	0	43	10	0	0	0	0	0	0	491,282	0.19	0.08

Table F 9 Number of LID controls in cost effective solutions

R_T New-High	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	0	0	0	30	171	40	0	0	99	0	156	0	2,379,573	0.62	0.18
HIS 25	0	0	0	30	171	40	133	0	0	0	0	0	2,273,631	0.52	0.20
HIS 100	0	0	0	30	171	40	0	0	0	0	0	0	1,904,912	0.88	0.22
CC 5	0	0	0	30	171	40	0	0	0	0	156	0	1,407,840	0.58	0.17
CC 25	0	0	0	30	171	40	133	0	0	0	156	0	3,850,616	1.11	0.31
CC 100	0	0	0	30	171	40	0	0	0	0	156	25	3,209,844	0.98	0.35

Table F 10 Number of LID controls in cost effective solutions

R_T New-Unrestricted	# RB Zone 1	# RB Zone 2	# RB Zone 3	# IT Zone 1	# IT Zone 2	# IT Zone 3	# PP Zone 1	# PP Zone 2	# PP Zone 3	# BR Zone 1	# BR Zone 2	# BR Zone 3	Cost ($)	Q_P Reduction (cms)	R_T Reduction (ha.m)
HIS 5	133	0	0	0	171	40	133	0	0	0	624	99	2,887,737	0.55	0.22
HIS 25	0	0	0	30	171	40	133	0	0	0	624	99	4,007,250	1.06	0.30
HIS 100	0	0	0	30	171	40	0	0	0	0	624	99	2,902,353	1.03	0.34
CC 5	0	0	0	0	171	40	133	0	0	0	624	0	2,717,187	0.50	0.25
CC 25	0	0	0	30	171	40	0	0	0	0	624	99	2,238,721	0.82	0.31
CC 100	0	0	0	30	171	40	133	0	0	0	624	99	4,474,490	1.16	0.47

Table F 11 Typical cost-effective solutions for peak flow reduction

	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23
Retrofit Low	0	0	0	0	1	1	0	0	0	0	0	0	11	8	6	4	8	9	1	1	1	7	6	6
Retrofit High	0	0	0	0	1	1	0	0	0	0	0	0	6	7	6	5	7	7	7	3	1	6	3	4
New Development Low	0	0	0	1	1	1	0	0	0	0	0	0	8	8	6	8	7	7	6	5	4	4	4	5
New Development High	0	0	0	1	1	1	0	0	0	0	1	0	11	9	11	9	9	13	6	5	1	5	5	6
New Development Unrestricted	0	0	0	1	1	1	0	0	0	0	1	0	14	7	9	7	10	11	6	6	7	7	2	7

Table F 12 Typical cost-effective solutions total runoff reduction

	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23
Retrofit Low	0	0	0	0	1	1	0	0	0	0	1	0	6	7	3	4	5	9	1	6	3	7	7	5
Retrofit High	0	0	0	0	1	1	0	0	0	0	1	0	6	4	5	3	3	5	2	5	1	4	6	4
New Development Low	0	0	0	1	1	1	0	0	0	0	0	0	8	6	8	5	6	6	1	3	1	1	2	1
New Development High	0	0	0	1	1	1	0	0	0	0	1	0	9	8	11	9	8	6	3	3	5	1	2	7
New Development Unrestricted	0	0	0	1	1	1	1	0	0	0	1	1	11	7	6	11	7	10	2	4	3	1	1	1

Table F 13 Retrofit low HIS 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	3.73	3.53	0
0	0	0	0	0	0	0	0	0	0	1	0	14	19	6	17	26	21	6	2	2	5	1	5	3.73	3.53	21596
0	1	0	1	0	0	0	0	0	0	0	0	6	22	19	20	20	10	7	2	5	1	1	6	3.72	3.53	16512
1	1	2	0	1	0	0	0	0	0	0	0	26	4	20	18	3	27	3	5	6	4	6	1	3.71	3.53	60456
0	0	0	0	0	0	0	0	0	0	1	0	13	18	28	13	24	23	1	5	5	1	5	2	3.72	3.52	81220
1	0	1	0	1	0	0	0	0	0	1	0	26	6	13	13	7	9	1	5	4	1	6	4	3.69	3.51	179658
0	0	0	0	1	1	0	0	0	0	0	0	9	5	2	17	5	5	2	5	2	2	1	2	3.70	3.53	76552
0	0	0	0	1	0	0	0	0	0	1	0	2	6	5	12	3	23	3	5	5	1	7	4	3.70	3.51	166758
0	0	0	0	1	0	0	0	0	0	1	0	9	6	7	17	5	6	1	5	1	1	1	2	3.70	3.52	106672
0	0	0	1	0	0	0	0	0	0	0	1	5	22	19	20	20	10	7	2	5	1	1	6	3.73	3.53	22485
0	0	0	0	1	0	0	0	0	0	1	0	2	5	11	12	3	7	1	4	3	1	2	1	3.71	3.52	96757
0	0	1	0	1	0	0	0	0	0	1	0	2	6	5	12	3	23	3	5	5	1	7	4	3.70	3.51	168020
1	0	0	0	0	0	0	0	0	0	0	1	15	18	9	17	25	14	1	1	4	4	3	1	3.73	3.53	6130
0	0	1	0	1	0	0	0	0	0	1	0	2	5	3	18	5	22	3	5	5	2	4	3	3.69	3.51	136622
1	1	2	1	0	0	0	0	0	0	0	1	4	18	10	17	26	14	7	1	7	4	3	4	3.72	3.53	30165

Table F 14 Retrofit low HIS 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.99	4.78	0
0	0	1	0	0	0	0	0	0	0	0	0	3	21	12	22	23	21	2	1	6	5	2	5	4.99	4.78	1263
0	1	0	0	0	0	0	0	0	0	1	0	15	16	8	6	6	26	2	3	3	5	4	1	4.98	4.77	69002
0	0	0	0	1	0	0	0	0	0	0	0	23	6	8	21	5	7	2	1	1	2	5	3	4.96	4.77	72740
0	0	0	0	1	0	0	0	0	0	1	0	20	5	8	16	6	28	4	1	4	1	6	2	4.95	4.76	147978
0	0	0	0	1	0	0	0	0	0	1	0	22	6	23	20	3	28	3	1	3	1	6	2	4.96	4.76	138488
0	0	0	0	1	1	0	0	0	0	0	0	28	6	3	20	5	7	1	1	6	1	6	1	4.95	4.77	87398
0	0	0	0	0	0	0	0	0	0	1	1	21	6	22	7	2	26	6	7	3	1	7	3	4.97	4.76	121048
0	0	1	0	1	0	0	0	0	0	0	0	17	4	6	16	5	30	3	1	3	1	5	1	4.97	4.77	60445
0	0	0	0	1	1	0	0	0	0	0	1	16	7	3	21	2	7	7	4	1	5	6	1	4.96	4.77	80727
0	0	0	0	1	1	0	0	0	0	1	0	21	7	9	13	7	7	2	1	2	1	5	1	4.93	4.76	177930
0	0	0	0	1	1	0	0	0	0	0	1	16	6	3	21	2	7	7	4	1	5	6	2	4.97	4.77	76004
0	0	0	0	1	1	0	0	0	0	0	1	15	7	3	21	7	7	6	3	1	1	6	1	4.94	4.77	107843
0	0	0	1	1	0	0	0	0	0	1	1	9	7	2	20	6	6	6	5	3	1	7	5	4.93	4.75	214630
0	0	0	0	1	1	0	0	0	0	1	0	21	7	2	20	6	6	2	1	3	1	5	1	4.94	4.76	161661
0	0	0	1	0	0	0	0	0	0	1	1	8	7	2	20	6	6	6	5	1	1	7	5	4.97	4.76	127304
0	0	0	0	0	1	0	0	0	0	0	0	28	8	4	18	3	7	1	1	5	1	6	1	4.98	4.78	16014
0	0	0	0	1	1	0	0	0	0	1	1	9	7	2	20	6	5	6	5	3	1	7	5	4.93	4.75	212469
0	0	0	0	0	0	0	0	0	0	1	1	26	6	5	19	7	20	4	6	1	6	2	4	4.99	4.77	58854

Table F 15 Retrofit HIS 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	6.88	6.41	0
0	0	0	0	0	0	0	0	0	0	1	0	14	19	7	18	27	22	6	3	3	5	1	5	6.89	6.41	25708
0	1	1	0	0	0	0	0	0	0	0	0	10	25	14	12	2	24	7	2	2	2	1	4	6.87	6.41	9090
1	0	1	0	0	0	0	0	0	0	1	0	23	13	21	9	8	2	4	6	1	1	5	1	6.88	6.40	88362
0	0	1	0	0	0	0	0	0	0	1	0	20	14	20	11	8	2	4	6	1	1	5	1	6.88	6.40	86594
0	1	0	0	0	0	0	0	0	0	1	0	22	14	5	9	22	18	4	6	1	2	5	1	6.86	6.40	93159
1	0	1	0	1	0	0	0	0	0	0	0	25	8	12	6	9	3	6	6	2	1	1	4	6.83	6.40	111021
0	0	0	0	1	0	0	0	0	0	1	0	18	10	22	3	9	19	5	1	7	5	7	1	6.82	6.39	209965
0	0	0	0	1	0	0	0	0	0	1	0	29	6	8	3	7	10	5	1	6	3	7	7	6.85	6.39	172002
0	0	1	1	0	0	0	0	0	0	0	1	10	18	13	11	20	6	5	6	4	4	1	6	6.87	6.41	30012
0	0	1	1	0	0	0	0	0	0	0	1	8	16	12	11	21	6	4	6	2	4	1	7	6.87	6.41	28329
0	0	1	0	1	0	0	0	0	0	1	0	20	6	19	19	6	15	5	1	7	3	7	5	6.85	6.39	167842
0	0	0	0	1	0	0	0	0	0	1	0	18	8	21	2	8	20	5	1	6	5	7	4	6.83	6.39	190984
0	1	0	0	0	1	0	0	0	0	1	0	21	14	5	11	22	7	4	5	1	1	4	5	6.85	6.40	94595
1	0	0	0	0	1	0	0	0	0	0	0	3	10	5	2	11	8	4	5	5	7	7	5	6.86	6.41	204923
1	0	0	0	1	0	0	0	0	0	0	1	2	7	7	2	8	9	5	4	3	6	7	7	6.84	6.40	113740
0	0	0	0	1	1	0	0	0	0	1	0	18	10	4	3	8	8	5	1	6	1	7	5	6.81	6.39	221911
0	0	1	0	1	0	0	0	0	0	1	0	18	6	19	17	8	20	5	1	6	5	7	4	6.84	6.39	178688
0	0	0	0	1	1	0	0	0	0	0	0	2	10	4	2	6	8	5	1	6	1	7	5	6.83	6.40	122649
1	0	0	0	1	1	0	0	0	0	1	0	2	10	14	3	9	16	4	1	6	4	7	6	6.80	6.38	253506
0	0	0	0	1	1	0	0	0	0	0	0	2	2	5	8	7	7	2	5	5	6	3	7	6.85	6.40	73840
0	0	0	0	1	0	0	0	0	0	1	0	16	6	7	18	4	18	4	2	6	3	7	3	6.87	6.39	159845
1	0	0	0	1	1	0	0	0	0	1	0	17	10	5	3	9	14	4	7	1	7	7	6	6.79	6.38	263265
0	0	0	0	1	1	0	0	0	0	0	0	3	9	5	2	11	8	4	5	4	7	6	4	6.81	6.40	144342
0	0	0	0	1	1	0	0	0	0	0	0	3	2	6	2	9	8	4	5	1	7	4	7	6.84	6.40	87398

0	0	0	0	1	1	0	0	0	0	0	0	2	9	5	7	7	9	5	5	5	5	7	4	6.82	6.40	124005
1	3	0	0	0	1	0	0	0	0	0	0	3	10	5	2	11	8	3	5	5	7	7	5	6.86	6.41	43975

Table F 16 Retrofit low CC 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.72	4.53	0
0	1	1	1	0	0	0	0	0	0	0	0	7	24	8	7	23	28	3	2	6	1	4	5	4.71	4.53	191301
0	1	0	0	0	0	0	0	0	0	1	0	26	5	24	26	4	29	3	3	3	1	3	5	4.71	4.52	57179
0	0	0	0	0	0	0	0	0	0	1	0	19	5	15	2	7	27	1	5	2	2	2	6	4.72	4.52	45754
1	0	0	0	1	0	0	0	0	0	0	0	17	5	14	8	7	5	3	2	3	3	3	5	4.69	4.52	78575
0	0	0	0	1	0	0	0	0	0	0	0	16	4	13	7	6	2	2	1	2	2	1	4	4.70	4.52	64605
0	0	0	0	1	0	0	0	0	0	1	0	16	2	2	13	2	2	1	7	1	1	4	5	4.72	4.51	106976
0	0	0	0	1	0	0	0	0	0	1	0	15	3	2	2	2	2	1	6	1	1	4	5	4.71	4.51	109643
1	0	0	0	1	0	0	0	0	0	1	0	15	6	4	2	6	2	1	5	1	1	4	5	4.68	4.51	149329
0	0	2	0	1	0	0	0	0	0	0	0	16	4	13	7	6	2	2	1	2	2	1	4	4.70	4.52	67130
0	0	0	0	1	0	0	0	0	0	1	0	16	5	3	2	5	4	1	1	3	1	5	1	4.69	4.51	130733
1	0	0	0	1	0	0	1	0	0	1	0	15	9	2	2	5	2	1	5	1	1	6	5	4.67	4.50	323009
0	0	0	0	1	0	0	1	0	0	1	0	15	5	2	2	5	2	1	5	1	1	6	5	4.68	4.50	294125
0	0	0	0	1	0	0	0	0	0	1	0	15	6	2	2	2	2	1	4	1	1	4	5	4.70	4.51	121756
0	0	0	0	1	0	0	0	0	0	1	0	14	8	2	2	7	3	1	5	1	1	6	5	4.67	4.50	190186
0	0	0	0	1	0	0	1	0	0	1	0	13	4	2	2	3	2	1	6	1	1	6	4	4.69	4.50	280612
0	0	0	0	1	0	0	1	0	0	1	0	15	4	2	2	4	2	1	6	1	1	6	4	4.69	4.50	286035

Table F 17 Retrofit low 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	7.06	6.59	0
0	0	1	0	0	0	0	0	0	0	0	0	3	21	12	22	23	21	2	1	6	5	2	5	7.06	6.58	1263
3	1	3	1	0	0	0	0	0	0	0	1	2	23	14	23	5	2	6	5	6	2	6	7	7.05	6.58	37905
0	0	0	0	1	0	0	0	0	0	0	0	3	10	17	20	9	4	1	1	3	7	7	1	7.01	6.57	121549
0	1	0	0	1	0	0	0	0	0	0	0	4	7	16	20	8	4	1	1	3	6	7	1	7.02	6.58	103616
0	0	0	0	1	0	0	0	0	0	1	0	10	8	30	20	6	20	1	1	1	6	7	1	7.03	6.56	180137
1	1	1	0	0	0	0	0	0	0	1	0	7	8	12	29	21	29	1	6	2	5	5	1	7.05	6.57	96190
0	1	0	0	1	0	0	0	0	0	0	0	2	6	16	18	6	2	1	4	1	5	7	1	7.03	6.58	85991
0	1	0	0	0	1	0	0	0	0	0	0	18	27	5	28	3	8	2	6	1	4	2	3	7.04	6.58	26553
0	0	0	0	1	0	0	0	0	0	1	0	9	6	28	20	7	20	1	2	1	6	7	1	7.04	6.56	176114
0	0	1	1	1	0	0	0	0	0	0	1	7	7	21	9	7	10	1	1	4	1	7	7	7.03	6.57	118367
0	1	0	0	0	1	0	0	0	0	0	0	2	26	5	22	6	2	1	1	7	2	6	3	7.05	6.58	18418
0	0	0	1	1	1	0	0	0	0	0	0	4	9	6	2	7	10	1	1	4	2	7	1	7.01	6.57	132689
1	0	0	0	1	0	0	0	0	0	0	0	2	2	5	4	2	2	1	1	4	1	4	1	7.07	6.58	31122
0	0	0	0	1	1	0	0	0	0	1	0	15	2	2	17	2	5	1	7	7	3	7	3	7.06	6.56	153033
1	0	1	0	0	0	0	0	0	0	1	0	14	5	11	17	3	29	1	7	1	6	5	1	7.06	6.57	92474
0	0	3	0	1	0	0	1	0	0	1	0	11	9	29	2	8	22	2	6	1	7	7	1	7.00	6.55	357232
0	0	0	1	1	1	0	0	0	0	0	0	10	8	7	4	8	9	1	1	5	2	7	1	7.00	6.57	139468
0	0	0	0	1	0	0	0	0	0	1	0	3	7	12	18	9	7	1	1	5	1	7	1	7.02	6.56	189628
0	1	0	1	0	1	0	0	0	0	0	0	18	27	5	28	3	8	2	6	1	4	2	6	7.03	6.58	51507
2	1	0	1	0	0	0	0	0	0	0	1	8	22	14	23	6	3	5	5	6	2	7	7	7.05	6.58	40485
2	0	1	1	1	0	0	0	0	0	0	1	6	7	20	7	7	10	1	1	4	1	7	7	7.03	6.57	120546
0	0	0	0	1	0	0	0	0	0	1	0	20	9	13	19	9	5	1	1	1	6	7	1	7.01	6.56	203186
0	0	0	0	1	0	0	1	0	0	1	0	9	9	28	2	6	23	2	7	1	6	7	1	7.01	6.55	346710
0	0	2	0	1	0	0	1	0	0	1	0	11	9	29	2	12	22	2	7	1	7	7	1	6.99	6.55	381774

0	0	0	1	1	1	0	0	0	0	1	0	11	9	19	19	13	9	1	1	1	1	7	6	6.98	6.55	279405
0	0	0	1	1	1	0	0	0	0	0	0	11	9	7	4	9	11	1	1	5	1	7	1	6.99	6.57	155738
0	0	0	1	1	0	0	0	0	0	1	0	10	9	30	21	10	20	1	1	1	7	7	1	7.00	6.56	222717
0	0	0	1	1	1	0	0	0	0	1	0	11	9	2	19	13	9	1	1	1	1	7	6	6.99	6.55	256356
0	0	3	0	1	0	0	1	0	0	1	0	10	11	10	18	2	22	1	7	3	7	7	7	7.02	6.55	342363
0	0	0	0	1	1	0	0	0	0	1	0	14	2	2	11	2	7	1	7	6	3	7	4	7.05	6.56	155745

Table F 18 Retrofit low CC 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	8.60	8.40	0
0	1	0	0	1	0	0	0	0	0	0	0	5	9	3	24	9	2	5	6	6	1	3	4	8.57	8.39	122597
0	0	0	0	1	0	0	0	0	0	0	0	16	12	25	5	2	7	7	1	4	6	6	5	8.58	8.39	97144
1	0	0	0	1	1	0	0	0	0	0	0	23	3	4	28	2	7	3	3	1	7	7	7	8.60	8.39	53915
4	1	4	0	1	1	0	0	0	0	1	1	13	2	6	14	2	4	2	7	1	7	7	7	8.59	8.37	192204
0	1	0	0	0	1	0	0	0	0	0	0	9	8	12	30	4	15	6	1	7	1	5	1	8.58	8.39	45534
3	1	4	0	1	1	0	0	0	0	1	1	13	2	6	14	2	8	1	7	1	7	7	6	8.59	8.37	193804
0	0	1	0	1	0	0	0	0	0	0	0	14	13	16	28	12	2	4	6	1	1	6	1	8.56	8.38	159418
0	0	1	0	0	1	0	0	0	0	0	0	21	16	5	23	2	9	1	6	1	6	6	7	8.59	8.40	21344
0	0	0	0	1	0	0	0	0	0	1	0	5	12	2	23	9	2	5	6	1	1	5	1	8.58	8.37	220439
2	0	0	1	1	1	1	1	0	0	0	0	6	15	23	2	14	11	1	1	1	7	3	2	8.54	8.37	408281
0	0	0	0	1	0	0	0	0	0	1	0	4	7	2	28	3	11	5	7	4	1	7	1	8.62	8.37	181761
1	0	0	0	1	0	0	0	0	0	1	0	4	7	5	29	2	2	5	7	4	1	2	1	8.61	8.38	118995
0	0	0	1	1	1	0	0	0	0	1	0	13	12	7	28	11	8	4	7	1	1	7	1	8.56	8.36	298654
1	0	0	0	1	1	0	0	0	0	0	0	27	3	6	14	2	7	3	3	1	7	7	7	8.60	8.39	56626
0	0	0	0	1	0	0	0	0	0	1	0	5	14	12	29	11	2	5	7	1	1	4	1	8.57	8.37	237133

2	1	3	0	0	1	0	0	0	0	1	0	14	2	5	13	2	8	1	7	1	6	6	6	8.58	8.38	135141
1	0	0	0	1	1	0	0	0	0	0	0	27	3	6	14	2	19	3	3	1	7	7	7	8.59	8.39	728956
0	1	1	0	0	0	0	0	0	0	1	0	6	2	4	11	2	7	1	7	1	7	7	6	8.59	8.38	122178
1	0	0	0	1	1	0	0	0	0	0	1	25	10	9	25	10	17	6	3	3	1	1	1	8.56	8.38	168938
0	0	0	1	1	1	0	0	0	0	1	0	14	14	14	29	12	16	5	7	1	1	7	1	8.55	8.36	339328
0	0	0	0	1	1	0	0	0	0	1	0	3	14	11	29	12	16	5	7	3	1	7	1	8.56	8.36	315729
1	0	0	0	1	1	0	0	0	0	1	0	13	16	21	29	20	11	1	7	1	7	1	3	8.55	8.37	310287
0	0	0	1	1	1	0	1	0	0	0	0	14	13	16	2	13	17	4	7	1	1	7	1	8.53	8.37	364073
0	0	0	0	1	1	0	0	0	0	0	0	3	12	12	29	11	14	5	6	3	6	5	1	8.55	8.38	182304
0	0	0	1	1	1	0	0	0	0	1	0	25	15	10	30	10	2	5	7	1	1	1	1	8.56	8.37	254838
0	0	0	1	1	1	0	0	0	0	0	0	17	13	16	29	12	17	4	7	1	1	7	2	8.54	8.38	227595
1	0	0	0	1	1	0	0	0	0	0	1	3	10	8	29	9	16	5	2	6	1	1	1	8.56	8.38	162346

Table F 19 Retrofit high HIS 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	3.73	3.53	0
1	1	1	0	0	0	0	0	0	0	0	0	14	25	6	28	23	5	3	1	6	5	1	3	3.72	3.53	21463
0	0	0	0	0	1	0	0	0	0	0	0	10	2	4	2	23	3	3	1	1	3	1	2	3.70	3.53	51597
0	0	0	0	0	1	0	0	0	0	1	0	10	2	3	2	4	2	1	2	3	4	1	2	3.72	3.52	79175
0	0	0	0	0	1	0	0	0	0	1	0	11	2	2	2	4	3	1	2	1	4	1	2	3.72	3.52	81887
0	0	0	1	0	1	0	0	0	0	0	0	4	2	5	2	2	3	5	1	1	1	2	3	3.70	3.52	96121
0	0	0	1	0	1	0	0	0	0	0	0	6	2	4	2	5	5	5	1	1	1	4	1	3.68	3.52	123237
0	0	0	0	0	1	0	0	0	0	1	0	2	3	2	3	20	2	1	5	1	3	5	2	3.69	3.50	195056
0	0	0	0	0	1	0	0	0	0	1	0	2	3	2	30	20	4	1	4	1	1	5	2	3.68	3.50	205158
0	1	0	0	1	0	0	0	0	0	0	0	13	3	18	3	3	19	3	1	6	3	3	1	3.66	3.51	214203
0	0	0	0	1	1	0	0	0	0	0	0	12	2	3	3	4	4	2	2	1	5	1	2	3.64	3.50	246078
0	0	0	0	1	1	0	0	0	0	1	0	10	2	2	2	4	3	3	1	1	3	1	2	3.66	3.50	267488

0	0	0	0	1	1	0	0	0	0	0	0	2	3	3	2	4	4	1	5	1	5	1	2	3.62	3.50	278617
0	1	0	0	1	1	0	0	0	0	1	0	12	2	3	2	4	3	2	3	1	4	1	2	3.64	3.50	300902
0	0	0	0	1	1	0	0	0	0	0	0	2	4	3	2	5	3	3	1	1	5	4	3	3.60	3.50	328782
0	0	0	0	1	1	0	0	0	0	0	1	2	5	2	2	4	2	2	1	1	7	4	2	3.62	3.50	332269
1	0	0	0	1	1	0	0	0	0	0	0	14	4	4	2	5	3	1	4	1	2	4	2	3.59	3.50	337488
0	0	0	0	1	1	0	0	0	0	1	0	8	2	2	2	3	2	1	5	1	1	5	1	3.66	3.48	361065
0	0	0	0	1	1	0	0	0	0	1	0	13	2	2	26	3	4	1	4	1	1	5	1	3.64	3.48	371167
0	0	0	0	1	1	0	0	0	0	0	0	15	5	4	2	5	4	1	4	1	3	3	2	3.58	3.50	374879
1	0	0	0	1	1	0	0	0	0	1	0	13	2	2	26	3	4	1	5	1	1	5	1	3.64	3.48	380617
1	0	0	0	1	1	0	0	0	0	1	0	21	2	2	2	4	4	1	4	3	2	5	1	3.61	3.48	400209
0	0	0	0	1	1	0	0	0	0	1	0	21	2	3	2	5	4	1	4	4	2	5	1	3.60	3.48	428110
1	0	0	0	1	1	0	0	0	0	1	0	21	3	3	2	5	4	1	4	4	2	4	1	3.58	3.48	438232
1	0	0	0	1	1	0	0	0	0	1	0	21	4	3	2	5	4	1	6	1	2	5	2	3.56	3.47	508807

Table F 20 Retrofit high HIS 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.99	4.78	0
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	4.98	4.78	15655
0	0	0	0	0	1	0	0	0	0	0	0	22	2	2	12	5	4	2	2	2	1	4	1	4.96	4.77	48886
0	0	0	0	0	1	0	0	0	0	0	0	8	18	5	11	5	5	4	1	6	3	3	1	4.94	4.77	73290
0	1	0	0	0	1	0	0	0	0	0	0	25	4	7	13	2	6	1	1	6	4	3	1	4.92	4.77	107926
1	0	1	0	0	0	0	0	0	0	1	0	11	19	3	14	20	11	7	6	3	3	3	4	4.99	4.76	123016
0	0	0	0	0	1	0	0	0	0	1	0	30	17	5	9	3	4	4	1	1	1	2	5	4.96	4.76	125823
0	1	0	0	0	1	0	0	0	0	1	0	8	18	5	11	2	5	1	1	5	4	2	2	4.94	4.76	149613
0	0	0	1	0	1	0	0	1	0	0	0	6	6	5	5	6	5	1	2	4	1	3	4	4.91	4.76	184698
0	0	0	0	0	1	0	0	0	0	1	0	29	5	3	8	3	4	4	1	5	1	7	3	4.93	4.74	243477
0	0	0	0	0	1	0	0	0	0	1	0	26	5	7	2	2	4	5	1	7	1	7	5	4.92	4.74	265170
0	0	0	0	1	1	0	0	0	0	0	0	22	2	2	6	5	4	2	2	2	1	6	1	4.89	4.75	266415
0	0	0	1	0	1	0	0	0	0	1	0	7	5	5	3	6	6	1	1	4	1	5	1	4.90	4.74	284054
0	0	0	0	1	1	0	0	0	0	0	0	11	2	6	23	5	4	1	1	2	1	3	1	4.88	4.74	288108
0	0	0	0	1	1	0	0	0	0	0	0	2	2	4	21	6	5	1	1	3	1	5	1	4.86	4.74	311156
0	0	0	0	1	1	0	0	0	0	0	0	11	4	5	20	4	5	1	1	2	3	1	1	4.87	4.74	330138

0	0	0	0	1	1	0	0	0	0	0	0	21	4	4	20	5	4	2	1	2	1	6	1	4.85	4.74	342340
0	0	0	0	1	1	0	0	0	0	0	0	6	3	5	21	6	5	1	1	4	1	5	1	4.84	4.74	349119
1	0	0	0	1	1	0	0	0	0	0	0	26	3	5	21	6	5	1	1	4	1	5	1	4.84	4.74	352401
0	0	0	0	1	1	0	0	0	0	0	0	11	4	6	20	6	5	1	1	2	1	3	1	4.82	4.74	387081
0	0	0	0	1	1	0	0	0	0	1	0	6	5	3	6	2	5	1	1	1	1	5	1	4.88	4.72	438078
0	0	0	0	1	1	0	0	0	0	1	0	29	3	2	26	5	4	1	2	3	1	5	1	4.87	4.72	442890
0	0	0	0	1	1	0	0	0	0	0	0	21	6	5	21	6	5	1	2	1	2	1	1	4.79	4.74	446736
0	0	0	0	1	1	0	0	0	0	1	0	29	3	2	26	5	5	1	2	3	1	5	1	4.86	4.72	451025
0	0	0	0	1	1	0	0	0	0	1	0	6	3	2	21	6	5	1	1	4	1	5	1	4.84	4.72	470617
0	0	0	0	1	1	0	0	0	0	1	0	24	4	2	24	6	5	1	1	4	1	5	1	4.82	4.72	503156
0	0	0	1	1	1	0	0	0	0	0	0	6	6	5	5	6	5	1	2	4	1	3	1	4.78	4.73	506174
0	0	0	0	1	1	0	0	0	0	1	0	6	5	4	6	6	5	1	1	1	2	5	1	4.80	4.71	546542
0	0	0	0	1	1	0	0	0	0	1	0	7	6	6	6	6	6	1	1	4	1	5	1	4.77	4.71	598062
0	0	0	1	1	1	0	0	0	0	1	0	7	6	6	6	6	6	1	1	4	1	5	1	4.76	4.71	666991
0	0	0	1	1	1	0	0	0	0	1	0	6	10	7	5	6	5	1	3	1	1	6	1	4.75	4.70	822981
0	0	0	1	1	1	0	0	0	0	1	0	6	15	7	5	6	5	1	6	1	1	6	1	4.73	4.69	1004181

Table F 21 Retrofit High HIS 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	6.88	6.41	0
1	1	0	0	0	0	0	0	0	0	0	0	13	29	3	25	27	10	6	1	3	2	3	4	6.86	6.41	18938
0	0	0	0	0	1	0	0	0	0	0	0	21	4	2	12	3	5	1	7	1	4	1	1	6.83	6.40	57020
0	1	0	0	0	1	0	0	0	0	0	0	6	6	4	14	6	4	2	4	1	4	3	1	6.83	6.40	75387
0	0	0	0	0	1	0	0	0	0	0	0	8	2	4	2	9	6	2	1	1	1	1	2	6.82	6.40	76002
0	1	0	0	0	1	0	0	0	0	0	0	21	4	3	12	20	5	1	7	1	4	4	2	6.82	6.40	78099
0	1	0	0	0	1	0	0	0	0	0	0	6	6	5	2	4	6	2	1	1	3	2	1	6.80	6.40	97080
0	1	0	0	0	1	0	0	0	0	0	0	7	19	9	11	6	13	1	1	3	4	4	6	6.78	6.40	175716
0	0	0	0	0	1	0	0	0	0	1	0	7	6	3	2	5	4	2	6	1	1	4	1	6.86	6.38	197217
0	1	0	0	0	1	0	0	0	0	1	0	7	6	3	2	6	4	2	4	1	1	4	1	6.83	6.38	200536
0	1	0	0	0	1	0	0	0	0	1	0	6	5	4	2	8	6	1	2	1	1	4	1	6.81	6.38	209893
0	1	0	0	0	1	0	0	0	0	1	0	7	6	3	2	6	7	2	4	1	1	4	1	6.80	6.38	224940
0	1	0	0	0	1	0	0	0	0	1	0	22	4	8	2	7	6	1	4	1	1	5	1	6.78	6.37	269621

0	1	0	0	1	1	0	0	0	0	0	0	15	2	2	13	5	6	1	2	1	1	2	1	6.75	6.38	298340
0	1	0	0	1	1	0	0	0	0	0	0	13	2	6	5	5	6	1	2	1	1	1	2	6.74	6.37	320032
0	0	0	0	1	1	0	0	0	0	1	0	11	4	3	5	2	5	3	7	1	1	1	3	6.82	6.36	339747
0	0	0	0	1	1	0	0	0	0	0	0	3	2	5	15	7	6	1	1	1	1	1	1	6.72	6.37	350475
0	0	0	0	1	1	0	0	0	0	1	0	9	2	5	2	4	7	1	4	1	1	2	1	6.82	6.36	360501
0	0	0	0	1	1	0	0	0	0	1	0	9	2	3	2	5	7	2	4	1	1	2	1	6.80	6.36	375415
0	0	0	0	1	1	0	0	0	0	0	0	2	2	5	15	8	7	1	1	1	1	1	1	6.70	6.37	384370
0	0	0	0	1	1	0	0	0	0	1	0	3	2	4	5	6	7	1	6	1	3	1	3	6.75	6.36	393234
0	0	0	0	1	1	0	0	0	0	1	0	3	2	5	3	6	7	1	6	1	4	1	3	6.74	6.36	398657
0	0	0	0	1	1	0	0	0	0	1	0	3	2	7	3	7	6	1	6	1	4	1	3	6.72	6.36	427129
0	0	0	0	1	1	0	0	0	0	0	0	13	5	5	6	7	6	1	7	1	1	2	2	6.68	6.36	448092
0	0	0	0	1	1	0	0	0	0	0	1	20	5	6	5	6	7	1	7	1	1	2	3	6.70	6.36	450782
0	0	0	0	1	1	0	0	0	0	0	0	4	5	7	5	7	7	1	6	1	4	1	2	6.67	6.36	467073
0	0	0	0	1	1	0	0	0	0	1	0	8	4	4	8	2	5	3	6	1	3	6	3	6.82	6.34	467502
0	0	0	0	1	1	0	0	0	0	1	0	8	4	4	3	2	5	3	7	1	3	6	3	6.81	6.34	473670
0	0	0	0	1	1	0	0	0	0	0	0	16	5	5	6	8	7	1	7	1	1	2	2	6.66	6.36	481987
0	0	0	0	1	1	0	0	0	0	1	0	8	4	6	3	2	7	2	7	1	2	6	2	6.79	6.34	500786
0	0	0	0	1	1	0	0	0	0	1	0	7	3	5	7	6	5	1	6	1	1	5	3	6.75	6.34	517727
0	0	0	0	1	1	0	0	0	0	0	0	9	6	7	11	8	7	1	4	1	1	1	1	6.64	6.36	525373
0	1	0	0	1	1	0	0	0	0	1	0	8	4	6	3	3	7	4	7	1	1	6	3	6.74	6.34	542201
0	0	0	0	1	1	0	0	0	0	1	0	23	6	5	5	6	7	1	6	1	1	3	3	6.70	6.34	580214
0	0	0	0	1	1	0	0	0	0	0	0	9	8	7	4	8	6	1	6	1	1	1	1	6.62	6.35	582316
1	0	0	0	1	1	0	0	0	0	1	0	23	6	5	5	6	7	1	6	1	1	3	3	6.70	6.34	583497
0	0	0	0	1	1	0	0	0	0	1	0	13	5	7	6	8	6	1	7	4	5	3	3	6.67	6.34	608075
0	0	0	0	1	1	0	0	0	0	1	0	23	7	8	4	7	6	1	7	1	5	2	2	6.65	6.34	627116
0	0	0	0	1	1	0	0	0	0	1	0	13	7	7	6	7	12	1	7	5	5	2	3	6.64	6.34	670502
0	0	0	0	1	1	0	0	0	0	0	0	9	10	7	5	9	7	1	4	1	1	1	2	6.60	6.35	681290
0	0	0	0	1	1	0	0	0	0	1	0	14	7	7	6	8	14	1	7	5	6	2	3	6.62	6.34	712532
0	0	0	0	1	1	0	0	0	0	1	0	11	10	7	5	8	8	1	7	5	1	1	2	6.60	6.34	735640
0	0	0	1	1	1	0	0	0	0	0	0	9	10	6	5	9	6	1	6	1	1	1	2	6.58	6.34	751574
0	0	0	1	1	1	0	0	0	0	1	0	11	10	5	5	8	8	1	7	5	1	1	2	6.57	6.33	824906
0	0	0	0	1	1	0	0	0	0	1	0	11	10	7	5	8	8	1	7	5	1	6	2	6.59	6.32	864140
0	0	0	1	1	1	0	0	0	0	0	0	9	10	6	5	8	25	1	4	1	1	1	2	6.56	6.34	880375
0	0	0	0	1	1	0	1	0	0	0	0	2	10	8	4	9	25	1	2	5	3	1	1	6.56	6.34	1155353

Table F 22 Retrofit high CC 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.72	4.53	0
0	0	0	0	0	1	0	0	0	0	0	0	27	4	3	6	4	2	1	5	1	7	1	2	4.71	4.52	38039
0	0	0	0	0	1	0	0	0	0	0	0	27	15	2	18	7	4	2	1	2	1	6	1	4.70	4.52	48886
1	0	0	0	0	1	0	0	0	0	0	0	12	5	4	6	5	4	1	6	1	6	1	1	4.68	4.52	63015
0	0	0	0	0	1	0	0	0	0	1	0	17	3	2	5	6	3	3	6	1	4	3	6	4.70	4.50	157959
0	0	0	0	0	1	0	0	0	0	1	0	7	3	4	3	5	3	5	5	1	3	3	6	4.70	4.50	162637
1	1	0	0	0	1	0	0	0	0	1	0	15	4	3	9	21	4	1	3	5	4	3	6	4.67	4.50	171950
1	1	0	0	0	1	0	0	0	0	1	0	15	4	4	9	6	4	1	3	5	4	3	6	4.66	4.50	177374
1	0	0	0	1	0	0	0	0	0	0	0	17	3	5	7	5	22	5	6	1	6	1	3	4.64	4.50	253351
1	0	0	0	1	1	0	0	0	0	0	0	14	2	3	16	4	5	5	1	5	1	4	3	4.64	4.49	257495
1	0	0	0	1	1	0	0	0	0	0	0	14	2	4	17	5	5	5	1	1	1	4	3	4.61	4.49	288679
2	0	0	0	0	1	0	0	0	0	1	0	17	3	4	5	9	4	6	7	1	1	7	1	4.66	4.48	292473
1	0	0	0	1	1	0	0	0	0	0	0	15	3	4	7	5	5	5	4	1	7	5	4	4.60	4.49	321218
0	0	0	0	1	1	0	0	0	0	1	0	17	3	5	6	4	4	4	6	1	6	1	6	4.63	4.48	355272
0	0	0	0	1	1	0	0	0	0	1	0	17	3	5	6	4	5	4	6	1	6	1	4	4.62	4.48	363406
0	0	0	0	1	1	0	0	0	0	0	0	18	4	4	5	6	5	4	6	1	7	6	6	4.57	4.49	376235
0	0	0	0	1	1	0	0	0	0	1	0	13	3	5	5	5	5	5	5	1	2	1	5	4.60	4.48	382999
0	0	0	0	1	1	0	0	0	0	0	0	18	5	5	9	6	6	2	6	1	7	5	4	4.56	4.49	422332
0	0	0	0	1	1	0	0	0	0	1	0	14	5	4	7	5	5	5	5	1	2	1	4	4.58	4.48	442654
0	0	0	0	1	1	0	0	0	0	1	0	7	3	4	5	3	5	5	6	1	6	6	6	4.63	4.46	460723
0	0	0	0	1	1	0	0	0	0	1	0	7	3	5	5	3	5	5	6	1	1	6	6	4.62	4.46	466146
0	0	0	0	1	1	0	0	0	0	1	0	8	3	4	7	4	5	5	5	1	7	6	3	4.60	4.46	480315
1	0	0	0	1	1	0	0	0	0	1	0	17	6	5	7	5	6	2	5	1	7	1	4	4.56	4.47	492033
0	0	0	0	1	1	0	0	0	0	1	0	8	3	4	6	5	4	5	6	1	7	6	6	4.58	4.46	504109
0	0	0	0	1	1	0	0	0	0	1	0	18	4	5	6	6	4	4	6	1	1	5	6	4.56	4.46	542131
0	0	0	0	1	1	0	0	0	0	1	0	18	5	5	7	6	4	4	6	1	1	5	6	4.54	4.46	574670
0	0	0	0	1	1	0	0	0	0	1	0	13	6	5	4	6	5	4	5	1	7	5	3	4.52	4.46	609176
0	0	0	1	1	1	0	0	0	0	1	0	18	6	4	7	6	6	2	6	1	4	5	5	4.50	4.45	777823

Table F 23 Retrofit high CC 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	7.06	6.59	0
1	0	0	0	0	0	0	0	0	0	0	0	11	22	28	27	16	19	6	2	1	1	2	5	7.06	6.58	3283
0	0	0	0	0	1	0	0	0	0	0	0	23	5	2	4	8	2	2	2	5	1	2	3	7.06	6.58	32616
0	0	1	0	0	1	0	0	0	0	0	0	10	3	2	22	8	2	6	4	1	2	6	5	7.05	6.58	35141
0	0	1	0	0	1	0	0	0	0	0	0	14	8	2	19	16	3	2	1	2	1	1	1	7.04	6.58	43276
0	0	0	0	0	1	0	0	0	0	0	0	26	5	2	21	13	5	1	1	3	1	1	2	7.02	6.57	57020
0	0	0	0	0	1	0	0	0	0	0	0	12	6	4	2	13	6	3	4	4	2	1	3	7.00	6.57	76002
0	1	0	0	0	1	0	0	0	0	0	0	11	6	5	21	7	6	4	1	2	1	5	4	6.98	6.57	97080
0	0	0	0	0	1	0	0	0	0	1	0	11	21	5	7	7	4	1	7	1	1	1	5	7.02	6.56	137131
1	0	0	0	0	1	0	0	0	0	1	0	13	5	3	3	7	6	4	7	1	1	1	1	7.00	6.56	145837
0	1	0	0	0	1	0	0	0	0	0	0	25	10	8	2	10	14	4	1	2	2	1	2	6.96	6.57	178428
1	1	0	0	0	1	0	0	0	0	1	0	2	4	3	21	7	11	1	5	5	6	1	1	6.98	6.56	189830
0	0	0	1	0	1	0	0	0	0	0	0	8	5	13	9	13	12	2	2	1	1	7	5	6.95	6.56	254750
1	0	0	0	0	1	0	0	0	0	1	0	3	8	2	5	2	5	1	4	1	6	7	2	7.01	6.54	267975
0	1	0	0	0	1	0	0	0	0	1	0	16	9	3	24	4	6	1	5	6	7	6	1	6.97	6.54	274373
0	1	0	0	0	1	0	0	0	0	1	0	16	8	8	24	4	6	1	5	5	7	6	1	6.96	6.54	301489
0	0	0	0	1	1	0	0	0	0	0	0	12	2	4	2	6	6	2	1	1	1	1	3	6.94	6.54	319291
0	0	0	0	1	1	0	0	0	0	0	0	12	2	2	2	7	6	1	1	1	1	1	2	6.92	6.54	334205
0	0	0	0	1	1	0	0	0	0	0	0	12	3	2	2	6	6	2	1	1	5	1	1	6.94	6.54	340984
1	0	0	0	1	1	0	0	0	0	0	0	2	2	6	2	7	6	3	1	1	1	1	4	6.90	6.54	359180
1	0	0	0	1	1	0	0	0	0	0	0	11	2	5	23	8	8	1	4	1	1	1	1	6.88	6.54	395787
0	1	0	1	1	1	0	0	0	0	1	0	3	2	2	5	2	6	1	1	1	5	6	2	6.99	6.52	419560
1	0	0	0	1	1	0	0	0	0	0	0	12	5	2	22	8	6	5	4	2	2	1	1	6.86	6.53	460865
0	0	0	0	1	1	0	0	0	0	1	0	11	4	2	22	6	6	6	7	1	1	2	6	6.93	6.52	471199
0	0	0	0	1	1	0	0	0	0	1	0	2	3	5	22	7	6	4	7	1	1	2	1	6.90	6.52	480690
1	0	0	0	1	1	0	0	0	0	1	0	2	3	5	22	7	6	4	7	1	1	2	1	6.90	6.52	483972
1	0	0	0	1	1	0	0	0	0	0	0	2	5	5	2	8	8	4	5	1	5	1	4	6.84	6.53	493405
1	0	0	0	1	1	0	0	0	0	1	0	13	5	4	3	7	6	5	7	1	1	1	6	6.87	6.52	517927
1	0	0	0	1	1	0	0	0	0	1	0	13	5	2	22	8	6	5	7	2	1	1	2	6.86	6.52	532841
0	0	0	0	1	1	0	0	0	0	0	0	14	7	6	2	8	6	3	7	1	1	1	5	6.82	6.53	544354
1	0	0	0	1	1	0	0	0	0	1	0	13	5	8	22	8	6	5	7	2	1	1	2	6.84	6.52	565381
0	0	0	0	1	1	0	0	0	0	0	0	2	8	8	11	8	7	5	5	1	5	3	1	6.80	6.52	595874

1	0	0	0	1	1	0	0	0	0	1	0	3	6	8	6	3	6	6	4	1	4	7	2	6.94	6.50	604815
0	0	0	0	1	1	0	0	0	0	1	0	14	7	6	15	8	6	3	7	1	1	1	5	6.82	6.51	616330
0	0	0	0	1	1	0	0	0	0	1	0	13	5	2	3	7	5	1	5	1	3	7	4	6.88	6.50	637528
0	0	0	0	1	1	0	0	0	0	1	0	9	4	8	4	8	6	1	6	1	1	6	3	6.87	6.50	651891
0	0	0	0	1	1	0	0	0	0	1	0	11	4	8	5	8	6	1	7	1	1	6	3	6.86	6.50	658059
0	0	0	0	1	1	0	0	0	1	0	0	2	9	8	11	8	6	5	5	1	6	1	1	6.80	6.52	658965
0	0	0	0	1	1	0	0	0	0	0	0	15	9	6	2	8	16	4	3	1	1	1	5	6.78	6.52	690780
0	0	0	0	1	1	0	0	0	0	1	0	14	7	2	6	8	6	1	1	1	4	7	4	6.82	6.50	711829
0	0	0	0	1	1	0	0	0	0	1	0	14	7	4	6	8	6	1	1	1	4	7	4	6.82	6.50	722676
0	0	0	0	1	1	0	0	0	0	1	0	2	8	5	6	8	6	1	1	1	1	7	5	6.80	6.50	760638
0	0	0	0	1	1	0	0	0	1	0	0	2	9	7	21	8	22	6	5	1	3	2	1	6.78	6.52	771876
1	0	0	0	1	1	0	0	0	0	0	0	23	10	7	22	10	24	1	3	2	6	5	1	6.76	6.52	848624
0	0	0	0	1	1	0	0	0	0	1	0	14	8	13	6	8	9	1	6	1	1	7	5	6.78	6.49	859268
1	0	0	0	1	1	0	0	0	0	0	0	2	11	18	2	9	22	1	3	1	1	1	3	6.76	6.52	898789
1	0	0	0	1	1	0	0	0	0	1	0	3	15	14	4	9	6	1	7	1	1	7	5	6.76	6.48	1103272
1	0	0	0	1	1	0	0	0	0	1	0	3	15	14	4	9	11	1	7	1	1	7	6	6.75	6.48	1143946
1	0	0	0	1	1	0	0	0	0	1	0	3	15	14	4	9	19	1	7	1	1	7	6	6.74	6.48	1209024

Table F 24 Retrofit high CC 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	8.60	8.40	0
0	0	1	0	0	1	0	0	0	0	0	0	12	14	2	5	29	5	1	2	4	1	3	1	8.58	8.39	59545
0	1	0	0	0	1	0	0	0	0	0	0	12	11	2	20	10	8	1	6	1	1	4	5	8.56	8.38	97080
1	1	0	0	0	1	0	0	0	0	0	0	17	2	4	11	6	7	1	1	3	1	7	1	8.56	8.38	103074
1	1	0	0	0	1	0	0	0	0	0	0	18	2	7	6	7	10	1	6	3	2	5	1	8.54	8.38	143748
0	0	0	0	1	1	0	0	0	0	0	0	14	2	4	28	2	6	2	5	3	1	3	1	8.59	8.36	216250
0	0	0	0	1	1	0	0	0	0	0	0	14	2	3	27	2	8	1	7	2	4	3	1	8.58	8.36	227097
1	1	0	0	0	1	0	0	0	0	1	0	13	3	7	2	9	10	5	1	4	1	4	6	8.55	8.36	255816
0	1	0	0	0	1	0	0	0	0	1	0	17	4	10	2	16	14	1	7	2	3	2	1	8.54	8.36	286950
1	1	0	0	0	1	0	0	0	0	0	0	23	2	7	27	8	28	1	3	4	4	3	1	8.52	8.37	290174
0	0	0	0	1	1	0	0	0	0	1	0	13	3	3	26	2	6	1	4	2	1	3	1	8.61	8.34	348238
0	1	0	0	1	1	0	0	0	0	0	0	13	2	6	11	6	8	4	1	4	2	5	1	8.52	8.35	362062

1	1	0	0	0	1	0	0	0	0	1	0	13	4	8	3	9	10	5	7	3	1	7	1	8.52	8.34	375347
0	1	0	0	1	1	0	0	0	0	0	0	18	2	6	11	7	8	5	1	4	2	5	1	8.50	8.35	387822
1	1	0	0	0	1	0	0	0	0	1	0	16	4	8	3	9	13	1	7	3	1	7	1	8.52	8.34	399752
0	0	0	0	1	1	0	0	0	0	0	0	10	2	3	7	10	9	3	6	3	1	6	2	8.48	8.35	441313
0	0	0	0	1	1	0	0	0	0	0	0	4	3	5	7	9	9	2	3	4	1	6	5	8.49	8.34	458939
0	0	0	0	1	1	0	0	0	0	0	0	13	3	4	8	10	9	3	6	4	1	6	3	8.48	8.34	479276
0	0	0	0	1	1	0	0	0	0	1	0	13	2	5	15	4	8	1	7	6	1	6	1	8.59	8.32	489940
0	0	0	0	1	1	0	0	0	0	0	0	16	2	6	11	11	10	4	2	4	1	4	1	8.46	8.34	491478
1	0	0	0	1	1	0	0	0	0	1	0	13	2	7	14	5	9	1	7	6	1	5	1	8.57	8.32	512264
0	0	0	0	1	1	0	0	0	0	0	0	14	2	14	20	11	9	1	1	4	2	1	6	8.46	8.34	526729
1	0	0	0	1	1	0	0	0	0	1	0	13	2	7	15	6	9	1	7	6	1	5	1	8.56	8.32	538024
2	0	0	0	1	1	0	0	0	0	1	0	13	2	7	4	7	11	1	4	4	1	5	1	8.54	8.32	564832
0	0	0	0	1	1	0	0	0	0	1	0	11	4	7	2	8	9	1	7	7	1	2	3	8.51	8.32	574240
0	0	0	0	1	1	0	0	0	0	1	0	11	4	7	2	9	9	1	7	5	1	2	3	8.50	8.32	600000
0	0	0	0	1	1	0	0	0	0	0	0	12	7	6	2	10	10	2	6	6	1	7	6	8.44	8.33	628414
0	0	0	0	1	1	0	0	0	0	1	0	13	5	5	9	10	10	1	7	6	1	1	1	8.48	8.32	629888
1	0	0	0	1	1	0	0	0	1	1	0	17	4	11	2	4	9	2	7	6	4	7	1	8.58	8.30	647941
1	0	0	0	1	1	0	0	0	1	1	0	17	4	10	10	4	11	1	7	6	4	7	1	8.58	8.30	656731
1	0	0	0	1	1	0	0	0	0	1	0	11	4	10	2	6	9	1	7	1	1	7	1	8.56	8.30	670772
0	0	0	1	1	1	0	0	0	0	0	0	12	6	6	17	9	9	3	4	5	1	4	1	8.46	8.32	686496
1	0	0	0	1	1	0	0	0	0	0	0	11	9	6	2	10	10	1	6	6	1	6	1	8.42	8.32	696775
0	0	0	0	1	1	0	0	0	0	1	0	10	5	11	2	7	9	1	7	3	1	6	1	8.54	8.30	705512
0	0	0	0	1	1	0	0	0	0	1	0	12	5	8	2	8	10	1	7	7	1	6	1	8.51	8.30	723137
0	0	0	1	1	1	0	0	0	0	0	0	14	7	6	17	9	9	3	4	1	2	1	4	8.44	8.32	735304
0	0	0	0	1	1	0	0	0	0	1	0	11	5	7	2	9	9	1	7	3	1	6	3	8.50	8.30	735339
0	0	0	0	1	1	0	0	0	0	0	0	4	10	12	10	10	10	5	4	1	1	7	1	8.41	8.32	758570
0	0	0	0	1	1	0	0	0	0	0	0	12	10	6	7	11	12	3	4	3	1	4	3	8.40	8.32	768061
0	0	0	0	1	1	0	0	0	0	0	0	17	11	10	11	10	10	1	4	6	1	2	1	8.40	8.32	780263
1	1	0	0	1	1	0	0	0	1	1	0	17	4	11	19	7	14	1	7	6	5	7	1	8.47	8.30	784120
1	1	0	0	1	1	0	0	0	0	1	0	13	5	8	4	9	11	5	7	3	1	7	1	8.45	8.30	801670
0	0	0	0	1	1	0	0	0	0	0	0	14	12	10	2	12	11	1	5	6	1	6	1	8.38	8.32	872458
1	0	0	0	1	1	0	0	0	0	1	0	11	12	4	4	9	9	1	1	6	1	5	1	8.44	8.30	887419
0	0	0	0	1	1	0	0	0	0	1	0	12	12	11	15	11	7	4	7	5	1	3	1	8.41	8.30	942957
2	0	0	0	1	1	0	0	0	0	1	0	13	12	11	26	12	8	1	7	7	1	2	1	8.40	8.30	957717

1	0	0	0	1	1	0	0	0	0	0	0	13	12	7	26	12	26	1	6	5	1	2	4	8.36	8.32	981493
1	0	0	0	1	1	0	0	0	1	1	0	16	13	11	15	8	9	1	7	7	1	7	1	8.45	8.28	1027900
1	0	0	0	1	1	0	0	0	1	1	0	16	12	11	14	9	10	1	7	7	1	7	1	8.43	8.28	1029256
2	0	0	0	1	1	0	0	0	0	1	0	12	12	11	15	11	8	1	7	6	1	7	1	8.41	8.28	1060457
0	0	0	0	1	1	0	0	0	0	1	0	13	12	7	26	12	27	1	7	7	1	2	1	8.37	8.30	1084021
0	0	0	0	1	1	0	0	0	0	1	0	14	12	11	3	12	12	1	6	7	2	7	1	8.40	8.28	1106024
0	0	0	1	1	1	0	0	0	0	0	0	14	17	9	15	13	12	3	4	1	2	1	4	8.36	8.30	1201700
0	0	0	1	1	1	1	0	1	0	0	0	14	19	10	27	17	20	1	5	1	3	1	6	8.34	8.30	1581318

Table F 25 New development low HIS 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	3.73	3.53	0
1	1	1	0	0	0	0	0	0	0	0	0	14	25	6	28	23	5	3	1	6	5	1	3	3.72	3.53	21463
0	0	0	0	0	1	0	0	0	0	0	0	7	3	4	17	2	3	1	1	1	1	7	5	3.70	3.53	34597
0	1	0	1	0	1	0	0	0	0	0	0	2	2	3	2	2	4	1	4	6	1	2	1	3.69	3.52	67795
1	1	0	1	0	1	0	0	0	0	0	0	2	2	4	4	13	5	1	4	7	6	6	1	3.68	3.52	81347
1	0	0	0	1	0	0	0	0	0	0	0	27	2	14	24	5	28	4	3	4	2	3	2	3.66	3.51	149312
0	0	0	0	1	1	0	0	0	0	0	0	13	2	3	12	4	4	2	1	5	1	1	1	3.64	3.50	166078
0	0	0	1	1	1	0	0	0	0	0	0	3	3	2	2	3	3	1	1	5	1	3	1	3.65	3.50	182765
0	0	0	0	1	1	0	0	0	0	0	0	13	3	3	11	4	4	2	1	5	1	1	1	3.62	3.50	186617
0	0	0	1	1	1	0	0	0	0	0	0	2	3	2	2	4	3	1	1	3	1	4	1	3.63	3.50	193890
0	0	0	1	1	1	0	0	0	0	0	0	2	3	2	2	4	5	1	2	4	1	4	1	3.62	3.50	204160
0	0	0	0	1	1	0	0	0	0	0	0	2	4	2	12	5	4	1	1	1	1	5	2	3.60	3.50	219993
0	0	0	0	1	1	0	0	0	0	0	0	2	4	4	12	5	4	1	1	1	1	4	1	3.59	3.50	226840
0	0	0	0	1	1	0	0	0	0	0	0	5	5	3	6	5	5	1	1	4	1	4	1	3.58	3.50	249091
0	0	0	1	1	1	0	0	0	0	0	0	5	6	3	6	5	6	1	1	4	1	4	1	3.56	3.49	309423
0	0	0	1	1	1	0	1	0	0	0	0	2	2	2	2	3	3	2	1	1	1	1	5	3.65	3.48	724329
0	0	0	1	1	1	0	1	0	0	0	0	2	2	3	8	3	3	1	1	1	1	3	1	3.64	3.48	732887
0	0	0	1	1	1	0	1	0	0	0	0	2	2	4	2	4	3	1	1	1	1	4	4	3.61	3.48	747436
0	0	0	0	1	1	0	1	0	0	0	0	2	3	2	2	4	4	1	1	1	1	4	2	3.60	3.48	750432
0	0	0	0	1	1	0	1	0	0	0	0	2	4	3	12	4	4	1	1	1	1	5	2	3.58	3.48	774394
0	0	0	0	1	1	0	1	0	0	0	0	8	5	3	2	5	4	1	1	1	1	5	3	3.56	3.48	811194

0	0	0	1	1	1	0	1	0	0	0	0	5	6	4	2	5	7	1	5	1	1	4	2	3.54	3.47	881796

Table F 26 New development low HIS 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.99	4.78	0
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	4.98	4.78	15655
0	0	0	0	0	1	0	0	0	0	0	0	25	4	2	8	7	4	2	5	1	3	1	1	4.96	4.77	32886
0	0	0	0	0	1	0	0	0	0	0	0	26	2	5	20	6	5	1	6	1	1	1	1	4.94	4.77	48290
0	0	0	0	1	0	0	0	0	0	0	0	9	2	5	12	2	7	1	5	2	3	6	7	4.99	4.76	97249
0	0	1	0	1	0	0	0	0	0	0	0	27	2	10	2	3	10	1	7	1	1	1	4	4.98	4.76	116034
0	1	0	0	1	0	0	0	0	0	0	0	16	2	6	2	3	10	1	1	1	3	2	1	4.95	4.76	129164
0	1	0	0	1	0	0	0	0	0	0	0	17	2	7	3	4	11	2	1	1	3	2	1	4.92	4.76	145424
0	0	1	0	1	0	0	0	0	0	0	0	26	2	12	3	5	10	2	7	2	1	3	4	4.92	4.76	148554
1	1	1	0	1	0	0	0	0	0	0	0	25	3	11	16	4	15	2	5	4	5	1	1	4.90	4.76	171771
0	0	0	0	1	1	0	0	0	0	0	0	2	2	4	27	5	5	1	1	1	1	1	1	4.88	4.74	190896
0	0	0	0	1	1	0	0	0	0	0	0	12	2	4	5	6	5	1	1	1	1	1	1	4.86	4.74	207156
1	0	0	0	1	1	0	0	0	0	0	0	11	4	7	6	3	5	1	1	1	3	4	1	4.89	4.74	213006
0	0	0	0	1	1	0	0	0	0	0	0	2	4	5	24	4	5	1	1	1	1	3	1	4.87	4.74	219138
0	0	0	0	1	1	0	0	0	0	0	0	2	4	4	6	5	4	1	1	1	1	1	1	4.85	4.74	226840
0	0	0	0	1	1	0	0	0	0	0	0	2	3	5	3	6	5	1	6	1	1	1	1	4.84	4.74	231119
0	0	0	0	1	1	0	0	0	0	0	0	2	3	6	27	6	5	1	1	1	1	1	1	4.84	4.74	234542
0	0	0	0	1	1	0	0	0	0	0	0	2	4	6	27	6	5	1	1	1	1	1	1	4.82	4.74	255081
0	0	0	0	1	1	0	0	0	0	0	0	18	6	4	28	6	5	4	1	1	1	1	3	4.80	4.74	289313
0	0	0	0	1	1	0	0	0	0	0	0	21	7	4	9	7	15	3	2	1	2	1	1	4.78	4.74	377461
1	0	0	0	1	1	0	0	0	0	1	0	17	6	12	8	6	16	3	4	1	1	1	1	4.76	4.73	505959
0	0	0	1	1	1	1	0	0	0	1	0	10	5	8	8	5	3	1	3	1	1	1	1	4.80	4.72	539647
0	0	0	1	1	1	0	0	1	0	1	0	9	7	8	14	10	18	3	4	1	2	1	1	4.73	4.72	738368
0	0	3	1	1	1	1	1	1	0	0	0	8	5	8	2	10	17	5	2	1	1	6	4	4.75	4.70	1241005
0	0	3	1	1	1	0	1	1	0	1	0	10	6	3	3	10	18	4	4	1	1	1	1	4.73	4.70	1271247
0	0	3	1	1	1	0	1	1	0	1	0	10	6	3	5	10	18	4	6	1	1	1	1	4.72	4.70	1326490
0	0	3	1	1	1	1	1	1	0	1	0	9	6	8	2	10	18	5	4	1	1	1	1	4.72	4.69	1401309

Table F 27 New development low HIS 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	6.88	6.41	0
1	1	0	0	0	0	0	0	0	0	0	0	13	29	3	25	27	10	6	1	3	2	3	4	6.86	6.41	18938
0	0	0	0	0	1	0	0	0	0	0	0	7	2	2	8	3	5	1	1	1	1	1	1	6.83	6.40	38020
0	0	0	0	0	1	0	0	0	0	0	0	19	2	6	8	6	5	1	1	2	1	4	2	6.82	6.40	51713
0	1	0	0	0	1	0	0	0	0	0	0	11	2	5	6	2	6	5	2	1	1	1	1	6.80	6.40	69080
1	1	0	0	0	1	0	0	0	0	0	0	19	7	7	10	12	11	2	3	1	4	2	1	6.78	6.40	104883
1	0	0	0	1	1	0	0	0	0	0	0	12	2	4	7	2	3	5	1	3	1	1	1	6.86	6.38	135129
0	0	0	0	1	1	0	0	0	0	0	0	12	2	3	8	2	5	3	5	1	1	1	1	6.84	6.38	138692
0	0	0	0	1	1	0	0	0	0	0	0	9	2	2	5	2	6	1	1	1	1	4	1	6.84	6.38	140404
0	0	0	0	1	1	0	0	0	0	0	0	12	2	5	6	2	7	5	1	1	1	1	1	6.82	6.38	155808
0	1	0	0	1	1	0	0	0	0	0	0	12	2	6	6	2	7	5	3	1	1	1	1	6.80	6.38	174887
0	0	0	0	1	1	0	0	0	0	0	0	11	2	4	7	5	6	5	1	1	1	1	1	6.78	6.37	196031
0	0	0	0	1	1	0	0	0	0	0	0	8	2	2	8	6	6	1	1	1	6	1	1	6.75	6.37	205445
0	0	0	0	1	1	0	0	0	0	0	0	11	2	2	8	7	5	1	1	1	6	1	2	6.74	6.37	216570
0	0	0	0	1	1	0	0	0	0	0	0	12	2	5	6	7	6	4	1	1	1	1	1	6.72	6.37	231975
0	0	0	0	1	1	0	0	0	0	0	0	10	2	6	5	8	6	5	1	1	1	1	1	6.70	6.37	251658
0	0	0	1	1	1	0	0	0	0	0	0	11	6	6	6	2	2	1	1	1	4	1	1	6.79	6.36	281182
0	0	0	0	1	1	0	0	0	0	0	0	7	4	6	6	8	6	2	1	1	6	1	1	6.68	6.36	292736
0	0	0	1	1	1	0	0	0	0	0	0	11	7	5	7	2	2	1	1	1	1	1	1	6.78	6.36	299154
0	0	0	1	1	1	0	0	0	0	0	0	11	2	6	5	7	6	1	5	1	1	1	1	6.69	6.36	300010
0	0	0	0	1	1	0	0	0	0	0	0	5	5	7	5	7	7	1	1	1	5	5	1	6.67	6.36	305573
0	0	0	0	1	1	0	0	0	0	0	0	6	5	6	6	8	6	1	1	1	6	1	1	6.66	6.36	313276
0	0	0	0	1	1	0	0	0	0	0	0	6	6	7	6	8	7	1	1	1	6	1	1	6.64	6.36	342373
0	0	0	0	1	1	0	0	0	0	0	0	12	8	7	8	8	6	1	1	1	1	6	2	6.62	6.35	378316
0	0	0	1	1	1	0	0	0	0	0	0	11	6	6	5	9	8	1	1	1	7	1	1	6.60	6.35	424956
0	0	0	1	1	1	0	0	0	0	0	0	12	8	7	9	9	6	1	1	2	5	6	1	6.58	6.34	467746
0	0	0	1	1	1	0	0	0	0	0	0	12	8	8	6	9	21	1	1	1	1	1	1	6.56	6.34	545624
0	0	0	1	1	1	0	0	0	0	0	0	11	11	17	6	9	7	1	1	1	7	1	3	6.57	6.34	561029
0	0	0	1	1	1	0	0	0	0	0	1	11	12	17	9	9	8	6	1	1	7	1	3	6.56	6.34	607614

Table F 28 New development low CC 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.72	4.53	0
1	0	0	0	0	1	0	0	0	0	0	0	12	3	2	7	4	2	1	1	3	1	3	2	4.72	4.52	25899
0	0	0	0	0	1	0	0	0	0	0	0	23	6	2	16	8	4	1	1	5	4	2	4	4.70	4.52	32886
0	0	0	0	0	1	0	0	0	0	0	0	8	5	5	2	5	5	1	1	1	1	1	3	4.67	4.52	48290
0	0	0	1	0	1	0	0	0	0	0	0	7	4	5	3	5	5	1	1	1	1	1	1	4.66	4.51	90651
0	0	0	0	1	1	0	0	0	0	0	0	21	2	2	2	2	2	2	1	1	1	1	1	4.71	4.50	119865
0	0	0	0	1	1	0	0	0	0	0	0	12	2	2	2	2	3	1	1	1	1	1	3	4.70	4.50	125000
0	0	0	0	1	1	0	0	0	0	0	0	27	2	5	18	2	5	2	1	1	1	1	1	4.68	4.50	145539
0	1	0	0	1	1	0	0	0	0	0	0	21	2	3	2	3	3	1	1	5	1	1	2	4.66	4.50	160338
1	0	0	0	1	0	0	0	0	0	0	0	23	3	23	2	5	29	3	2	2	3	1	5	4.64	4.50	169851
0	1	0	0	1	1	0	0	0	0	0	0	9	2	3	2	4	3	1	1	6	1	5	2	4.64	4.50	176598
0	0	0	0	1	1	0	0	0	0	0	0	27	2	5	2	5	5	3	1	1	1	1	1	4.62	4.49	194319
0	0	0	0	1	1	0	0	0	0	0	0	12	3	5	2	5	6	2	1	1	1	1	1	4.60	4.49	219993
0	0	0	0	1	1	0	0	0	0	0	0	20	4	4	2	6	5	1	1	1	2	1	3	4.57	4.49	248235
0	0	0	0	1	1	0	0	0	0	0	0	20	5	7	2	6	5	3	1	1	2	1	3	4.56	4.49	279044
0	0	0	1	1	1	0	0	0	0	0	0	6	5	6	2	5	5	1	1	1	1	1	1	4.56	4.48	295731
0	0	0	1	1	1	0	0	0	0	0	0	5	6	6	2	6	5	1	2	1	1	1	4	4.54	4.48	327395
0	0	0	1	1	1	0	0	0	0	0	0	7	7	7	2	8	10	1	1	1	1	1	5	4.52	4.48	419822
0	0	0	0	1	1	0	1	0	0	0	0	7	7	6	3	6	5	1	1	1	1	4	1	4.52	4.46	883937
0	0	0	1	1	1	0	1	0	0	0	0	6	6	6	7	10	10	1	1	6	7	6	1	4.49	4.46	994762

Table F 29 New development low CC 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	7.06	6.59	0
1	0	0	0	0	0	0	0	0	0	0	0	11	22	28	27	16	19	6	2	1	1	2	5	7.06	6.58	3283
0	0	0	0	0	1	0	0	0	0	0	0	2	26	2	3	6	2	1	2	2	1	1	4	7.06	6.58	22616
0	0	1	0	0	1	0	0	0	0	0	0	23	5	2	2	9	2	1	2	6	3	3	2	7.05	6.58	25141
0	0	0	0	0	1	0	0	0	0	0	0	16	5	2	2	9	4	1	1	1	1	5	1	7.03	6.57	32886
0	0	0	0	0	1	0	0	0	0	0	0	21	21	2	23	9	5	1	1	1	1	5	2	7.02	6.57	38020

0	0	0	0	0	1	0	0	0	0	0	0	12	28	4	7	2	6	1	1	3	1	2	2	7.00	6.57	50002
0	0	0	0	0	1	0	0	0	0	0	0	21	8	8	16	2	8	1	1	4	1	2	2	6.98	6.57	73964
0	0	0	0	1	0	0	0	0	0	0	0	2	3	4	6	2	2	2	3	5	3	5	3	7.07	6.56	117788
0	0	0	0	1	1	0	0	0	0	0	0	2	2	2	2	2	3	4	1	1	1	1	1	7.06	6.55	125000
0	0	0	0	1	1	0	0	0	0	0	0	2	2	2	5	2	5	1	1	1	1	1	1	7.03	6.55	135269
0	0	0	1	0	1	0	0	0	0	0	0	9	6	9	2	8	10	1	1	1	1	1	1	6.96	6.56	139432
0	0	0	0	1	1	0	0	0	0	0	0	2	2	3	2	6	7	2	3	2	1	2	1	6.94	6.54	214003
0	0	0	0	1	1	0	0	0	0	0	0	2	6	2	5	2	5	1	1	1	1	1	1	6.98	6.54	217426
0	0	0	0	1	1	0	0	0	0	0	0	11	2	2	2	7	6	4	1	1	2	1	2	6.92	6.54	221705
0	0	0	0	1	1	0	0	0	0	0	0	8	3	2	2	6	6	2	1	1	1	1	1	6.94	6.54	225984
0	0	0	0	1	1	0	0	0	0	0	0	13	3	2	2	7	6	4	1	1	2	1	2	6.91	6.54	242244
0	0	0	0	1	1	0	0	0	0	0	0	2	2	2	2	8	7	1	2	1	1	4	1	6.90	6.54	243100
0	0	0	0	1	1	0	0	0	0	0	1	2	2	4	3	7	10	2	1	1	1	2	1	6.90	6.54	257026
0	0	0	0	1	1	0	0	0	0	0	1	2	2	4	2	8	11	3	1	1	1	3	1	6.88	6.54	278421
0	0	0	0	1	1	0	0	0	0	0	0	2	5	2	2	8	7	1	2	1	1	3	1	6.86	6.53	304718
0	0	0	0	1	1	0	0	0	0	0	0	2	7	2	3	7	9	1	1	1	3	4	2	6.84	6.53	339805
0	0	0	0	1	1	0	0	0	0	0	0	2	7	8	3	7	9	1	1	1	2	1	1	6.82	6.53	360345
0	0	0	1	1	1	0	0	0	0	0	0	9	7	9	2	7	3	1	1	1	1	1	1	6.85	6.52	384734
0	0	0	0	1	1	0	0	0	0	0	0	9	7	9	2	8	12	1	1	1	1	2	1	6.80	6.53	395432
0	0	0	1	1	1	0	0	0	0	0	0	8	7	10	2	6	11	1	1	1	1	1	1	6.83	6.52	407840
0	0	0	1	1	1	0	0	0	0	0	0	9	6	9	2	7	12	1	1	1	1	1	1	6.81	6.52	410408
0	0	0	1	1	1	0	0	0	0	0	0	9	7	8	2	7	11	1	1	1	1	1	1	6.80	6.52	422389
0	0	0	1	1	1	0	0	0	0	0	0	9	7	10	2	8	13	1	1	1	1	2	1	6.78	6.52	455765
0	0	0	1	1	1	0	0	0	0	0	0	11	9	8	16	8	11	1	4	1	1	4	1	6.75	6.51	501978
0	0	0	1	1	1	0	0	0	0	0	0	11	10	14	2	8	27	1	1	2	1	3	1	6.74	6.51	613232
0	0	0	1	1	1	0	0	0	0	1	0	10	10	8	7	8	12	1	4	2	1	4	1	6.71	6.50	702303
0	0	0	0	1	1	0	1	0	0	0	0	4	7	12	2	8	7	1	3	1	1	5	2	6.76	6.50	947266
0	0	0	0	1	1	0	1	0	0	0	0	2	8	11	2	8	9	1	1	1	1	3	1	6.74	6.50	974652
0	0	0	1	1	1	0	1	0	0	0	0	9	8	11	2	8	15	1	1	1	1	3	1	6.71	6.49	1057235

Table F 30 New development low CC 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	8.60	8.40	0
0	0	1	0	0	1	0	0	0	0	0	0	14	14	2	4	21	5	2	1	3	1	2	4	8.58	8.39	40545
1	0	0	0	0	1	0	0	0	0	0	0	16	18	2	2	12	9	1	1	4	1	5	3	8.56	8.38	61842
1	0	0	0	0	1	0	0	0	0	0	0	14	2	6	12	5	8	1	1	1	5	1	1	8.55	8.38	70400
0	1	0	0	0	1	0	0	0	0	0	0	29	30	7	10	6	11	2	4	1	1	3	1	8.54	8.38	101600
0	0	0	0	1	1	0	0	0	0	0	0	19	2	3	19	2	7	1	4	1	1	1	1	8.58	8.36	148962
0	0	0	0	1	1	0	0	0	0	0	0	19	2	3	19	2	8	1	4	1	1	1	1	8.58	8.36	154097
0	0	0	0	1	1	0	0	0	0	0	0	19	2	8	19	2	11	1	3	1	1	1	1	8.56	8.35	186617
1	1	0	0	0	1	0	0	0	0	0	0	3	2	8	3	21	27	1	1	1	3	2	4	8.52	8.37	190463
0	1	0	0	1	1	0	0	0	0	0	0	2	2	3	23	6	6	1	5	2	2	5	2	8.54	8.35	224523
0	0	0	0	1	1	0	0	0	0	0	0	22	2	2	26	8	7	1	3	3	1	1	1	8.52	8.35	243100
0	0	0	0	1	1	0	0	0	0	0	0	22	2	2	23	9	7	1	6	1	1	1	1	8.50	8.35	259360
0	0	0	0	1	1	0	0	0	0	0	0	24	6	9	23	3	6	1	1	1	1	1	2	8.57	8.34	262783
0	0	0	0	1	1	0	0	0	0	0	0	22	7	6	21	2	10	1	1	1	1	1	1	8.54	8.34	277332
0	0	0	0	1	1	0	0	0	0	0	0	23	2	6	16	10	7	1	4	1	2	1	2	8.48	8.34	289313
0	0	0	0	1	1	0	0	0	0	0	0	22	4	4	25	8	7	1	4	1	1	4	3	8.52	8.34	291025
0	0	0	0	1	1	0	0	0	0	0	0	22	3	8	23	9	7	1	5	1	3	4	3	8.49	8.34	300439
0	0	0	0	1	1	0	0	0	0	0	0	22	3	7	24	10	7	2	6	1	3	4	4	8.48	8.34	313276
0	0	0	0	1	1	0	0	0	0	0	0	7	2	6	23	10	15	1	3	2	2	1	1	8.46	8.34	330392
0	0	0	0	1	1	0	0	0	0	0	0	7	3	6	18	10	17	1	6	1	2	3	3	8.46	8.34	361200
0	0	0	0	1	1	0	0	0	0	0	0	22	7	6	21	10	10	1	1	1	1	1	1	8.44	8.33	407414
0	0	0	0	1	1	0	0	0	0	0	0	17	9	6	14	10	10	1	1	1	1	1	1	8.42	8.32	448492
0	0	0	0	1	1	0	0	0	0	0	0	21	10	14	14	10	9	1	1	1	1	1	1	8.41	8.32	491282
1	0	0	0	1	1	0	0	0	0	0	0	21	11	6	14	10	11	1	5	1	1	1	4	8.40	8.32	497988
1	0	0	0	1	1	0	0	0	0	0	0	21	11	7	14	10	11	1	5	1	1	1	1	8.40	8.32	501411
0	0	0	0	1	1	0	0	0	0	0	0	21	12	6	22	11	18	2	6	1	3	1	5	8.38	8.32	567448
0	0	0	0	1	1	0	0	0	0	1	0	21	12	6	22	11	17	2	6	1	3	1	5	8.35	8.31	745340
0	0	0	0	1	1	0	1	0	0	0	0	18	9	6	17	8	10	1	3	1	1	1	1	8.40	8.30	983210
0	0	0	0	1	1	0	1	0	0	0	0	22	10	6	18	9	8	1	1	1	1	1	2	8.38	8.30	1009739
0	0	0	0	1	1	0	1	0	0	0	0	18	11	5	18	10	10	1	1	1	2	1	3	8.36	8.30	1053385
0	0	0	0	1	1	0	1	0	0	0	0	16	12	6	22	10	16	1	1	3	5	1	4	8.34	8.29	1108156

0	0	0	0	1	1	0	1	0	0	0	0	3	12	20	21	16	20	1	1	2	1	3	1	8.32	8.29	1274182

Table F 31 New development high HIS 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	3.73	3.53	0
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	3.71	3.53	39390
0	0	2	1	0	0	0	0	0	0	0	0	2	26	2	3	9	30	1	3	2	4	6	3	3.71	3.52	84752
0	0	0	0	0	1	0	0	0	0	0	0	2	25	2	14	4	2	1	3	2	1	1	2	3.70	3.52	90464
0	0	0	1	0	0	0	0	0	0	0	0	4	6	13	4	9	27	1	1	1	2	1	4	3.68	3.52	119196
0	0	0	0	0	1	0	0	0	0	0	0	2	25	3	4	4	4	1	3	3	6	1	5	3.66	3.52	145235
0	0	0	1	0	1	0	0	0	0	0	0	2	25	3	4	4	4	1	3	3	6	1	5	3.63	3.50	221641
0	0	0	1	0	1	0	0	0	0	0	0	4	25	4	9	4	4	1	3	3	6	1	4	3.60	3.50	299519
0	0	0	0	1	0	0	0	0	0	0	0	30	2	2	12	2	30	1	2	6	5	1	1	3.65	3.46	386734
1	0	1	0	1	0	0	0	0	0	0	0	25	2	2	8	2	13	1	1	1	1	2	1	3.64	3.46	401379
0	1	0	0	1	0	0	0	0	0	0	0	27	2	3	12	2	29	1	3	1	2	1	1	3.59	3.47	426124
0	0	0	0	1	0	0	0	0	0	0	0	26	2	2	10	3	11	1	3	5	2	1	1	3.57	3.46	450063
0	1	0	0	1	0	0	0	0	0	0	0	25	2	2	9	3	11	1	3	5	2	1	1	3.50	3.47	489453
1	1	0	0	1	0	0	0	0	0	0	0	27	2	11	12	3	28	1	4	5	1	1	1	3.50	3.47	497785
0	0	0	0	1	0	0	0	0	0	0	0	23	2	2	13	4	11	1	2	5	1	1	1	3.49	3.45	513392
0	1	0	0	1	0	0	0	0	0	0	0	3	2	13	14	4	29	1	3	1	2	1	1	3.47	3.47	552782
0	0	0	0	1	0	0	0	0	0	0	0	24	2	2	11	5	29	1	1	1	1	2	1	3.44	3.45	576721
0	0	0	0	1	0	0	0	0	0	0	0	24	3	2	14	4	29	1	1	1	1	1	1	3.42	3.45	596405
0	0	0	1	1	0	0	0	0	0	0	0	4	3	10	8	2	29	1	1	1	4	1	1	3.52	3.44	606058
0	0	0	1	1	0	0	0	0	0	0	0	3	2	7	5	4	6	1	3	2	6	1	1	3.44	3.44	615472
0	0	0	1	1	0	0	0	0	0	0	0	2	2	2	3	5	3	1	1	1	1	1	1	3.42	3.44	648848
0	0	0	0	1	0	0	0	0	0	0	0	24	3	2	11	5	30	1	1	1	1	1	1	3.37	3.45	659734
0	0	0	1	1	0	0	0	0	0	0	0	2	3	9	3	4	15	1	1	1	1	1	1	3.40	3.43	668532
0	0	0	1	1	0	0	0	0	0	0	0	4	3	8	3	4	14	1	1	1	1	1	1	3.37	3.43	711322
0	0	0	1	1	0	0	0	0	0	0	0	5	3	12	2	4	8	1	1	5	1	1	3	3.36	3.43	728438
0	0	0	0	1	0	0	0	0	0	0	0	24	4	2	11	5	29	1	1	1	1	2	1	3.32	3.44	742746
0	0	1	0	1	0	0	0	0	0	0	0	24	4	2	11	5	30	1	1	1	1	2	1	3.32	3.44	749059
3	0	0	0	1	0	0	0	0	0	0	0	10	4	2	12	5	17	1	1	1	3	1	1	3.32	3.44	767744

0	0	0	1	1	0	0	0	0	0	0	0	2	4	9	3	5	16	1	5	1	1	2	1	3.30	3.43	814873
0	0	0	1	1	0	0	0	0	0	0	0	4	4	2	2	5	16	1	5	1	1	1	1	3.27	3.42	853384
0	0	0	1	1	0	0	0	0	0	0	0	5	4	13	3	5	16	1	1	1	5	1	1	3.26	3.42	879058
0	0	0	1	1	0	0	0	0	0	1	0	4	3	2	4	5	4	4	1	1	6	1	4	3.31	3.42	902716
0	0	0	1	1	0	0	0	0	0	1	0	5	3	20	3	5	26	1	1	1	2	1	3	3.30	3.42	919832
1	0	0	0	1	1	0	0	0	0	0	0	5	4	4	10	5	5	1	5	1	1	1	2	3.23	3.42	930546
0	0	0	1	1	1	0	0	0	0	0	0	5	3	8	2	4	6	1	1	1	5	1	1	3.28	3.41	983215
0	0	3	1	1	1	0	0	0	0	0	0	3	5	2	7	4	4	1	3	2	5	1	1	3.25	3.41	1023548
0	0	0	1	1	0	0	0	0	0	0	0	5	6	2	4	5	17	1	1	1	1	1	1	3.22	3.42	1049363
0	0	0	1	1	1	0	0	0	0	0	0	4	4	9	7	5	3	1	4	1	1	1	1	3.19	3.41	1081632
0	0	0	1	1	1	0	0	0	0	0	0	7	4	9	8	5	3	1	4	1	6	1	1	3.18	3.41	1150096
0	0	0	1	1	1	0	0	0	0	0	0	4	7	9	7	5	3	1	3	1	6	1	1	3.16	3.40	1330670
0	0	0	1	1	1	0	0	0	0	1	0	3	5	5	4	4	7	1	4	2	6	1	3	3.16	3.40	1374390
0	0	0	1	1	0	0	0	0	1	1	0	9	5	2	4	5	16	1	3	1	1	3	1	3.14	3.41	1433874
0	0	0	1	1	1	0	0	0	0	1	0	4	4	21	10	5	3	1	3	1	4	1	1	3.14	3.39	1486659
0	0	0	1	1	1	0	0	0	0	1	0	4	6	6	15	5	15	1	1	1	1	1	5	3.13	3.39	1611067
1	0	0	1	1	1	0	0	0	0	1	0	3	6	2	14	5	15	1	4	1	7	1	1	3.12	3.40	1695090
0	0	0	1	1	1	0	0	0	0	1	0	5	5	2	15	7	15	1	2	1	7	2	3	3.10	3.40	1737323
0	0	0	1	1	1	0	0	0	0	1	0	5	8	6	15	5	7	1	4	1	1	1	1	3.07	3.39	1790309
0	0	0	1	1	0	0	0	1	0	1	0	6	3	2	8	5	16	1	1	1	1	1	3	3.25	3.38	1868373
0	0	0	1	1	0	0	0	1	0	1	0	6	3	2	4	5	16	4	1	1	6	2	4	3.23	3.38	1915198
0	0	0	1	1	0	0	0	1	0	1	0	4	5	14	3	5	8	1	1	1	7	1	3	3.19	3.37	1970213
0	0	0	1	1	1	0	0	0	0	1	0	9	8	2	4	5	5	1	5	1	2	4	1	3.06	3.39	1976838
0	0	0	1	1	0	0	0	1	0	1	0	4	4	21	7	5	3	1	3	1	4	1	1	3.17	3.38	2008406
0	0	0	1	1	0	0	0	1	0	1	0	6	5	14	3	5	8	1	1	1	6	2	4	3.16	3.37	2076944
0	0	0	1	1	0	0	0	1	0	1	0	6	5	14	3	5	8	1	4	1	5	1	4	3.13	3.37	2169138
0	0	1	1	1	0	0	0	1	0	1	0	9	5	16	4	5	16	1	3	4	3	2	1	3.11	3.37	2255811
0	0	1	1	1	0	0	0	1	1	1	0	9	5	16	4	5	16	1	3	4	3	2	1	3.10	3.37	2325119
0	0	0	1	1	1	0	0	1	0	1	0	4	4	21	7	5	3	1	3	1	4	1	1	3.11	3.36	2379573
0	0	0	1	1	1	0	0	1	0	1	0	4	8	5	4	5	8	1	4	3	2	1	4	3.07	3.36	2634442
0	0	0	1	1	1	0	0	1	0	1	0	4	8	5	4	5	8	1	4	3	2	3	4	3.03	3.36	2762324
0	0	0	1	1	0	1	0	1	0	1	0	8	5	2	7	2	27	1	1	1	1	2	1	3.35	3.34	3163679
0	0	0	1	1	0	1	0	1	0	0	0	4	6	13	14	5	29	1	3	1	7	2	1	3.17	3.34	3193326
0	0	0	1	1	1	0	0	1	0	1	0	9	8	2	4	5	30	1	5	1	2	4	1	3.02	3.36	3396069

0	0	0	1	1	1	1	0	1	0	1	0	4	4	6	15	5	7	1	1	3	1	1	5	3.13	3.32	3403297
0	0	0	1	1	0	1	0	1	0	1	0	10	5	14	10	5	27	1	2	1	7	3	1	3.12	3.33	3525280
0	0	0	1	1	0	1	0	1	0	1	0	10	5	14	10	5	30	1	3	1	7	3	1	3.10	3.33	3577325
1	0	0	1	1	1	1	0	0	0	1	0	5	8	28	15	5	29	1	2	7	7	2	1	3.06	3.34	3728414
0	0	0	1	1	1	1	0	1	0	1	0	5	8	6	9	5	5	5	2	1	6	1	4	3.07	3.31	3742035
0	0	0	1	1	1	1	0	1	0	1	0	5	8	6	15	5	8	1	4	1	7	1	5	3.04	3.32	3933416
0	0	0	1	1	1	1	0	1	0	1	0	5	8	6	15	5	8	1	2	4	7	5	5	3.04	3.32	4085090
0	0	0	1	1	1	1	0	1	0	1	0	10	5	14	12	5	30	1	3	1	7	4	1	3.02	3.31	4479699
0	0	0	1	1	1	1	0	1	0	1	0	5	23	13	9	5	30	1	2	1	7	2	1	3.05	3.29	5660494
1	0	0	1	1	1	1	0	1	0	1	0	5	23	13	9	5	30	1	4	1	1	2	1	3.03	3.30	5772917
0	0	0	1	0	1	0	1	0	0	0	0	2	26	2	7	3	2	1	3	2	1	1	1	3.45	3.28	5888683
0	0	0	1	0	1	0	1	0	0	0	0	2	25	2	14	4	3	1	3	2	1	1	1	3.44	3.28	5939175
0	0	0	1	0	1	0	1	0	0	0	0	2	25	6	14	4	3	1	3	2	5	1	1	3.41	3.27	5993946
0	0	1	1	0	1	0	1	0	0	0	0	5	6	6	7	5	5	1	2	1	5	1	1	3.38	3.27	6075569
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0	0	0	1	0	1	0	1	0	0	0	0	5	6	7	8	3	6	1	3	1	6	1	1	3.36	3.27	6107768
1	0	1	0	1	0	0	1	0	0	0	0	9	2	24	8	2	14	1	1	1	1	2	1	3.38	3.24	6110355
1	1	1	0	1	0	0	1	0	0	0	0	9	2	24	8	2	14	1	1	1	1	2	1	3.36	3.26	6149745
0	0	0	0	1	0	0	1	0	0	0	0	6	2	2	23	3	10	1	2	2	1	2	1	3.31	3.24	6159039
0	0	0	0	1	0	0	1	0	0	0	0	6	2	2	9	4	30	1	4	6	1	1	1	3.28	3.24	6222368
0	0	0	0	1	0	0	1	0	0	0	0	6	3	2	24	3	9	1	2	2	1	2	1	3.26	3.24	6242051
1	0	0	0	1	0	0	1	0	0	0	0	6	3	2	24	3	9	1	2	1	1	2	2	3.26	3.24	6250384
0	0	0	0	1	0	0	1	0	0	0	0	9	3	2	9	4	30	1	5	6	1	1	1	3.22	3.24	6305381
1	0	0	0	1	0	0	1	0	0	0	0	4	3	2	12	4	5	1	5	1	1	1	2	3.22	3.24	6313713
0	0	0	0	1	0	0	1	0	0	0	0	5	4	9	10	4	7	1	5	1	2	3	1	3.20	3.24	6388393
0	0	0	1	1	0	0	1	0	0	0	0	4	3	12	6	4	29	1	1	2	5	1	1	3.17	3.22	6433135
0	0	0	1	1	0	0	1	0	0	0	0	5	3	12	6	4	30	1	1	5	1	1	4	3.16	3.22	6454530
0	0	0	0	1	1	0	1	0	0	0	0	5	4	3	9	3	5	1	4	1	1	1	1	3.16	3.22	6490838
0	0	0	0	1	1	0	1	0	0	0	0	5	4	2	6	4	4	1	2	1	1	1	1	3.14	3.22	6519936
0	0	0	0	1	1	0	1	0	0	0	0	5	4	2	12	4	5	1	3	1	1	1	1	3.13	3.22	6540475
1	0	0	0	1	1	0	1	0	0	0	0	5	4	2	12	4	5	1	5	1	1	1	2	3.13	3.22	6548807
1	0	0	0	1	1	0	1	0	0	0	0	5	4	4	10	4	5	1	5	1	1	1	2	3.11	3.22	6576193
0	0	0	1	1	1	0	1	0	0	0	0	5	3	8	7	4	6	1	5	1	6	1	1	3.07	3.20	6713586
0	0	0	1	1	1	0	1	0	0	0	0	5	5	15	2	4	6	7	3	1	6	2	1	3.05	3.20	6954066

0	0	0	1	1	1	0	1	0	0	0	0	5	5	5	15	4	20	1	3	1	3	2	1	3.04	3.20	7160314
0	0	0	1	1	1	0	1	0	0	1	0	5	7	8	9	4	6	7	1	1	6	2	1	3.01	3.21	7241922
0	0	0	1	1	1	0	1	0	0	1	0	5	7	5	9	4	6	7	3	1	6	2	1	2.98	3.21	7304933
0	0	0	1	1	1	0	1	0	0	0	0	5	5	18	15	4	22	1	3	1	3	2	1	3.03	3.20	7379399
0	0	2	1	1	1	0	1	1	0	0	0	3	4	2	6	3	3	1	3	1	4	1	1	3.12	3.18	7460802
0	0	2	1	1	1	0	1	1	0	0	0	4	5	2	7	4	3	1	3	2	5	1	1	3.06	3.17	7632818
0	0	1	1	1	1	0	1	1	0	0	0	4	5	15	7	5	4	1	6	2	4	1	1	3.04	3.17	7888380
0	0	0	1	1	1	1	1	0	0	0	0	5	5	2	6	4	4	1	3	1	1	3	1	3.05	3.16	7968914
0	0	0	1	1	1	0	1	0	0	1	0	4	7	28	5	5	30	4	1	1	1	1	2	3.02	3.20	7969596
0	0	0	1	1	1	0	1	1	0	1	0	7	3	21	8	5	5	1	3	1	4	1	1	2.99	3.17	8115079
0	0	0	1	1	1	0	1	0	0	1	0	5	8	28	15	5	30	1	2	1	1	2	1	2.97	3.20	8232779
0	0	0	1	1	1	0	1	0	0	1	0	5	8	28	15	5	30	1	4	1	1	2	1	2.96	3.20	8336869
0	0	0	1	1	1	1	1	0	0	0	0	5	7	15	2	4	6	7	3	1	6	2	1	3.04	3.16	8336908
0	0	0	1	1	1	1	1	0	0	1	0	5	7	8	2	4	6	7	3	1	6	2	1	2.97	3.16	8532876
0	0	0	0	1	1	1	1	1	0	0	0	7	4	2	7	4	3	6	2	1	1	1	1	3.09	3.14	8621964
0	0	0	0	1	1	1	1	1	0	0	0	5	4	3	15	5	4	1	4	2	6	1	1	3.07	3.14	8719526
0	0	0	1	1	1	1	1	1	0	0	0	2	4	2	7	5	4	1	6	2	1	1	1	3.05	3.13	8795076
0	0	0	1	1	1	1	1	1	0	0	0	7	4	2	7	4	3	6	2	1	1	1	1	3.04	3.12	8818182
3	0	0	1	1	1	1	1	0	0	0	0	5	8	5	15	5	28	1	4	2	3	1	1	3.02	3.16	8878809
1	0	0	1	1	1	1	1	0	0	1	0	5	7	17	15	5	13	1	4	1	7	2	1	2.96	3.17	8979219
0	0	2	1	1	1	1	1	1	0	0	0	5	5	11	7	5	4	1	6	2	6	1	1	3.02	3.13	9078134
1	0	0	1	1	1	1	1	0	0	1	0	5	8	28	16	5	29	1	1	1	7	1	1	3.00	3.16	9325683
0	0	0	1	1	1	1	1	1	0	1	0	5	3	16	9	5	5	1	3	1	4	3	1	2.97	3.13	9352803
1	0	0	1	1	1	1	1	0	0	1	0	5	8	28	15	5	29	1	2	1	7	2	1	2.96	3.16	9437390
1	0	0	1	1	1	1	1	1	0	1	0	5	5	21	9	5	5	3	4	1	7	5	1	2.94	3.13	9775551
0	0	0	1	1	1	1	1	0	0	0	0	5	28	2	9	4	4	1	3	1	1	1	1	3.07	3.12	9891041
3	0	0	1	1	1	1	1	1	0	0	0	26	7	6	13	4	30	1	3	1	7	1	1	3.02	3.12	10133726
0	0	0	1	1	1	1	1	1	0	1	0	10	5	14	12	5	30	1	3	1	7	4	1	2.94	3.13	10188675
2	0	2	1	1	1	1	1	1	0	1	0	5	19	13	10	5	3	1	2	1	7	1	1	3.00	3.12	10452489
0	0	3	1	1	1	1	1	1	0	0	0	4	22	5	7	4	28	1	4	2	4	1	1	3.03	3.10	10821720
0	0	0	1	1	1	1	1	1	0	0	0	7	22	6	7	4	28	6	4	1	1	1	1	3.01	3.10	10880660
0	0	0	1	1	1	1	1	1	0	1	0	5	23	21	9	5	4	1	3	1	7	1	1	2.97	3.10	10933097
0	0	0	1	1	1	1	1	1	0	1	0	5	23	21	9	5	4	1	3	1	7	3	1	2.95	3.10	11060979
0	0	0	1	1	1	1	1	1	0	1	0	5	23	13	9	5	30	1	2	1	7	2	1	2.95	3.10	11369470

0	0	0	1	1	1	1	1	1	0	1	0	5	23	4	8	5	26	1	6	1	2	3	1	2.94	3.10	11431920
0	0	0	1	1	1	1	1	1	0	1	0	5	23	21	8	5	26	1	6	1	2	3	1	2.94	3.10	11664698
0	0	0	1	1	1	1	1	1	0	1	0	5	29	21	8	5	26	1	6	1	2	3	1	2.94	3.08	12162773

Table F 32 New development high HIS 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.99	4.78	0
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	4.96	4.78	39390
1	1	0	0	0	0	0	0	0	0	0	0	13	29	3	25	27	10	6	1	3	2	3	4	4.96	4.77	47723
0	0	0	0	0	1	0	0	0	0	0	0	6	16	4	8	4	2	1	5	5	1	3	1	4.93	4.76	117850
0	0	0	0	0	1	0	0	0	0	0	0	6	16	3	8	4	4	2	4	5	1	3	1	4.91	4.76	145235
0	0	0	0	0	1	0	0	0	0	0	0	28	5	4	8	5	4	3	6	4	1	4	2	4.90	4.76	158928
0	0	0	0	0	1	0	0	0	0	0	0	14	3	6	11	5	6	1	1	3	1	1	5	4.88	4.75	227392
0	0	0	1	0	1	0	0	0	0	0	0	4	7	4	5	2	2	1	4	4	2	1	1	4.88	4.74	241325
0	0	0	1	0	1	0	0	0	0	0	0	5	19	4	6	3	2	4	2	4	1	1	4	4.87	4.74	266999
0	0	0	1	0	1	0	0	0	0	0	0	5	16	4	8	2	3	4	5	1	1	1	6	4.85	4.74	296096
0	0	0	1	0	1	0	0	0	0	0	0	6	20	2	6	4	5	1	7	5	1	3	2	4.83	4.74	322626
0	0	0	1	0	1	0	0	0	0	0	0	6	16	4	8	8	5	1	5	1	1	4	2	4.81	4.73	358569
0	0	0	0	1	0	0	0	0	0	0	0	21	2	24	17	2	6	6	6	1	1	3	1	4.95	4.70	386734
1	0	1	0	1	0	0	0	0	0	0	0	27	2	15	17	2	29	3	4	6	5	3	1	4.94	4.70	401379
0	1	0	0	1	0	0	0	0	0	0	0	6	2	15	20	2	30	2	3	1	3	1	1	4.90	4.71	426124
0	0	0	1	0	1	0	0	0	0	0	0	7	6	9	8	4	5	1	3	5	1	2	1	4.80	4.73	448428
0	0	0	0	1	0	0	0	0	0	0	0	16	2	21	26	3	22	6	4	6	1	2	6	4.89	4.69	450063
0	1	0	0	1	0	0	0	0	0	0	0	6	2	15	20	3	30	2	1	1	4	1	1	4.81	4.70	489453
0	0	0	0	1	0	0	0	0	0	0	0	17	2	20	24	4	22	7	5	7	1	2	7	4.81	4.69	513392
0	0	0	1	1	0	0	0	0	0	0	0	2	2	21	2	3	13	4	6	3	1	2	5	4.88	4.68	517911
0	1	0	0	1	0	0	0	0	0	0	0	17	2	20	24	4	22	7	5	7	1	2	7	4.74	4.70	552782
0	0	0	1	1	0	0	0	0	0	0	0	6	2	19	5	2	6	2	4	4	1	1	2	4.87	4.68	552999
1	1	0	0	1	0	0	0	0	0	0	0	4	2	15	19	4	30	1	1	1	4	1	1	4.74	4.70	561115
0	0	0	1	1	0	0	0	0	0	0	0	2	2	30	2	4	30	7	3	4	1	1	7	4.80	4.67	581240
1	0	0	0	1	0	0	0	0	0	0	0	22	2	20	21	5	20	5	2	4	1	1	2	4.72	4.68	585054
0	0	0	0	1	0	0	0	0	0	0	0	28	3	19	24	4	22	7	5	7	1	2	6	4.76	4.68	596405

1	1	0	0	1	0	0	0	0	0	0	0	27	2	19	18	5	19	6	4	5	1	1	3	4.70	4.70	624444
0	0	0	0	1	0	0	0	0	0	0	0	12	2	10	20	6	17	2	1	4	2	1	1	4.67	4.68	640050
0	0	0	1	1	0	0	0	0	0	0	0	2	2	30	2	5	30	7	7	1	1	1	7	4.72	4.67	644569
1	0	1	0	1	0	0	0	0	0	0	0	23	2	21	22	6	20	5	2	4	2	2	2	4.66	4.68	654695
0	0	0	0	1	0	0	0	0	0	0	0	28	3	19	24	5	22	7	5	7	1	2	4	4.68	4.67	659734
1	0	0	0	1	0	0	0	0	0	0	0	22	3	24	7	5	2	4	7	4	3	1	2	4.68	4.67	668066
0	0	0	0	1	0	0	0	0	0	0	0	21	3	17	22	6	10	3	6	4	5	1	1	4.63	4.67	723063
0	0	0	1	1	0	0	0	0	0	0	0	2	3	30	2	5	30	6	7	3	4	1	7	4.68	4.66	727582
1	0	0	0	1	0	0	0	0	0	0	0	22	3	25	3	6	3	3	5	3	3	4	4	4.61	4.67	731396
1	0	0	0	1	0	0	0	0	0	0	0	22	3	24	3	7	2	3	7	3	3	4	4	4.60	4.67	794725
0	0	0	0	1	0	0	0	0	0	0	0	27	4	2	6	6	3	1	4	1	2	1	2	4.57	4.67	806076
0	0	0	0	1	1	0	0	0	0	0	0	6	2	8	9	5	5	1	1	3	7	1	3	4.63	4.66	810960
0	0	0	0	1	1	0	0	0	0	0	0	28	3	2	12	6	3	1	6	1	1	1	6	4.58	4.65	834066
0	0	2	0	1	1	0	0	0	0	0	0	28	3	2	12	6	3	1	6	1	1	1	5	4.58	4.65	846691
0	0	0	0	1	0	0	0	0	0	0	0	7	4	18	17	7	18	7	5	1	1	1	1	4.55	4.66	869405
0	0	0	0	1	0	0	0	0	0	0	0	28	5	2	6	6	2	1	5	1	3	1	2	4.53	4.66	889088
0	0	0	1	1	1	0	0	0	0	0	0	5	4	8	7	2	3	1	5	1	1	4	2	4.70	4.64	899347
1	0	1	0	1	0	0	0	0	0	0	0	23	5	2	5	6	3	1	5	4	1	2	2	4.52	4.66	903733
1	0	2	0	1	0	0	0	0	0	0	0	5	5	2	5	6	3	2	5	1	1	2	6	4.52	4.66	910046
0	0	0	1	1	1	0	0	0	0	0	0	7	2	8	4	4	5	1	5	5	5	4	2	4.64	4.64	931011
1	0	0	0	1	0	0	0	0	0	0	0	22	5	24	3	7	2	3	7	3	3	4	4	4.50	4.66	960750
0	0	0	0	1	1	0	0	0	0	0	0	28	5	4	8	5	4	3	6	4	1	4	2	4.51	4.64	984687
0	0	0	0	1	1	0	0	0	0	0	0	14	5	6	11	5	4	1	5	3	1	1	4	4.49	4.64	1012073
0	0	0	0	1	1	0	0	0	0	0	0	28	5	2	6	6	4	2	4	1	2	1	5	4.47	4.64	1020631
0	0	0	0	1	1	0	0	0	0	0	0	28	5	6	5	6	2	1	4	3	2	1	1	4.47	4.64	1034323
0	0	0	0	1	1	0	0	0	0	0	0	28	5	6	5	6	4	1	5	2	2	1	1	4.44	4.64	1075402
0	0	0	0	1	1	0	0	0	0	0	0	28	5	8	21	6	5	1	4	1	1	1	5	4.42	4.64	1123327
0	0	0	0	1	1	0	0	0	0	0	0	28	5	7	20	7	5	1	4	2	1	1	5	4.40	4.63	1172963
0	0	0	1	1	1	0	0	0	0	0	0	6	7	4	9	4	2	1	5	5	1	4	3	4.50	4.62	1229686
0	0	0	1	1	1	0	0	0	0	0	0	6	7	5	9	4	2	1	5	5	1	4	3	4.50	4.62	1243378
0	0	0	0	1	1	0	0	0	0	0	0	27	6	8	21	7	4	1	4	3	1	3	4	4.37	4.63	1249129
0	0	0	1	1	1	0	0	0	0	0	0	6	6	9	8	4	4	1	5	3	1	4	5	4.47	4.62	1251936
0	0	0	1	1	1	0	0	0	0	0	0	8	6	9	8	4	4	1	5	3	1	4	5	4.46	4.61	1294726
0	0	0	0	1	1	0	0	0	0	0	0	28	6	6	5	8	6	4	5	1	1	2	5	4.36	4.63	1326151

0	0	0	1	1	1	0	0	0	0	0	0	9	6	8	5	6	4	1	3	5	1	4	2	4.32	4.61	1416250
0	0	2	1	1	1	0	0	0	0	0	0	7	6	9	9	7	4	1	5	1	1	4	2	4.32	4.62	1480223
0	0	0	1	1	1	0	0	0	0	0	0	7	6	8	9	10	4	4	4	1	3	4	3	4.30	4.61	1643893
0	0	0	1	1	1	0	0	0	0	0	0	6	7	5	10	8	15	1	4	3	3	4	1	4.27	4.61	1767984
0	0	0	1	1	1	0	0	0	0	0	0	6	7	12	10	8	15	1	4	3	3	4	1	4.26	4.61	1863833
0	0	0	0	1	1	1	0	0	0	0	0	21	4	4	3	3	6	1	2	1	1	1	1	4.67	4.60	2032911
0	0	0	0	1	1	1	0	0	0	0	0	21	4	4	3	3	9	1	2	1	1	1	1	4.66	4.60	2094529
0	0	0	0	1	1	1	0	0	0	0	0	3	5	3	24	4	3	1	4	1	1	5	1	4.58	4.59	2103943
0	0	0	0	1	1	1	0	0	0	0	0	28	3	10	21	5	4	3	6	4	1	4	5	4.56	4.60	2117636
0	0	0	1	1	0	1	0	0	0	0	0	5	4	22	9	5	5	1	5	2	1	4	5	4.54	4.60	2121549
0	0	0	0	1	1	1	0	0	0	0	0	28	4	2	4	6	3	3	3	3	1	1	6	4.50	4.59	2133896
0	0	0	0	1	1	1	0	0	0	0	0	28	5	7	21	5	4	3	6	4	1	4	5	4.46	4.58	2242582
0	0	0	0	1	1	0	0	0	0	1	0	28	10	3	25	8	17	3	4	5	1	3	6	4.23	4.61	2250857
0	0	0	1	1	1	1	0	0	0	0	0	5	4	2	9	5	5	1	5	2	1	6	5	4.47	4.58	2273631
0	0	0	0	1	1	1	0	0	0	0	0	28	5	10	21	5	4	3	6	4	1	4	5	4.46	4.58	2283661
0	0	0	0	1	1	1	0	0	0	0	0	29	4	8	5	7	4	3	4	3	1	1	5	4.42	4.59	2299921
0	0	0	0	1	1	1	0	0	0	0	0	28	5	3	5	7	4	3	4	3	1	1	5	4.40	4.58	2314470
0	0	0	0	1	1	1	0	0	0	0	0	28	5	6	5	7	4	3	4	3	1	1	5	4.38	4.58	2355548
0	0	0	0	1	1	1	0	0	0	0	0	2	6	3	22	7	5	5	4	2	1	1	5	4.35	4.58	2418021
0	0	0	1	1	1	1	0	0	0	0	0	5	4	22	9	5	5	1	5	2	1	6	5	4.43	4.57	2547487
0	0	0	0	1	1	1	0	0	0	0	0	21	8	4	3	5	9	1	4	2	1	1	1	4.39	4.58	2553238
0	0	0	0	1	1	1	0	0	0	0	0	28	6	10	22	8	5	5	4	1	1	1	5	4.33	4.58	2577200
0	0	0	0	1	1	0	0	0	0	1	0	28	10	3	22	8	27	4	4	5	1	6	6	4.21	4.62	2648072
0	0	0	0	1	1	1	0	0	0	0	0	19	8	3	3	9	8	1	2	3	1	1	4	4.31	4.58	2772323
0	0	0	0	1	1	0	0	0	0	1	0	28	10	27	22	8	27	4	4	5	1	3	6	4.20	4.61	2784877
0	0	0	0	1	1	1	0	0	0	0	0	28	10	7	11	8	9	3	3	5	1	2	6	4.29	4.58	2950329
0	0	0	0	1	1	1	0	0	0	1	0	22	8	15	2	7	18	7	2	2	1	1	4	4.27	4.56	3191201
3	0	4	0	1	1	0	0	1	0	1	0	23	8	15	2	7	18	7	5	2	2	4	7	4.20	4.58	3278340
0	0	0	1	1	1	0	0	0	0	1	0	28	10	27	22	8	27	4	4	5	1	3	6	4.14	4.59	3494575
0	0	0	1	1	1	1	0	0	0	0	0	28	10	7	11	8	9	3	3	5	1	2	6	4.24	4.56	3612958
0	0	0	0	1	1	1	0	0	0	1	0	27	10	18	22	6	27	4	4	5	1	1	6	4.24	4.56	3623918
0	0	0	0	1	1	1	0	0	0	1	0	10	10	19	22	8	5	4	4	5	1	6	6	4.20	4.56	3632112
0	0	0	0	1	1	1	0	0	0	1	0	28	10	10	22	8	27	4	4	5	1	3	6	4.17	4.56	3768916
0	0	0	0	1	1	1	0	0	0	1	0	28	10	27	22	8	27	4	4	5	1	6	6	4.16	4.56	4193517

3	0	4	0	1	1	1	0	1	0	1	0	23	8	15	2	7	18	7	2	2	2	4	7	4.24	4.53	4339022
3	0	4	0	1	1	1	0	1	0	1	0	23	8	15	2	7	14	7	5	2	2	4	7	4.18	4.53	4413001
3	0	4	0	1	1	1	0	1	0	1	0	23	8	15	2	7	18	7	5	2	2	4	7	4.18	4.53	4495157
1	0	0	0	0	1	0	1	0	0	0	0	19	22	2	5	4	2	3	5	1	3	1	5	4.68	4.52	5807773
0	0	0	0	0	1	0	1	0	0	0	0	16	22	3	13	3	2	4	7	7	1	1	1	4.67	4.52	5813133
0	0	0	0	0	1	0	1	0	0	0	0	6	16	4	11	4	2	1	5	5	1	4	2	4.66	4.52	5826826
1	0	0	0	0	1	0	1	0	0	0	0	19	22	2	5	5	5	2	1	2	2	1	5	4.63	4.52	5869390
0	0	0	0	0	1	0	1	0	0	0	0	27	4	7	12	5	5	1	6	3	1	1	5	4.61	4.51	5929522
0	0	0	1	0	1	0	1	0	0	0	0	6	20	2	6	4	2	1	7	5	1	3	1	4.61	4.50	5969984
2	0	0	0	0	1	0	1	0	0	0	0	14	5	8	12	5	6	2	1	5	1	6	5	4.60	4.51	5980419
0	0	0	1	0	1	0	1	0	0	0	0	6	16	4	8	4	2	1	5	5	1	4	2	4.59	4.49	6005928
0	0	0	1	0	1	0	1	0	0	0	0	6	20	2	6	4	5	1	7	5	1	3	1	4.57	4.49	6031602
0	0	0	1	0	1	0	1	0	0	0	0	6	16	4	8	8	5	1	5	1	1	4	2	4.55	4.49	6067545
0	0	0	0	1	0	0	1	0	0	0	0	22	2	24	17	2	19	5	1	3	1	2	1	4.64	4.47	6095710
1	0	0	0	1	0	0	1	0	0	0	0	6	2	22	8	2	5	3	5	1	1	2	6	4.63	4.47	6104042
0	0	0	1	0	1	0	1	0	0	0	0	6	4	7	9	5	5	1	4	2	1	1	5	4.54	4.49	6112903
0	0	0	0	1	0	0	1	0	0	0	0	23	2	21	17	3	19	5	1	3	2	2	1	4.58	4.46	6159039
0	0	0	0	1	0	0	1	0	0	0	0	6	2	22	8	4	2	1	5	4	1	3	6	4.50	4.46	6222368
1	0	0	0	1	0	0	1	0	0	0	0	6	2	21	7	4	2	1	5	4	1	2	6	4.50	4.46	6230701
0	0	0	0	1	0	0	1	0	0	0	0	21	3	24	23	3	20	5	5	6	1	2	4	4.52	4.46	6242051
0	0	0	0	1	0	0	1	0	0	0	0	22	2	14	22	5	29	5	1	3	2	2	2	4.46	4.46	6285697
0	0	1	0	1	0	0	1	0	0	0	0	7	2	20	6	5	6	3	3	4	1	1	5	4.46	4.46	6292010
2	0	0	0	1	0	0	1	0	0	0	0	22	2	14	22	5	29	5	1	3	2	2	2	4.46	4.46	6302362
0	0	0	0	1	0	0	1	0	0	0	0	28	3	21	23	5	20	5	5	6	1	2	4	4.41	4.45	6368710
0	0	0	0	1	1	0	1	0	0	0	0	7	3	6	12	3	2	1	1	3	1	1	5	4.47	4.44	6387287
0	0	0	1	1	0	0	1	0	0	0	0	7	2	20	6	4	28	1	2	4	3	1	2	4.42	4.44	6414307
0	0	0	0	1	0	0	1	0	0	0	0	21	3	24	23	6	20	5	5	6	1	2	4	4.40	4.46	6432039
0	0	0	0	1	0	0	1	0	0	0	0	7	4	9	8	5	6	1	3	4	5	1	2	4.37	4.45	6451722
0	0	0	1	1	0	0	1	0	0	0	0	7	2	20	6	5	6	3	3	4	1	1	2	4.38	4.44	6477636
0	0	1	1	1	0	0	1	0	0	0	0	7	2	20	6	5	6	3	3	4	1	1	5	4.38	4.44	6483949
0	0	0	0	1	1	0	1	0	0	0	0	27	2	9	12	5	5	1	6	4	1	1	4	4.36	4.44	6533628
0	0	1	0	1	0	0	1	0	0	0	0	7	5	2	6	5	5	3	3	4	1	1	2	4.34	4.45	6541048
0	0	0	1	1	0	0	1	0	0	0	0	6	4	2	5	4	29	1	6	4	1	4	2	4.34	4.43	6554658
0	0	0	0	1	1	0	1	0	0	0	0	14	3	6	12	5	6	1	1	3	1	1	5	4.30	4.43	6596102

0	0	0	1	1	1	0	1	0	0	0	0	7	2	9	7	4	3	1	6	5	1	4	2	4.35	4.42	6625439
0	0	0	0	1	1	0	1	0	0	0	0	6	4	7	12	5	3	1	6	3	1	1	5	4.30	4.43	6631190
0	0	0	1	1	1	0	1	0	0	0	0	6	4	2	5	4	2	1	6	4	1	4	1	4.32	4.41	6645122
0	0	0	0	1	1	0	1	0	0	0	0	27	4	6	12	5	5	1	6	2	1	1	5	4.27	4.43	6658575
0	0	0	0	1	1	0	1	0	0	0	1	27	4	7	12	5	6	1	4	3	1	1	1	4.26	4.42	6731976
0	0	0	1	1	1	0	1	0	0	0	0	7	5	2	6	4	3	1	6	5	1	4	2	4.27	4.41	6774348
0	0	0	0	1	1	0	1	0	0	0	0	14	5	8	12	5	6	2	1	4	1	6	6	4.24	4.42	6789513
0	0	0	1	1	1	0	1	0	0	0	0	6	4	7	9	5	5	1	4	2	1	1	5	4.21	4.40	6855649
0	0	0	1	1	1	0	1	0	0	0	0	7	6	9	9	4	5	1	5	5	1	4	2	4.20	4.40	7007126
0	0	3	1	1	1	0	1	0	0	0	0	7	6	9	9	7	4	1	5	1	1	4	2	4.18	4.41	7195512
0	0	0	1	1	1	0	1	0	0	0	1	7	7	9	10	4	15	1	5	3	1	4	2	4.18	4.40	7347900
0	0	0	1	1	1	0	1	0	0	0	0	7	6	8	9	10	4	4	4	1	1	4	3	4.16	4.41	7352869
0	0	0	1	1	1	0	1	0	0	0	0	8	5	22	9	5	19	1	5	2	1	3	5	4.14	4.40	7474392
0	0	0	1	1	1	0	1	0	0	0	0	9	5	29	9	5	19	1	5	2	1	6	4	4.14	4.40	7591637
0	0	0	0	1	1	1	1	0	0	0	0	3	5	3	24	4	3	1	4	1	1	5	1	4.30	4.38	7812919
0	0	0	1	1	0	1	1	0	0	0	1	7	7	9	10	4	15	1	5	3	1	4	2	4.27	4.38	8111394
0	0	0	0	1	1	1	1	0	0	0	0	28	5	6	5	9	4	3	4	3	1	1	5	4.21	4.38	8191182
0	0	0	0	1	1	1	1	0	0	0	0	28	5	6	6	9	18	3	4	3	1	1	5	4.18	4.38	8478731
0	0	0	1	1	1	1	1	0	0	0	1	7	7	9	10	4	15	1	5	3	1	4	2	4.16	4.35	8564717
0	0	0	1	1	1	1	1	0	0	0	0	9	5	21	9	5	19	1	5	1	1	6	1	4.14	4.35	8698912
0	0	0	1	1	1	1	1	0	0	0	1	4	25	11	3	6	5	1	1	1	1	5	1	4.15	4.33	9885205
0	0	0	1	1	1	1	1	0	0	0	0	7	22	9	21	7	15	1	5	3	1	4	2	4.11	4.35	9998872
0	0	0	1	1	1	1	1	0	0	0	1	4	25	11	24	6	21	1	5	1	1	5	1	4.13	4.34	10303691

Table F 33 New development high HIS 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	6.88	6.41	0
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	6.85	6.41	39390
0	0	0	1	0	0	0	0	0	0	0	0	2	25	2	2	5	2	1	1	3	1	1	5	6.88	6.40	67848
0	0	0	1	0	0	0	0	0	0	0	0	2	23	3	6	3	6	1	2	3	1	1	5	6.86	6.40	84964
1	1	1	0	0	0	0	0	0	0	0	1	2	11	12	11	8	18	1	5	3	5	1	1	6.84	6.41	93204
0	0	1	0	0	1	0	0	0	0	0	0	23	4	2	2	8	3	3	1	7	4	3	7	6.83	6.40	117316

1	0	1	0	0	1	0	0	0	0	0	0	23	3	2	2	10	3	3	2	4	4	3	3	6.82	6.39	125648
0	0	0	0	0	1	0	0	0	0	0	0	6	4	2	3	7	5	1	1	1	7	3	3	6.79	6.39	152082
0	0	0	1	0	1	0	0	0	0	0	0	2	27	2	2	5	2	1	1	4	1	1	5	6.87	6.38	158312
0	1	1	0	0	1	0	0	0	0	0	0	20	3	2	2	8	4	2	1	7	4	2	6	6.78	6.39	177245
0	0	0	1	0	1	0	0	0	0	0	0	2	25	2	2	6	3	1	1	4	1	1	4	6.84	6.38	178851
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0	0	0	0	1	1	0	1	0	0	0	0	3	3	2	23	5	5	1	1	3	2	4	3	6.13	6.03	6520791
0	0	0	0	1	1	0	1	0	0	0	0	5	2	4	6	7	4	1	1	3	1	2	1	6.08	6.04	6571284
0	0	0	0	1	0	0	1	0	0	0	0	2	4	2	14	7	2	1	3	5	1	1	4	6.07	6.05	6578381
0	0	0	0	1	1	0	1	0	0	0	0	2	2	5	6	7	4	1	1	3	1	2	1	6.07	6.04	6584976
0	0	0	0	1	0	0	1	0	0	0	0	4	5	5	16	6	5	1	4	3	1	2	1	6.06	6.05	6598064
0	0	0	0	1	0	0	1	0	0	0	0	4	5	5	14	7	5	1	4	3	1	4	1	6.03	6.05	6661393
1	0	0	0	1	0	0	1	0	0	0	0	4	5	5	14	7	5	1	4	3	1	2	1	6.02	6.05	6669726
0	0	0	0	1	1	0	1	0	0	0	0	2	5	3	23	5	4	1	1	1	2	4	3	6.06	6.02	6679970
0	0	0	0	1	1	0	1	0	0	0	0	3	5	6	22	5	3	1	1	1	2	4	3	6.05	6.02	6700509
0	0	0	0	1	1	0	1	0	0	0	0	3	3	12	23	6	5	1	1	1	2	4	3	6.02	6.02	6721049
0	0	0	0	1	1	0	1	0	0	0	0	2	5	6	23	5	4	1	1	1	2	4	3	6.03	6.02	6721049
0	0	0	0	1	0	0	1	0	0	0	0	2	7	22	22	6	23	1	1	3	1	4	1	6.00	6.04	6764089
0	0	3	0	1	0	0	1	0	0	0	0	2	7	22	22	6	23	1	1	3	1	4	1	6.00	6.04	6783027
0	0	0	0	1	1	0	1	0	0	0	0	2	5	12	23	5	4	1	1	1	2	4	3	6.01	6.02	6803205
0	0	0	0	1	0	0	1	0	0	0	0	14	7	25	27	7	2	4	4	1	4	1	1	5.97	6.04	6827419
1	0	0	0	1	1	0	1	0	0	0	0	5	3	11	2	8	5	1	1	3	7	5	2	5.97	6.02	6842347
0	0	0	0	1	1	0	1	0	0	0	0	2	4	7	2	8	5	1	1	1	2	4	4	5.94	6.02	6862256
0	0	0	0	1	1	0	1	0	0	0	0	2	5	7	21	8	5	1	1	1	2	4	3	5.90	6.01	6945268
1	0	0	1	1	1	0	1	0	0	0	0	6	4	11	2	8	5	1	1	3	7	4	4	5.87	6.00	7078787
0	0	0	1	1	0	0	1	0	0	0	0	9	8	3	22	7	25	1	2	3	1	1	1	5.86	6.01	7213624
0	0	0	0	1	1	0	1	0	0	0	0	26	7	27	17	6	10	1	3	5	1	1	1	5.83	6.00	7361187
0	0	0	0	1	1	0	1	0	0	0	0	12	8	27	14	6	10	1	1	5	1	1	1	5.82	6.00	7444200
0	0	0	0	1	1	0	1	0	0	0	0	10	12	6	10	7	14	1	2	4	2	3	1	5.79	6.01	7634187
1	0	0	0	1	1	0	1	0	0	0	0	25	9	17	13	12	6	1	1	1	6	1	4	5.78	6.01	7696435
0	0	0	0	1	1	1	1	0	0	0	0	3	3	2	23	5	5	1	1	3	2	4	3	6.09	5.98	7737608
0	0	0	1	1	1	0	1	0	0	0	0	9	12	7	2	9	2	1	4	3	1	1	1	5.79	5.99	7745681
0	0	0	1	1	1	0	1	0	0	0	0	11	9	22	7	5	14	1	3	4	2	1	1	5.75	5.97	7759374
0	0	0	1	1	1	0	1	0	0	0	0	11	9	22	11	7	14	1	3	4	2	1	1	5.66	5.97	7903148
0	0	0	1	1	1	0	1	0	0	0	0	11	11	15	16	9	19	1	3	6	1	3	1	5.63	5.98	8224073
0	0	0	0	1	1	1	1	0	0	0	0	12	8	6	21	6	10	1	1	5	1	1	1	5.78	5.95	8373468
0	0	0	0	1	1	1	1	0	0	0	0	12	8	27	14	6	10	1	1	5	1	1	1	5.76	5.95	8661017

0	0	0	1	1	1	0	1	1	0	0	0	11	12	22	10	6	2	1	3	1	1	1	1	5.73	5.95	8743858
0	0	0	1	1	1	0	1	1	0	0	0	7	12	3	27	7	14	5	3	4	2	2	1	5.68	5.95	8780658
0	0	0	1	1	1	0	1	0	0	0	0	11	9	22	10	24	14	1	3	4	2	1	1	5.61	5.99	8975466
0	0	0	1	1	1	0	1	1	0	0	0	7	12	22	27	7	14	5	3	4	2	2	1	5.65	5.95	9040821
0	0	0	1	1	1	0	1	1	0	0	0	11	12	22	11	7	14	1	3	4	2	2	1	5.62	5.94	9057937
0	0	1	0	1	1	1	1	1	1	0	0	7	9	12	6	2	2	2	7	7	1	1	2	6.10	5.94	9062230
1	0	1	0	1	1	1	1	1	1	0	0	7	9	30	6	2	2	7	7	7	1	1	6	6.08	5.93	9331903
0	0	0	1	1	1	1	1	0	0	0	0	11	11	23	2	9	22	1	3	4	1	3	1	5.60	5.93	9552144

Table F 34 New development high CC 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.72	4.53	0
1	1	0	0	0	0	0	0	0	0	0	0	13	29	3	25	27	10	6	1	3	2	3	4	4.70	4.52	47723
0	0	0	1	0	0	0	0	0	0	0	0	2	4	24	2	2	4	1	5	4	1	6	1	4.71	4.51	67848
3	1	3	0	0	0	0	0	0	0	0	0	13	11	13	9	7	17	2	1	1	1	6	1	4.70	4.52	83325
0	0	0	0	0	1	0	0	0	0	0	0	21	4	2	2	6	3	3	1	5	3	2	2	4.68	4.51	111003
0	0	0	0	0	1	0	0	0	0	0	0	21	4	5	10	6	3	1	2	4	1	5	1	4.65	4.51	152082
1	0	0	0	0	1	0	0	0	0	0	0	15	4	3	21	2	5	1	6	3	1	4	6	4.64	4.50	174107
1	1	0	0	0	1	0	0	0	0	0	0	14	20	4	21	2	4	1	3	4	1	4	6	4.62	4.50	206651
0	1	0	0	0	1	0	0	0	0	0	0	6	2	3	17	2	6	1	1	1	2	3	4	4.61	4.50	225704
1	1	0	0	0	1	0	0	0	0	0	0	14	20	4	21	2	6	1	3	4	1	4	6	4.61	4.50	247729
0	0	0	1	0	1	0	0	0	0	0	0	6	6	3	3	6	4	1	2	5	3	1	1	4.59	4.48	302942
0	0	0	1	0	1	0	0	0	0	0	1	6	6	3	3	6	4	1	2	5	3	1	1	4.58	4.48	361442
0	0	0	0	1	0	0	0	0	0	0	0	30	2	23	21	2	29	2	1	1	1	2	5	4.68	4.45	386734
0	0	1	0	1	0	0	0	0	0	0	0	21	2	17	10	2	18	7	7	1	1	3	2	4.68	4.45	393046
0	0	0	1	0	1	0	0	0	0	0	1	6	6	8	3	7	3	1	3	6	1	4	1	4.58	4.48	419032
0	1	0	0	1	0	0	0	0	0	0	0	15	2	19	9	2	18	1	4	4	1	1	3	4.63	4.46	426124
0	0	0	1	0	1	0	0	0	0	0	0	6	6	8	4	10	7	1	1	1	5	4	1	4.55	4.48	437303
1	0	0	0	1	0	0	0	0	0	0	0	19	2	23	6	3	8	1	6	1	1	5	1	4.62	4.44	458395
0	0	0	0	1	0	0	0	0	0	0	0	16	3	18	11	2	16	1	5	4	1	1	2	4.63	4.44	469746
1	0	3	0	1	0	0	0	0	0	0	0	19	2	23	6	3	8	1	6	1	4	5	1	4.62	4.44	477333
0	1	0	0	1	0	0	0	0	0	0	0	16	2	17	10	3	16	1	5	3	1	1	2	4.55	4.45	489453

0	0	0	0	1	0	0	0	0	0	0	0	16	2	18	11	4	16	1	5	4	1	1	2	4.54	4.44	513392
0	0	1	0	1	0	0	0	0	0	0	0	16	2	16	10	4	14	1	4	2	1	2	1	4.54	4.44	519705
0	1	0	0	1	0	0	0	0	0	0	0	16	2	18	11	4	16	1	5	4	1	1	2	4.48	4.45	552782
2	1	0	0	1	0	0	0	0	0	0	0	15	2	9	9	4	18	1	3	4	1	1	2	4.48	4.45	569447
0	0	0	0	1	1	0	0	0	0	0	0	10	3	3	11	2	2	1	1	1	1	4	1	4.59	4.42	573903
0	0	0	0	1	0	0	0	0	0	0	0	5	2	22	10	5	9	3	1	1	3	3	5	4.46	4.44	576721
0	0	0	0	1	1	0	0	0	0	0	0	11	2	6	27	3	3	1	1	1	1	5	1	4.56	4.42	615837
0	0	0	1	1	0	0	0	0	0	0	0	4	2	22	3	4	13	3	1	4	4	2	4	4.50	4.42	628309
0	0	1	1	1	0	0	0	0	0	0	0	4	2	22	3	4	13	3	1	4	4	2	2	4.50	4.42	634622
0	0	0	0	1	0	0	0	0	0	0	0	8	2	23	11	6	10	3	2	2	3	3	5	4.41	4.43	640050
0	0	0	0	1	1	0	0	0	0	0	0	11	2	6	5	4	3	1	1	1	1	5	1	4.47	4.42	679166
0	0	0	0	1	0	0	0	0	0	0	0	9	2	24	12	7	9	1	3	2	3	3	5	4.39	4.43	703380
1	0	3	0	1	0	0	0	0	0	0	0	12	4	5	10	4	3	1	1	1	1	5	2	4.42	4.42	706687
0	0	0	1	1	0	0	0	0	0	0	0	5	2	22	5	5	13	3	1	4	3	3	5	4.40	4.41	721591
0	0	0	0	1	0	0	0	0	0	0	0	7	3	7	9	6	20	4	1	1	5	6	4	4.35	4.42	723063
0	0	0	0	1	0	0	0	0	0	0	0	11	4	23	22	5	28	1	4	2	1	3	1	4.35	4.42	742746
1	0	0	0	1	0	0	0	0	0	0	0	9	3	24	12	7	10	3	3	3	3	3	5	4.34	4.42	794725
0	0	0	0	1	1	0	0	0	0	0	0	8	3	3	3	5	4	1	1	5	4	2	1	4.33	4.40	804969
0	0	0	0	1	0	0	0	0	0	0	0	8	4	22	11	6	9	3	2	2	1	3	4	4.30	4.42	806076
0	0	1	0	1	0	0	0	0	0	0	0	10	4	6	21	6	2	2	1	1	1	4	7	4.30	4.42	812388
0	0	0	0	1	1	0	0	0	0	0	0	11	4	5	3	4	3	1	1	1	5	2	2	4.36	4.40	831499
1	0	0	0	1	1	0	0	0	0	0	0	12	4	5	10	4	3	1	1	4	1	5	2	4.36	4.40	839831
0	0	0	0	1	1	0	0	0	0	0	0	2	4	3	3	5	2	1	1	1	6	2	1	4.32	4.40	846903
1	0	0	0	1	1	0	0	0	0	0	0	11	4	5	10	5	2	1	1	1	2	5	1	4.30	4.40	882621
0	0	0	0	1	0	0	0	0	0	0	0	22	5	7	11	6	21	1	3	1	1	1	5	4.26	4.41	889088
0	0	1	0	1	0	0	0	0	0	0	0	10	5	12	21	6	3	1	1	1	1	4	1	4.26	4.41	895401
0	0	0	0	1	1	0	0	0	0	0	0	3	4	3	3	5	5	1	1	4	6	2	1	4.27	4.40	908521
2	0	0	0	1	1	0	0	0	0	0	0	21	4	2	2	6	3	3	1	5	3	2	2	4.26	4.40	933744
0	0	0	0	1	1	0	0	0	0	0	0	21	4	5	10	6	3	1	2	4	6	5	1	4.23	4.40	958157
1	0	0	0	1	1	0	0	0	0	0	0	19	4	6	9	6	4	1	3	5	1	4	1	4.21	4.39	1000722
0	0	0	0	1	1	0	0	0	0	0	0	6	5	3	3	6	4	1	3	5	4	1	1	4.19	4.39	1034323
0	0	0	1	1	1	0	0	0	0	0	0	4	6	6	3	3	3	1	1	4	1	5	1	4.35	4.38	1062805
0	0	0	1	1	1	0	0	0	0	0	0	7	4	3	3	5	4	6	2	1	1	2	1	4.23	4.38	1067084
0	0	0	1	1	1	0	0	0	0	0	0	7	4	3	3	5	5	1	2	1	1	2	1	4.21	4.37	1087623

0	0	0	1	1	1	0	0	0	0	0	0	6	4	3	3	6	3	1	3	5	3	1	1	4.19	4.38	1088479
0	0	0	0	1	1	0	0	0	0	0	0	2	5	6	19	6	5	1	3	1	1	5	1	4.16	4.39	1095941
1	0	0	0	1	1	0	0	0	0	0	0	19	5	7	10	6	5	1	3	1	1	5	1	4.16	4.39	1117966
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0	0	0	1	1	1	0	0	0	0	0	0	6	5	3	3	6	4	1	3	5	4	1	1	4.13	4.37	1192030
0	0	0	1	1	1	0	0	0	0	0	0	6	6	3	3	6	4	1	2	5	3	1	1	4.11	4.37	1275043
0	0	0	1	1	1	0	0	0	0	1	0	7	4	3	2	5	4	1	2	4	4	2	1	4.20	4.36	1302577
0	0	0	1	1	1	0	0	0	0	1	0	7	4	3	3	5	5	1	2	1	1	2	1	4.19	4.36	1327395
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0	0	0	1	1	1	0	0	0	0	0	0	8	6	4	2	6	7	1	2	5	4	1	1	4.08	4.37	1388864
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0	0	0	1	1	1	0	0	0	0	0	0	7	6	9	4	7	4	1	3	6	1	4	1	4.08	4.36	1446203
0	0	0	1	1	1	0	0	0	0	1	0	8	5	3	3	6	4	1	3	5	4	1	1	4.09	4.35	1462696
0	0	0	1	1	1	0	0	0	0	0	1	7	6	9	4	7	4	1	3	6	1	4	1	4.05	4.36	1514368
0	0	0	1	1	1	0	0	0	0	1	0	8	5	3	3	6	4	1	3	5	4	2	1	4.07	4.35	1526637
0	0	0	1	1	1	0	0	0	0	1	0	8	5	3	3	6	4	1	3	5	4	3	1	4.06	4.35	1590578
0	0	0	1	1	1	0	0	0	0	1	0	6	5	2	4	7	5	1	4	5	1	3	1	4.03	4.35	1674288
0	0	0	1	1	1	0	0	0	0	1	0	8	5	9	4	7	5	1	3	1	1	4	1	4.02	4.35	1824824
0	0	0	1	1	1	0	0	0	0	1	0	9	6	9	4	7	5	1	3	6	1	4	1	3.98	4.35	1929231
0	0	0	1	1	1	0	0	1	0	0	0	5	6	4	3	5	2	1	5	6	1	1	1	4.16	4.34	2068684
0	0	0	1	1	1	0	0	1	0	0	0	6	5	3	3	6	4	1	1	5	5	1	1	4.10	4.34	2097781
0	0	0	1	1	1	0	0	1	0	0	0	7	6	5	4	7	2	1	1	6	6	1	1	4.07	4.33	2256104
2	0	0	1	1	1	0	0	0	0	1	0	5	7	13	4	7	21	1	3	5	1	3	1	3.97	4.35	2262786
2	0	0	1	1	1	0	0	0	0	1	0	5	7	13	4	7	21	1	4	5	1	3	1	3.96	4.35	2314831
0	0	0	1	1	1	0	0	1	0	0	0	7	6	13	5	6	6	1	1	6	5	5	1	4.05	4.33	2388753
0	0	0	1	1	1	0	0	1	0	0	0	7	6	13	5	7	6	1	1	6	5	5	1	4.04	4.33	2452083
0	0	0	1	1	1	1	0	0	0	0	1	4	7	6	4	5	2	1	6	4	1	5	1	4.14	4.32	2521866
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0	0	0	0	1	1	1	0	0	0	1	0	8	6	7	19	6	4	1	3	6	1	2	1	4.06	4.32	2680741
0	0	0	1	1	1	1	0	0	0	0	0	6	7	13	6	9	7	6	6	6	3	6	1	4.03	4.32	2976243
0	0	0	1	1	1	1	0	0	0	1	0	6	5	2	27	7	5	1	4	5	1	3	1	4.02	4.31	2989522
0	0	0	1	1	1	1	0	0	0	1	0	5	5	13	8	7	6	2	4	6	1	3	1	3.98	4.30	3057986
2	0	0	0	1	1	0	0	1	0	1	0	9	6	6	24	9	25	1	7	7	5	4	1	3.98	4.34	3330020
0	0	0	1	1	1	1	0	1	0	0	0	6	6	2	5	5	7	4	6	6	1	6	1	4.09	4.29	3390765

0	0	0	1	1	1	1	0	0	0	1	0	6	7	13	6	9	7	6	6	6	3	2	1	3.94	4.30	3424195
0	0	0	1	1	1	1	0	1	0	0	0	6	7	5	6	5	5	6	6	6	3	6	1	4.07	4.29	3478056
0	0	0	1	1	1	1	0	0	0	1	0	6	7	13	6	9	7	6	6	6	3	6	1	3.92	4.31	3679959
0	0	0	1	1	1	1	0	1	0	0	0	6	7	5	6	9	5	6	6	6	3	6	1	4.01	4.29	3731373
0	0	0	1	1	1	1	0	1	0	0	0	6	7	29	5	5	7	1	6	6	1	6	1	4.06	4.28	3843483
0	0	0	1	1	1	1	0	1	0	1	0	6	7	14	5	5	7	1	6	6	1	1	1	4.02	4.27	4022102
0	0	0	1	1	1	1	0	1	0	1	0	6	7	14	5	5	7	4	6	6	1	3	1	3.99	4.27	4149984
2	0	0	0	1	1	1	0	1	0	1	0	20	6	3	18	8	29	2	5	5	5	3	6	3.97	4.29	4356555
2	0	0	0	1	1	1	0	1	0	1	0	9	6	6	24	9	25	1	7	7	5	4	1	3.96	4.29	4546837
3	0	0	0	1	1	1	0	1	0	1	0	19	8	20	18	9	25	2	7	7	5	3	1	3.94	4.28	4848953
2	0	0	0	1	1	1	0	1	0	1	0	20	8	21	18	9	29	2	7	7	5	3	1	3.94	4.28	4936470
1	0	0	0	0	1	0	1	0	0	0	1	15	6	8	14	18	6	1	2	1	1	3	1	4.35	4.26	5991924
0	0	0	1	0	1	0	1	0	0	0	0	5	5	3	3	2	5	1	6	5	1	3	1	4.34	4.25	6011062
0	0	0	0	1	0	0	1	0	0	0	0	10	2	23	23	2	30	1	6	3	1	3	1	4.38	4.22	6095710
1	0	0	0	1	0	0	1	0	0	0	0	4	2	4	9	2	10	2	1	1	1	2	3	4.38	4.22	6104042
2	0	0	0	1	0	0	1	0	0	0	0	4	2	4	19	2	18	2	1	1	1	2	3	4.38	4.22	6112375
0	0	0	1	0	1	0	1	0	0	0	0	6	6	8	4	14	7	1	1	5	4	4	1	4.29	4.24	6146279
0	0	0	0	1	0	0	1	0	0	0	0	8	2	24	23	3	30	1	5	1	1	1	1	4.32	4.22	6159039
0	0	0	0	1	0	0	1	0	0	0	0	11	2	23	22	4	28	1	6	3	1	3	1	4.24	4.21	6222368
1	0	0	0	1	0	0	1	0	0	0	0	4	2	13	10	4	20	3	1	1	1	2	1	4.24	4.21	6230701
0	0	0	0	1	0	0	1	0	0	0	0	9	2	23	11	5	10	1	6	2	2	2	1	4.21	4.21	6285697
0	0	0	0	1	0	0	1	0	0	0	0	8	3	23	23	4	20	1	5	1	1	5	1	4.19	4.21	6305381
0	0	0	0	1	1	0	1	0	0	0	0	2	3	3	3	2	5	1	1	1	6	2	1	4.26	4.19	6344497
0	0	0	0	1	0	0	1	0	0	0	0	11	3	4	10	5	2	1	5	5	1	5	1	4.17	4.21	6368710
2	0	0	0	1	0	0	1	0	0	0	0	10	4	23	22	4	28	1	6	2	1	2	3	4.16	4.20	6405058
1	0	0	0	1	1	0	1	0	0	0	0	11	3	4	11	4	2	1	1	1	1	5	1	4.15	4.19	6431563
0	0	0	0	1	0	0	1	0	0	0	0	9	4	22	22	5	29	1	6	6	5	2	2	4.14	4.21	6451722
2	0	0	0	1	1	0	1	0	0	0	0	8	2	3	23	5	5	1	6	6	6	1	1	4.14	4.19	6468137
0	0	0	0	1	1	0	1	0	0	0	0	11	3	4	4	4	5	1	5	1	1	7	1	4.12	4.19	6484848
0	0	0	0	1	1	0	1	0	0	0	0	2	4	3	3	4	5	1	1	1	6	2	1	4.09	4.18	6554168
0	0	0	0	1	1	0	1	0	0	0	0	2	4	3	3	5	5	1	1	1	6	2	1	4.06	4.18	6617497
0	0	0	1	1	1	0	1	0	0	0	0	5	5	3	3	2	5	1	6	5	1	3	1	4.16	4.17	6646834
0	0	0	0	1	1	0	1	0	1	0	0	15	4	6	15	5	4	1	1	3	1	1	5	4.06	4.18	6664222
0	0	0	1	1	1	0	1	0	0	0	0	4	4	3	3	5	5	1	1	5	6	2	1	4.03	4.16	6732414

1	0	0	0	1	1	0	1	0	0	0	0	15	6	8	15	5	4	1	2	4	1	3	4	4.02	4.18	6839779
0	0	0	1	1	1	0	1	0	0	0	0	4	6	7	4	4	6	1	1	5	4	4	1	4.00	4.16	6914699
1	0	0	0	1	1	0	1	0	0	0	1	15	6	8	15	5	4	1	2	4	1	3	4	4.00	4.17	6915379
0	0	0	1	1	1	0	1	0	0	0	0	7	6	7	4	4	6	1	1	5	4	4	1	3.98	4.16	6978884
0	0	0	1	1	1	0	1	0	0	0	0	5	7	14	5	5	7	1	1	5	6	4	1	3.95	4.16	7203104
0	0	0	1	1	1	0	1	0	0	0	0	6	7	5	5	5	15	1	6	5	1	6	1	3.93	4.16	7265577
0	0	0	0	1	1	1	1	0	0	0	0	11	3	4	11	4	2	1	1	1	1	5	1	4.13	4.14	7640047
0	0	0	0	1	1	1	1	0	0	0	0	11	3	4	4	4	6	1	1	1	1	5	1	4.08	4.13	7722204
0	0	0	1	1	1	0	1	1	0	0	0	5	6	4	3	5	2	1	5	6	1	1	1	3.98	4.13	7777660
0	0	0	1	1	1	1	1	0	0	0	0	5	5	3	3	2	5	1	6	5	1	3	1	4.13	4.12	7863651
0	0	0	1	1	1	1	1	0	0	0	0	6	5	14	3	2	5	1	6	5	1	6	1	4.11	4.12	8035667
0	0	0	1	1	1	1	1	0	0	0	0	2	4	14	5	5	5	1	6	5	1	6	1	4.00	4.12	8065620
0	0	0	1	1	1	1	1	0	0	0	0	3	5	3	16	6	5	1	6	5	1	6	1	3.97	4.12	8129805
0	0	0	1	1	1	1	1	0	0	0	0	3	5	14	16	6	5	1	6	5	1	6	1	3.96	4.11	8280425
0	0	0	1	1	1	1	1	0	0	0	0	5	7	14	5	5	7	1	1	5	6	4	1	3.93	4.11	8419921
0	0	0	1	1	1	0	1	0	0	1	0	9	17	9	4	7	5	1	3	6	1	4	1	3.91	4.16	8551346
0	0	0	1	1	1	0	1	0	0	1	1	9	17	5	4	7	5	1	3	6	1	4	1	3.90	4.15	8564740
0	0	0	1	1	1	1	1	0	0	0	0	6	7	14	5	5	15	1	6	5	1	6	1	3.92	4.11	8605629
0	0	0	1	1	1	1	1	1	0	0	0	6	7	6	5	5	7	1	2	5	1	6	1	3.91	4.08	9237524
0	0	0	1	1	1	1	1	0	0	0	0	6	7	8	21	15	27	1	2	5	1	6	1	3.90	4.13	9471699
1	0	0	0	1	1	1	1	1	0	1	0	14	6	21	25	9	25	7	7	7	5	3	1	3.89	4.10	10388932
1	0	0	0	1	1	1	1	1	0	1	0	9	25	21	25	9	25	7	7	7	5	3	1	3.89	4.08	11966171

Table F 35 New development high CC 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	7.06	6.59	0
0	0	1	0	0	0	0	0	0	0	0	0	3	21	12	22	23	21	2	1	6	5	2	5	7.06	6.58	6313
0	1	0	0	0	0	0	0	0	0	0	0	25	5	23	15	19	3	3	3	3	5	1	3	7.04	6.58	39390
0	1	1	0	0	0	0	0	0	0	0	0	10	25	14	12	2	24	7	2	2	2	1	4	7.03	6.58	45703
1	1	3	0	0	0	0	0	0	0	0	1	5	12	14	13	11	16	3	6	4	5	1	1	7.02	6.58	115494
0	0	0	0	0	1	0	0	0	0	0	0	23	23	2	2	2	4	4	1	1	3	4	1	7.00	6.56	131542
1	0	0	0	0	1	0	0	0	0	0	0	20	20	3	5	7	3	2	1	4	1	5	6	7.01	6.56	133029

0	0	0	0	0	1	0	0	0	0	0	0	6	10	3	4	8	4	2	1	1	5	2	1	6.99	6.56	145235
0	0	0	0	0	1	0	0	0	0	0	0	15	25	2	11	19	5	6	1	4	4	4	1	6.98	6.56	152082
0	0	0	0	0	1	0	0	0	0	0	0	12	25	4	2	7	5	4	1	1	2	3	1	6.96	6.56	179467
0	0	0	0	0	1	0	0	0	0	0	0	15	26	6	2	6	5	7	1	1	3	3	1	6.94	6.55	206853
1	0	0	0	0	1	0	0	0	0	0	0	6	28	6	2	8	7	1	1	1	3	5	1	6.91	6.55	256264
0	0	0	1	0	1	0	0	0	0	0	0	2	8	7	5	8	4	2	1	1	1	3	1	6.95	6.54	280691
0	0	0	0	0	1	0	0	0	0	0	0	27	7	8	11	6	8	1	3	5	4	5	1	6.90	6.55	295856
0	0	0	1	0	1	0	0	0	0	0	0	6	11	2	5	8	4	2	1	1	6	3	1	6.94	6.53	297807
0	0	1	1	0	1	0	0	0	0	0	0	5	2	3	5	8	6	5	1	1	6	2	3	6.91	6.54	337496
0	0	0	1	0	1	0	0	0	0	0	0	5	11	2	9	8	7	1	1	1	5	3	3	6.90	6.53	355146
1	0	0	1	0	1	0	0	0	0	0	0	6	11	2	5	8	7	2	1	1	6	3	1	6.88	6.54	367758
0	0	0	0	1	0	0	0	0	0	0	0	2	2	7	2	2	2	1	4	5	2	3	2	7.08	6.50	386734
0	0	1	0	1	0	0	0	0	0	0	0	2	2	7	2	2	2	1	4	5	2	3	2	7.08	6.50	393046
0	0	0	1	0	1	0	0	0	0	0	0	6	13	4	7	5	7	2	3	5	1	4	4	6.85	6.53	395369
0	1	0	0	1	0	0	0	0	0	0	0	2	2	7	2	2	2	1	4	5	2	3	2	7.04	6.50	426124
0	0	0	0	1	0	0	0	0	0	0	0	24	2	21	14	3	28	1	1	5	6	1	1	7.05	6.49	450063
2	0	0	1	0	1	0	0	0	0	0	0	6	21	7	7	3	7	3	1	2	1	1	1	6.84	6.53	453112
1	2	0	0	1	0	0	0	0	0	0	0	16	2	4	2	2	24	5	1	6	4	4	2	7.04	6.50	473846
0	1	0	0	1	0	0	0	0	0	0	0	26	2	12	8	3	2	4	6	4	6	1	1	6.98	6.50	489453
1	1	0	0	1	0	0	0	0	0	0	0	26	2	12	8	3	2	4	6	4	6	1	1	6.97	6.50	497785
0	3	0	1	0	1	0	0	0	0	0	0	6	13	4	7	5	7	2	3	5	3	4	4	6.85	6.52	513539
0	0	1	0	1	0	0	0	0	0	0	0	11	2	17	15	4	27	1	5	4	5	1	3	6.98	6.48	519705
1	0	0	0	1	0	0	0	0	0	0	0	2	2	15	12	4	3	6	1	1	2	2	1	6.98	6.48	521725
0	0	0	1	0	1	0	0	0	0	0	0	7	2	11	5	18	9	4	1	5	1	1	1	6.82	6.52	545134
0	1	0	0	1	0	0	0	0	0	0	0	2	2	15	12	4	3	6	1	1	2	3	1	6.88	6.49	552782
1	1	0	0	1	0	0	0	0	0	0	0	2	2	15	12	4	3	6	1	1	2	3	1	6.87	6.49	561115
0	0	0	0	1	0	0	0	0	0	0	0	11	2	20	16	5	2	1	2	2	5	2	1	6.88	6.48	576721
0	0	1	0	1	0	0	0	0	0	0	0	11	2	4	17	5	2	1	6	1	6	3	1	6.88	6.47	583034
0	1	0	0	1	0	0	0	0	0	0	0	11	2	29	16	5	2	1	2	2	5	2	1	6.79	6.49	616111
0	0	0	0	1	0	0	0	0	0	0	0	2	2	7	10	6	9	1	2	4	3	1	2	6.79	6.47	640050
0	0	1	0	1	0	0	0	0	0	0	0	11	3	4	17	5	2	1	6	1	6	3	1	6.85	6.46	666046
0	1	0	0	1	0	0	0	0	0	0	0	2	2	15	11	6	3	6	1	1	4	1	1	6.73	6.49	679440
0	0	0	0	1	0	0	0	0	0	0	0	11	2	17	5	7	14	1	6	1	2	5	1	6.70	6.47	703380
0	0	1	0	1	0	0	0	0	0	0	0	21	2	18	14	7	17	1	1	4	5	1	3	6.70	6.47	709692

0	0	0	0	1	0	0	0	0	0	0	0	2	3	7	10	6	9	1	2	4	5	1	2	6.76	6.46	723063
0	0	0	0	1	0	0	0	0	0	0	0	11	2	4	6	8	2	1	6	1	3	4	1	6.64	6.47	766709
0	0	1	0	1	0	0	0	0	0	0	0	22	2	19	15	8	17	2	1	3	4	2	4	6.64	6.46	773021
0	0	0	1	1	0	0	0	0	0	0	0	5	5	7	5	2	9	1	1	1	1	2	5	6.89	6.44	780641
0	0	0	0	1	0	0	0	0	0	0	0	2	3	19	12	7	12	6	3	5	1	3	1	6.67	6.45	786392
0	0	0	1	1	0	0	0	0	0	0	0	5	5	8	8	2	9	1	4	1	1	2	5	6.88	6.44	793478
1	0	1	0	1	0	0	0	0	0	0	0	3	3	20	12	7	12	1	4	6	3	4	1	6.66	6.45	801037
0	0	0	0	1	0	0	0	0	0	0	0	27	2	18	14	9	2	2	5	3	5	4	1	6.61	6.46	830038
0	0	0	0	1	0	0	0	0	0	0	0	22	3	22	12	8	12	4	5	6	3	3	1	6.61	6.45	849721
0	0	0	1	1	0	0	0	0	0	0	0	3	5	3	3	4	22	1	1	6	1	6	1	6.83	6.43	855952
1	0	1	0	1	0	0	0	0	0	0	0	22	3	20	12	8	12	4	5	6	4	4	1	6.60	6.45	864366
1	0	0	1	1	0	0	0	0	0	0	0	3	5	3	7	4	22	1	1	6	1	6	1	6.81	6.43	881400
0	0	0	0	1	0	0	0	0	0	0	0	4	5	22	22	6	3	2	3	3	1	1	3	6.65	6.44	889088
0	0	0	0	1	0	0	0	0	0	0	0	14	3	5	29	9	6	6	2	4	4	4	1	6.58	6.45	913051
0	0	1	1	1	0	0	0	0	0	0	0	5	2	3	5	8	18	5	2	1	6	1	2	6.59	6.44	917891
0	0	0	0	1	0	0	0	0	0	0	0	11	4	4	7	8	2	1	6	1	7	4	1	6.56	6.44	932734
0	0	1	0	1	0	0	0	0	0	0	0	22	4	22	13	8	14	4	4	5	3	4	1	6.56	6.44	939047
0	0	0	1	1	0	0	0	0	0	0	0	4	5	5	5	5	20	2	1	6	1	6	1	6.72	6.42	949234
0	0	0	1	1	0	0	0	0	0	0	0	5	5	22	6	5	14	6	1	1	1	1	1	6.69	6.42	974908
0	0	0	1	1	0	0	0	0	0	0	0	6	4	19	7	6	10	1	1	6	1	1	6	6.63	6.42	980899
0	0	0	0	1	0	0	0	0	0	0	0	14	4	8	29	9	11	7	1	4	4	4	2	6.53	6.44	996063
0	0	0	1	1	0	0	0	0	0	0	0	4	5	5	5	6	20	3	3	6	5	6	6	6.61	6.41	1012563
0	0	0	0	1	0	0	0	0	0	0	0	22	5	19	8	8	11	4	5	4	4	3	1	6.50	6.43	1015747
0	0	1	0	1	0	0	0	0	0	0	0	11	5	4	17	8	2	1	1	1	7	4	1	6.50	6.43	1022059
0	0	0	1	1	0	0	0	0	0	0	0	5	5	7	5	6	14	6	1	1	1	1	5	6.60	6.41	1033958
0	0	0	1	1	0	0	0	0	0	0	0	4	5	21	4	7	12	1	4	7	5	3	1	6.54	6.41	1071613
0	0	0	0	1	0	0	0	0	0	0	0	20	5	8	4	9	12	5	4	4	2	4	1	6.47	6.43	1079076
1	0	0	0	1	0	0	0	0	0	0	0	6	5	22	11	9	3	1	3	3	1	1	3	6.46	6.43	1087408
0	0	2	1	1	1	0	0	0	0	0	0	5	2	3	5	8	6	5	1	1	6	2	1	6.50	6.42	1110517
1	0	0	1	1	0	0	0	0	0	0	0	2	6	24	5	7	20	1	2	6	4	3	5	6.49	6.41	1124448
0	0	0	0	1	1	0	0	0	0	0	0	5	5	3	9	8	3	1	1	4	3	1	1	6.46	6.41	1140443
0	0	0	0	1	0	0	0	0	0	0	0	20	6	8	4	9	12	6	4	4	2	4	2	6.42	6.43	1162088
0	0	0	0	1	1	0	0	0	0	0	0	5	5	6	9	8	3	1	1	4	3	1	1	6.43	6.40	1181521
1	0	1	0	1	0	0	0	0	0	0	0	10	7	4	17	8	7	1	1	1	1	4	1	6.40	6.42	1196417

0	0	3	1	1	1	0	0	0	0	0	0	5	3	5	6	8	6	1	1	4	6	2	1	6.45	6.40	1231507
1	0	0	1	1	0	0	0	0	0	0	0	5	6	24	3	8	6	1	1	1	6	3	1	6.40	6.41	1243404
0	0	0	0	1	0	0	0	0	0	0	0	15	7	8	11	9	9	1	2	4	1	5	1	6.38	6.42	1245101
2	0	0	0	1	0	0	0	0	0	0	0	15	7	8	11	9	9	1	2	4	1	5	2	6.37	6.42	1261766
0	0	0	0	1	1	0	0	0	0	0	0	5	6	7	3	6	9	1	2	5	4	5	1	6.44	6.40	1274803
0	0	0	0	1	1	0	0	0	0	0	0	5	6	8	6	8	3	1	1	7	3	2	1	6.37	6.40	1291919
1	0	0	0	1	0	0	0	0	0	0	0	21	7	8	20	10	19	1	1	1	1	4	2	6.36	6.42	1316763
1	0	0	0	1	0	0	0	0	0	0	0	14	8	6	5	9	7	1	1	3	1	4	2	6.34	6.42	1336446
0	0	0	0	1	1	0	0	0	0	0	0	5	6	7	6	7	9	1	2	6	4	5	1	6.36	6.39	1338132
0	0	0	1	1	1	0	0	0	0	0	0	6	6	8	5	5	9	1	3	7	1	6	5	6.46	6.37	1391432
0	0	0	0	1	1	0	0	0	0	0	0	14	7	5	12	8	7	1	2	5	4	1	1	6.28	6.39	1416010
0	0	0	1	1	1	0	0	0	0	0	0	6	6	8	29	5	9	4	3	7	1	3	6	6.45	6.38	1494128
0	0	0	0	1	1	0	0	0	0	0	0	5	7	8	8	8	10	1	6	7	1	6	1	6.25	6.39	1518706
0	0	0	0	1	1	0	0	0	0	0	0	2	8	8	7	8	7	1	4	7	1	3	1	6.23	6.38	1540101
0	0	0	0	1	1	0	0	0	0	0	0	2	7	8	8	9	10	1	6	7	1	3	1	6.21	6.39	1582035
1	0	2	1	1	1	0	0	0	0	0	0	2	10	2	6	7	6	1	1	4	6	3	1	6.31	6.38	1646023
0	0	0	1	1	1	0	0	0	0	0	0	6	5	17	5	8	12	1	1	1	6	5	1	6.27	6.37	1683260
0	0	0	1	1	1	0	0	0	0	0	0	5	10	2	3	8	7	2	1	1	3	4	1	6.21	6.36	1760282
0	0	0	1	1	1	0	0	0	0	0	0	14	7	5	12	8	7	1	2	5	4	1	1	6.17	6.36	1783388
0	0	0	0	1	1	0	0	0	0	0	0	2	8	14	6	10	14	6	6	1	7	4	2	6.16	6.38	1892691
2	0	0	0	1	1	0	0	0	0	0	0	2	8	14	6	10	14	6	6	1	7	4	2	6.15	6.38	1909356
0	0	0	0	1	1	0	0	0	0	0	1	2	8	8	8	13	10	1	5	7	1	3	1	6.13	6.38	1996195
1	0	0	1	1	1	0	0	0	1	0	0	6	11	2	5	8	12	2	1	1	6	3	1	6.15	6.36	2121243
1	0	0	1	1	1	0	0	0	0	0	0	6	11	17	5	8	12	2	1	1	6	3	1	6.10	6.35	2189668
0	0	0	1	1	1	0	0	0	0	0	0	7	9	9	8	14	9	1	6	7	1	3	3	6.05	6.35	2258357
0	0	0	1	1	1	0	0	0	0	0	0	7	9	9	8	14	15	1	6	7	1	3	3	6.04	6.35	2381592
0	0	0	1	1	1	0	0	0	0	0	0	10	9	8	8	14	14	1	6	2	1	3	1	6.01	6.35	2411545
0	0	3	1	1	1	0	0	0	0	1	0	6	13	2	5	11	6	4	1	4	6	3	2	6.12	6.34	2479326
0	0	3	1	1	1	0	0	0	0	1	0	6	13	7	16	11	6	4	1	4	6	2	1	6.09	6.33	2530918
0	0	3	1	1	1	0	0	0	0	1	0	6	13	7	16	11	6	4	1	4	6	3	1	6.08	6.33	2594859
0	0	0	0	1	1	0	0	0	0	1	1	2	8	8	8	12	25	1	5	7	1	3	1	5.99	6.35	2700802
0	0	3	1	1	1	0	0	0	0	1	0	13	13	8	8	11	6	1	1	4	1	3	1	6.03	6.33	2724085
0	0	3	1	1	1	0	0	0	0	1	0	6	13	8	8	11	6	1	5	4	1	3	1	5.99	6.33	2782500
2	0	0	0	1	1	1	0	0	0	1	0	5	7	6	10	5	10	1	2	5	4	4	1	6.42	6.32	2902469

2	0	0	0	1	1	1	0	0	0	1	0	5	5	6	10	10	7	1	2	1	4	3	2	6.25	6.32	2927531
0	0	3	1	1	1	0	0	0	0	1	0	13	13	8	8	11	6	1	5	4	1	3	1	5.94	6.32	2932265
0	0	3	1	1	1	0	0	0	0	1	0	13	13	8	8	11	7	6	5	4	1	3	1	5.94	6.32	2952804
2	0	0	0	1	1	1	0	0	0	1	0	5	5	6	10	10	22	1	2	1	4	3	2	6.21	6.32	3235619
0	0	0	0	1	1	1	0	0	0	1	0	10	11	2	9	10	6	1	2	1	3	3	4	6.12	6.30	3333631
0	0	0	0	1	1	1	0	0	0	1	0	10	11	2	10	10	6	1	3	1	3	3	4	6.10	6.30	3385676
0	0	0	0	1	1	1	0	0	0	1	0	10	11	2	9	10	6	1	2	1	3	5	4	6.09	6.30	3461513
0	0	0	1	1	1	1	0	0	0	0	0	10	11	2	10	15	6	1	3	1	3	3	4	6.04	6.31	3619804
0	0	0	1	1	1	1	0	0	0	1	0	10	11	2	10	10	6	1	3	1	3	3	4	6.01	6.28	3658916
0	0	0	0	1	1	1	0	0	0	1	0	2	7	8	10	12	21	1	5	1	3	5	5	5.97	6.30	3802501
0	0	0	0	1	1	0	0	1	0	1	0	10	14	15	10	10	5	1	6	2	4	6	5	5.94	6.32	3829073
0	0	0	1	1	1	1	0	0	0	1	0	10	11	16	10	10	6	1	3	1	3	3	4	5.95	6.27	3850616
0	0	0	0	1	1	0	0	1	0	1	0	10	14	15	10	10	14	1	6	2	4	6	5	5.91	6.32	4013926
0	0	0	0	1	1	0	0	1	0	1	0	10	17	9	10	10	22	1	6	1	4	6	5	5.90	6.32	4345121
0	0	0	0	1	1	1	0	0	0	1	0	10	17	9	10	10	22	1	6	1	4	6	5	5.88	6.29	4656187
0	0	0	0	1	1	1	0	1	0	1	0	10	7	9	10	10	22	1	6	1	4	6	5	5.93	6.27	4731812
0	0	0	0	1	1	1	0	1	0	1	0	10	7	17	10	10	22	1	6	1	4	6	5	5.92	6.27	4841354
0	0	0	0	1	1	1	0	1	0	1	0	10	14	15	10	10	8	1	6	2	4	6	5	5.86	6.26	5107508
0	0	0	0	1	1	1	0	1	0	1	0	10	14	15	10	10	14	1	6	2	4	6	5	5.85	6.26	5230743
0	0	0	0	1	1	1	0	1	0	1	1	10	17	9	10	10	22	1	6	6	4	4	3	5.86	6.26	5520065
0	0	0	0	1	1	1	0	1	0	1	0	10	17	9	10	10	22	1	6	1	4	6	5	5.84	6.26	5561938
0	0	3	0	1	0	0	1	0	0	0	0	21	2	22	11	4	17	6	1	5	4	3	1	6.52	6.24	6241306
0	0	0	0	1	1	1	0	1	0	1	0	10	17	9	10	21	22	1	6	1	4	6	5	5.80	6.28	6258559
0	0	0	0	1	0	0	1	0	0	0	0	8	2	5	10	5	12	5	1	1	3	1	1	6.43	6.24	6285697
0	0	0	0	1	0	0	1	0	0	0	0	8	2	4	12	6	14	6	1	1	4	6	1	6.36	6.24	6349026
0	0	0	0	1	0	0	1	0	0	0	0	8	2	4	12	7	14	6	1	1	3	2	1	6.33	6.23	6412356
0	0	0	1	1	0	0	1	0	0	0	0	4	2	3	5	6	13	1	3	5	5	5	5	6.33	6.21	6472501
0	0	0	0	1	0	0	1	0	0	0	0	11	2	4	6	8	2	1	6	1	3	4	1	6.32	6.24	6475685
1	0	0	1	1	0	0	1	0	0	0	0	4	2	3	5	6	13	1	3	7	5	5	6	6.32	6.22	6480834
0	0	0	0	1	0	0	1	0	0	0	0	2	3	2	11	7	2	1	2	3	5	3	1	6.29	6.22	6495368
0	0	0	0	1	0	0	1	0	0	0	0	2	4	23	17	6	20	1	1	1	2	4	6	6.27	6.22	6515052
0	0	0	0	1	0	0	1	0	0	0	0	22	4	22	15	7	13	1	5	2	1	3	1	6.24	6.22	6578381
0	0	0	1	1	0	0	1	0	0	0	0	4	5	15	5	4	21	1	3	6	4	6	6	6.36	6.20	6594881
0	0	0	1	1	0	0	1	0	0	0	0	9	4	18	4	4	14	4	2	7	3	6	2	6.34	6.19	6614564

1	0	0	0	1	0	0	1	0	0	0	0	10	4	21	6	8	2	1	4	1	5	3	3	6.22	6.22	6650043
0	0	0	1	1	0	0	1	0	0	0	0	4	5	3	4	5	14	6	2	7	5	1	6	6.27	6.19	6653931
0	0	0	0	1	0	0	1	0	0	0	0	22	5	22	12	7	11	2	5	3	1	3	1	6.20	6.21	6661393
1	0	0	1	1	0	0	1	0	0	0	0	4	5	3	4	5	14	6	3	7	5	6	6	6.26	6.20	6662264
0	0	0	1	1	0	0	1	0	0	0	0	4	4	5	4	7	9	3	3	6	4	5	6	6.21	6.20	6697577
0	0	0	1	1	0	0	1	0	0	0	0	4	5	5	5	6	20	3	3	6	5	6	6	6.20	6.19	6721539
1	0	0	0	1	0	0	1	0	0	0	0	3	5	22	10	8	2	1	4	3	5	3	3	6.18	6.21	6733055
0	0	0	1	1	0	0	1	0	0	0	0	4	6	5	5	6	21	1	3	6	5	6	6	6.17	6.19	6804552
0	0	0	0	1	0	0	1	0	0	0	0	3	6	4	6	8	2	1	6	1	3	4	1	6.15	6.21	6807735
1	0	0	1	1	0	0	1	0	0	0	0	4	6	5	5	6	21	1	3	7	5	6	6	6.15	6.19	6812884
1	0	0	1	1	0	0	1	0	0	0	0	4	6	25	4	7	20	1	2	7	5	3	1	6.13	6.19	6871935
0	0	1	0	1	1	0	1	0	0	0	0	3	6	6	12	6	7	1	3	5	4	5	1	6.09	6.19	6935321
0	0	1	0	1	1	0	1	0	0	0	0	2	6	8	11	6	11	1	1	5	4	4	1	6.08	6.19	7044863
0	0	0	1	1	1	0	1	0	0	0	0	6	5	8	5	5	13	1	5	6	1	1	5	6.07	6.15	7099552
0	0	0	1	1	1	0	1	0	0	0	0	6	6	8	5	5	9	1	5	7	1	6	5	6.04	6.15	7100408
0	0	0	1	1	1	0	1	0	0	0	0	6	6	8	8	5	9	1	5	7	1	6	5	6.03	6.15	7113245
0	0	0	0	1	1	0	1	0	0	0	0	2	8	5	12	6	10	1	4	6	4	5	1	6.01	6.17	7142958
0	0	0	0	1	1	0	1	0	0	0	0	2	7	10	12	8	7	1	2	6	4	1	1	5.98	6.17	7193450
0	0	0	0	1	1	0	1	0	0	0	0	2	7	16	12	12	8	1	2	6	4	1	1	5.95	6.18	7549463
0	0	0	0	1	1	0	1	0	0	0	0	2	8	8	8	13	10	1	5	7	1	3	1	5.93	6.18	7627341
0	0	0	1	1	1	0	1	0	0	0	0	17	5	8	7	14	9	1	1	7	3	3	1	5.89	6.16	7831261
0	0	0	1	1	0	1	1	0	0	0	0	4	5	5	5	6	20	3	3	6	5	6	6	6.14	6.14	7938356
0	0	0	1	1	1	0	1	0	0	0	0	7	9	8	8	14	9	1	6	7	1	3	1	5.84	6.15	7953640
0	0	0	1	1	0	1	1	0	0	0	0	4	5	25	3	7	20	1	1	7	2	3	1	6.11	6.14	7993127
0	0	0	1	1	1	0	1	0	0	0	0	7	9	8	8	14	13	1	6	7	1	3	1	5.84	6.15	8035797
1	0	0	1	1	0	1	1	0	0	0	0	4	6	25	4	7	20	1	2	7	5	3	1	6.09	6.14	8088752
0	0	0	1	1	0	0	1	1	0	0	0	6	10	21	7	6	22	1	1	7	1	1	6	6.01	6.14	8093701
0	0	1	1	1	0	0	1	1	0	0	0	6	10	20	7	7	22	1	1	7	4	5	5	6.00	6.14	8163343
0	0	0	1	1	1	0	1	1	0	0	0	6	6	8	4	8	9	1	2	5	4	3	1	5.89	6.12	8191867
0	0	0	1	1	1	0	1	1	0	0	0	6	6	8	4	14	9	1	2	5	4	3	1	5.88	6.13	8571843
0	0	0	1	1	1	0	1	1	0	0	0	6	6	8	8	14	9	1	2	7	1	3	1	5.86	6.13	8588959
0	0	0	1	1	1	0	1	1	0	0	0	17	6	8	8	14	9	1	2	7	1	3	1	5.81	6.12	8824304
0	0	0	1	1	1	0	1	1	0	0	0	7	9	8	8	14	9	1	6	7	1	3	1	5.80	6.12	8859391
0	0	0	1	1	1	0	1	1	0	0	0	8	9	8	8	14	9	1	6	7	1	3	1	5.79	6.12	8880786

0	0	0	1	1	1	0	1	1	0	0	0	17	9	7	6	14	9	6	1	7	1	2	1	5.77	6.12	9051091
0	0	0	1	1	0	1	1	1	0	0	0	21	5	25	7	5	15	7	1	5	4	5	1	6.08	6.10	9153051
0	0	4	0	1	1	1	1	1	0	0	0	20	6	6	10	7	14	6	1	5	4	7	1	5.93	6.09	9283930
0	0	0	0	1	1	1	1	1	0	0	0	2	7	19	12	6	8	1	2	6	4	1	1	5.91	6.09	9333134
0	0	0	1	1	1	1	1	1	0	0	0	12	5	5	7	5	15	7	1	5	4	7	1	5.95	6.07	9359048
0	0	4	0	1	1	1	1	1	0	0	0	26	9	6	10	7	14	6	1	5	4	7	1	5.89	6.09	9532967
0	0	0	1	1	1	1	1	1	0	0	0	21	5	23	7	5	15	7	1	5	4	7	1	5.93	6.07	9798073
0	0	3	1	1	1	1	1	1	0	0	0	21	6	6	7	9	15	7	1	5	4	7	3	5.82	6.07	9920563
0	0	3	1	1	1	1	1	1	0	0	0	21	6	6	7	9	26	7	1	5	4	7	3	5.79	6.07	10146494
0	0	2	1	1	1	1	1	1	0	0	0	20	25	22	7	5	15	7	1	7	1	2	1	5.87	6.06	11435863
0	0	2	1	1	1	1	1	1	0	0	0	20	25	22	4	8	15	7	1	7	1	2	1	5.77	6.06	11613013
0	0	2	1	1	1	1	1	1	0	0	0	20	25	22	24	8	15	7	5	7	1	2	1	5.76	6.06	11698593
0	0	3	1	1	1	1	1	1	0	0	0	8	25	22	7	16	15	7	1	7	1	2	1	5.74	6.07	11882056

Table F 36 New development high CC 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	8.60	8.40	0
0	0	0	0	0	1	0	0	0	0	0	0	6	14	2	3	8	2	1	1	1	7	2	7	8.60	8.38	90464
0	0	1	0	0	1	0	0	0	0	0	0	14	7	2	29	14	2	1	1	5	6	2	6	8.60	8.38	96777
1	1	3	0	0	0	0	0	0	0	0	1	5	12	14	13	11	16	3	6	4	5	1	1	8.58	8.39	115494
0	0	0	0	0	1	0	0	0	0	0	0	12	15	2	8	7	5	1	1	6	1	2	7	8.58	8.37	152082
1	0	0	0	0	1	0	0	0	0	0	0	13	10	3	2	9	6	1	1	5	6	3	2	8.56	8.36	194646
0	0	0	0	0	1	0	0	0	0	0	0	21	8	8	6	9	5	3	1	1	1	2	6	8.55	8.36	234238
0	0	0	0	0	1	0	0	0	0	0	0	28	2	5	25	8	7	1	1	5	6	1	6	8.54	8.36	234238
0	1	0	0	0	1	0	0	0	0	0	0	27	2	4	25	7	7	2	1	5	2	7	4	8.53	8.36	259936
0	1	0	0	0	1	0	0	0	0	0	0	28	2	5	25	8	8	2	1	5	6	6	6	8.51	8.35	294168
0	1	0	0	0	1	0	0	0	0	0	0	28	4	10	22	7	8	2	1	5	5	6	6	8.50	8.35	362632
0	0	0	0	1	0	0	0	0	0	0	0	30	2	7	18	2	3	1	1	3	1	4	2	8.64	8.31	386734
0	0	0	1	0	1	0	0	0	0	0	0	13	7	2	2	10	2	2	1	1	7	5	4	8.54	8.34	393657
0	0	3	1	0	1	0	0	0	0	0	0	13	6	2	2	2	2	1	1	5	7	5	2	8.54	8.34	412595
1	1	0	0	1	0	0	0	0	0	0	0	30	2	8	19	2	11	1	1	3	1	5	3	8.62	8.31	434456
0	0	0	1	0	1	0	0	0	0	0	0	10	8	6	9	9	3	5	1	6	1	4	5	8.51	8.33	434735

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0	0	0	0	1	1	1	0	1	0	1	0	19	16	22	9	11	26	5	7	7	1	5	7	7.46	7.99	5790522
2	0	0	0	1	1	1	0	1	0	1	0	19	16	15	9	24	26	5	7	7	1	1	7	7.42	8.01	6278853

0	0	0	1	1	0	0	1	0	0	0	0	2	7	3	9	5	25	4	1	1	6	1	3	7.99	7.98	6798561
0	0	0	0	1	1	1	0	1	0	1	0	19	16	22	9	29	26	5	7	7	1	5	7	7.35	8.01	6930447
0	0	0	0	1	1	0	1	0	0	0	0	12	3	23	3	6	10	3	1	6	1	3	5	7.88	7.97	6974365
1	0	0	0	1	0	0	1	0	0	0	0	14	9	22	30	8	15	1	3	1	7	5	3	7.73	7.98	7065106
0	0	0	1	1	0	0	1	0	0	0	0	18	7	3	9	4	25	3	1	2	6	1	3	7.98	7.96	7077552
0	0	0	0	1	0	0	1	0	0	0	0	30	9	5	8	9	2	1	1	5	1	2	2	7.72	7.98	7120102
0	0	0	1	1	0	0	1	0	0	0	0	18	7	3	9	5	25	4	1	1	6	1	3	7.90	7.95	7140881
0	0	0	1	1	0	0	1	0	0	0	0	18	7	3	9	6	25	4	1	1	6	1	3	7.82	7.95	7204210
1	0	0	1	1	0	0	1	0	0	0	0	10	8	23	8	8	6	6	1	4	4	1	6	7.70	7.95	7246775
0	0	0	0	1	1	0	1	0	0	0	0	24	8	6	6	10	6	5	1	5	2	1	6	7.63	7.94	7327811
0	0	0	0	1	1	0	1	0	0	0	0	29	8	10	2	10	6	5	1	6	1	4	7	7.61	7.94	7382582
0	0	0	1	1	1	0	1	0	0	0	0	5	9	11	2	9	4	5	1	6	1	1	5	7.65	7.91	7506913
0	0	0	0	1	1	0	1	0	0	0	0	10	8	22	9	10	9	5	1	6	1	1	6	7.56	7.93	7608513
0	0	0	0	1	1	0	1	0	0	0	0	14	8	9	21	10	18	5	5	6	1	1	6	7.53	7.93	7615360
0	0	0	1	1	1	0	1	0	0	0	0	6	9	4	8	11	6	5	1	1	1	4	5	7.59	7.91	7625869
2	0	0	1	1	1	0	1	0	0	0	0	6	9	4	8	11	6	5	1	1	1	4	5	7.58	7.92	7642534
0	0	0	1	1	1	0	1	0	0	0	0	9	8	20	8	8	7	6	1	6	1	1	6	7.55	7.90	7656678
0	0	0	1	1	1	0	1	0	0	0	0	16	8	4	7	9	9	2	1	2	1	1	6	7.52	7.90	7687487
0	0	0	1	1	1	0	1	0	0	0	0	16	8	4	8	9	9	2	1	2	1	1	6	7.52	7.90	7691766
0	0	0	1	1	1	0	1	0	0	0	0	10	8	23	8	8	7	6	1	4	1	1	6	7.54	7.90	7719151
0	0	0	1	1	1	0	1	0	0	0	0	16	8	18	2	9	9	2	1	2	1	1	6	7.49	7.89	7857791
0	0	0	1	1	1	0	1	0	0	0	0	16	8	18	9	9	9	2	1	2	1	1	6	7.47	7.89	7887744
0	0	0	1	1	1	0	1	0	0	0	0	7	8	10	9	10	26	5	1	6	1	5	7	7.46	7.90	7998142
0	0	0	1	1	1	0	1	0	0	0	0	19	9	18	9	9	13	2	1	2	2	1	6	7.43	7.89	8117098
0	0	0	1	1	1	0	1	0	0	0	0	16	8	18	9	9	23	2	1	2	1	1	6	7.42	7.89	8175293
0	0	0	1	1	1	0	1	0	0	0	0	19	8	22	9	10	25	5	1	6	1	1	6	7.40	7.89	8398656
0	0	0	1	1	1	0	1	0	0	0	0	19	8	22	9	10	29	5	1	6	1	1	6	7.38	7.89	8480813
0	0	0	1	1	1	1	1	0	0	0	0	2	9	10	2	7	5	6	1	6	1	4	7	7.65	7.87	8539733
0	0	0	1	1	1	1	1	0	0	0	0	2	9	11	2	9	4	6	1	6	1	1	7	7.61	7.87	8659545
0	0	0	1	1	1	1	1	0	0	0	0	2	9	10	2	9	5	6	1	6	1	1	7	7.59	7.87	8666391
0	0	0	1	1	1	1	1	0	0	0	0	5	9	11	2	9	4	6	1	6	1	1	7	7.59	7.86	8723730
0	0	3	1	1	1	1	1	0	0	0	0	5	9	11	2	9	4	6	1	6	1	1	7	7.58	7.86	8742667
0	0	0	1	1	1	1	1	0	0	0	0	7	8	4	9	10	8	5	1	1	1	5	7	7.50	7.86	8763097
0	0	0	1	1	1	0	1	0	0	0	0	12	11	29	10	11	30	5	1	7	1	1	7	7.33	7.88	8764083

0	0	0	1	1	1	1	1	0	0	0	0	3	9	11	8	10	18	6	1	6	1	1	7	7.44	7.85	9057492
0	0	0	1	1	1	1	1	0	0	0	0	7	8	10	9	10	26	5	1	6	1	5	7	7.39	7.85	9214959
0	0	0	1	1	1	0	1	0	0	0	0	19	12	18	26	20	22	5	4	7	1	3	4	7.32	7.89	9320353
0	0	0	1	1	1	0	1	1	0	0	0	18	12	5	8	11	20	5	4	5	1	2	1	7.34	7.86	9338639
0	0	0	1	1	1	1	1	1	0	0	0	2	9	10	2	7	5	6	1	6	1	4	7	7.56	7.84	9445484
0	0	0	1	1	1	1	1	0	0	0	0	19	8	22	9	10	26	5	1	6	1	1	7	7.35	7.84	9636013
0	0	0	1	1	1	0	1	1	0	0	0	19	13	18	8	11	21	4	4	6	1	2	4	7.31	7.85	9641593
0	0	0	1	1	1	1	1	0	0	0	0	19	13	18	24	11	22	5	4	6	1	1	4	7.32	7.84	10041662
0	0	0	1	1	1	1	1	1	0	0	0	16	8	18	3	10	9	5	1	6	1	1	6	7.38	7.82	10047967
0	0	0	1	1	1	1	1	0	0	0	0	19	13	18	26	11	22	5	4	7	1	1	4	7.32	7.84	10050220
4	0	0	1	1	1	0	1	1	1	0	0	19	16	21	9	15	26	7	7	3	1	1	6	7.30	7.86	10369360
0	0	0	1	1	1	0	1	1	0	0	0	19	13	18	8	23	21	4	4	6	1	2	4	7.26	7.87	10401543
4	0	0	1	1	1	1	1	1	0	0	0	19	10	8	9	10	21	6	6	6	1	1	6	7.33	7.81	10446724
3	0	0	1	1	1	1	1	1	0	0	0	19	10	8	9	10	28	6	6	6	1	4	6	7.31	7.81	10582166
2	0	0	1	1	1	1	1	1	0	1	0	15	10	17	5	11	19	3	2	5	1	1	6	7.45	7.80	10648680
0	0	0	1	1	1	1	1	0	0	0	0	12	13	18	26	23	22	5	4	7	1	1	4	7.27	7.85	10660405
0	0	0	1	1	1	0	1	1	0	0	0	19	13	18	8	28	21	4	4	6	1	2	4	7.23	7.87	10718189
2	0	0	1	1	1	1	1	1	0	1	0	15	10	17	5	10	19	7	5	5	1	1	6	7.39	7.80	10741485
2	0	0	1	1	1	1	1	1	0	1	0	15	10	17	5	11	19	7	5	5	1	1	6	7.38	7.80	10804815
0	0	0	1	1	1	1	1	1	0	0	0	14	13	18	26	11	22	5	4	7	1	1	4	7.27	7.81	10848996
0	0	0	1	1	1	1	1	0	0	0	0	19	13	18	24	27	22	5	4	6	1	1	4	7.25	7.85	11054929
2	0	0	1	1	1	1	1	1	0	1	0	15	10	17	5	11	19	7	5	5	1	6	6	7.33	7.79	11124520
2	0	0	1	1	1	1	1	1	0	0	0	19	11	14	9	24	21	5	7	7	1	1	7	7.26	7.83	11481837
1	0	0	1	1	1	1	1	1	0	0	0	17	16	19	7	18	26	5	4	6	2	1	4	7.25	7.82	11628404
1	0	0	1	1	1	1	1	1	0	0	0	7	16	14	9	24	26	5	7	1	1	1	7	7.24	7.83	11734523
0	0	0	1	1	1	0	1	1	0	0	0	19	28	18	8	28	21	4	4	6	1	2	4	7.22	7.87	11963378
3	0	0	1	1	1	1	1	1	0	0	0	17	16	12	7	29	26	6	4	6	2	1	7	7.20	7.83	12245841
3	0	0	1	1	1	1	1	1	0	0	0	17	16	19	7	29	26	6	4	6	2	1	7	7.20	7.83	12341690

Table F 37 New development unrestricted HIS 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	3.73	3.53	0
0	0	0	1	0	0	0	0	0	0	0	0	2	4	4	2	4	2	3	1	5	1	5	4	3.71	3.52	67848
0	0	0	1	0	0	0	0	0	0	0	0	3	4	4	2	4	2	3	1	4	1	5	4	3.70	3.52	89243
1	0	0	0	0	0	0	0	0	0	0	1	21	5	3	4	6	24	1	4	5	2	1	1	3.68	3.52	127009
0	0	0	1	0	0	0	0	0	0	0	0	5	4	5	2	5	2	4	2	5	1	4	4	3.68	3.52	132033
0	0	0	0	0	1	0	0	0	0	0	1	19	3	4	26	3	4	2	1	4	1	1	1	3.61	3.50	248637
0	0	0	0	0	1	0	0	0	0	0	1	20	4	8	26	5	5	2	1	4	1	1	1	3.60	3.50	323947
0	0	0	0	1	0	0	0	0	0	0	0	25	2	7	2	2	23	2	6	1	1	2	3	3.65	3.46	386733.6
1	0	0	0	1	0	0	0	0	0	0	0	27	2	2	11	2	21	1	3	5	1	3	2	3.64	3.46	420316
0	0	0	0	1	0	0	0	0	0	0	0	22	2	2	17	3	19	5	3	1	1	1	1	3.57	3.46	450063
1	0	0	0	1	0	0	0	0	0	0	0	27	2	14	17	3	2	6	1	2	1	1	2	3.56	3.45	483645
0	0	0	0	1	0	0	0	0	0	0	0	26	2	7	3	4	24	4	5	1	1	3	3	3.49	3.45	513392
1	0	0	0	1	0	0	0	0	0	0	0	21	2	7	4	4	25	4	6	1	1	3	3	3.48	3.45	546975
0	0	0	0	1	0	0	0	0	0	0	0	27	2	2	16	5	26	1	4	4	2	1	2	3.44	3.45	576721
0	0	0	0	1	1	0	0	0	0	0	0	20	2	7	2	3	2	3	3	7	1	1	6	3.51	3.44	608991
0	0	0	0	1	1	0	0	0	0	0	0	22	2	5	2	4	2	2	4	3	1	2	1	3.43	3.44	644934
0	0	0	0	1	0	0	0	0	0	0	0	26	3	5	16	5	17	4	4	3	1	3	1	3.37	3.45	659734
0	0	0	0	1	1	0	0	0	0	0	0	23	2	3	15	5	2	2	4	2	1	1	1	3.39	3.44	680878
1	0	1	0	1	0	0	0	0	0	0	0	20	4	3	13	4	16	5	6	5	1	3	4	3.36	3.44	737997
0	0	1	0	1	0	0	0	0	0	0	0	26	4	5	11	5	11	4	4	5	1	3	4	3.32	3.44	767744
0	0	0	0	1	1	0	0	0	0	0	0	20	4	4	26	5	2	2	1	4	1	1	1	3.27	3.42	860596
0	0	0	0	1	1	0	0	0	0	0	1	20	4	4	26	5	2	2	1	4	1	1	1	3.23	3.41	950305
0	0	0	0	1	0	0	0	0	0	1	0	10	3	7	2	3	2	6	1	5	2	1	1	3.48	3.40	1028219
1	0	0	0	1	0	0	0	0	0	1	0	15	2	4	25	4	28	5	1	3	1	1	1	3.46	3.40	1042119
0	0	0	0	1	0	0	0	0	0	1	0	21	3	7	2	4	2	6	1	5	1	1	1	3.41	3.39	1091549
1	0	0	0	1	1	0	0	0	0	0	1	9	5	3	26	5	6	2	5	4	3	3	1	3.16	3.41	1135364
0	0	1	0	1	0	0	0	0	0	1	0	21	3	3	2	2	24	1	3	6	1	1	1	3.38	3.40	1146023
0	0	0	0	1	0	0	0	0	0	1	0	23	2	3	14	5	19	3	2	5	2	1	1	3.35	3.40	1149933
0	0	0	0	1	0	0	0	0	0	1	0	22	2	2	16	4	19	6	3	7	1	1	1	3.31	3.40	1164671
0	0	0	0	1	0	0	0	0	0	1	0	24	2	2	16	5	17	5	3	6	1	1	1	3.24	3.40	1228000
1	0	0	0	1	0	0	0	0	0	1	0	22	2	2	16	5	18	5	3	6	1	1	1	3.23	3.39	1261583
0	0	0	0	1	0	0	0	0	0	1	0	22	3	2	16	5	18	5	3	7	1	1	1	3.18	3.39	1311013

0	0	0	0	1	0	0	0	0	0	1	0	22	3	6	15	6	23	6	3	7	1	1	1	3.15	3.39	1374342
1	0	0	0	1	0	0	0	0	0	1	0	21	4	5	26	5	23	3	3	5	1	1	1	3.11	3.38	1427608
1	0	0	0	1	0	0	0	0	0	1	0	21	5	5	26	5	23	3	3	6	1	1	1	3.08	3.38	1510621
0	0	0	0	1	1	0	0	0	0	1	1	24	4	6	3	4	3	7	3	5	1	1	1	3.07	3.36	1589897
1	0	0	0	1	0	0	0	0	0	1	0	22	6	5	27	6	24	3	4	7	1	1	1	3.03	3.38	1735030
1	0	0	0	1	1	0	0	0	0	1	1	24	4	5	2	4	15	2	3	5	1	1	1	3.04	3.35	1856257
1	0	0	0	1	1	0	0	0	0	1	0	8	5	4	4	6	12	1	3	4	2	1	1	2.98	3.36	1897191
2	0	0	0	1	1	0	0	0	0	1	1	7	4	3	4	6	11	1	3	4	3	1	1	2.98	3.35	1903238
1	0	0	0	1	1	0	0	0	0	1	1	9	5	4	5	6	9	1	4	4	3	1	1	2.92	3.35	2003350
0	0	0	0	1	1	0	0	0	0	1	1	15	4	6	4	7	2	2	4	3	1	2	2	2.91	3.36	2285744
0	0	0	0	1	1	0	0	0	0	1	0	22	5	6	16	6	15	4	5	6	1	2	1	2.88	3.37	2494624
1	0	0	0	1	1	0	0	0	0	1	1	9	5	13	26	5	9	1	5	4	4	2	1	2.85	3.35	2527200
1	0	0	0	1	1	1	0	0	0	1	1	23	3	5	29	4	14	7	2	1	1	1	1	3.22	3.31	2876585
3	0	0	0	1	1	0	0	0	0	1	1	9	5	4	13	5	12	1	5	4	1	2	6	2.83	3.35	2882193
1	0	0	0	1	1	1	0	0	0	1	1	23	3	5	29	4	14	7	2	4	1	1	1	3.18	3.31	2887737
3	0	0	0	1	1	1	0	0	0	1	0	23	3	4	29	4	23	7	3	5	1	1	1	3.12	3.32	3114421
1	0	0	0	1	1	1	0	0	0	1	1	23	3	4	29	4	23	7	3	5	1	1	1	3.07	3.31	3140682
2	0	0	0	1	1	0	0	1	0	1	1	9	5	5	26	5	12	1	2	5	4	2	1	2.96	3.32	3188124
3	0	0	0	1	1	0	0	0	0	1	1	9	5	3	26	5	12	1	5	4	3	3	6	2.78	3.35	3254376
1	0	0	0	1	1	1	0	0	0	1	1	23	3	5	29	4	10	7	6	4	1	3	1	2.92	3.31	3889604
0	0	0	0	1	1	0	0	0	0	1	1	15	14	9	2	6	27	7	4	3	1	3	3	2.74	3.35	4062864
0	0	0	0	1	1	0	0	0	1	1	1	15	12	9	2	6	27	4	4	4	1	3	3	2.71	3.34	4075238
1	0	0	0	1	1	1	0	0	1	1	1	23	3	5	29	4	14	7	6	4	1	3	1	2.91	3.31	4215587
1	0	0	0	1	1	1	0	0	0	1	1	23	18	5	29	4	14	7	6	4	1	3	1	2.82	3.30	5216949
1	0	0	0	1	1	1	0	0	0	1	1	23	18	5	29	4	14	7	6	4	1	3	6	2.79	3.30	5566394
2	0	0	0	1	0	1	0	1	0	1	0	12	26	4	10	6	12	1	6	1	3	2	1	2.90	3.27	6093444
1	0	0	0	1	0	0	1	0	0	0	0	22	2	7	17	3	26	4	6	2	1	3	3	3.31	3.24	6192621
0	0	0	0	1	0	0	1	0	0	0	0	21	3	2	15	3	24	7	4	7	1	2	2	3.26	3.24	6242051
0	0	0	0	1	0	0	1	0	0	0	0	27	3	17	16	4	23	1	1	1	1	1	1	3.22	3.24	6305381
0	0	0	0	1	0	0	1	0	0	0	0	22	4	2	26	4	3	5	2	4	1	3	1	3.20	3.24	6388393
0	0	0	0	1	0	0	1	0	0	0	1	22	4	2	26	4	3	5	2	4	1	3	1	3.16	3.23	6478102
0	0	0	0	1	1	0	1	0	0	0	0	8	5	5	28	4	6	1	4	4	1	1	1	3.11	3.22	6685105
0	0	0	0	1	1	0	1	0	0	1	0	25	2	7	3	3	2	6	1	5	1	1	2	3.21	3.20	6813111
0	0	0	0	1	1	0	1	0	0	1	0	22	2	5	2	4	2	2	1	1	1	1	2	3.16	3.20	6849054

0	0	0	0	1	1	0	1	0	0	1	0	15	2	5	2	3	2	5	2	3	1	1	2	3.12	3.20	6863793
0	0	0	0	1	0	0	1	0	0	1	0	15	3	7	2	4	2	6	2	5	2	1	3	3.07	3.21	6878592
0	0	0	0	1	1	0	1	0	0	1	0	22	2	5	2	4	2	2	2	3	1	1	2	3.07	3.20	6927122
0	0	1	0	1	0	0	1	0	0	1	0	21	3	3	15	4	24	1	3	6	1	1	2	3.04	3.21	6981657
0	0	0	0	1	1	0	1	0	0	1	0	22	4	5	2	3	2	1	2	3	1	1	1	3.04	3.19	7029818
0	0	0	0	1	0	0	1	0	0	1	1	21	3	5	15	4	24	1	3	4	1	1	2	2.99	3.20	7116258
0	0	0	0	1	1	0	1	0	0	1	0	22	4	5	27	5	2	5	2	4	1	1	1	2.98	3.19	7156476
0	0	0	0	1	1	0	1	0	0	1	0	22	4	5	27	5	2	1	4	4	1	1	1	2.94	3.19	7312611
1	0	0	0	1	1	0	1	0	0	1	0	22	4	6	16	4	16	2	4	4	1	1	2	2.92	3.19	7584106
0	0	0	0	1	1	0	1	0	0	1	0	27	4	6	16	4	16	2	3	4	1	2	2	2.86	3.19	7858333
4	0	0	0	1	0	1	1	0	0	1	0	22	2	15	28	3	21	7	2	4	1	1	1	3.14	3.16	8083397
3	0	0	0	1	0	1	1	0	0	1	0	22	2	5	28	4	20	7	2	3	1	1	1	3.09	3.16	8113144
0	0	0	0	1	0	1	1	0	0	1	0	22	4	5	25	4	9	5	2	4	1	1	1	3.02	3.16	8178422
1	0	0	0	1	1	0	1	0	0	1	0	24	4	5	2	4	16	2	4	4	3	3	2	2.84	3.20	8342166
0	0	0	0	1	1	1	1	0	0	1	0	22	4	5	26	4	10	5	2	4	1	1	1	2.94	3.14	8474278
0	0	0	0	1	1	1	1	0	0	1	0	22	4	5	26	4	10	5	4	4	1	1	1	2.90	3.14	8630413
0	0	0	0	1	1	1	1	0	0	1	0	22	4	4	26	4	10	5	2	4	1	2	1	2.87	3.14	8846461
0	0	0	0	1	0	1	1	1	0	1	0	19	5	2	13	6	16	7	7	1	5	1	3	2.93	3.12	9684181
1	0	0	0	1	1	1	1	0	0	1	0	22	4	5	16	4	16	2	3	4	1	6	2	2.83	3.15	10638545
2	0	1	0	1	0	1	1	0	0	1	0	9	26	5	27	4	12	1	5	1	3	2	4	2.91	3.12	10716940
1	0	0	0	1	1	1	1	0	0	1	1	22	4	5	16	4	16	2	3	4	1	6	2	2.77	3.14	10798143
0	0	0	0	1	0	1	1	1	0	1	0	19	28	2	13	6	16	7	7	1	5	1	3	2.94	3.08	11593471
2	0	1	0	1	0	1	1	1	0	1	0	12	26	5	10	6	12	1	6	1	3	2	4	2.86	3.09	11827417
1	0	1	0	1	0	1	1	1	0	1	0	12	26	5	10	6	12	1	6	1	3	3	4	2.83	3.09	12179711

Table F 38 New development unrestricted HIS 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.99	4.78	0
0	0	0	0	1	0	0	0	0	0	0	0	20	2	15	2	5	19	3	6	1	2	3	2	4.72	4.68	576721
0	0	0	0	1	0	0	0	0	0	0	0	5	2	16	2	2	29	1	3	1	2	2	1	4.95	4.70	386734
0	0	0	0	1	0	0	0	0	0	0	0	20	2	15	2	4	19	2	6	1	1	2	1	4.81	4.69	513392
2	0	0	0	1	0	0	0	0	0	0	0	4	2	20	2	5	28	3	3	1	1	3	2	4.72	4.68	643886.
1	0	0	0	1	0	0	0	0	0	0	0	27	2	20	2	6	11	1	2	1	1	3	1	4.66	4.68	673633
0	0	1	0	1	0	0	0	0	0	0	0	12	2	23	19	5	18	3	6	1	1	3	2	4.72	4.68	601719
0	0	0	0	1	0	0	0	0	0	0	0	6	2	15	2	3	19	2	3	1	1	1	1	4.89	4.69	450063
0	0	0	0	1	0	0	0	0	0	0	0	23	3	17	6	6	9	1	1	1	2	1	2	4.63	4.67	723063
0	0	0	0	1	0	0	0	0	0	0	0	22	2	15	2	6	19	3	6	5	1	6	2	4.67	4.68	640050
0	0	0	0	1	0	0	0	0	0	0	0	10	4	23	2	6	23	4	1	1	3	1	3	4.57	4.67	806076
0	0	0	0	0	0	0	0	0	0	0	1	27	6	10	22	3	22	4	1	4	2	1	1	4.96	4.77	89709
0	0	1	0	1	0	0	0	0	0	0	0	7	5	25	3	6	5	3	3	2	1	2	1	4.52	4.66	914086
1	0	0	0	1	0	0	0	0	0	0	0	26	2	15	17	4	27	5	1	2	5	2	1	4.80	4.68	546975
0	0	0	0	1	0	0	0	0	0	0	0	10	3	22	2	4	12	3	1	1	2	1	2	4.76	4.68	596405
1	0	0	0	1	0	0	0	0	0	0	0	23	3	14	19	3	26	6	3	2	6	1	2	4.84	4.68	566658
0	0	0	0	1	0	0	0	0	0	0	0	7	6	19	8	7	9	7	4	1	1	6	1	4.47	4.66	1035430
1	0	3	0	1	0	0	0	0	0	1	0	9	3	26	2	4	11	5	3	1	1	1	2	4.64	4.60	1356259
1	0	0	0	1	1	0	0	0	0	0	1	22	3	2	6	5	3	5	6	5	3	2	1	4.60	4.64	897746
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	5	7	6	4	2	1	1	1	4.41	4.60	1472093
0	0	0	0	0	1	0	0	0	0	0	0	23	3	2	6	4	4	5	6	5	3	1	1	4.93	4.76	131542
0	0	0	1	1	1	0	0	0	0	1	1	18	10	7	19	9	6	6	7	6	1	3	1	3.76	4.52	4050581
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	8	15	6	4	2	5	1	1	4.28	4.59	1662081
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	6	7	6	4	2	1	1	1	4.34	4.60	1535422
0	0	0	0	1	0	0	0	0	0	1	0	7	6	15	8	7	9	3	5	4	1	1	1	4.19	4.59	1842844

0	0	0	0	0	1	0	0	0	0	0	1	21	2	3	8	4	4	5	6	4	3	2	1	4.87	4.74	234944
0	0	0	0	0	1	0	0	0	0	0	0	21	2	3	7	3	4	4	5	3	2	2	1	4.91	4.76	145235
0	0	0	1	1	0	0	1	0	0	1	0	5	6	12	2	6	13	7	4	1	1	1	4	4.10	4.39	7542456
0	0	0	0	1	1	0	0	0	0	0	1	22	3	2	16	7	3	5	6	5	3	2	1	4.52	4.64	990822
0	0	0	0	1	1	0	0	0	0	0	1	22	3	2	6	6	3	5	6	4	1	2	1	4.55	4.64	923775
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	7	23	5	4	1	1	1	1	4.30	4.59	1598751
0	4	1	0	1	1	1	1	1	1	0	0	25	2	2	11	4	6	1	1	6	1	7	2	4.40	4.32	9278330
1	0	0	1	1	1	0	1	0	0	1	0	5	6	12	18	6	4	7	4	1	4	2	3	3.95	4.37	8298850
4	0	0	1	1	1	1	1	1	0	1	0	9	10	7	19	8	7	1	7	3	5	2	1	3.86	4.28	11298089
0	0	0	1	1	1	1	0	1	0	1	1	19	11	27	19	9	8	6	4	5	1	4	1	3.71	4.44	6740447
0	0	0	0	1	1	0	0	0	0	0	1	24	5	2	6	6	3	5	4	4	1	2	1	4.46	4.63	1089800
0	0	0	1	1	1	0	1	0	0	1	0	8	9	5	3	5	7	6	5	1	6	3	1	3.88	4.36	8880688
0	0	0	0	1	0	0	0	0	0	1	0	5	5	15	8	7	8	3	5	4	1	1	1	4.23	4.59	1759831
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	6	6	6	3	2	1	1	1	4.44	4.60	1457355
4	0	0	0	1	1	1	1	0	0	1	1	19	4	3	19	9	8	6	7	4	1	3	5	3.87	4.31	10388145
1	0	0	1	1	1	0	1	0	0	1	1	8	9	5	29	8	7	6	6	4	6	3	2	3.80	4.35	9453177
0	0	0	0	1	0	0	0	0	0	1	0	5	4	14	6	5	7	6	3	2	1	1	4	4.52	4.60	1394025
1	0	0	0	1	0	0	0	0	0	0	0	6	4	17	3	6	8	6	2	1	1	6	4	4.56	4.66	839658
0	0	0	1	1	1	0	1	0	0	1	1	8	9	4	8	9	7	6	5	4	5	2	4	3.84	4.35	9055206
1	0	0	1	1	1	0	0	0	0	1	1	4	9	12	6	8	8	1	5	4	1	2	1	3.89	4.52	3142760
4	0	0	1	1	1	1	1	1	0	1	0	18	10	5	2	8	7	1	7	3	5	3	1	3.81	4.28	11776392
0	0	0	1	1	1	0	0	0	0	1	1	10	8	7	3	9	7	6	6	4	1	2	1	3.86	4.52	3194092
0	0	0	1	1	1	1	0	1	0	1	1	19	8	28	19	9	7	6	3	5	1	3	1	3.90	4.44	6020619
3	0	0	1	1	1	0	1	0	0	1	1	8	9	5	22	8	8	6	4	4	5	1	1	3.95	4.35	8513152
0	4	0	0	1	1	1	1	1	1	0	0	25	2	2	11	4	2	1	1	6	1	7	2	4.42	4.32	9171176
0	0	0	1	1	1	1	0	0	0	1	1	18	10	7	7	9	8	6	5	6	1	5	1	3.67	4.47	5872746
1	4	0	0	1	1	0	1	1	0	0	1	19	3	2	6	4	3	1	5	4	1	6	1	4.35	4.36	8075666

0	0	0	1	1	1	0	0	0	0	1	1	9	8	2	3	9	7	6	6	6	1	2	1	3.87	4.52	3111668
1	0	0	0	1	1	0	1	0	0	1	0	5	6	12	28	6	4	7	4	1	4	2	3	4.00	4.38	8098353
3	0	0	1	1	1	1	1	1	0	1	1	19	11	15	16	9	7	1	4	4	5	1	1	3.92	4.28	11191134
0	0	0	0	1	1	0	0	0	0	1	1	9	7	10	2	8	4	6	6	6	1	1	1	4.00	4.55	2405482
0	0	0	0	1	0	0	0	0	0	1	0	7	8	15	8	7	9	3	5	4	1	1	1	4.16	4.58	2008869
0	0	0	1	1	1	1	0	1	0	1	1	17	11	27	19	9	2	6	4	5	1	4	1	3.75	4.44	6574422
0	3	0	0	1	1	1	1	1	1	0	1	24	2	2	13	6	4	1	1	6	1	4	2	4.31	4.32	9348385
4	0	0	1	1	1	1	1	1	0	1	1	19	5	2	16	9	6	1	4	4	4	1	1	3.95	4.28	10528095
4	0	0	1	1	1	1	1	1	0	1	1	14	11	14	20	9	6	1	5	3	1	3	1	3.79	4.28	11946728
4	0	0	0	1	1	0	1	0	0	0	1	19	4	12	18	5	8	1	5	5	4	2	1	4.19	4.40	7030106
0	0	0	1	1	1	0	0	0	0	1	1	9	7	2	3	8	6	5	6	6	1	2	1	3.90	4.53	2944787
0	0	0	1	1	1	1	0	0	0	1	1	14	10	2	3	9	7	6	5	6	1	3	1	3.79	4.47	4909294
0	0	0	1	1	1	0	1	0	0	1	1	8	9	4	8	9	7	6	3	4	5	2	4	3.87	4.35	8899071
0	0	0	1	1	0	0	1	0	0	1	0	5	6	12	9	6	4	7	4	1	1	2	3	4.04	4.39	7958286
0	0	0	1	1	1	0	0	0	0	1	1	8	10	7	4	9	4	6	7	6	1	3	1	3.78	4.52	3731367
0	0	0	1	1	1	1	0	0	0	1	1	4	9	17	19	8	6	6	7	4	6	1	1	3.91	4.48	4179266
3	0	0	1	1	1	1	0	1	0	1	1	16	10	27	19	9	6	5	4	4	1	1	1	3.93	4.44	5491572
0	0	0	0	0	1	0	0	0	0	0	1	10	6	2	2	11	6	5	6	6	1	2	1	4.83	4.74	269765
0	0	0	1	1	0	0	1	0	0	1	0	5	6	12	2	6	13	7	3	1	1	1	3	4.13	4.39	7464389
2	0	0	0	1	1	1	1	0	0	1	1	8	5	3	19	8	8	6	7	6	5	1	5	3.93	4.31	9576346
4	0	0	0	1	1	0	1	0	0	0	1	19	4	11	18	5	8	1	6	4	5	2	1	4.21	4.40	7012696
1	0	0	0	1	1	0	0	0	0	0	1	14	3	2	2	4	3	5	6	5	1	2	1	4.68	4.64	834417
0	0	0	0	1	1	0	0	0	0	1	0	8	7	10	2	8	7	6	4	6	1	1	1	4.07	4.56	2213821
4	0	0	1	1	1	1	1	1	0	1	1	19	11	5	19	9	7	1	7	4	5	4	1	3.76	4.28	12492457
0	0	0	0	1	1	0	0	0	0	0	1	20	7	7	20	8	6	4	7	7	1	3	1	4.26	4.61	1523718
0	0	0	1	1	1	0	0	0	0	1	1	13	12	3	25	9	6	6	6	6	1	4	1	3.72	4.52	4388343
2	0	0	0	1	1	1	1	0	0	1	1	8	5	12	19	8	8	6	7	6	5	1	5	3.90	4.31	9699581

0	0	1	0	1	1	0	0	0	0	0	1	24	5	2	6	6	3	5	4	4	1	2	1	4.44	4.63	1114798
0	0	0	1	1	1	0	0	1	0	1	1	19	11	17	15	9	5	6	5	6	6	4	4	3.68	4.49	5599421
0	0	0	1	1	1	0	0	0	0	1	1	9	8	7	6	9	6	5	6	2	1	1	1	3.95	4.53	2771683
1	0	0	1	1	1	1	1	0	0	1	1	19	11	12	27	8	8	6	5	4	1	3	6	3.76	4.31	11380684
0	0	0	1	1	1	0	1	0	0	1	1	7	9	4	23	7	8	4	3	1	5	1	1	4.00	4.35	8229046
0	0	0	0	1	1	0	0	0	0	0	1	9	7	8	7	7	4	6	5	5	1	1	1	4.31	4.61	1425568
2	0	0	0	1	1	1	1	0	0	1	1	19	6	3	19	9	8	6	7	6	1	3	5	3.80	4.31	10494440
4	0	0	1	1	1	1	0	1	0	1	1	20	11	7	20	9	6	1	5	4	5	3	1	3.78	4.44	6273990
0	0	0	1	1	1	0	0	0	0	1	1	10	8	7	12	9	7	6	5	4	1	2	6	3.83	4.52	3503980
0	0	0	1	1	1	1	0	0	0	1	1	7	9	2	7	8	7	5	7	4	1	1	1	3.93	4.48	4007250
0	0	0	0	1	1	0	0	0	0	1	1	9	6	10	2	8	6	6	7	6	1	1	1	3.99	4.55	2441615
0	0	0	1	1	1	0	0	1	0	1	1	19	11	12	23	9	5	7	4	6	1	4	4	3.71	4.49	5487121
0	0	0	1	1	1	0	0	0	0	1	1	7	9	3	7	9	6	6	3	4	5	1	3	4.06	4.52	2674424
0	0	0	0	0	1	0	0	0	0	0	1	20	7	11	20	8	6	4	5	7	1	3	1	4.79	4.74	396718
0	0	0	0	1	1	0	0	0	0	0	1	22	3	2	6	5	3	5	6	4	1	2	1	4.61	4.64	860446
0	0	0	1	1	1	1	0	1	0	1	1	17	11	27	19	9	18	6	4	5	1	4	6	3.68	4.44	7252494
0	0	0	0	1	1	0	0	0	0	1	1	9	6	10	2	8	6	6	3	6	1	1	1	4.14	4.54	2129345
0	0	0	1	1	1	1	0	0	0	1	1	14	10	16	2	9	7	6	5	6	1	3	1	3.76	4.47	5096714
3	0	0	1	1	1	0	0	0	0	1	1	8	9	5	22	8	8	6	4	4	5	1	1	3.97	4.52	2804176
0	0	0	0	1	1	0	0	0	0	0	0	7	7	2	19	6	6	6	5	5	1	1	1	4.40	4.64	1227734
3	0	0	1	1	1	0	0	0	0	1	1	8	9	5	14	8	8	6	4	2	5	1	1	4.00	4.52	2762509
4	0	0	1	1	1	1	1	1	0	1	1	17	5	2	16	9	6	1	1	4	6	1	1	4.14	4.28	10251103
2	0	0	0	1	1	1	1	0	0	1	1	19	11	12	19	4	7	6	4	3	4	1	1	4.07	4.32	9398889
3	4	0	0	1	1	0	1	1	0	0	1	24	2	2	17	4	3	1	1	5	1	3	1	4.40	4.36	8063536
0	0	0	1	1	1	0	1	0	0	1	0	8	9	4	8	9	7	6	4	1	5	2	3	3.91	4.37	8677763
0	0	0	1	1	1	1	0	0	0	1	1	8	9	2	8	9	6	6	7	5	1	2	1	3.84	4.48	4465308
1	4	0	0	1	1	0	1	1	0	0	1	19	3	2	6	3	3	1	5	4	1	6	1	4.42	4.36	8012337

0	0	0	1	1	0	0	1	0	0	1	0	5	6	12	9	6	4	7	3	1	1	2	3	4.06	4.38	7880218
3	0	0	1	1	1	0	1	0	0	1	1	8	9	5	22	8	8	6	4	4	5	1	5	3.92	4.35	8792708
0	0	0	1	1	1	1	0	0	0	1	1	14	10	16	13	9	28	6	6	6	1	3	1	3.72	4.47	5653174
0	0	0	0	1	1	0	0	0	0	1	1	24	4	9	2	8	4	6	6	6	1	1	1	4.11	4.56	2142752
0	0	0	0	1	1	0	0	0	0	0	1	9	5	9	2	7	6	5	7	6	1	1	1	4.32	4.62	1318032
4	3	0	0	1	1	0	1	1	0	0	1	18	4	2	16	4	6	1	1	4	5	1	1	4.30	4.36	8163484
1	0	1	0	1	0	0	0	0	0	1	0	9	3	26	2	5	11	5	3	1	1	1	2	4.56	4.60	1369593
3	0	0	0	1	1	0	0	0	0	1	1	5	3	5	22	8	8	6	4	4	5	1	1	4.19	4.55	2024302

Table F 39 New development unrestricted HIS 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	6.88	6.41	0
0	0	0	0	0	0	0	0	0	0	0	1	14	8	12	22	5	21	2	2	2	2	4	1	6.89	6.40	82274
0	0	0	0	0	0	0	0	0	0	0	1	14	8	11	23	6	23	3	3	3	2	4	1	6.88	6.40	85991
0	0	0	0	0	0	0	0	0	0	0	1	2	4	2	24	2	21	1	1	6	2	3	1	6.82	6.40	97144
1	0	0	0	0	0	0	0	0	0	0	1	3	3	2	22	2	21	3	2	7	6	3	1	6.80	6.39	134444
0	0	0	0	0	1	0	0	0	0	0	0	16	5	3	2	8	8	2	6	2	1	2	2	6.75	6.38	227392
0	0	0	0	0	1	0	0	0	0	0	0	4	20	7	20	7	9	1	3	1	1	2	1	6.72	6.38	302702
0	0	0	1	0	1	0	0	0	0	0	0	6	7	3	2	8	7	5	1	1	1	1	1	6.71	6.36	360281
0	0	0	0	1	0	0	0	0	0	0	0	17	2	19	18	3	16	1	1	4	1	6	2	6.86	6.32	450063
0	1	0	0	0	1	0	0	0	0	0	0	6	22	10	21	6	8	1	1	1	5	4	3	6.68	6.36	480802
0	0	0	0	1	0	0	0	0	0	0	1	2	2	4	23	2	19	2	1	6	6	4	1	6.83	6.31	483878
0	0	0	1	0	1	0	0	0	0	0	0	10	6	4	15	8	6	6	5	1	1	1	1	6.65	6.35	494641
0	0	0	0	1	0	0	0	0	0	0	0	16	2	19	18	4	16	1	1	5	1	6	2	6.79	6.31	513392
0	0	0	1	0	1	0	0	0	0	0	0	9	7	3	16	8	11	5	5	1	1	2	5	6.64	6.36	566529
0	0	0	0	1	0	0	0	0	0	0	0	18	2	18	14	5	2	1	5	1	6	1	1	6.69	6.31	576721

1	0	0	0	1	0	0	0	0	0	0	0	6	2	16	16	5	9	1	1	1	2	1	2	6.68	6.30	610304
0	0	0	0	1	0	0	0	0	0	0	0	18	2	18	14	6	2	1	6	1	7	2	1	6.60	6.30	640050
0	0	0	0	1	0	0	0	0	0	0	0	2	2	2	4	7	2	1	1	6	1	4	1	6.51	6.30	703380
2	0	0	0	1	0	0	0	0	0	0	0	2	4	21	21	4	11	1	1	1	1	1	1	6.70	6.28	746582
0	0	0	0	1	0	0	0	0	0	0	0	2	5	27	24	4	10	1	1	6	1	1	2	6.64	6.28	762430
0	0	0	0	1	0	0	0	0	0	0	0	2	2	3	5	8	2	1	2	6	1	5	1	6.46	6.30	766709
0	0	0	1	1	0	0	0	0	0	0	0	6	2	15	11	5	13	1	5	1	3	1	1	6.62	6.28	768660
1	0	0	0	1	0	0	0	0	0	0	0	3	4	4	4	5	2	2	3	3	4	1	1	6.59	6.28	776329
0	0	0	0	1	0	0	0	0	0	0	0	18	4	18	24	6	12	1	6	1	7	1	1	6.51	6.28	806076
0	0	0	0	1	0	0	0	0	0	0	0	2	2	29	5	9	2	1	3	5	1	5	1	6.43	6.29	830038
2	0	0	0	1	0	0	0	0	0	0	0	3	3	4	6	7	2	4	2	4	4	2	1	6.48	6.28	853557
0	0	0	0	1	0	0	0	0	0	0	1	16	2	4	23	8	19	1	1	5	2	5	1	6.42	6.28	860135
0	0	0	0	1	0	0	0	0	0	0	0	2	3	7	4	9	2	1	1	4	1	5	1	6.39	6.28	913051
0	0	0	0	1	0	0	0	0	0	0	0	2	4	24	18	8	8	1	5	1	1	1	1	6.38	6.27	932734
0	0	0	0	1	0	0	0	0	0	0	0	2	4	8	5	9	2	1	2	4	1	5	1	6.35	6.27	996063
0	0	0	0	1	0	0	0	0	0	0	0	2	5	24	19	8	9	1	6	1	1	1	1	6.31	6.26	1015747
0	0	0	0	1	0	0	0	0	0	1	0	5	2	15	2	5	22	1	1	1	2	1	1	6.75	6.23	1071865
0	0	0	0	1	0	0	0	0	0	0	0	6	6	14	14	8	2	3	3	2	3	5	2	6.27	6.26	1098759
0	0	0	0	1	0	0	0	0	0	1	0	6	2	16	2	6	22	1	1	2	3	1	1	6.65	6.23	1135194
0	0	0	1	1	0	0	0	0	0	0	0	6	5	16	13	7	13	1	5	1	3	1	1	6.30	6.24	1152914
0	0	0	0	1	0	0	0	0	0	0	0	3	6	22	22	9	12	1	1	1	2	2	1	6.24	6.26	1162088
0	0	0	1	1	0	0	0	0	0	0	0	10	5	19	2	7	11	1	4	1	1	5	3	6.28	6.24	1191425
0	0	0	0	1	1	0	0	0	0	0	0	17	4	9	2	8	7	1	6	1	3	1	1	6.23	6.24	1221744
0	0	0	0	1	1	0	0	0	0	0	0	16	5	3	2	8	8	2	6	2	1	2	2	6.20	6.24	1243139
0	0	0	0	1	1	0	0	0	0	0	0	16	6	3	2	8	8	2	6	2	1	2	2	6.15	6.23	1326151
1	0	0	0	1	0	0	0	0	0	1	0	2	4	27	23	6	2	4	1	3	1	1	2	6.56	6.20	1334802
0	0	0	0	1	0	0	0	0	0	1	0	8	4	11	2	7	8	1	1	1	3	1	4	6.48	6.20	1364549

0	0	0	0	1	0	0	0	0	0	1	0	2	4	22	24	8	16	1	1	3	1	1	1	6.42	6.20	1427878
0	0	0	1	1	0	0	0	0	0	0	0	9	7	3	10	8	4	6	5	1	1	1	3	6.12	6.22	1433617
0	0	0	0	1	1	0	0	0	0	0	0	16	6	10	5	9	8	1	2	1	2	1	5	6.08	6.22	1485330
0	0	0	0	1	0	0	0	0	0	1	0	2	5	21	24	8	16	2	1	3	1	1	3	6.35	6.19	1510891
0	0	0	0	1	0	0	0	0	0	1	0	2	6	19	5	8	25	1	1	1	1	1	1	6.30	6.18	1593903
0	0	0	1	1	1	0	0	0	0	0	0	10	7	3	11	8	4	6	3	1	1	2	1	6.05	6.20	1604526
0	0	0	1	1	1	0	0	0	0	0	0	10	7	3	15	9	4	5	5	1	1	2	4	6.02	6.20	1684971
0	0	0	0	1	1	0	0	0	0	1	0	17	5	10	21	6	7	1	1	1	3	1	5	6.36	6.16	1686935
0	0	0	0	1	1	0	0	0	0	0	0	16	8	9	19	10	10	2	5	4	5	1	5	6.00	6.22	1742070
0	0	0	1	1	0	0	0	0	0	1	1	2	6	25	2	8	12	1	1	6	1	1	1	6.25	6.15	1758895
0	0	0	1	1	1	0	0	0	0	0	0	10	7	3	16	8	11	5	5	1	1	2	5	5.99	6.20	1769695
0	0	0	1	1	0	0	0	0	0	1	1	2	6	24	9	8	12	4	1	6	2	1	1	6.23	6.15	1788848
0	0	0	1	1	0	0	0	0	0	1	0	6	5	16	12	6	12	1	5	2	3	1	1	6.14	6.16	1892720
0	0	0	1	1	0	0	0	0	0	1	0	6	6	16	2	6	13	1	5	2	3	1	5	6.11	6.15	1932943
0	0	0	1	1	0	0	0	0	0	1	0	6	5	16	13	7	13	1	5	2	3	1	1	6.05	6.15	1960328
0	0	0	0	1	0	0	0	0	0	1	0	3	5	19	5	9	25	1	6	4	1	1	1	5.94	6.17	1964557
0	0	0	1	1	0	0	0	0	0	1	0	10	5	20	2	7	11	1	5	1	1	1	3	6.03	6.15	1998839
0	0	0	0	1	0	0	0	0	0	1	0	10	6	28	3	9	10	1	6	1	4	1	1	5.89	6.17	2047570
0	0	0	1	1	0	0	0	0	0	1	0	3	5	14	2	9	22	1	6	4	1	1	1	5.93	6.16	2053800
0	0	0	0	1	1	0	0	0	0	1	0	17	4	9	2	8	7	1	6	1	3	1	1	5.90	6.15	2107225
0	0	0	0	1	0	0	0	0	0	1	0	3	7	14	2	9	22	1	6	4	1	1	1	5.85	6.16	2130582
0	0	0	0	1	1	0	0	0	0	1	0	9	5	2	2	9	7	1	6	1	4	1	6	5.84	6.15	2157717
0	0	0	1	1	0	0	0	0	0	1	0	3	7	14	2	9	22	1	6	4	1	1	1	5.84	6.15	2219825
0	0	0	1	1	1	0	0	0	0	1	0	11	5	7	3	9	11	1	2	1	5	1	6	6.04	6.12	2260750
0	0	0	0	1	1	0	0	0	0	1	0	17	5	10	2	9	7	1	6	1	3	1	1	5.79	6.14	2267260
0	0	0	1	1	1	0	0	0	0	1	0	11	5	6	3	9	11	1	3	1	1	1	6	5.99	6.11	2325125
0	0	0	1	1	1	0	0	0	0	1	0	9	5	2	2	9	7	1	6	1	4	1	6	5.76	6.12	2375330

0	0	0	1	1	1	0	0	0	0	1	0	4	6	12	3	9	11	1	6	1	4	1	6	5.70	6.11	2574732
0	0	0	1	1	1	0	0	0	0	1	0	11	5	11	2	9	12	1	6	1	4	1	6	5.68	6.11	2644051
0	0	0	1	1	1	0	0	0	0	1	0	10	6	9	2	9	11	1	6	1	3	1	6	5.63	6.10	2657744
0	0	0	1	1	1	0	0	0	0	1	1	4	7	6	24	9	13	1	6	5	2	1	2	5.60	6.09	2869840
0	0	0	1	1	1	0	0	0	0	1	1	17	7	12	3	9	13	1	3	4	2	1	2	5.85	6.08	2902353
0	0	0	1	1	1	0	0	0	0	1	1	17	7	14	13	9	13	1	3	4	2	1	2	5.83	6.08	2972529
0	0	0	1	1	1	0	0	0	0	1	1	17	7	18	5	9	6	1	6	4	2	1	1	5.58	6.08	3013607
0	0	0	1	1	1	0	0	0	0	1	1	17	6	13	2	11	13	1	6	4	1	1	1	5.55	6.08	3119726
0	0	0	1	1	1	0	0	0	0	1	1	17	7	18	5	9	13	1	6	4	1	1	1	5.54	6.08	3157381
0	0	0	1	1	1	0	0	0	0	1	1	17	7	14	3	11	13	1	6	4	2	1	2	5.49	6.07	3290600
0	0	0	1	1	1	0	0	0	0	1	1	9	11	11	5	9	13	6	6	4	4	1	2	5.47	6.06	3292311
0	0	0	1	1	1	0	0	0	0	1	1	16	11	17	5	10	13	1	6	4	2	1	2	5.42	6.06	3587562
0	0	0	1	1	1	0	0	0	0	1	1	17	11	17	5	10	13	1	6	4	2	1	5	5.38	6.06	3818624
0	0	0	1	1	1	0	0	0	0	1	1	17	12	25	5	9	13	2	6	5	2	2	2	5.36	6.05	4127777
0	0	0	1	1	1	0	0	0	0	1	0	8	10	9	4	9	13	1	6	4	5	4	2	5.31	6.08	4154271
0	0	0	1	1	1	0	0	0	1	1	1	11	14	27	7	8	11	1	5	2	1	2	4	5.50	6.04	4253062
0	0	0	1	1	1	0	0	0	1	1	1	17	15	13	4	9	14	1	5	4	1	2	5	5.41	6.04	4462179
0	0	0	1	1	1	0	0	0	1	1	0	17	8	9	19	9	22	2	6	2	5	3	3	5.27	6.07	4475894
0	0	0	1	1	1	0	0	0	0	1	1	9	13	16	4	10	14	1	6	6	2	3	4	5.22	6.05	4525356
0	0	0	1	1	1	0	0	0	1	1	1	17	10	11	26	10	19	1	5	4	5	2	5	5.27	6.04	4583242
0	0	0	1	1	1	0	0	0	0	1	1	9	11	11	5	9	13	1	6	4	4	5	2	5.16	6.05	4835817
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0	0	0	1	1	1	0	0	0	1	1	1	14	15	9	29	9	22	4	6	2	4	3	3	5.20	6.04	5227899
0	0	0	1	1	1	0	0	0	1	1	1	14	15	9	19	9	22	4	6	2	5	3	3	5.17	6.04	5260946
0	0	0	1	1	1	0	0	0	0	1	1	9	13	16	4	10	11	2	6	3	2	5	5	5.07	6.05	5294228
0	0	0	1	1	1	0	0	0	0	1	1	9	13	16	4	10	14	2	6	6	2	5	4	5.03	6.04	5297109
0	0	0	1	1	1	0	0	0	1	1	1	17	13	15	5	9	13	1	6	3	4	4	6	5.09	6.03	5450782

0	0	0	1	1	1	0	0	0	1	1	1	17	13	24	19	9	13	1	5	6	5	4	5	5.06	6.03	5572956
0	0	0	1	1	1	0	0	0	1	1	0	14	11	9	9	9	22	1	6	1	5	6	1	4.98	6.06	5752537
0	0	0	1	1	1	1	0	0	1	1	1	17	15	13	26	9	19	1	5	4	1	2	5	5.37	6.00	5875830
0	0	0	1	1	1	1	0	0	1	1	1	17	14	13	7	9	13	1	6	6	3	2	6	5.22	5.99	5895347
0	0	0	1	1	1	0	0	0	1	1	1	17	11	9	18	9	22	3	6	2	5	6	3	4.95	6.04	6123382
0	0	0	1	1	1	1	0	0	1	1	1	23	14	13	7	9	29	1	6	6	3	2	6	5.19	5.99	6352344
0	0	0	1	1	1	1	0	0	1	1	1	17	13	15	5	9	13	1	6	3	1	4	6	5.16	5.99	6440088
0	0	0	1	1	1	0	0	0	1	1	1	25	11	9	11	9	22	6	6	5	5	7	1	4.92	6.04	6590986
0	0	0	1	1	1	1	0	0	1	1	1	17	13	15	5	9	13	1	6	3	4	4	6	5.07	5.99	6667599
0	0	0	1	1	1	0	0	0	1	1	1	17	17	9	7	9	22	3	6	2	5	6	6	4.90	6.04	6784056
0	0	0	1	1	1	0	0	0	1	1	1	25	11	9	11	9	22	6	6	5	5	7	6	4.86	6.04	6940431
0	0	0	1	1	1	0	1	0	1	0	1	16	4	3	2	8	9	1	2	5	1	1	1	5.80	5.96	7455981
0	0	0	1	1	1	0	1	0	1	0	1	16	4	4	2	8	9	1	2	5	1	1	1	5.79	5.95	7469674
0	0	0	1	1	1	0	1	0	0	0	1	17	6	6	4	8	13	1	4	4	2	3	1	5.69	5.96	7665942
0	0	0	1	1	1	0	1	0	0	0	1	17	6	6	7	8	13	1	1	4	2	3	1	5.68	5.96	7678779
0	0	0	1	1	1	0	1	0	0	1	1	15	4	4	2	9	7	1	1	5	1	1	1	5.88	5.92	7860138
0	0	0	0	1	1	0	1	0	0	1	0	16	6	9	19	9	9	1	5	2	5	1	4	5.62	5.95	8008566
0	0	0	1	1	1	0	1	0	0	1	1	15	4	4	2	9	7	1	3	5	1	1	1	5.75	5.91	8016273
0	0	0	1	1	1	1	0	0	1	1	1	17	28	15	19	9	13	1	6	4	5	4	6	5.03	5.99	8052249
0	0	0	1	1	1	0	1	0	0	1	1	15	4	4	2	9	7	1	4	5	1	1	1	5.64	5.91	8094341
0	0	0	1	1	1	0	1	0	0	1	0	10	6	8	18	9	8	1	4	1	1	1	4	5.55	5.92	8203739
0	0	0	1	1	1	0	1	0	0	1	1	16	4	4	2	9	12	1	5	4	1	1	1	5.60	5.92	8292782
0	0	0	1	1	1	1	0	0	1	1	1	17	28	15	19	13	13	1	6	4	5	4	6	4.99	6.00	8305565
0	0	0	1	1	1	0	1	0	0	1	0	10	7	9	18	9	9	1	4	1	2	1	4	5.52	5.92	8320983
0	0	0	1	1	1	0	1	0	1	0	1	17	6	24	19	9	12	1	5	5	5	1	5	5.48	5.94	8711544
0	0	0	1	1	1	0	1	0	1	1	0	16	6	9	19	9	9	1	5	3	4	1	4	5.43	5.91	8781734
0	0	0	1	1	1	0	1	0	1	1	0	16	6	9	19	9	9	1	5	3	5	1	4	5.40	5.91	8857571

0	0	0	1	1	1	0	1	0	1	1	1	17	7	24	5	9	12	1	5	4	1	1	4	5.41	5.88	9165110
0	0	0	1	1	1	0	1	0	1	1	1	17	7	8	4	9	12	1	5	4	1	2	2	5.38	5.88	9187845
0	0	0	1	1	1	0	1	0	1	1	1	17	5	24	6	9	12	1	5	5	5	1	4	5.34	5.88	9310429
0	0	0	1	1	1	0	1	0	1	1	1	17	6	24	19	9	12	1	5	5	3	1	5	5.34	5.88	9367284
0	0	0	1	1	1	0	1	0	1	1	1	17	6	24	19	9	12	1	5	5	5	1	5	5.28	5.88	9518958
0	0	0	1	1	1	0	1	0	0	1	1	17	9	24	12	9	12	6	5	4	7	3	1	5.27	5.89	9817639
0	0	0	1	1	1	0	1	0	1	1	1	17	7	24	6	9	13	1	5	4	2	3	1	5.27	5.88	9827851
0	0	0	1	1	1	0	1	0	1	1	0	17	7	9	10	9	12	1	5	1	7	3	1	5.19	5.90	9908512
0	0	0	1	1	1	0	1	0	1	1	1	17	7	24	5	9	10	1	5	4	5	3	1	5.19	5.88	9989466
0	0	0	1	1	1	0	1	0	1	1	1	17	7	24	5	9	10	1	5	6	7	3	1	5.12	5.88	10148575
0	0	0	1	1	1	1	1	0	1	1	1	9	7	24	5	8	11	1	1	5	2	3	1	5.53	5.84	10456269
0	0	0	1	1	1	0	1	0	1	1	1	17	9	24	12	9	12	6	5	4	7	3	1	5.11	5.88	10493439
0	0	0	1	1	1	1	1	0	1	1	1	10	7	24	6	9	12	1	1	5	2	3	1	5.52	5.84	10565812
0	0	0	1	1	1	0	1	0	1	1	1	17	7	24	6	10	13	1	5	4	7	3	6	5.08	5.88	10619810
0	0	0	1	1	1	1	1	0	1	1	1	17	7	14	6	9	13	1	1	6	4	3	1	5.43	5.84	10754579
0	0	0	1	1	1	1	1	0	1	1	1	9	7	24	6	9	13	1	4	6	4	3	1	5.20	5.83	10954550
0	0	0	1	1	1	0	1	0	1	1	1	10	13	24	19	9	13	1	5	6	3	4	5	5.03	5.87	10980493
0	0	0	1	1	1	0	1	0	1	1	1	17	13	24	19	9	13	1	5	6	5	4	5	4.95	5.87	11281932

Table F 40 New development unrestricted CC 5

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	4.72	4.53	0
0	0	0	0	1	0	0	0	0	0	0	0	16	2	15	12	2	2	7	7	6	4	1	1	4.68	4.45	386734
0	0	0	0	1	0	0	0	0	0	0	0	4	2	7	7	4	2	4	7	5	1	1	1	4.54	4.44	513392
0	0	0	0	1	0	0	0	0	0	0	0	3	2	6	7	3	2	4	6	5	1	1	1	4.62	4.44	450063
0	0	0	0	1	0	0	0	0	0	0	0	25	2	24	21	5	22	1	1	4	1	5	4	4.46	4.44	576721
0	0	0	0	0	0	0	0	0	0	0	1	6	6	8	13	12	2	2	7	3	3	1	1	4.71	4.52	85991
0	0	0	0	1	0	0	0	0	0	0	0	11	3	28	18	6	24	4	3	5	1	1	1	4.35	4.42	723063
0	0	0	0	1	0	0	0	0	0	0	0	14	5	12	26	6	2	3	6	6	1	5	1	4.26	4.41	889088
0	0	0	0	0	0	0	0	0	0	0	1	2	4	10	10	2	2	4	3	5	1	2	1	4.67	4.52	93426
3	0	0	0	1	0	0	1	0	0	0	0	9	4	17	13	4	5	3	3	4	2	5	1	4.16	4.20	6489141
0	0	0	0	0	0	0	0	0	0	0	1	2	4	9	9	2	2	4	2	1	1	2	1	4.73	4.52	78556
0	0	1	0	1	0	0	0	0	0	0	0	16	2	15	12	2	2	7	7	6	4	1	2	4.68	4.45	411731
0	0	0	0	1	0	0	0	0	0	0	0	16	3	5	2	2	9	5	1	1	4	1	1	4.63	4.44	469746
0	0	0	0	1	0	0	0	0	0	0	0	12	4	27	18	6	8	3	3	6	1	1	1	4.30	4.42	806076
0	0	0	0	1	0	0	0	0	0	0	0	14	2	12	27	6	2	3	6	6	1	4	1	4.41	4.43	640050
0	0	0	0	1	0	0	0	0	0	1	0	17	5	16	3	4	13	5	1	1	1	1	1	4.40	4.36	1257574
0	0	0	0	1	0	0	0	0	0	1	0	12	5	2	8	6	2	5	4	1	2	1	1	4.04	4.35	1618435
0	0	0	0	1	0	0	0	0	0	1	0	12	5	19	7	8	2	5	4	1	1	1	1	3.99	4.35	1745093
0	0	0	0	1	0	0	0	0	0	0	1	16	4	11	26	7	2	5	1	6	3	5	1	4.24	4.40	966549
0	0	0	0	1	0	0	0	0	0	1	0	12	4	2	7	4	18	4	2	2	1	1	1	4.40	4.36	1252629
0	0	0	0	1	0	0	0	0	0	1	0	17	4	16	6	6	2	5	1	4	1	1	1	4.31	4.36	1301220
0	0	0	1	1	0	0	1	0	0	0	0	9	6	6	5	4	2	5	6	3	1	1	1	4.06	4.18	6784868
1	0	0	0	1	0	0	0	0	0	0	0	27	2	17	2	6	11	4	2	1	3	4	5	4.40	4.43	673633
1	0	0	0	1	0	0	0	0	0	1	0	2	4	6	6	3	2	6	2	3	1	1	1	4.48	4.36	1222882
0	0	0	0	1	0	0	0	0	0	1	0	12	4	2	8	5	8	3	4	1	1	1	1	4.15	4.35	1472093

1	0	0	0	1	0	0	0	0	0	0	1	14	5	12	26	7	2	5	1	4	1	5	2	4.19	4.40	1145598
0	0	0	1	1	0	0	0	0	0	1	0	11	5	29	10	7	8	5	4	4	1	2	1	3.87	4.32	2362275
3	0	0	0	1	0	0	0	0	0	0	1	23	5	9	17	5	21	1	1	4	1	2	1	4.27	4.39	1016215
0	0	0	1	1	0	0	0	1	1	1	1	11	15	19	8	11	3	4	4	7	4	4	1	3.51	4.26	5617718
0	0	0	0	1	0	0	0	0	0	1	0	11	7	11	2	7	7	5	4	3	1	1	1	3.96	4.34	1847789
0	0	0	0	1	0	0	0	0	0	1	0	11	3	27	6	5	18	4	3	3	1	1	1	4.28	4.36	1311013
0	0	0	0	1	1	0	0	0	0	0	1	2	2	3	6	4	6	6	3	6	2	7	1	4.39	4.40	796850
0	0	0	1	1	0	0	0	0	0	1	0	6	6	15	6	8	10	3	5	6	1	3	1	3.76	4.32	2848470
2	0	0	0	1	0	0	0	0	0	0	1	24	4	11	17	7	2	5	1	6	2	5	1	4.24	4.40	1033714
4	0	0	0	1	1	1	1	0	0	1	1	8	10	8	9	6	6	2	4	1	6	1	1	3.81	4.07	9426955
1	0	0	0	1	0	0	1	0	0	0	1	27	2	26	28	4	2	2	4	3	1	1	1	4.22	4.20	6341942
0	3	0	0	1	1	0	1	0	0	0	1	2	2	4	8	3	4	6	2	5	3	6	1	4.20	4.16	6884073
0	0	0	0	1	0	0	0	0	0	1	0	12	4	2	8	6	11	5	4	5	1	1	1	4.08	4.35	1535422
0	0	0	0	1	1	0	1	0	0	0	0	2	2	3	6	3	2	6	1	4	2	5	1	4.28	4.20	6263196
0	0	1	1	1	0	0	0	0	0	1	0	6	6	15	6	8	10	3	5	6	1	3	1	3.75	4.32	2873468
0	0	0	1	1	0	0	1	0	0	1	0	11	3	12	6	4	2	5	2	2	1	1	1	4.08	4.15	7156111
0	0	0	0	1	0	0	1	0	0	1	0	12	4	7	10	5	12	4	3	4	1	1	1	3.99	4.17	7103001
0	0	0	0	1	1	0	1	1	0	1	0	11	6	7	13	5	3	4	3	1	1	3	1	3.73	4.11	9125998
0	0	0	1	1	0	0	0	0	1	1	0	8	4	20	12	6	4	2	4	1	1	1	1	4.00	4.32	1903014
0	0	0	0	1	1	0	1	1	0	1	0	11	6	7	11	5	3	4	3	1	1	2	1	3.79	4.11	8740121
0	0	0	1	1	1	0	0	0	0	1	0	11	6	8	7	9	13	3	5	4	1	3	1	3.64	4.30	3421605
0	0	0	0	1	0	0	0	0	0	1	0	10	3	19	2	5	3	1	4	1	1	1	1	4.20	4.36	1389080
0	0	0	1	1	0	0	0	1	0	1	1	10	6	19	13	11	2	1	4	5	6	4	1	3.64	4.28	4460977
0	0	0	1	1	1	0	1	0	1	1	0	12	14	16	28	5	13	2	6	4	5	3	1	3.56	4.11	10272161
0	0	0	1	1	1	0	1	0	0	1	0	10	6	7	13	5	3	4	6	1	1	3	1	3.67	4.12	8740526
0	3	0	0	1	1	0	1	0	0	0	1	2	3	4	8	3	4	6	2	5	3	6	1	4.16	4.15	6967086
0	0	0	1	1	1	0	0	0	0	1	0	5	6	14	14	3	3	3	1	5	1	1	1	4.32	4.32	1735955

0	0	0	1	1	1	1	1	0	0	0	0	5	6	8	2	3	2	5	6	2	1	1	1	4.08	4.11	8012560
0	0	0	1	1	1	0	0	0	0	1	0	9	6	7	7	10	2	3	5	1	1	3	1	3.69	4.30	3202521
0	0	0	1	1	0	0	0	1	1	1	0	10	5	7	2	7	6	5	4	3	1	1	1	3.89	4.27	3024252
0	0	1	1	1	0	0	0	0	0	1	0	11	6	7	6	8	10	4	4	1	1	2	1	3.83	4.31	2516499
0	0	0	1	1	1	0	0	1	1	1	1	11	25	15	7	11	6	4	4	4	4	1	1	3.67	4.24	5625410
0	0	0	0	1	1	0	1	0	0	0	0	2	2	4	9	2	4	6	1	6	4	6	1	4.31	4.20	6254638
0	0	0	0	1	1	0	1	0	0	1	0	6	6	5	3	6	4	4	3	1	1	2	1	3.80	4.14	7890853
0	0	0	0	1	1	1	1	0	0	1	1	8	10	15	11	6	6	2	4	1	6	2	1	3.74	4.08	9774351
0	0	0	1	1	1	0	1	0	0	1	0	10	6	3	13	5	3	4	3	1	1	3	1	3.72	4.12	8451553
0	0	0	0	1	1	0	0	0	0	1	0	11	6	8	7	9	13	3	5	4	1	3	1	3.71	4.32	3139807
0	0	0	1	1	0	0	0	1	0	1	1	8	12	19	4	9	2	2	4	5	3	4	1	3.60	4.27	4751093
0	0	0	1	1	1	1	1	0	0	1	0	11	6	6	14	3	3	5	1	1	1	1	1	4.07	4.08	8680576
4	0	0	0	1	1	1	1	0	0	1	1	8	10	9	9	6	6	5	4	4	6	2	3	3.68	4.07	9977455
0	0	0	0	1	1	1	0	0	0	1	0	9	5	7	14	5	3	5	1	1	1	1	1	4.22	4.28	2717187
0	0	0	1	1	0	0	0	0	1	1	0	6	5	20	12	4	2	1	4	3	1	1	1	4.11	4.32	1793530
0	0	1	1	1	0	0	0	0	0	0	0	6	6	14	6	8	10	3	4	6	1	2	1	4.15	4.39	1294301
0	0	0	1	1	0	0	0	1	0	1	0	7	6	13	5	7	9	6	4	4	1	3	1	3.73	4.28	3629940
0	0	0	1	1	0	0	0	0	0	1	0	7	6	13	5	7	9	6	4	4	1	3	1	3.77	4.32	2724189
0	3	0	0	1	1	0	1	0	0	0	1	2	2	4	8	3	4	6	2	3	3	6	1	4.23	4.16	6876638
0	0	0	1	1	0	0	1	1	0	1	0	7	5	7	9	5	12	4	3	4	1	1	1	3.86	4.11	8296541
0	0	0	1	1	0	0	0	1	1	1	0	10	5	7	2	7	6	5	3	3	1	1	1	3.98	4.27	2946185
0	0	0	1	1	1	0	1	0	1	1	0	12	14	16	28	5	10	2	6	4	5	3	1	3.56	4.11	10210544
0	0	0	1	1	0	0	0	0	1	1	1	8	15	19	12	11	2	3	4	7	3	4	1	3.56	4.30	4566012
0	0	0	0	1	1	0	1	0	0	1	0	12	5	7	10	5	10	4	3	4	1	1	1	3.87	4.14	7509256
0	0	0	1	1	1	0	0	1	1	1	1	11	25	15	7	11	6	4	4	4	2	1	1	3.70	4.24	5473736
0	0	0	1	1	0	0	0	0	1	1	0	10	5	7	2	7	6	5	4	3	1	1	1	3.94	4.31	2118501
1	0	0	0	1	0	0	1	0	0	0	1	27	2	26	28	4	2	2	4	5	1	1	1	4.19	4.20	6349377

0	0	0	0	1	0	0	1	0	0	1	1	12	4	7	10	5	12	4	3	4	1	1	1	3.96	4.15	7192710
0	0	0	1	1	0	0	0	1	1	1	0	10	5	8	2	7	7	3	4	4	1	2	1	3.84	4.27	3364032
0	0	0	0	1	0	0	0	0	0	1	0	6	6	13	4	7	9	6	4	4	1	2	1	3.91	4.34	2150653
0	0	0	1	1	1	1	1	0	0	1	0	10	5	6	14	5	4	5	2	1	6	1	1	3.89	4.07	8801433
0	0	0	1	1	1	1	1	0	0	1	0	10	6	7	7	3	3	5	2	1	1	1	1	4.01	4.08	8720988
0	0	0	1	1	0	0	0	0	1	1	0	8	4	20	12	6	4	2	2	1	1	1	1	4.18	4.32	1746879
0	0	0	1	1	1	0	0	0	1	1	1	11	25	9	8	11	3	4	4	6	4	4	1	3.47	4.26	5745228
0	0	0	1	1	0	0	0	1	1	1	0	10	5	7	7	7	6	5	4	2	1	1	1	3.88	4.27	3045647
0	0	0	0	0	1	0	0	0	0	0	1	2	2	3	6	4	6	6	3	6	2	7	1	4.57	4.49	283458
0	0	0	0	1	1	0	1	1	0	1	0	11	6	7	13	5	19	4	3	1	1	3	1	3.71	4.11	9454625
0	0	0	1	1	1	1	1	0	0	0	0	5	6	8	2	4	2	5	6	2	1	1	1	4.01	4.11	8075889
0	0	0	1	1	1	0	0	1	1	1	1	13	13	19	8	11	30	4	4	6	4	4	1	3.39	4.24	6389104
0	0	0	0	1	0	0	0	0	0	0	1	14	5	3	3	6	3	3	1	6	1	1	2	4.19	4.40	1056121
0	0	0	0	1	1	0	1	0	0	1	0	10	5	6	13	4	2	4	1	1	1	1	1	4.10	4.15	7111785
0	0	0	0	1	1	0	0	0	0	0	0	2	5	3	6	4	4	6	3	6	1	1	1	4.32	4.40	907665
0	0	0	0	1	1	0	1	0	0	0	0	6	2	5	3	6	5	4	3	1	1	7	1	4.12	4.19	6542186
0	0	0	0	0	1	0	0	0	0	0	1	2	25	7	6	10	5	3	3	6	1	5	1	4.55	4.49	317690
0	0	0	0	1	1	1	0	0	0	1	0	9	5	7	14	7	3	5	1	1	1	1	1	4.15	4.28	2843846
0	0	0	1	1	0	0	0	0	0	1	0	5	5	15	5	8	10	2	5	6	1	2	1	3.87	4.33	2353907
0	0	3	0	1	1	0	1	0	0	1	0	10	5	6	14	5	3	5	3	1	6	1	1	3.91	4.14	7426781
0	0	0	1	1	1	0	0	0	0	1	0	5	2	4	13	2	3	3	1	4	1	1	1	4.58	4.35	1199368
0	0	0	0	1	1	0	1	0	0	0	0	5	5	6	3	6	5	4	3	1	1	7	1	4.02	4.18	6804917
0	0	0	1	1	1	0	0	0	0	1	1	11	25	9	8	11	3	4	4	6	4	4	1	3.55	4.28	5343036
0	0	0	0	1	1	1	1	0	0	1	1	8	10	15	6	6	6	2	4	3	6	2	1	3.72	4.08	9781786
0	0	0	1	1	1	0	0	0	0	1	0	11	6	8	7	10	7	3	6	5	1	4	1	3.58	4.30	3825643
0	0	0	1	1	1	0	0	1	0	1	0	9	6	7	7	10	2	3	5	1	1	3	1	3.65	4.27	4108272
0	0	0	1	1	1	1	1	0	0	1	0	10	5	6	14	5	23	1	2	1	6	1	1	3.86	4.07	9191678

0	0	0	0	1	0	0	0	0	0	1	0	10	3	19	2	7	3	1	4	1	1	1	1	4.10	4.36	1515739
0	0	0	1	1	0	0	0	0	1	1	0	8	4	20	3	6	4	1	4	1	1	1	6	4.01	4.32	1841455
0	0	0	0	0	1	0	0	0	0	0	0	20	2	3	6	4	6	6	3	6	2	7	1	4.64	4.51	186314

Table F 41 New Development unrestricted CC 25

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	7.06	6.59	0
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0	0	0	1	1	1	0	0	0	0	1	1	9	14	9	15	11	6	1	3	4	6	1	3	5.95	6.23	3375324
0	0	0	1	1	1	0	1	0	0	1	1	9	10	13	7	7	22	5	6	6	1	3	2	5.41	6.05	9791601
0	0	0	1	1	0	0	0	0	0	1	0	7	6	14	23	10	5	1	6	4	1	1	2	5.95	6.31	2375581
0	0	0	1	1	1	0	0	0	1	1	0	8	8	13	14	12	17	1	7	4	1	5	2	5.37	6.23	4927430
0	0	0	1	1	1	0	0	0	0	1	1	12	23	9	9	11	7	1	6	6	1	6	6	5.11	6.21	6562175
0	0	0	1	1	1	0	1	0	0	0	0	9	7	12	12	7	5	1	6	2	1	3	2	5.91	6.14	7376831
0	0	0	1	1	1	1	1	0	0	1	1	9	8	2	8	4	6	5	1	3	3	1	2	6.16	6.03	9004193
0	0	0	0	1	1	0	0	0	0	1	0	9	8	10	22	12	7	1	6	4	1	1	2	5.79	6.29	2706285
0	0	0	1	1	1	0	0	0	0	1	1	4	8	13	6	12	15	1	6	5	1	2	1	5.62	6.23	3518734
0	0	1	1	1	0	0	0	0	0	1	1	9	5	14	2	7	7	1	1	5	1	1	1	6.48	6.32	1783598
0	0	0	1	1	1	0	0	0	0	1	1	12	23	9	9	11	7	1	6	6	1	6	3	5.15	6.21	6352508
0	0	0	0	1	1	0	0	0	0	0	0	2	6	6	11	8	4	3	5	2	1	1	1	6.36	6.40	1285073
0	0	0	1	1	1	0	1	0	0	1	1	16	14	13	13	17	14	1	7	5	1	3	5	5.32	6.07	11052085
0	0	0	0	1	1	0	0	0	0	1	1	7	6	5	27	8	6	1	1	3	1	1	1	6.36	6.30	1893594
0	0	0	1	1	1	0	0	0	0	1	1	9	14	9	23	11	6	1	5	4	1	1	2	5.70	6.23	3495802
0	0	3	1	1	1	1	1	0	0	1	1	9	8	12	17	7	7	1	1	5	1	1	2	5.87	6.02	9472586
0	0	0	1	1	1	0	0	0	0	1	0	10	6	4	11	10	4	1	5	4	1	1	4	5.94	6.27	2469279
0	0	0	1	1	1	0	1	0	0	1	0	9	7	13	12	7	5	1	5	2	1	2	2	5.67	6.08	8583814
0	0	0	1	1	1	0	1	0	0	0	0	8	6	6	2	3	7	1	1	4	1	1	3	6.20	6.16	6935238
0	0	0	1	1	1	0	1	0	0	0	0	9	4	2	10	7	8	2	1	4	2	1	1	6.04	6.16	7043925
0	0	0	1	1	1	0	0	0	0	1	0	10	6	4	11	10	9	1	5	4	1	1	4	5.88	6.27	2571975
0	0	0	1	1	1	0	1	0	0	1	0	8	7	7	9	7	5	1	5	5	1	1	1	5.75	6.09	8081549
0	0	3	1	1	1	0	1	0	0	1	1	9	22	16	8	27	27	1	5	5	1	5	3	5.22	6.08	13037239

0	0	0	1	1	0	0	0	0	0	1	1	8	5	14	2	7	7	1	1	5	3	1	1	6.51	6.31	1737206
0	0	3	1	1	1	1	1	0	0	1	1	9	8	16	16	7	7	1	4	5	2	1	2	5.64	6.02	9757281
0	0	0	1	1	1	0	1	0	0	0	0	9	7	12	12	8	6	1	1	6	1	5	2	5.87	6.14	7460700

Table F 42 New development unrestricted CC 100

v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	v15	v16	v17	v18	v19	v20	v21	v22	v23	o1	o2	o3
0	0	0	0	0	0	0	0	0	0	0	0	28	6	22	13	22	13	1	1	6	3	6	1	8.60	8.40	0
0	0	0	0	1	0	0	0	0	0	0	0	2	3	4	6	10	2	2	3	5	3	5	1	8.28	8.24	976380
0	0	0	0	1	0	0	0	0	0	0	0	30	2	9	17	7	10	1	1	1	3	4	1	8.47	8.27	703380
0	0	0	0	1	0	0	0	0	0	0	0	30	2	23	9	2	18	3	1	5	3	4	1	8.64	8.31	386734
0	0	0	0	1	0	0	0	0	0	0	0	23	3	13	10	3	19	2	2	3	1	1	1	8.64	8.28	533075
0	0	0	0	1	0	0	0	0	0	0	0	20	4	9	17	7	9	1	1	2	2	1	2	8.45	8.24	869405
0	0	0	0	1	0	0	0	0	0	0	0	29	2	15	17	10	9	2	1	1	3	4	1	8.29	8.26	893367
0	0	0	0	1	0	0	0	0	0	0	0	29	2	15	17	5	9	2	1	1	3	4	1	8.60	8.28	576721
0	0	0	0	1	0	0	0	0	0	0	0	27	2	4	21	8	17	1	3	3	2	2	5	8.40	8.26	766709
0	0	0	0	1	0	0	0	0	0	0	0	24	2	17	19	9	14	1	2	5	1	5	1	8.34	8.26	830038
1	0	0	0	1	0	0	0	0	0	0	0	28	2	13	5	12	24	5	6	1	1	3	5	8.24	8.25	1053608
0	0	0	0	1	0	0	0	0	0	0	0	25	2	13	5	11	23	6	2	1	1	1	4	8.26	8.25	956696
0	0	0	0	1	0	0	0	0	0	0	0	29	2	11	16	6	9	1	1	1	3	4	1	8.54	8.27	640050
0	0	0	0	1	0	0	0	0	0	0	0	30	4	23	9	2	18	3	1	5	3	4	1	8.63	8.28	552759
0	0	0	0	1	0	0	0	0	0	0	0	25	8	14	6	11	23	5	2	1	1	1	5	8.06	8.19	1454772
0	0	0	0	1	0	0	0	0	0	0	0	30	4	23	9	8	18	3	1	5	3	1	1	8.38	8.23	932734
1	0	0	0	1	0	0	0	0	0	0	0	20	3	17	16	9	11	1	3	1	1	1	3	8.32	8.24	946633
1	0	0	0	1	0	0	0	0	0	1	0	9	6	20	19	10	8	1	1	1	1	1	3	8.23	8.12	1754144
1	0	0	0	1	0	0	0	0	0	1	0	3	5	20	18	9	12	1	2	1	1	1	4	8.34	8.12	1685870
0	0	0	0	1	0	0	0	0	0	0	0	25	7	13	5	11	23	6	2	1	1	1	4	8.11	8.20	1371759

0	0	0	0	1	1	0	1	0	0	1	0	28	13	12	11	10	27	4	7	1	1	6	2	6.98	7.83	11149285
0	0	0	0	1	0	0	0	0	0	1	0	22	6	16	20	9	23	1	2	1	1	1	2	8.31	8.11	1735300
1	0	0	0	1	1	0	1	0	0	1	0	2	13	12	11	10	25	3	7	1	5	1	2	7.22	7.84	9212407
1	0	0	0	1	0	0	0	0	0	1	0	3	4	20	14	6	5	1	1	5	1	1	4	8.57	8.16	1334802
0	0	0	0	1	1	0	0	0	0	0	0	19	5	5	10	7	2	3	6	3	2	4	3	8.41	8.20	1083960
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1	0	0	0	1	1	0	1	0	0	1	0	2	9	12	11	10	25	3	7	1	5	4	2	7.15	7.84	10037986
0	0	0	0	1	1	0	0	0	0	0	0	2	3	2	25	10	7	3	6	1	1	1	3	8.20	8.21	1169540
1	0	0	0	1	1	0	0	0	0	0	0	26	6	7	6	10	8	5	5	1	1	1	3	8.03	8.16	1541163
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0	0	0	0	1	1	0	0	0	0	1	0	22	11	5	9	13	12	2	7	1	1	1	1	7.36	8.02	3130952
0	0	0	0	1	0	0	0	0	0	1	0	26	7	12	5	10	2	2	1	6	1	1	5	8.19	8.12	1803574
0	0	0	0	1	1	0	0	0	0	0	0	26	7	7	5	10	8	4	4	1	1	1	3	7.99	8.16	1590593
0	0	0	0	1	1	0	0	0	0	0	0	13	5	6	15	6	3	4	4	3	2	3	2	8.46	8.20	1054863
0	0	0	0	1	0	0	0	0	0	1	0	2	4	22	17	8	11	1	1	1	1	1	4	8.43	8.15	1427878
0	0	0	0	0	1	0	0	0	0	0	0	11	15	7	20	9	6	1	1	1	1	1	1	8.54	8.36	241085
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0	0	0	0	1	1	0	0	0	0	0	0	2	7	2	28	10	8	3	4	1	1	1	3	8.03	8.17	1522129
0	0	0	0	0	1	0	0	0	0	0	0	2	3	2	25	10	7	3	6	1	1	1	3	8.55	8.37	193160
0	0	0	0	1	0	0	0	0	0	1	0	2	4	22	17	7	11	1	1	1	5	1	4	8.51	8.15	1364549
2	0	0	0	1	1	0	0	0	0	1	0	5	7	11	18	10	10	1	6	1	1	1	2	7.76	8.04	2639089
0	0	0	0	1	0	0	0	0	0	1	0	20	5	27	2	8	13	6	7	1	1	1	3	8.08	8.11	1979296
0	0	0	0	1	1	0	0	0	0	0	0	19	4	4	18	9	4	1	3	1	1	1	2	8.28	8.20	1154991
0	0	0	0	1	0	0	0	0	0	1	0	20	6	4	16	8	23	1	2	1	1	1	4	8.37	8.12	1671971
0	0	0	0	1	1	0	0	0	0	1	0	28	13	12	11	23	27	4	7	1	2	6	2	6.99	7.99	6263589
0	0	0	0	1	1	0	0	0	0	1	0	28	13	12	11	13	20	4	7	1	2	6	2	7.07	7.98	5486522

1	0	0	0	1	0	0	0	0	0	1	0	5	3	11	18	9	10	1	1	1	1	1	4	8.37	8.16	1441777
0	0	0	0	1	1	0	0	0	0	1	0	2	10	3	10	13	13	1	7	1	4	1	1	7.39	8.03	3041093
0	0	0	0	1	0	0	0	0	0	1	0	15	5	27	10	11	13	6	7	1	1	1	3	7.83	8.10	2169283
0	0	0	0	1	1	0	0	0	0	0	0	8	10	8	6	10	8	6	1	1	1	1	1	7.87	8.14	1853324
0	0	0	0	1	0	0	0	0	0	1	0	19	3	2	15	7	22	1	2	1	1	1	3	8.53	8.16	1359604
0	0	0	0	1	0	0	0	0	0	1	0	3	3	20	18	10	12	1	1	4	3	1	3	8.33	8.16	1471524
0	0	0	0	1	1	0	0	0	0	0	0	26	7	7	8	9	8	1	3	1	1	1	3	8.05	8.16	1527264
1	0	0	0	1	1	0	1	0	0	1	0	2	10	12	10	10	16	1	7	1	5	6	1	7.03	7.84	10707899
1	0	1	0	1	0	0	0	0	0	0	0	3	4	20	14	6	5	1	1	5	1	1	4	8.52	8.23	864656
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2	0	0	0	1	1	0	0	0	0	1	0	24	9	2	25	11	8	1	7	1	1	1	2	7.52	8.04	2782198
0	0	0	0	1	1	0	0	0	0	1	0	24	4	10	25	11	13	1	7	1	1	1	2	7.65	8.07	2512208
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0	0	0	1	1	1	0	0	0	0	0	0	8	9	11	10	11	15	2	6	1	1	1	4	7.75	8.10	2248943
2	0	0	0	1	1	0	0	0	0	1	0	24	4	2	25	11	7	1	7	1	1	1	2	7.75	8.08	2346596
0	0	0	0	1	1	0	0	0	0	1	0	23	4	9	24	10	13	5	7	1	1	1	1	7.72	8.07	2435186
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0	0	0	0	0	1	0	0	0	0	0	0	24	6	7	8	9	8	1	2	1	1	1	2	8.52	8.36	282163
0	0	0	1	0	1	0	0	0	0	0	0	8	9	11	10	11	15	2	6	1	1	1	4	8.43	8.31	711159
0	0	0	1	1	1	1	1	0	0	1	1	11	11	5	7	9	17	1	7	1	1	1	1	7.17	7.75	10266478
1	0	0	0	1	1	0	1	0	0	1	0	2	12	12	11	10	12	3	4	1	1	1	2	7.51	7.84	8628182
0	0	0	0	1	1	0	0	0	0	1	0	23	8	9	24	10	13	5	7	1	1	1	1	7.54	8.04	2767237
2	0	0	1	1	1	0	0	0	0	1	1	10	17	29	17	17	16	1	7	1	1	1	1	7.16	7.95	4742042
0	1	0	0	0	1	0	0	0	0	0	0	21	10	7	19	8	12	1	5	1	1	1	2	8.48	8.34	521880
0	0	0	0	1	1	0	0	0	0	1	0	8	10	6	2	8	11	6	7	1	1	1	2	7.67	8.04	2724447

0	0	0	0	1	0	0	0	0	0	1	0	8	8	6	9	11	13	4	1	1	1	1	2	8.11	8.11	1949916
0	0	0	0	1	0	0	0	0	0	1	0	22	10	5	5	13	12	4	7	1	1	1	4	7.56	8.07	2711005
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0	0	1	0	1	0	0	0	0	0	0	0	3	4	20	14	6	5	1	1	5	4	1	4	8.53	8.24	831073
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0	0	0	0	1	0	0	0	0	0	1	0	19	3	5	19	8	22	1	2	1	1	1	3	8.46	8.15	1422933
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2	0	0	1	1	1	0	0	0	0	1	0	10	17	4	17	17	10	1	7	1	1	1	1	7.24	7.98	4197931
0	0	0	1	1	1	0	0	0	0	0	0	12	9	6	10	9	9	6	3	5	1	1	3	7.86	8.11	2016166
1	0	0	1	1	1	0	1	0	0	1	0	9	8	5	7	9	16	1	7	1	1	1	1	7.28	7.83	8692320
0	0	0	1	1	1	1	1	0	0	1	1	11	11	5	7	9	6	1	7	1	1	1	1	7.27	7.76	10040547
2	0	0	1	1	1	0	0	0	0	1	0	10	17	8	17	17	16	1	7	1	1	1	1	7.19	7.97	4375937
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1	0	0	0	1	1	0	1	0	0	1	0	2	9	12	11	10	25	3	7	1	5	5	2	7.07	7.84	10423862
0	0	0	0	1	1	0	0	0	0	0	0	19	4	6	18	9	4	1	3	1	1	1	2	8.27	8.19	1182377
0	0	0	0	1	0	0	0	0	0	1	0	2	4	22	17	2	11	1	1	1	1	1	4	8.67	8.20	1047903
0	0	0	0	1	1	1	0	0	0	1	0	2	11	8	6	14	15	1	7	3	1	1	2	7.26	7.96	4513794
0	0	0	0	1	1	0	0	0	0	1	0	28	13	9	11	19	27	4	7	1	2	6	2	7.02	7.99	5969194
0	0	0	1	1	1	1	1	0	0	1	1	11	11	5	7	9	17	1	2	1	1	1	1	7.54	7.75	9876141
0	0	0	1	1	1	1	0	0	0	1	1	2	11	5	7	8	11	1	7	1	1	1	1	7.60	7.95	4178383
0	0	0	0	1	1	0	0	0	0	1	0	23	6	8	28	10	12	5	1	1	1	1	1	8.07	8.08	2098574
0	0	0	1	1	1	1	0	0	0	1	1	14	17	29	17	17	16	1	7	1	3	1	1	7.10	7.90	5977274
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0	0	0	0	1	1	0	0	0	0	0	0	19	4	4	5	7	7	3	5	2	1	1	3	8.36	8.20	1089950
0	0	0	1	1	1	0	1	0	0	1	1	9	11	5	4	9	17	1	7	2	1	1	6	7.23	7.79	9347197
0	0	0	1	1	1	0	1	0	0	1	1	9	11	5	4	9	17	1	7	5	1	1	6	7.20	7.79	9358349
1	0	0	1	1	1	1	1	0	0	1	1	16	11	13	7	14	17	1	7	1	1	1	1	7.11	7.75	10833224
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0	0	0	1	1	1	1	1	0	0	1	1	11	11	5	3	7	11	1	7	1	1	1	1	7.33	7.76	9999469
1	0	0	1	1	1	1	1	0	0	1	0	11	11	13	7	9	17	1	7	1	1	5	2	6.96	7.75	11874553
2	0	0	1	1	1	1	0	0	0	1	1	13	17	29	6	17	16	1	7	5	1	3	1	7.04	7.86	6762598
0	0	0	0	1	1	0	0	0	0	1	0	18	6	6	10	3	7	1	2	1	1	1	1	8.55	8.11	1603256
0	0	0	0	1	0	0	0	0	0	1	0	22	9	9	6	13	12	4	7	1	1	1	4	7.59	8.07	2627992
0	0	0	0	1	1	0	0	0	0	0	0	7	2	4	6	9	8	1	1	1	1	2	1	8.23	8.22	1071123
0	0	0	0	1	1	0	0	0	0	0	0	8	3	8	23	10	7	5	6	1	1	1	1	8.16	8.20	1251697
0	0	0	0	1	1	0	0	0	0	0	0	6	11	7	10	12	16	1	7	2	1	1	1	7.76	8.13	2213616
0	0	0	0	1	1	0	0	0	0	1	0	2	9	7	6	14	7	1	7	2	1	1	2	7.43	8.03	2952945
0	0	0	0	1	1	0	0	0	0	1	0	25	13	11	3	22	17	3	7	1	2	1	1	7.24	8.02	4051792
0	0	0	1	1	1	0	1	0	0	1	0	10	10	5	4	10	17	3	1	1	1	1	1	7.59	7.83	8448784

0	0	0	0	1	1	0	0	0	0	1	0	2	7	2	18	11	9	1	1	1	5	1	4	8.04	8.08	2101142
0	0	0	0	1	1	0	0	0	0	0	0	8	9	9	24	11	15	1	6	1	1	1	4	7.83	8.14	1991108
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1	0	0	0	1	1	0	0	0	0	0	0	26	2	4	6	11	7	5	5	1	1	1	3	8.15	8.21	1210824
1	0	0	1	1	1	1	1	0	0	1	1	16	11	13	7	14	17	1	7	1	1	5	1	6.91	7.73	12376730
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0	0	0	1	1	1	0	0	0	0	1	1	14	17	29	17	23	16	1	7	1	3	1	6	7.08	7.95	5489878
0	0	0	1	1	1	0	1	0	0	1	1	9	11	5	4	9	4	1	5	5	1	1	4	7.48	7.80	8795427
0	0	0	0	1	1	0	0	0	0	1	0	28	13	6	11	13	20	4	7	1	2	6	2	7.10	7.99	5404366
0	0	0	1	1	0	0	1	0	0	1	1	9	11	5	4	9	4	1	5	5	1	1	4	7.52	7.83	8622806
0	0	0	1	1	1	1	1	0	0	1	1	11	11	5	7	9	17	1	7	5	1	1	1	7.14	7.74	10281348
1	0	0	1	1	1	0	0	0	0	1	0	9	11	3	5	17	10	1	7	1	1	1	1	7.30	8.00	3579837

Appendix G: IDF Curves

The first IDF curve presented, Figure G 1, is an IDF for the Windsor Airport curve based on historical data. The IDF curve was produced by Environment Canada. That IDF curve was used when the use of an IDF curve was necessary during the process of designing the LID controls. The second IDF curve, Figure G 2, represents the IDF curve developed using the IDF climate change tool (Srivastav et al., 2015). This IDF curve was developed with historical data for the Windsor airport station. The final IDF curve included, Figure G 3, also uses the IDF climate change tool. This time the data used is future climate change data for the RCP 8.5 scenario. This is discussed in section 7.2.1. The final graph provides a comparison of different climate change scenarios for a 100 year return period event.

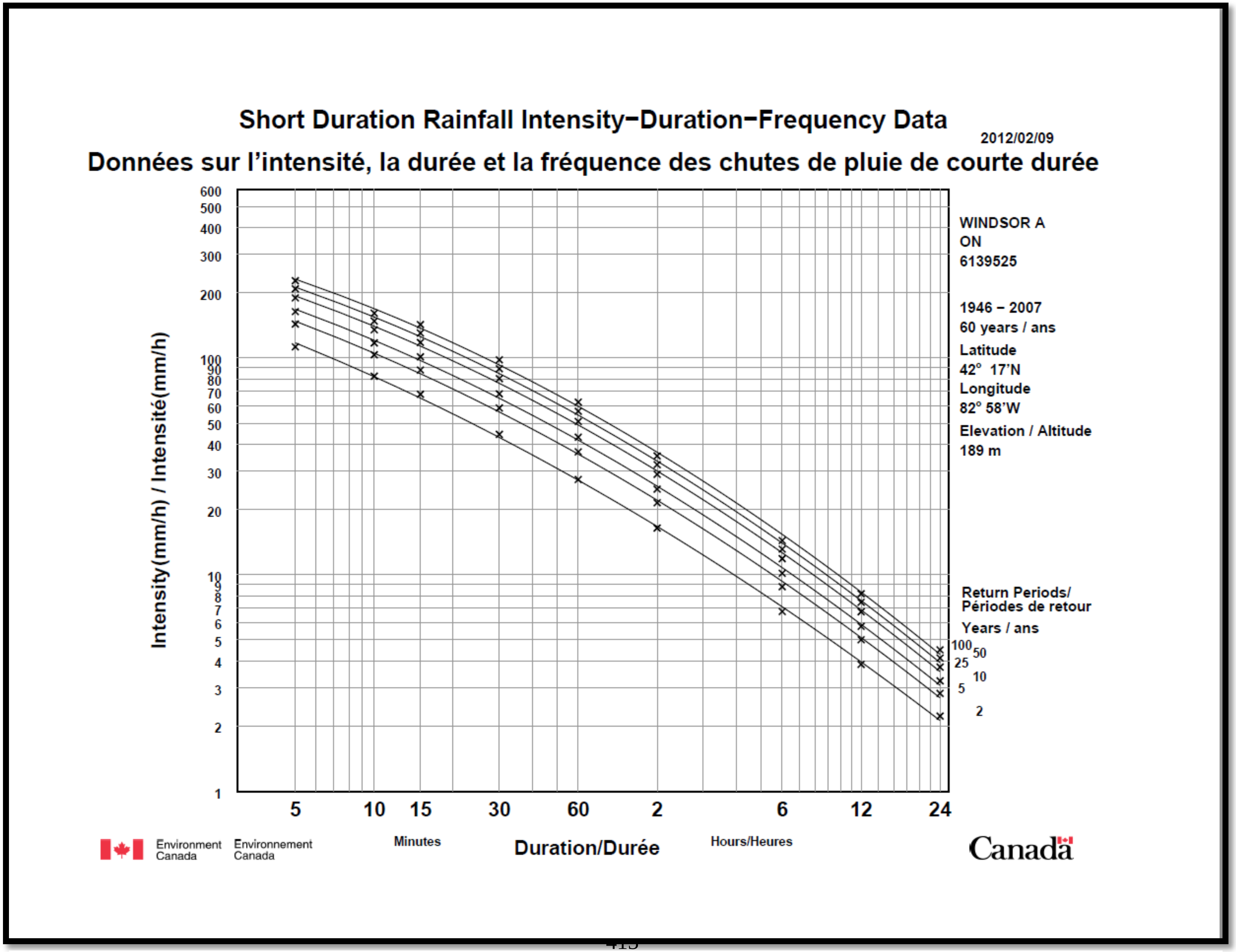

Figure G 1 Environment Canada IDF curve for Windsor Airport

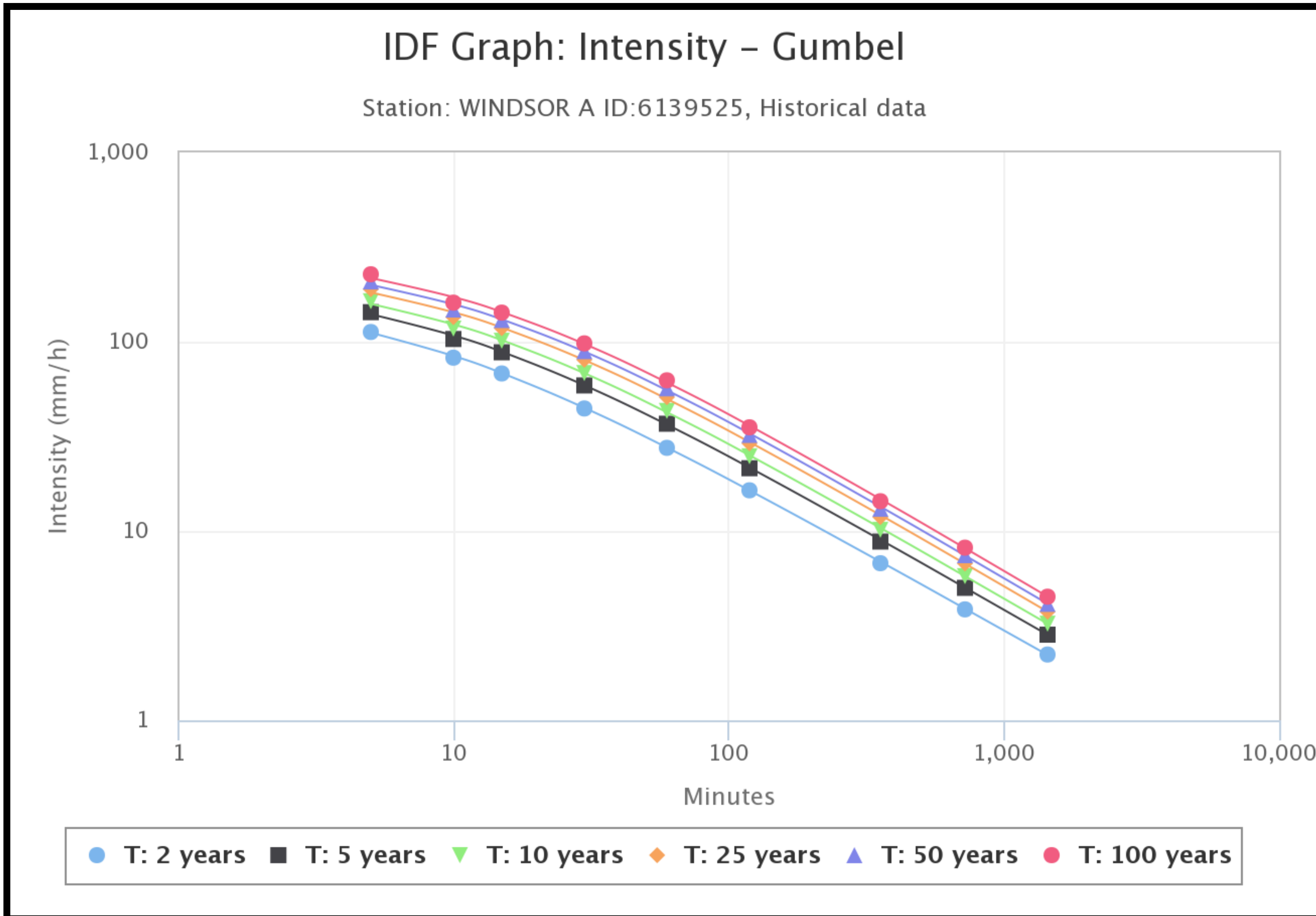

Figure G 2 IDF CC Tool curve for historical data

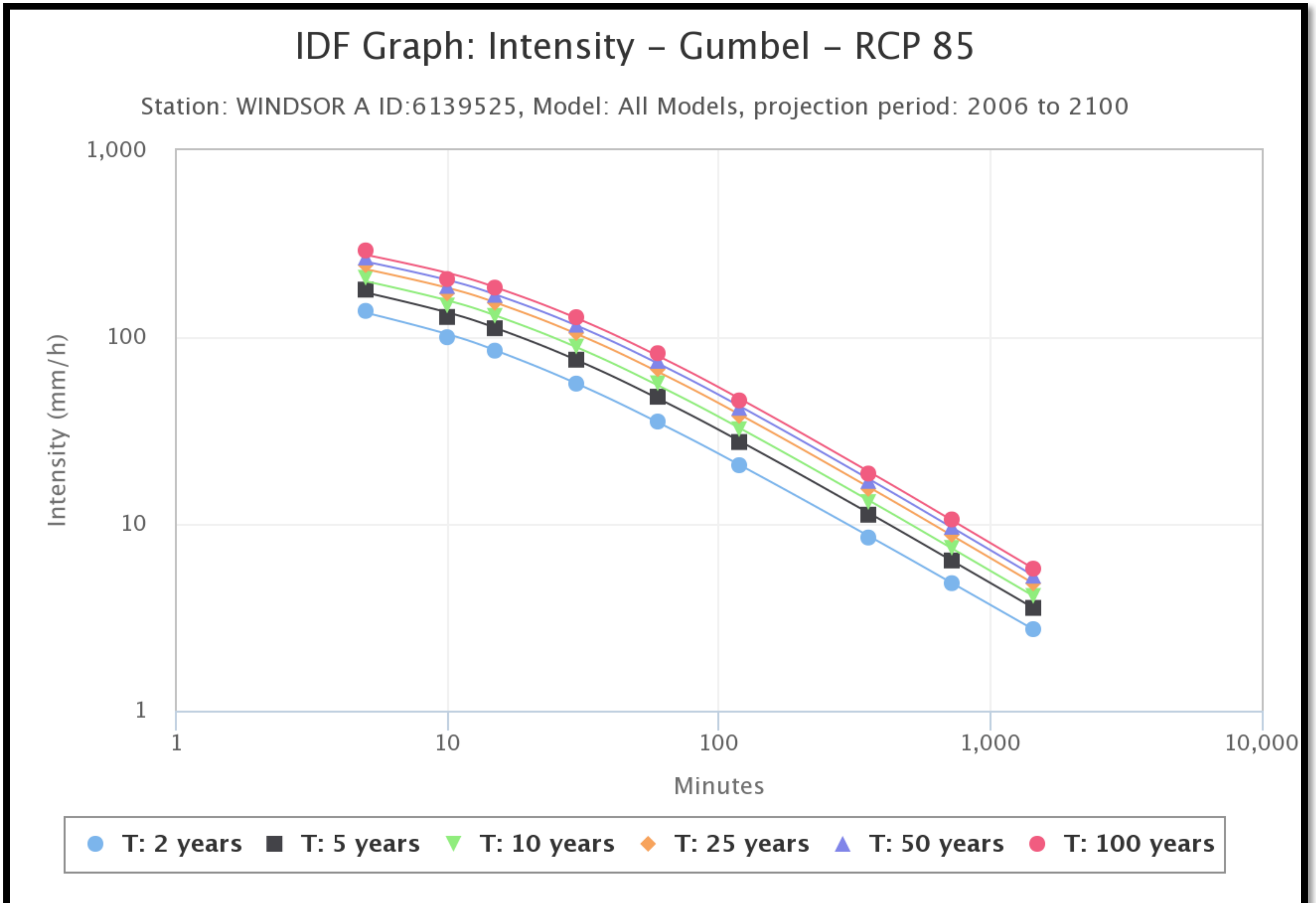

Figure G 3 IDF CC Tool curve for RCP 8.5 data

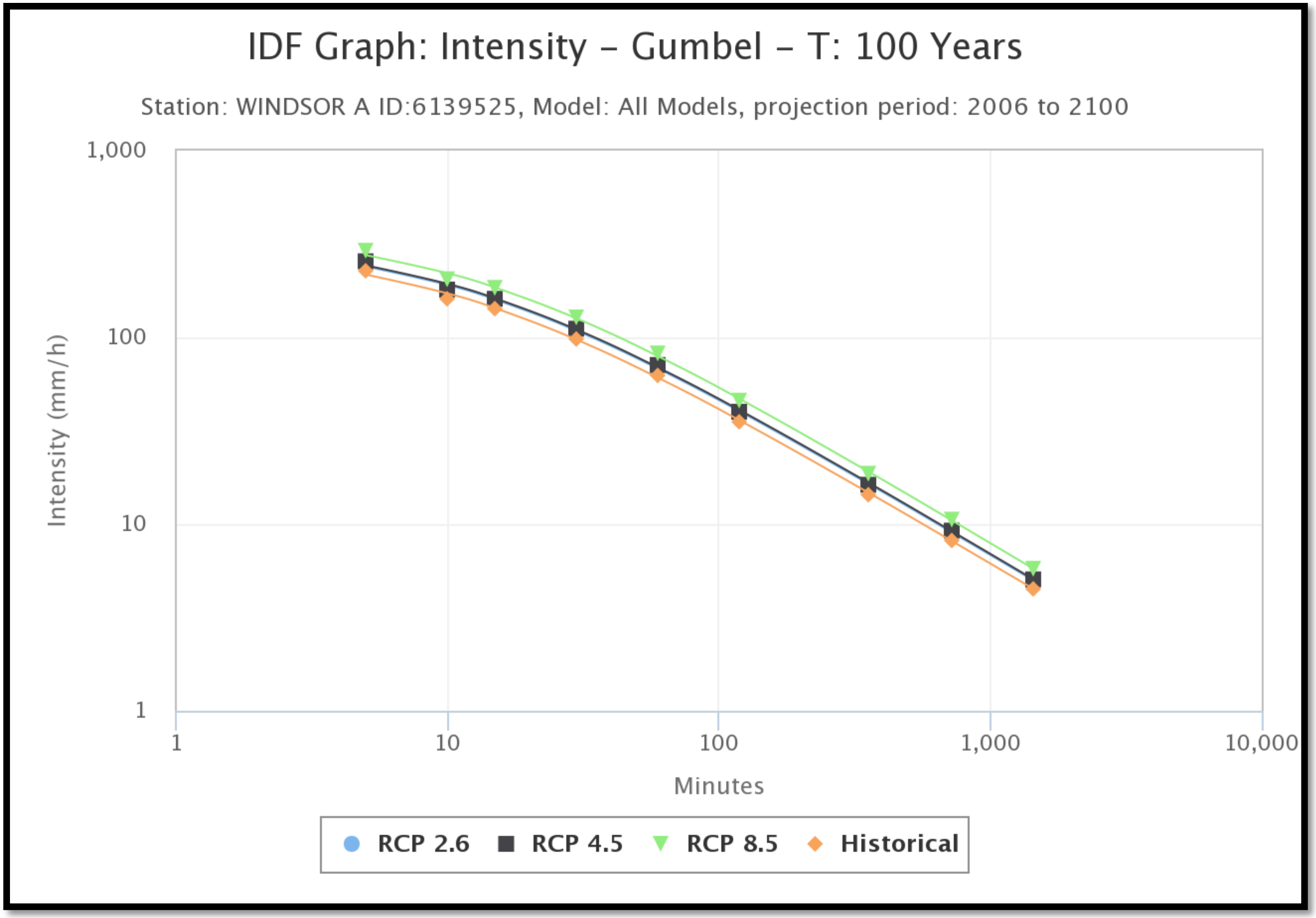

Figure G 4 Comparison of IDF curves for the 100 year return period

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