P.O. Box 1749
Halifax, Nova Scotia
B3J 3A5 Canada

Environment & Sustainability Standing Committee
January 3, 2013

TO: Chair and Members of Environment & Sustainability Standing Committee

Original Signed

SUBMITTED BY: ______________________________
Jane Fraser, Director, Planning & Infrastructure

DATE: November 26, 2012

SUBJECT: **Solar Orientation Regulation**

INFORMATION REPORT

ORIGIN

April 16, 2012, Item 6.3.1: MOVED by Councillor Watts, seconded by Councillor Sloane that the Environment and Sustainability Standing Committee direct staff to consider solar orientation, as outlined in Solar Nova Scotia's presentation of April 16, 2012, and report back to the Standing Committee as to how input from Solar Nova Scotia and the best practices for solar orientation can be included in the Regional Plan Five Year Review.

BACKGROUND

Passive Solar Subdivisions

Passive solar design is about the orientation of a building and the placement of windows and mass in order to capture the heat from the sun and then to store it in the mass of the building.

One of the first things to consider when designing a house is the orientation to the sun. The long axis of the house should be oriented directly east-west, with one of the long sides of the house pointing south. The south wall should then be designed so that the majority of the windows in the house are on that side and that there is a minimum of windows on the north side.

Regional Plan Policy

The Regional Plan currently provides policy direction with respect to solar orientation.

S-15 HRM shall consider the following:
… (p) opportunities to orient development to maximize the capture of solar energy…

This policy is not enacted with any provision in the Subdivision By-Law. As such, there is no regulatory requirement for development to consider solar orientation.

Committee Presentation from Solar Nova Scotia

On April 16, 2012, Solar Nova Scotia provided a presentation with respect to opportunities to design subdivisions considering solar orientation. The presentation can be viewed at: http://www.halifax.ca/boardscom/swrac/documents/PassiveSolarandtheSubdivisionPresentation-Roscoe.pdf

DISCUSSION

Following the motion of committee, staff undertook two projects:

1. Genivar was contracted to perform a Cost/Benefit Analysis of passive solar designed subdivisions (Attachment 1); and

2. Green Power Labs was contracted to evaluate the potential energy savings of optimizing the configuration of homes in subdivisions for passive solar design (Attachment 2).

Following preliminary review of the reports, Staff has requested Quality Urban Energy Systems of Tomorrow (QUEST) to review the reports and prepare a recommendation for Regional Plan Review to meet the original request from this Committee.

Preliminary observations include:

- A solar orientation by-law would not impact the number of lots in rural subdivisions;
- A solar orientation by-law would result in a reduction of lots in suburban subdivisions;
- Energy analysis shows that solar orientation in isolation provides nominal value; adn
- Energy analysis shows in a holistic approach, a passive solar home has substantial energy reductions.

During preparation of this report, staff discussed current and recent activities with the Nova Scotia Home Builders Association (regarding Building Code advancements) and Efficiency Nova Scotia (regarding incentives). It is apparent that the progressive state of code and incentives in Nova Scotia is yielding homes that are as energy efficient as any in Canada.

Questions that arose included:

- If a solar orientation in isolation provides only nominal energy value, what is the municipal role here?
- Is the objective of energy efficiency in new building stock better met through Nova Scotia Building Code?
- If Passive Solar requires a systems approach, what and who are the pieces of the system? And, who is better positioned to deliver?

QUEST (from www.questcanada.org):

QUEST is a collaborative network of stakeholders who are actively working to make Canada a world leader in the design, development and application of Integrated Community Energy Solutions (ICES). Integrating our energy systems requires collaboration from all sectors - from the energy, technology and infrastructure industries, the gas and electric utilities, all levels of government, civil society groups and community leaders, researchers, and the consulting community. These are the stakeholders that make up the QUEST Network. Together we are making Integrated Community Energy Solutions in Canadian communities a reality.

In 2009, Halifax Regional Municipality (HRM) signed a memorandum of understanding to join QUEST. Based on this, Motions of Committee appearing to require a multi-jurisdictional systems approach, staff have forwarded to QUEST for consideration, discussion, and recommendation.

<u>Building Code</u>

During preparation of this report, staff met with the Nova Scotia Home Builders Association (NSHBA) to discuss how homebuilders in Nova Scotia are responding to the challenge of energy efficiency. Nova Scotia and NSHBA have a positive story to tell. In 2010, the Nova Scotia Building Code adopted most of the implications of the Model National Energy Code which resulted in an approximately 25% improvement. Recent data (January to August 2012) supplied by the Nova Scotia Home Builders Association, is as follows:

Category	**Rating**
Average EnerGuide Rating for a new standard home:	81.5
Average EnerGuide Rating for an R2000 home:	85.0
Average EnerGuide Rating for a Performance Plus home:	84.0

Efficiency Nova Scotia incentive, Performance Plus

Efficiency Nova Scotia offers an incentive program for new homes. Homes in the program are given an EnerGuide rating between 1 and 100 - the higher the number, the more efficient the home. Rebates are paid once the home has received its final EnerGuide rating following final inspection and a blower door test. To be eligible for rebates, the completed home must have a final EnerGuide rating of at least 83, and meet all program eligibility criteria.

The improvements by industry and incentives offered by Efficiency Nova Scotia are relevant for consideration with respect to the municipality's role regarding building energy efficiency.

BUDGET IMPLICATIONS

There are no impacts to the 2012/2013 Operating or Project Budget.

FINANCIAL MANAGEMENT POLICIES / BUSINESS PLAN

This report complies with the Municipality's Multi-Year Financial Strategy, the approved Operating, Project and Reserve budgets, policies and procedures regarding withdrawals from the utilization of Project and Operating reserves, as well as any relevant legislation.

COMMUNITY ENGAGEMENT

This work initiated with a community presentation by Solar Nova Scotia at the Environment and Sustainability Standing Committee.

ATTACHMENTS

Attachment 1: Genivar Cost/ Benefit Analysis
Attachment 2: Green Power Labs Energy Analysis

A copy of this report can be obtained online at http://www.halifax.ca/commcoun/cc.html then choose the appropriate Community Council and meeting date, or by contacting the Office of the Municipal Clerk at 490-4210, or Fax 490-4208.

Original Signed

Report Prepared by: Richard MacLellan, Manager, Energy & Environment, 490-6056

Attachment 1

GENIVAR

Passive Solar Subdivisions

A Cost/Benefit Analysis for the Halifax Regional Municipality

Project # 121-21837-00

Prepared for: Halifax Regional Municipality.

Prepared by: GENIVAR Inc.

October 15, 2012

Table of Contents

1 Introduction

The Halifax Regional Municipality (HRM) Energy and Environment Office and the Environment and Sustainability Standing Committee of Council are seeking a cost/benefit analysis regarding passive solar subdivisions in HRM. GENIVAR Inc. was retained to undertake this cost/benefit analysis, which may lead to implementing a passive solar orientation policy and/or bylaw related to subdivisions. This analysis is based on the Environment and Sustainability Standing Committee's request to consider Solar Nova Scotia's presentation of April 16, 2012 and best practices for solar orientation for potential inclusion in the Regional Plan Five Year Review (RP+5).

Purpose & Objectives

The purpose of this study is to provide the Energy and Environment Office with a cost/benefit analysis of passive solar subdivisions in HRM. The objectives are as follows:

- To identify criteria required to create passive solar subdivisions in HRM
- To apply the identified passive solar criteria to two approved subdivisions in HRM, one urban and one rural
- To analyze the two passive solar subdivisions (above) with regards to cost/benefit
- To discuss what other Canadian Municipalities are doing with passive solar subdivisions

Methodology

Our approach to this analysis includes four steps, as follows:

- Background research
- Identifying criteria required for passive solar subdivisions
- Applying passive solar criteria to two previously approved subdivisions in HRM
- Analysis of subdivisions, including cost/benefits

2 Background

Solar energy is clean, abundant, and renewable. Today's technology can capture solar energy and distribute it in several different ways, both active and passive. Active solar technologies involve the use of mechanical systems such as solar panels and photovoltaic arrays, amongst other systems. Passive solar buildings, on the other hand, take advantage of the sun’s energy through building orientation, materials, and landscaping.

According to the Nova Scotia Department of Energy, capturing the sun’s energy through south-facing windows, for example, can provide between 30% and 60% of annual heating requirements in Nova Scotia. Other benefits achieved through passive solar design include:

- Lower heating and cooling costs
- Provides natural light
- Reduction in energy consumption/reduction of fossil fuel emissions

Passive Solar Subdivisions

Passive solar subdivisions are neighbourhoods that are designed to allow as much solar penetration as possible into a building. They are designed with most of the streets running in an east-west direction so that buildings can better exploit the sun with south facing windows.

The angle the sun’s rays make with a surface determine how much energy that surface receives. In the winter when the sun is low in the sky, the sun’s rays are more parallel to the ground, thus hitting windows perpendicular to the glass. In the summer when the sun is high in the sky, the angle at which the sun reaches the earth increases, and more light is reflected. Therefore, orienting the building away from true south will impact the time of day for best solar gain.

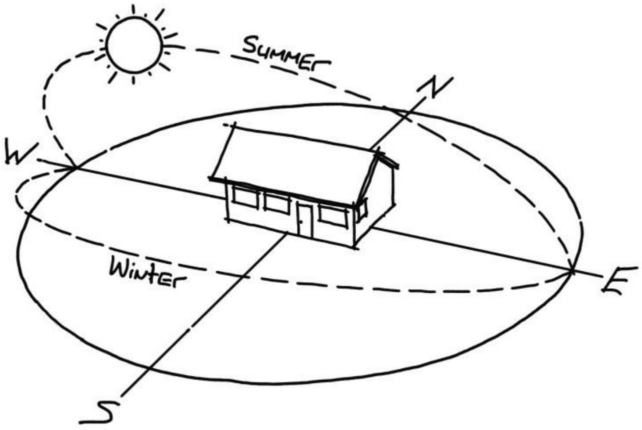


Figure 1: Summer and winter sun position

Passive Solar in the Halifax Regional Municipality

According to Regional Municipal Planning Strategy policy, HRM shall consider solar orientation for Open Space Design subdivisions. Policy S-15(p) states “HRM shall consider… opportunities to orient development to maximize the capture of solar energy.” From our research, we did not uncover any other policy in HRM that suggests the consideration or mandatory requirement for passive solar orientation in subdivision development.

3 Primary Criteria for Passive Solar Subdivisions

The intent of passive solar subdivision design is to plan for street layouts and building lots that take advantage of sunlight. Three criteria are essential in designing an effective passive solar subdivision:

1. Orient Roads East-West

Street layout is the primary criteria to achieve passive solar gain; therefore the majority of streets should be oriented with an east-west alignment. East-west oriented streets allow the most passive solar light to enter into a building; however, it may not be possible to achieve 100% east-west street orientation given site constraints, in which case, lot layout becomes important. The following provides a description regarding different street orientations:

a. As many streets as possible should be oriented along an east-west alignment. It is reasonable to vary the orientation of the streets up to 30º from true south in order to work with contours of the land, and add visual interest.

b. For roads that are oriented north-south, house placement should be staggered one house deep at intervals, or by arranging houses in groups around short cul-de-sacs off north-south roads.

c. Houses that are on diagonal roads that run northwest-southeast or southwest-northeast, can face within 30º of south by skewing the houses within the lots.

2. Orient Lots North-South

Lots should be oriented north-south on east-west oriented streets. This is optimal for allowing the most solar gain. These long and narrow lots have long rear yards, which allow for optimal solar penetration into the yards and buildings, especially for lots where the rear yard faces south. This allows properties to have a natural southerly aspect. Lots between Street A and B illustrate in Figure 2 are north-south facing.

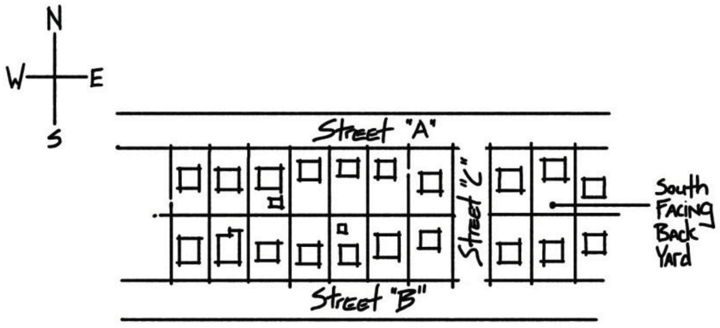


Figure 2: Subdivision with north-south facing lots.

3. Orient the Long Side of Buildings East-West

The long side of a building should be oriented east-west to receive sunlight between 9:00am and 3:00pm during the winter months. The nearer the long side orientation is to true south, the greater the potential solar gains if there are windows. The majority of windows in buildings should be on the south side of the building to allow for solar infiltration. Therefore, if buildings are oriented with their front entrance facing the street (the front of the house), buildings on the north side of the road would have the majority of windows in the front of the house, and a house on the south side of the road would have the majority of windows in the rear of the house.

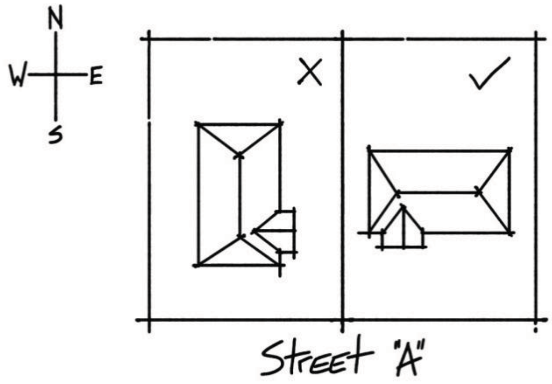


Figure 3: Long side of building facing south.

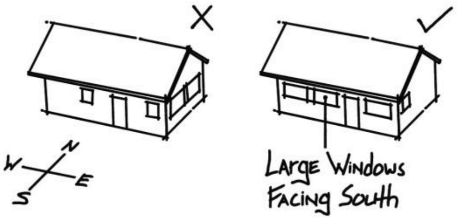


Figure 4: Majority of windows facing south.

4 Secondary Criteria

While passive solar subdivisions are largely achieved through street layout and the orientation of the building footprint, it is important to consider building design and lot specific elements. We are considering these elements as secondary criteria necessary for creating an effective passive solar subdivision. They are briefly discussed for consideration; however, we did not include them as part of our analysis in section 5.

Building Footprint and Exterior Design

Building footprint plays an important role in passive solar heating. A shape as close to square or rectangular as possible is optimum to minimize corners and maximize floor area in relation to the outside wall area. This compact design minimizes exterior wall surface area, corners, and joints, which are all associated heat loss potential. “Thermal bridges” are created at corners and joints, thereby increasing opportunities for heat to escape.

On the outside of the house, overhangs are one of the best design elements to consider as they can influence the amount of sunlight entering a building. In the summer, when the sun is high in the sky, overhangs should be designed to shade the room keeping it cool. In the winter, when the sun is low, overhangs should allow the full sun to enter, warming the air, as well as the floor, walls and other features. It's important that overhangs are properly sized. If they are too short, and allow the summer sun in through south facing windows, the interior can become uncomfortably hot and require the use of artificial coolants such as air conditioners. If they are too long, living areas will stay dark and cool not only in the summer, but in the winter as well.

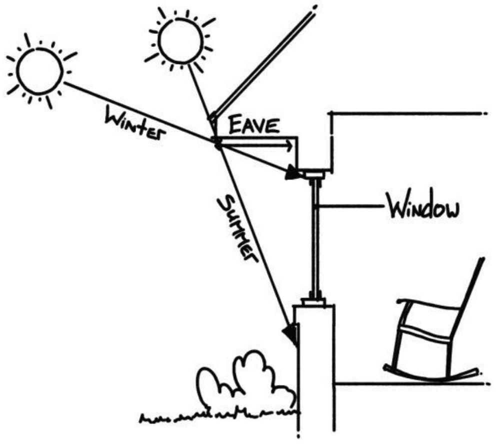


Figure 5: Overhangs above south facing windows.

Building Materials & Thermal Mass

Thermal mass refers to the building materials that absorb heat during sunny days and release it overnight and during cloud covered days. Common building materials with good thermal mass include gypsum board, ceramic tiles, concrete and brick. The thicker the building material, the greater the thermal capacity for storing heat.

Windows also play an important role in passive solar heating building design. Their main function is to allow solar rays to penetrate through. They are also responsible for heat loss. Some older style windows are responsible for upwards of 35% of total heat loss in a house[1]. Energy efficient windows are recommended as an ideal window to use in passive solar design buildings to permit maximum solar gain while minimizing heat loss.

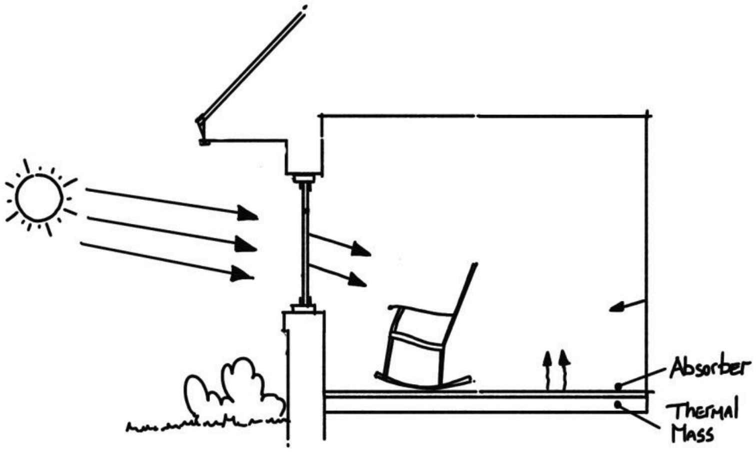


Figure 6: Thermal mass absorbing and releasing heat.

Lot Features

Slopes

Slopes are an important consideration when designing for passive solar gain. A steep north-facing slope will have limited or no solar access. East and west oriented slopes may require particular patterns to optimize window orientation for solar gain and views.

Landscaping

Landscaping plays an important role in heating and cooling buildings. In the winter, deciduous trees that shed their leaves can permit sunlight penetration into the home, thus heating it, while in the summer, the leaves on the trees can reduce direct sunlight from entering and heating the home.

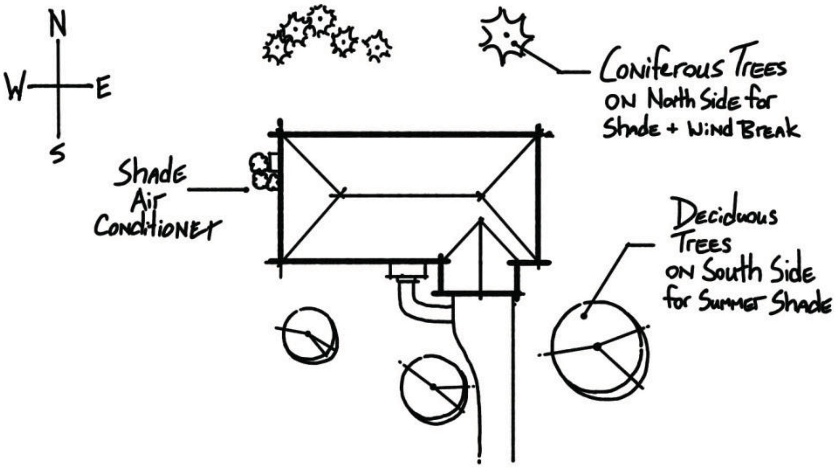


Figure 7: Landscaping around building.

Trees and shrubs on the west and northwest side of a home will block the summer setting sun, and evergreen plants on the north side will break winter winds and strip away heat. Additionally, the shade created by trees and the effect of grass and shrubs will reduce air temperatures adjacent the house and provide evaporative cooling.

---

[1] Henderson, S., D. Roscoe, and J. Ward (2009). *Canadian Solar House Manual.* Solar Nova Scotia.

5 Criteria Applied to the HRM Context

To analyze the current cost/benefit of applying the passive solar criteria to subdivisions, two randomly selected HRM approved subdivisions were reviewed. One subdivision was chosen within the Urban Settlement designation of the HRM Regional Municipal Planning Strategy and the other subdivision was chosen from the Rural Commuter designation. The two subdivisions in this analysis include:

- Herring Cove Village, Herring Cove, urban settlement designation under the Regional MPS
- Lakecrest Acres, Upper Sackville, rural commuter designation under the Regional MPS

These two subdivisions were randomly selected from a variety of approved subdivisions undertaken by GENIVAR. Neither subdivision was chosen based on qualities in support or against passive solar criteria. These two subdivisions; however, vary in average lot sizes, with the average size lots of Herring Cove Village being 10,350 SF and the average lot size for Lakecrest Acres being 58,900 SF. The objective is to identify costs and benefits with different HRM subdivisions regardless of location or size.

For both subdivisions, the analysis process included:

- Select two previously approved subdivisions
- Apply primary criteria listed in Section 3
- Review the subdivisions for Land Use By-law/Development Agreement infringements
- Highlight Land Use By-law/Development Agreement infringements
- Alter the subdivisions to meet both passive solar criteria and Land Use By-law/Development Agreement requirements.

Note that the subdivision street layout was not altered in applying the primary criteria for passive solar subdivisions. Altering the approved street layout would lose the element of comparison analysis. To understand the impact of applying solar criteria to subdivisions, it was necessary to work with existing conditions.

As a limitation of this exercise, it is important to note that the secondary criteria discussed in Section 4 were not considered when modifying the subdivision layouts for passive solar gain. The modified passive solar subdivisions were made on a 2-dimensional layout, using primary criteria from section 3.

Subdivision 1: Herring Cove Village

Herring Cove Village is located along Herring Cove Road. It is zoned Herring Cove Residential (HCR) under the *Planning District 5 (Chebucto Peninsula) Planning Land Use By-law,* is within the urban settlement designation of the Regional Plan, and is within the Urban Service Area. The subdivision layout was approved through Development Agreement with 46 lots in 2011. The average lot size is 10,350 SF with a range of lot sizes between 6,007 SF and 27,722 SF. The approved subdivision is relatively rectangular shaped, with the shorter edge fronting along Herring Cove Road. Development is not proposed on the eastern side of the subdivision, because it is set aside as a watercourse buffer and conservation land. Due to site constraints, including the watercourse buffer, the proposed main road, Norawarren Drive, runs in a north-south direction. Reginald Court, the shorter street, runs in an east-west direction. Figure 8 illustrates the approved subdivision plan - Concept Plan 1.0 (Appendix A).

Figure 8: Concept Plan 1.0 - Herring Cove Village

We applied passive solar primary criteria to the Herring Cove Village subdivision. In this exercise, we did not change the road network; however, we did modify the orientation of the building footprint to meet criteria 3 – orient the long side of the buildings due south. As the lots are narrow and shadows from neighbouring buildings could limit the amount of sunlight into the home, we implemented criteria 1b – stagger houses one house deep at intervals.

After setting up the subdivision to meet the primary passive solar criteria, we identified the areas that infringe on zoning requirements and watercourse setback requirements. As shown in concept plan 1.1 (Appendix A), areas of infringement are highlighted in red. There are a total of 23 infringements, which are all found along Norawarren Drive, the road that runs North-South. The nine lots that front on Reginald Court do not have any infringements as the road travels in an east-west direction, which is ideal for passive solar subdivisions.

Following the identification of infringements, we manipulated the proposed subdivision lot lines and repositioned the building footprints so that primary passive solar criteria are met and that there are no zoning and watercourse infringements. The result is a net loss of 9 lots from the original approved subdivision, totaling 37 lots, or a 20% reduction in lot yield. Concept Plan 1.2 shows the passive solar subdivision after primary criteria have been applied and lot lines have been adjusted (Appendix A).

The following table summarizes characteristics of the subdivision, and identifies HCR zone and watercourse requirements, and the consequential infringements:

Herring Cove Village		
Original Subdivision (Version 1.0)	**46 lots**	
Subdivision Characteristics	Road direction: Norawarren Drive – 13° East of South; 16° West of South Reginald Court – 73° East of South Water and sewer serviced lots – in the Urban Service Area Average lot size: 10,366 SF	
Planning District 5 (Chebucto Peninsula) Land Use Bylaw		Passive Solar Subdivision HCR Zone Requirements and Watercourse Infringements (Version 1.1)
HCR Zone Requirements/DA Requirements		
Minimum Front or Flankage Yard	20 ft (6.1m)	8
Minimum Side Yard	8 ft (2.4m)	5
Minimum Rear Yard	8 ft (2.4m)	6
Maximum Lot Coverage	35%	n/a
Minimum Lot Area (full services)	6,000 SF (558m^2)	n/a
Minimum Lot Frontage	60 ft (18.3m)	n/a
Non-disturbance Watercourse Setback	100 ft (30.48m)	4
Total HCR Zone Requirements and Watercourse Infringements		**23**
Passive Solar Subdivision (Version 1.2)		**37 lots (net loss of 9 lots)**

After applying passive solar criteria to Herring Cove Village, we conclude the following:

- 23 infringements of the land use bylaw were noted, all in violation of side, rear, and front yard setbacks, and watercourse setbacks
- Streets running north-south required building footprint manipulation so that the long side of the building orients within 30º of south to maximize solar gain
- Small lots can cause setback infringements, especially side yards, when building footprints are rotated within 30º of south to maximize solar gain

Subdivision 2: Lakecrest Acres

Lakecrest Acres is located in Upper Sackville. It is zoned Rural Residential (R-6) under the *Beaver Bank, Hammonds Plains and Upper Sackville Land Use By-law*. It is within the Rural Commuter Designation of the Regional Municipal Planning Strategy and is within the sewer service area. The subdivision was approved with 20 large lots in 2010. The average lot size is 58,900 SF, with a range of lot sizes between 48,269 SF and 100,754 SF. There is a watercourse buffer at the west of the subdivision beside Lisle Lake. The main road, Rhodora Drive, runs in a north-south direction, while Bramblewood Court and Kernwood Drive run in an east-west direction. Figure 8 illustrates the approved subdivision plan - Concept Plan 1.0 (Appendix B).

Figure 9: Concept Plan 1.3 - Lakecrest Acres

We applied primary criteria to the Lakecrest Acres subdivision. As with Herring Cove Village, we did not change the road network; however, we did modify the orientation of the building footprint to meet criteria 3 – orient the long side of the buildings due south. The lots at Lakecrest Acres are considerably larger than the lots at Herring Cove Village, and as a result the side yards are much wider. In some cases, there is 20m between the homes. We did not stagger the houses (criteria 1b) for this subdivision.

With passive solar primary criteria applied to Lakecrest Acres, we have noted that there are no zone requirements or watercourse infringements. As a result, there is a 0 net loss of lots. Concept Plan 1.4 shows the passive solar subdivision (Appendix B).

The following table summarizes characteristics of the subdivision, and identifies R-6 zone and watercourse requirements:

Lakecrest Acres Subdivision (Phase 9)		
Original Subdivision (Version 1.4)	**20 lots**	
Subdivision Characteristics	Road direction: Rhodora Drive – 43º East of South Bramblewood Court – 47º West of South Kernwood Drive – 28º West of South Sewer serviced lots – in the Sewer Service Area Average lot size: 58,895 SF	
Beaver Bank, Hammonds Plains and Upper Sackville LUB Requirements		Passive Solar Subdivision R-6 Zone Requirements and (Version 1.5)
R-6 Zone Requirements		
Minimum Front or Flankage Yard	20 ft (6.1m)	0
Minimum Side Yard	8 ft (2.4m)	0
Minimum Rear Yard	8 ft (2.4m)	0
Maximum Lot Coverage	35%	n/a
Minimum Lot Area (central sewer)	10,000 SF (929m^2)	n/a
Minimum Lot Frontage (central sewer)	75 ft (22.9m)	n/a
Non-disturbance Watercourse Setback	66 ft (20m)	0
Total R-6 Zone Requirements and Watercourse Infringements		**0**
Passive Solar Subdivision (Version 1.4)		**20 lots (0 net loss of lots)**

After applying passive solar criteria to Lakecrest Acres, we conclude the following:

- No land use bylaw setback and watercourse infringements occur
- Streets running north-south required building footprint manipulation so that the long side of the building faces within 30° of south to maximize solar gain
- Larger lots have less potential of infringing on land use bylaw requirements

Cost/Benefit Analysis

We have identified both costs and benefits related to passive solar subdivisions in HRM based on the subdivisions reviewed. They are listed as follows:

Benefits associated with passive solar subdivisions in HRM:

- Creation of unique subdivisions (non-conventional with uniform setbacks) for north-south oriented roads
- Opportunities for flexibility with setback requirements for urban settlement subdivisions
- Opportunities for passive solar design on large rural commuter subdivisions without setback infringements
- In the rural commuter designated area, there is a zero net loss of lots, as identified through our example of Lakecrest acres

Costs associated with passive solar subdivisions in HRM:

- Infringements on zone requirements
- Flexibility so that not all streets will have a uniform front yard setback.
- When subdivisions on smaller lots are approved with passive solar design, there is a possibility of yielding fewer lots (less property tax revenue)
- In the urban settlement designated area, Herring Cove Village, has a net loss of nine lots

In our opinion, zoning setbacks are both a cost and a benefit. As a cost, setback requirements can limit the number of properties that can benefit from passive solar orientation, because building orientation can cause the building to infringe on front, side, rear, and watercourse setbacks. As a benefit, designing passive solar subdivisions is an opportunity for flexibility in setback requirements if lots will take advantage of solar design. If HRM were to pursue solar orientation as part of subdivision requirements, zoning flexibility will be necessary.

Based on our analysis, we also note that there are fewer, if any, costs associated with large rural properties. It is our opinion that subdivisions developed in the rural commuter designation be designed using passive solar criteria.

6 Other Canadian Municipalities

In Canada, passive solar subdivisions are relatively unknown. There are some communities across the Country that encourage passive solar design for individual lots; however, we were unable to locate communities where passive solar subdivisions are encouraged through policy, with the exception of Gibsons, British Columbia.

Gibsons is a small community located on the Sunshine Coast. In 2008, the municipality adopted a new zone, called a cluster zone, for an area of land that was previously undeveloped. This cluster zone allows flexibility for a range of housing styles and lot configurations. Development within this zone is encouraged to include passive solar design elements, most notably, windows facing within 30º of south. The solar orientation provisions in the cluster zone are a loose interpretation, encouraging passive solar design, not requiring it. Furthermore, as was mentioned by a planner in Gibsons, one of the Town's major challenges would be to enforce south facing windows, as all the views looking out into the Bay face east.

As we are unaware of municipalities in Canada including provisions in their Land Use Bylaws or policy statements in their community plans, we see this as an opportunity for HRM to be one of the first, if not the first, municipality in the county to create such policy statements.

7 Conclusion and Consideration

We have identified passive solar criteria and applied it to two different subdivisions in HRM. It is our opinion that passive solar subdivisions would work in HRM; however, flexibility with respect to setbacks may be needed. As identified with the Herring Cove Subdivision, without flexibility to the setback requirements, both zoning and watercourse, there is a 20% reduction in lot yield. As HRM is currently undergoing a five-year review of the Regional Plan, it is in our opinion that provisions for passive solar orientation be implemented into the revised plan. We offer the following as next steps:

Consideration:

Based on this cost/benefit analysis, the Regional Plan review committee should consider making passive solar criteria a requirement for subdivisions built in the rural commuter designation.

8 References

Halifax Regional Municipality (2000, with amendments to 2012). Beaver Bank, Hammond Plains and Upper Sackville Land Use Bylaw.

Halifax Regional Municipality (1995, with amendments to 2011) Planning District 5 (Chebucto Peninsula) Land Use Bylaw.

Halifax Regional Municipality (2006). Regional Municipal Planning Strategy.

Halifax Regional Municipality (2006). Regional Subdivision Bylaw.

Henderson, S., D. Roscoe, and J. Ward (2009). *Canadian Solar House Manual.* Solar Nova Scotia.

Kachadorian, J. (2006). *The Passive Solar House.* Chelsea Green Publishing Company. Vermont.

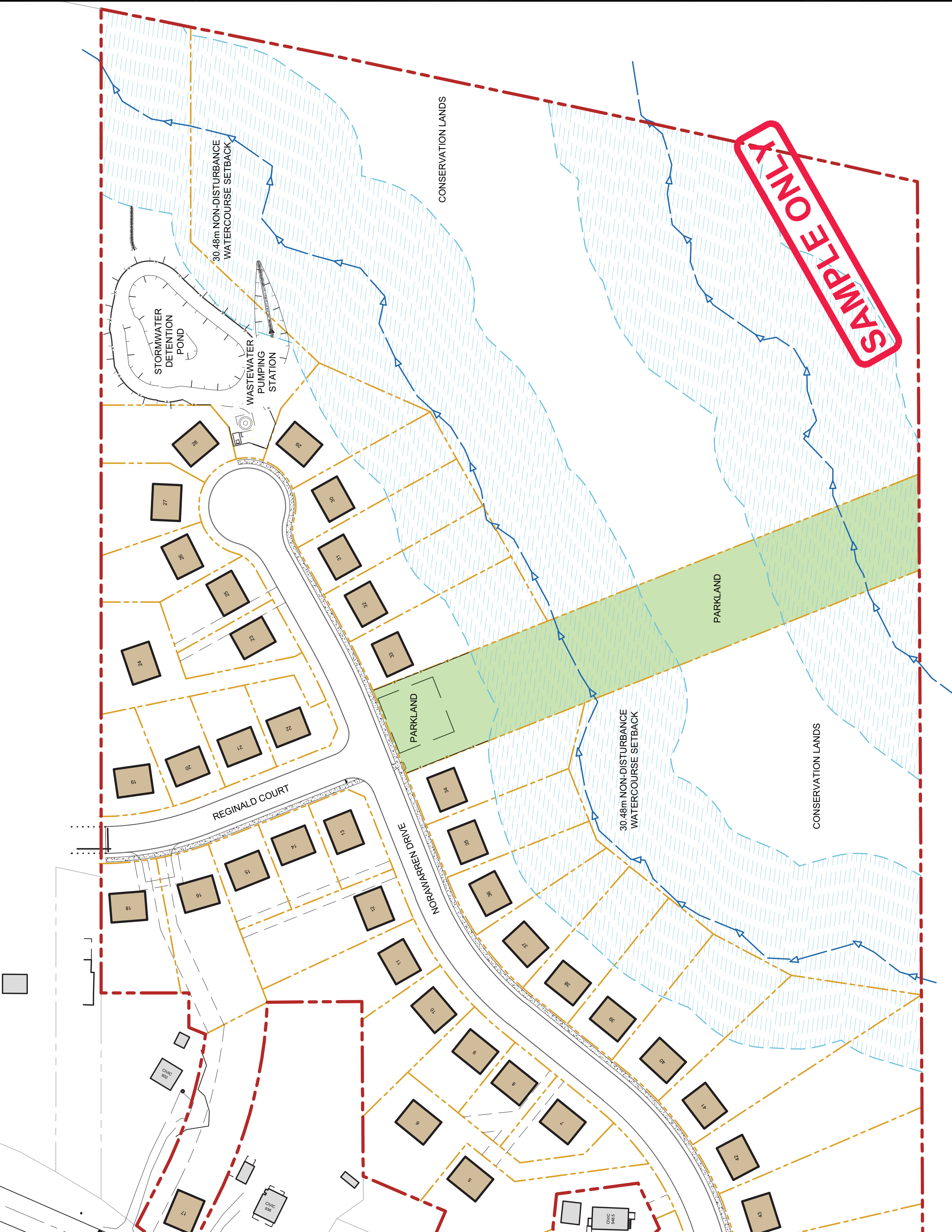
Town of Gibsons (2005). Bylaw No 985-4.

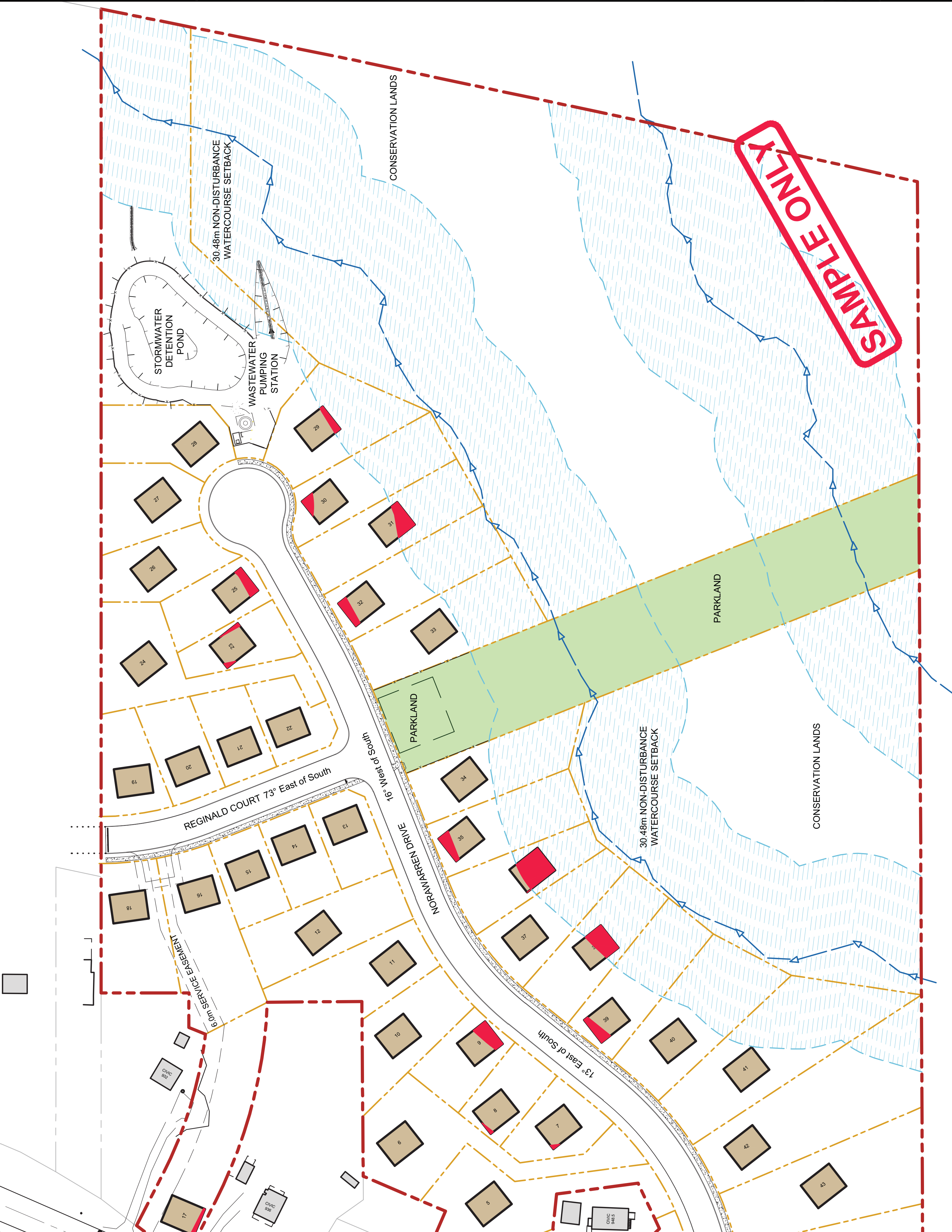
Appendices

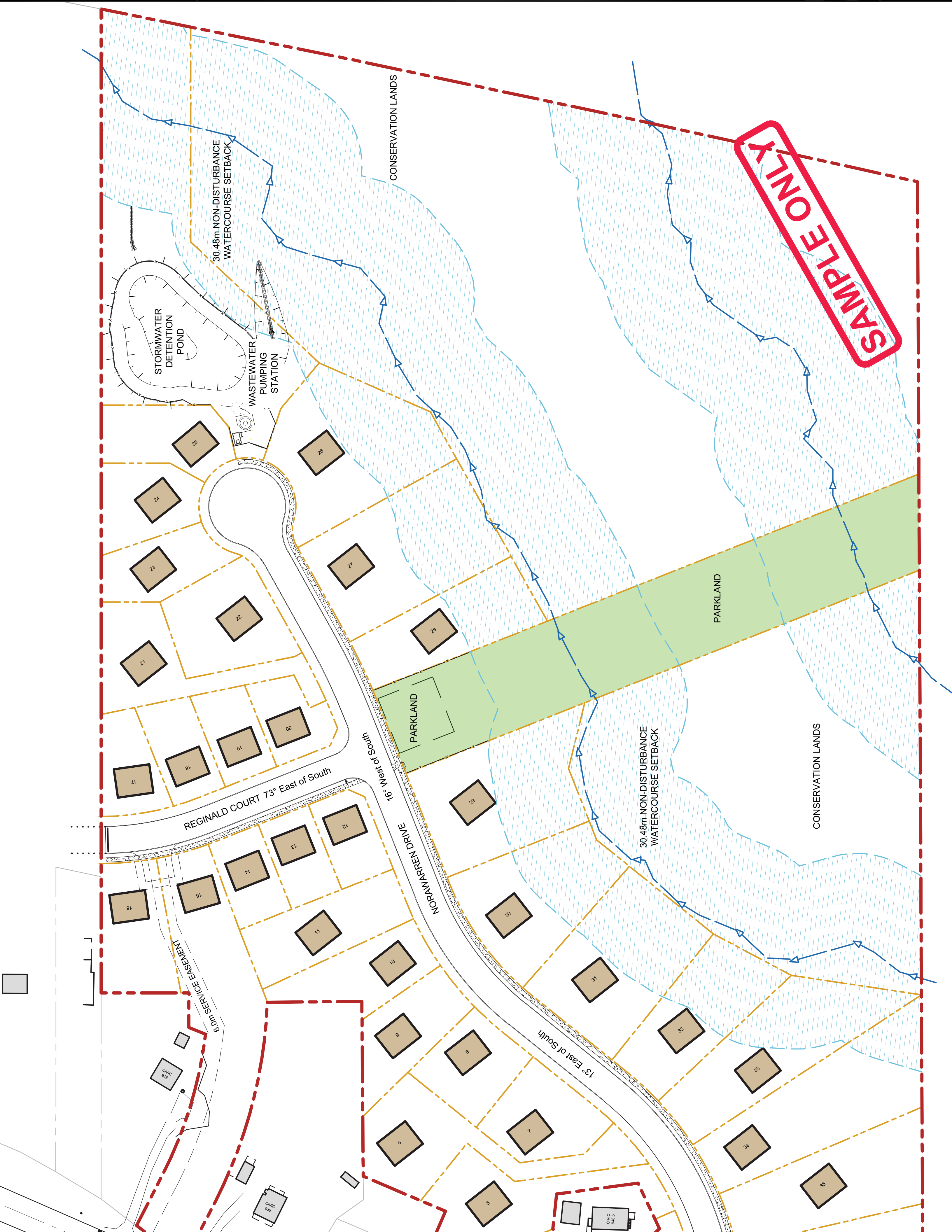
Appendix A (Herring Cove Village Concept Plans)

Appendix B (Lakecrest Acres Concept Plans)

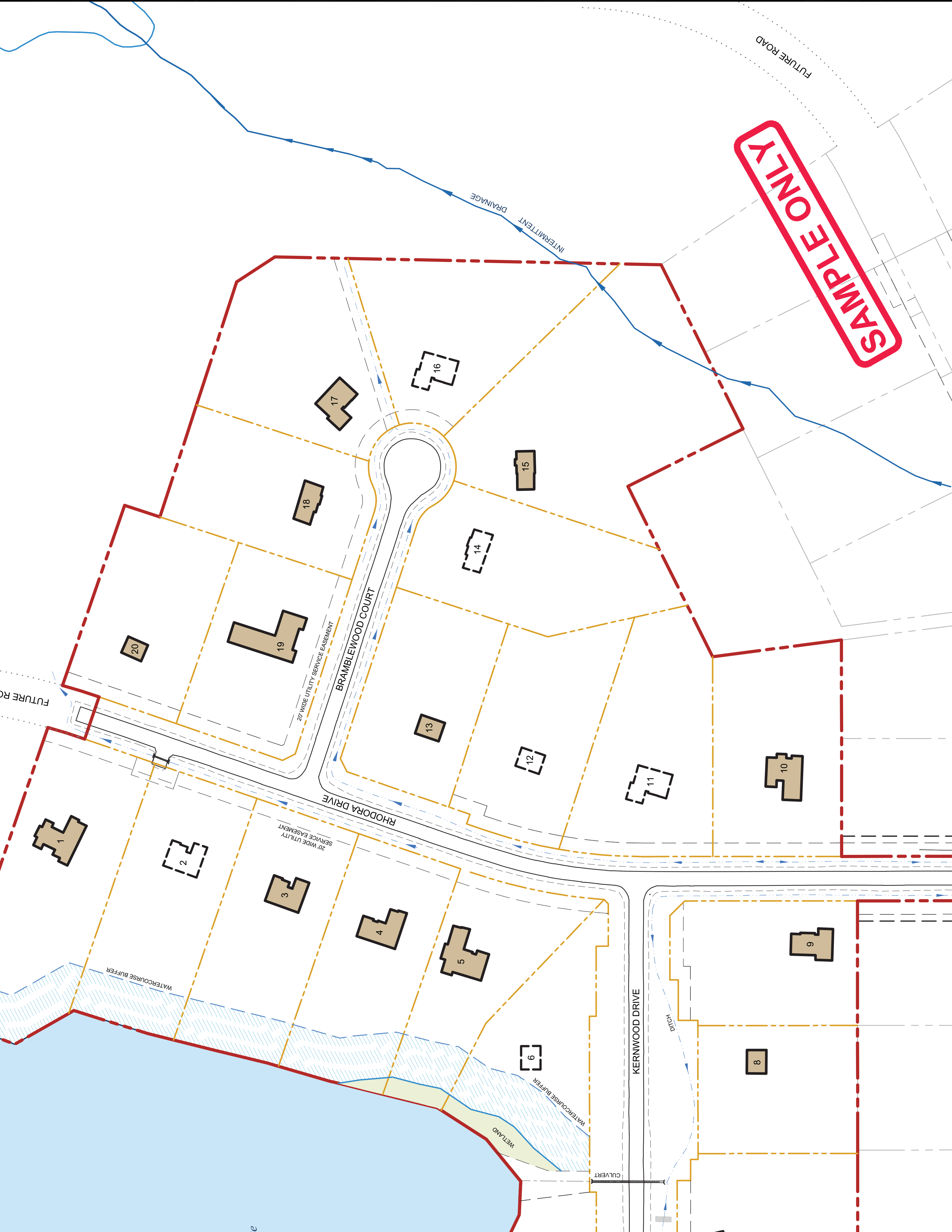
Appendix A (Herring Cove Village Concept Plans)

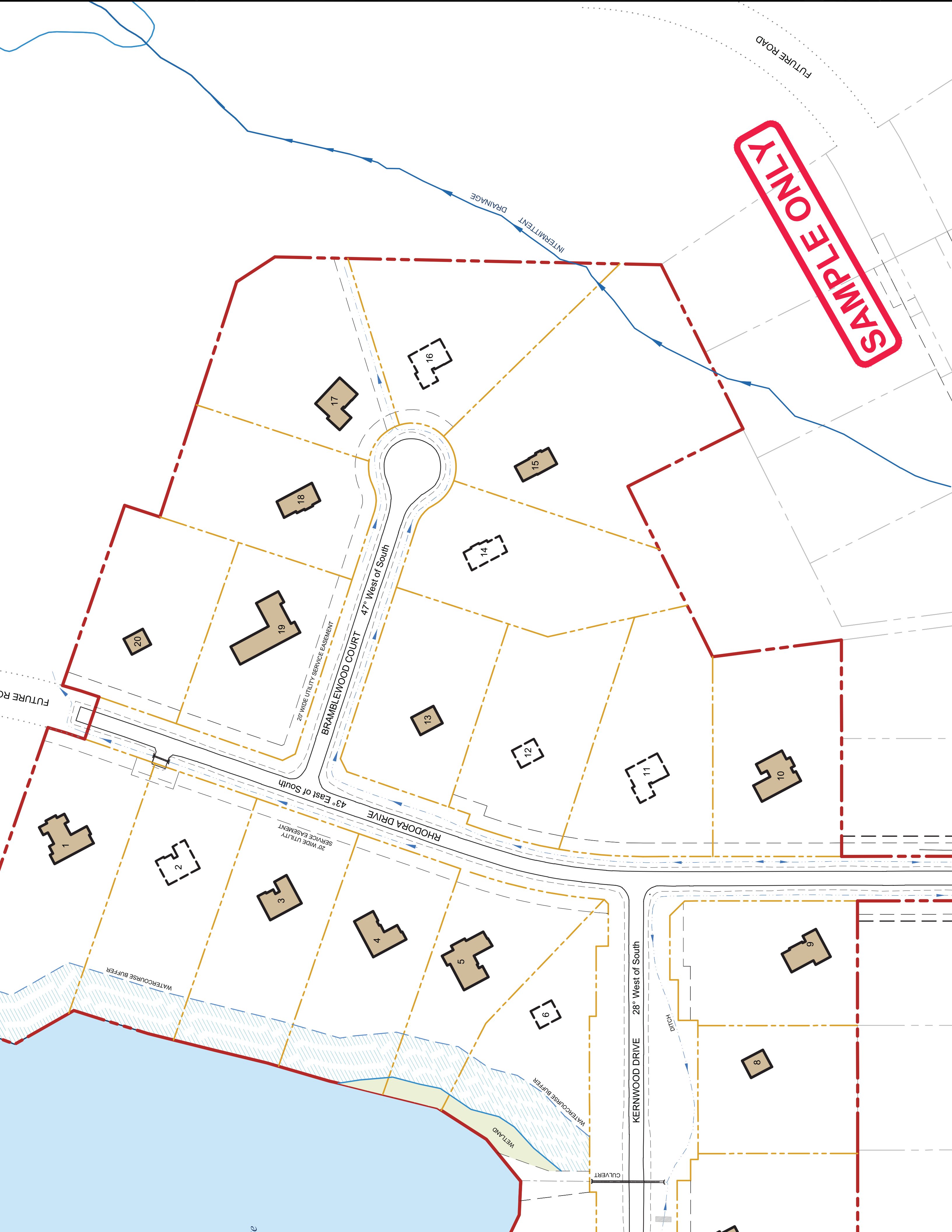

SAMPLE ONLY
CONSERVATION LANDS
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
STORMWATER DETENTION POND
WASTEWATER PUMPING STATION
PARKLAND
PARKLAND
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
CONSERVATION LANDS
REGINALD COURT
NORAWARREN DRIVE
28
29
27
30
26
31
25
32
23
24
33
22
21
20
19
34
13
14
15
16
18
35
36
12
11
37
38
10
39
9
40
8
7
41
6
42
5
43
17
CIVIC 932
CIVIC 936
CIVIC 948.5


SAMPLE ONLY
CONSERVATION LANDS
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
STORMWATER DETENTION POND
WASTEWATER PUMPING STATION
PARKLAND
PARKLAND
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
CONSERVATION LANDS
REGINALD COURT 73° East of South
16° West of South
NORAWARREN DRIVE
13° East of South
6.0m SERVICE EASEMENT
CIVIC 932
CIVIC 936
CIVIC 948.5
29
28
30
27
31
26
25
32
33
24
23
22
21
20
19
34
13
14
35
15
16
18
12
37
11
39
10
9
40
41
8
7
6
42
43
5
17


CONSERVATION LANDS
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
STORMWATER DETENTION POND
WASTEWATER PUMPING STATION
PARKLAND
PARKLAND
30.48m NON-DISTURBANCE WATERCOURSE SETBACK
CONSERVATION LANDS
REGINALD COURT 73° East of South
16° West of South
NORAWARREN DRIVE
13° East of South
6.0m SERVICE EASEMENT
CIVIC 932
CIVIC 936
CIVIC 948.5
25
26
24
27
23
22
28
21
20
19
18
17
29
12
13
14
15
18
11
30
10
31
9
8
32
33
7
6
34
35
5

Appendix B (Lakecrest Acres Concept Plans)


FUTURE ROAD
SAMPLE ONLY
INTERMITTENT DRAINAGE
16
17
15
18
14
20
19
20' WIDE UTILITY SERVICE EASEMENT
BRAMBLEWOOD COURT
FUTURE RO
13
12
11
10
RHODORA DRIVE
20' WIDE UTILITY SERVICE EASEMENT
1
2
3
4
5
9
WATERCOURSE BUFFER
KERNWOOD DRIVE
DITCH
8
6
WATERCOURSE BUFFER
WETLAND
CULVERT


FUTURE ROAD
SAMPLE ONLY
INTERMITTENT DRAINAGE
16
17
15
18
14
19
20
20' WIDE UTILITY SERVICE EASEMENT
BRAMBLEWOOD COURT
47° West of South
13
12
11
10
FUTURE RO
43° East of South
RHODORA DRIVE
20' WIDE UTILITY SERVICE EASEMENT
1
2
3
4
5
6
9
8
WATERCOURSE BUFFER
WATERCOURSE BUFFER
WETLAND
CULVERT
KERNWOOD DRIVE
28° West of South
DITCH

SOLAR ENERGY FOR MUNICIPALITIES

Solar Assessment – Subdivision Planning
Halifax, Nova Scotia

Prepared for the Halifax Regional Municipality

Green Power Labs Inc

One Research Drive,
Dartmouth, Nova Scotia,
Canada, B2Y 4M9
Phone: (902) 466-6475
Fax: (902) 466-6889

November 2nd, 2012

This report was prepared by Green Power Labs Inc. (GPLI) for the Halifax Regional Municipality. The materials in this report reflect GPLI's best judgment based on the information available to the company at the time of report preparation. Any use of this report by a third party, or any reliance on or decisions made based on it, are the responsibility of such third parties. GPLI accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Contents

1. Introduction

Green Power Labs was retained by the Halifax Regional Municipality (HRM) to evaluate the potential energy savings of optimizing the configuration of homes in subdivisions for passive solar design.

The evaluation follows a Cost/Benefit Analysis "Passive Solar Subdivisions" by Genivar[1]: this report identifies primary criteria for subdivision design as road orientation, building lot orientation, and orientation of the longer face of the home to be a south elevation; it also identifies secondary criteria to include the shape of the home, building materials (notably, windows and building mass), the site, and landscaping. The report provides as qualitative assessment of the benefits and costs including passive solar design considerations in subdivision planning. The report uses two example subdivisions to demonstrate the potential impact of optimized passive solar criteria in suburban and rural settings.

This report develops quantitative estimates of energy savings which may be achieved through passive solar design. In drawing conclusions for each of the two subdivisions described in the Genivar report, we:

- Identify, for a single building, the average energy consumption of construction to current standards
- Identify, for a single building, the impact of energy conservation measures and passive solar design on energy consumption
- Identify, for a single building, the impact of orientation on energy consumption
- Quantify the impact of orientation and passive solar design on the example subdivisions.

For the two subdivision examples, we also identify the available solar resource for active systems before and after optimizing passive design and/or building orientation.

---

[1] Genivar, Halifax, NS: Passive Solar Subdivisions Cost/Benefit Analysis; DRAFT – 2012-09-28

2. Energy Consumption - Construction to Current Standards

A number of variables affect the impact of passive solar design and building orientation on energy use. This section describes a 'standard new home' built to current regulations[2], and the impact of varying some of these parameters.

2.1. Building Size and Shape

Energy use varies significantly with size and shape of the building. Increasing the gross building area and ceiling heights increases the size of the building envelope and the energy loss through the envelope. (For approximate reference: energy use increases at a rate of half the increase in gross building area, and at about half the increase in floor-to-floor height.)

Also, as identified in the Genivar report: "the building footprint plays an important role in passive solar heating. A shape as close to square or rectangular as possible is optimum to minimize corners and maximize floor area in relation to the outside wall area. This compact design minimizes exterior wall surface area, corners, and joints, which are all associated heat loss potential."

A standard building size and shape was selected for this study based on typical gross building areas of the two example subdivisions (approximately 2,200 sq.ft.). A compact configuration of two storey construction with a rectangular shape was used: the building dimensions are 42 ft. by 26 ft. by 18 ft.. The effect of basement type on energy use is discussed below; however, the base building used for the analysis included no basement.

2.2. Building Envelope

The standard building used current Nova Scotia regulations for minimum building insulation requirements:

- Wall Insulation: R-21 ($ft^2 \cdot °F \cdot h/Btu$)
- Roof Insulation: R-31
- Ground Floor Slab Insulation: R-10
- Windows: the regulations limit the transmittance, or U Factor, of windows to 1.8 $Btu/ft^2 \cdot °F \cdot h$, effectively preventing the use of single pane or double glazed clear windows.

---

[2] Nova Scotia Building Code Regulations (2011)

Double Low-e Argon Filled windows with wood frames were used for the standard building: U-1.7; SHGC of 0.40[3].

- Air infiltration: a practical limit for good standard construction practice was used ('tight construction' for the RETScreen analysis; 1.5 air changes/hour[4], or 490 CFM, for the HOT2000 analysis)

The regulations do not limit the rate of uncontrolled air infiltration through the envelope.

2.3. Space Heating

Our study compares the energy required for space heating, independently from the space heating method. However, as shown in the following tables, the method of space heating and the fuel type affect energy cost and greenhouse gas (GHG) emissions significantly.

Table 1: Unit Space Heating Cost by Heating Method

Space heating method	units	Conversion (kWh/unit)	Space heating efficiency	Unit cost	Space Heating Cost ($/kWh of heating)
Electric	kWh	1	100%	0.12638[5]	0.1264
Electric heat pump	kWh	1	225%[6]	0.12638	0.0562
Oil furnace	L	10.68	85%	1.07[7]	0.1179
Natural gas furnace	GJ	277.8	90%	11.322[8]	0.0453

Table 2: Greenhouse Gas Emissions by Heating Method

Space heating method	units	Conversion (kWh/unit)	Space heating efficiency	unit GHG emissions (kgCO_2e/unit)	GHG emissions (kgCO_2e/kWh of heating)
Electric	kWh	1	100%	0.790	0.790
Electric heat pump	kWh	1	225%	0.790	0.351
Oil furnace	L	10.68	85%	2.685	0.295
Natural gas furnace	GJ	277.8	90%	50.30	0.201

---

[3] Gentek window; RetScreen product database

[4] HOT2000 energy model

[5] http://www.nspower.ca/en/home/aboutnspi/ratesandregulations/electricityrates/domesticservicetariff.aspx

[6] http://oee.nrcan.gc.ca/equipment/heating/3678

[7] http://www.kentmarketingservices.com/dnn/LinkClick.aspx?fileticket=iAq1c241qw4%3d&tabid=134&mid=898

[8] http://www.heritagegas.com/residential/residential-rates.html

HRM's Solar City database of 1593 homes reporting space heating method was used to identify trends in space heating fuels. Figure 1 below indicates a trend towards electrically heated homes, which includes homes with heat pumps.

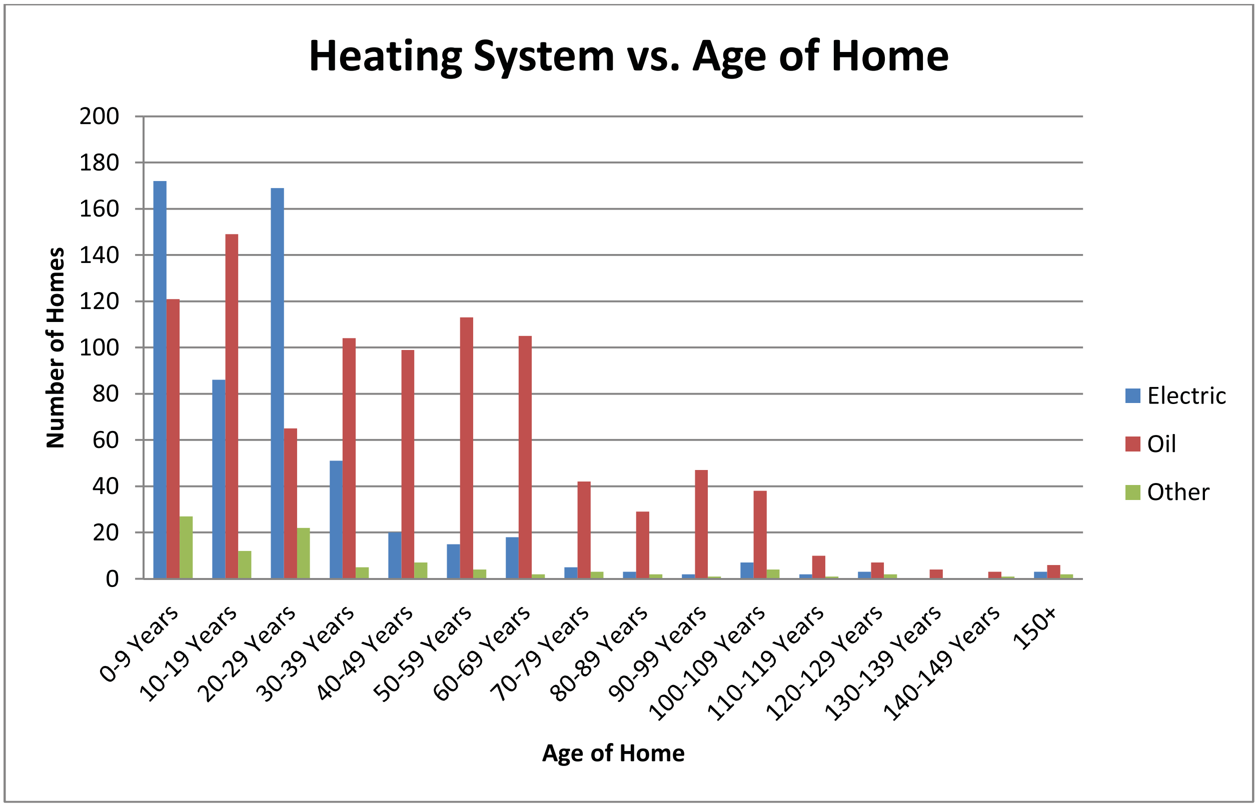


Figure 1: Heating System Type vs. Age of Home

Where required for comparisons in this study, an electrically heated home is considered as the base case. The potential impact of air conditioning is not considered in this analysis.

2.4. Ventilation

Mechanical ventilation is a requirement of the current regulation: a ventilation rate of 74 CFM (35 L/s), 75% fresh air, and a heat recovery rate of 50% was used as for the reference case in the analysis.

2.5. Energy Screening Model

The RETScreen[9] Energy Efficiency Measures screening tool was used to characterize the energy use of the standard building, and to evaluate the impact of changes to building orientation, insulation, window type and ventilation heat recovery.

2.6. Screening Results

2.6.1. *Reference Building*

The reference standard building, facing south-east or south-west (azimuth 60^0) was found to use 15.39 MWh (15,390 kWh) annually: for electric space heating, this represents a cost of $1,945 annually and GHG production of 12.2 tCO_{2e} annually.

2.6.2. *Orientation and Wall Insulation*

Using the RETScreen screening tool, the orientation of the longer face of the building was modeled in 15^0 increments from 0^0 (due south) to 90^0 (east or west). As shown in the following table, for buildings constructed to basic current standards for insulation, the variation in azimuth creates a maximum variation in energy use of 340 kWh annually, or 2.2%.

Table 3: Space Heating Energy by Building Orientation and Insulation

Building Orientation	**Space Heating Energy** (MWh/year)	
	Standard Insulation	**50% Additional Insulation**
0^0	15.05	14.08
15^0	15.09	14.10
30^0	15.22	14.16
45^0	15.34	14.25
60^0	15.39 *	14.29
90^0	15.38	14.28

* reference building

Increasing the building insulation by 50% reduces energy use by 1,100 kWh annually, or 7.1%; it also reduces the significance of building orientation.

---

[9] RETScreen ® International, Natural Resources Canada

2.6.3. Windows – Materials, Location and Orientation

The fenestration ratio (ratio of window area to wall area) is a significant factor in energy conservation: in general, more windows tend to increase a home’s energy requirements. Windows on north-facing elevations increase the space heating energy requirements while – depending on various design factors - windows on south-facing elevations may reduce space heating.

Given that windows provide natural light and opportunities for natural ventilation, we compared the window construction and the ratio of windows on the north and south faces, while keeping the total fenestration ratio constant. The following table compares the use of double glazing (low-e, argon-filled) with triple glazing for windows distributed (a) primarily on the north elevation, (b) uniformly, and (c) primarily on the south elevation.

Table 4: Space Heating Energy by Window Glazing Type and Distribution

Window Glazing	**Space Heating Energy By Fenestration Ratio** (MWh/year)			
	East / West	35%	35%	35%
	North	**45%**	**35%**	**25%**
	South	**25%**	**35%**	**45%**
Double glazed		15.67	15.05 *	14.68
Triple glazed		13.46	13.11	12.95

* reference building - orientation 0^0

As shown, for the reference case, the use of low-e triple glazing reduces energy use by 1,940 kWh annually, or 12.9%. The distribution of glazing affects energy use by 990 kWh annually, or 6.6%.

2.6.4. *Air Infiltration and Ventilation*

The energy requirements related to air infiltration and ventilation are described in the following table.

Table 5: Space Heating Energy attributed to Air Infiltration and Ventilation

Air Infiltration	**Space Heating Energy** (MWh/year)		
	Nominal Ventilation Energy Loss	No Ventilation Energy Loss	**Energy Lost to Ventilation**
'Tight Construction'[10]	15.39 *	13.91	**1.48**
Zero Infiltration	11.39		
Energy Lost to Air Infiltration	**4.00**		

* reference building

Air infiltration is a major contributor to energy loss and, for a given location, is determined by the building's construction details, the windows and doors selected, and the quality of construction.

Ventilation energy loss is a function of the rate of ventilation, heat recovery, and the air leakage which occurs within the heat recovery system.

The losses selected for the reference building are consistent with good construction practice.

---

[10] per RETScreen analysis

3. Passive Solar Design

3.1. Building Envelope

The potential improvements to the building envelope, as quantified by the renewable energy screening tool RETScreen® are tabulated below:

Table 6: Building Envelope - Opportunities for Improvement

Properties	Base Case	Improvements	Energy Savings	% Savings
Windows	Double-glazed, low-e, argon filled windows.	Triple-glazed low-e windows.	1,940 kWh	12.9%
Insulation	R-21 in Walls, R-31 in Roof.	R-30 in Walls, R-45 in Roof.	1,100 kWh	7.1%
Fenestration	Fenestration is 35% S / 35% N.	Fenestration is 45% S, 25% N.	370 kWh	2.5%

3.2. Building Mass

The thermal inertia of a home – particularly in the areas of the home which may be exposed to direct sunlight – has a significant impact on energy performance: buildings with greater thermal inertia are able to utilize daytime heat gain and solar irradiation to reduce night-time heating requirements. The following table uses the reference building and HOT2000[11] residential energy analysis software to demonstrate the effect of construction type on energy use.

Table 7: Space Heating Energy by Construction Type

Construction Type	**Space Heating Energy By Fenestration Ratio** (MWh/year)			
	East / West **North** **South**	35% **45%** **25%**	35% **35%** **35%**	35% **25%** **45%**
Light Wood Frame		15.13	14.80*	14.52
Medium Wood Frame		13.92	13.48	13.10
Masonry/Concrete Elements		11.47	10.59	9.80

* reference building, facing due south

---

[11] http://canmetenergy.nrcan.gc.ca/software-tools/hot2000/968

Increasing the energy inertia of the building reduces energy use, particularly where the window area is increased on the south elevation.

3.3. South-Facing Window Area

The area of south-facing windows may be optimized for buildings with construction materials which increase the energy inertia. The table below identifies the optimum fenestration on the south elevation for two building envelope examples: (a) base case, and (b) improved envelope – extra insulation and triple glazing.

Table 8: Space Heating Energy by South-Facing Window Area

Fenestration Ratio – South Wall*	**Space Heating Energy** (MWh/year)	
	Base Case, with Masonry/Concrete Elements	**Improved Envelope, with Masonry/Concrete Elements**
25%	10.33	6.53
35%	10.02	6.20
45%	9.80	6.08
55%	9.71	6.20
65%	9.74	6.29
75%	9.91	6.45

*north wall: 25%; east and west walls: 35%

3.4. Orientation

The effect of orientation on energy use is much greater for passive solar designs than for homes which are not designed to optimize solar gain. The following table uses the optimum fenestration, as identified above, for homes with the azimuth of the main wall facing south, 45^0 from south, and due east or west.

Table 9: Space Heating Energy by Building Orientation (Passive Solar Design)

Building Orientation	**Space Heating Energy** (MWh/year)	
	Base Case, with Masonry/Concrete Elements	**Improved Envelope, with Masonry/Concrete Elements**
0^0	9.71	6.08
45^0	10.34	6.53
90^0	11.41	7.12

In both the base and the improved envelope cases, orienting the building 45^0 from optimum increases the energy use by 7%, and orienting 90^0 from optimum increases energy use by 18%.

3.5. Energy Use At and Below Grade Level

The base model considers a slab at grade (RETScreen) or an unheated crawl space (HOT2000). The HOT2000 analysis indicates that the addition of a heated basement increases energy use by 7 MWh/year, regardless of building mass, energy conservation measures or orientation of the building.

3.6. Passive Design – Summary

Passive design includes a combination of increasing the thermal inertia of the building through the use of masonry and/or concrete; window materials, size and distribution; and insulation and air tightness. The addition of building mass and optimizing the size and location of windows was found to reduce energy use to 9.71 MWh annually; further improvements to the building envelope (insulation and triple glazing) may reduce energy further to 6.08 MWh annually.

The selection of passive design features and heating system(s) will depend on the design objectives (minimizing cost, GHG, and/or overall energy use): for instance, where natural gas is not available, there may be greater life-cycle value in installing a heat pump than in improving insulation.

For the purpose of this study, a home which is built to passive design standards is assessed to have an energy requirement for space heating of 10.0 MWh annually.

4. Example Subdivisions – Impact of Orientation and Passive Solar Design

The evaluation of a reference home to minimum regulated standards, and a passive design home, were applied to the example subdivisions referenced in the Genivar report.

As noted above, a single reference standard building, facing south-east or south-west (azimuth 60^0) was assessed to use 15.39 MWh annually. Optimizing the orientation to due south reduces the space heating energy by only 340 kWh annually, or 2.2%. However, the reference solar design home is assessed to use only 10.0 MWh annually, and orienting the building east or west of optimum increases the energy use by 7% for 45^0, or 18% for 90^0 from optimum.

Table 10 summarizes the effect of passive design and re-orientation of homes in a 46-lot suburban subdivision where traditional methods would place homes generally at 90^0 to the ideal orientation.

Table 10: Energy Use and Cost - Suburban Subdivision (46 homes)

Base Case		**Passive Design Without Optimum Orientation (Az 90^0)**		**Passive Design; Location and Orientation Optimized (Az 0^0)**	
Space Heating Energy (MWh/year)	**Space Heating Cost** ($/year)	**Space Heating Energy** (MWh/year)	**Space Heating Cost** ($/year)	**Space Heating Energy** (MWh/year)	**Space Heating Cost** ($/year)
707.9	89,480	542.8	68,610	460.0	58,140
Mutual shading effect:		59.4	7,458	-	-
707.9	89,480	602.2	76,119	460.0	58,140
(reference)		(-15%)		(-35%)	

The first line of Table 10 indicates that, for passive-design homes with electrical heating, the re-orientation reduces the energy cost of space heating by $10,500 annually.

However, for this subdivision, the mutual shading of houses with uniform setbacks reduces the area of windows on the south elevation, and puts some of these windows in shade most of the time. Based on our screening of varied fenestration ratios, we estimate the effect of mutual shading to add 1.3 MWh heating to the space heating requirement of homes which otherwise use passive design methods.

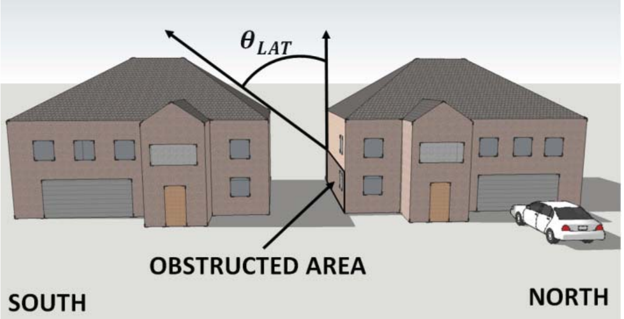


Figure 2: Solar Obstructions - Houses with Uniform Setbacks

Accordingly, optimizing the location as well as orientation reduces energy use considerably: we estimate a reduction in energy use of 142 MWh annually, or $18,000 for electrically-heated homes without heat pumps ($8,000 annually for homes with heat pumps).

Table 11 summarizes the effects for a 46-lot rural subdivision where homes generally at 45^0 to the ideal orientation. For passive-design homes with electrical heating, the re-orientation reduces the energy cost of space heating by $1,800 annually for electrically-heated homes without heat pumps ($800 annually for homes with heat pumps).

Table 11: Energy Use and Cost - Rural Subdivision (20 homes)

Base Case		**Passive Design Without Optimum Orientation (Az 45^0)**		**Passive Design With Orientation Optimized (Az 0^0)**	
Space Heating Energy (MWh/year)	**Space Heating Cost** ($/year)	**Space Heating Energy** (MWh/year)	**Space Heating Cost** ($/year)	**Space Heating Energy** (MWh/year)	**Space Heating Cost** ($/year)
307.8	38,910	214.0	27,050	200.0	25,280
(reference)		(-30%)		(-35%)	

5. Conclusions

Green Power Labs evaluated the potential energy savings of optimizing the configuration of homes in subdivisions for passive solar design.

The energy used for space heating was evaluated for a reference home built to the minimum standards of the current Nova Scotia Building Regulations. Various energy conservation measures and passive design features were evaluated using RETScreen and HOT2000 software, from which a reference energy use was assessed for a passive design. The energy use of the reference standard home and the passive design home were assessed for varying orientations for unobstructed site conditions.

It was found that the orientation of homes built to minimum standards has only a nominal effect on the building's energy use for space heating. The reference home was assessed to use 15,400 kWh of space heating annually; having the longer wall of the home facing due south reduces energy use for space heating 340 kWh annually, or 2.2%, when compared to facing due east or west.

However, passive design homes have the potential to reduce energy use significantly: our analysis identified that a reduction in space heating energy use by 5,400 kWh annually, or 35%, to 10,000 kWh may be expected for a typical range of passive design homes which are sited without solar obstruction and oriented with a longer wall facing south.[12] For these homes, siting is more critical: our analysis indicates that homes orientated with a short wall facing south use 18% more space heating energy than homes with a long wall facing south, and a partial obstruction of the south wall, e.g., in subdivision developments with roads running north-south, may increase energy requirements by a further 10-15%.

Two example subdivisions were evaluated for the effect of implementing passive solar design techniques, including the relocation and re-orientation of homes to have their major axis face due south:

- For the suburban example of 46 homes, it was found that running streets north-south and requiring uniform setbacks would undermine the value of passive solar design significantly: optimizing the location as well as orientation reduces energy use considerably: we estimate a reduction in energy use of 31%, or 142 MWh annually, or $18,000 for electrically-heated homes without heat pumps ($8,000 annually for homes with heat pumps).

---

[12] (The extent to which passive design principles are adopted may depend on the builder's objectives, and would be optimized on a case-by-case analysis. Our assessment of the space heating energy use of passive design homes considered relatively conventional construction materials and construction methods.)

- For the rural example of 20 homes without solar obstructions on streets which run at 45^0 to east-west, re-orienting the homes would reduce energy use by 7%, or only 14 MWh annually (i.e., $1,800 for electrically-heated homes without heat pumps, or $800 annually for homes with heat pumps).

Appendix A Available Solar Resource

For reference, the solar resource of the standard home described in this report is presented in the following table:

Building Orientation (Az.)	**Solar Resource** (MWh/year)		
	Roof[1]	**Walls**[2]	**Total**
0^0	71.6	61.4	133.0
45^0	67.9	64.4	132.3
90^0	62.0	59.2	121.2

[1] based on south-facing half of roof area, where applicable, at optimum slope for solar gain

[2] based on the unobstructed wall area, net windows, of two most south-facing walls

The data indicate that, for a building which utilizes a heat pump for space heating and is orientated as much as 45^0 from due south, roof-mounted PV panels are capable of providing more electricity than is required for space heating:

Space Heating Power Requirement:	
Space heating energy use: passive design home - base case; orientation 45^0	10.34 MWh/year
Space heating power requirement (heat pump COP 225%)	**4.60 MWh/year**
Photovoltaic Power Supply:	
Solar resource – roof, azimuth 45^0:	67.90 MWh/year
Solar resource – net roof obstructions of, e.g., 20%	54.30 MWh/year
Solar power at panel, e.g., thin film roofing application – 13% efficiency	7.06 MWh/year
Solar power to grid, e.g., system efficiency of 75%	**5.29 MWh/year**