# Tools to Support British Columbia Local Government Climate Change Mitigation Policy

*A comparative study of two models that assess the greenhouse gas impacts of future residential settlement patterns for the District of Sechelt*

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# Executive Summary

The Province of British Columbia is taking action to mitigate greenhouse gases causing climate change. Central to this commitment is *Bill 27* (2008), requiring local governments to include greenhouse gas reduction targets in their Official Community Plans and Regional Growth Strategies. The province's vision for mitigating land use and transportation greenhouse gas emissions is compact communities. A compact community displays three primary characteristics: medium to high density, centred and connected land use and advanced building design.

Acting on climate change to positively influence these factors requires local governments to revisit land use policies and regulations. Better information and tools can support local government policy decisions that aim to reduce greenhouse gases. My research evaluates two models that assess the greenhouse gas impacts of existing land use patterns and future policy scenarios to support local governments in scoping open source climate change tools. Planning practice needs simpler, more transparent transportation-land use models that differentiate between policy options available to local governments (Allen 2008).

The ideal transportation-land use model is:

- *Affordable*: inexpensive to acquire, learn and operate (Batty 2008).
- *Accessible*: uses standard software available to a range of stakeholders (Moore 2008)
- *Relevant*: variables are under the influence of local government policy (Moore 2007)
- *Transparent*: capable of linking each variable to certain impacts *(*Klosterman, 2008)
- *Real-time*: capable of altering scenarios quickly for interactive use *(*Ingram 2009)
- *Comprehensive*: capable of incorporating all major factors contributing to greenhouse gas impacts (Deal et al. 2008)
- *Simple*: flexible to the limited data available to local governments (Klosterman 2008)

I evaluate the Sustainability Solutions model and the UBC Development Pattern model using two primary methods. The first method involved completing a statutory analysis of local government powers demonstrating that the models' endogenous variables are directly tied to local government functions. There are extensive powers for local governments to regulate or provide incentive for compact, energy efficient development. In the second method, I apply both models against the same datasets using the District of Sechelt as a case study. The District is a small municipality within the Sunshine Coast Regional District, a coastal region approximately 50 kilometres northwest of Vancouver.

The case study reveals opportunities and challenges for local government scoping models that are inexpensive to acquire, learn and operate. Local governments can effectively measure energy reductions in future scenarios with limited data. Both models illustrate energy consumption based on the energy efficiencies of compact housing types. The Sustainability Solutions model assesses the feasibility of alternative low-carbon community energy systems.

The Sustainability Solutions model measures transportation greenhouse gas emissions with two primary variables: reduction in average trip length and modal shifts to

alternative transportation. The lack of accessible transportation data is the main obstacle for local governments with limited resources to integrate land use and transportation impacts. Considering transportation impacts is important because the reduction in average trip distances associated with compact development scenarios is the most influential variable in reducing transportation greenhouse gas emissions.

I offer recommendations for further research to benefit the future generation of open source models. Senior levels of government can show leadership by continuing to provide and advocate for better data that is available to local governments. If further research can demonstrate cost-effective ways for local governments to acquire data on transportation behaviour, the open source models provide an affordable and effective tool for local governments to meet legislative requirements and effectively plan for greenhouse gas reductions.

## 1.0 Introduction

Under the direction of the 2007, 2008 and 2009 Throne speeches, the Province of British Columbia has recognized climate change mitigation as a priority for local governments now and into the future. Climate change mitigation is an approach to reduce and eventually eliminate Green House Gas Emissions (GHGE) that contribute to global warming. There is extensive research that correlates higher residential densities in proximity to essential services with reduced community-wide GHGE. A variety of factors that affect greenhouse gas emissions are influenced by a community's land use pattern, including:

- *Building energy efficiency*: Single attached dwellings consume approximately 30% less energy per capita than single detached dwellings (Farahbakhsh et al. 1998).
- *Building energy source*: Higher densities make renewable energy sources, such as community district energy systems, more feasible (Holland Barrs et al. 2008: 21).
- *Transportation modal split*: Doubling density in neighbourhoods with access to public transit and services can reduce per capita vehicle kilometers travelled by over 30% (Clear et al. 2002: 3).
- *Average vehicle trip distance*: For every kilometre a dwelling is moved away from a neighbourhood centre, vehicle kilometers travelled per dwelling increases by approximately 1 kilometre (CMHC 1999: iii).

Local governments need for better information and tools to support policy decisions, and planning practice needs simpler, more transparent land use-transportation models that differentiate between policy options available to local governments (Allen 2008; Moore 2008; Moore 2007; Klosterman 2008; Timmermans 2008). My research aims to advance the understanding, accessibility, and value of this practice by comparing two greenhouse gas land use-transportation models using the District of Sechelt as an academic case study.

The Sustainability Solutions model and the UBC Development Pattern model use density and location of growth as the two land use variables affecting greenhouse gas emissions. The Sustainability Solutions Group was hired in 2007 by the Islands Trust in BC to estimate the greenhouse gas emissions of three parcel specific build out settlement pattern scenarios on Saltspring Island. The projects used an excel-based greenhouse gas scenario model to capture the greenhouse gas implications of residential energy efficiency, district heating feasibility and vehicle kilometres travelled. The UBC Development Pattern model uses a pattern approach to generate future scenarios. Development patterns are collections of street, open space, parcel and building case studies that are applied to areas with statistically similar land uses and densities. Each development pattern has a proportion of case studies that sum to 100% of its area. The model captures greenhouse gas emission reductions based on the energy performance of more compact residential development; an additional model is needed to assess transportation impacts.

The case study demonstrates that local governments can effectively measure energy reductions in future scenarios with limited data. Both models illustrate energy consumption based the energy efficiencies of compact housing types, including duplexes, row houses and apartments. The Sustainability Solutions model coarsely assesses the feasibility of clean district heating community energy systems. Neither model captures local government's authority to promote green building design.

The high cost of trip diaries presents the biggest challenge for local governments with limited resources to integrate land use and transportation impacts. Senior levels of government can show leadership by continuing to provide and advocate for varying levels of data available to local governments.

## 2.0 Climate change-land use connection

If current emission rates continue into the future the earth will warm at a more rapid pace and contribute to extreme changes to the climate system caused by increases in air temperature, ocean temperature, glacier melting and sea level rise (IPCC 2007).
A 60 to 80% reduction of total GHGE from 1990 levels by 2050 is required to stabilize the effects of climate change (Bartholomew 2007). The province of British Columbia (BC) has shown leadership in legislating a province-wide GHGE reduction of 80% from 2007 levels by 2050 (Province 2007). To meet this target, private vehicle dependence and building energy consumption need to be mitigated. Cumulatively, these two contributors of carbon dioxide account for up to 55% of total GHGE (Ingram, 2009). The authority of local governments to regulate building density and location makes them a prime candidate to act on climate change. *Bill 27* (2008) requires local governments to include GHGE reduction policies, targets and actions in their Official Community Plans by 2010 (Province 2008a). The BC Climate Action Charter (2007) commits signatory local governments to measure community-wide GHGE and plan for compact, complete communities (Province et al. 2007). The BC Climate Action Charter states its goal as the creation of "complete, compact, more energy efficient rural and urban communities" (2007). A compact community's built environment displays three primary characteristics: medium to high density, centred and connected land use, and green building.

Compact communities feature medium to high densities rather than low density sprawl (Province et al. 2007). Higher densities are associated with a diverse housing stock. In-home energy consumption varies between housing types; for example, apartment units consume significantly less energy than single family homes because shared walls and ceilings reduce heating demands (Bartholomew et al. 2008).

High densities and mixed uses enhance the feasibility of efficient district heating energy systems (NRC 1985). District heating systems produce electricity, hot water and/or cold water from non-conventional heat sources. Electricity is distributed from a central plant through underground wires and pipes for space heating and hot water use in serviced buildings (Newman et al. 2006). District heating's GHGE impact depends on two factors. First, if the system services mixed uses, peak hours for heating vary between the commercial and residential uses; efficiency gains from this distribution pattern can reduce energy consumption by 10-20% (Infrastructure 2008). Second, the source of the heat will have a considerable impact on GHGE; for example, natural gas will not reduce GHGE as much as carbon neutral sources like wood, sewer heat, heat released from adjacent buildings or geothermal; use of a renewable heating source can reduce energy consumption between 70-100% (S. Tynan, Personal Communication 2009, October 14 2009).

The second principle of compact communities is centred and connected land uses, or as the Charter states, “integrated land use and transportation planning” (Charter 2007). Residential units near public transit and common services like schools, employment centres and grocery stores reduce overall vehicle kilometres travelled. Case studies across North America demonstrate a 20 to 40% decrease in vehicle kilometres travelled when comparing a compact settlement pattern to a sprawling one (Bartholomew et al. 2007; Clear et al. 2002; Gard 2007). Where settlement patterns are at distance from services, compact communities remain accessible to alternative forms of transportation through connected transportation networks and pedestrian friendly design (Bartholomew 2007: 20; Litman 2005: 19).

The third principle of compact communities is green building (Charter 2007). The design of the built environment influences GHGE due to factors like embodied energy, parcel landscaping and dwelling siting for solar and interior appliances. The complexity of incorporating parcel specific design factors leaves green building out of most land use-transportation impact assessment tools in practice (Bartholomew 2006). Green building is not captured by the Sustainability Solutions model; the UBC Development Pattern considers it with a variable that is exogenous to local government policy levers. Compact community characteristics that are not captured in either model are the retention of forests and farmland (Charter 2007: 3). Wooded areas act as carbon sinks and local food production can supplement transported food demands (Bartholomew, 2007: 1).

The principles of compact communities are connected, encompassing the vision of complete communities set forth by the province. It is these principles that local governments can address today to effectively meet *Bill 27* (2008) requirements and Climate Action Charter (2007) commitments.

## 3.0 Strategies and tools to plan for compact communities

### 3.1 Scenario planning

Scenario planning generates land use policy scenarios about the future based on a collection of policies, and the impacts associated with them (Hopkins et al. 2007). It requires local governments to revisit land use policies that will have an impact on the environment. This practice differs from forecasting or visioning because the focus is on comparing possible futures that are not necessarily the most likely or desirable (Hopkins et al. 2007). Once a preferred scenario is selected, however, resulting policies and actions may be implemented to steer the community towards that future.

Scenarios are theoretical because the practice is incapable of accounting for the “wickedness” of planning issues and the irrational forces that impact the future (Geertman 2008: 215). Hopkins et al. (2007: 5) state that policy decisions based on future scenarios can be “oblivious to the complexity of the planning situations in terms of uncertainty, distributed authority, contesting interests, and the dynamics of getting from the present to the future.” Moore (2007) argues the future is complex and unknown, but certain outcomes are more likely than others; it is planners who believe future outcomes can be influenced by policies today. Understanding the environmental direction of policy scenarios, based on grounded and explicit assumptions, is more relevant than their accuracy (Moore 2007). Proving policies produce less GHGE than alternative options results in public accountability, stronger funding proposals and fulfillment of legislated requirements (Klosterman 2008).

## 3.2 GHGE scenario modeling

Scenario planning relies on planning support systems, a term used to describe software used to compile, analyze and or visualize information (Geertman 2008). The Sustainability Solutions model and UBC Development Pattern model are embedded in planning support systems like Microsoft Excel, Microsoft Access and Geographic Information Systems (GIS). I refer to the practice of scenario planning and the planning support system that it draws upon as GHGE scenario modeling.

GIS is a planning support tool for spatial analysis and map representation. Land use planning maps symbolically represent physical characteristics of the real world such as topography, roads, or political boundaries. Certain cautions should be noted when GIS supports decision making. Legal parcels are only a representation of a legal survey's true location and configuration. Natural areas and environmental constraints represent absolute boundaries that are less clearly defined in reality (Burrough 1998). GIS is a powerful tool only if it is treated as a conceptual model of reality that complements empirical knowledge.

## 3.3 Obstacles to GHGE scenario modeling in practice

The majority of planners have limited experience using and interpreting scenario models (Geertman 2008; Geertman et al. 2005). Training, hardware and software costs, consulting costs, data shortages and a lack of political support are bottlenecks to the wider adoption of the practice (Allen 2008; Geertman et al. 2005; Moore 2008). Moore (2008: 232) considers three primary options available to local governments scoping land use-transportation scenario models: 1) create an in-house model using GIS, 2) purchase a standard model for in-house use, or 3) hire consultants to run custom models. The first option requires significant research and time, the second option may lack compatibility with the statutory framework and data availability of a community, and the third option may not be feasible for local governments with limited financial resources.

## 3.4 Future open source GHGE scenario models

### *Sustainability Solutions model*

The Sustainability Solutions Group completed a report in 2007 in cooperation with Holland Barrs Consulting and the Islands Trust entitled "GHG implications of different settlement patterns for Saltspring Island" (Holland Barrs et al 2007). The report generated three future scenarios by assigning varying forms of compact development to the parcel fabric. An Excel-based energy and transportation model measured the GHGE impacts of the scenarios. Each land use and transportation variable has its own spreadsheet tab that calculates GHGE totals based on data entry inputs, constant assumptions and tonnes of carbon dioxide equivalent conversions. Two spreadsheets measure the GHGE reductions of compact development based on the future increase in energy efficient attached housing and district heating servicing. The transportation spreadsheets measure the GHGE reduction of compact development with two primary variables: reduction in average trip length and modal shifts to alternative transportation. The model also measures the GHGE impact of future road construction; this variable is not integrated into the District of Sechelt case study. The assumptions and variables are labelled within each spreadsheet so that they can be customized to each community's dataset. The intuitive design of the model connects the multiple spreadsheets to one primary data entry spreadsheet.

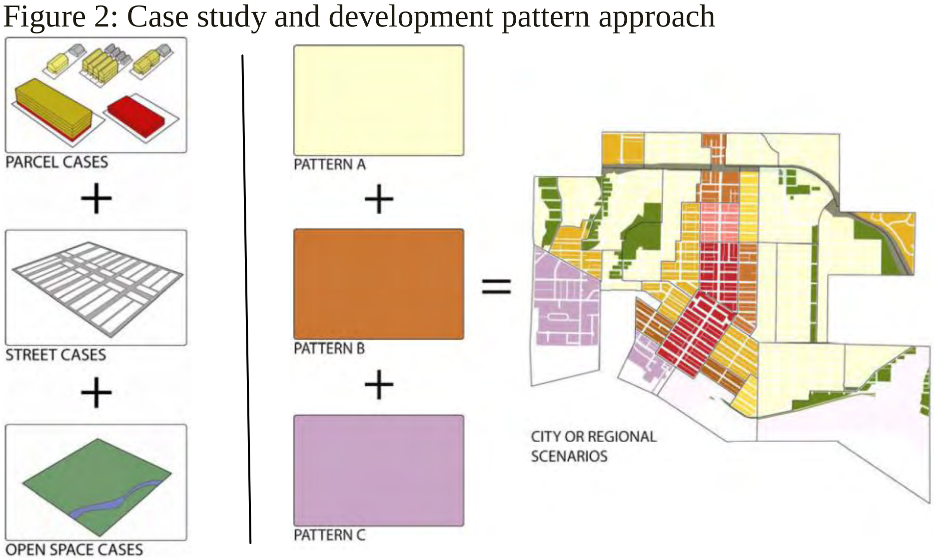
Figure 1: Sustainability Solutions primary data entry spreadsheet example

| **Inputs from GIS Analysis** | **2009 baseline** | **Business as usual scenario** | **Compact development scenario** |
|---|---|---|---|
| 1. Number of units within 500m of service centre | 587 | 1194 | 2233 |
| 2. Number of units within 400m of public transportation | 3164 | 6622 | 9059 |
| 3. Average trip length | 7.5 | 7.5 | 7.5 |
| 4. Number of units with biomass district heating | 0 | 1817 | 3996 |
| 5. Number of attached units | 735 | 3155 | 4916 |
| 6. Total kilometres of paved roads | 138 | 153.67 | 148.32 |

***UBC Development Pattern model***

The City of North Vancouver in cooperation with the University of British Columbia completed the "North Vancouver 100 Year Sustainability Vision" (2008). The project considered a range of factors to help the city be completely carbon-neutral by the year 2107. The model developed at UBC uses a development pattern approach to generate spatially logical settlement pattern scenarios. Development patterns are collections of street, open space, parcel and building case studies that are applied to areas with statistically similar land uses and densities. Each development pattern has a proportion of case studies that sum to 100% of its area. The development pattern approach uses three Microsoft Access tables to generate GHGE impacts: development patterns, land use cases and energy assumptions. The model is intuitive and efficient because of its drop down menu design and querying powers.

Figure 2: Case study and development pattern approach




(Miller et al. 2008)

The coarse transportation model added to the North Vancouver project is not applied to the District of Sechelt case study because its assumptions and data are specific to a high density urban environment. Modal shift assumptions for units near services and transit were guided by the indicator of jobs per hectare. Basing modal shift on jobs per hectare is not as meaningful for small municipalities that have minimal mixed uses. Moreover, to capture the variance in vehicle kilometres travelled, the model relied on Vancouver trip diary data to estimate the number of vehicle trips per household per day. The estimates are not applicable to small municipalities. To get a complete picture of community-wide GHGE, the Sustainability Solutions transportation model is run as an additive to the UBC Development Pattern model.

## 4.0 Research Background

My research compares the Sustainability Solutions energy model and the UBC Development Pattern energy model. Both organizations are revising their models with funding support from Canada Mortgage and Housing Corporation and the Pacific Institute of Climate Solutions in preparation for open source release.

### 4.1 Research purpose

- Improve the awareness and understanding of low cost GHGE scenario models to support the formation of attitudes about the practice (Allen 2008).
- Determine the extent of local government authority to influence the models' variables (Bartholomew 2006).
- Support common objectives between academics, consultants and planners for the research, development and practice of GHGE scenario modeling (Waddell 2005).
- Provide insight into the GHGE output differences between models (Allen 2008).
- Demonstrate the processes, skills, data and resources needed, excluding public participation, to run the models.
- Recommend further research, programs and partnerships to address data and capacity challenges.

### 4.2 Research question

Using the District of Sechelt as a case study, what are the challenges and opportunities for two greenhouse gas scenario models and how do they differ? Additionally, what variables and assumptions within these models can be addressed through the authority and influence of BC local governments?

### 4.3 Research audience

Existing land use-transportation models are intended for communities experiencing growth; the main variables are the future location and density of the building stock. A 2007 survey of land-use transportation scenario modeling projects in the United States reveals the practice is most popular for local governments experiencing high growth rates in states with growth policies or legislation (Bartholomew 2006). The geographic distributions of the projects proved to be clustered around urban growth nodes on the West Coast and East Coast. In California, the *Global Warming Solutions Act* (2006) commits the state to 1990 GHGE levels by 2020; to support reduction targets, local governments must assess GHGE in the construction of land use plans (Bartholomew 2007). The other states with clusters of local government land use-transportation scenario projects have climate action plans that identify growth-related land use sprawl as a significant contributor to GHGE (Delaware 2000; Maryland 2008; Oregon 2004; Virginia 2008; Pennsylvania 2007; Washington 2008). The practice is not applicable for stagnant or shrinking communities that do not project meaningful land use changes in future years; however, if future models can capture urban design variables the practice may extend to stagnant communities assessing the implications of retrofitting and reusing buildings.

### 4.4 Research scope

My research is a project-based, academic study that does not incorporate public participation. The public plays an integral role in the future of scenario planning; provoking people's thoughts and perceptions about the future is most effective when integrated with the development of a land use plan (Jones et al. 2005 194). Public participation must be taken into account when local governments create or revisit land use plans although public buy-in for visions of compact development may be a challenge because people enjoy the privacy, safety and culture of the suburbs (LGA 1996: 879-3; Grant 1999). The extent to which compact development will occur in the future is uncertain but it may become more prevalent with future demand and the environmental implications of sprawl. Recent studies suggest that the demand for compact development may rise in the future as baby-boomers retire near services (Pitkin et al. 2008). Furthermore, Logan et al. (2007) found that approximately one third of home-buyers prefer homes associated with smart growth, an alias for compact communities. Part of this attraction relates to the increased access to open space that results from more compact development. For example, various studies in North America have identified a 15-30% increase in value for developments near open space (Curran 2003).

## 5.0 British Columbia local government statutory analysis

The BC Climate Action Charter (2007: 3) states that local governments should "develop a range of actions that can affect climate change, including initiatives such as: assessment, taxation, zoning or other regulatory reforms or incentives to encourage land use patterns that promote increased density, smaller lot sizes, encourage mixed uses and reduced GHG emission." A statutory analysis is necessary to understand the connection between BC local government authority and variables within the Sustainability Solutions model and the UBC Development Pattern model. Effective scenario models clearly differentiate between policy options by using variables that are under the authority, if not the influence, of local governments (Moore 2007). The models' variables are aggregated into five categories for statutory analysis: density, district heating energy systems, proximity to services, public transit accessibility, street connectivity and future road construction. Some policy tools discussed have yet to be implemented in practice or analyzed in case law due to their recent introduction into legislation. Local government powers should be confirmed by a legal opinion before implementation.

Local governments are empowered by the Province through the *Local Government Act* and the *Community Charter*. The *Community Charter* details additional powers available to municipalities that do not extend to electoral districts under the governance of Regional Districts. Both statutes provide the legal framework, duties, functions and authority for local governments to carry out their responsibilities.

Parts 25 and 26 of the *Local Government Act* provide the primary land use and management tools for local governments. Regional Growth Strategies and Official Community Plans are the primary vehicles for local governments to strategically plan for land use decisions within municipalities, electoral districts and region-wide. A Regional Growth Strategy provides long range planning policy direction for rural electoral areas and municipalities within the regional district and gives a basis for decisions regarding implementation of provincial policies and programs in the area. An Official Community Plan is a statement of goals and objectives to guide decisions on planning and land use management within the plan area of a municipality or rural electoral district, respecting the purposes of local government. An Official Community Plan must include a statement of consistency with the goals and objectives set out in a Regional Growth Strategy that encompasses its plan area (LGA 1996: S. 865). The future-oriented policies of these documents guide the implementation of local government regulations. For example, if an Official Community Plan states a policy objective to encourage higher densities and mixed uses near services, the Zoning Bylaw would interpret this objective and regulate density, size, siting and land use accordingly (LGA 1996: 903-1).

The province has significant powers to alter the future direction of land use planning in BC. The Minister of Community and Rural Development may change guidelines for developing Regional Growth Strategies or Official Community Plans as well as the content that is required (LGA 1996: S. 870). The Minister may require local governments to alter either strategic plan if he or she "believes that all or part of the bylaw is contrary to the public interest" (LGA 1996: S. 874-1). The province influences local government functions with funding support. Existing funding programs include Towns for Tomorrow, the Infrastructure Planning Grant Program, Local Motion and Spirit Squares. The programs vary, but are primarily focused on supporting sustainable infrastructure, improving access to alternative transportation and amenities and creating vibrant neighbourhood centres (Province 2009). In 2007 and 2008, the province awarded Green Cities Awards and funding for local government initiatives consistent with the principles of compact communities (Province 2008c).

## 5.1 Density

Local governments are equipped with extensive powers to plan for and regulate land use density. A Regional Growth Strategy works towards "avoiding urban sprawl and ensuring that development takes place where adequate facilities exist or can be provided in a timely economic and efficient matter," and "settlement patterns that minimize the use of automobiles and encourage walking, bicycling and the efficient use of transit" (LGA 1996: S. 849-2b). Official Community Plans must include, with a minimum time horizon of five years, "the approximate… amount, type and density of residential development required to meet anticipated housing needs" (LGA 1996: S. 877-1a).

Local governments are empowered to precede strategic planning with regulatory zoning bylaws that regulate the use and density of land, buildings and other structures (LGA 1996: S. 903-1c); legislation does not limit the size of regulatory zones. Spot-zoning is a common practice in BC to re-zone a specific parcel for higher density developments; the District of Sechelt refers to the spot-zoning parcels as comprehensive development zones. Reactive re-zoning provides the opportunity to negotiate amenities or community-based financial donations (B. Huot, Personal Communication, October 23 2009).

Proactive planning uses area-wide zoning controls to achieve higher densities. Local governments may allow bonus densities in designated areas (LGA 1996: 904-1). Conditions for bonus densities may include park dedications, cash-in-lieu or affordable or special needs housing (LGA 1996: 904-2). These specific conditions can be stipulated as part of a re-zoning where the land owner and the local government enter into a development agreement. Development agreements can serve two objectives for local governments: higher building densities and secured amenity features. To give confidence to developers proposing complex and expensive higher density developments, local governments can lock in zoning designations over a specified time as part of a phased development agreement which must include, in part, the allowable density and timing of the development (LGA 1996: 905.1). Phased development agreements require a public meeting and a zoning bylaw amendment (CRM et al. 2008: 5; LGA 1996: 905.3-1).

There are many incentive-based policies available for local governments to encourage specified forms of density. Development cost charges are monies collected by local governments to offset the costs of servicing new development. Under S. 933 of the LGA, they can be charged to anyone who receives subdivision approval or a building permit (LGA 1996: 933); the rates can be charged on a sliding scale depending on the number of units per hectare or the building type (MCD 2000: 2.16). Local governments must define certain categories of development that are eligible for the development cost charge exemptions; one of the categories for waiving charges is “a subdivision of small lots that is designed to result in low greenhouse gas emissions” (LGA 1996: S. 933.1-1c). Additional financial incentives can be implemented by municipalities to encourage the revitalization of certain areas. Under S. 226 of the *Community Charter*, municipal taxes can be waived for certain developments that meet the criteria set forth in a revitalization program bylaw. The bylaw needs to detail the types of land uses, activities and circumstances that make a development eligible for the tax exemption; accordingly, the bylaw may include specified building types or densities for the benefit and revitalization of the municipality (2003: S. 226-5). A legal opinion is recommended to confirm that density could stand as the purpose for revitalization (2003: S. 226-2). It may need to be a side objective that compliments other revitalization criteria (B. Huot, Personal Communication, October 23 2009).

The intensification of density is supported by the BC Agricultural Land Commission. The provincial agency designates Agricultural Land Reserves in local government boundaries to support the protection and retention of farm land. Under the Agricultural Land Commission Act (2002), local government zoning must be consistent with provincial policy in these areas. Accordingly, the reserves support compact development that reduces the tension to develop farm land into suburban and large lot residences.

## 5.2 District heating community energy systems

Regional Growth Strategies work towards “planning for energy supply and promoting efficient use, conservation and alternative forms of energy” (LGA 1996: S. 849-2m). Local governments can promote district heating servicing by defining conditions in development agreements. Conditions for bonus densities may include the “provision of amenities, including the number, kind and extend of amenities” (LGA 1996: 904-2); installing piping to be connected to a district heating source could be considered such a condition (S. Tynan, Personal Communication, October 14 2009). Phased development agreements may secure district heating infrastructure as required features or amenities of the development (LGA 1996: 905.1-4). This policy tool is particularly relevant because it is meant for higher density, multi-year developments (CEA 2008: 19). It requires a public meeting and a Zoning Bylaw amendment (LGA 1996: 905.3-1).

Local governments can designate development permit areas in their Official Community Plans that establish objectives to promote energy conservation and GHGE reductions (LGA 1996: S. 919.1-1). The development permit area can stipulate “specific features in the development” and “machinery, equipment and systems external to building and other structures” (LGA 1996: S. 920-10.1). Local governments may stipulate district heating piping installation for buildings within the development permit area. There is no legislation that states a local government can force a private development to connect to district heating. However, the cost of installing district heating piping is a primary deterrent to its wider use. If the piping installation is required as part of a development permit there would be little incentive to refuse the service.

Community specific studies may demonstrate that savings from municipal servicing can justify short term financial commitments to develop district heating (CEA 2008: 17). Development cost charge reductions are permitted for small lot developments or development that is designed to have a low environmental impact (LGA 1996: S. 933.1).

Rate reduction criteria can be based on district heating installation or property tax exemptions. The criteria for a development to be exempt from certain taxes are quite broad, only stating the purpose to revitalize the municipality (Community Charter 2003: S. 226-2); the revitalization bylaw must include the eligible properties, the extent of the exemption and the duration of the exemption (Community Charter 2003: 226-4). All being considered, the burden of providing financial incentives may not be feasible for local governments who already struggle to find the resources or expertise to assess district heating feasibility (CEA 2009).

A logical solution may be local government collaboration and partnerships with private district energy providers. Terasen Energy Services, a subsidiary of Fortis, is actively involved in district heating servicing; its operations include Dockside Green in Victoria and what is to be the Olympic Athlete's Village in Whistler (Terasen 2009). However, without drastic changes to existing energy taxes for non-renewable sources the incentive to encourage wider-spread usage of district heating in Canada may not exist for energy providers. To fill this void, BC municipalities have the option to own and operate district heating systems (LGA 1996: S. 195-1; Community Charter 2003: S. 185-1). The incentive for municipalities to take a direct role include the retention of local jobs, the recovery and use of local biomass sources and stable energy pricing (MCD 2009: 15). Municipalities may establish a bylaw to charge customers in the service area if a petition is signed by over 50% of the eligible landowners (Community Charter 2003: S. 211, 212 and 216). If the vote is in favour, the service area charge applies to all properties regardless if landowners choose to receive it. These powers were used by the City of North Vancouver to create the Lonsdale Energy Corporation, a city-owned company that operates a natural gas district heating system. The system serves 11 buildings with the capability for expansion under its service area bylaw (NRCAN 2009b). North Vancouver's district heating system was made possible by significant funding from the Federation of Canadian Municipalities (FCM) and the Canada-BC Municipal Rural Infrastructure Fund.

### 5.3 Proximity to services

Local government authority to control the location of density is demonstrated by the functions of Official Community Plans and Regional Growth Strategies. An Official Community Plan works towards "the approximate location, amount and type of present and proposed commercial, industrial, institutional, agricultural, recreation and public utility land uses" (LGA 1996: S. 877-1ab). The District of Saanich established an urban containment boundary in its 2008 Official Community Plan to concentrate residential development in locations close to services while retaining forest carbon sinks and agricultural land (District of Saanich 2008: 4-9). Regardless of how Official Community Plans state their compact development objectives, zoning bylaws provide the teeth to regulate spatial zoning boundaries (LGA 1996: S. 903-1).

Incentive-based policy tools are available to local governments for encouraging development close to services. The rates of development cost charges can vary based on the location of density (MCD 2005: 2); a municipality can vary its municipal taxes for "different areas of the municipality" as part of a tax revitalization bylaw (Community Charter 2003: S. 226-5b). Local governments have the authority to fast track development applications or offer rebates for specified features of a development based on the developments location (Community Charter 2003: S. 210). Studies demonstrate financial incentive provided by local governments may be recovered by future servicing savings. A study looking at the Central Okanagan region of B.C. found that a more compact growth scenario would cost 34% less in servicing costs than a conventional settlement pattern (B.C. et al. 2009). This is consistent with a Toronto study that identified a savings of 30% between compact and dispersed settlement patterns (Curran 2003: 24)

## 5.4 Access to conventional transit

The ability of local governments to influence the number of dwellings near conventional public transit depends on its authority to locate density and its influence on the geographic extent and frequency of transit. The BC Transit Plan (2008) supports the use of these powers to, "increase population and employment densities near transit hubs and transit corridors"; Regional Growth Strategies are meant to work towards, "settlement patterns that minimize the use of automobiles and encourage walking, bicycling, and the efficient use of public transit" (Province 2008b; LGA 1996: S. 849-2); Official Community Plans and subsequent zoning bylaws control allowable densities near conventional public transportation (LGA 1996: S. 877-1a and S. 903-1c).
The frequency and extent of public transportation in BC is administered by two authorities: TransLink (formally known as the South Coast British Columbia Transportation Authority) delivers transportation services, including public transit, for the Metro Vancouver region, while BC Transit oversees transit throughout the rest of the province.

The purpose of the BC Transit is to provide public transportation that "supports regional growth strategies, official community plans and economic development of the transit service areas" (BC Transit Act 1996: S. 3.1). Transit service areas are determined by local government with approval by BC Transit's Board of Directors. The Sunshine Coast Transit Business Plan (2006) states the objective to "integrate transit planning with local and regional land use planning." Service costs are shared between BC Transit and local governments (TA 1996: S. 11 and 12). Local governments can fund transit services with two main revenue streams: revenue from passenger fares and property taxes. A small portion of revenue comes from transit system advertising on buses, benches, and shelters. Local governments are entitled to all the ridership revenue and remaining funds can be acquired through a tax on legal property values within the transit service area (SCTA 2006: 44; S. 14-1). Transit services in the Victoria and Vancouver areas have access to a fuel tax, with a number of other funding sources available to TransLink (Translink 2009).

The frequency and extent of transit service is largely dependent on provincial funding. Beginning in 2001, the province limited its funding to existing transit service on the Sunshine Coast, with no monies available for transit expansion. To combat potential service cuts, the District of Sechelt and the Sunshine Coast Regional District covered a greater proportion of costs than normally required. The flex-funding agreement is custom to the Sunshine Coast and is not stated as a tool in the BC Transit Act. Other flex-funding agreements usually involve a third funding partner such a First Nations local government (T. Wegwitz, Personal Communication, October 26 2009).

Whether or not official regional transit commissions exist, local government councils in transit service areas can request transit planning and service reviews from BC Transit. Therefore, local governments have an influence over transit service but the ultimate authority for Transit Business Plans lies with BC Transit. The challenge for local governments is the heavy reliance on provincial funding. To address this need, the BC Transit Plan (2008) calls for a $14 billion federal and provincial commitment to expanding transit and doubling ridership in the province by 2020. The plan effectively puts an end to the spending freeze implemented in 2001 and should promote more transit-friendly neighbourhoods.

### 5.5 Street connectivity

The Sustainability Solutions model estimates average trip length per household for existing settlement patterns and future scenarios. GIS analysis can calculate distance to specific destinations following the digital road network. Street connectivity influences the length of household trips to common destinations. Land use patterns direct street connectivity, which local governments control.

Regional Growth Strategies have the purpose of working towards "the efficient movement of goods and people while making effective use of transportation and utility corridors" (LGA 1996: 949-2c). Official Community Plans must include statements and map designations for the "approximate location and phasing of major road, sewer and water systems" (LGA 1996: S. 877-1e). Local government can "regulate and prescribe the minimum standards for the dimensions, locations, alignment and gradient of highways in connection with subdivisions of land" (LGA 1996: S.938). There are, however, differences in authority between regional districts and municipalities. The construction of new roads in electoral areas governed by regional districts is under the authority of the Ministry of Transportation. Subdivision road standards in electoral areas must be approved by the Minister responsible for the Transportation Act (LGA 1996: 938-3.1a). Local governments may apply local improvement charges to a defined number of parcels to fund road construction. After the road is developed to specified standards, the Ministry of Transportation will administer it. These improvements are usually completed on a small scale in rural neighbourhoods (CEA 2009). Conversely, municipalities hold possession of their road network and have the authority not only to plan but construct new roads (Community Charter 2003: S. 35). Municipalities have more authority over the future of their road-network but regional districts have an important role in planning for new roads in collaboration with the Ministry of Transportation.

### 5.6 Kilometres of future roads

Section 5.5 describes local government's authority to influence road-networks including new construction.

## 6.0 District of Sechelt case study

I have selected the District of Sechelt to compare and evaluate the Sustainability Solutions model and the UBC Development Pattern model. The municipality encompasses nine neighbourhoods, over 4,000 hectares of land and is home to an estimated 9,200 residents. I choose the community as a case study because its regional nature, high growth rate and high development capacity ensures noticeable differences in GHGE between the existing settlement pattern and future scenarios.

The District of Sechelt experienced significant growth over the past twenty years, with an average annual growth rate of 3.2% from 1986 to 2006 (District of Sechelt 2009b). BC Stats projects continued growth at an annual rate of 1-2% in the time period 2006-2026 (District of Sechelt 2009b). The projected population increase is based on the future migration of retired baby-boomers; it is an attractive community for retirement because of its ocean setting, recreational opportunities and proximity to Vancouver.

BC Stats growth projections are likely a conservative estimate based on the high amount of recent rezoning and subdivision approvals. The processing of existing applications is expected to direct changes in the settlement pattern over the next 10-15 years (District of Sechelt 2009b). The majority of these approvals are in neighbourhoods outlying the town centre. However, with the municipality's potential to triple its existing population, alternative policies and regulations that encourage more compact development could considerably reduce the municipality's long term community-wide GHGE. The case study is for academic purposes; there is no expectation that the future scenarios will support decision making for the District of Sechelt.

### 6.1 Data Preparation

The first consideration when preparing spatial settlement patterns is the data required (Burrough 1998). GIS spatial data is represented as polygons (e.g. legal parcels), lines (e.g. roads) or points (e.g. buildings). Attributes of the spatial features are stored in a geodatabase. Spatial features can graphically represent attributes in the geodatabase. The data required to generate existing settlement patterns and future scenarios is available to almost all local governments in BC (ICIS 2009):

Figure 3: GIS data requirements to generate future settlement pattern scenarios

| *Required* | *Recommended* | | |
|---|---|---|---|
| <u>Polygon Shapefile</u> | <u>Polygon Shapefile</u> | <u>Line Shapefile</u> | <u>Point File</u> |
| -legal parcels | -parks | -road network | -dwellings |
| -zoning | -Crown land | -contours | |
| | -municipal boundary | -municipal servicing | |
| | -environmental constraints | | |

Assumptions give meaning to data. The accuracy of the assumptions, that is, their ability to represent reality, depends on the quality of data and the amount of input from local, experienced individuals (Geertman 2008: 215). I created assumptions in consultation with planning and development staff at the District of Sechelt to generate the existing settlement pattern and future settlement scenarios. Planners and development officers, holding experience in subdivision requirements and approval, are valuable resources to provide proper consideration for community-specific assumptions; their understanding of past development trends can guide future assumptions.

## 6.2 Existing settlement pattern (2009 baseline)

***2009 baseline method***

I designed a methodology to estimate the location and density of the District of Sechelt's existing settlement pattern that is applicable for small municipalities in BC (Attachment 1). Parcels currently undevelopable (i.e. parks, crown land) or unlikely to house a considerable number of dwellings (i.e. Park and Assembly, Industrial, Marine and Water zoning designation) are excluded from the residential build out scenarios. The existing settlement pattern data set is used as a 2009 baseline for the Sustainability Solutions model and the Design Centre for Sustainability model.

***2009 baseline results***

The District of Sechelt's baseline housing stock totals 4,530 dwelling units for a population of 9513.[1] The estimate demonstrates a 3.8% annual growth rate since the 2006. The housing stock is comprised of detached single family dwellings (78%), attached dwellings (4%), low-rise apartment units (12%) and mobile homes (6%). Neighbourhoods with the highest percent of the total population are West Sechelt (31%), Sechelt (22%) and Davis Bay (17%) (Map **2**).[2] The dispersed settlement pattern reflects the District of Sechelt's dependence on private vehicle use. In 2006, 86% of residents commuted to work as a vehicle driver or passenger.

## 6.3 Scenario planning considerations

Three considerations guided the construction of future scenarios for the District of Sechelt: the scenario's time horizon, the number of scenarios to be assessed and the nature of the policy embedded in each scenario. Scenarios with time horizons require projections and assumptions about how much growth will occur and where. I have chosen to avoid this contentious and difficult practice by preparing residential spatial build out scenarios. A residential spatial build out is a land use map that estimates the total number of dwellings allowable as defined by zoning regulations. The only requirement to justify

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[1] The baseline population estimate of 9513 is 3% higher than District of Sechelt's estimate of 9200. The latter estimate assumes a 2% annual growth rate since 2006. Significant development activity over the last three years may suggest a higher growth rate than 2%.

[2] I calibrated the baseline housing stock results with 2006 census data. The 2006 dwelling stock data was 76% detached dwellings; 17% attached dwellings and low-rise apartments; and 7% mobiles homes.[2] The calibration combines attached housing and low-rise apartments because the 2006 census combines duplexes with certain types of low-rise apartments (Statistics Canada 2009)

a build out analysis is to assume that growth will continue in the future, and at some future, the development capacity of the community may become saturated. Build out scenarios are effective at informing the environmental direction of policy but cannot inform GHGE reduction targets without further analysis. Reduction targets require a time horizon to work towards (e.g. a 33% GHGE reduction from 2009 baseline by 2020). One option to integrate targets is to assume a percentage of the build out developments will be built in certain locations over a defined time horizon.

The most obvious future to assess is one that assumes no changes to the District of Sechelt's existing *Subdivision and Development Bylaw* (2007). The business as usual scenario is compared to an alternative scenario that incorporates policy associated with the principles of compact development. The number of future scenarios is an important consideration. Bartholomew et al. (2006: 6) argues that two future scenarios can lead to a 'good' and a 'bad' option while three future scenarios may lead to a compromise in the middle. Avin (2007: 133) argues that four future scenarios provides an appropriate variance of policy options for comparison. My research does not aim to support municipal decision making, and therefore, two future scenarios is sufficient to compare the GHGE scenario models: build out settlement pattern with existing regulations and build out settlement pattern with compact development regulations.

Avin (2007: 107) argues that alternative future scenarios should "push one's imagination to consider different and even 'uncomfortable' changes" as long as it is used to support decision making and not guide it. I held a charrette with the District of Sechelt planning staff to inform an academic general future land use map for the compact development scenario (Map **3**). Intensification scenarios aimed to be aggressive but grounded in realistic densities. The development capacities of parcels outside areas identified for residential intensification are down-zoned. Reducing the allowable density in these regions allows the models to compare similar build out populations between scenarios. The compact development scenario transfers future development in the business as usual scenario to more compact neighborhoods near services. Down zoning parcels outside of an urban containment boundary is challenging to implement in practice because it limits landowners' ability to subdivide. Rather than regulatory controls, municipalities may discourage sprawl development by substantially increasing suburban development cost charge rates (District of Sechelt 2009b: 5).

In addition to down-zoning, the general future land use map identifies three compact development growth nodes: Sechelt Village, Wilson Creek service centre and some intensification on green field sites in East Porpoise Bay. Sechelt Village is the primary service centre for the municipality. Wilson Creek has a secondary service centre with small scale health services, a grocery store, restaurants and other commercial space. Wilson Creek's surrounding area has the potential to be serviced by municipal sewerage expansions systems in the next 50 years (Planner, Personal Communication, August 27 2009). In the south portion of East Porpoise Bay, approximately 21 hectares of vacant land may be developed into detached and multi-family housing. The potential infill depends on whether or not a municipal sewage system can service the area (Planner, Personal Communication, August 27 2009).

Recent residential and mixed use re-zonings in the District of Sechelt provide an indicator of densities and housing mixes permissible by municipal council (Duncan Cavens, Personal Communication, November 3 2009). One such re-zoning is the Silverback Comprehensive Golf Course Development in East Porpoise Bay (Map **4**). The un-built development calls for 1600 dwelling units, 70% of which is attached and low-rise apartments (Sechelt 2007). The density, excluding the golf course, is approximately 1 unit per 400 metres squared. Similar densities and housing mixes are applied to greenfield parcels near Sechelt Village in the compact development scenario.

Select parcels are increased to densities not allowable in Sechelt's existing *Subdivision and Development Bylaw* (2007). The highest density re-zoning that council has approved is an un-built apartment complex west of Sechelt's village centre that holds a net density of approximately 1 unit per 80 square metres. The highest density in the compact development scenario is low-rise apartments in the village centre that has a density of 1 unit per 50 metres squared or floor area ratio of approximately 2.2.[3] The significant majority (>90%) of the higher densities in the compact development scenario are associated with row housing and low-rise apartments not exceeding densities already passed by council.

### 6.4 Method to generate future scenarios

The Sustainability Solutions model pilot project for Saltspring Island prepared future scenarios with parcel specific spatial build outs. The model calculates density thresholds to determine future housing characteristics. I identified the permitted dwelling types by the allowable uses in the *Subdivision and Development Bylaw* (2007) (Map 4). Parcels in the compact development scenario replicate the business as usual scenario except for legal parcels that are reduced or increased in density (Attachment 2) (Map 5).

I recommend local governments prepare future scenarios using the UBC development pattern approach rather than parcel specific analysis. Development patterns illustrate land uses in a spatially logical manner to involve stakeholders and display land uses in a more meaningful way. For example, each development pattern can be displayed logically by average density or GHGE per capita. The development patterns are also capable of changing and measuring baseline or future scenarios quickly for discussion or monitoring (Hopkings 2007; Avin 2007). Creating scenarios with parcel specific analysis demands significant geodatabase analysis to change scenarios and is difficult to represent at the community-wide scale. Moreover, parcel level detail may divert attention from the substantive community-wide issues being addressed (D. Cavens, Personal Communication, October 29 2009).

For the UBC Development Pattern model, a total of fourteen case studies are assigned to the development patterns for the District of Sechelt. I selected three single attached parcel case studies and three low-rise apartment parcel case studies from UBC Development Pattern database. I calibrated the case studies with the density similar parcels in the District of Sechelt's existing settlement pattern. I created six detached dwelling case

[3] Floor area ratio is the ratio of total building floor area on a parcel (floor area ratio= total floor area/parcel area)

studies by approximating the average parcel sizes of residential neighbourhoods in the municipality.

Figure 4: Residential case studies used for the District of Sechelt's future scenarios

| case id | case code | case study description | case site area (m2) | attached units | detached units | apt lowrise units | floor area (m2) | floor area ratio (FAR) |
|---|---|---|---|---|---|---|---|---|
| 1 | D-1 | Detached, two dwellings on 6 hectare parcel | 60000 | 0 | 2 | 0 | 400 | 0.01 |
| 2 | D-2 | Detached, two dwellings on 1.4 hectare parcel | 14000 | 0 | 2 | 0 | 400 | 0.03 |
| 3 | D-3 | Detached, one dwelling on 2000 square metre parcel | 2000 | 0 | 1 | 0 | 200 | 0.10 |
| 4 | D-4 | Detached, one dwelling on 1200 square metre parcel | 1200 | 0 | 1 | 0 | 200 | 0.17 |
| 5 | D-5 | Detached, one dwelling on 900 square metre parcel | 900 | 0 | 1 | 0 | 200 | 0.22 |
| 6 | D-6 | Detached, one dwelling on 660 square metre parcel | 660 | 0 | 1 | 0 | 200 | 0.30 |
| 7 | A-1 | Attached, side by side duplex | 495 | 2 | 0 | 0 | 297 | 0.60 |
| 8 | A-2 | Attached, 7.5 metre rowhouse | 248 | 1 | 0 | 0 | 124 | 0.50 |
| 9 | A-3 | Attached, 5 metre rowhouse | 165 | 1 | 0 | 0 | 132 | 0.80 |
| 10 | LR-1 | Low-rise apartment, 2-3 stories | 1980 | 0 | 0 | 16 | 1782 | 0.90 |
| 11 | LR-2 | Low-rise apartment, 2-4 stories | 1980 | 0 | 0 | 23 | 2574 | 1.30 |
| 12 | LR-3 | Low-rise apartment, 4-5 stories | 1980 | 0 | 0 | 39 | 4356 | 2.20 |
| 13 | MU-1 | Mixed use, low-profile, ground level commercial support | 1980 | 0 | 0 | 12 | 1056 | 0.53 |
| 14 | MU-2 | Mixed use, medium profile, ground level commerical support | 1980 | 0 | 0 | 31 | 2785 | 1.41 |

The mix of development patterns in the business as usual scenario aims to replicate the characteristics of the existing settlement pattern by identifying common land use mixes that are likely to extend to vacant residential areas with similar zoning schemes (Map 6). The percentage of parcel specific land use cases within each distribution pattern is determined through an iterative process to ensure a general fit with the District of Sechelt's allowable densities and land uses (Attachment 4). Ideally, applying development patterns precedes a build out study that identifies the community's allowable densities. I calibrated the development pattern densities to the parcel specific build out densities for the Sustainability Solutions model.

Case study percentages are assigned to development patterns to represent the business as usual scenario. I altered four distribution patterns to transfer density in the compact development scenario. As shown in Figure 5, development pattern 4.1 and 4.2 are applied to reduce density in outlying areas; development pattern 9.1 and 11.1 increase density in the growth node areas.

Figure 5: Development patterns for business as usual scenario

**1.0 Rural residential**

-77% detached dwelling (60,000m2 average lot size)

-15% road right of way

-8% open space

**2.0 Semi-rural residential**

-77% detached dwelling (14,000m2 lot size)

-15% road right of way

-8% open space

**3.0 Medium lot residential and multi- unit housing with open space**

-9% detached housing (900m2 lot size)

-2% row housing (0.5 floor are ratio)

-2% duplex (0.6 floor area ratio)

-15% road right of way

-73% open space

**4.0 Big lot residential and medium lot residential**

-20% detached dwelling (900m2 lot size)

-50% detached dwelling (1200m2 lot size)

-27% road right of way

-8% open space

**5.0 Medium lot residential**

-64% detached dwelling (900m2 lot size)

-1% row housing (0.5 floor area ratio)

-27% road right of way

-8% open space

**6.0 Row housing and multi-unit housing**

-50% row housing (0.5 floor area ratio)

-10% low-rise apartment (2-3 stories, 0.9 floor area ratio)

-30% road right of way

-10% open space

**7.0 Medium lot residential with limited multi-unit housing**

-55% detached dwelling (900m2 average lot size)

-10% row housing (0.5 floor area ratio)

-27% road right of way

-8% open space

**8.0 Small lot residential**

-65% detached dwelling (660m2 lot size)

-27% road right of way

-8% open space

**9.0 Small lot residential with low density multi-family housing**

-38% detached housing (660m2 lot size)

-8% row housing (0.5 floor area ratio)

-14% low-rise apartment (2-3 stories, 0.9 floor area ratio)

-30% road right of way

-10% open space

-3% open space

**10.0 Multi-unit residential with limited mixed use**

-27% low-rise apartment with commercial support (0.5 floor area ratio)

-40% LR-1 low-rise apartment (2-3 stories, 0.9 floor area ratio)

-30% road right of way

-3% open space

**11.0 Low-density mixed use**

-55% MU-1 low-rise apartment with commercial support (0.5 FAR)

-5% LR-1 low-rise apartment (2-3 stories, 0.9 FAR)

-35% road right of way

-5% open space

Figure 6: New development patterns for compact development scenario

<u>Reducing density of business as usual</u>

**4.1 Big lot residential**

-65% D-3 detached housing (2000m2 average lot size)

-27% road right of way

-8% open space

**4.2 Big lot residential and medium lot residential**

-35% D-5 detached dwelling (900m2 average lot size)

-30% D-4 detached dwelling (1200m2 average lot size)

-27% road right of way

-8% open space

<u>Increasing density from business as usual</u>

**9.1 Small lot residential with high density multi-housing**

-38% D-6 detached dwelling (660m2 average lot size)

-11% A-3 row housing (0.8 FAR)

-11% LR-2 low-rise apartment (2-4 stories, 1.3 FAR)

-30% road right of way

-10% open space

**11.1 Medium-density multi-unit residential with mixed use surrounding service centre**

-5% MU-1 low-rise apartment with commercial support (2-3 stories, 0.5 FAR)

-50% MU-2 low-rise apartment with commercial support (2-4 stories, 1.5 FAR)

-5% LR-3 low-rise apartment (4-5 stories, 2.2 FAR)

-35% road right of way

-5% open space

## 6.5 Future scenario build out results

The District of Sechelt's build out housing stock ranges between 12,191 and 12,265 units based on the respective methods of the UBC Development Pattern approach and the Sustainability Solutions parcel specific approach. The total build out population ranges between 25,601 (Design Centre for Sustainability) and 25,757 residents (Sustainability Solutions). The business as usual scenario cements a sprawling settlement pattern that significantly increases the proportion of detached dwellings in Tuwanek, North Sandy Hook, South Sandy Hook and West Sechelt (Map 4). Approximately 3500 units are transferred in the compact development build out scenario by reducing density in West Sechelt, West Porpoise Bay, Tuwanek, North Sandy Hook, South Sandy Hook and Davis Bay. The density is re-distributed to the three growth nodes (Map 5).

Figure 7: Housing stock of residential build out scenarios

| | **UBC Development Pattern Model** | | **Sustainability Solutions Model** | |
|---|---|---|---|---|
| | Business as usual residential build out | Compact development residential build out | Business as usual residential build out | Compact development residential build out |
| Detached dwelling (%) | 74% | 59% | 74% | 60% |
| Attached dwelling (%) | 10% | 14% | 26% | 40% |
| Low-rise apartment (%) | 16% | 27% | | |
| Total (numberic) | 12207 | 12191 | 12265 | 12265 |

Figure 8: Population location of residential build out scenarios

| | Business as usual residential build out | Compact development residential build out | % change |
|---|---|---|---|
| West Sechelt | 24% | 20% | -4% |
| West Porpoise Bay | 9% | 8% | -1% |
| Tuwanek | 3% | 2% | -1% |
| North Sandy Hook | 12% | 5% | -7% |
| South Sandy Hook | 12% | 1% | -11% |
| East Purpoise Bay | 4% | 6% | 2% |
| Sechelt and area | 19% | 43% | 24% |
| Davis Bay | 15% | 12% | -3% |
| Wilson Creek service centre | 1% | 4% | 3% |

## 6.6 Assessing the greenhouse gas emissions of future scenarios

The location and density of settlement patterns are translated into GHGE by making assumptions about residential energy sources, heating demand and vehicle kilometres travelled. The assumptions precede a review of information and data in literature and practice. If the Sustainability Solutions model and the UBC Development Pattern model used the same assumptions and variables for similar settlement patterns, similar results would be produced. Explicitly stating and evaluating each model's variables informs the differences between the two models.

***Household energy source***

Both models' must consider the source of energy that serves the building stock. The Ministry of Environment's Community Energy and Emissions Inventory (2007) provides each local government with estimates of energy consumption and GHGE from on-road transportation, solid waste, buildings and deforestation. The report for the District of Sechelt estimates 66% of the residential connections are hydro electricity and 34% are natural gas. Hydro electricity is a clean energy source; the combustion of natural gas emits 30% and 45% less CO2 than oil and coal respectively (Natural Gas 2004). Alternative heating sources like wood or solar are not captured by the report. I weighted the GHGE factors for hydro electricity and natural gas to determine the kilograms of carbon dioxide equivalent (kgCO2eq) per gigajoule.

Figure 9: Converting energy source into GHGE

| | Energy source: % of total (CEEI 2007) | GHGE Factor (kgCO2eq/GJ) (Pembina 2007) | (% total * GHGE factor) |
|---|---|---|---|
| Hydro Electricity | 0.66 | 2.1 | 1.3 |
| Natural Gas | 0.34 | 49.9 | 17.0 |
| | | Weighted Emissions Factor (kgCO2eq/GJ) | **18.3** |

Carbon dioxide equivalents are the universal standard to compare the release or mitigation of GHGE. Gases other than CO2 that contribute to global warming are translated into equivalent CO2 units based on their potential to cause global warming. CO2 is not as potent as other gases like methane, but the sheer high volume caused by fossil fuel combustion makes it a prime contributor to global warming. Both models output GHGE as tonnes of carbon dioxide equivalent (tCO2eq).

***Dwelling Energy Efficiency***

Single attached and apartment units are more energy efficient than detached dwellings because shared walls and ceiling reduce heating demands. Single attached units include duplexes, triplexes, fourplexes, row houses and apartments. Apartments are categorized into low-rise apartment (<5 stories) and high-rise apartment (>5 stories).

The Sustainability Solutions models pilot project for Saltspring Island assumes single attached dwellings are 30% more energy efficient than detached dwellings based on national heating averages (Farahbakhs et al. 1998). A 30% reduction rate is an effective assumption for small communities that have an even distribution of low-density single attached housing types. Medium sized municipalities must distinguish between attached dwellings that differ in energy performance (e.g. duplex versus a low-rise apartment unit). The BC Hydro Energy Conservation Review (2007) illustrates average residential energy consumption in gigajoules by provincial regions. The lower mainland region is categorized into four dwelling types: detached dwelling (109 GJ), row house (58 GJ), low-rise apartment (29 GJ) and high-rise apartment (45 GJ).[4] Most of the District of Sechelt's single attached units are row housing as defined by BC Assessment. I assume the average energy assumption of single attached units in the District of Sechelt is 41% by dividing the Farahbakhs et al. (1998) estimate of 30% for single attached units and BC Hydro's estimate of 52% for row houses. I incorporated the energy efficiencies of low-rise apartments by weighting the existing housing mix. I assume the average energy consumption of all attached dwellings is 38 GJ.

Figure 10: Attached housing energy consumption for Sustainability Solutions model

| Dwelling type | Number of units | % of total | annual energy consumption (GJ) | (% of total * annual energy consumption) |
|---|---|---|---|---|
| Single attached unit | 205 | 0.27 | 64 | 17.3 |
| Low-rise apartment | 530 | 0.72 | 29 | 20.9 |
| Average baseline energy consumption of attached housing stock | | | | **38.2** |

The UBC Development Pattern model does not aggregate energy efficiencies for attached dwellings because its categorizes units into detached, duplex, row house, low-rise apartments (<5 stories) and high-rise apartments (>5 stories)

***District heating community energy source***
The Sustainability Solutions model assumes that densities higher than 55 units per hectare have the feasibility to install district heating in future scenarios. The assumption is based on 2007 personal communication with Natural Resource Canada staff (Holland Barrs et al. 2007). The models pilot project assumes units eligible for district heating are served by a biomass district heating system. Biomass refers to organic material such as wood chips, bark, good waste and landfill gas that can be burned to produce energy. Burning clean biomass that is sustainably produced is considered carbon neutral because it taps into the carbon cycle (Maker et al. 1999).

The UBC Development Pattern model relies on community specific district heating feasibility studies to make scenario assumptions (D. Cavens, Personal Communication, October 14 2009). The model's North Vancouver pilot project used local knowledge and studies to make assumptions about the future expansion of the cities existing district heating system (Miller et al. 2008b: 30).

***Future design-based energy efficiencies***
Newer houses are generally more energy efficient because of advancements in building form and household appliances. Increasing energy efficiency is largely dependent on factors like air-leakage, insulation, ventilation (NRCAN 2009c). The Sustainability Solutions model does not incorporate standard assumptions about future residential energy performance improvements. Existing residential energy averages are uniformly applied to future scenarios.

[4] High-rise apartments are less energy efficient than low-rise apartments because of their compromised thermal efficiency (i.e. glass walls) and common amenities (e.g. elevators, gyms, swimming pools) (N. Miller, Personal Communication, November 19 2009).

The UBC Development Pattern model includes an exogenous variable from a report published by the David Suzuki Foundation (2002) entitled "Kyoto and Beyond." The report estimates that energy performance of residential buildings can be reduced by 50% from 2002 averages by the year 2030. BC Stats projects the District of Sechelt to be approximately half of its build out population by 2030 (Sechelt 2009b). Accordingly, the David Suzuki report acts as a conservative estimate of design-based energy reductions for a build out future that is beyond the time horizon of any applicable research. The energy consumption averages of dwelling types in future scenarios are adjusted as follows: detached unit (56 GJ), attached unit (33 GJ), low-rise apartment unit (15 GJ) and high-rise apartment unit (22 GJ).

***Residential GHGE Output***

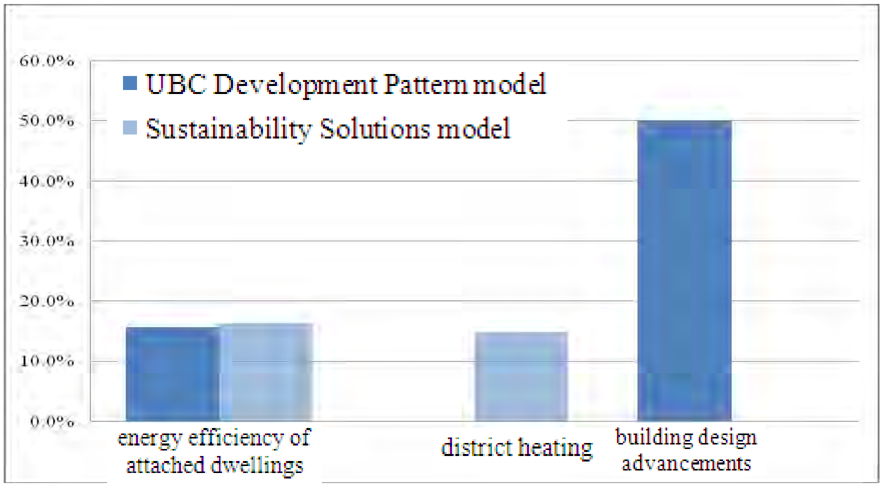
The UBC Development Pattern model demonstrates an 11% change between future scenarios based on the energy efficiency of more compact dwelling types. The models exogenous building design variable causes significant future reductions from the baseline. The Sustainability Solutions model shows similar energy efficiency reductions (12%); its district heating assumption accounts for the remaining reductions.

Figure 11: District of Sechelt per capita residential GHGE (tCO2eq)

| | 2009 Baseline | Business as usual scenario | Compact development scenario | % change between future scenarios |
|---|---|---|---|---|
| UBC Development Pattern model | 0.84 | 0.41 | 0.36 | **11%** |
| Sustainability Solutions model | 0.85 | 0.65 | 0.40 | **39%** |

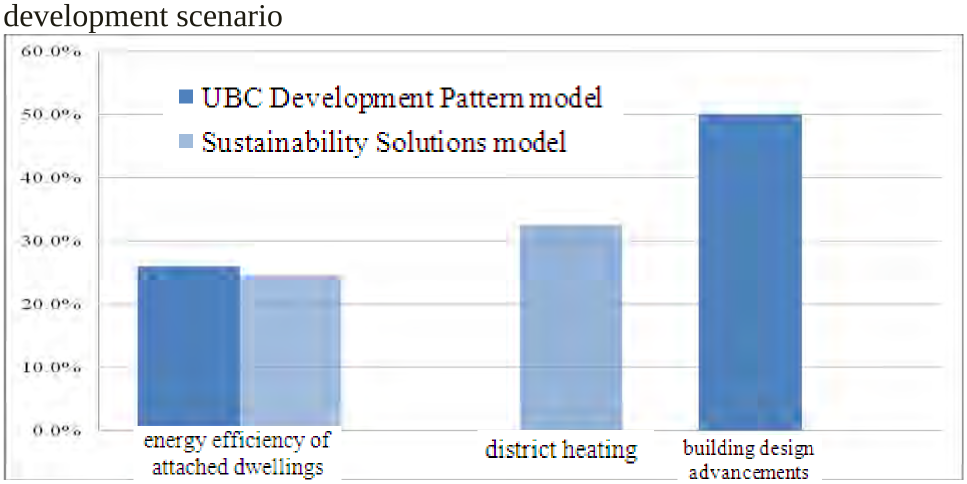
For the business as usual scenario, the variables measuring energy efficiency reductions in both models' rival the reductions seen by the district heating variable in the Sustainability Solutions model. The exogenous green building variable in the UBC Development Pattern Model reduces total residential GHGE by 50%, more than energy efficient dwellings and district heating combined.

Figure 12: Variable impact (%) on reducing greenhouse gases for the business as usual scenario




For the compact development scenario, the energy efficiency variables further reduce GHGE because of the increase in compact dwelling types. The increase in densities over 55 units per hectare in the compact development scenario increase the population eligible for district heating. District heating servicing translates into greater GHGE reductions than energy efficiencies. Like the business as usual scenario, green building dominates reductions at 50% for the UBC Development Pattern model.

Figure 13: Variable impact (%) on reducing greenhouse gases for the compact development scenario



***Transportation GHGE***

The Sustainability Solutions model adopts the traditional four-step model to assess transportation GHGE. The four-step model assesses: 1) the number of trips, 2) trip distribution, 3) modal-split and 4) route direction. The first three steps require assumptions about residents' travel behaviour derived from detailed trip diaries (McNally 2000). Specific trip destinations such as schools and service centres are weighted based on trip frequency to measure trip distance (Attachment 7). The third step assumes shifts to alternative modes of transport that reduce vehicle kilometres travelled. The fourth step, route direction, refers to the transportation network that the trips will follow. The four step model assesses travel behaviour within the plan area; regional travel is excluded (Cavens 2009). This limitation is deemed acceptable because provincial legislation only requires local governments to include GHGE reduction targets and actions in the area defined by their Official Community Plans (Province 2008).

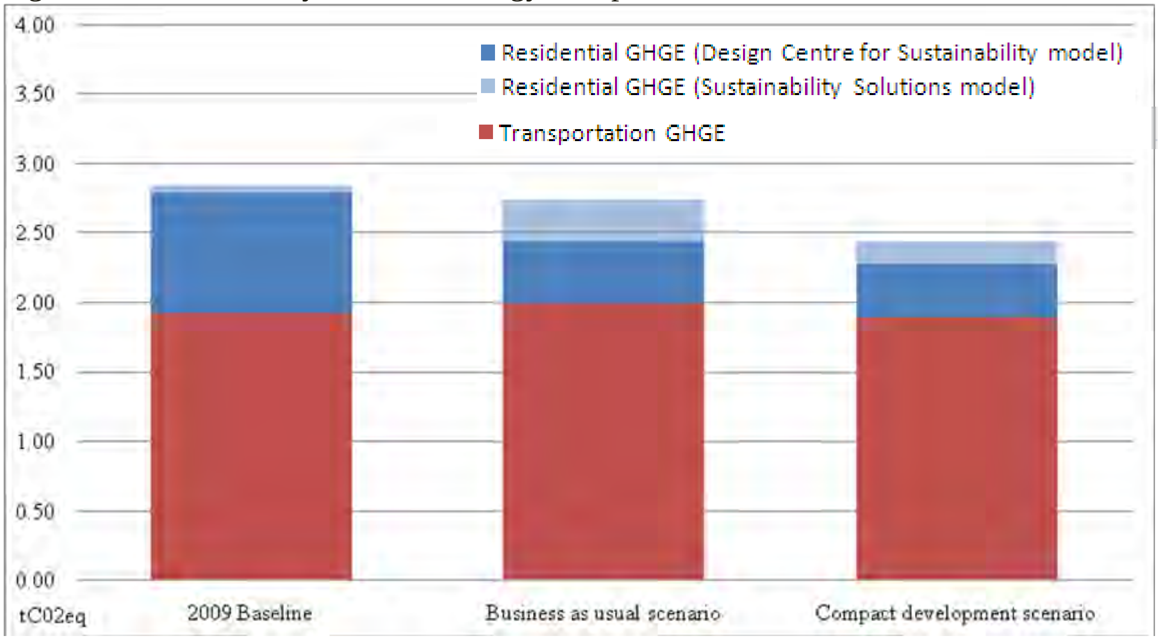
Like many municipalities, the District of Sechelt does not have data on travel behaviour. I have adopted total trips per day (6.6), percent of trips by car (69%) and average distance travelled (7.5 kilometres) from the Victoria Capital Regional District's "Household Travel Survey" (2006). These inputs act as an illustrative proxy to demonstrate theoretical transportation impacts for the District of Sechelt.

Shifts to alternative forms of transportation are assessed in the model. The model assumes that 70% of trips to the service centre are walking for populations within 500 metres. The assumption is derived from a study assessing walking habits in Toronto, Ottawa-Carleton and Thunder Bay. The percent of people who walked within one kilometre of a service centre varied from 33% in Thunder Bay to 75% in Toronto (Hawthorne 1989). The logic for 70% is that the climate of BC is more conducive to walking year round and the distance threshold for walking is 500 metres rather than 1 kilometre (Holland Barrs et al. 2007: 20). The two service centres in the District of Sechelt, Sechelt centre and Wilson Creek, were identified based on local knowledge and the presence of a grocery store.

Conventional public transit is defined as a fixed-route transit service using conventional transit buses. The population within 400 metres of a road served by conventional public transit is considered to have accessible service. In the Sunshine Coast Transit service area, 4.3% of commuter trips are made by public transit. Of the people who commute, 43% percent would otherwise travel in a private vehicle (BC Transit 2006). The remaining percentage of travellers will walk, cycle or not travel at all. Therefore, the model assumes that 4.3% of total trips are made by public transit for units within the 400 metre transit buffer, 43% of which will offset private vehicle use.

I calculated the number of units within 500 metres of a service area and 400 metres of a public transit route using GIS buffer analysis. For the Sustainability Solutions model's parcel-specific dataset, I selected all parcels that had their centroid in the buffer area. For the UBC Development Pattern model, I extrapolated the number of units based on the proportion of the pattern area inside the buffer area. The difference between the two methods is less than 1%.

Figure 14: Sustainability Solutions energy transportation model

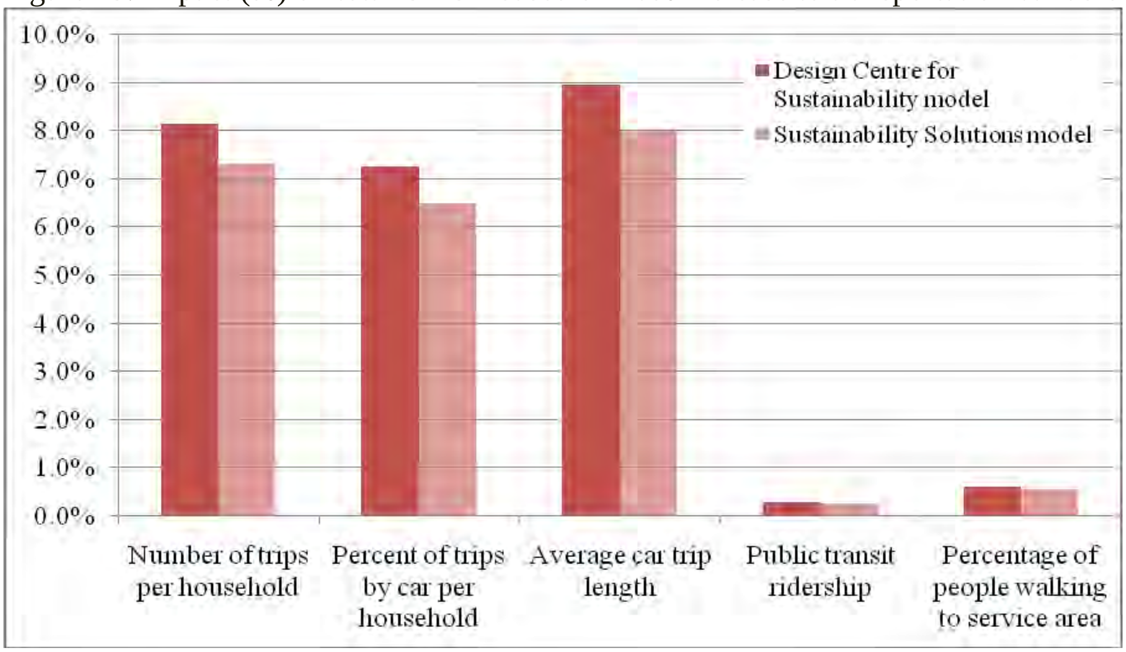



Transportation accounts for the majority of community-wide GHGE. The business as usual scenario shows a 3.5% increase in transportation GHGE from the baseline due to a per capita decrease of populations near transit and services. The compact development scenario reduces GHGE from the business as usual scenario by 4.5%; 3% is from walking trips and 1 % from increases in public transit accessibility. If public transit expands to unserviced areas in East Porpoise Bay, West Porpoise Bay and Sandy Hook in the future, its impact on GHGE reductions will be more pronounced.

Applying theoretical changes in average trip distance for the District of Sechelt reveals the significant impact GHGE impact of private vehicle use. Various studies show a 20 to 40% decreases in vehicle kilometres travelled when comparing a compact settlement pattern to a sprawling one (Bartholomew et al. 2007; Clear et al. 2002: 3; Gard 2007: 45). In the Sustainability Solutions pilot-project for Saltspring Island, the average trip distance decreased by 24% from the business as usual scenario to the compact development scenario. Assuming the baseline average trip distance of 7.5 kilometres increases by 10% in the business as usual scenario due to exacerbated sprawl and decreases by 10% in the compact development scenario, GHGE reductions drop from 4% to 23%.

The impact of vehicle behavior is reinforced by assessing the sensitivity of each transportation variable. A sensitivity analysis assesses the variation or uncertainty of model inputs by quantifying their influence on total outputs. The analysis supports decision making by better understanding the uncertainty of the variables (Wallace 2000). I increased each transportation variable by 10% in the compact development scenario and documented the change. Figure 14 demonstrates the change as a percent of community-wide GHGE. The UBC Development Pattern model is more influenced by the transportation sensitivity analysis because its energy-based emissions share a lower proportion of total GHGE. The uncertainty of the transportation model is based on its private vehicle use variables; a 10% increase to the values for number of trips, percent of trips by car and average car trip length cause significant changes to community-wide GHGE. The sensitivity analysis confirms the illustrative nature of transportation GHGE estimations for the District of Sechelt. Alternatively, transit ridership and the percentage of people willing to walk to the service area has a total community-wide impact of less than 2%.

Figure 15: Impact (%) on total GHGE based on 10% increase to transportation variable




Finally, the Sustainability Solutions transportation model can assess GHGE impacts from the construction of new roads. Compact development may reduce the need for roads servicing green field sprawl-type development. The model draws upon a Finnish report by Eskola et al. (1999) that estimate a carbon dioxide emission rate of 263 to 563 tonnes per kilometre of road depending on the aggregate and concrete that is used. The model uses a conservative estimate of 346 tonnes per kilometre to assess the impacts of new paved roads in B.C. (Holland Bars et al. 2007: 23). I left new roads out of the GHGE totals for the District of Sechelt because I lacked the tools to broadly calculate road length for the two scenarios. The District of Sechelt's Official Community Plan identifies 16 kilometres of potential service roads not yet built; the new roads translate into 5536 $tCO_2eq$. If considered, road construction would account for 11% of total transportation related emissions for the business as usual scenario.

## 7.0 Recommendations

### 7.1 Local governments scoping open source models

The District of Sechelt case study reveals opportunities and challenges for local governments scoping models that are inexpensive to acquire, learn and operate. The lack of transportation data continues to limits the effectiveness of open source models. The Sustainability Solutions model, using a development pattern or parcel specific approach, can illustrate transportation GHGE reductions in compact scenarios with trip diary data. Trip diaries may not be feasible for municipalities; they can cost up to $50,000 (Y. Herbert, Personal Communication, October 24 2009; Batty 2008: 29). If local governments are without local, regional or provincial transportation behaviour data, I do not recommend small municipalities use the Sustainability Solutions model to assess transportation GHGE. Evaluating the shift to public transportation and walking trips in compact development scenarios does not provide a comprehensive assessment of transportation potential emissions reductions. The main variable to reduce transportation emissions is the shorter trip distances in compact development scenarios.

If local governments have access to trip diary data, or choose to assess residential GHGE alone, both models' provide attractive features. The UBC Development Pattern model is capable of illustrating energy consumption based on case studies like duplexes, row houses and apartments. It is effective tool to assess scenarios with detailed data on the future housing stock. The Sustainability Solutions model distinguishes between detached and attached dwellings. This approach is effective for small communities with limited housing types.

The Sustainability Solutions model illustrates the significant impact that district heating can have in reducing residential GHGE, but the variable fails to comprehensively acknowledge factors like mixed use, climate, clean energy sources, competing energy prices and finance costs (NRC 1985). Moreover, district heating feasibility varies based on site considerations like infrastructure and density clusters. The proliferation of spot zoning in the District of Sechelt demonstrates the uncertainty of the variable. Many higher-density parcels are not near each other but are still over the density threshold. I recommend local governments assess the number of units that meet the district heating density threshold as an information tool rather than supporting policy decisions.

The UBC Development Pattern model broadly assumes future housing stocks will cut their energy consumption by 50% by 2030. I do not recommend local governments incorporate building design variables unless they are tied to local government policy levers. Exogenous variables make it difficult to convey what GHGE reductions can be influenced by local government authority. Furthermore, they may skew the proportions of GHGE between energy and transportation sectors. For example, if building advancements are applied without considering advancements in the transportation sector, transportation will capture a disproportionate volume of emissions.

## 7.2 Opportunities for model improvements

Models are only as strong as the assumptions and data that guide them. Opportunities to improve the models depend on external factors and trends like further research or program development. The BC Ministry of Environment is exploring secondary indicators for local governments to track and monitor GHGE reduction progress to support its Community Energy and Emissions Inventory (MOE 2009). Research focuses on tracking four sectors that significantly influence community-wide GHGE: land use, transportation, buildings and solid waste. The four sectors incorporate a range of potential stakeholders with valuable expertise or data, including the Ministry of Community and Rural Development; the Ministry of Energy, Mines and Petroleum Resources; Ministry of Transportation; BC Assessment; BC Stats; GeoBC; BC Hydro and Terasen Gas (Mary Storzer, Personal Communication, November 10). The project purpose is to identify indicators and monitor the effectiveness of local government policy changes using third party data. The Ministry of Community and Rural Development has the opportunity to act as a communication hub bringing together agencies with capacity to improve open source scenario models.

**Stronger Variable Assumptions**

***Vehicle kilometres travelled***

Land use-transportation modelling could benefit from research on cost-effective methods for local governments to acquire data on community's average trip distance. The five year Census data has a monitoring element that trip diaries do not; the following data could also illustrate the GHGE reductions in compact development scenarios:

- *Population by housing type*: higher density housing averages less people per unit and as a result, lower average vehicle trips
- *Total car trips per day by housing type*: higher density housing averages fewer car trips per day

***Modal shifts to alternative forms of transportation***

The District of Sechelt case study demonstrates that compact development scenarios increase modal shifts to alternative forms of transportation. Applying a uniform ridership rate does not capture differences within the municipal plan's area. Ridership rates are influenced by the accessibility and demand for transit. Higher densities establish the demand for transit and distribute the demand for transit throughout the day (Province et al. 2009).

BC Transit has installed automated passenger counters on select buses operating in Victoria and plans to expand installation to all service areas over the next several years (T. Wegitz, Personal Communication, October 26 2009). The geo-coded electronic counters are mounted on bus entrances and exits to tally the volume and location of incoming and exiting passengers. The data can be imported to each bus stop in GIS to spatialize ridership rates. Sub-plan area ridership data will reflect the higher ridership rates in service areas where compact development is transferred.

The Sustainability Solutions model assumes modal shifts to walking and cycling for populations within 500 metres of a service area. The variable would benefit from further research that generally assess walking and cycling habits of populations within 1 kilometre of service centres for small (0-10,000 population), medium (>10,000-25,000) and large municipalities (>25,000 population) in BC. The majority of density in the District of Sechelt case study is transferred just west of the Sechelt 500 metre service centre buffer (Map 7 – development pattern 9.1). A conservative modal shift assumption for populations between 500 metres and one kilometre will capture populations that may offset private vehicle use by walking or cycling.

***Energy Efficiency***

Energy consumption can vary significantly within a community based on housing type, age, floor area and heating sources (NRCAN 2009a). Neighbourhoods with older housing stocks consume more energy. For example, a neighbourhood in Mission BC comprised of pre-1945 detached dwellings averaged three times more gigajoules than the average used the Lower Mainland average used for the District of Sechelt (Webster et al. 2009). There is an opportunity for GHGE scenario modeling to access data from programs that measure housing energy performance.

Ideal household data is energy intensity: a measure of the average energy consumption standardized for one square metre of floor space (NRCAN 2009d). Major BC utility and tax authority agencies have explored the possibility of combining databases to generate parcel specific and community specific energy intensity data (G. Henderson, Personal Communication, November 10 2009). The Energy Benchmarking Initiative brings partners Terasen Gas (natural gas), BC Hydro (electricity) and BC Assessment (floor area) together. The initiative's pilot project aimed to determine the energy intensity for approximately 6,500 public buildings across the province (G. Henderson, Personal Communication, November 10 2009). The primary driver for the initiative is to provide a tool that building operators and owners can use to assess their building energy performance. The initiatives future is uncertain with the recent introduction of the national Building Energy Benchmarking System (G. Henderson, Personal Communication, November 10 2009). The Natural Resources Canada program is generating a web-based tool for the public to assess their energy use but it does not attempt to align major utility databases (Canada 2008). I recommend the continuation of both programs. Merging provincial utility databases could potentially allow local governments to download neighbourhood specific energy intensity de-aggregated by dwelling type, size, age and presence of alternative heating.

A second option to inform local energy efficiencies is local government EnerGuide rating databases. The 0 to 100 rating is assigned by a qualified energy inspector and considers factors like air-leakage, insulation, ventilation and energy source (NRCAN 2009c). The process to translate ratings into energy consumption depends on open source tools such as the HOT2000 software, created by Natural Resources Canada (Webster 2009). EnerGuide ratings are driven primarily by municipal or provincial grant programs that subsidize the cost of inspection. Increasing participation will provide sound samples for local governments to generate energy proxies that incorporate building design for future scenario assumptions. For example, the highest EnerGuide ratings in the District of Sechelt could info act as a proxy for future housing efficiencies supported by certain local government policies.

***District Heating***
Research needs to outline criteria and thresholds to scope district heating opportunities at the community-wide scale. A BC municipal survey reveals that 87% of respondents need more support to assess the feasibility of district energy (CEA 2009). Natural Resources Canada intends to research district heating systems as part of its projects in the time period 2008 to 2012. I recommend further research on the following topics: methods to identify district heating potential on a community-wide scale, and tools to assess the cost-benefit thresholds of mixed uses and densities required for district heating. More costly feasibility studies could precede the broad-based assumptions if significant potential for district heating is demonstrated. The drawback is that mixed use assumptions require more labour to incorporate commercial and industrial land use inputs.

***Road Building***
The models' are not capable of estimating the road length of land use scenarios in real time. The Sustainability Solutions model uses local knowledge to estimate future road lengths; the UBC Development Pattern model only estimates the percent of the landscape dedicated as road. The development pattern approach has the opportunity to estimate road length based on the proportion of area dedicated for road. Accordingly, the total road network of scenarios could be quickly estimated to illustrate the GHGE reductions of compact development road networks.

**Other factors influencing community-wide GHGE**
Effective models incorporate all major factors contributing to community-wide GHGE by reflecting physical realities on a regional, local and neighbourhood scale (Deal et al. 2008: 61; Klosterman 2008: 90; Moore 2008: 241).

***Deforestation***
The BC Ministry of Environment's Community Energy and Emission Inventory reports estimate deforestation rates for each Regional District. The reports define deforestation as the removal of wooded areas for urban development and agricultural uses. The estimates are drawn from a study by the Canadian Forest Service and Environment Canada. Forest change was assessed in sample areas using orthophotos dated 2000 and 2006. As a national study with limited samples in B.C., the deforestation estimates act as "preliminary data provided for information rather than decision-making or comparison purposes" (MOE 2009).

Rather than providing information that is not locally relevant, I recommend the province refine a method for municipalities to illustrate the GHGE impacts of deforestation. The B.C. Ministry of Forests and Range Vegetation Resource Inventory estimates the spatial location of forests in the province by type and age, two variables used by the Community Energy and Emission Inventories to estimate the carbon retention of the forested land. It is recommended that the BC Ministry of Forests and Range partner with the Ministry of Environment to produce a manual that estimates the carbon retention of different forest classes in the Vegetation Resource Inventory. Both scenario models can estimate the building footprint and road area that overlay different vegetation classes in future scenarios.

***Adaptation***

Climate change adaptation aims to limit the effects or vulnerability of communities to climate change. The Sustainability Solutions model and UBC Development Pattern model do not explicitly integrate adaptation measures. Adaptation is challenging to incorporate into models because it depends on global environmental and economic factors. Bartholomew et al. (2007: 40) states that "while it is not possible or appropriate to include all global-scale influences into scenario analyses, those that have ready ties to local and regional conditions… should be incorporated." For example, limiting scenario development capacity on floodplains, wetlands and coastal zones help address the effects and risks of climate change. Further research is recommended to explore methods to integrate mitigation principles into GHGE scenario models designed to assess mitigation.

## 8.0 Conclusion

The Sustainability Solutions model and the UBC Development Pattern are accessible and affordable tools for local governments with trip diary data to illustrate the relationship of land use and GHGE. The models' are embedded into standard database software that is useable for a range of stakeholders. The models can clearly be linked to quantifiable GHGE that can inform policy decisions.

The location and density of settlement patterns are the main variables of both models. These two variables are primary functions of local government authority. There are many regulatory and incentive tools for local governments to encourage higher densities closer to services. Higher densities improve the feasibility for community energy systems. Local government can encourage district heating systems in many ways, from establishing conditions for development approvals to owning and operating the system. In addition to the location and density of land uses, local governments have a role to plan for public transportation and road construction, two variables in the Sustainability Solutions model.

The Sustainability Solutions model and the UBC Development Pattern model offer different approaches and variables for local government to consider. The models' should be seen as a framework to measure a range of land use variables, including household energy performance, district heating and vehicle kilometres travelled. Improving scenario modeling depends on further multi-agency research and data collection that enables better assumptions and comprehensive variables. The province can show leadership by continuing to provide and advocate for varying details of data that local governments with limited resources can use. If further research can demonstrate cost-effective ways for local governments to acquire transportation behaviour data, the open source models provide an excellent tool to meet legislative requirements and effectively plan for GHGE reductions.

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## Attachment 1 – Method to create existing settlement pattern dataset (2009 baseline)

The method I used to assess the location and density of the District of Sechelt's existing settlement pattern is applicable for small municipalities in BC. The list of assumptions may inform municipalities scoping similar work, but should not be automatically adopted without due consideration to the unique characteristics of each place.

I compiled varying sources of data into one master legal parcel geodatabase using GIS overlay tools, including land use, parcel improvement value and zoning designation. The table below is a theoretical geodatabase of four parcels with attributes to create existing settlement patterns. The first vertical column (feature ID) is the common identifier for each parcel. The first horizontal row identifies the column number and relates to the numeric headings below. Data sets generated for the existing settlement patterns were inputted into both models.

**Theoretical existing settlement pattern geodatabase**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| feature ID | parcel area (m2) | B.C. Land Titles Property Identifier (PID) | actual use code | actual use descriptor | Improvement value ($) | municipal zoning |
| 1 | 20000 | 025-145-142 | 000 | Single Family Dwelling | 69500 | R-1 (Residential) |
| 2 | 40500 | 009-479-783 | 000 | Single Family Dwelling | 62600 | RR-1 (Rural) |
| 3 | 21737 | 015-962-857 | 650 | Schools & Universities | 300000 | PA-1 (Assembly) |
| 4 | 6399 | 016-923-457 | 050 | Multi Family (Apartment) | 500900 | R-4 (Residential) |

| 1 | 8 | 9 | 10 |
|---|---|---|---|
| feature ID | Sustainability Solutions model unit types | UBC Development Pattern model unit types | Existing dwelling units |
| 1 | detached | detached | 1 |
| 2 | detached | detached | 1 |
| 3 | non-residential | non-residential | 0 |
| 4 | attached | low-rise apartment | 18 |

**1-2** **ArcGIS default values**

GIS assigns each spatial feature a feature ID number (column 1). I calculated the area of each spatial polygon using a GIS tool (column 2).

**3-7** **Land use information**

BC Land Title and Survey is an independent corporation that administers Parcel Identification numbers (PIDs) for taxable parcels in BC (column 3). The PID is permanently assigned to a parcel regardless of ownership transfer; it accesses land title records (BC Online 2007). The BC Integrated Cadastral Information Society (ICIS)[1] includes PIDs as core attribute data for local government parcel layers (ICIS 2008).

The provincial tax authority, BC Assessment, rolls out an annual excel database de-aggregated by local government. The database includes BC Land Title Parcel Identification Numbers (PIDs) as an identifier for parcel specific data. I used the PID column as the common identifier to join the tax authority database with the District of Sechelt's parcel geodatabase. The database has actual use codes (column 4) and land improvement values (column 6). Actual use codes are three digit codes that identify the principle use for taxable parcels in the province. There are a total of 699 actual use codes categorized into six groups: residential; farm; commercial; industrial; transportation, communication and utility; and civic, institutional and recreational. The land use descriptor (column 5) is the text description of the actual use code. The land improvement value (column 6) identifies the financial value of structures or buildings on a developed property. I assume parcels with less than $15,000 of building improvements are vacant.

I inputted zoning designations (column7) to identify regulatory land use controls for each parcel. I assume that parcels zoned as Park and Assembly, Industrial, Marine and Water has no residential capacity although there may be limited residential use (e.g. park groundskeeper, marina attendant). Parcels without an actual use code are assumed to be non-taxable Crown lands ineligible for residential development.

**8-10** **Existing settlement pattern**

I re-aggregated the BC Assessment actual use codes into the dwelling categories of each model. The Sustainability Solutions model distinguishes between the energy consumption of detached dwellings and attached units (column 8). Attached units include single attached units (e.g. duplex, row house) and apartment units. The UBC Development Pattern model distinguishes between energy consumption for detached dwellings, single attached units, low-rise apartments (<5 stories) and high-rise apartments (>5 stories) (column 9).

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[1] ICIS is a not-for-profit agency created through a partnership between local governments, the province of B.C. and major utility companies. Its purpose is to house and share province-wide environmental, cadastral and utility data to foster data standardization and accessibility. To date, 165 local governments are members of ICIC which gives them the authority to download parcel data stored in the ICIS database (ICIS 2007).

**Re-aggregating BC Assessment actual use codes into the models' energy consumption categories**

| Sustainability Solution Model: Dwelling Type | UBC Development Pattern Model: Dwelling Type | Actual Use Code | Actual Use Descriptor |
|---|---|---|---|
| Detached Dwelling | Detached Dwelling | 0 | Single Family Dwelling |
| | | 20 | Residential Outbuilding Only |
| | | 40 | Seasonal Dwelling |
| | | 60 | 2 Acres Or More (Duplex) |
| | | 62 | 2 Acres Or More (Seasonal Dwelling) |
| | | 70 | 2 Acres Or More (Outbuilding) |
| | | 63 | 2 Acres Or More (Manufactured Home) |
| | | 120 | Vegetable & Truck |
| | | 180 | Mixed |
| | | 190 | Other |
| | | 239 | Bed & Breakfast Operation Less Than 4 Units |
| Attached Dwelling | Attached Dwelling | 33 | Duplex (Suo Front) |
| | | 34 | Duplex Up & Down (Suo Bottom) |
| | | 35 | Duplex Single Unit Ownership (Side) |
| | | 49 | Fourplex |
| | | 60 | 2 Acres Or More (Duplex) |
| | Low-Rise Apartment | 050* | Multi-Family (Apartment Block) |
| | | 052** | Multi-Family (Garden Apartment & Row) |
| Residential, Vacant | Residential, Vacant | 1 | Vacant Residential Less Than 2 Acres |
| | | 61 | 2 Acres Or More (Vacant) |
| | | 181 | Mixed (Vacant) |
| Non-Residential | Non-Residential | 200 | Store(S) And Service Commercial |
| | | 204 | Store(S) And Offices |
| | | 208 | Office Building (Primary Use) |
| | | 209 | Shopping Centre (Neighbourhood) |
| | | 210 | Bank |
| | | 216 | Commercial Strata-Lot |
| | | 220 | Automobile Dealership |
| | | 222 | Service Station |
| | | 224 | Self-Serve Service Station |
| | | 226 | Car Wash |
| | | 228 | Automobile Paint Shop, Garages, Etc. |
| | | 232 | Motel & Auto Court |
| | | 236 | Campground (Commercial) |
| | | 240 | Greenhouses And Nurseries (Not Farm Class) |
| | | 254 | Neighbourhood Pub |
| | | 256 | Restaurant Only |

*Parcels require field work to identify the number of units
**Parcels require orthophoto analysis to identify the land use

The number of existing dwelling units (column 10) is implied by the actual use descriptor (e.g. single family dwellings, duplexes, triplexes and fourplexes). For land uses designated as mixed use or apartment, I used various field work methods to identify the number of units: counting mail boxes, counting entrance directories, visual counts of balconies, conversation with inhabitants or commercial owners and telephone calls to building administrative services.

I interpreted ortho-photos to identify the number of units on legal parcels with multiple detached dwellings. I examined development agreements to determine the number of units for spot zoning comprehensive developments.

## Attachment 2 – Creating future scenarios with a parcel specific approach

The Sustainability Solutions model relies on GIS parcel specific spatial and geodatabase analysis to create future land use scenarios. The table below is a theoretical geodatabase of four parcels with attributes to create future settlement patterns. The first vertical column (feature ID) is the common identifier for each parcel. The first horizontal row identifies the column number and relates to the numeric headings below. Data sets generated for the existing settlement patterns were inputted into both models.

### Re-aggregating BC Assessment actual use codes into the models' energy consumption categories

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| feature ID | parcel area (m2) | B.C. Land Titles Property Identifier (PID) | actual use code | actual use descriptor | municipal zoning | future municipal sewer service | Minimum parcel size or unit per area (m2) |
| 1 | 20000 | 025-145-142 | 000 | Single Family Dwelling | R-1 (Residential) | Yes | 500 |
| 2 | 40500 | 009-479-783 | 000 | Single Family Dwelling | RR-1 (Rural) | No | 6600 |
| 3 | 21737 | 015-962-857 | 650 | Schools & Universities | PA-1 (Assembly) | Yes | 900 |
| 4 | 6399 | 016-923-457 | 050 | Multi Family (Apartment) | R-4 (Residential) | Yes | 225 |

| 1 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|
| feature ID | road setback | environmental constraint | park dedication | parcel area after constraint (m2) |
| 1 | 20% | 0 | 5% | 15200 |
| 2 | 15% | 20% | 5% | 26163 |
| 3 | 0% | 0 | 0 | 0 |
| 4 | 20% | 0 | 0 | 5119 |

| 1 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|
| feature ID | business as usual build out land use | business as usual build out units | compact development minimum parcel size or unit per area (m2) | compact development build out detached units | compact development build out attached units | compact development total units |
| 1 | detached | 30 | 500 | 30 | 0 | 30 |
| 2 | detached | 3 | 40000 | 1 | 0 | 1 |
| 3 | non-residential | 0 | 0 | 0 | 0 | 0 |
| 4 | attached | 22 | 80 | 0 | 80 | 80 |

| 1-2 | **ArcGIS default values** |
|---|---|

| 3-8 | **Land use information** |
|---|---|

Municipal zoning (column 7) informs the allowable density on residential properties. Zoning defines minimum parcel size or area per unit (column 8). The presence of municipal sewerage service (column 9) impacts allowable density as defined in the *Subdivision and Development Bylaw 420* (2007). It is assumed that municipal sewerage systems will extend to neighbourhoods in East Porpoise Bay, West Porpoise Bay and West Sechelt in future scenarios (Sechelt 2008).

**District of Sechelt's allowable densities and residential land uses (Zoning Bylaw)**

| | Zoning | Density Allowed (metres squared) | | Primary Dwelling Type at Build Out |
|---|---|---|---|---|
| Residential | R-1 | *500 or 900 | Minimum parcel size (m2) | Detached |
| | R-1A | *700 or 2000 | Minimum parcel size (m2) | Detached |
| | R-1B | *900 or 2000 | Minimum parcel size (m2) | Detached |
| | R-2 | 1110 | Minimum parcel size (m2) | Detached |
| | R-7 | *500 or 2000 | Minimum parcel size (m2) | Detached |
| | R-3 | 900 | Minimum parcel size (m2) | Detached |
| | R-4 | 225 | Area (m2) per unit | Attached |
| | R-4A | 163 | Area (m2) per unit | Attached |
| | R-4B | 250 | Area (m2) per unit | Detached |
| Rural | RR-1 | 6600 | Minimum parcel size (m2) | Detached |
| | RR-2 | 40000 | Minimum parcel size (m2) | Detached |
| Commercial | C-1 | 1000 | Minimum parcel size (m2) | Attached |
| | C-2 | 120 | Area (m2) per unit | Attached |
| | C-3 | 1000 | Minimum parcel size (m2) | Attached |
| | C-4 | 235 | Minimum parcel size (m2) | Attached |
| | C-5 | 200 | Area (m2) per unit | Attached |
| | C-6 | 550 | Minimum parcel size (m2) | Attached |
| | C-7 | 550 | Minimum parcel size (m2) | Attached |
| Comprehensive Development | CD- 5 | n/a | n/a | Detached |
| | CD- 7, 13, 27 | | | Detached/Attached |
| | CD- 1, 6, 10, 12, 18, 20, 21, 22, 26 | | | Attached |

*higher densities permitted with municipal sewerage service

**9-12** **Development Assumptions**

Three factors limit the future development capacity of existing parcels: road setbacks (column 9), environmental constraints (column 10) and park dedications (column 11). The development capacity of mixed use and residential parcel areas is reduced by 20% for road setbacks; rural parcel areas are reduced by 15%. The narrower dimension of the road network in rural areas accounts for the smaller reduction (Planner, Personal Communication, August 24 2009). Environmental constraints (Map **1**) merge existing development permit areas with slopes greater than 25%. Development permit areas identify environmentally sensitive or hazardous areas that require greater precautionary measures before development. The areas are represented spatially in Official Community Plans and typically require a building permit review of environmental standards (LGA 1996: S. 919-1). Development permit areas are implemented in the District of Sechelt for slopes, beach front escarpments, rockfall hazards, watercourses, gravel pit areas and shoreline and foreshore areas. I created broad assumptions about the impact of constraints on development in consultation with District of Sechelt planning staff. The development capacity of parcels that have greater than 50% of their area covered by an environmental constraint is reduced by 20%. The development capacity of parcels that have less than 200 metres squared of non-constraint land is reduced by 40%. Two hundred metres squared signifies the average footprint of a detached dwelling. The development capacity of parcels that have the potential to subdivide into three additional lots is reduced by 5% for park dedication (Sechelt 2007).

**13-14** **Scenario 1: Business as usual residential build out**

I identified density for the business as usual build out scenario (column 14) by dividing the parcels capable land (column 12) by its minimum parcel size or units allowed per area (column 8). I distinguished between detached and attached dwellings based on the allowable building types in the zoning bylaw.

**15-18** **Scenario 2: Compact development build out**

I created a academic general future land use map (**Map 2**) in consultation with the District of Sechelt's planning staff to identify parcels to be down-zoned or increased in density for the compact development build out scenario (column 15). Three main methods guide the compact development scenario (Holland Barrs et al. 2007):

1. The "business as usual scenario and compact development scenario have the same total build out population.

2. Only density derived from future subdivisions in the business as usual scenario can be considered for transfer in the compact development scenario.

3. Existing dwelling units can only be redeveloped to higher densities in the compact development scenario.

The compact development scenario has an individual column for detached dwellings (column 16) and attached dwellings (column 17) because large greenfield parcels that are increased in density are assumed to have a combination of both dwelling types in the future. I used a common proportional mix of 25% detached dwellings and 75% attached dwellings.

# Attachment 3: UBC Development Pattern model development pattern calculations

## Business as usual development pattern calculations

| A. development pattern description | B. development pattern area (m2) | C. case study | D. % of pattern area | E. proportion of development pattern area (m2) (B*D) | F. case study parcel size | G. total parcels (E/F) | H. case study units | I. total units (G*H)) |
|---|---|---|---|---|---|---|---|---|
| 1.0 rural | 6687552 | GREENSPACE | 8% | 535004 | 0 | 0 | 0 | 0 |
| | | D-1 detached | 77% | 5149415 | 60000 | 86 | 2 | 172 |
| | | STREETS | 15% | 1003133 | 0 | 0 | 0 | 0 |
| 2.0 semi-rural | 6819706 | GREENSPACE | 8% | 545576 | 0 | 0 | 0 | 0 |
| | | D-2 detached | 77% | 5251174 | 14000 | 375 | 2 | 749 |
| | | STREETS | 15% | 1022956 | 0 | 0 | 0 | 0 |
| 3.0 medium lot and multi-unit residential with open space | 728388 | GREENSPACE | 73% | 524439 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 2% | 12383 | 248 | 50 | 1 | 50 |
| | | A-1 duplex | 2% | 12383 | 495 | 25 | 2 | 50 |
| | | D-5 detached | 9% | 65555 | 900 | 73 | 1 | 73 |
| | | STREETS | 15% | 152961 | 0 | 0 | 0 | 0 |
| 4.0 big and medium lot residential | 7317539 | GREENSPACE | 8% | 585403 | 0 | 0 | 0 | 0 |
| | | D-5 detached | 20% | 1463508 | 900 | 1626 | 1 | 1626 |
| | | D-4 detached | 45% | 3292893 | 1200 | 2744 | 1 | 2744 |
| | | STREETS | 27% | 1975736 | 0 | 0 | 0 | 0 |
| 5.0 medium lot residential | 3643736 | GREENSPACE | 8% | 291499 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 1% | 36437 | 248 | 147 | 1 | 147 |
| | | D-5 detached | 64% | 2331991 | 900 | 2591 | 1 | 2591 |
| | | STREETS | 27% | 983809 | 0 | 0 | 0 | 0 |
| 6.0 attached and multi-unit residential | 207244 | GREENSPACE | 10% | 16580 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 10% | 20724 | 1980 | 10 | 16 | 167 |
| | | A-2 row housing | 50% | 103622 | 248 | 418 | 1 | 418 |
| | | STREETS | 30% | 62173 | 0 | 0 | 0 | 0 |
| 7.0 medium lot with limited multi-unit residential | 483698 | GREENSPACE | 8% | 48370 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 10% | 48370 | 248 | 195 | 1 | 195 |
| | | D-5 detached | 55% | 266034 | 900 | 296 | 1 | 296 |
| | | STREETS | 27% | 130598 | 0 | 0 | 0 | 0 |
| 8.0 small lot residential | 187943 | GREENSPACE | 8% | 15035 | 0 | 0 | 0 | 0 |
| | | D-6 detached | 65% | 122163 | 660 | 185 | 1 | 185 |
| | | STREETS | 27% | 50745 | 0 | 0 | 0 | 0 |
| 9.0 small lot with low-density residential | 1097594 | GREENSPACE | 10% | 109759 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 14% | 153663 | 1980 | 78 | 16 | 1242 |
| | | A-2 row housing | 8% | 87808 | 248 | 354 | 1 | 354 |
| | | D-6 detached | 38% | 417086 | 660 | 632 | 1 | 632 |
| | | STREETS | 30% | 329278 | 0 | 0 | 0 | 0 |
| 10.0 multi-unit with limited mixed use | 17753 | GREENSPACE | 3% | 533 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 40% | 7101 | 1980 | 4 | 16 | 57 |
| | | MU-1 low-rise | 27% | 4793 | 1980 | 2 | 12 | 29 |
| | | STREETS | 30% | 5326 | 0 | 0 | 0 | 0 |
| 11.0 low density mixed use | 114961 | GREENSPACE | 5% | 5748 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 5% | 5748 | 1980 | 3 | 16 | 46 |
| | | MU-59 | 55% | 63229 | 1980 | 32 | 12 | 383 |
| | | STREETS | 35% | 40236 | 0 | 0 | 0 | 0 |
| **Totals** | **27306114** | | **1100%** | | | | | **12207** |

## Compact development pattern calculations

| A. development pattern description | B. development pattern area (m2) | C. case study | D. % of pattern area | E. proportion of development pattern area (m2) (B*D) | F. case study parcel size | G. total parcels (E/F) | H. case study units | I. total units (G*H)) |
|---|---|---|---|---|---|---|---|---|
| 1.0 rural | 6687552 | GREENSPACE | 8% | 535004 | 0 | 0 | 0 | 0 |
| | | D-1 detached | 77% | 5149415 | 60000 | 86 | 2 | 172 |
| | | STREETS | 15% | 1003133 | 0 | 0 | 0 | 0 |
| 2.0 semi-rural | 7331548 | GREENSPACE | 8% | 586524 | 0 | 0 | 0 | 0 |
| | | D-2 detached | 77% | 5645292 | 14000 | 403 | 2 | 806 |
| | | STREETS | 15% | 1099732 | 0 | 0 | 0 | 0 |
| 3.0 medium lot and multi-unit residential with open space | 728388 | GREENSPACE | 73% | 524439 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 2% | 12383 | 248 | 50 | 1 | 50 |
| | | A-1 duplex | 2% | 12383 | 495 | 25 | 2 | 50 |
| | | D-5 detached | 9% | 65555 | 900 | 73 | 1 | 73 |
| | | STREETS | 15% | 152961 | 0 | 0 | 0 | 0 |
| 4.1 big lot residential | 5633006 | GREENSPACE | 8% | 450640 | 0 | 0 | 0 | 0 |
| | | D-3 detached | 65% | 3661454 | 2000 | 1831 | 1 | 1831 |
| | | STREETS | 27% | 1520912 | 0 | 0 | 0 | 0 |
| 4.2 big and medium lot residential | 2127827 | GREENSPACE | 8% | 170226 | 0 | 0 | 0 | 0 |
| | | D-5 detached | 35% | 744739 | 900 | 827 | 1 | 827 |
| | | D-4 detached | 30% | 638348 | 1200 | 532 | 1 | 532 |
| | | STREETS | 27% | 574513 | 0 | 0 | 0 | 0 |
| 5.0 medium lot residential | 2414455 | GREENSPACE | 8% | 193156 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 1% | 24145 | 248 | 97 | 1 | 97 |
| | | D-5 detached | 64% | 1545251 | 900 | 1717 | 1 | 1717 |
| | | STREETS | 27% | 651903 | 0 | 0 | 0 | 0 |
| 6.0 attached and multi-unit residential | 207244 | GREENSPACE | 10% | 16580 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 10% | 20724 | 1980 | 10 | 16 | 167 |
| | | A-2 row housing | 50% | 103622 | 248 | 418 | 1 | 418 |
| | | STREETS | 30% | 62173 | 0 | 0 | 0 | 0 |
| 7.0 medium lot with limited multi-unit residential | 315234 | GREENSPACE | 8% | 31523 | 0 | 0 | 0 | 0 |
| | | A-2 row housing | 10% | 31523 | 248 | 127 | 1 | 127 |
| | | D-5 detached | 55% | 173379 | 900 | 193 | 1 | 193 |
| | | STREETS | 27% | 85113 | 0 | 0 | 0 | 0 |
| 8.0 small lot residential | 171955 | GREENSPACE | 8% | 13756 | 0 | 0 | 0 | 0 |
| | | D-6 detached | 65% | 111771 | 660 | 169 | 1 | 169 |
| | | STREETS | 27% | 46428 | 0 | 0 | 0 | 0 |
| 9.0 small lot with low-density residential | 371763 | GREENSPACE | 10% | 37176 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 14% | 52047 | 1980 | 26 | 16 | 421 |
| | | A-2 row housing | 8% | 29741 | 248 | 120 | 1 | 120 |
| | | D-6 detached | 38% | 141270 | 660 | 214 | 1 | 214 |
| | | STREETS | 30% | 111529 | 0 | 0 | 0 | 0 |
| 9.1 small lot and medium density multi-unit residential | 1218936 | GREENSPACE | 10% | 121894 | 0 | 0 | 0 | 0 |
| | | LR-2 low-rise | 11% | 134083 | 1980 | 68 | 23 | 1558 |
| | | A-3 row housing | 11% | 134083 | 165 | 813 | 1 | 813 |
| | | D-6 detached | 38% | 463196 | 660 | 702 | 1 | 702 |
| | | STREETS | 30% | 365681 | 0 | 0 | 0 | 0 |
| 10.0 multi-unit with limited mixed use | 17753 | GREENSPACE | 3% | 533 | 0 | 0 | 0 | 0 |
| | | LR-1 low-rise | 40% | 7101 | 1980 | 4 | 16 | 57 |
| | | MU-1 low-rise | 27% | 4793 | 1980 | 2 | 12 | 29 |
| | | STREETS | 30% | 5326 | 0 | 0 | 0 | 0 |
| 11.1 medium density mixed use | 114961 | GREENSPACE | 5% | 5748 | 0 | 0 | 0 | 0 |
| | | LR-3 low rise | 5% | 5748 | 1980 | 3 | 39 | 113 |
| | | MU-1 low rise | 5% | 5748 | 1980 | 3 | 12 | 35 |
| | | MU-2 low rise | 50% | 57481 | 1980 | 29 | 31 | 900 |
| | | STREETS | 35% | 40236 | 0 | 0 | 0 | 0 |
| **Totals** | **27340622** | | **1300%** | | | | | **12191** |

## Attachment 4: Sustainability Solutions model formulas

Formulas are built into the Sustainability Solutions excel-based model. The following formulas are derived from a report by Sustainability Solutions entitled “The GHG Implications for Different Settlement Patterns on Saltspring Island” (Holland Barrs et al. 2007). The value and reference beside each variable represents the custom inputs used for the District of Sechelt.

### Residential GHGE formulas

**GHGE reduction from heat demand and energy source**

$GHGE_{CHP} = H_{D55} * P_{CHP} * E_H$

Where:

$E_H = \sum(E_{NG} * F_{NG,} E_E * EF_{EE}) / E_T$

And:

$H_{D55}$ Number of units with a density over 55 units per hectare – GIS analysis

$P_{CHP}$ Percent of energy provided by energy source

$E_H$ Energy per unit – 109.2 gigajoules (BC Hydro 2007)

$E_{NG}$ Energy consumption of natural gas – 128667 gigajoules (MOE 2007)

$EF_{NG}$ Emissions Factor for natural gas – 49.9 kgC02eq (Pembina Institute 2004)

$E_E$ Energy consumption of electricity – 379446 gigajoules (MOE 2007)

$EF_{EE}$ Emissions Factor for electricity – 2.08 kgC02eq (Pembina Institute 2004)

$E_T$ Conversion from kilograms of C02eq to tones of C02eq - 1000

**GHGE reduction from attached unit energy efficiency**

GHGEefficiency= HA* PCHP - GHGCHP

Where:

GHGefficiency GHGE reduction from attached unit energy efficiency

HA Number of attached units – GIS analysis

PCHP Percent of energy provided by district heating

### Transportation GHGE formulas

**Average Trip Length**

GHGEdistance= (TLC * HTT * PTC * EF1)- GHGwalk – GHGtransit

Where:

GHGEdistance GHGE reduction from reduced average trip length

TLC Trip length cars - 7.5 kilometres (CRD 2007)

HTT Dwelling total trips - 6.7 per day (CRD 2007)

PTC Percentage trips by car - 69% (CRD 2007)

EF1 Emissions factor for small vehicles – 0.352 (EPA 2005)

GHGH0.5km Greenhouse gas reduction from Dwellings within 500 metre

GHGH0.4kmt Greenhouse gas reduction from Dwellings within 400 metre of transit

**GHGE reductions from units within 500 metres from a service centre**

GHGwalk= H0.5km * Pww * (P0.5km)(HTT)* EF1

Where:

GHGEwalk GHGE reduction from Dwellings within 500 metres

H0.5km Dwellings within 500 metres – GIS analysis

Pww Percentage willing to walk – 70% (Hawthorne 1989)

P0.5km Percentage of trips within 500 metres– (CRD 2007)

HTT Dwelling total trips – 6.7 per day (CRD 2007)

EF1 Emissions factor for small vehicles – 0.352 (EPA 2005)

**GHGE reductions from modal shift to public transit**

$GHGE_{transit} = (H_{0.4kmt} * P_{TC} * P_{TP} * H_{TT} * T_{LC} * EF_1) - (T_{LP} * EF_2)$

Where:

$GHGE_{transit}$ GHGE reduction from Dwellings within 400 metres of transit

$H_{0.4kmt}$ Dwellings within 400 metres of public transit – GIS analysis

$P_{TC}$ Percentage trips by car – 69% (CRD 2007)

$P_{TP}$ Percentage of trips by public transport – 5.4% (SCRD 2006)

$H_{TT}$ Dwelling total trips– 6.7 per day (CRD 2007)

$T_{LC}$ Trip length cars – 7.5 kilometres (CRD 2007)

$EF_1$ Emissions factor for small vehicles – 0.352 (EPA 2005)

$T_{LP}$ Trip length public transport – GIS analysis (SCRD 2006)

$EF_2$ Emissions factor for diesel (Bowen 2002)

**GHGE Reduction from kilometres of road**

$GHGE_{road} = (L_P * EF_P))/Y$

Where:

$GHGE_{road}$ GHGE reduction from decreased road

$L_P$ Length of paved roads – GIS analysis

$EF_G$ Emissions factor for pavement (P=paved) – 346 tC02/km (Eskola et al. 1999)

Y Lifetime of the road – 40 years (Eskola et al. 1999)

# Attachment 5: UBC Development Pattern model: GHGE impacts

| | |
|---|---|
| | Community inputs |
| | Community assumptions |
| | Automatic calculations |

## Residential GHGE

### Baseline (2009)

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Energy consumption (GJ) | GHG Emissions (tCO2eq) | |
|---|---|---|---|---|---|
| Detached Unit | 3531 | 109 | 384879 | 7043 | (BC Hyrdo 2007) |
| Attached Unit | 205 | 58 | 11890 | 218 | |
| Low-Rise Apartment | 530 | 29 | 15211 | 278 | |
| Total | 4266 | | 411980 | **7539** | |

### Business as usual build out

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Energy consumption (GJ) | GHG Emissions (tCO2eq) | |
|---|---|---|---|---|---|
| Detached Unit | 9068 | 56 | 507808 | 9293 | (BC Hyrdo 2007)<br>(David Suzuki Foundation 2002) |
| Attached Unit | 1214 | 33 | 40062 | 733 | |
| Low-Rise Apartment | 1925 | 15 | 28875 | 528 | |
| Total | 12207 | | 576745 | **10554** | |

### Compact development build out

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Energy consumption (GJ) | GHG Emissions (tCO2eq) | Source |
|---|---|---|---|---|---|
| Detached Unit | 7236 | 56 | 405216 | 7415 | (BC Hyrdo 2007)<br>(David Suzuki Foundation 2002) |
| Attached Unit | 1675 | 33 | 55275 | 1012 | |
| Low-Rise Apartment | 3280 | 15 | 49200 | 900 | |
| Total | 12191 | | 509691 | **9327** | |

## Transportation GHGE

### Units within 500 metres of a service centre

| | Variables | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source |
|---|---|---|---|---|---|
| No. of houses within 500 m | | 587 | 1345 | 2329 | |
| Percent reduction in household driving | 70.0 | 411 | 942 | 1630 | (NTL 1990) |
| Total number of trips for the households per year | 6.7 | 997357 | 2285256 | 3957146 | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 688176 | 1576827 | 2730431 | (CRD 2007) |
| Average trip length | 7.5 | 7.5 | 7.5 | 7.5 | (CRD 2007) |
| Total VKT Reduction (km) | 52.0 | 2683888 | 6149624 | 10648679 | (CRD 2007) |
| Total GHG reduction (tC02e) | 0.4 | -945 | -2165 | -3748 | (EPA 2005) |

## Units within 400 metres of conventional transit service

| | Variables | | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source |
|---|---|---|---|---|---|---|
| No. of houses within 400 m | Existing | Future | 3164 | 5277 | 8663 | |
| Total number of trips for the households per year | 6.7 | 6.7 | 7679819 | 12808598 | 21027267 | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 69.0 | 5299075 | 8837933 | 14508814 | (CRD 2007) |
| Mode shift to public transport | 4.3 | 4.3 | 227860 | 380031 | 623879 | (BC Transit 2006) |
| Average trip length | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | (CRD 2007) |
| Reduction in VKT (km) | | | 1708952 | 2850233 | 4679093 | |
| Gross GHG reduction (kgC02e) | 0.4 | 0.4 | 601551 | 1003282 | 1647041 | (EPA 2005) |
| Annual litres used by the bus per year | 171480.0 | 235364.7 | 9466 | 129921 | 129921 | (SCRD 2006) |
| Annual GHG emissions bus | 2.9 | 2.9 | 27176 | 373004 | 373004 | (Transport Canada 2008) |
| Net GHG reduction (tCO2e) | | | -574 | -630 | -1274 | |

## Average trip distance

| | Variables | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source |
|---|---|---|---|---|---|
| Average trip length per household | | 7.5 | 7.5 | 7.5 | (CRD 2007) |
| Number of trips per year | 6.7 | 10354649 | 29629441 | 29590605 | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 7144707 | 20444314 | 20417517 | |
| Total VKT | | 53585306 | 153332356 | 153131380 | |
| GHGs (tC02eq) | 0.4 | 18862 | 53973 | 53902 | (EPA 2005) |

# Attachment 6: Sustainability Solutions model: GHGE impacts (tables)

| | |
|---|---|
| | Community inputs |
| | Community assumptions |
| | Automatic calculations |

## Residential GHGE

### Baseline (2009)

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Total energy consumption (GJ) | GHG Emissions (tCO2eq) | Source |
|---|---|---|---|---|---|
| Detached Unit | 3531 | 109 | 384879 | 7043 | (BC Hyrdo 2007) |
| Attached Unit | 735 | 76 | 56081 | 1026 | (Farahbakhs et al. 1998) |
| Total | 4266 | | 440960 | **8070** | |

### Business as usual build out

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Energy consumption (GJ) | GHG Emissions (tCO2eq) | Source |
|---|---|---|---|---|---|
| Detached Unit | 9110 | 109 | 992990 | 18172 | (BC Hyrdo 2007) |
| Attached Unit | 3155 | 76 | 240727 | 4405 | (Farahbakhs et al. 1998) |
| Total | 12265 | | 1233717 | **22577** | |

### Compact development build out

| Dwelling Types | Number of Households | Energy use (GJ/unit) | Energy consumption (GJ) | GHG Emissions (tCO2eq) | Source |
|---|---|---|---|---|---|
| Detached Unit | 7349 | 109 | 801041 | 14659 | (BC Hyrdo 2007) |
| Attached Unit | 4916 | 76 | 375091 | 6864 | (Farahbakhs et al. 1998) |
| Total | 12265 | | 1176132 | **21523** | |

## Transportation GHGE

### Units within 500 metres of a service centre

| | Variables | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source |
|---|---|---|---|---|---|
| No. of houses within 500 m | | 587 | 1194 | 2233 | |
| Percent reduction in household driving | 70.0 | 411 | 836 | 1563 | (NTL 1990) |
| Total number of trips for the households per year | 6.7 | 997357 | 2028696 | 3794034 | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 688176 | 1399800 | 2617884 | (CRD 2007) |
| Average trip length | 7.5 | 7.5 | 7.5 | 7.5 | (CRD 2007) |
| Total VKT Reduction (km) | 52.0 | 2683888 | 5459220 | 10209747 | (CRD 2007) |
| Total GHG reduction (tC02e) | 0.4 | -945 | -1922 | -3594 | (EPA 2005) |

## Units within 400 metres of conventional transit service

| | Variables | | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source |
|---|---|---|---|---|---|---|
| No. of houses within 400 m | Existing | Future | 3164 | 5277 | 9059 | |
| Total number of trips for the households per year | 6.7 | 6.7 | 7679819 | 12808598 | 21988458 | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 69.0 | 5299075 | 8837933 | 15172036 | (CRD 2007) |
| Mode shift to public transport | 4.3 | 4.3 | 227860 | 380031 | 652398 | (BC Transit 2006) |
| Average trip length | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | (CRD 2007) |
| Reduction in VKT (km) | | | 1708952 | 2850233 | 4892982 | |
| Gross GHG reduction (kgC02e) | 0.4 | 0.4 | 601551 | 1003282 | 1722330 | (EPA 2005) |
| Annual litres used by the bus per year | 171480.0 | 235364.7 | 9466 | 129921 | 129921 | (SCRD 2006) |
| Annual GHG emissions bus | 2.9 | 2.9 | 27176 | 373004 | 373004 | (Transport Canada 2008) |
| Net GHG reduction (tCO2e) | | | -574 | -630 | -1349 | |

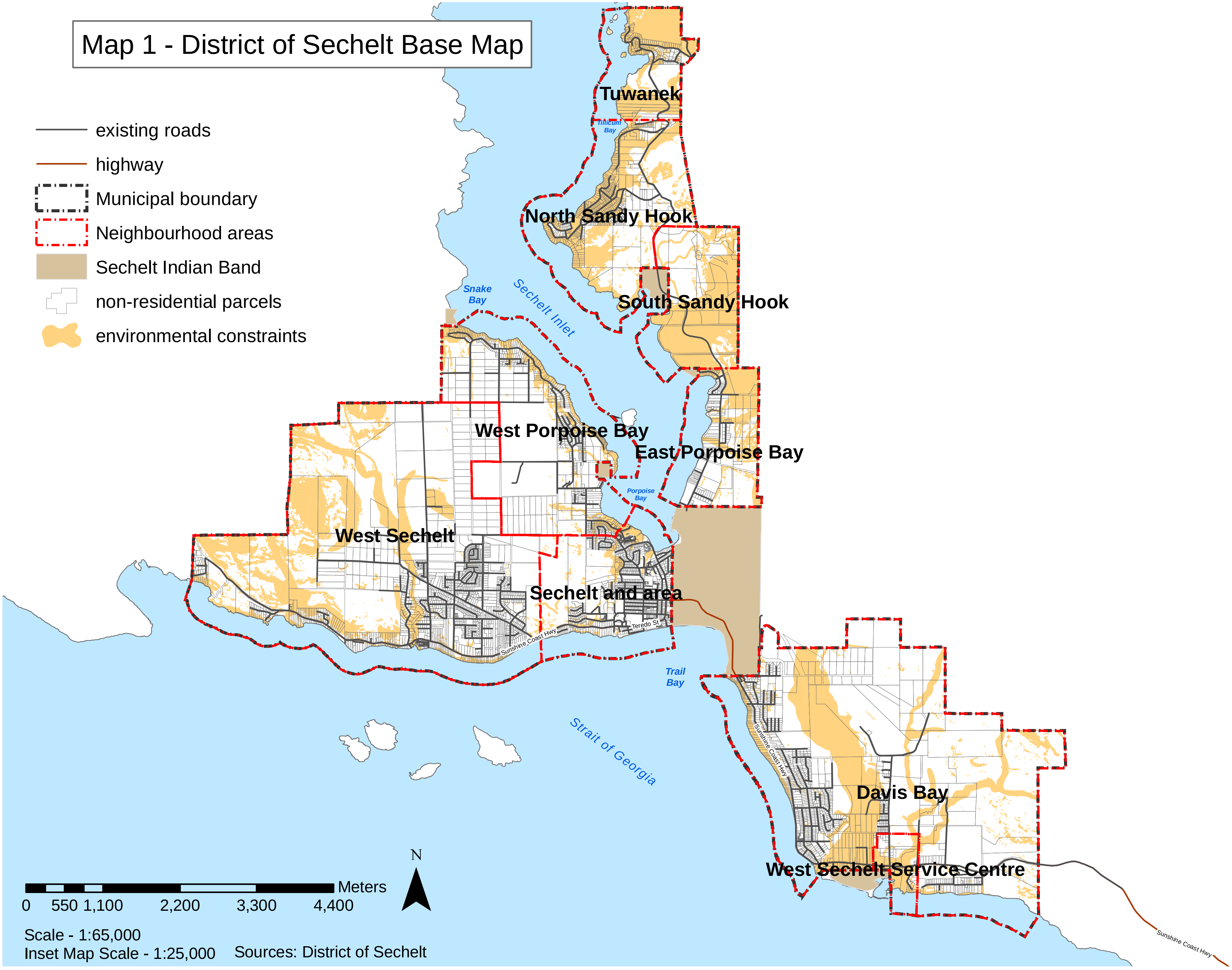
## Average trip distance

| | Variables | 2009 Baseline | Business as Usual Scenario | Compact Development Scenario | Source | Source |
|---|---|---|---|---|---|---|
| Average trip length per household | | 7.5 | 7.5 | 7.5 | (CRD 2007) | (CRD 2007) |
| Number of trips per year | 6.7 | 10354649 | 29770221 | 29770221 | (CRD 2007) | (CRD 2007) |
| Percent of trips taken by car | 69.0 | 7144707 | 20541453 | 20541453 | | |
| Total VKT | | 53585306 | 154060895 | 154060895 | | |
| GHGs (tC02eq) | 0.4 | 18862 | 54229 | 54229 | (EPA 2005) | (EPA 2005) |

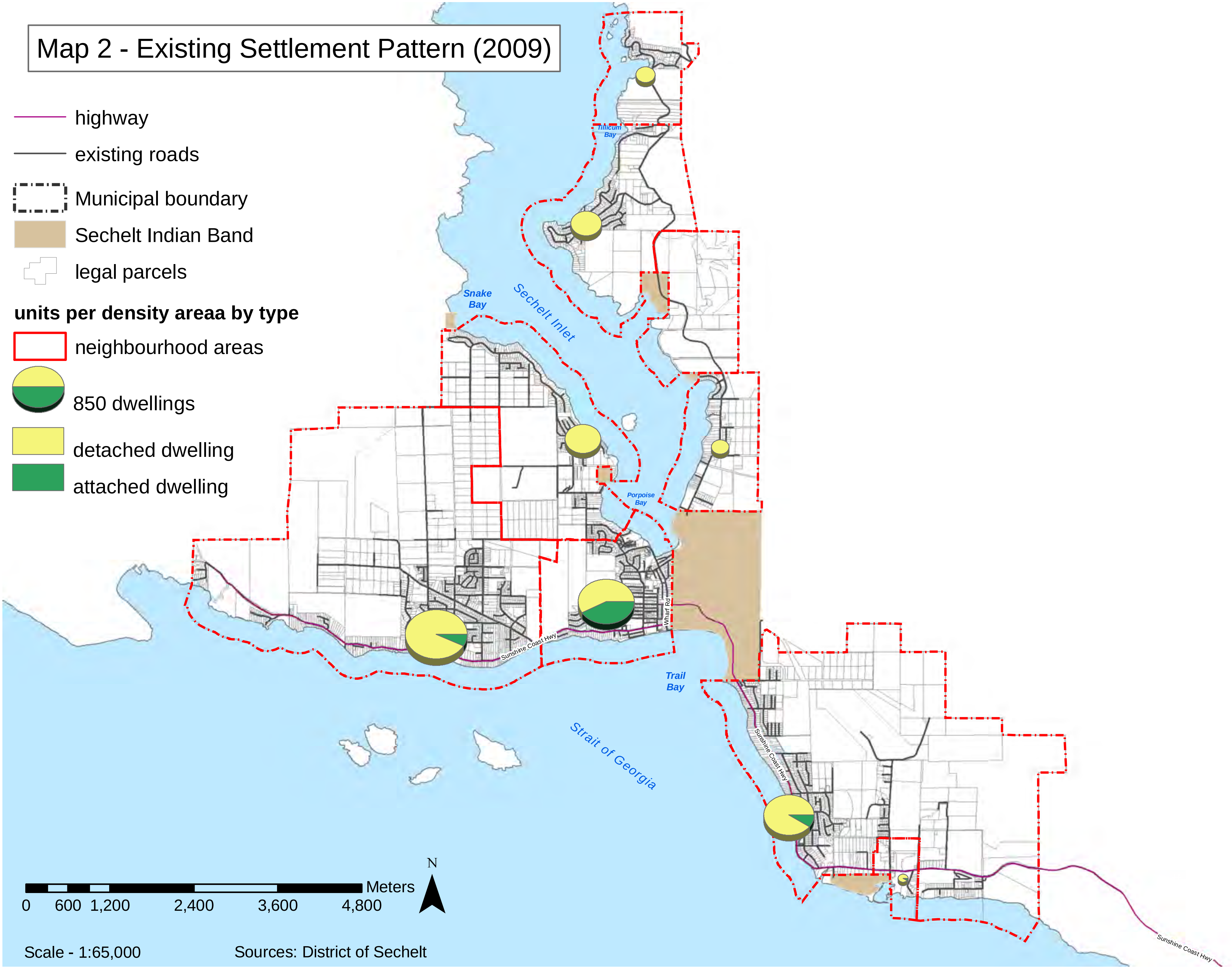
## Attachment 7: Calculating average trip distance with a trip diary

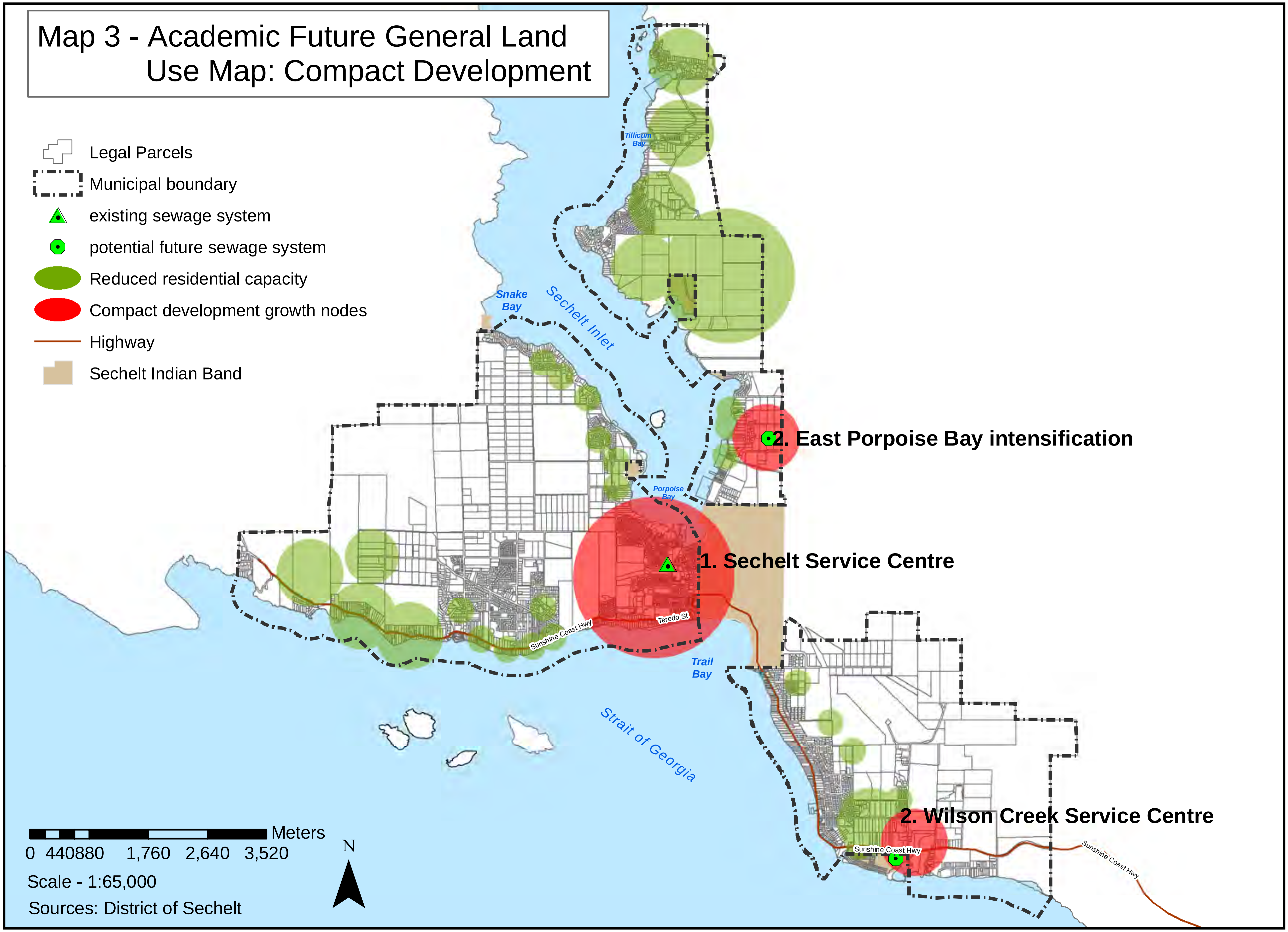
The Sustainability Solutions model can assess the average trip distance of future scenarios with a community trip diary that estimate total trips per dwelling, percentage of trips by car, trip length and common trip destinations. GIS can calculate the average distance of dwellings to common destinations following the shortest distance in the road network (e.g. schools, service centers, business parks) (Holland Barrs et al. 2007). The destinations can be weighted by the frequency of trips to certain destinations. The average trip distance of each dwelling to the weighted destination is aggregated into a community-wide average.

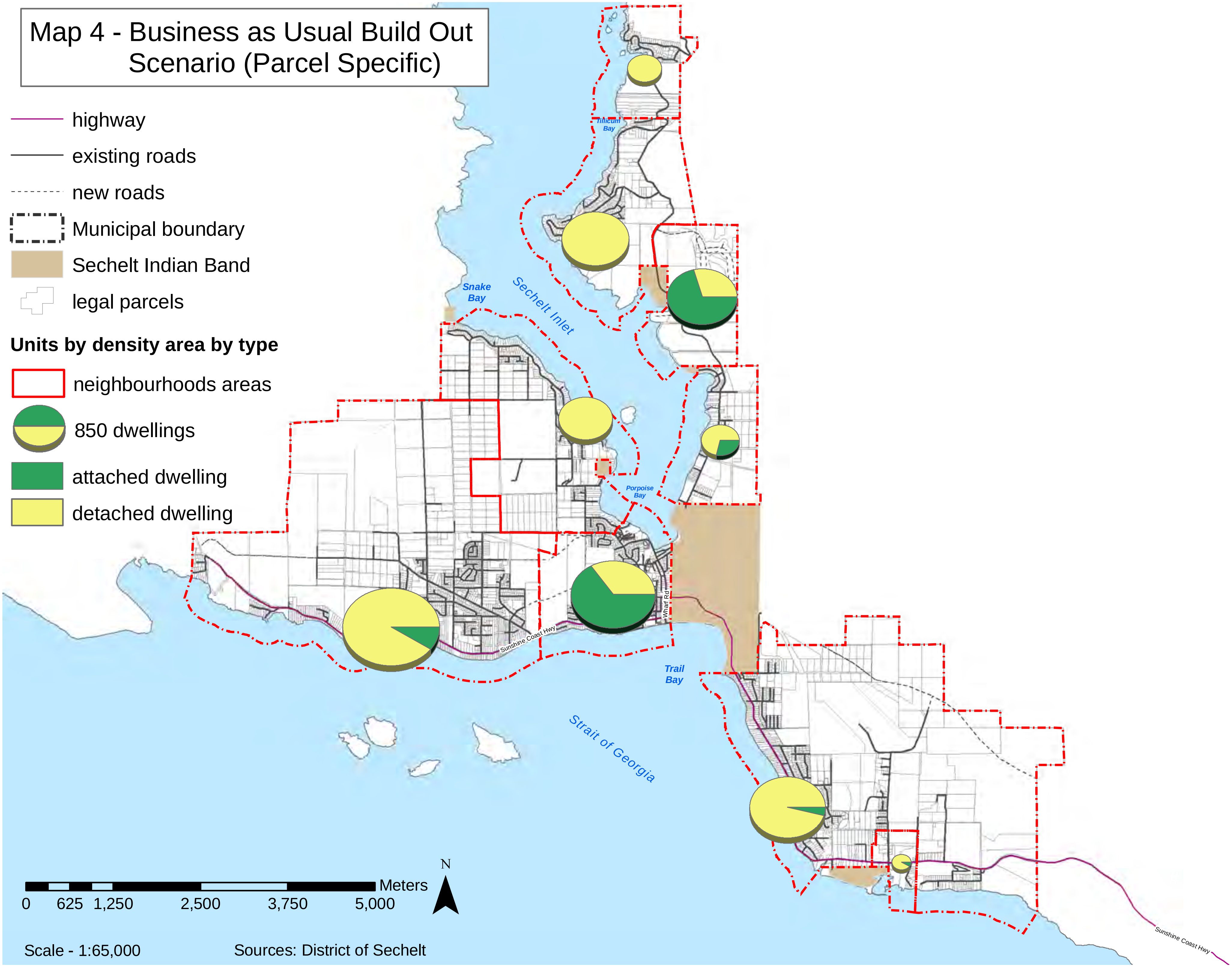
# Map 1 - District of Sechelt Base Map



# Map 2 - Existing Settlement Pattern (2009)

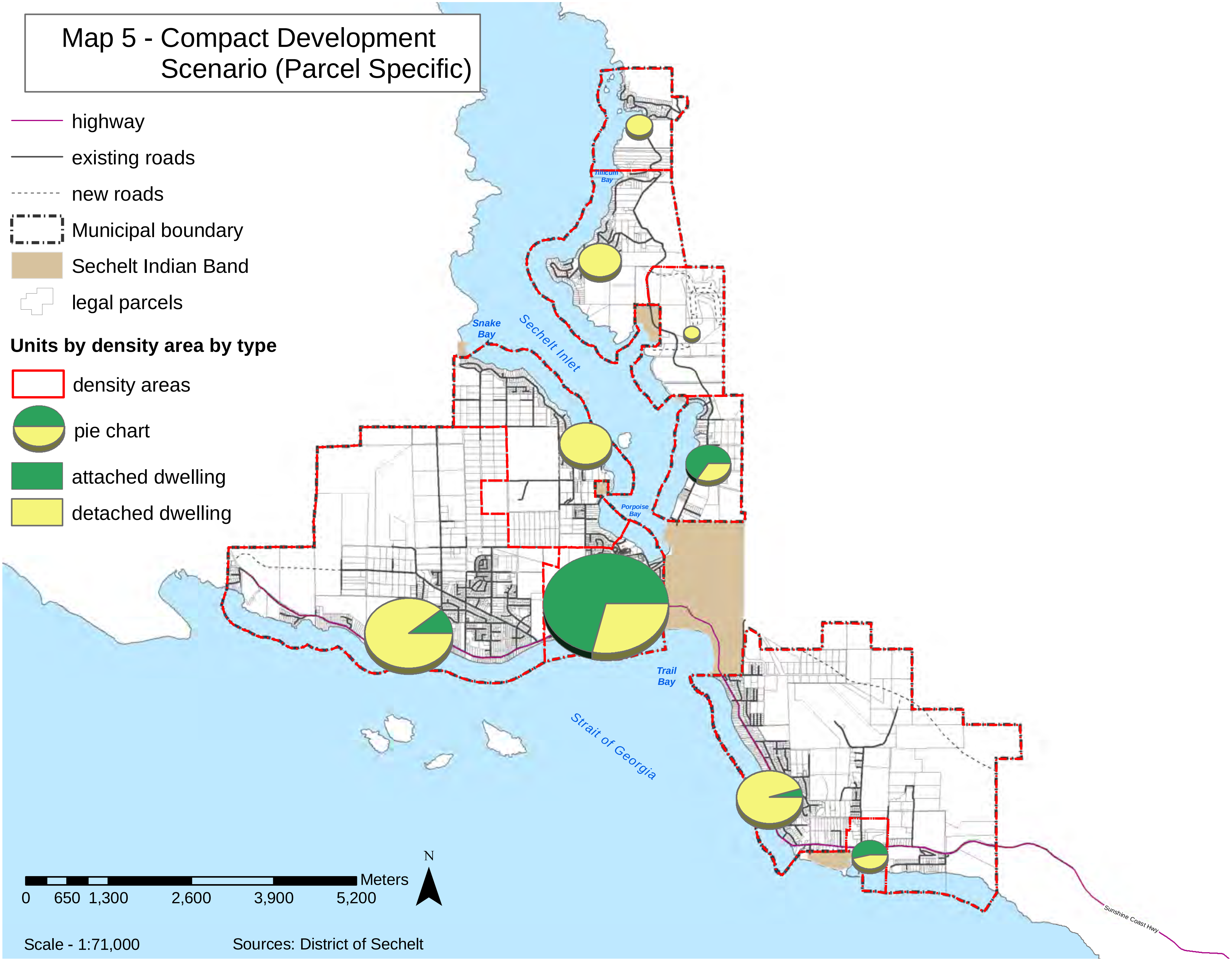


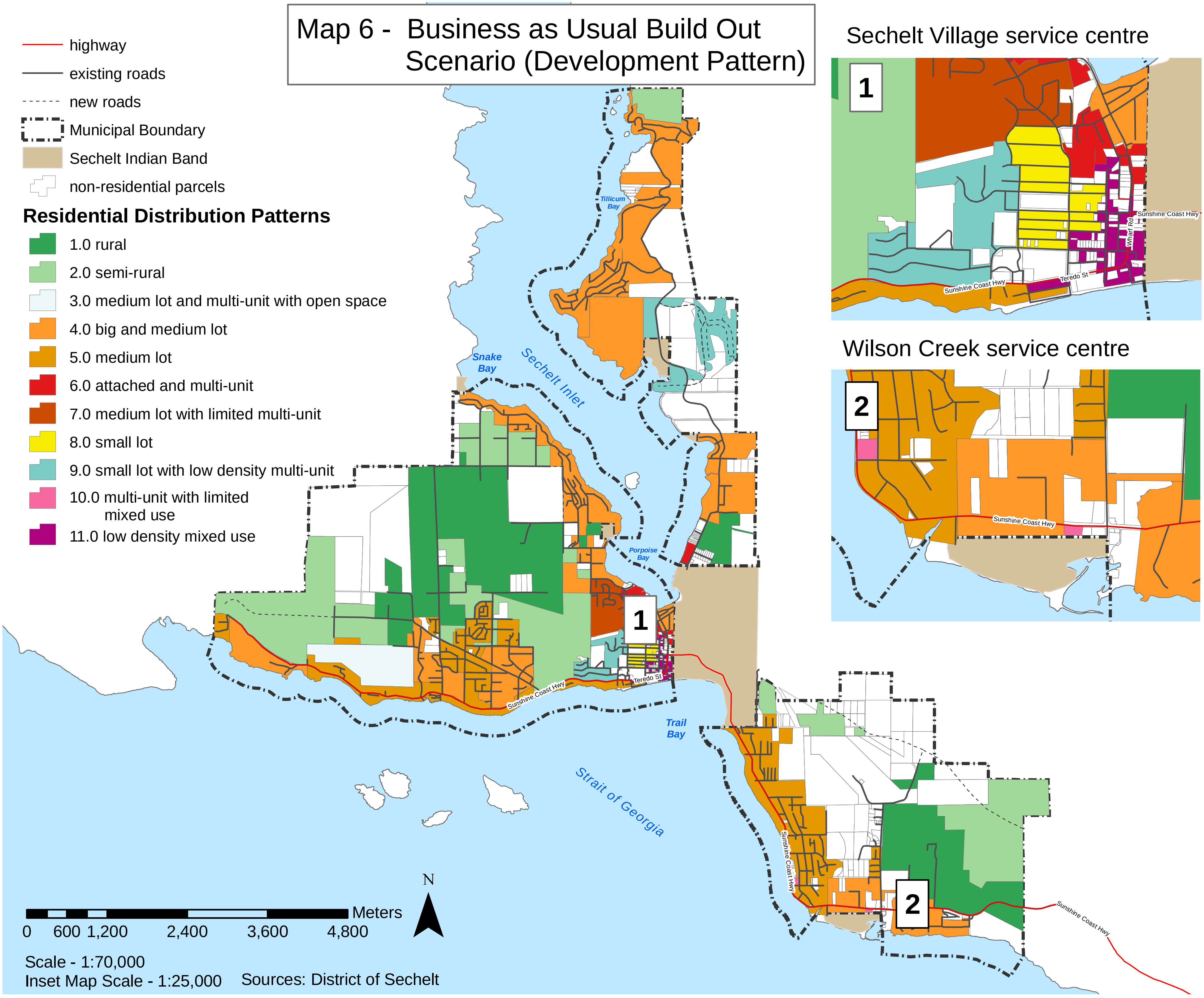

Map 3 - Academic Future General Land Use Map: Compact Development
Legal Parcels
Municipal boundary
existing sewage system
potential future sewage system
Reduced residential capacity
Compact development growth nodes
Highway
Sechelt Indian Band
Tillicum Bay
Snake Bay
Sechelt Inlet
Porpoise Bay
2. East Porpoise Bay intensification
1. Sechelt Service Centre
Teredo St
Sunshine Coast Hwy
Trail Bay
Strait of Georgia
2. Wilson Creek Service Centre
Sunshine Coast Hwy
Sunshine Coast Hwy
Meters
0 440880 1,760 2,640 3,520
Scale - 1:65,000
Sources: District of Sechelt
N



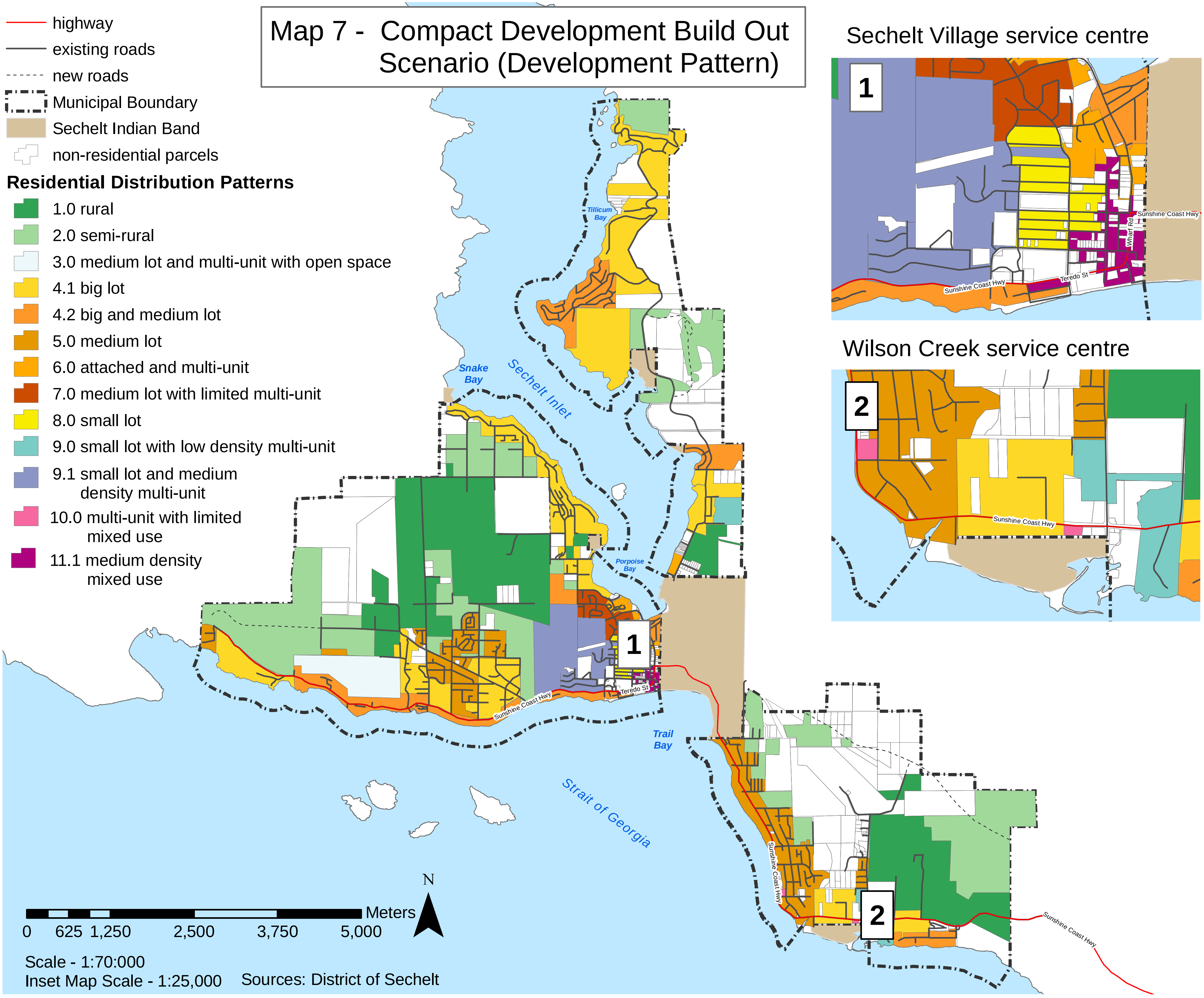
Map 4 - Business as Usual Build Out Scenario (Parcel Specific)
highway
existing roads
new roads
Municipal boundary
Sechelt Indian Band
legal parcels
Units by density area by type
neighbourhoods areas
850 dwellings
attached dwelling
detached dwelling
Tillicum Bay
Snake Bay
Sechelt Inlet
Porpoise Bay
Wharf Rd
Sunshine Coast Hwy
Trail Bay
Strait of Georgia
Sunshine Coast Hwy
Meters
0
625
1,250
2,500
3,750
5,000
N
Scale - 1:65,000
Sources: District of Sechelt

Map 5 - Compact Development Scenario (Parcel Specific)





Map 6 - Business as Usual Build Out Scenario (Development Pattern)
highway
existing roads
new roads
Municipal Boundary
Sechelt Indian Band
non-residential parcels
Residential Distribution Patterns
1.0 rural
2.0 semi-rural
3.0 medium lot and multi-unit with open space
4.0 big and medium lot
5.0 medium lot
6.0 attached and multi-unit
7.0 medium lot with limited multi-unit
8.0 small lot
9.0 small lot with low density multi-unit
10.0 multi-unit with limited mixed use
11.0 low density mixed use
Sechelt Village service centre
Wilson Creek service centre
Tillicum Bay
Snake Bay
Sechelt Inlet
Porpoise Bay
Trail Bay
Strait of Georgia
Sunshine Coast Hwy
Teredo St
Wharf Rd
1
2
N
Meters
0 600 1,200 2,400 3,600 4,800
Scale - 1:70,000
Inset Map Scale - 1:25,000
Sources: District of Sechelt



Map 7 - Compact Development Build Out Scenario (Development Pattern)
highway
existing roads
new roads
Municipal Boundary
Sechelt Indian Band
non-residential parcels
Residential Distribution Patterns
1.0 rural
2.0 semi-rural
3.0 medium lot and multi-unit with open space
4.1 big lot
4.2 big and medium lot
5.0 medium lot
6.0 attached and multi-unit
7.0 medium lot with limited multi-unit
8.0 small lot
9.0 small lot with low density multi-unit
9.1 small lot and medium density multi-unit
10.0 multi-unit with limited mixed use
11.1 medium density mixed use
Sechelt Village service centre
Wilson Creek service centre
Sunshine Coast Hwy
Teredo St
Wharf Rd
Tillicum Bay
Snake Bay
Sechelt Inlet
Porpoise Bay
Trail Bay
Strait of Georgia
1
2
N
Meters
0 625 1,250 2,500 3,750 5,000
Scale - 1:70:000
Inset Map Scale - 1:25,000
Sources: District of Sechelt