Chapter 10

Collaborative Processes and GeoSpatial Tools in Support of Local Climate Change Visioning and Planning

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Abstract. GEOIDE NCE funding has enabled a decade of collaborative development of geospatial decision-support tools on sustainability issues, working with several regional and local governments, and multiple academic teams. Project strengths have been the innovative development and/or application of geospatial tools to climate change within collaborative processes, the on-going development of relationships between researchers and local communities, and longitudinal project evaluation, made possible through on-going, multi-year GEOIDE grants. The linked projects have led to increased local government awareness and capacity-building around climate change, the development of localized and down-scaled climate change scenarios tied to local issues, local champion support, and early uptake of spatial planning tools and project outputs within communities. The flexibility of the Local Climate Change Visioning process has allowed the adaptation of geospatial tools to a range of contexts and thematic areas. It is one stream of activities that integrates climate change within the operations of municipal and regional governments.

Keywords: climate change, decision making, geospatial tools, geovisualization, Local Climate Change Visioning.
1 Introduction

Over the past decade, GEOIDE NCE funding has enabled the collaborative development of geospatial climate change decision-support tools with regional and local governments and academic teams within a process termed “Local Climate Change Visioning” or LCCV (Shaw et al., 2009; Burch et al., 2010b; Pond et al., 2010a; Sheppard et al., 2011; Cohen et al., 2012a; Burch et al., submitted 2012). This chapter outlines the research trajectory and collaborative networks that were formed, provides an overview of project processes, and highlights key outputs and preliminary outcomes.

1.1 Background and Research Questions

In the face of urgent challenges to mitigate greenhouse gas emissions (Anderson and Bows, 2011) and adapt to escalating climate change impacts (IPCC, 2007), local governments are emerging as a necessary site of climate action (Adger et al., 2005; Bai, 2007; Province of British Columbia, 2007 & 2008): engaging with local governments and citizens in order to integrate climate change within local planning processes for both adaptation and mitigation has become critical (cf. Snover et al., 2007; Picketts et al., 2012). However, incorporating climate change at the local scale faces challenges, including: climate model downscaling (Shaw et al., 2009), policy response options that are generally formulated at the national scale (Parry et al., 2007), the challenges of science communication (Moser and Dilling, 2007; Shome and Marx, 2009; O’Neill and Nicholson-Cole, 2009), an external expert-driven knowledge generation process that has not benefitted from local input and meaningful engagement (Shaw et al., 2009), and the need for cross-silo local planning as well as the inter-disciplinarity required by sustainability science (Robinson and Tansey, 2006).

The range and relative newness of these challenges calls for better participatory processes and tools to support local stakeholders and municipal decision-making under conditions of considerable uncertainty (Bizikova et al., 2011). Drawing together a range of disciplinary approaches, Sheppard et al. (2008), Shaw et al. (2009), Burch et al., (2010b), and Sheppard et al. (2011) have posited that a process utilizing participatory co-production of knowledge, inter-disciplinary research teams, localized scenarios, and geovisualization tools could help to meet the need for awareness-building, co-production of knowledge, capacity-building, and more effective local decision-making around climate change.

Participatory processes involving stakeholders and scientists provide a way to bridge the global to local scale in terms of knowledge production (Shaw et al., 2009), using co-production of knowledge (Gibbons 1999; Robinson and Tansey, 2006; Bizikova et al., 2011) and shared learning that potentially enables more creative decision-making (Newig et al., 2008). A process that includes local stakeholders is also posited to ensure local ownership towards and accountability for the process (UKCIP 2009 in Shaw et al., 2009), as well as improved outcomes, including enhanced legitimacy (Lange, 2011; Larsen and Gunnarsson-Östling, 2009) and more meaningful and inclusive results (Dryzek, 2000). Localized, co-produced knowledge is posited to
overcome public barriers to engaging on climate change (Lorenzoni et al., 2007; Burch et al., 2010a), avoiding the common information deficit model approach to engagement around climate change (Shove, 2010).

In the planning field, deliberative processes are posited to strengthen outcomes (Healey, 1997; Salter et al., 2010); Arnstein’s “ladder of participation” provides a framing tool as to the level of participation at various decision-making stages (cf. Schlossenberg and Shuford, 2005; Arnstein, 1969). Inter-disciplinary research teams and approaches should be able to handle the complexities of “wicked problems” (Rittel and Webber, 1973), in this case, global to local socio-ecological challenges (Miller et al., 2008; Tansey and Robinson, 2006). Transdisciplinary action research (TDAR) (Schroth et al., 2011b) goes beyond interdisciplinary approaches in bringing academic research to bear on real-world problems (Walter et al., 2007; Miller et al., 2008) through high levels of collaboration and joint decision-making (Walter et al., 2007), while participatory integrated assessments (PIA) are designed to provide meaningful participation into the decision-making process around sustainable futures (Salter et al., 2010).

A critical characteristic of global climate change research has been the development of global scenarios (Nakicenovic et al., 2000; Cohen and Waddell, 2009), developing out of a historically diverse range of approaches to scenarios and their uses (cf. Bradfield et al., 2005; Bishop et al., 2007; Pulver and VanDeveer, 2009). Global change scenarios share key components: they are multi-dimensional, with internal coherence among diverse elements; they are schematic, aiming not for precision and detail but for essential elements and plotlines that show large-scale patterns and a variety of future pathways and conditions; and they have a degree of likelihood, although their probability may not be defined. They incorporate varying degrees of quantitative modeling and qualitative narrative, as well as challenges in integrating the two (Parson et al., 2007; Swart et al., 2004).

Within environmental governance and sustainability science, scenarios can systematically frame complex future pathways, capturing surprise, human choices, and environmental responses, enabling examination of critical issues informing policy decisions, including the feasibility and implications of normative futures (Robinson, 2003; Swart et al., 2004). Scenarios offer a way to handle future uncertainty (Bizikova et al., 2011) and they can illustrate the relationships between key drivers such as economy, environmental values, emissions, and radiative forcing (Shaw et al., 2009). Scenarios thus offer a structured, integrative and knowledge-based method of thinking about the future (Swart et al., 2004; Robinson, 2003). In linking policy to stakeholder communities and decision-makers, they may become “boundary objects”, locations of collaboration between science and political processes (Pulver and VanDeveer, 2009). By illustrating the relationships between choices and future consequences, and by enabling participation, they arguably enable more robust decision-making (Bizikova et al., 2011; Shaw et al., 2009; Swart et al., 2004; Robinson, 2003; Raskin et al., 2002).

The geovisualizations described in this chapter draw on the fields of transdisciplinary scholarship, participatory integrated assessment, and sustainability scenarios, as well as Public Participation Geographic Information Systems (PPGIS). The
latter seeks to form “open and transparent access to spatially enabled data and information handling tools for people interested in place-based problem solving and decision-making in a specific socio-political context” (Jankowski and Nyerges, 2003). PPGIS as a field of inquiry integrates research about place and people, technology and data, and process, as well as outcomes and evaluation. Sieber (2006) highlights that PPGIS is socially constructed and argues that it is therefore necessary to include social science in the analysis of PPGIS. She also refers to Harvey and Chrisman (2004) who point out that the analysis of any GIS implementation requires an analysis of the underlying social relationships and interactions. Diverse web and GIS technologies can be combined to facilitate gathering and processing of local knowledge (Rantanen and Kahila, 2009), while other research has addressed the potential of distributed or different-place collaborative GIS (MacEachren et al., 2006). Further research is required to explore the role of visualization, interactive interfaces, and the emerging discipline of visual analytics (Andrienko et al., 2007).

Geospatial planning tools, developed and communicated using visual media in a structured framework incorporating the best available data, knowledge, and modelling provide one way to engage both experts and stakeholders in planning processes (Bishop and Lange, 2005; Sheppard et al., 2011). GIS-based 3D landscape visualization can fulfill these functions (Bishop and Lange, 2005; Appleton and Lovett, 2003). Sheppard (2005) and Nicholson-Cole (2005) argue that 3D visualizations can also make climate change impacts and mitigation/adaptation solutions more tangible and salient for the public and situate climate change within local places, as called for by Lorenzoni et al. (2007), and demonstrated in a local planning process by Salter et al. (2009). Various previous studies, reviewed in Sheppard (2012), have attempted to integrate climate change and response scenarios, spatial modelling, landscape visualization, and participatory processes in various combinations, but none of these has been systematically evaluated for effectiveness with users/participants.

The Local Climate Change Visioning (LCCV) process, developed by the Collaborative for Advanced Landscape Planning (CALP) at the University of British Columbia with GEOIDE NCE support, has piloted, tested, and adapted such an integrated set of tools, developed within collaborative local partnerships and networks. The LCCV process has been developed through a series of projects, starting with a pilot project in two Metro Vancouver communities, to a second iteration with a small, rural community, to case studies in three provinces and one territory. Evaluation goals have shifted over the life of the projects, from initial testing of awareness and learning about climate change, to testing particular geovisualization tools and a simpler scenario development process, to evaluating the effectiveness for capacity-building and decision-support using a longitudinal evaluation and case study comparison.

The LCCV projects have thus explored both tool/process development, as well as evaluation of the overall social effects, focusing on answering the following questions: how can geospatial modeling and visualizations be developed and embedded within collaborative learning processes in order to support better informed local decision-making on climate change? Do these tools/processes improve the effectiveness of local climate change planning and decision-making?
In order to answer these questions, the LCCV had to be developed, tested, and evaluated. Methodologically, there are therefore two different evaluation components: the first examines LCCV development, including the processes, tools, and their immediate outputs. The second evaluates impacts and outcomes. Planning literature on evaluation has focused primarily on the former, usually on short-term successes and participants’ perception of a process (Shipley, 2002). Shipley calls for evaluation of substantive project goals, including results over time (2002); similarly, Larsen and Gunnarsson-Östling caution against only measuring deliberative processes, rather than impacts and outcomes (2009). As the GEOIDE projects have sought to answer dual methodological questions, an overview of “effectiveness” and related evaluation methodologies is warranted.

Using Moser’s framework (2009) as a guide, and drawing on Jankowski and Nyerges (2003), Walter et al. (2007), Larsen and Gunnarsson-Östling (2009), and Salter et al. (2010) we have chosen to assess project process, outputs, and outcomes. In this context, a project is considered effective when the process of planning includes climate change and climate science, with process defined as the “establishment of, or improvements in, the process of communication and interaction between scientists and decision-makers [and affected or interested stakeholders]” (Moser, 2009: 14). Additional process results include shared goal definition, legitimacy and fairness, including whether participants felt heard (Walter et al., 2007; Larsen and Gunnarsson-Östling, 2009), and public engagement (Shaw et al., 2009).

Related measures of effectiveness include project outputs or products, which are tangible results including project reports (Walter et al., 2007). In the case of LCCV, proposed outputs included downscaled scenarios across climate projections for local areas linked to locally available expert modeling, verified scientific data integrated with local knowledge and issues, and communication of collaborative scenarios or designs using a variety of digital visualization tools including 2D (e.g. mapping, photomontage) and 3D digital landscape visualizations. Taken together, the process and outputs (or, simply, the process with embedded tools) can be measured for immediate impacts on both stakeholder and expert/public participants, including immediate changes in awareness, attitude and knowledge (Walter et al., 2007), affective response (Sheppard, 2005), as well as new scientific insights, i.e., impacts on the researchers themselves (Walter et al., 2007).

Project outcomes are the “wider and/or longer-term” effects (Jankowski and Nyerges, 2003; Walter et al., 2007; Moser, 2009:14; Salter et al., 2010). The long-term effectiveness of decision-making support is “notoriously difficult to interpret, measure, track, and evaluate” (Moser, 2009: 11; see also Rohmsdahl and Pyke, 2009). Climate change planning and decision-making occur within a complex set of local government institutions and practices (Roberts, 2008; Burch, 2010a and 2010b; Basset et al., 2010): only rarely is a decision or policy change attributable to a specific project (Walter et al., 2007). Geospatial tools and processes that link academics and scientists to local communities thus operate alongside many other influences: geospatial support, through a process of local climate change visioning, is only one stream of activities among several influencing decision-making. Therefore, evaluation of LCCV outcomes has not sought primarily to find causal relationships between the process
and local decisions, but instead has looked for broader institutional changes that enable effective decision-making.

Effectiveness in outcomes is therefore broadly defined as: increased capacity and competence building through issue-driven shared learning, which contribute to increased civic capacity; the distribution of socially-robust knowledge, including adding depth to deliberations about local climate change impacts and response options; the uptake of new and existing spatial planning and visualization tools (eg. GIS, participatory GIS, spatial modeling, and 3D landscape visualizations); decision-making, including an increased capacity to act; building trust; building new networks that increase social resilience; and, transformative or incremental change towards a shared goal (Robinson and Tansey, 2006; Walter et al., 2007; Larsen and Gunnarsson-Östling, 2009; Moser, 2009; Salter et al., 2010). Short projects with minimal post-project evaluation periods often preclude study of outcome effects, which may take several years to come to fruition (Walker et al., 2007; Yarnal et al., 2009). We return to the challenges of measuring effectiveness below.

1.2 Project Overview and Methodology

In an early GEOIDE project, Georgia Basin Quest, a spatially-based socio-economic model was developed for exploring alternative future scenarios based on participants’ world views, policy assumptions, land use trends, etc (Robinson and Tansey, 2006; Robinson et al., 2006). This project was followed by a GEOIDE SII project (2004-2007), which piloted an innovative, collaborative, inter-disciplinary process between UBC, government researchers, and local communities (Sheppard et al., 2008; Shaw et al., 2009; Burch et al., 2010b; Sheppard et al., 2011; Bizikova et al., 2011; Cohen et al., 2012a). Holistic, localized future scenarios were developed to illustrate choices and trade-offs across a range of climate change response options, from “Do Nothing” to “Deep Sustainability” (Shaw et al., 2009). The SII project built on the earlier Quest modeling by bringing climate change and impacts projections into localized scenario development (Shaw et al., 2009).

A bridging project, predominantly funded by others during the pilot year of GEOIDE P32 (2008-2012), explored the application of these tools and processes within a more rural, less well-resourced community, the City of Kimberley (Schroth et al., 2009; Cohen et al., 2012b; Burch et al., submitted 2012). Based on the Kimberley project, and drawing from the SII project, CALP produced a Guidance Manual on the LCCV process and tools (Pond et al., 2010a) for interested practitioners and for use during the next GEOIDE project, P32.

Project 32 has permitted two further developments: a) extending the evaluation of the longer-term outcomes from SII and Kimberley and, b) nationalizing the reach of the process with researchers and partners from several universities and local governments, as well as continuing work with the Corporation of Delta, one of CALP’s

1 The BC Real Estate Foundation, the BC Ministry of Community and Rural Development (now Ministry of Community, Sport, and Cultural Development), and the Swiss National Sciences Foundation.
long-standing municipal partners. The four-year comparison of five case studies (Kimberley and four P32 projects), covering Canadian urban, suburban, rural, and Arctic communities, has helped to address the need for more comparative studies of climate change. This has led to further development, as well as divergence, in process, outputs, and outcomes, tailored to local community needs and building on local researchers’ strengths.

All projects share a common methodological base to develop the tools for decision-support, characterized by: a) addressing climate-related issues at hamlet to regional scales, b) spatially-based approaches integrating scientific data, modeling and in some cases landscape design, c) participatory processes where academic research teams collaborate with local stakeholders and inter-disciplinary experts, d) exploration of possible future pathways using scenarios or design options and, e) the use of 2D and/or 3D visualization tools. Each project has increased our understanding of the opportunities and challenges in developing Local Climate Change Visioning, through on-going GEOIDE network relationships and partners such as Natural Resources Canada, Environment Canada, and Provincial and local government bodies.

Common methodological development of characteristics a) and b) will be discussed in the project descriptions below (Section 2), while c) is demonstrated through examples of project outputs, and in the numerous project publications. Methodological discussion of participatory processes and scenario development is warranted here.

Participatory processes are here broadly defined to include collaboration between scientific researchers, stakeholders, various “publics”, and local knowledge holders (e.g. planning practitioners, decision-makers, elders). Such collaboration may cross scientific disciplines and include decision-makers as well as various government agencies; collaboration may also network across research teams from different institutions, and in widely varying locations (Pike et al., 2005). For some networked projects, specialized network infrastructure has been developed and evaluated (cf. Yarnal et al., 2009).

Building on prior projects (cf. Robinson et al., 2006; Salter et al., 2009), the LCCV projects employed a variety of participatory practices locally at the case study level, including stakeholder workshops, and meetings with planning practitioners, citizens’ groups, and decision-makers (e.g. Mayor and Council), as well as consultations with various disciplinary experts. Public workshops and public open houses were held in some of the cases. The networked P32 projects, involving research teams at four different universities were treated methodologically as a case study project. Each case study’s internal research team brought their own strengths to their case study, ranging from agent-based modeling to landscape architecture, within the general methodological framework outlined above. In addition, early goal setting for each study was done through stakeholder and community participation, a common methodology in transdisciplinary action research (TDAR), so that the projects’ foci necessarily diverged to meet local needs.

Various frameworks exist for assessing participatory processes. In PPGIS, for example, Jankowski and Nyerges (2001) have suggested empirical testing of eight categories through experimentation. Although we used similar categories to guide the cross-case comparison, we chose a multiple-case study approach rather than a quanti-
tative experiment. Multiple-case studies are well established valid research methods in various disciplines (Yin, 2003), including landscape related disciplines (Francis, 2001). In contrast to an experiment, case studies do not follow generalization logic but rather replication logic, i.e. the research item, here the LCCV process, is replicated and the comparison looks for similarities, differences, and unexpected results. Retrieved data includes participant feedback as well as insights and observations of the researchers themselves. Although the results cannot be generalized in the same way experimental results can, a multiple case study is more powerful in capturing social-institutional and group participant influences as well as evaluating longitudinal social outcomes. For this project, Kimberley as well as the P32 projects (Calgary, AB; Clyde River, Nunavut; Metro Toronto, ON; Delta, BC) were treated as case studies.

Scenario methods may range from qualitative, participatory, narrative storyline development, to quantitative computer modeling (van Notten et al., 2003; Newig et al., 2008); in addition, various methods including forecasting and backcasting may be employed (Börjeson et al., 2006; Swart et al., 2004). The localized SII scenarios were developed based on the global assessment and future studies literature (Nakicenovic and Swart, 2000; Raskin, 2005; Carpenter et al., 2005; Swart et al., 2004; Raskin et al., 2002). They were constructed using a two-step qualitative downscaling approach: first, global trends were downscaled regionally, and compared to the quantitative, regional, socio-economic Quest scenario model (Shaw et al., 2009). The second step downscaled to specific municipalities, supplementing the qualitative storyline with local quantitative data (ibid; Cohen et al., 2012a). Four main themes were covered: biophysical impacts, response options (including both adaptation and mitigation), socio-economic change, and governance (Shaw et al., 2009). The four scenarios that were developed became known as the “Four Worlds” (see Figure 1), covering a full range of possible GHG emissions’ pathways.

For Kimberley, the scenario method was simplified to two stakeholder-driven qualitative scenarios (integrated mitigation and adaptation versus adaptation only), backed up with quantitative modeling and spatial analysis of forest fire risks and mountain pine beetle susceptibility under climate change (Pond et al., 2009; Schroth et al., 2009). In P32, qualitative and/or quantitative scenarios with measured indicators were used in most projects, except one case study where landscape design, i.e. an iterative, future solution-oriented method, was employed. While the earlier projects (SII and Kimberley) focused on a broad thematic divergence in the scenarios – posititve alternate adaptation and mitigation futures, and widely varying GHG emissions scenarios (cf. Shaw et al., 2009), in some cases the P32 projects instead explored multiple adaptation scenarios, or a variety of adaptive design solutions, without specific assumptions on or modeling of GHG emissions.

Project results have been measured through mixed methods. For LCCV development, the processes and outputs were documented by the research teams. However, project outputs do not themselves measure the immediate impacts of project processes and tools on participants. Therefore, process and output impacts were measured for both SII and Kimberley using quantitative and qualitative questionnaires, provided to participants at final workshops and Open Houses (Cohen et al, 2012a; Schroth et al.,
Changes in awareness, attitude, and understanding were evaluated through the comparison of quantitative pre- and post-questionnaires. The visualization tools themselves were tested in additional quantitative and qualitative questions. Additional evaluation methods included qualitative post-process/Open House interviews, and in Kimberley, video-taping of participants at a GoogleEarth station. These were used to triangulate tool assessment with the questionnaires (Schroth et al., 2009 & 2011a).

A longer-term effectiveness study of the initial projects was conducted to capture potential outcomes from SII and Kimberley. For this research, effectiveness was defined as the ability of the LCCV to foster understanding of, support for, and action on climate change for both the individuals and local governments who participated. Rather than measuring policy outcomes, with difficult causation, the qualitative indicators chosen to evaluate effectiveness were longer-term shifts in awareness and understanding, support for climate policy, and an increased profile of climate change within the local government. Semi-structured interviews were conducted with stakeholder participants in the LCCV processes in Delta, North Vancouver and Kimberley one to three years after the project had been completed. A qualitative method of data collection was chosen to evaluate the long-term effectiveness of these processes because effectiveness is socially complex and not easily quantified: interviews are more able to garner important contextual information (Merton et al., 1990).

For P32, process, outputs and outcomes (including decision support effectiveness), as well as LCCV adaptability under various case study conditions, were measured using mixed methods, through internal reporting templates, a researcher workshop, and cross-project qualitative stakeholder questionnaires. These methods allowed for the collection of data across the range of effects including: outputs (such as the creation of models, scenarios, and geovisualization products), impacts (project legitimacy, knowledge generation), as well as potential outcomes (such as capacity building and changed policy decisions). Early results on process and tools were gathered and shared at a network researcher workshop in May 2011, following case study methods. The stakeholder questionnaires, still being gathered and analyzed, will be used to substantiate researcher insights.

2 Developing Processes and Tools, with Multiple Outcomes

This section briefly describes and summarizes results from the SII and Kimberley projects, and provides descriptions of the current comparative case studies, with preliminary findings

**GEOIDE SII – Laying the Groundwork.** The 2004-2007 GEOIDE SII project saw a cross-disciplinary research team at UBC pilot the Local Climate Change Visioning process with two Metro Vancouver communities, the Corporation of Delta and the District of North Vancouver. The project brought together local and scientific experts to integrate downscaled climate projection data into land-use development scenarios, and develop ways to communicate project findings using information visualization,
2D mapping, and 3D visualization (Shaw et al., 2009; Cohen et al., 2012a; Sheppard et al., 2011, Burch et al., 2010b). The process was designed “to integrate the best available science…. local GIS mapping, and stakeholder knowledge to visualize potential climate change impacts in a clear and compelling way, and to present possible policy and behavioural choices for communities” (Sheppard et al., 2011: 403).

The core research team included expertise in international climate policy, regional planning, landscape architecture, and digital 3D visualization. An extended, interdisciplinary research team of university, federal and provincial researchers, and local and regional practitioners and non-governmental experts provided additional expertise in sea level rise modeling, impacts and adaptation, GHG mitigation, and local planning issues. Through a series of workshops with local working groups in each community and various members of the extended research team, the future scenarios and visualizations were developed and/or vetted2.

Outputs included a “visioning package” illustrating and exploring the “Four Worlds” scenarios (Shaw et al., 2009). The visuals explicitly link to climate science and localized scenarios (Figure 1). Visualizations range from 3D landscape illustration of scientific data (shown in Cohen et al., 2012a), to experiential and up-close portrayals of adaptation action impacts (Figure 2). They were shown in five public workshops in both communities, as well as in one practitioner workshop for planners from the region. Overall, approximately 150 participants and 12-15 municipal staff saw the final project presentations, yielding approximately 160 completed questionnaires.

Fig. 1. SII Delta project: scenario modeling linked to land use visualizations (modeling: Carmichael/GB-Quest; landscape visualizations: Flanders, CALP).

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2 The process is described in greater detail in Shaw et al., 2009; Burch et al., 2010b; and Cohen et al., 2012a.
The effects of the visualizations and other workshop components were measured through pre- and post- quantitative and qualitative questionnaires, administered to participants, including a sample of the public and practitioners, at the time of the final project presentations. Due to the small sample size (e.g. about 20 in North Vancouver), as well as the potential for self-selection bias (individuals coming to the workshops tended to be already concerned with climate change), questionnaire results should be treated cautiously (Cohen et al., 2012a).

In evaluating the process outputs, the scenario framework was readily adopted by project participants (Burch et al., submitted 2012). A large majority (75%) of post-test respondents agreed or strongly agreed that community policies to reduce GHGs must be in place within 10 years; the presentations were considered credible and positively evaluated by the participants (for detailed results, see Cohen et al., 2012a; Tatebe et al., 2010, and Sheppard et al., 2008). Following the project, iconic images such as the snowpack visualizations (in Cohen et al., 2012a), have been widely presented, with considerable media coverage (Burch et al., submitted 2012).

In terms of the process, the post-project qualitative study has found that participants felt that the LCCV was effective because it was run by a credible, trusted third-party institution, included visually compelling visualizations informed by the latest science, and was integrated and holistic. The study has also found that project outputs (reports, visualizations and visioning package) have not always been readily available post-project for participants and that sustained follow-up is needed to encourage uptake of products and methods. As part of the project team’s iterative learning over the larger GEOIDE project’s trajectory, this concern is being addressed in the final Delta project (P32, described in section 2.3), with funding secured to make project materials web-available.

In terms of longer term outcomes, the LCCV process seems to broaden and deepen dialogue (Burch et al., 2010b), and can raise previously overlooked important issues (Cohen et al., 2012a). The post-project qualitative study findings also suggest that the LCCV process supported local champions, increased staff support for climate policy,
led to at least one new study on hazards, increased environmental concern in general, and increased the profile of climate change within local government. Direct causal outcomes such as behaviour change, environmental activism, and concrete changes in policy have not been found. Rather, the LCCV process has worked as a reinforcing agent for action on climate change within the local governments. Other non-LCCV factors that encouraged and supported climate action, as expressed by study participants, include: local impacts attributed to climate change (e.g. flooding), support from leadership, and most of all, provincial legislation on climate change mitigation (as found in Province of BC, 2007 & 2008).

One of the challenges identified by SII researchers at the time of the project was that of providing a way to “link the research outcomes to municipal and other decision-making” (Shaw et al., 2009: 461). This issue is being addressed in the follow-up P32 Delta project, with a policy recommendations report going to Council.

**Kimberley, BC – Adapting the Process.** The Kimberley process differed from the SII project in that it was not a stand-alone research exercise, but was instead embedded in a joint process alongside the Kimberley Climate Adaptation Project (KCAP), a community-driven project working to identify local climate change impacts, assess local risks and vulnerabilities, and develop adaptation planning recommendations for the City (Columbia Basin Trust, web; Pond et al., 2010b; Cohen et al., 2012b).

Kimberley is a small town near Cranbrook in the East Kootenays, with approximately 6000 inhabitants. Originally evolved from mining camps, Kimberley’s mine closed in 2001, and today tourism, outdoor recreation, and amenity migration provide the main sources of income. Smaller, rural communities such as Kimberley may not necessarily have the resources and tools to engage in spatial climate change planning and 3D visualizations. Thus, CALP was brought onto the Kimberley project to enhance local engagement and project outcomes through scenario development, mapping and visualization of climate change impacts, and linkage of response options to community planning and land use.

The community KCAP process relied on a local Steering Committee and Coordinator, citizen and stakeholder working groups, and community open houses and workshops. CALP’s process intersected at various points with the community process, particularly for problem definition, impacts pathways mapping, scenario development, data and visualization review, and a final Open House. With the community located about 800 km from the university, researchers visited the community multiple times, and Kimberley Steering Committee members traveled to Vancouver; the project used Skype and conference calling as well. CALP also worked with researchers from the GeoSpatial Centre at Selkirk College, located within the larger Kootenay region.

Outputs included a set of technical posters, still in use in the Kimberley planning office, a 3D virtual globe model of the city in GoogleEarth with information overlays for various development scenarios and climate change impacts, and an annotated presentation. In collaboration with the Pacific Climate Impacts Consortium, the project piloted a downscaling method for calculating and spatializing future snowpack conditions. All of these, along with the KCAP adaptation recommendations, were
presented at a final community Open House, attended by approximately 50 people (just under 1% of Kimberley’s population).

Open House participant evaluation consisted of mixed quantitative and qualitative methods (questionnaires, interviews, and video-taping of virtual globe interactions) focused on assessment of virtual tools and the utility of interactivity (Schroth et al., 2009; Schroth et al., 2011a), as well as participant levels of understanding. As an example of findings (see also Schroth et al., 2009 & 2011b), in the post questionnaire, participants (n=38) were asked “If you were asked for your opinion on mitigation and adaptation strategies for climate change in Kimberley, would the visualizations you have seen help you?” 90% answered “helped a lot” or “helped a little” (Figure 3).

![Participant rating of visualization benefits in Kimberley](image)

**Fig. 3.** Kimberley project: participant rating of visualization benefits in Kimberley.

Other questions explored the utility of various visualization media, with a focus on interactivity and virtual globes (e.g. Google Earth). Interestingly, the response to Google Earth was bi-modal: while about 2/3 ranked Google Earth as their first choice of visualization medium, about 1/3 rejected it (Schroth et al., 2011a). In this way, the Kimberley project has also contributed to researcher knowledge, another form of social impact (Walter et al., 2007), particularly around the use of virtual globes in planning practice.

The Kimberley project also illustrated that the local effectiveness and impacts of the project process, products, and outcomes must be evaluated within the local context. For example, only CAD rather than GIS had previously been available to the community; GIS data was gathered, integrated, and generated for the project, resulting in an integrated GIS database of current conditions, future land use plans, and biophysical risks and impacts, increasing local planning capacity. Simple spatial analyses such as walking circles (distance to services, a common planning metric)
arguably represented a breakthrough in local community understanding. In terms of outcomes, the final KCAP report to Council (Liepa, 2009) contained over 70 actionable adaptation and mitigation recommendations.

In terms of longer-term outcomes, the post-project qualitative study, which interviewed seven project participants, found that a dozen of the recommendations have subsequently informed policy and organizational change within the City. For example, Kimberley has adopted a new sprinkler bylaw, and made operational decisions, such as purchasing a more fuel efficient fire truck, which fit within KCAP recommendations. Although none of the measures can be linked solely to the KCAP, a wider “ecosystem of change” towards more sustainable operations and policies seems to be developing within Kimberley.

**GEOIDE P32 – Adapting to Multiple Contexts.** The GEOIDE P32 project sought to test the replicability and effectiveness of local climate change visioning as a way to develop, integrate and deliver available data and local knowledge, spatial modeling, and visualizations to support decision-making around climate-related challenges. Over four years, researchers at the Universities of British Columbia, Toronto, Waterloo, and Calgary have collaborated with local partners to explore how LCCV changes as it is applied to other contexts – from downtown Toronto, to a regional watershed in Alberta, to a Hamlet in Nunavut. Project processes, challenges, and outputs to date can be reported on, with some preliminary outcomes, and insights into potential longer-term outcomes.

### 2.1 Calgary – moving to the watershed scale

The Elbow River in southern Alberta, Canada, originates from Elbow Lake in the Canadian Rockies and enters the City of Calgary where it merges into the Bow River. The watershed covers some 1240 km², with 65% in the Kananaskis district and the remainder in the rural municipality of Rocky View (20%), the Tsuu T’ina Nation (10%), and the City of Calgary (5%). The watershed supports several uses including supplying part of Calgary’s drinking water, irrigation for crops, and various recreational activities (Elbow River Watershed Partnership, 2012). Since 1960, the population of Calgary has increased by approximately 35% per decade, with a land-cover expansion at the city’s periphery of about 14% per decade. The sprawling city is expected to reach 1.5 million inhabitants in 2020 and 2.3 million over the next 50-70 years (Plan it Calgary, 2007). If current trends continue, such expansion will cause loss of productive agricultural lands, forest cover, surface water bodies, and increasing levels of water pollution.

Lying in the rain shadow of the Rocky Mountains, the western Prairie Provinces are the driest areas of southern Canada. Scientists project that climate change effects will combine with cyclic droughts and rapidly increasing human activity to cause a crisis in future water availability. Alberta already experiences climate extremes, and the projected increase in average temperatures of 3 to 5°C over the next 40 years will amplify these extremes, increasing the risk of more severe and frequent droughts (Schindler and Donahue, 2006). Consequently, a reduction in average water supply is
expected in the near future, already indicated by a trend of significant decrease in surface water in southern Alberta watersheds.

Managing water resources is therefore a critical issue requiring a comprehensive understanding of several interrelated factors, particularly land use, climate, and hydrological processes. The University of Calgary’s research team in GIS and Environmental Modelling in the Department of Geomatics Engineering, in collaboration with Alberta Environment (AENV) and the Danish Hydrological Institute (DHI) in Cambridge, Ontario, has engaged in a GEOIDE P32 and other-funded project which aims at engaging stakeholders and providing decision makers with an integrated set of geospatial modeling tools. The goal is to anticipate changes in water availability, develop long-range plans to avoid adverse land-use and climate changes impacts on water supply, and make informed decisions to better prepare for the future.

The project’s focus has thus been on the development and linkage of a land-use cellular automaton (CA) model with a comprehensive hydrological/climate model (MIKE SHE) to simulate future land development and climate change scenarios, and investigate their impacts on the major hydrological processes of the Elbow River watershed. An additional critical component of the modeling system consists of a web-supported agent-based model (ABM) designed to incorporate the perspective of different stakeholders concerned by water resource management issues in the watershed. The stakeholders represented as agents include citizens, planners, developers and different government and non-profit organizations. The ABM serves as a simulation laboratory through which the stakeholders are able to view and evaluate various scenarios of land development based on their values and preferences, examine how their perspectives are perceived by other stakeholders, and reach an acceptable agreement regarding the location of a proposed land development project. An easy-to-use web interface was developed to hide the complexity of the modeling environment and facilitate the interactions of the users with the system (Pooyandeh and Marceau, 2012).

The project has generated numerous outputs. Historical (1985-2010) land-use maps of the Elbow River watershed, produced from remote sensing images at a spatial resolution of 30 m, were used to identify the main factors driving and constraining land-use changes and development. The CA model was built to simulate land-use changes over the next 25 years based on projected population growth (Figure 4). The hydrological model, once adequately calibrated and validated, was linked to the land-use model to assess the impact of land-use changes on the key hydrological processes in the watershed (Hashani et al., 2011; Wijesekara et al., 2012). The results revealed a potential significant negative impact on the sustainability of ground/surface water supplies and groundwater storages in the future in addition to an increased risk of flash floods. On-going research, with additional post-GEOIDE project funding provided by Tecterra, consists in integrating AENV datasets to conduct the simulation of five climate change scenarios using the MIKE SHE hydrological/climatological model to evaluate their influence on the watershed’s hydrology.
Furthermore, interviews were conducted with several stakeholders regarding water management issues in the watershed. This information was used to express their values and perspectives in the agent-based model that allow users to visualize maps of land development scenarios, conduct spatial analyses, and negotiate the most suitable location for land development in the watershed. Initial results conducted with a hypothetical land development plan indicate that the model is able to find the most satisfactory location for all agents (stakeholders) involved in the evaluation and negotiation process (Pooyandeh and Marceau, 2012). Work is in progress to run the model with additional agents and data corresponding to real land development scenarios to assess the utility of the proposed system in guiding decision making.

For the project’s participatory process, the research team brought together representatives of various organizations, including the Calgary Regional Partnership, the Rocky View Municipal District, the City of Calgary, the Elbow River Partnership, the Implementation Committee of the Elbow River Basin Water Management Plan, Action for Agriculture, and Alberta Environment to openly share their perspectives on land development, climate change, and water management in the watershed. Two workshops with more than 40 participants were held at the University of Calgary in 2010 and 2011, allowing scientists and stakeholders to share opinions and expertise, along with providing feedback on the models being developed. These discussions generated several positive immediate social impacts. First, they allowed representatives of these organizations to express their views, sometimes conflicting, in an open academic environment considered as politically neutral. Second, they provided a rich data and information content that was required to understand the complexity of the environmental and political issues in the watershed. An effort was made by the re-
search team to avoid focusing on the technical sophistication of the models being developed, but rather to stimulate input from the stakeholders regarding the usefulness of the models at delivering meaningful results. A third and possible fourth workshop will be held in the near future with the stakeholders to present the final results of the modeling system and further assess its utility in terms of facilitating community engagement to achieve a common goal regarding water resource management in the watershed.

A major challenge in this project was the acquisition of various datasets to ensure the calibration and validation of the models being developed. Data sharing agreements between organizations were signed and numerous meetings were held to discuss dataset quality and adequacy. This critical step in the modeling exercise required far more time and expert resources than originally planned. However, resolving this issue is a fundamental positive component of the experience gained in this project.

A long-term outcome of the project is the opportunity for expanding this collaborative research. AENV considers the Elbow River watershed as a test bed and has indicated their interest in applying the study to the South Saskatchewan Regional Plan Area that includes the whole southern region of Alberta from Red Deer to the US border. Cross-case study questionnaires for this case study are being gathered, in order to substantiate researcher insights on outcomes.

In summary, this project has employed a participatory process with stakeholders that allowed for shared learning around different (and opposing) viewpoints about land-use change and water resource management. Key learnings have been that the acquisition of high-quality data necessary for modeling along with the development, testing and linkage of the models required more time than anticipated. The inclusion of climate change scenarios is in progress. Once the modeling exercise has been completed, the results will be presented and discussed with the stakeholders and an evaluation will be conducted regarding the utility of the models to increase awareness, public participation, and decision making about water resource management.

2.2 Toronto + Waterloo – Urban Adaptation and Mitigation Challenges

Over the past five years, the City of Toronto has taken several concrete steps to adapt to and mitigate local climate change impacts, ranging from conducting a city-wide inventory of greenhouse gas (GHG) emission sources, to site-specific efforts supporting low albedo and green roof retrofits (EcoRoof Incentive program). The Green Development Standard (City of Toronto, 2006; revised 2010) is particularly noteworthy as this bylaw requires new developments to satisfy performance metrics for air and water quality, GHG emissions, energy efficiency, and other factors relating to environmentally sustainable built form.

The Toronto GEOIDE case study sought to complement these efforts with geo-visualization methods and tools that help policy-makers and, ultimately, the public, to explore where planning policy and mitigation efforts can best be targeted. Given the complexity of how macro-level climate change impacts are manifested spatially across urban settings and the limitations on local resources to mitigate these effects,
geovisualization tools are particularly important as aids for learning, communication, and decision-making processes.

The case study team consisted initially of geovisualization, participatory GIS, and landscape architecture researchers from the Universities of Toronto and Waterloo, City of Toronto staff (Environmental Planning), Environment Canada, and a local NGO, the Clean Air Partnership (CAP). In keeping with TDAR approaches, two main research foci were identified through team discussions: a) reducing heat island effects and, b) increasing green energy production through rooftop photovoltaics. The heat island concern stemmed from the recent marked increase in summer temperature extremes observed in Toronto (and other large urban areas), and higher levels of mortality and hospital admissions among vulnerable populations (Toronto Public Health, 2005), and the threat of climate change worsening the problem. Interest in assessing the solar power potential of individual buildings resulted from the Ontario government’s Green Energy Act (2009), which provides incentives for property owners to generate electricity from renewable sources and, ultimately, reduce greenhouse gas emissions from some conventional electricity sources (e.g. coal) as well as the need for future large scale power generation infrastructure. A key geovisualization challenge common to both research foci is that policies to reduce urban heat effects and promote renewable power generation are largely aspatial in nature even though the opportunities to make meaningful contributions to either issue varies spatially across the city. Hence, these visualization approaches were driven by a need to help decision makers (e.g. City staff, individual homeowners, etc.) to interactively explore spatial variability in heat and rooftop PV suitability, and to identify tangible linkages between policies and action strategies across multiple scales.

In terms of tool development, addressing a complex issue such as local climate change within a multi-faceted environment that is typical of large urban centres provided several lessons regarding how geovisualization methods can support problem exploration and learning. From a technical perspective, access to spatial data of the appropriate resolution for representing phenomena such as temperature variations across space, building characteristics (e.g. height, roof configuration, etc.) and shading effects due to vegetation and structures proved to be challenging initially. A multi-scale approach (city, neighbourhood, property) was adopted to alleviate this problem by permitting some issues (e.g. surface temperature variations) to be represented at city-wide scales with comparatively coarse data (i.e. Landsat TM), while high resolution LiDAR data available for selected neighbourhoods was used to characterize built form and vegetation.

From the project process, an important, and initially least recognized, project learning was recognition of the broad range of objectives, preferred foci and ontologies within the study team for understanding both the urban environment and climate change concerns. To a large extent, this simply reflects the complexity of urban scale climate change analysis and the varied analytical frames and responsibilities of different individuals and agencies; such challenges in inter-disciplinary work are well reflected in the literature (cf. Robinson, 2003). Interestingly, the early geovisualization outputs (see below) provided a common point of reference, solidifying the team’s
focus and ultimately providing a stronger base to capitalize upon the team’s diverse expertise.

Initial discussions had been quite wide ranging and included issues rooted in existing policy initiatives or concerns such as increasing tree canopy coverage, renewal of residential towers to improve energy efficiency, heat-related health ailments, and the potential for flooding under feasible future climate scenarios, among others. The practical lens of initially limited data availability, particularly with regard to high resolution thermal imagery and downscaled climate projections for the City, spawned an iterative and informal process of developing, discussing and refining prototype visualization outputs (e.g. 3D images of modelled vegetation at street scales, mapping of Landsat thermal imagery across the City). Central to these efforts was a desire to investigate how macro climate change and GHG reduction concerns could be translated and visualized at the neighbourhood and property scales that local bylaws most often target.

The case study has generated two primary types of output, with divergent practical applications, from its first stage of exploratory visualization. The first type involved the mapping of variations in surface heat using various 2D and 3D cartographic approaches. On a city-wide scale, surface temperature variations were represented as topographic surfaces on which orthophotos were draped to highlight correspondence between land use and heat effects. In addition, detailed 3D visualizations of specific buildings and vegetation provided a basis to search for patterns in surface temperature variations and identify where mitigation strategies could have the most significant impact (Figure 5). For example, the Green Development Standard requires developers to construct green roofs on all new buildings greater than 2,000 square meters or provide cash in lieu; thus, current policy considers only the building, but not the building’s context. The 3D visualizations enable context-dependent policy decisions about building-scale interventions. The visualizations therefore allow planners to consider whether it may be better to accept cash payments in locales with strong urban forests and apply the funds in other areas where the cooling impact is needed most.
Fig. 5. P32 Toronto: 3D temperature map with urban forest canopy, University of Toronto area. The visualization combines remote sensed heat mapping, 3D urban form, ortho imagery and GIS Urban Forest data. It reveals, for example, the increase in heat from the new Varsity Stadium artificial turf, where there is no evapotranspiration.

The second broad type of output from this project was the development of a web-GIS application and associated solar modelling to allow users to explore solar panel feasibility on individual buildings. Solar insolation was modelled for two study areas within the city (broader Central Business District and the Black Creek area) using the ArcGIS Solar Analyst tools. Within an urban context, solar insolation on individual roofs varies primarily with topography, shading from trees and nearby buildings and the characteristics of the roof (e.g. roof slope, aspect, obstructions such as chimneys). These characteristics were captured in selected areas from LiDAR data provided by team partner Optech Inc. and 3D data derived from the City’s Urban Design CAD model, and used to populate building footprints with height values and, where possible, to develop roof profiles. These data were used in a web-GIS tool built using ESRI’s Flex API to allow users to interactively explore variations in solar potential across the study areas. Users can easily retrieve estimates of the financial returns and GHG reductions associated with different solar panel configurations that they define interactively on specific buildings (Figure 6). Other capabilities of the web-GIS tool, including solar transects and land cover charting, were also developed to allow users with varying skill sets and interests to interactively explore existing spatial data sets (e.g. multiple Landsat thermal imagery snapshots, high resolution land-cover data derived from Quickbird imagery) that they otherwise would not be able to access and learn from.
Formal testing of the visualization products and the web-GIS tools will take place in 2012 including the administration of cross case study questionnaires, which will allow for substantiation of some of the assumed impacts. In terms of longer term outcomes, this work aims to increase public awareness and understanding about urban micro-climates and how solar energy could contribute to improved implementation of urban heat island mitigation, GHG reduction, and reduced electricity costs to households and businesses participating in the Feed-in Tariff (FIT) and Micro-FIT incentive programs. Web-mapping techniques of this type are increasingly being used by governments as one way to complement and extend existing processes of public participation in decision making and, particularly, to reach out to individuals who are not able or willing to engage in traditional place- and time-specific meetings (Hall et al, 2010; Stern et al, 2009). Moreover, given that the City of Toronto’s revised Green Development Standard (2010) includes specific performance measures related to tree shading and green roof provision for new development, there is further potential for tools of this type to be extended and integrated into routine planning practice.

Two important outcomes can be identified at this time: first, on-going networking has enabled the team and the research to be expanded to incorporate new partners, particularly the Toronto and Region Conservation Authority (TRCA). The new linkage with the TRCA has resulted in collaboration between University of Toronto landscape architecture students and private sector property owners, in order to develop green infrastructure design options for sites in the industrial and commercial district centered on Pearson International Airport. This collaboration has led to on-the-ground implementation of a green parking lot as a heat island mitigation measure. Second, collaboration was also initiated with the TRCA to leverage the solar and heat mapping work for their Toronto and Brampton Sustainable Neighbourhood retrofit.
Action Plan (SNAP) sites, integrating testing and dissemination of results within an established community participation process.

In summary, the project process has illustrated some of the ontological and epistemic challenges in working with inter-disciplinary teams, and pragmatic challenges in integrating disparate data sets across multiple scales. Project outputs have led to new partnerships, with the potential to increase understanding of urban solar conditions for both planners and the public. Finally, project outcomes include implementation of a small-scale micro-climate adaptation project, as well as enhanced collaborative networks between academic researchers and Toronto environmental organizations for on-going, applied research. Five new small-scale micro climate change adaptation case studies have been funded for 2012 as part of the Toronto Region Conservation Authority’s Partners in Project Green initiative that will utilize the visualizations, tools and data sets assembled as part of the GEOIDE study.

2.3 Clyde River – Planning for Growth in a Small Northern Hamlet

Clyde River, Nunavut, is a hamlet of approximately 900 residents on the North Coast of Baffin Island located just north of the Arctic Circle, and 750 km north of Iqaluit. There are no roads, power grid, or other physical infrastructure connections. Daily transport and travel to Clyde River is by air, with an additional summer sea-lift shipment. Electricity, heat and transportation energy are provided by diesel fuel and gasoline, imported during the summer sea-lift. Most major decisions for Clyde River are made within and paid for by territorial authorities in Iqaluit, which feed into sparsely distributed regional planning authorities as well as the local Hamlet office.

The Clyde River project used spatial planning, scenarios, 2D and 3D visualizations, as well as participatory processes (focus groups, community open houses, and community mapping, all working with translators) to bring together local and scientific knowledge, build social learning around planning issues, and visualize potential future resilient pathways for the community.

In terms of process, researchers at UBC partnered with Ittaq, the local Inuit research centre, as well as Natural Resources Canada researchers studying landscape hazards. Initially, the project focused on relationship building: UBC researchers (1 or 2 per trip) met with community members to explain the project, ask for feedback, and identify priority issues. They also met with Government of Nunavut staff, particularly Community and Government Services, the Department of Environment, the Nunavut Energy Secretariat, Qulliq Energy Corporation, and the City of Iqaluit’s Department of Engineering, during the Iqaluit lay-overs on the way to or from Clyde River. These first two visits, along with a third trip for participatory community mapping, shifted the project’s thematic focus from direct climate change related issues to include the locally-identified critical challenge of housing.

Scenario development was thus based on four dominant concerns: landscape hazards, housing (the current challenge, as well as how to plan for future population growth), walkability within the community (later broadened to cover multiple quality of life issues), and energy resilience. Following review by Hamlet staff and members of the community and Council, the four initial planning scenarios were refined by the
UBC researchers to two final, spatially divergent scenarios (Figure 7) that explore different development alternatives while incorporating more resilient energy production and quality of life concerns in building design and arrangement.

Due to the long distances, and challenges in online communications, the scenario development process was carried out primarily by the university researchers, based on findings and community reviews during trips. Climate change was captured indirectly through hazards and energy resilience issues, rather than addressed directly as a scenario driver or indicator. This was for two reasons: first, community members expressed climate change ―fatigue‖, instead wanting researchers to deal with immediate issues such as housing; and, second, localized future projections for a secondary climate change impacts were not available (with the exception of sea level rise which is projected to be negligible for the Clyde River, as it is part of a region undergoing uplift). Data on current permafrost extents, for example, is still being mapped; preliminary, draft data was only available to UBC researchers towards the end of the project.

Outputs include community and expert mapping (done by hand during two workshops, and converted to GIS by researchers); a typology and 3D representation of current and possible future housing types, including low energy row houses; community planning scenarios with 3D visualizations; and, a simple integrated assessment of indicators for hazards, energy demand, quality of life, and housing units/population. These have been communicated using PowerPoint presentations and webinars, fostering rich researcher-community and researcher-Government staff discussions. A bilingual (English/Inuktitut) set of project posters will further enable project sharing with the community and various Government of Nunavut staff.

Fig. 7. P32 Clyde River: scenario visualizations contrasting future development options: compact Lower Town or solar-oriented Upper Town (image credit: Cheng, CALP).

The immediate impacts from the process and tools have been evaluated through researcher observation, participant comments, and by the cross-case study questionnaires. Researcher insights are that LCCV potentially bridges between local knowledge, scientific expertise, and government decision-makers, particularly for communities at a distance from territorial decision-making with additional language, cultural, and institutional barriers. Feedback from community partners suggests that the mapping exercises and 3D visualizations have fostered new conversations and understanding around the community’s future and growth options. The cross-case study ques-
tionnaires are still being analysed, and longer-term outcomes cannot yet be measured; the final researcher trip to the community has yet to be completed.

The key learning has been that, given the complex set of environmental, socio-economic, cultural, and institutional conditions facing the far north, long-term resilience in Arctic communities such as Clyde River will be challenging to achieve, regardless of the availability of climate change projections or other scientific modeling. On-going planning processes will need to address many inter-related challenges, in addition to simply bringing added professional capacity, resources, and interdepartmental communication. Although the research team encountered dedicated and highly skilled practitioners throughout collaborating institutions in Nunavut, holistic and accessible processes may additionally bridge from residents and communities to practitioners and government, as well as fill a gap in official planning procedures.

2.4 Delta RAC – Operationalizing Adaptation

Building on the GEOIDE SII project, CALP continued to work with the Corporation of Delta on Project 32 in an alliance with Natural Resources Canada’s Regional Adaptation Collaborative (RAC), in order to model, visualize and evaluate potential sea level rise and storm surge flood impacts and adaptation options. While the province of British Columbia has recently provided updated guidelines and tools for flood risk management, local governments must assess their own flood risk and vulnerability, and integrate these with planning policies to implement flood protection actions. The challenge facing local governments is that they must address adaptation planning within a context of scientific uncertainty, while at the same time building public support for possibly politically-contentious climate and flood adaptation policy and action.

For the project process, CALP researchers worked with a core group of five Delta staff (the local climate change “champions”) and a citizen working group to identify sea level rise impacts and vulnerabilities, generate adaptation scenario options, determine environmental, economic, and social indicators, and review materials. Key experts (Environment Canada, the BC Inspector of Dikes, and engineering consultants) provided feedback on technical issues such as indicator measurement and dike infrastructure options. In addition, an engineering study was commissioned to specifically model the impacts, spatial flood extent, and water depth of possible breach events associated with 1.2 meters of sea level rise, the current BC Ministry of Environment high projection for Delta for 2100.

There are two key project outputs. First, a comprehensive graphic package of posters and presentation was produced to combine the risk and vulnerability assessments, 2D scenario mapping, indicator graphics, and 3D landscape visualizations. The work explores four flood management scenarios: Hold the Line, Reinforce and Reclaim, Build Up, and Managed Retreat. Managed Retreat is a potentially controversial adaptation option in which parts of the community are moved out of highly vulnerable areas. The package has been reviewed with the core staff team and the working group to assess policy implications and social acceptability. Second, two reports are being prepared: a technical report outlining the assumptions behind the
scenarios and visualizations, and a Policy Implications and Recommendations report for Delta staff and Council. The second report used the visualization/scenario package to develop a set of detailed policy implications for each adaptation scenario across a range of themes, from agriculture to civic infrastructure. Shared, cross-scenario policy recommendations, as well as recommendations for community engagement around sea level rise planning, will be included. This project output, which directly engages with policy development, is posited to contribute to longer-term outcomes, particularly around policy-making and decision-support.

Further long-term outcomes are anticipated as UBC researchers have already been asked to provide staff workshops (beyond the core staff team) as a capacity-building tool within the municipality, along with a similar workshop for the Delta Mayor and Council, which may inform local decision-making in future. Additional project outputs include: a dedicated project website making the project materials publically available; use of the visuals by local and international media to explain potential sea level rise impacts, following a presentation at the American Association for the Advancement of Science’s annual conference (Flanders 2012); and use of the materials by a provincial ministry in a national Adaptation Primer on sea level rise. The project materials, along with visualizations from earlier projects, are also being used in online courses for BC public servants. All of these are posited to contribute to raised public and government awareness, and increase knowledge about climate change, sea level rise, and adaptation options. This in turn builds local government capacity for climate change adaptation, supporting longer-term decision-making, although the outcomes have not yet been directly evaluated.

A final key outcome that has already been noted by researchers has been broadening the adaptation conversation to include a range of hard (infrastructure) and soft (non-engineered) approaches, particularly introducing new options that were previously off the table such as “Managed Retreat” (Figure 5).

The LCCV process in Delta seems to have created a robust tool for understanding and evaluating adaptation options; through the RAC partnership, this process is influencing best practice in the emerging field of adaptation planning in Canada.

Fig. 7. P32 Delta: 3D landscape visualization of managed retreat, shown here with a sea level rise and storm surge inundation event after relocation of most of the neighbourhood. With long-term planning, low-lying residential neighbourhoods could be converted to habitat areas (image credit: Flanders, CALP).
3 Discussion

3.1 Key Outcomes for Practice and Policy, SII to P32

Overall project results have been broad, with a wide variety of immediate impacts from the participatory processes and outputs, and on-going outcomes. Participatory, iterative processes, involving stakeholders throughout, have led to credible outputs (Moser, 2009), based both on underlying science, local knowledge (Rantanen and Kahila, 2009), and trust relationships with the research team. Participatory processes also seem to provide local capacity-building, particularly around awareness and understanding of the local impacts and response options related to climate change (Shaw et al., 2009). This should in turn lead to improved decision-making in the future. Strong local partnerships can lead, as shown by Toronto, to design and implementation of built projects. Taking the time to build trust in partnerships can lead to broader deliberation about more contentious issues, including moving the discussion to the public arena, as has been the case in the work between UBC researchers and the Corporation of Delta. However, questions remain about how to scale up and broaden the capacity-building, and embed enhanced tools and processes into mainstream planning procedures.

In terms of outputs, the projects have resulted in new modeling (all projects) and emerging integrated models (Calgary), as well as downscaled climate scenarios with local storylines and relevance – in some ways, anticipating the new direction in socio-economic modeling set out by the IPCC (Moss et al., 2010). Visual outputs include mapping, indicators, and 3D and virtual globe (e.g. Google Earth) visualizations of critical local climate-related issues and response options. In addition, production of the LCCV Guidance Manual, based on Kimberley as well as SII, was a major P32 output, available to case study teams in year two of P32.

Visualization evaluation has shown that visualizations can add value to data by effectively conveying salient information and helping to encourage discussion, build awareness, and improve understanding, particularly of local issues, risks, trends, and response/policy options (Sheppard et al., 2008; Tatebe et al., 2010; Burch et al., 2010b). The process and the tools taken together have had measurable impacts on participants, including increased awareness and understanding (Sheppard et al., 2008; Schroth et al., 2009; Cohen et al., 2012a).

In terms of scientific and practitioner impacts, multiple peer-reviewed journal articles, conference papers, book chapters, and other grey literature publications cumulatively point to an emerging field of local climate change planning and outreach, and an emerging Canadian research cluster. New research on the application of GIS spatial modelling and 3D visualization to climate change (SII), hybrid modeling (Calgary), the use of virtual globes in planning (Kimberley), and web-based interfaces (Toronto) are adding new scientific knowledge to their respective fields. Intensive research training has also been undertaken for Highly Qualified Personnel (HQP) ranging from undergraduates to post-doctoral fellows, in areas of growing demand for expertise that lie between traditional disciplines. The long-term project has offered
both shorter term training, as well as the rare opportunity for some HQP to hone skills over successive project cycles in diverse settings.

In terms of outcomes, the many presentations, workshops, training sessions, and media coverage that have taken place beyond the initial participatory processes have served as a significant extension effort which would otherwise be difficult to fund, enabling researcher, practitioner, stakeholder, and public capacity-building. Local climate change visioning has thus contributed to longer-term outcomes, in particular a culture of change on thinking about and planning for climate change in several Canadian communities. The longest running project, the GEOIDE SII and P32 in Delta (2.1 and 2.3) illustrates the momentum of successive visioning and visualization projects that build long-term, on-going relationships. The continuation of projects beyond the GEOIDE funding period (Calgary, Toronto) suggest success in partnerships as well as tools.

The projects have attracted considerable interest and coverage in the media, particularly the more novel 3D landscape views of future conditions, with increased attention and wider appreciation of available and emerging geospatial and 3D tools available within the field, as suggested by Sheppard (2005). This suggests a latent and largely untapped demand for such products in envisioning community futures. Several visual project outputs have gained widespread and on-going use: for example, the BC Pacific Institute for Climate Impacts will be using LCCV visualizations in their online Impacts and Adaptation courses for BC public servants. This value-added outcome is a key benefit of working with geomatics and visual media in collaboration with other researchers, and of sharing the results.

There have been some unexpected results: reaching implementation (Toronto); intense media uptake of project outputs (SII, Delta P32); and that climate change planning work is becoming mainstreamed into planning practice. Community energy and GHG planning, and local adaptation planning are emerging areas within municipalities, to which resources and staff are being allocated. These various practices still needs to be complemented with an integrated assessment to identify possible synergies and conflicts; our early projects (SII, Kimberley) in particular illustrate that a structured visioning process to convey the big picture of multiple choices and consequences is at least feasible.

3.2 Key Learnings, Challenges, and Recommendations for Further Research and Networking

As shown by the outcomes in 3.1, it is possible to engage with climate-related themes using inter-disciplinary research teams, modeling, and visualizations in participatory processes. Here, we discuss the learnings that apply to further research and management of collaborative and networked projects, as the GEOIDE SII and P32 projects have provided numerous insights to help run future projects.

Based on SII to P32 experience, we have found scenarios to be helpful in exploring and handling future uncertainty, and in demonstrating choices and consequences. Two divergent future directions warrant further testing. First, we recommend exploration of deeper collaboratively-generated scenarios, particularly a participatory ap-
proach to define key drivers (Bishop et al., 2007). Given that it may not be possible to explore the full range of scenarios (a resource-intensive approach), stakeholders could be asked to select the most locally relevant scenarios, in keeping with TDAR scholarship. For example, as compared to SII, the Kimberley bridging project focused on an adaptation/mitigation and an adaptation only scenario, rather than a full range of future scenarios. Other projects have moved into exploring multiple adaptation scenarios only (e.g. P32 Delta). Secondly, for current, known vulnerabilities in specific locations, that will be exacerbated by climate change in the future, such as urban heat islands in Toronto or wildfire in Kimberley, design solutions may be more effective than broader scenario-based projects, at least to support immediate, short-term decision-making. Further research into which scale, and in which planning phase, design rather than scenarios should be used would be helpful in accelerating implementation of local climate change responses.

In terms of data integration, modeling, and geospatial tools, the projects overall found that integrating climate science at the local level continues to be challenging, particularly in “data poor” areas. Downscaled climate projections and impacts data are still difficult to obtain, or may not yet exist; local climate projections and impacts data may need to be modeled on a project-by-project basis. The Kimberley and Clyde River case studies have demonstrated the value of using existing conditions data and currently available model outputs to advance community learning with better tools/processes. SII, Toronto, and Delta combined existing data sets and modeling with project-specific data integration and/or modeling. Calgary has developed robust, project-specific, integrated models with diverse datasets, which has taken the most time. However, all of these approaches have taken longer than anticipated. Unless this is overcome through provision, for example, of centralized regional hubs of expertise that are available to communities, it represents an additional challenge to resource-limited planning jurisdictions.

In terms of data, we have also found that not all spatial data integration is successful (Toronto), neither should all spatial data be visualized in 3D due to the level of uncertainty in the data (snowpack projections, Kimberley). Volunteered geographic information (VGI), often discussed in relation to PPGIS, may enable new data sources and is worth exploring in future projects (Goodchild, 2007). Lastly, how to express uncertainty, particularly in visualizations (cf. Bizikova et al., 2011) still requires further research.

This project has engaged in two scales of collaboration: locally, with stakeholder/public participation and inter-disciplinary research teams, and nationally as externally networked projects across research institutions. The scientific process has been considerably enriched by input from local stakeholders who are non-technical or represent different disciplines that those on the research team. The networked case study approach has enabled process flexibility in order to adapt to and take advantage of local community and researcher expertise, with project goals and themes at least partially defined by partners.

One of our key learnings has been that face-to-face collaborations are easier to maintain in trans-disciplinary action research than long-distance collaborations, possibly a function of the number and ease of interactions. It is easier to consult when an
expert is on the same campus, or a stakeholder is in the same region; informal meetings and social events also build the social networks supportive of collaborations (Yarnal et al., 2009). Web-based tools can be used to collapse distances (MacEachren et al., 2006); however, in some cases the infrastructure is not yet reliable (e.g. Nunavut, or rural community halls that do not have internet access). However, long-distance collaborations across research teams face the additional challenges of finding time within multiple busy research and teaching schedules (see also Yarnal et al., 2009 for discussion of these challenges). Future networked projects would do well to structure consistent meetings, take advantage of as well as create opportunities to meet face-to-face, and take advantage of emerging web-based technologies (which also reduce carbon footprints), discussed below.

In terms of project failings, one of our biggest challenges came with developing sufficient inter-disciplinary capacity in our networked teams. While inter-disciplinary learning about modeling approaches, scales, and policy contexts has been advanced across the research teams through multiple joint workshops between 2008 and 2011, we were not able to successfully deal with how to build 3D capacity where 3D landscape visualization experts (predominantly but not exclusively landscape architects) were not directly involved on the project team. Similarly, we were less successful in sharing specialized modeling. In other words, the networked research teams did not all have the same capacity, and working across distances and institutions made capacity-building across the teams more difficult. This may be a question of scale: the final P32 project involved, at the final case study stage, small, dispersed teams working on individual projects, rather than working on building a network. Resources could have been allocated differently, to directly build networking capabilities (e.g. software, etc, cf. Yarnal et al., 2009), but would have involved a trade-off in terms of individual case study outputs and potential long-term local outcomes (policy recommendations, new modeling techniques, built projects).

Web-based geotools may be able to provide an even stronger support of different-place collaboration (MacEachren et al., 2006) and it is recommended to further explore the potentials of emerging technologies such as collaborative web mapping tools and web resources for group work. Other solutions might include having HQP spend considerable time (several weeks to months) housed at alternate networked institutions, or engaging more directly in cross-team training. We were more successful in ensuring that experienced social scientists were available to advise, develop and analyze evaluation methods with participants. This may be due to the fact that social science materials are easily web-dispersed (word documents), while 3D visualizations and expert modeling require specialized software and hardware.

In addition to ensuring adequate time for data challenges, and building inter-disciplinary team capacity, collaborative projects that are engaged in social outcomes research require more time, as well as researcher flexibility, than experimental projects that measure quantitative effects. Structured, well-managed, and flexible projects should allow for: exploration including dead-ends, time to solve data challenges, and the development of strong evaluation frameworks. It is important to plan for the additional project management and project time required for collaboration. Pohl, studying collaboration between natural and social scientists, found that “the pressure
to produce usable results should be reduced if collaboration is to emerge” (2005: 1159), while Moser calls for “a clear understanding of the essential role of learning by all parties involved... and a clear policy of refusing to punish early mistakes” (2009: 19). Yarnal et al., 2009 detail the additional time it takes to set up collaborative projects.

We have found similar time results (see Pond et al., 2010a for a detailed breakdown of project steps): the first year of a cross-case study is spent setting up the research protocols, defining the goals and setting up workplans, inviting and organizing stakeholders, and building relationships. Data gathering may also begin in this phase. Depending on modeling depth, as well as data availability, the next few months to years may be spent on data and scenario development; visualizations also take time to develop, review, and refine. In a participatory process, the scenarios, design iterations, model development, integrated data, and visualizations all need to undergo iterative reviews with the wider team (partners, stakeholders, citizen working groups, etc). This means that three years may be just enough time to start to see early results and outputs. In some cases, where relationships exist (e.g. Delta P32), or parallel processes are underway (e.g. Kimberley), project timelines may be tightened.

Therefore, the role of a federal funding agency that prioritizes collaborative and applied use of decision-making tools has been of considerable value to the partner communities, enabling in-depth engagement with researchers that contributes to policy development and social learning. A key benefit has been the ability of researchers to advance exploratory planning on issues considered too sensitive at the time for inclusion in formal planning processes. The GEOIDE network has facilitated sharing of geospatial technologies such as analyses based on LiDAR data, webtools, virtual globes, and hybrid modeling. As well, the nation-wide collaboration made it possible to test tools and processes in a range of typical contexts across Canada. And, the long-term funding made evaluation of social outcomes possible, often difficult for action research projects.

The final project challenge has been in the overall project evaluation in terms of process, tools/outputs, immediate impacts, and longer-term outcomes, for three reasons. First, while the teams developed an evaluative framework, it has proven overwhelming to document. Stronger research team protocols, developed and maintained from the outset, could aid in this. Secondly, the evaluation of longer-term outcomes requires post-project funding and time, which P32 funding provided for SII and Kimberley evaluation. The opportunity to think in terms of longer time frames in order to measure outcomes is critical, and likely the reason that so few projects evaluate social/institutional impacts over time. Thirdly, in term of methodology, impacts and longer-term outcomes are more difficult to evaluate than development results where one can count reports and papers, or measure immediate knowledge gain within a workshop. Mixed methods are recommended, with a focus on triangulating results (cf. Burch et al., 2010b; Schroth et al., 2009).

Geospatial tools need to be integrated within structured, iterative processes, although this may pose challenges for planning agencies with limited resources. All case studies showed that the political context, or rather the social-institutional constructs (Jankowski and Nyerges, 2003), are of major importance. Even the most suc-
cessful GIS aids cannot work around social-institutional barriers (Burch et al., 2010a) but depend on the political context. Therefore, it is critical that geovisualizations and PPGIS put adequate resources into the social-institutional framing of the tool application: the social process is as critical as tool development. This would include having skilled process facilitators, supporting local champions, and deliberately working across silos. The strength of the LCCV process rests largely in the capacity to build durable and inclusive collaborations that provide critical data and insights to shape scenarios and visualizations for enhanced community deliberation. These social learning processes may also serve to spur local climate change responses long after GEOIDE project completion.

4 Conclusions

The networked GEOIDE projects have led to the development of localized and down-scaled climate change scenarios tied to local issues, the development of innovative spatial and hybrid models, the uptake of spatial planning tools and project outputs within communities, local champion support, and capacity-building around climate change planning and engagement. In framing climate change around local issues, “climate change” often becomes particularized into local themes such as urban heat islands, water availability, or energy resiliency, potentially a sign of climate change “mainstreaming” (Kok and de Coninck, 2007).

These projects have demonstrated that the geospatial models, maps, and visualizations generate discussion, insight, and change because they are embedded within facilitated, participatory processes. In all cases, the use of mapping, visual representation of numerical modeling, and images of possible futures, has generated discussion and insight that might otherwise be missed. Such discussion and insights happen, however, not because of the discrete geo-visualization artifacts by themselves, but through the facilitated relationship-building process built into the action-research.

While traditional planning has often been sectoral, effective climate change mitigation and adaptation requires integrated approaches and therefore tools that support interdisciplinary work and better decision-making. The GEOIDE projects on local climate change visioning have demonstrated the integrative capabilities and broad applicability of combined land-use, expert and stakeholder models; the utility of the resulting 3D landscape visualizations; and the communicative potential of geospatial webtools. The results suggest that such geospatial tools and participatory processes can bring considerable benefits in building capacity of community partners and supporting decision-makers facing climate change challenges, and warrant further research, development and application in practice.

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