PARTICIPATORY SPATIAL ANALYSIS, HIGH RESOLUTION REMOTE SENSING DATA AND ECOSYSTEM SERVICES VALUATION APPROACH AS TOOLS FOR ENVIRONMENTAL CONSENSUS BUILDING.

A Dissertation Presented

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Helena Voinov Vladich

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Dissertation Examination Committee:

Saleem H Ali

____________________________________ Advisor

Saleem Ali, Ph.D.

Robert Costanza

______________________________________ Co-advisor

Robert Costanza, Ph.D.

____

William Breck Bowden, Ph.D.

______________________________________ Chairperson

Joshua Farley, Ph.D.

______________________________________ Dean, Graduate College

Domenico Grasso, Ph.D.

January 25, 2013

ABSTRACT

This dissertation examines how - Spatial Analysis, GIS Hydrological Modeling coupled with the use of high resolution remote sensing (Lidar) data - can become an effective tool for environmental conflict resolution. While developing the alternative system approaches to the stormwater management as part of the project ***Redesigning the American Neighborhood*** **(RAN)** program, funded by EPA and managed by the University of Vermont, a new participatory tool for environmental consensus building was tested. Retrofitting an existing stormwater system can be costly. This is often viewed as a burden for the neighborhood residents and can stir up a conflict environment between the residents, and the city and state regulators. To help mitigate the conflict and design new, alternative, landscape based stormwater management system a new participatory framework for environmental consensus building was developed – **Participatory Spatial Analysis (PSA**). Communities were directly engaged in this process, following a deliberative planning model. The cumulative result of applying this framework together with the developed innovative methodology to derive the spatial **M**icro **S**tormwater **D**rainage network **D**ensity **(MSDD)** index leads us through the multiple working mediating atelier-type sessions with the stakeholders towards the **Integrated Modular Landscape - Based Stormwater Management (IMLaS)** plan for action.

Applying PSA framework in conjunction with the spatial methodology for the development of indices such as MSDD led to a process for ecosystem services detection and valuation of overlooked urban ecosystems at micro-scale while building trust between researchers and stakeholders. The dissertation research concludes that spatial imaging technology can be constructively applied as a deliberative tool for consensus building in watershed management. Such a process has its limitations with reference to data availability and the willingness for the community to engage in a complex deliberative process. However, as communities become more willing to embrace technological tools such applications have considerable potential for being more widely applied as a means of environmental conflict resolution.

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1.1. Introduction

The natural environment provides people with goods and services that are fundamental to human wellbeing. Damage to the environment is seriously degrading these services and this will have economic implications. Damage to ecosystem services poses environmental risks, such as flooding or water pollution, and may to have to be replaced by expensive human services. Another risk could be the loss of irreplaceable ecosystem services such as the loss of biodiversity. Ecosystem services that are related to water quality and quantity control and protection should be at the top of the priority list as services of key importance to humanity (Millennium Ecosystem Assessment (Program), 2005; Aylward et al., 2005)**.**

We are at a point of urgent need to develop tools that can detect ecosystem services related to water quality and flood control in modified systems and can accurately evaluate these services. We need to create better tools that would allow us to disseminate this information to the inhabitants of those systems, city, state and the national officials, international community, and would help us to make informed decisions on human modified ecosystems and mitigate current and future environmental conflicts.

The complexity of this project results from the inherent interconnection of several areas of expertise:

1. Landscape -based stormwater management and consequences of land use change
2. Analysis of the complexities of the human-nature system
3. Participatory remote sensing and GIS -based hydrologic modeling and its use in environmental decision making and conflict resolution
4. Concept of ecosystem services, its detection, creation and valuation.
5. Problem of discounting of the future. The flow of costs and benefits over time.
6. Policies and market mechanisms to achieve environmental goals: taxes, subsidies payments for ecosystem services and governmental regulations
7. Public participation in environmental decision making and conflict resolution

1.1.1. Land Use Change Effects on the Lake Champlain Water Quality and the Call for the Landscape-Based Stormwater Management

Nutrient loading, particularly from nonpoint sources, is the leading cause of water quality problems in the nation's lakes and rivers (Novotny, 1995; Carpenter et al., 1998; US EPA, 1998b, 2004; Mueller, Helsel, & Kidd, 1996). Eutrophication often impairs popular lake uses; consequently, efforts to reduce or control nutrient inputs are usually a high priority for water management. (Ghebremichael, Veith, & Watzin, 2010; Lake Champlain Basin Program., 2002, 2008a; Parry, 1998; US EPA, 1993, 1991, 1994, 1995) In Lake Champlain (Vermont/New York/Quebec), phosphorus (P) is typically the limiting nutrient and is a critical concern because excess P loading has accelerated eutrophication for several decades (Lake

Champlain Basin Program, 1979; Meals & Budd, 1998; Medalie & Smeltzer, 2004; Rosen et al., 2000; Stickney, Hickey, & Hoerr, 2001)

Stormwater management has become a front-burner issue for environmental, economic and social reasons:

1. Stormwater can affect not only ecological systems but human health and wellbeing. It is a vehicle or mechanism by which pollutants are carried downstream to our receiving waters (Vermont Department of Environmental Conservation, n.d.; Watzin, Fuller, Bronson, & Gorney, 1993).
2. We pay the economic price of storm water mismanagement: the costs of after-the-fact storm water management are high, most particularly "end of the pipe" or downstream solutions, which are often passed along to the taxpayer via property, water, and sewer taxes (Andoh & Declerck, 1999; Hinds, Voinov, & Heffernan, 2005; Lloyd, Wong, & Chesterfield, 2002; White & Howe, 2004).
3. Storm water mismanagement can adversely affect valuable and valued public resources, such as Lake Champlain (Lake Champlain Basin Program, 1979). Further, private property can be adversely affected as a result of erosion and flooding(Donnelly, 1989).

Many of the problems associated with storm water are caused by the simple fact that we are rapidly changing the landscape where we live. The change in land use over the past 60 years has been swift, leaving fewer natural landscapes and dramatically increasing areas that are impervious, where water can no longer infiltrate into the ground.

Converting land to residential and commercial use has significantly changed the capacity of watersheds to retain water and assimilate nutrients and other materials that now flow freely from the land into aquatic systems, streams, and wetlands (Brabec, 2002a; Klein, 1979). Extensive conversion of native forests and grasslands to shallow-rooted non-native species and impervious surfaces such as roads, sidewalks, driveways, and roof tops, significantly decreases rainfall interception, evapotranspiration, and soil infiltration. The result is a typical pattern of increased “flashiness” in developed areas; i.e. higher high flows and lower low flows (Allan, 2004). Some studies suggest that current high flow discharges may be 200 to 400 times greater than historical levels (Apfelbaum, 1995).

In Chittenden County, stormwater flows west through some of the most intensely developed land in Vermont. Polluted runoff from city streets, residential neighborhoods, Interstate 89 and shopping mall parking lots finds its way into small streams, which then carry the pollutants from their banks into Lake Champlain. The part of the Potash Brook Watershed that runs through the City of South Burlington alone contains all or a portion of six streams impaired by stormwater runoff, the highest number community in Vermont. Unmanaged stormwater is causing water pollution, erosion, flooding, and unstable streambanks in parts of South Burlington. Private stormwater systems that are not maintained become a public problem. Expired permits and difficulty in obtaining valid stormwater permits has been hindering property transfers in South Burlington (Hinds et al., 2005).

Cleaning up stormwater pollution across the Champlain Basin was estimated to require enormous amounts of public and private money, more than $18 million in South Burlington alone. Statewide, the estimated cost is in the tens of millions, stormwater regulators say (Page, 2006). Addressing stormwater pollution is important to the health of Lake Champlain because stormwater runoff is loaded with phosphorus, (which feeds algae blooms, among other things) and has become a major water quality concern for the lake (Bowden et al., 2006; Lake Champlain Basin Program., 2008a; Mueller et al., 1996)

1.1.2. What Should Be Done to Achieve this Goal?

To approach this goal we need to come up with a Storm Water Management Plan at the level of small scale subwatesheds and to develop and test tools that will allow homeowners, developers, and city/state officials to apply a mix of stormwater interventions at various spatial scales to optimize environmental, social, and economic goals associated with stormwater management. The use of ideas, technologies, engineering approaches, spatial analyses and ecologies specifically tailored to a particular neighborhood is helping to achieve the dual goals of effective stormwater management and public acceptance (Bowden et al., 2006)

1.1.3. Understanding the System Approach

The complexity of the goal and task of tackling the problem across multiple interlinked disciplines requires the adaptation of the system approach to the problem.

Complex systems are characterized by strong (usually non-linear) interactions between the parts, complex feedback loops, that make it difficult to distinguish cause from effect, and significant time and space lags, discontinuities, thresholds and limits (Costanza, Wainger, Folke, & Mäler, 1993). All this makes it difficult to simply aggregate small-scale behavior to arrive at large scale results (Rastetter et al., 1992; Von Bertalanffy, 1969). Ecological systems are generally considered among the most complex because they are characterized by a large number of diverse components, nonlinear interactions, scale multiplicity, and spatial heterogeneity (Wu & David, 2002). Linked together with economic and social systems - the resulting system becomes overwhelmingly complex.

Classic (or reductionist) scientific disciplines tend to dissect their subject to smaller and smaller isolated parts in effort to reduce the problem to it essential elements. To allow the dissection of system components it must be assumed that interactions and feedbacks between system elements are negligible or that the links are essentially negligible or they can be added up in order to accurately represent the behavior of the whole (Von Bertalanffy, 1969). Complex systems violate the assumptions of reductionist technics and therefore are not well understood, using perspectives of classical science. Moreover, the system always has emergent properties that can be described as ‘the whole is more than the sum of parts’. To capture this complexity and irregularities, the is a need in development of system analysis, which requires the scientific method to be simultaneously applied across many disciplines, scales, resolutions, and system types in integrative manner.

There are situations where it is pertinent to study ‘the system’ as a particular site, as in an environmental impact assessment, and others where ‘the system’ must be defined at a larger and more aggregate scale, as in determining the cumulative impacts of many disturbances of particular sites, or impacts at the global scale when determining international policy.

Chittenden County is the most developed county in Vermont. Therefore, looking at watershed management at this scale, we must recognize that we are dealing with a dynamic spatial complex system, which consists of three subsystems: ecological, economic and social. Even if we look only at the ecological and economic systems we would agree that they are undeniably complex and share many characteristics (Limburg, O’Neill, Costanza, & Farber, 2002). Both are complex networks of component parts linked by dynamic processes. So in order to approach the process of decision making related to such systems, it is worthwhile understanding and appreciating the inherent complexities of ecological and economic systems, particularly as the dynamics of economic systems increasingly affect ecological ones.

1.1.4. Identifying the Tools to Achieve the Goal

To support decision makers in the process of understanding these complexities a wide range of models have been developed at different temporal and spatial scales (Costanza & Voinov, 2004; Tague & Band, 2004; US EPA, 1998a; A. Voinov et al., 1999; Westervelt, 2001).

Selecting the correct modeling tool is one of the most important phases of any modeling exercise. Model selection should be determined based on the goals of the participants, the availability of data, the project deadlines and funding limitations rather than being determined by scientists preferred modeling platform and methodology. Some models are used to formalize concepts of watershed, stream, and receiving water processes and as such explore existing dynamics and characteristics. Models can also be predictive or used to compare proposed management plans and explore their effects on other processes. Modeling tools can be especially useful in communicating complex processes, spatial patterns, and data in a visual format that is clear and compelling and, when appropriately applied, can empower stakeholders to move forward with concerted efforts to address an ecological problem (see Table 1.1a and 1.1b). Successful participatory modeling requires appropriate modeling tools and paradigms. (A. Voinov & Gaddis, 2008).

Model characteristic	Indices	Spatial models	Process models
Software examples	Spreadsheet (Excel)	Geographic Information System	Stella, Simile, C++
Model examples	Phosphorus index	Map of landuse change	Stella-based plant growth
Spatial scale	Field	Vector or grid	Not spatially explicit
Time scale	Year	Snap-shot	Seconds–years
Output format	Coefficients	Spatial layers (maps)	Time series
Application	Rank and prioritize	Calculate and compare spatial data.	Mass balance of local (vertical) processes.
Major advantages	Fast and simple	Spatially distributed	Dynamic
Major limitations	Simplistic	No temporal dimension.	No spatial dimension

Table 1.1 a. Modeling paradigm and watershed management. *Source*: Adapted from: Voinov & Gaddis (2008)

Model characteristic	Vector-based spatial models	Raster-based spatial models
Software examples	Hydrologic Simulation Program—Fortran (HSPF), C++	Spatial modeling environment (SME), C++
Model examples	BASINS, RHESSys	LMF, DHSVM
Spatial scale	Hydrologic Response Unit (HRU)	Grid-based (scale depends on wshed size)
Time scale	Seconds–days	Seconds–days
Output format	Vector maps. Point time-series	Raster maps. Point time-series.
Application	Prediction of stream flow and nutrient transport	Simulation of processes over space and time
Major advantages	Run-time, automated data preparation and input	Ability to capture both temporal and spatial dynamics.
Major limitations	Aggregated HRU. No neighborhood relationships	Complexity. Run-time. Data availability and preparation

Table 1.1 b. Modeling paradigm and watershed management. *Source*: Adapted from: Voinov & Gaddis (2008)

1.1.5. Ecosystem Services and Ecosystem Services Values

In business what gets measured gets managed.−
Lord Adair Turner, Chairman of the UK Financial Services Authority

Ecosystem services: Human societies are complex, adaptive systems, but they are embedded within even more complex, adaptive ecosystems (Limburg et al., 2002). The suite of terrestrial, aquatic, aerial, and subterranean interacting ecosystems throughout the world provide the basic support required for human life. We place value on ecosystem functions because they are essential for our continued existence. We also place value on ecosystems for our cultural and emotional needs. From an ecological perspective, the concept of value has a different connotation because ecosystems do not have systems of value**.** “Ecosystem service” is a term coined to make apparent that the structure and function of ecosystems provide value (some of which can be monetary expressed, and some of it cannot) to humans (Daily, 1997).

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Costanza et al., 1997; Daily, 1997; De Groot, Wilson, & Boumans, 2002; Millennium Ecosystem Assessment (Program), 2005)

Provisioning Goods produced or provided by ecosystems	**Regulating** Benefits obtained from regulation of ecosystem processes	**Cultural** Non-material benefits from ecosystems
• food • fresh water • fuel wood • genetic resources	• climate regulation • disease regulation • flood regulation	• spiritual • recreational • aesthetic • inspirational • educational
Supporting Services necessary for production of other ecosystem services • Soil formation • Waste Treatment and Nutrient cycling • Primary production		

Table 1.2. Typology of ecosystem goods and services. *Source:* Adapted from: Millennium Ecosystem Assessment (2005)

On a practical side, advantages to employing the concept of ecosystem services are that it allows to:

- Bring together economic and ecological concepts in a dynamic conceptual system
- Make use of the best available economic tools and methods to reveal meaningful values for non-marketed environmental systems
- Be used by decision makers to evaluate tradeoffs between land use change and human-centered values (Costanza et al., 2007)

Ecosystems and Value: Ecosystem service valuation (ESV) is the process of assessing the contributions of ecosystem services to human wellbeing. It provides a means of enhancing the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes (Costanza et al., 2007; Millennium Ecosystem Assessment (Program), 2005; Troy & Wilson, 2006).

The concept of valuation of ecosystem services has been surrounded by much controversy. Many ecologists say that the ecological system is invaluable because its continued stable operation is essential for human survival, thereby making the argument that it is the ecosystem's rules that count, not humanity's self-centered concept of its place in the universe. So, to many ecologists, it is not the biosphere that is in jeopardy—it has survived dinosaurs and asteroids—it is *Homo sapiens* that is in jeopardy because the species is undermining the ability of the biosphere to maintain essential flows of ecosystem goods and services (Limburg et al., 2002). While this is ultimately true with respect to the ecological system, it is not quite the same case with ecological services from the point of view of environmental decision making. This is because ecosystems themselves become the source of the functions that they provide, and when used by humans, they become called services (see fig 1.1).

The concept of ecosystem services is inherently anthropocentric: it is the use of certain ecosystem functions by humans and their subsequent implicit categorization and ranking of those services that enables basic ecological structures and processes to be translated into quantifiable values. Total human dependence on ecosystem functions is indubitable. The challenge lies in incorporating this understanding into the decision-making process when faced with a social system that is driven by neo-classical economic principles. Simply describing ecosystems as invaluable, (that is, assigning a price tag of "infinity" to ecosystem services),

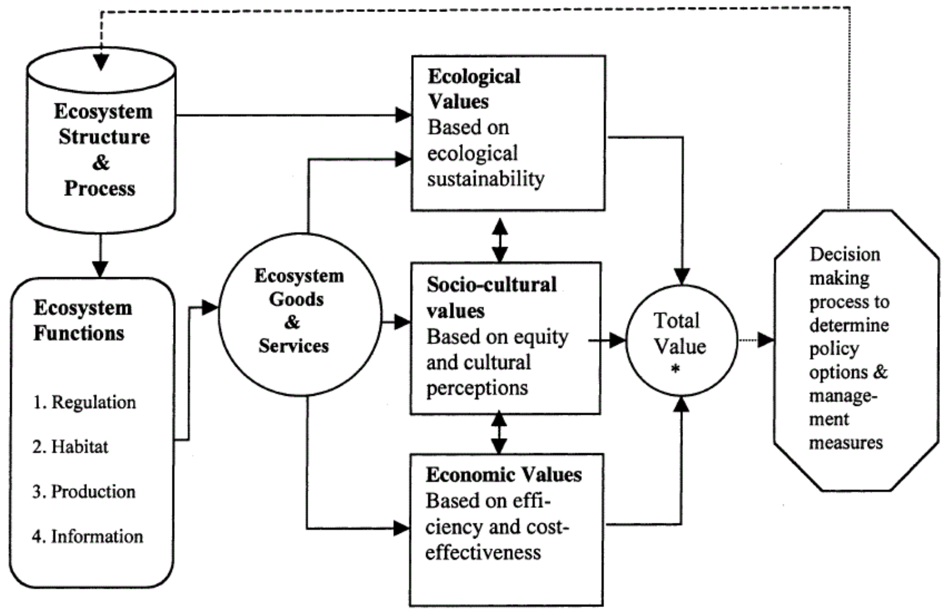

Figure 1.1. Framework for integrated assessment and valuation of ecosystem functions, goods and services. *Source*: Adapted from: De Groot et al. (2002).

practically equals to assigning a "zero" monetary value to those services at times of environmental decision making. This distorts the way decision makers incorporate the value of ecosystem services into the process and inevitably leads to ecologically unsustainable decisions being made. This has been the *modus operandi* for hundreds, thousands of years, while ecosystems have been generally in a stable, more or less pristine condition. However, the pace of economic growth and development of human activity over the past century has disrupted the delicate balance between ecosystem capacity and human need, which now requires a fundamentally different approach.

This balance has been shifted so much that one must now take a two-pronged approach to any valuation problem, selecting one of the two valuation methodologies on a case-by-case basis. The first methodology utilizes traditional economic thinking and only considers the human-based concepts of willingness-to-pay (for goods and services) or willingness-to-accept (for disease, environmental degradation, etc.). These human values, and the marginal analytic methods to elucidate those values, are limited to situations when ecosystems are relatively intact and functioning in normal bounds that are far from any bifurcation point. A completely different approach is required when, due to an increase in the magnitude of economic activity, there is an increase in the risk that the assimilative capacity of the ecosystem will be exceeded. As this happens, the ecological system can enter a condition of 'meta-stability' (Farley, 2008a; Limburg et al., 2002; Tikhonov, 1950). A kind of threshold, or region of rapid transition, is reached and even a minor disturbance can move the system to a new state. Examples include gradual increases in nutrients transforming an oligotrophic lake into a eutrophic lake, overgrazing transforming grassland into a desert scrub ecosystem, and overfishing causing the sudden collapse of a fishery.

As the ecosystem is forced away from the state of a singular stable equilibrium, the relevant value concepts shift from utility to risk avoidance If the fundamental value is life support, then the relevant cost of a human action is directly related to the risk that the action will destabilize or irrevocably alter the life support system. We can think of ecological values under risk-avoidance as translating into insurance premiums that would willingly be paid to protect against the risk of destabilization (Costanza & Arnold, 1990; Limburg et al., 2002).

As noted by Limburg (2002), that another challenge is that the economic values of natural systems are frequently too narrow to reflect the wide range of multi-dimensional value contexts of natural systems. Economic welfare valuations become even more limited in their applicability when we understand that preferences toward ecosystems' services may be vague or uninformed, tend to change over time, and are likely to change substantially with new information. It could be that in this context, ecologically based values might be chosen rather as indicators of conditions and scarcities of some potentially valuable natural services than economic values.

The realization that neither the economic, nor the ecological valuation method, that exists today, will work well in all circumstances, prompts the search for better valuation methods. Ideally, an ESV study ought to encompass all the components and dynamic feedbacks between the valuation subject and the object, including ecological structures and processes, ecological functions, ecosystem services, and human welfare. This, however, still remains the challenge (Boumans et al., 2002). But it is exactly this type of forward-looking study that is of greatest relevance to decision makers (Turner, Paavola et al. 2003).

Despite the growing body of literature on ecosystem services (Daily et al., 2009; De Groot, Alkemade, Braat, Hein, & Willemen, 2010; Fisher, Turner, & Morling, 2009; Turner et al., 2003), and development of new spatially explicit ecosystem services modeling methods (Daily et al., 2009; Kareiva, Tallis, Ricketts, Daily, & Polasky, 2011; Morimoto, Wilson, Voinov, & Costanza, 2003; Nelson et al., 2009; Troy & Wilson, 2006) still many challenges remain on the way to structurally integrating ecosystem services in environmental decision making, landscape planning and management of natural resources.

1.1.6. Environmental Conflict Resolution, Environmental Governance and Public Participation in Environmental Decision Making

Environmental conflicts are unique due to their complexity, inherited uncertainty, and their 'unwillingness' to recognize political boundaries**.** What is important to note is that environmental conflicts are about governing ecosystems commons and preserving it for the future generations. It is well known though that ecologists discount future less than economists which poses tremendous challenges for the process of environmental conflict resolution and decision making (Ali, 2003; Daly & Farley, 2003; Farley & Costanza, 2002; Farley, 2008a; Speth, 2005)**.**

We can name three key underlying components of any environmental conflict:

- Environmental Protection
- Economic Development
- Social Justice

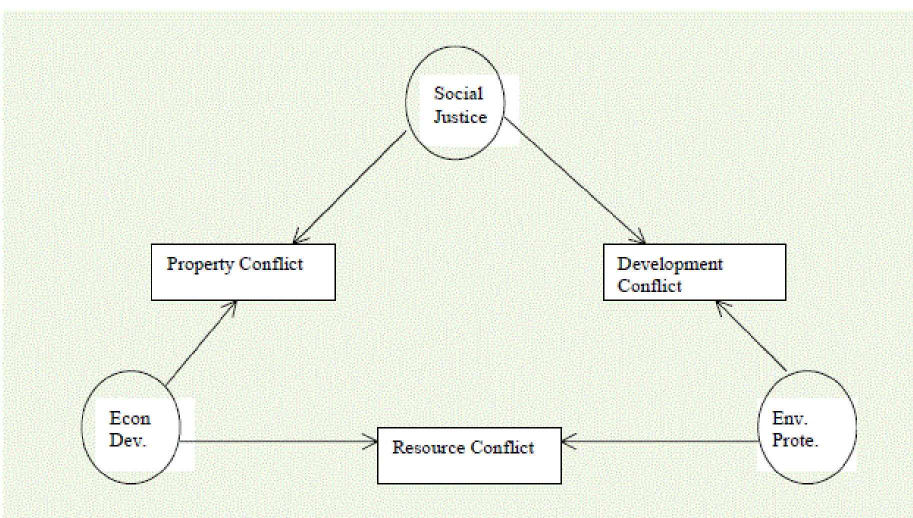

Figure 1.2. Anatomy of an environmental conflict. *Source:* Adapted from: S. Ali (2004)

These three types of conflicts emerge in between following components:

- Development conflict (between environmental protection and social justice)
- Resource conflict (between environmental protection and economic development)
- Property conflict - (not strictly environmental, between economic development and social justice)

Along with increasing complexities and global changes that manifest themselves at all levels, there have been three processes of changes in the social domain:

1 - Globalization

2 - Democratization and increase in the number of social factors, including:

- New media, internet
- New social movements
- International organizations
- Nongovernment organizations (NGOs)
- Litigations

3 - Specialization and fragmentation

All of these challenges require a new system of coordination and governance, which goes beyond the traditional systems that have been developed so far. Through the history we can distinguish three types of coordination:

- 1929 - 70 – State -centric coordination
- 1970 - 2001 – Market-centric coordination
- 1990 - present - An emergence of a new network-centric coordination

This is at 70s, in the midst of the state-centric coordination, when the new field of **Environmental Diplomacy** was first developed. The first attempt at global environmental governance, meaning not only action from governments, but many non-profit and non-governmental organizations as well, came from the understanding that large-scale environmental concerns can be addressed only through international agreement and cooperation (Speth, 2005).

The emergence of environmental concern has started in 60s in US first. And the drivers at first were not global at all - the concerns have been domestic - local air and water pollution, strip-mining, highway construction, noise pollution, dams and streams channelization, clear-cutting, hazardous waste damps, local nuclear power plants, exposure to toxic chemicals, oil spills and suburban sprawl. Concerns about these issues culminated in the passage of the National Environmental Policy Act in 1969 and in the first Earth day a few months later. In early 1970s - EPA and CEQ were established, Clean Air and Water Acts were passed, and federal courts were deluged with lawsuits brought by a new generation of Environmental advocacy organizations, often founded by major US foundations. Congress responded with far-reaching, and tough deadlines for industry (Speth, 2005).

A policy window had emerged and a tipping point – a phase change - was reached; Government action, that had once been impossible, became inevitable.

Speth (2005) lists a number of factors that lead to these changes:

1. Rising demand for environmental amenity in an increasingly affluent postwar population. (Rising per capita income during that time period prompted the first exodus to suburbia during that time period. At the same time, National Parks visitation doubled between 1954 and 1962, and then doubled again by 1971, with most National Parks today operating at or beyond their carrying capacity).

2. Pollution and blight were blatant and obvious to all.

3. Social and antiwar movement of the 1960s had given rise to a new questioning and politically active generation

4. The view that major corporations were getting away with murder became widespread. Rachel Carson wrote *Silent Spring* in 1962, Ralph Nader wrote *Unsafe at any speed* in 1965.

5. Industry was caught off guard.

6. Certain key precipitating events took place: Cuyahoga River in Cleveland bursting into flames; the Interior Department proposing to flood the Grand Canyon, Santa Barbara oil spill in 1969 (Speth, 2005).

As mentioned previously, these were all domestic issues. Global-scale issues did not receive popular attention until the 1970s, prompted by a slew of reports and publication on the topic, with Limits to Growth by Dennis and Donella Meadows among them (D. H. Meadows, Meadows, Randers, & Behrens III, 1972). Then, only in 1980s, a series of reports began to pull together all issues into coherent agenda for international action.

Cumulatively, these reports stressed ten principal concerns that differed from the agenda of 1970s, and formed the new grouping of publicly accepted high-priority action items:

1. Depletion of the stratospheric ozone layer

2. Climate change due to greenhouse gases

3. Loss of crop and grazing land due to desertification, erosion, conversion of land to nonfarm uses

4. Depletion of the world's tropical forests, leading to loss of forest resources, and serious watershed damage

5. Mass extinction of species from global loss of wildlife habitat and the associated loss of genetic resources

6. Rapid population growth, burgeoning third world cities, and ecological refugees

7. Mismanagement and shortages of freshwater resources

8. Overfishing, habitat destruction and pollution in marine environment

9. Threats to human health from organic chemicals

10. Acid rain and the effects of complex mix of air pollutants on fisheries, forests and crops (Speth, 2005)

This agenda emerged and was moved forward by a relatively small internationals community of leaders in science, government, the United Nations and Civil Society, which was given a name “Epistemic Community” twenty years later by P.Haas (P. Haas, 1992). They moved these issues forward; therefore governments had little choice, but to respond.

Comparison of the politics of the global agenda with the original, predominantly domestic shows some inherent contrasts:

First Movement (1970s): Domestic	**New Movement: Global**
Understandable scientifically	Technically complicated
Highly visible impacts	Remote or difficult to perceive impacts
Current problems	Future problems
Us/here	Them/there
Acute problem	Chronic problem

Table 1.3. Comparison of the politics of the global agenda with the original, predominantly domestic. *Source:* Adapted from Speth (2005).

Comparing domestic and global environmental issues can be described through the words of ecologist Simon Levin (2000):

> The familiar acronym NIMBY (not in my backyard) expresses the principle that people can best be motivated to take action, when the problem and rewards hit closest to home. The nature of the process of addressing local issues makes for tighter feedback loops, a key element in maintaining resiliency in any system. Increasingly, however, we are being challenged by a new class of problems, including global climate change, and biodiversity loss, in which the feedback loops are weaker and less specific, changes are slower and signals less clear (hence the delay of recognizing them).

1.1.7. Participatory Modeling Approach to Stormwater Management

Stormwater belongs to the commons that require governing and its management is being made more and more intricate by the complexity of natural systems and the added complexity of the human socio-economic systems built within watersheds. Thus, while decision-making processes are being constrained by feasibility limitations and short time horizons, the consequences of wrong decisions are becoming more obvious and more dramatic, affecting larger geographic areas. Under such circumstances, standard scientific analysis is inadequate and must be reinforced with local knowledge and iterative participatory interactions in order to derive solutions which are well understood, politically feasible, and scientifically sound (A. Voinov & Gaddis, 2008).

Participatory modeling is of high suitability for the integrated water resources management, which incorporates systems theory and aims to protect and improve water resources, while considering economic and social concerns and goals of the community. Integrated watershed management requires the development of solutions for unique local situations, a task that is often best accomplished by engaging stakeholders and the public at the local level in the research process (Duram & Brown, 1999). Participatory modeling provides a platform for integrating scientific knowledge with local knowledge and, when executed well, provides an objective space for stakeholders to contribute information regarding water resource issues of interest (Rhoads, Wilson, Urban, & Herricks, 1999; A. Voinov & Gaddis, 2008). Participatory modeling is educational, integrates social and natural processes, can support a local decision making process, and lead participants to the constructive solutions (Argent & Grayson, 2003; Korfmacher, 2001).

1.2. Significance and Limitations of This Study

This research demonstrates how Spatial Analysis, GIS Hydrological Modeling together with the use of high resolution remote sensing (LiDAR and Quick Bird) data, from being analytical tool can be transformed into an effective tool for environmental conflict resolution. While developing alternative system approaches to stormwater management as part of the project *Redesigning the American Neighborhood* (RAN) program, funded by EPA and managed by the University of Vermont, we have created a new participatory tool for environmental consensus building.

1.2.1. Significance of this Study

Significance of this study is tripartite, and comes from the interconnection of the three disciplines that entails: stormwater management; ecological economics and public participation in environmental decision making and conflict resolution (see

Chapter 5). All of the three disciplines are interconnected around the nucleus of Participatory Spatial Analysis (PSA) based on high resolution LiDAR and Quick Bird data (Fig.5.5).

There is much concern about the environmental impacts of stormwater runoff from residential properties. Local and state agencies nationwide realize the need for stormwater management and potential value of low-impact design practices. However there are few tools that can help residents make informed decisions about alternative methods for distributed stormwater management.

Retrofitting an existing stormwater system could be costly. This is often viewed as a burden for the residents of a particular neighborhood, and can stir up conflict between residents, the city and the state. To help mitigate the conflict and design a new, alternative, landscape-based stormwater management system, a new participatory framework for environmental consensus building – **Participatory Spatial Analysis (PSA**) was developed. The cumulative result of applying this framework together with the developed innovative methodology to derive the spatial **M**icro **S**tormwater **D**rainage network **D**ensity **(MSDD)** index lead the process through multiple working mediating atelier-type sessions with the stakeholders towards an **Integrated Modular Landscape - Based Stormwater Management (IMLaS)** plan for action.

This approach allows building trust between researchers and the stakeholder community, redirecting the conflict energies into a search for constructive solutions.

And being applied on different scales - nationally and internationally - it has the potential not only to become a foundation for the change in people's understanding of meaning of ecosystem services and impact on services values in human-modified environment, but to also become a mediating tool in environmental dispute resolution.

1.2.2. Limitation of the Study

The key limitation of the study of the process of environmental decision making with the involvement of multiple stakeholders is that it is very complex and lengthy. It requires time (in this case the time commitment was five years for the research, analysis and alternative plan development and another five years for implementation, with certain portions of the plan still awaiting implementation at the time of publication); financial support for a multidisciplinary team of researchers; and the need for input from an experienced professional in the area of conflict mitigation. Complexity of the tool and data availability (high resolution LiDAR and multispectral Quick Bird data) constrains the technical side of the project.

The implementation stage has shown that the presence of a research team (intensity) is essential for active public participation. The observation that has been made during implementation stage, is that after the end of RAN project - it has been considerable lack of residents participation in projects development (DiPietro, 2012).

Another limitation is the necessity for interdisciplinary training of research team members. The complexity of a project requires analysis and synthesis from more than one discipline: it requires the interdisciplinary system approach. Assembling such a team of researchers can be challenging, and there are not many schools worldwide, where it is possible to receive training in hydrology, spatial analysis, ecological economics and environmental conflict resolution all at the same time, and in one place. University of Vermont is unique in this respect, offering training in all required subjects, provided by Spatial Analysis Laboratory, Gund Institute for Ecological Economics, Institute for Environmental Diplomacy and Security and Water Resources and Lake Studies Center, – where all institutions are inter-connected under one umbrella of the Rubinstein School of Environment and Natural Resources.

1.3. Dissertation Structure and Organization

This dissertation is a step by step exploration of the different stages of the process of environmental decision making related to retrofitting the stormwater system in the Butler Farms/Oak Creek Village neighborhoods, located in South Burlington, VT. The five chapters represent the five different aspects of this process.

1.3.1. Research Goals

The research goal of this dissertation is to investigate the role of participatory spatial analysis, high resolution remote sensing data and ecosystem services valuation approach as tools for alternative stormwater management techniques at multiple scales, and their usefulness as a tool in environmental consensus building.

1.3.2. Research Objectives

The key objectives of this research were to:

- Develop a conceptual framework for the process of environmental decision making based on GIS modeling, and high resolution LiDAR and remote sensing data

- Create a tool and alternative approach to the neighborhood stormwater management plan that would help achieve the objective of returning the hydrologic characteristics of impaired streams to a regime that closely parallels the hydrologic properties of streams not currently impaired, and in the specific case of the South Burlington, Vermont case study, adjusting stormwater flows to the Lake Champlain total maximum daily loads (TMDLs)

- Provide a methodology for targeting and prioritizing residential stormwater BMPs at three different scales
- Provide a methodology for conducting a broad cost/benefit analysis (BCBA) for comparative analysis of stormwater BMPs intervention scenarios
- Educate neighborhood residents through a detailed visualization of the processes on the watershed living landscape

Additional objectives, made possible by participatory spatial analysis (PSA), based on high resolution LiDAR and Quick Bird data, were to:

- Achieve not only stormwater-related behavior change, but a much greater level of "systems thinking" and more effective public engagement in local stormwater management decisions and solutions;
- Facilitate trust-building between residents, researchers and city representatives through a high level of visual detail that coincides with the residents' everyday "backyard experience";
- Redirect the conflict to constructive modes of communication and facilitate the process of goals-setting;
- Increase the negotiating power of neighborhood residents;
- Provide the analytical basis for cultivating an understanding between neighborhood, City and State that assists to negotiate the process details, methods and resource allocation between the City and the State.

1.3.3. Dissertation Chapters

Chapter one - establishes the background problem, the objectives and the significance of undertaking this study. Subsequent to this introductory chapter the rest of this dissertation is presented in four chapters.

Chapter two - discusses the use of high resolution LiDAR data to target and prioritize residential stormwater best management practices. It presents participatory remote sensing and GIS - based hydrologic analysis and modeling in relation to landscape -based stormwater management.

Chapter three - lays out the history of the conflict in the Butler Far/Oak Creek neighborhood in South Burlington, Vermont and the use of the power of spatial analysis and high resolution remote sensing data to promote environmental consensus building.

- Chapter four describes the Integrated Modular Landscape –Based Stormwater management (IMLaS) framework, based on Participatory Spatial Analysis, High resolution Remote sensing Data and the concept of Ecosystem Services valuation. Chapter 4 talks about the approaches to the problem of discounting the future, the flow of costs and benefits over time and decision-making tools, which allow stakeholders to determine priorities between conventional and alternative approaches to stormwater management.

Chapter five uses the case study of stormwater management plan development in South Burlington, Vermont, to answer the following question: What complexity level of technological tools and other factors lead to the success in the process of public involvement in environmental decision making?

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CHAPTER 2: USE OF HIGH RESOLUTION LIDAR DATA TO TARGET AND PRIORITIZE RESIDENTIAL STORMWATER BEST MANAGEMENT PRACTICES

2.1. Abstract

Recent advances in high resolution remote sensing imagery deliver much higher spatial accuracy and have important practical applications for a wide range of management goals, as more areas across the nation undergo conversion to residential and commercial land use.

Precise terrain information, such as LiDAR data, allowed to effectively reconstruct and analyze micro storm drainage networks and precisely identify the “Source Areas” and “Areas of Opportunities”. This information was used for the development of the Micro Stormwater Drainage Density (MSDD) index, which was instrumental for the goal of targeting the effective intervention areas for best management practices of mid and small scales. The 2.4 Quick Bird imagery was used in additional analysis, development of an NDVI index and the area imperviousness assessments. The MSDD index and the impervious surfaces information has been used to assess quantities/volumes of runoff for the 1 year/24 h storm is 2.1 inches of rain (Chittenden County, Table 1.2 in the Vermont Stormwater Manual, 2002) for the selected area of mid-size BMP. The developed approach is generic, can be applied anywhere else where LiDAR and Quick Bird data are available, and might be very effective in helping to cut costs associated with engineering analysis and design. In

addition, this approach has already been tested in practice and has been determined to be a very useful mediating tool in conflict mitigation between neighborhood, developer, the city and state stakeholders (Voinov Vladich 3, 2012).

2.2. Introduction

Converting land to residential and commercial use has significantly changed the capacity of watersheds to retain water and assimilate nutrients and other materials that now flow freely from the land into aquatic systems, streams, and wetlands (Brabec, 2002b; Klein, 1979). The gradual removal of the native plant habitat and replacement with shallow-rooted non-native and impervious surfaces such as roads, sidewalks, driveways, and roof tops significantly decreases rainfall interception, evapotranspiration, and soil infiltration. This generally results in increased "flashiness" in developed areas; i.e. higher high flows and lower low flows (Allan, 2004; Detenbeck et al., 2000). Some studies suggest that high flow discharges may be 200 to 400 times greater than historical levels (Apfelbaum, 1995).

Lowland environments, such as rivers and wetlands, have historically been used to receive and treat runoff created elsewhere in the watershed. Some studies, however, suggest that stormwater, sediment loads, and the various other contaminants contained within typical runoff waters can be best managed ”at the source” (N. A. Zakaria, Ab Ghani, Abdullah, Mohd, & Ainan, 2003; Nor Azazi Zakaria, Ghani, & Lau, 2011). (N. A. Zakaria et al., 2003; Nor Azazi Zakaria et al., 2011). Although typically the land cost incurred through a distributed local stormwater treatment process, the efficiency and reduction in potential contaminant problems may be greater when using this approach (Apfelbaum, 1995).

Appfelbaum (1995) suggests, that the landscape with many micro-depressional storage opportunities and a large buffering capacity has a potential of more efficient runoff reception and processing than would a single bio-filtration wetland in a downstream position in the watershed. This happens due to much higher cumulative infiltration surface and evapotranspiration, since each buffer area or depressional wetland dispersed over the watershed would receive and treat a smaller volume of water and contaminants (Apfelbaum & Chapman, 1999). Another potential advantage of distributed stormwater treatment facilities would be significantly reduced long-term maintenance costs. These facilities are powered by sun, would not require maintenance and an expensive pipe and culvert infrastructure to collect and transport water to the treatment facility (Prince George's County Department of Environmental Resources (PGDER)., 1997; US EPA, 2007). Centralized stormwater facilities, such as detention ponds or bio-filtration wetlands, on the other hand, have high maintenance requirements, high construction costs, and potential problems that include decreases in removal efficiency for some materials in the short and long term (Apfelbaum, Eppich, Price, & Sands, 1995). Some empirical data suggest that the use of upland vegetation systems in combination with ponded areas has resulted in the rate and volume of discharge being essentially unchanged before and after development (Apfelbaum et al., 1995). Low-impact Development (LID) design strategies that are geared toward the use of undisturbed areas and on-lot and distributed retention storage are recommended not only to reduce runoff volume, but also provide ecosystem restoration (Apfelbaum & Chapman, 1999). The use of on-lot retention and/or detention has a potential to attenuate the peak runoff rate with volume remaining the same as the pre-development condition. Distributed on-lot system would also approximate the frequency and duration of the runoff rate much closer to the pre-development condition than those typical of conventional management practice. (Apfelbaum, 1995; Bedan & Clausen, 2009; Dietz & Clausen, 2008; Jenny, Shoemaker, Riverson, Alvi, & Cheng, 2006; Kirk, 2006; Prince George's County Department of Environmental Resources (PGDER)., 1997).

Existing residential developments pose several principal challenges, one of which is the focus of the current chapter:

- *Technological tools*: Tools are needed that will allow users to (1) identify points of intervention at different, subwatershed scales and (2) target locations for the use of best management practices (BMPs) at different scales (Voinov Vladich 2, 2012).

This project was undertaken as a part of the *Redesigning the American Neighborhood* (RAN) program has been undertaken and managed by the University of Vermont. The goal of the RAN program was to develop and test tools that enable homeowners, developers, and city/state officials to optimize a mix of stormwater interventions at various spatial scales to optimize environmental, social, and economic goals associated with stormwater management. As its premise, the project took the notion that there is no single, all-encompassing, centralized solution for stormwater management in developed watersheds. Rather, it was understood that each watershed has numerous potential points of intervention. Intervention can be of different sales, can occur at several different levels, including the household, farmstead, city block, mall, industrial park, and roadway. By using a diverse palette of ideas, technologies, engineering approaches, and ecologies specifically tailored to a particular neighborhood, the project findings would help achieve the dual goals of effective stormwater management and public acceptance (McIntosh, Bowden, Fitzgerald, Hackman, Kirk, Todd, Vladich, et al., 2006).

An important portion of the RAN program efforts was focused on two existing neighborhoods: Butler Farms and Oak Creek Village (BF/OCV) in South Burlington, Vermont (see fig. 2.1). Stormwater management is of concern to the residents of these and other similar neighborhoods because residents in Vermont bear the responsibility for maintaining state stormwater discharge permits, since most of the Chittenden County area is subject to the EPA National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II Final Rule for municipal separate storm sewer systems (MS4s) (US EPA, 2000, 2012). Most of the these permits were allowed to expire in the 1990's through inaction by local and state regulatory authorities, which resulted in over a decade of exacerbating uncontrolled stormwater runoff, which had severely damaged local streams (Bowden et al., 2006; Fitzgerald, 2007; Foley, 2008) and continues to significantly impair Lake Champlain (T. O. Manley, Manley, & Mihuc, 2004; Thomas Owen Manley & Manley, 1999; Meals & Budd, 1998; Medalie & Smeltzer, 2004; Troy, 2007a).

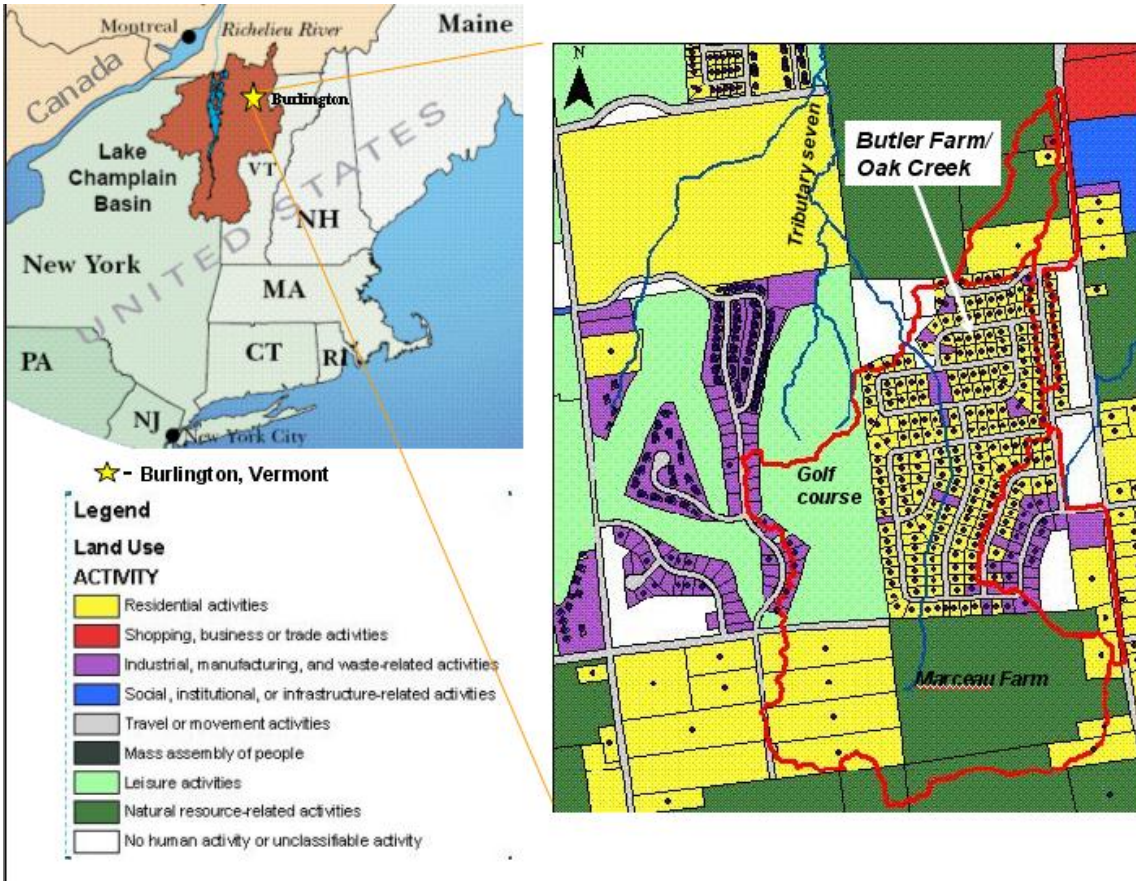

Figure 2.1. Butler Farms/Oak Creek watershed, located in South Burlington, Chittenden County, Vermont, USA

As a consequence, the Vermont Agency of Natural Resources (VTANR) started the process of developing total maximum daily load (TMDL) analyses to support new watershed-wide permits to control stormwater runoff. The costs to retrofit neighborhoods with failed stormwater treatment systems to these new standards were initially estimated as several thousand dollars per household. As a result, one can understand that the social and political impacts of this environmental management process have been substantial.

Preliminary data analysis showed that the Butler-Farms/Oak Creek Village neighborhoods are built on clay soils with very poor drainage. Moreover the site was graded in such a way that the neighborhood received water from large portions of a golf course on the west side, and from agricultural areas on the south side. The project was designed as participatory effort with much involvement of residents as stakeholders. The information gathered through a series of stakeholders meetings and a number of neighborhood surveys showed that most of the concern about stormwater was related to drainage problems that result in flooded basements and driveways, standing water on properties, eroded and clogged swales (Bowden et al., 2006). These concerns were somewhat contrary to the environmental issues related to stormwater, since the residents were mostly interested in faster removal of stormwater, while for the sake of environmental quality it would be much better to increase the retention time and let more water infiltrate at the source.

A variety of approaches to compare alternative BMP implementation scenarios was developed, as a part of the RAN program. This evaluation phase was designed to allow community members and local regulators to learn about potential approaches and compare the relative costs and benefits of each intervention using ecological, social, and economic criteria. For example, one option that could solve many of the problems faced by the BF/OCV neighborhoods was the construction of a large detention pond where the tributary leaves the neighborhood. Initial estimates indicated that this option would have been very expensive and would have dealt with local backyard flooding ineffectively, noting once again that this was a more immediate concern to many homeowners (RAN5: Redesigning the American Neighborhood, 2007; StanTec Inc, 2006; Voinov Vladich 4, 2012). At the same time, atlternative, stormwater management approaches, that take advantage of source control strategies, like onsite rain gardens, have been known to have the potential to help both the stormwater runoff and local flooding issues as well as provide amenity benefits including improved lifestyle and enhanced property values (Geoghegan, Wainger, & Bockstael, 1997; Godwin, Parry, Burris, Chan, & Punton, 2008; Guillette & Studio, 2005; Leggett & Bockstael, 2000). Because time, space, and cost are always critical constraints, the first step of the RAN project was to quickly identify, where it is most appropriate to apply the specific BMPs ranging from the traditional large-scale, end-of-the-pipe solutions to smaller-scale alternative low-impact design solutions.

In this particular case study RAN research team had the luxury of federal and state funding to participate in this effort and the City of South Burlington hired a professional civil engineer to develop engineering feasibility analysis and comparative cost estimates. Duplicating this effort for other neighborhoods would be costly and time consuming. There is a critical need, therefore, to streamline this process by developing general solutions and tools that can be customized for specific future needs.

High-resolution remote sensing data and sophisticated GIS processing software and hardware are becoming more readily available to local planners and regulators across the country and there are new GIS and remote sensing - based applications to the urban water quality management that are continuously being developed (Goetz, 2006; Sawaya, Olmanson, Heinert, Brezonik, & Bauer, 2003; Goetz, Wright, Smith, Zinecker, & Schaub, 2003; Williams, 2005; W. Zhou, Troy, & Grove, 2008; Berezowski, Chormański, Batelaan, Canters, & Van de Voorde, 2012). These new techniques strive to quantify the temporal and spatial characteristics of stormwater movement through residential neighborhoods in great detail and are being used to develop new approaches to resolve stormwater management problems. The purpose of this project was to develop a methodology to target and prioritize traditional and alternative stormwater best management practices (BMPs) for existing residential developments, by utilizing available technologies including high-resolution remote sensing data (3 m LiDAR and 2.4 m Quickbird) and ArcGIS hydrological and other modeling tools.

2.3. Study Site

The *Redesigning the American Neighborhood* (RAN) project managed by the University of Vermont is designed to identify cost-effective solutions to stormwater problems in existing residential neighborhoods that are typical of the northeast USA (Bowden et al., 2006). The project focuses on a case study of the Butler Farms/Oak Creek Village communities in South Burlington, VT (see fig. 2.1) to address the issue of targeting and prioritizing best management practices (BMPs) in high-density residential neighborhoods.

South Burlington's climate is moderate for Vermont. There are four frost-free months in the summer and three months of almost entirely below-freezing weather in the winter. Annual precipitation is 1 meter of rainfall equivalent distributed fairly equally over the year. Total annual snowfall is generally slightly over 2 meters (78.8 inches).

Stormwater of these two neighborhoods drain into the Tributary 7 of Potash Brook. Potash Brook flows west through some of the most intensely developed land in Vermont. Polluted runoff from city streets, Interstate 89 and shopping mall parking lots plowed into the brook, collecting pollutants from its banks of 7½ square miles of South Burlington into the Champlain Lake. South Burlington contains all or a portion of six streams impaired by stormwater runoff, the highest number of any community in Vermont and Potash Brook is one of them.Unmanaged stormwater is causing water pollution, erosion, flooding, and unstable streambanks in areas of South Burlington. Private stormwater systems that are not maintained become a public problem. Expired permits and difficulty obtaining a valid stormwater permit are hindering property transfers in South Burlington.

The tributary receives the majority of the storm water generated by these two communities. The Butler Farms/Oak Creek Village communities (combined) occupy nearly 150 acres of land. There are 258 homes, with an average lot size of 1/5-1/3 acre (0.08 - 0.12 ha). This results in approximately 20% impervious surface, where limited stormwater treatment, which is a common in northeastern communities add to the picture. This imperviousness falls into the “high risk” category according to multiple studies showing that when impervious surface values are greater than 25%, streams are likely to have water quality problems, and values from 10-25% indicate the watershed is "at risk" for water quality problems (Arnold & Gibbons, 1996; Brabec, 2002b; Deacon, Soule, Smith, & (US), 2005; Schueler, 1992). Clay soils with low infiltration rate, which are found in Butler Farms/Oak Creek Village neighborhoods, exacerbate the problem.

Cleaning up stormwater pollution across the Champlain Basin will require, as estimated, more than $18 million of public and private money in South Burlington alone. Regulators have also estimated that statewide, the bill could mount into tens of millions. At the same time, addressing this issue is important for a number of reasons, including the health of Lake Champlain. Stormwater runoff is loaded with phosphorus, a fertilizer that feeds algae blooms and has become a major water quality concern for the lake (Bowden et al., 2008; Lake Champlain Basin Program., 2002, 2008a; Lake Champlain Basin Program, 1979; Page, 2006).

2.4. Geospatial Data

Geospatial data used in this study include high-resolution color-infrared digital aerial imagery, LIght Detection And Ranging (LIDAR) data, the stream hydrologic network, roads, houses location point data, land use, engineered catchments pipeline network and inlet points.

The LiDAR (Light Detection And Ranging optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light) point data have been, collected for Chittenden County, Vermont by EarthData International in January 2005 with an ALS40 sensor at 3 meter post spacing.

The Vermont Center for Geographic Information (VCGI http://www.vcgi.org/) provided the digital data for the stream hydrologic network, roads, houses location point data, land use, engineered catchments pipeline network and inlet points.

DigitalGlobe High-resolution 2.4m multispectral satellite imagery from the Quickbird have been acquired by VCGI in the summer 2004 for Chittenden County of Vermont. The imagery is 4-band color- nearinfrared, with green (466–620 nm), red (590–710 nm), blue (430–545nm) and near-infrared (NIR1) bands (715–918 nm).

Very high resolution multispectral color and color infra-red digital orthophotography with a pixel of 16 centimeters using imagery have been collected with the Leica ADS40 digital pushbroom sensor and processed with the ISTAR system. This data set was produced by EarthData International for Chittenden County, Vermont in 2005 and supplied to Chittenden County Metropolitan Planning Organization (CCMPO).

2.5. Methods

High resolution LiDAR data and IDW interpolation tool from ArcGIS 9.2 ToolBox were used to derive digital elevatiom model (DEM) surface at the first stage of analysis. A GIS hydrologic model was developed, using the hydrologic modeling capabilities of ArcGIS, to calculate the stormwater drainage network, stream network, and watershed/subwatersheds delineation on the base of the derived DEMs.

The processing methods of ERDAS IMAGINE 8.7 (geospatial data authoring system, incorporates geospatial image processing and analysis, remote sensing and GIS capabilities into a powerful, convenient package processing methods), were applied to calculate Normalized Difference Vegetation Index (NDVI). The NDVI index was used as a basis in conjunction with the threshold method to identify and delineate impervious surfaces.

The Stormwater Drainage Network Density (MSDD) index, aimed to target landscape depressions as the areas for small and mid-scale best management practices (BMPs), was developed as the first part of the ArcGIS ModelBuilder tool ("Hydrologic analysis"). Stormwater runoff volumes and sediment quantities were estimated for the delineated landscape depressions, using the SIMPLE method.

All processing was automated using ArcGIS ModelBuilder.

2.5. Results

This approach consists of a series of logical steps in processing the data, as described in the following sections.

2.5.1. Step 1. Identify the Source Areas and Areas of Opportunities

LiDAR data offers extremely precise terrain analysis, compared to use of DEM data with coarser resolution. Results of analysis showed that the modeled water drainage network follows the stormwater pipelines, street curves, even depressions along the property lines (Figure 2.2 and 2.2a). This kind of information was very useful and allowed RAN team not only to delineate the main stream of permanent hydrological importance (Fig.2.2), but also to: (1) visualize the micro stormwater "raindrop" drainage pathways (Fig. 2.2a), (2) develop a quantitative assessments of the terrain, amount of the stormwater runoff, (3) improve the reliability of results and (4) develop new methods for BMP placements. It was also: (6) instrumental in demonstrations with stakeholders, since it correlates precisely with the residents on the ground observations "raindrop" pathways on their own properties, (7) constituted the basis for the trust between RAN research team and the residents of Butler Farms/Oak Creek Village communities and (8) provided the cognitive bridge between the local backyard actions and their impacts on the water quality in the stormwater runoff following to the tributary and sequentially to the lake.

Figure 2.2. The main stream calculated based on the LIDAR data

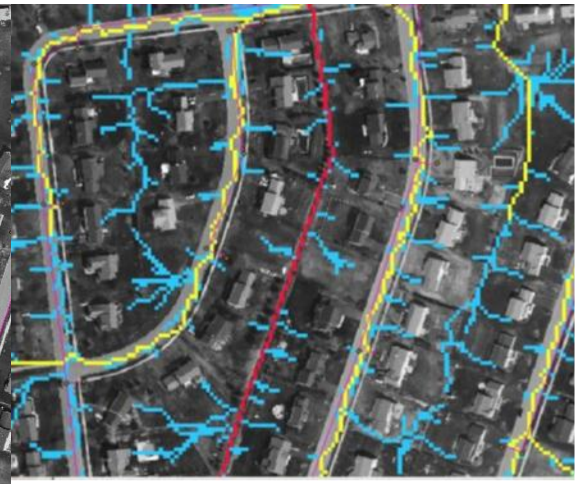

Figure 2.2a. Micro Stormwater Drainage Network calculated based on LIDAR data

Water does not recognize political/administrative boundaries and the outline of the total watershed, in most cases, does not correspond to the outline of the private parcel or the municipal entity. The logical unit of land management, from the whole system analysis point of view, is a watershed encompassing the area of the interest. Thus, the hydrologic terrain analysis was conducted by applying the hydrological modeling tools of ArcGIS to the LiDAR data in order to delineate: (1) the total watershed, encompassing the Butler Farms/Oak Creek Village neighborhoods, and (2) internal subwatersheds and their interconnections. Spatial analysis tasks were also to identify: (1) the "Source Areas"; (2) the critical points of intervention; and (3) the 'Areas of Opportunities', where interventions of different scales would be applicable.

"Source Areas" were defined as the watershed sub-areas, external to the boundaries of the Butler Farms/Oak Creek Village neighborhoods, which contributed heavily to the total runoff. Since the biggest part of the "Source Areas" was (is) laying beyond the Butler Farms/Oak Creek Village neighborhoods outline, the assessment of the “Source Areas” stormwater contribution was inaccessible for the conventional technical runoff estimates provided by the hired engineer. Consequently, the assessment of the “Source Areas” stormwater contribution was inaccessible to the stakeholders involved in the decision-making process regarding BMPs choices (since the conventional estimates do not count for the external runoff inputs and are based only on the area of the neighborhood itself).

“Areas of Opportunities” - were defined as the areas, encompassed by the Butler Farms/Oak Creek Village neighborhoods boundaries, where mid-scale BMPs and small-scale dispersed BMPs would be most appropriate.

The following areas of the total watershed, encompassing the Butler-Farms/Oak Creek Village neighborhoods, were identified as the result of Step 1 of the analysis (Fig.2.3):

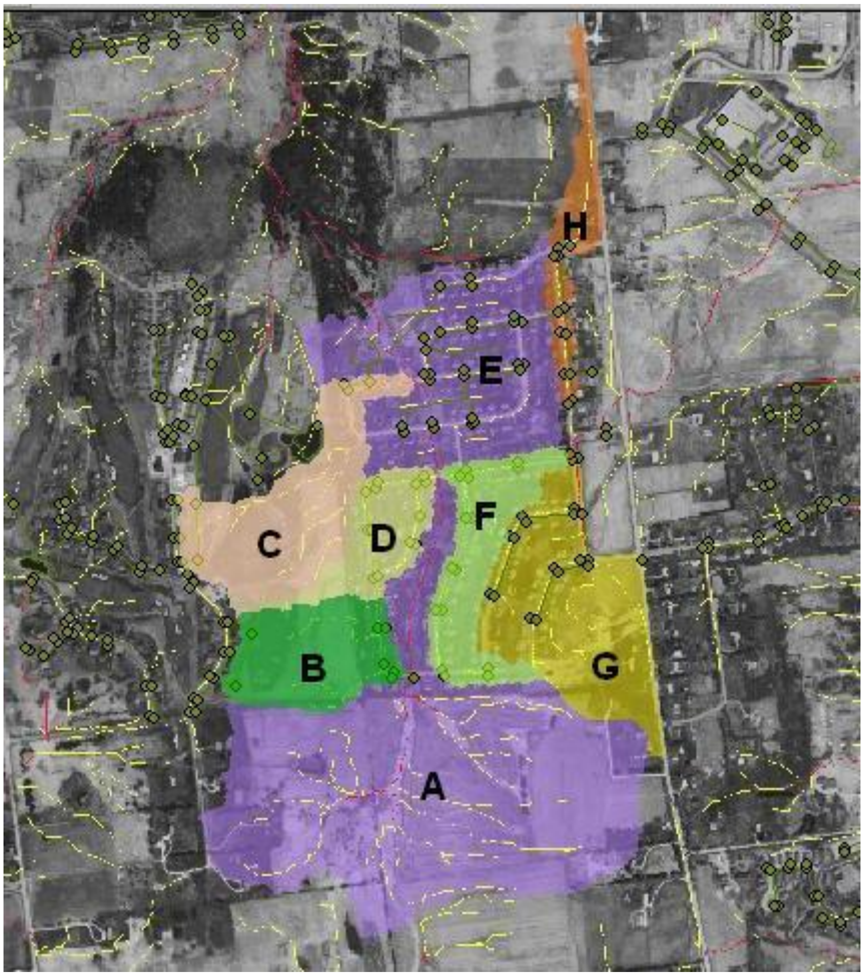

Figure 2.3. Source Areas and Areas of Opportunities delineated on the base of 3m LiDAR elevation data. **Key**: **A, B** and **C** – **"Source Areas**"; **D,E** and **F** - **"Areas of Opportunities**"; **G** and **H** - Areas, artificially connected by piping, during the process of the re-grading and construction

- A, B, and C: Areas where large-scale, alternative engineering solutions should be implemented. Most of these areas extend well beyond the administrative boundaries of the neighborhoods and are beyond residents' control.
- D, E, and F: Areas where dispersed, small- and midscale BMPs are most

appropriate.

- G and H: Areas that were found to have become artificially connected to the Potash Brook watershed during development and re-grading. Because they bring additional water into the watershed, they make it even harder for residents to comply with stormwater regulations. Restoring natural stormwater pathways would be one way to reduce stormwater loadings from these areas.

2.5.2. Step 2. Develop and Apply the Micro Stormwater Drainage Network Density (MSDD) index

The outline of the "Areas of Opportunities", identified at the step 1 of the analysis, where one could manage an effective response from the alternative mid-scale and small-scale BMPs was very important step for the following development of the alternative stormwater management plan and for the next step of the participatory process. Distributed, landscape based alternative BMPs were (and still are) not considered to be a mainstream solution for stormwater management. The project team met less than a lukewarm acceptance by the Butler-Farms/Oak Creek Village neighborhoods residents, when suggested the alternative approaches to stormwater management at the beginning of the RAN project. Based on this observation, targeting and placing such BMPs had to be very carefully planned, since BMPs placement ineffectiveness potentially could cause a substantial disservice to the whole idea of the alternative distributed BMPs approach. Thus, the next step after selecting the preferable areas for the alternative distributed BMPs would be most effective (see areas D, E, F of figure 2.3) was the step 2: developing the algorithm of targeting the areas for the most effective alternative distributed mid-sale and small-scale stormwater management solutions.

A quantitative spatial measure to assess the Micro Storm Water Drainage Density (MSDD) index was developed, to identify the areas for the most effective mid-sale and small-scale stormwater management solutions. MSDD index was based on the calculations of the density of the line features, representing the fine scale of the "rain drop" pathways, converted from the grid features of the Arc GIS generated drainage network (Silverman, 1986). LiDAR data resolution is sufficiently fine to calculate MSDD index at the single property of the neighborhood scale. MSDD index is used to visualize, distinguish and quantify the areas of most effective midscale BMP interventions, such as e.g. constructed wetlands and the areas of effective small-scale BMPs, such as e.g. rain gardens. The threshold for this index was identified on the basis of (1) the information about DEM resolution, (2) the average residential parcel size, (3) the average imperviousness for the area, and (4) EPA recommendations for the private rain garden size, which constitute 15-30% of impervious area (UW, 2005; WI DNR, 2003). The index is well correlated with the earlier stakeholder survey/assessments, that produced a visual identification and mapping of the "areas of flood concern", such as a poorly drained standing water along the property lines or scattered micro-depressions. There is a clear visual correlation between the "raindrop pathways" delineation (Fig.2.4) and the calculated MSDD index (Fig.2.5) for the selected potential mid-size BMP. This area is selected from area E (see fig.2.3), which was defined at the first step of the analysis as one of the "Areas of Opportunities" where the landscape-based mid-scale BMPs and small-scale distributed BMPs are most appropriate.

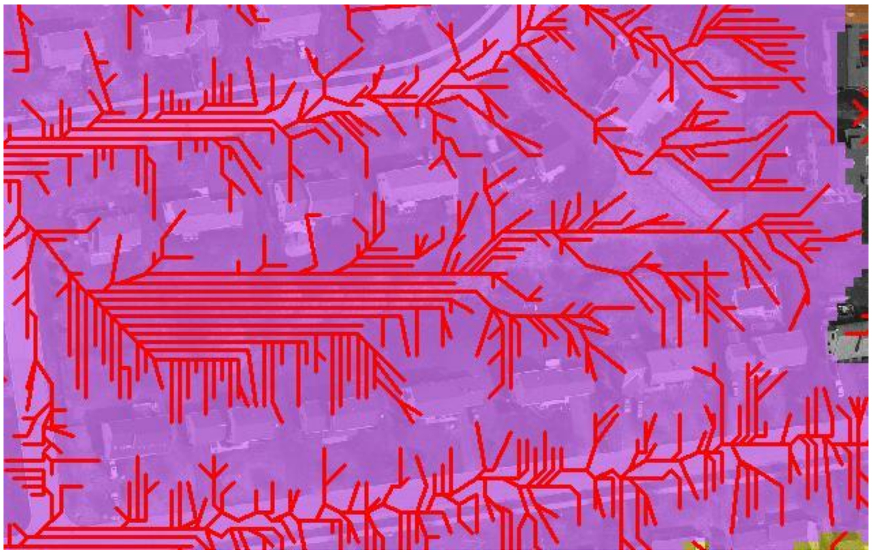

Figure 2.4. "Raindrop pathways": a micro stormwater drainage network

The spatial visualization of streamflows at the fine scale, that was allowed by the LiDAR data, was a turning point in the discussions with the stakeholders (Voinov Vladich 3, 2012), due to the fact that stakeholders were able to visualize, how their local decisions could make a difference in relation to their impact on the resulting water quality in streams and Lake Champlain (RAN1: Redesigning the American Neighborhood, 2006).

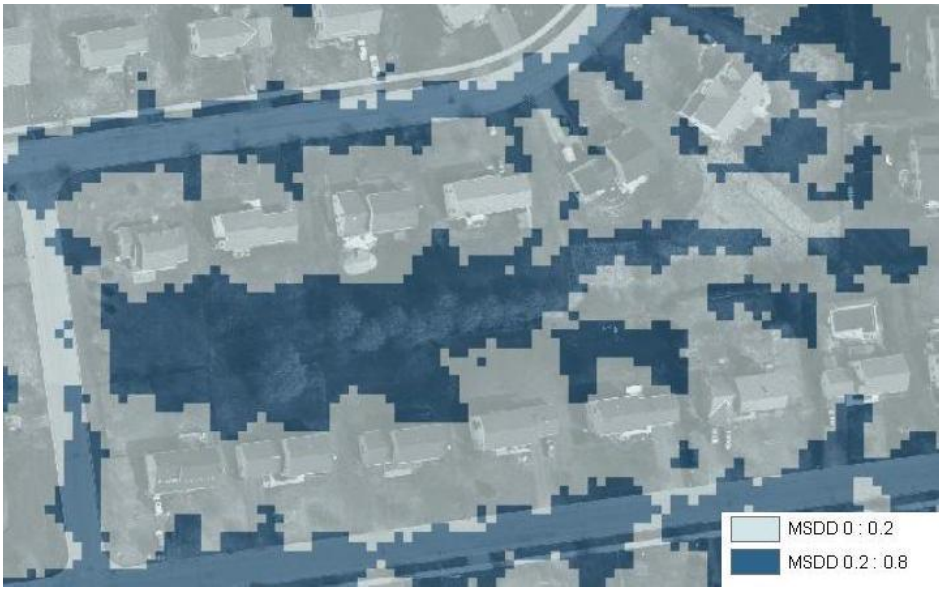

Figure 2.5. Spatial representation of reclassified MSDD index – the density of micro storm water drainage network for clear identification and delineation of mid-scale BMPs areas

The reclassified MSDD index was instrumental to the targeting of the areas for mid-scale BMPs and the introduction/restoration of the water regulation and flood prevention ecosystem services. This ability later became the basis for the integrated modular landscape-based stormwater management plan (IMLaS) in Butler Farms/Oak Creek Villages Neighborhoods (Voinov Vladich 4, 2012).

2.5.3. Step 3. Calculate Water Volumes and Quantities for the Chosen Mid-Range BMP Areas

The next step, after selecting and quantifying the preferable areas for the alternative distributed BMPs, was to suggest the sizes of intervention. In order to do so, it was it was first necessary to estimate impervious area within the delineated subwatersheds. As a first step in addressing this question, an Arc GIS Model/Tool was developed to estimate the amounts of water and sediments that could be intercepted and accumulated by mid-range BMPs.

Increasing the impervious surface area has long been known to increase non-point source pollution discharges into streams, including chemical and sediment runoff from parking lots and roads (Arnold & Gibbons, 1996; Brabec, 2002b; Deacon, Soule, Smith, et al., 2005; US EPA, 1983), and to increase storm peak discharge and runoff volumes, while decreasing stream baseflow. Although Impervious surfaces are not the source of pollution, they: (1) are significantly contribute to the hydrologic changes that deteriorate waterways; (2) are a major component of the urbanized land uses that do generate pollution; (3) prevent pollutants from disintegration in the soil by preventing percolation; and (4) serve as an efficient pollutants carriage mechanism, transporting pollutants into streams (Arnold & Gibbons, 1996).

To monitor these negative impacts, natural resource managers quantified the degree, extent, and spatial distribution of impervious surface areas using various methods including ground surveys, aerial photography interpretation, and satellite remote sensing. Satellite imagery, at first Landsat TM and ETM+, has been used as an approach with the capability to effectively estimate the percentage of the impervious cover in urban areas (Dougherty, Dymond, Goetz, Jantz, & Goulet, 2004; Goetz et al., 2004; Jantz, Goetz, & Shelley, 2004). With the development of multispectral digital imagery approaching that of small to medium scale photography, such as IKONOS and Quick Bird, new possibilities opened for environmental applications. (Knapp, 2007; Li, Ouyang, Zhou, & Chen, 2011; Sawaya et al., 2003; Weng, 2012; Weiqi Zhou, 2008). Several tests have been performed to identify which spectral transformation provided the strongest relationship to the percent of impervious surface area. For Quick Bird data, a correlation of 0.90–0.95 suggested that the normalized difference vegetation index (NDVI) provided the best relationship.

High resolution 2.4m Quick Bird and 0.15m MPO NIR (satellite scenes collected between 2003 and 2005) have been used to calculate Normalized Difference Vegetation Index (NDVI):

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

Two sets of data have been instrumental to produce the NDVI - 2.4m multispectral Quick Bird data and 15 cm MPO NIR data. The comparison of impervious surfaces, identified based on these data, matches well with the NDVI index, calculated on the basis of the very high resolution MPO NIR data seen on orthophoto imagery (Fig.2.6). Quick Bird imagery appeared to be most suitable for this particular application, as it is more economical in cost and is replicable in time, compared to the very high resolution multi-spectral, 16 cm CCMPO NIR imagery (Morrissey, Brangan, Meriska,, & O'Neil-Dunne, 2004). Therefore, for future applications, the use of Quick Bird data for such purposes might help to cut cost and processing time.

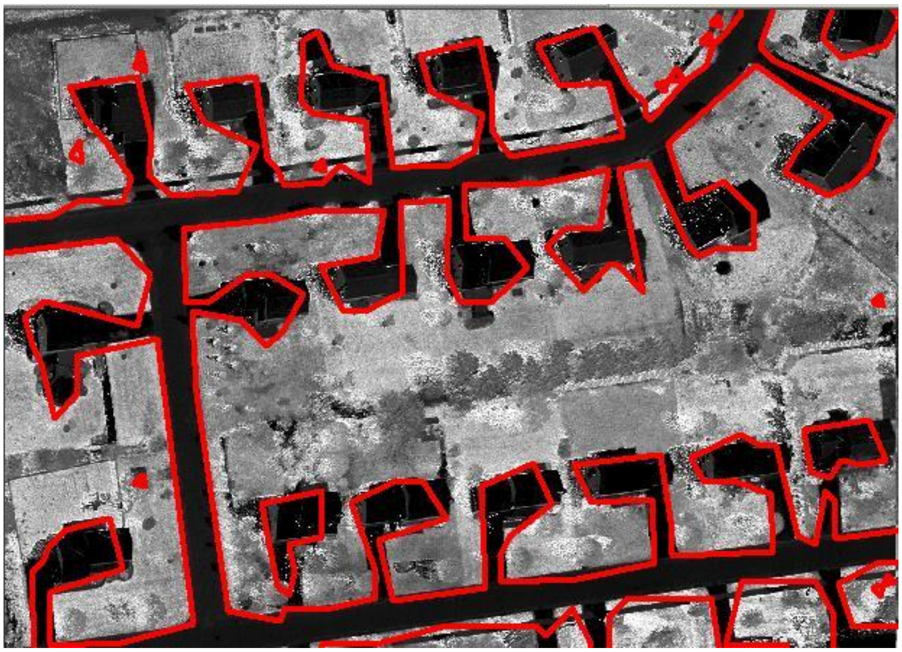

Figure 2.6. Impervious surfaces outlined based on the 2.44m multispectral Quick Bird image (red line) versus NDVI on the basis of 16cm CCMPO NIR image

Impervious surfaces have been outlined on the basis of the NDVI index, applying the water mask and impervious threshold method (Morrissey et al., 2004). A comparison of impervious surfaces identified using this approach agreed well with orthophotographs of the same area (see fig. 2.6).

The NDVI index and the developed ArcGIS ModelBuilder Tool have been employed to calculate and delineate the impervious surfaces areas in the delineated subwatershed to calculate potential volume of water retention by the landscape depression (see fig. 2.7). Area was selected from subwatershed E (see fig.2.3) – defined at the first step of the analysis as – “Area of Opportunities”, where landscape-based mid-scale BMPs and small-scale distributed BMPs are most appropriate.

The example of calculating stormwater runoff retention volume is presented in the final RAN report (Bowden et al., 2008). Using the impervious surface area derived as explained above (step 2) (13.7% of the total 3.263 acres or 0.447 acres) the water quality protection volume (WQv) recommended for this area by the Vermont Stormwater Manual (2002) would be 0.042 acre-feet or about 1847 cubic feet of runoff. The channel protection volume (CPv) for the 1 year/24 h storm is 2.1 inches of rain (Chittenden County, Table 1.2 in the Vermont Stormwater Manual, (VDEC, 2002)). For this same area this storm generates 0.33 acre-feet or 13,269 cubic feet of runoff according to the calculations in Section 1.3 of the Vermont Stormwater Manual. To contain this volume in a BMP in which the average water level rises only 1 ft would require a device of about 120 feet x 120 feet or 50 feet x 287 feet. A device of this size would service ~12-14 homes, as depicted in figure 2.7.

This example shows the possibility to estimate and suggest the size the of the mid-range BMP, chosen with the use of MSDD index. If added to a stormwater management system, this approach has a potential to: (1) minimize the need for stormwater structures; (2) enhance the living environment; (3) minimize the negative impacts of urban development; and not only (4) reduce costs to the developer, but also (5) reduce stormwater system maintenance costs (Voinov Vladich 4, 2012).

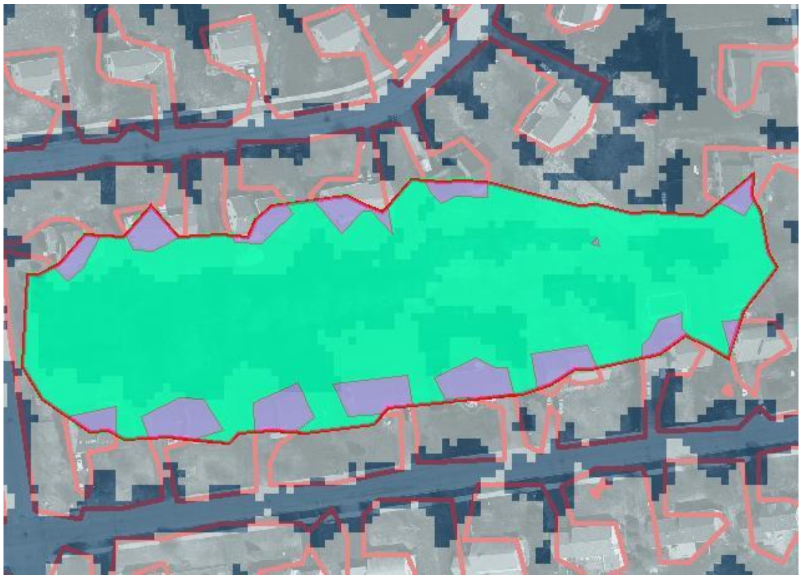

Figure 2.7. Mid-size BMP subwatershed delineation for calculation of alternative LID BMP sizing, on the basis of MSDD index, including the overlay with the impervious surfaces (selected from area E, where landscape –based mid-scale BMPs and small-scale distributed BMPs are most appropriate (fig.2.3))

2.6. Discussion

The whole system hydrologic analysis, based on high resolution LiDAR and Quick Bird data, provided results, quite different from the conventional engineering stormwater assessment. Results of Step 1 became turning point in and provided the ground for the resolution of the conflict between Butler Farms/Oak Creek Village communities (discussed in details in chapter 3 (RAN1: Redesigning the American Neighborhood, 2006; Voinov Vladich 3, 2012)). Results of all steps, including the application of MSDD index, were used as the basis for the development of the alternative distributed integrated modular landscape - based stormwater management plan (IMLaS) (discussed in details in chapter 4 (RAN3: Redesigning the American Neighborhood, 2008; Voinov Vladich 4, 2012)).

The call for adaptation to climate change emphasizes another importance of the MSDD index and the algorithm for targeting multiple scales BMP practices.

The objective of conventional engineering feasibility analysis for the stormwater management plan is to capture 90% of annual storm events and to remove 80% of total suspended solids (TSS) and 40% of total phosphorus. The second objective is to protect stream channels from degradation due to increased rates of runoff. Engineering technical specifications use the annual 12 hours storm event, which in Vermont produces (1”) of rain (RAN6: Redesigning the American Neighborhood, 2006). These calculations are based on the traditional New England precipitation pattern. The climate change, however, is predicted to increase the frequency of severe storms in New England. To evaluate, how such precipitation trends may be affecting annual floods in New England, Collins (2009) investigated hydroclimatic trends in 28 long-term annual flood series in New England watersheds with minimal land use change, and no flood regulation, over their periods of record.

Collins (2009) used continuous flood records through 2006 and averaged 75 years in length. Twenty-five of the 28 annual series showed growing upward trends in annual flood amounts via the nonparametric Mann-Kendall trend test, 40% (10) of which had $p<0.1$ (Figure 2.8) (Collins, 2009).

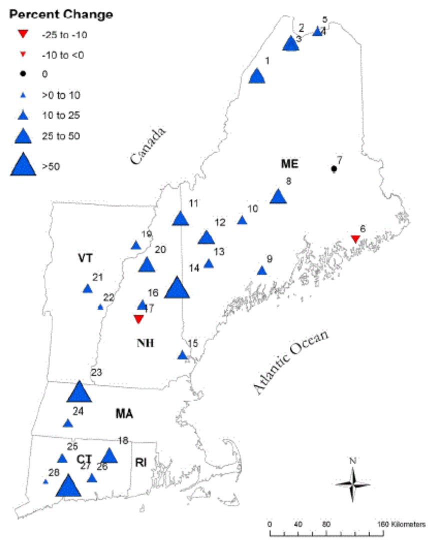

Figure 2.8.Trend directions and magnitudes for the 28 annual flood series analyzed by Collins (2009). Trends are expressed as percent changes in the annual flood magnitude over the period of record at each gauge.

The Northeast is projected to see a steady increase in precipitation, with total increase of around 10 to 25 percent. Rainfall is expected to become more intense and periods of heavy rainfall are expected to become more frequent (NOAA Fisheries Service, 2011).

It is practical to use traditional flood frequency estimates from existing studies for the design of stormwater management plans. The results of Collins (2009) suggest, however, that flood frequency estimates based on time series of flood data that end in the 1970s and 1980s might not be representative of the modern climatic regime and might produce underestimates. Collins (2009) results were emphasized soon after publication by hurricane Irene of 2011, Vermont worst natural disaster since the flood of 1927. For example, Walden, Vermont, received 7.6 inches of rain

Sunday, August 29, 2011, about as much two months precipitation amount (BurlingtonFreePress wire reports, 2011).

This poses an additional challenge for planning and constructing new or retrofitting the old stormwater systems and emphasizes the need for the tools that enhance the ability to utilize the landscape features that can both provide flood-prevention ecosystem services and serve as a basis for the alternative, distributed stormwater management plan.

In order to assess how precipitation patterns affect the behavior and characteristics of a watershed**,** historical NOAA rainfall data (NOAA, 2002) have been obtained. Additional calculations were performed for the higher levels of precipitation, than it is suggested by a conventional engineering approach, have been chosen to address the possibility of increased storms frequencies of higher magnitudes. NOAA data show that the 25 years, two hours storm could produce 5.08 cm (2”) of rain. Taken the delineated subwatershed area (Fig.2.7) as an example and following the approach of the SIMPLE method the runoff from stormwater was calculated, taking an effective portion of the 5.08 cm (2”) rain (Appendix 1).

Calculated return of two hours storm For the delineated subwatershed, – was 104.6 Tons of water. This amount of runoff can be retained by the landscape depression and then percolated to the groundwater or evapotranspired by plants.

The algorithm for the water volumes and quantities calculation is constructed on the same basis as the second part of ArcGIS ModelBuilder Tool development, which allows the watershed imperviousness assessment by land use.

2.7. Conclusions

Planning and regulatory agencies realize the value of stormwater management and design practices that can be implemented at a variety of scales to control and treat the quality and quantity of stormwater draining from residential properties. Experience has also shown that involvement of developers and homeowners in the process leading to decisions about alternative stormwater management treatments is important to acceptance and success of these approaches. This applies both to the residential development stage as well as to improvements in existing neighborhoods. However there are few tools available to help stakeholders make informed decisions about the alternative methods of distributed stormwater management. In addition, the different stakeholders have different levels of technical expertise and need a common, relatively intuitive means to communicate with one another. This research have shown how high-resolution remote sensing data and GIS tools can provide essential information to compare and prioritize scenarios for traditional and alternative stormwater best management practices (BMPs). 3m LiDAR and 2.4 m Quick Bird multispectral image data have been used in conjunction with the Model Builder capabilities of ArcGIS, version 9, to develop a Micro Stormwater Drainage Density (MSDD) index. This index has been instrumental to target hydrologic "Source Areas" and to define "Areas of Opportunities", best suited for locations for stormwater BMPs, that ranged from larger and more traditional approaches to smaller low-impact designs (LID). This approach has a potential to become a cheaper alternative to preliminary engineering feasibility analyses and could significantly contribute to full-scale engineering surveys usually required for stormwater planning, taking into account landscape flood-prevention ecosystem services at times of increasing frequency of extreme flood events.

The approach that has been developed here is generic and could be applied anywhere that LiDAR and Quick Bird data are available.

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CHAPTER 3: UTILIZING THE POWER OF PARTICIPATORY SPATIAL ANALYSIS AND HIGH RESOLUTION REMOTE SENSING DATA TO PROMOTE ENVIRONMENTAL CONSENSUS BUILDING: A CASE STUDY OF A NEIGHBORHOOD IN SOUTH BURLINGTON, VERMONT

3.1. Abstract

The purpose of this paper is to demonstrate how, from being used only as an analytical tool - spatial analysis, GIS hydrological modeling and access to high resolution remote sensing data can be effectively applied to the resolution of environmental conflicts. In a course of using the developed targeting and prioritization methodology for residential stormwater best management practices (BMPs) in a participatory process, related to retrofitting stormwater management system in Butler-Farms/Oak Creek Village neighborhoods, South Burlington, Vermont, a new property of spatial analysis tool was observed, which allowed the use of this tool for environmental conflict resolution and consensus building. Participatory spatial analysis (PSA), when used in conjunction with high resolution remote sensing data, is a powerful not only for visualization, education, and research, but for trust building and decision making at the neighborhood, city and state levels.

3.2. Introduction

Since the term *environmental conflict* first appeared, in the 1960s, our understanding of the role of science in consensus building has been gradually changing. Starting as a purely neutral source of authority, a venue for discovery, and an independent mechanism of accountability, the role of science sometimes has slowly mutated in our society to the point where it is used more as a shield than an agent of truth, when creating an illusion of arbitrating between alternative policy viewpoints or choices, science is often employed instead as a tool for political persuasion (Ozawa, 1996). Furthermore, it can be more and more frequently observed that in difficult or intractable cases, scientific uncertainty, complexity and disagreement can prolong conflict, exacerbate poor relationships and actually provide a rationale for avoiding resolution (Martin & Richards, 1995; Ozawa, 2006).

In “Science in Environmental Conflicts”, Ozawa (1996) asks whether science can play a role in resolving environmental conflict—and answers in the affirmative way. Ozawa observes that during the 1980s, as a byproduct of innovations in decision making (which included direct negotiations between individuals and representatives of groups engaged in environmental disputes), an alternative role for science emerged. In some environmental mediation cases, parties now explicitly agree that the technical information and analysis necessary to understand current conditions and to identify possible options for action is one of the first topics on the agenda (Ali, 2003; Susskind & Cruikshank, 1987). Thus, scientific analysis has become a tool in the negotiation process. Almost from the start, stakeholders discuss what kinds of technical knowledge are pertinent; moreover, the results of the scientific analysis are openly discussed and subject to agreement (Ozawa & Susskind, 1985).

Ozawa (1996) notes that for science to play a facilitative role in conflict resolution, the decision-making process must be deliberately structured to ensure the following:

- All stakeholders must have access to scientific expertise and analysis.
- To prevent participants from clinging to technical positions with the aim of obtaining political gains, a period of time should be explicitly set aside to address political concerns.
- Experts invited to participate in the decision-making process must commit to sharing scientific information as a means of educating, rather than intimidating, stakeholders.

If these conditions are met, scientific analysis may sustain dialogue, enabling stakeholders to develop a constructive understanding of the various perspectives on an environmental conflict.

One environmental issue that is receiving increasing attention is the impact of sprawling residential development, and the resulting stormwater impact on overall lakes and rivers water quality and quantity. The conversion of undeveloped land to residential and commercial use has significantly changed the capacity of watersheds to retain water and assimilate nutrients and other materials, which now flow freely from the land into aquatic systems (Brabec, 2002b; Klein, 1979). Native forestlands, with large canopies and deep root systems that are well-suited for water retention, have largely been replaced by impervious surfaces or by shallow-rooted, nonnative species, which cannot intercept rainfall nearly as well and have entirely different evapotranspiration patterns. Such changes have significantly increased amounts of stormwater runoff (Allan, 2004; Detenbeck et al., 2000); according to some studies, discharges may be 200 to 400 times greater than historical levels (Apfelbaum, 1995).

Until recently, the stormwater management has been dominated by the "end-of-the-pipe" approach, which calls for the construction of large detention ponds in the lower parts of drainage streams. This approach requires significant capital investment and complex technologies; is expensive to maintain; and fails to address a number of smaller stormwater management issues. Moreover, as Appfelboum (1995) points, in areas with higher levels of population density (and therefore higher impervious surface coverage), it has been found that the end-of-the-pipe approach is not sufficient to effectively manage stormwater.

Meanwhile, it has been observed that landscapes with many upland microdepressional storage opportunities and substantial buffering capacity may be more efficient at processing runoff than a single, centrally located detention pond or biofiltration wetland situated downstream (Apfelbaum & Chapman, 1999; Apfelbaum et al., 1995). As a result of this finding, numerous alternative approaches have appeared, which tend to be smaller in scale, dispersed in character, and better suited for the characteristics of the local landscape and natural watershed. Some empirical data suggest that when upland vegetation systems are combined with ponded areas, the rate and volume of discharge may be essentially unchanged between before and after development (Apfelbaum, 1995).

It is relatively easy to employ the whole spectrum of traditional and alternative approaches at the design stage of new development. The issue becomes much more complicated when existing developments are compelled to meet new, more rigorous requirements for stormwater quality and quantity.

Existing residential developments pose several principal challenges, two of which are following:

- *Technological tools*: Tools are needed that will allow users to (1) identify points of intervention at different, subwatershed scales and (2) target locations for the use of best management practices (BMPs) at different scales (Voinov Vladich 2, 2012).
- *Tools for environmental conflict resolution*: Because a retrofit of an existing stormwater system can be costly, and comes in the form of a coercive regulation from city and state authorities, residents may view it as a burden—which can lead to conflict between residents and state and local governments.

The goal of this chapter is to show that participatory spatial analysis (PSA), when used in conjunction with high-resolution remote-sensing data, is a powerful approach not only for visualization, education, and research, but also for trust building and decision making at the neighborhood, city, and state levels.

3.3. Study Site

The research on which this chapter was based was undertaken as part of the *Redesigning the American Neighborhood* (RAN) project, a program of the University of Vermont (UVM). The goal of the RAN project was to find cost-effective solutions to stormwater problems in small residential neighborhoods, which are typical of the northeastern United States (Bowden et al., 2008; McIntosh, Bowden, Fitzgerald, Hackman, Kirk, Todd, Voinov Vladich, et al., 2006). The RAN project team undertook a case study of the Butler Farms/Oak Creek neighborhoods to address the issue of targeting and prioritizing best management practices (BMPs) in high-density residential neighborhoods, as it was seen as the traditional northeastern residential development. The design of this particular community—with lots between one-fifth and one-third of an acre, approximately 20% impervious surface, and limited and outdated stormwater treatment—is common in the American landscape. Typically, such developments are located on the fringes of suburbs, and sometimes extend to the rural countryside.

Chittenden County is home to 23% of Vermont's people and jobs (VDES, 2002; Hinds et al., 2005) and has six streams on the state's list of waters impaired by urban stormwater runoff (Smyth, Watzin, & Manning, 2007). Most of these impaired waters discharge directly into Lake Champlain, which is prized for its recreational value and is the source of drinking water for most of the county. Nonpoint sources (NPS) contribute about 90% of the total phosphorus load to Lake Champlain (Lake Champlain Basin Program, 2008b), TMDL studies showed roughly 30 - 37% of NPS phosphorus loading, attributable to Vermont urban runoff (Lake Champlain Basin Program., 2002; Thomas Owen Manley & Manley, 1999). More recent study puts this value at over 50% (Troy, 2007b).

3.4. Research Objectives

The goal of the case study was to tackle complex and sensitive issues associated with retrofitting the stormwater system in an existing neighborhood, during a time of considerable conflict and uncertainty. The specific objectives were as follows:

- Develop the second part of the spatial analysis tool, described in (Voinov Vladich 2, 2012) in order to analyze and understand the hydrologic processes at the scale of the watershed where the neighborhood is located
- Create a tool with high visualization power, in order to disseminate information and promote the results of the analyses to stakeholders
- Assess how residents perceive stormwater issues and what they know about stormwater-related problems
- Collect information about behavior patterns and daily practices related to stormwater in the neighborhoods

- Evaluate the overall level of environmental awareness and willingness to act and/or change in the neighborhoods
- Educate neighborhood residents about the results of the analysis
- Refine the data about the system, through active stakeholder participation
- Devise a strategy to create a turning point that would lead away from tension and conflict toward trust and acceptance
- Create a constructive environment for negotiation and consensus building regarding an alternative approach to stormwater management.

3.5. Methods and Data

3.5.1. Technological Tools

The PSA was based on high-resolution LiDAR (Light Detection And Ranging optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light) and QuickBird data (for a description of PSA data, see Appendix 1.1). ERDAS IMAGINE 8.7 processing methods (geospatial data authoring system, incorporates geospatial image processing and analysis, remote sensing and GIS capabilities into a powerful, convenient package) were applied to calculate the Normalized Difference Vegetation Index (NDVI) in conjunction with the threshold method as a basis for impervious surfaces identification and delineation.

The Micro Stormwater Drainage Density (MSDD) index, aimed to target landscape depressions as the areas for small and mid-scale best management practices

(BMPs), was developed as the first part of the ArcGIS ModelBuilder tool ("Hydrologic analysis"). Stormwater runoff volumes and sediment quantities were estimated for the delineated landscape depressions, using the SIMPLE method (Voinov Vladich 2, 2012).

To assess the percentage of impervious area for different land use categories within the subwatershed and the total watershed (see Appendix A3), the project team used the second part of the ArcGIS ModelBuilder tool (Summary Statistics).

All processing was automated using ArcGIS ModelBuilder.

3.5.2. Public Participation

At the beginning of the project, the City of South Burlington established the Stormwater Working Group (SWG), a group of neighborhood volunteers who met about once a month with RAN team members, city officials, and an engineer to tackle technical questions. It was during these meetings that three distinct options for stormwater management were presented, discussed, and voted on (see section 4.9.3) (RAN2: Redesigning the American Neighborhood, 2007). A Web site that included all SWG-related information, documents, data, and communications was used throughout the decision-making process: http://www.uvm.edu/~ran/?Page=homeowners.html

Survey: At the beginning of the project, the RAN team undertook an initial survey of the residents of the Butler Farms and Oak Creek neighborhoods. The survey was developed with three goals in mind:

- To understand how people perceived the stormwater issues and determine what they knew about stormwater-related problems
- To collect information about behavior patterns and daily practices related to stormwater
- To evaluate residents' overall level of environmental awareness and willingness to act and/or change.

  The rate of return for the survey was ~50% (99 completed out of 200 administered)

The results of the survey can be found in the Annual Report, Project Years 1 and 2 (2003–2005), dated by November 27, 2006, (http://www.uvm.edu/~ran/?Page=documents.html) (Bowden et al., 2006).

The PRIZM system, which was developed for market research and reflects the neighborhood lifestyle by combining urbanization and socioeconomic status with lifestyle components including household composition, mobility, ethnicity, and housing characteristics, was used to assess demographic characteristics, including socioeconomic status, household characteristics, and lifestyle behavior (Claritas, 1999).

3.6. Three Classes of the Participatory Modeling Approach in Facilitating Consensus Building

To be useful in a participatory framework, models need to be transparent and flexible enough to change in response to the needs of the group. In some cases, tools as simple as Microsoft Excel—which is usually readily available and often already familiar to stakeholders—may be the right choice. Simulation (process) models help to determine the mechanisms and underlying driving forces of patterns otherwise described statistically; however, they are not practical for exploring the role of the spatial structure of an ecosystem. Alternatively, geographic information systems (GIS) explicitly model the spatial connectivity and landscape patterns present in a watershed, but they have limited ability to simulate a system's behavior over time (Westervelt, 2001).

The complexity of the models used must be dictated by the questions posed by the stakeholder group (as well by available data and information). Models that are too simple are less precise and have less explanatory value, but a model that is too complex may not be transparent to stakeholders. In many cases, a simple model that can be readily communicated and explained is more useful than a complex model that has narrow applicability, high data costs, and greater uncertainty. In short, successful participatory modeling requires appropriate modeling tools and paradigms. In addition, the use of a complex model for which there is little data for model development and calibration may not be scientifically sound. In our research, we are committed to ensuring that science plays a constructive role in environmental conflict resolution; we treat it as an agent of discovery, an independent mechanism of accountability, and a means of education and mediation. When modeling a problem to help find a solution, we use the same approach.

The RAN project used GIS spatial analysis in addition to a STELLATM implementation of the simple TR-55 routing model (RAN8: Redesigning the American Neighborhood, Fitzgerald, & Bowden, 2006). The fine-scale spatial visualization of stream flows permitted by LiDAR data was a turning point in the discussions, because stakeholders could actually see how their local decisions could make a difference.

Participatory Modeling (PM), a general approach to involving stakeholders in the modeling process,is designed to assist in decision making, conflict resolution, and general management of the process (A. Voinov & Gaddis, 2008). PM is driven by the goals of the stakeholder group and is not limited by the use of any specific modeling tools or requirements to ask particular types of management questions. The goal of the PM approach is to make the modeling development process transparent and share the excitement of modeling with the stakeholders. This, in turn, makes it possible to:

- Educate stakeholders about the processes and functions of the environmental system
- Solicit input and data about the system
- Define scenarios, types of output, and the uses of the model
- Create a constructive environment for negotiation and consensus building

PM is a powerful tool for decision making. Under the PM approach, a series of models are built, with citizens' participation at various stages of the project.. As part of the model-development process, information is collected, the information is tested against information obtained from residents, and assumptions and data sets are translated into the formal language of models.

There are three main types of PM: Dynamic Landscape Modeling (DLM); Mediated Modeling (MM), and Participatory Spatial Analysis (PSA). For the RAN project, each type was evaluated for its potential usefulness.

Dynamic Landscape Modeling (DLM) combines spatial and temporal scales and is capable of serving in a wide range of constructive roles in environmental conflict resolution: as a tool for discovery, education and mediation and as an independent mechanism of accountability. In addition, the outcome of DLM may be dynamically complex and spatially explicit; therefore, stakeholder involvement in DLM is typically mostly observational (Brown Gaddis, Vladich, & Voinov, 2007; A. A. Voinov, Voinov, & Costanza, 1999; A. Voinov, Gaddis, & Vladich, 2004; A. Voinov, Bromley, et al., 2004).

In the RAN project, time and funding were constrained and decisions had to be made at a very fine scale (the size of one rain garden—an area 3 to 5 meters in diameter), which would require very complex models if the temporal aspect had to be included. Because of these requirements, the DLM approach did not appear to be applicable.

Mediated Modeling (MM) is a non-spatial form of PM that focuses on building a conceptual model together with stakeholders (Van den Belt, 2004). It assumes a extended deep involvement on the part of a relatively small number of stakeholders who are committed to long-term participation. The process creates common ground for discussion, develops trust between participants, and helps discipline deliberation and decision making. The focus on building the model yields a shared understanding of the system and its dynamics, and makes it possible to analyze temporal trends and trade-off scenarios; however, because it is not spatially explicit, it is not designed to produce precise, fine-scale spatially explicit results, and to determine exactly where to locate small- and midscale BMPs to achieve maximum effectiveness.

Participatory Spatial Analysis (PSA) is the spatially explicit class of the three participatory modeling approaches. PSA uses the power of spatial terrain analysis—and, in this case, newly available high-resolution remote-sensing (LiDAR) data—to reach PM goals with respect to education, system analysis, and environmental consensus building. Given the limiting factors of costs and available space (since the project was operating in an already developed neighborhood), the goal of the PSA algorithm, developed as part of the RAN project (Voinov Vladich 2, 2012) was to identify where it would be most appropriate to apply the BMPs of various scales, ranging from traditional, large-scale, end-of-the-pipe engineering solutions to small- and midscale alternative solutions, such as rain gardens and retention swales. The PSA approach does not employ a dynamic component. It uses ArcGIS ModelBuilder capabilities in hydrologic modeling (ARC GIS 9.2) to produce spatially explicit snapshot of hydrological landscape characteristics at the scale of data available.

As high-resolution remote-sensing data become more readily available across the country, our understanding of and ability to replicate the movement of water through the landscape is significantly improved, allowing innovative approaches to the technical, social, and engineering aspects of stormwater management and nonpoint pollution control (Han & Burian, 2009; Hodgson, Jensen, Tullis, Riordan, & Archer, 2003).

3.7. History of the Stormwater Issue in Vermont

Polluted stormwater runoff is often transported to municipal storm sewer systems (MS4s) and ultimately discharged—untreated—into local rivers and streams. To address this problem, in 2000 the U.S. Environmental Protection Agency (EPA) instituted the Storm Water Phase II Rule (US EPA, 2012). The purpose of the rule was to establish an MS4 stormwater management program that would improve the health of the nation’s waterways by reducing the quantity of pollutants carried into storm sewer systems. The Phase II Rule automatically covers all small MS4s located in “urbanized areas”, as defined by the U.S. Census Bureau (Hinds et al., 2005).

In 2001, when the State of Vermont began gearing up to implement the Phase II Rule, no codes for total maximum daily loads (TMDLs) had been prepared for impaired waters, and over 1,000 state stormwater discharge permits had expired—most without notice to the property owners. In June 2001, when the Vermont Water Resources Board (VWRB) ruled that no new or increased discharges of pollutants could be added to any impaired waterway in the absence of a TMDL code, Chittenden County—and the City of South Burlington in particular—became the epicenter of a political and legal crisis. The VWRB ruling freezed stormwater permit issuance and renewal, restraining many property transfers and developments and triggering a multiyear legal and legislative process intended to clear the backlog of expired permits, develop effective TMDL codes, and clarify standards for new development (Hinds et al., 2005).

3.8. City of South Burlington Stormwater Utility

Roughly two years after beginning the implementation of the Phase II Rule, the City of South Burlington began exploring the creation of a municipal stormwater utility to deal with its unique land use pattern. South Burlington, with 17,000 residents, is Vermont's fifth-largest municipality and is by far the fastest-growing part of Chittenden County, with a burgeoning employment base and an average of 250 new housing units constructed annually. South Burlington is home to Burlington International Airport, to Vermont's largest shopping mall, and to over 100 miles of state and city roadways. The city also contains all or part of six impaired watersheds, and over one-quarter of all state lands with expired stormwater discharge permits (Hinds et al., 2005).

Faced with a pressing need for a stable and robust funding stream to deal with backlogged capital projects and increased maintenance requirements, the South Burlington city government spent three years studying stormwater management options. In the spring of 2004, the city recommended establishing Vermont's first stormwater utility, to be supported by a fee of $4.50 per month per equivalent residential unit. Before the city would take over existing stormwater systems, however, it required that they be retrofitted to meet the state requirements. (Hinds et al., 2005).

3.9. Oak Creek/Butler Farms Village (BF/OCV): Initial Assessments; and Outreach

Because many residents associated stormwater with political conflict and with being prohibited from selling their property (Appendix A2; (Page, 2006), the beginning of the RAN project—including the call for public participation in the development of stormwater management options—coincided with increasing tension between the neighborhoods and the City of South Burlington. In other words, the RAN project started in an environment that was not conductive to the paced, regular development of a stormwater management plan. Moreover, conflict with the city exacerbated the already challenging task of working in an existing neighborhood.

Although it is relatively easy, in the case of new construction, to meet standards for low-impact, ecologically sound stormwater management—particularly if incentives are available and there is willingness to use them—retrofitting existing, traditionally constructed developments to meet such standards is a much greater challenge. Thus, the RAN project set out, through a combination of monitoring, research, engagement, and demonstration projects, to develop generic, replicable approaches for identifying practicable, low-impact stormwater management alternatives for existing suburban environments. The purpose of these new approaches was (1) to enable stakeholders, regulators, and researchers to collectively visualize alternative futures and (2) to optimize a mix of stormwater management interventions at various scales to best balance environmental, social, and economic criteria (Bowden et al., 2006).

Among the specific objectives of the RAN project were the following (Bowden et al., 2006):

(1) Assessment: Develop a framework to assess opportunities for intervention in adaptive stormwater management at various spatial scales, and apply this framework to the Butler-Farms/Oak Creek Village neighborhoods case study.

(2) Participation: Involve community stakeholders in the development and evaluation of objectives 1 and 2, through town or neighborhood meetings relying on whole-watershed visualization tools and multicriteria decision aids designed to promote shared learning among participants.

In contrast to the traditional approach to stormwater management, which relies on the construction of centralized engineered facilities for stormwater treatment, the goal of the RAN project was to find numerous potential points of intervention at different scales. Objective (1) - assessment considered a diverse palette of ideas, technologies, engineering approaches, and ecosystem services, with the intent of changing various components of the neighborhoods to lessen and manage stormwater impacts. One of the most critical elements of the project was the engagement of neighborhood residents in shared learning and decision making (objective (2)), both to resolve existing conflicts and to ensure the long-term acceptance and success of the neighborhood stormwater management effort.

3.9.1. Education and Outreach

The city suggested to the RAN project team that the Butler Farms/Oak Creek neighborhoods be used as a testing ground for the team's efforts to explore how community decision making affects the choice and scale of stormwater management interventions. Working with city officials, RAN team initiated discussions and eventually began an outreach program and assessment that addressed both the Butler Farms and Oak Creek neighborhoods.

The goal of the education and outreach efforts was to evaluate (1) the impact of community decision making on the choice and scale of stormwater management interventions and (2) the subsequent impact on water quality. At the outset, in 2003, the RAN project team intended not only to provide residents with information, but also to work on defining political, communication, and decision-making problems associated with water quality and stormwater management.

When the project began, the residents' interest in and response to the information provided by the project team was pretty low. To activate the process, the city authorized the creation of a "Stormwater Study Group" (SWG) that consisted of roughly 25 volunteers from the neighborhood, to explore the ecological, financial, and aesthetic implications of various approaches to stormwater management The city also set aside funds to hire a civil engineer to provide the SWG with technical support. The goal of the engineering assessment was to create detailed design of an upgrade for the neighborhoods' failing stormwater system and assess the cost of implementing such a design.

Starting time of the project was marked by the state's legal tangle with stormwater permits and the city's utility development process. During that time the residents of Butler Farms and Oak Creek as well as other two dozen residential neighborhoods in South Burlington gradually discovered that their homes were subject to long-expired state stormwater discharge permits and that their neighborhoods' stormwater systems did not meet the stringent new standards. Neither Butler Farms nor Oak Creek neighborhood had a homeowners' association to deal with stormwater permitting issues, and both had substantial problems with flooding and water quality. Unsurprisingly, problems with home sales, frustration with localized flooding, and confusion about the relationship between the city's stormwater utility and the state permit impasse led to frustration and even outright anger on the part of residents (Hinds et al., 2005).

The tension was exacerbated when homeowners found out that before the city would take over the existing detention ponds and other stormwater structures, the systems first had to be upgraded to 2002 standards. Reaching out to the residents of Butler Farms in the midst of the stormwater permit crisis took time, patience, and persistence. Citizens who had discovered that the title to their home was threatened by a stormwater permit, and that the new fee of $54 per year charged by the city would not address that threat, did not make for an especially easygoing or receptive audience.

The positive side of that realization was significantly increased interest and participation in the SWG.

Involving neighborhood residents as stakeholders in this process proved to be invaluable from the beginning. Through stakeholder meetings and neighborhood surveys, the project team learned that incoming storm and snowmelt water was not only a concern for South Burlington's environmental management team, but had been the source of many complaints from residents. This was another reason to form SWG. When the project team met with residents, they showed a strong interest in mapping and cataloguing their local knowledge of stormwater problem areas. SWG met about once a month with RAN team members, city officials, and an engineer to tackle technical questions in an increasingly participatory and collaborative way.

3.9.2. The Results of RAN and Regional Surveys

Figures 3.1. and 3.2 offer evidence of the disconnect between how much residents valued Lake Champlain and its health, and how they viewed the connections between land use practices and the quality of the water in streams and in the lake (Bowden et al., 2006)

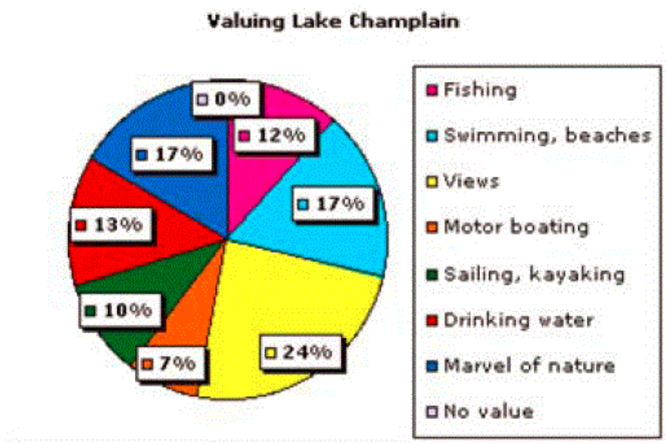

Figure 3.1. Responses to the following RAN survey question: "What do you value Lake Champlain for?" *Source:* Adapted from Bowden et al. (2006).

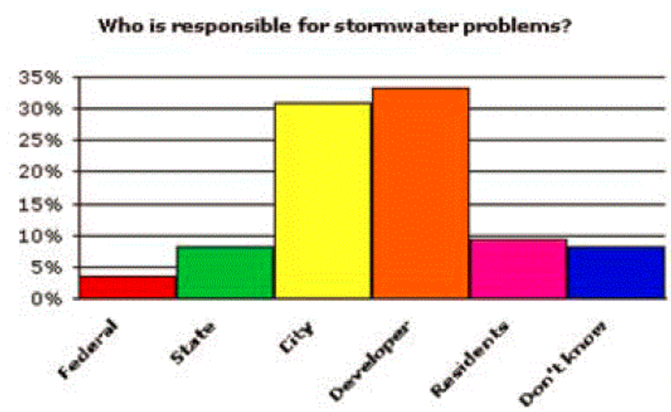

Figure 3.2. Responses to the following RAN survey question: "If stormwater is a problem in your neighborhood, who do you think has primary responsibility for fixing the problem?" *Source:* Adapted from Bowden et al., (2006)

Despite the value assigned to the lake, the RAN survey showed that residents were applying little systems thinking to regional or neighborhood stormwater issues; nor did residents perceive the link between backyard practices and the cumulative outpouring of nonpoint pollutants into the lake as obvious or straightforward (Bowden et al., 2006). Finally, residents did not realize that the state-established TMDL cap had created the need to take action at the individual level, and they were reluctant to pay out-of-pocket costs to retrofit stormwater systems.

In light of the survey findings, one of the project team's objectives was to establish a connection between local actions and the quality of the water in Lake Champlain. At the local scale, where conventionally built, medium-density residential neighborhoods are responsible for much of the nonpoint pollution of streams and lakes, achieving the connection would mean (1) returning impaired watersheds and streams to a condition that would approximate the hydrological properties of unimpaired watersheds and streams and (2) adjusting stormwater flows to Lake Champlain to meet the TMDL standards.

The RAN survey showed that a great deal of effort, time, and technical expertise would be required (1) to convey the value of a systems approach to stormwater management, (2) to come up with a detailed plan for identifying, creating, and using landscape features for small- to midscale BMPs, and (3) to make such a plan acceptable to the public. Figure 3.3, which depicts the response to the question

“What are the solutions?”, illustrates residents’ preference for conventional engineering solutions. Moreover, as figure 3.4 shows, residents were willing to adopt a mix of practices to improve stormwater quality, but were not interested in contributing time and money to such efforts.

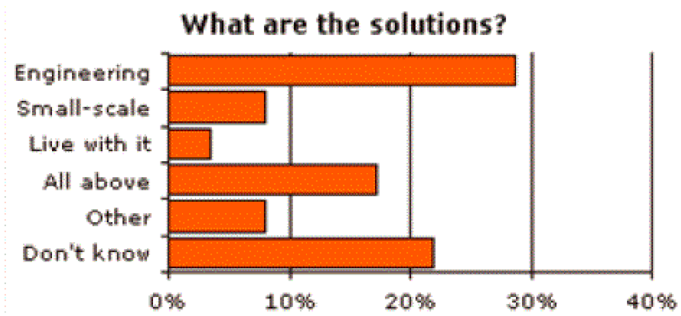

Figure 3.3. Responses to the following survey question: “What are the solutions? ” *Source:* Adapted from Bowden et al., (2006).

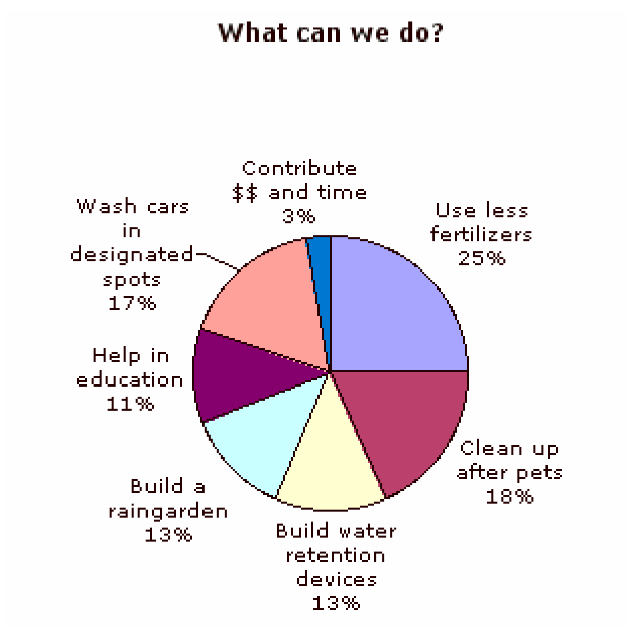

Figure 3.4. Responses to the following survey question: "What can we do?" *Source:* Adapted from Bowden et al., (2006).

When the results of the Butler Farms/Oak Creek neighborhood surveys were compared to those of the Chittenden County Regional Stormwater Education Program survey (see table 3.1), the project team noted an unusually high level of pesticide and fertilizer use in the Butler Farms and Oak Creek neighborhoods. In both surveys, however, respondents' significant level of concern for the environment was paired with a disinclination to change behavior (Hinds et al., 2005).

		Chittenden County Regional Survey	Butler Farms Neighborhood
Use pesticides?	***Yes***	**39%**	**82%**
	No	61%	18%
Use lawn fertilizers?	***Yes***	**40%**	**85%**
	No	60%	15%
Always clean up after pets?	Yes	72%	73%
	No	28%	27%
Where does stormwater go?			
	Don't know	**27%**	**32%**
	Streams/Lake Champlain	20%	19%
	Stormwater treatment system	27%	35%
	Wastewater treatment plant	3%	10%
	Absorbed into ground	19%	2%
	Other	4%	2%

Table 3.1 Comparison of responses to a regional survey and to the Butler Farms/Oak Creek survey. *Source:* Adapted from Hinds et al. (2005).

Using Claritas data, the project team assessed the demographic characteristics of the Butler Farms/Oak Creek neighborhoods: the results showed that the neighborhoods are among the 1.92% of U.S. marked by *both* affluence and the highest education level. The survey findings were thus consistent with those of other studies, which indicate that higher education levels do not necessarily translate into sound environmental decisions or a willingness to accept systems thinking (Blake, 1999; Courtenay-Hall & Rogers, 2002; Kollmuss & Agyeman, 2002). In short, citizens with advanced degrees often display behavior patterns that are totally divorced from those recommended by best management practices.

Findings of RAN and regional surveys indicated that there is no straightforward way to achieve the objectives of the RAN project.

3.9.3. Preliminary Hydrologic and Costs Assessments

The topic of stormwater management was (and is) of concern to the Butler Farms and Oak Creek Village neighborhoods for a variety of environmental reasons, and as aspect of general neighborhood wellbeing. Preliminary data analysis and research showed that the neighborhoods had been built on clay soils with very poor drainage, and that they served as a nexus for incoming water (from a large golf course to the west and agricultural areas to the south) (Voinov Vladich 2, 2012).

The engineer's preliminary assessment showed that between two proposed conventional solutions for upgrading the stormwater system for the two neighborhoods the total cost is expected to be between $1 and $2 million, which came out to approximately $3,000 - $5,000 per household. And, even though the education about alternative dispersed BMPs was met with a positive response, there was no way to bring the alternative approach to fruition in the neighborhood: at the beginning stage of the project there was no exact understanding of where the most sensitive points to intervention were, no mechanism existed to identify where to effectively locate mid-scale versus small-scale BMPs, and it was no interest among residents in possibly spending even more money for something they haven't been convinced is pertinent to their household.

Thus, the next step was to devise a strategy that would shift the balance of opinion in favor of the alternative approach.

3.10. Applying the PSA Framework

To tackle complex and sensitive issues at a time of crisis, the RAN project team developed the following list of tasks:

- Develop a tool that could be used to analyze and understand the hydrological processes at the scale of the watershed where the neighborhood is located.
- Educate residents about the results of the analysis.
- Use active stakeholder participation to refine the data about the system.
- Devise a strategy to create a turning point that will lead away from tension and conflict and toward trust and acceptance.
- Create a tool with high visualization power to help disseminate information and promote the results of the analyses to the stakeholders.
- Create a constructive negotiation and consensus-building environment in which to present the alternative approach to stormwater management.

- Create a tool to identify locations for BMPs at various scales.

PSA approach has been chosen as the most effective and best suitable in this case, since, combined with high resolution LiDAR data it was: (1) instrumental in demonstrations with stakeholders, since it correlates precisely with the residents on the ground observations “raindrop pathways” on their own properties, (2) constituted the basis for the trust between RAN research team and the residents of Butler Farms/Oak Creek Village communities and (3) provided the cognitive bridge between the local backyard actions and their impacts on the water quality in the stormwater runoff following to the tributary and sequentially to the lake.

3.10.1. Identifying the “Source Areas” and “Areas of Opportunities”

The project team applied ArcGIS modeling tools to the LiDAR data to identify and delineate “Source Areas” and “Areas of Opportunity”. “Source Areas” are defined here as subwatershed areas that contribute heavily to the total runoff (most of which, in this case, were located outside the neighborhoods, and were therefore inaccessible to stakeholders’ decisions regarding BMPs). “Areas of Opportunities” are those where interventions, at various scales, would be appropriate.

As a result of the initial PSA, the following areas were identified (see fig. 3.5):

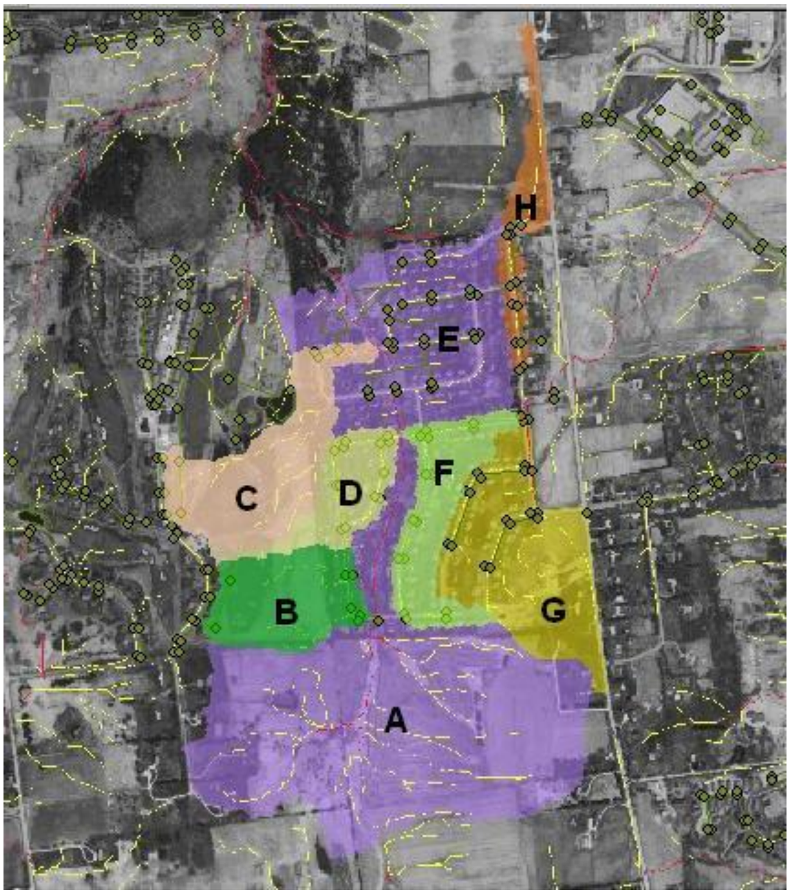

Figure 3.5. Source Areas and Areas of Opportunities delineated on the base of 3m LiDAR elevation data. **Key**: **A, B** and **C** – **“Source Areas**”; **D,E** and **F** - **“Areas of Opportunities**”; **G** and **H** - Areas, artificially connected by piping, during the process of the re-grading and construction

- A, B and C – identified as mostly “Source Areas”. Most of those areas extended well beyond the administrative boundaries of the Butler-Farms/Oak Creek Village neighborhoods and were (and are) well beyond the control of the neighborhoods residents (Golf Course and Marceau Farm upstream properties geographically belong to the areas A, B and C). A, B and C “Source Areas” covered significant portion of the total watershed, encompassing the Butler-Farms/Oak Creek Village neighborhoods, bringing a significant amount of incoming sediments and stormwater runoff. The findings of "Source Areas" had very important implications for the resulting development of the alternative distributed stormwater management plan. Similarly, identification of the areas A, B and C was important for the negotiation process between the Butler-Farms/Oak Creek Village neighborhoods, the city and the state officials, since these results showed that a significant portion of the additional stormwater runoff, going through the Butler-Farms/Oak Creek Village neighborhoods, was causing recurring flooding, made it harder for the residents to comply with the stormwater regulations and made them responsible for the stormwater runoff, external to the neighborhoods. The engineering solutions were recommended along the boundaries of the Butler-Farms/Oak Creek Village neighborhoods, to protect the neighborhoods from the recurrent flooding, caused by incoming runoff from areas A, B and C, before conventional or alternative stormwater management solutions could be applied inside the Butler-Farms/Oak Creek Village neighborhoods;

- D, E, F - identified as the "Areas of Opportunities", where the conventional or alternative mid-scale BMPs and the small-scale distributed BMPs were most appropriate;
- G, H – hydrologic analysis, based on LiDAR data showed, that, according to the resulting subwatresheds delineation, the areas G and H were artificially connected

by piping to the Butler-Farms/Oak Creek Village neighborhoods stormwater system during the process of the regrading and construction. Thus, the stormwater runoff from the areas G and H added significant amounts of stormwater and pollutants, running through the Butler-Farms/Oak Creek Village neighborhoods. These findings had very important implications for the consequent development of the alternative distributed stormwater management plan. Similarly, identification of the areas G and H was important for the negotiations between the Butler-Farms/Oak Creek Village neighborhoods and city and state officials, since these results showed that yet another portion of the additional, artificially generated stormwater runoff, going through the Butler-Farms/Oak Creek Village neighborhoods, made it only harder for the residents to comply with the stormwater regulations. Restoring the natural stormwater pathways was recommended as one of the ways to reduce stormwater loadings, coming from the Butler-Farms/Oak Creek Village neighborhoods area.

3.10.2. An Imperviousness Assessment Model for the Butler Farms/Oak Creek Neighborhoods and the Encompassing Watershed

The spatial analysis (Summary Statistics) showed that the total area contributing stormwater to the Butler Farms/Oak Creek neighborhoods was three times the size of the neighborhoods alone, and that the level of imperviousness in the neighborhoods was twice the average of the contributing areas (Appedix A3) (see table 3.2). During the decision-making process, these findings created extensive negotiation opportunities for residents of the Butler Farms/Oak Creek neighborhoods (see description of the “Sources Areas” A, B and C and fig. 3.5).

	Area (acres)	Percentage of impervious surfaces
Butler Farms/Oak Creek	110.6	28
All contributing subwatersheds	315	14

Table 3.2 Total areas and percentage of impervious surfaces for Butler Farms/Oak Creek neighborhoods and contributing watersheds

3.10.3. Establishing Trust

PSA was of particular importance for building trust:

1. Identifying the “Source Areas” (see areas A, B and C on fig.3.5) and assessing total contributing area versus the area of Butler Farms/Oak Creek neighborhoods itself, helped residents, city and state see the whole picture and understand that a significant portion of the additional stormwater runoff was flowing through the Butler-Farms/Oak Creek Village neighborhoods.

2. Identifying, that areas G and H (see fig.3.5) were artificially connected by piping to the Butler-Farms/Oak Creek Village neighborhoods stormwater system, during the process of the regarding and construction during the process of the regarding and construction was important for the negotiations between the Butler-Farms/Oak Creek Village neighborhoods, the city and the state officials, since it brought the understanding that yet another portion of the additional, artificially

generated contribution of stormwater runoff, combined with the runoff from areas A, B and C was going through the Butler-Farms/Oak Creek neighborhoods.

3. Because the results of the analysis and developed indices were easily visualized by stakeholders, PSA approach gained even more trust-building value.

Identification of “Source areas” A,B, C and artificially connected areas G and H, in addition to the information regarding clay soils with poor drainage properties, explained why the Butler-Farms/Oak Creek neighborhoods had suffered from standing water on the properties, repeated flooding from snow melt and storms, and clogged and eroded swales—all of which had led residents to repeatedly complain to the city.

These findings brought the understanding that the Butler-Farms/Oak Creek neighborhoods case study requires special attention and assistance.

Once the trust was established, it became clear that there is a pressing need to work with the city, upgrade the neighborhood’s privately-owned stormwater system to State standards, and turn over the system to the newly-formed stormwater Utility – thereby relieving neighbors of individual responsibility for the state discharge permit.

Moreover, results of the analysis together with the history of flooded basements and driveways, standing water on properties, and eroded and clogged swales highlighted the fact that alternatively redesigned stormwater system would greatly benefit neighborhood residents as well as the environment.

3.11. Consensus Building Outcomes

The results of the PSA were presented at a meeting of the SWG that included the state commissioner for the environment, and the chief of the stormwater section at the Vermont Agency of Natural Resources (RAN1: Redesigning the American Neighborhood, 2006). The practical outcomes yielded by this particular meeting were the culmination of all the previous consensus-building efforts.

There were two primary meeting objectives: (1) to provide information to residents of Butler Farms and Oak Creek neighborhoods who had not been as involved in the process as the members of the SWG had been, and (2) to ensure that the state officials had the opportunity to hear residents' concerns about the stormwater situation in the Butler Farms and Oak Creek neighborhoods.

This meeting yielded three very important conclusions:

1. Because these neighborhoods are located in a complicated area of the watershed, many of the stormwater problems they experience are well beyond their control, and therefore require higher-level decision making.
2. Because of the absence of the homeowners associations, there was no available mechanism for the neighborhoods to make a community-wide decision about stormwater management.

3. The timing of the next steps was uncertain: the EPA had to approve the Potash Brook TMDL code, and the state had to issue a General Permit. If either of these steps were to be challenged in court, further delay would result. This possibility was of grave concern to residents, who wanted to know when they could expect to clear their titles, either through a valid stormwater permit or through a utility takeover of the system.

Two agreements and one proposal emerged in the course of the meeting:

- Given the time gap that might arise, the city's utility would accept the Butler Farms/Oak Creek stormwater system, regardless of the status of the state or EPA permits, once an engineering alternative had been constructed that was consistent with the Engineering Feasibility Assessment (EFA/2002 Best Fix) standard (such an arrangement had already been made for several other residential systems). The city was willing to accept responsibility for obtaining the permits once a state General Permit was in place.
- Any system for which a valid engineering plan had been developed and for which funding was set up would be able to apply for coverage under the General Permit; once a valid Notice of Intent to seek coverage was in place, the system would be in compliance, as long as construction occurred within a reasonable time frame.
- Under existing state authority, a municipality with a valid utility has the authority create "special benefit" districts and to collect funds from affected ("benefited") property owners, in order to recover the capital cost of an improvement specific to a geographic area. Such actions do not require a vote by those who are affected,

but obviously the city would want to ensure that there is consensus about both the solution and the costs before proceeding with such a district. The city is also the only body that is in a position to seek grants or other state funding to help offset costs.

These ideas suggested a potential way forward that would include the following steps:

1. Complete the full engineering feasibility analysis of the primary options (small-scale distributed system, midscale meso-systems, and superpond) and complete a cost analysis (construction and maintenance) for each option. (Note: small-scale distributed system was later named alternative distributed Integrated Modular Landscape-based Stormwater management plan (IMLaS); another name for midscale meso-systems was - option 1a; and another name for super pond was - option2 (Voinov Vladich 4, 2012)).
2. SWG will work with the city on funding, cost, and payment structure.
3. Ask the engineer to formally request that the stormwater utility take over the stormwater system.

Because of the findings of the hydrological analysis and the fact that the Butler Farms/Oak Creek neighborhoods were such a large project, with a high proportion of publicly owned impervious surface, the city was willing handle the contracting and financing for implementing a solution, despite the fact that many small condo associations were doing so on their own.

3.12. Discussion

As noted earlier, the project team's early discussions with residents about a systems approach to stormwater management attracted only lukewarm interest and participation. But growing awareness of the financial implications of the mandatory retrofit and the moratorium on home sales invigorated the process dramatically, and attendance at meetings jumped by an order of magnitude.

The challenge was then to put alternative stormwater management into the context of systems thinking. It appeared that in the face of a significant potential for financial impact, an intensive, detailed, and neighborhood-specific education program; PSA; and community decision-making could offer an opportunity to incorporate systems thinking into the choice of solutions. The final outcome of this project was to reveal how these objectives could be balanced.

3.13. Conclusions

It is in the context of environmental consensus building and conflict resolution that science comes closest to exhibiting the full spectrum of its constructive value. In the case of the Butler Farms/Oak Creek neighborhoods, scientific knowledge was shared not to prove the superiority of one policy over another, but to educate all participants about the status and quality of available information. Moreover, the role of science went beyond that of discovery. By working together to construct a joint understanding of the technical aspects of the standard-setting task, groups with competing political interests learned to listen to one another and to appreciate each other's talents, skills, and knowledge base. Importantly, those with specialized expertise were explicitly reminded that their role was to educate the group on technical issues—not to intimidate.

The fact that the PSA results presented at the SWG meeting agreed with residents' experiences and local knowledge made the results highly convincing (RAN1: Redesigning the American Neighborhood, 2006). This congruence increased trust between residents, researchers, and the city. The PSA results also made it possible to identify effective intervention areas for BMPs at different scales, and helped the city strengthen its negotiations with the state, through the use of precise spatial analysis.

A number of factors built the foundation for consensus:

- Providing the methodology for targeting and prioritizing residential stormwater BMPs at three different scales
- Providing the basis for comparative cost/benefit analysis of conventional and alternative stormwater BMPs intervention scenarios (described in details in (Voinov Vladich 4, 2012)
- The ease of educating neighborhood residents by enabling them to visualize the effect of various processes on the living landscape of the watershed
- Increasing the level of systems thinking and obtaining more effective public engagement in local stormwater management decisions and solutions.

- Facilitating trust building between residents, researchers, and city representatives through a high level of visual detail that coincided with residents' everyday observations on the ground
- Redirecting the conflict to constructive mode and facilitating the goal-setting process
- Building up the negotiating power for the neighborhood residence
- Providing the basis for an understanding between city and state officials that helped with the negotiation of process details, methods, and resource allocation.

The decision making process was also directly affected by the following:

- Making clear which steps were needed to reach the desired solution
- Helping to properly time the steps in the process
- Allocating the resources needed to accomplish those steps

In conclusion, any environmental conflict where water quality or quantity is at stake is likely to benefit from the application of PSA based on high-resolution LiDAR and remote-sensing data during the stakeholder engagement process.

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CHAPTER 4: PARTICIPATORY SPATIAL ANALYSIS, ECOSYSTEM SERVICES VALUATION AND THE DEVELOPMENT OF AN INTEGRATED MODULAR LANDSCAPE-BASED STORMWATER MANAGEMENT FRAMEWORK: TURNING A NUISANCE INTO AN ASSET

4.1. Abstract

There is widespread concern about the environmental impacts of stormwater runoff from residential properties. Local and state agencies, in particular, are aware of both the need for stormwater management and the potential value of low-impact design (LID) practices. However there are few tools that can help residents make informed decisions about alternative methods for distributed stormwater management.

Retrofitting an existing stormwater system can be costly. This is often viewed as a burden for the neighborhood residence and can stir up a conflict between residents and state and local governments. To help mitigate a local conflict and design a new, alternative, landscape based stormwater management system, a participatory framework for environmental consensus building – Participatory Spatial Analysis (PSA) has been developed as part of the project Redesigning American Neighborhood (RAN), School of Environment and Natural Resources, University of

Vermont. The cumulative result of applying this framework along with a developed innovative methodology to derive the spatial Micro Stormwater Drainage Density (MSDD) index, which allows to target small and medium scale best management practices (BMPs), introduction of the concepts of ecosystem services, reference state, broad cost-benefit analysis (BCBA) ultimately led, through the multiple working mediating atelier-type sessions with the stakeholders, towards the alternative Integrated Modular Landscape - Based Stormwater Management (IMLaS) plan for action.

4.2. Introduction

The natural environment provides people with goods and services that are fundamental for human well-being, and those services that are related to the protection of water quality and quantity are of key importance to humanity. When environmental damage degrades such services, the economic implications can be serious. Damage to ecosystem services poses environmental risks, such as flooding or water pollution, which may to have to be replaced by costly human-designed services.

In some less-developed areas, healthy, functioning ecosystems provide significant water-regulating services (Costanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment (Program), 2005). Where extensive urban development has been undertaken, however, overland flow over impervious areas dominates, and ecosystems have been modified to such an extent that water-regulating ecosystem services are difficult to detect (Arnold & Gibbons, 1996;

Brabec, 2002b; Schueler, 1992). When rain falls on such areas, a variety of engineered systems collect, concentrate, and then abruptly discharge the stormwater into local receiving waters; this process accelerates the hydrologic cycle, causing the rainwater to accumulate contaminants, including suspended sediments, heavy metals, hydrocarbons, and pathogens that may impair the use of the receiving waters (Bowden et al., 2006; Burns et al., 2005; Paul & Meyer, 2008; Walsh et al., 2009).

Centralized, engineered stormwater treatment facilities are typically used to substitute for landscape-based water-regulating services—a strategy whose short-term economic costs and benefits are relatively easy to quantify (Hartigan, 1986). In the case of conventional detention ponds, for example, the costs of construction, assessed through conventional cost-benefit analysis (CBA), can easily be compared to the benefits gained by protecting the downstream value of the receiving waters (Braden & Johnston, 2004). The short-term environmental benefits (e.g., contaminant settling and discharge reduction) are also well-known (Wakelin, Elefsiniotis, & Wareham, 2003).

However, some long-term ecological and social costs—such as the absence of protection for upstream receiving waters and the failure to protect against some impairments, like pathogens—are less easy to assess or quantify (Lieb & Carline, 2000). One reason for the difficulty of such assessments is that local water-regulating ecosystem services are part of regional and global cycles that are excluded from conventional CBA (Costanza, 2006; Daly & Farley, 2003; Farley, 2008b). Nor are the costs of maintaining an engineered substitute compared to those associated with those of restored ecosystem structures and services, powered by the sun. Finally, the social costs/benefits of restoring landscape-based structures and services are rarely explored. In the long run, the absence of broad accounting during the process of decision making, often lead conventional CBA to inefficient outcomes (Costanza, 2006). The question then is whether a conventional engineered approach to stormwater management is really the best option, or whether it is just the easiest one to implement, either socially or operationally.

Instead of using costly engineered solutions, alternative approaches to stormwater management rely on targeting and utilizing landscape micro-depressions to restore ecosystem services (Voinov Vladich 2, 2012). Low-impact, ecologically designed stormwater management practices are relatively easy to implement in the case of new construction, given adequate incentives or willingness. Retrofitting existing, traditionally constructed developments to meet a low-impact, ecologically designed standard is a much greater challenge (Bowden et al., 2006).

Existing residential developments pose three principal challenges:

- *Technological tools*: Tools are needed that will allow users to (1) identify points of intervention at different, subwatershed scales and (2) target locations for the use of best management practices (BMPs) at different scales (Voinov Vladich 2, 2012)
- *Tools for environmental conflict resolution*: Because a retrofit of an existing stormwater system can be costly, and comes in the form of a coercive regulation

from city and state authorities, residents may view it as a burden—which can lead to conflict between residents and state and local governments (Voinov Vladich 3, 2012)

- *Decision-making tools that account for sustainability and intergenerational justice*: It is necessary to develop methods and present the full range of costs and benefits (economic and noneconomic) in the course of a decision-making process, which allow stakeholders to determine priorities between conventional and alternative approaches to stormwater management

This chapter describes final step of the application of participatory spatial analysis to the development of an integrated modular landscape-based stormwater (IMLaS) management approach. This chapter also discusses the three concepts—the valuation of ecosystem services, BCBA, and the reference state—that the RAN project team used to enable stakeholders, regulators, and researchers to (1) collectively visualize alternative futures and (2) optimize a mix of stormwater management interventions at various scales to best balance environmental and social, as well as economic, criteria.

There are two major problems with conventional CBA. One is the exponential discounting future costs and benefits. issues to address during the decision making process is the problem of discounting the future (Ali, 2003; Farley, 2008b; Heal, 2000; Weiss, 1990). One way to enlarge "the shadow of the future" (Axelrod, 1985) p.30 in the context of decision making is by introducing the envisioning of the reference state - the notion of "Psychological ownership" (Zerbe, 2001) p.20 into the process of decision making (Farley & Costanza, 2002; Kahneman & Miller, 1986; Zerbe, 2001).

Another is the failure to account for the full range of costs and benefits. An approach that can enlarge decision-making considerations beyond the traditional confines of economic efficiency is broad cost-benefit analysis (BCBA), which consider a broader set of goals by including ecological sustainability and social fairness, and broader range of costs and benefits by including four main types of capital that contribute to human well-being: built, human, social, and natural (Costanza, 2006).

The research on which this chapter was based was undertaken as part of the University of Vermont's RAN program, which was focused on evaluating the social acceptability and environmental outcomes of different scales of stormwater management approaches in a Butler Farms/Oak Creek neighborhoods of South Burlington, Vermont, facing an expensive stormwater system upgrade.

4.3. Study Site, Research Objectives, Methods and Data

4.3.1. Study Site

See section 3.3.

4.3.2. Research Goal

The goal of this chapter is to empirically show that the complex of various technological and ecological economic tools, discussed herein, lead to more efficient results in decision-making. This is achieved by harnessing the existing experience of working with stakeholders to develop approaches to identify practicable low-impact stormwater management alternatives in existing suburban environments. These tools help to prioritize sustainability and promote equitable intergenerational solutions, which becomes increasingly appropriate as we approach ecological thresholds.

4.3.2.1. Research Objectives

When non-excludable, intergenerational goods and services are at stake in decision making, conventional approaches to valuation, such as CBA, lead to inefficient outcomes: the use of single metrics will always favor the conversion of the landscape into development, with a resulting increase in imperviousness or conventional engineering solutions for stormwater management. Another perennial problem associated with CBA is the convention of discounting the future, and thereby reducing the present value of future environmental benefits from today's actions. This approach can work as long as the carrying capacity of the landscape can support the transition; but when the carrying capacity is threatened, additional mechanisms are required to maintain ecological balance:

- Regulation is required to set the caps, and thereby restore and protect the carrying capacity required for the health of the watershed

- New technological tools are critical for ensuring the allocative efficiency of the decisions that must be made in order to meet regulatory caps
- BCBA, which captures secondary benefits associated with natural, social, and human capital, is essential for balanced decision making
- It is essential to bring the concept of ecosystem services and the valuation of such services into the decision-making process
- To enlarge "the shadow of the future" and make it easier to distinguish between changes that lead to losses and those that lead to gains, it is critical to introduce the concept of the reference state into decision making.

4.3.2.2. Research questions

- How can participatory spatial analysis (PSA) and Micro Stormwater Drainage Density (MSDD) index (Voinov Vladich 2, 2012) be used to develop an alternative solution for stormwater management in an existing neighborhood?
- In addition to regulation and filtration of storm water runoff, the alternative distributed landscape-based approach to stormwater management could provide an array of ecosystem services, ranging from habitat for important species to scenic beauty (e.g. stream restoration, storm water parks, rain gardens, etc.). Can all of these different services be measured in the same units (e.g. dollars)?
- Can the introduction of the reference state and BCBA help move stakeholders toward acceptance of an alternative approach to stormwater management?
- How efficiency of decision can benefit from the use of BCBA?

4.3.3. Methods and Data

4.3.3.1. Technological Tools

The PSA was based on high-resolution LiDAR (Light Detection And Ranging optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light) and QuickBird data (for a description of PSA data, see Appendix 1.1). ERDAS IMAGINE 8.7 processing methods (geospatial data authoring system, incorporates geospatial image processing and analysis, remote sensing and GIS capabilities into a powerful, convenient package) were applied to calculate the Normalized Difference Vegetation Index (NDVI) in conjunction with the threshold method as a basis for impervious surfaces identification and delineation.

The Micro Stormwater Drainage Density (MSDD) index, aimed to target landscape depressions as the areas for small and mid-scale best management practices (BMPs), was developed as the first part of the ArcGIS ModelBuilder tool ("Hydrologic analysis"). Stormwater runoff volumes and sediment quantities were estimated for the delineated landscape depressions, using the SIMPLE method (Voinov Vladich 2, 2012).

To assess the percentage of impervious area for different land use categories within the subwatershed and the total watershed (see Appendix A3), the project team used the second part of the ArcGIS ModelBuilder tool (Summary Statistics).

To develop a distributed integrated modular landscape-based stormwater (IMLaS) management plan (option3), the project team used one layer of the MSDD index, along with (1) the results of the hydrological analysis for the entire watershed, (2) South Burlington Impervious Surfaces layer, derived from 2.44m multispectral Quick Bird Data and (3) data on land use and engineering pipes.

Layer of MSDD index together with the results of the whole watershed hydrological analysis, the developed layer of impervious surfaces, land use and engineering pipes data, were used in the process of the option 3 development - distributed alternative integrated modular landscape-based (IMLaS) stormwater management plan.

All processing was automated using ArcGIS ModelBuilder.

4.3.3.2. Public Participation

At the beginning of the project, the City of South Burlington established the Stormwater Working Group (SWG), a group of neighborhood volunteers who met about once a month with RAN team members, city officials, and an engineer to tackle technical questions. It was during these meetings that three distinct options for stormwater management were presented, discussed, and voted on (see section 4.9.3) (RAN2: Redesigning the American Neighborhood, 2007). A Web site that included all SWG-related information, documents, data, and communications was used throughout the decision-making process:

http://www.uvm.edu/~ran/?Page=homeowners.html

Survey: At the beginning of the project, the RAN team undertook an initial survey of the residents of the Butler Farms and Oak Creek neighborhoods. The survey was developed with three goals in mind:

- To understand how people perceived the stormwater issues and determine what they knew about stormwater-related problems
- To collect information about behavior patterns and daily practices related to stormwater
- To evaluate residents' overall level of environmental awareness and willingness to act and/or change.

The results of the survey can be found in the Annual Report, Project Years 1 and 2 (2003–2005), November 27, 2006 (http://www.uvm.edu/~ran/?Page=documents.html) (Bowden et al., 2006).

The Claritas database was used to assess demographic characteristics, including socioeconomic status, household characteristics, and lifestyle behavior (Claritas, 1999).

4.3.3.3. Decision-making tools that prioritize sustainability and intergenerational justice

This chapter describes several tools: (1)Valuation of the ecosystem services (see section 4.4); (2) Policy implications of the correspondence between three regions of ecosystem services supply-demand curve and three stages of the relationship between impervious cover and stream quality (see section 4.5, 4.6); (3) Broad cost benefit analysis (BCBA) (see section4.7); (4) Reference state (see section 4.8).

BCBA is seen as a form of multicriteria decision analysis (MCDA), in which the biophysical implications of alternatives are carried forward as far as possible in the analysis (Costanza, 2006).

Data on options 1a and 2 costs have been provided by J. Meyers (StanTec Inc, 2006), cited in (RAN5: Redesigning the American Neighborhood, 2007), data on implementation costs of option 3 have been provided by T. DiPietro, Deputy director of Public Works of South Burlington, Vermont (DiPietro, 2012).

4.4. Valuing Ecosystem Services

When developing economic and noneconomic incentives to move stakeholders toward acceptance of an alternative approach to stormwater management, there are several important considerations. First, discussions of restoring ecosystem services—or creating an ecosystem that would have new functions, and therefore provide services that have not been present before— involve both infinite value and our limited current knowledge of that value (Daly & Farley, 2003; Farley, 2008b).

Second, one should recognize the even more complex ecological-economic systems exhibit dynamic, nonlinear behavior; as a result, a clear understanding of the part rarely translates into a clear understanding of the whole (Limburg et al., 2002). Thus, discussions of restoring or creating ecosystem structures—whether theoretical or practical—involve an unknown number of ecological services. This fact becomes even more important when the supply-demand curve for a particular ecosystem service (Fig. 4.1.) exhibits signs of inelastic demand or of exceeding carrying capacity to such an extent that the system is at risk of collapse (discussed below).

4.4.1. Excludability

To explain the supply-demand curve, and what it implies with respect to valuation and decision making, it is first necessary to define non-excludability of resource (Daly & Farley, 2003).

To be assessed as a market good with a market price, a resource must be excludable: that is, people who do not pay to use the resource can be prevented from using it. We also know, from the behavioral sciences, that if someone cannot be prevented from using a resource regardless of whether they pay, they are unlikely to pay. Under most circumstances, ecosystem services are non-excludable resources; thus, they lack the characteristics of the perfect market commodity. Thus, it is very difficult to assign a single monetary value to them. And because market prices do not reflect the marginal value of non-excludable resources, markets fail to "invisibly" manage ecosystem preservation. The fact that ecosystem services do not match characteristics of the perfect market commodity, making valuation of ecosystem services with a single monetary value a challenging task.

Although some ecosystem structures can be made excludable, many ecosystem services, such as climate regulation or flood regulation, are inherently non-excludable. If land is privately owned, the market will pay the owners for the benefits of conversion (e.g., for timber and farmland created by clearing forests), but it will fail to pay owners for the benefits of conservation (e.g., water and climate regulation provided by intact forests). Thus, even when the nonmonetary benefits of conservation outweigh the monetary benefits of conversion, market forces systematically favor the conversion of ecosystem structures to market production over their conservation to provide ecosystem services (Farley, 2008a).

Economic valuation—that is, assigning dollar values to ecosystem services—is one way to render ecosystem services visible and attempt to ensure that they have a place in public discourse. Unlike governmental regulations such as the Clean Water Act (1977) and Clean Air Act (1970), which are essentially coercive, the valuation of ecosystem services appeals to our rational side, encouraging a reconsideration of our apprehension and appreciation of ecosystems. By assigning value to ecosystem services, we bring into everyday environmental resource management and decision making the notion that the restoration and conservation of ecosystems are both valuable and sensible. The first global scope analysis of ecosystem services values, which was assessed and visualized through geographic information systems (GIS), was described by Costanza et al. (1997) in "The Value of the World's Ecosystem Services and Natural Capital," which appeared in *Nature* in 1997.

4.4.2. Can a Single Metric Provide a Meaningful Value?

Monetary valuation assumes that all the relevant attributes of environmental resources can be measured in the same unit: money. Many researchers have found, however, that the attributes of environmental assets are fundamentally different from each other, and that a single measure does not reflect all the important information (Aldred, 2006; Farley, 2008b; Vatn & Bromley, 1994).

One reason is that ecological– economic systems exhibit highly complex, dynamic, and nonlinear behavior in which a clear understanding of the part rarely translates into a clear understanding of the whole, since everything is part of the intricate connected complex web. Complex systems are characterized by the the presence of abrupt, irreversible thresholds (Limburg et al., 2002). At such thresholds marginal actions have non-marginal impacts and marginal analysis becomes inappropriate (Farley, 2008b).

There are several reasons that using monetary units to assign a summary value to environmental assets might yield insufficiently nuanced results. First, as noted earlier, ecological-economic systems exhibit highly complex, dynamic, and nonlinear behavior—and, as a result, a clear understanding of the part rarely translates into a clear understanding of the whole. Complex systems are characterized by the presence of abrupt, irreversible thresholds (Limburg et al., 2002), where marginal actions have non-marginal impacts, and marginal analysis is therefore inappropriate (Farley, 2008b). Second, the time lag between the loss of an ecosystem (or species) and a noticeable loss of ecosystem services may be greater than a human life span. For example, scientists believe that even if we stopped emitting all greenhouse gases today, the climate would continue to be affected for another century (Meehl et al., 2005).

Thus, it is important to emphasize that in the realm of ecosystem services valuation, full-range comparisons between economic and ecological systems are impossible, because of the incommensurability between the characteristics of environmental and economic systems. Furthermore, there is a widespread belief that ecosystem services are a human right, rather than a commodity, which is reflected in the U.S. Endangered Species Act and in some national constitutions, such as those of Costa Rica and Brazil (Farley, 2008b).

4.5. Three Regions of Ecosystem Services Supply-Demand Curve

To reach balanced decisions, it is important to understand the supply-demand curve for ecosystem services. Another consideration to bear in mind while choosing policy mechanisms and valuation methods is the actual presence of three regions in the ecosystem services supply-demand curve. As a whole, ecosystem services are just as essential and non-substitutable for human survival as food, water or energy. As noted earlier, such resources can, under certain conditions, exhibit price-inelastic demand, meaning that large changes in price lead to small changes in quantity demanded, or, vice versa, small changes in supply will lead to large changes in price (Farley, 2008a).

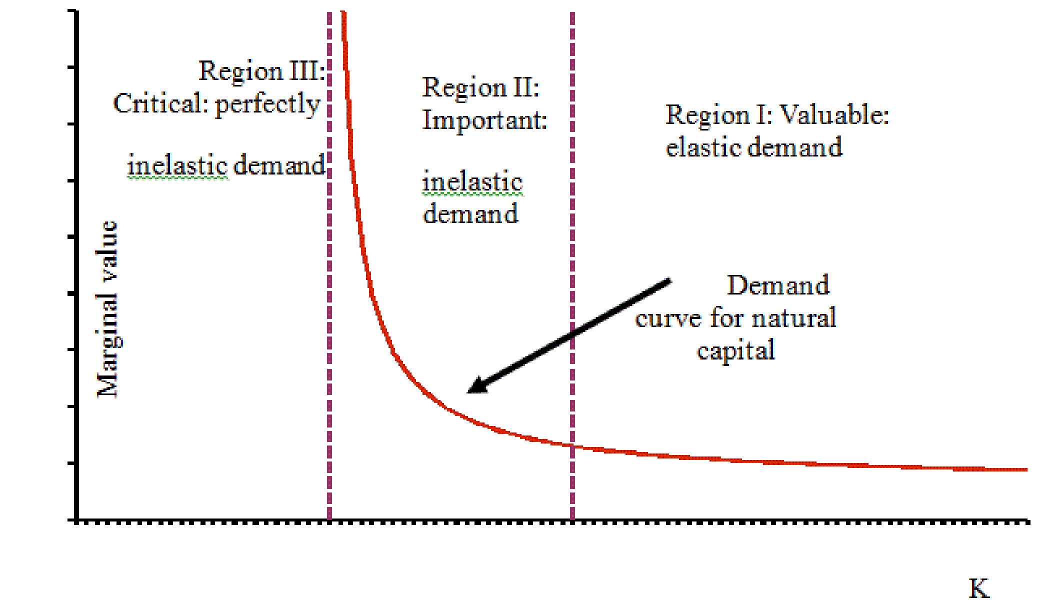

Figure 4.1. Three regions of ecosystem services supply-demand curve. *Source*: Adapted from: J.Farley (2008a). K: ecosystem carrying capacity

As Farley (2008a) has defined (Fig. 4.1), the supply-demand curve for natural capital can be divided into three regions, each of which requires a different approach to the valuation of ecosystem services and the development of policies to address ecological harm. In region I, natural capital is abundant, and its marginal value is very low and changes slowly. When the quality and quantity of natural capital decline, however, there is a fairly rapid rise in marginal value, and we enter region II of the supply-demand curve. As natural capital stocks approach the threshold of criticality, the benefits they provide are increasingly important and substitution becomes increasingly difficult, leading toward the highly inelastic demand that is characteristic of region III. At the threshold of criticality, the demand curve is almost vertical, and the marginal value approaches infinity. Beyond this point, marginal valuation becomes irrelevant (Farley, 2008a).

The supply-demand curve can help determine when it might make the most sense to rely on valuation methods to address ecological degradation, or when a regulatory approach might be the better choice, and when the two should be combined.

Region I. Monetary valuation may be appropriate in region I, where natural capital is relatively abundant. In this region, the marginal value of ecosystem services can be calculated, and those estimates can be turned over to a central authority, which would then integrate them into prices—either by taxing activities that lead to ecosystem degradation or paying for activities that protect and restore ecosystems.

Region II. In region II, the carrying capacity of the ecosystem is approaching uncertainty and natural capital declines to the point that demand becomes inelastic. Although it may still be possible to calculate the marginal value of ecosystem services, the risk of rapid change means that it will be difficult to rely on those values for decision making. In this region, instead of using prices (economic signals) to determine the appropriate level of resource use, it would be simpler—and more compatible with free markets and democracy—to use governmental regulation to determine price, and thereby address supply. Such price determinations should take into account both ecological factors and moral obligations to future generations.

Region III. In region III, the ecosystem's carrying capacity is overwhelmed, and urgent intervention is needed for the ecosystem is to survive. In this region, marginal valuation is entirely inappropriate: future generations hold the rights to the survival and health of the ecosystem, and those rights do not commensurate with monetary value. In region III, the only appropriate policy response is to restore the ecosystem's carrying capacity beyond the critical threshold first, just distribution second (polluters pay principle) and economic efficiency third (Farley, 2008a).

4.5.1. The Three Regions of the Supply-Demand Curve for Ecosystem Services and the Three Stages of Stream Impairment

For many ecosystems, efforts to identify find the boundaries between the three regions entail significant uncertainty. However, many years of research in the fields of water management including stream health (Arnold & Gibbons, 1996; Beach, 2001; Deacon, Soule, & Smith, 2005; Schueler, 1992) have shown, that in the case of stormwater management in urbanized areas, the relationship between stream health and impervious coverage, which is both a reliable and integrative indicator of the impact of development on water resources, exhibits three distinct categories (see fig.4.2), that corresponds to three regions of ecosystem services supply-demand curve (fig. 4.1).

The horizontal lines of figure 4.2 mark two threshold values of the imperviousness at which: (1) degradation first occurs (l0%), and at which (2) carrying capacity of the watershed becomes overwhelmed and non-supporting the stream quality (25%). Upper threshold of 30 % is reported by Arnolds and Gibbons (1996).

These thresholds create three stages of stream quality, which can be characterized as "sensitive" (less than l0%), "impacted" (10%-30%), and "non-supporting" (over 25-30%).

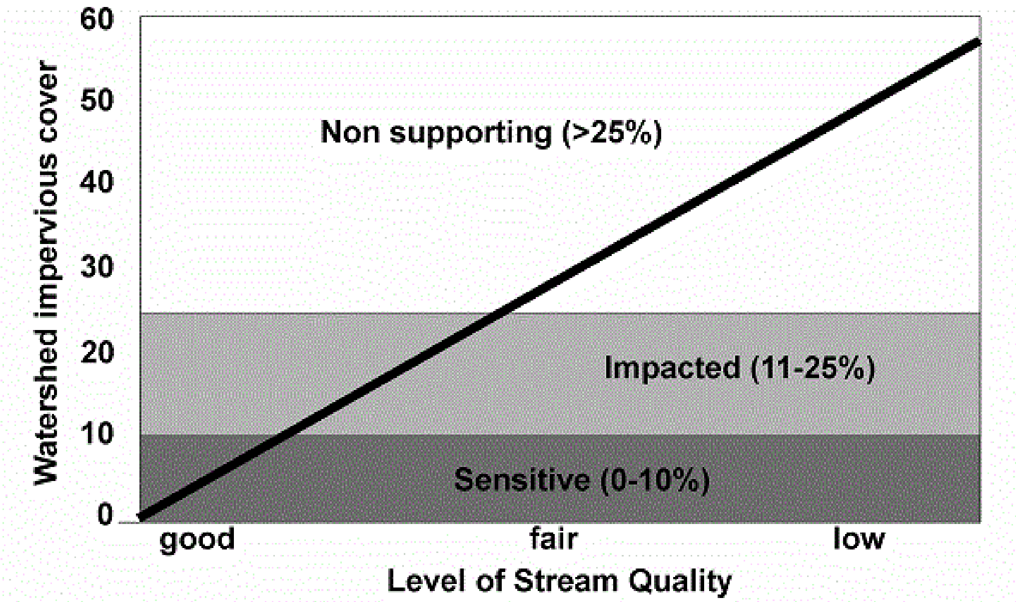

Figure 4.2. Relationship between impervious cover and stream quality. *Source*: Adapted from Schueler (1992).

The sensitive stage (0–10% impervious) corresponds to region I of the supply-demand curve for ecosystems, the impacted stage (11–25% impervious) to region II, and the non-supporting stage (>25-30% impervious) to region III.

There are two aspects of substitutability of different kinds of landscape ecosystem services that are important to note while comparing between three regions of ecosystem services supply-demand curve and three stages of the relationship between impervious cover and stream quality.

One aspect corresponds to the flood protection ecosystem service - that only one which is usually considered and substituted by conventional approach to stormwater management. This aspect does not mean that when the level >25-30% of watershed imperviousness is reached; there is no more possibility for storm water management. Those services could be substituted by either a conventional engineering approach or alternative distributed one.

Second aspect corresponds to non-substitutability of certain ecosystem services, such as habitat restoration, nutrient cycling, ground water recharge, climate regulation, aesthetic beauty, which constitute - from point of view of stormwater management - secondary benefits that are never considered by conventional storm water treatment engineering design and never are part of conventional cost-benefit analysis. This aspect of similarity is quite appropriate and important to emphasize, while solving a dilemma of the choice between conventional engineering approach and the Alternative Integrated Modular Landscape- based Stormwater management plan (IMLaS) which is geared towards the use and restoration of the full scope of landscape provided ecosystem services, while conventional engineering is strictly related to the flood-protection ES.

With the aim to restore and/or protect the carrying capacity of any lake watershed, the correspondence between the three regions of the ecosystem service supply-demand curve and the three stages of the relationship between impervious cover and stream quality suggests three principal policy implications at the scale of the smallest jurisdiction with decision-making authority:

First: as long as the imperviousness level of the watershed is below 10%, the carrying capacity of this watershed may be suitable for the conventional engineering approach for stormwater management and conventional CBA approach for costs assessment.

Second: once the level of imperviousness exceeds 10%, bringing the stream quality to the stage II, impacted, governmental regulations are recommended to address stormwater management. Depending on the imperviousness, low impact designs and the use of landscape characteristics are recommended to enhance the conventional approach to stormwater management. It is recommended to enhance CBA by BCBA in order to arrive to more efficient decision choices in the long run.

Third: once the health of a stream is in the highly impacted or non-supporting stage III, restoration becomes first priority. Conventional stormwater management approaches alone are not sufficient to substitute for the full range of lost ecosystem services; alternative approaches are preferred. CBA is inappropriate.

When comparing a conventional engineered approach, which is strictly limited to providing stormwater management services, to the IMLaS plan, which is designed to restore the full scope of landscape-based ecosystem services, it is important to keep in mind the ways in which the three levels of a stream health correspond to the three regions of the demand-supply curve for ecosystem services.

4.5.2. BF/OCV: Policies Implications

In the course of its work on the Butler Farms/Oak Creek stormwater system, the project team determined through GIS analysis that the level of impervious surfaces had reached 28% of the watershed (see Appendix A3), indicating that the ecosystem carrying capacity had been exceeded. This placed the neighborhoods in between highly impacted and non-supporting stages, with respect to stream health, and in the transitional zone between regions II and III of the supply-demand curve for ecosystem services. These findings lead to following understanding:

- There was an urgent need for intervention to restore the health of the ecosystem. With respect to stormwater management, this meant introducing a total maximum daily load (TMDL) cap on pollutants was overdue
- Conventional stormwater management approaches alone are not sufficient to substitute for the full range of lost ecosystem services; alternative approaches, utilizing landscape characteristics are preferred
- The information provided by CBA was not sufficient to support a choice between conventional engineered and landscape-based approaches to stormwater management. Given the seriousness and complexity of the needs, BCBA was a more appropriate tool. Since the system's carrying capacity had been overwhelmed, the issue of intergenerational justice was already present. As an

evaluative tool, CBA is deficient in this respect as well, because it reduces the present value of environmental benefits that will accrue in the future (Farley, 2008b; Heal, 2000).

4.6. BF/OCV – The Regulatory Approach: Capping Total Maximum Daily Load

The conflict between the residents of the Butler Farms/Oak Creek neighborhoods, the City of South Burlington, and the State of Vermont was a manifestation of the discounting future problem, set off by a regulatory approach to the issue of non-point pollution. In 2001, the state government responded to the degradation of water quality in Lake Champlain and Vermont streams by establishing TMDLs for pollutants. The City of South Burlington, in turn, created its first stormwater Utility and established a requirement for all stormwater systems to be upgraded to meet the new state standards; moreover, residents of neighborhoods located in impaired watersheds were under a moratorium that prevented them from selling their houses until the neighborhood had met the new standards (Hinds et al., 2005; Voinov Vladich 3, 2012).

It was obvious, that the top-down regulatory approach was not working well by itself, since it had not been well received at the local level. The out-of pocket costs of the stormwater system retrofit, which, in the case of the Butler Farms and Oak Creek neighborhoods, has been estimated by engineer as approximately $5,000 per household (Table 4.1), has led to the series of bitter conflicts and lawsuits.

Moratorium on selling the houses- before retrofits are completed —which were announced at the same time as the establishment of the new utility— has worsened the confrontation even more (Hinds et al., 2005; Voinov Vladich 3, 2012).

Although the regulation led to a crisis, it also created an opportunity to develop and implement an alternative stormwater management plan.

The city and the state had two goals: (1) to find a way to resolve the conflict with the neighborhoods and (2) to help the neighborhoods find a way to retrofit their stormwater system.

The neighborhoods had no choice but to comply with the city and state requirements; the question was how that compliance would be implemented. There were two approaches to consider: using a conventional, engineered approach to substitute the flood prevention service of the landscape, or taking an alternative approach, through which the natural ecosystem functions and services of the landscape could be restored. Decision making involved a lengthy, iterative process that engaged a number of different stakeholders: city planners, an engineering firm hired by the city, academic researchers, and neighborhood residents.

4.7. The concept of Broad Cost-Benefit Analysis

Current guidelines from the U.S. Environmental Protection Agency recommend following the maxims of standard economic theory: "A core set of economic assumptions should be used in calculating benefits and costs" (cited in

Arrow et al., 1996, p.222). Avoided cost, however, neither is a full measure of the value of a specific ecosystem service, nor is it the value of the whole spectrum of services provided by the landscape. Conventional CBA also does not take into account that the flow of costs and benefits over time for restored ecosystem structure, powered by sun, versus engineered substitutes, subjected to effects of entropy, is different. Furthermore, if one would perform such assessment of future costs with conventional valuation techniques - he would typically discount future costs and benefits at an exponential rate to arrive at a net present value.

Thereby, CBA: (1) considers built capital only, (2) undervalues natural capital, (3) completely disregards social capital and (4) discounts the future. Therefore, CBA leads to an inefficient outcome in case on environmental decision making in general and is completely insufficient when the ecosystem carrying capacity is exceeded.

As noted earlier, in addition to the traditional goal of economic efficiency, BCBA considers a broader set of goals that include ecological sustainability and social fairness (Costanza, 2006). BCBA takes into account four types of capital that have limited substitutability:

1. Natural capital (traditionally referred to as land), which includes ecological systems, mineral deposits, and other aspects of the natural world
2. Human capital (traditionally referred to as labor), which includes both the physical labor of humans and the know-how stored in their brains

3. Manufactured capital, which includes all machines and other infrastructure of the human economy
4. Social (or cultural) capital, a recently developed concept that includes the web of interpersonal connections, institutional arrangements, rules, and norms that allow human interactions to occur (Berkes & Folke, 1994; Costanza, 2006).

Generally, BCBA includes both monetary and nonmonetary criteria. Some elements of the four types of capital, however, can be brought under a single monetary umbrella, which opens up the possibility for natural, human, and social capital to regain value in modern decision-making processes. Without such efforts to the precious value of ecosystem services would be zero in the context of decision making. Acknowledging the levels of uncertainty and incommensurability that are inherent in such efforts, one can still argue that the notion of valuing ecosystem services, which was introduced by Costanza (1997), has created a shift in the perceptions of what nature does for humans. Once the idea of ecosystem services valuation had been established, the notion of payments for ecosystem services (PES) was the next practical step. Recent public policy advances in the direction of sustainability are based largely on BCBA and PES; for example, it was through the use of BCBA and PES that Germany became Europe's "green" (Buehler, Jungjohann, Keeley, & Mehling, 2011).

4.8. The Reference State

Instead of being determined by legal entitlements, the appropriate choice of approach to deal with the problem appears to depend on the reference state that people associate with the availability of, or access to, environmental goods; in other words, what Zerbe (2001, p. 20) refers to as “psychological ownership” may be more important than legal ownership. Although this is not an entirely operational definition, a reference state can be thought of as one that is in line with community standards of the “expected” or “normal” state (Kahneman & Miller, 1986; Knetsch, 2005).

The findings of Knetsh (2005) suggest that decision making (and perhaps conflict resolution) would be more effective if stakeholders first constructed an image of a common “reference state” that is acceptable—or even inspiring—to all parties. In other words, the visioning process comes first. (This approach has been pioneered by Farley and Costanza in *Envisioning shared goals for humanity: a detailed shared vision of a sustainable and desirable USA in 2100* (Farley & Costanza, 2002)).

Rather than being independent of reference positions, the behavioral findings suggest that people’s valuations are far more likely to be reference dependent, with losses being commonly valued substantially more than gains (Bateman, Munro, Rhodes, Starmer, & Sugden, 1997; Knetsch, 2005). Adam Smith (1812) p.311 made this observation over two centuries ago: “We suffer more . . . when we fall from a better to a worse situation, than we ever enjoy when we rise from a worse to a better” (cited in Camerer, Loewenstein, & Rabin (2003)).

Once a shared future has been elaborated, it becomes “psychologically owned” by all stakeholders, and the focus of the evaluation process naturally shifts from willingness to pay (WTP) to willingness to accept (WTA). Because all discrepancies within the shared vision are regarded as losses, stakeholders become more willing to accept “sacrifices”—which are, in fact, no longer considered sacrifices but constructive actions in support of shared goals.

Including an explicitly articulated reference state in a decision-making process enlarges what Axelrod (1985) called “ the shadow of the future” and therefore, catalyzes the cooperation during the process of decision making (Ali, 2003).

4.8.1. Valuing Future Gains and Losses

The temporal aspect—assigning a present value to future gains and losses—is particularly complex in the process of choosing a reference state. In general, stakeholders find it difficult to see the connections between today’s actions and temporally distant consequences. More specifically, unless there is a way to acquaint stakeholders with the full range of future gains and losses associated with a decision, they will be unable to properly value those gains and losses. To address this need, the RAN project team introduced stakeholders to the concept of ecosystem services; innovative tools has been developed as part of participatory spatial analysis to assist in envisioning of alternative reference states, thereby informing, enriching, and empowering the negotiation and decision-making process (Voinov Vladich 2, 2012; Voinov Vladich 3, 2012).

As noted earlier, the flow of costs and benefits for restoration versus engineered substitutes differs over time—but conventional CBA does not take these differences into account. One reason for the differences in the flow of costs and benefits is that ecosystem services are typically maintained by solar energy and other attributes of the natural landscape, whereas built capital substitutes require constant flows of raw material and energy to overcome the effects of entropy. Therefore, the maintenance costs associated with an engineered solution create a future loss, while the restored natural ecosystem services yields a future gain. Moreover, an engineered substitute is more likely to experience catastrophic failure as the result of a flood event, and to engender accompanying losses.

In order to enhance accounting - the notion of the stormwater retention and regulation by natural landscape depressions and other ES has been introduced to stakeholders in order to suggest a fuller scope of decisions and move towards the sustainable outcome. This was exactly the goal of the alternative landscape-based stormwater management plan in the case study of Butler Farms /Oak Creek neighborhoods.

Given that many of the consequences of regulatory, policy, and project options extend over lengthy time periods, the current practice of using a single rate to discount gains and losses may create a distorted basis for decision making (Knetsch, 2005). To establish a broader scope for decision making and help stakeholders move toward a sustainable outcome, the stakeholders have been introduced to the notion of retaining and regulating stormwater by means of ecosystem services, provided by natural depressions in the landscape, as well as secondary benefits of the alternative landscape- based approach. The provision of such services and benefits was exactly the goal of the landscape-based stormwater management plan developed in the course of the case study of the Butler Farms/Oak Creek neighborhoods.

4.8.2. BC/OCV- Reference states of different scales

While introducing the reference state into discussion in the case of Butler Farms /Oak Creek neighborhoods, it is necessary to take into account the nested complexity of multiple reference states in respect to multiple spatial scales. The Butler Farms/Oak Creek neighborhoods were a perfect example of a situation with a fundamental conflict between spatial and temporal scales of interest (Few, Brown, & Tompkins, 2007), in which the spatial and temporal scale of the point of concern and the required regional reference state are much larger than the scale of local decision making and action.

The **regional reference state** - is the high quality of the water in the Lake Champlain which makes the lake attractive as a recreational destination and the safe source of the water supply. Evidence of having the sense of "psychological ownership" of this reference state active in residents opinions came from a RAN survey of the Butler Farms/Oak Creek neighborhoods, which had been undertaken at the beginning of the project, geared toward assessing how much residents valued the lake and its health, and how they viewed the connections between land use practices and the quality of the water in the streams and the lake (Bowden et al., 2006) (see fig.4.4.).

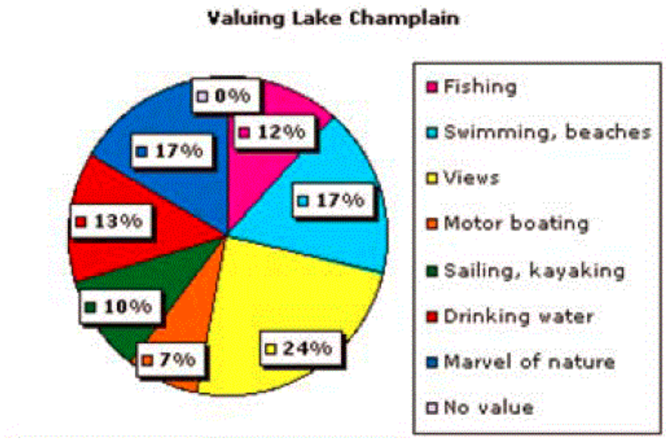

Figure 4.4. Responses to the following RAN survey question: "What do you value Lake Champlain for?" *Source:* adapted from Bowden et al. (2006)

In contrast to the psychological ownership of the reference state of the regional scale, RAN survey has shown, that the reference states of the small/local scale may have been more difficult to define for the residents themselves, because the link between backyard practices and the cumulative outpouring of nonpoint pollutants into the lake was not obvious or straightforward (Bowden et al., 2006). TMDL cap, which has been established by the state, has not been understood as the need of the action at individual level and residents were resistant to paying out-of- pocket costs for retrofitting stormwater systems (Fig.4.5).

Therefore one of objectives of the project was the reinstatement of the **local reference state**. At the local scale—conventionally built, medium-density residential neighborhoods, which are responsible for much of the nonpoint pollution of streams and lakes—the local reference state meant returning impaired watershed and stream of the neighborhood emplacement to a condition that closely parallels the hydrologic properties of streams that are not impaired adjusting stormwater flows to the Lake Champlain to TMDLs.

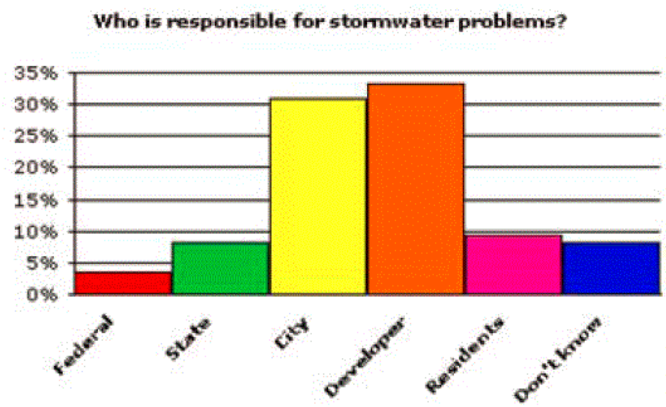

Figure 4.5. Responses to the following RAN survey question: "If stormwater is a problem in your neighborhood, who do you think has primary responsibility for fixing the problem?" *Source:* adapted from (Bowden et al., 2006)

In the context of the RAN project, PSA was envisioned as a means of achieving the following goals:

- Assisting residents to understand the interconnectedness between individual actions, stream health, and the health of Lake Champlain—and thereby avoid "the tyranny of small decisions" (Kahn, 1966) cited in (Odum, 1982) p. 728
- Connecting the visions for the regional reference state at the local scale
- Developing vision of the local reference state
- Helping to mitigate the conflict between the residents and city and state authorities

- Helping residents to adjust to the regional reference state, which was reinforced
- Helping to broaden approaches to CBA.

Engaging the city leading authority in the concept of whole system analysis, BCBA, secondary benefits and in the process of developing the vision of the local reference state was the key to the constructive decision making process (Hinds et al., 2005; RAN7: Redesigning the American Neighborhood, 2006).

4.9. Design Options for Stormwater Management

While the project team was working with the Storm Water study Group (SWG), the members requested various stormwater treatment designs, ranging from a large detention pond (the "superond" scenario) to distributed LID installations. The SWG also requested cost estimates, which were provided by Jack Myers, of Stantec, Inc. (formerly Dufresne-Henry, Inc.), a national consulting firm with an office in South Burlington (Bowden et al., 2006).

The treatment options that were developed in collaboration with the SWG represented different levels of "hard" versus "green" engineering and centralized versus dispersed treatment. The consultations with Myers, which began in 2005, resulted in two main engineered approaches to treatment.

4.9.1. Option 1a

Under option 1a, several relatively small-scale treatment systems would be distributed throughout the neighborhoods. The existing stormwater pond just

Treatment Options Presented at Meetings	Opinion of Probable Cost	Lbs of TSS Removed	Acres of Impervious Area Treated	$'s Per Acre Treated	Impervious Area that is Public (%)	Public Cost	Private Cost	Per Unit Cost
Option 1a **Butler Farms**								
Option 1a Areas 18 & 15a (Smaller Pond in Common Area)	$416,000	2059	6.1	$68,197	44%	$182,749	$233,251	**$1,609**
Oak Creek								
Area 1 (Micro Pool by Hinesburg Rd)	$231,000	1284	3.2	$72,188	57%	$131,670	$99,330	
Area 2 (Retrofit	$385,000	1760	4.1	$93,902	42%	$161,700	$223,300	
Areas 3,9,10, & 12a (Convert Swales to Treatment System)	$426,000	1184	3.1	$137,419	47%	$200,220	$225,780	
Subtotal Oak Creek	$1,042,000	4228	10.4	$100,192		$493,590	$548,410	**$4,941**
Total Option 1a	**$1,458,000**	**6287**	**17**	**$85,765**		**$676,339**	**$781,661**	
Option 2								
Treat all Areas both Developments (except Areas 1 and 19)	$2,098,000	12220	30.02	$69,887	44%	$923,120	$1,174,880	
Area 1	$231,000	1284	3.2	$72,188	57%	$131,670	$99,330	
Total	**$2,329,000**	**13504**	**33.22**	**$70,108**	**45%**	**$1,048,050**	**$1,280,950**	**$5,004**

Table 4.1. Treatement options 1a and 2with probable cost estimate, pollution reduction estimate, and areas of land treated, developed by Stantec Inc (2006); cited in (RAN5: Redesigning the American Neighborhood, 2007)

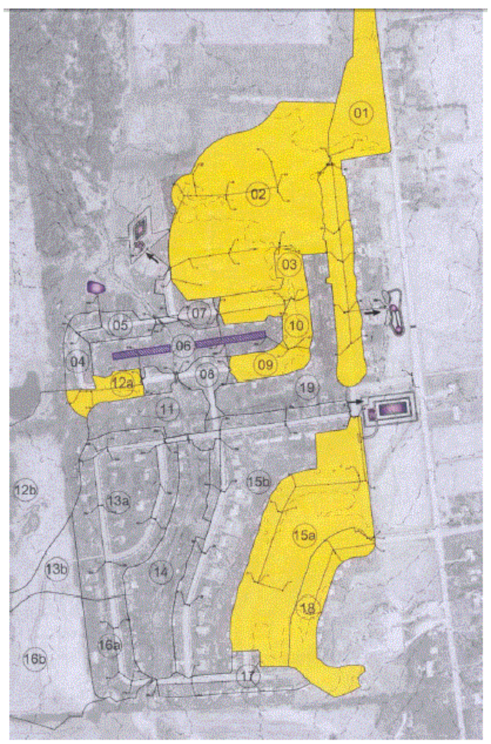

Figure 4.6. Subareas of the Butler Farms/Oak Creek neighborhoods; areas in yellow would be addressed by the infrastructure called for in option 1a. developed by Stantec Inc (2006); cited in (RAN5: Redesigning the American Neighborhood, 2007)

downstream of the neighborhoods would be retrofitted at or near its current size. Two additional small ponds would be constructed along the east side of the neighborhoods, and existing swales behind and between many of the lots would be converted into vegetated treatment systems. The average cost per household cost for this plan was estimated to be $4,941 (see fig. 4.6 and table 4.1).

4.9.2. Option 2

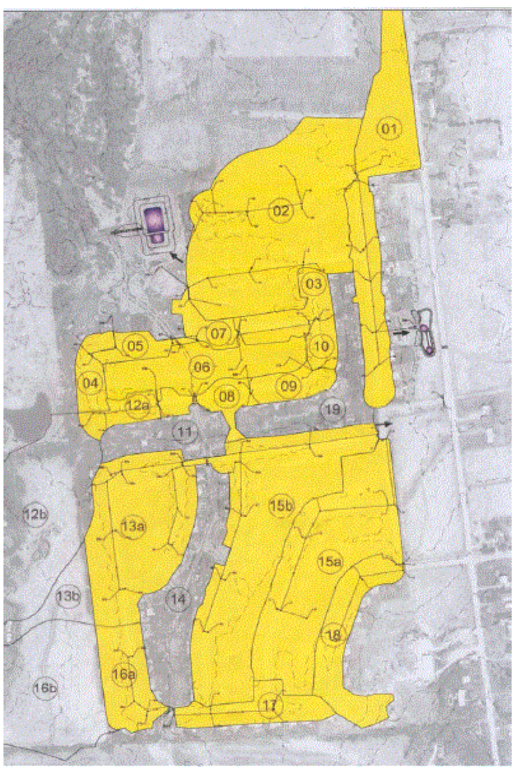

Figure 4.7. Delineated subareas of the BF/OCV neighborhoods. The areas in yellow are those treated by Option 2 with locations of required infrastructure; developed by Stantec Inc (2006); cited in (RAN5: Redesigning the American Neighborhood, 2007)

Under option 2 “super pond”, the capacity of the existing wet detention pond downstream of the neighborhoods would be significantly enlarged to accommodate all areas of the neighborhoods whose runoff could feasibly be routed to a structure in that location. The cost for this option was estimated to be $5,004 per household (see fig. 4.7).

4.9.3. Option 3: IMLaS

The first two options were developed by an engineer, at an earlier stage of the project, before participatory analysis results were presented and many educational events were conducted. Despite the fact that option 1 did not treat the whole area and did not address local flooding concerns, the lower per-household cost associated with that option suggested that even greater cost savings could be achieved through a more comprehensive embrace of LID principles.

During the first stage of the PSA, the project team presented LiDAR and QuickBird data to the SWG; this emerged as a turning point in the decision-making process. As a result of the presentation, the SWG asked the project team to develop option 3, a “whole picture,” small-scale, distributed IMLaS management plan (Bowden et al., 2008; RAN 1: Redesigning American Neighborhood, 2006).

To create a bridge from the standard engineered approach to an alternative distributed system approach, three levels of complexity had to be considered:

- The spatial characteristics of the neighborhood itself: patterns of land use and parcels ownership, patterns of imperviousness (Appendix 3);

- Patterns of natural depressions (based on Micro Stormwater Drainage Density (MSDD) index (Voinov Vladich 2, 2012); soils, vegetation;

- Inflows from surrounding areas to identify the impact to the neighborhood and best places for intervention and Best Management Practices (BMPs) of different scales (see fig.2.3 from chapter 2) (Voinov Vladich 2, 2012);

- Finally, spatial pattern of internal sub-watersheds, their expanded space beyond the limits of the BF/OCV neighborhood itself and their interconnections (see fig.4.8), including both: (1) natural interconnections (hydrology) and (2) engineered interconnections (pipes)

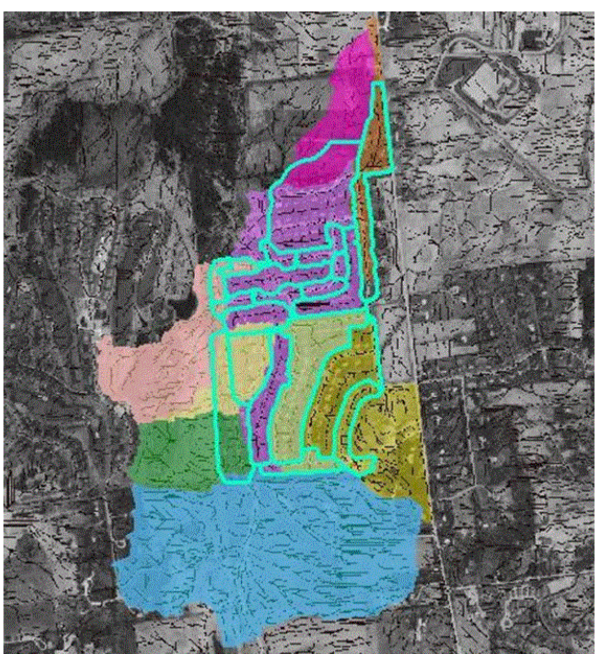

Figure 4.8. Natural and engineered
interconections of BF/OCV subwatersheds

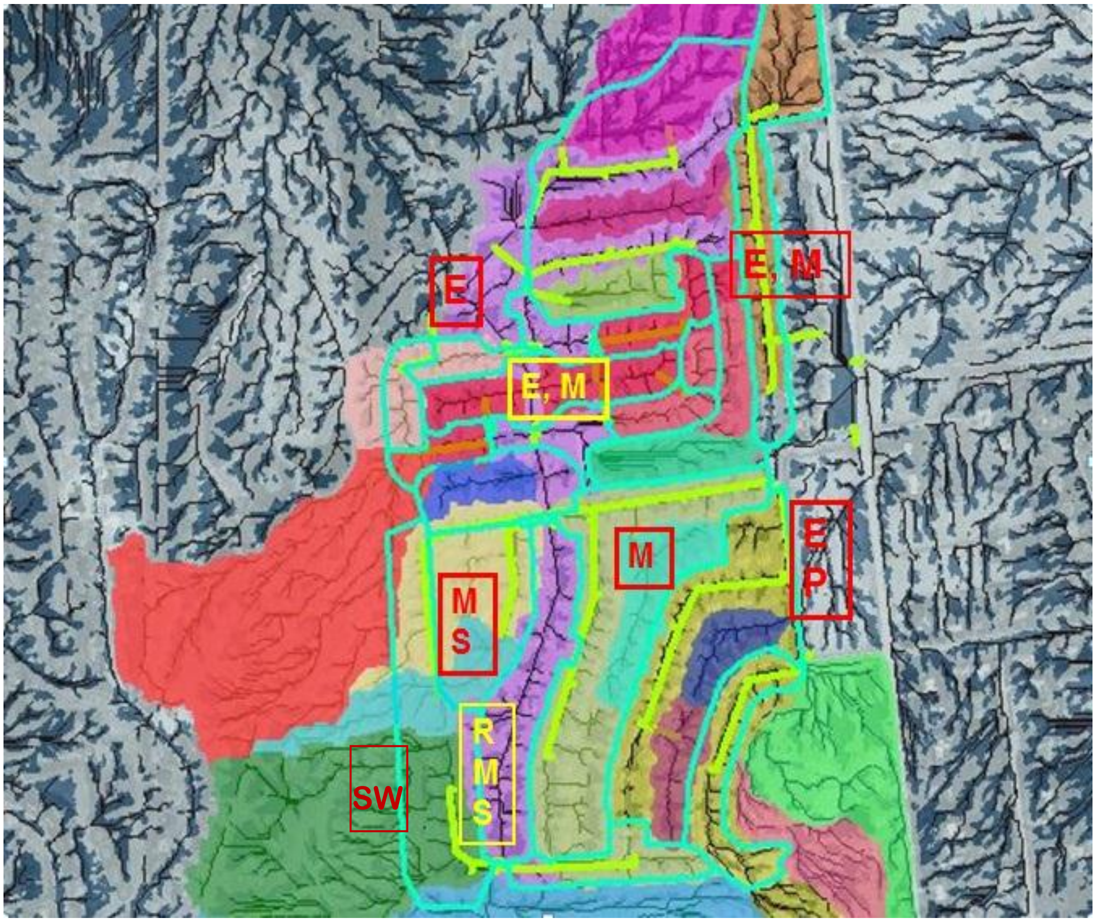

Figure 4.9. Graphic depiction of option 3: integrated modular landscape-based stormwater management (IMLaS). **Key: E**: Engineered solutions (retrofit of old, dysfunctional ponds; new green designs; constructed wetlands; bio-infiltration areas, and naturalized ponds); **M**: Midscale best management practices (BMPs) developed on the basis of Micro Stormwater Drainage Density (MSDD) index and inherited pipe system; **S:** Small-scale BMPs (rain gardens, porous pavement, etc.); **SW:** Protection from incoming flow (e.g., swales); **R:** Stream and floodplain restoration; **P:** Stormwater Park

Result of the spatial analysis has shown that the total area contributing stormwater to the Butler Farms/Oak Creek neighborhoods was three times the size of the neighborhoods alone, while the neighborhood imperviousness is twice more than the average in the contributing areas (Appedix A3) (Table 4.2). During the decision-making process, these findings created extensive negotiation opportunities for BF/OCV residents.

	Area (acres)	Percentage of impervious surfaces
BF/OVC neighborhoods	110.6	28
All contributing watersheds	315	14

Table 4.2. Total areas and percentage of impervious surfaces for Butler Farms/Oak Creek Village (BF/OCV) neighborhoods and contributing watersheds

Several months after the SWG requested the development of option 3, all three options were presented at a meeting of the SWG held at South Burlington City Hall (RAN2: Redesigning the American Neighborhood, 2007). When it emerged that the per-household cost for the IMLaS management approach was comparable to that of the engineered options, project team addresses several additional questions:

- What distinguishing characteristics of option 3 might make it more appealing to stakeholders?
- Might a visioning process, which would lead to the development of a reference state, increase stakeholders' willingness to accept option 3?
- Would the introduction of the notion of ecosystem services help achieve an environmentally balanced decision?
- Might BCBA, as opposed to CBA, be useful in reaching a balanced decision?

4.10. Primary and Secondary Benefits of the Three Options

"But valuation studies only matter in any practical sense when they influence on the ground decisions. Even when valuation studies have dubious economic and scientific validity, however, they may serve to attract the attention of decision makers and the public, and lead to positive change. For policy and decision-makers, hard science is often less influential than good storytelling, and monetary valuation can help tell an important story about environmental values."

Joshua Farley. 2008. Environmental valuation and its applications.

Conventional, business-as-usual approaches are appealing, at least at first glance. They require no thinking "outside of the box", and seem much easier to implement. In the Butler Farms/Oak Creek case, extra effort on education and participatory spatial analysis was required to persuade residents to even consider an alternative option (Bowden et al., 2006; Hinds et al., 2005; RAN5: *Redesigning the American Neighborhood*, 2007; Voinov Vladich 3, 2012).

The starting point for such considerations was that total cost for any approach should be equal or comparable to that for other approaches. Under conventional CBA, this meant that the monetary value of the restored ecosystem services should be equivalent to the avoided costs for large-scale engineering substitutes.

At first glance, all three options have comparable economic costs; however, if we apply BCBA and include secondary benefits, we obtain completely different results.

4.10.1. Primary benefits of three options:

Option 1a (see fig. 4.6):

- Clears titles
- Treats only part of the watershed
- Provides limited help for the problem of recurrent basement flooding in the treated portion of the watershed

Option 2 (see fig. 4.7) Centralized “Super Pond” approach:

- Clears titles
- Treats the entire watershed
- Provides limited help for the problem of recurrent basement flooding
- Requires heavy excavation work
- Requires the use of the city owned upland natural areas

Option 3, the IMLaS management approach,

- Clears titles
- Treats the entire watershed

- Provides protection against basement flooding (with the help of the small-scale and mid-scale BMPs as a side product of MSDD targeted infiltration basins)
- Does not require the use of city owned upland natural areas

4.10.2. Local Secondary benefits of Option 3: IMLaS

Option 3 IMLaS (see fig. 4.9) also has a number of secondary benefits at the local scale of the neighborhood:

- Distributed innovative character of the alternative stormwater management plan increased possibilities to search for external funding for various elements of the plan, thereby potentially lowering the required out-of –pocket cost per household. External funding can be considered as a type of the payment for ecosystem services.

- Increased possibilities of the cost-sharing with neighboring properties owners, thereby potentially lowering the required cost per household even further. Cost-sharing with neighboring properties – is the outcome from the negotiations with the owners of big neighboring properties such as golf course, agricultural filed, property, designed for the future development - related to the results of the whole system hydrological analysis. This analysis shown that the area of BF/OCV neighborhood: (1) represents only one third of the total watershed, collecting the stormwater, (2) contains multiple inflow pouring points, collecting the water and sediments from all surrounding, external to BF/OCV properties. Being affluent in terms of house values, this neighborhood suffers tremendously from flooding during snowmelt and storm events due to the lack of the comprehensive spatial terrain analysis prior to the construction (Voinov Vladich 2, 2012; Voinov Vladich 3, 2012).

- Proposed Stormwater Park at the entrance to the neighborhoods, with two ponds for recreation. The park would enhance the "face appeal" of the neighborhoods, thereby potentially increasing the desirability of the real estate and potential increase of the property value up to 20 % (Crompton, 2005; Geoghegan et al., 1997).
- Proposed Stormwater Park: creating a new (and unique) space for recreation and social interaction
- Proposed Stormwater Park: providing a stormwater related educational resource for the neighborhoods.
- Proposed stream and flood plain restoration, porous pavement, rain gardens, swales – have a potential to naturally mitigate stormwater runoff at the medium and small scale of individual household
- Additional improvements of the neighborhood aesthetics—for example, through visually attractive naturalized pond designs and the transformation of a "ditch" into a natural-looking creek

The idea of a park initially developed in response to a second RAN survey, which asked residents whether they would like to have a park in the neighborhood. The neighborhoods lack of social capital was fairly obvious from the first RAN neighborhood survey (Bowden et al., 2006). Apart from the sidewalks (where people walk their dogs), the Butler Farms/Oak Creek neighborhoods lacked any structure that would provide an opportunity for people to interact. Although it would be difficult to assign a monetary value to the Stormwater Park, the structure of the park provides whole array of ecological, educational, aesthetic, hedonic social benefits that go beyond only social necessity, identified through the survey.

4.10.3. Macro Secondary benefits of Option 3: IMLaS

The use of natural landscape features such as depressions, natural designs, and plants would increase ecological functionality in the following areas (De Groot et al., 2002; Todd, 1999):

- Water regulation: infiltration, evapotranspiration and therefore reduced runoff
- Water supply: recharge of groundwater aquifers
- Climate regulation: evapotranspiration
- Pollution control: nutrients removal by plants, trees, sedimentation
- Pollination
- New habitat structures
- Carbon sequestration

Some values of the secondary benefits of various scales can be expressed in monetary terms; some can be assessed through various indicators. Improvements in ecological functioning, for example, can be assessed through monitoring and spatial indicators, and social benefits through surveys.

- Through the use of Participatory Spatial Analysis (PSA) and the development and use of the spatial indexes (MSDD), it is possible to reveal and assess the ecological functions and services of the urbanized landscape, such as those, related to primary benefit of flood protection, stormwater runoff accumulation, retention, infiltration, evapotranspiration capacity, as well as secondary benefits, and therefore – to ecosystem services (which always exist, however neglected they may be). Values can be assigned through assessments of the following: (1) the volume of potential stormwater retention; (2) the percentage of impervious surfaces in a given subwatershed
- The amount of water that would be accumulated, percolated, and stored in a particular landscape feature (such as a depression) during and after a storm event
- The amount of retained nutrients and polluting agents
- The amount of evapotranspiration from wetland plants and trees (e.g., willows, cattails).

4.11. Option 3: Valuing Ecosystem Services

Once implementation costs have been estimated for all options, it is theoretically possible to compare the flow of costs and benefits over time for engineered versus alternative stormwater solutions. For example, according to several studies, annual maintenance costs for engineered approaches to stormwater management are generally 3 to 5% of construction costs (Schueler, Kumble, & Heraty, 1992; US EPA, 1999), versus zero maintenance costs for restored ecosystem structures.

In practice, however, out-of-pocket costs have more influence on decision making than anything else. Because alternative approaches lack precedents and policies recommendations, perceived risks are higher; thus, even the out-of pocket implementation cost for different approaches is comparable, communities tend to choose conventional approach. In addition, as mentioned earlier, LiDAR based PSA results demonstrated that due to it' location on the watershed and poor pre-construction terrain analysis, Butler Farm Oak Creek Village neighborhood was getting stormwater and sediments from the area more than three times larger than neighborhood itself (Voinov Vladich 2, 2012; Voinov Vladich 3, 2012). Thus, keeping in mind the extensive RAN educational efforts, the introduced PSA based reference state for an alternative stormwater management, additional incentives were needed to make the environmental approach acceptable to residents (Hinds et al., 2005).

Estimated BF/OCV Project Cost w/out Grants

updated on 8/3/11

Project Component	Estimated Cost**	Homeowner / Utility Funds: Neighborhood Cost (based on 55% privately owned impervious area)	Homeowner / Utility Funds: Stormwater Utility Cost (based on 45% City owned impervious area)
Engineering Oversight During Construction	$ 78,000.00	$ 42,900.00	$ 35,100.00
Stream Restoration	$ 118,000.00	$ -	$ 118,000.00
OCV Pond Retrofits and Associated Pipe Replacement	$ 921,425.00	$ 506,783.75	$ 414,641.25
New Butler Farms Pond*	$ 299,000.00	$ 164,450.00	$ 134,550.00
Totals	$ 1,416,425.00	$ 779,033.75	$ 637,391.25
		$ 1,416,425.00	

* Estimate includes engineering oversight during construction.
**All estimates include 15% contingency

Estimated Cost / Unit (neighborhood cost / 257 units)	$ 3,031.26

Neighborhood Cost	$ 779,033.75
Loan Pay Back Period (years)	10
Interest Rate(%)	5%
Annual Cost	$ 99,154.32
Annual Cost / 257 homes	$ 385.81
Increase to monthly SW fee (Annual Cost / 257 homes / 12 months)	$ 32.15
Monthly SW Fee (based on projected ERU rate of $5.94/month)	$ 38.09

Table 4.3. Estimated costs for option 3, without grants. *Source:* DiPietro (2012).

In the case of the Butler Farms/Oak Creek neighborhoods, the novelty of the approach and the dispersed spatial distribution of the various elements of the plan allowed to apply for external grants and to sequence the implementation and the rest of the payments in time (over 10 years, financed by City of Burlington), making it possible to significantly decrease residents' out-of-pocket costs and to accept the plan (see tables 4.3 and 4.4).

Estimated BF/OCV Project Cost		Grant Funds		Homeowner / Utility Funds	
Project Component	Estimated Cost	SAFETEA Grant Cost	EPA Demo Grant Cost	Neighborhood Cost (up to 55% based on privately owned impervious area)	Stormwater Utility Cost (based on 45% City owned impervious area)
EPA Demo Grant - Engineering Oversight During Construction	$ 78,000.00	$ -	$ 58,500.00		$ 19,500.00
Stream Restoration*	$ 118,000.00	$ -	$ 88,500.00	$ -	$ 29,500.00
OCV Pond Retrofits*	$ 921,425.00	$ -	$ 535,652.00	$ 200,550.00	$ 185,223.00
New Butler Farms Pond* *	$ 299,000.00	$ 200,000.00	$ -	$ 54,450.00	$ 44,550.00
Total	$ 1,416,425.00	$ 200,000.00	$ 682,652.00	$ 255,000.00	$ 278,773.00
* Estimate includes engineering oversight during construction. *Estimate includes 15% contingency		$ 882,652.00		$ 533,773.00	

Max construction dollars available in EPA Demo Grant are $682652. Reached limit

Estimated Cost / Unit (neighborhood cost / 257 units)	$ 992.22

Neighborhood Cost	$ 255,000.00
Loan Pay Back Period (years)	10
Interest Rate(%)	5%
Annual Cost	$ 36,011.40
Annual Cost / 257 homes	$ 140.12
Increase to monthly SW fee (Annual Cost / 257 homes / 12 months)	$ 11.68
Monthly SW Fee (based on projected ERU rate of $5.94/month)	$ 17.62

Table 4.4. Estimated costs for option 3, with grants: US EPA demonstration grant and SAFETEA grant, administered by the Vermont Agency of Transportation. *Source:* DiPietro (2012).

4.11.1. Substitute Costs

There are two ways to calculate substitute costs for flood-protection ecosystem services: avoided cost and replacement cost (Millennium Ecosystem Assessment (Program), 2005; Ranganathan, 2008).

4.11.2. Avoided Costs

Knowing the per-cubic-meter monetary value of treating stormwater (a figure, calculated on the basis of the size of the landscape depression area, identified by MSDD index and its percentage of impervious surfaces) makes it possible to assess avoided cost. Typical costs for wet detention ponds (including permitting, design, construction, and maintenance) range from $17.50 to $35.00 per cubic meter ($0.50

to $1.00 per cubic foot) of storage area (CWP, 1998; US EPA, 1999). But because of the cost of land and the difficulty of finding suitable sites, retrofitting a wet detention pond in a developed area may be five to 10 times as costly as constructing a pond of the same size in an undeveloped area (Schueler et al., 1992; US EPA, 1999). Thus, avoided costs in a built-up neighborhood are between $87.5 and $350 per cubic meter.

Valuating flood-protection landscape ecosystem service with the avoided cost method based on MSDD index, has a potential to become a basis for defining payments for ecosystem services or other incentives at the level of individual household, the same way the percent of impervious surfaces is used to calculate stormwater utility fees in South Burlington, (which became the highlight of EPA guidelines (US EPA, 2009)). These incentives might make it attractive for landowners to choose transform landscape depressions into ecosystem structures such as e.g. rain gardens or small constructed wetlands. This methodology has a potential to be used to decrease the required volume of detention ponds. However these guidelines are yet to be developed.

At the moment of the decision making process in the Butler Farms/Oak Creek neighborhoods, no such guidelines were available, thus this valuation method could not be adopted by South Burlington planners, and neither did it yield any visible positive response during the SWG meetings.

Due to special circumstances of Butler Farms/Oak Creek neighborhoods, discussed at the beginning of this section, other leverage points were much more effective in shifting the balance of opinion away from conventional stormwater management toward option 3:

- The systems approach of the IMLaS management plan (as opposed to the conventional, “single planet”, disconnected from the interactions with the cosmos around, approach) provided stakeholders with a much greater understanding of the complexity of the system, including the network of internal interconnections.
- The spatially and temporally distributed character of the alternative approach created additional funding opportunities, through grants and through negotiation with the owners of neighboring properties.
- The application of BCBA led to the consideration of all four types of capital: built, natural, human, and social. The idea of the Stormwater Park sparked a dialogue that ultimately (1) broadened to include a range of ecological, economic, and social dimensions and (2) brought out the notion of visible secondary benefits that could be expressed in terms of both market and nonmarket values.
- The process of envisioning a new set of ecosystem structures introduced the local, neighborhood-level reference state, allowing the creation of a whole new spectrum of valuable additional benefits that addressed the social, cultural, aesthetic, recreational, and educational aspects of the neighborhoods. The potential for the emergence of a newly created ecosystem structures yielded a

number of new ideas: the creation of a Stormwater Park on unused, city-owned land, which became a focal point for the entrance to the neighborhood; small-scale, green-design detention ponds; constructed wetlands; and rain gardens at the level of individual residences. Such ideas led to a shift in residents' sense of psychological ownership of the future reference state; as a consequence, the nuisance of retrofitting a stormwater system was transformed from a burden into an asset.

4.11.3. Replacement Costs and payment for Ecosystem Services

To get the total cost of the project - the cost of $186,000 for the Oak Creek Village Micropool (Appendix A6), that has been financed separately by SAFETEA grant, administered by the Vermont Agency of Transportation – has been added to the Totals of the tables 4.3 and 4.4.

Project costs (PC) (table 4.3)	$1,416,425.00
Oak Creek Village Micropool costs	$186,000.00
Total project costs	$1,602,425.00
Replacement costs for flood-protection services, taking into account the entire contributing area (315 acres,	$5,087.06/acre

14% of which were impervious)	
Replacement costs for flood-protection services, taking into account the Butler Farms/Oak Creek area only (110.6 acres, 28% of which were impervious)	$14,488.47/acre
Per-household costs before grants and utility funds (BG) (257 units)	$6,532.12
Per-household costs after grants and utility funds (AG) (257 units) (WTP)	$992.22
Per-household difference BG - AG (257 units)	$5,539.90

Table 4.5. Project costs, Replacement costs, WTA and WTP per household in the Butler Farms/Oak Creek neighborhoods.

The after grants per-household costs are the costs that have been accepted by residents through the voting process, so this costs can be considered as willingness to pay (WTP). As it was mentioned - that the estimated costs of option2 –“superpond” $5,000 per household (Table 4.1), has led to the series of bitter conflicts and lawsuits. This option was the one to treat the whole area, according to engineering specifications. LiDAR based PSA results showed that this plan would neither resolved any recurrent flooding issues in the neighborhood, nor provided other secondary benefits of the option 3. However, without grants and utility funds, this plan would not be accepted. Thus one can argue that willingness to accept (WTA) the status quo of malfunctioning stormwater systems and therefore polluting the lake is equal to the total costs per household of option_3, before grants and utility funds (BG). The ratio WTA to WTP in this case is 6.6, which is close to the mean WTA to WTP ratio of 45 studies, reported by Horowitz & McConnell (2002) (cited in Farley (2008b)).

A number of factors made it possible to apply for grants:

- The systems approach of the IMLaS management plan, considering complexity of the sub-watersheds system, including the network of internal interconnections
- Distributed character of IMLas gave the possibility to for the gradual financing and implementation time-scale
- Because the IMLaS framework relied on high-resolution LiDAR data and MSDD indexes to target areas for small- and midscale BMPs, it allowed the highly efficient allocation of funds
- The spatially distributed character of option 3 saved a large piece of a public land (big enough to have been considered as a potential site for a school) that would otherwise have been used for an option 2 “superpond”
- The plan mitigated recurrent flooding, contributed by surrounding properties.
- The plan offered multiple secondary benefits (see section 4.10)

- Creative approach and full engagement of the city leadership at the neighborhood-level reference state, suggested by the IMLaS framework

4.12. Option 3: Follow-up

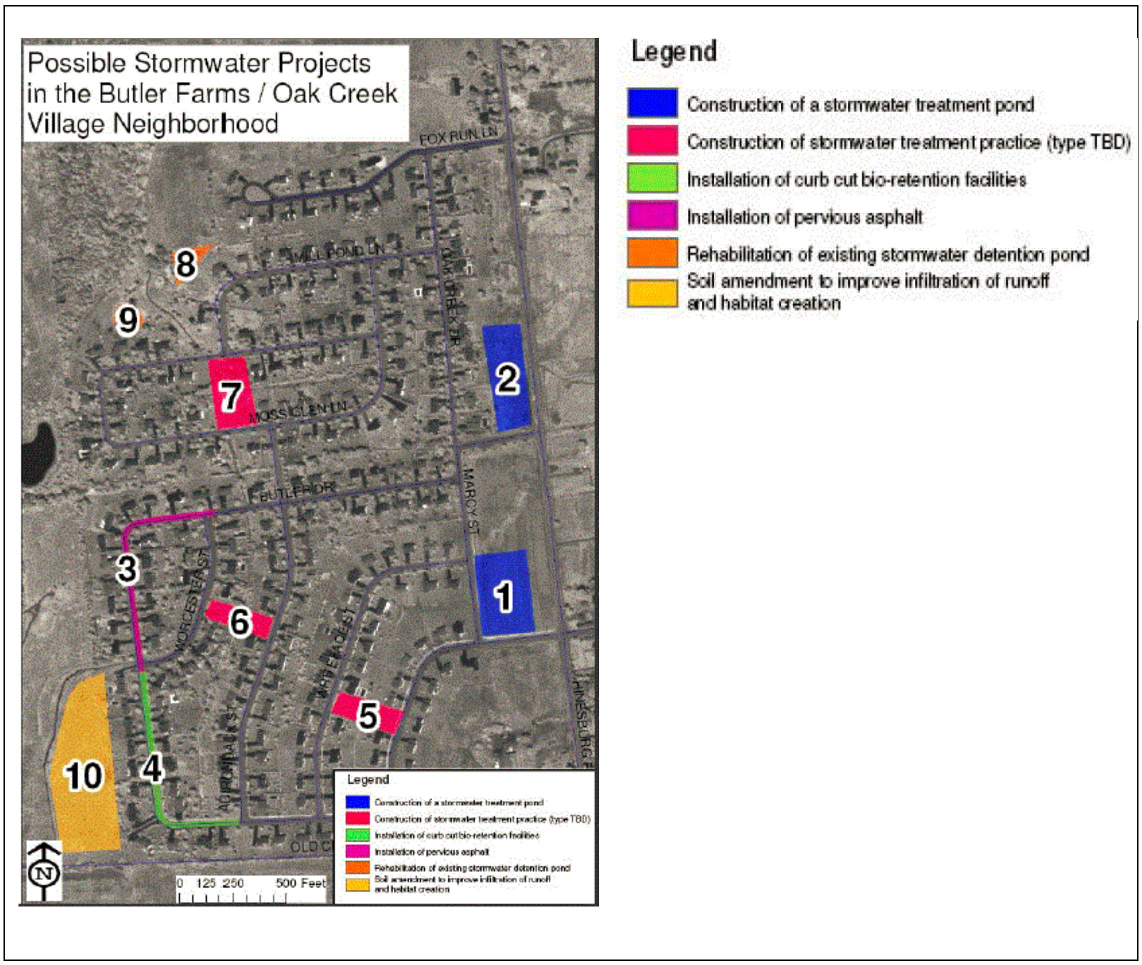

Figure 4.10. Proposed stormwater projects in the Butler Farms/Oak Creek neighborhoods by Office of Planning and Zoning of South Burlington, based on IMLaS framework. *Source:* Adapted from *(RAN3: Redesigning the American Neighborhood*, 2008)

Option 3 became the core of the city's stormwater management proposal for the Butler Farms/Oak Creek neighborhoods (RAN3: Redesigning the American Neighborhood, 2008). And, later, the project had proceeded to the implementation stage (see fig. 4.10) (City of South Burlington Planning and Zoning, 2011; RAN6: Redesigning the American Neighborhood, 2006).

4.13. Discussion. IMLaS: Addressing the Issues of Discounting the Future and Allocative Efficiency

Yes, everyone would like Lake Champlain to be perfect, but such a large-scale vision is unlikely to lead stakeholders to accept substantial monetary sacrifices. What sometimes helps in such situations is a vision of a large-scale catastrophic event. For example, in the event of a catastrophic weather condition (of the sort that is becoming increasingly common, thanks to climate change), an engineered solution is much more likely to collapse, bringing about substantial losses. A vision of this degree of severity may help to shift public opinion somewhat, but it is rarely enough demonstrate to stakeholders the effects of individual, small-scale decisions (Few et al., 2007).

And yes, the flow of costs and benefits for landscape restoration versus engineered substitutes differ over time, because ecosystem services are typically maintained by solar energy, whereas built capital substitutes require constant flows of raw material and energy. Yes, in the long run, an alternative stormwater management plan will bring gains, whereas an engineered plan will require maintenance and will therefore bring losses. Moreover, the restoration and creation of ecosystem functions will bring about a wide array of other services, beyond stormwater retention and regulation that cannot be measured solely in monetary terms.

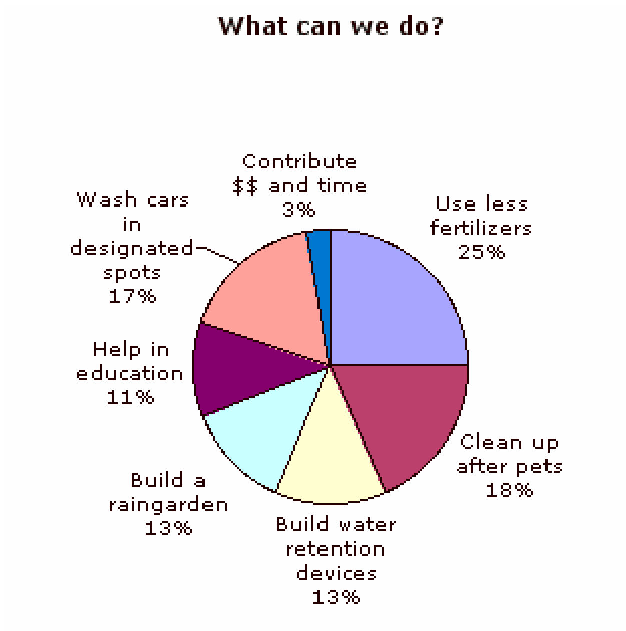

Figure 4.11. Responses to the following survey question: “What can we do”? *Source:* adapted from Bowden et al., (2006).

Yes, awareness of and accounting for secondary benefits is important to the decision-making process. But a great deal of effort and technical expertise are required to convey the value of such benefits to the public, and to come up with a detailed plan for identifying, creating, and using ecosystem services. As shown in figure 4.11, which depicts the responses to one of the surveys undertaken as part of the RAN project, residents were willing to adopt a mix of practices to improve stormwater quality, but were not interested in contributing time and money to such efforts.

One difficulty with regulations, which operate according to a command-and-control model, is that they offer no antidote to the problem of discounting the future. In the case of the Butler Farms/Oak Creek neighborhoods, for example, the imposition of TMDL sparked conflict because, among other reasons, residents were unable to grasp the future value of today's out-of-pocket costs. Regulations also have other disadvantages as a means of improving environmental conditions; as Daly and Farley (2003) note:

> The disadvantage is that in general, regulations fail to meet the criteria for allocative efficiency and thus are often not the most cost-effective way to reach a desired goal. Moreover, they fail to provide incentives for surpassing a goal, bringing pollution below the regulated level.

Thus, there is a need for the tools and approaches that can address the issue of discounting the future and alleviate weaknesses of macro-regulations by providing the technical basis for policies or market mechanisms that can efficiently act at the micro-level such as: taxes, subsidies, cap and trade systems or payments for ecosystem services thereby allowing micro-freedom to achieve macro-control. The RAN project and IMLaS approach has been geared toward both of those goals by: (1) addressing the problem of discounting the future and (2) enhancing the macro-level regulations, enabling them to act efficiently at the micro level:

The problem of discounting the future was addressed during the decision-making process by reconnecting Butler Farms/Oak Creek residents to several distinct components of the stormwater management:

- The project team used extensive educational efforts GIS-based PSA, hydrologic analysis based on high-resolution LiDAR and Quick Bird data, to demonstrate to residents how small-scale, backyard actions were connected to lake health at a large scale (Bowden et al., 2006; Hinds et al., 2005; Voinov Vladich 3, 2012)
- The team also helped residents connect a large-scale vision of the beauty and health of the lake to a vision of the potential beauty and health of a small watershed and tributary that run through the subwatershed, where the neighborhoods are located, directly to the lake
- By introducing the notion of ecosystem services—in particular, the capacity of the landscape to provide stormwater retention services—the project team enlarged the scope of possible solutions
- Using the IMLaS framework, the project team introduced residents to the secondary benefits of the distributed landscape-based approach and increased their awareness of the difference in the flow of costs and benefits over time between centralized, engineered stormwater solutions and alternative, dispersed solutions
- By targeting and prioritizing BMPs for residential stormwater (Voinov Vladich 2, 2012), an IMLaS management approach provides a technical basis for policies or market mechanisms that can act efficiently at the micro level, thus increasing allocative efficiency

In the case study of the Butler Farms/Oak Creek neighborhoods, the visioning process included an assessment of current and future costs and benefits for all three management options, many of which are hard to express in monetary terms.

Alternative plan IMLaS combines landscape features and small and mid-scale green engineering designs such as constructed wetlands (Todd, 1999). Monetary values were developed for only two ecosystem services provided by the IMLaS management plan: stormwater retention and storm-peak mitigation services during a storm event. These figures were based on: (1) the MSDD index that was developed as part of the terrain analysis and (2) the substitute-cost method of valuation (Voinov Vladich 2, 2012). As a result, the values (1) reflect only a limited part of the full range of ecosystem services provided, (2) do not account for the flow of costs and benefits over time for restoration versus engineered substitutes, and (3) do not account for the costs associated with catastrophic weather events.

Although the costs associated with catastrophic weather events are an area for future research, it is already known that the convention of discounting the future is such an obstacle that hypothetical scenarios of catastrophic events have no effect on decision making—even in the case of decisions to site nuclear power plants in seismic zones, for example (Costanza, Cleveland, Cooperstein, & Kubiszewski, 2011). Yes, the Fukushima nuclear disaster of March 21, 2011, led the Japanese government to choose a nuclear-free future, but the decision occurred after the meltdown, not before.

Decisions are made without a full accounting of costs because conventional valuation techniques typically arrive at a net present value by discounting future costs (in the case of conventional approaches) and future benefits (in the case of alternative approaches) at an exponential rate, and entirely fail to address values and indicators that cannot be measured in monetary terms. Admittedly, it would be difficult to develop an approach that would directly or indirectly account for total true costs. One approach that has been suggested, however, is a flexible assurance bonding system (Costanza, R., Perrings,1987, Costanza et al. 2011), in which all decisions that are potentially environmentally harmful to the environment incorporate full costs (including subsidies, climate impacts, the risk of accidents, and the safe disposal of waste). Although this approach would be difficult to implement with precision, it would still create enough transparency and understanding to influence decision making.

Another approach would be to establish a desirable reference state for the environment at the macro scale, then develop policies or market mechanisms that would influence decision making at the micro scale. The RAN project began with the total absence of such mechanisms (or of any basis for them), in the heated atmosphere of the conflict between Butler Farms/Oak Creek residents and the City of South Burlington. These circumstances required novel approaches and tools that eventually led to a pivotal point for regaining trust and building a basis for constructive decision making (Voinov Vladich 2, 2012): The PSA based on high-resolution LiDAR and multi-spectral Quick-Bird data that - has brought the relief to the conflict (Voinov Vladich 3, 2012). The MSDD index has created a basis for the micro-scale policies (subsidies) and mechanisms (PES) to achieve the micro and macro-scale reference state (Voinov Vladich 2, 2012).

Although secondary benefits (see section 4.10) are usually excluded from conventional CBA, they played a significant role in stakeholder meetings and in in Butler Farms/Oak Creek decision-making process.

4.14. Conclusion

Although land may be excludable at the neighborhood level, the water-regulating ecosystem services that are generated by the land belong to non-excludable public resources—that is, the benefits of such ecosystem services go well beyond the local scale, both spatially and temporally, and are publicly shared. Moreover, water regulation is a source of intergenerational benefits that are destined to be enjoyed by future generations.

The correspondence between three regions of ecosystem services supply-demand curve and three stages of the relationship between impervious cover and stream quality suggests following policy implications for urban stormwater management:

- Once the level of the imperviousness exceeds 10%, bringing the stream quality to the stage II, impacted, governmental regulations are recommended to address stormwater management. Depending on the imperviousness, low impact designs and the use of landscape characteristics are recommended to enhance the conventional approach to stormwater management. It is recommended to enhance CBA by BCBA in order to arrive to more efficient decision choices in the long run.

- Once the health of a stream is in the highly impacted or non-supporting stage (III), restoration becomes a first priority. Conventional stormwater management approaches alone are not sufficient to substitute for the full range of lost ecosystem services; alternative approaches are preferred. CBA is inappropriate.

LiDAR based PSA showed that the area that contributed stormwater to the Butler Farms/Oak Creek Village neighborhoods was three times larger than the neighborhoods themselves, rendering Butler Farms and Oak Creek Village the recipients of the stormwater management actions of others. At the same time, the impervious area in the Butler Farms/Oak Creek Village neighborhoods was 28%—which was double the imperviousness of the surrounding properties, and placed the carrying capacity of the neighborhoods landscape to the area of threshold between regions II and III of the supply-demand curve for ecosystem services (fig 4.1); thus, indicating that it is under threat with respect to broad range of both – substitutable and non-substitutable ecosystem services.

To address this situation, two conventional engineered options and an alternative option (IMLaS) were developed and presented to the members of the SWG. Costs assessments of all three options were very close. Due to the extensive educational efforts, whole-system approach, multiple secondary benefits, based on the ecosystem services, targeted by PSA and MSDD index, the stakeholders consensus was that IMLaS was the best option (RAN2: Redesigning the American Neighborhood, 2007). Engaging the city leading authority in the concept of whole system analysis, BCBA, secondary benefits and in the process of developing the vision of the local reference state was the key to the constructive decision making process.

Valuating flood-protection landscape ecosystem services with the avoided cost method based on MSDD index, has a potential to become a basis for defining payments for ecosystem services or other incentives at the level of individual household, the same way the percent of impervious surfaces is used to calculate stormwater utility fees in South Burlington, (which became the highlight of EPA guidelines (US EPA, 2009). These incentives might make it attractive for land owners to choose to transform landscape depressions into ecosystem structures such as e.g. rain gardens or small constructed wetlands. This methodology has a potential to be used to decrease the required volume of detention ponds. However these guidelines are yet to be developed.

4.15. Acknowledgements

See section 5.10.

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CHAPTER 5: TECHNOLOGICAL TOOLS, PUBLIC INVOLVMENT, AND OTHER FACTORS CONTRIBUTING TO SUCCESS IN ENVIRONMENTAL DECISION MAKING: A CASE STUDY OF THE DEVELOPMENT OF A STORMWATER MANAGEMENT PLAN IN SOUTH BURLINGTON, VERMONT

We cannot solve our problems with the same thinking we used when we created them.– *Albert Einstein*

5.1. Abstract

Stormwater belongs to the commons - and, like other parts of the commons, it requires governance. Unlike land, however, water cannot be constrained to recognize private and/or political boundaries. It possesses non-excludable properties, with results of the local decisions spilled over to the level of the much larger spatial and temporal scales. Observation of numerous environmental decision making processes related to stormwater reveals that the invisible grip of "tyranny of small decisions" (Kahn, 1966; Odum, 1982) often prevails, leading to unsustainable decisions, threatening well-being of the future generations and intractable conflicts. At the same time, the consequences of poor decisions are becoming more obvious, deleterious, and of larger scales. Stormwater management is becoming increasingly complicated, both because of the

complexity of natural systems and the complexity of the human socio-economic systems. However, despite expressed concerns regarding the outcome of managerialist tendencies in cases where conflict between scales of interest manifests itself, there are few adaptive management tools that can assist successful environmental conflict resolution and decision making.

The goal of this chapter is to empirically show that the various approaches and solutions, developed on the basis of participatory spatial analysis (PSA), can be aggregated into a comprehensive "solution toolbox", which, when applied appropriately, leads to more efficient results and successful outcome in a participatory process of environmental decision making and conflict resolution. This is achieved by harnessing the existing experience of working with stakeholders to develop approaches to identify practicable low-impact stormwater management alternatives in existing suburban environments of Butler-Farms/Oak Creek Village neighborhoods, South Burlington, Vermont.

5.2. Introduction

Public participation is a desirable component of public policy making in decision making concerning environmental issues due to three reasons. First is the changing nature of pressing environmental priorities, as the focus of attention shifts from large-point sources of pollution to more diffuse and widely distributed sources, such as urban and agricultural runoff. Because of their complexity, these problems are not conducive to centralized, hierarchical command and control decision making

(Dryzek, 1997). Instead, they often require knowledge, commitment, and action from multiple levels of government, special interests, and the general public over long periods of time.

Second, there is an emerging realization that general public and experts bring valid but very different perspectives to decision-making about risks. Multiple studies have noted that even the most technical tools of environmental decision making, risk assessment, and cost-benefit analysis require significant additional non-partisan judgments that are most naturally coming from involving the public (Beierle, 1999).

Third, the public has demonstrated that it can be very effective in holding up projects with environmental impacts while manifesting a legitimate concern regarding appropriate risks management. Active public involvement may be one of the few ways to start resolving the issues of mistrust, as Slovic (1993) has noted in the study of trust and nuclear power plant management.

These reasons lead to the recognition of the importance of public, and were notably cited as part of Principle 10 of the Rio Declaration on Environment and Development (UN, 1992). Similarly, the National Research Council (1996), as quoted in (Beierle, 1999), argued that public participation "is critical to ensure that all relevant information is included, that it is synthesized in a way that addresses parties' concerns, and that those who may be affected by a risk decision are sufficiently well informed and involved to participate meaningfully in the decision" (National Research Council (NRC)., 1996, p.30).

With the consensus view is that stakeholder inputs improve the outcomes in complex environmental issues of societal importance, from time to time various authors have voiced some concerns that unless managed appropriately, involving stakeholders can be problematic (Cheng & Mattor, 2006; Few et al., 2007). These concerns relate to the area of decision making where fundamental conflict prevails between scales of interest, particularly where the policy response entails radical interventions and costs. Conflicting scales issues could be (1) spatial: either local versus global, as in adaptation to climate change issues (Few et al., 2007), or local versus regional, as in watershed non-point pollution issues (Hinds et al., 2005; Voinov Vladich 3, 2012); and/or (2) temporal, with the aim of providing inter-generational benefits to be captured by future generations through the actions of the present generation (Ali, 2003; Few et al., 2007; Heal, 2000). Despite expressed concerns regarding the outcome of managerialist tendencies in cases where conflict between scales of interest manifests itself (Few et al., 2007); there are few adaptive management tools that can assist successful environmental conflict resolution and decision making.

The case study of stormwater management decision making in Butler Farms/Oak Creek Village neighborhoods, South Burlington, Vermont represents valuable example of public participation in the decision making process, with a highly visible conflict between the regional and local scales. The beginning of the Redesigning American Neighborhood (RAN), targeted toward finding alternative solutions for the stormwater management in existing typical New England neighborhood, coincided with increasing tension between City of South Burlington neighborhoods and the city and state, which was a manifestation of the conflict between regional and local scales, as well as the problem of discounting the future, set off by a regulatory approach to the issue of urban stormwater management. The Butler-Farms/Oak Creek Village neighborhoods were suggested by the city as the most challenging case study example. Political and legal crisis in the city greatly complicated the course of the project and set up unexpected new challenges.

There were three key challenges to working within an existing residential development, and given the background of the conflict:

- *Technological tools*: Tools are needed that will allow users to (1) identify points of intervention at different, subwatershed scales and (2) target locations for the use of best management practices (BMPs) at different scales (Voinov Vladich 2, 2012).
- *Tools for environmental conflict resolution*: Because a retrofit of an existing stormwater system can be costly, and comes in the form of a coercive regulation from city and state authorities, residents may view it as a burden—which can lead to conflict between residents and state and local governments (Voinov Vladich 3, 2012).
- *Decision-making tools that prioritize sustainability and intergenerational justice*: It is necessary to develop economic and noneconomic incentives to persuade stakeholders, in the course of a decision-making process, to accept an alternative

approach to stormwater management, instead of more familiar conventional ones (Voinov Vladich 4, 2012).

This chapter is cumulative chapter of the whole process of decision making process regarding the effective stormwater management which includes a broad array of technologies. The focus of this chapter is to empirically show that the various approaches and solutions developed on the basis of participatory spatial analysis (PSA) can be aggregated into a comprehensive "solution toolbox", which, when applied appropriately, leads to more efficient results and successful outcome in a participatory process of environmental decision making and conflict resolution.

This research has been accomplished as part of a project *Redesigning the American Neighborhood* **(RAN)** program, managed by the University of Vermont that looks at the Butler Farms/Oak Creek neighborhood in South Burlington, VT.

5.3. Study Site, Research Questions, Methods, Data

5.3.1. Study Site

See section 3.3.

5.3.2. Research Questions

In the Butler Farms/Oak Creek case study, several technically complex tools were used (e.g., GIS, hydrologic modeling, remote sensing) to help stakeholders make decisions about the best options for stormwater management in their neighborhoods.

- How can we judge whether the use of those tools was successful?
- How can public participation and the application of complex technical tools be combined?
- What specifically was necessary to ensure that the use of participatory spatial analysis (PSA), MSDD index and IMLaS framework were successful?
- How the situation of stormwater management in in the Butler-Farms/Oak Creek Village (BF/OCV) neighborhoods related to the concerns raised by Few et al. (2007)?

5.3.3. Methods and Data

See section 4.3.3.

5.4. Factors Associated with Success

How do we judge success?

One way to answer this question is to employ a framework that evaluates the outcomes of participatory processes using a set of social goals.

5.4.1. Five Social Goals

The goals are as follows (Beierle & Cayford, 2002; Beierle, 1999):

- Incorporating public values into decision
- Improving the substantive quality of decisions
- Resolving conflict among competing interests
- Building trust in institutions

- Educating and informing the public

These goals can be used to measure the outcomes of participatory processes, and one can see that they allow a broader view of outcomes than is typical. Normally, the “outcome” of a decision-making process refers to its substantive decisions, conclusions, or recommendations-such as what stormwater management plan should be adopted or what environmental problems should receive priority attention. However, interpreting achieving those decisions as only “outcome”, misses some of the most important results of participatory processes-opening the decision process to the public. How well they are achieved, often depends as much on how participants feel about the decision making process as on the achieved decisions themselves. (Beierle & Cayford, 2002; Beierle, 1999)

5.4.2. Other Important Driving Forces of Success

The successful outcome of a participatory process also depends on following four characteristics (Beierle & Cayford, 2002):

- The responsiveness of the lead agency
- The motivation of the participants
- The quality of deliberation
- The degree of public control

Case study of BF/OCV is an example of the responsiveness of the lead agency and the motivation of the participants having the greatest importance to a successful outcome which is in accord with the findings of Beierle and Cayford (2002).

5.4.3. Analysis of the Implementation Stage

The real surprise, however, comes from analysis of Beierle and Cayford (2002) of the implementation stage. Authors list five stages of implementation:

1. Output of the public participation process, such as recommendation or agreement
2. Decision or commitment on the part of the lead agency
3. Changes in law, regulation, or policy
4. Actions taken on the ground
5. Changes in environmental quality.

The common assumption is that involving the public, although it takes a lot of time, will lead to quicker success at the implementation stage. But the findings of Beierle and Cayford (2002) contradict this expectation. In most reported studies, that implementation rarely goes beyond the third or fourth stage Very few cases have been found reporting on changes on environmental quality. This is explained by the long time needed to reach those results.

While assessing the success of the decision making process it would be important to emphasize the conclusion of Beierle and Cayford (2002) regarding the implementation stage. What was found is that implementation - is not really connected to success of the decision making process itself. In some cases, what fosters and hinders the implementation stage is not participation per se. Principal drivers behind implementation come from the larger regulatory context, such as program budget, regulatory power, and staff, and public participation is simply one piece of a decision making process.

5.4.4. The Potential for Dual Outcomes in Environmental Conflict Resolution and Decision Making

It is important to note the potential for duality that is inherent in any environmental conflict or decision-making process. An example of duality can be found in the fact that scarcity or abundance of resources can lead either toward conflict or toward cooperation (see fig. 5.1).

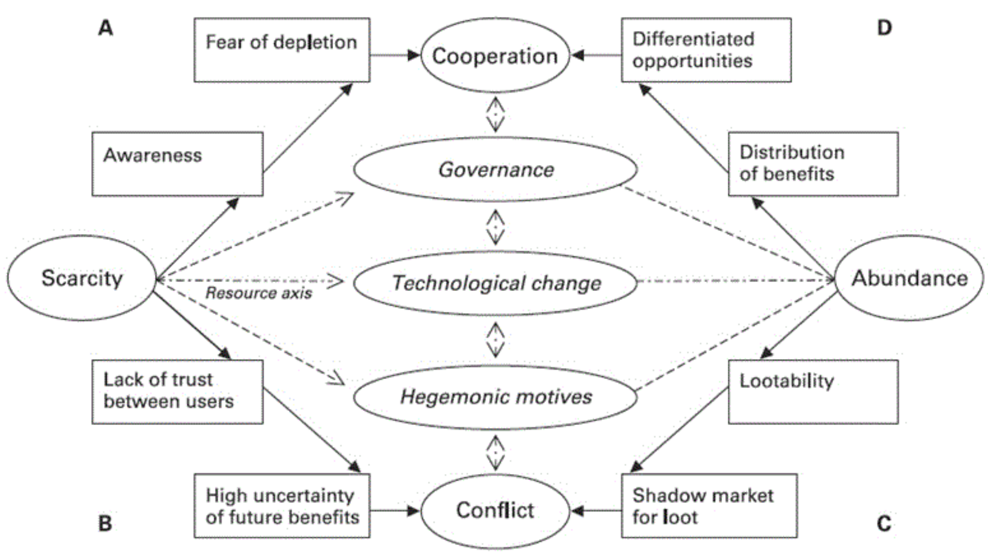

Figure 5.1. Contending pathways of environmental security discourse. *Source:* Adapted from S. Ali (2007), (p.4).

Any difficult environmental issue can be an entry point for negotiation in a conflict situation and can also provide a valuable exit strategy from intractable deadlocks in negotiations because of their global appeal. The same environmental issue can become a source of a bitter violent conflict. Thus, the environmental issue by itself is not a sufficient condition for conflict resolution. (S. Ali, 2007).

Pathway B, in figure 5.1, represents the classic “tragedy of the commons” scenario: in environmental management terms this pathways represents the conflict between spatial and temporal scales of interest, in ecological economics terms, this pathway implies inability to discriminate the ends from the means, in economic terms, this pathway implies a relatively high discount rate for the future.

What is important, to avoid path B, is the type of governance and the process of negotiations and decision making process.

Through the history we can distinguish three types of coordination:

- 1929 - 70 – State -centric coordination
- 1970 - 2001 – Market-centric coordination
- 1990 - present -- Emergence of new network-centric coordination

Because of the apparent failure, on the part of the state –centric coordination, to govern complex environmental problems, new modes of governance have been proposed in recent years (Newig, Günther, & Pahl-Wostl, 2010). In one such mode, known as the network model, multilevel political networks composed of stakeholders interested in the same issues. The networks are organized with the purpose to negotiate and agree on solutions.

By integrating stakeholders from different sectors, governance networks can provide an innovative, learning-oriented environment and pave the way for adaptive and effective governance. Epistemic communities, which are able to dissociate themselves from political bickering and catalyze cooperation, are a type of network that is particularly important for addressing environmental governance problems (P. Haas, 1992).

Similar to the contending pathways of environmental security discourse, the same feature can be viewed as strength or weakness, depending on which pathway (process) will be chosen to reach the goal. The network approach to environmental governance also has strengths and weaknesses:

Strength: The main argument favoring network governance over traditional, command-and-control regulation or market regulation is that network governance can better deal with intrinsic uncertainty and with decision making under conditions of bounded rationality (limited information) (P. M. Haas, 2004). Such conditions specifically apply in the case studies with the fundamental conflict between spatial scales, global versus local, where network institutions can (1) create synergy between different competencies and sources of knowledge and (2) encourage individual and collective learning, thereby making it easier to address complex and interrelated problems (Dedeurwaerdere, 2007; P. M. Haas, 2004).

Weakness: Environmental governance in general and network-centered coordination, in particular, face challenges characterized by complexity and uncertainty, which are inherent in issues associated with the environment and sustainability (Newig, Voss, & Monstadt, 2007).

Strength: Environmental policy makers often operate under conditions of uncertainty: they may not understand the technical aspects of the issues they are regulating. Their limited understanding affects their ability to define the interests of the state and to develop suitable solutions for the scales, larger than local (e.g. cross-boundary or cross-regional environmental regulation). Environmental crises also exacerbate uncertainty for decision makers (P. Haas, 1992). To reduce uncertainty, decision makers seek expert knowledge and advice on issues such as (1) the scale of environmental problems, (2) cause-and-effect relationships between ecological processes, and (3) how (science-based) policy options will play out.

Weakness: However, decision making and conflict resolution that assume the supremacy of science are likely to alienate developing countries at the global scale and the public at the local scale, where stakeholders all too often complain about disparities in scientific and technical expertise.

Like other phenomena and circumstances, even crises can be viewed from different perspectives. On the one hand, environmental crises exacerbate uncertainty and potential chaos. At the same time, crises have the potential to lead to cooperation and the search for new solutions. As S.Ali (2007) notes:

> "Positive exchanges and trust-building gestures are a consequence of realizing common environmental threats. Often a focus on common environmental harms (or aversions) is psychologically more successful in leading to cooperative outcomes than focusing on common interests (which may lead to competitive behavior)". (p. 5).

Three important concepts, if precipitated to the contemporary western mode of thinking, can become leverage points, addressing duality of the outcome and helping to avoid pathway B (see fig.5.1) in the course of the process of environmental consensus building, where the fundamental conflict between temporal and spatial scales of interest manifests itself: The principle of "participating consciousness"; The end-means spectrum; The vision of sustainable future. These concepts have a potential to increase the possibility of positive outcomes.

5.4.4.1. The Principle of "Participating Consciousness"

First concept relates to the conflict between spatial scales of interests. As Morris Berman (1981) recommends in *Re-Enchantment of the World*, we need to reactivate the principle of "participating consciousness", which involves identification, merging oneself with one's surroundings, and interlinking the destiny of individuals with the destiny of the planet—in other words, embracing a worldview that has been gone since the beginning of the industrial era. The change is as desperately needed as it is difficult to attain. The notion that we are separate from the world around us is deeply embedded in Western culture, however, and difficult to change.

5.4.4.2. The End-Means Spectrum

Second concept relates to the ability to distinguish between ends and means. Second concept is best introduced by the figure 5.2: “The ends-means spectrum”, adapted from the book of H.Daly & J. Farley *Ecological economics* (2003). The ultimate end, highest good is depicted at the top of the spectrum. All other intermediate ends are instrumental and derivative to the ultimate end. This missing link is very important to restore, since, as elegantly phrased by H Daly & J. Farley (2003): “The error of treating as ultimate that which is not is, in theological terms, idolatry” (p.49). At the bottom of the spectrum is ultimate means, low-entropy matter-energy, whose net production cannot possibly be created by human activity.

> The middle-range nature of the problem of political economy is significant. It means that, from the perspective of the entire spectrum, economics is, in a sense, both too materialistic and not materialistic enough. …Economic value has both physical and moral roots. Neither can be ignored. –H Daly & J. Farley, Ecological economics (p.50).

Restoring the full spectrum and reconnecting the middle-range means of decision making to the ultimate means and higher ends is another difficult tusk, since the current perception of the ultimate end is economic growth.

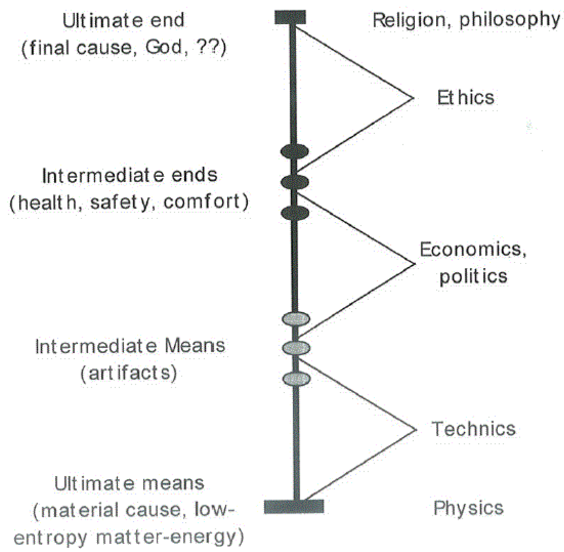

Figure.5.2.The ends - means spectrum. Source: Adapted from Daly & Farley (2003) p. 49.

Second concept is intimately interlinked with the first and third concepts. First concept, restoring the connection between actions on the local scale to the consequences on the large scale, assists the resolution of the conflict between spatial scales of interests, thereby enlarging practical use of the spectrum in a decision making toward the end of ultimate means. Third concept, addressing the problem of discounting future, assists the resolution of the conflict between temporal scales of interests, thereby enlarging practical use of the spectrum in a decision making toward the end of ultimate ends.

5.4.4.3. The Vision of Sustainable Future

Third concept relates to the problem of discounting the future. Another important leverage point that increases the possibility of positive outcome is reframing the goals and shifting the vision towards sustainable possibilities in order to enlarge “the shadow of the future” (Ali, 2003; Becker, 2012; Farley & Costanza, 2002; Kasser & Leeson, 2012; Ostrom, 1990). Methodologically, it can be addressed by introducing the reference state (Voinov Vladich 4, 2012), reframing the goals, transforming the nuisances, causing the crisis into the assets, followed by interactive backcasting, incorporated into the process of decision making (see 5.6.6)

When the issue is the cause of the deep conflict between spatial or temporal scales of interest, reframing the goals, transforming the nuisances, causing the crisis into the assets, might become important leverage points (D. Meadows, 1999) in the process of involving multiple stakeholders into the process of decision making.

For example, in environmental security negotiations, one approach is to frame environmental concerns as a means of peace building, instead of as matters related to resource scarcity, which can lead to conflict. An analogous approach can be used in environmental decision making regarding stormwater management: instead of focusing on transforming an environmental nuisance—which means, for example, attenuating peak flow, cleaning the polluted stormwater runoff, and fulfilling state requirements—we can focus on the asset of improved environmental health and quality of life, and on increases in property values resulting from the discovery of hidden ecosystems and the creation of new ones that are capable of providing valuable functions and (Geoghegan et al., 1997; Voinov Vladich 4, 2012).

Understanding these three concepts and integrating them into environmental decision making and conflict resolution may help to disentangle complex and deep-rooted conflicts, which are often accompanied by loss of trust, and thereby avoid traveling further down the path to conflict.

Reactivating the principle of participating consciousness, understanding the ends-means spectrum, and shifting our vision toward sustainable possibilities are not easy tasks. Nevertheless, knowing where leverage points are may allow an epistemic community to move closer to Margaret Mead's famous observation: "Never doubt that a small group of thoughtful and committed people can change the world. Indeed, it is the only thing that ever has."

5.4.5. Epistemic Communities and the Trinity of Forces

With respect to the environment, exhibiting non-excludable properties, such as ozone layer, non-point stormwater pollution or resource scarcity, especially water, the conflict of interest between the global/regional and domestic/local scales (spatial or temporal), is becoming increasingly obvious. The challenges are so complex and the conflicts so severe that violence sometimes results. In many places - the future projections for the water crisis are called – "water wars" (Poff et al., 2003; Shiva, 2002; Swain, 2001). In the search for conflict resolutions, it may be useful to look at the trinity of forces that, according to Carl von Clausewitz (Von Clausewitz, 1832, 'On War', cited in Bassford, (2007)), constitute the basis of conflict/war:

> 1) Primordial violence, hatred, and enmity, which are to be regarded as a blind natural force;
> 2) The play of chance and probability, within which the creative spirit is free to roam; and

> 3) Its element of subordination, as an instrument of policy, which makes it subject to *pure reason*
>
> The first of these three aspects concerns more the people; the second, more the commander and his army; the third, more the government….

Later, a very different and much more abstract version of the trinity appeared, based on Clausewitz's actual wording and interpreted in the light of late 20th-century nonlinear mathematics and Complexity science. This view was most notably put forward by Alan Beyerchen in 1992 (Beyerchen, 1992), by providing the parallels between the trinity of forces (emotion, chance, and rationality (Fig.5.3) and the trinity of actors (people, army, and government).

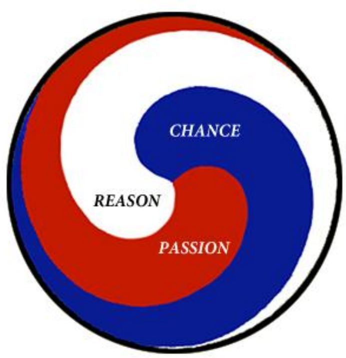

Figure 5.3. An Alan Beyerchen perception of the Clausewitz's trinity of war. *Source:* Adapted from fig.5 of Bassford (2007)

And if we look at Clausewitz's/Beyerhen trinity of forces, we might notice that the process of environmental decision making is often driven by the same trinity, where public participation brings emotion into the process, government regulation brings reason, and epistemic communities, at their best, bring all three components the trinity:

- Science (rational, structured, conventional reasoning)
- Passion
- Creative spirit and innovative ideas

Thus, epistemic communities can potentially constitute the powerful whole of the Clausewitz/Beyerhian trinity to become a leader in such conflicts - to lead, in this case, to the conflict resolution. This realization brings a sense of hope, along with tremendous responsibility. It may also explain why, since the 1960s, and the publication of Rachael Carson's *Silent Spring* (1962), epistemic communities have had a greater and greater impact on policy decisions.

Nonetheless, the role of epistemic communities – still stays dual in all major global and local environmental issues (Ozawa, 1996, 2005).

5.5. Butler Farms/Oak Creek Case Study: Call for Public Participation

The beginning of the Redesigning American Neighborhood (RAN) project itself and the call for public participation in the case of stormwater management in the Butler-Farms/Oak Creek Village neighborhoods coincided with increasing tension between the neighborhoods and the City of South Burlington.

The conflict between the residents of the Butler Farms/Oak Creek neighborhoods, the City of South Burlington, and the State of Vermont was a manifestation of the conflict between regional and local scales, as well as the problem of discounting the future, set off by a regulatory approach to the issue of non-point pollution. RAN project has been launched at times of City of South Burlington decision to retrofit the old stormwater systems to attenuate the peak flows and reduce non-point pollution, coming to the tributaries of the Lake Champlain, to the limits of the recently adopted State Total Daily Maximum Loads (TMDL). This has been complicated by the absence of finalized TMDLs codes for the impaired waters, by over than 1,000 expired state stormwater discharge permits, by Vermont Water Resources rule that no new or increased discharges of pollutants could be added to any impaired waterway without a TMDL, by high out of pocket costs per household estimated around $5,000 (StanTec Inc, 2006; Voinov Vladich 4, 2012) and by the moratorium on selling the houses until the retrofit of the stormwater systems would be accomplished after which the City of South Burlington became an epicenter of a political and legal crisis (Hinds et al., 2005; Page, 2006; Voinov Vladich 3, 2012).

Although the regulation led to a crisis, it also created an opportunity to develop and implement an alternative stormwater management plan.

The city and the state had two goals: (1) to find a way to resolve the conflict with the neighborhoods and (2) to help the neighborhoods find a way to retrofit their stormwater system.

The neighborhoods had no choice but to comply with the city and state requirements; the question was how that compliance would be implemented. There were two approaches to consider: using a conventional, engineered approach to substitute the flood prevention service of the landscape, or taking an alternative approach, through which the natural ecosystem functions and services of the landscape could be restored. Decision making involved a lengthy, iterative process that engaged a number of different stakeholders: city planners, an engineering firm hired by the city, academic researchers, and neighborhood residents.

In sum, RAN project started in an environment that was not conductive to the paced, regular development of a watershed management plan. Conflict with the city exacerbated the already challenging technical task of developing the stormwater management plan in existing typical New England neighbprhoods to meet low-impact, ecologically sound standards. On this basis, the goal of the RAN project was to develop generic replicable approaches for identifying practicable, low-impact stormwater management alternatives for existing suburban environments, through a combination of monitoring, research, engagement, and demonstration projects, including the development of an Integrated Modular Landscape - Based Stormwater Management (IMLaS) (Bowden et al., 2006; Voinov Vladich 4, 2012). The purpose of this effort was (1) to enable stakeholders, regulators, and researchers to collectively visualize alternative futures and (2) to optimize a mix of stormwater management interventions at various scales to best balance environmental, social, and economic criteria (Bowden et al., 2006).

The RAN project focused on the following working objectives (Bowden et al., 2006):

#1- Assessment: Develop a framework to assess opportunities for intervention in adaptive stormwater management at various spatial scales, and apply this framework to the Butler-Farms/Oak Creek Village neighborhoods case study.

#2- Evaluation: Compare the costs and benefits of the alternatives identified for the case study in objective 1 and consider potential market-based incentives that could facilitate implementation of the identified alternatives.

#3 - Participation: Involve community stakeholders in the development and evaluation of objectives 1 and 2, through town or neighborhood meetings relying on whole-watershed visualization tools and multi-criteria decision aids designed to promote shared learning among participants.

#4 - Implementation: Initiate a demonstration project that can be used as a focal point to test ideas and designs generated by objectives 1 through 3.

5.6. Fostering Success in Participatory Process

Tools and approaches, used to achieve objectives #1, #2 and #3 involve many diverse elements (Bowden et al., 2008). The focus of this chapter is to empirically show that the various approaches and solutions developed on the basis of participatory spatial analysis (PSA) can be aggregated into a comprehensive "solution toolbox" (fig. 5.4, 5.5a, 5.5b), which leads to more efficient results and successful outcome in a participatory process of environmental decision making and conflict resolution.

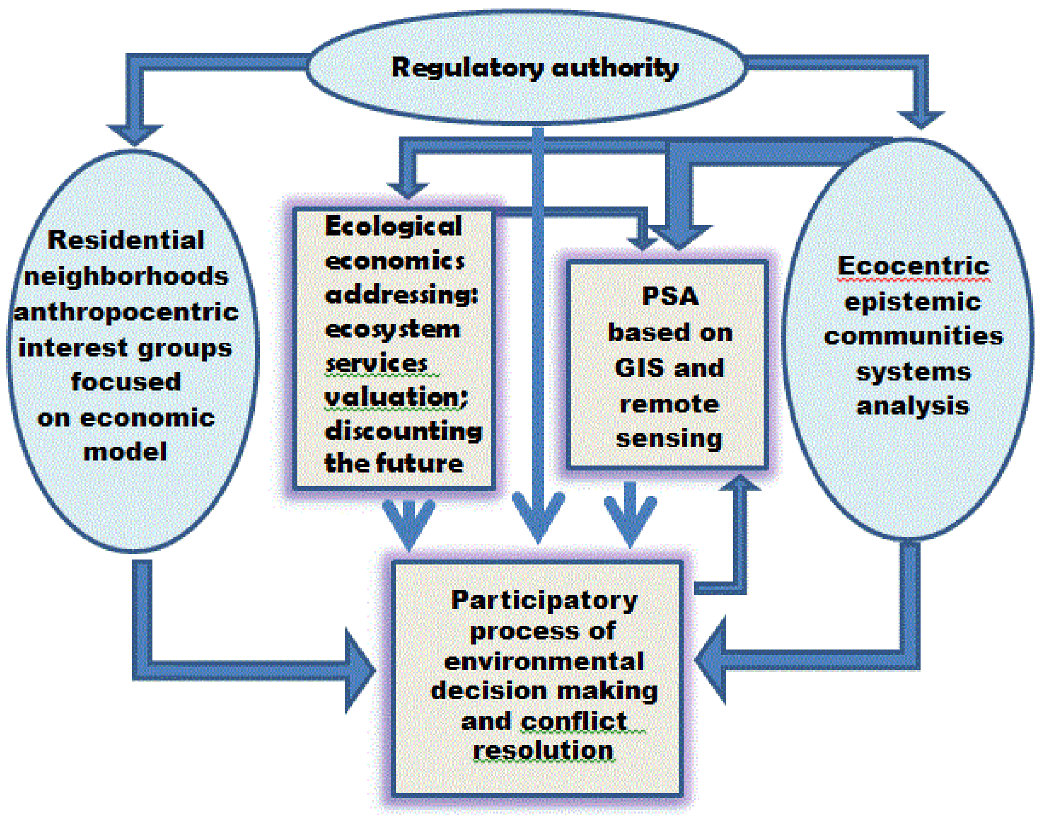

Fig.5.4. The use of participatory spatial analysis (PSA) in a participatory process of environmental decision making and conflict resolution, regarding stormwater management.

5.6.1. The Choice of Participatory Spatial Analysis

In adaptation planning, some situations may be better suited to expert-led discussion, but with public inclusion providing a democratic check on the value judgments of experts.– *Few R., Brown K., Tomkins E.L. Public participation and climate change adaptation: avoiding the illusion of inclusion.*

Escalating tensions between the Butler Farms/Oak Creek neighborhood and the city led the research team to recognize the need for innovative tools that would accomplish the following:

- Facilitate both the redirection of the conflict to constructive mode and the goal-setting process
- Begin building trust between residents, researchers, and the city
- Provide a methodology for targeting and prioritizing residential stormwater best management practices (BMPs) at three different scales
- Identify effective intervention areas for BMPs at different scales
- Provide a methodology for cost-benefit analysis of alternative intervention scenarios
- Educate neighborhood residents by enabling them to visualize the effects of various processes on the living landscape of the watershed
- Provide a basis for understanding between city and state officials, and thereby help to negotiate the methods, process details, and resource allocation between the two jurisdictions

The requirements, described above, led to the development of a framework that would employ participatory spatial analysis (PSA), high-resolution remote sensing data, and ecosystem services valuation as tools for environmental consensus building. In this framework, science plays a constructive role in environmental conflict resolution: it is treated as an agent of discovery, an independent mechanism of accountability, and a means of educating stakeholders and mediating conflict. Participatory Spatial Analysis (PSA) is described in details in (Voinov Vladich 2, 2012; Voinov Vladich 3, 2012).

5.6.2. Potential for Differing Outcomes in the Use of Complex Participatory Modeling Tools

The development and use of complex technological tools is not a panacea by itself. The same tool used in different case studies might lead to different outcomes. In order to assess how successful is the use of the tool it would be necessary to assess how effectively the tools help to achieve the five social goals, defined by Beierle and Cayford (2002) (see section 5.4.1).

With these goals in mind, we can examine two different case studies that used the same complex, spatially explicit spatially explicit dynamic landscape participatory modeling approach.

The first example is the watershed that feeds St. Albans Bay, on Vermont's Lake Champlain. Most of the watershed is in agricultural use, although it also includes a fast-growing urban area. Despite the expenditure of a considerable amount of money and effort, nonpoint phosphorus loading to the watershed has remained a persistent problem, causing escalating tension between farmers, city dwellers, and owners of lakefront property had a cascading effect: first, it helped to identify a new solution, which differed from what had traditionally been used; second, it led to greater community acceptance of the solution choice; finally, acceptance led to the implementation of the most cost-effective suggestions (Gaddis, 2007).

The same the spatially explicit dynamic landscape participatory was also applied to the James River, Virginia, which faces significant development pressure, largely owing to population increases. To identify acceptable and sustainable solutions for water management within the basin, it was clear that a comprehensive planning process, involving all key stakeholders, was needed. Initially, there was extensive participation in the modeling effort; involvement quickly declined, however. Eventually, it became clear that two key stakeholders were engaged in a background conflict. In addition, one of the key stakeholders, the US Army Corps of Engineers, had some internal opposition to the project, that influenced the outcome in a negative way (A. Voinov & Gaddis, 2008).

Dynamic Landscape Model (DLM) was used in both cases. The results, however, were dramatically different In St. Albans, the use of PM was successful. It is only be fair to note, however, that after the researchers had finished their analysis, completed the model, and left, stakeholders and policy makers were unable to continue using the model on their own, because it was complex and not user-friendly. The participatory modeling undertaken for the James River, in contrast, was not successful.

On the basis of these two examples, one might notice, that, when complex technical tools are used, the outcome, meaning "successful" participatory process, may not depend on the tool as much as on other factors. One such factor, identified by researchers of James River study, is the preexisting history of the conflict. In case of the James River, water planning had long been a source of tension between some of the stakeholders. The participatory modeling (PM) effort could not move forward until stakeholders reached consensus—but a network of historic connections between stakeholders, both professional and personal, dominated the participatory process (A. Voinov & Gaddis, 2008).

5.6.3. The Influence of Context on the Participation Process

T. Beierle and J. Cayford (2002) have undertaken extensive research on how context influences the environmental decision-making process. Their analysis demonstrates that the participation process itself, rather than its context, is largely responsible for the success or failure of public participation, according to social goals (see section 5.4.1). In the course of their research, Beierle and Cayford considered the effect of three contextual factors on public participation:

- Issue type
- Level of preexisting conflict and mistrust
- Institutional context (i.e., differences across agencies or across local, state, and national decision-making processes)

In the case of issue type, Beierle and Cayford's analysis shows that whether an environmental issue is site-specific or is addressed at the policy level (i.e., as an issue that affects a state or a nation as a whole), there is little difference in success rates.

Findings for the second contextual factor are counterintuitive to the conclusion of the James River case study, that preexisting conflict, including mistrust, would have a strong effect on results, Beierle and Cayford's (2002) analysis shows only a moderate relationship between preexisting conflict and the success of public participation. Specifically, Beierle and Cayford found that:

> Despite the plausibility of the expectations that the quality of preexisting relationships may influence results, …. preexisting conflict and mistrust have more impact on success only when the processes are less intensive. In other word, robust participation processes do a better job of transforming poor preexisting relationships than do less robust processes, but the history of the conflict is not itself a significant barrier to the prospects of success. (Beierle & Cayford, 2002, p.39)

Finally, Beierle and Cayford (2002) found that the third factor, institutional context, has little effect on success.

In sum, context has less impact on participatory environmental decision making than might have been supposed. Instead, the process itself is highly important to a successful outcome.

5.6.4. The Intensity of the Participation Process

Beierle and Cayford (2002) use the term "process intensity" to distinguish between types of participatory processes and investigated how different kinds of participatory processes relate to success. They identify four mechanisms for participation, which exist on a continuum from the least to the most intense:

- Public meetings and hearings
- Advisory committees (not seeking consensus)

- Advisory committees (seeking consensus)
- Negotiation and mediation.

According to this classification, as a participatory process increases in intensity, it moves from being oriented toward gathering information from a wide range of people toward working on agreements among a small group of defined interests. Another characteristic of increased intensity is greater capacity on the part of process participants—meaning that they have more experience with the issues under discussion, more experience influencing public decision making, and more experience with participatory efforts. This greater capacity makes the process more effective in solving problems and implementing decisions. It is important to note, however, that increasing intensity tends to require more funding and staff support (Bierle and Cayford, 2002).

Common sense might lead one to describe public meetings and hearings as "intense"—because they tend to be characterized by conflicting opinions, arguments, and emotion, whereas negotiation and mediation may appear calm, professional, structured, and organized by comparison. It might be more useful to think in terms of effectiveness or robustness, rather than intensity. Irrespective of what intensity is called, Beierle and Cayford's (2002) analysis shows an impressive correlation between the intensity and the success of the process. The correlation is so clear that the authors caution against the temptation to use more intensive processes for all environmental decision making. Despite its effectiveness in achieving the five social goals, the most intense form of participation carries risks, including: (1) higher costs and (2) the exclusion of the larger public from the process—which may lead, in turn, to unexpected results and impediments (Beierle & Cayford, 2002).

5.6.5. Combining the Intensity with Public Participation

The real challenge is to find a way to combine the intensity of participatory process and broader public participation. This requires artistry —and perhaps the establishment of an epistemic community (see sections 5.4.4; 5.4.5).

Beierle and Cayford (2002) suggest three approaches to meeting this challenge:

- Having the participants in the "intensive" process, such as participatory modeling, commit to communication and accountability among stakeholders
- Creatively combining various types of participatory mechanisms
- Using modern networking capabilities, such as the Internet, to organize a large-group deliberative process.

When charged with the long history of the conflict, however, the interplay of social dimensions of the participatory process is so intricate, that yet another approach is useful to have in a tool palette: a complex series of feedback loops, suggested by S. Ali (2007), p.6:

> The key to a constructive approach in environmental peace-building is to dispense with linear causality and instead consider the conflict de-escalation process as a nonlinear and complex series of feedback loops.

5.6.6. Reference State and Interactive Backcasting

Interactive backcasting, a technical approach to crafting sustainable solutions in the course of environmental decision making (Hisschemöller, 2002; Mulder & Biesiot, 1998; Van de Kerkhof, Hisschemoller, & Spanjersberg, 2002), in case of conflict between scales of interest, involves developing a vision of desirable future (regional and local reference states) (Farley & Costanza, 2002; Voinov Vladich 4, 2012) then working backward to determine what conditions would be necessary to achieve that state.

Backcasting originated in critiques of predictive forecasting, which held that because science is a social process, it carries risks, such as following conventional pathways and excluding alternative views. As K. H. Dreborg (1996) notes, dominant trends in predictive forecasting might lead one to overlook solutions that would presuppose the breaking of trends. Thus, backcasting should intentionally seek opportunities to break with dominant trends. Dreborg (1996) argues in favor of backcasting as a paradigm rather than a method, a recipe rather than a tool; in other words, it is an overarching approach that may involve a variety of specific methods.

Interactive backcasting focuses on producing images of the future. According to Holmberg (1998), this process involves four steps:

- The identification of long-term sustainability criteria
- The analysis of the present state in comparison to these criteria
- The development of a vision of a desirable, sustainable future (reference state)

- The design of a pathway to the desirable, sustainable future

5.7. The Cumulative Process

First part of RAN project objective #4 (Implementation) - was *not* focused on proving the technical feasibility of *a particular* stormwater management technology. Rather, it was focused on development of a participatory process, leading to effective stormwater management, that might include a broad array of technologies or approaches and that had the *a priori* backing of the involved stakeholders (Bowden et al., 2006). Development of a successful participatory process, leading to an effective stormwater management came as a result of going through the process of achieving first three objectives of the project: #1 – Assessment; #2 – Evaluation; #3 - Public Participation, all of which were challenged by the conflict between the Butler Farms/ Oak Creek neighborhoods and local authorities.

5.7.1. Adaptive Approaches to Assessment, Evaluation, and Public Participation

Under the pressure of heated conflict and in an effort to respond to the urgency of special circumstances, it is often necessary to make ad hoc choices (Voinov Vladich 3, 2012). Initially, the research team intended to use spatially explicit, dynamic modeling to achieve objectives 1 and 2 (assessment and evaluation) and as the centerpiece of objective 3 (public participation) (see section 5.5). However, it soon became clear that this approach would require more time and funding than the team had available. Meanwhile, the heated environment of the conflict called for a relatively quick, effective approach. The recent release of high-resolution LiDAR and QuickBird data led to the decision to use PSA (Voinov Vladich 3, 2012), which became the core of a participatory framework that incorporated modeling into the decision-making process (see fig. 5.5a and 5.5b)

Objective #1 (assessment) was focused on finding opportunities for intervention at different spatial scales and levels of community involvement. To meet this objective, the research team developed a PSA framework based on a systems approach. To assess how and where to use various types of intervention in a whole-watershed context, the team used high-resolution LiDAR data to develop a micro stormwater drainage density (MSDD) index (Voinov Vladich 2, 2012). For objective #2, evaluation, the research team introduced the concept of ecosystem services to the analysis. Using QuickBird data, the team assessed the impervious area of the watershed and the neighborhood. Finally, using the MSDD index, the team identified areas that would potentially benefit from the use of midscale BMPs and quantified their retention capacity (Voinov Vladich 2, 2012).

The availability of 2.4 QuickBird imagery was instrumental in conducting additional analyses, developing the NDVI index, and assessing imperviousness. The information on impervious surfaces was used to assess the runoff for the areas targeted for small - and midscale BMPs.

Methods developed for objectives #1 and #2 became the basis for the first stage of objective #4, implementation. The goal of objective #4, first stage, was the development of an alternative distributed (IMLaS) management plan. Given the high level of conflict, the fundamental premise was that overall success would depend on objective #3, participation by community stakeholders; thus, objectives #1, #2, and #4 were intimately linked to objective #3. Stakeholders included homeowners, developers, resource managers, and policy makers (Bowden et al., 2006).

The results of the first stage of analysis, which was completed through the use of LiDAR and QuickBird data, was presented at the November, 2006, meeting of the Stormwater Study Group (SWG). To ensure that both officials would hear residents' concerns about the situation in the Butler Farms/ Oak Creek neighborhoods, the meeting was attended by Jeff Wennberg, the state's commissioner for the environment, and Pete LaFlamme, chief of the stormwater section at the state's Agency of Natural Resources. The presentation was a turning point in the decision-making process, particularly with regard to the development of possible options for retrofitting the neighborhood's stormwater system. As a direct result of the presentation, the SWG requested from RAN team the development of a "whole-picture," small-scale, distributed IMLaS management plan (Bowden et al., 2008; RAN1: Redesigning the American Neighborhood, 2006; Voinov Vladich 3, 2012).

Several months later, at another meeting of the SWG, the research team presented two engineering options in addition to the alternative distributed IMLaS management plan; the consensus among SWG participants was that the IMLaS option was “best” (RAN2: Redesigning the American Neighborhood, 2007, p.3). The choice took into consideration the multiple secondary benefits of IMLaS, which are described in detail in chapter 4 (Voinov Vladich 4, 2012) of this dissertation..

Among the secondary benefits that had the greatest influence on the decision made at the SWG meeting were the following:

- The use of IMLaS created the possibility for negotiating and sharing the cost of the retrofit with surrounding properties.
- IMLaS offered protection against repeated flooding.
- The fact that IMLaS was innovative, environment-oriented, and distributed in time and space opened opportunities to obtain additional grants and thereby lower residents’ out-of-pocket costs.

In June 2007, IMLaS was presented by the city as the core of the city’s stormwater management proposal for the Butler Farms/Oak Creek neighborhoods (RAN 3: Redesigning the American Neighborhood, 2008). The decision to move forward was discussed at numerous neighborhood meetings. The city also created a special assessment district to fund the project, which voters approved in a citywide vote (DiPietro, 2012). By 2010 the project had reached the implementation stage (City of South Burlington Planning and Zoning, 2011; RAN 4: Redesigning the American Neighborhood, 2010).

Engaging the city leading authority in the concept of whole system analysis, BCBA, secondary benefits and in the process of developing the vision of the local reference state was the key to the constructive decision making process (Hinds et al., 2005; RAN7: Redesigning the American Neighborhood, 2006).

5.7.2. Steps of Participatory Process

"Across all the conceptions of quality, one result is consistent: more intensive forms of stakeholder involvement are more likely to produce higher-quality decisions. The result runs counter to the fears that politics is trumping decision quality. These same intensive processes are the most 'political' forms of public involvement."

Bierle T.C., 2002. The quality of stakeholder-based decisions

The tripartite complexity of the RAN project research effort comes from the interconnection of three disciplinary areas: stormwater management, ecological economics, and public participation in environmental decision making and conflict resolution. All three disciplines came together in the course of complex, atelier-type meetings with stakeholders (stormwater working group (SWG)). Part of the meetings were based on a Participatory Spatial Analysis (PSA), based on high-resolution LiDAR and QuickBird data and included internal feedback loops around PSA (see fig.5.5a and 5.5b).

The process began with deep conflict between the city and the neighborhoods (Fig. 5.5a, step 1) (Voinov Vladich 3, 2012). Using spatial information about the terrain that was as precise as the LiDAR data would allow, the research team reconstructed and analyzed the micro storm- drainage networks; the team then precisely identified “Source Areas” and “Areas of Opportunity”, which were used to develop the MSDD index and to target areas for BMP interventions at various scales (Fig.5.5.a Steps 2 and 3) (Voinov Vladich 2, 2012).

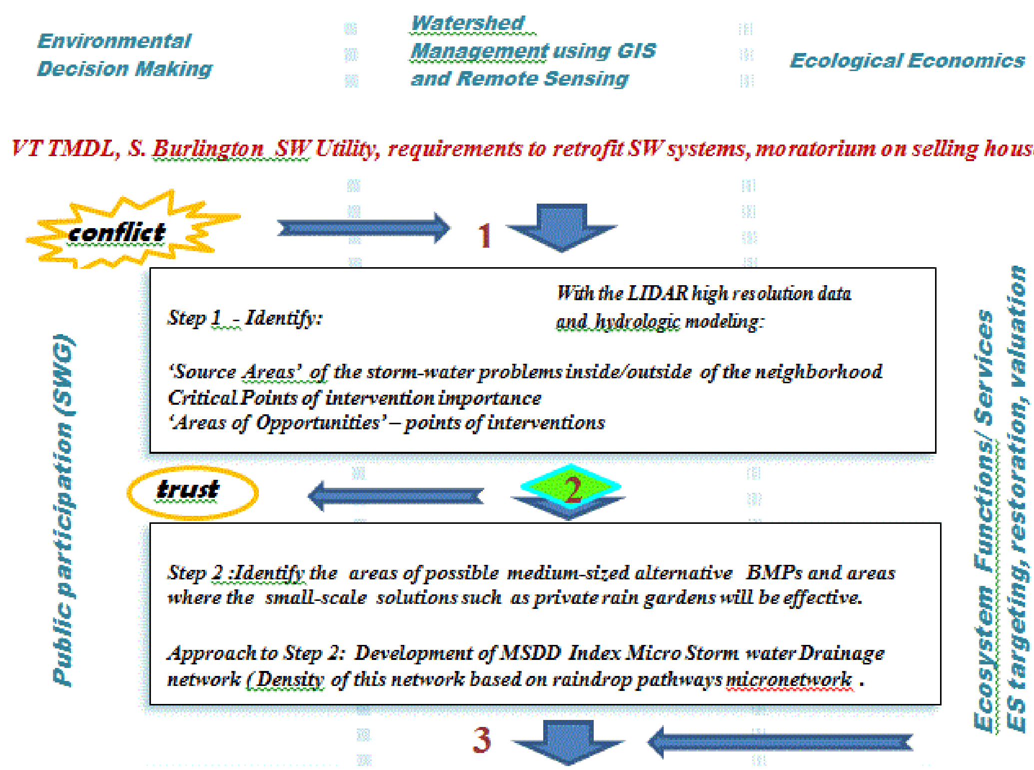

Figure 5.5.a. Steps 1 and 2 of participatory process of environmental decision making based on GIS modeling, high resolution LiDAR and remote sensing data

The approach turned out to be highly useful in mitigating conflict between the neighborhoods, developers, the city, and the state. It also helped to build trust between residents and researchers and became a turning point in the development of a constructive dialogue (RAN1: Redesigning the American Neighborhood, 2006; Voinov Vladich 3, 2012).

Steps 3 and 4 of figure 5.5a and 5.5.b correspond to the introduction of the concept of landscape-based ecosystem services into the analysis. This step expanded the metrics being applied to stormwater management beyond the attenuation of peak flows or reductions in contaminant levels, to include improvements in community well-being, ecosystem health, and economic development. It was possible to expand the metrics because combination of PSA with the concept of landscape ecosystem services and the notion of a reference state or vision of a desirable and to identify secondary benefits of the alternative stormwater management plan (Fig.5.5b, step 4) (Farley & Costanza, 2002; Voinov Vladich 4, 2012).

At the beginning of the project, the city authorized the creation of the SWG, which consisted of roughly 25 neighborhood volunteers. The goal of the SWG was to explore the ecological, financial, and aesthetic implications of various feasible approaches to fixing the neighborhood's stormwater system (Bowden et al., 2006; Voinov Vladich 3, 2012). In the course of the stakeholder meetings, the SWG requested information about stormwater treatment designs, ranging from a conventionally engineered large detention pond (the "superpond" scenario) to distributed low-impact design (LID) installations (figure 5.5b, green diamond 4) (RAN 1: Redesigning the American Neighborhood, 2006). In addition to requesting performance information for each alternative, the SWG requested estimated engineering costs (Bowden et al., 2008).

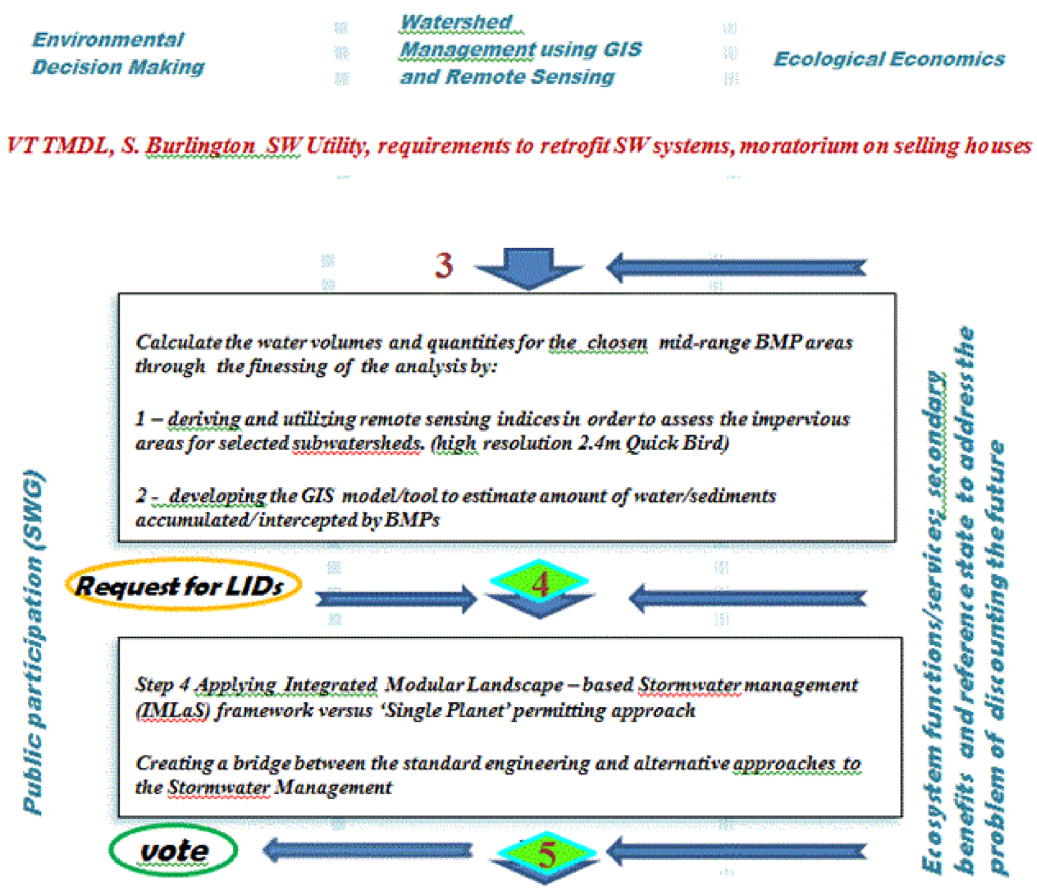

Figure 5.5.b. Steps 3, 4 and 5 of participatory process of environmental decision making based on GIS modeling, high resolution LiDAR and remote sensing data

As noted in section 5.7.1 (figure 5.5, green diamond 5), the SWG ultimately voted to approve the IMLaS management plan (RAN2: Redesigning the American Neighborhood, 2007; Voinov Vladich 4, 2012). Interactive backcasting has been used to search for the ways to make alternative distributed plan for stormwsater management achievable (see section 5.6.6)

5.7.3. The Implementation Stage

Although Beierle and Cayford (2002) found that implementation is not closely connected to the success of a decision-making process, which they classify as successful after the acceptance of a suggested plan (stage 1 of implementation), it is worth noting that the Butler Farms/Oak Creek project has advanced with several items of the plan as far as the stage 4 along the five stages of implementation (see section 5.4.2): (1) - Output of the public participation process, such as recommendation or agreement; (2) – Decision or commitment on the part of the lead agency; (3) – Changes in law, regulation or policy; (4) - Actions taken on the ground; (5) - Changes in environmental quality.

At the time of writing, implementation of the alternative distributed stormwater management plan, based on Integrated Modular Landscape-based Stormwater management (IMLaS), option 3 (see Fig.4.9, chapter 4 of this dissertation (Voinov Vladich 4, 2012) and fig.5.6) included the following:

- Two new detention ponds, with a blend of conventional and green designs, funded by a combination of US EPA demonstration grant and SAFETEA grant, administered by the Vermont Agency of Transportation and South Burlington Stormwater Utulity (fig.5.6, areas 1and 2)
- Retrofit of old non-functioning storm-water ponds (fig.5.6. areas 8 and 9)
- Stream buffers undertaken as part of an U.S. EPA demonstration project (fig.5.6, area 6)

- A flood-plain restoration project (fig.5.6, area 7)

There are plans to install water-quality monitoring stations in the spring of 2013 and establish new sustainable-agriculture project and butterfly garden.

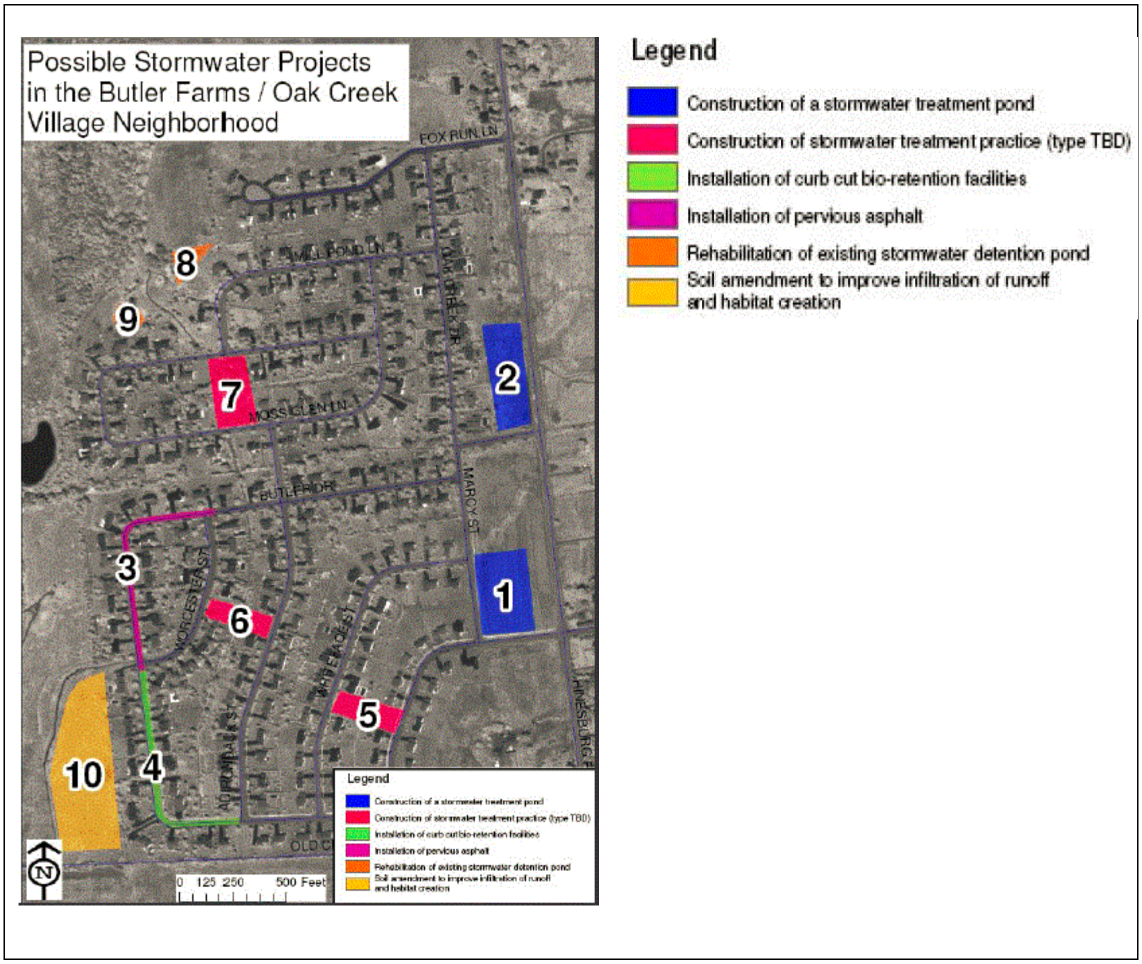

Figure 5.6. Proposed stormwater projects in the Butler Farms/Oak Creek neighborhoods by Office of Planning and Zoning of South Burlington, based on IMLaS framework. *Source:* Adapted from (RAN3: Redesigning the American Neighborhood, 2008)

The implementation stage demonstrated that the presence of the research team was essential for active public participation. Once the RAN project ended, residents participation in project development dropped significantly

(City of South Burlington Planning and Zoning, 2011; DiPietro, 2012). The implementation stage demonstrated that the interaction between research team and the city was essential not only for active stakeholders participation, but also for the alternative plan implementation. After the RAN project ended, several elements of the plan, related to the various stakeholders' approval were not implemented:

- Street edge alternatives (curb cut rain gardens)(fig.5.6, area 4) were not installed due to concern by neighbors and ultimately the cost. The cost per impervious acres treated was very high.
- The "golf course swale" (fig.5.6, area 10) was not constructed because city could not come to terms regarding use of the property needed with the property owner
- Porous pavement (fig.5.6, area 3) – was not installed, since city was concerned about use of this technology on a street after observing failures in other parts of VT (DiPietro, 2012).

5.8. Discussion

5.8.1. Objectives Associated with Stormwater Management: Stormwater Quality, Ecological Economics, and Public Participation

The goal of the RAN project was to develop approaches for identifying practicable, low-impact stormwater management alternatives in existing suburban environments through a combination of monitoring, research, engagement, and demonstration projects. To move toward this goal, the research team needed to (1) develop a stormwater management plan at the neighborhood (subwatershed) level and (2) develop and test tools that would allow homeowners, developers, and city and state officials to apply a mix of stormwater interventions at various spatial scales to optimize the environmental, social, and economic goals associated with stormwater management.

Among the accomplishments of the RAN project was the development of an IMLaS framework based on the MSDD index (Voinov Vladich 4, 2012). As a result of the RAN project, ideas, technologies, engineering approaches, spatial analyses, and ecologies specifically tailored to a particular neighborhood are helping to achieve the dual goals of effective stormwater management and public acceptance (Bowden et al., 2006). Although initial use of PSA was intended as a hydrologic spatial analysis of the watershed, where the Butler Farms/ OakCreek neighborhoods are located, it role expanded in the course of the project. The importance of the study increased significantly after the research team began using high-resolution LiDAR and

QuickBird data to develop an MSDD index and a framework for targeting and assigning priority to BMPs at different scales (Voinov Vladich 2, 2012). In the final phase of the study an alternative distributed Integrated Modular Landscape –based Stormwater Plan (IMLaS) was developed, which Butler Farms/ Oak Creek neighborhoods residents and the City of South Burlington selected by as the plan for action.

The study is a result of the interconnection of three disciplinary areas: stormwater management, ecological economics, and public participation in environmental decision making, all of which were factors in the PSA (Fig.5.5a and 5.5b).

With respect to the goal of improving stormwater quality, the PSA based IMLaS/MSDD framework helped the research team accomplish the following:

- Analyze and understand the hydrologic processes at the scale of the watershed, encompassing Butler Farms/ Oak Creek neighborhoods
- Define locations for BMPs at various scales
- Use a whole-systems (encompassing watershed) versus a "single planet" (neighborhoods areas, cut out by administrative boundaries) approach

- Employ the spatial landscape features with flexible, "distributed " characteristics

- Identify, evaluate, utilize and restore ecosystem services, which is present or have a potential to be manifested in a landscape
- Helps with the recurrent various scales flooding in the neighborhood
- Create a basis for alternative low-impact stormwater management designs in the existing residential neighborhoods (Voinov Vladich 2, 2012; Voinov Vladich 3, 2012; Voinov Vladich 4, 2012)

With regard to ecological economics, a PSA based IMLaS/MSDD framework has the following advantages:

- Applying PSA in conjunction with MSDD spatial index, creates the foundation for the detection and valuation of ecosystem services—which, in turn, can lead to the discovery and quantification of the value of overlooked urban ecosystems at the micro-scale level (Voinov Vladich 2, 2012).
- Because an IMLaS/MSDD framework can target areas for alternative small and midscale BMPs—and for the creation, restoration, and enhancement of stormwater retention and peak-storm mitigation services—it allows for the efficient allocation of funds in the course of the decision-making process.
- An IMLaS/MSDD framework can help to address the problem of discounting of the future, by introducing a local scale reference state and connecting it to the regional reference state (quality of the water in the Lake Champlain) by (enlarging the shadow of the future)

- Establish a basis for a system of fines and rewards at multiple scales, which are linked to the quality and quantity of the stormwater runoff that accumulates and flows from individual properties and residential neighborhoods
- The distributed character of the IMLaS/MSDD approach saved a large piece of public land that would otherwise have been used for a superpond (the parcel was big enough to be considered for another use—the construction of a school) (Voinov Vladich 4, 2012)

Because of its high visualization power (ability to present data in an accessible visual format), an IMLaS/MSDD framework can help to achieve a number of public participation goals:

- Disseminating the results of analyses and other information to stakeholders
- Achieving not only stormwater-related behavioral change, but a higher level of systems thinking and more effective public engagement in environmental local stormwater management decisions and solutions
- Enabling process facilitators to devise a strategy for turning away from tension and conflict and toward trust and acceptance
- Refine the data about the system through the active stakeholders participation
- Facilitating trust building between residents, researchers, and local government representatives

- Facilitating trust building between residents, researchers, and local government representatives through the high level of visual detailization coinciding with the residents' everyday "backyard experience"
- Strengthening neighborhood residents' negotiating power
- Providing a basis for understanding between state and local government officials that, in turn, can help with the negotiation of process details, methods, and resource allocation between the two levels of government (Voinov Vladich 3, 2012).

5.8.2. Connecting to the Five Social Goals

By step 2 of the process (fig. 5.5, green diamond 2), it had already become clear that the RAN project in general, and the PSA in particular, were meeting all five of the social goals defined by Bierle and Cayford (2002) (see section 5.4.1) (Voinov Vladich 3, 2012). Despite high tensions at the beginning of the process, the use of PSA,high-resolution remote sensing data, hydrologic modeling, and the valuation of water-regulating ecosystem services in a human- modified environment to promote environmental consensus building and craft an IMLaS in the Butler Farms/Oak Creek neighborhoods was very successful. The fact that residents had the option to choose between three different versions of the stormwater management plan put the process in line with recommendations for adaptive planning from Few et al. (2007). The intensity of the process was very high; it also met all other criteria important for a successful outcome:

- A responsive lead agency
- Motivated participants
- High-quality deliberation
- High level of public control

In the case of the Butler Farms/Oak Creek neighborhoods, the city had two desired outcomes: (1) mitigating the conflict and (2) the retrofitting of existing stormwater management facilities in accordance with the requirements established by the VWRB. The residents' desired outcomes were (1) title clearance; (2) help with recurrent basement flooding, and (3) minimization of costs for the required retrofit. A set environmental issues that is as complex as those affecting the Butler Farms/Oak Creek neighborhoods— including contested priorities and obvious conflict between temporal and spatial scales set up multiple challenges. Palette of tools, developed by RAN team on the basis of PSA/MSDD effectively helped with "An honest, informed approach to participation that could better enable agencies to tailor inclusive processes of decision-making to the task in hand"(Few et al., 2007).

5.8.3. Reactivating Three Principles

"Solution toolbox", developed by RAN team on the basis of participatory spatial analysis (PSA) was instrumental in reactivating the principle of participating consciousness, understanding the ends-means spectrum, and shifting the vision toward sustainable possibilities during participatory process of environmental decision making and conflict resolution.

Mitigating conflict between spatial and temporal scales of interests as well as enlarging the practical use of the end-means spectrum were addressed during the decision-making process by reconnecting Butler Farms/Oak Creek residents to several distinct components of the stormwater management:

- The project team used extensive educational efforts GIS-based PSA, hydrologic analysis based on high-resolution LiDAR and Quick Bird data, to demonstrate to residents how small-scale, backyard actions were connected to lake health at a large scale (Bowden et al., 2006; Hinds et al., 2005; Voinov Vladich 3, 2012)
- The team also helped residents connect a large-scale vision of the beauty and health of the lake to a vision of the potential beauty and health of a small watershed and tributary, that run through the subwatershed, where the neighborhoods are located, directly to the lake
- By introducing the notion of ecosystem services—in particular, the capacity of the landscape to provide stormwater retention services—the project team enlarged the scope of possible solutions
- Using the IMLaS framework, the project team introduced residents to the secondary benefits of the distributed landscape-based approach and increased their awareness of the difference in the flow of costs and benefits over time between centralized, engineered stormwater solutions and alternative, dispersed solutions (Voinov Vladich 4, 2012)

Reactivating the three principles and integrating them into participatory process in the case study of the Butler Farms/Oak Creek helped to disentangle complex and deep-rooted conflict, restore the trust, and direct the decision making process toward sustainable solution.

5.8.4. Addressing Concerns Regarding Public Participation in Environmental Decision Making

The shift in opinion in favor of an alternative approach brings up concerns about managerialist tendencies that have been raised by Few et al. (2007). Such tendencies may arise in the context of strategic planning, when there is a conflict between scales of interest—for example, when local stakeholders have to sacrifice benefits to meet the needs of stakeholders working from broader temporal or spatial scales. One way to address such conflict is through a managerialist approach, which involves containing public response as a means of exerting control over decision making. The possibility for managerialism is even higher when public participation threatens to undermine agency objectives. Although containment may bring an agency the desired results, Few et al. (2007) argue that it ultimately leads to public dissatisfaction, heightened mistrust, hostility, defiance, and opposition. In such an environment, participatory exercises can potentially do more harm than good. As noted by Beierle and Cayford (2002), the degree of public control is one of the four factors of success (see section 5.4.2).

Although the incompatibility of scales (regional versus local) in the case of the Butler Farms/Oak Creek neighborhoods was not as great as it is, for example, in the case of climate change (global versus local), it was still present, and clearly caused tensions between the state and the city (which had a shared strategic perspective) and neighborhood residents (who were in the realm of spatial and temporal immediacy). The issue of uncertainty, however, did not play a decisive role in this case, as it does in the case of climate change. Quite the opposite: the relationship between the percent of imperviousness, land use practices, spatial and temporal stormwater patterns, and the quality of the water in the rivers and lakes has been well researched, monitored, described, established—and is fairly certain (Voinov Vladich, 2012). As a result, stormwater management has very certain desired outcomes. And, in case of an existing neighborhood, achieving these outcomes is a great challenge.

As described in Voinov Vladich 3 (2012), the Butler Farms/Oak Creek case was a particularly challenging one. Nevertheless three factors—a diverse palette of tools and ideas, developed in the context of the RAN project (Bowden et al., 2008); PSA based on GIS modeling, high-resolution LiDAR, and remote sensing data; and the responsiveness of the lead agency—enabled stakeholder participation to achieve the criteria for effectiveness set forth by Millennium Ecosystem Assessment (2005):

> Ultimately, the effectiveness of stake-holder participation depends on:
>
> - Whether it makes any difference in decision making,
> - Whether it contributes to the establishment as well as the achievement of objectives, and
> - Whether it provides an opportunity to work through difficult issues rather than avoid them.

It should also provide stakeholders with an opportunity to learn, and to reconsider the values they place on freshwater services. (Millennium Ecosystem Assessment Program, 2005)

5.9. Conclusions

There may be many ways to produce decisions of high technical quality, but there are relatively few methods that do so while also educating the public, eliciting public values, resolving conflict, and building trust in agencies, as many stakeholder processes do.− *Bierle T.C., The quality of stakeholder-based decisions*

In the case of Butler Farms/Oak Creek, the use of PSA and the development of an IMLaS/MSDD framework for stormwater-related environmental decision making proved successful. All the criteria defined by Beierle and Cayford (2002), which use social goals to evaluate the outcomes of participatory processes, were met. This success can be attributed to multiple factors, one of which was the IMLaS/MSDD framework itself. This framework can be applied to any environmental conflict in which water quality or quantity is at stake, and may be beneficial during the process of working with stakeholders. Among the advantages of the IMLaS/MSDD framework are the opportunities to build trust between researchers and stakeholders and to redirect the energy of conflict toward the search for constructive solutions. If applied at different scales—nationally and internationally, for example—such a framework has the potential not only to become a foundation for real change in peoples' understanding of ecosystem services, including the value of such services in a human-modified environment, but also to become a mediating tool in the environmental negotiation process.

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APPENDIX A1. CHAPTER 2: ASSESSING STORMWATER RUNOFF FOR THE DELINEATED LANDSCAPE DEPRESSION AREA, TARGETED BY THE MICRO STORM DRAINAGE DENSITY (MSDD) INDEX

In order to assess how precipitation patterns affect the behavior and characteristics of a watershed**,** historical NOAA rainfall data (NOAA, 2002) have been obtained. Additional calculations were performed for the higher levels of precipitation, than it is suggested by a conventional engineering approach, have been chosen, to address the possibility of increased storms frequencies of higher magnitudes. NOAA data show that the 25 years, 2 hours storm could produce 5.08 cm (2") of rain.

A 5.08cm rainfall for the delineated (Fig.2.7) area of mid-size BMP, calculated by Arc GIS ModelBuilder Tool = 13200 sq. meters (3.263 acres), yields 670.56 cubic meters of water (6.526 acre-inches, where an acre-inch is the volume of 1" of water were it sits atop of one acre of land).

Finally storm water runoff volumes and sediment quantities have been estimated for the delineated watershed using the SIMPLE approach. The SIMPLE method estimates stormwater runoff pollutant loads for urban areas (Center for Watershed Protection., 2004; Prince George's County Department of Environmental Resources (PGDER)., 1997; Schueler, 1987; US EPA, 1983; Whalen, Cullum, & Division, 1988). The SIMPLE technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. The SIMPLE method estimates stormwater runoff pollutant loads for urban areas and should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method.

The SIMPLE method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land use and stormwater management scenarios. The SIMPLE method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to over emphasize the precision of the results obtained. For example, it would be inappropriate to use the SIMPLE method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% impervious cover). The SIMPLE method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling may be needed to analyze larger and more complex watersheds. In the future some might wish to apply a more rigorous model. But the benefit to cost of that effort would likely not be great.

In addition, the SIMPLE method estimates only pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected.

Taken the delineated subwatershed area (Fig.2.7) as an example and following the approach of the SIMPLE method we calculated the runoff from stormwater, as follows:

1. The runoff coefficient was estimated by using formula:

$Rv = 0.05 + (0.9 * IA)$ (2)

where IA is the impervious area proportion. In our case, the first part of Arc GIS Model Tool yields IA as 0.137.

Therefore:

$Rv = 0.05 + (0.9 * 0.137) = 0.173$

2. Next, we calculate the runoff – effective portion of the 5.08 cm (2'') rain

$R = P * Pf * Rv$ (3)

where R = runoff (cm/inches)

P = precipitation (cm/inches)

Pf = fraction of rain events that produce runoff (~0.9)

Rv = runoff coefficient

In this case, R = 5.08 cm * 0.9 * 0.173 = 0.79 cm (0.312 inches) runoff.

3. And, finally, we calculate Volume/Quantity of the water

$V = R * A,$ (4)

where V – volume,

R –runoff (cm/inches),

A = area (sq m/acres),

$Q = k * V,$ *(5)*

where Q – water quantity,

k - conversion unit

For the delineated subwatershed,– the return of 2 hours storm is 104.6 Tons of water, that can be retained by the landscape depression and then percolated to the groundwater or evapotranspired by plants.

4. To calculate how much total loading occurs due to this runoff:

$L = k2 * V * EMC$ *(6)*

where L = loading in kg

k2 = unit conversion

V = volume of runoff (Step 3, equation (4))

EMC = event mean concentration of the pollutant (mg/L)

This example shows us how effectively we are able to estimate and suggest the size of mid-range BMP, chosen with the use of MSDD index. The algorithm for the water volumes and quantities calculation is constructed on the same basis as the second part of ArcGIS ModelBuilder Tool development, which allows the watershed imperviousness assessment, by Land Use.

APPENDIX A1.1. CHAPTERS 3, 4, 5: PARTICIPATORY SPATIAL ANALYSIS (GEOSPATIAL) DATA.

Geospatial data used in this study include high-resolution color-infrared digital aerial imagery, LIght Detection And Ranging (LIDAR) data, the stream hydrologic network, roads, houses location point data, land use, engineered catchments pipeline network and inlet points.

The LiDAR (Light Detection And Ranging optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light) point data have been, collected for Chittenden County, Vermont by EarthData International in January 2005 with an ALS40 sensor at 3 meter post spacing.

The Vermont Center for Geographic Information (VCGI http://www.vcgi.org/) provided the digital data for the stream hydrologic network, roads, houses location point data, land use, engineered catchments pipeline network and inlet points.

DigitalGlobe High-resolution 2.4m multispectral satellite imagery from the Quickbird have been acquired by VCGI in the summer 2004 for Chittenden County of Vermont. The imagery is 4-band color- nearinfrared, with green (466–620 nm), red (590–710 nm), blue (430–545nm) and near-infrared (NIR1) bands (715–918 nm).

Very high resolution multispectral color and color infra-red digital orthophotography with a pixel of 16 centimeters using imagery have been collected with the Leica ADS40 digital pushbroom sensor and processed with the ISTAR system. This data set was produced by EarthData International for Chittenden County, Vermont in 2005 and supplied to Chittenden County Metropolitan Planning Organization (CCMPO)

South Burlington Impervious Surfaces Data, derived from 2.44m multispectral Quick Bird Data (Data Credit to Leslie Morrissey and Jarlath O’Neil Dune, Rubinstein School of Natural Resourses (RSENR), University of Vermont)

APPENDIX A2. CHAPTER 3: POLLUTION BILL COMES DUE

By Candace Page

SOUTH BURLINGTON -- A light June rain fell on the bright green lawns and sloping driveways of the Butler Farms subdivision and began to collect some of the dirt it would carry to Lake Champlain.

Rainwater gurgled down a gutter on deserted Butler Drive. Lawn clippings swirled in the gritty stream. A rainbow slick of oil coated the surface.

The runoff poured into a storm drain in front of Greg and Carole Lothrop's house and into Tributary 7 of Potash Brook. The tributary, more ditch than stream, ran faster and faster, dirtier and dirtier, through Butler Farms and neighboring Oak Creek Village, then north to join the main brook.

Potash Brook rushed west through some of the most intensely developed land in Vermont. Polluted runoff from city streets, Interstate 89 and shopping mall parking lots plowed into the brook, ripping dirt from its banks. Just south of Queen City Park, the brook dumped the scourings from 7 1/2 square miles of South Burlington into Shelburne Bay.

Cleaning up those scourings -- and stormwater pollution across the Champlain Basin -- will require enormous amounts of public and private money, more than $18 million in South Burlington alone. Statewide, the bill could mount into tens of millions, stormwater regulators say.

The job is important to the health of Lake Champlain because stormwater runoff is laced with phosphorus, a fertilizer that feeds algae blooms and has become a major water quality concern for the lake.

Stormwater carries traces of many pollutants -- bacteria, oil, pesticides, heavy metals -- but it delivers one-third of all the phosphorus reaching the lake.

Stormwater, the experts like to say, is everybody's fault.

Experts know it -- but most of us do not. Most of us have no idea how we contribute to stormwater pollution. When we're told, we can be reluctant to change how we fertilize our lawns or pave our driveways.

We're even less thrilled about the cost of cleaning up.

Cost estimates make neighbors fume

At Butler Farms and Oak Creek Village, 258 homeowners learned this summer that controlling stormwater will cost each of them up to $5,000. Failure to act could create legal difficulties when residents want to sell their homes.

The neighborhood's reaction can be summed up like this: "Are you nuts?!"

"Vermont likes to go after neighborhoods like mine," fumed Bryan Hunt, a retired New York City firefighter who lives on Whiteface Street. "Excuse me, who is going to pay for all this?"

What would residents of Butler Farms and Oak Creek Village do if they were not required to install new stormwater treatment?

"They'd do nothing," said Chris Smith, a financial planner, City Council member and resident of Oak Creek Drive since 1994. "Doing nothing isn't the right answer, but I'm telling you, that's what people think."

While most Vermonters aren't required to install stormwater controls for existing homes, Butler Farms residents are not the only exception to the rule.

About 3,000 home or condominium owners in South Burlington and a smaller number in other Chittenden County communities might be required to improve stormwater controls by October 2007.

Breaking down the cleanup challenge

South Burlington's expensive cleanup illustrates the size of the challenge Vermont faces, in financing stormwater improvements and educating Vermonters about how each person can help:

-- Cost: Preventing future pollution adds costs to new development. For developments built without stormwater controls, the price of retrofits averages $30,000 an acre.

-- Cost-benefits: Because each stormwater source is relatively small, it is difficult or impossible to quantify the benefits to the lake obtained from an improvement project, even a costly one.

-- Many changes are voluntary: Although Vermont has taken important steps to reduce future pollution, retrofitting existing roads and developments is largely voluntary.

-- Changing behavior: Voluntary cleanup moves slowly. It requires homeowners and governments not just to spend money but to change the way they manage their property, from re-engineering roadside drainage to cleaning up after their dogs.

W. Breck Bowden, a University of Vermont professor of watershed science, said there is nothing unusual in the stormwater contribution -- or the attitude -- of Butler Farms residents. They stand for all of us.

"People don't make a connection between what happens in their back yard and what happens to the lake," he said. "They don't want to be told to do things differently, and that includes the way they fertilize their lawns and wash their cars."

Stormwater excavates with a bulldozer's power

Stormwater pollutes two ways.

First, it washes dirt and pollutants off lawns and paved surfaces.

Second -- and worse, stormwater specialists say -- pavement doesn't absorb or slow runoff. Stormwater channeled by culverts or roadside ditches can hit a stream literally with the force of a bulldozer, plowing tons of phosphorus-laced dirt from streambeds and banks.

As a result, developments like Butler Farms cause three times as much phosphorus pollution per acre as farmland they replace and 40 times as much as naturally forested land.

Vermont has cleaned up sewage treatment plants and worked to limit farm pollution. Still, the amount of phosphorus reaching Lake Champlain has increased.

"The likelihood is that urban development in the watershed has offset phosphorus reductions we've accomplished in agriculture," said Eric Smeltzer, state government's lead Lake Champlain researcher.

Without new controls, stormwater problems will only grow as land is converted to homes, highways and shopping malls.

Power of the law is brought to bear

South Burlington has so many streams damaged by stormwater that the city set up a new stormwater utility to help build, improve and maintain control systems. Every homeowner pays a $4.50 monthly stormwater fee.

The city doesn't pay for stormwater improvements at private commercial developments or residential subdivisions like Butler Farms, but will take over maintenance once they are built to state standards.

Those improvements are required by new state regulations to restore the health of Potash Brook and 16 other Vermont streams -- 14 of them in the Lake Champlain basin -- so damaged by stormwater that they are on a federal list of "stormwater-impaired" streams.

The regulations were adopted after the Conservation Law Foundation, an environmental advocacy organization, successfully challenged permits for new development in the Potash Brook watershed. The foundation argued that Vermont was failing to protect stormwater-damaged streams as required by law.

In response, lawmakers passed tough cleanup plans, not for the lake, but for damaged streams.

Lake Champlain will see phosphorus reductions as the brooks are restored, but scientists and regulators cannot quantify that benefit.

An initial estimate found a phosphorus reduction of just one-third ton from reducing pollution wash-off into all 14 streams. The savings should be greater than that if streambank erosion also is reduced.

Lack of evidence about the benefits of cleanup creates skeptics.

"Show me the benefit to the lake," Smith, the city councilor, said after learning the cost of stormwater control in his neighborhood.

Pete Laflamme, the state's stormwater chief, said persuading people to spend money or change their habits to clean up a stream like Potash Brook, as opposed to the lake, can be a tough sell.

"You go out and tell people, 'I want $5,000 from you to build a stormwater pond because there are no mayflies in the brook,'" he said. "People will say, 'I don't care about the mayflies; it's an urban stream. There are shopping carts and dead dogs in it.'"

Neighborhood asks, 'Why us?'

In the lottery of suburban life, Butler Farms and Oak Creek Village drew a terrible stormwater card.

The development is built on clay soils that don't soak up rainwater. A rudimentary stormwater system installed when the development was built in the 1980s does not work well.

And, although residents didn't know it, the developers' state stormwater permits expired years ago.

To obtain a new permit, the two subdivisions must rebuild stormwater controls to meet state standards, work that could cost $5,000 a household.

"Montpelier thinks we're all millionaires in this neighborhood," said Dr. Paul Newhouse, a psychiatrist at the UVM College of Medicine. "Their attitude is we are just whining when we should be prepared to cough up the money."

"Everybody benefits from a cleaner lake, not just me and my neighbor," said Mary Lou Newhouse. Like others in the subdivision, she said the cost should be shared by a wider group of taxpayers in South Burlington or across Vermont.

People at Butler Farms say they care about the health of Lake Champlain. A request for volunteer homeowners to host two demonstration rain gardens, a stormwater control strategy, attracted 50 interested neighbors.

Carole Lothrop, who has lived on Butler Drive for 14 years, said she still fertilizes her lawn and garden, but has cut back since learning she could be contributing pollution.

"We're ecology-minded. We want to do our part," said Greg Lothrop, who installed a rain barrel to trap runoff from their roof.

Others, like Ray Forsell, a firefighter who lives on Moss Glen Lane, said they have not changed personal habits that might affect stormwater pollution. Forsell still fertilizes his lawn once a year and washes his car in the driveway.

"I'm unconvinced that anything our neighborhood does will improve Lake Champlain," he said. "To me, our best option is to go the Legislature and get them to change this crazy law."

Contact Candace Page at 660-1865 or e-mailcpage@bfp.burlingtonfreepress.com

APPENDIX A3. CHAPTERS 3, 4: AN IMPERVIOUSNESS ASSESSMENT MODEL FOR THE BUTLER FARMS/OAK CREEK NEIGHBORHOODS AND THE ENCOMPASSING SUBWATERSHED

This model is the second part of the two-part outreach tool for the Storm Water Assessment project in the Potash Brook watershed, South Burlington, Chittenden County, Vermont. The goal is to calculate the percent of impervious surfaces by land use for the subwatershed, delineated in the first part of the tool.

The calculations are based on:

1. *Land Use data of year 2000 by parcel for Chittenden County using the American Planning Association standards (data credit to Chittenden County RPC and Information Visualization Services (IVS);*
2. *South Burlington Impervious Surfaces Data, derived from 2.44m multispectral Quick Bird Data (Data Credit to Leslie Morrissey and Jarlath O'Neil Dune, Rubinstein School of Natural Resourses (RSENR), University of Vermont) NDVI Threshold method used to define impervious areas;*
3. *Subwatershed Outline created with the Watershed Delineation Model (part 1) that allows the user to delineate the subwatershed of one's choice, based on USGS DEM_24 Elevation data.*

The model has 4 general steps:

1. ***UNION*** *of Chittenden County Land Use Data and Impervious Surfaces Data;*
2. ***CLIP*** *the resulting layer by the specified watershed; and*
3. ***SELECT*** *the Impervious polygons in the clipped watershed*
4. ***Calculate SUMMARY STATISTICS*** *to find the Impervious Areas by different Land Use categories for the required Watershed and the total Area of the Watershed*

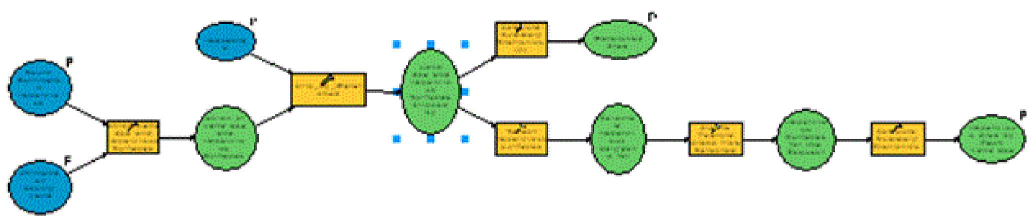


Figure A3.1. Imperviousness assessment model for the Butler Farms/Oak Creek neighborhoods and the encompassing watershed

Step 1. UNION of Chittenden County Land Use Data and Impervious Surfaces Data

The preprocess of the Land Use Data and Impervious Surfaces Data is required:

a) ***Add Field*** *to the Land Use Attribute table and name it LU_CODE. We need to aggregate the Land Use Categories to the General Level, using the American Planning Association Standards (http://www/planning.org/lbcs)*

The General Categories (field: ACTIVITY) are:

1000 – 1999 - Residential

2000 – 2999 – Shopping, business, Trade

3000 – 3999 – Industrial, Manufacturing, Waste

4000 – 4999 – Social, Institutional,

5000 – 5999 – Travel or Movement

6000 – 6999 – Mass Asembly

7000 – 7999 – Leisure Activity

8000 – 8999 – Natural Resources

9000 – 9999- No known Human Activity

The VBA script used for calculation LU_CODE field:

Dim result as an integer

IF (([ACTIVITY] > = 1000) and ([ACTIVITY] < 1999)) Then

result = 1

ElseIf (([ACTIVITY] >= 2000) and ([ACTIVITY] < 2999)) Then *result = 2*

ElseIf (([ACTIVITY] >= 3000) and ([ACTIVITY] < 3999)) Then

result = 3

ElseIf (([ACTIVITY] >= 4000) and ([ACTIVITY] < 4999)) Then

result = 4

ElseIf (([ACTIVITY] >= 5000) and ([ACTIVITY] < 5999)) Then

result = 5

ElseIf (([ACTIVITY] > = 6000) and ([ACTIVITY] < 6999)) Then

result = 6

ElseIf (([ACTIVITY] >= 7000) and ([ACTIVITY] < 7999)) Then

result = 7

ElseIf (([ACTIVITY] >= 8000) and ([ACTIVITY] < 8999)) Then

result = 8

ElseIf (([ACTIVITY] > = 9000) and ([ACTIVITY] < 9999)) Then

result = 9

End If

Lu_code = result

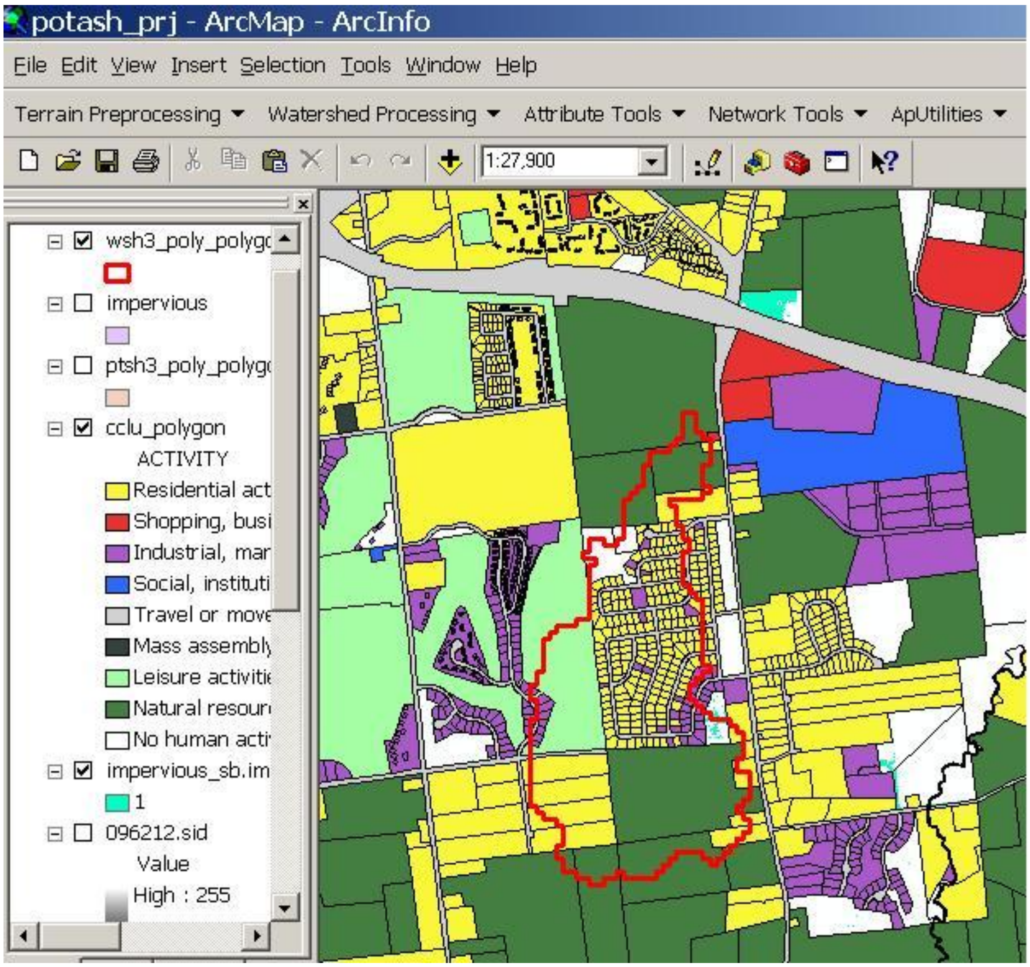


Figure A3.2. An example of Land Use overlaid by the requested Watershed

*b) **Add Field** to the Impervious Surfaces Attribute Table, called IMP_YES. This is the indicator of the presence of impervious surfaces, that will be used in step 3 for* *selecting the impervious surfaces from the Land Use and Impervious 'Unioned' feature Class clipped by watershed.*

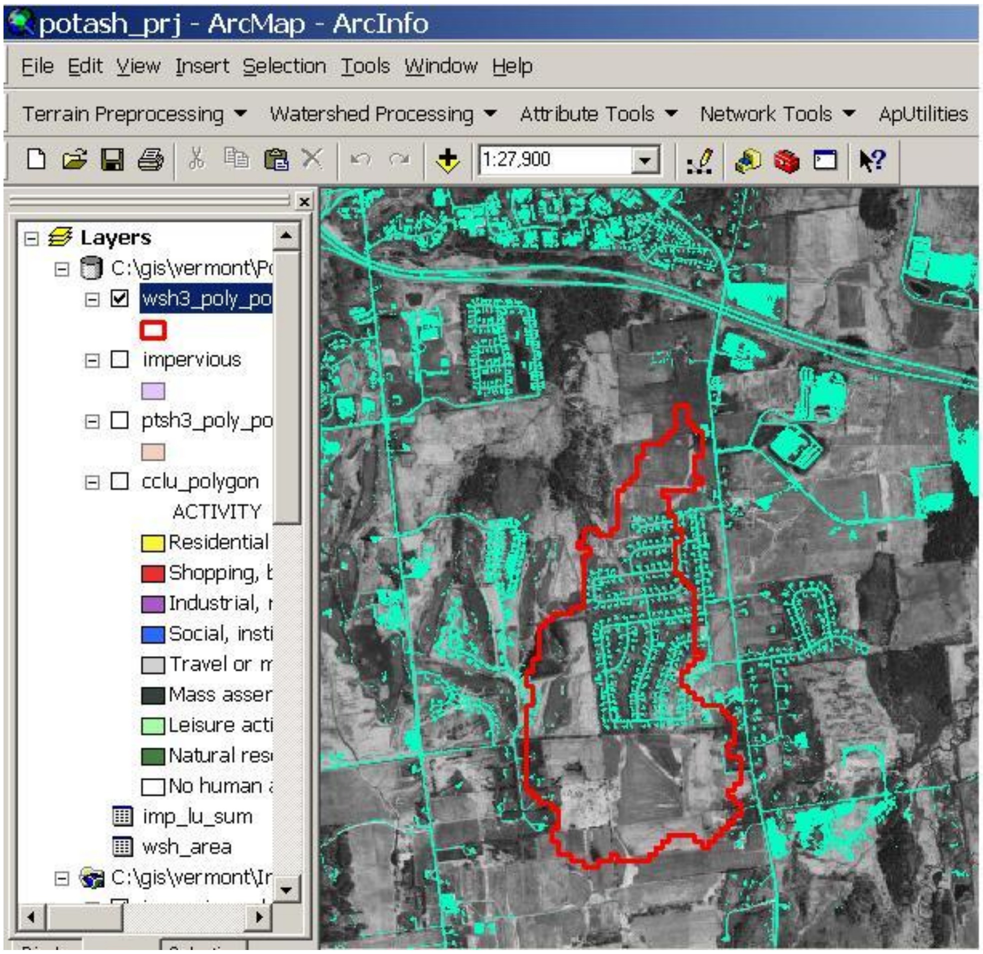


Figure A3.2. An example of Impervious Surfaces data overlaid by the requested Watershed

c) ***UNION Land Use and Impervious Surfaces layers*** *used to calculate the geometric intersection of Land Use and Impervious Feature Classes in order to be* *able to calculate the Impervious Area by the Land Use Type (step 4) and the percent of Impervious Areas (step 6). The resulting Extent is set to the Impervious Surfaces Data, since this Feature Class has the smaller spatial extent.*

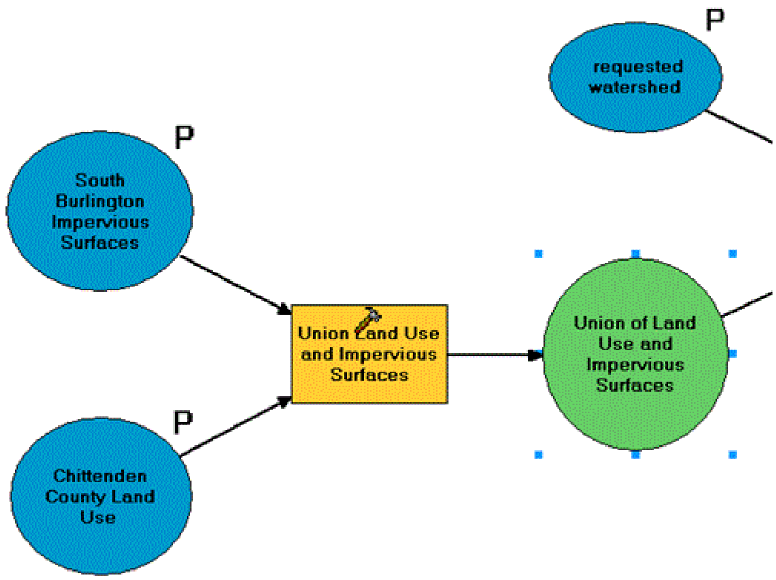


Figure A3.4. Step1- UNION of Land Use and Impervious Surfaces layers

Step 2. CLIP the resulting 'Unioned' layer by the specified watershed

***CLIP** tool is used for the 'Unioned' Land Use and Impervious Surfaces in order to extract the features that are overlaid by the required Watershed. The spatial extent is set to the Watershed, since it covers much smaller area.*

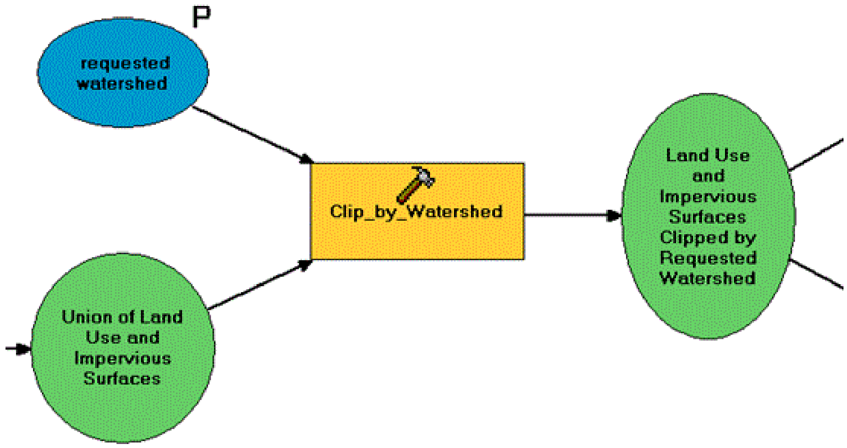


Figure A3.5. Step 2 - CLIP the resulting 'Unioned' layer by the specified Watershed

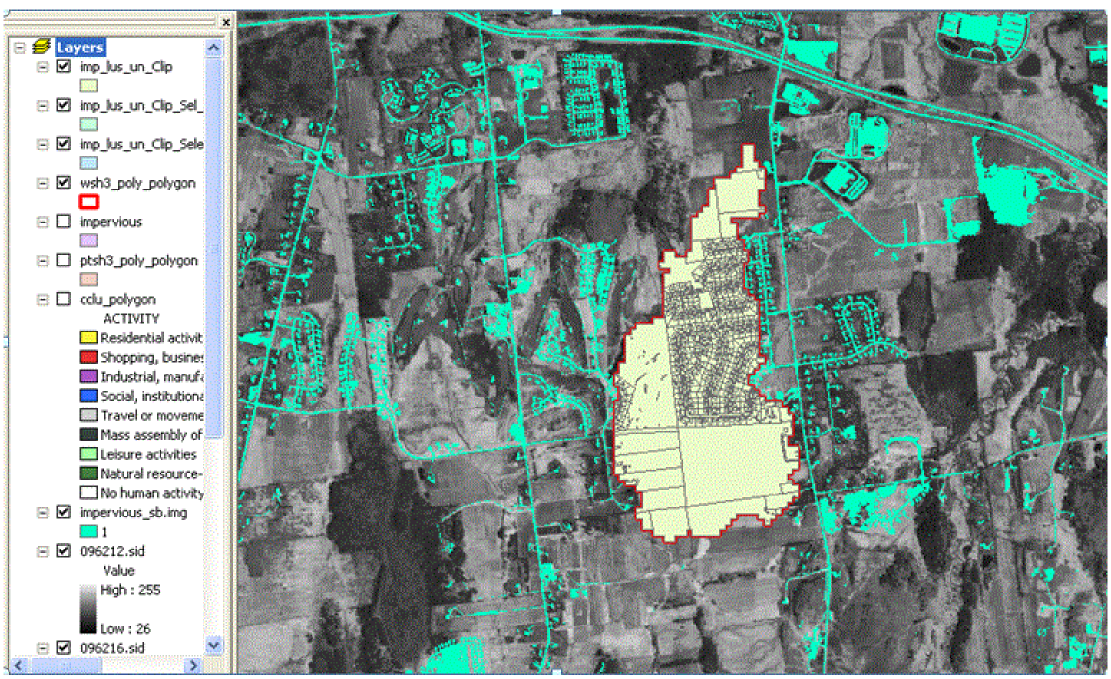


Figure A3.6. Step 2 - result of Clipping the Unioned layer by specified Watershed

Step 3. SELECT the Impervious Polygons in the Clipped Watershed

*a) **SELECT** tool is used to extract the Impervious polygons from the clipped feature class. Features are selected for extraction on the basis of the condition that attribute Imp_Yes = 1 (see section b in step 1).*

*b) To retain selected features a new feature class is created using the **Copy Features** tool.*

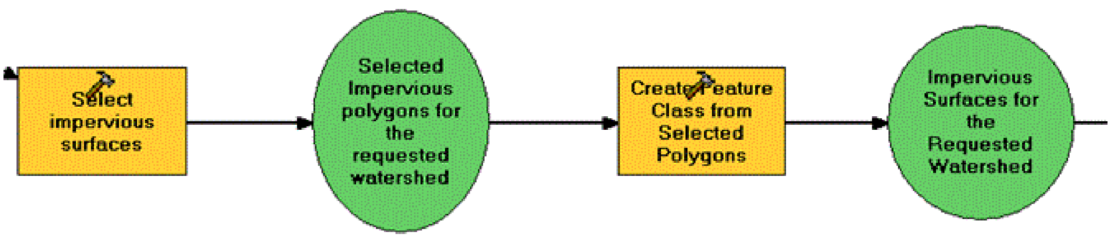


Figure A3.7. Step 3 – SELECT Impervious polygons from the clipped Watershed

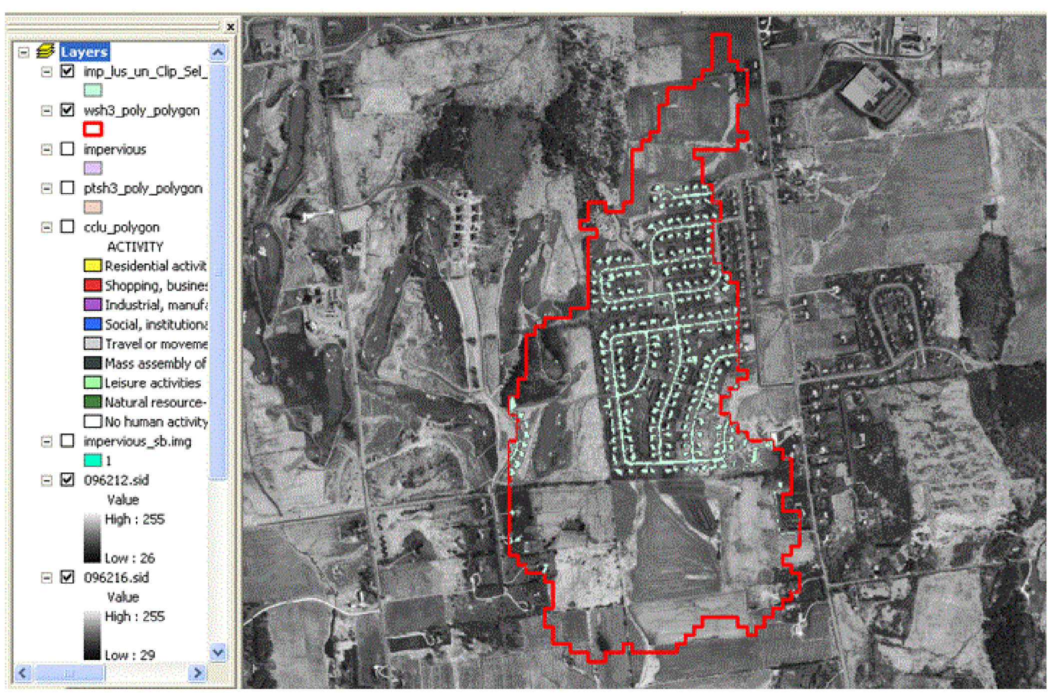


Figure A3.7. Result of Step 3 - SELECT tool is used to extract Impervious polygons from the clipped feature class.

Step 4. Calculate SUMMARY STATISTICS to find the Impervious areas by different Land Use categories for the required watershed and the total area of the encompassing watershed

*a) **SUMMARY STATISTICS** tool is used to calculate SUM of Shape area by Land Use type for Impervious Surfaces for the Requested Watershed feature class. Case field is LU_CODE. The output is a table in the Geodatabase. The SUM_FIELD contains the needed information.*

*b) **SUMMARY STATISTICS 2** tool is used to calculate SUM of Shap_area field of Land Use and Impervious surfaces, clipped by the requested watershed. The output is a table in the Geodatabase. The SUM_FIELD contains the needed information.*

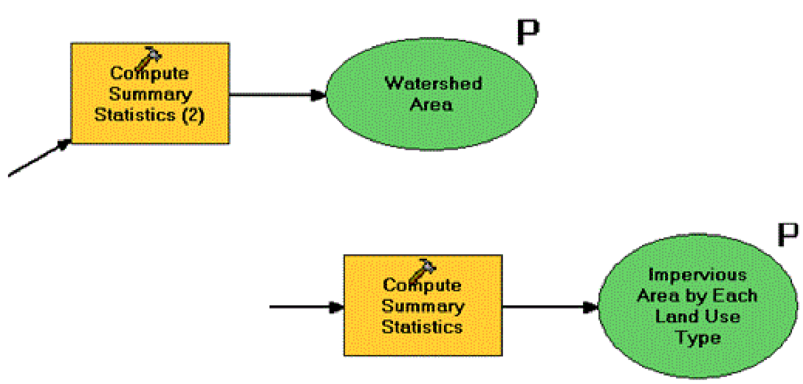


Figure A3.9. Step 4 - calculate SUMMARY STATISTICS to find the Impervious Area, sorted by different Land Use categories for the required Watershed and the Total Area of the Watershed

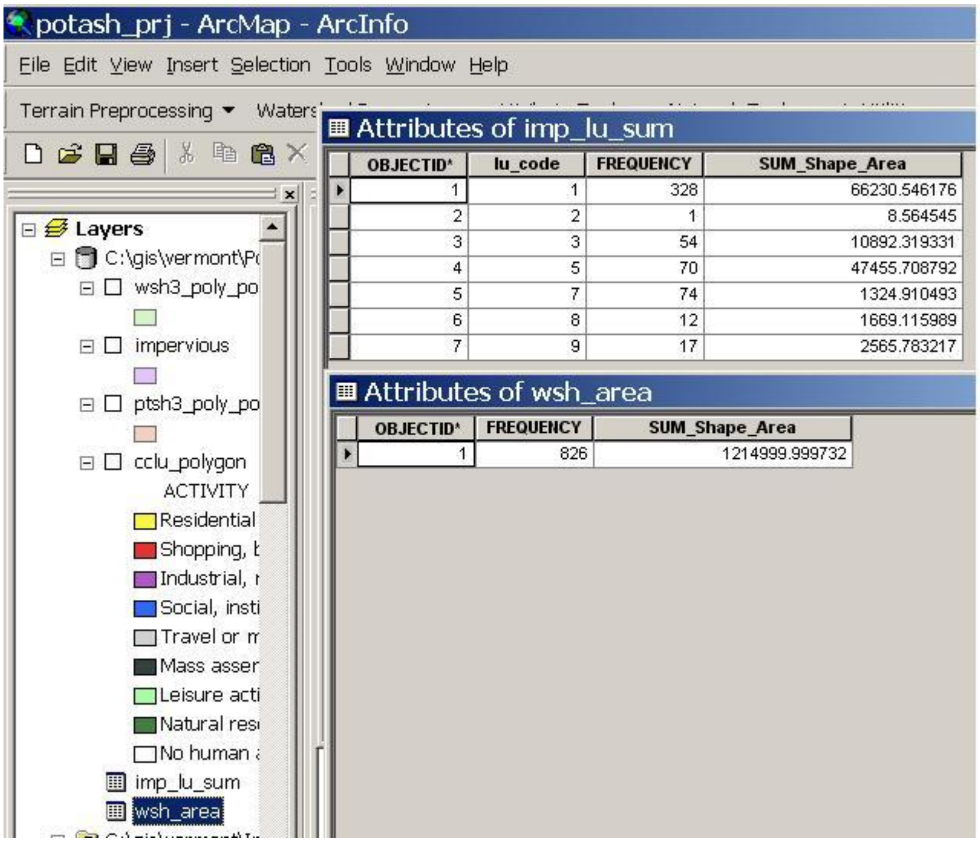


Figure A3.10. Step4 - an example of the resulting SUMMARY STATISTICS

<u>*Useful Notes:*</u>

- *Do not forget to set the path to the ToolBoxes(Model) to your current working directory (Tools → Options → Geoprocessing → My Toolboxes → Set Path; Check the Model Builder box to display valid parameters*

- *Before running the model another time it is always a good idea to Validate Entire Model (Model→ Validate Entire Model) and Delete Intermediate Data (Model → Delete Intermediate Data)*

- *It matters! While compiling the model in subsequent sessions, especially from the different labs or offices - watch out for the mapped drives! Check the specifications for the output data at all steps, it should be the same and correspond to your current working drive.*

- *Running the model step by step (<RCl> only on each tool in sequence → run) is a very helpful verification process, which is instrumental also to identify the most correct next step.*

- *Everything you want the end user to be able to see and change, define as parameters, including the final output*

- *In order to avoid an annoying need to delete all the intermediate data created by multiple runs of the model, make all intermediate outputs as shapefiles – do not put them in a geodatabase.*

- *Do not store metadata in the Word format*

APPENDIX A4. CHAPTER 4: STORMWATER PARK ECOLOGICAL DESIGN PROJECT BASED ON THE IMLAS APPROACH

Excerpt from RAN final report

A team of four University of Vermont students, mentored by Professor John Todd, used ecological problem solving to create a design for a wetland park to help treat stormwater runoff from the south east section of the Butler Farms neighborhood. Rather than focusing solely on treating a predetermined storm volume, their planning focused on creating a stormwater treatment wetland that provides wildlife habitat, recreational open space, educational opportunities, and aesthetic value. A schematic of the proposed wetland design is presented in Figure 5.

Figure A3-1. Location and design for a “front door” wetland natural area park in the eight-acre field adjacent to the BF/OCV neighborhoods.

The wetland was designed to have two sediment forebays to treat incoming stormwater from the two discrete stormwater outfalls. The students designed zones of perpetually wet, regularly inundated, seasonally or occasionally inundated and upland vegetation to help stabilize soil, remove pollutants, remove excess water through transpiration, and shield the park from traffic noise. The diversity of vegetation was intended to maximize both stormwater treatment capacity and wildlife habitat. Additional proposed components of the wetland eco-park included a boardwalk, an observation tower, and outdoor sculptures to encourage educational engagement and a broader sense of community among residents.

The design results were presented to the BF/OCV community during a SWG meeting in 2008. The designs generally received good reviews. However, uptake of this (or any other stormwater management schemes) is effectively on hold until issues surrounding the Vermont stormwater permit process for impaired watersheds can be resolved.

http://www.uvm.edu/~ran/Reports/08-12-08_RAN_Final_Report_PY3.pdf

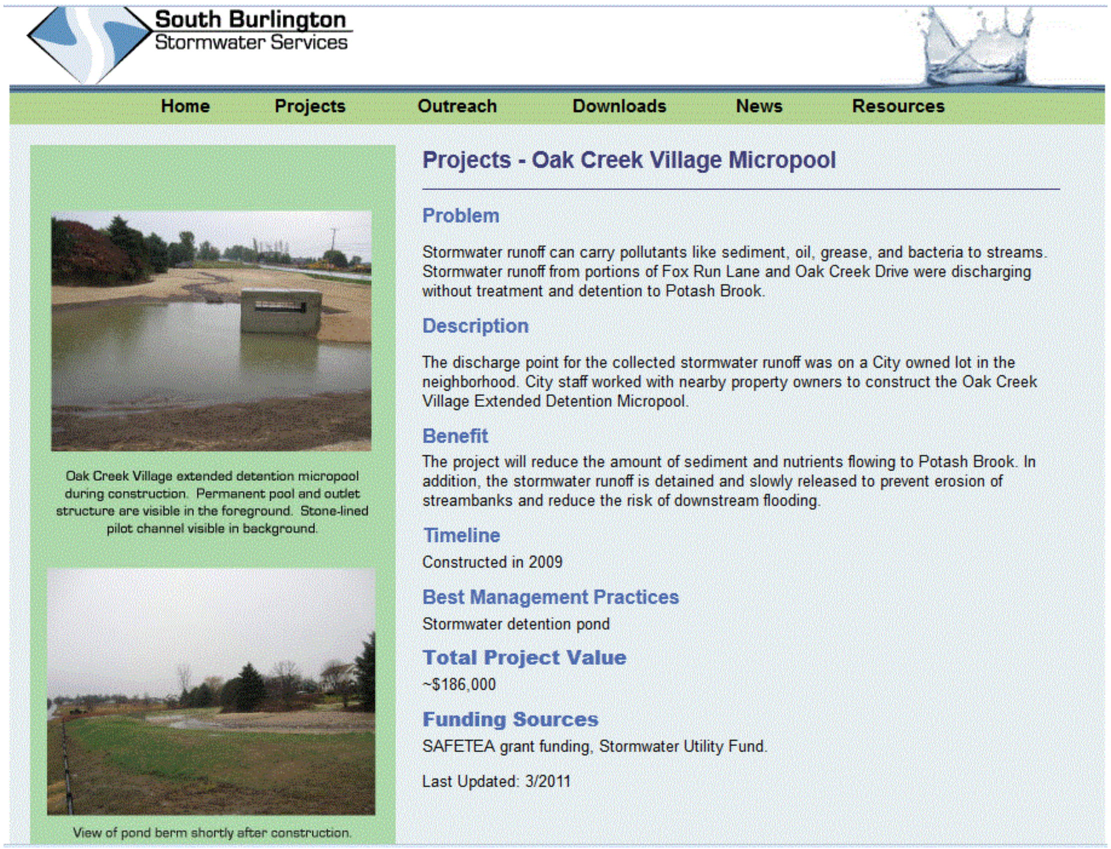
APPENDIX A5. CHAPTER 5: EXERPT FROM: LEVERAGE POINTS: PLACES TO INTERVENE IN A SYSTEM

By Donella Meadows

Key concepts:

- 12. **Numbers:** Constants and parameters such as subsidies, taxes, and standards
- 11. **Buffers:** The sizes of stabilizing stocks relative to their flows
- 10. **Stock-and-Flow Structures:** Physical systems and their nodes of intersection
- 9. **Delays:** The lengths of time relative to the rates of system changes
- 8. **Balancing Feedback Loops:** The strength of the feedbacks relative to the impacts they are trying to correct
- 7. **Reinforcing Feedback Loops:** The strength of the gain of driving loops
- 6. **Information Flows:** The structure of who does and does not have access to information
- 5. **Rules:** Incentives, punishments, constraints
- 4. **Self-Organization:** The power to add, change, or evolve system structure
- 3. **Goals:** The purpose or function of the system
- 2. **Paradigms:** The mindset out of which the system—its goals, structure, rules, delays, parameters—arises.
- 1. **Transcending Paradigms**

APPENDIX A6. CHAPTERS 4, 5: IMLAS IMPLEMENTATION STAGE: OAK CREEK VILLAGE MICROPOOL


South Burlington
Stormwater Services

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Oak Creek Village extended detention micropool during construction. Permanent pool and outlet structure are visible in the foreground. Stone-lined pilot channel visible in background.

View of pond berm shortly after construction.

Projects - Oak Creek Village Micropool

Problem

Stormwater runoff can carry pollutants like sediment, oil, grease, and bacteria to streams. Stormwater runoff from portions of Fox Run Lane and Oak Creek Drive were discharging without treatment and detention to Potash Brook.

Description

The discharge point for the collected stormwater runoff was on a City owned lot in the neighborhood. City staff worked with nearby property owners to construct the Oak Creek Village Extended Detention Micropool.

Benefit

The project will reduce the amount of sediment and nutrients flowing to Potash Brook. In addition, the stormwater runoff is detained and slowly released to prevent erosion of streambanks and reduce the risk of downstream flooding.

Timeline

Constructed in 2009

Best Management Practices

Stormwater detention pond

Total Project Value

~$186,000

Funding Sources

SAFETEA grant funding, Stormwater Utility Fund.

Last Updated: 3/2011

Figure A4-1. IMLas implementation stage. Oak Creek Village Micropool.

Source:http://www.sburlstormwater.com/projects/oak_creek.shtml