WATERWORKS!
MANAGING WATER ON THE FALSE CREEK MUD FLATS

by

ANAIS SHERRY MARIE LARUE

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Department of LANDSCAPE ARCHITECTURE

The University of British Columbia
Vancouver, Canada

Date April 21st 2003

ABSTRACT

This thesis proposes an alternative sewer and storm water management strategy for a newly proposed mixed-use light industrial community that is to reside on the 10.0 hectares Trillium & city park site. This site is currently up for redevelopment on the False Creek Flats of Vancouver. The potential environmental impacts of this development on the adjacent False Creek Inlet, and the Pacific Ocean will be fairly significant if new ecological models of sewer and storm water management are not implemented.

The methodology is broken down into five parts. The first section describes the local policies and that are centered on water quality and protection. The second section describes the natural hydrological cycle, and how the conventional sewage and stormwater system disrupts the natural interaction of water with the landscape. This is followed by a brief outline of the environmental impacts that are associated with conventional stormwater and wastewater treatment. The third section explores some of the precedents and case studies that have successfully implemented alternative stormwater and wastewater management strategies on the community level. The fourth section gives a description of the Trillium site, covering the history and its present day conditions. The fifth section outlines the design program for the Trillium site that is based on the outcome of the preceding analysis. The final section proposes an alternative sewage and stormwater management design for the Trillium site based on the findings described in the design program.

In conclusion the final design proposal for the Trillium site illustrates how an alternative sewage and stormwater management model can be effectively implemented into a community design to meet specific environmental water quality standards and local policy. However, the healing and ongoing protection of local waterways would require that all communities throughout the city and the Lower Mainland adopt similar alternative systems. The central idea then is to prohibit pollution of water altogether, rather than simply permitting specified amounts of pollutants into the environment. Only then will we really start to live in closer harmony with the natural world.

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CHAPTER I Water Crisis in the Modern City

1.1 Introduction

> *"Under every city there is a dark and hidden Venice, but we no longer celebrate our waterways out in the open. In its myriad cycles water is the source of all life, but when we, in industrial societies, harness it for our use in plumbing and sewage we keep it underground, in pipes as part of a system that is efficient for the user but displaces the problem to a distant site".(Nancy & Jack Todd, 1994)*

This thesis proposes an alternative sewer and storm water management strategy for a newly proposed mixed-use light industrial community that is to reside on the 6.8 hectares Trillium site. This site is currently up for redevelopment on the False Creek Flats of Vancouver. The potential environmental impacts of this development on the adjacent False Creek Inlet, and the Pacific Ocean will be fairly significant if new ecological models of sewer and storm water management are not implemented.

Such concern arises from reviewing the current design proposals for the Trillium site which indicates that the proposed liquid waste (sewage, domestic and light industrial wastewater), management plan is to connect to the city's centralized waste treatment system that sends sewage and wastewater to the Iona Wastewater Treatment Plant and stormwater to the Clark Drive out fall system.

Studies conducted by the Department of Fisheries and Oceans (DFO), indicate that the Iona Wastewater Treatment Plant is the largest single source of municipal pollution in BC. The pollution problem originates from the discharge of large volumes of low quality treated wastewater into the Pacific Ocean. Discharge rates from the Iona facility, which receives combined sewer and stormwater effluent from the City of Vancouver area, can

range from 180 cubic feet per second on a typical summer day, to as high as 650 cubic feet during heavy rainfall events. The DFO agency has also reported, that the impacts on the aquatic environment by the Iona treatment facility is extensive as tests revealed that all fish placed 2.2 km from the outfall pipe died within 9 minutes (Sierra Sewage Report, 2000).

Compounding the problem are the seasonal overflows of the combined sewer and stormwater systems. In the Vancouver area, the combined systems typically overflow approximately 500 times per year, or 140 times each into the Burrard Inlet, the Fraser River, and 45 times into both English Bay and False Creek (GVRD, 2000a). The resulting discharge amounts to 28 billion liters of raw sewage of which 21.2 million cubic feet goes into the False Creek Inlet.

The large outflows and adverse environmental effects (a few being a decrease in stream water levels, fish disease and die-off, health risk to humans and other animals) due to low-quality treated sewage, raw sewage and contaminated stormwater discharged into Vancouver's surrounding water bodies, has prompted two major law suits against the Greater Vancouver Regional District (GVRD). In both cases the Sierra Legal Defense Fund investigated and charged the GVRD with violations to the Fisheries Act for the discharge of substances deemed to be harmful to fish.

Although there are no current or future plans to upgrade the Iona Treatment Facility. The City of Vancouver and the GVRD are currently making efforts to alleviate some of the problem by replacing combined sewers with separate systems that will reduce the volumes of raw sewage reaching the waterways.

However, the mere separation of the two systems is not enough as stormwater runoff will now bypass treatment facilities altogether. This is problematic as large volumes of urban runoff containing concentrated levels of toxic hydrocarbons, heavy metals, coliform bacterial and other synthetic substances will still be discharged into the surrounding water bodies of Vancouver and the Lower Mainland region (NRC, 1993). Further, the conventional stormwater system requires a massive underground system of catchbasins and pipes designed to quickly remove stormwater from the impervious surfaces of the city and discharge it into nearby water bodies. This artificial linear system disrupts the natural water cycle that constantly replenishes and purifies water and instead depletes and pollutes the water contained in natural systems. The depletion and pollution of water not only threatens the lives of fish and other aquatic organisms, it also threatens all terrestrial life including human life.

Encouragingly, The City of Vancouver and GVRD have made a commitment to improve, protect, and conserve the inland and coastal water systems of the Georgia Basin region by setting a number of environmental policies and initiatives, which is an important step. However, conventional sewage and stormwater management practices are at the heart of the problem and must be replaced if environmental objectives are to be met.

There are many precedents and case studies that demonstrate that there are some sound ecological alternatives to dealing with the problem of sewage and stormwater management that have been found to be cost effective and environmentally sensitive. Unlike conventional wastewater management systems that impose a continuing threat to aquatic and human life, the alternative embraces a new ecological approach that

establishes healthy and vital connections between water, ecology and the city environment.

Further, if alternatives are not adopted the future redevelopment of the False Creek Flats (308 hectares) will have an additional impact on the already ailing waters of the False Creek Inlet and the Pacific Ocean which together already receives 416 billion liters of low-quality treated sewage each day (Sierra Sewage Report, 2000).

1.2 Thesis Goal and Objectives

With this in mind, the goal of this thesis is to propose an alternative sewage and stormwater management plan for the Trillium site that sets a precedent for wastewater and stormwater management on the False Creek Flats and for other communities of the Lower Mainland.

The following is a list of objectives that are designed to lead to the achievement of this goal:

- Adopt a waste treatment program that would meet the treatment standards of wastewater required by sustainable development and the province.
- Reduce the environmental impacts associated with contaminated stormwater and sewage entering into local water bodies.
- To provide a cost effective alternative for the City of Vancouver, the GVRD and the communities of the region.

The methodology needed to accomplish this goal is broken down into five parts. The first section will briefly describe the local policies and initiatives set out by the City of Vancouver and the GVRD that are centered on water quality and protection. The second

section will briefly describe the natural hydrological cycle, and how the conventional sewage and stormwater system disrupts the natural interaction of water with the landscape. This is followed by a brief outline of the environmental impacts that are associated with conventional stormwater and wastewater treatment. The third section will explore some of the precedents and case studies that have successfully implemented alternative stormwater and wastewater management strategies on the community level. The fourth section will give a description of the Trillium site, covering the history and its present day conditions. The fifth section explains the design program for the Trillium site that is based on the explored policies and precedents. Finally, the last section proposes an alternative sewage and stormwater management design for the Trillium site based on the findings described in the design program.

CHAPTER II Local Policy and Initiatives

> *"Chances for our children to enjoy their fundamental human right to clean, safe, healthy water are in deep trouble." (Lavigne, 2002)*

The City of Vancouver and the GVRD are determined to play a key role in the stewardship and protection of the surrounding water bodies of the Lower Mainland region. The following policy and initiatives demonstrate that desire and outline a number of recommendations and bylaws that have been established to guide sustainable development and community planning in a direction that will help meet the environmental objectives for water quality and protection.

1. Creating Our Future (1991) set a goal of maintaining and improving the region's livability and environmental quality. A number of key strategies where developed to address issues related to water which include pollution prevention, water conservation and managing stormwater. The plan recommends that the City:

    a. Adopt source control strategies that avoid the introduction of pollutants into water.

    b. Implement strategies that reduce the demand for potable water.

    c. Explore augmenting potable water supply with non-potable water sources.

    d. Manage stormwater in a manner that improves water quality.

    e. Maintain and create open channel amenities that enhance livability

    f. Recharge groundwater.

2. The GVRD's Liquid Waste Management Plan Stage 2 (1999) recommends member municipalities:

   a. Take an integrated planning approach to municipal stormwater management.

   b. Integrate watershed catchment, and master drainage plans in the Official Community Planning process.

3. The City of Vancouver Watercourse Protection Bylaws requires:

   a. Residentially zoned land restricts impermeable coverage to a maximum of 60%.

   b. Regulation of quantity and quality of discharged wastes into the public sewerage system, storm drainage system or any watercourse.

   c. Buildings to install low-flow fixtures as a means of conserving water.

4. City Plan (1995) recommends that the City:

   a. Use incentives, education, promotion, fees, and regulations to encourage individuals and businesses to help improve the environment and conserve resources;

   b. Reduce combined-sewage overflows by continuing to separate storm runoff and sanitary sewer systems; and

   c. Expand waste reduction and water conservation programs.

The above demonstrates the City and GVRDs desire for change. As well, the environmental commitment to improving coastal and inland water quality set forth in local policy, establishes the foundation and support needed for this thesis. Further, it offers an opportunity to discard outdated sewage and stormwater practices that contribute to the problem, and instead move forward and embrace sound alternative solutions that are designed to manage wastewater in a more holistic manner.

CHAPTER III Conventional Sewage and Stormwater Practices

"The health of a watershed is compromised when the effective impervious area (comprised of streets and rooftops) exceeds 10 percent of an entire watershed" (Centre for Watershed Protection, 1996).

3.1 The Natural Watershed and the City

In a healthy watershed unaffected by development, the majority of rain that falls on the site infiltrates the soil. Most of this infiltrated rainwater flows through the subsurface and slowly recharges rivers, streams and deep groundwater aquifers. In this scenario, less than 5 percent of fallen rainwater will flow across the surface as runoff. Vast clusters of trees with large canopies and understory plant communities is another important component of the natural water cycle.

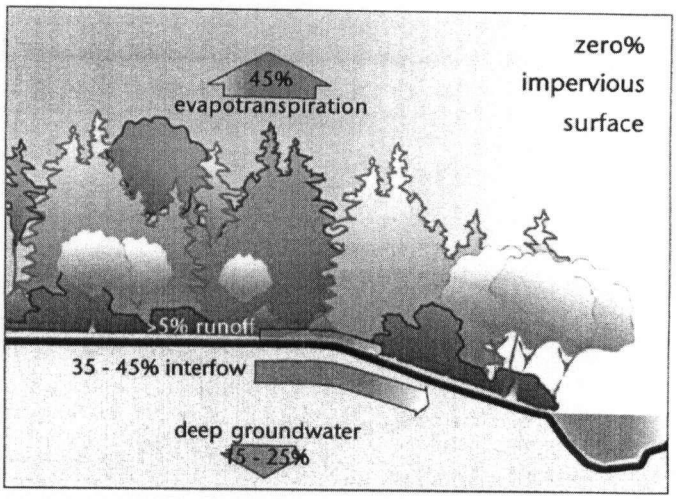

Figure 1:
Pre-development hydrology (Urban Landscapes, 2002)

Rainwater is taken up by plants and trees and released back into the atmosphere through a process called evapotranspiration. In a predevelopment situation this process accounts for 45% of the total water in the cycle (Luymes, 2000). This exemplifies the effectiveness that vegetation, humus and porous soils play in absorbing, infiltrating, and transpiring rainwater.

However, this system has its limits. Research suggests that the overall integrity of an entire watershed is significantly compromised when the effective impervious area exceeds 10 percent of the entire watershed (Centre for Watershed Protection, 2000). Therefore, it is not surprising that the vast impervious surfaces of most North American cities has been identified as the single most important contributor to the disruption of a healthy functioning watershed.

In Vancouver, the typical urban watershed is almost totally covered with impervious surfaces. In fact, some areas of the city (commercial and multifamily), have up to 90% of its surface covered by impervious rooftops, streets, parking lots and driveways (GVRD, Greenroof Workshop Proceedings, 2002). Rainwater, unable to penetrate these hard surfaces, is quickly converted to runoff. Runoff then flows over the hard surfaces picking up many of the substances that have been deposited on them before it reaches the underground storm and sewer system of the city.

Thus, the impervious surfaces of the city not only prevent the absorption and filtration of rainwater by soils and plants, they also serve as an efficient conveyance system for the delivery of pollutants and high volumes of stormwater into local waterways, and contribute to the hydrological changes that compromise waterways (Arnold and Gibbons, 1996).

Some of the negative impacts on watershed ecology include:

- Reduced groundwater levels (leads to rise in water temperature that effects reproductive cycles of fish and other aquatic life).
- Increased flood potential during the wet season.
- Destabilized stream banks.

- Habitat destruction.
- Fish contamination, disease and die-off.
- Increased water pollution.

3.2 Runoff – 'Non-Point Source' (NPS) of Pollution

The delivery of toxic pollutants into the storm and sewers of the city is an incidental one as they are not directly discharged into the system. Rather, they are usually picked up off the surfaces of the city by stormwater runoff, and delivered into the city's underground infrastructure. The contaminants that reach waterways in the manner are called non-point source (NPS) pollutants.

Commercial and residential streets have been demonstrated to be a potent source for many NPS pollutants, such as sediments, cadmium, copper, zinc, lead, oil and grease. Concentrated levels of toxins found on commercial streets, predominately reflect the magnitude of traffic volumes, street cleaning and maintenance activities. Residential streets contribute lower levels of sediment, metals and hydrocarbons, than that of commercial streets. However, residential streets are found to accumulate four times the levels of bacteria, phosphorous and nitrogen as compared to commercial streets (Centre for Watershed Protection, 1996).

The origin of bacteria and nutrients typically arise from run-off from lawns and gardens. This occurs as lawns and gardens become saturated during a rain event or by excess irrigation. In either case, water unable to absorb into the ground flows across the surface,

picking up nutrients and pet wastes as it travels into nearby catch-basin and storm drains that are typically located along residential street.

In addition, toxic molecules can be transported through the atmosphere and deposited across the surfaces of the city. Elements such as cadmium, strontium, zinc, nickel, lead and many different types of organics, have been recorded as common contaminates found in atmospheric fallout. During a storm event, these pollutants are picked up by run-off, flushed into the underground system and conveyed to the local water systems. Alarmingly, in most North American cities, the deposition rate of metals and organics from the atmosphere ranges from 170 to 320 kg/ha/mo for wet and dry fallout respectively (Centre for Watershed Protection, 1996).

3.3 Sewage – 'Point Source' (PS) Pollution

This direct source of water contamination is commonly referred to as 'Point Source' pollution. Industrial, commercial and domestic processes that produce wastewater are typically connected to the city's sewer lines and thus, discharge directly into them. Usually, wastewater from these activities, are pumped to a nearby treatment plant for processing before being discharged into the receiving water bodies and depending on the quality of treatment the effluent can contain concentrated levels of chemical and other pollutants known to be harmful to the aquatic environment and water quality.

3.4 Sewage Treatment Facilities.

Conventional sewage treatment generally falls into one of three different categories either the treatment facility treats to a primary, or a secondary or a tertiary level. Primary treatment is usually defined as a physical process in which the sewage flow is slowed

down, and the solids are separated from the liquids. A large portion of the suspended solids can then settle naturally due to gravity. The settled sludge is then removed from the bottom and disposed of in a variety of ways. Floatable solids, oil, and grease are then skimmed off the surface before the wastewater is discharged into the receiving environment.

There are three primarily indicators that are used to measure treated sewage water discharge to ensure the quality meets environmental standards: 1) the quantity of total suspended solids present; 2) the amount of oxygen used up by bacteria which decompose organic material found in sewage (commonly referred to as the biological oxygen demand or BOD); and 3) the levels of fecal coliform bacteria.

By today's environmental standards primary treatment alone is an inadequate form of sewage treatment as it fails to significantly reduce indicator levels. Secondary treatment (the standard treatment level for Vancouver and the GVRD) provides a better quality treatment of effluent than the primary process in that reduces BOD and suspended solids by 85-90%, and removes 90 to 99% of coliform bacteria compared to the primary levels that remove less than half of these amounts (Sierra Sewage Report, 2000).

The fundamental process involved at the secondary level is biological oxidation. In this process, oxygen is provided to aid micro-organisms in breaking down organic matter, considerably reducing the suspended solids and the BOD. Because of the increased quantity of suspended solids removed in secondary treatment, considerably more sludge, and hence more harmful chemicals are extracted than in primary treatment processes, and the sludge is then disposed of in a variety of ways depending on its level of toxicity. However, not all toxic substances are removed in the secondary treatment process as

many harmful organic molecules remain suspended in water and never settle out. As a result, secondary treatment discharge has been found to be deleterious to the aquatic environment.

The main function of tertiary treatment systems involves taking the secondary process of biological oxidation a few steps further. Different types of clarifiers are utilized to achieve advance forms of filtration to further reduce suspended solids and reduce the BOD. There are also additional components that can be incorporated at the tertiary stage that can further remove toxic molecules not removed during the secondary process. However, upgrading primary and secondary facilities to function at tertiary levels is extremely expensive and most cities including Vancouver lack the funds to support the upgrades.

3.5 Environmental Impacts of Point Source and Non-Point Source Pollution.

Suspended solids are particulate matter from sewage that floats in water. These solids, when present in significant amounts can pose a threat to the vital ecological balance of aquatic habitats. Large concentrations of solids suspended in the upper water column, can prevent sunlight from penetrating into the water where it is needed by photosynthetic organisms such as the phytoplankton for reproduction and growth. Without sunlight, photosynthetic organism growth is inhibited, and food shortages can develop for other organisms higher up in the food chain. In flowing waters, suspended solids become very abrasive and can cause damage to the surface of gills as they pass through fish. Suspended solids will eventually settle out and fall to the bottom of water bodies.

However, a large build up of solids on the river, lake or ocean floor can lead to further aquatic problems as benthic organisms become smothered and die-off.

Large levels of suspended solids can also disrupt the delicate oxygen balance of water. Organic materials contained in the suspended solids that are dumped into receiving waters contribute to the increase in the biological oxygen demand (BOD). More specifically, the BOD increases as the oxygen levels approach depletion. This arises from the utilization of oxygen by microorganisms to catabolize organic material in the sewage waste. The more oxygen is used up, the less chance these environments have of recovering, even after the discharge of pollutants is terminated. When dissolved oxygen reaches very low levels, aquatic organisms die.

Fecal coliform, a type of bacteria found in the intestinal tracts of warm-blooded mammals is in of itself not a hazard to humans. However, its presence in urban water bodies provides an indication that fecal matter is present and that the water may be contaminated with other pathogens that cause human disease, such as hepatitis B, Cholera, and typhoid. Acceptable level of fecal coliform in urban water ways is approximately 200 organisms per 100 milliliter (Sierra Report, 2000). Higher concentrations pose a health hazard to humans coming into direct contact with the water, resulting in beach closures and warning about shell fish consumption.

Toxic chemicals such as mercury, lead, phenols and chlorinated organics commonly discharged into the sewer system from industrial processes and domestic activities (paints, detergents, household chemicals) are also extremely harmful to the aquatic environment and humans. For example, smaller aquatic organisms may consume small amounts of mercury. These organisms lower on the food chain are consumed by larger

fish and animals higher up on the food chain. Instead of passing through the body Mercury is deposited into the tissues and bones of body and after time as more contaminated organisms are consumed large concentration of Mercury may accumulate. This process is known as bioaccumulation, and is one of the ways through which contaminants in sewage effluent can affect the human population. High concentrations of mercury affect the brain functions in humans and can even result in death.

Further many of the toxic substances found in sewage and stormwater discharge are capable of disrupting the endocrine system of fish, birds, reptiles, amphibians and mammals. Endocrine disruption results as foreign chemicals effect the functioning of the natural hormones system disturbing the natural balances responsible for healthy growth, development and reproduction. As pollution increases or persists in the aquatic environment more and more ecological communities will be affected, and the overall imbalance and our healthy relationship to the aquatic environment will be in danger.

CHAPTER IV Alternative Sewage Treatment Systems

> *"Of the fifteen volatile compounds listed as carcinogenic by the EPA contained in the septage as it entered the first tank, fourteen had been completely removed by the aquatic ecosystem. The remaining substance was ninety-nine per cent removed." (Nancy & Jack Todd, 1994)*

4.1 The Wetland Model and Solar Aquatics

Wetland treatment systems offer a high quality (tertiary level), and environmentally sound alternative to conventional treatment. Marshes have a very high capacity for recycling wastes and converting them to nutrients. The wetland community of plants, micro-organisms and insects work to purify the sewage flowing through them. Disinfection occurs naturally, as harmful bacteria die off and nitrates, phosphates, phenols and other highly toxic trace metals are taken up by the wetland environment. In many communities the constructed wetland model has been transformed into an efficient system that carries outs the same ecological processes within a community greenhouse. This is an ideal system for urban communities to adopt, especially since the large parcels of land needed for a constructed wetland can be extremely expensive or just not available in dense city areas. This greenhouse system is commonly referred to as Solar Aquatics because natural light is the only source of energy needed for the system to operate.

The following precedents demonstrate the practical application of the Solar Aquatic system within a variety of community settings. They also demonstrate the environmental, economic and social benefits many communities have had in implementing this system.

Many of the communities that adopted this model were able to achieve several common goals that lead to the:

- Protection and enhancement the environment.
- Protection of ocean and river water quality.
- Transformation of waste into a local resource.
- Conservation of water.
- Exploration of wastewater recycling opportunities.
- Ability to offer educational opportunities within their community and the city at large.

4.2 South Burlington, Vermont

An experimental sewage treatment facility in South Burlington, Vermont was built in 1996 to provide tertiary treatment using biological processes rather than chemical ones. The project was collaboration between the community of South Burlington, The Environmental Protection Agency and Ocean Arks International.

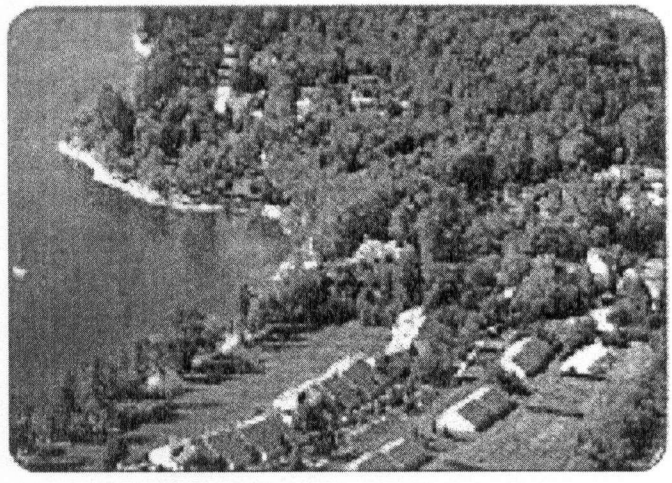

Figure 2:

South Burlington's Solar Aquatic Facility is located close to Lake Champlain (Ocean Ark International, 1999).

The South Burlington wastewater greenhouse is located in the heart of the community and treats 80,000 gallons of municipal sewage per day. This

is the amount of waste produced by approximately 1,600 residents that are not connected to the city's conventional sewage grid. Instead sewage from the surrounding residents flows to an underground anaerobic reactor adjacent to the greenhouse where much of the initial sludge is removed and digested by bacteria. The effluent then flows through a series of five open air silos that contain a variety of aquatic plant species, invertebrates and microorganisms that metabolize the incoming effluent.

At this stage the BOD, total suspended solids, and fecal coliform levels are significantly reduced. Next the effluent moves into a settling tank where the remaining biosolids drop.

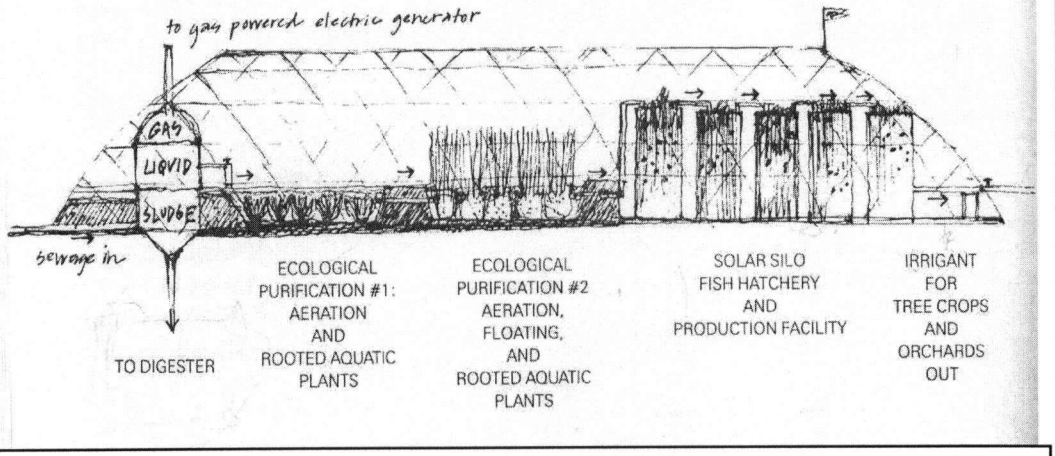

Figure 3:

Sketch of decentralized Solar Aquatic neighborhood treatment facility (Ocean Ark International, 1999)

After the biosolids settle out the effluent passes through a series of lava rock beds into small constructed wetland beds. These beds support a variety of plants and micro-organisms that operate aerobically and provide the final purification process where nitrification and suspended solids digestion occurs. The final product is clean water that can be reused by the community to meet a number of water needs.

Table 1: South Burlington's Efficacy Chart (Ocean Ark International, 1999)

			Target	Actual
Wastewater Characteristics	Units	Influent	Effluent	Effluent
Chemical Oxygen Demand (COD)	mg/L	454	<50	31
Biochemical Oxygen Demand (BOD)	mg/L	219	<10	5.9
Total Suspended Solids (TSS)	mg/L	174	<10	4.8
Total Nitrogen	mg/L	23	<10	2.2
Total Kjeldahl Nitrogen	mg/L	23	5	1.3
Ammonia	mg/L	14.0	1	0.25
Total Phosphorous	mg/L	4.8	3	2.2
Fecal Coliform	col/100ml	9,380,833	<2,000	1177

Overall the greenhouse functions as a stable ecosystem that purifies, recycles and conserves water within the community. It requires little maintenance, no chemicals and no discharge of effluent into natural water bodies. Further the greenhouse treatment facility is able to produce it own revenues to cover operating costs by selling nutrient rich sludge fertilizer to local garden centers and farmers, through tropical and aquatic plants sales, and through organic mushroom and other food crop production – all of which are grown within the facility. It also saves on energy costs as the methane gas produced in the initial anaerobic process provides sufficient energy to supply power for the facility. Thus, energy requirements are reduced from one-third to one-sixth of conventional sewage treatment systems.

4.2 Errington, BC

A local example of a Solar Aquatics system is in Errington, BC. The Errington system is similar to the one in South Burlington and is the first natural sewage treatment system of this type in British Columbia. The Errington project demonstrates the viability of a solar

dependent treatment system in a climatic zone similar to that of Vancouver, which is typically defined by overcast skies and rain during the winter months.

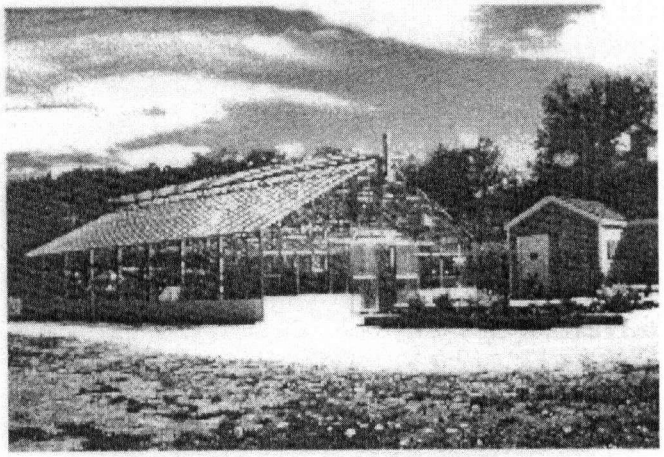

Figure 4:

Errington's wastewater treatment facility is located in the heart of the neighborhood. (Eco-Tek, 1999)

The community of 46 homes in Errington implemented a solar aquatic treatment facility after a failed septic system contaminated ground water and drinking water supplies. The solar aquatic system was chosen over conventional treatment systems as it was the most affordable option for the community. With a budget of $200,000 a 210 square meter greenhouse designed to treat up to 52 cubic meters (13,800 gpd) of sewage per day was constructed in June 1996. Like South Burlington, the Errington natural treatment system uses a diverse number of aquatic plants, small invertebrates and microorganisms to metabolize the effluent and purify water. Further, Errington covers yearly operating costs of $14,000 through bedding plants, tropical and wetland plants sales. (Green Buildings BC, 2000).

4.3 China Canal Restorer Project

In 2001, the China Canal Restorer Project implemented an alternative sewage management plan. Prior to adopting an alternative treatment plan the community of 12,000 discharged raw sewage directly into an adjacent canal. Growing health and

environmental concerns over the large discharge of sewage into the 600 meter canal, furthered by limited capital resources, prompted the community to adopt a modified solar aquatic system. This modified system does not require a greenhouse as the climate in the region mild enough all year-round to support the plants and organisms required to do the work. In this system, domestic and commercial sewage and wastewater from the surrounding community enters through a number of spill holes located along the open canal after going through the anaerobic treatment stage. The canal is divided into a number of sections that contain the organisms and aquatic plants needed to metabolize the waste in the water.

In reality the China Canal is a series of floating gardens expanding linearly along the landscape. The lush planting of native Chinese wetland plants creates a habitat for a variety of insects, birds, reptiles and amphibians. The green network of plants, water and stone, is also intended to entice people to take a stroll along the canal's promenade and enjoy the scenery along the flourishing banks of the neighborhood community.

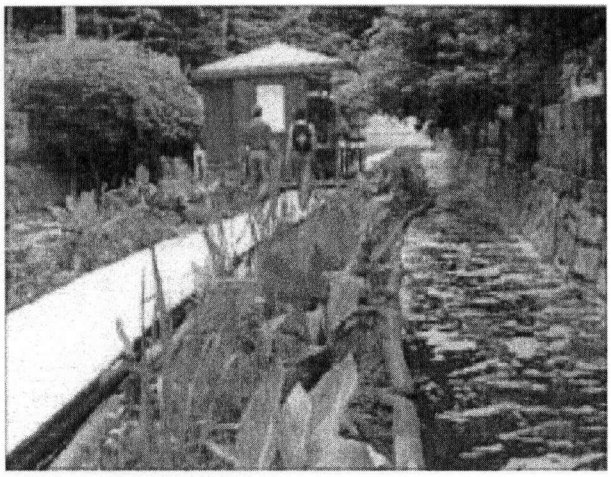

Figure 5:

China Canal Water Garden Promenade (Ocean Ark International, 1999)

The China Canal Restorer project provides an example of how eloquently wastewater treatment processes can be integrated into the heart of an urban neighborhood. The

project also demonstrates how human processes and natural processes can be combined to enhance environmental and social value.

CHAPTER V Alternative Stormwater Management Practices

5.1 Ecological Infrastructure

As discussed earlier the overall integrity of the entire watershed is significantly compromised when the effective impervious area (comprised of streets and rooftops), exceeds 10 percent of the entire watershed. Thus, keeping the impervious surface area of a development site to absolute minimum and implementing a management plan that maintains or enhances the sites natural drainage pattern within the context of the larger watershed, is pivotal to maintaining a healthy watershed.

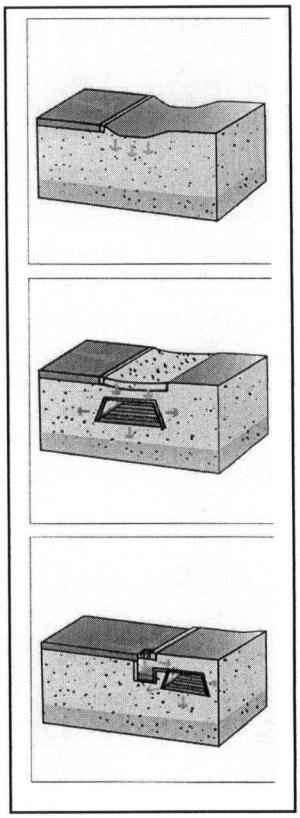

Figure 6:

Ecological Infrastructure:

The Roadside Swale, The Crushed Stone Verge & The Curb and Gutter systems. (Urban Landscape, 2002)

Ecological infrastructure offers an opportunity for designers to take a more natural holistic approach to stormwater management and reduce impervious surface coverage. As well, ecological infrastructure is an integrated system comprised primarily of natural materials which are designed to mimic natural drainage systems and patterns that occur within the local watershed.

Typically, ecological infrastructure uses a combination of sand, gravel, microorganisms and water tolerant plants to achieve specific infiltration rates and clean runoff of NPS pollutants. These elements are combined to form structural devices (such as, bioswales, infiltration basins, and detention basins) that mitigate rainwater across the surface of the

landscape, but within the site, giving time for infiltration and ground water recharge to occur. Further, designing with natural elements offers an opportunity to create inspiring landscapes that connect people with nature and ecology.

There are a number of precedents that demonstrate that ecological infrastructure is a viable alternative to conventional stormwater infrastructure. As well, these precedents illustrate that alternative stormwater management systems can be designed and implemented to meet a number of environmental objectives. The next section explores some of these precedents that have been established in Canada, the United States, Australia and Europe.

5.2 The East Clayton, Surrey

In 1999, the City of Surrey was the first city in British Columbia to initiate a large scale planning process with the goal of building a community that meets local, provincial, and federal policy objectives for sustainable development. From this process the East Clayton Neighborhood Concept Plan (NCP) was developed. One of the primary goals of the NCP was to protect a lower watershed area from the impacts of developing 250 hectares of land located upland from the flood plains of the Serpentine and Nicomekl Rivers and the Agricultural Land Reserve.

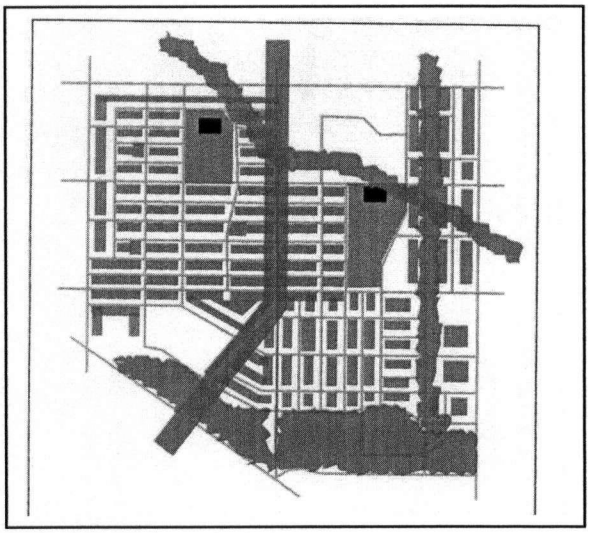

Figure 7:

East Clayton's interconnected green system (grey areas) functions as a mini-watershed (Urban Landscapes, 1999)

The final outcome was an interconnected surface stormwater system designed to mimic and maintain the natural drainage patterns that were originally occurring on the site. Thus, the yard, the street, the block and the park were all designed to function as mini-watersheds that worked together to mitigate rainwater in much the same manner as the natural watershed. Therefore, to maintain and in some cases enhance the natural drainage of the site, a set of specific performance standards and guidelines were developed. In particular, water infiltration rates, maximum impervious cover, and tree canopy coverage were specifically formulated to ensure stormwater would be effectively mitigated throughout the neighborhood. Further, specific structural elements such as, infiltration trenches, grass swales, soil amendments and subsurface overflow systems were also specifically tailored to handle particular stormwater volumes water in a safe and efficient manner.

For example, in the case of a large storm event the system is designed to deliver excess water away from the street and residential yards, via subsurface overflow system, to nearby secondary retention and treatment ponds located in adjacent neighborhood parks or school/park sites. These back-up retention sites are designed to handle stormwater volumes for the 5 year storm through to the 100 year storm. Where necessary, deep well infiltration devices are in place to ensure large

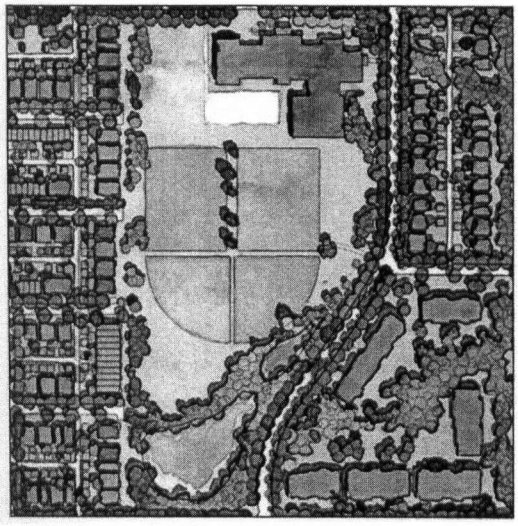

Figure 8:

East Clayton's School/Park site has areas designed to hold the 100 year storm. (Urban Landscapes, 2002)

volumes of stormwater can be successfully mitigated on these sites.

Further, ponds and wetlands are designed with maximum practical water retention. This ensures that infiltration occurs at a slow rate, allowing time for pollutants to settle out and time for wetland plants to remove toxins from rainwater. To further ensure that infiltration standards are met, a maximum impervious cover of 45 percent is set for low to medium density areas.

Impervious surface restrictions also apply to streets in which a minimum of 40 percent of the right-of-way must be able to adsorb rainwater. As well, all the streets are designed to be as narrow as possible. This provides room for street side swales, verges and trenches to be incorporated into the right-of-way area. As well, planted swales are given grades between 1 to 6 percent to allow time for plants to sequester metals and excess nutrients contained in runoff.

Recognizing the important role that trees play in the hydrological cycle, the NCP sets a number of canopy coverage targets. For example, school/park sites are required to have 40 percent of the site covered in tree canopies. Neighborhood parks require 30 percent coverage and, streets and parking lots require 60 to 50 percent respectively. Riparian and wetland areas are required to retain the existing forest and understory plantings. Thus, the cumulative effect is a forest in the city that is large enough to make a significant contribution to the flow of the natural water cycle, and provide habitat value and climate control.

5.3 Concord Roads Trial Project, Australia

The East Clayton NCP proposal for an elaborate interconnect green network that manages stormwater in the same manner that nature does is indeed very appealing. It establishes important connections between the built environment and ecology that are much needed in order to heal and protect the surrounding environment. But does the ecological model work? The Concord Roads Trial Project provides one of many case studies that have been conducted to answer these questions.

The initial objective of the Concord project was two-fold: one was to determine if the alternative stormwater system could significantly reduce the volume of untreated runoff entering Powell's Creek; and the second objective was to determine the alternative system could effectively remove contaminates from runoff, store it and make it available for reuse.

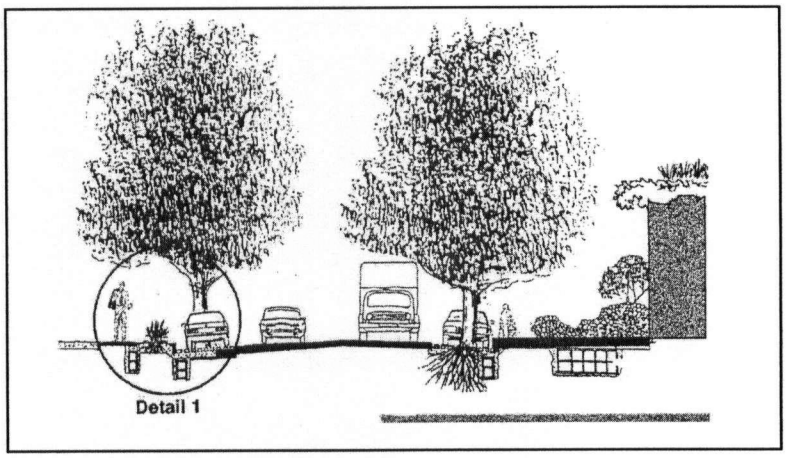

Figure 9:

Street-side and sidewalk infiltration chambers (Concord Roads Case Study, JTChair, 2000).

The first stages of the project involved the retrofitting of a five block, low-density residential neighborhood, with a stormwater system designed to enhance infiltration and remove nutrients and other toxic chemicals. Two different systems were installed. One

system was installed under the parking lanes of the streets and the other was installed under the grass boulevards that ran along the edges of the streets.

To enhance infiltration, the parking lane surface and the adjacent sidewalk were laid with grid-paving blocks with turf planting in the cells. In the second system, the boulevard was planted with grass which allowed for sufficient absorption of stormwater. In both systems, the subsurface stormwater purification system was identical. The runoff that seeps through the surface of both systems is filtered through a biological sand filter as it passes into the cell blanket layer that diverts it into underground percolation tanks, where stormwater then seeps into underlying detention tanks for storage. If the detention tanks overflow during large storm events, the overflow is simply diverted through a backup pipe to Powell's Creek. The stored water is then available for reuse by the local neighborhood residents for summer-time irrigation.

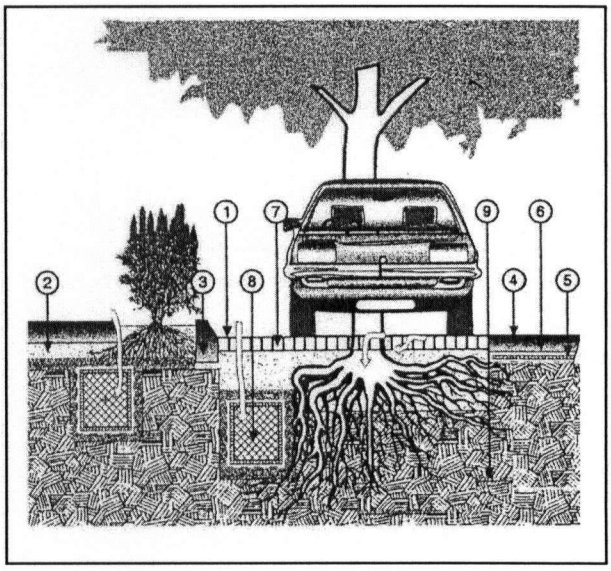

Figure 10:

Detail 1: 1. Turf, 2. EcoSoil, 3. Concrete curb, 4. Pervious road surface, 5. Drainage cell, 6. Filter fabric, 7. Grass geo block, 8. Ecological channel, 9. Heavy soil or clay (Concord Roads Case Study, JTChair, 2000).

The second stage of the project involved a series of efficacy tests conducted by the Australian Water Technologies for the Concord Council. Sampling was carried out over the course of a four-month period during 10 storm events. The results demonstrated that the system was able to reduce runoff volumes to Powell's Creek by a substantial 75%.

The results also demonstrated the systems' capacity to significantly reduce the metal and nutrient content of the runoff originating from the test site.

	Physical Parameters	**Metals**			**Nutrients**		**Other**
	turbidity	copper	zinc	lead	phosphorus	nitrogen	suspended solids
% **Reduction**	90.7	93.6	99.4	97.9	78.6	25.9	82.8

Table 2: Percent Reduction of Pollutants Downstream (Concord Roads Case Study, JTChair Case Study, 2000).

5.4 Water Pollution Control Laboratory, Portland, Oregon

The Water Pollution Control Laboratory project offers another example of the success of turning to alternative stormwater management practices for the resolution of stormwater drainage issues. Again the project demonstrates alternative systems efficacy of treating stormwater and reducing discharge volumes into nearby waterways. However, unlike the Concord Project which collects and treats runoff originating from the community itself, the Water Pollution Control Laboratory Project intercepts and treats large volumes of stormwater runoff, originating from an adjacent upland residential community. The problem is unique in that it demonstrates the flexibility of alternative systems to manage stormwater originating from both on and off the site. It also demonstrates the success of constructed wetland ecological systems in treating large volumes of stormwater runoff. Further, the project illustrates how thoughtful stormwater management design can

transform open spaces into places that illicit curiosity and delight in the natural hydrological cycle.

In the late 1990's the Portland Bureau of Environmental Services (BES) purchased a former industrial site along the banks of the Willamette River under the Saint John's Bridge in Northeast Portland, Oregon. The BES already had a firm philosophy regarding alternative stormwater management and advocated the need for local residents, businesses and industries to adopt on-site management that improved water quality and reduced high volume flows into the Willamette River. Therefore, the Company made a commitment to healing and improving the newly acquired six-acre site.

The site had a host of problems ranging from an eroding riverbank that edge the property, contaminated soil from former industrial processes, to a collapsed stormwater pipe that had previously drained untreated runoff directly into the Willamette River from a 55-acre neighborhood and commercial catchment area uphill from the site.

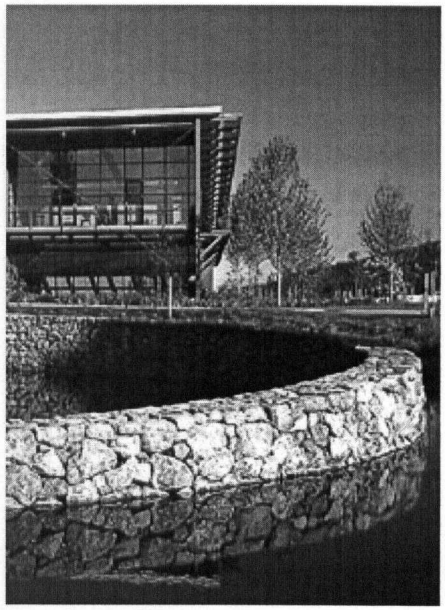

Figure 11:

BSE Storm water wall marks the ebb and flow of seasonal rainwater (Photo Murase, 1998).

The solution to the problem was to create a stormwater garden that would capture and treat runoff originating from the site and the uphill community. It was also to serve as an educational resource that would demonstrate how a small wetland ecological system could be integrated into a site to clean stormwater.

Stormwater originating from the uphill catchment area enters the stormwater garden through a twelve inch diameter outflow pipe. At the outflow an arc-shaped basalt stone channel captures the incoming stormwater and dissipates the energy of the flow. In the channel larger particles settle out as stormwater seeps into the next cell through weep holes in the side of the flume. Next wetland plants such as cattails, slough sedge, and soft rush go to work breaking down pollutants or sequestering metals and other contaminants which remain there until the plants contaminated parts are harvested. There is a second pond that serves as a temporary detention. This is where most of the remaining sediments drop to the bottom and stay there as water slowly percolates into the underlying earth and slowly travels across the subsurface terrain to finally seep into the Willamette River.

The design took advantage of the opportunity to unite the stormwater garden with the adjacent neighborhood park. By blending the adjacent park edges with the stormwater garden offered an opportunity to draw attention to the facility and the stormwater garden, and entice people to come on to the site and learn about the important role ecology can play in a city landscape.

A few problems with the system did arise. During the summer months the water levels of the pond were substantially reduced due to the dry, hot summers of Portland, and as a result the pond starting to exhume an unpleasant order. This was due to eutrophication in which case anaerobic bacteria started to flourish and produced a foul smelling gas as low water levels became depleted of oxygen. However, the problem has a few simple solutions. For instance, the ponds could be drained in the early summer, or they could be replenished with water periodically throughout the summer months. Replenishment could occur by installing a natural greywater treatment system in which greywater from the

BSE facility could be reused for indoor activities, (thereby conserving potable water). As well, some treated greywater could be diverted to maintain healthy pond levels during the summer.

5.5 Green Rooftops: Europe and North America

A typical development watershed (commercial/multi-family) in the GVRD region consists of 40-65% rooftops, 35-10% parking and driveways, 10-15% streets, and 0-10% landscaping (GVRD Green Roof Workshop, 2002).

Reducing impervious surface coverage in the built environment does not only mean addressing what is occurring on the ground plan, but also the less noticeable impervious surfaces from the expansive rooftops of any city, town, or community. The runoff generated by a collection of rooftops with impervious surfaces is quite substantial. For example just one millimeter of rain falling on 19 hectares of rooftops, amounts to 100 tones of runoff (most likely contaminated with atmospheric pollution), that is typically flushed into the cities underground storm system. Green rooftops offer one viable solution to this problem. Ecoroofs are green rooftops with light weight soil and vegetation to capture rainwater instead of sending it straight into stormwater sewers. Therefore Ecoroofs act like sponges, capturing rainwater at its source. About one-third of the water that falls on an ecoroof in a year is taken up by plants and returned to the air through transpiration (GVRD Green Roof Workshop, 2002). Studies have demonstrated that peak runoff volumes can be reduced by 80% when the building tops of a community are planted with vegetation and have a soil depth of at lease 300mm (GVRD Green Roof Workshop, 2002).

Figure 12:

Green roof on top of The Vancouver Public Library planted with fescue grasses (GVRD, Green Roof Workshop Proceedings, 2002).

Therefore, eco-roofs can play an important role in reducing the impervious surfaces of the city by reducing runoff, filtering out atmosphere pollutants and offering additional green space within a community. Drought tolerant self-sustaining plants that consist of low groundcover plants and sedums are well suited for eco-roofs and for the pacific coastal climate. The soil layer ranges between 2 to 6 inches and often consists of a mixture of topsoil, compost and perlite to lighten the load. Under the soil, a filter fabric cloth lies to keep the soil from clogging holes in the perforated pipe. The perforated pipe and a small drainage system are needed to collect the small amount of runoff that will occur when saturation levels are exceeded. To prevent moisture damage to the actual roof

a waterproof membrane is placed between the roof of the house and the green roof infrastructure. Eco-roofs planted with a variety of sedum species is preferred, as saturated sedum and soil layer can weigh a maximum of 80 kg per square meter, where as the weight of a saturated turf roof is about 250kg per square meter. On an average the cost of installing an eco-roof is a little more than conventional roofs ($10 to $15 a square foot, compared with $3 to $9 a square foot for a new conventional roof). But it is argued that eco-roofs pay for themselves over the long term because they last twice as long as conventional roofs and have environmental benefits associated with managing stormwater (GVRD, Green Roof Workshop Proceedings, 2002).

There are a variety of other rooftop treatments available. Garden roofs for instance offer some degree of rainwater retention and some habitat value, but the greatest potential is for human use. Roof top gardens offer pleasant social spaces and extra places for gardening especially in medium to high density areas where plots for gardening are not always available. Roof top gardens also offer a place to escape or a place to view the surroundings from a different, elevated perspective. There are also agri-roofs and greenhouse roofs that can capture rainwater in a variety of ways and then reuse the rainwater to grow food.

Of all the types of green rooftop treatments currently available, the eco-roof has been demonstrated to be the most cost effective. It requires very little structural modification in a retrofit situation and a new flat-top building can be easily designed to incorporate this type of green infrastructure. As a natural alternative to conventional design, the eco-roof has a high value for its' ecological and esthetic contribution, as well for its' low maintenance and its ability to absorb and hold water. Thus, in a community setting in

which green-roofs and infiltration swales along streets are standard, peak runoff can be reduced to 92% (GVRD, Green Roof Workshop Proceedings, 2002).

5.6 Conclusion

> *"Urban ecology provides the conceptual vehicle for urban design, whose principles invoke a basic shift in values. We begin to see wastes as resources that contribute to environmental health and diversity, drawing maximum benefits from the means available."*
>
> (Hough, 1995)

Practical work throughout the world is demonstrating that the application of biological solutions to sewage and stormwater management is not only effective, but also cheaper. Also, these types of ecological systems reduce, if not eliminate, NPS and PS pollutants. Moreover, green infrastructure designed to mitigate a community's stormwater and sewage can play a vital role in healing the environment. Further, these alternative systems have demonstrated that they can restore, conserve and protect water quality and quantity. As a whole, green infrastructure provides a much needed alternative approach to urban design.

CHAPTER VI Site Analysis

6.1 History of the False Creek Mud Flats

In the late nineteenth century, the Flats supported a rich diverse ecological marsh land habitat for a variety of birds, insects and animals. It formed the salt water mouth of a receiving fresh water basin for a number of streams such as the Brewery Creek stream for the southern banks, and extended all the way to Clark Drive. The Flats also provided a marshy recreational area for nearby residents in Strathcona. In the early 1900's with the advent of rail, the Great Northern Railway and Canadian Northern Pacific began to fill the inlet using the excavations from the leveling of Mount Pleasant.

Figure 13:

False Creek Flats in the mid 1800's. (City of Vancouver Historic Archives)

By 1918, the entire upper portion of the inlet was filled in to provide freight yards and railway operations to serve the city centre, completely destroying the natural fresh water and salt water ecology that once defined the Flats.

With the construction of the Union Pacific railway station in the early 1920's, land was subdivided into parcels suitable for industrial activity and the Flats became the central distribution area for the city and staging grounds for the Port of Vancouver. For almost

half a century, the Flats have served as a freight receiving and distribution centre for the Downtown and the Port. By the 1980's the continued growth of the central area of Vancouver and the associated inflation of land prices forced many of the large scale industrial activities to abandon the flats and relocate outside the city.

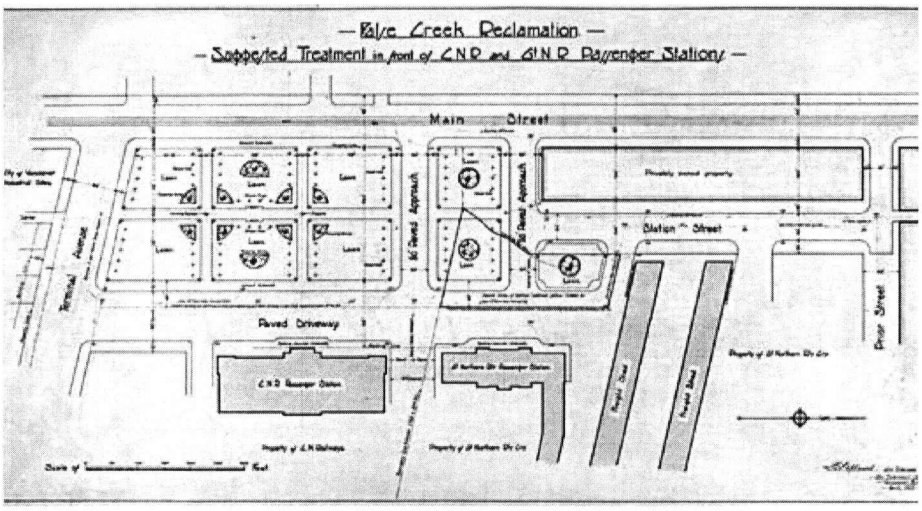

Figure 14:

The proposal for the False Creek Reclamation Project showing Main Street, the CNR and GNR passenger stations and design for Thorton Park. (City of Vancouver Historic Archives)

6.2 Context Today

The Flats comprises of 125 ha (308 acre) of land roughly bounded by Prior St. and Malkin Avenue on the north, Great Northern Way on the south, Vernon Drive on the east, and the Pacific Central Station on the west.

In March 1995, the City Council approved the Industrial Lands Policies (ILP) which supports the retention of the 125 ha (308 acre) parcel of the Flats for city-serving industry, transport, and service uses. In addition, the City set forth an Urban Structure Plan (USP), outlining issues relating to industrial use, industrial live/work use,

commercial use, transportation services, public amenities, and the interface between the Flats and its neighbors. Both the ILP and the USP describe the Flats as an important and vital location for traditional city-serving industries and for the rapidly growing new high-tech industry that is seeking to establish itself close to the City's vibrant downtown area.

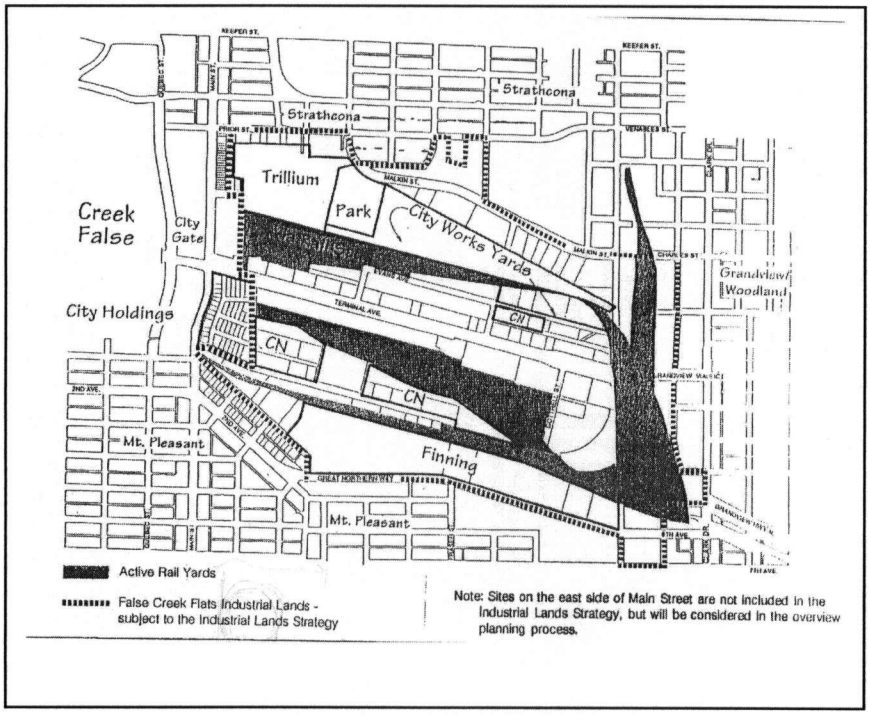

Figure 15:

The False Creek Flats boundary and Trillium site Context (City of Vancouver Industrial Land Strategy, 1996).

The Trillium site is a 6.8 hectare (16.8 acre) parcel on the northwest corner of the Flats. It is mostly vacant, with the exception of two small buildings on the property recently purchased on Prior Street. The Strathcona neighborhood is to the north, separated by food wholesalers and Prior Street. To the west lies the Main Street area that is focused on Thornton Park, where the CityGate development is progressing. To the south, Pacific Central Station has recently upgraded as a multi-modal transportation facility with

passenger train and bus services. The design and programming of the new 3.2 hectare, city park on the east has undergone a park planning exercise with the residents of Strathcona.

The Trillium site, a 6.8 hectare (16.8 acres), is of particular concern to the City and developers as it has the potential for a more urban character due to its close location to the newer mixed-use City Gate development and residential neighborhoods of Strathcona and Thornton Park. As well, the eastern portion of the site is edged by 3.2 hectare of land that the City has designated for a future neighborhood park. Thus, offering the opportunity for the Trillium site to incorporate it into its new urban structure. As a result of the Trillium's appealing location, two development purposes have been but forth to the City for consideration in the last few years.

The first, put forth by the IBI group, described a new community where local craftsmen and artists worked and lived in a compact light industrial neighborhood. The site was divided into three areas in which 760 industrial live/work units, occupying approximately 62,000 square meters (660,000 sq. ft.) would define the northern part of the site which is adjacent to the Strathcona residential neighborhood. The central portion of the site was designed to act as the social heart of the community and was defined by commercial live/work buildings, a community centre, and public open spaces. The third portion of the site, located next to the Union Pacific Train Station was dedicated to light industrial processes where higher volume traffic flows and noise would be suited to the industrial character occurring to the south. Together the central and southern portion of the site will be comprised of 50,000 square meters (420,000 sq. ft.) of light industrial, cultural, recreational, retail, and office uses.

The IBI group also saw the future park as an open green space that served the residents of Strathcona as well as the new residents of the Trillium site. In considering the future programming of the park, the City held a series of public open house meetings. Through these meetings, it was determined that the residents of Strathcona preferred a more nature-oriented park which created a habitat for birds, insects and small animals as well as, providing the community with garden plots to satisfy the growing demands for the extension of the successful Strathcona community gardens.

The second proposal was for a light industrial technology park. The design was put forth by Tech-Park, a prominent American company that specializes in the development of campus-style business parks. Rather than building to reflect the adjacent residential neighborhood of Strathcona, the developer's proposal was designed to reflect the large, monolithic built structure of The City Gate development situated to the west of the Trillium site. Further, the campus style business park and associated technology activities was a move to re-enforce the high-tech vision the City had for the majority of the Flats. The development proposal also considered the adjacent city park in its plans. However, instead of providing a more nature oriented park as desired by the surrounding residents, the Tech-Park proposal viewed the park serving as a active open-space, with soccer and baseball fields to meet the recreational needs of the Tech-Park employees.

Unfortunately, neither the IBI proposal or the Tech-Park, or the City's USP have taken into consideration alternative forms of sewage and stormwater management for the site. Regardless of the City's and the GVRD's environmental policies and commitments for improving and protecting the water quantity and quality of the region, there is no current consideration of implementing change.

By adopting conventional water management systems both proposals miss the opportunity to establish an important ecological precedent in community design. This is a precedent that is urgently needed if the City's vision of creating an environmentally healthy city that protects and enhances our waterways is ever to materialize.

6.3 Topographical Watershed

The Mud Flats lies at the base of a small, but very distinct watershed. It begins from the up-land areas of Commercial Drive to the east, Hasting Street to the north, and to 29th avenue to the south. At one time the Flats was a dynamic estuary that supported three salmon bearing streams; Brewery Creek that flowed onto the Flats from south, China Creek that flowed from the North, and X Creek that flowed from the upper regions of the east. These creeks no longer flow across the land as they were piped underground in the early 1900's during the filling of the Flats and the development of the upland areas. The important role that the mud flats once played as an intermediary between inland fresh water systems and coastal saltwater systems needs some consideration. Before the filling in of the Flats the mud flat estuary was a dynamic eco- system of plants, animals, insects and other organisms that thrived on the organic nutrients that the streams brought into the Flats from the upland areas.

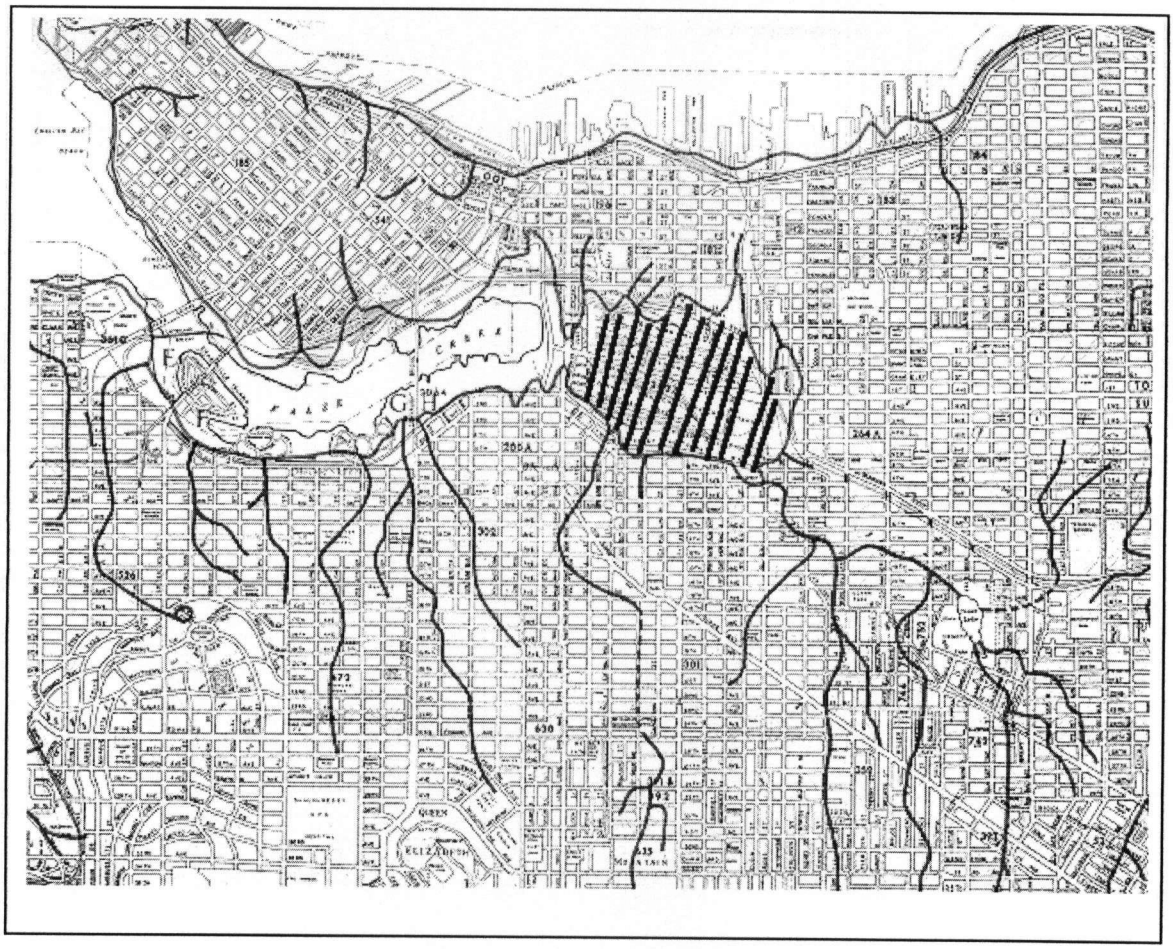

Figure 16:

Context and original stream locations prior to development of Vancouver. The original shoreline of False Creek is also indicated stretching all the way to Clark Drive (The Lost Streams of Vancouver, 1998).

This lost mud flat eco-system and its nutrient cycles and filtering properties are the precise model that many of the precedents draw from. Thus, the history of the site offers an opportunity to reestablish part of the lost mud flat eco-system and demonstrate how vital and healing links can be made between natural systems and human processes.

6.4 Existing Sewer and Storm System

The Flats is currently under-serviced for sewer and water. This is because many parcels are developed with low intensity uses such as rail yards. As such, the Mud Flats discharges very little stormwater directly into False Creek and the Trillium site does not contribute any stormwater at all. The areas surrounding the site are drained into False Creek via the Clark Drive outfall located at the end of Terminal Ave.

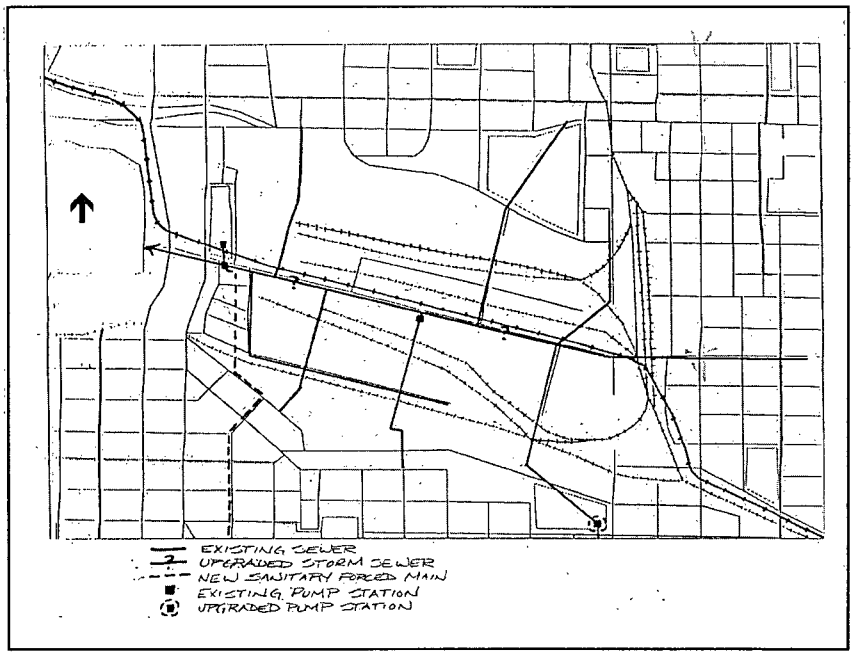

Figure 17:

Existing sewer and storm system of the False Creek Mud Flats. (City of Vancouver Industrial Land Strategy, 1996)

The Clark Drive outfall system does pass across the Flats. It is a major combined storm sewer system that services the upland neighborhoods that surround the Flats to the north, south and east, by pumping sewage to the Iona treatment facility. Three main pumping stations are located around the axis of Terminal Ave., to ensure continued sewage flow to Iona. One is located at the southern edge of Thornton Park, with a second adjacent to the first on the other side of Terminal Ave. The third is further east and located at about the halfway point along Terminal Ave.

The Trillium site has no existing sewer or storm infrastructure that services the site. However, there is an existing 48-inch diameter storm main, running in a north-south direction under the central portion of the site from Dunley Street. This line drains the residential area north of the Trillium site into the Clark Drive outfall line.

6.5 Existing Features and Drainage Patterns

Today, the only historic remnants that remain are a few long narrow concrete pads that lay across the landscape indicating where train freight was once unloaded and stored. The rest of the land is made up of rocky infill soil (at least the first couple of meters), and covered with invading weeds. The park site is similar in terms of invading weeds. The City parks department has randomly planted a few cedar, alder and fir seedlings across the site.

The site is predominately flat due to the level ground required for trains and freight movement. Therefore, most of the rain that falls on the site is absorbed directly where it falls or, collected and temporary retain in the lowest area which is on the park land. As well, many smaller depressions scattered randomly across both sites eventually fill with rainwater forming a number of puddles.

Due to the vast majority of the site being naturally permeable, the flat character of the two sites and the invading weeds (perennial grasses, flowers and shrubs) and the other young tree species planted by the city, the land seems to be functioning like a miniature watershed: infiltrating, collecting and storing all the rainwater that falls on the site.

Figure 18:

Current topographic drainage pattern of the False Creek Inlet (City of Vancouver, Van Map 2002).

This drainage pattern is similar to what occurs in a meadow where rainwater is temporarily detained on the surface of the landscape in depression, as it slowly infiltrates into the soil and evaporates back into the atmosphere.

Thus, behind the boarded up property lines of Trillium and park site exists a slow evolving ecological system that is re-establishing its long lost hydrological patterns. Today, it is a place where rainwater falls onto an abandoned portion of the city landscape and is not quickly ushered away across asphalt surfaces into underground pipelines but instead, where water once again participates in its age old ritual with the land.

6.6 Heritage Features

A historic site plan indicates that the property has an interesting funnel shape form, with the narrowest part to the east and the widest end to the west. The land's form reflects the site's function which is to disperse trains from the incoming line across the site. The plan also reveals that Union Station, the first passenger station built in Vancouver in the 1920s, was located at the southwestern corner of the property and adjacent to Union Station. This is where the proposed sites are, for two long narrow freight houses that were to serve as a temporary storehouse for incoming rail shipments.

Today the site's historic past is retained by its peculiar shape and a few long narrow concrete pads where workers once unloaded freight from the resting box-cars. The historic Union Station, freight houses, and the tracks have all been removed from the site.

CHAPTER VII The Design Brief

"As the pieces of this ecological jigsaw puzzle are united, we come closer to understanding how to meet our essential needs while living in harmony with the natural world."

(Erik Wells, Ocean Arks International, 2000)

7.1 Introduction

The environmental policies and initiatives adopted by the City of Vancouver and the GVRD, and the alternative sewage and stormwater management systems implemented in the precedents and case studies all have one primary goal and that is; to protect natural water bodies and eco-systems from the impacts of human processes and development. In this section the principles that were implemented to meet this common goal have been distilled into a set of six guiding principles; Site as Watershed, Surfaces as Sponges, Interconnected Networks of Green, Visible Systems, Nutrient Cycles and Realigning Conflicting Histories. As well, a design brief summery table has been developed to outline the specific objectives and targets, that were established by the City, the GVRD and the precedents, that must be met to ensure the a successful design proposal is developed.

Together the six principles, the summery table objectives and the explored history, present day context, and geophysical features of the Trillium site will then be united to form the final water management design proposal for the Trillium site.

7.2 Site as Watershed

The stormwater precedents demonstrate the need for water to remain at its source for as long as possible if it is to function like a mini-watershed. This principle is important as it allows rainwater more opportunity to reconnect with its natural course of collection, storage, infiltration, evaporation, and transpiration. Once this natural pattern is allowed to occur, the peak flow levels and the discharge volumes of runoff reaching the surrounding waterways is reduced to the levels experienced prior to development. This allows down stream hydrology to function more effectively. As well, restoring natural water drainage patterns will help protect aquatic habitat and life from destructive water and temperature fluctuations and NPS pollution. Therefore, it is important to understand the natural drainage patterns that once flowed across the land or are currently defining the site and incorporate this understanding into the overall site design.

7.3 Surfaces as Sponges: Filtering Out the Impurities

Runoff from the rooftops, streets and other urban surfaces usually contain a concentrated amount of toxins. A combination of natural elements such as dense forest canopies, grassy swales, vegetative areas and humus rich soil layers have successfully demonstrated the capacity to filter out impurities contained in runoff. Thus, in a community setting, increasing a site's capacity to absorb rainwater or to direct contaminated runoff from hard surfaces to green treatment areas is required, if rainwater is to be cleansed of its' toxins. Further, simply reducing the amount of hard surfaces or impervious surfaces that make-up the built environment will create more available space for the land to be a living sponge. Reducing the width of streets, integrating street side

grassy swales that clean and absorb rainwater, planting large canopy street trees, planting rooftops, will not only increase the absorptive area of the community but it will also increase it's cleansing capacity. When the city landscape functions as a sponge we will be closer to mimicking the beneficial systems of nature.

However, it is important to keep in mind that diverting the conveyance of non-point source toxins that contaminate the aquatic environment to where they contaminate the terrestrial environment is not the solution to the problem. Another important factor that must be addressed through community monitoring and local policy is eliminating or significantly reducing, non-point source pollutants that fall on hard surfaces from automobile and domestic activities.

7.4 Interconnected Networks of Green

Like the human body good circulation between the component parts is essential to the healthy function of the whole. The natural water cycle has been disrupted from its flow across and through the landscape for centuries due to careless development. Restoring the workings of the natural hydrological cycle in an urban context is vital to both a healthier city and regional watershed. This means that both natural and human systems must be combined in a manner that contributes to the overall health of both. Therefore streets, public parks, school yards, city squares, and greenways must combine to form a continuous working network of green; all of which compliment each other as smaller parts of a larger drainage system.

7.5 Visible Systems

Ecological systems that are hidden render them difficult to understand as an important part of human life. Rainwater channeled across a site dramatically reveals the interaction between the landscape and the water that falls on it. The GVRD has acknowledged the need to implement green infrastructure as a move to improve and protect the water bodies surrounding the city as well as to conserve water. Therefore, adults and children must be engaged in this process by designing interesting surface water systems that not only educate and reconnect people with the water cycle but also delight their senses.

7.6 Nutrient Cycles: Sewage as a Delightful Resource

Decentralized liquid waste systems are available which will decrease loading on the Greater Vancouver's regional sewer infrastructure and provide higher quality water treatment. Small, decentralized biological systems that treat and recycle community wastewater have been advanced by many as one possible long-term solution to wastewater disposal problems. Natural wastewater treatment systems are not only cost effective, they also provide a number of other important benefits such as eliminating raw sewage discharge into local waterways, reducing the demand on local water reservoirs, contributing to a community by providing clean water for a variety of uses, and returning nutrients and energy back into urban environment. Natural wastewater treatment systems are aesthetically pleasing and provide stimulus for community activities that work in harmony with the environment (such as nutrient recycling, horticultural activities and products, education programs, recycled water....recycling waste as a nutrient source for a

variety of activities such as, city gardening, urban farming, and as a nutrient source for depleted urban soils, etc).

7.7 Realigning Conflicting Histories

The history of the site is also important to the character and identity of the city. The False Creek Mud Flats has undergone a dramatic change since the advent of the railway in the early 1900's. This drastic change from a healthy natural mud flat ecosystem to an industrial landscape occurred without any consideration for the important role the Mud Flats once played in the larger watershed of the area. Today, we have the opportunity to recall the history of the Mud Flats and the railroad, learn from our past mistakes, and design a new community which recalls part of this history but also moves forward and celebrates a new found ecological ethic. This new ecological ethic is the foundation for building new communities that are more harmonious with nature and that have a much reduced disruptive impact on the environment.

Table 3: Design Brief Summery ***Summery of Objective and Targets:***
Rainwater
Hold and absorb 100% of rainwater on the site.
At least 50% of the built form should be pervious.
No more than 54% of the overall site is covered in impervious material
Restore infiltration capacity wherever possible
Reveal the urban ecology of rainwater through design.
Streets
Make streets that clean water, provide habitat, and accommodate people.
Design streets that speak (Streets should reveal ecological process, the history of the site the movement of water, through the site).
Reduce road widths to the minimum required.
Reduce parking ratios and parking stall sizes (encourage underground parking).
Use porous surfaces where possible.
Use swales and open systems rather than curb and gutter systems.
Ensure at least 50 to 60% forest cover of street surface.
Open Space
Ensure that 80% of the community park has marsh land habitat value.
Provide recreation for the community that evolves around ecological water systems.
Create a connected ecological water network.
Create opportunities for learning about the natural water cycle and the site's historic ecosystem
Ensure neighborhood parks have at least 30% forest cover and parks have at least 40% Provide social and ecological opportunities for the community in the design of plazas, roads and public spaces.
Wastewater
Treat and recycle100 % of the wastewater on site.
Transform wastewater into a local resource (i.e., create educational, recreational and neighborhood economic opportunities)

CHAPTER VIII WaterWorks! Managing Water of the False Creek Mud Flats

8.1 Hierarchy of Systems

In a natural setting the intricate flow of water through a watershed can be viewed as water passing through an interconnect series of systems. These systems build upon each other as one smaller system moves water into the next larger system and then into the next. Each system increases in physical size and in the volume of water it can hold or convey. The watershed keeps moving the majority of water that falls within its reaches down along and through the landscape until it reaches its final destination; which could be anything from a wetland, a lake, the ocean or simply a depression in the ground. This final destination is not really the end resting place, it is only a temporary place until the water molecules can once again rejoin the cycle that they must continuously pass through. The Mud Flats itself was once the receiving body to the larger watershed area that drained from the surrounding upland areas. It had a rich ecological system of aquatic and terrestrial organisms that where connected to not only to the waters of the Pacific Ocean that flowed into the Mud Flats during high tide but, also to the streams that flowed from the upper reaches of the water shed.

Managing stormwater and wastewater on the site takes it clues from the natural hierarchy system that was once present in the landscape. The proposed Mud Flat community (Trillium site) and the adjacent park (Figure 19) are designed to become a self-contained watershed system that is divided into a hierarchy of systems (courtyard, street, plaza and park), that moves rainwater along and into the landscape. The streets, plaza and linear

green spaces function much like little streams in that they convey excess water from larger storm events through road side swales and water conducting boulevards to nearby

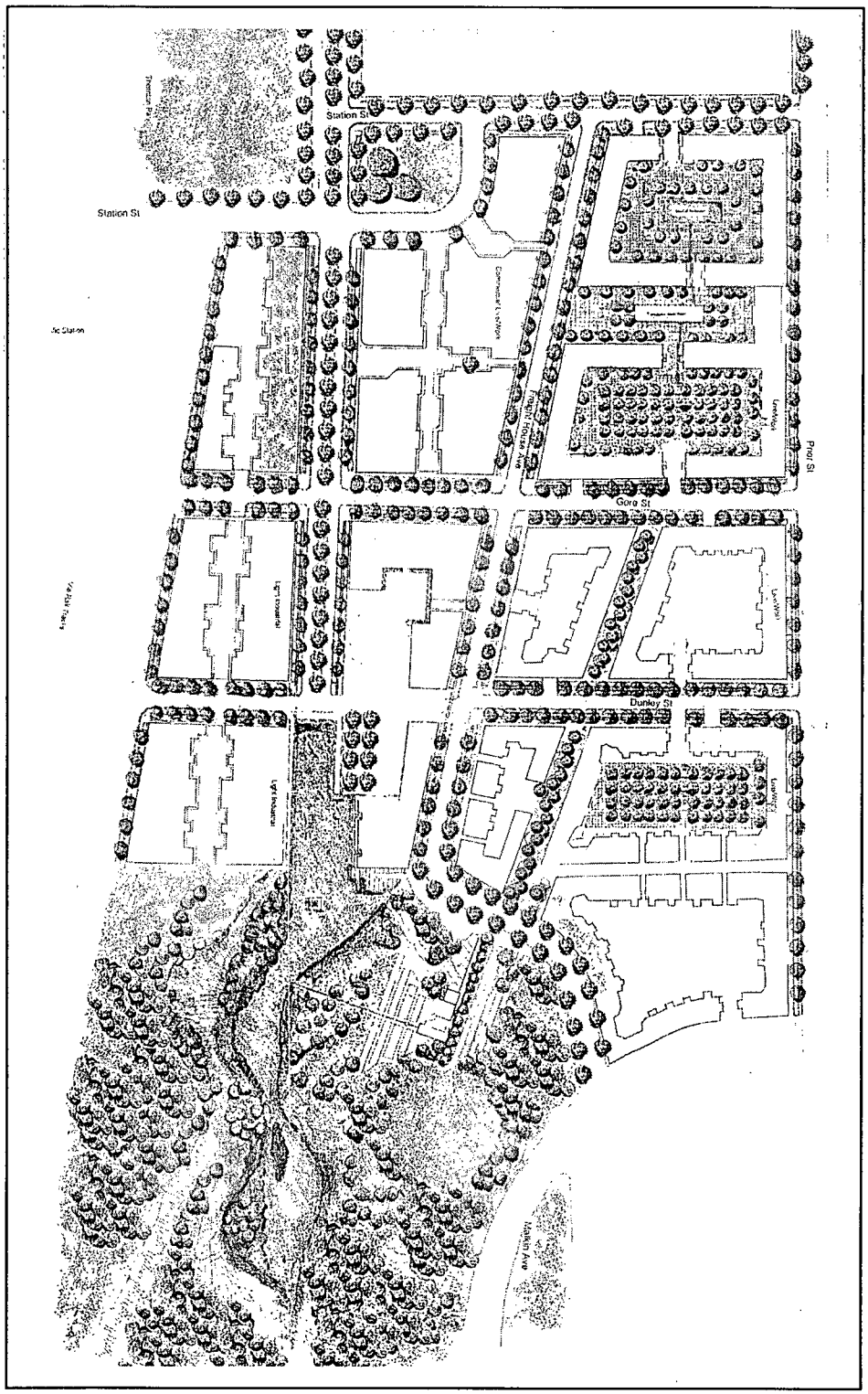

Figure 19:
Master Plan for the Mud Flat Community Trillium site. (Illustration by Anais LaRue).

mini-wetlands located in a neighborhood pocket park, or a rain garden located in the centre of a courtyard. As runoff volumes build or larger storm events release their water onto the landscape, the excess stormwater from the smaller systems is conveyed through overflow channels into the adjacent Marsh Land Park.

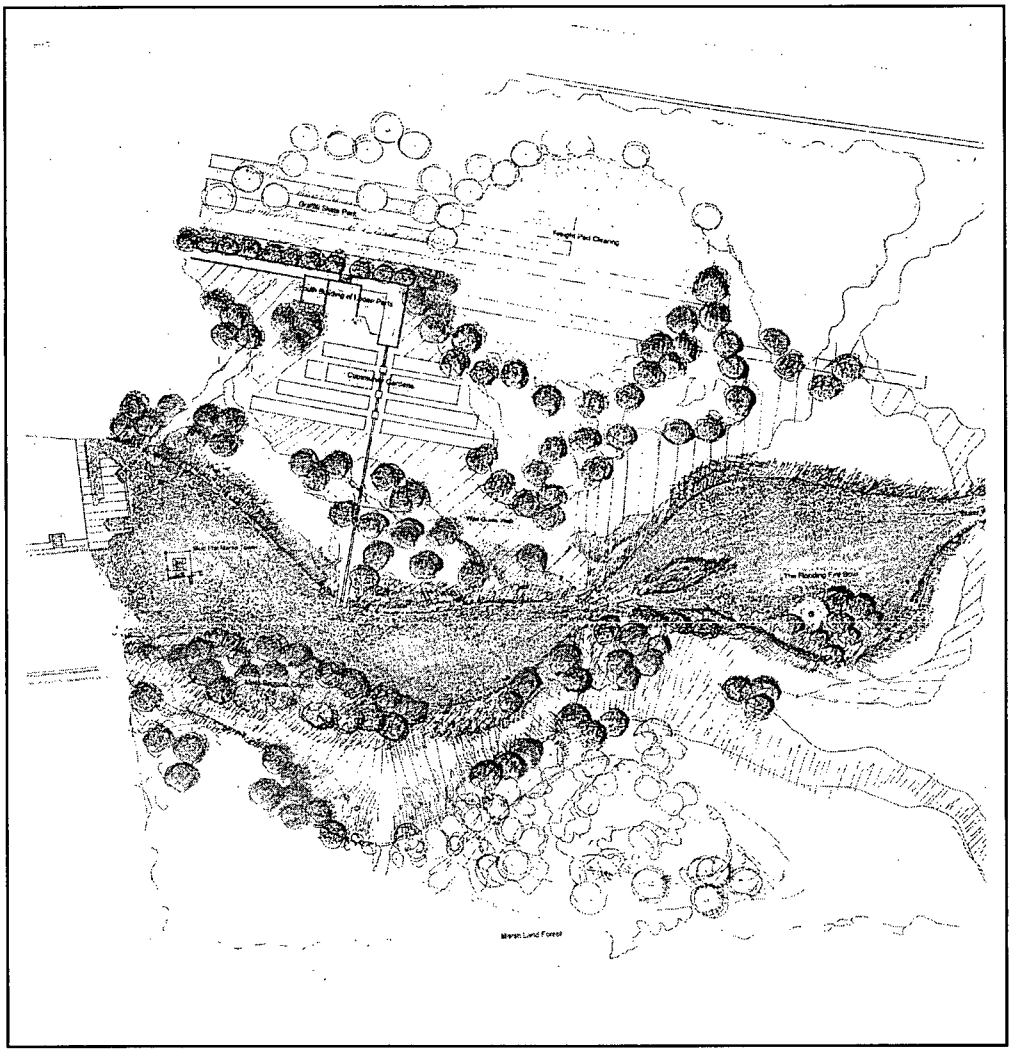

Figure 20:
The 3.2 hectare Marsh Land Park site mitigates stormwater originating both from the park and the overflow from the adjacent Mud Flat Community (Illustration by Anais LaRue).

The Marsh Land Park site is designed as a wetland ecosystem that is designed to retain a specific volume of water all year round and also serve to detain storm volumes up to the

100 year storm[1]. As well as serving as a means to mitigate stormwater the wetland system allows water the time it needs to slowly infiltrate into the ground and provide the soil and the plants needed to cleanse it of its impurities.

The courtyard, street, plaza, and park all play an important role in the integrity of the system. Each is connected to the other to ensure that stormwater is dispersed across the community in a safe and efficient manner. As well, by connecting these four components, the entire site becomes an interconnected web of green life that move more than just water. But it is an interconnected ecological system that also moves people, animals, insects, birds and many other microscopic organisms through the unique green structure of the landscape. Thus, this interconnected network functions much like a natural watershed in which rainwater is collected, conveyed, stored, infiltrated, cleansed and transpired.

[1] Amount of Parkland required to mitigate the 100 year storm volume for Trillium site is 0.458 acres or 1853.8 meters square retaining 0.5 meter water depth. (Calculated from Q=CiA x 0.002780; where i=30.0 mm/hr, C=0.68, A=16.76 acres). Amount of Parkland required to retain the 100 year storm volume for the park site is 90.23 meters square retaining 0.5 meter water depth (Calculated from Q=CiA x 0.002780; where i=30.0 mm/hr, C=0.15, A=7.4 acres for park site)

8.2 Softening the Hard Stuff

National Ave, Freight House Ave and the Rain Garden Walk marks the historic alignment of the railroad freight line that once fanned out across the landscape. Today they have been transformed into neighborhood streets with narrow travel lanes and soft green shoulders that serve as a rainwater absorption system along the roadway. All neighborhood streets have large canopy street trees and sidewalk infiltration systems that capture rainwater along their grassy filter strips. Excess runoff is directed into nearby tree wells. The tree wells are designed to direct overflow to the street where infiltration occurs through porous pavers and gravel verges that define the parking lane along the streets. Runoff that enters gravel verges eventually seeps into underground drywells for storage, reuse or

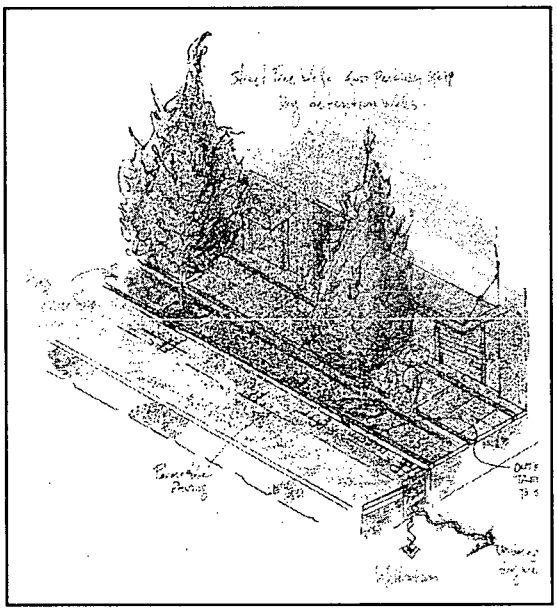

Figure 21:
Streets as Streams: Sketch of rain water passing through porous pavers and infiltrating into the soil layer or being redirected to underground storage cells for reuse. (Illustration by Anais LaRue)

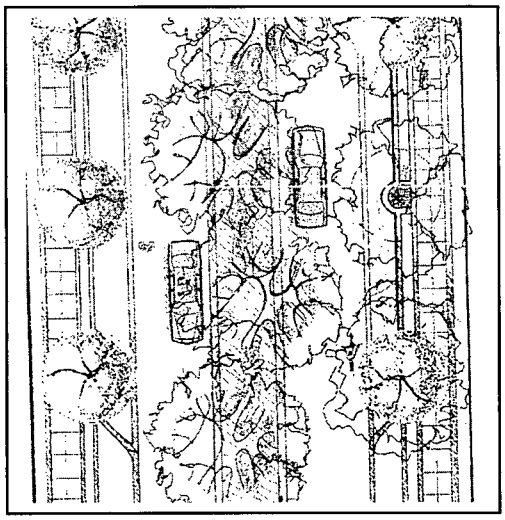

Figure 22:
National Ave Plan View: Central boulevard swale that receives and treats runoff from the narrow street. A network of large canopy trees lines all the streets. (Illustration by Anais LaRue).

slow recharge to the water table not too far below.

The absorptive surface layer of the site is extended from the ground up to the rooftops. The majority of residential buildings and all the industrial buildings are covered with a thin layer of soil and a lush planting of vegetation especially selected for their ability to absorb rainwater and survive the wet winter climate of Vancouver. Some roofs serve as gardens for food production and as places of respite and peace from the activities below. This ensures that the rooftops also contribute to ecological make-up of the site.

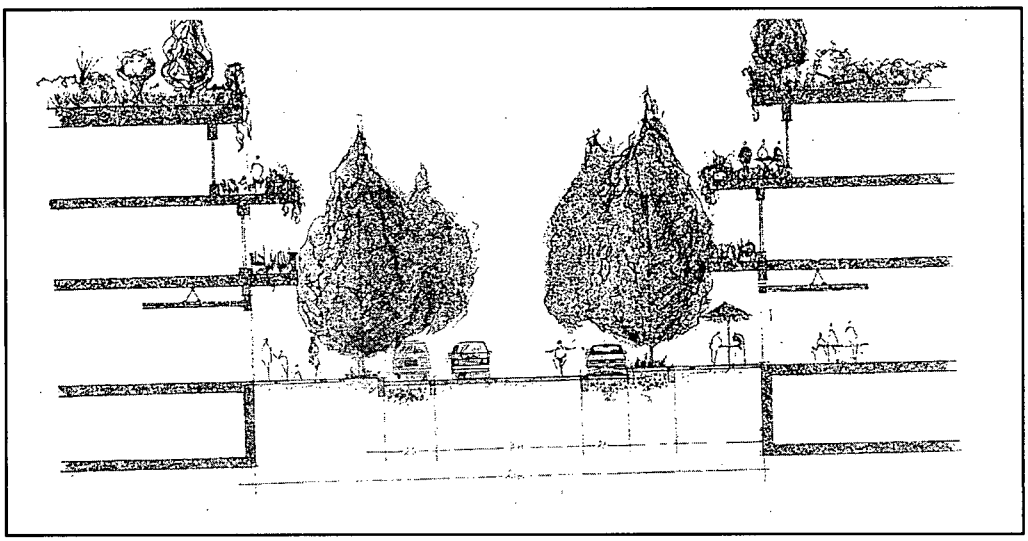

Figure 23:
Streets & Rooftops behave like sponges soaking up and filtering rainwater and releasing it into the soil layer. Underground storage cells hold excess water as it slowly infiltrates into the lower levels (Illustration by Anais LaRue).

8.3 The Play of Water across the Land

The prolonged slow release of rainwater over the course of the winter months is a defining characteristic of the Pacific West Coast Region. Revealing the winter water cycle does not require a strong design intervention as the fluid element of water creates its own watery expression in the landscape. The seasonal fluctuations are recorded in the

Marshland Park, as water levels swell during the rainy season covering more land in the winter and receding back to a smaller water system in the summer. Plants such as

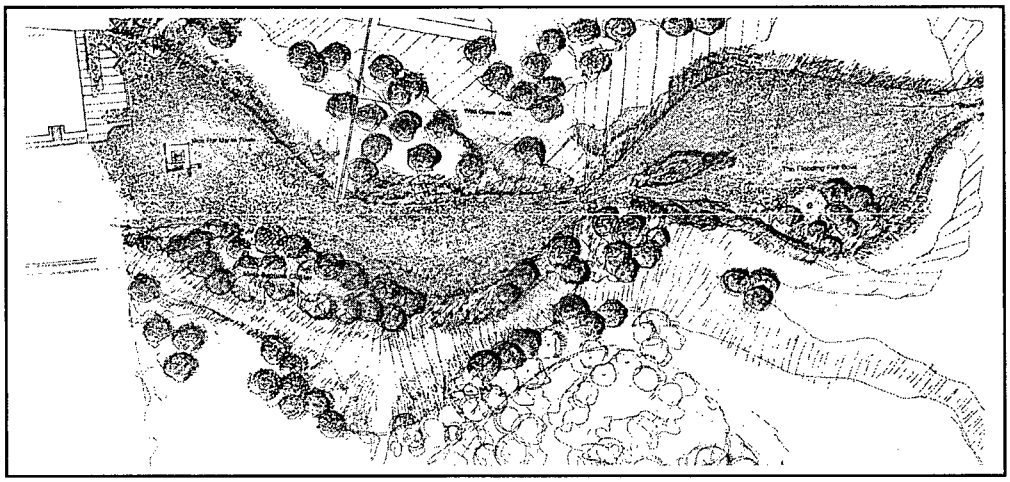

Figure 24:
The wetland area expands and contracts in response to incoming rainwater during the wet season. During the hot dry months of summer, water levels are maintained by the controlled release of purified sewage water into the wetland from the House of Ecology sewage treatment facility (Illustration by Anais LaRue).

Cattails and reed plants that line the edge of the water during the summer become surrounded with water. Animal trails and footpaths meandering close to the water's edge disappear during months of heavy rainfall, forcing those who come to the park during this time to higher ground where paths have not yet been submerged.

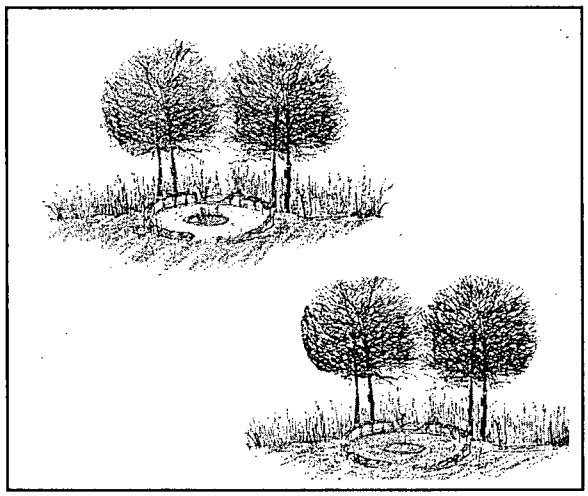

Figure 25:
The Fire Circle recording the seasonal rainfall levels (Illustration by Anais LaRue).

The Fire Stone Circle also reveals the ebb and flow of water during the course of the year as the earth floor of the open air structure eventually floods

with water. The changing water levels mark the stone column wall and give a visual cue to the volume of rainwater the marsh is receiving over the course of a year. During the summer it functions as a secluded place amongst the tall marsh grasses for a small gathering of people to have a warm evening fire.

The unrefined landscape of the marsh with its tall grasses, lush wetland plants and trees offers an enticing landscape to explore and play in as intertwines both natural and urban hydrological systems into a dramatic wetland landscape that resides right in the heart of a neighborhood community.

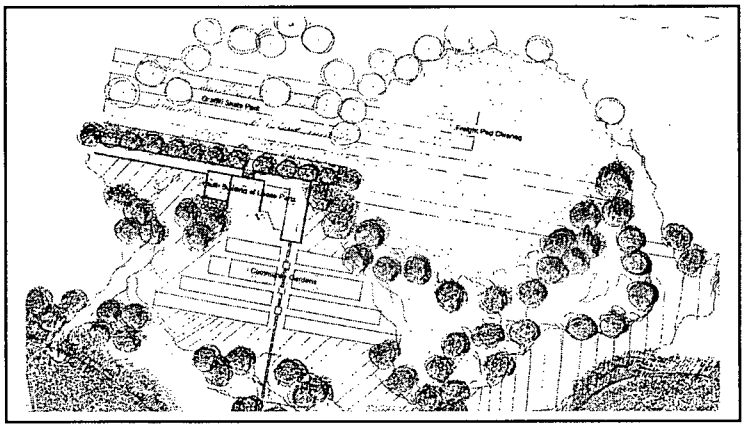

Figure 26:
The Northern portion of Marsh Land Park is a place where teenagers can gather, create and learn about recycling water, ecology and urban farming (Illustration by Anais LaRue).

The northwest corner of the park is dedicated to the youth of the community. A number of stormwater design elements link this part of the site with the community and the park. The youth Centre of Loose Parts is integrated with garden plots and green houses where an open canal system is used to draw water from the Marsh Land water reservoir for summer time irrigation. The Freight Pad Clearing is a small clearing located at the edge of the youth Centre of Loose Parts. The clearing is surrounded by water loving trees such as alders and swamp cypress that both filter water and create terminus to the Rainwater Garden Walk that begins in the heart of the residential neighborhood.

The Rainwater Garden Walk meanders down one of the old historic freight line tracks collecting runoff from the surrounding courtyard blocks in a bioswale lined with a lush planting of plants that collect, store and infiltrate stormwater. The area is planted with water tolerant plants and shade trees which provide bird habitat and allow the collected stormwater to slowly infiltrate into the ground or evaporate back into the atmosphere. During large storm events overflow is directed from the Rainwater Garden under the bridge that crosses Freight House Ave and into the Marsh Land Park. This waterway network then continues in an open channel that flows into a rainwater basin that surrounds the Centre of Loose Parts. Here the water can be further filtered and reused for a variety activities associated with the programming of the youth centre, such as water for gardening, pottery making and flushing toilets. Overflow from the rainwater basin is conducted along the greenhouse and garden irrigation cannel to the Marshland park waterway.

The Mud Flat Community Centre also serves as an ecological and historic resource centre for the Centre of Loose Parts as well as the surrounding community at large. The

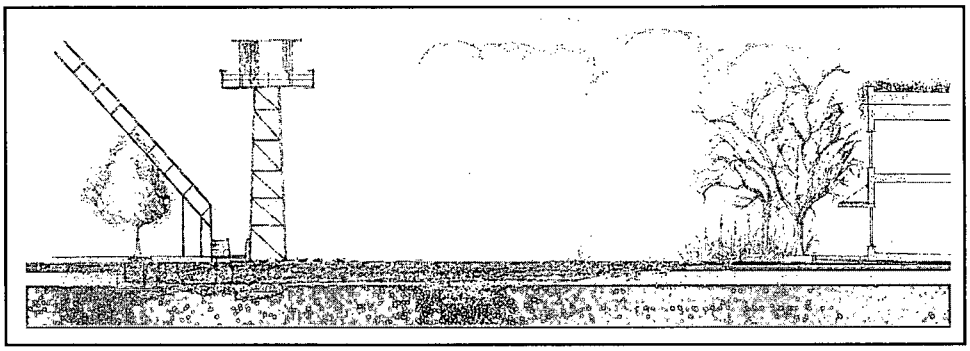

Figure 27:
Mud Flats Tower looking out over Marsh Land Park connecting the community to the natural ecology of the park (Illustration by Anais LaRue).

Marshland waters surround the community centre on the south and east side, establishing

a connection between the community centre and its ecological focus. A boat and docking allows visitors to paddle out to the Marsh Tower where one can climb to the top and enjoy the view and see how the Mud Flat Community forms an important ecological relationship with the Marshland Park.

8.4 Sewage Delights

The House of Ecology is the community's main wastewater treatment facility. It is one of the larger two decentralized sewage treatment facilities. It handles a larger volume of domestic and industrial wastewater and is located in the central area of the community to

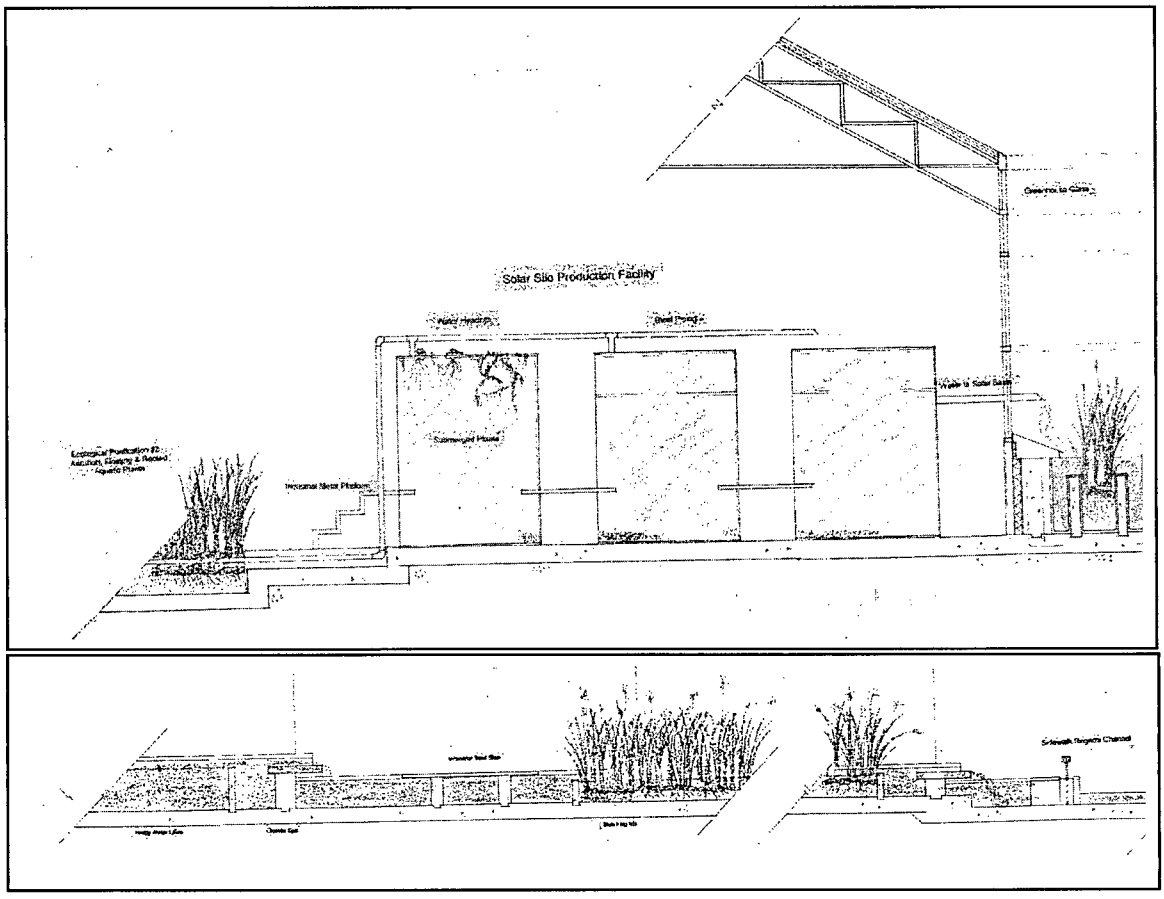

Figure 28:
The House of Ecology community sewage treatment greenhouse (top) and detail of the Iris Water Basin (below) that surrounds the greenhouse and which receives purified wastewater from the House of Ecology (Illustration by Anais LaRue).

serve as a show piece for visitors to the site. It is designed to cleanse, purify and recycle the neighborhoods domestic and commercial waste water. The facility is operated and maintained by members of the community and open to the public. The facility demonstrates how wastewater and ecological systems work in harmony to purify and recycle wastewater.

The facility is constructed of glass and thus reveals how light, biology, waste and water combine as an interconnected living system. Visitors can follow the flow of wastewater into the greenhouse, through the collection of lush plant communities that are involved in the purification process and then out again as purified water ready to meet the needs of the community once again. As an element of play, some of the out flow pipes from the House of Ecology pass through the glass walls filling the outdoor Water Iris Basin which

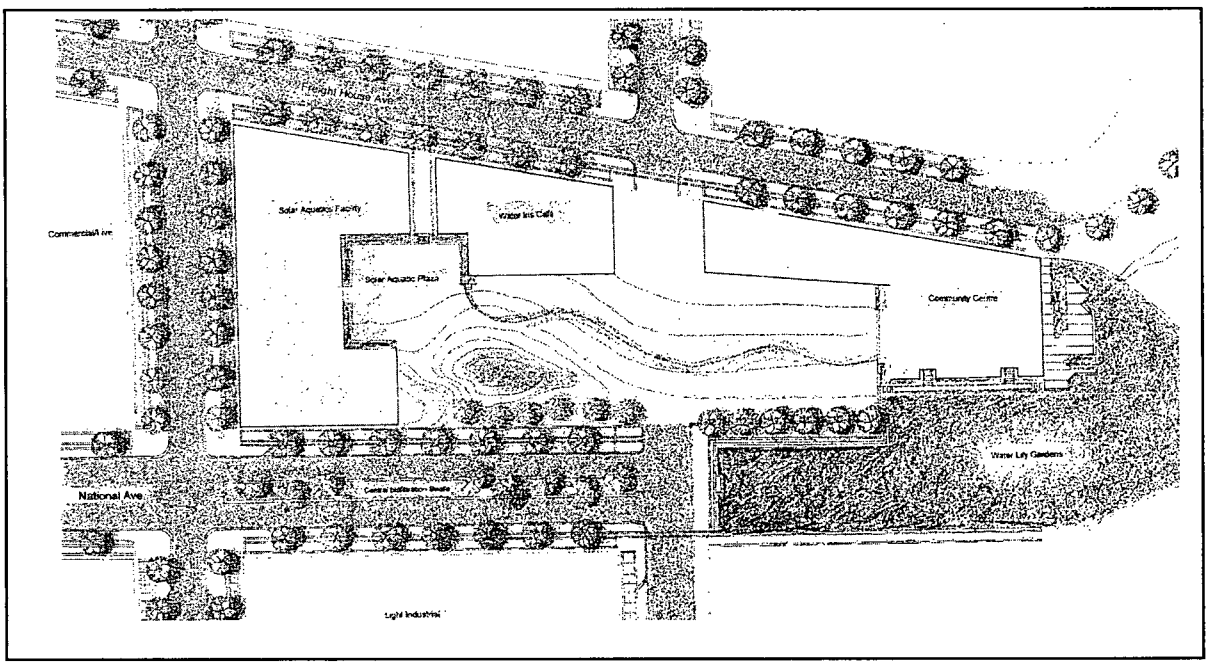

Figure 29:
The Heart of the Community: The Marshland Community plaza is anchored by The House of Ecology to the west where purified sewage water is released into outdoor basins and flow through an open canal in the plaza into the Mud Flat Community Centre indoor water gardens. Eventually water is released into the waters of the Marsh Land Park that meet the edge of the Community Centre (Illustration by Anais LaRue).

surrounds the eastern portion of an outdoor plaza with clean sparkling water.

The House of Ecology anchors the western end of the public plaza where weekend markets and sidewalk regattas are held. The weekend markets offer a place educate the public about alternative water management within a community. The market also offers an opportunity to sell the horticultural products produced by the treatment facility such as tropical and aquatic plants, nutrient rich soils and other organic produced grown within the community.

8.5 The Living Courtyard

A Black Water Bioshelter, is located in a public courtyard space between two residential courtyards. The bioshelter is a smaller facility than the House of Ecology, and it is

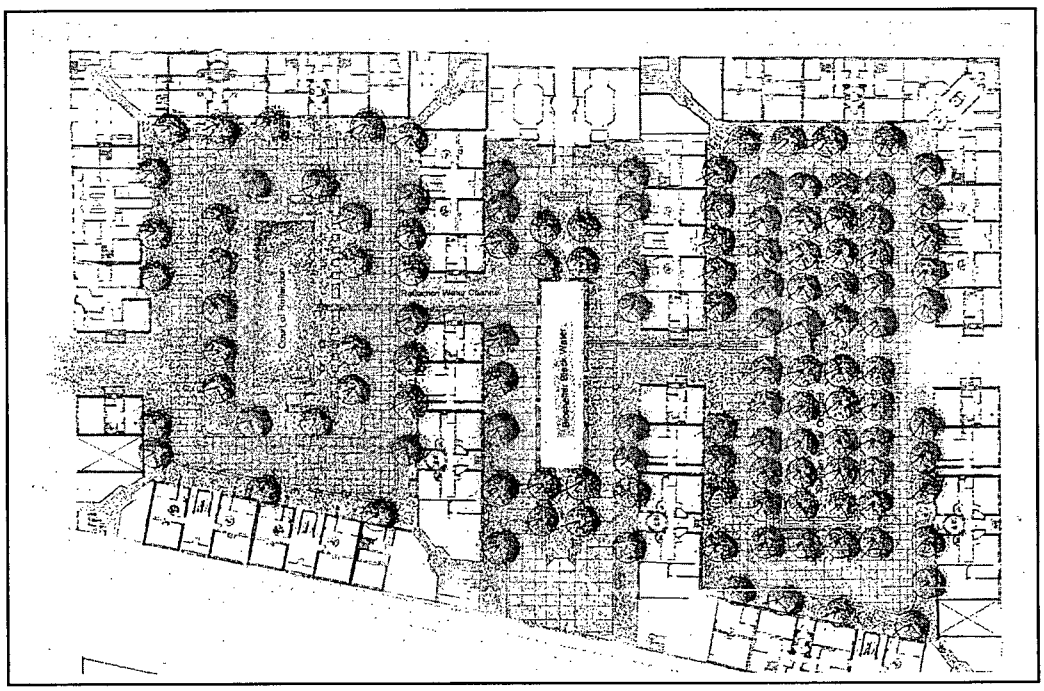

Figure 30:
The Court of Reflection and the Sunken Orchard Court receive irrigation and nutrients from the courtyard bioshelter. (Illustration by Anais LaRue).

designed to cleanse and recycle the domestic wastewater of neighborhood blocks along the north side of the site.

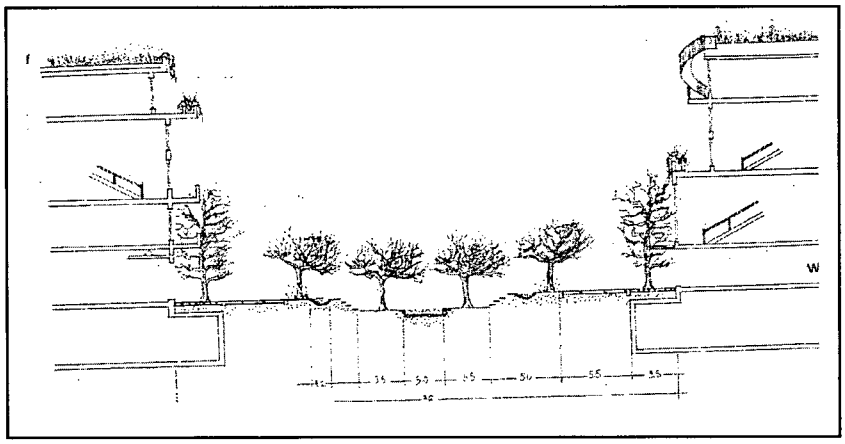

Figure 31:
The Sunken Orchard Court serves as a summer splash basin and winter stormwater detention basin (Illustration by Anais LaRue).

During the summer months, purified wastewater is directed into one of two open cobblestone canals that direct flow into the interior spaces of the courtyards. One canal directs nutrient rich wastewater into the irrigation channels of the Sunken Water Orchard at specific times of the day. The system is capable of meeting the water and nutrient needs of the orchard for the entire growing season, producing an abundance of fruit for the neighborhood community. The second canal directs purified water into the Court of Reflection. Here the Court of Reflection serves as splash basin for residents to cool their feet during the hot summer months, or a place for evening relaxation and contemplation along the cool water's edge.

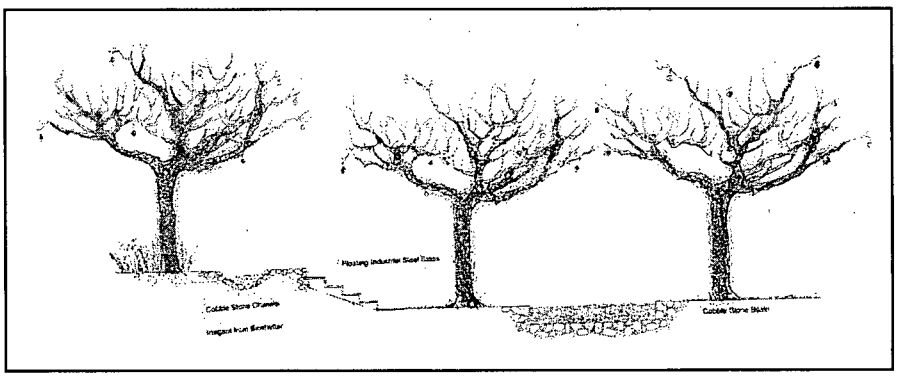

Figure 32:
The Sunken Orchard Court serves as a summer splash basin and winter stormwater detention basin (Illustration by Anais LaRue).

During the winter months the lower portions of both the Court of Reflection and the Sunken Water Orchard act as temporary storage basins that receive stormwater runoff

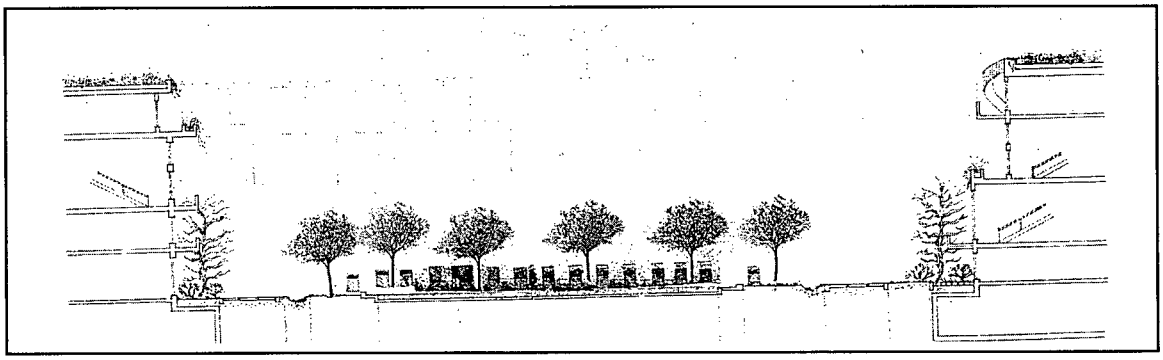

Figure 33:
The Court of Reflection cross section with central water basin that is fed by the purified sewage water released from the bioshelter into open canals. The water is used both for summer irrigation and maintaining the water levels in the central water basin
(Illustration by Anais LaRue).

from the surrounding courtyard site. Each courtyard functions as a small catchment area that manages its own runoff. Rainwater that does not infiltrate through the permeable pavers of the interior courtyard is directed as surface flow to the interior

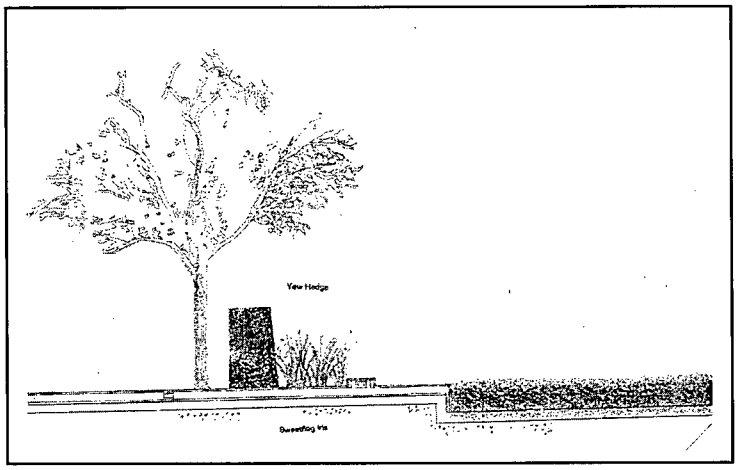

Figure 34:
The Court of Reflection: Section showing canal that feeds the central water basin during the summer. During the winter stormwater from the surrounding court yard passes into the bioswale that surrounds the central basin. Here plants remove toxins before water runoff seeps into central basin (Illustration by Anais LaRue).

of the court. First the runoff flows over the grassy edges of the interior court, some infiltrates and the rest flows into crushed gravel trenches and moves through a series of

plants and grasses that remove many pollutants before the water finally collects in the lower basins for temporary storage.

8.6 Concluding Remarks

The final design for the Trillium site on the Mud Flats illustrates how an alternative sewage and stormwater management system can be effectively implemented into a community design to meet specific environmental water quality standards and local policy. However, the healing and ongoing protection of local waterways would require that all communities throughout the city and the Lower Mainland adopt similar alternative systems. The central idea then is to prohibit pollution of water altogether, rather than simply permitting specified amounts of pollutants into the environment. Only then will we really start to live in closer harmony with the natural world.

As demonstrated by this thesis, an effective solution for dealing with water management problems would be to address the issue at a neighborhood level. Decentralizing the management of water by turning the responsibility over to the members of each community would be an option that places the health and care of the environment directly into the hands of people who use water each day. Communities disconnected from the City's sewer and stormwater system will no longer be contributing to the pollution of Vancouver's surrounding water bodies. Instead, they will function in harmony with the natural hydrological.

Small decentralized sewage treatment systems located within the neighborhood, allows the community to reduce and control pollutants at their source. Further, as examined in the Burlington and Errington precedents, decentralized wastewater treatment centers can

stimulate local "green" economies as waste products are converted into resources. The stormwater management precedents also demonstrate the success that green infrastructure has in reestablishing the hydrological cycle within the city, as well as creating habitat and green networks for the people and animals. Managing rainwater where it falls is needed to restore and protect the integrity of our rivers, streams and oceans. By adopting alternative water management systems that mimic the natural processes of nature, the City of Vancouver and the GVRD have a true opportunity to protect and heal the waterways of the surrounding region.

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