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Development of stormwater exfiltration systems

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Development of Stormwater Exfiltration Systems

By

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The undersigned certify that they have read, and recommend to the School of Graduate Studies for acceptance, a project entitled "Development of Stormwater Exfiltration Systems" submitted in partial fulfillment of the requirements for the degree of Master of Engineering in the program of Civil Engineering.

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ABSTRACT

Pollutant loading from urban runoff has been established as a major cause of receiving water degradation. In an effort to control this problem at the source many Best Management Practices (BMP) have been developed. In this report, the Atlantis Exfiltration Tanks System, was developed as a potential BMP for the City of Sarnia. In order to analyze the efficiency and performance characteristics of the Atlantis Exfiltration Tanks, it is necessary to conduct pilot study before implementation. For this purpose, the highly impervious parking lot of the Newton's Park in Sarnia was selected to develop the Atlantis Exfiltration System (AES). The construction of AES was completed in summer of 2004. AES is an "at source" base water purification and storage system. This report includes the construction and performance of AES followed by conclusions and recommendations for further study.

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DEDICATION

To my Parents for their love and Support

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CHAPTER 1

1.1 Background

The quantity of stormwater runoff increases due to the less available pervious spaces to infiltrate rainwater and snowmelt. The greatly increased runoff volumes and the subsequent erosion and sediment loadings to surface waters that accompany these changes are of concern. Hydrologic and hydraulic changes result from site clearing, grading, and the addition of impervious surfaces and maintained landscapes. Hydrological changes to the watershed are directly related to an increased amount of impervious surface. Roads, parking lots, sidewalks, rooftops, and other impervious surfaces decrease the infiltrative capacity of the ground and result in changes to peak runoff frequency, time to peak, runoff volume, and runoff velocity, which in turn disturb the receiving stream channel and wetlands. Stream channels respond by either increasing their cross-sectional area to accommodate the higher flows or down-cutting the channel. This channel instability begins a cycle of stream bank erosion and habitat degradation, and may increase the frequency and severity of flooding.

In response to these detrimental ecological stresses that urbanization places on a watershed, best management practices (BMPs) have been developed to reduce water quantity impacts and water quality constituents normally associated with stormwater runoff from urbanization. Best management practices (BMPs) can be used to mitigate the downstream effects of increased peak flows in receiving waters. For example, detention facilities can help maintaining the rate and/or duration of flows at predevelopment levels. The basic concept of a detention facility is to collect water from developed areas and release it at a slower rate than the rate at which it enters the system. The difference between the inflow and outflow is then temporarily stored in a pond or vault. Due to space limitations in the urban environment, best management practices are frequently designed to provide multiple benefits. Whenever possible, best management practices provide both water quantity and water quality benefits.

Best management practices (BMPs) are used to mitigate the effects of highways and roads on local conditions, in terms of both water quantity and water quality effects. BMPs are used to reduce peak flows, to reduce runoff volumes, and to reduce the magnitude and concentrations of constituents in runoff. Numerous studies have been done on the effectiveness of BMPs, although past studies have emphasized more traditional BMPs such as wet and dry ponds and vegetative practices. A new, emerging area of BMPs includes technologies for highly urbanized and highly impervious areas. Many of these practices use existing stormwater and wastewater technologies, modifying them to fit into the urban environment.

Stormwater exfiltration system is the artificial forcing of urban runoff away from surface discharge and into the underlying soil. It is qualitatively different from surface detention methods, which are treatment or delay mechanisms that ultimately discharge all runoff to streams. In this study we are using Atlantis permeable tanks which provide an "at source" water purification, storage, and pollutant removal. Water can be reutilized by percolation into the ground to recharge water table and general water management. Tanks help in purifying, collecting, and releasing clean water to environment.

1.2 Problem Identification

The significance of water pollution has identified St. Clair River basin as one of Area of Concerns (AOC) of the Great Lake basin. The pollution is due to combined sewer overflows, storm sewer outfall discharge and discharge from Sarnia Water Pollution Control Centre (WPCC). This pollution causes beach closures and with industrial sources downstream, contribute to the significant degradation of benthic and fisheries habitat in the St. Clair River (UMA study, 1993). To address wet weather pollution problem, the City of Sarnia undertook a number of pollution control studies to assess the pollution problem and to develop alternatives solutions for reducing pollutants loads discharged to St. Clair River from municipal outfalls. Theses studies include Flood Relief and

Combined Sewer Overflow Study by Paul Theil Associates Limited (1988), Sarnia Pollution Control Planning Study by UMA Engineering (1993).

The preferred remedial measures are the end-of-pipe pollution control identified in UMA's Engineering Study. In this report all three main sources of pollution (stormwater, combined sewer overflows and wastewater discharges) addressed. Recommendations were made to reduce the frequency and volume of combined sewer overflows (CSOs) to less than five overflows per year respectively by storing the peak wet weather flows in four underground storage tanks located in the vicinity of main diversion chambers (Exmouth, Wellington, Cromwell and Devine). The residual overflow volume will be disinfected prior to discharge. The stormwater will be treated in a stormwater management retention pond and discharged in the vicinity of Devine Street, downstream of the City Core. The Sarnia Water Pollution Control Centre (WPCC) will be upgraded to provide full primary treatment to all flows and secondary treatment to flows up to three times dry weather flow.

As per recommendation, an underground storage tank of size (80m x 40m x 3.36m) has been constructed near to Devine Street diversion chamber. The size of tank is larger than the recommended size for the Devine Street. At the present time, the City is considering to implement the rest of recommendations suggested by the UMA Engineering Study. In the mean time a number of steps taken by City to control wet weather pollution. Downspout disconnection in the residential areas is one of those steps and downspout disconnection can have impact on the CSO volume and frequency in CS watersheds and runoff volume in the SS watersheds and consequent water pollution control costs. Therefore the City is interested to find out the impact of downspout disconnection on further planning and implementation of control measures and to find out the cost-effective Best Management Practices (BMPs) measures that will meet the City's water pollution control objectives.

"Verification Test Plan for the Atlantis Exfiltration Tanks" (Li 2005) is the part of study which is undertaken to analyze the new best management practice.

1.3 Objective and Scope

The problem of water pollution is worldwide. Since last century, people had become concerned about water pollution, largely because of the prevalence of waterborne diseases. The present conditions are very serious. Pollution is a problem in almost all waterways- Rivers, lakes, estuaries, and even oceans, once erroneously thought to be able to assimilate almost every thing. The seriousness of water pollution can be illustrated by following examples in the United States. In the mid 1960's the Arkansas River was found routinely to have large amount of sodium in the water, making it not unfit for drinking. A 1964 outbreak of New Jersey was attributed in part to water pollution since polluted streams provided extensive breeding grounds for the mosquito carries of the disease. As late as 1965 a Midwestern river was dumped 300,000 pounds of paunch manure (partially digested material in the stomachs of slaughtered cattle into the Missouri river each day). This contributed to the unsightliness of the river, led to its condemnation for reaction and sports.

Great lakes provide prime examples of serious lake pollution. Lake Erie, for example, receives waste discharge of over ten million people, of which 45% receives primary and secondary treatment, 50% receives only primary treatment, and the remaining receives 5% no treatment at all. Pollutants from these discharges and other have lead to reduction in the commercial and sport fishery in the area. For example, in 1925 about 25,000 lbs of Cisco were harvested each year, while in the mid 1960's only about 1,000 lbs were harvested. Cisco population largely replaced by undesirable species such of crap and catfish. Parts of Michigan also were used as a "dumping ground" for many wastes.

If widespread water pollution is continuously unabated, it will result in a lake of un potable water for domestic purposes at a time when demand is increasing e.g. a reduction in crop production and higher food costs; the elimination of certain fishes used for food and sport and the destruction of other aquatic life; higher cost for manufacturing of products which depends on high water quality. Due to these entire facts, the objective and the scope of water pollution problems should address the following points clearly by using Atlantis exfiltration tanks as a BMP of stormwater management:

- Does the BMP provide both stormwater quantity and quality control?
- Are data available on BMP effectiveness?
- Is the BMP applicable to site conditions?

To investigate the above points, the Atlantis tanks exfiltration unit is evaluated in this project, in accordance to the Ministry of Environment guidelines. In order to investigate the feasibility of exfiltration tank with field results, a pilot study at the Parking lot of Newton Park was conducted.

Figure 1- Newton Park Sarnia, Ontario

1.4 Structure of Report

In this report, Chapter two is a literature review which shows past and current exfiltration and infiltration practices used for stormwater management. Chapter three describes the construction of Atlantis tanks and its criteria. Chapter four shows the field analysis results, followed by the fifth chapter of conclusions and recommendations.

CHAPTER 2

2.0 Literature Review

Exfiltration and Infiltration is used intensely in many local areas of the North America. This chapter reviews some cases and experiences with stormwater Exfiltration/infiltration in different regions and covers the different devices used, models use for the design and analysis, performance of technology, and the Atlantis tanks uses in different parts of world.

2.1 Basic Definitions

<u>Exfiltration:</u>

Retention of stormwater for temporarily basis below ground and allowing water to percolate to surrounding soil is known as exfiltration. Stormwater runoff may store in perforated pipes, coarse aggregates, exfiltration trenches, exfiltration tanks etc. for quality treatment and quantity control purposes. Stormwater runoff contains high concentration of pollutants so by exfiltration it will:

- Retain the first flush of runoff and improve water quality
- It filters the contamination of water before entering receiving waters.
- It recharges groundwater
- It helps to reduce runoff volume, so helpful in downstream flooding.
- It reduces channel degradation

<u>Infiltration:</u>

Retaining or detaining of water within soils to reduce runoff. This is process of entry of water into soil at surface level. Leaky wells, retention trenches, infiltration basis, injection wells etc. have been used for infiltration.

2.2- History by Cases and Experiences

The first recorded case of artificial replenishment of groundwater was in 1959, when the Denver Union Water Company averted a threatened water famine at its pipeline intake by spreading water over the alluvial gravel cone at the mouth of South Platte Canyon in Colorado (Muckel, 1959). In 1895, flood waters were spread over an alluvial fan at the mouth of San Antonio Canyon in California to sustain wells in the upper Santa Ana Valley (O'Hare et al., 1986). These early practices acquired the term "water is spreading" because their purpose was to spread water over an area of soil larger than would occur naturally, thereby increasing flow to aquifers. This system was very useful in drought seasons in western U.S. Spreading system can now be seen adjacent to nearly every stream in Southern California, including those where infiltration and percolation rates are not ideal (Muckel, 1959). Long Island, New York has the longest and best documented experience with specifically urban stormwater infiltration in the U.S (Ku and Simmons, 1996: Seaburn and Aronson, 1974). The island's infiltration program began in 1935 as drainage plans and infiltration basins, and increased from 14 in 1950 to over 3,000 in 1960 as reported by U.S. Geologist survey. Most basins are owned and maintained by local government agencies: some are privately owned (Aronson and Seaburn, 1974). Maintenance is variable. Where it is done, it consists mainly of collecting and removing bulk debris and cutting and removing grass on the floor of the basin. About 91 % of the basins are dry within 5 days after 2.5 cm rainfall (Ku and Simmons, 1986).

Hawaii's use of recharge wells demonstrates the turning to the filtration in response to changing urban design standards. Infiltration practices surveyed by Peterson and Hargis, (1973) indicated 26 basins had been constructed to compensate for poor surface drainage. Roanoke, Virginia exemplifies the retrofitting of recharge wells in urban areas to solve local drainage problems. Roanoke is underlain by dolomite and limestone, farming a karstic topography characterized by sinkholes and few surface streams (Breeding and Dawson, 1977). The residual soil is fine-textured and deep. Precipitation averages about 95 cm/yr. Thomas Manor in arid El Paso, Texas was one of the first development outside Long Island incorporating infiltration for the purpose of managing urban discharge. It was designed by Glenn English, with the Federal Housing Authority. The project demonstrates a direct economic advantage of infiltration in flood protection. It was cited as an example of the benefits of on-site stormwater management in the 1960s, when the concept of stormwater management was first gaining acceptance nationwide (Jones, 1967; Newville, 1967). From a land use and aesthetic viewpoint, Florida is home to some of the country's finest and most diverse landscape design in implementing infiltration. Infiltration is common in Florida as a protection of water quality. It is regulated at regional and locals level under the name "retention" (Livingston and McCarron, no date). In 1980, Maryland had the most creative initiative in infiltration and in stormwater management in general. The state's infiltration program was aimed at an ambitious range of environmental objectives including storm flow volume reduction, base flow augmentation, water quality improvement, groundwater recharge and combating of saltwater intrusion into aquifers. In 1984, the state adopted a set of standards and specifications (Maryland Water Resources Administration, 1984) that required developers to consider infiltration on site with soil at least as conductive as silt loam (0.68 cm/h). By 1992, about 1,000 infiltration basins of various types had been built in Maryland (Lindsey, Roberts and Page, 1992) .Nowadays almost the entire U.S are adopting different type of infiltration devices and technologies to control runoff, recharge groundwater, control pollution and manage storm.

Buekeboom (1982) applied infiltration in Calgary, Alberta. The site was a new dinner theater requiring largely impervious surfaces, but having no storm sewer or other public discharge point. A basin was constructed under the parking pavement; an auxiliary inlet fed surface runoff from the escarpment area to it using a pipe. To take snowmelt in account, the design storm volume was doubled, giving 138 cubic meter required capacity. Boring gave hydraulic conductivities and ground water levels. No hydraulic or pavements problems resulting from freezing in the basin have been reported. In Ottawa, Ontario, in 1985, the city government relocated Riverside Drive into a 20 year old landfill site (Johnson Sustronk Weinstein and Weinstein and Associated, 1983). Part of the landfill was excavated, relocated off the roadway, and replaced with surplus rock fill. The void space in the rock provided a reservoir for roadway drainage. The median was surfaced with open river stone for drainage into the rock sub base. Supplemental drop inlets connected to perforated pipes in the rock in the event inclement weather would seal the river stone. After two years of operation the project had experienced no problems with drainage or stability. However, the designer anticipate that flushing and cleaning of the river stone and inlets may be required in the future to maintain rapid drainage (W.S. Beveridge, Regional Municipality of Ottawa-Carleton Transportation Department, 1987).Infiltration is the world's oldest technical solution to the problem of disposing of rainwater falling on urban surfaces, and it is now known that it can reduce many of inherent detrimental effects related to modern sewer systems. By utilizing the natural infiltration process, flooding problems or the unacceptable pollution of surface waters during rain can be reduced or avoided (Geldof et al., 1993). In Japan highly urbanized river basin is getting popular by introducing 33,294 infiltration pits over 1423 ha, 285 km of infiltration trenches and 494,000 square meter of permeable pavement. Infiltration introduced in other Japanese cities has proved that infiltration control storm runoff, spring water restoration (Shoichi Fujita, 1997). In the city of Copenhagen, infiltrations structures are known to exist over 100 years old. In 1994, a case study was set up in central Copenhagen to anaylaze long term behavior of infiltration trenches which were mostly used in Denmark (Eric Warnaars, Peter Steen Mikkelsen, 1999).

2.3-Performance

Exfiltration and Infiltration is the most proper approach of Stormwater Management. The use of structural BMPs is attractive in that groundwater recharge is also achieved. Potential pollutants are prevent, from entering the receiving waters and they are relevantly simple to construct (Scott Taylor, G.F. Lee, 1998). In Pennsylvania, Watschke and Mumma (1989) obtained analogous results for infiltration through grass. They observed experimental turf plots seeded in various mixtures of Kentucky bluegrass (lolium perenne), and annual ryegrass (Lolium multiflorum). Quantity of runoff was insignificant due to the soil porosity maintained by vegetation and organic matter. Infiltration exploits the physical, chemical and biological powers of soil to trap, attenuate and transform pollutants before they reach aquifers or streams. Detailed reviews of process and magnitudes were presented by Chang and Page (1985), and Gerba and Goyal (1985). The degree of purification increases with distance of travel through a soil. Dissolved solids in infiltrated water decrease with subsurface travel distance (Bianchi and Muckel, 1970) Many chemicals and nearly all pathogenic bacteria are filtered out within 1 to 3 m of vertical percolation or 15 to 60 m of lateral movement (Jackura, 1980). For this reason it has been recommended in California that the floor elevations of infiltration basins maintain a 3 m vadose zone above the water table (Jackura, 1980,O'Hare et al., 1986). Many of infiltration's pollutant removal mechanism may be ineffective where soils are extremely permeable and contain little clay or organic matter. Under these conditions water percolates directly to the water table without filtering, adsorption or residence time in the vadose zone. For this reason the Washington State Department of Ecology (1992, chapter 3) requires that the soil in the first 45 cm under a basin floor have hydraulic conductivity not exceeding 6 cm/h. During infiltration of water into the soil, almost all solids are removed by filtration and adsorption in the initial centimeters of soil. Groundwater tends to be nearly free of suspended solids because of the filtering and adsorptive properties of soil (Bianchi and Muckel, 1970). Microorganisms filtered in the soil can be effective in plugging soil pores as clay and silt particles. An improvement in water quality may come at the expense of infiltration rate, as it may for other solids. Unlike other solids, microorganism can be removed from soil pores by oxidation (Bianchi and Muckel, 1970). Wigington et al. (1983) confirmed that heavy metals such as lead accumulate in the top few centimeters of soil and that movement downward through the soil is limited. The quantities and rates of accumulation in basin soils are highly variable and dependent on the land use. A nutrient, particularly nitrogen and phosphorus in urban runoff is transported on the surface of suspended soil particles. Infiltrations filter and sorb these particles out of runoff. Degree of removal depends partly on the travel distance through the soil. For instance, distances of 9 m have produced 50% removal, and distances over 100 m have led to 90% reduction (O'Hare et al., 1986). Organic compounds include chemicals, mostly derived from petroleum, are nearly insoluble in water in flowing runoff and can be mixed with the water or sorbed on sediment particles (Ku and Simons, 1986). Infiltration reduces surface volume during storm events. It eliminates all flow or the first portion of a flow near the source, thereby reducing the potential for flooding at all points down stream. The infiltration systems reduces runoff and control downstream flood (Ellington and Ferguson, 1991). They compared the flood control effects of detention and infiltration by modeling storm discharge from two urban sites near Atlanta: one residential and one industrial sites. According to there studies, infiltration is capable of reducing volume and peak rate of storm flow at the point of discharge and consistently downstream and eliminating all causes of aggravated urban flooding and drainage problems. They also compared the erosion effects of different stormwater management approaches by using velocity at the principal discharge point as an index of erosion potential. The conclusions are infiltration reduced both volume and rate consistently in a watershed, allowing flow rate to return quickly to low levels without aggravating stream channel erosion. Infiltration is the only method of stormwater management capable of maintaining or restoring soil moisture and groundwater reservoirs, and consequently supporting downstream base flow. Ferguson (1990) compared the performance of alternative basin geometries in terms of total disposition of inflows in an average year. The results showed that the stormwater infiltration transforms direct runoff into subsurface recharge and base flow. Stormwater runoff is usually polluted to some degree by oxygen demanding components, nutrients, heavy metals and organic micro pollutants. It is necessary to reduce at the source level and infiltration technology is the beautiful way to treat stormwater (P.S. Mikkelsen, 1994).

2.4- Groundwater contamination

One of the issues associated with exfiltration systems is the potential for groundwater contamination. Recent research on a series of systems that had been installed for 12 to 45 years indicated roadway runoff can influence the concentration of heavy metals and polyaromatic hydrocarbons (PAHs) in the underlying soils. However, this study also found that pollution concentrations decline with depth in the soil column, reaching background levels at soil depths less than 1.5 m (4.9 ft). Furthermore, the pollutants captured in the soil tended not to repartition back into infiltrating stormwater (Mikkelsen et al., 1996). An earlier evaluation of infiltrating stormwater in sandy soil in Florida seems to confirm the capture of certain heavy metals, particularly lead and zinc

(McKenzie, 1988). However, where systems infiltrate directly into highly permeable soil (gravelly) layers without passing through fine-grain soil layers, stormwater pollutants appear to have a greater influence on surficial groundwater aquifers (Adolfson Associates, 1995). However, dissolved pollutants might still enter the groundwater together with rainwater (Shoichi Fujita, 1997). A case study in Switzerland showed that an infiltration system was effective pollutant trap of Cu, Zn, Cd, Pb, possibly Ni, but many pesticides, deicing salts might pass directly through the infiltration systems resulting groundwater pollution (Mikkelsen and Boller, 1997) From the case studies it was observed that metals and mineral oils contaminated the soil over a radius of at least one meter around infiltration installations. Where soil is finer and water table deep infiltration is favorable to treat water, this should be considered in site criteria (M. Legret, G. Raimbault, 1999). Roadside soils are heavily affected by traffic activities. In some cases, infiltration basins beside road side can cause contamination of groundwater after certain period. To prevent groundwater contamination in the long run, soils should be replaced after certain period (Dierkes and Geiger, 1999).

2.5- Atlantis Tank System Uses

Atlantis tanks were used for in Powells creek, concord, Australia in 1998. (Stormwater filtration & Re use system, www.atlantiscorp.com.au/projects) Stormwater runoff infiltrates from roadside to an underground permeable tanks which in turn exfiltrate to the surrounding soil. This can recharge groundwater and reuse water for irrigation purpose. Australian Water Technologies carried out independent monitoring of the water quality including stormwater at surface level, as well as after infiltration and in the tanks. Ten samples were collected during rainfall events over a six-month period. Analysis of the data indicated substantial water quality improvement. The PAH contamination in the storm water was reduced by 97.2% which turbidity, suspended solids (SS), zinc (Zn) and Lead (Pb) were all reduced by at least 99%.

Guyra, located in Northern New South Wales, has stormwater runoff problems. The stormwater of South Guyra drains into Urandangie Creek, which in turn discharges into Malpas Dam. Previous studies showed that the nutrient level in this Creek was four times higher than any other feed streams into the dam. (Guyra Shire Council, 1999). As Malpas Dam is the main water supply for Armidale, this issue was of a matter of priority. Guyra Shire Council required a system to collect and treat surface runoff at source on the 20 meter wide residential Sandon Street and part of the park in Hardinge Street. An Atlantis system, composed of a high infiltration area of grass swales alongside the road, above Eco Soils and Atlantis Ecological tanks for infiltration and storage was used to control storm runoff.. In total, 356 m3 of Atlantis Ecological tanks were installed 500mm underneath the surface ground, creating a system to store and exfiltrate stormwater. A 150mm permeable surface of Eco Soils was placed under the grass to remove nutrients and other contamination such as organic matter, oil grease sediments and heavy metals from the surface runoff.(Dec. 1999 , Road Drainage with Atlantis Tanks, www.atlantiscorp.com.au/projects).

The Storm water infiltration Basin (SIB) is measured 31 meters by 15 meters. It is designed for a 1 in 2 year 1 hour (40 mm) rainfall runoff event, providing a design runoff volume to be treated (per event) of approximately 1 ML (Martens and Associates, 1998). Stormwater enters the SIB via a rectangular channel (width: 35 cm; height: 20 cm) along the entire length of the basin. The contaminated storm water then infiltrates a 300mm layer of Atlantis Ecosoil which removes dissolved and suspended solids, heavy metals such as Cu, Pb, Zn, TP, TKN and faecal coliforms. The Ecosoil cleans contaminated storm water in three ways – physically, chemically and biologically. (May, 2000).

Runoff nutrient and sediment from sports fields is a major factor in waterway pollution and bush land weed infestation. In the past sports fields have been used as stormwater detention basins but it has become apparent that this practice is likely having a significant deleterious effect on aquatic and riparian eco systems. In response to this situation Baulkham Hills Councils used the Atlantis Ecological Tank System to provide a solution at the Ted Horwood Reserve. This reserve is in the upper region of the Parramatta River catchment area and any sports field run-off passes through bushland on its way to river.

In December 2005 Burlington Ontario, a 378 m^3 tanks project was installed at the Royal Botanical Garden. In this project runoff from rooftop, roads and other pervious surfaces enters to this filtration unit through catch basin. This system detains the water and prevents area from flooding. This system was designed to detain a 100 – year storm event.

In summer 2005 three Atlantis systems were installed in the three different parking lots of Thornhill Square mall in Thornhill, Ontario. They were designed to manage 100 – year storm event. All three systems receive runoff overflowing from the main stormwater pipes and serve as off-line detention systems. When storm pipes are no longer full, the systems drain water back into pipes and eventually discharge to the receiving waters.

The exfiltration system was also installed in Niagara Falls - Ontario, at a senior citizen house to detain water and exfiltrate into native soils and other such as the Town of Markham, Ontario

2.6 Commonly used Models

SCS (Soil Conservation Service) Model

The SCS Model is an empirically developed approach to the water infiltration process. It simulates water infiltration through a loamy sandy soil. In this model, first finding a mathematical function whose shape as a function of time matches the observed features of the infiltration rate. This function is then provided a physical explanation of the process (Jury et al., 1991). The purpose is to calculate the daily infiltration into the subsurface. The commonly used semi-empirical infiltration model in the fields of soil physics and hydrology is the SCS Model. Sw = 8.2 inches, daily rainfall amount P= 0.1 to 10.0 inches should be assumed.

$$\mathbf{R = (P - 0.2\,Sw)\,\text{^}2 \,/\, (P + 0.8Sw)}$$

Philip's Two-Term Model

The Philip's Two-Term model is a truncated power series solution developed by Philips (1957). This model simulates vertical infiltration of water into a homogeneous sandy soil. Philips (1957) suggested the use of the two-term model in applied hydrology when t is not too large. Duration, t = 1 to 24 hrs, S = 1 cm / h1/2, Constant A = 7.6 cm /h and Saturated Hydraulic conductivity K = 21 cm/h should be assumed.

q(t) = ½ S t^-1/2 + A

I(t) = St^1/2 + At

Constant Flux Green-Ampt Model

For the constant flux Green-Ampt model, two formulations are required, one for the condition that the application rate *(r)* is less than the saturated hydraulic conductivity *(Ks)*, and one for the condition that the application rate is greater than the saturated hydraulic conductivity. When *r<Ks*, the infiltration rate *(q)* is always equal to the surace application rate *(r)*, and the surface never becomes saturated. When *r>Ks* , the surface becomes saturated at the time of the initial application *(t0)*.

Layered Green-Ampt Model

The Green-Ampt Model has been modified in this application to calculate water infiltration into non-uniform soils by several researchers (Bouwer, 1969; Fok, 1970; Moore, 1981; Ahuja and Ross, 1983). The implementation for layered systems (GALAYER) utilized for this project was that developed by Flerchinger et al. (1989). Specifically, the model could be utilized for the determination of water infiltration over time in vertically heterogeneous soils. Two simulation scenarios were selected for inclusion in the applications worksheet. The first scenario was to estimate water infiltration into a soil with two layers (sand over a loam), and the second scenario was designed to estimate the water infiltration into a soil with three layers (sand over loam, over clay).

Explicit Green-Ampt Model

The initial Green-Ampt model was the first physically-based model/equation describing the infiltration of water into soil. It has been the subject of considerable developments in soil physics and hydrology owing to its' simplicity and satisfactory performance for a great variety of water infiltration problems. This model yields cumulative infiltration and the infiltration rate as an implicit function of time (*i.e.*, given a value of time (t), values of the cumulative infiltration (I) and the infiltration rate (q) can be directly obtained). Thus, the model functions are $q(t)$ and $I(t)$, rather than of $t(q)$ and $t(I)$. The Explicit Green-Ampt model as defined and utilized for this project's application was developed by Salvucci and Entekhabi (1994), which provides a straightforward and accurate estimation of infiltration for any given time. This formulation supposedly yields an error of less than 2% at all times when compared to the exact values resulting from the Implicit Green-Ampt Model.

Infiltration/Exfiltration Model

The vertical movement of soil water in subsurface conditions can be divided in two processes: 1) infiltration and 2) exfiltration. Exfiltration is the process dominating during drying periods, and water released during this period can be thought of as being released through evaporation to the atmosphere. The model (INFEXF) selected for this project is a formulation of the Philips model developed by Eagleson (1978) to account for water infiltration during the wetting season and exfiltration during the drying season. Infiltration and exfiltration as described in this application assumes the soil medium to be effectively semi-infinite and the internal soil water content at the beginning of each storm event and inter-storm period is assumed to be uniform at its' long-term and space-time average.

Infiltration: $\mathbf{f_I = \frac{1}{2} S_i t^{-1/2} + 1/2(K_I + K_0)}$

Exfiltration: $\mathbf{f_e = 1/2 S_e t^{-1/2} - \frac{1}{2} (K_I + K_0) - ME_v}$

CHAPTER 3

DESIGN AND CONSTRUCTION OF ATLANTIS EXFILTRATION TANKS

This chapter discusses the four phases of design and construction Atlantis tanks Exfiltration system. The chapter is divided into following parts:

(a) Selection through Drainage System Selection Tool.
(b) Design consideration according to Ministry of Environment guidelines manual 2003.
(c) Atlantis tanks construction parameters.
(d) City of Sarnia study site selection planning, design, and construction.

3.1 Selection through DSST

In order to select an effective BMP system, for stormwater management, it is necessary to determine which type of BMP is most appropriate based on runoff flow, pollutant constituents, physical characteristics of site, and the intended usage of site. So for this test study of Exfiltration tanks, we used an electronic toll for the suitability, which helped us to figure out the BMP's appropriateness according site considerations and constrains, soil type, water table and related components. DSST (Drainage System Selection Tool), was developed by J.F. Sabourin and Associates Inc. in 1997 for the evolution of roadside ditches and other related stormwater management practices. The tool will identify whether or not the selected BMP is compatible with the site characteristics and development characteristics. The Atlantis exfiltration tanks were not included in design features listed in the tool, so we added that feature in user defined drained features which allowed us to put the site characteristics and analyze the results of the matrix. Table 1, shows physical and land development characteristics and Table 2 shows the result we have got after the selection of these characteristic

Table 1: for selection of alternative drainage features based on site characteristics. If a feature has "X" in the column relating to a specific site characteristics, it is not compatible. If a feature has an "O" in the column relating to a specific site characteristic, it may or may not be compatible. It is potentially not compatible, it is as conditional. If a feature has not any sign of "X" or "O" and it is blank it means the feature is compatible.

In the Planning we studied site characteristics and put the remarks accordingly, following are the brief reasons why we put "X" and "O" while checking site characteristics for exfiltration tanks system.

Soils are incompatible with the presence of water:

Soil with high carbonate content may not be compatible with the presence of high water contain

Groundwater quality is at risk:

"X" represents a high potential for ground water pollution which may affect water supply source.

Soil infiltration rates:

It is not recommended for the soil where sub-soil infiltration rate is less than 15 mm/hr. If soil infiltration is low as 2.5 mm/hr, we should put "X" in site characteristics column for exfiltration tanks system. Atlantis tanks systems are good for soils of high infiltrate rate.

Depth of groundwater or bedrock:

If the distance between bedrock and groundwater is less than 1.5 m from the facility it is not recommended to install exfiltration system. Exfiltration system should have enough room of native soil to filter water which can be further purified through the soil media. "X" represent that it is not suitable where depth of ground water is low than 1.5 m. In this site ground water ranges may reach with the limit of 1.5 m to 4 m. so we put 0 in the characteristics.

No source of continuous flow:

Exfiltration tanks system can work in any condition where continuous flow may not be available.

Depth of drainage outlet:

"X" shows that if system discharge outlet is greater than 2.0 m in depth is not suitable for system.

Surface slopes:

Exfiltration tanks are installed underground and its main source of getting water is pipes. So it doesn't affect much on system.

Climate is vulnerable to cold and snowy winters:

Exfiltration system can work in cold climate and it should installed under ground > 1m below grade for frost protection.

Surface soils are highly suspended to erosion:

Due to lot of erosion soils may clot the system so if proper maintenance or pretreatment is necessary. "O" shows it may compatible.

Drainage area is less than 5.0 ha or space is limited:

Exfiltration system is compatible in any area where it can install properly.

Table 2: for selection of alternative drainage features based on development characteristics. This table follows the same principles as "Table A"

Types of land use:

Atlantis exfiltration tanks are suitable for residential area and it may work well in commercial area. Most of exfiltration and infiltration systems have pre treatment so they could be used in commercial area such as parking lots. But in the Atlantis exfiltration tanks we are not installing any pre treatment facility, so it is compulsory to have proper maintenance for the system. It is not recommended in industrial area due to heavy hazardous pollutants or spells. So "X" is chosen for site characteristics column.

Row planning:

Exfiltration system need maintenance so it is recommended that it should not be installed when road surface width less than 2.5 m. In our case we have enough space in park surroundings so it can work, it may work when roadside width between 2.5 m to 5m. If sidewalks are available next to road and trees within row it may work with proper room for maintenance. If below ground franchise utilities' cables or pipes can be relocated, exfiltration system can get enough space.

Lot planning:

Exfiltration system can work with the spacing between entrances less than 5m in lot level if the system is maintained properly. Safe side in this model we put "O". Imperviousness greater than 75% has no effect on exfiltration systems. For back to front drainage or reverse slope driveways, exfiltration systems can be applied.

Table 3 is the resultant table which is used to identify compatible drainage features based on the site and development characteristics identified on "Table A" and "Table B". In this case result shows that exfiltration system is compatible.

Table-1 – Drainage System Selection-Tool

Drainage Features	Site Characteristics: Soils are incompatible with the presence of water	Ground water quality is at risk	Soil Infiltration rate: Surface infiltration <13 mm/hr	Surface infiltration < 60 mm/hr	Sub surface infiltration < 2.5 mm/hr	Depth of groundwater or bed rock (m): < 1.5	1.5 - 4.0	No sources of continuous flow	Depth of drainage outlet (m): < 1.0	1.0 - 2.0	>2.0	Surface slopes %: < 1.0	>5.0	Climate is vulnerable to clod and snowy winters	Surface soils are highly susceptible to erosion	Drainage area is less than 5.0 ha or space is limited
Street curbs																
Storm sewers with foundation drain connections																
Shallow storm sewers with sump pumps																
Shallow ditches or swales (no culverts)																
Shallow perforated pipe exfiltration system																
Deep perforated pipe exfiltration system																
Deep perforated pipe filtration system																
Oil and Grit separators																
Horizontal infiltration / exfiltration trenches																
Vertical exfiltration wells & perforated catch basins																
Atlantis Exfiltration Tanks		**X**			**X**	**X**	**O1**		**X**	**O15**					**O10**	

Blank - Compatible alternative, gives a score of "1" in Table - 3

X - Not compatible alternative, gives a score of " 0" in Table - 3

O - May or may not be compatible, gives a score of "0.5" in Table - 3

Table 2 - Drainage System Select Tool

Drainage Features	Development Characteristics											
	Type of land use			Row planning					Lot Parking			
	Residential	Commercial	Industrial	[ROW width] [Road surface width] [Sidewalk Width (m)		Sidewalks next to road	Trees within ROW	Below ground franchise utilities	Spacing between entrances < 5.0 m	Imperviousness >75%	Back to front drainage	Reverse slope driveways
				< 2.5	2.5 - 5.0							
Street curbs												
Storm sewers with												
foundation drain connections												
Shallow storm sewers												
with sump pumps												
Shallow ditches or												
swales (no culverts)												
Shallow perforated pipe												
exfiltration system												
Deep perforated pipe												
exfiltration system												
Deep perforated pipe												
filtration system												
Oil and Grit separators												
Horizontal infiltration /												
exfiltration trenches												
Vertical exfiltration wells &												
perforated catch basins												
Infiltration basins												
Wet ponds												
Dry ponds												
Atlantis Exfiltration Tanks		**O2**	**X**	**O4**			**O7**	**O8**	**O**			

Blank - Compatible alternative, gives a score of "1" in Table - 3

X - Not compatible alternative, gives a score of " 0" in Table - 3

O - May or may not be compatible, gives a score of "0.5" in Table - 3

Table 3: Identification of compatible drainage features

(use to compile results from Tables 1 and 2, optional)

S.No.	Drainage system features	Compatibility checks (refer to Tables 1 and 2)		
		Table 1 Site characteristics	Table 2 Development characteristics	Overall Score (1) x (2)
1	Street curbs	1	1	1
2	Roads with one-sided cross slopes	0.5	0	0
3	Porous pavement with storage structure	0.5	1	0.5
4	Porous pavement with exfiltration system	0.5	0.5	0.25
5	Storm sewers with foundation drain connections	1	1	1
6	Shallow storm sewers with sump pumps	1	1	1
7	Roadside ditches with culverts	0.5	0	0
8	Shallow ditches or swales (no culverts)	1	0.5	0.5
9	Shallow perforated pipe exfiltration system	1	0.5	0.5
10	Deep perforated pipe exfiltration system	1	1	1
11	Deep perforated pipe filtration system	1	1	1
12	Raised culverts	0.5	0	0
13	Dipped driveways	0.5	0.5	0.25
15	Oil and Grit separators	1	1	1
16	Greenbelts and backyard swales	0.5	0.5	0.25
17	Horizontal infiltration trenches	1	0.5	0.5
18	Vertical exfiltration wells and perforated catchbasins	1	1	1
19	Infiltration basins	0	1	0
20	Wet ponds	0	1	0
21	Dry Ponds	0	1	0
23	**Atlantis exfiltration tanks**	1	1	1

Notes on Overall Score values

Score	Suggestion
1	This drainage feature is potentially compatible with both site and development characteristics
0.5	This drainage feature may be compatible, however a cautionary note was generated for Table 1 or Table 2
0.25	This drainage feature may be compatible, however a cautionary note exists for both Table 1 and Table 2
0	This drainage feature is potentially not compatible with both site and development characteristics

3.2 Ministry of the Environment Stormwater Management Planning and Design Manual 2003

In March 2003, the Ontario Ministry of Environment released the Stormwater Management Planning and Design Manual which incorporated changes according to the feedback they received from various sources including: (1) user's survey given to individuals who obtained the 1994 Manual or attended a seminar in 1994; and (2) a questioner circulated in 1997 to provincial agencies, conservation authorities, municipalities and other stormwater management professionals. All these related agencies and stakeholders provided their inputs and directions throughout the development of the manual.

The 2003 manual incorporates water quantity, erosion control, water quality protection, and water balance principles into the selection and design of Stormwater Management Practices. Before using exfiltration tanks system for parking lots, we should consider those principles for our case study.

For the planning and designing of Atlantis Tank Infiltration system we have consider the 2003 MOE, guidelines which ensure that the groundwater, base flow characteristics, and water quality, are prevented. The topography, soil type, depth to bedrock, depth of seasonally high water table, and drainage area are the factors considered in the design and site selection of the Atlantis Exfiltration system.
In Table 4.1 of the MOE guidelines, shows the physical constrains for SWMP Types, and provide guidelines about soil type, bedrock, groundwater, and area. Our prototype exfiltration unit satisfies the guidelines of the MOE manual.

3.2.1 Design guidelines

<u>Drainage Area</u>

Exfiltration Tanks can be implemented for small drainage Area (< 2 ha). It is for small volume of water.

Land use

It can be implemented for residential land uses. Exfiltration tanks can be best for cluster housing, small car parking. It is not suitable for industrial land uses due to high risk of groundwater contamination and/ or dry weather dry spills.

Water Table Depth

The seasonally high water depth should be > 1 m below the bottom of the infiltration tank.

Soils

Exfiltration tanks are not suitable if the native soil has a percolation rate < 15 mm /h.

Bedrock Depth

The depth to bedrock should be >1 m below the exfiltration tank.

Size

For the facility sizing the volumetric quality criteria are presented in Table 3.2 of the 2003 MOE design manual. For the infiltration 40 cubic meters are minimum requirement if the protection level is enhanced with 80% S.S removal.

Storage Configuration

The depth of the storage should be large enough to detain the stormwater up to the time it infiltrate in surrounding soil. If the water is conveyed through pipe system, it is encouraged that uniform distribution of water in the tank.

Location

It should be ensured that exfiltration tank should not interfere with sewage system leaching beds.

Storage Media

Filter fabric should cover the exfiltration tanks and the surrounding soil should have large gradation so there should be no clogging in system.

Filter layer

The filter layer under the tank should be sand. The sand layer should be approximately (0.15 m - .30 m).

Other apparatuses such as pipe distribution overflow pipes, and construction measures should be taken into consideration. It is observed that failure of BMPs is after lack of maintenance. So it important that monitoring and maintenance of Exfiltration tanks be done properly.

3.3 Construction of Atlantis Exfiltration Tanks.

These permeable tanks are important element of the Exfiltration system for parking lots, which providing 'at source' water purification, storage and pollutant removal. At these exfiltration tanks stormwater runoff is collected for temporary storage then water infiltrate in to surrounding soils and recharge ground water table. Atlantis exfiltration tanks are pre- fabricated, modular tanking systems designed specifically for underground storage, infiltration, recycling and transportation of water. The tank modules are constructed from selected polypropylene, making them resistant to chemical and bacterial attack. It currently manufactured in three forms.

Atlantis Aqua Cube:

Single module (410mm*467mm*610mm)

Double module (410mm*930mm*610mm), and

Triple module (410mm*1340mm*610mm)

Atlantis Matrix Cube:

Single module: (408mm*450mm*685mm)

Double module (408mm*880mm*685mm)

Triple module (408mm*1310mm*685mm)

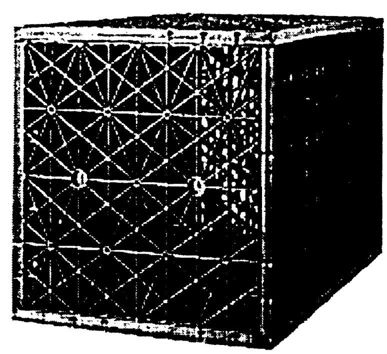

Figure 2 -Atlantis Matrix Cube

Atlantis Titan

It comprise a layered stack of drainage cells, 416mm height, 52mm* 260mm*480mm in size modules

Before any type of infiltration system installation or design of any project for infiltration system following information is required to initiate design for the proposed site.

3.3.1 Functions of Atlantis Exfiltration Tanks in Parking lot

Atlantis Exfiltration tanks provide the following functions:

- To reduce the runoff volume and peak discharges from a site.
- Contribute in the reduction of downstream flooding and channel degradation.
- To filter contaminates out of water before it recharge groundwater aquifer.
- To retain the "first flush" of stormwater runoff

3.3.2 Required Conditions for Atlantis Exfiltration Tanks Construction

Before construction of Atlantis Exfiltration Tanks it is observed that this pilot study site has sandy soil and the groundwater table is below the invert of Exfiltration System by more than 1 meter. This is highly impervious parking lot at residential and a neighborhood park there is low risk of spills.

Field Condition

It is the key factor before installing Exfiltration system; it is essential that subsoil is sufficiently permeable. It is essential that field hydraulic conductivity tests be undertaken to confirm assumptions of hydraulic conductivity adopted during the concept design stage. Recommended percolation rate of soil for the exfiltration facility should be ≥ 15 mm / h. In the design consideration of Atlantis tank exfiltration system is to be ensuring that the base of an exfiltration system is always above the groundwater table and consideration of seasonal variation of groundwater table. Bottom of exfiltration system should be >1 m above the ground water level so stormwater have enough room to infiltrate in the surrounding soil.

Location of Exfiltration System

Exfiltration tanks should not be placed near building footings to remove the influence of continually wet subsurface or greatly varying soil moisture contents on the structural integrity of these structures.

Compaction

Compaction of backfill soil is necessary for equally distribution of load. Compaction is very important to the successful installation of exfiltration tanks. Light weight equipment should be used to avoid localized high impact and penetration of soils in tanks. Recommended compaction ratio should be 90% on wet sand for each 300 mm to 500 mm layer.

Soil Cover

Sand, granular material, eco soils are recommended material for back fill or soil cover of exfiltration system. Soils and sand should be gently placed on the tank (not drooped from height) so as to prevent impact damage to the system.

Installation

The exfiltration tanks should be installed properly and assured that there will be no damage in the tanks. Tanks should be surrounded with a permeable geo textile prior to backfilling.

3.3.3 Technical Specifications

For successful installation of Atlantis tanks we should consider following technical considerations:

Description of Work

Excavation and base preparation should be done, according designer's recommendations and shown on drawings, to provide adequate support for project design loads and safety from excavation sidewalls. Atlantis system products including tanks, geotextile, pipes, bends, inlets, and permeable soil (if it is not native material)

Quality Assurance

Skilled and experienced workers with suitable record in ground foundation, plumbing workers and water workers are required for good construction of system. When products arrive on site for installation they should be stored on smooth, clean surface, free of dirt, mud and waste. Appropriate equipment should be available (e.g. hoist truck, excavators, etc.) depending on the size of the tanks and site condition.

Cold Weather

Do not use-frozen materials or material mixed or coated with ice or frost. Do not build on soils saturated with water, (soft soils) reactive clays or muddy sub- grade, unless it's covered with a minimum layer of clean sand to about 100 mm or more.

Protection during construction

Protect partially completed installation against damage from other construction traffic when work is in progress. Follow the completion of backfill, with highly visible construction tape, fencing and other means until construction is complete to prevent area being used as storage, vehicle parking or temporary traffic area.

3.4 SARNIA CASE STUDY

To explore new technologies in stormwater management, we have studied Atlantis exfiltration tanks system. Before the installation of system, it was necessary to analyze the site with certain criteria's include: water table, soil characteristics, catchment area, surface slopes, land use, and other site characteristics. After the detail survey, Newton Park's parking lot was selected for the installation of an exfiltration unit.

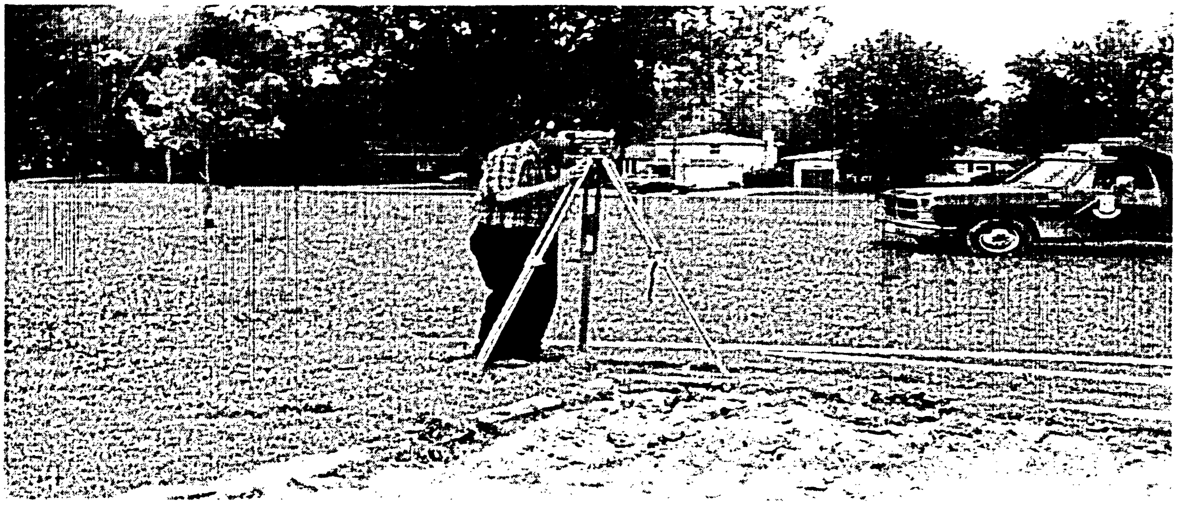

Figure 3- Newton Park, City of Sarnia – Survey of Parking lot for Exfiltration Tank System.

Figure 4- Proposed location of theAtlantis Tank System (Courtesy of Dr. James Y. Li)

3.4.1 PLANNING

The study site (parking lot) is approximately 0.25 acre in size and it located at the east end of the Newton Park at the exit to McCrie Crescent. AMEC Earth & Environment Limited did the geotechnical investigation before the design of the exfiltration system. On March 23, 2004, a borehole was drilled up to 6.7 m below ground surface and samples were taken for further investigations. A 50 mm diameter PVC groundwater monitoring well was installed in the test hole at the completion of soil sampling of 6.1 m. After the site selection we evaluated site characteristics with the help of Drainage System Selection Tool. Table 4 shows the soil characteristics of site. The borehole located 9m west and 11m north of the existing catch basin. And a piezometer was installed with the slot from 5 to 20 ft. Infiltration rate was determined to be 0.01 cm/s

Table 4 - Soil characteristics of the site

Below Grade (ft)	Soil Type
0-8	Beach sand
8-13	Coarse sand
13-18	Fine sand
18-22	Silty sand
>22	Clay
10	Water table on March 23, 2004

Table 1 of Selection Tool:

The following characteristics existed on selected site:

Groundwater quality may be at risk if system fails to purify water from pollutants. Groundwater is available < 1.5m below the exfiltration tanks system. Depth of drainage outlet is between 1.0 to 2.0 m. There is no source of continuous flow. Surface slopes less than 1%. Climate is vulnerable to cold and snowy winters. And the drainage area is less than 5.0 ha.

Table 2:

The development characteristics of the Parking lots are; the land use is residential we can consider it in a way as commercial because it serves the municipal park. It is a paved parking lot and the imperviousness is almost 75%.

Table 3:

After choosing the site characteristics the resultant table C shows, the value of 1 which is positive sign that we can use the exfiltration system to overcome the issue of stormwater.

3.4.2 DESIGN

The exfiltration tank system was designed for 10 m^3 with 2% slope for entire parking lot, and divided in two parts. Each tank system has 5 m^3 which satisfies the requirements of Ministry of Environment which allow 4 m^3 for the size of 1000 m^2. Total 8 single module tanks are required for in one m^3 and the dimension of one module is 408 mm (W) X 685 mm (L) X 450 mm (H). Eighty units will satisfy the volume requirement. Two new catch basins constructed in the parking lot and connected with a newly constructed manhole. The coarse sediment will be trapped at the new manhole. The effluent from the new manhole will then enter in the Atlantis Exfiltration System through elbow pipes. First year our study focused on one tank system. A check valve was installed at the elbow pipe to second tank unit which can be open for flow in second year study when it will focus on both tanks. The tanks are covered with the fiber cloth and a sampling pipe system was installed to facilitate data collection. Each exfiltration tank has one 8" diameter pipe which comes out from the ground for maintenance purpose.

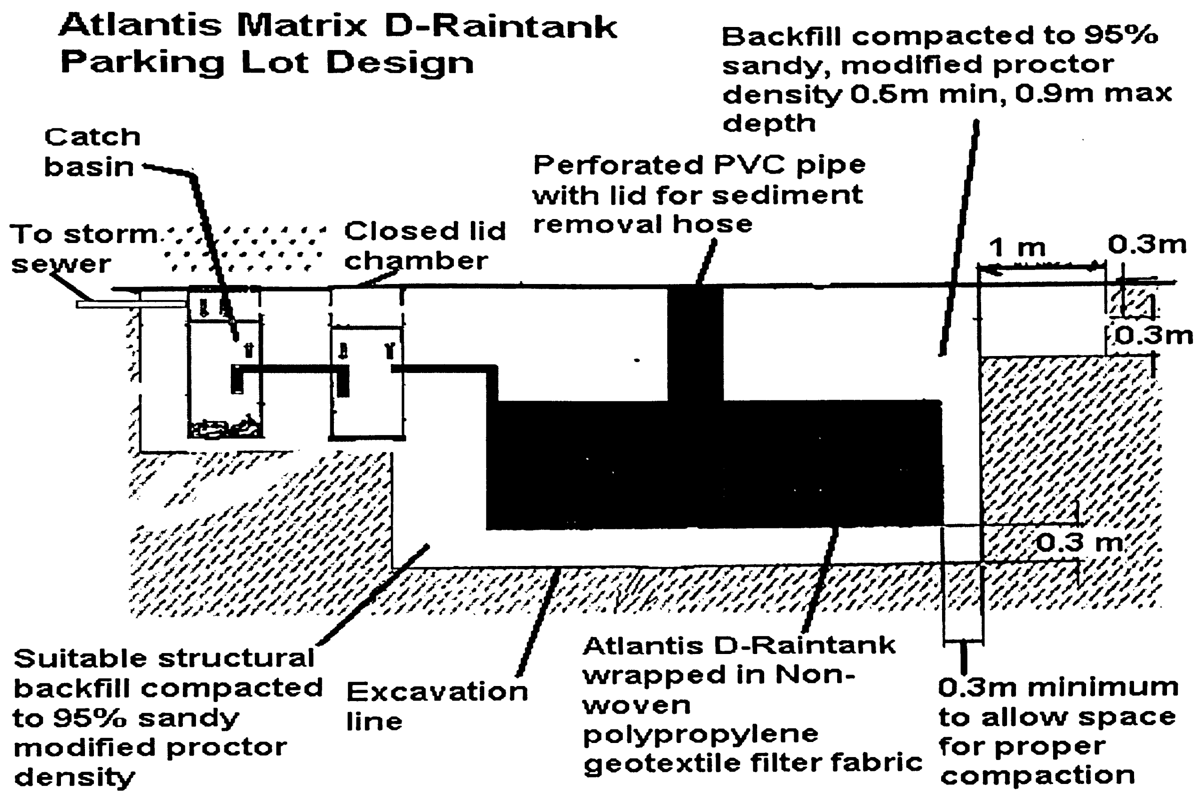

Figure 5- Typical setup for the Atlantis Matrix D-Rain tank for parking lot application

The layout of Atlantis Tank System of Newton Park's parking lot is illustrated in Fig. 6, which can be implemented at other parking lots with similar site conditions

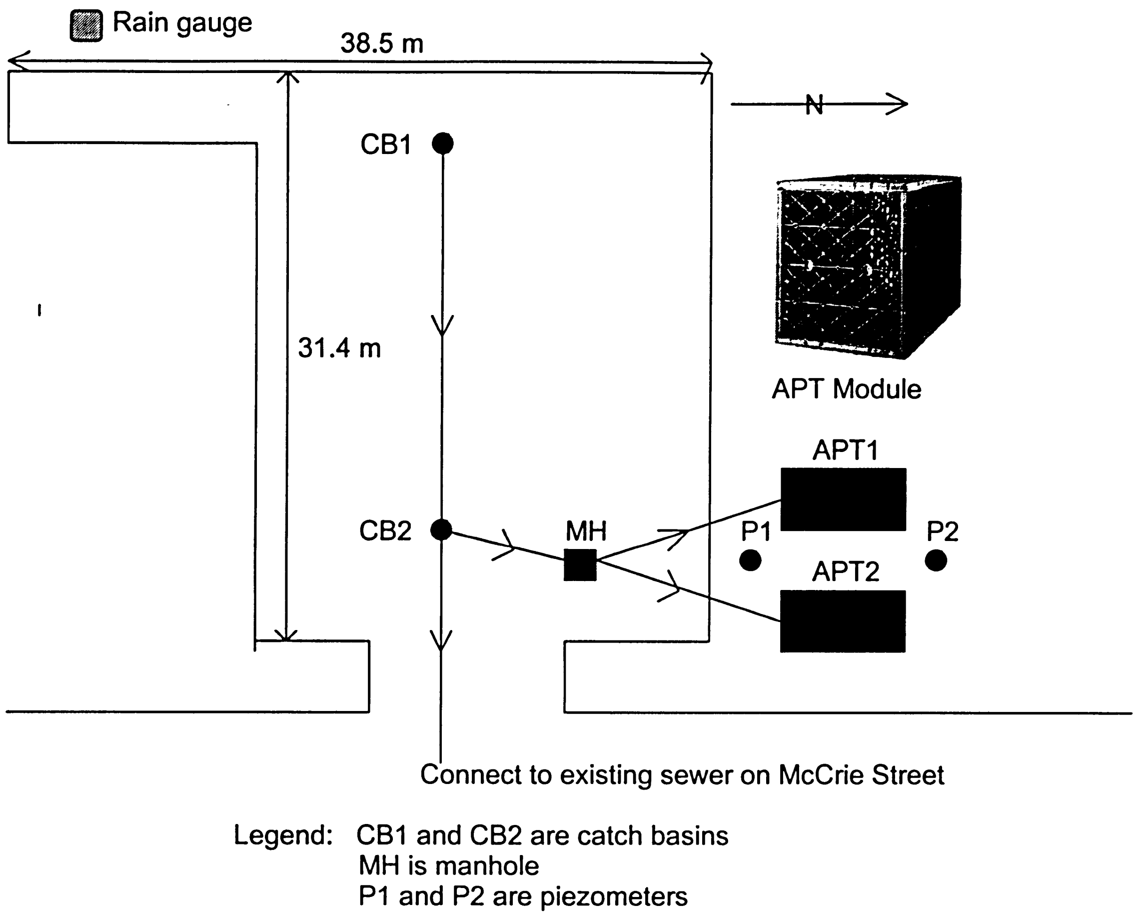

Figure 6 - Layout of the Atlantis Exfiltration Tank in Parking Lot (Li 2006)

3.4.3 Construction of Atlantis Tank

A local contractor was hired to construct and install the exfiltration system in the summer of 2004. The Atlantis Tank System constructed on August 26 – 27, 2004. This system was designed and constructed in such a way that entire runoff of parking lot flow towards the catch basins. When runoff enters in the catch basins, the water level will rise and push water into the new manhole, which in turn, will push water into the Atlantis Exfiltration System. Water stored inside the system. It will exfiltrate into the surround soil through the bottom and sides.

1. Excavation and Installation of Catch basins and manhole:

In the existing parking lot, excavation of paved area was done to install two new catch basins and one manhole connected with PVC pipe. Figure 7 and 8 illustrate the works.

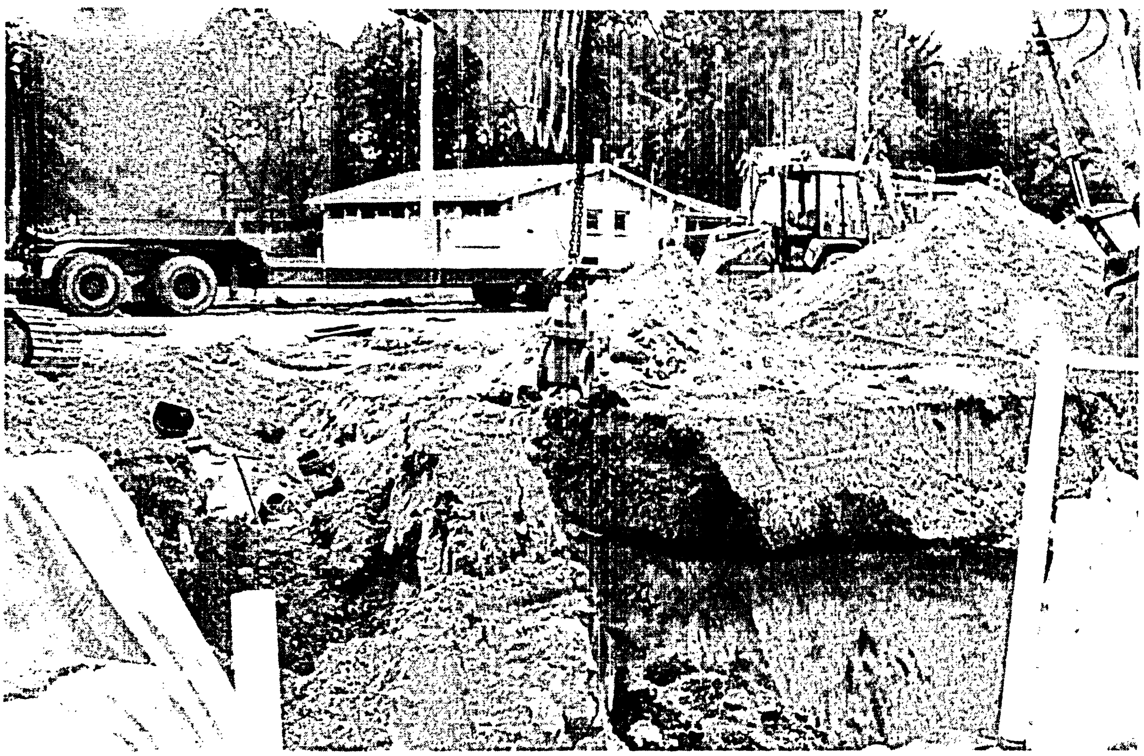

Figure 7 – Excavation for Catch basins and Manhole

Figure 8 – Installation of Manhole

2. Installation of monitoring Conduits:

For the monitoring conduits nylon wire with hooks fixed in catch basins and in manholes with steel hooks to pass monitoring conduits after competition of construction.

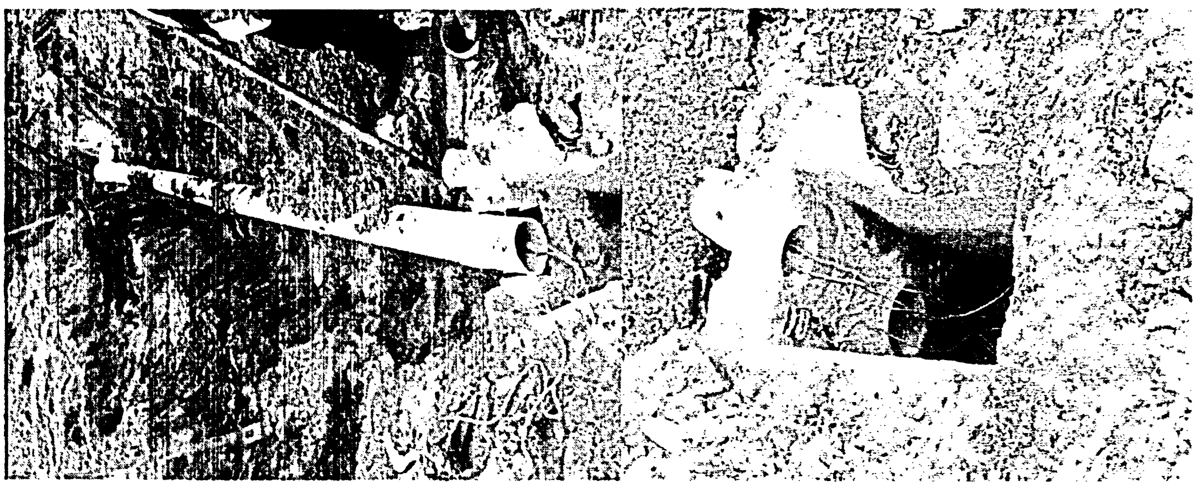

Figure 9 - Installation of nylon rope for monitoring conduits

3. Excavation for Atlantis Tanks:

After the excavation and installation of the catch basins and the manhole, outlet pipes from the manhole were positioned. Excavation for Atlantis Tanks was than carried out for both units beside the paved parking lot. It was also observed that after the first few inches of clay layer, the soil was sandy down to the bottom of tanks. Before the installation of the tanks, the ground was leveled with 2% slope.

Figure 10 – Excavation for the Atlantis Tanks System

4. Construction and Placement of Atlantis Tanks:

Individual units of the Atlantis Tanks were assembled together on site using wooden hammer. Each Atlantis tank was wrapped with filter cloth according to manufacturer specification. Both units were placed underground with the help of a crane. Figure 11, shows the construction of the tank.

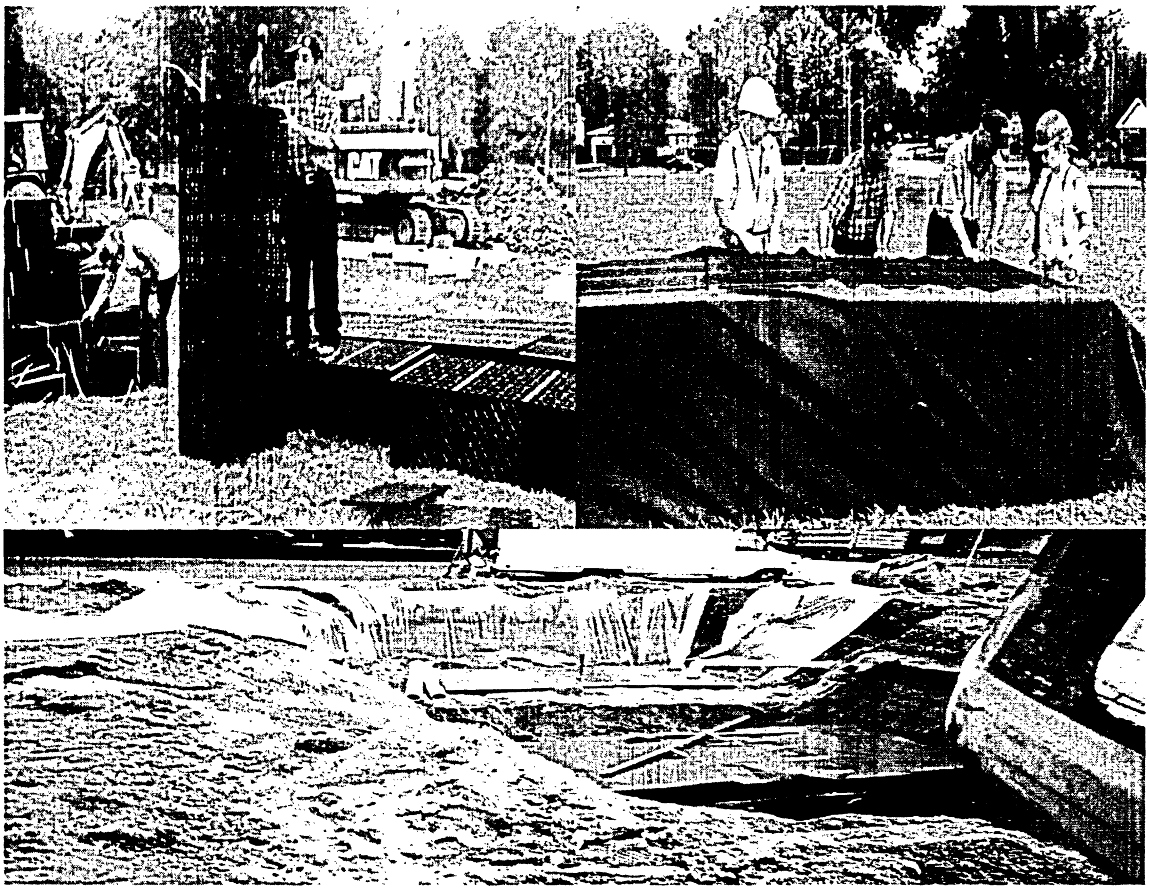

Figure 11 – Construction and Placement of the Atlantis Tank System

5. Installing of connecting pipes from the manhole:

Connecting pipes were installed between the man hole and both Exfiltration Tanks. Tank no. 1 is directly connected to the manhole using an inverted elbow pipe. Tank no. 2 is connected by an inverted elbow pipe with a valve which is closed for first year study. After the first year, the valve will be opened and both tanks will receive effluent from manhole.

Figure 12 – Installing of connecting pipes and valve from manhole.

6. Placement of plastic sheets around Atlantis Tank Systems:

Plastic sheets were placed one meter from all sides and from top of the tank to ensure that rainfall infiltration at the park will not enter in the system. Enough overlapping length of sheet was installed. The void space (one meter) between the tanks was filled with native sand.

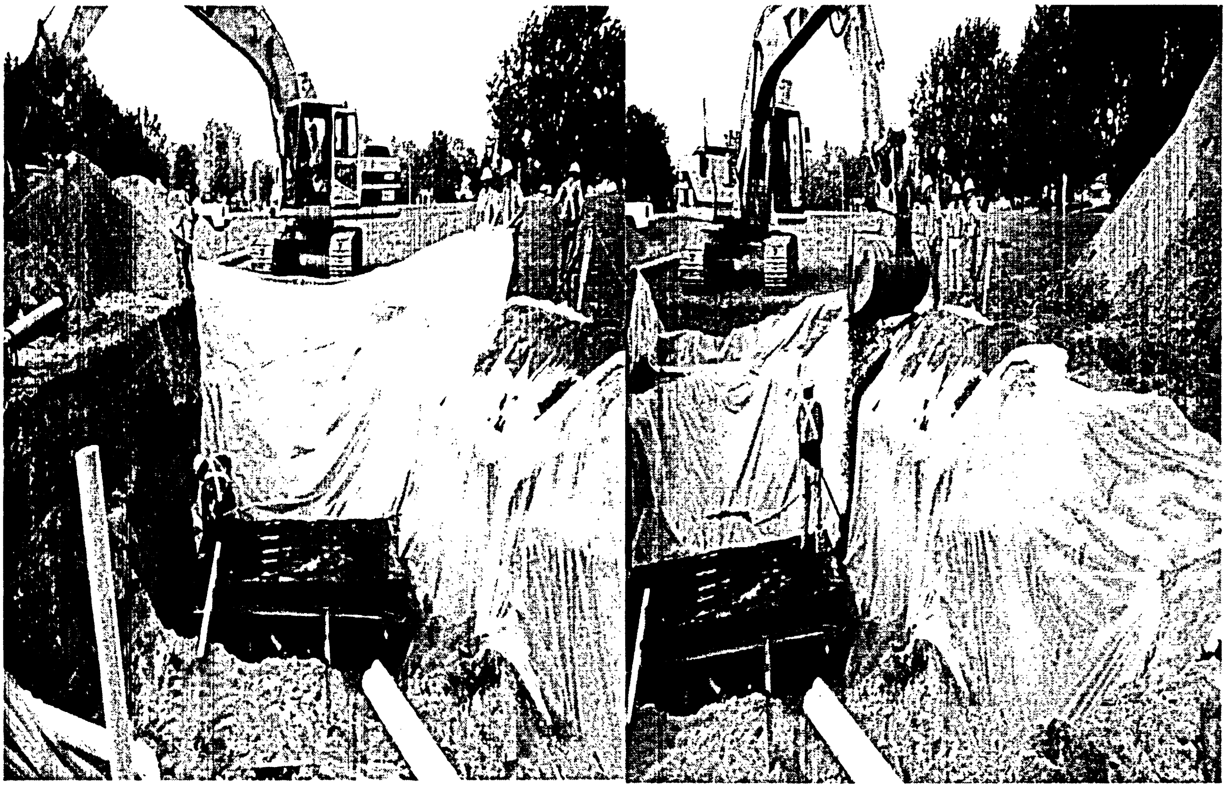

Figure 13 – Plastic sheet placement surrounding of the Atlantis Exfiltration System

7. Backfill of Atlantis Exfiltration Tanks:

After successful installation of tanks, pipes from manhole and placing of plastic sheets were done. The exfiltration units were backfilled with native soil. Samples of the back fill material were collected for further laboratory investigations which will be shown at the end of report. Before backfilling two vertical PVC pipes (200 mm) were inserted into the units for future maintenance using a vacuum hose. Figure 14 shows the back fill procedure and the maintenance pipe.

Figure 14 – Backfill of the Atlantis Exfiltration System

8. Re surfacing of the parking lot of Newton's Park:

Compaction of soil has been done in different layers to avoid from air voids. Before covering tanks entirely, PVC pipes were connected for the monitoring conduits. Wooden sticks also place on all corners of both units for the future reference and foot prints of tanks. Ground resurfaced and left for grass to grow so it should not be viewed differently from the rest of the park. Figure 15 and 16 shows the final construction works of this project.

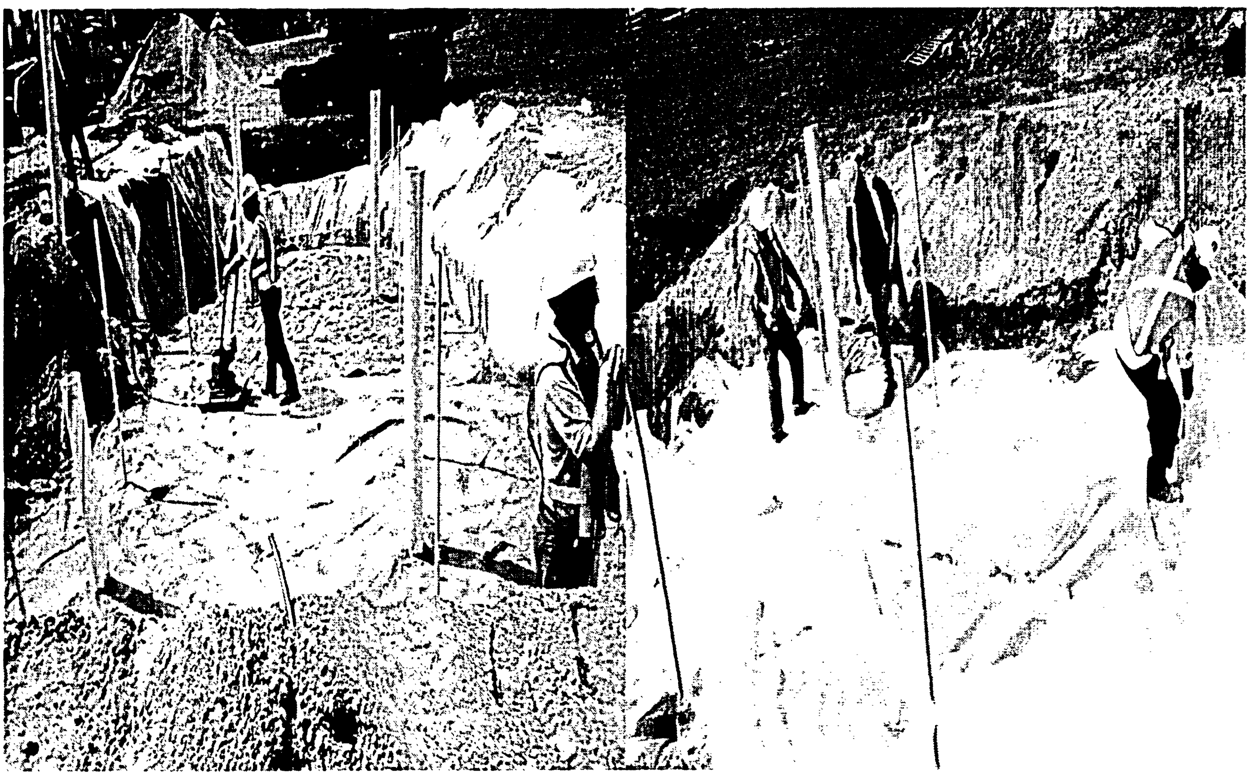

Figure 15 – Compaction of backfill and placing plastic sheet on top of the system

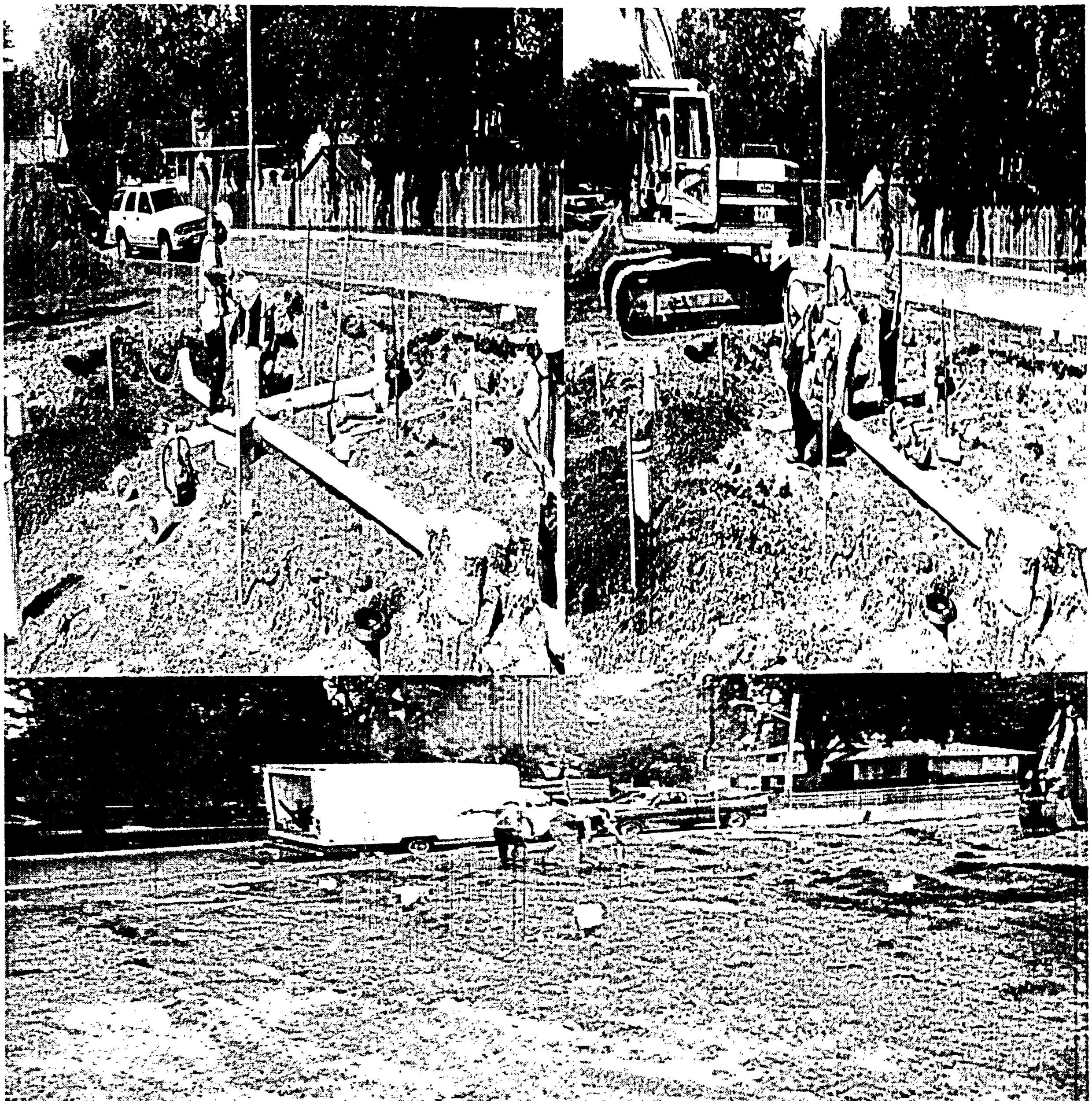

Figure 16 - Placing pipes for monitoring conduits and surfacing ground.

The Atlantis Exfiltration System is located at the north east corner of the parking lot entrance. Parking at the corner should be reserved for monitoring and maintenance of the equipment.

CHAPTER 4

ANALYSIS OF EXFILTRATION TANKS

4.1 Sampling and Analysis

The purpose of Atlantis exfiltration tanks to reduce the quantity of runoff to sewer system and reduce the runoff pollutant loadings. For this, performance evaluation has been done initially and it will be continued for in future studies. We took the backfill soil samples and investigated for the hydraulic conductivity and soil gradation. Precipitation is measured by a tipping bucket, fixed on the top of the parking building. Flows at Catch basin no.1, and the Atlantis exfiltration tank are calculated from the water level measurements. Four Telog water level meters are used for level measurement at the new downstream catch basin no. 2, the new manhole, and the two Atlantis Exfiltration Systems. An area velocity flow logget is installed at the inlet pipe of the new manhole for flow measurement. Figure 17 shows the location of the water level meters and the flow logget.

For the quality measurement, two ISCO automatic wastewater samplers are used for collecting water samples at catch basin 2 and Atlantis Exfiltration 1 which is open for storm water. Pollutech Inc. is hired to collect and analyze water samples after each after rainfall event. Pollutech Inc. ships the discrete samples to Ryerson University for TSS analysis. The processing of water sampling bottles is as follows:

- Collect the sample in 1L plastic sampling bottle and mix it by shaking.
- For making composite sample by pouring half of bottle into a large jar and mix it well.
- For discrete water sample remaining half of 1 litter bottled should be poured into another bottle.
- Send all these discrete water samples to Ryerson University.

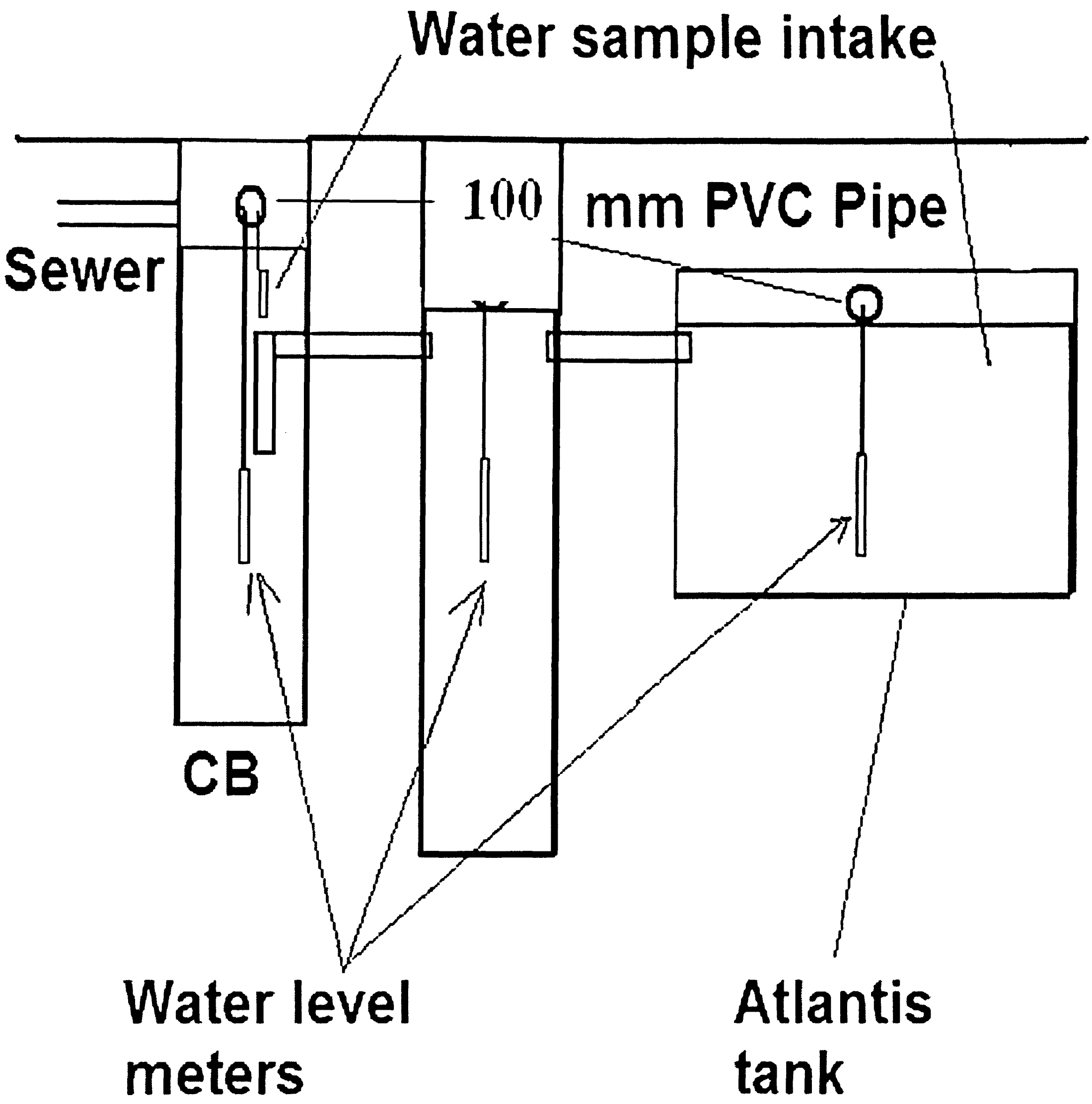

Figure 17 – Water quality and quantity sampling locations at Parking lot (Courtesy of Dr. James Y. Li)

Table 5 – Backfill soil of the AES Hydraulic Conductivity, using the Constant Head method

Sample no.	1	2	3	4	5
Specimen ID.	A-5	A-6	A-7	A-11	A-15
Length of specimen (L) in m	0.117	0.117	0.117	0.117	0.117
Area of specimen (m)	0.00817	0.00817	0.00817	0.00817	0.00817
Quantity of water (Q) in ml	900	900	900	900	900
Constant head (h) in m	1.29	1.29	1.29	1.29	1.29
Elapsed time (t)	226	198	218	266	240
Measured temperature (centigrade)	15	15	15	15	15
K T (m/sec)	$4.42*10^{-5}$	$5.04*10^{-5}$	$4.58*10^{-5}$	$3.75*10^{-5}$	$4.162 * 10^{-5}$
K (adjusted to 20 centigrade)	$5.01*10^{-5}$	$5.71*10^{-5}$	$5.519*10^{-5}$	$4.255*10^{-5}$	$4.72* 10^{-5}$

Notes: All Samples were collected on August 26, 2004.

Sample no. 1 is subsurface soil taken from South West corner of Tank no. 2
Sample no.2 is subsurface soil taken from South West corner of Tank no. 1
Sample no. 3 is subsurface soil taken from North East corner of Tank no. 1
Sample no. 4 is backfill soil taken from Tank no. 1
Sample no. 5 is side wall soil of Tank no. 2

The hydraulic conductivity of a soil is a measure of the soil's ability to transmit water under saturated conditions when submitted to a hydraulic gradient. Hydraulic conductivity is one of the hydraulic properties of the soil. The hydraulic conductivity determines the ability of the soil fluid to flow through the soil matrix system under a specified hydraulic gradient. The soil fluid retention characteristics determine the ability of the soil system to retain the soil fluid under a specified pressure condition. The native backfill soil is also a positive indicator for the success of Atlantis Exfiltration System.

Hydraulic Conductivity and sieve analysis of the backfill soil were conducted at the Environmental Engineering laboratory of Ryerson University, Toronto.

Table 6 – Backfill soil sieve analysis

Sample # 1	Date: August 26, 2004
Side wall of Tank number one, soil after 3 ft excavation	
Total weight for sample = 636.13 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	0
1/2 "	13.54
3/8"	5.97
4"	22.43
10	38.97
20	33.58
Pan	521.47
20	1.58
40	135.91
60	280.98
80	73.07
100	11.97
200	5.61
Pan	9.77

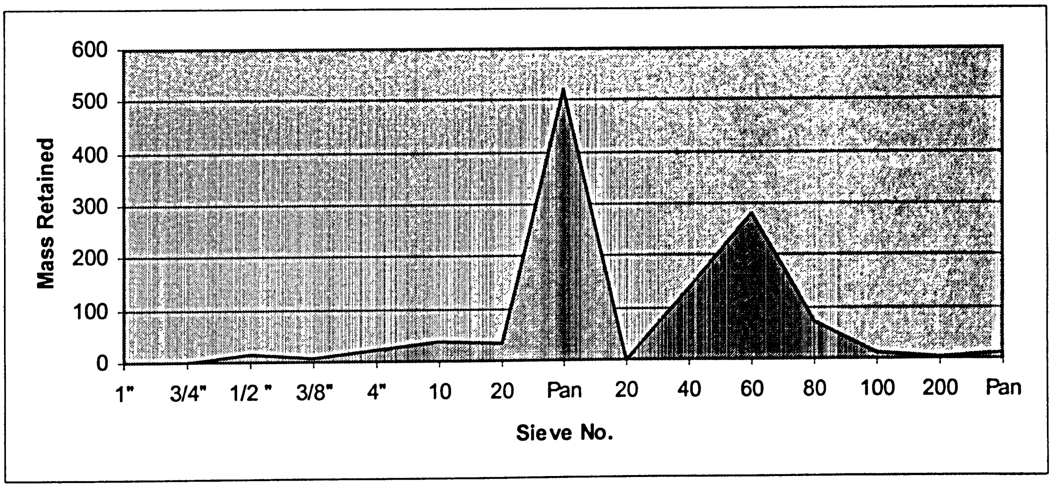

Figure 18 – Representation by chart of the backfill soil sieve analysis.

Table 7 – Backfill soil sieve analysis

Sample # 2	Date : August 27,04
Side wall of Tank number Two, Soil after 3 ft excavation	
Total weight for sample 1322.35	
Sieve No	Mass retained
1"	0
3/4"	0
1/2 "	23.98
3/8"	11.41
4"	41.38
10	47.75
20	125.54
Pan	1070.31
20	9.72
40	371.52
60	601.08
80	52.39
100	10.88
200	7.54
Pan	17.12

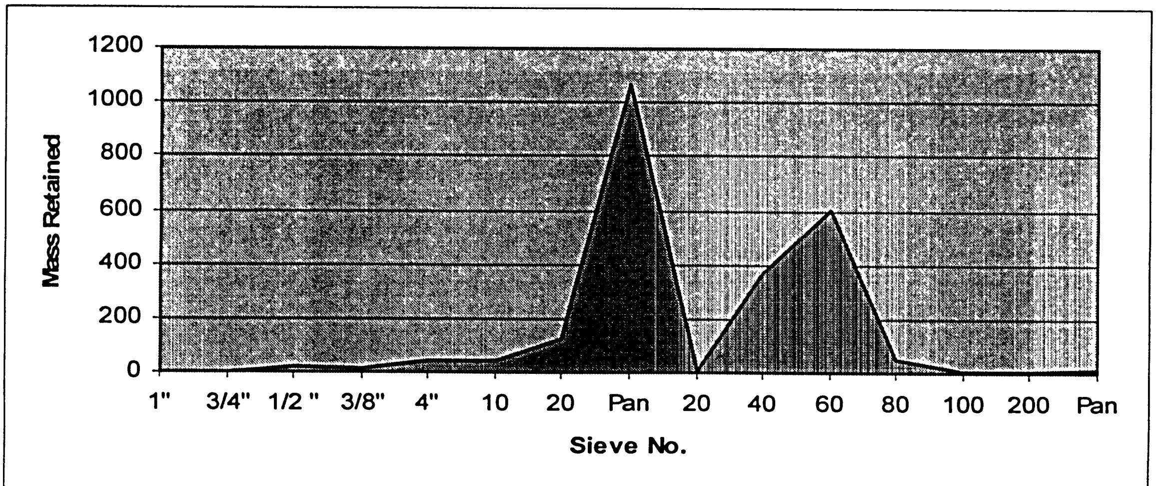

Figure 19 – Representation by chart of the backfill soil sieve analysis

Backfill material

The above sieve analysis shows that the native material is sandy soil as recommended by the manufacturer of Atlantis Tanks. Further tables of sieve analysis are in Appendix- A

4.2 Water Sampling Analysis

Water quality samples after each rain event were analyzed by Pollutech Incorporation. Discrete samples which were collected on November 29, 2005 at 8:00 am were sent to Ryerson University for TSS parameter (Table 8). Pollutech Inc. also analyzed following parameter on a number of events as shown in Tables 9 to 12.

- Total Suspended Solids – TSS
- Total Phosphorus
- Total Kjeldahl Nitrogen
- Metal ICP
- Total Coliform

4.3 Basic definitions of parameters analyzed

<u>Totals Suspended Solids (TSS):</u>

Total suspended solids include all particles suspended in water which will not pass through a filter. Suspended solids are usually present in stormwater runoff. However, increase of TSS in a water body may cause its ability to support aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and decreases level of dissolved oxygen. TSS concentration less than 20, 40 – 80, and greater than150 mg/L considered clear, cloudy and dirty respectively. These numbers may vary depends on the nature of particles.

<u>Total Phosphorus:</u>

Phosphorus is a nutrient that is present in high quantities in fertilizers, pesticides and organic wastes. Agricultural runoff is the main source of Phosphorus in the environment. It causes problems in aquatic environments by stimulating the intense growth of algae which triggers the process of eutrophication. This can lower the dissolved oxygen content in water, creating an uninhabitable environment. The State criterion for Total Phosphorus in a healthy aquatic environment is 0.025 mg/L.

Total Kjeldahl Nitrogen (TKN):

TKN is total nitrogen which refers the amount of nitrogen which give rise to nitrate ions. Total Nitrogen is the sum of nitrate (NO_3), nitrite (NO_2), organic nitrogen and ammonia (all expressed as N). Note that for laboratory analysis purposes, Total Kjeldahl Nitrogen (TKN) is made up of both organic nitrogen and ammonia.

Metal ICP:

Increase traffic on roads contributing to potential pollution. Stormwater contains many heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Pt, Sb, V and Zn) and fuels which affect on the quality of the receiving waters. The metals analysis is very important in stormwater management. In our case we have summarized the concentration of Aluminum, Copper, Lead and Zinc.

Total Coliforms:

Total coliforms are a group of indicator bacteria with common characteristics and are used to indicate unacceptable water quality. Within the total coliform group, the E.coli bacteria are specifically used to indicate fecal contamination. High coliforms counts are usually an indication of surface water intrusion to wells. When coliforms are greater than 200cts/100ml, then can obscure the growth of coliform and are unacceptable.

4.4 TSS analysis at Ryerson University

Table 8 - Lab experiment result of Total Suspended Solids

Location: (Newton Park – Parking Lot), City of Sarnia Ontario.

Description	Sample 1A	Sample 2A	Sample 2B	Sample 2C	Sample 2D	Sample 2E	Sample 2F
Weight of aluminum dish	0.939 g	0.954 g	0.961 g	0.962 g	0.960 g	0.944 g	0.942 g
Weight of aluminum dish + Filter	1.056 g	1.070 g	1.069 g	1.080 g	1.078 g	1.061 g	1.062 g
Weight of filter (B)	0.117 g	0.116 g	0.108 g	0.118 g	0.118 g	0.117 g	0.12 g
Weight of filter + Residue (dried) (A)	0.138 g	0.117 g	0.1095 g	0.119 g	0.119 g	0.120 g	0.122 g
Volume of sample	490 ml	0.02 ml		0.02 ml	0.02 ml	0.04 ml	0.04 ml
Calculated TSS	**42.857 mg/L**	**50 mg/L**	**75 mg/L**	**50 mg/L**	**50 mg/L**	**75 mg/L**	**50 mg/L**

Calculations:

$$\text{mg TSS / L} = \text{(A-B) x 1000/ Sample Volume (L)}$$

Where, A = Weight of filter and Solid (grams)

B = Weight of filter (grams).

The above results show the range of TSS from 42 to 75 mg/L. Out of seven samples analyzed five samples were found to have a TSS ≤ 50 mg/L which is typical for stormwater runoff from fully impervious parking lot.

Figure 20 – Analysis of discreet Samples for TSS at Ryerson University, Toronto.

4.5 Rainfall and runoff volume

Rainfall data from the rain gauge were collected and compared while the water samples were collected for laboratory analysis. In total, 19 events were recorded where 18 event's runoff volume captured by system were calculated. Thirteen events have less than 100% volume captured by system. Table 9 shows the percentage of rainfall captured and Runoff volume.

Table 9 – Summery of rainfall and runoff volume

Date and Time	Rainfall volume (mm)	Rainfall duration (min)	Average rainfall intensity (mm/hr)	Runoff volume captured (mm)	% Rainfall captured
07/04/06 06:44:54.0	2.8	28	6.0	1.6	57%
08/24/06 22:50:54.0	5.2	68	4.6	2.9	56%
09/27/06 18:15:00.0	9	33	16.4	3.0	33%
07/26/06 17:29:54.0	13.2	58	13.7	3.0	23%
08/28/06 17:52:54.0	20.2	351	3.5	3.0	15%
07/30/06 15:58:54.0	17.2	28	36.9	6.8	39%
08/19/06 11:44:54.0	7.2	222	1.9	6.9	95%
08/24/06 05:50:00.0	11.4	38	18.0	9.7	85%
06/29/06 12:34:54.0	23.8	63	22.7	12.2	51%
07/20/06 18:06:54.0	20.8	33	37.8	12.2	59%
09/22/06 23:04:54.0	21.2	124	10.3	13.6	64%
07/14/06 21:59:54.0	61.8	128	29.0	47.7	77%
11/30/06 06:02:47.0	61.8	1440	2.6	60.6	98%

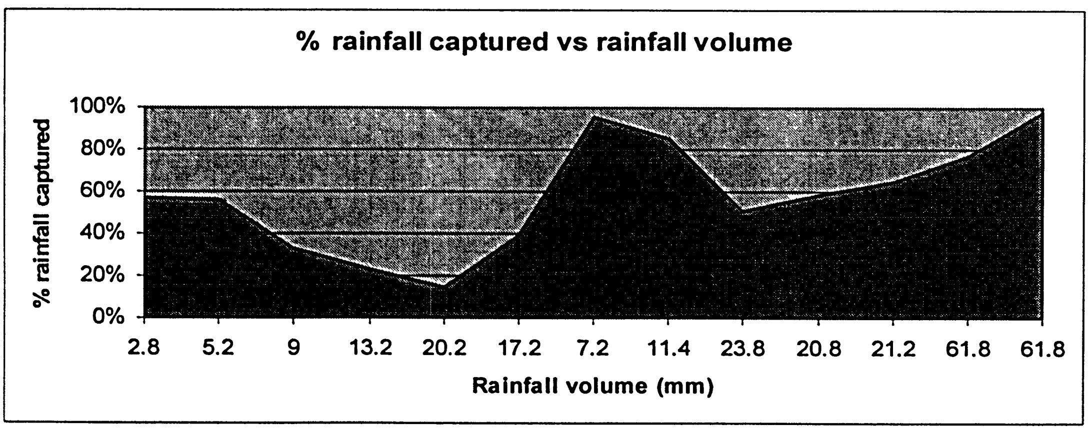

Figure 21 – Representation by chart of Rainfall captured and Runoff volume.

Date and Time	Rainfall volume (mm)	Rainfall duration (min)	Average rainfall intensity (mm/hr)	Runoff volume captured (mm)	% of Rainfall captured	TKN conc. at catch basin (mg/L)	TKN conc. at ATS (mg/L	T. Phosphorus at catch basin (mg/L	T.Phosphorus at ATS (mg/L	TSS conc. at catch basin (mg/L)	TSS conc. at ATS (mg /L)
12/12/06 21:00:47.0	1.2	30	2.4	4.9	410%	1.4	1.2	0.13	0.04	67	5
11/30/06 06:02:47.0	61.8	1440	2.6	60.6	98%						
11/17/06 22:57:00.0	0.6	26	1.4			0.5	1.1	0.03	0.09	3	9
11/13/06 22:57:00.0						0.6	1.9	0.03	0.05	5	9
10/03/06 07:00:00.0											
09/22/06 23:04:54.0	21.2	124	10.3	13.6	64%						
09/27/06 18:15:00.0	9	33	16.4	3.0	33%	0.7	1.1	0.07	0.3	7	1
08/19/06 11:44:54.0	7.2	222	1.9	6.9	95%						
08/24/06 05:50:00.0	11.4	38	18.0	9.7	85%						
08/24/06 22:50:54.0	5.2	68	4.6	2.9	56%						
08/26/06 21:56:54.0	34.8	141	14.8	59.0	169%						
08/27/06 04:09:54.0	19.6	463	2.5	39.9	204%						
08/28/06 17:52:54.0	20.2	351	3.5	3.0	15%						
07/04/06 06:44:54.0	2.8	28	6.0	1.6	57%						
07/12/06 01:14:54.0	66.8	269	14.9	67.9	102%	1.1	2.4	0.07	0.17	53	43
07/14/06 21:59:54.0	61.8	128	29.0	47.7	77%						
07/17/06 23:52:54.0	11.2	141	4.8	14.8	132%	0.5	1	0.07	0.09	1	27
07/20/06 18:06:54.0	20.8	33	37.8	12.2	59%						
07/26/06 17:29:54.0	13.2	58	13.7	3.0	23%	0.9	1.1	0.1	ND	9	18
07/30/06 15:58:54.0	17.2	28	36.9	6.8	39%						
06/29/06 12:34:54.0	23.8	63	22.7	12.2	51%						

Table 10 - above table shows concentration of TSS, TKN and Total Phosphorus

Table 11 – Concentration of metals at the Catch Basin and the Atlantis Exfiltration Tank Level

Date and Time	Rainfall volume (mm)	Rainfall duration (min)	Average rainfall intensity (mm/hr)	Runoff volume captured (mm)	% of Rainfall captured	Total Al at catch basin (μg/L)	Total Al at ATS (μg/L)	Total Cu at catch basin (μg/L)	Total Cu at ATS (μg/L)	Total Pb at catch basin (μg/L)	Total Pb at ATS (μg/L)	Total Zn at catch basin (μg/L)	Total Zn at ATS (μg/L)
12/12/06 21:00:47.0	1.2	30	2.4	4.9	410%	920	350	6	3	3.9	1.5	65	32
11/30/06 06:02:47.0	61.8	1440	2.6	60.6	98%								
11/17/06 22:57:00.0	0.6	26	1.4			ND	0.1	ND	ND	ND	ND	0.01	0.02
11/13/06 22:57:00.0						0.1	0.2	ND	ND	ND	ND	0.06	0.02
10/03/06 07:00:00.0													
09/22/06 23:04:54.0	21.2	124	10.3	13.6	64%								
09/27/06 18:15:00.0	9	33	16.4	3.0	33%								
08/19/06 11:44:54.0	7.2	222	1.9	6.9	95%								
08/24/06 05:50:00.0	11.4	38	18.0	9.7	85%								
08/24/06 22:50:54.0	5.2	68	4.6	2.9	56%								
08/26/06 21:56:54.0	34.8	141	14.8	59.0	169%								
08/27/06 04:09:54.0	19.6	463	2.5	39.9	204%								
08/28/06 17:52:54.0	20.2	351	3.5	3.0	15%								
07/04/06 06:44:54.0	2.8	28	6.0	1.6	57%								
07/12/06 01:14:54.0	66.8	269	14.9	67.9	102%	280	480	3	3	2.1	1.8	29	26
07/14/06 21:59:54.0	61.8	128	29.0	47.7	77%								
07/17/06 23:52:54.0	11.2	141	4.8	14.8	132%	ND	0.4	ND	ND	ND	ND	ND	0.03
07/20/06 18:06:54.0	20.8	33	37.8	12.2	59%								
07/26/06 17:29:54.0	13.2	58	13.7	3.0	23%	0.1	0.3	ND	ND	ND	ND	0.03	0.04
07/30/06 15:58:54.0	17.2	28	36.9	6.8	39%								
06/29/06 12:34:54.0	23.8	63	22.7	12.2	51%								

Table 12 – Concentration of Total Coliform and E.Coli at the Catch Basin and the Atlantis Exfiltration Tank Level

Date and Time	Rainfall volume (mm)	Rainfall duration (min)	Average rainfall intensity (mm/hr)	Runoff volume captured (mm)	% of Rainfall captured	Total Coliform at catch basin (#/100 ml)	Total Coliform at ATS (#/100 ml)	E.Coli at catch basin (#/100 ml)	E.Coli at ATS (#/100 ml)
12/12/06 21:00:47.0	1.2	30	2.4	4.9	410%				
11/30/06 06:02:47.0	61.8	1440	2.6	60.6	98%				
11/17/06 22:57:00.0	0.6	26	1.4			1800	1300	320	1000
11/13/06 22:57:00.0						800	320	280	300
10/03/06 07:00:00.0									
09/22/06 23:04:54.0	21.2	124	10.3	13.6	64%				
09/27/06 18:15:00.0	9	33	16.4	3.0	33%				
08/19/06 11:44:54.0	7.2	222	1.9	6.9	95%				
08/24/06 05:50:00.0	11.4	38	18.0	9.7	85%				
08/24/06 22:50:54.0	5.2	68	4.6	2.9	56%				
08/26/06 21:56:54.0	34.8	141	14.8	59.0	169%				
08/27/06 04:09:54.0	19.6	463	2.5	39.9	204%				
08/28/06 17:52:54.0	20.2	351	3.5	3.0	15%				
07/04/06 06:44:54.0	2.8	28	6.0	1.6	57%				
07/12/06 01:14:54.0	66.8	269	14.9	67.9	102%	>200	>200	>200	>200
07/14/06 21:59:54.0	61.8	128	29.0	47.7	77%				
07/17/06 23:52:54.0	11.2	141	4.8	14.8	132%	60	>20000	30	3400
07/20/06 18:06:54.0	20.8	33	37.8	12.2	59%				
07/26/06 17:29:54.0	13.2	58	13.7	3.0	23%	>20000	>20000	>20000	>20000
07/30/06 15:58:54.0	17.2	28	36.9	6.8	39%				
06/29/06 12:34:54.0	23.8	63	22.7	12.2	51%				

4.6 Results of Water Samples

By analyzing the above summary tables, we can see the effectiveness of the Atlantis Exfiltration system

For the water quality analysis, Total Suspended Solids, Total Kjeldahl Nitrogen (TKN) and Total Phosphorus are considered. We can see the pollutant concentrations are sometimes higher in Atlantis Exfiltration Tank system. If we check metals concentrations, presence of e-coli and Total Coliforms also sometimes higher in Atlantis Exfiltration System than at the catch basin. The AES detains the water and allows the stored runoff to infiltrate to surrounding soil. Tanks are covered with geo textile for the filter the runoff. Native sandy soil is a natural layer of filter and the recharge water will be free from heavy pollutants loadings. From catch basin to the system, pollutants are sometime reduced due to the settlement of TSS at the manhole. Without this system all those pollutants enter in the storm sewer and require treatments before discharging to the receiving water. It reduces the runoff entering the storm system because the captured runoff volume will be dissipated to the groundwater and the settled sediments can be sucked out through maintenance pipe. Based on field monitoring result, the AES captured more than 60% of runoff volume. In any case no overflow of system was observed. If we compare the above data of runoff and data summarized by MOE in its 2003 Stormwater Design manual with the Provincial Water Quality Objective we can see that many pollutants should not be present in drinking water. For instance Coliforms, TKN, AL, and remain have very low concentration (Table 1.2 -MOE Stormwater Design Manual 2003). The exfiltration system does not only treat the quality of water but also reduce quantity of runoff which is also a major concern in the City of Sarnia, Ontario.

CHAPTER 5

5.1 Conclusions

Development of Exfiltration Tank Systems consist of site selection criteria, design and construction requirement, and field performance analysis. Following the suggested design and construction guidelines in this report will result in satisfactory results. It is also observed that this system does not require long time to construct and can perform right away where soil is permeable. The conclusions drawn from the study can be divided into the following three areas:

1) Literature Review

Exfiltration practices have been adopted for many decades in different parts of the world. Their application in the field of stormwater management to control quantity and quality purposes is relatively new. However, their reputation shows positive for stormwater exfiltration purposes.

2) The Design and Construction of System

This AES has simple design and standard construction. The cost is generally cheaper than most of BMP. For typical parking lots, the design in this report can be considered as an example. Site selection criteria should be considered before implementing.

3) Field Performance

Field analysis results shows more than 60% of runoff volume enter the Exfiltration System can be diverted from the storm sewer system. The surrounding soil can provide filtering function of stormwater. The observed pollutant concentrations show that runoff can contains contaminants higher than those identified in the Provincial Water Quality Objectives. Therefore, this system can be useful for controlling the Quantity and the Quality of runoff.

5.2 Recommendations

City of Sarnia has problems with stormwater runoff and pollutant loadings, and has implemented Best Management Practices since 1993 (e.g. Downspout disconnection etc.). By using the Atlantis Exfiltration System, positive results have been found in first year of study. In the field analysis it is observed that pollutants loading can be higher at the Tanks than that at the upstream catch basin, which may be concern of ground water pollutants. It is advised that further study should focus on ground water quality. Field analysis shows that a fair amount of Total Suspended Solids and other pollutants entered the Atlantis Exfiltration System which may eventually clog the system. As a result, regular maintenance should be conducted. The pilot study has demonstrated that the Atlantis Exfiltration System can capture and treat stormwater at the source efficiently and effectively. Part of the treatment process involves percolation and oxygenation through the system itself. This system may also be useful for sites close to sewer outlets as it allows for the diversion of high polluted runoff before from the receiving water. The load bearing capacity of a single module was found to be 94.52 kN/m3 by the University of Technology in Sydney, Australia. (Single module specifications are 410mm*467mm *610mmwith the flow rate of 2280 L/min.). This Exfiltration system offers versatile low cost design solutions for urban stormwater problems. The stormwater system will be continuously monitored over the next four years.

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APPENDIX – A

Tables of sieve analysis, backfill material

Sample # 2	Date: August 26, 2004
Side wall of Tank number one, soil after 3 ft excavation	
Total weight for sample 1038.31 grams	
Sieve No	Mass returned (in grams)
1"	37.05
3/4"	13.86
1/2 "	66.43
3/8"	32.74
4"	118.83
10	335.81
20	169.8
Pan	260.42
20	5.14
40	107.53
60	113.38
80	25.51
100	3.23
200	2.1
Pan	2.14

Sample # 3	Date: August 26,2004
Tank number one North east corner	
After 10 ft excavation, base soil	
Total weight for sample 1170 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	13.8
1/2 "	38.27
3/8"	52.11
4"	141.21
10	282.49
20	228.48
Pan	411.88
20	8.09
40	146.33
60	191.74
80	39.47
100	6.53
200	4.99
Pan	13.03

Sample # 4	Date: August 26,2204
Tank number One North west corner	
After 10 ft excavation, base soil	
Total weight for sample 1027.10 grams	
Sieve No	Mass returned (in grams)
1"	17.68
3/4"	0
1/2 "	87.49
3/8"	98.67
4"	239.67
10	187.79
20	74
Pan	320.73
20	2.9
40	62.8
60	100.29
80	69.5
100	16.9
200	9.61
Pan	15.58

Sample # 5	Date: August 26,2004
Tank number one south east corner	
After 10 ft excavation, base soil	
Total weight for sample 1108.18 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	42.34
1/2 "	32.41
3/8"	33.95
4"	229.1
10	29.6
20	130.98
Pan	335.25
20	1.44
40	50.83
60	111.8
80	116.6
100	30.77
200	12.44
Pan	9.77

Sample # 6	Date: August 26,2004
Tank number one south west corner	
After 10 ft excavation, base soil	
Total weight for sample 1141.18 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	29.75
1/2 "	24.93
3/8"	65.11
4"	178.25
10	251.74
20	198.03
Pan	392.1
20	5.11
40	124.2
60	198.04
80	49.48
100	7.97
200	3.78
Pan	4.12

Sample # 1	Date: August 27, 2004
Side wall of Tank number Two, soil after 3 ft excavation	
Total weight for sample 1108.39 grams	
Sieve No	Mass retained
1"	0
3/4"	0
1/2 "	15.6
3/8"	5.93
4"	95.83
10	265.42
20	189.54
Pan	534.26
20	11.45
40	256.74
60	225.16
80	29.45
100	3.77
200	2.29
Pan	4.62

Sample # 3	Date: August 27,2004
Tank number Two, North east corner	
After 10 ft excavation, base soil	
Total weight for sample 1207.51 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	0
1/2 "	35.82
3/8"	58.12
4"	182.87
10	516.94
20	241.98
Pan	170
20	4.6
40	91.87
60	32.63
80	13.41
100	7.37
200	12.78
Pan	7.34

Sample # 4	Date: August 27,2004
Tank number Two, North west corner	
After 10 ft excavation, base soil	
Total weight for sample 1178.98 grams	
Sieve No	Mass returned (in grams)
1"	58.14
3/4"	46.06
1/2 "	75.67
3/8"	60.76
4"	216.72
10	273.75
20	307.65
Pan	137.16
20	8.93
40	49.81
60	40.96
80	10.02
100	2.2
200	5.02
Pan	23.3

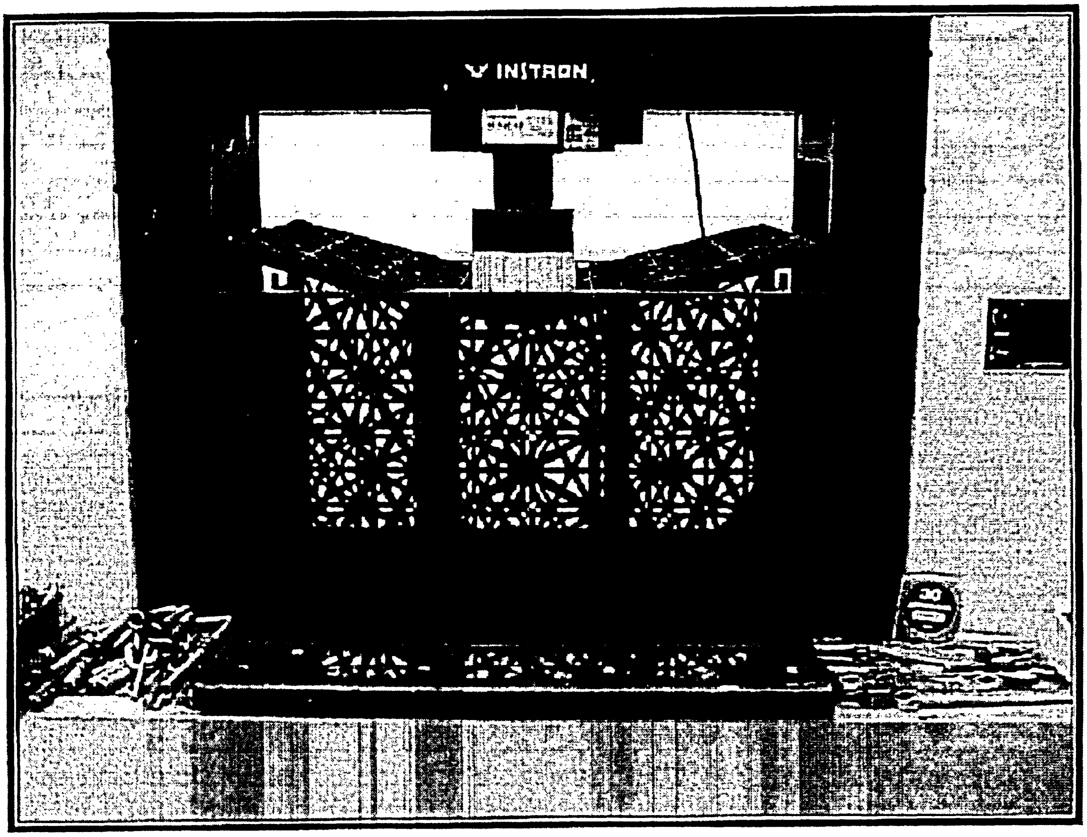
Sample # 5	Date: August 27,2004
Tank number Two, South east corner	
After 10 ft excavation , under ground soil	
Total weight for sample 1121.51 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	12.6
1/2 "	16.39
3/8"	54.77
4"	370.27
10	208.91
20	137.75
Pan	319.69
20	4.92
40	72.74
60	120.34
80	79.8
100	21.82
200	13.38
Pan	8.26

Sample # 6	Date: August 27,2004
Tank number Two, South west corner	
After 10 ft excavation, under ground soil	
Total weight for sample 1167.22 grams	
Sieve No	Mass returned (in grams)
1"	0
3/4"	62.73
1/2 "	46.37
3/8"	60.77
4"	161.12
10	226.51
20	198.2
Pan	406.96
20	6.69
40	145.9
60	196
80	40.13
100	6.71
200	5.07
Pan	4.36

APPENDIX – B

Compression test of Atlantis Tank Modules

COMPRESSION TEST



FAIL @ 850 POUNDS

Figure – Laboratory compression Test of Atlantis Tank Module

SGS

CLIENT: STORMWATER SOLUTIONS LLC
311 N. Robetson Blvd. Ste 397
Beverly Hills, CA 90211
Attn: Manuel Arriagada

Test Report No: 176546	**April 28, 2003**

SAMPLE ID: The Client identified as submitted component of a drainage system.

Atlantis 30mm Drainage Cell
Atlantis 52mm Drainage Cell
Atlantis Strip Filler Pipe
Atlantis D-Raintank

DATE OF RECEIPT: The samples were received on April 9, 2003 and were assigned Sample Tracking Number 36267.

TESTING PERIOD: April 28, 2003.

AUTHORIZATION: Authorization Check received on April 9, 2003.

TEST(S) REQUESTED: Testing per Client protocol

TEST RESULTS: See page 2

Testing Conducted By

Youlong Mao
Technician

Signed for and on behalf of SGS U.S. Testing Company Inc.

Tom Clark
Manager, Mechanical Evaluation Services

ULTIMATE LOAD TEST

Procedure:

The Atlantis components were brought to equilibrium at 75° F for 24 hours. The components were placed on a flat table of the Universal Testing Machine. A 127mm x 127mm loading fixture was used to apply a load at the rate of 0.5 inch per minute to all but the 30mm component. A 51mm X 107mm loading fixture was used in that case. The load rate was 0.5 inch per minute. The test machine was activated and the component was loaded to failure. A digital picture was taken of the set-up at failure. These are included in the appendix of the report.

Testing was conducted on April 28, 2003.

Results:

The results were tabulated below. For consistency to the published information provided by the client, the load per 10.76 square foot was calculated and included.

Component	Ultimate Load (psi)	Ultimate Load Pounds per 10.76 sq ft	Ultimate Load Kg/sq meter
Atlantis 30mm Drainage Cell	116.7	180.768	82.258
Atlantis 52mm Drainage Cell	166.0	257.207	116.954
Atlantis Strip Filler Pipe	24.8	38,426	17,472
Atlantis D-Raintank	34.0	52,680	23,954

* * * * * * * *

End of Report

APPENDIX – C

Following results of TKN, TSS and Total Phosphorus

Maxxam Job #: A647676
Report Date: 2006/05/31

Pollutech Enviroquatics Ltd
Client Project #: 711F\NEWTON PARK
Project name:
Your P.O. #: 711F
Sampler Initials:

RESULTS OF ANALYSES OF WATER

Maxxam ID		M14545		M14546		
Sampling Date		5/19/2006 10:30		5/19/2006 14:00		
COC Number		419500		419500		
	Units	**711F0603**	**QC Batch**	**711F0602**	**RDL**	**QC Batch**
INORGANICS						
Total Kjeldahl Nitrogen (TKN)	mg/L	0.7	977674	1.1	0.1	977677
Total Phosphorus	mg/L	0.07	977821	0.3	0.02	977821
Total Suspended Solids	mg/L	7	976232	300	1	976232

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A669980
Report Date: 2006/07/24

Pollutech Enviroquatics Ltd
Client Project #: 711F
Project name: 711F NEWTON PARK
Sampler Initials:

RESULTS OF ANALYSES OF WATER

Maxxam ID		N08052		N08053		
Sampling Date		7/12/2006 15:00		7/12/2006 15:00		
COC Number		402099		402099		
	Units	**711F 0604 NEWT01**	**RDL**	**711F 0605 NEWT02**	**RDL**	**QC Batch**
INORGANICS						
Total Kjeldahl Nitrogen (TKN)	mg/L	1.1	0.2	2.4	0.1	1013846
Total Phosphorus	mg/L	0.07	0.04	0.17	0.02	1013243
Total Suspended Solids	mg/L	53	1	43	1	1013030

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A672318

Report Date: 2006/07/31

Pollutech Enviroquatics Ltd
Client Project #: 711F/CALVIN DEKKER
Project name: NEWTON PARK
Your P.O. #: 711F
Sampler Initials:

RESULTS OF ANALYSES OF WATER

Maxxam ID		N18606		N18607		
Sampling Date		7/18/2006 13:00		7/18/2006 13:00		
COC Number		425781		425781		
	Units	**711F0606 NEWT01**	**QC Batch**	**711F0606 NEWT02**	**RDL**	**QC Batch**
INORGANICS						
Total Kjeldahl Nitrogen (TKN)	mg/L	0.5	1017615	1	0.1	1017615
Total Phosphorus	mg/L	0.07	1016729	0.09	0.02	1016724
Total Suspended Solids	mg/L	1	1017516	27	1	1017516

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A676360
Report Date: 2006/08/15

Pollutech Enviroquatics Ltd

Client Project #: 711F

Project name: NEWTON PARK
Your P.O. #: 711F
Sampler Initials:

RESULTS OF ANALYSES OF WATER

Maxxam ID		N36521			N36522		
Sampling Date		7/27/2006 14:00			7/27/2006 14:00		
COC Number		402100			402100		
	Units	**711F0608 NEWT01**	**RDL**	**QC Batch**	**711F0609 NEWT02**	**RDL**	**QC Batch**
INORGANICS							
Total Kjeldahl Nitrogen (TKN)	mg/L	0.9	0.1	1024467	1.1	0.2	1024059
Total Phosphorus	mg/L	0.1	0.04	1023944	ND	0.04	1023943
Total Suspended Solids	mg/L	9	1	1022376	18	1	1022376

ND = Not detected
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A647676

Report Date: 2006/05/31

Pollutech Enviroquatics Ltd
Client Project #: 711F\NEWTON PARK

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		M14545	M14546		
Sampling Date		5/19/2006 10:30	5/19/2006 14:00		
COC Number		419500	419500		
	Units	**711F0603**	**711F0602**	**RDL**	**QC Batch**
METALS					
Total Aluminum (Al)	mg/L	0.2	9.5	0.1	976682
Total Antimony (Sb)	mg/L	ND	ND	0.2	976682
Total Arsenic (As)	mg/L	ND	ND	0.2	976682
Total Barium (Ba)	mg/L	ND	0.06	0.02	976682
Total Beryllium (Be)	mg/L	ND	ND	0.005	976682
Total Bismuth (Bi)	mg/L	ND	ND	0.2	976682
Total Boron (B)	mg/L	ND	ND	0.02	976682
Total Cadmium (Cd)	mg/L	ND	ND	0.005	976682
Total Calcium (Ca)	mg/L	24	55	0.05	976682
Total Chromium (Cr)	mg/L	ND	0.02	0.01	976682
Total Cobalt (Co)	mg/L	ND	ND	0.02	976682
Total Copper (Cu)	mg/L	ND	0.02	0.02	976682
Total Iron (Fe)	mg/L	0.24	13	0.02	976682
Total Lead (Pb)	mg/L	ND	ND	0.05	976682
Total Magnesium (Mg)	mg/L	1.4	16	0.05	976682
Total Manganese (Mn)	mg/L	0.02	0.22	0.01	976682
Total Molybdenum (Mo)	mg/L	ND	ND	0.02	976682
Total Nickel (Ni)	mg/L	ND	ND	0.05	976682
Total Phosphorus (P)	mg/L	0.1	0.6	0.1	976682
Total Potassium (K)	mg/L	ND	3	1	976682
Total Selenium (Se)	mg/L	ND	ND	0.2	976682
Total Silicon (Si)	mg/L	1	16	0.2	976682
Total Silver (Ag)	mg/L	ND	ND	0.01	976682
Total Sodium (Na)	mg/L	23	66	0.5	976682
Total Strontium (Sr)	mg/L	0.14	0.11	0.01	976682
Total Sulphur (S)	mg/L	8.1	3.8	0.5	976682
Total Tin (Sn)	mg/L	ND	ND	0.2	976682
Total Titanium (Ti)	mg/L	ND	0.28	0.01	976682
Total Vanadium (V)	mg/L	ND	0.03	0.01	976682
Total Zinc (Zn)	mg/L	0.04	0.07	0.01	976682

ND = Not detected
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A669980
Report Date: 2006/07/24

Pollutech Enviroquatics Ltd
Project name: 711F NEWTON PARK

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		N08052	N08053		
Sampling Date		7/12/2006 15:00	7/12/2006 15:00		
COC Number		402099	402099		
	Units	**711F 0604 NEWT01**	**711F 0605 NEWT02**	**RDL**	**QC Batch**
METALS					
Total Aluminum (Al)	mg/L	280	480	5	1013313
Total Antimony (Sb)	mg/L	ND	ND	1	1013313
Total Arsenic (As)	mg/L	ND	ND	1	1013313
Total Barium (Ba)	mg/L	9	8	5	1013313
Total Beryllium (Be)	mg/L	ND	ND	0.5	1013313
Total Bismuth (Bi)	mg/L	ND	ND	1	1013313
Total Boron (B)	mg/L	ND	ND	10	1013313
Total Cadmium (Cd)	mg/L	ND	ND	0.1	1013313
Total Calcium (Ca)	mg/L	21000	14000	200	1013313
Total Chromium (Cr)	mg/L	ND	ND	5	1013313
Total Cobalt (Co)	mg/L	ND	ND	0.5	1013313
Total Copper (Cu)	mg/L	3	3	1	1013313
Total Iron (Fe)	mg/L	370	600	50	1013313
Total Lead (Pb)	mg/L	2.1	1.8	0.5	1013313
Total Lithium (Li)	mg/L	ND	ND	5	1013313
Total Magnesium (Mg)	mg/L	1900	2100	50	1013313
Total Manganese (Mn)	mg/L	10	20	2	1013313
Total Molybdenum (Mo)	mg/L	2	ND	1	1013313
Total Nickel (Ni)	mg/L	2	3	1	1013313
Total Potassium (K)	mg/L	900	950	200	1013313
Total Selenium (Se)	mg/L	ND	ND	2	1013313
Total Silicon (Si)	mg/L	1100	1000	50	1013313
Total Silver (Ag)	mg/L	ND	ND	0.1	1013313
Total Sodium (Na)	mg/L	8100	17000	100	1013313
Total Strontium (Sr)	mg/L	69	35	1	1013313
Total Tellurium (Te)	mg/L	ND	ND	1	1013313
Total Thallium (Tl)	mg/L	ND	ND	0.05	1013313
Total Thorium (Th)	mg/L	ND	ND	1	1013313
Total Tin (Sn)	mg/L	ND	ND	1	1013313
Total Titanium (Ti)	mg/L	8	12	5	1013313
Total Tungsten (W)	mg/L	ND	ND	1	1013313
Total Uranium (U)	mg/L	ND	ND	0.1	1013313
Total Vanadium (V)	mg/L	7	8	1	1013313
Total Zinc (Zn)	mg/L	29	26	5	1013313
Total Zirconium (Zr)	mg/L	ND	ND	1	1013313

ND = Not detected
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Maxxam Job #: A672318
Report Date: 2006/07/31

Pollutech Enviroquatics Ltd
Client Project #: 711F/CALVIN DEKKER

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		N18606		N18607		
Sampling Date		7/18/2006 13:00		7/18/2006 13:00		
COC Number		425781		425781		
	Units	**711F0606 NEWT01**	**QC Batch**	**711F0606 NEWT02**	**RDL**	**QC Batch**
METALS						
Total Aluminum (Al)	mg/L	ND	1017840	0.4	0.1	1016676
Total Antimony (Sb)	mg/L	ND	1017840	ND	0.2	1016676
Total Arsenic (As)	mg/L	ND	1017840	ND	0.2	1016676
Total Barium (Ba)	mg/L	ND	1017840	ND	0.02	1016676
Total Beryllium (Be)	mg/L	ND	1017840	ND	0.005	1016676
Total Bismuth (Bi)	mg/L	ND	1017840	ND	0.2	1016676
Total Boron (B)	mg/L	ND	1017840	ND	0.02	1016676
Total Cadmium (Cd)	mg/L	ND	1017840	ND	0.005	1016676
Total Calcium (Ca)	mg/L	12	1017840	19	0.05	1016676
Total Chromium (Cr)	mg/L	ND	1017840	ND	0.01	1016676
Total Cobalt (Co)	mg/L	ND	1017840	ND	0.02	1016676
Total Copper (Cu)	mg/L	ND	1017840	ND	0.02	1016676
Total Iron (Fe)	mg/L	ND	1017840	0.5	0.02	1016676
Total Lead (Pb)	mg/L	ND	1017840	ND	0.05	1016676
Total Magnesium (Mg)	mg/L	0.71	1017840	2.3	0.05	1016676
Total Manganese (Mn)	mg/L	ND	1017840	0.01	0.01	1016676
Total Molybdenum (Mo)	mg/L	ND	1017840	ND	0.02	1016676
Total Nickel (Ni)	mg/L	ND	1017840	ND	0.05	1016676
Total Phosphorus (P)	mg/L	ND	1017840	ND	0.1	1016676
Total Potassium (K)	mg/L	ND	1017840	ND	1	1016676
Total Selenium (Se)	mg/L	ND	1017840	ND	0.2	1016676
Total Silicon (Si)	mg/L	ND	1017840	1.1	0.2	1016676
Total Silver (Ag)	mg/L	ND	1017840	ND	0.01	1016676
Total Sodium (Na)	mg/L	7.3	1017840	12	0.5	1016676
Total Strontium (Sr)	mg/L	0.03	1017840	0.05	0.01	1016676
Total Sulphur (S)	mg/L	2.1	1017840	4.8	0.5	1016676
Total Tin (Sn)	mg/L	ND	1017840	ND	0.2	1016676
Total Titanium (Ti)	mg/L	ND	1017840	0.02	0.01	1016676
Total Vanadium (V)	mg/L	ND	1017840	0.02	0.01	1016676
Total Zinc (Zn)	mg/L	ND	1017840	0.03	0.01	1016676

ND = Not detected
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: A676360

Pollutech Enviroquatics Ltd
Client Project #:

Report Date: 2006/08/15

711F Newton Park

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		N36521	N36522		
Sampling Date		7/27/2006 14:00	7/27/2006 14:00		
COC Number		402100	402100		
	Units	**711F0608 NEWT01**	**711F0609 NEWT02**	**RDL**	**QC Batch**
METALS					
Total Aluminum (Al)	mg/L	0.1	0.3	0.1	1025151
Total Antimony (Sb)	mg/L	ND	ND	0.2	1025151
Total Arsenic (As)	mg/L	ND	ND	0.2	1025151
Total Barium (Ba)	mg/L	ND	ND	0.02	1025151
Total Beryllium (Be)	mg/L	ND	ND	0.005	1025151
Total Bismuth (Bi)	mg/L	ND	ND	0.2	1025151
Total Boron (B)	mg/L	ND	ND	0.02	1025151
Total Cadmium (Cd)	mg/L	ND	ND	0.005	1025151
Total Calcium (Ca)	mg/L	17	25	0.05	1025151
Total Chromium (Cr)	mg/L	ND	ND	0.01	1025151
Total Cobalt (Co)	mg/L	ND	ND	0.02	1025151
Total Copper (Cu)	mg/L	ND	ND	0.02	1025151
Total Iron (Fe)	mg/L	0.22	0.45	0.02	1025151
Total Lead (Pb)	mg/L	ND	ND	0.05	1025151
Total Magnesium (Mg)	mg/L	1.4	2.1	0.05	1025151
Total Manganese (Mn)	mg/L	0.02	0.02	0.01	1025151
Total Molybdenum (Mo)	mg/L	ND	ND	0.02	1025151
Total Nickel (Ni)	mg/L	ND	ND	0.05	1025151
Total Phosphorus (P)	mg/L	ND	0.1	0.1	1025151
Total Potassium (K)	mg/L	ND	1	1	1025151
Total Selenium (Se)	mg/L	ND	ND	0.2	1025151
Total Silicon (Si)	mg/L	0.4	0.8	0.2	1025151
Total Silver (Ag)	mg/L	ND	ND	0.01	1025151
Total Sodium (Na)	mg/L	14	5.5	0.5	1025151
Total Strontium (Sr)	mg/L	0.05	0.06	0.01	1025151
Total Sulphur (S)	mg/L	4.5	7.4	0.5	1025151
Total Tin (Sn)	mg/L	ND	ND	0.2	1025151
Total Titanium (Ti)	mg/L	ND	ND	0.01	1025151
Total Vanadium (V)	mg/L	ND	0.01	0.01	1025151
Total Zinc (Zn)	mg/L	0.03	0.04	0.01	1025151

ND = Not detected

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Maxxam Job # A647676 Pollutech Enviroqualities Ltd.

Report Date: 2006/05/31 Client no. 711F/ Newton Park

MICROBIOLOGY (WATER)

Maxxam ID		M14545	M14546		
Sampling Date		5/19/2006 10:30	5/19/2006 14:00		
COC Number		419500	419500		
	Units	**711F0603**	**711F0602**	**RDL**	**QC Batch**
MICROBIOLOGICAL					
Background	CFU/100mL	>20000	>20000	10	974916
Coliform	CFU/100mL	13000 (1)	480 (1)	10	974916
Escherichia coli	CFU/100mL	380	300	10	974917
Fecal coliform	CFU/100mL	500	310	10	974918

Maxxam Job # A669980 Pollutech Enviroqualities Ltd.

Report Date: 2006/07/24 Client no. 711F/ Newton Park

MICROBIOLOGY (WATER)

Maxxam ID		N08052	N08053		
Sampling Date		7/12/2006 15:00	7/12/2006 15:00		
COC Number		402099	402099		
	Units	**711F 0604 NEWT01**	**711F 0605 NEWT02**	**RDL**	**QC Batch**
MICROBIOLOGICAL					
Fecal coliform	CFU/100mL	>200	>200	N/A	1011413
Background	CFU/100mL	>200	>200	N/A	1011412
Coliform	CFU/100mL	>200	>200	N/A	1011412
Escherichia coli	CFU/100mL	>200	>200	N/A	1011412

Maxxam Job # A672318 Pollutech Enviroqualities Ltd.

Report Date: 2006/07/31 Client no. 711F/ Newton Park

MICROBIOLOGY (WATER)

Maxxam ID		N18606	N18607		
Sampling Date		7/18/2006 13:00	7/18/2006 13:00		
COC Number		425781	425781		
	Units	**711F0606 NEWT01**	**711F0606 NEWT02**	**RDL**	**QC Batch**
MICROBIOLOGICAL					
Background	CFU/100mL	4000	>20000	10	1015104
Coliform	CFU/100mL	60	>20000	10	1015104
Fecal coliform	CFU/100mL	40	3500	10	1015106
Escherichia coli	CFU/100mL	30	3400	10	1015105

Maxxam Job # A672318 Pollutech Enviroqualities Ltd.

Report Date: 2006/07/31 Client no. 711F/ Newton Park

MICROBIOLOGY (WATER)

Maxxam ID		N36521	N36522		
Sampling Date		7/27/2006 14:00	7/27/2006 14:00		
COC Number		402100	402100		
	Units	**711F0608 NEWT01**	**711F0609 NEWT02**	**RDL**	**QC Batch**
MICROBIOLOGICAL					
Background	CFU/100mL	>20000	>20000	10	1021785
Coliform	CFU/100mL	>20000	>20000	10	1021785
Fecal coliform	CFU/100mL	>20000	>20000	10	1021787
Escherichia coli	CFU/100mL	>20000	>20000	10	1021786

Where,

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

(1) Values reported may be baised low due to overgrowth.