Salinity Management and Filtration/Treatment of Petroleum Contaminates in Storm Water Catchment Systems for Landscape Irrigation Use

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Abstract: Products and practices used in the management of salinity levels and removing petroleum contaminates that accumulate in storm water catchment systems which may have detrimental effects on turf and plant growth are presented in this paper with a review of several irrigation projects installed in the United States northern climates. How run-off water that contains ice-melt products, hydrocarbons and other contaminates are prevented from entering the irrigation water supply are revealed this paper. Projects such as a large public park and recreation area bordering the coastline and commercial sites that utilize parking lot and roof top run-off are cited as examples. The value of this paper will be that the reader will have a more comprehensive understanding of the water quality issues that are pertinent and unique to storm water catchment systems including identifying the contaminates and how they adversely affect plant growth as well as methods to remove or treat contaminates.

Stormwater For Irrigation Use Overview and Brief History

Stormwater catchment systems for irrigation use have been in practice by farmers for centuries. The simplest systems utilize trenches or catch basins with piping systems to channel water to retention ponds or holding tanks and cisterns. Water quality issues that affect crop production may include pesticides and herbicides introduced to the soil by the farmers and excess salinity from soils breaking down from repeated applications of irrigation water. Filtration of irrigation water in these systems usually only required screens for removing debris that would obstruct distribution flow and perhaps filters that would capture and remove finer particles of sediment and sand from the water supply.

Rainwater harvesting for landscape irrigation use has grown at a phenomenal rate within the last 4 decades since the passing of the USEPA Clean Water Act in 1972 which the Environmental Protection Agency mandates and enforces water quality guidelines as a condition for consideration in construction practices in residential, commercial and municipal development. Along with the Clean Water Act, The National Pollutant Discharge Elimination System (NPDES) authorizes most states to implement the Stormwater NPDES permitting program in which the EPA is the permitting authority and Construction Site Managers are required to obtain these permits prior to the start of construction. More recently, the US Green Building Councils' (www.usgbc.org) Leadership in Energy and Environmental Design (LEED) program which incorporates Water Efficiency (WE) as a category with a potential 11 points of the 110 points available for LEED certification and irrigation WE credits which can account for 10% of the total WE points. Rainwater harvesting systems figure prominently in helping attain LEED credits in landscape irrigation system designs.

Primary rainwater collection sources for landscape irrigation use are roof-top rainwater and storm water run-off collected from impervious surfaces such as sidewalks and parking lots as well as permeable “hardscape” products used to help minimize storm water from reaching municipal sewer treatment systems.

The demand for bringing the most efficient rain water harvesting systems to market has resulted in the creation of hundreds of companies designing and producing the components necessary for maximizing the efficiency and versatility of these systems. As the demand for rainwater collection systems increases particularly in areas of rapid residential and commercial development, the quality of the water captured may often be overlooked or not given due consideration as to whether it contains elements or contaminants that may prove detrimental to landscape plants and turf.

Potential Water Quality Issues

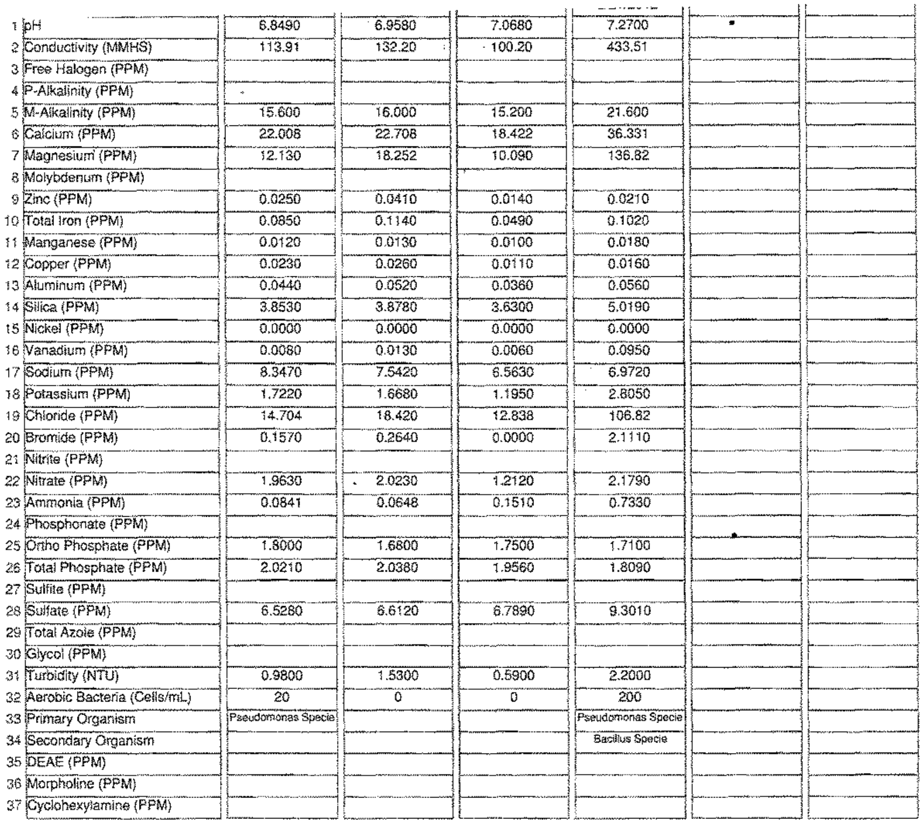
Developing new building sites or renovating existing buildings that will be incorporating rainwater catchment systems offer a plethora of potential contaminants that may require various methods of treatment prior to application to the landscape.

Most rainwater harvesting systems incorporate products from multiple manufacturers and the filtering components may include:

- catch basins, gutters and drains with screens to prevent the bulkiest of materials from entering the collection system piping
- initial or pre-filtration devices to remove additional debris, sediment and other non-biodegradable materials from the water supply
- a submersible pump with an intake screen mounted on a sled in the bottom of the tank or a foot valve with screen connected to the suction line of an above-grade suction lift pump
- pump control systems that may incorporate additional in-line automatic flush filters, sand separators and wye strainers
- filters and/or screens on automatic control valves and sprinkler heads

While these filtering mechanisms will remove enough solid type materials from entering and clogging the nozzles and orifices of the points of distribution whether they be drip emitters or sprinkler heads, these filters will do little to prevent chemicals that may have an adverse impact on plant growth and development.

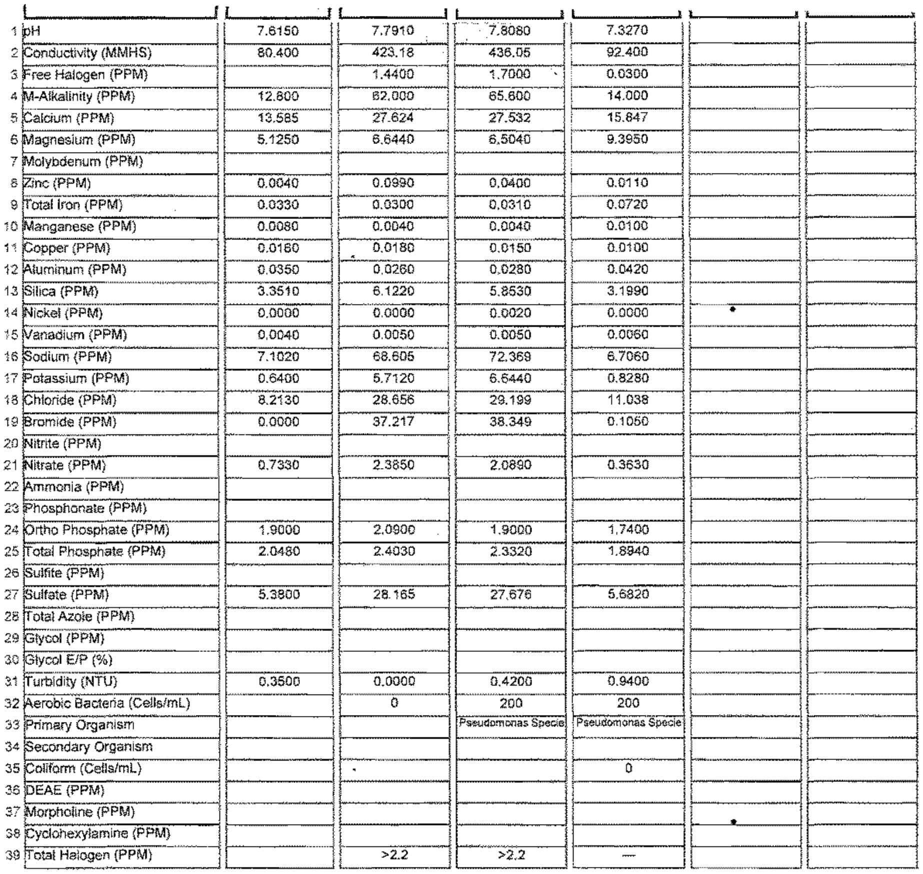
New construction sites where redevelopment is replacing buildings that were built long before many building materials were considered hazardous to human health such as asbestos, lead based paints, zinc and mercury may still be present in soils and or surfaces that will be exposed to rain water prior to it reaching the catch basins. Not all these elements may prove detrimental to plant development but as shown in the example below, the results of water samples taken from a newly constructed memorial site in which storm water is being stored for both irrigation use and non-potable indoor use, elements such as alkaline, magnesium, potassium, chloride, bromide, nitrate, ammonia, sulfate and silica were present at levels that the Landscape Architect deemed unacceptable for use without treatment.



1	pH	6.8490	6.9580	7.0680	7.2700		
2	Conductivity (MMHS)	113.91	132.20	100.20	433.51		
3	Free Halogen (PPM)						
4	P-Alkalinity (PPM)						
5	M-Alkalinity (PPM)	15.600	16.000	15.200	21.600		
6	Calcium (PPM)	22.008	22.708	18.422	36.331		
7	Magnesium (PPM)	12.130	18.252	10.090	136.82		
8	Molybdenum (PPM)						
9	Zinc (PPM)	0.0250	0.0410	0.0140	0.0210		
10	Total Iron (PPM)	0.0850	0.1140	0.0490	0.1020		
11	Manganese (PPM)	0.0120	0.0130	0.0100	0.0180		
12	Copper (PPM)	0.0230	0.0260	0.0110	0.0160		
13	Aluminum (PPM)	0.0440	0.0520	0.0360	0.0560		
14	Silica (PPM)	3.8530	3.8780	3.6300	5.0190		
15	Nickel (PPM)	0.0000	0.0000	0.0000	0.0000		
16	Vanadium (PPM)	0.0080	0.0130	0.0060	0.0950		
17	Sodium (PPM)	8.3470	7.5420	6.5630	6.9720		
18	Potassium (PPM)	1.7220	1.6680	1.1950	2.8050		
19	Chloride (PPM)	14.704	18.420	12.838	106.82		
20	Bromide (PPM)	0.1570	0.2640	0.0000	2.1110		
21	Nitrite (PPM)						
22	Nitrate (PPM)	1.9630	2.0230	1.2120	2.1790		
23	Ammonia (PPM)	0.0841	0.0648	0.1510	0.7330		
24	Phosphonate (PPM)						
25	Ortho Phosphate (PPM)	1.8000	1.6800	1.7500	1.7100		
26	Total Phosphate (PPM)	2.0210	2.0380	1.9560	1.8090		
27	Sulfite (PPM)						
28	Sulfate (PPM)	6.5280	6.6120	6.7890	9.3010		
29	Total Azole (PPM)						
30	Glycol (PPM)						
31	Turbidity (NTU)	0.9800	1.5300	0.5900	2.2000		
32	Aerobic Bacteria (Cells/mL)	20	0	0	200		
33	Primary Organism	Pseudomonas Specie			Pseudomonas Specie		
34	Secondary Organism				Bacillus Specie		
35	DEAE (PPM)						
36	Morpholine (PPM)						
37	Cyclohexylamine (PPM)						

Stormwater collected for irrigation use was stored in a separate cistern from other non-potable water collection tanks and water sample testing results are shown in the far right data column. The conductivity (433.51 MMHS), magnesium (136.82 PPM), chloride (106.8 PPM), nitrate (2.179 PPM), sulfate (9.3010 PPM) and turbidity (2.200 NTU) were at levels higher than what were considered suitable for re-introducing back into the landscape environment through irrigation spray heads and drip tubing, especially in a public facility with high pedestrian volume. Little can be done to remediate water once it reaches the storage tank except diluting it with fresh water and in this particular example, it was an extremely large tank requiring a large amount of city water to flow into the tank.

The next example shows new data of samples taken 1 week later after water in the cistern was diluted by allowing city water to flow into the cistern and run-off channeled into the city sewer system.



1	pH	7.6150	7.7910	7.8080	7.3270		
2	Conductivity (MMHS)	80.400	423.18	436.05	92.400		
3	Free Halogen (PPM)		1.4400	1.7000	0.0300		
4	M-Alkalinity (PPM)	12.800	62.000	65.600	14.000		
5	Calcium (PPM)	13.585	27.624	27.532	15.847		
6	Magnesium (PPM)	5.1250	6.6440	6.5040	9.3950		
7	Molybdenum (PPM)						
8	Zinc (PPM)	0.0040	0.0990	0.0400	0.0110		
9	Total Iron (PPM)	0.0330	0.0300	0.0310	0.0720		
10	Manganese (PPM)	0.0080	0.0040	0.0040	0.0100		
11	Copper (PPM)	0.0160	0.0180	0.0150	0.0100		
12	Aluminum (PPM)	0.0350	0.0260	0.0280	0.0420		
13	Silica (PPM)	3.3510	6.1220	5.8530	3.1990		
14	Nickel (PPM)	0.0000	0.0000	0.0020	0.0000		
15	Vanadium (PPM)	0.0040	0.0050	0.0050	0.0060		
16	Sodium (PPM)	7.1020	68.605	72.369	6.7060		
17	Potassium (PPM)	0.6400	5.7120	6.6440	0.8280		
18	Chloride (PPM)	8.2130	28.656	29.199	11.038		
19	Bromide (PPM)	0.0000	37.217	38.349	0.1050		
20	Nitrite (PPM)						
21	Nitrate (PPM)	0.7330	2.3850	2.0890	0.3630		
22	Ammonia (PPM)						
23	Phosphonate (PPM)						
24	Ortho Phosphate (PPM)	1.9000	2.0900	1.9000	1.7400		
25	Total Phosphate (PPM)	2.0480	2.4030	2.3320	1.8940		
26	Sulfite (PPM)						
27	Sulfate (PPM)	5.3800	28.165	27.676	5.6820		
28	Total Azole (PPM)						
29	Glycol (PPM)						
30	Glycol E/P (%)						
31	Turbidity (NTU)	0.3500	0.0000	0.4200	0.9400		
32	Aerobic Bacteria (Cells/mL)		0	200	200		
33	Primary Organism			Pseudomonas Specie	Pseudomonas Specie		
34	Secondary Organism						
35	Coliform (Cells/mL)				0		
36	DEAE (PPM)						
37	Morpholine (PPM)						
38	Cyclohexylamine (PPM)						
39	Total Halogen (PPM)		>2.2	>2.2	—		

Levels of conductivity went from 433.51 MMHS to 92.4 MMHS, magnesium went from 136.62 PPM to 9.395 PPM, chloride 106.82 PPM to 11.038 PPM, nitrate 2.179 PPM to 0.363 PPM, sulfate 9.301 PPM to 5.68 PPM and turbidity went from 2.200 NTU to 0.94 NTU. Had water samples been tested prior to filling the tank, a considerable amount of city water could have been saved by allowing initial storm water to run off into the sewer system before being channeled into the cistern.

Once construction of site is complete and the landscape is established, collected rain-water quality can be impaired by the introduction of applied pesticides and herbicides to the landscape, hydro-carbons (Hydrogen-Carbon organic compound found naturally occurring in crude oil) or other petroleum based products spilled on parking lot surfaces as well as ice-melting compounds that are carried by run-off rainwater into the stormwater collection system. There are various methods of filtering and/or treating water with these impairments and will be reviewed in the following pages.

Salinity Management

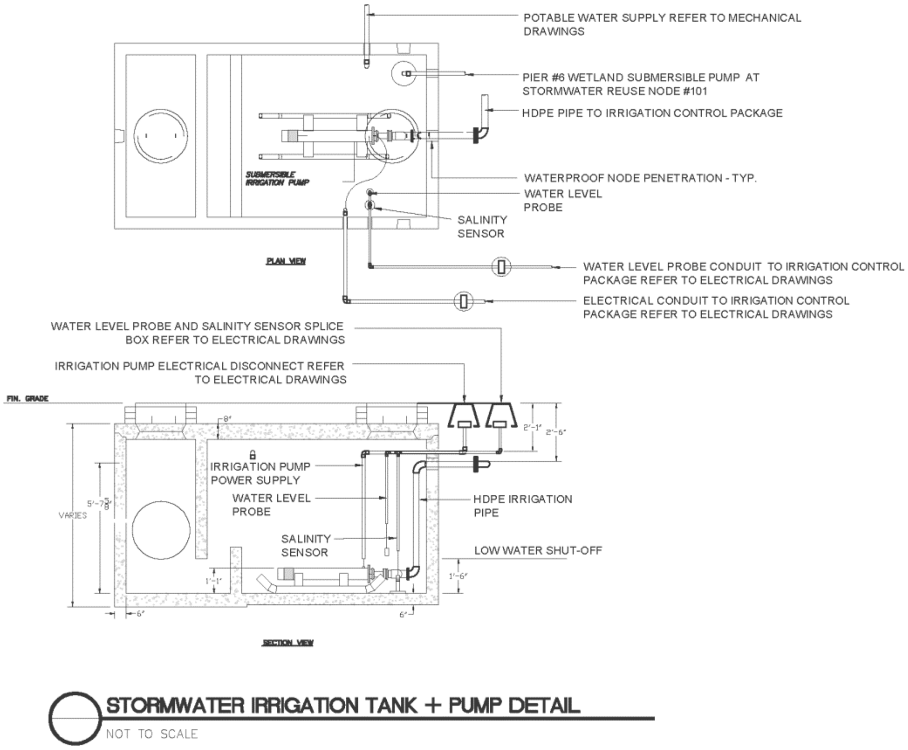
Nature can provide a challenge to irrigation water quality where landscapes such as parks and playing facilities that are on ocean waterfront property and are subject to high levels of salt after storm surges and high winds carry sea spray hundreds of feet in-shore. Salinity is a term used to describe a concentration of (ionic) salt species including calcium(Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Ci^{+}), bicarbonate (HCO_3), carbonate (CO_3^{2}), sulfate (SO_4^{2}) and others. Salinity is expressed in terms of electrical conductivity (EC) and is measured in units of millimhos per centimeter, micromhos per centimeter or deciSiemens per meter. The EC of a water sample is proportional to the concentration of disolved ions in the water sample, hence the EC is a simple indicator of total salt concentration. High concentrations of salt in soils compete with plants for available water. Some salts have a toxic affect on plants and can burn roots and/or foliage. High concentrations of sodium in soils can lead to a high dispersion of soil aggregates, thereby damaging soil structure and interfering with soil permeability. (Institute, 2012).

Water and soil sample analysis is necessary to monitor which salt species are present and at what levels to determine the potential risk to plants, especially during irrigation season. Standard laboratory analysis will include total concentration of salinity expressed as EC or as Total Disolved Solids (TDS). Different plant species have different tolerances to salinity and the test results should be reviewed by a turf grass or plant science specialist.

Salinity levels may also increase due to stormwater run-off from parking lots, roads and sidewalks where de-icing treatments are applied periodically prior to and during winter storm events. Many de-icing treatments are derived from all natural agricultral products and renewable resources which pose little threat to landscape plants and grasses however salinity levels increase in storm water catchment systems due to the presence of sodium chloride (natural brine), magnesium chloride and potassium which depending on the solution are combined with the natural ingredients for effectiveness. Since these products are applied in winter, the harmful effects of these treatments is usually minimized by the diluting effect that spring rainfall events have in washing away these products before storm water is captured for irrigation use, however analysis of water samples taken prior to refilling cisterns or tanks may reveal the need to divert initial rainfall to a run-off site.

Mitigating salinity levels in captured storm water and minimizing any potential harmful effects to the landscape is achieved by implementing some common irrigation practices in product selection and the scheduling of irrigation cycles. Water applied either at surface or subsurface level to plants reduces the risk of foliage damage as well as most of the products that apply water in this fashion are also the more efficient method of irrigation. Better efficiency helps prevent over-watering thereby helping reduce levels of salts being applied to the landscape. Scheduling irrigation cycles with less frequency and longer runtimes promotes not only deep root growth but also may provide a leaching affect to salts already in the soil structure.

Monitoring salinity levels in water collected for irrigation use can be achieved by incorporating salinity sensors which are typically suspended in the cistern or holding tank by a pull rope similarly as the water level sensor is suspended. In-line sensors are also available for monitoring salinity prior to intake to the cistern. The salinity sensor monitors EC levels and communicates to the pump control center via hardwire cable. High-low salinity level parameters are pre-set in the control panel and will over-ride pump starts if levels exceed parameters. The following Stormwater Irrigation Tank and Pump Detail is of a stormwater catchment node installed at a municipal coastal waterfront park.



Typical Stormwater Irrigation Pump Detail Showing Salinity Sensor

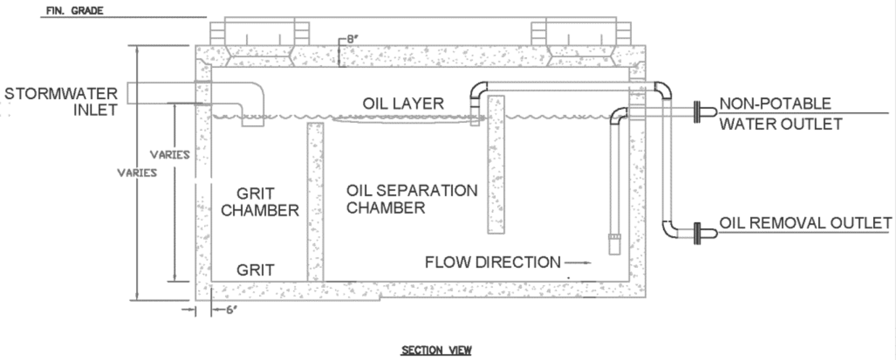
When salinity levels exceed that which are safe to apply to the landscape, a course of action to reduce salinity in the system will depend on what design elements were incorporated into the system to deal with salinity. Most cistern systems are designed with a connection to a potable water source to provide a back-up supplement to stormwater collection along with a discharge outlet to allow excess water to run-off into storm sewer systems, retention ponds or biofiltration areas. Allowing potable water to enter into the holding tank and releasing over-flow levels to run-off areas, salinity level will drop as stormwater is replaced by fresh water. If salinity levels are monitored regularly, potable water can be tapped for diluting purposes at a flow rate that may prevent the necessity of having the entire stormwater contained in a tank to be flushed out the run-off outlet.

Of the many EC sensors available on the market today, the pictured example is typical of a suspended type sensor which this particular unit also provides data on water temperature.

Hydro-Carbon Filtration and Treatment

Hydro-carbons are introduced into the stormwater collection system in a variety of ways from within the landscape. Oil or gas spills on parking lot surfaces, run-off from vehicle washing centers, contaminated soils on construction sites and leaking dumpsters. In most cases, incidents of spills and leakage occur infrequently and require immediate remedial action in containing and removing the pollutants before they reach water sources however some facilities utilizing reclaimed water sources for non-potable use may require installation of an oil water separator to extract hydro-carbons from the run-off water.

Oil water separators are passive, physical separation systems designed for removal of oils, fuels, grease and hydraulic fluids from water. There are two types of water separators in use today. The oldest type is gravity or conventional separation, with simple separation via gravity (density differential between two immiscible liquids leading one of them to rise above the other). This system, when designed properly provides a certain tank length, width and depth that maintains a wide, quiet spot in the pipeline to give oils time to rise. This design, also known as an API (American Petroleum Institute) separator, generally provides a discharge of oil in the concentration of 100 parts per million based on a 150 micron droplet size. The API type design relies on a large water volume which in turn requires a large tank compared to the coalescing separator system.



CONVENTIONAL OIL WATER SEPARATOR TYPICAL

NOT TO SCALE

The above diagram outlines the conventional or gravity type separator tank in which storm water enters the tank from the left and is allowed to flow slowly from the grit collection chamber to the oil separation chamber where oil droplets coalesce, float to the surface and are prevented from flowing beyond the barrier wall. The cleaner water flows under the barrier wall and is drawn out of the tank by a suction lift pump utilizing a suction line with foot valve. Oil contained in the oil separation chamber is siphoned off by a separate pump and directed to the waste oil containment tank.

The newer separator design or coalescing separator utilizes coalescing plate(s) available in a variety of designs but all having a relatively large enough surface area to collect oil particles as they pass by and allowing them to coalesce into larger droplets which then are able to float to the surface of the water level in the tank and be collected for removal from the system. (*www.oil-water-separator.net/separators-coalescing-theory.html*. (2004). Retrieved August 22, 2012, from www.oil-water-separator.net: http://www.oil-water-separator.net.)

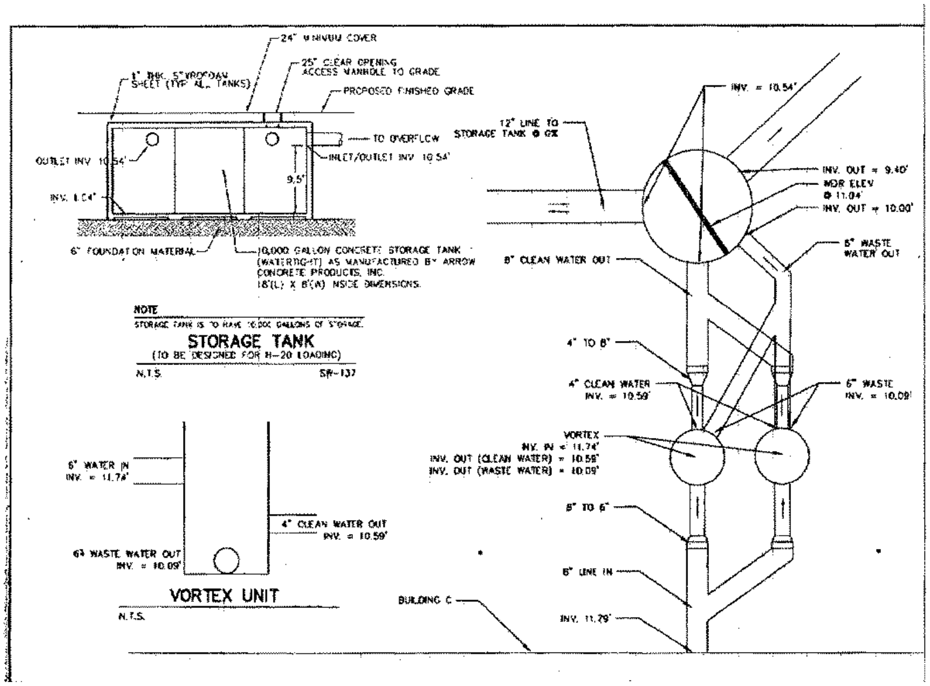
Sites utilizing stormwater collection systems should have water and/or soil samples analyzed prior to storing for re-release into the landscape to determine if the presence of hydro-carbons exist. Adding oil-water separators to stormwater collection systems will easily add tens of thousands of dollars in materials and installation costs to a project.

There are a multitude of oil water separating units, each designed for specific applications including treating industrial waste, run-off from vehicle washing facilities, drains from kitchen facilities and vehicle service stations.

Pre-Filtration Devices

Depending on which contaminates are present within a site, there are many products available to prevent contamination of irrigation water prior to entry into the storage and distribution system. Catch basins and piping systems that feed cisterns and/or retention ponds can begin the filtration process by incorporating initial or pre-filtration units that include vortex filters, gravity-type in-line rain water filters, first flush diverters and screens on pump suction lines.

The diagram below outlines the flow of storm water collected from an apartment building roof-top and parking lot with catch basins feeding an 8” drain pipe. The 8” drain pipe splits in two 6” pipes that each feed a separate vortex filter. Storm water is filtered and clean water is directed to a 4” outlet and waste water exits the vortex via a 6” drain pipe. The 2, 4” clean water pipes are sized up to 6” and are joined prior to entering a separation chamber. Waste water also is pipe to the separation chamber. Clean water at this point can either be allowed to flow to the storage tank for irrigation use or re-directed to the waste water out flow should the storage tank be full.



First flush filters or flush water diverters help maintain water quality prior to storing for landscape irrigation use by preventing the first flush of water to reach the tank and instead diverts it to a debris chamber. Diverters can be installed in downspouts, above ground on posts or wall-mounted, below grade as pictured above. This below-ground first flush diverter in which initial run-off from parking lot and/or roof tops is flushed of the bulkiest materials and clean water is directed to storage tank while debris that is trapped in the diverter chamber is gravity drawn to an outlet and sent to waste water area.

Conclusion

In many states, the regulatory and permitting process governing how stormwater run-off is to be controlled and how it can be used has been relegated to water purveyors who under the auspices of state and local governmental agencies, insure that water quantity and quality are protected for public access. Water purveyors as well as local, state and federal government agencies also have influence over how reclaimed water sources such as stormwater collection systems, whether it be roof top rainwater harvesting or sidewalk and parking lot drainage systems can be used as an irrigation supply for landscapes in both private and public facilities.

This paper provides only a very brief overview of some of the potential water quality issues that are present when utilizing stormwater for reuse. Products for every aspect of reclaimed water systems are available from manufacturers worldwide, with some specializing in only one particular component such as a sensor, a filter or a tank while some companies offer complete systems.

Design considerations should bear in mind the old adage “An ounce of prevention is worth a pound of cure” which is very appropriate when it comes to preventing stormwater contaminates form being reintroduced into the landscape. Recognizing what contaminates may already be present in at a particular construction site or what potential contaminates may be introduced into stormwater run-off as the landscape is maintained will help determine which products or what type of system will best serve to improve water quality. To properly design an irrigation system that incorporates stormwater as a supplemental or even primary water source requires a team effort that includes the input from the civil engineer to provide anticipated flow rates based on topography and area square footage, the landscape architect to provide plant tolerances to salinity and plant water requirements, lab testing facilities to provide soil and water analysis and the property management company as to how the system will be maintained and water quality monitored.

Resources and References

Texas Water Resources Institute, (2012) 1500 Research Parkway, A110, 2260 TAMU, College Station, TX, 77843-2260 twri@tamu.edu

US Green Building Council, LEED Rating System, 2011, Washington D.C.

Oil-water-separator.net: http://www.oil-water-separator.net, retrieved August 22, 2012