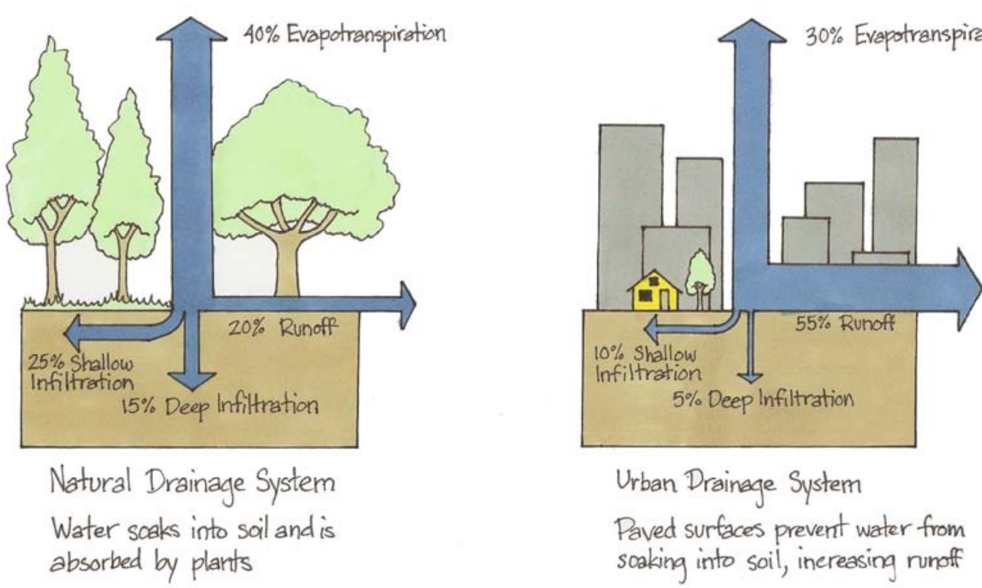
SECTION 13
WATER QUALITY

13.1 INTRODUCTION

Like many urban areas, stormwater in the Okanagan region routinely carries large loads of hydrocarbons, chemicals released from the paving materials, road salt, pathogens, detergents and landscaping chemicals including fertilizer and pesticides. It may also carry other contaminants when people illegally dispose of materials down storm drains. Resolving water quality issues is complicated by runoff volumes. Both the total runoff volume and the peak storm flow increase with urban roads and roofs (Figure 13.1).

Very little rain water is retained on urban properties in District of West Kelowna. In a modest 1cm rainfall, a single home roof will generate 2600 litres of stormwater and a city block 150 m long by 10 m wide will produce 15,000 litres. As this study shows, Okanagan stormwater quality is impacted by roadway run-off, agricultural drainage and animal feces. Even after DWK stormwater mixes with creek flows, contaminant concentrations are high enough to impact stream life and ultimately impact Okanagan Lake.

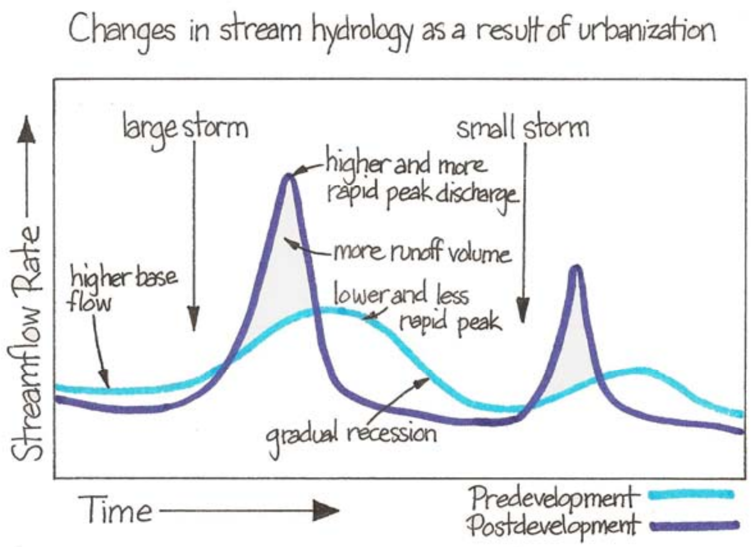
Figure 13.1: Stormwater Distribution in Natural and Urbanized Drainage Systems



Urban impervious surfaces (driveways, walkways, roofs) skew the drainage system from the natural 40% infiltration / 20% runoff to the urban 15% infiltration / 55% runoff, with expensive consequences in stormwater management (Figure 13.1).

The increased volume of stormwater also hits water courses in shorter, larger peaks from urban areas (Figure 13.2).

Figure 13.2: Urban Stream Hydrology; Powers Creek Inflow Plume



Stormwater treatment is complicated by the several orders of magnitude changes in flow and water quality within hours of a storm. Currently there is no water chemistry treatment of stormwater in the Okanagan beyond the naturally occurring filtration performed by riparian areas and ground infiltration, and a few stormwater detention wetland ponds. Even the existing filtering capacity of riparian areas is often damaged by urban stormwater. The recently deployed stormwater contact units are basically gravel and oil traps and are not designed to improve overall water chemistry or provide disinfection.

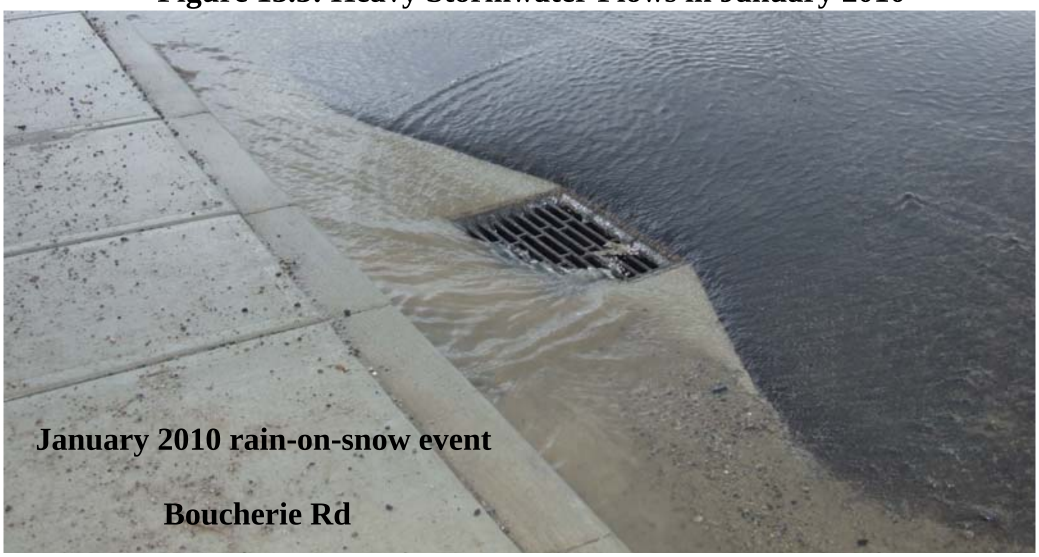
Most streams convey stormwater after they pass through an urban area in the Central Okanagan. Stormwater-laden creek flows enter Okanagan Lake and form plumes (Figure 13.2). A surface flow of buoyant debris is often visible following a storm but the travel path of the plumes is more complicated. If the particulate load is heavy during the initial flush of rain washing materials off the streets into the stormwater, then the inflow can form a density plume that travels along the lake bottom like a dirty cloud. During the summer, the stormwater plume should be trapped by the thermocline and remain in the surface water. It will often travel parallel to the shore dropping large particulates quickly while finer particulates and bacteria will travel further. During the non-stratified winter period, stormwater can form a deep pool in front of the outfall or creek and travel as a packet of water, diluting as it moves with water currents.

These stormwater packets are the most immediate potential source of contaminants to domestic water intakes including WFN#9, Shanboolard and Sunnyside intakes. Both Smith Creek and Powers Creek discharge into Gellatly Bay – a key summer destination adjacent to these intakes - and both of these creeks are currently degraded by stormwater.

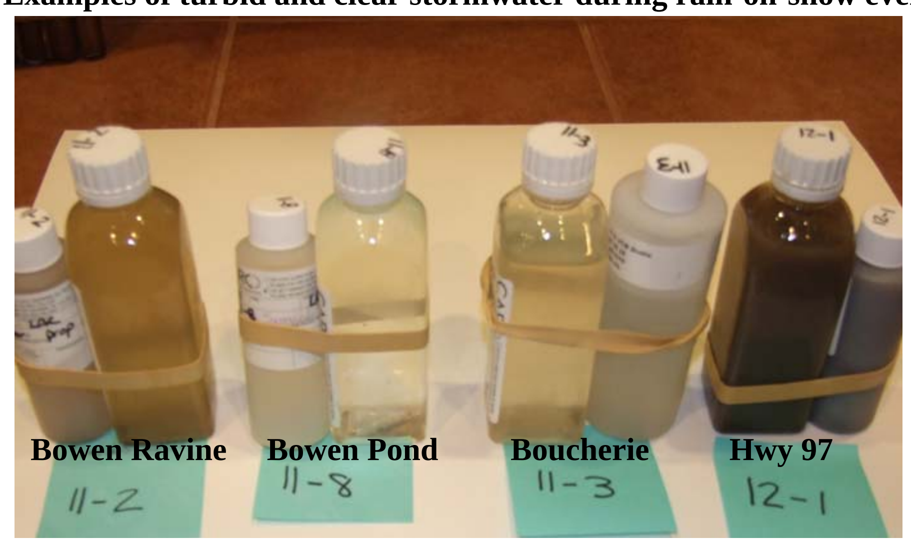
Excess nutrients carried in by stormwater stimulate algae in the vicinity of the stormwater outfall or creek. The increased growth can become attached periphyton slimes or planktonic algae blooms and include cyanobacteria, creating a localized risk. Nutrient enriched halos along Okanagan Lake were often encountered around stream mouths that convey stormwater in the Central Okanagan. These halos were marked by significantly increased algae growth with its characteristic odors.

A lake is always a reflection of its watershed. With increasing urbanization within the Central Okanagan, stormwater is now a key component of that reflection in Okanagan Lake.

Figure 13.3: Heavy Stormwater Flows in January 2010



Examples of turbid and clear stormwater during rain-on-snow event



13.2 STUDY DESIGN

Three parameters were selected to indicate the impact of stormwater quality on receiving drainages in District of West Kelowna (DWK) and ultimately on Okanagan Lake. Each one acts as an indicator for a class of contaminants:

Nitrate indicates the nutrient loading from lawns, gardens and agricultural areas.

Chloride is a persistent constituent of salt and indicates road salt and septic contributions.

E. coli are a group of bacteria that indicate fecal contamination from livestock, pet and avian feces near roads and from damaged septic fields.

There are literally hundreds of other parameters that could be studied in DWK stormwater. This trio of analyses was chosen because it identifies stormwater quality problem areas and is cost-effective. A stormwater monitoring program should be financially sustainable because long-term data for a limited parameter set provides a better indication of change than intermittent, detailed sampling. There are relatively inexpensive Hach-kit or field probes that could be purchased and used by DWK staff for nitrate, chloride and turbidity but bacterial parameters are best sent to an accredited lab.

13.3 SAMPLING

District of West Kelowna stormwater samples were collected from three seasonal / flow regimes:

November 26 2009: fall rain event - small storm during mild, dry weather

January 11 2010: rain-on-snow event - high flow rates and most samples were turbid

April 12 2010: no rain, during a light freshet – low flows and low turbidity

Sample sites were selected from major drainages and known problem areas in DWK. Additional sample sites were added in January based on the November results. The conditions in April were much drier than normal and several sites had no flow (11-2 Boucherie Rd at Tuscany Villa; 11-3 storm drain in Bowen Ck ravine). An additional sample was collected in April from the seepage along West Kelowna Estates, Parkinson Road.

One of the Bowen Creek sub-channels is ditched along Boucherie Road and travels through the Quail's Gate property before entering Green Bay via a broad, braided channel. Because there is interest in using this water for irrigation, more detailed sampling was conducted at this location and is reported in section 13.5 of this report.

Figure 13.4 shows the sampling points used in this study. GPS of the sampling points is contained in Appendix 13.3.

13.4 WATER QUALITY SAMPLING RESULTS FOR INDICATOR PARAMETERS

Stormwater samples from the District of West Kelowna showed diverse water chemistry, depending on the human activities and natural flows in the area. Results for the selected stormwater chemistry parameters are presented in this section. The full data set for the three indicator parameters is graphed in Figure 13.5 (see also Appendix 13.1).

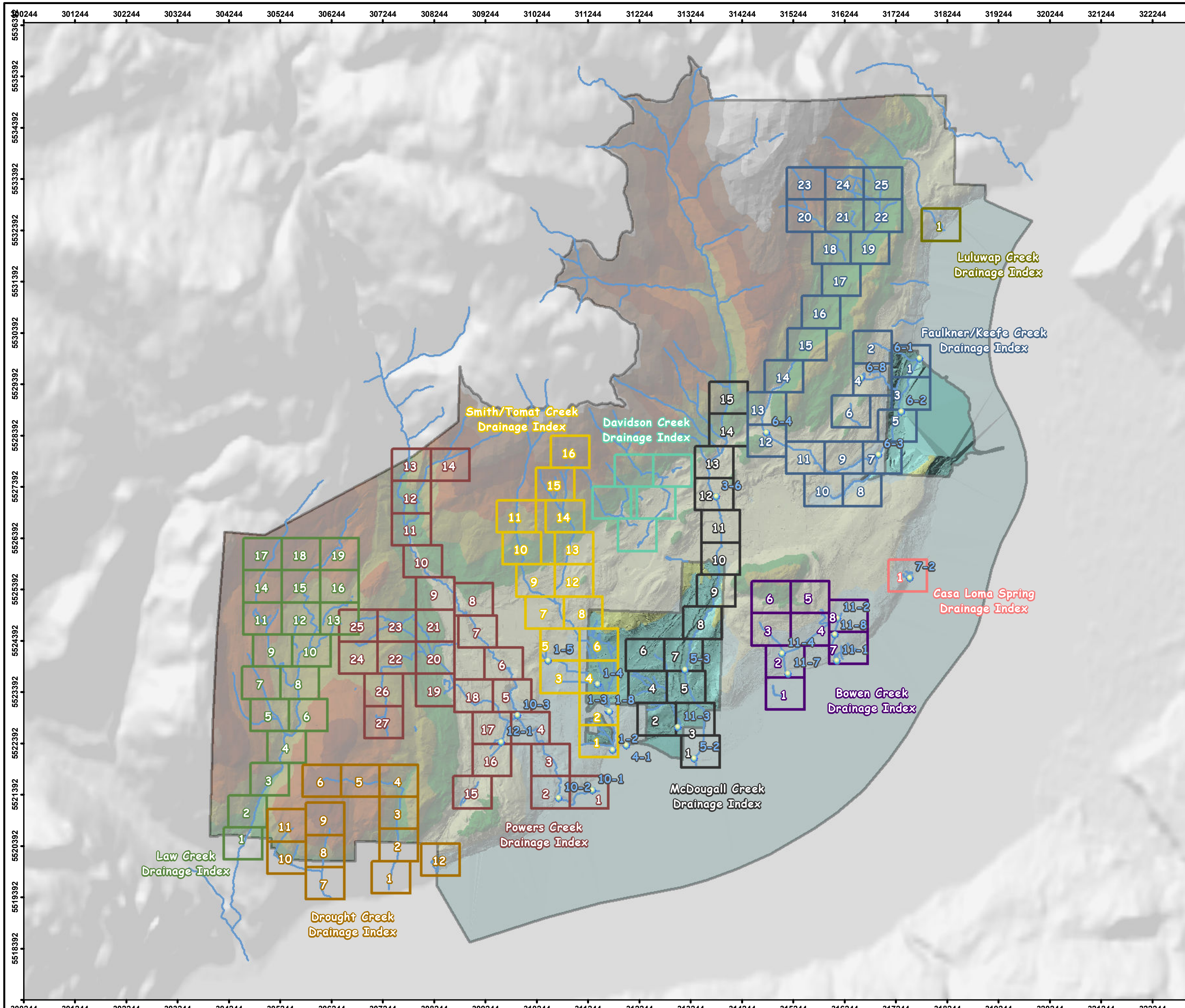


Figure 13.4 - Water Quality Sampling Point Locations

Project:	Sensitive Habitat Inventory and Mapping Update
Location:	District of West Kelowna
Project No.:	09-466
Prepared for:	District of West Kelowna
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	December, 2010

Meters 1,000 500 0 1,000 2,000

1:75,000

N S W E

SOURCE INFORMATION

Base Map:	82E
Orthophoto:	Province of British Columbia
Waterbody Information:	District of West Kelowna Streams
Location Information:	Field, GPS (Trimble GeoXT)
Feature Information:	Airphoto and Topographic Estimate Field Inventory (RDCO SHIM)
Date of Inventory:	2001-2003
Inventory Management:	Brent Magnan

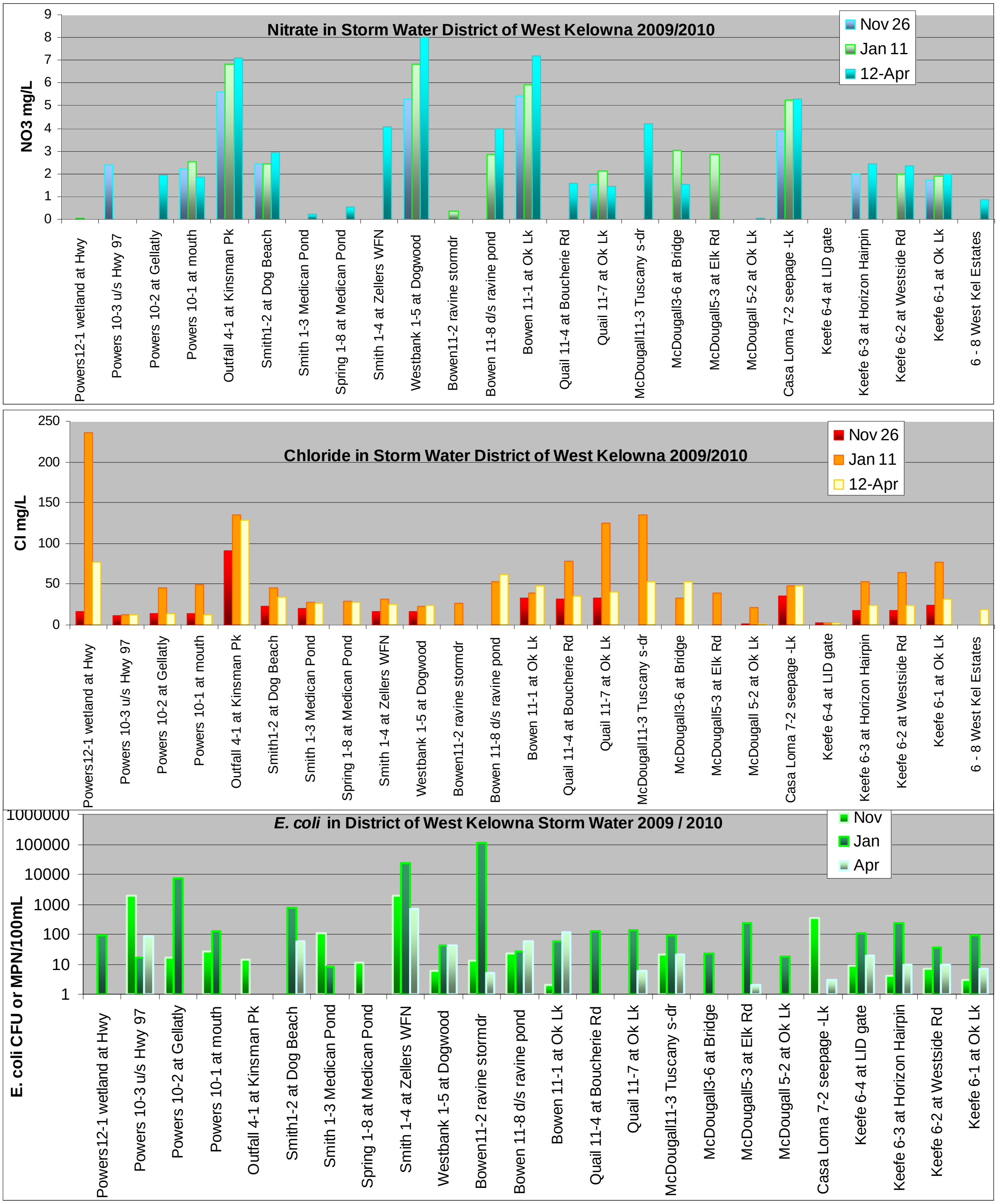
LEGEND

- Water Quality Sampling Locations (Summer, 2010)
- Stream
- District of West Kelowna Boundary
- Smith/Tomat Creek Drainage Index
- Davidson Creek Drainage Index
- Powers Creek Drainage Index
- McDougall Creek Drainage Index
- Luluwap Creek Drainage Index
- Law Creek Drainage Index
- Faulkner/Keefe Creek Drainage Index
- Drought Creek Drainage Index
- Casa Loma Spring Drainage Index
- Bowen Creek Drainage Index

ECOSCAPE Environmental Consultants Ltd.

DISTRICT OF WEST KELOWNA

Figure 13.5: Nitrate, Chloride and E. coli in DWK Stormwater



NOTE: Logarithmic scale for *E. coli*; Site numbers were derived from Basin numbers within the RDCO Westside Master Drainage Plan, 1999

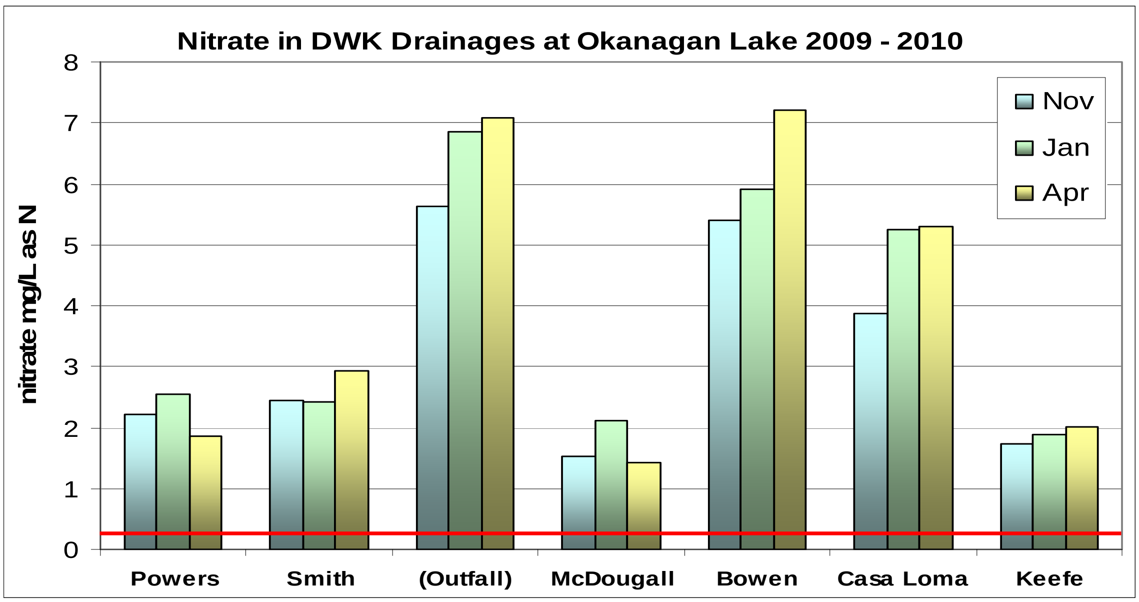
Nitrate

The major drainages in DWK showed escalating nitrate concentrations as the creeks received more and more stormwater before discharging to Okanagan Lake. Nitrates increased significantly as flows traveled through agricultural or residential areas. Many of the sites with high nitrate concentrations in the November sample set were also high in the January and April sets. While all of the sample sites showed nutrient enrichment from either agriculture or urban areas, a low-flow outfall, Bowen Creek and the Casa Loma springs/seepage had very high nitrate concentrations in all three sample sets (Figure 13.6). These drainages may be picking up nitrates from old septic fields or from orchards.

At the time of sampling, both McDougall and Keefe Creeks had riparian areas capable of removing nutrients and they had the lowest nutrient concentrations on all three sample dates (Figure 13.6, 13.7). Unfortunately, both were damaged after the sampling concluded. Several large areas of the McDougall riparian buffers have been stripped back to 15 m or less during 2010 to allow for subdivision development and an automotive repair centre within WFN jurisdiction. A boat storage facility within WFN jurisdiction punctured LID’s main water line in summer 2010 and the flows were diverted to Keefe Creek where they caused extensive siltation. Both streams may now have reduced capacity to filter nitrates.

Figure 13.6: DWK Creek Discharges to Okanagan Lake with Stormwater Influence

Nitrate mg/L	Powers	Smith	(Outfall)	McDougall	Bowen	Casa Loma	Keefe
Nov	2.21	2.45	5.63	1.52	5.41	3.88	1.73
Jan	2.55	2.43	6.85	2.12	5.91	5.24	1.88
Apr	1.86	2.92	7.09	1.43	7.21	5.29	2.01



NOTE: Red line is Okanagan Lake average nitrate concentration

In all creek systems except Smith, the upland reaches had low nitrate concentrations (<0.01 – 0.05 mg/L as N) while the lower reaches showed nutrient enrichment as stormwater collected nutrients off lawns/gardens, agricultural areas and possibly septic fields (Figure 7). Smith Creek begins as a spring in the Ruffli Rd area - an area with low intensity animal husbandry, agriculture, a plant nursery and septic fields. Residents report that a pig farm was located in the area prior to subdivision and the smell of pig manure is unpleasant if they dig deeper than the fill layer in their yards. The resulting nitrate concentrations are extremely high, ranging from 5.2 to 8.0 mg/ nitrate as N. A gravel extraction / silt–infill operation commenced operation in the draw on upper Ruffli Road after the sampling was completed. Blasting residual from this operation can further increase nitrogen concentrations.

At the interface with Okanagan Lake, creeks in DWK carrying stormwater ranged from 1.52 to 7.21 mg/L nitrate as N (Figure 13.5). This range is very high and contributes to a "halo" of enriched algae growth around the mouth of these creeks. This nutrient-rich halo was particularly evident on Smith Creek at the Dog Beach where the filamentous algae *(Spirogyra/Mougeotia)*) generated a pungent skunky odor during the spring and summer. A cyanobacteria bloom led by *Anabaena* (also *Aphanizomenon flos-aquae, Dichothrix, Scytomena*) was detected here in October, and November 2009 as part of this study (Appendix 13.4). Cyanobacteria blooms can produce toxins as they decay.

MoE data gives a range of total nitrogen of 0.13 – 0.35 mg/L as N for Okanagan Lake. Creeks within the DWK carried 4 – 21 times the upper range of nitrate expected in Okanagan Lake and are therefore a significant source of nutrient enrichment. The International Lake Environment Committee lists the risk of eutrophication on Okanagan Lake as "serious". Of the tons of nutrients entering Okanagan Lake every year, the majority will arrive via creeks and outfalls (MoE database).

Soluble nutrients are usually not effectively removed in stormwater ponds that rely on sedimentation only. Nutrient removal from stormwater can be accomplished in cattail wetlands designed for that purpose, but these systems require large tracts of low-slope land – definitely a premium commodity in West Kelowna.

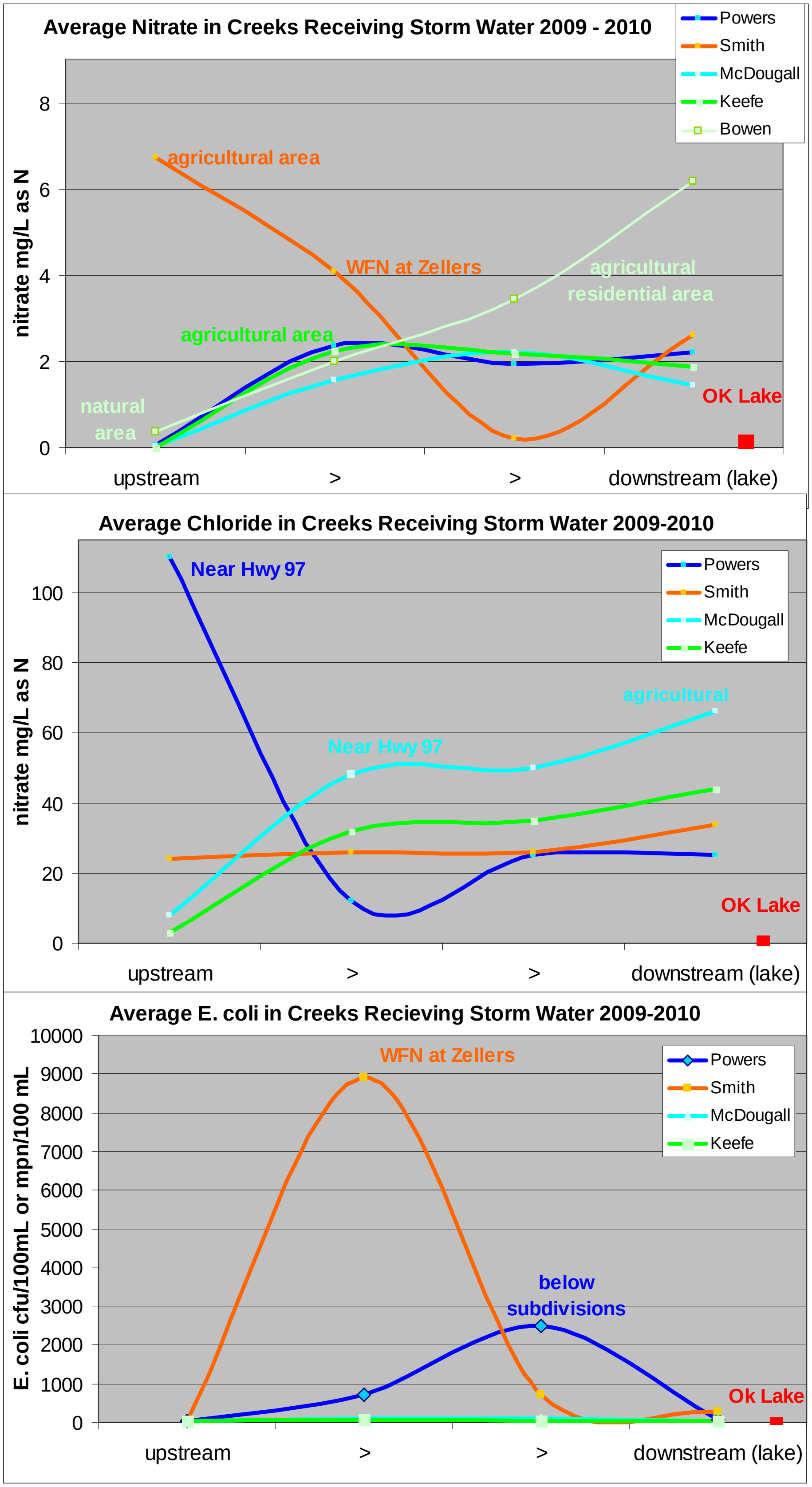
Chloride

Chloride is an urban stormwater contaminant that is contributed primarily by winter road salting and sanding (Baker, 2007). Other sources of chloride include residential use of de-icers and fertilizers. In this study, chloride concentrations increased where run-off from Highway 97 entered a drainage system. Other roads in West Kelowna did not contribute the salinity that flows off the highway did. As expected, the winter samples showed higher chloride concentrations from road salt than fall or spring samples (Appendix 1). January samples with very high chloride concentrations include Hwy 97 drainage to Powers Creek at 236 mg/L Cl- and the storm drain on Boucherie Rd / Tuscany Villa at 135 mg/L Cl- .

Chloride is challenging to treat in stormwater. It is a conservative ion that seldom participates in chemical reactions compared to other ions, but it also is not as harmful to the environment for the same reason. In this study, chloride was used as a "marker" for more harmful metal ions such as sodium and zinc. In most cases, metal concentrations correlated with chloride (Appendix 13.1 Figure 1).

Saline flows from Hwy 97 should not discharge directly into creeks with low winter flows wherever possible. While wetlands are better than most ecosystems at retaining metals, they can only perform limited removal when stormwater retention times are a matter of hours or less. Large wetland facilities would be ideal but impractical to intercept Hwy 97 flows in DWK. Sediment-bound metals can be removed in small stormwater ponds that have sufficient capacity to allow sand and silt to settle out. A pond's removal of salt and metals will be enhanced when a sedge component can be planted. Sedges have a high salt tolerance and withstand both flooding and drought.

Figure 13.7: Average Parameters in Creek Systems, District of West Kelowna



Bacteria

Escherichia coli are a species of bacterium normally present in intestinal tract of humans and other warm-blooded animals. While most *E. coli* strains are harmless, a few are pathogenic, but the presence of these bacteria indicates possible contamination with other pathogenic bacteria that are harder to test for. *E. coli* are often used to detect fecal contamination of water. DWK stormwater sites with high *E. coli* counts are identified below. They should be investigated and remediated to prevent the potential for illness.

E. coli counts were low (20 – 40 cfu/100 mL) for raw water in the upper reaches of every creek system of West Kelowna (Figure 13.5, 13.7). Once the drainage system received run-off from urban paved areas, *E. coli* counts climbed.

Urban stormwater routinely carries pet and bird feces and may include human *E. coli* if septic systems do not perform properly, such as may be the case in the Bowen Creek ravine immediately below Boucherie Rd. City of Kelowna conducted *E. coli* typing and found human *E. coli* in creeks after they received stormwater. The suspected source of the human *E. coli* was malfunctioning septic systems. They also documented an apparent drop in canine (dog) *E. coli* from 2006 to 2008 that may be the result of a campaign to get owners to pick up after their pets (Appendix 3). *E. coli* typing should be considered for the sites where *E. coli* were consistently high, including the Tomat Creek discharge to Smith Creek.

Bacterial numbers were very high at urbanized sites in the January samples despite low temperatures (Figure 13.7). By observation, fewer pet owners pick up dog feces in the winter. In contrast, bacterial numbers were generally moderate in April. Pet feces have been noted on streets throughout district, and especially at the Smith Ck dog beach in the winter months.

Bacteria counts were particularly high along ditched and urbanized Smith Creek. The agricultural area in the Westbank Creek tributary to Smith Creek contributed 6 to >1000 cfu/100 mL *E. coli*. Low intensity animal husbandry and old septic fields contribute to the *E. coli* loading. Ditches in the area that were constructed to help drain groundwater could be planted with riparian vegetation (willow sedge cattail) to increase their filtering capacity for nutrient removal. Further down Westbank Creek, riparian areas that should act as a filter have been cleared. These creek banks could be re-planted with the owner's cooperation.

One of the largest *E. coli* contributors detected in this sampling is the culverts discharging Tomat Creek flows from WFN developed lands behind Zellers. Bacterial numbers are consistently high, ranging from 700 to 24,000 *E coli cfu*/100 mL and even overgrown with *E. coli* - a result too high to count. The infill of the former Old

MacDonald's Farm site with its septic disposal field or septic fields in the upstream mobile home parks may be the cause. Again, *E. coli* typing would help pinpoint the source(s) of the bacteria loading to WFN/DWK stormwater.

13.5 WATER QUALITY RESULTS FOR BOWEN CREEK AT QUAIL'S GATE VINEYARD

A separate but related study was conducted on the stormwater and Bowen Creek flows ditched along Boucherie Road. The flows are picked up in a culvert under Boucherie Road and piped across Quail's Gate vineyard and discharged to a braided channel into Green Bay.

Quail's Gate stormwater samples were collected on three occasions:

January 15 2010: followed rain on snow event

February 11 2010: followed storm

April 12 2010: no rain during a light freshet

Samples were collected from the seepage before it passes under Boucherie Road, and from the braided channels as it flows to Okanagan Lake.

The results are presented in Table 13.1. The key differences between the ditched flows at Boucherie Road and the flows at Okanagan Lake after passing through the volunteer cattail stand include:

Decreased: nitrate (35%), total N (33%), total suspended solids and total iron

No significant change: alkalinity, chloride, pH

Increased: Water color (50%) *E. coli* counts and total phosphorus (65%)

Table 13.1:
Water Chemistry of Bowen Seepage/Stormwater Near Quail's Gate Winery

high result result of concern result of high concern	Quail's Seep 2009/10	11-4 Quail's Boucherie 15-Jan-10	11-7 Quail's at Ok Lk 15-Jan-10	11-4 Quail's Boucherie 11-Feb-10	11-7 Quail's at Ok LK 11-Feb-10	11-4 Quail' Boucherie 12-Apr-10	11-7 Quail' at Ok LK 12-Apr-10
Colour, True	Color Unit	8	14	7	16	<5	
Alkalinity, Total as CaCO3	mg/L	457	452	534	491	521	
Carbon, Total Organic	mg/L	8.1	8.8	17.4	13.1	13.6	
Chloride	mg/L	33.3	38.9	40.1	40.8	53.3	52.7
Nitrogen, Nitrate as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Nitrite as N	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen, Dissolved Kjeldahl,	mg/L	0.37	0.25	0.33	0.34	0.36	0.31
Nitrogen, Nitrate+Nitrite as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Total Dissolved	mg/L	3.38	3.1	4.91	3.64	4.58	1.87
Phosphorus, Total	mg/L	0.1	0.1	0.13	0.23	0.03	
Phosphorus, Dissolved	mg/L	0.07	0.09	0.05	0.04	0.02	
Solids, Total Suspended	mg/L	15	2	104	2	10	
pH	pH Units	8.28	8.27	8.28	8.26	8.39	
Iron	mg/L	0.4	<0.10	7.23	<0.10	1.23	
E. coli	CFU/100m	130	140	<1	7	<1	6
Conductivity (EC)	uS/cm					1220	
Hardness (as CaCO3)	mg/L					400	
Calcium	mg/L					71.4	
Iron	mg/L					1.23	
Magnesium	mg/L					53.8	

Bacterial de-nitrification would be the main process behind the nitrate reduction in the volunteer cattail stand, while settling/filtering of solids would be primarily responsible for the drop in suspended solids and iron. pH was buffered and stabilized to a relatively high range by the high alkalinity. Increased water color and total phosphorus would be caused by exposure to decayed material in the winter months. Decayed organic materials release nutrients and color to water, particularly under anaerobic soil conditions. Waterfowl use of the area would contribute to the increased *E. coli* concentrations.

In terms of chemistry that could affect this water's use as irrigation water, the Bowen Ck seepage/stormwater is very alkaline, hard and has high conductivity. The resulting pH ranged from 8.26 to 8.39. Iron concentrations were also high, probably with most of it occurring in particulate forms. The total suspend solids load can also be very high (15 – 104 mg/L). The turbid initial flushing during the first few hours of a storm would probably need to bypass any irrigation system and could be addressed by a lake-side constructed wetland. Nitrogen and phosphorus concentrations were very high. While the nutrients conveyed by these flows would be beneficial to agriculture as "fertigation", the alkalinity may be unsuitable for irrigating grapes long-term. There may be a benefit to mixing the relatively soft, low iron Lakeview Irrigation District water with the stormwater prior to irrigation.

Some or all of the Bowen/stormwater flow could be treated below the Quail's vineyard in a constructed wetland using a multi-stage design (Figure 13.13). It should have a settling basin prior to subsurface flow-through cells designed for macrophyte harvesting to allow permanent nutrient and metal removal.

Areas above the high water mark could be planted in sections with the locally rare Giant wild rye *Leymus condensatus* in drier areas and shrub willow *Salix spp*. in wetter areas to provide the main plant structure. These plants uptake nutrients and metals directly and their root zones also host bacteria that perform biofiltration for nutrients and metals. Since this wetland would provide habitat opportunities, monitoring of metal/toxin concentrations would be recommended. A functional wetland would take about three years to mature but would improve the water quality reporting to Green Bay.

The first phase of this design would involve conveying Bowen water further down Boucherie Road and delivering it to a 200 m long serpentine channel planted with local cattail, bulrush, shrub willow and red osier dogwood. This phase can be monitored for the sedimentation rates and stormwater volumes that a future multi-stage wetland system would have to manage.

Stormwater samples with high turbidity allow bacteria to attach onto particulate surfaces, potentially accelerating bacterial removal from storm flows in a wetland. Turbidity will also reduce bacterial counts reported from the lab because bacterial samples are filtered before processing. This underestimate of bacteria should be taken into account during wetland design.

13.6 WATER QUALITY RESULTS - FULL METALS SCAN

Due to cost, a full metals scan was completed on the first set of DWK stormwater samples only. The total metals results were graphed to locate high groundwater contributions in Appendix 13.1, Figure 1. They indicate that Outfall 4-1, Medican Pond, Bowen Creek at Okanagan Lake and upper Westbank Creek all receive significant groundwater inflow.

Although creeks receiving stormwater would never be considered for drinking water, comparing the metals scan to the Canadian Drinking Water Guidelines provides the suitability of that water for uses involving animal or human contact and irrigation. Total metals concentrations that exceeded the CDWG at one or more DWK site includealuminum, iron, manganese, selenium, sodium, and uranium.

Aluminum and zinc increase when water is exposed to those metals such as during passage through galvanized culvert. The sites that exceeded the CDWG for aluminum and had elevated zinc concentrations were the Power’s Creek volunteer wetland that receives highway run-off and the Casa Loma seepage. No problems are anticipated from these metals.

The iron and manganese guidelines are based primarily on aesthetic concerns as opposed to toxicity concerns. Both metals behave similarly and are released from substrates under anaerobic conditions. Anaerobic conditions occur in permanently saturated soils. The sites with high iron and manganese include: Power’s Creek volunteer wetland, outfall 4-1 Smith Creek at Medican Pond, Smith Creek at the Dog Beach and McDougall Creek at Elk Rd. No problems are anticipated from these metals.

Selenium is a concern for drinking water and is a common contaminant of granular fertilizer. It was high in the outfall 4-1 and the Casa Loma seepage. The later site is a greater concern because the flows are far larger than the outfall. Similarly, sodium also exceeded the CDWG for sodium in the low-flow outfall. Smith Creek below Hwy 97 also had elevated sodium concentrations. Excessive exposure to these metals can cause health concerns.

Uranium is locally abundant in the Okanagan, particularly in gravelly deposits in former lake sediments. As such, it can increase in groundwater. Sites where total uranium exceeded CDWG include the outfall 4-1, Smith Creek at Medican Pond, Bowen Creek at Okanagan Lake and the Casa Loma seepage – all sites where groundwater inflows are expected. These sites would not be suitable as drinking water (Appendix 1).

When the stormwater total metals data is considered as a whole, sites where remediation is indicated include: the low volume outfall 4-1, lower Smith Creek, lower Bowen Creek and the Casa Loma seepage.

This stormwater total metals dataset can be mined for other concerns in the future.

13.7 STORMWATER QUALITY ENHANCEMENT OPPORTUNITIES

Stormwater ponds and stormwater retention/detention facilities will always be a necessary part of a stormwater management program, however they accumulate pollutants and are expensive to install and maintain. DWK should consider a multiple-barrier approach aimed at reducing urban stormwater pollution by encouraging source reduction in addition to stormwater facilities.

Stormwater Source Reduction - Divert /Utilize Rainwater

Reducing the volume of stormwater at its source would reduce the overall cost of stormwater treatment for District of West Kelowna.

Reducing the amount of stormwater can be achieved by retaining rainwater on properties whenever subsurface drainage is appropriate. Instead of an expensive liability, rainwater remains a valuable commodity when it is used as irrigation water and is not discharged to the stormwater system. Expensive techniques involve storing rainwater in cisterns or in underground reservoirs and pumping it for irrigation. Simpler techniques for rain harvesting and rain gardens are presented in Figures 13.8 and 13.9.

Figure 13.8 contrasts a suburban landscape that is poorly designed and does not retain stormwater falling on the impervious surfaces (driveway, walkway, roof) with a landscape that does. The rainwater–retaining landscape is not only more attractive, it will cost less to irrigate. It features:

Gutter-fed rain barrel directed to garden(s)

Lowered rain gardens in swales that are capable of absorbing adjacent runoff

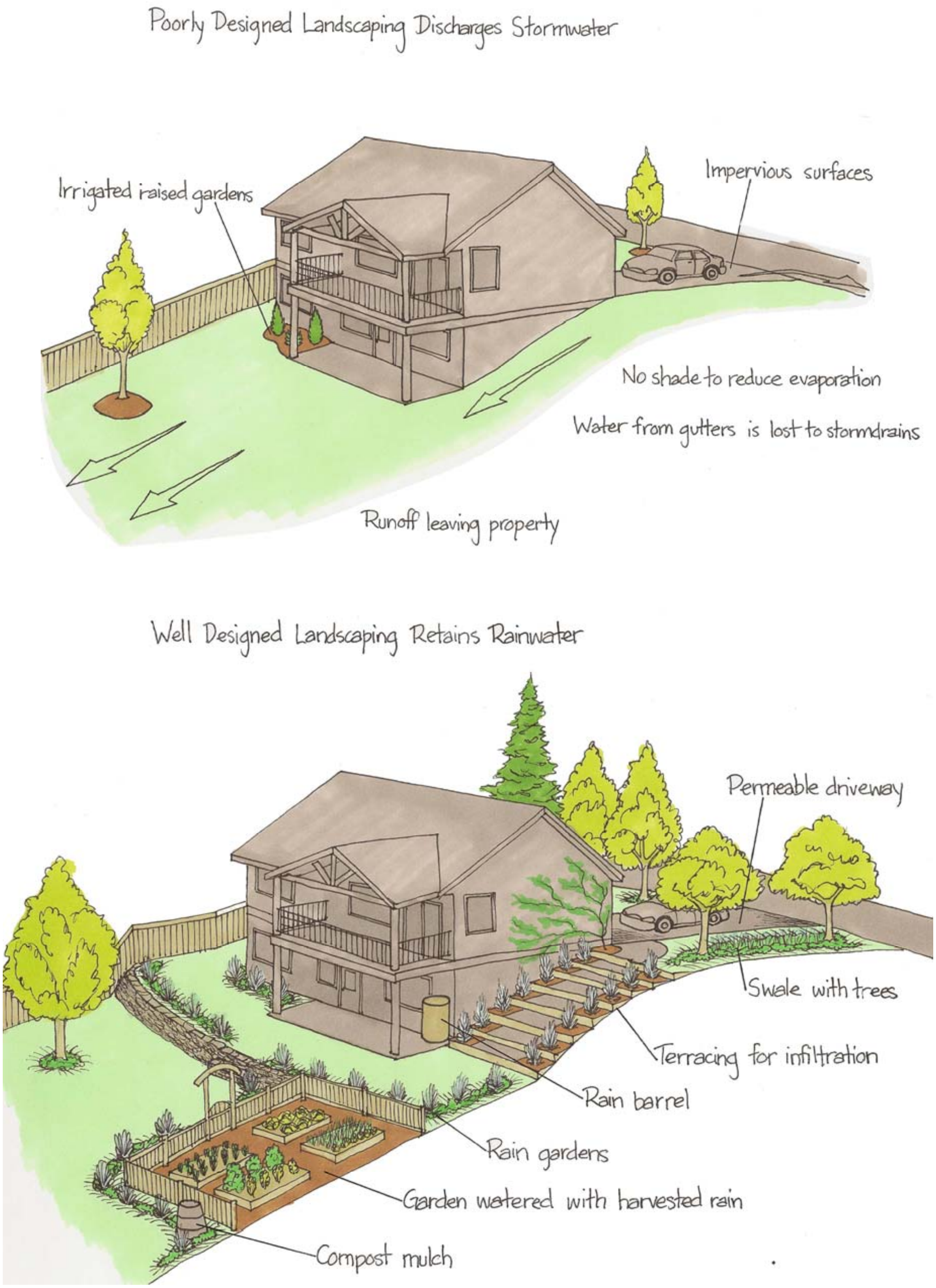
Terracing to encourage infiltration to ground

Permeable driveway (gravel crush or crushed limestone)

Large soak-away zones or rain garden swales can be developed on DWK public property. These rain garden swales temporarily store rain water where it re-charges the root zone, and gradually releases surplus water to ground where impurities can be filtered out (Figure 13.9) that temporarily store the rainwater, gradually releasing it to ground. Drainage pipe connected to storm sewers would still be necessary to safely convey excess stormwater during large rainfall events.

Stormwater use or treatment that involves infiltration to groundwater should not be sited in areas with high water tables or where there are shallow soils over bedrock. Where infiltration is contemplated for a large development, a groundwater hydrologist should be consulted. Managing stormwater for onsite erosion and sediment control on large developments would also greatly reduce sediment inputs to stormwater ponds.

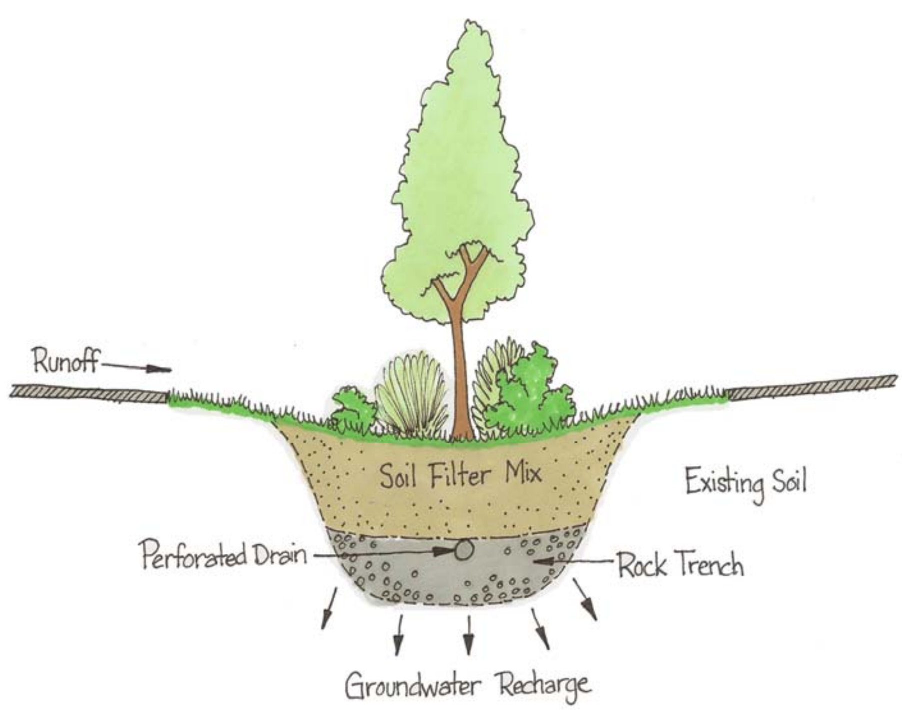
Figure 13.8: Techniques for Retaining Rainwater on Residential Properties



Commercial and residential developments can be retro-fitted with the raingarden/swale concept and they can minimize impervious walk-ways (Figure 13.9). New development properties could incorporate underground detention reservoirs or soak-away infiltration galleries to reduce peak stormwater discharges. At sites where it is hydrologically appropriate, these methods recharge the groundwater and maintain normal velocities in creeks, thus avoiding undercutting creek banks and undermining roadways.

There are several products available for pervious side walks that incorporate recycled tire chips. Alternately, crushed limestone can be laid and will form into a pervious solid surface within a year (G. O'Roarke, pers. comm.).

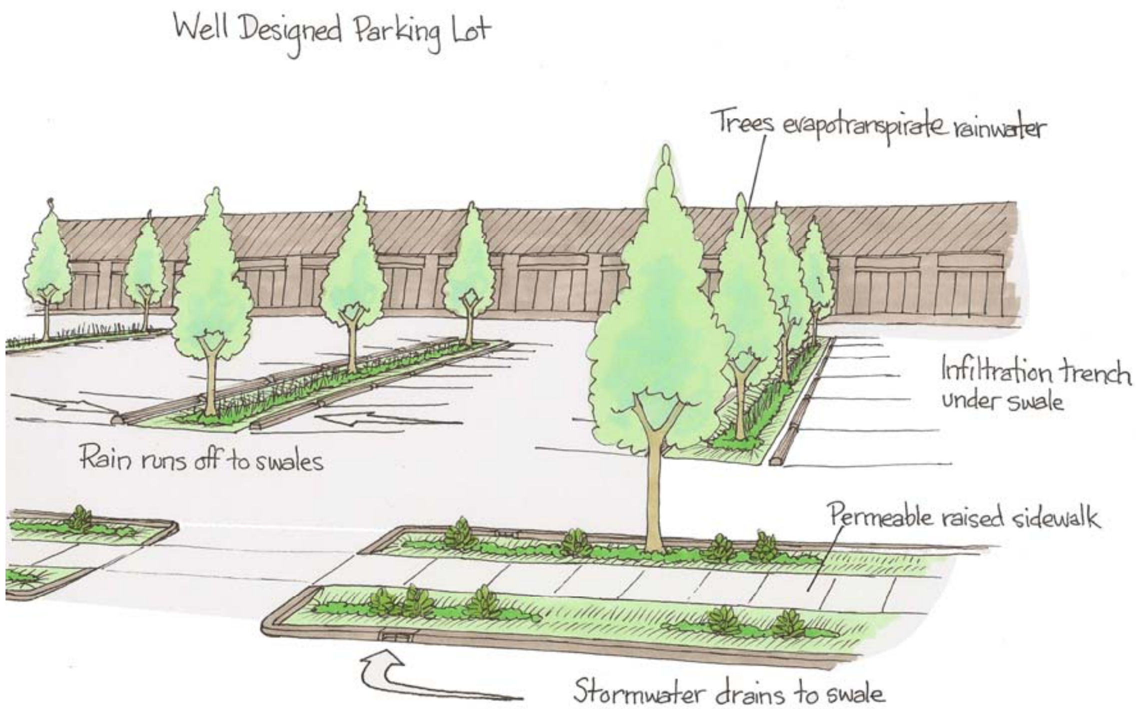
Figure 13.9: Cross Section of a Rain Garden Swale

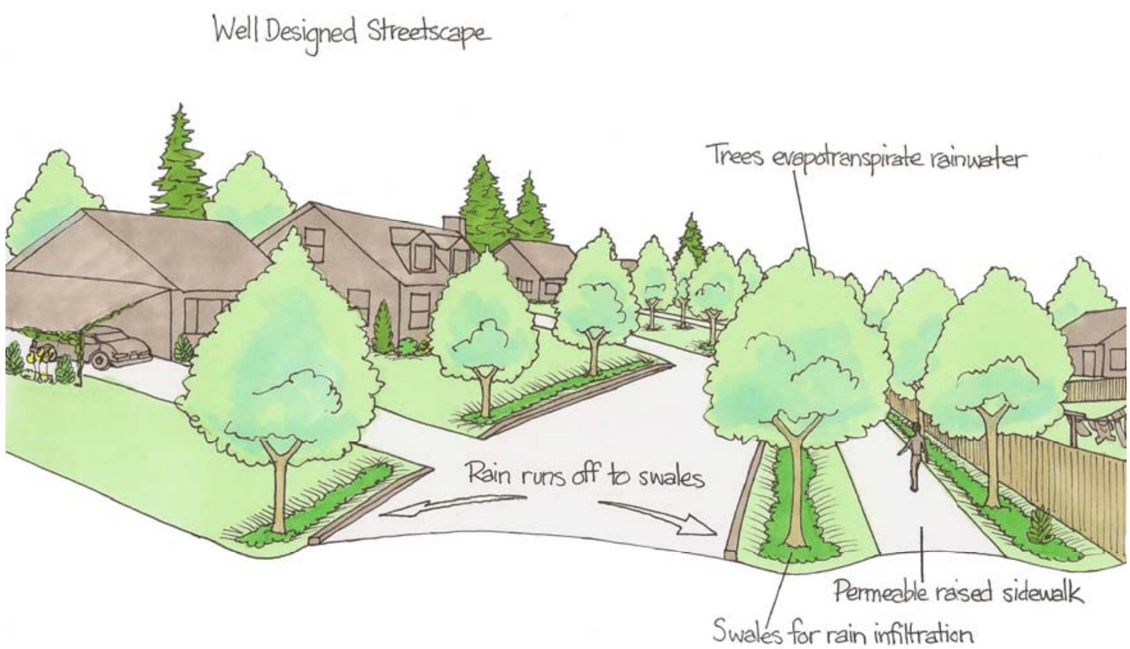


The City of Toronto Urban Forestry Services is currently engaged in a project to double the tree canopy in Toronto for a variety of benefits including reducing stormwater peaks. The value of trees for this purpose should be recognized in DWK.

Figure 13.10:

Well-Designed Parking Lot and Streetscape for Rainwater Retention





Treatment in Stormwater Ponds and Constructed Wetlands

When suitable land is available, constructed wetlands are a cost-effective means improving stormwater quality (Weiss et al, 2007). Constructed wetlands consist of interacting plants and animals that remove contaminants from the water column by mechanical filtration and biochemical conversion. These processes are summarized in Table 13.2.

Table 13.2: Contaminant Removal Mechanisms in a Constructed Wetland

Parameter	Removal mechanism in a constructed wetland
Suspended solids	Sedimentation, filtration
Biol. O2 Demand	Microbial degradation (aerobic, anaerobic) accumulation of organic material
Nitrogen	Bacterial de-nitrification; plant uptake; ammonia volatilization
Phosphorus	Soil adsorption/precipitation with Al, Fe, Ca, clay minerals; plant uptake
Pathogens	Sedimentation, UV deactivation, zooplankton predation; excretion of antibiotics from macrophyte roots
Trace metals	Adsorption/complexation with organic matter, plant uptake, microbial transformations

After Brix, 1993.

A major component of the wetland environment is microbial activity, which is limited by substrate surface area, nutrients and water temperature. The microbial contribution to wetland efficacy can be improved by increasing a wetland's substrate surface area and increasing water circulation rates through that substrate (Stewart at al., 2008). Even though constructed wetlands perform less effectively in cold weather, they can be designed to remain operational through the winter months. The effects of constructed wetlands on wildlife need to be monitored and ecotoxicological risks controlled (Crow et al., 2007).

One of the biggest constraints on the application wetlands and stormwater ponds in DWK is the shortage of low-slope land near water courses. Although they are not as good as large multi-stage wetlands, small stormwater ponds and wetlands can be effective if they are carefully designed. Table 13.3 summarizes a number of emerging styles of constructed wetlands/storm ponds in order of complexity.

Table 13.3: Types of Constructed Wetland/Pond Systems for Stormwater Treatment

Type	Main use	Main constraint	Lifespan
Dry detention	Used on high sediment stormwater settled sediment can be readily cleaned out	Provides the least water quality treatment of all pond systems	>20 yrs
Infiltration trenches	Used on the perimeter of parking lots or road to direct water to trees/shrub roots	Limited capacity high maintenance costs	N/A
Simple 2 stage surface flow	Highway run-off with brief detention and little treatment	Storm inflow volumes short-circuit especially when pond freezes	>5 yrs
Multi-stage sub-surface flow	Water travels slowly through root zones of marsh/ pond/ meadow for polishing stormwater and infiltrating	Low peak capacity; may accumulate toxicity –become unsuitable as habitat	>10 yrs
Harvested Wetlands	Reeds/sedge/cattail/or duckweed is grown then harvested for salt removal	More labor-intensive management	>10 yrs
Bio-island	Uses floating bio-island to maximize natural microbial water tmt for metal, nutrient, organic contaminant removal	Bio-island matrix is proprietary and expensive	>5 years
Biofilter	Mimic water treatment in natural wetland using planted filter strips	Can take years to establish	>10 yrs
Filter	Incorporates granular filtering media for debris and contaminant removal	Need constant maintenance	> 2 yrs
Alum-based	Used for highly contaminated stormwater	Creates sludge, sludge disposal issues	N/A
Massive >5 ha	Polishing stormwater to strict standards by incorporating many features of the ponds shown above	Large land acquisition	>10 yrs
Retention underground	Hold stormwater underground in pipe gallery then infiltrate it to ground for nutrient, metal, bacterial removal	Infiltrated volume cannot exceed groundwater capacity, can introduce contaminants	N/A
Detention underground	Temporary u/g storage then gradual release to wetland (beneath parking lots) to reduce peak loading rates to wetlands	Require pre-screening and maintenance of storage vessel	N/A

(Berezowski, 1995; Crow et al., 2007; Pries 2010; Reddy and Smith, 1989; Stewart et al., 2008; Zwick, 2010)

Stormwater Treatment in Small Constructed Ponds and Wetlands

The easiest stormwater treatment ponds to install in District of West Kelowna are the small surface flow ponds that perform primarily as settling and detention basins (Figure 13.11, 13.12) Stormwater sampling conducted in this study indicates that constructed ponds or wetlands large enough for suspended sediment to settle (sand / silt) also achieve a significant reduction in *E. coli* bacteria loads. The pond retained at the Lakewind (Medican) property is an excellent example of a functional pond that lowers bacteria counts despite resident waterfowl. It receives a mixture of stormwater and a diverted spring (Figure 13.11).

The appropriate sizing of a stormwater facility to achieve contaminant removal can be calculated from Table 13.4. The fall velocity of sand is rapid at >100 m/day, while fine clay is slow at 1 m/day and for free-floating bacteria, the fall velocity is negligible at 0.00354 m/day (Hayco, 2009; USGS 2007). The settling of individual bacteria would take months; but only a day or less after bacteria clumps with other materials (larger sediment particles, organics). Table 13.4 presents fall velocities in still water at 10-20^{o}C.

Table 13.4: Size and Fall Velocity Estimates for Stormwater Particulates

Material	Size	Fall velocity
Inorganic		
Sand	>63 – 100 microns	> 100 m/day
Silt	4 – 63 microns	21 m/day
Clay	0.1 – 4 microns	1 m/day
Marl	<1.5 microns	0.6 m/day
Biological		
Organic clumps	> 100 microns	>100 m/day
Large algae and diatoms	22 – 70 microns	< 50 m/day
Small algae	6 – 14 microns	<1 m/day
Lg filament cyanobacteria	5 x 200 microns	0.1 m/day
Sm filament cyanobacteria	1 x 100 microns	>0.007 m/day
Giardia / crypto cysts	4 – 8 microns	0.02 - 0.1 m/day
Bacteria – *E. coli*	0.7 – 10 microns	>0.0035 m/day

(Dia and Boll, 2006; USGS 2007; Hayco, 2009; Larratt 2010)

Very fine particles cannot be settled out in a simple pond but can be removed by filtering the water through a band of wetland vegetation.

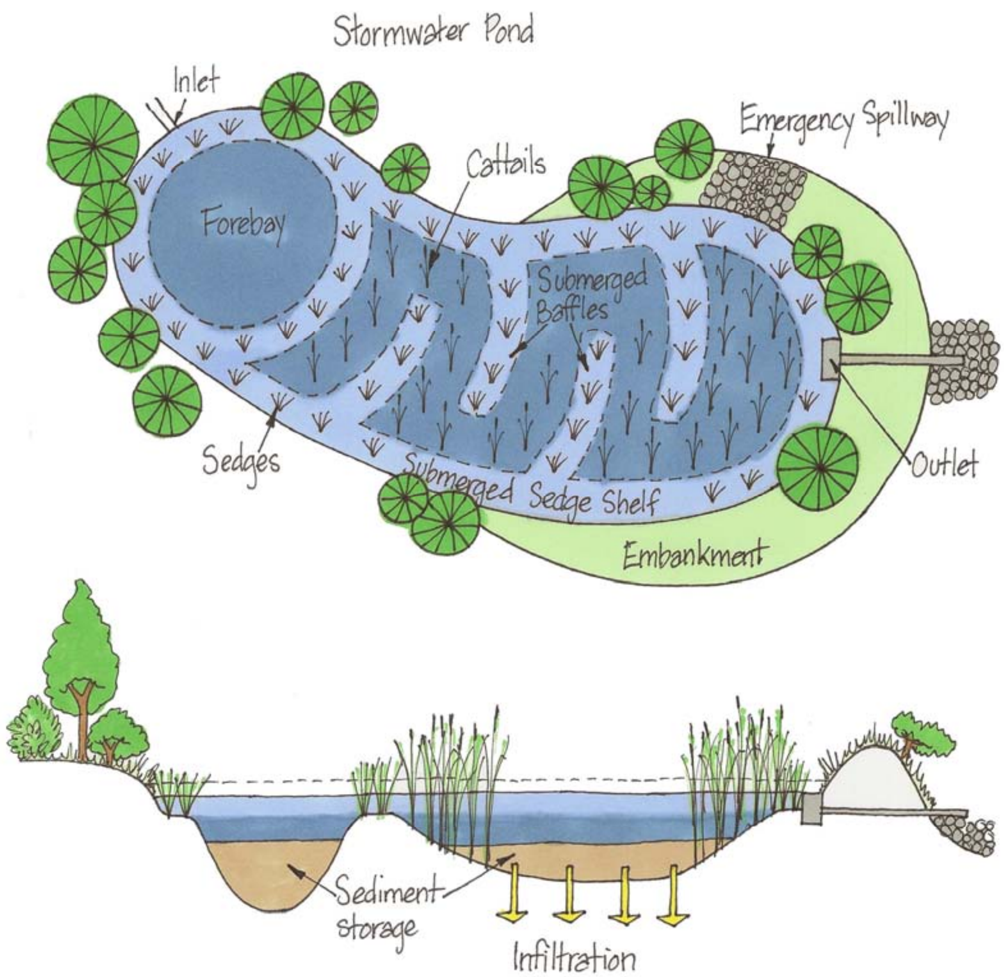
Figure 13.11: Constructed and Enhanced Stormwater Ponds in DWK

Stormwater ponds adjacent to Smith Creek, above Hwy 97

Preserved and enhanced ponds on Smith Creek, below Hwy 97

Figure 13.12 gives a generic design of a surface flow stormwater pond/wetland. It features a forebay for grit accumulation, submerged baffles to prevent short-circuiting in lower flows but allows storm peaks to travel quickly, and sedge/cattail plantings to further improve water quality. Unless the pond is lined to prevent it, water will infiltrate to ground.

Figure 13.12: Generic Design of Surface Flow Stormwater Ponds/Wetlands



The embankment around the perimeter of the pond could be planted with riparian vegetation. The submerged shelf could be planted with sedge, while rush and cattail will thrive in the deeper water. All of these riparian plants will host bacteria along their roots that sequester metals. Periodic dredging of accumulated sediment would be required.

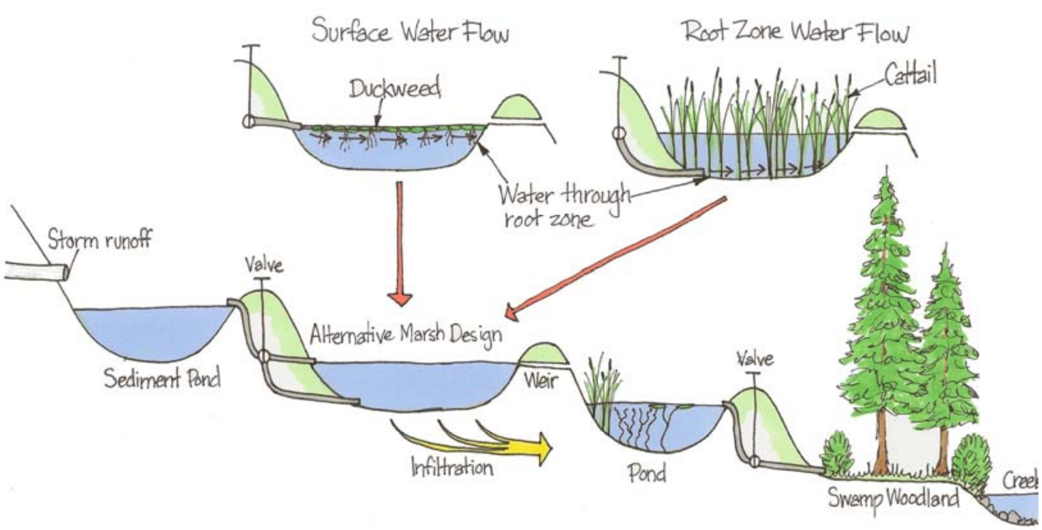
Harvesting the emergent vegetation can further improve nutrient and salt/metal removal from a stormwater system. Many researchers report limited value of wetlands for salt removal, however research involving selected harvesting of halophytic macrophytes (duckweed, cattail, sedge) has been effective for long-term salt removal (Hegedus et al., 2010). More metal including sodium is also taken up into the woody tissue of willows (Reddy and Smith, 1987). Small stormwater ponds could be developed below Highway 97 to intercept saline runoff and below the existing Medican pond to intercept storm flows.

Stormwater Treatment in Multi-stage Wetlands

Multi-stage wetlands are large and there are only a few locations in District of West Kelowna where they would be feasible. Like simple flow-through wetlands, multi-stage wetlands encourage initial sediment deposition but they also provide biological nutrient and bacteria removal. Pathogenic bacteria can be consumed in these wetlands by zooplankton and deactivated by sunlight or by aging (Wetzel, 2007).

Where metals and nutrients are excessive, wetland segments can be designed for harvesting using suitable plants (duckweed *Lemna minor;* cattail *Typha latifolia*; sedge *Carex spp*.; spikerush *Eleocharis spp*.; bulrush *Scirpus spp*.). Lower cells can pass water through the root zones of shrub willows for further polishing. These plants provide uptake and host microbes that remove nutrients and metals from stormwater. Since constructed wetlands that treat stormwater provide habitat opportunities, monitoring metal/toxin concentrations would be recommended.

Figure 13.13: Generic Design of Multi-stage Wetland for Stormwater Treatment



After Berezowski, 1996.

A good example of a multi-stage wetland is the wetland system on lower Keefe Creek (Figure 13.14). To be functional, multi-stage wetlands must be much larger than stormwater ponds. The Quail's Gate site would be an excellent choice for a constructed multi-stage wetland. There may be a second opportunity for a multi-stage wetland adjacent to the Medican pond, below Hwy 97 on WFN land. There is an existing depression on the property and management of WFN parking lot flows will be important to Smith Creek.

Figure 13.14: Enhanced Wetland on Lower Keefe Creek

Preserve and Restore Riparian Areas

Preserve wetlands and riparian areas

Existing wetlands should be conserved at all costs – purchasing land for a constructed wetland to treat stormwater can be prohibitively expensive or hydraulically impossible. Similarly, all riparian areas should be conserved to meet or exceed all legislation and bylaws.

Restore riparian areas

Riparian areas in the DWK can be restored by planting native trees/shrubs as nursery stock or as live stakes. Willow, cottonwood, red osier dogwood are all suitable as stakes. Willow poplar and cottonwood can be obtained as nursery stock. In several cases, the creek banks will have to be stabilized with rip-rap and/or live logs and re-sloped before planting can proceed. Restoration of damaged riparian areas with native shrubs along Smith Creek is a top priority, and then damaged stretches of McDougal, Keefe and Powers Creeks need to be addressed.

Direct communication with residents on water courses

Numerous examples of riparian damage by adjacent land-owners was noted during the sampling for this project. Riparian damage is documented in the SHIM section 5.3 of this report. In one extreme case, a resident near Bowen Creek built a shed on a bridge over the creek. Residents should be informed of the value of retaining riparian vegetation and encouraged to restrict fertilizer use and storage of hazardous chemicals near the watercourses of DWK.

13.8 SUMMARY

Key Findings for Stormwater Quality

In all creek systems except Smith, the upland reaches had low nitrate concentrations (<0.01 – 0.05 mg/L as N) and the lower reaches showed nutrient enrichment as stormwater collected nutrients off lawns/gardens, agricultural areas and possibly septic fields.

At the interface with Okanagan Lake, creeks in DWK carrying stormwater ranged from 1.52 to 7.21 mg/L nitrate as N while the range of total nitrogen is 0.13 – 0.35 mg/L as N for Okanagan Lake. The stormwater nitrate loading causes a “halo” of enriched algae growth around the mouth of these creeks.

In this study, chloride concentrations increased where run-off from Highway 97 entered a drainage system. Other roads in West Kelowna did not contribute the salinity that flows off the highway did. Most metal concentrations correlated with chloride in the DWK stormwater quality sampling.

E. coli counts were low (20 – 40 cfu/100 mL) for raw water in the upper reaches of every creek system of West Kelowna. Once the drainage system received run-off from urban paved areas, *E. coli* counts climbed. Bacteria counts were particularly high along ditched and urbanized Smith Creek and Tomat Creek.

Stormwater sampling in this study indicate that constructed ponds or wetlands large enough for suspended sediment to settle (sand / silt) also achieve a significant reduction in *E. coli* bacteria loads. The appropriate sizing of a stormwater facility to achieve contaminant settling can be calculated from Table 13.4.

The depth in Okanagan Lake that stormwater / creek plumes travel in will be deeper in the fall/winter than in the summer. Stormwater plumes are the most immediate potential source of contaminants to shallow domestic water intakes in West Kelowna including WFN#9, Shanboolard and Sunnyside intakes.

DWK should consider a multiple-barrier approach aimed at reducing urban stormwater pollution by encouraging source reduction in addition to stormwater ponds, wetlands and detention storage. The ultimate recipient of stormwater from DWK and WFN lands is Okanagan Lake. Both Smith Creek and Powers Creek discharge into Gellatly Bay – a key summer destination and both creeks are currently degraded by stormwater.

Recommendations for Stormwater Quality Improvement

General

- Conserve all existing wetlands within DWK jurisdiction
- Conserve existing intact riparian areas on all creeks with DWK
- Conduct an *E. coli* ribo-typing experiment and include sample sites that showed consistently high bacterial counts in this study (e.g. Powers, Smith drainages); then target a reduction in the bacterial sources identified.
- Encourage reduction of stormwater volumes through a publicity blitz on rain gardens, and reducing impermeable surfaces in hydraulically suitable areas
- Incorporate swales into subdivision and parking lot design
- Consider detention reservoirs beneath large parking lots to reduce peak storm flows
- Residents with creeks adjacent to their properties should be informed of the value of retaining riparian vegetation and encouraged to restrict fertilizer use and storage of hazardous chemicals near creeks in DWK
- Encourage dog-owners to pick after their pets during the winter months, particularly at the DWK Gellatly dog beach

Specific

- Engage WFN in discussion of construction of an off-channel multi-stage wetland beside the Medican pond to treat Hwy 97, parking lot and Smith Creek storm flows (on WFN lands)

- Small sedge stormwater ponds could be developed below Highway 97 to intercept saline runoff before it reaches creeks

- Small stormwater pond(s) could be developed immediately below the existing Medican pond to intercept Smith Creek storm flows.

- Re-plant damaged riparian areas with native shrubs along Smith Creek as a top priority, and then damaged stretches of McDougall, Keefe and Powers Creeks as indicated in the SHIM work

- Design and develop a multi-stage wetland below Quail’s Gate Winery to intercept and treat turbid stormwater based on samples collected in this study and additional water quality samples to be taken during a summer season

- Develop a multi-stage wetland below Quail’s Gate Winery to intercept and treat turbid stormwater. As a first phase, convey the Bowen drainage to a 200 m serpentine ditch planted with riparian species.

- Identify sources of nutrients in Casa Loma seepage and consider a small nutrient removal wetland (harvested) below the foot bridge in Kalamoir Park

- Identify cause/source of extremely high nutrient/ metal seepage discharging to Okanagan Lake immediately north of Kinsman Park (outfall 4-1 WFN land)

- Establish Gellatly Bay as a priority water quality area and commence remediation of creeks receiving stormwater that report to Gellatly Bay

Appendix 13.1: Stormwater Water Quality Data DWK 2009-2010

Table 1: DWK Stormwater Quality Results 2009 - 2010

high result result of concern result of high concern	rain event	Nitrate as N mg/L 0.01	Sodium mg/L 0.1	Chloride mg/L 0.1	E. coli CFU/100m 1
Powers12-1 wetland at Hwy	26-Nov-09		12.8	16.9	E.coli OG
Powers 10-3 u/s Hwy 97	26-Nov-09	2.4	8.89	11.1	17
Powers 10-2 at Gellatly	26-Nov-09		13.7	14.5	26
Powers 10-1 at mouth	26-Nov-09	2.21	12.8	14.3	14
Outfall 4-1 at Kinsman Pk	26-Nov-09	5.63	203	90.7	<1
Smith1-2 at Dog Beach	26-Nov-09	2.45	46.8	22.9	110
Smith 1-3 Medican Pond	26-Nov-09		136	20.2	11
Smith 1-4 at Zellers WFN	26-Nov-09		17	16.6	E. coli OG
Westbank 1-5 at Dogwood	26-Nov-09	5.31	13.4	16.6	6
McDougall3-6 at Bridge	26-Nov-09		8.39	1.19	13
McDougall5-3 at Elk Rd	26-Nov-09		40.9	31.4	23
McDougall 5-2 at Ok Lk	26-Nov-09	1.52	45.9	32.6	21
Bowen 11-1 at Ok Lk	26-Nov-09	5.41	83.4	33.3	350
Keefe 6-4 at LID gate	26-Nov-09	<0.01	11.5	2.16	2
Keefe 6-3 at Horizon Hairpin	26-Nov-09		35	17.5	9
Keefe 6-2 at Westside Rd	26-Nov-09	2.01	35.4	18.2	4
Keefe 6-1 at Ok Lk	26-Nov-09	1.73	37.3	23.6	7
Casa Loma 7-2 seepage -Lk	26-Nov-09	3.88	98.5	35.1	3

OG = overgrown

high result result of concern result of high concern	rain on snow	Nitrate as N mg/L 0.01	Chloride mg/L 0.1	E. coli CFU/100m 1	E. coli MPN/100m 3
Powers12-1 wetland at Hwy	11-Jan-10	0.06	236		91
Powers 10-3 u/s Hwy 97	11-Jan-10		13.1	17	
Powers 10-2 at Gellatly	11-Jan-10		46		7500
Powers 10-1 at mouth	11-Jan-10	2.55	48.9	130	
Outfall 4-1 at Kinsman Pk	11-Jan-10	6.85	135	<1	
Smith1-2 at Dog Beach	11-Jan-10	2.43	46		750
Smith 1-3 Medican Pond	11-Jan-10		28.2	8	
Spring 1-8 at Medican Pond	11-Jan-10		28.8	<1	
Smith 1-4 at Zellers WFN	11-Jan-10		31		24000
Westbank 1-5 at Dogwood	11-Jan-10	6.84	22.2	41	
Bowen11-2 ravine stormdr	11-Jan-10	0.37	26.9		110000
Bowen 11-8 d/s ravine pond	11-Jan-10	2.87	53.1	26	
Bowen 11-1 at Ok Lk	11-Jan-10	5.91	39.5	58	
Bowen 11-3 Tuscany st-dr	11-Jan-10		135		91
Quail 11-4 at Boucherie Rd	11-Jan-10	3.02	33.3	130	
Quail 11-7 at Ok Lk	11-Jan-10	2.85	38.9	140	
McDougall3-6 at Bridge	11-Jan-10		21.7	22	
McDougall5-3 at Elk Rd	11-Jan-10		78.3		230
McDougall 5-2 at Ok Lk	11-Jan-10	2.12	125	18	
Casa Loma 7-2 seepage -Lk	11-Jan-10	5.24	48.3	<1	
Keefe 6-4 at LID gate	11-Jan-10	0.02	2.59	110	
Keefe 6-3 at Horizon Hairpin	11-Jan-10		53.6		230
Keefe 6-2 at Westside Rd	11-Jan-10	1.98	63.9		36
Keefe 6-1 at Ok Lk	11-Jan-10	1.88	76.5	92	

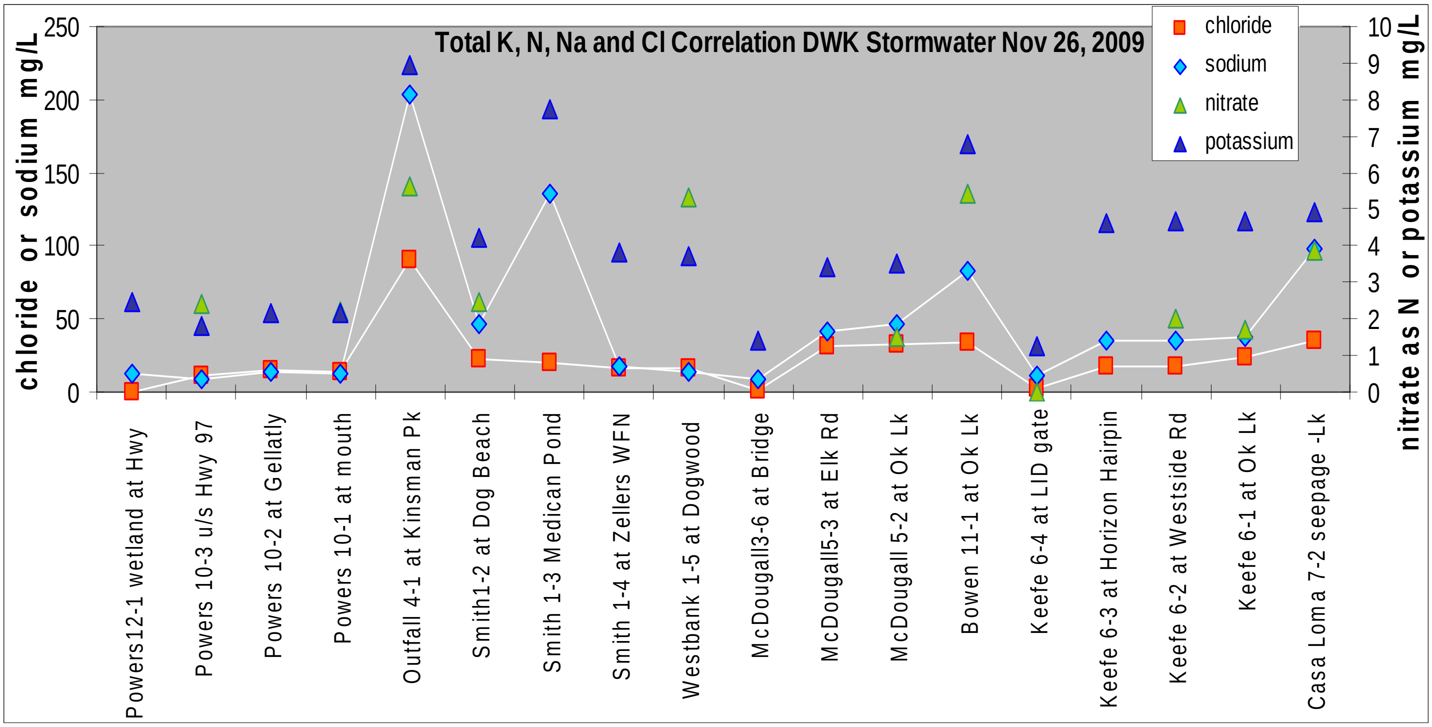
high result result of concern result of high concern	sm freshet	Nitrate as N mg/L 0.01	Chloride mg/L 0.1	E. coli CFU/100m 1	E. coli MPN/100m 3
Powers12-1 wetland at Hwy	12-Apr-10	<0.01	77	<1	
Powers 10-3 u/s Hwy 97	12-Apr-10	2.31	13.1	87	
Powers 10-2 at Gellatly	12-Apr-10	1.93	13.3	1	
Powers 10-1 at mouth	12-Apr-10	1.86	13	1	
Outfall 4-1 at Kinsman Pk	12-Apr-10	7.09	129	<1	
Smith1-2 at Dog Beach	12-Apr-10	2.92	33.6	58	
Smith 1-3 Medican Pond	12-Apr-10	0.21	26.4	1	
Spring 1-8 at Medican Pond	12-Apr-10	0.53	28	<1	
Smith 1-4 at Zellers WFN	12-Apr-10	4.09	25.8	700	
Westbank 1-5 at Dogwood	12-Apr-10	8.02	23.8	44	
Bowen 11-8 d/s ravine pond	12-Apr-10	3.98	62.4	5	
Bowen 11-1 at Ok Lk	12-Apr-10	7.21	47.4	120	
Quail 11-4 at Boucherie Rd	12-Apr-10	4.22	53.3	<1	
Quail 11-7 at Ok Lk	12-Apr-10	1.56	52.7	6	
McDougall3-6 at Bridge	12-Apr-10	0.04	1.37	60	
McDougall5-3 at Elk Rd	12-Apr-10	1.58	34.9	21	
McDougall 5-2 at Ok Lk	12-Apr-10	1.43	41	2	
Casa Loma 7-2 seepage -Lk	12-Apr-10	5.27	47.8	3	
Keefe 6-4 at LID gate	12-Apr-10	<0.01	3.06	20	
Keefe 6-3 at Horizon Hairpin	12-Apr-10	2.44	23.6	10	
Keefe 6-2 at Westside Rd	12-Apr-10	2.36	24	10	
Keefe 6-1 at Ok Lk	12-Apr-10	2.01	31.1	7	
6 - 8 West Kel Estates	12-Apr-10	0.87	18.5	1	

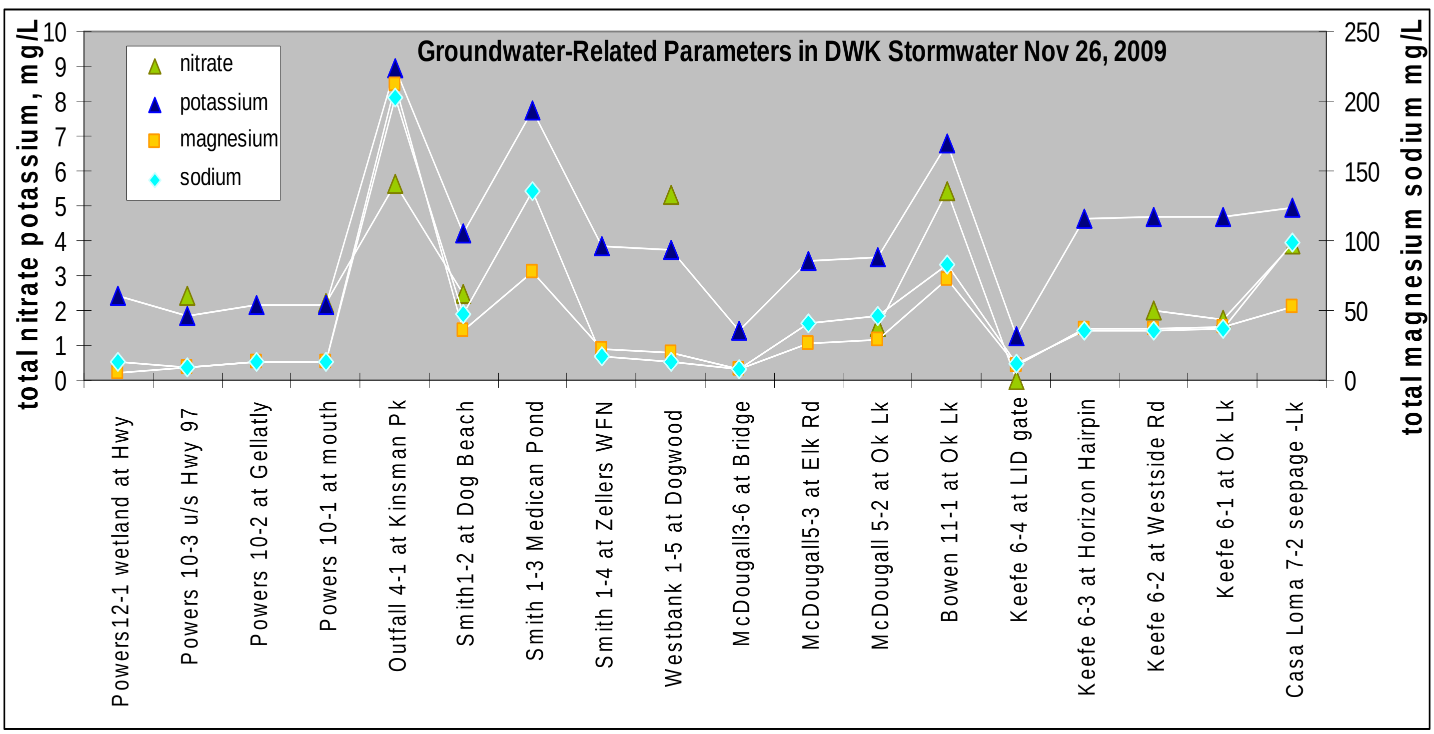
Appendix 13.1 Table 2

Table 2: Water Chemistry of Seepage/Stormwater Near Quail’s Gate Winery

high result result of concern result of high concern	Quail's Seep 2009/10	11-4 Quail's Boucherie 15-Jan-10	11-7 Quail's at Ok Lk 15-Jan-10	11-4 Quail's Boucherie 11-Feb-10	11-7 Quail's at Ok LK 11-Feb-10	11-4 Quail' Boucherie 12-Apr-10	11-7 Quail' at Ok LK 12-Apr-10
Colour, True	Color Unit	8	14	7	16	<5	
Alkalinity, Total as CaCO3	mg/L	457	452	534	491	521	
Carbon, Total Organic	mg/L	8.1	8.8	17.4	13.1	13.6	
Chloride	mg/L	33.3	38.9	40.1	40.8	53.3	52.7
Nitrogen, Nitrate as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Nitrite as N	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen, Dissolved Kjeldahl,	mg/L	0.37	0.25	0.33	0.34	0.36	0.31
Nitrogen, Nitrate+Nitrite as N	mg/L	3.02	2.85	4.58	3.31	4.22	1.56
Nitrogen, Total Dissolved	mg/L	3.38	3.1	4.91	3.64	4.58	1.87
Phosphorus, Total	mg/L	0.1	0.1	0.13	0.23	0.03	
Phosphorus, Dissolved	mg/L	0.07	0.09	0.05	0.04	0.02	
Solids, Total Suspended	mg/L	15	2	104	2	10	
pH	pH Units	8.28	8.27	8.28	8.26	8.39	
Iron	mg/L	0.4	<0.10	7.23	<0.10	1.23	
E. coli	CFU/100m	130	140	<1	7	<1	6
Conductivity (EC)	uS/cm					1220	
Hardness (as CaCO3)	mg/L					400	
Calcium	mg/L					71.4	
Iron	mg/L					1.23	
Magnesium	mg/L					53.8	

Appendix 13.1
Figure 1: Metals in District of West Kelowna Stormwater 2009 - 2010





NOTES: Groundwater appears to influence Outfall 4-1, Medican Pond (has spring inflow) and Bowen Ck at Okanagan Lake

Appendix 13.1
Table 2

high result
result of concern
result of high concern

Full Metals Scan from DWK SWMP Sampling, November 26, 2009

DWK SWMP Metals scan 2009			Powers12-1 v	Powers 10-3	Powers 10-2	Powers 10-1	Outfall 4-1 at	Smith1-2 at D	Smith 1-3 Me	Smith 1-4 at	Westbank 1-5	McDougall3-6	McDougall5-3	McDougall 5-	Bowen 11-1 a	Keefe 6-4 at	Keefe 6-3 at	Keefe 6-2 at	Keefe 6-1 at	Casa Loma 7-
			wetland Hwy	u/s Hwy	at Gellatly	at mouth	low volume	Dog Beach	Medican Pd	Zellers/Tom	Dogwood N	at bridge	Elk Rd	at Ok Lk	at Ok Lk	at LID gate	Horizon	Westside R	at OK Lk	seepage
Parameter	units	RDL	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09	26-Nov-09
Nitrate as N	mg/L	0.01		2.4		2.21	5.63	2.45			5.31			1.52	5.41	<0.01		2.01	1.73	3.88
Chloride	mg/L	0.1		11.1	14.5	14.3	90.7	22.9	20.2	16.6	16.6	1.19	31.4	32.6	33.3	2.16	17.5	18.2	23.6	35.1
Aluminum	mg/L	0.05	0.82	<0.050	<0.050	<0.050	<0.050	0.258	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.084	0.067	0.07	0.202
Antimony	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.0088	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium	mg/L	0.005	0.0387	0.0165	0.0202	0.0209	0.0282	0.0293	0.0346	0.0283	0.0206	<0.0050	0.0285	0.0293	0.0452	<0.0050	0.0414	0.0379	0.0428	0.011
Beryllium	mg/L	0.001	<0.0010	<0.0010	0.001	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0017	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010
Bismuth	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron	mg/L	0.02	0.039	0.032	0.033	0.027	0.049	0.048	0.056	0.049	0.045	<0.020	0.044	0.039	0.091	<0.020	0.038	0.038	0.034	0.052
Cadmium	mg/L	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	mg/L	1	28.1	37.5	47.2	44.7	490	96.5	124	78.9	96.8	36.3	88.3	94	92.3	46.2	152	146	139	92.8
Chromium	mg/L	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.0135	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0132	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt	mg/L	0.0005	0.00054	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Copper	mg/L	0.001	0.005	<0.0010	0.0013	0.0012	0.0037	0.0025	0.0024	0.0012	<0.0010	<0.0010	0.0029	0.0021	0.0021	0.0014	0.0011	0.0019	0.0021	0.0027
Iron	mg/L	0.1	0.88	<0.10	<0.10	<0.10	0.59	0.36	0.18	<0.10	0.1	<0.10	0.94	<0.10	<0.10	<0.10	0.24	0.2	0.2	0.26
Lead	mg/L	0.001	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium	mg/L	0.001	0.0036	0.0039	0.0045	0.0053	0.0192	0.0142	0.0176	0.0109	0.0095	0.0041	0.0125	0.0129	0.0148	0.0085	0.0135	0.0135	0.016	0.0106
Magnesium	mg/L	0.1	5.01	9.4	13.7	13.1	212	35.5	77.1	22.5	19.8	7.95	26.6	28.9	72.7	10.8	36.7	37.4	37.7	53.1
Manganese	mg/L	0.002	0.316	<0.0020	0.0025	0.0027	0.0035	0.019	0.0892	0.0035	<0.0020	<0.0020	0.0091	<0.0020	0.0042	<0.0020	0.0136	0.006	0.0226	0.0052
Mercury	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Molybdenum	mg/L	0.001	0.0013	0.0019	0.0027	0.0025	0.0119	0.0069	0.0232	0.0055	0.0027	0.0021	0.0047	0.0034	0.0088	0.0027	0.0027	0.0027	0.0036	0.0095
Nickel	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	0.0075	0.0027	0.0024	<0.0020	<0.0020	<0.0020	0.0037	0.0032	0.0024	<0.0020	0.0031	0.003	0.0029	0.0022
Phosphorus	mg/L	0.2	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Potassium	mg/L	0.1	2.44	1.83	2.16	2.17	8.94	4.21	7.73	3.82	3.73	1.4	3.42	3.53	6.78	1.26	4.64	4.67	4.67	4.93
Selenium	mg/L	0.003	<0.0030	<0.0030	<0.0030	<0.0030	0.249	<0.0030	0.0047	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0161	<0.0030	0.0072	0.0063	0.0065	0.0357
Silicon	mg/L	2	7.6	5.7	6.7	6.4	11.5	13.3	11.2	10.7	11.9	10.4	11.8	11.4	10.5	14.1	10	9.9	10.4	8.8
Silver	mg/L	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Sodium	mg/L	0.1	12.8	8.89	13.7	12.8	203	46.8	136	17	13.4	8.39	40.9	45.9	83.4	11.5	35	35.4	37.3	98.5
Strontium	mg/L	0.005	0.2	0.184	0.291	0.276	3.23	0.671	1.17	0.533	0.381	0.214	0.721	0.76	1.2	0.174	0.816	0.81	0.796	0.521
Tellurium	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Thallium	mg/L	0.0002	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thorium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Tin	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Uranium	mg/L	0.0002	0.00027	0.0029	0.00424	0.00403	0.0923	0.012	0.0305	0.0096	0.00847	0.0025	0.00874	0.00992	0.0312	0.00062	0.0178	0.0174	0.0181	0.057
Vanadium	mg/L	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc	mg/L	0.01	0.111	<0.010	<0.010	<0.010	<0.010	0.02	0.088	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.022
Zirconium	mg/L	0.001	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010

Appendix 13.2: *E. coli* Source Tracking in City of Kelowna Creeks Receiving Stormwater and at Beaches

City of Kelowna Creeks with Storm Water 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	13
Canine	6	25
Bovine		0
Horse		0
Song birds		0
Gulls	1	4
Duck	7	29
Canada Goose	1	4
Racoon		0
Deer	4	17
Unknown	2	8
SUM	24	100

City of Kelowna Creeks and Beaches 200(
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	8	8
Canine	15	14
Bovine	1	1
Horse		0
Song birds	14	13
Gulls	18	17
Duck	20	19
Canada Goose	16	15
Racoon	4	4
Deer	5	5
Unknown	4	4
SUM	105	100

City of Kelowna Creeks with Storm Water 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	5
Canine	2	3
Bovine	6	9
Horse	2	3
Song birds	14	21
Gulls	5	8
Duck	7	11
Canada Goose	12	18
Racoon	1	1
Deer	6	9
Unknown	8	12
SUM	66	100

City of Kelowna Creeks and Beaches 200ɛ
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	10	5
Canine	13	6
Bovine	21	10
Horse	11	5
Song birds	44	21
Gulls	18	8
Duck	18	8
Canada Goose	26	12
Racoon	6	3
Deer	19	9
Unknown	28	13
SUM	214	100

- Courtesy of City of Kelowna
M. Toma

Appendix 13.3: GPS Locations of DWK Stormwater Sample Points

Site Names by Drainage System	GPS	GPS – co ordinates
Smith/Tomat Creek Drainage		
1-5 Westbank Ck at Dogwood N.	237	N49.838565° W119.635982°
1-4 Smith Ck at Zellers WFN	410	N49.834713° W119.622351°
1-8 Spring at Medican Pond	409	N49.830068° W119.618979°
1-3 Medican Pond	409	N49.830148° W119.619230°
1-2 Smith Ck at Dog Beach	408	N49.823280° W119.617564°
4-1 Outfall at Kinsman Beach	407	N49.824225° W119.613980°
Powers Creek Drainage		
12-1 wetland at Hwy 97	403	N49.823971° W119.647947°
10-3 Powers u/s of Hwy 97	404	N49.828749° W119.643672°
10-2 Powers at Gellatly	405	N49.814506° W119.631762°
10-1 Powers at Mouth	406	N49.816103° W119.622752°
McDougall Creek Drainage		
11-3 storm drain at Tuscany villa		N49.827686° W119.600166°
3-6 McDougal at bridge	412	N49.868268° W119.592032°
5-3 McDougall at Elk Rd WFN	413	N49.837790° W119.598839°
5-2 McDougall mouth at Ok Lk	414	N49.822366° W119.595506°
Faulkner/Keefe Creek Drainage		
6-4 Keefe at LID gate	416	N49.879823° W119.578921°
6-3 Keefe at Horizon hairpin	417	N49.876594° W119.548420°
6-2 Keefe at Westside Rd WFN	420	N49.884319° W119.542687°
6-1 Keefe at mouth Ok Lk WFN	419	N49.893703° W119.538085°
6-8 West Kel Estates seepage		N49.889910° W119.553948°
Casa Loma Spring Drainage		
7-2 Casa Loma seepage	418	N49.855249° W119.538730°
Bowen Creek Drainage		
11-2 ravine stormdrain		N49.847707° W119.557943°
11-8 Bowen d/s ravine pond		N 49.844824° W 119.558562°
11-1 Bowen at mouth Ok Lk	415	N49.840280° W119.557872°
11-4 Quail at Boucherie Rd	426	N49.841204° W119.572650°
11-7 Quail at Ok Lk (braided)	428	N49.837725° W119.570827°

Appendix 13.4:
Shoreline Plankton Tows from Gellatly Bay, Okanagan Lake
November 3, 2009

Toxin Possible	cell size approx vol cubic microns	Algae samples in abundance classe	Okanagan Lake Gellatly Bay November 3 2009 Shoreline tows through shallow water 2009			
			Nov 3	*Nov 5*	*Nov 5*	*Nov 5*
	Biovolume	**DIATOMS**	Rotary B	Rotary B	Ferry Dock	The Cove
	80	Acnanthes spp.	P	P	P	P
		Asterionella formosa			P	
	230	Aulacoseira italica		L		
		Cymbella spp		P		P
		Fragilaria capucina		P		L
	120	Fragilaria crotonensis			C	L
	750	Gomphonema sp.	L	L		
	500	Navicula spp.			L	
		Pinnularia gibba				
	1500	Rapholodia gibba	L	P		L
	100	Synedra acus			C	L
	500	Tabellaria fenestrata				
		YELLOW-BROWN ALGAE				
		Botryococcus	D			
	500	Cryptomonas ovata				P
		DESMIDS				
		Cosmarium spp.				
		GREEN ALGAE				
	150	Closteriopsis longissima				
		BLUE-GREEN ALGAE				
X		Anacytis cyanea			**L**	
X		Anabaena planktonica	C			
		Pseudanabaena				P
X	2	Planktolyngbya limnetica	**L**	**C**	**C**	D
		Limnothrix redekei				
X	10	Planktothrix agardhii	**D**	**L**	L	**L**
X	5	Synechocystis sp.		M		L
X	5	Synechococcus	L			
		DINOFLAGELLATES				
	700	Peridinium sp. (large)				
		PROTOZOA				
	3	micro-flagellates	L	L	M	M
	20	Large flagellates	L	L	M	M
	180	ciliates		L	L	L
	1	bacteria	**H**	**H**	**M**	L
		detritus	**L**	**VH**	**C**	L
	5-100	silt	L	M	**L**	L
		DENSITY	high	mod	mod	mod
		Notes		debris!	copepods	

P=Present L=Low M=Moderate =Common H=High D=Dominsant