Methods for Measuring and Assessing Nonpoint Source Pollutant Control at a Regional Stormwater Management Facility

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Leonard A. Shabman, Director

TABLE OF CONTENTS

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1.0 OBJECTIVES AND BACKGROUND

ABSTRACT

This report summarizes work completed on the installation of water quality monitoring equipment and the assessment of initial baseline conditions at the Virginia Tech Regional Stormwater Facility located on the main campus in Blacksburg, Virginia. The long-term goal of the research is to assess the pollutant removal efficiency of the regional stormwater facility, consisting of an upper wet pond and a lower dry pond in series. It was constructed in September 1997. Results collected thus far indicate that the biological condition of the pond area was impaired prior to the construction disturbance at the site and remained so after construction. There is evidence of excessive sedimentation during construction and in the post-construction period. However, there is also some limited evidence that the biological condition in the lower ponding area is beginning to recover, although this is expected to take place at a very slow rate. Again, severe sedimentation and the delivery of attached pollutants is the primary cause of degradation. At this time, all four water quality samplers and flow stations have been installed at the regional pond facility and a complete weather station has been built atop the lower pond dam. The collection and analysis of longer-term data on pond performance can now begin.

OBJECTIVES

The intended function of the regional facility is to control flooding in the lower pond and to remove major non-point source (NPS) pollutants such as total nitrogen, total phosphorus, metals, bacteria, organic compounds, and suspended sediment in the upper pond. Greater removal of these constituents is expected when using a wet retention pond in conjunction with a dry detention pond. The purpose of this study was to install flow and water quality monitoring equipment and *begin* the assessment of pollutant removal performance by collecting grab samples for nutrients, total suspended solids, metals, and bacteriological analysis. In addition, seasonal macroinvertebrate surveys were conducted to assess biotic quality. Thus, a baseline condition could be established at the site. A further objective was to build a weather station for observing basic meteorological variables such as rainfall, air and soil temperature, pan evaporation, solar radiation, wind speed, and relative humidty. All instrumentation has been set up for automated data collection. Also wetland characteristics, functions, and values to the system will be investigated. In the future, when longer-term water quantity and quality measurements have been recorded at the selected monitoring sites, the overall performance of this stormwater management system will be compared to other urban stormwater control practices located on the Virginia Tech campus and elsewhere in the United States. This phase of the study deals only with the background monitoring equipment installation, initial grab sampling, and macroinvertebrate baseline stages of the total project.

BACKGROUND

There is a long history of government legislation and regulation to protect freshwater natural resources, but the foundation for today's programs lies in the Clean Water Act of 1972 and its amendments of 1987. The objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The act explains that pollution "means the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water."

Dramatic increases in impervious land cover resulting from human development produce two hydrologic changes in the watershed. First, it increases the volume of runoff that flows into natural drainage systems by reducing infiltration; and second, it decreases the time to reach the peak flow by smoothing the land surface. The energy of these runoff waters increases channel erosion and downstream flooding, alters stream channels, and damages wildlife habitat.

Not only does urban runoff differ in quantity from natural drainage water, but it also differs in quality. The National Water Quality Inventory has reported that urban runoff is a major source of water quality impairment, as shown in the following table.

Table 1. Top three source of water quality impairment (USEPA 1997)

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Municipal Point Sources
2	Municipal Point Sources	Urban Runoff / Storm Sewers	Urban Runoff / Storm Sewers
3	Urban Runoff / Storm Sewers	Hydrologic / Habitat Modification	Agriculture

Urban runoff carries with it high sediment loads from areas of low vegetative cover (ex: construction sites), high nutrient loads especially nitrogen and phosphorus (ex: fertilizer from lawns and deicing projects), and toxic chemicals including heavy metals (ex: corrosion of alloys, vehicles, pavement, paint). Also associated with urban runoff are pesticides, petroleum products, bacteria and viruses, and a high biological oxygen demand (BOD) due to organic matter inputs. The amount of pollutants carried in stormwater runoff or snowmelt is influenced by traffic density, amount of litter, fertilizer and pesticide use, construction site practices, animal waste, soil characteristics, topography of the area, percentage of impervious surfaces, atmospheric deposition, and precipitation.

The quality of stormwater runoff from developed watersheds must be improved before it is released into natural systems. Over the past fifty years, small ponds have become an integral part of this restoration process. Federal EPA mandates reducing non-point source pollution associated with urban and agricultural stormwater runoff (1990 NPDES rules pursuant to the Clean Water Act) and promoting the development of new and improved methods for reducing degradation of water quality in urban areas (Allan et al. 1997)

STORMWATER MANAGEMENT FACILITIES

Flood mitigation has been the primary motivation for the purpose of controlling urban runoff in the past. Dry detention basins are often implemented for this purpose on construction sites to temporarily store stormwater. These basins slow the runoff velocity and reduce the movement of sediment to downstream water bodies by releasing water at a controlled rate. Although this is an effective water quantity control and sediment load reduction measure, it does not improve the quality of urban runoff significantly. Dissolved pollutants pass through the facility, and often sediment and its adsorbed pollutants, and are resuspended during the subsequent storms and lost downstream (Adams and Dove 1984). Water quality improvements occur naturally by biological and bio-geochemical processes, particularly in wetlands. This led to a new generation of best management practices (BMPs) for stormwater runoff in urban areas, such as retention basins. Synonyms for retention basins include water quality ponds, wet ponds, and permanent water impoundments.

Both water quantity and water quality facilities are needed for efficient stormwater management. A water quality facility must capture and treat the first flush (most concentrated flow) of pollutants in the runoff. Retention basins capture the entire small storm events (rainfall depths less than 2.54 cm) and the first flush of larger storms, which carry the highest pollutant concentrations (Novotny 1994). The permanent pond partially alleviates certain problems that occur with dry detention basins. First, because they are usually designed as flood control facilities with sizable outlets, dry detention basins may allow the first flush to pass through, unimpeded, before substantial ponding occurs behind the outlet. Second, smaller storm events flowing into a dry detention basin may not be retained long enough for a significant settling of pollutants to occur. Most importantly, a retention basin is designed for an average hydraulic detention time of 1-2 weeks, as compared to the extended dry detention time of 12-24 hours (Novotny 1994). Detention time is the key factor affecting pollutant reductions through physical, biological, and biogeochemical processes. However, while retention basins capture the total volume from the majority of storms, dry detention basins are needed to capture large storm events that exceed the design criteria and assure flood mitigation downstream. Thus, both a wet retention and a dry detention basin are needed to complement each other in stormwater management.

A retention basin is less effective in water quality treatment if it is improperly designed or maintained. The primary design specification of a retention basin is its size. The facilities are designed to capture a certain volume of runoff and/or achieve a particular rate of nutrient removal given a minimum detention time. Wet pond retention time can be estimated by dividing the volume of the pond by the average flow rate. However, this method is oversimplified, for it assumes complete mixing and does not account for the frequent problem of short-circuiting. The inflow rate divided by the surface area of the pond may be a better predictor of pond performance. Other variables related to retention and mixing include seasonal changes in stormwater volume, inflow rates, and pond and stormwater temperatures (thermal gradients control vertical mixing) (Gain 1996). Furthermore, required retention time will change according to the time interval between the storms, individual constituent availability, micro flora and fauna population dynamics, oxidizing and reducing conditions, and dissolved oxygen concentrations (Gain 1996). The relationship of retention time to dissolved pollutants is highly problematic. It is doubtful that any significant removal of the dissolved fraction can occur with normal retention times.

Research still continues on the development of optimal design and standard criteria; however, stormwater retention ponds have several common characteristics. First, an impermeable subsurface layer is often needed to maintain the suggested permanent water pool depth of 3 to 10 feet (Novotny 1994). Wetland wildlife value is enhanced if the water is 15-24 inches deep for 25-50 percent of the water surface area and 3-4 feet for 50-75 percent of the water surface area (Adams and Dove 1984). Second, the pond is designed with mild side slopes (10:1 or less) which enhance the habitat values (Adams and Dove 1984). Third, additional basin volume is created to allow for temporary storage of storm water runoff, although Guo and Adams (1994) found that wet ponds with large permanent pools provide more efficient suspended solids removal than ponds which sacrifice area to temporary storage. Fourth, a release mechanism is installed to gradually dewater the temporary storage volume at the pre-development peak discharge rate to prevent harmful impacts on the downstream channel and habitat (Novotny 1994). Finally, during construction, topsoil should be conserved and later relaid on the basin's edge to act as a seedbed and to support emergent vegetation along the pond's edge.

SPECIFIC POLLUTANTS AND THEIR REMOVAL EFFICIENCIES

Design of wet ponds and constructed wetlands is currently more art than science, because their pollutant removal efficiencies are highly variable and complex. Researchers and regulatory agencies are trying to improve the current state of knowledge on these facilities. Removal mechanisms of bacteria, dissolved metals, and hydrocarbons must be understood in terms of process dynamics, hydrological interactions, and contaminant transport (Crumpton et al. 1995). Many other variables need to be considered in studies of wet pond facilities. A summary of factors to be considered in the design of these facilities is included in Table 2.

Table 2. Key factors for the design of wet ponds (Schueler 1987)

Hydrological budget	flow quantity and rate, rainfall, evaporation, infiltration, groundwater recharge
Contaminant detention time and accumulation	
Watershed morphology and size	
Pond morphology	
Soil composition	texture and chemistry
Plant community variables	composition and dominance, distribution and range, biomass and productivity potential, toxicity tolerance, environmental requirements, capacity to serve required functions
Microbiological populations	composition and dominance, distribution and range, productivity potential, toxicity tolerance, environmental requirements, capacity to serve required functions
Downstream morphology	
Erosion potential	
Habitat and other values	

The 1988 EPA Nationwide Urban Runoff Program (NURP) studies conducted in Lansing, Michigan demonstrated that wet detention basins exhibit some of the highest pollutant removal efficiencies of any Best Management Practice (BMP) (Hayes et al. 1993). Removal efficiency is defined as the ratio of pollutant effluent to the influent loadings. Retention basins, as measured by NURP, removed 75 percent of the total suspended solids (TSS), 66.7 percent of the BOD, 58.3 percent of the phosphorus, 30.8 percent of the nitrogen, and 95.3 percent of the lead (Adams and Dove 1984). Other sources suggest that wet ponds remove 80-90 percent of the TSS, 70-80 percent of the lead, 40-50 percent of the zinc, and 20-40 percent of the BOD and COD (Novotny 1994). Compared to dry ponds that include an infiltration system, wet ponds provide 2 to 3 times greater removal efficiency for total phosphorus (50-60% vs. 20-30%) and 1.3 to 2 times greater for total nitrogen (30-40% vs. 20-30%) (Novotny 1994).

Removal efficiencies are site specific, however, and are highly variable. The degree of variability in pollutant removal efficiencies is illustrated in Table 3 (Brown and Schueler, 1997). These data were collected from 29 wet pond sites. Values given for parameter indices are the removal efficiencies (as percent of loading) by wet ponds for each pollutant, based on event mean.

Table 3. Removal efficiencies (as percent of loading) for each pollutant *

Parameters	N	Average	Median	Maximum	Minimum
Nutrients					
Total phosphorus	30	52.01	47	91	12
Nitrate	19	32	24	97	-85
Total Khedjahl nitrogen	14	34.86	29	68	7
Total nitrogen	15	29.93	30	85	-12
Metals					
Cadmium	4	18.78	24.3	51.5	-25
Copper	14	60.41	57.4	90	38
Lead	25	68.89	73.5	95	23
Zinc	23	56.38	52	96	13
Physical parameters					
Total suspended solids	30	67.55	76.5	99	-33.3
Other parameters					
Bacteria	4	73.25	78	91	46
Organic carbon	20	41.97	44.5	90	-30

*From the National Pollutant Removal Performance Database for Stormwater Best Management Practices, August 1997, Whitney Brown and Thomas Schueler, Appendix G.

One reason for high variability in pollutant removal efficiencies is due to the wide range of definitions and designs in the systems. Often water quality ponds are defined as wetlands integrated within a detention pond. However, some stormwater management facilities do little to encourage the wetland characteristics promoted to enhance pollutant removal. Another source of variability in wet pond removal efficiencies is the high variability in external characteristics of the design, such as the basin's size in relation to the watershed it serves (Novotny 1994).

Pollutant removal efficiency is believed to change with the seasons, as addressed by Oberts (1990). Removal efficiencies usually decline during the winter months due to a reduction of biological activity as a result of cold temperatures. Sedimentation still occurs, but nutrients and metals are not retained well. Thick ice may also impede the performance by eliminating the permanent storage volume and causing a turbulent, pressurized condition beneath the ice layer that causes sediment resuspension. Water may be forced above the ice where sedimentation cannot effectively occur. Maintaining water movement and certain water depth prevents ice build-up and scouring of the deposited sediments.

Assessment of BMP performance should also consider potential limits to storm water treatment efficiency, as discussed by Schueler (1996). Table 4 lists apparent irreducible concentrations in storm water BMPs, perhaps due to internal production of nutrients and turbidity, or limitations of removal pathways. Existence of irreducible pollutant concentrations has implications not only for BMP performance assessment but also for understanding cumulative watershed impacts (Schueler, 1996).

Table 4. Limits to stormwater treatment efficiency: irreducible pollutant Concentrations Discharged from Urban BMPs (Schueler 1996)

Water Quality Parameter	Stormwater BMP Outlet Concentrations (mg/L)
Total Suspended Solids	20 to 40
Total Phosphorus	0.15 to 0.2
Total Nitrogen	1.9
Nitrate-N	0.7
Total Khedjahl Nitrogen	1.2

Sediment

Urban development, by means of erosion from construction sites, increases the amount of total suspended solids in runoff. Construction sites can generate soil losses up to 70 tons per acre per year, which is 15 times higher than the normal rate from croplands (Schueler 1987). High concentrations of sediment in streams produce adverse consequences for the aquatic habitat. Sediment pollutes streams by elevating their temperature, blocking light needed for aquatic vegetation, and impairing or destroying the feeding, respiration, reproduction, and juvenile survival of aquatic life.

A primary measure of stormwater control basin efficacy is the ability to settle out particulate matter in surface runoff. Sedimentation dynamics include temperature effects on water density, stratification (inflow may not mix and thus will pass through), and movement of the water by wind and currents (Allan et al. 1997). The resuspension of pollutants in subsequent storm events can allow a basin to be a "source" of surface water pollutants.

An important characteristic of sediment is the ability to transport other urban runoff pollutants. Pollutant adsorbance on particulate matter is related to particle size distribution and soil type (Allan et al. 1997). Silt and clay particulates have a very high surface area to volume ratios. Adsorption of toxicants and trace metals is greatly enhanced as this ratio increases. When elements are primarily dissolved in water or adsorbed onto small colloids that remain in suspension, concentrations may decrease by less than 20 percent as they pass through retention basins (Allan et al. 1997). Moderate declines range from 20 to 60 percent, but analytes (water quality parameters being analyzed) with strong associations to large settleable materials may decline in concentration by more than 60% (Allen et al. 1997). Settling removes these toxicants and trace metals from the water, but the deposited sediment can be re-mobilized due to bedload sediment movement, thus re-mobilizing the pollutants. Post-depositional mobility of redox-sensitive sediment-bound pollutants such as phosphorus and toxic trace metals is another important factor (Allan et al. 1997).

Nutrients

Approximately 80 percent of the nitrates and 75 percent of the phosphates input to lakes and streams in the U.S. are the result of human activities (AWMA 1993). Eutrophic conditions occur when soluble inorganic nitrogen concentrations in water reach 0.3 parts per million (ppm) and inorganic phosphorus concentrations reach 0.01 ppm (AWMA 1993).

Nutrients can be traced to atmospheric deposition, runoff, groundwater, and nitrogen fixation. Nitrogen in runoff comes from animal litter, livestock waste, and construction and residential fertilizer applications.

Phosphates attach to sediment particles because of their high adsorption capacity (Allan et al. 1997). Phosphates, however, do not tend to be removed permanently because anoxic conditions allow de-association of phosphorus from sediment and its subsequent release downstream. Phosphorus is the limiting nutrient in most freshwater ecosystems. (Allan et al. 1997).

Physical Parameters

Tolerance limits exist for the temperature, pH, dissolved oxygen content, and conductivity of water bodies. Elevated and highly fluctuating temperatures may result from inflow of heated waters or an increased sediment load adsorbing heat. pH may range from 6.0 to 9.0, but specific species may have narrow pH requirements and not tolerate large fluctuations. Optimum dissolved oxygen content is 5 mg/L (Virginia State Water Control Board 1997). Dissolved oxygen in water comes primarily from photosynthesis by aquatic plants, but also by diffusion from the atmosphere. The amount of dissolved oxygen in water depends on several factors including temperature (determines oxygen solubility and loss to the atmosphere), mixing, production rates, and use by organisms and chemical reactions. Adding either organic matter or nutrients increases the use of dissolved oxygen by biological organisms (AWMA 1993). Finally, electrical conductivity is a measure of salts in the water environment and is often used as a surrogate for total dissolved solids (TDS). Certain plant and animal species are known to be intolerant beyond certain threshold concentrations of electrical conductivity or salt.

Biological Parameters

Pathogenic bacteria in water originate primarily from livestock, wildlife, or faulty septic systems (Allen et al. 1997). Such pathogenic organisms are almost always present in water containing fecal coliform bacteria, and they occur in relatively equal numbers to that of fecal coliforms. Fecal coliforms include readily measurable E. coli and Klebsiella species. The EPA standard for boating and nonbody-contact water recreation is no more than 2000 fecal coliforms per 100 ml (AWMA 1993).

Trace Metals

Although minerals are essential for the life or optimum health of an organism, they are only required in small amounts. These trace elements result in toxicity when their quantities in natural systems become too great. Of the minerals that are being investigated in this study, copper and zinc are essential in trace quantities and lead and cadmium are nonessential heavy metals. The primary mode of treatment in a pond is the settling of particles. Zinc and lead, in particular, have high adsorption capacities, and may decline by more that 60 percent as a result of settling in retention ponds (Allan et al. 1997).

Other Pollutants

Organic matter input, including biodegradable refuse and waste may lead to a reduction in dissolved oxygen content of waters due to biological degradation processes and a related increase in biological oxygen demand. Oil, grease, and chemicals may pollute waters. Primary sources include vehicles that leak on to impervious surfaces of urban areas (Allen et al. 1997).

Biological Monitoring

For nearly 20 years, regulatory agencies concentrated almost exclusively on the physical and chemical properties of water and neglected the biological components (Adler 1995). Eventually it became apparent that the biological components of waters were continuing to decline in spite of the great attention being devoted to water quality (Karr 1995). Thus, the Environmental Protection Agency has come to recognize that biological integrity must be considered to accomplish the objective of the Clean Water Act. Biological integrity is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitats of a region" (Karr and Dudley 1981).

Biological criteria are "numeric or narrative expressions that describe the reference, or least-impacted, biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use" (EPA 1990). The EPA is moving toward the use of biocriteria for determining if a waterbody is meeting its designated aquatic life use, guiding water quality planning and management, and imposing regulatory controls, such as discharge permits for point sources and management practices for nonpoint sources. In order to implement biocriteria, it is necessary to be able to conduct accurate and economically feasible bioassessment and biomonitoring. Bioassessment is an evaluation of the condition of a water body using biological surveys and other direct measurements of the resident biota in surface waters (Gibson et al. 1996). Biomonitoring can be thought of as repeated bioassessment. Rosenberg and Resh (1993) define biomonitoring as "the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in a quality control program."

The use of resident biota to determine the condition of surface waters goes back to the late 19th Century, and there have been many different approaches since its inception. At the present, most biomonitoring for regulatory and natural resource management purposes is being done by what is called the "rapid bioassessment approach." Rapid bioassessment emphasizes cost effectiveness in conjunction with scientific validity. Although there are many different rapid bioassessment approaches (see Appendix 6.1 in Resh and Jackson, 1993, for a summary), they share some common features (Voshell et al. 1997). Sampling tends to be qualitative, in the sense that it is not a fixed area sampling scheme, but it is usually standardized according to the level of effort. Samples are often sub-sampled to manageable numbers (100-200 organisms). Organisms may be identified only to family or higher levels, but this varies considerably among different programs. There are no parameters based on absolute abundance. Rapid bioassessment approaches emphasize multimetric or aggregated indices based on specific categories of individual metrics or parameters. Data analysis and final interpretation are not based on inferential statistical testing, so replicate sampling is not required for computation of multimetric indices and evaluation of sites. If multiple samples are collected, they are typically composited to form a single sample. Data analysis and final interpretations are based on extensive background data and regional classifications determined previously by inferential and multivariate statistics. Relative to other approaches, rapid bioassessment approaches place greater emphasis on prior information. Inference about a particular site is based on a predictive approach rather than an hypothesis testing approach. An excellent published example of the state-of-the-art in rapid bioassessment with benthic macroinvertebrates is found in Barbour et al. (1996). Most contemporary bioassessment and biomonitoring are done with either benthic macroinvertebrates or fish.

Macroinvertebrates are generally considered to include the invertebrates that are large enough to be seen with the unaided eye during most of their life history (Voshell et al. 1997). Benthic refers to organisms spending most of their time on the bottom of surface waters or on objects protruding above the bottom. A high proportion of freshwater benthic macroinvertebrates are insects that are only aquatic as immatures, with the adult stage being spent in the terrestrial environment. Benthic macroinvertebrates have several characteristics that make them advantageous for use in bioassessments:

(1) They occur in almost all types of freshwater habitats. It seems that no habitat has size too small or large, temperature too cold or hot, current too slow or fast, substratum too soft or hard, nutrients too rich or poor, aquatic vegetation too lush or sparse, or detritus too abundant or scant to sustain a benthic macroinvertebrate community.

(2) There are many different taxa of benthic macroinvertebrates, and among these taxa there is a wide range of sensitivity to all types of pollution and environmental stress.

(3) Benthic macroinvertebrates have mostly sedentary habits so they are likely to be exposed to pollution or environmental stress. They are seldom able to detect pollution and move away from the source.

(4) The duration of their life history is sufficiently long that they will likely be exposed to pollution and environmental stress, and the community will not recover so quickly that the impact will go undetected. The most common life history is to produce one generation a year, and even among aquatic insects that become terrestrial adults, most spend about 10 months in the water.

(5) Sampling the benthic macroinvertebrate community is relatively simple and does not require complicated devices or great effort.

(6) Taxonomic identification is almost always easy to the family level and usually relatively easy to the genus level (Voshell et al 1997).

For these reasons, a base line survey of the benthic macroinvertebrates has been conducted in the immediate vicinity of the Virginia Tech regional stormwater management facility.

2.0 WATER QUANTITY AND QUALITY EVALUATION METHODS

STUDY AREA

This study is being conducted at the regional stormwater management facility located adjacent to the Virginia-Maryland School of Veterinary Medicine complex on the Virginia Tech campus. The facility design includes both an upper water quality (wet) pond and a lower 100-year-event stormwater quantity (dry detention) pond. These ponds capture runoff from the upper portion of the Virginia Tech campus and surrounding lands, and release into Stroubles Creek, a tributary of the New River. (See Figure 1 for a plan view of the facility and the location of sampling stations.)

The 255-acre watershed draining into the upper pond is the Virginia Tech campus area surrounding Lane Stadium, including a veterinary hospital, office buildings, parking lots, construction sites, cattle pasture, athletic facilities, lawn areas, and a vehicle maintenance facility. The water quality pond was designed to hold 13.09 acre-ft. of water, whereas the water quantity pond was designed to hold 23.78 acre-ft. The dry pond outflow peak design allows 273.16 cfs from a 2-year storm event, 414.05 cfs from a 10-year storm event, and 583.37 cfs from a 100-year storm event (Anderson & Associates, personal communication). The information regarding the pre-installation and post-installation peak flow rates for the lower dry pond is given in Table 5. The landuse in the watershed draining to the lower dry detention basin includes feed corn cultivation, stormflow drainage from the dairy pasture and manure spreading fields, and groundwater seeps. This additional drainage area is approximately 50 acres. The outflow from the dry detention basin flows into Stroubles Creek, a tributary of the New River.

Table 5. Quantity pond flow rates for storm events of various sizes

Storm Event:	2-yr	10-yr	100-yr
Pre-installation peak flow (cfs)	329.28	487.67	636.07
Post-installation peak flow (cfs)	273.16	414.05	583.37
% Reduction in peak flow	17%	15.1%	8.3%

SAMPLING LOCATIONS

Five ISCO water quality samplers and flow logger stations have been established: one above and one below each of the water quality and quantity ponds, and one sampling site is located downstream of the neighboring dairy facility's stormwater runoff which flows directly into the dry detention pond. A sixth site was only sampled concurrent with the macro-invertebrate survey, and the results for that site are not included in this report. Grab samples have been taken at all sites since February 1997 on a monthly basis for base flow and storm events, when possible.

Refer to the plan view of the site in Figure 1 to locate the sampling sites. Also, Figures 2-7 contain pictures of the study site. The first sampling station (QVA) is located between a 5'x 6' box culvert outfall and the wet pond entrance. The second sampling station (QVB) is located below the outfall of the wet pond. Following the outfall of the wet pond several hundred feet of natural stream was maintained. This stretch of stream contains several sources of water inflow and required that the third sampling station, site QVC, be established at the entrance to the dry detention facility. Another major source of storm flows located to the south of the quantity facility is a culvert, routed under

Southgate Drive, that drains the dairy lot grazing land. While this culvert is dry during non-storm periods, it flows during storm events. Site QVD was established at the outlet of this culvert in order to characterize the pollutant load from the dairy lot.

The last sampling site, QVE, was located at the outfall of the lower water quantity pond. However, QVE was relocated several times early in the study. Prior to the construction of the dry detention basin, the monitoring was conducted in the natural stream channel. When construction began, QVE was relocated to the diversion channel that routed water away from the dam. The earth filled dam constructed for the quantity facility was completed in mid-April 1997. The dam was built by a roller compacting imported clay. An emergency spillway structure was provided, with a grassed waterway leading to the natural channel adjacent to the principal spillway. Once the dam was completed, the site for QVE was moved to the outlet of the principal spillway of the quantity pond. The principal spillway was configured as a 2-feet diameter reinforced concrete pipe culvert with a single grate inlet.

Construction began earlier than expected on the stormwater management facility, and insufficient samples were collected prior to the construction to enable a pre- vs. post- installation water quality comparison. However, the major objective of the project was to measure pollutant removal efficiencies of the facility.

The upper water quality facility was constructed after the quantity facility. Construction was delayed by unforeseen excavation needs and rock blasting which extended from February 5 to August 6, 1997. Seeding of the area surrounding the wet pond occurred between September 4 and September 15, 1997. Fertilizer application associated with seeding is expected to have an impact on the sampling results.

WATER QUALITY SAMPLE ANALYSIS

Physical parameters of water quality including temperature, pH, conductivity, and dissolved oxygen (DO) were measured in the field at the time of sampling. The samples were taken to the Department of Biological Systems Engineering Water Quality Laboratory for analysis of total suspended solids, total Kjeldahl nitrogen (TKN), filtered TKN, ammonium, nitrate, total phosphorus (TP), filtered TP, orthophosphate, total organic carbon, chemical oxygen demand, total coliforms, fecal coliforms, and fecal streptococci. Extraction and analytical procedures were followed as outlined in the EPA approved standard operating procedures designed by the Water Quality Laboratory, department of Biological Systems Engineering, Virginia Tech. Fecal coliform colonies per 100 ml were reported, and are equivalent to indicator organisms per 100 ml. Therefore, the EPA standard of 200 indicator organisms/100 ml is equivalent to 200 fecal coliform colonies per 100 ml. The water samples for metals analysis were acidified promptly, then stored until digestion and analysis was made at the department of Civil Engineering's Water Quality Laboratory, Virginia Tech. The metal analytes of copper, lead, cadmium, and zinc were selected because they are commonly found in runoff from roads and parking lots.

The results of the sample analysis were separated into storm and baseline data sets, and plotted for the purpose of analysis.

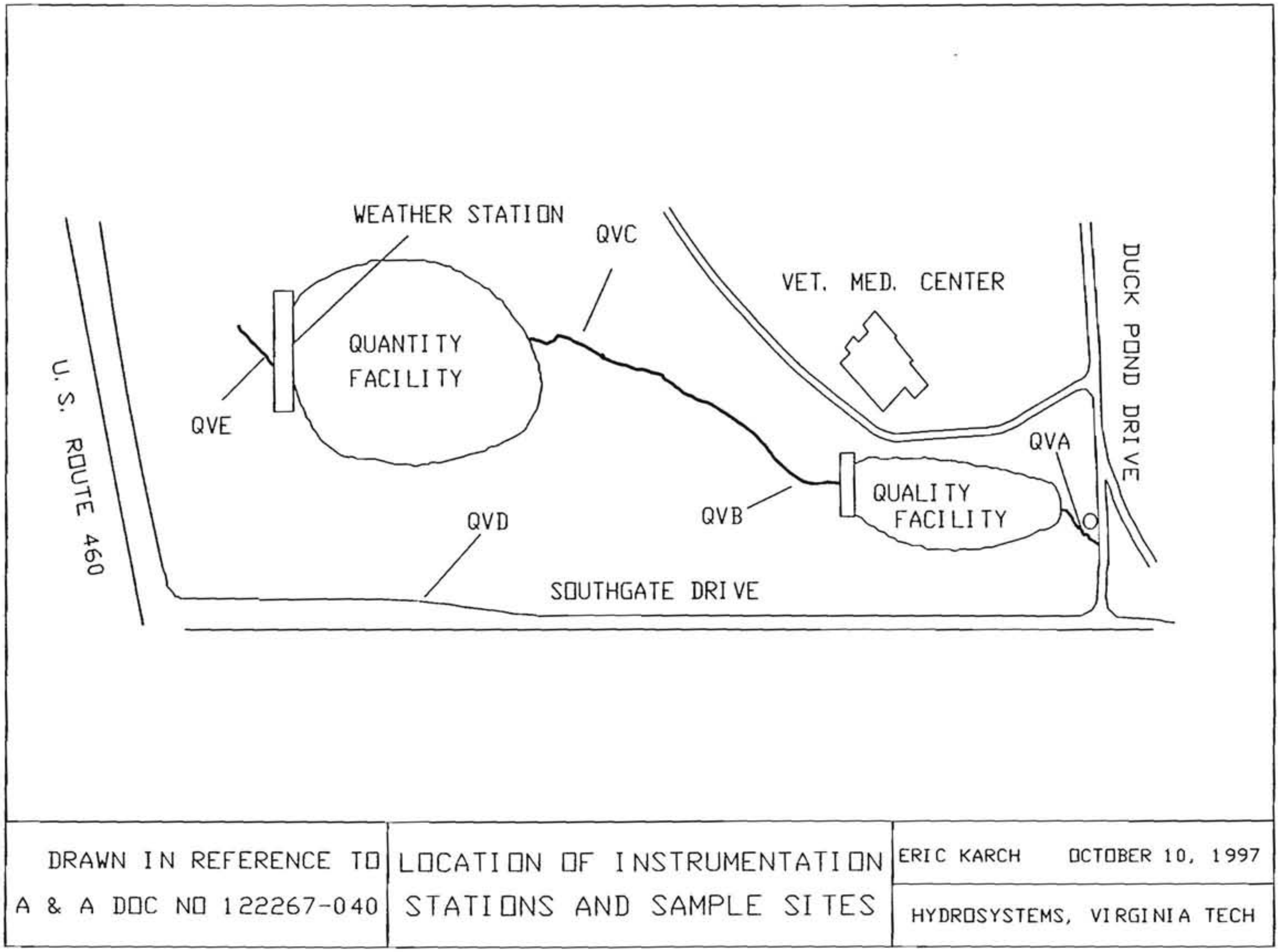


Figure 1: Plan view of the facility

Figure 2. Flow from the Duck Pond Drive culvert at sampling site QVA

Figure 3. Quality pond adjacent to the VA/MD Veterinary Medicine Center

Figure 4. The outlet to the quantity pond at sampling site QVB

Figure 5. The meandering natural stream at sampling site QVC

Figure 6. The low flow wetland state of the water quantity pond

Figure 7. Outlet of the water quantity pond at sampling site QVE

3.0 BENTHIC MACROINVERTEBRATE SAMPLING METHODS

DESIGN

Samples of benthic macroinvertebrates were taken on three occasions at four sites on the study stream where the Virginia Tech Wet-Pond Detention Facility was constructed. The study stream is a small, unnamed tributary of Stroubles Creek. Sampling sites were: QVA (upstream from the entire facility and just below the culvert where the study stream emerges from flowing under the Lane Stadium area), QVB (immediately below the upper pond), QVC (just above the lower pond), and QVE (just below the lower pond). Samples were also taken on the same three dates at two other sites on nearby similar streams, which are not affected by the Virginia Tech Wet-Pond Detention Facility. The other sites were on Stroubles Creek, upstream from the confluence with the study stream, and an unnamed tributary of Slate Branch, behind the satellite telecommunications facility at the Virginia Tech Corporate Research Center (CRC). At each site, the specific location for sampling was in riffle areas. The dates that samples were taken at all sites were: February 20, 1997, April 29, 1997, and August 29, 1997.

This study design was chosen to facilitate several spatial and temporal comparisons. The sampling dates reflected conditions before construction (February 20, 1997), during construction (April 29, 1997), and shortly after completion (August 29, 1997). No further changes in the benthic macroinvertebrate community would have been expected during 1997 because of the life history characteristics of the fauna. Site QVA might have a better biological condition than QVB, QVC, and QVE, because the study stream had not been subjected to agricultural activities or runoff from the Veterinary Medicine parking lots at that particular location. However, adverse impacts caused by culvert flow through the athletic facilities and suburban neighborhoods were likely at QVA. The entire reach of study stream upstream from Site A has been placed in underground culverts. Biological conditions at QVA are expected to remain the same in the future. Biological conditions at sites QVB, QVC, and QVE on the study stream should reflect the intended functions of the new facility to control NPS problems. The nearby sites on other streams should reflect biologically impaired conditions that are not expected to change. Thus, biological conditions at site QVB, QVC, and QVE were expected to be degraded before the construction of the facility, but they are expected to improve over time, while biological conditions in Stroubles Creek and the Corporate Research Center (CRC) stream should not improve.

All sampling was done according to the latest guidance document by EPA for rapid bioassessment (Barbour et al. 1997). A number of habitat and macroinvertebrate community measures were calculated for each site and compared spatially and temporally as described below.

HABITAT

Habitat is considered to be a primary determinant of biological potential. In water quality studies, habitat is analyzed for similarity so that macroinvertebrate data can be used to determine if pollution entering the water is causing impairment to the biological condition. However, agricultural activities and urbanization are likely to degrade the habitat so that the biological condition is impaired. In this instance, habitat will not be similar and acts as a variable that explains changes in the macroinvertebrate community structure. Habitat quality was measured by summing the numerical scores (0-20) for 10 habitat parameters as recommended in the latest guidance document by EPA for rapid bioassessment (Barbour et al. 1997):

1) epifaunal substrate/ available cover
2) riffle quality
3) embeddedness
4) channel alteration
5) sediment deposition
6) frequency of riffles (or bends)/pool/velocity-depth combinations
7) channel flow status
8) bank vegetative protection
9) bank stability
10) riparian vegetative zone width

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate communities were sampled by the techniques recommended in the latest guidance document by EPA for rapid bioassessment (Barbour et al. 1997). At each site, a standardized sample consisted of seven subsamples taken with a D-frame dip net (0.305 m wide). Two of the subsamples were 1-m sweeps of the left and right banks, respectively. The substratum in the bank subsamples was primarily terrestrial grasses and roots exposed to the current. The five remaining subsamples were taken by placing the D-frame net on the bottom within the riffle and disturbing the mineral substratum by hand immediately upstream of the net. The five riffle samples were chosen to reflect fast and slow current conditions. The seven subsamples were combined in the field to constitute the sample for the site.

Benthic macroinvertebrate samples were preserved in 95 percent ethanol, placed in 2-liter plastic buckets with leakproof lids, and returned to the Entomology laboratory on the Virginia Tech campus for final processing. Labels for each sample were made on plastic embossing tape and placed with the sample in its container. Information on the label included: project, site, and date. The same information was written with a wax pencil on the outside of the sample containers.

In the laboratory, each sample was washed in a 500-μm soil sieve. Coarse debris on the sieve was examined during washing, and conspicuous invertebrates were removed and saved. Material remaining on the sieve after washing was transferred to a 500-μm rectangular gridded sieve for subsampling. A random subsample of 200 organisms (± 10%) was obtained by using a random number table to choose 5 x 5 cm^2 quadrats from the rectangular sieve. The material in each 5 x 5 cm^2 quadrat was transferred to a white enamel pan, covered with clean water, and thoroughly examined to remove all macroinvertebrates. Macroinvertebrates were counted as they were removed, and successive quadrats were chosen until 200 organisms (± 10%) were obtained. All quadrats that were selected were sorted in their entirety.

All organisms were examined under a stereomicroscope at 5-45X magnification and identified primarily by the professional expertise of the investigators. When necessary, reference was made to up-to-date taxonomic literature (e.g., Merritt and Cummins 1996). Data were recorded on preprinted laboratory bench sheets.

DATA ANALYSIS

The approach that was used to analyze the benthic macroinvertebrate communities is known as categorization evaluation. This involves aggregating individual metrics into multimetric indices, then comparing the results to expected values for broad geographic areas, called eco-regions, that are known to have similar ecological characteristics. This is the approach that is recommended in the latest guidance document by EPA for rapid bioassessment (Barbour et al. 1997). Categorization evaluation requires that extensive studies be done to establish expected biological conditions within the eco-region of interest (Appalachian Ridges and Valleys, in this case). The specific categorization evaluation approach used to analyze the benthic macroinvertebrate communities in this study was the Macroinvertebrate Aggregated Index for Streams (MAIS), which was recently developed by Smith and Voshell (1997) for wadeable streams in several eco-regions within the mid-Atlantic highlands (including the Appalachian Ridges and Valleys). The MAIS involves calculating nine individual metrics, which are explained below.

1) *EPT Index (Ephemeroptera, Plecoptera, Trichoptera)* - calculated as the total number of taxa (kinds of organisms) within these three pollution-sensitive orders. Lower metric values are expected for streams that become polluted.

2) *# Ephemeroptera (Mayfly) Taxa* - calculated as the number of taxa (kinds) within this pollution-sensitive order. Metric values decline in streams that become polluted.

3) *% Ephemeroptera (Mayflies)* - calculated as the number of organisms in this pollution-sensitive order compared to the total number of organisms and expressed as a percent. Metric values decline in streams that become polluted.

4) *% 5 Dominant Taxa* - calculated as the number of organisms in the five most abundant taxa compared to the total number of organisms and expressed as a percent. This is a measure of community balance. Under natural conditions, there are many taxa and none of them comprise an especially high proportion of the total. When a stream becomes perturbed, there are usually a few taxa that are tolerant of the perturbation, and they comprise a very high proportion of the total numbers of organisms.

5) *Simpson Diversity Index* - integrates richness and evenness into a measure of general diversity. It is one of many diversity indices to choose from. The Simpson index has practically no assumptions about sampling. It ranges from 0 to 1, with high values indicating good biological condition.

6) *# Intolerant Taxa* - calculated as the number of macroinvertebrate taxa with tolerance values of 5 or less. High values indicate good biological condition.

7) *Modified Hilsenhoff Biotic Index (Modified HBI)* - calculated as:

   Modified HBI = $\sum x_i t_i / n$

where

x_i = number of individuals within a taxon

t_i = pollution tolerance value of a taxon (0 to 10, intolerant to tolerant, respectively)

n = total number of organisms in sample

The metric value gets higher when a stream becomes polluted. The HBI falls into a category of metrics called biotic indices, which contain information about the numbers and kinds of organisms, along with a numerical ranking of their tolerance to pollution. The HBI is referred to as "modified" because it was originally developed to monitor organic pollution with the stream fauna in Wisconsin (Hilsenhoff 1982, 1987, 1988). The tolerance values have been modified to reflect usual responses to most types of pollution by the stream fauna that occur in Virginia and surrounding states.

8) *% Scrapers* - calculated as the number of organisms that acquire their food by scraping periphyton from solid surfaces compared to the total number of organisms and expressed as a percent. Moderate enrichment from organic material or inorganic nutrients can cause an increase in this metric value. Heavy enrichment or sedimentation will cause the metric value to decline.

9) *% Haptobenthos* - calculated as the number of organisms that require clean, coarse, firm substratum for their existence compared to the total number of organisms and expressed as a percent. Sedimentation of fine particles of organic or inorganic matter or excessive growth of algae, bacteria, or fungi will cause this metric value to decline.

Values for these metrics were determined based on taxonomic identifications at the family level, then they were standardized by converting them to unitless scores of 2, 1, or 0 as follows (Smith and Voshell 1997).

Table 6. Aggregation of metrics into the MAIS scores

Metrics	Categories	Scores		
		2	1	0
EPT Index	Richness	≥ 8	3 - 7	≤ 2
# Ephemeroptera	Richness	≥ 4	1 - 3	0
% Ephemeroptera	Composition	≥ 18	1 - 17	0
% 5 Dominant Taxa	Balance	≤ 79	80 - 99	100
SDI	Balance	≥ 0.83	0.67 - 0.82	≤ 0.66
Modified HBI	Tolerance	≤ 4.21	4.22 - 5.55	≥ 5.56
# Intolerant Taxa	Tolerance	≥ 10	2 - 9	≤ 1
% Scrapers	Trophic	≥ 11	1 - 10	0
% Haptobenthos	Habit	≥ 84	53 - 83	≤ 52

After standardization, the unitless scores were summed (maximum total score = 18, minimum total score = 0), then biological condition was determined according to the following categories and biocriteria (Smith and Voshell 1997).

Table 7. Aggregation of metrics into the MAIS scores

MAIS Scores	Biological Condition Categories	Biocriteria
≥ 17	Very Good	Acceptable
13 - 16	Good	Acceptable
7 - 12	Poor	Unacceptable
≤ 6	Very Poor	Unacceptable

In addition to aggregating the metrics into the MAIS scores, individual metrics were also analyzed spatially and temporally. One additional metric that was not part of the MAIS was also included, taxa richness. Taxa richness is simply the total number of taxa (kinds of organisms) present. The health of a community is reflected through a measurement of the variety of taxa present. Generally, taxa richness decreases with decreasing water quality and habitat suitability.

4.0 WATER QUALITY RESULTS AND DISCUSSION

The wet pond detention facility should not only remove pollutants from stormwater, but the construction of the facility should cause a minimal impact on the existing ecosystem. Baseline water quality data from the drainage area serve the purpose of highlighting NPS pollutants that are most prevalent. This is an important piece of information, because the blasting and extensive earth moving necessary to construct the wet pond may have been a source of additional pollutants.

The results are presented here in graphical form for the period from February to December 1997, as they were available. More data will be collected in the next several seasons in order to better calculate removal efficiencies in the two-pond detention system.

TOTAL SUSPENDED SOLIDS

Construction greatly affected the TSS concentrations in the stormwater detention facility. Many samples collected at QVA, the influent to the wet pond, had concentrations below the detection limit. For both monthly baseflow (Figure 8) and storm event (Figure 9) samples, QVB consistently showed much higher sediment concentrations. In contrast, QVC, the site located upstream of the dry detention pond, exhibited higher TSS concentrations than QVE for both monthly baseflow and storm event samples. It appears that the dry pond is effective in removing some suspended sediment, however, construction of the facility has negatively impacted the effectiveness of the wet pond. Most of the results presented here were taken during the construction period.

Future samples should represent more steady state conditions and better show removal efficiencies of the sediment loads coming from the construction and urban development in the watershed. Eventually, the large volume of sediment deposits downstream of the stormwater management facility will move downstream, a more natural stream bed will form, and the system will reach a new steady state.

TEMPERATURE

Figure 10 is a plot of the monthly temperature at sites QVA, QVB, QVC, and QVE. Site QVB shows a definite decrease in temperature (5°C) compared to QVA in the winter months of November and December and a definite increase in temperature (nearly 10°C) in the summer months of July, August, and September. The dry pond shows no change in temperature between sites QVC and QVE.

Water temperature does not recover to the entering temperature when it has left the water quantity pond, which may negatively impact aquatic life in the receiving waters. Wet ponds can severely disturb the sensitive ecology of downstream water bodies. Rapid thermal increase during warmer months can increase downstream water temperatures by as much as 10°-11°F (Shueler 1987). High temperatures can stress and even kill sensitive fish populations, by exceeding fish tolerances or by altering the dissolved oxygen in the water.

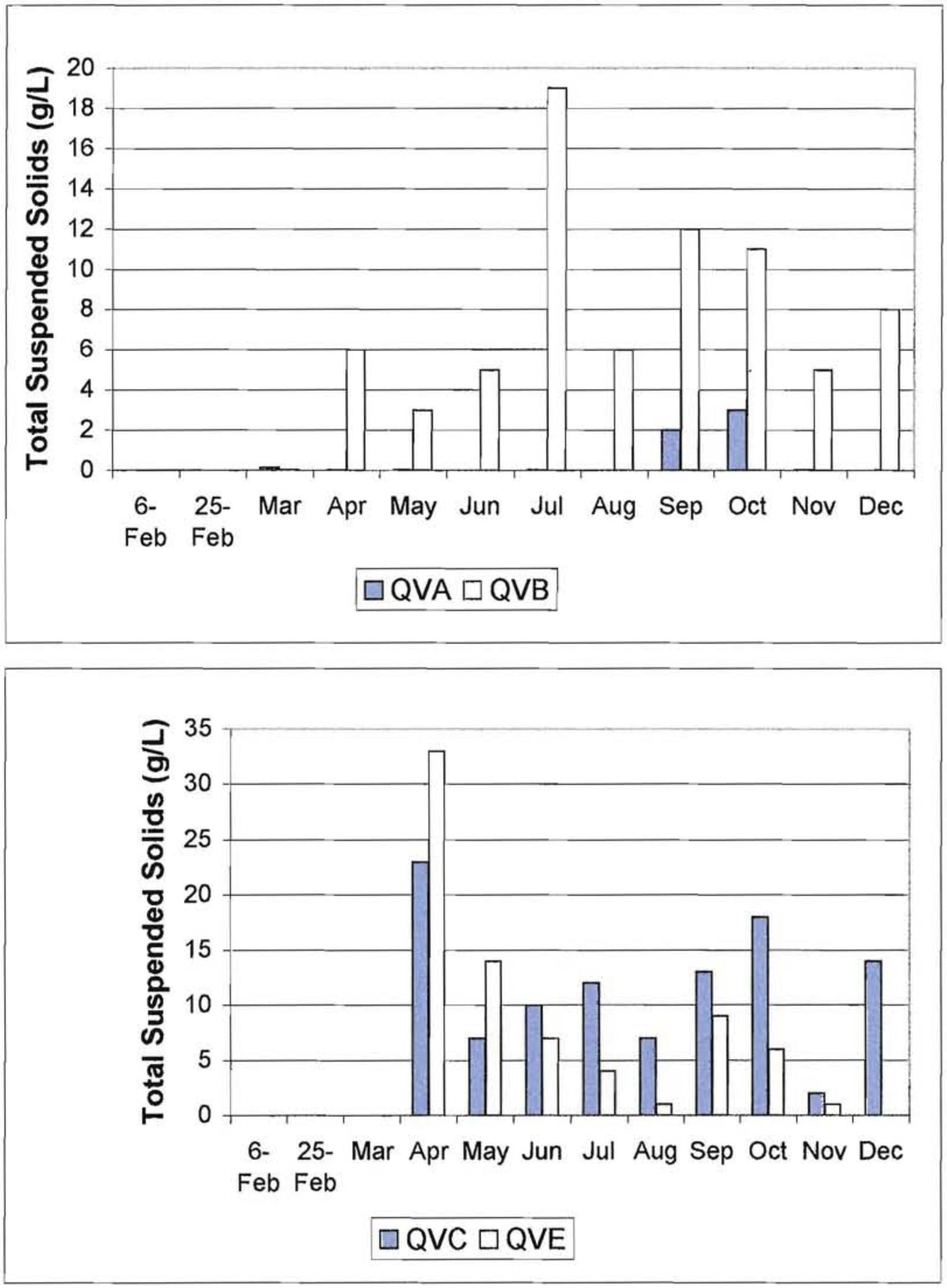
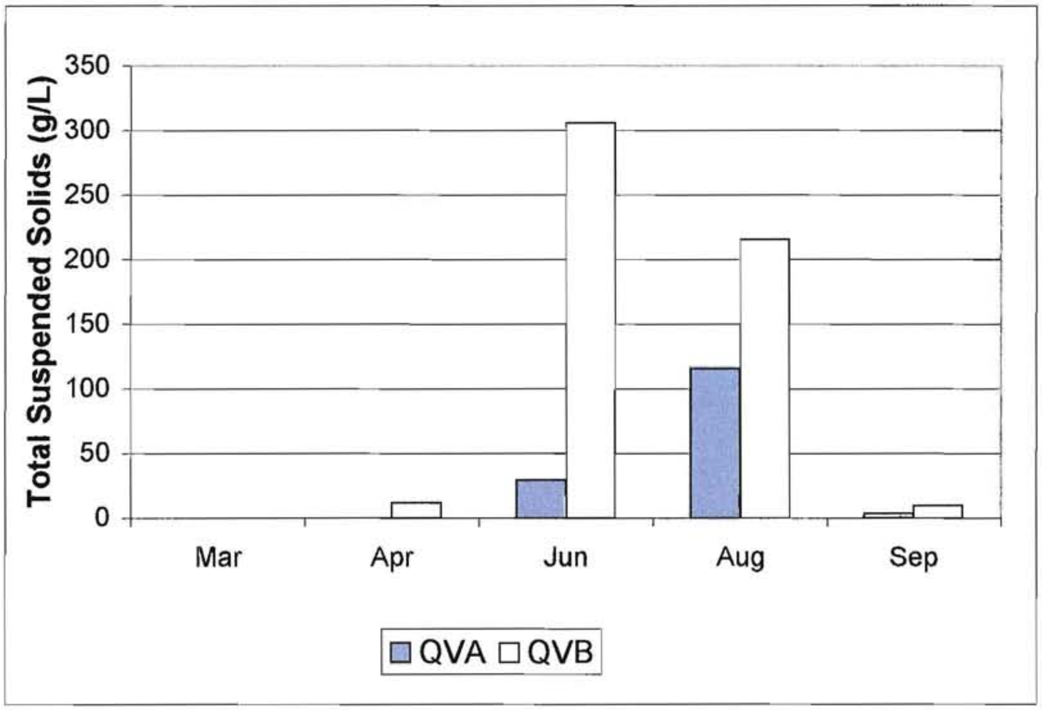


Figure 8. Concentrations of total suspended solids from baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997



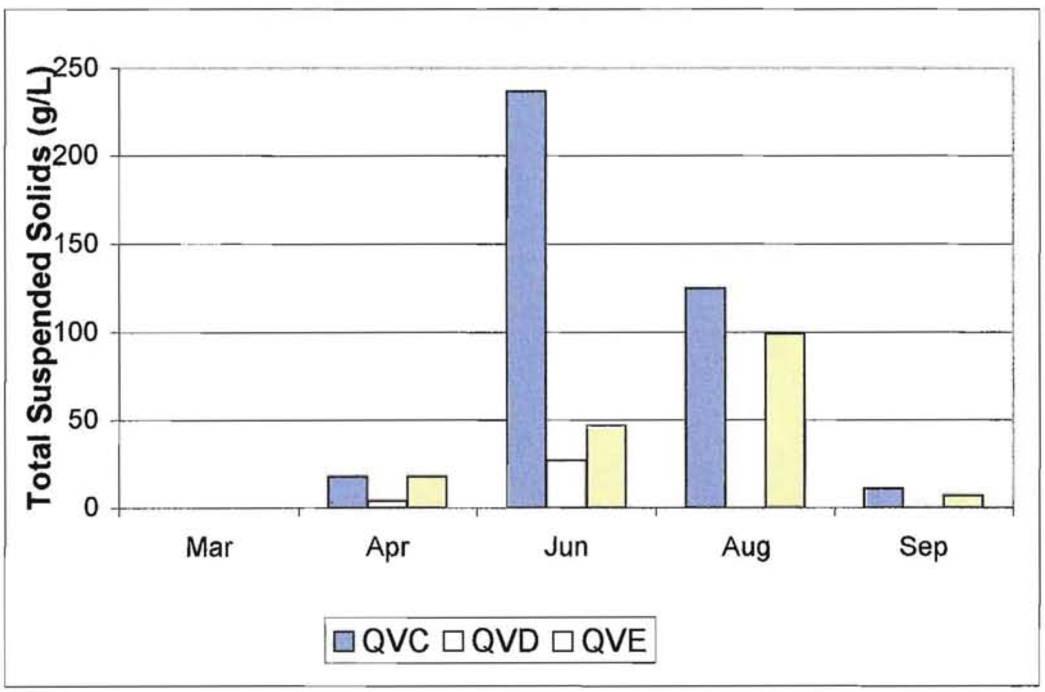
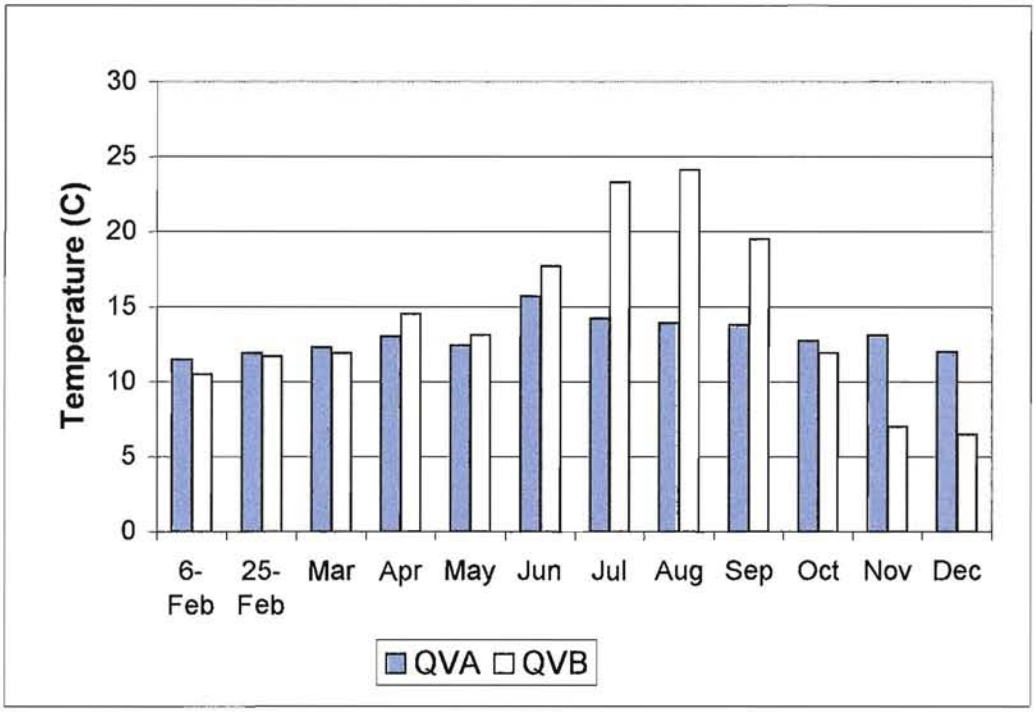


Figure 9. Concentrations of total suspended solids in storm event samples taken from the wet pond (QVA and QVB) and the dry pond (QVC, QVD, QVE), VT, 1997



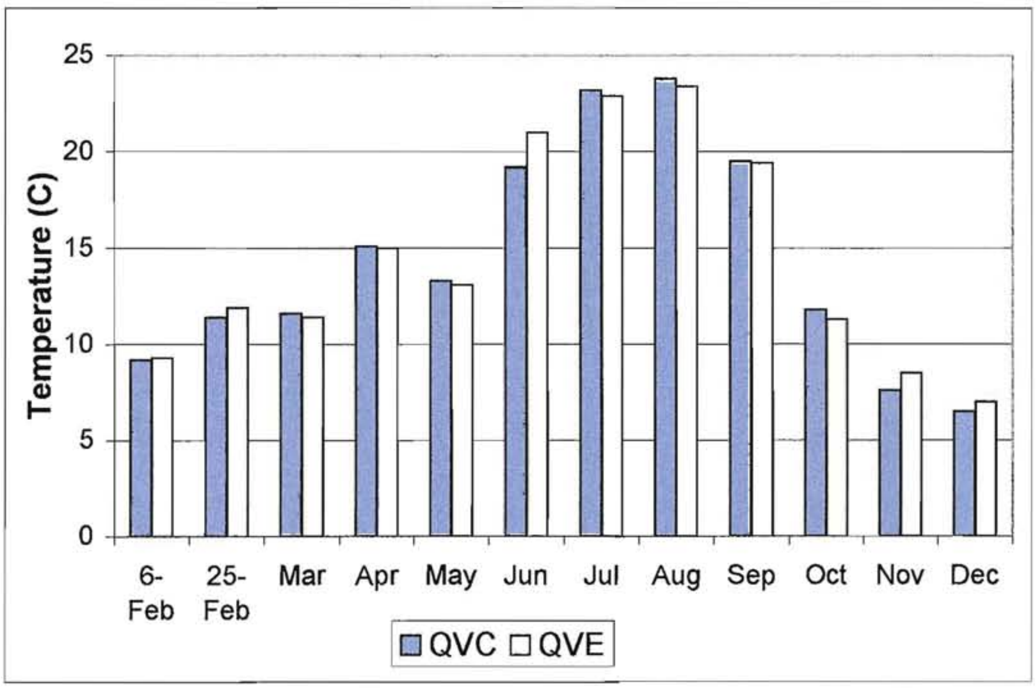


Figure 10. Temperature of baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997

Summer water temperatures in urban headwater streams can be increased due to several factors. Urban landscape is heated by solar radiation. As runoff from storm events passes over the surface of the watershed, it absorbs this heat. Secondly, construction of detention pond systems reduces shading by trees. Therefore, the detention of water in the pond allows time and surface area for the water to absorb solar radiation (Shueler 1987).

Raw urban runoff usually exceeds public health standards for bacteria levels. Older and more intensely developed urban areas produce the greatest bacteria levels compared to suburban and newer urban areas (Shueler 1987). Furthermore, animal handling facilities and agricultural/pasture land on which manure is applied can be sources of bacteria contamination in surface waters.

Figures 11 and 12 show that the occasional monthly and storm event samples for QVA, QVB, and QVC were close to the EPA standard for boating and nonbody-contact water recreation (2000 fecal coliform colonies per 100 ml) (AWMA 1993), but the majority of samples taken during storm events at QVD and QVE exceed this standard. These results are most likely due to the existence of the dairy facility above the QVD site, and the direction of this runoff to the outlet of the dry detention basin (site QVE). Another major contributor of fecal coliform is the duck and geese population utilizing the waters of the upper pond.

NUTRIENTS

Urban runoff typically contains high concentrations of soluble nutrients that are readily taken up by algae. Specifically, nitrogen and phosphorous are responsible for undesirable algal blooms (also known as eutrophication). Eutrophication occurs when nitrogen concentrations exceed 0.3 ppm and inorganic phosphorous concentrations exceed 0.01 ppm (AWMA 1993). Eutrophic symptoms include algal scums, water discoloration, strong odors, low DO levels, and release of toxins. Development sites with large impervious areas have the greatest nutrient export. Extensive use of livestock wastes as fertilizer is also a major contributor (Shueler 1987).

Nitrate and total nitrogen results are shown graphically in Figures 13,14,15,and 16. The first noticeable trend is the reduction of nitrate over time at all sites. Both baseflow and storm samples exhibit this decline. Lower concentrations at QVB compared to QVA, seem to show increased nitrate removal in the fall samples(July, August, September, and October) by the wet pond. This could be attributed to slight stabilization of the pond. Storm samples of total nitrogen follow the same pattern, but the baseflow samples are slightly more erratic. Fall months show spikes in the total nitrogen concentrations at QVE. As with nitrate, concentrations of total nitrogen are consistently higher at QVE compared to QVC. Manure is spread over the adjacent dairy land as fertilizer. Nitrates contained in this runoff (QVD) add to the total concentrations at QVE. Also, land directly surrounding the quantity pond is used for growing corn. Fertilizer applied to the land and not taken up by the crops may move into the quantity pond through groundwater or runoff. Nitrogen levels are greater than the 0.1 mg/l needed for eutrophication.

Figures 17 and 18 are plots of total phosphorus, orthophosphate, and ammonium results from all sites. Concentrations are fairly consistent at QVA and QVB. Total phosphorous, orthophosphate, and ammonium concentrations at QVC and QVE are of the same order of magnitude, but runoff from the dairy land (QVD) shows large spikes in March and June. These can also be explained by the manure spreading practices of the dairy farm.

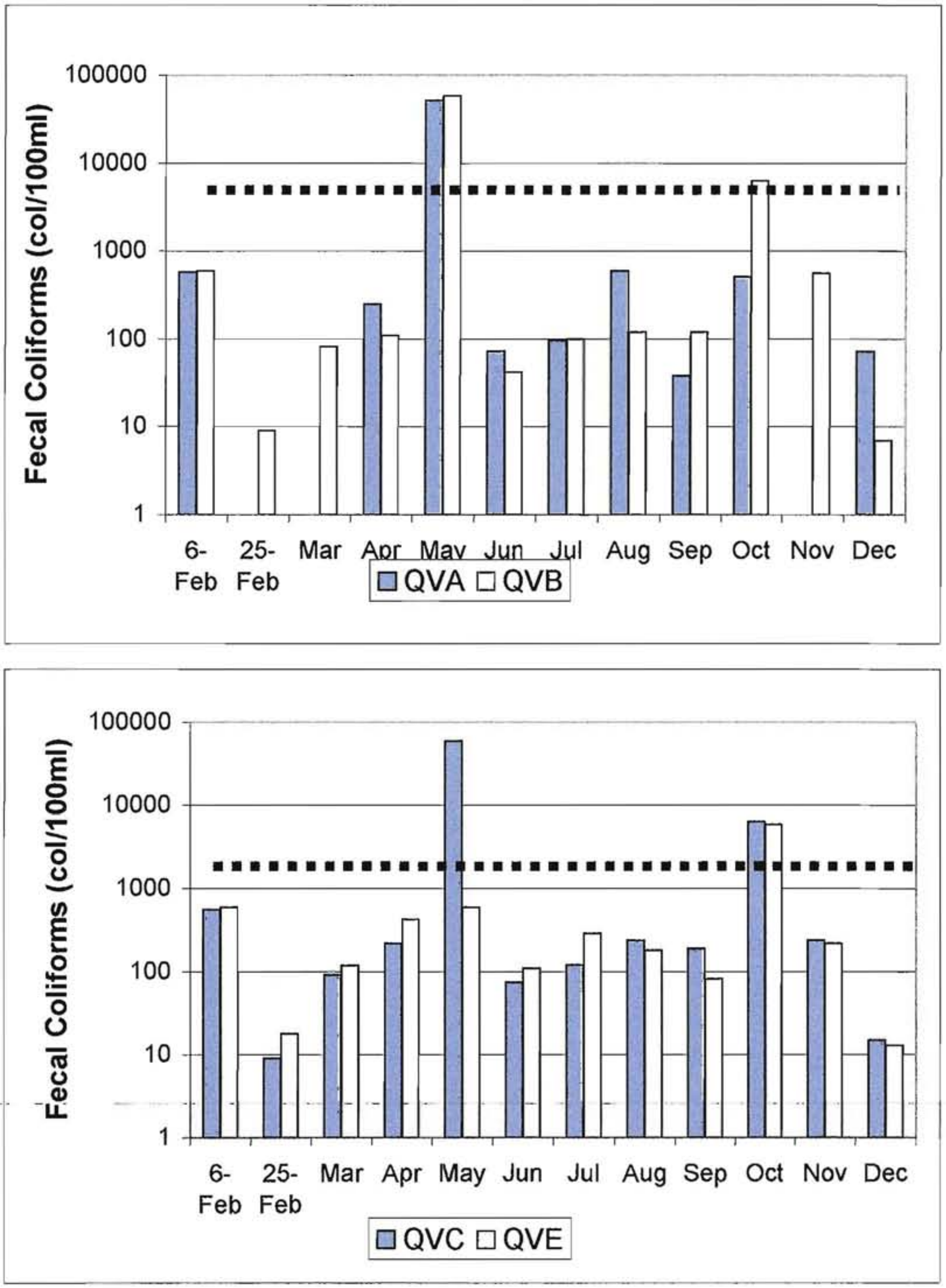


Figure 11. Number of fecal coliform colonies from baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997 Dashed line indicates EPA standard for boating and nonbody-contact water recreation

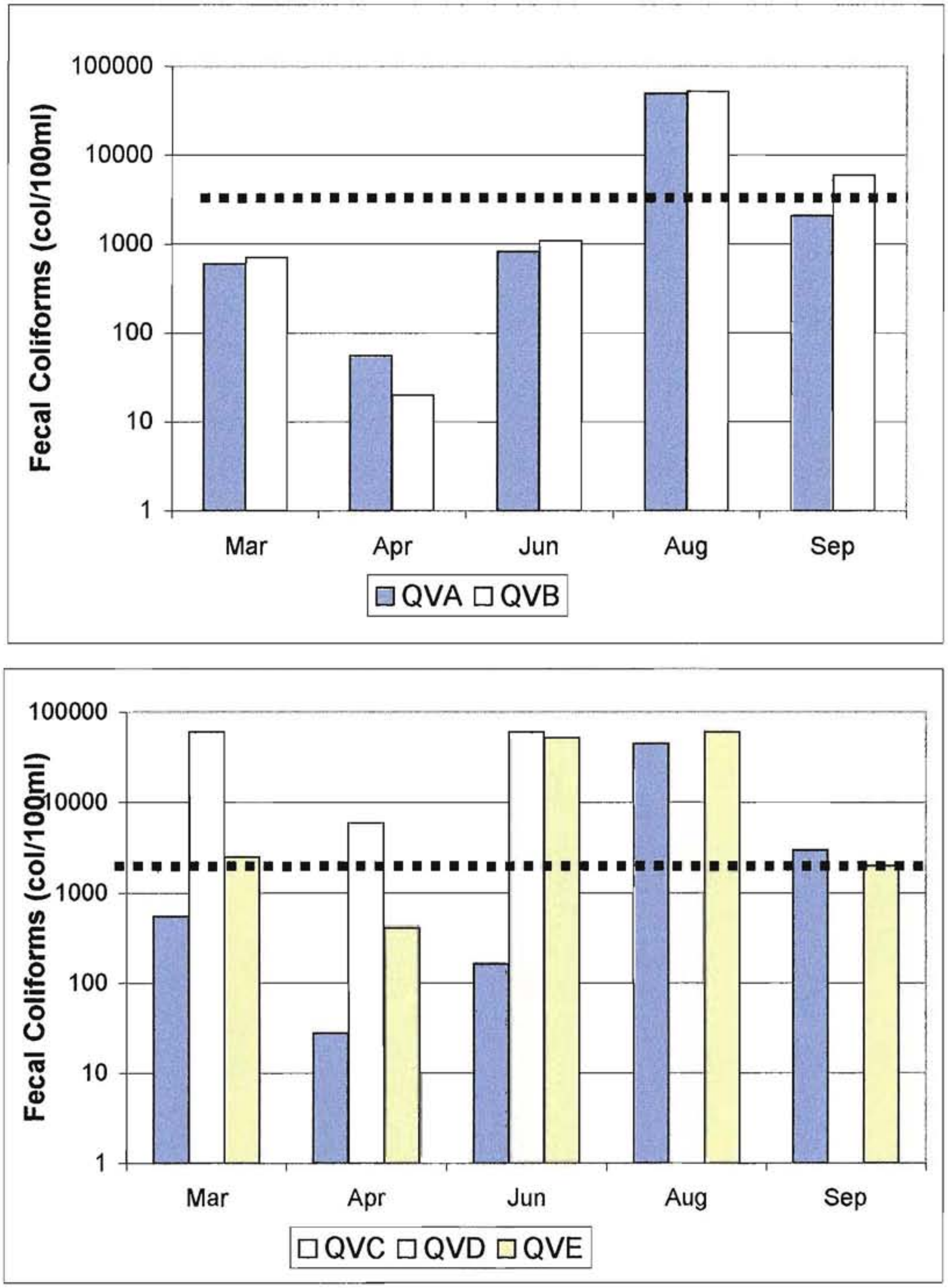


Figure 12. Number of fecal coliform colonies in storm event samples taken from the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997. Dashed line indicates EPA standard for boating and nonbody-contact water recreation

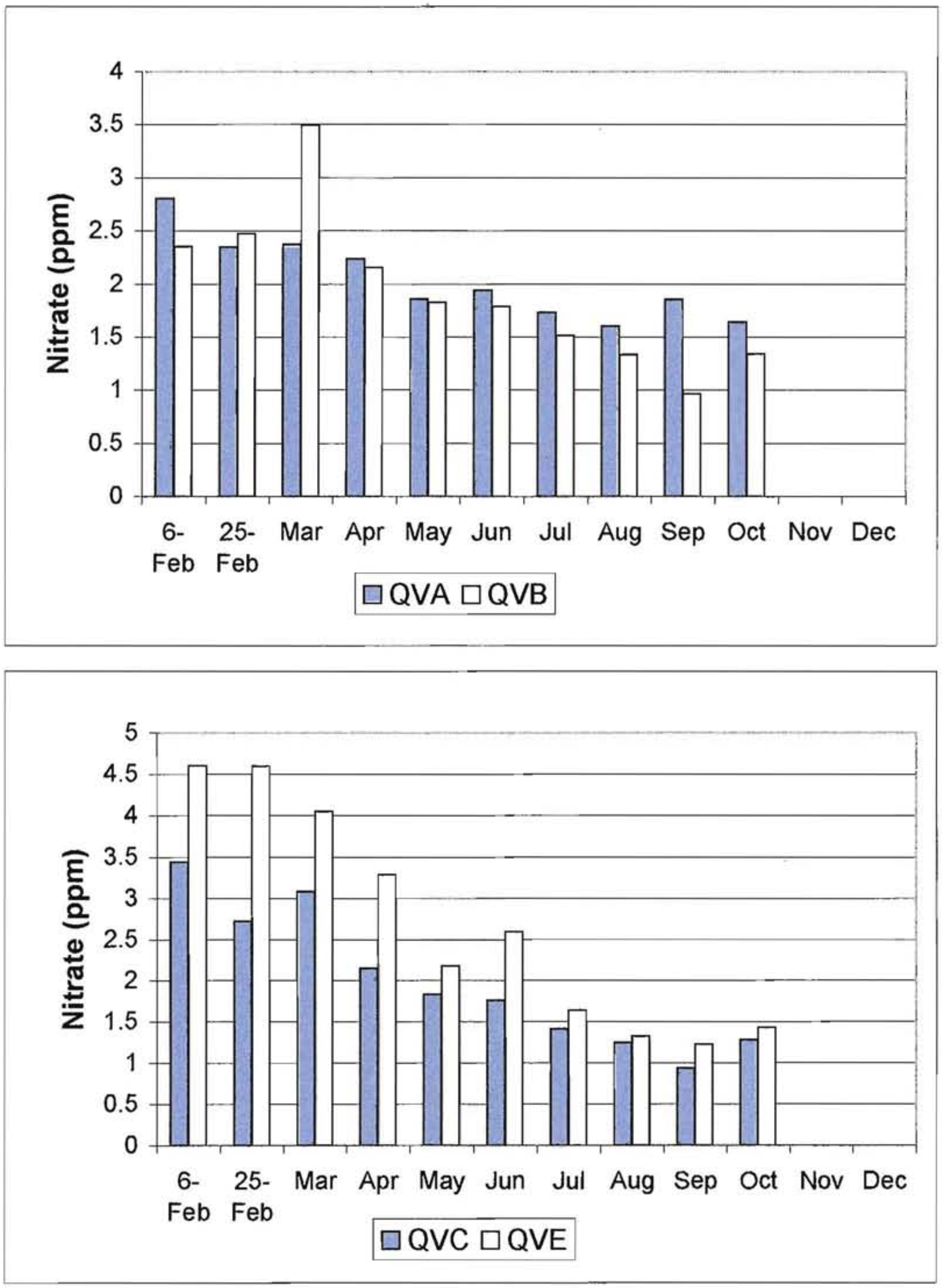


Figure 13. Concentrations of nitrate from baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997

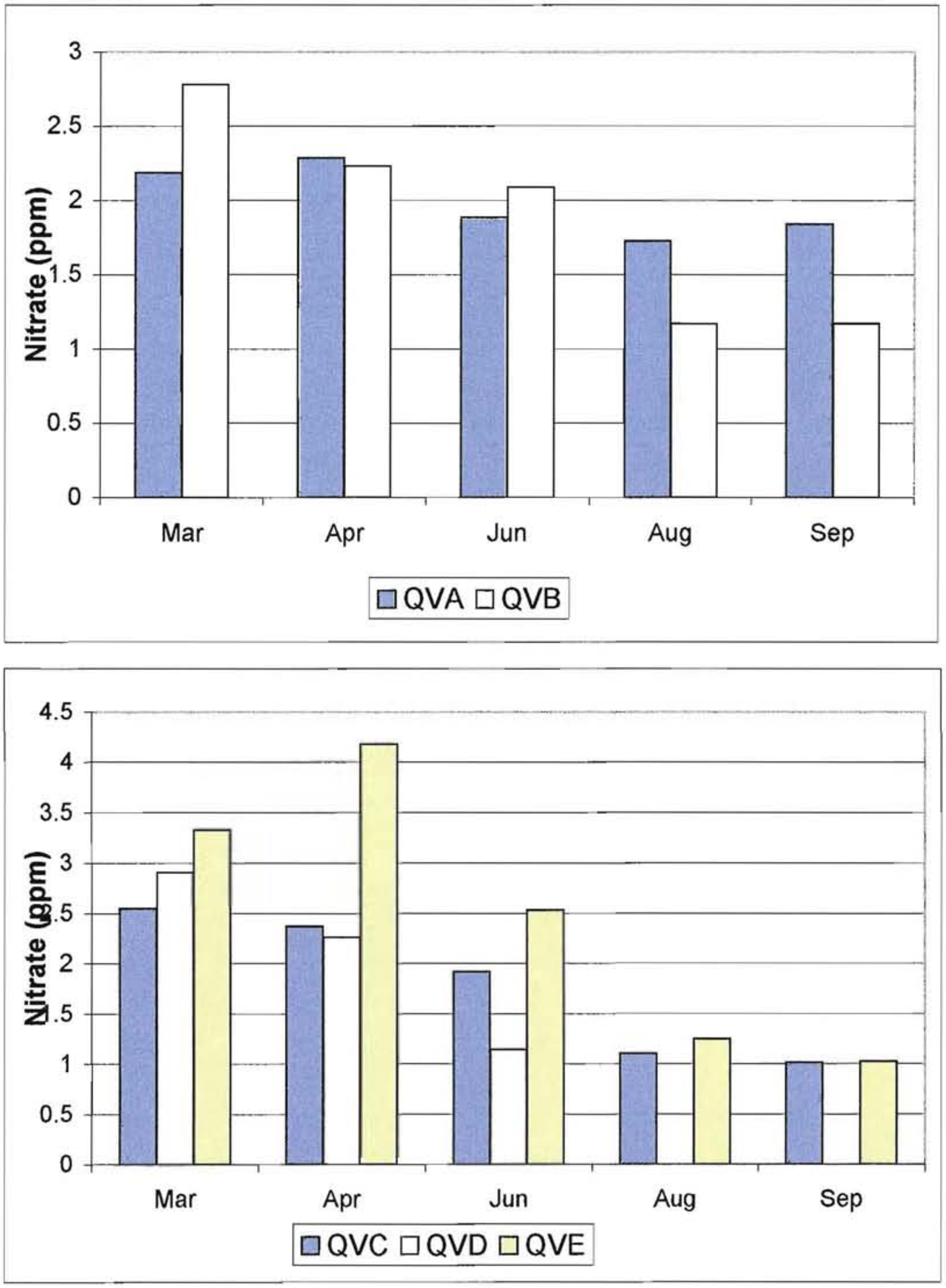
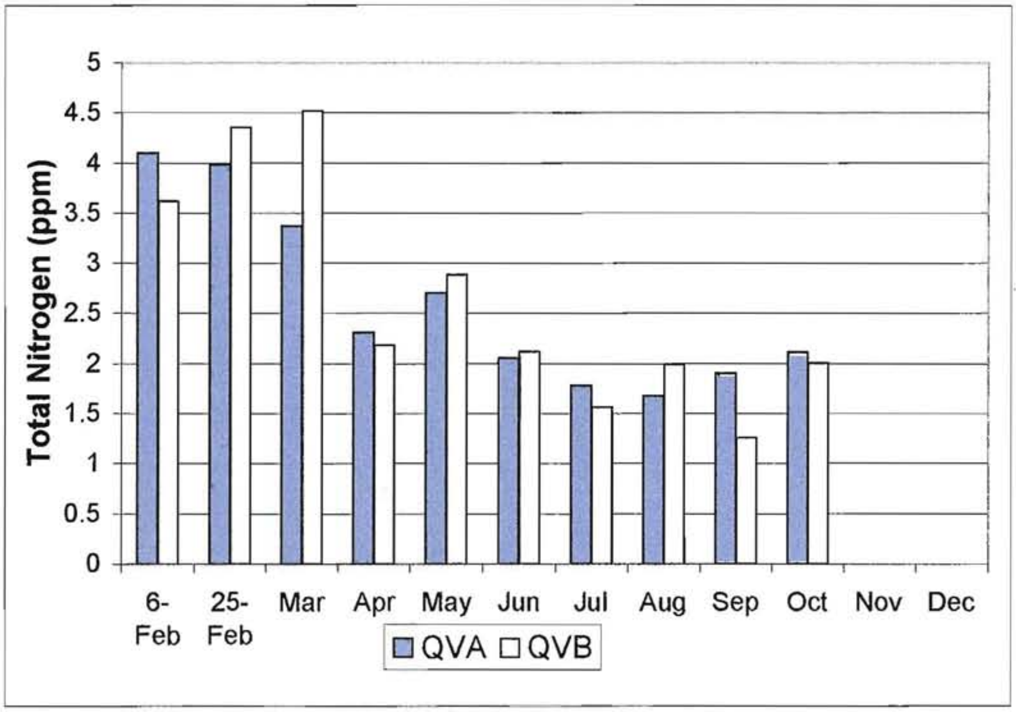


Figure 14. Concentrations of nitrate in storm event samples taken from the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997



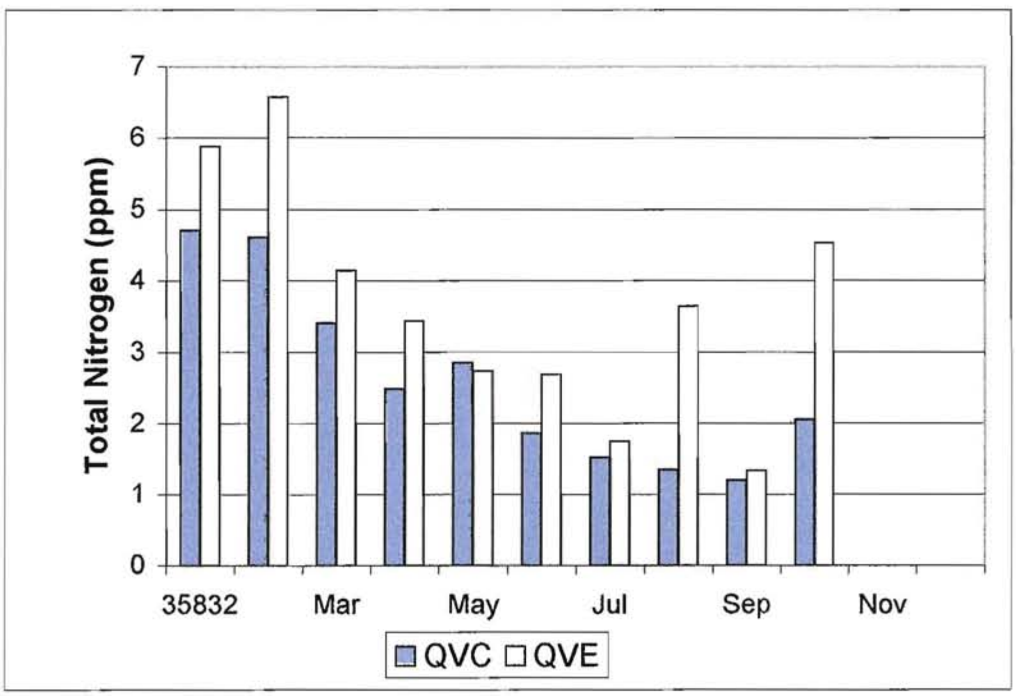


Figure 15. Concentrations of total nitrogen from baseflow samples taken at the the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997

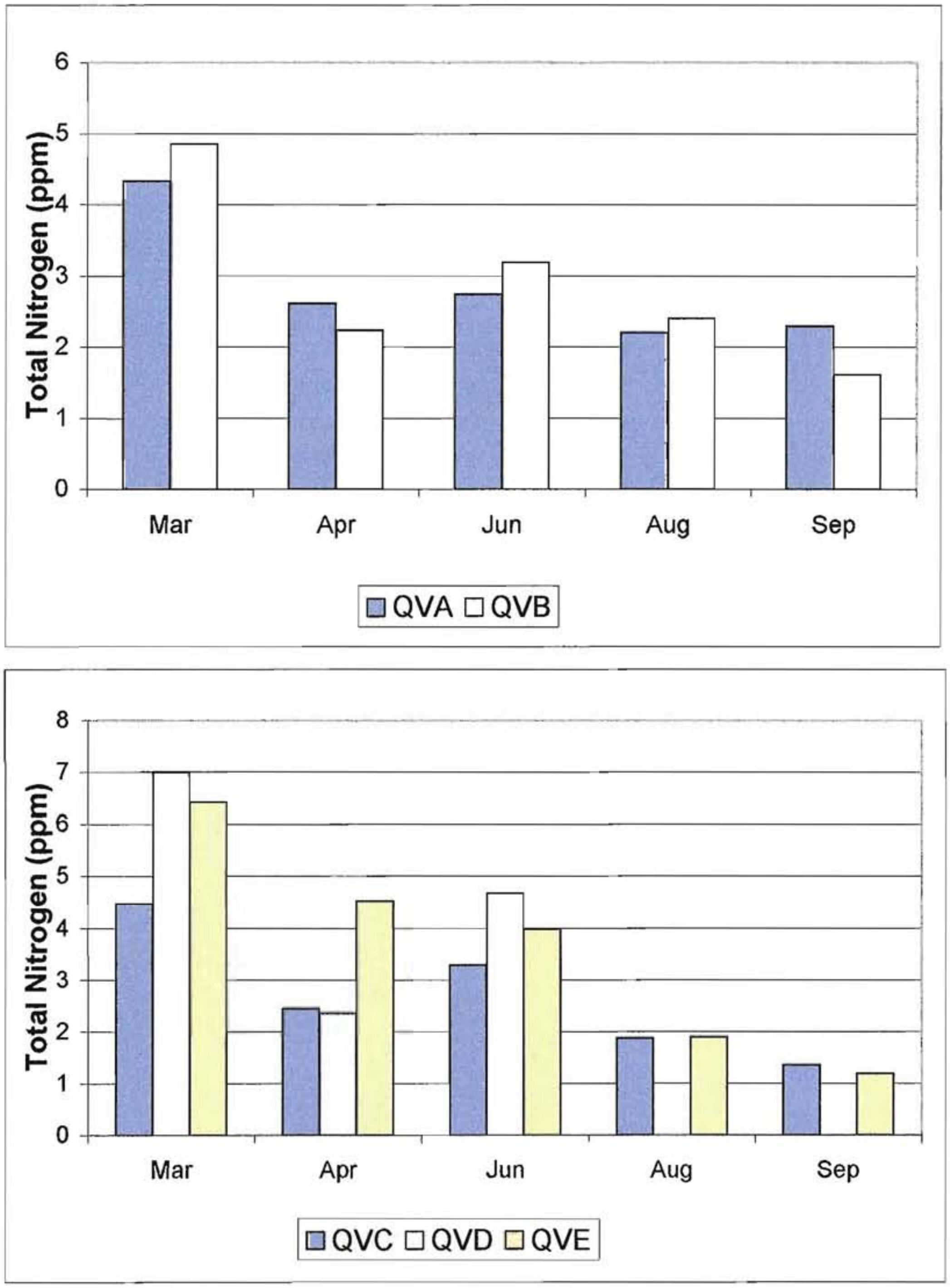


Figure 16. Concentrations of total nitrogen in storm event samples taken at the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997

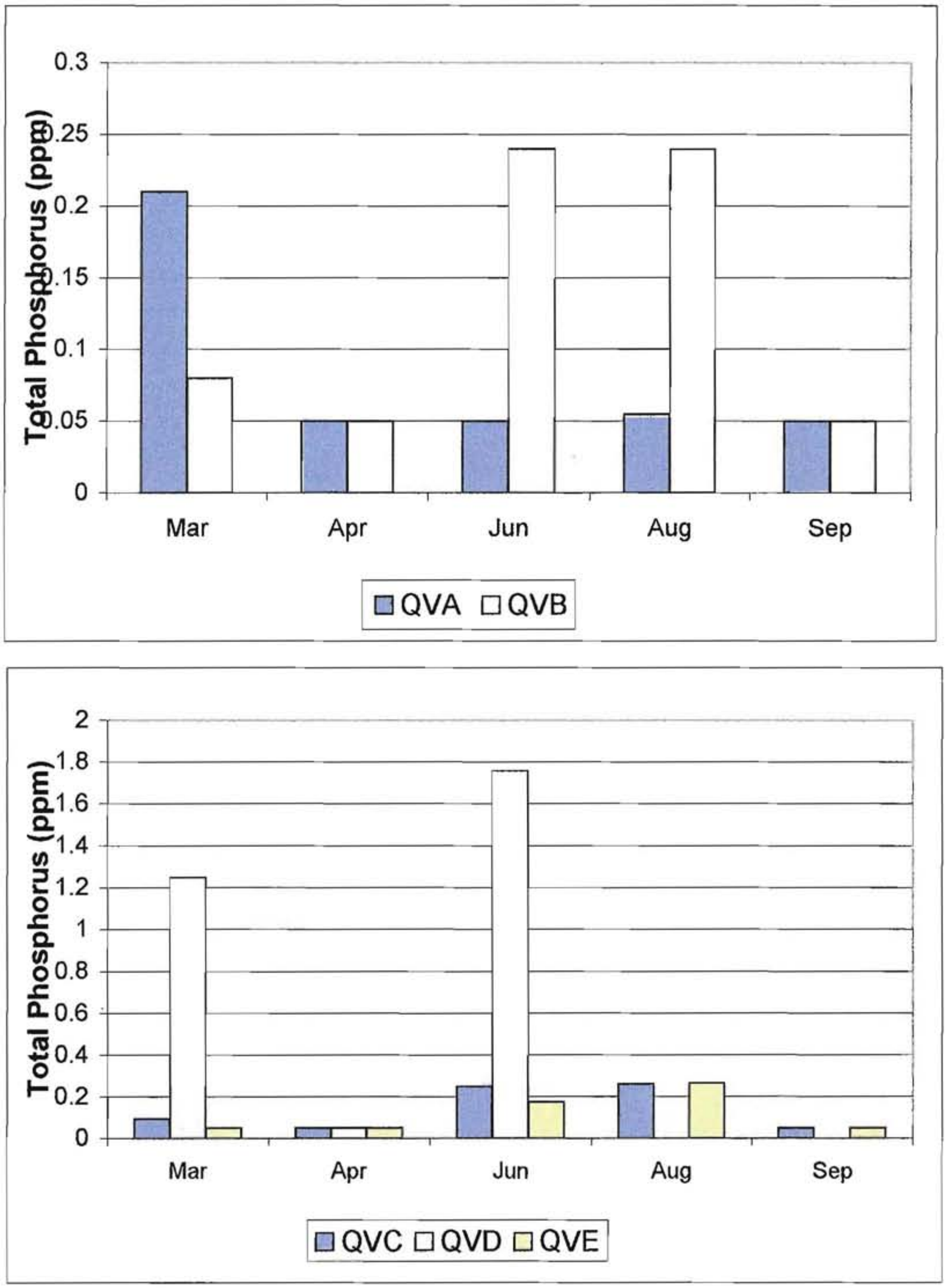
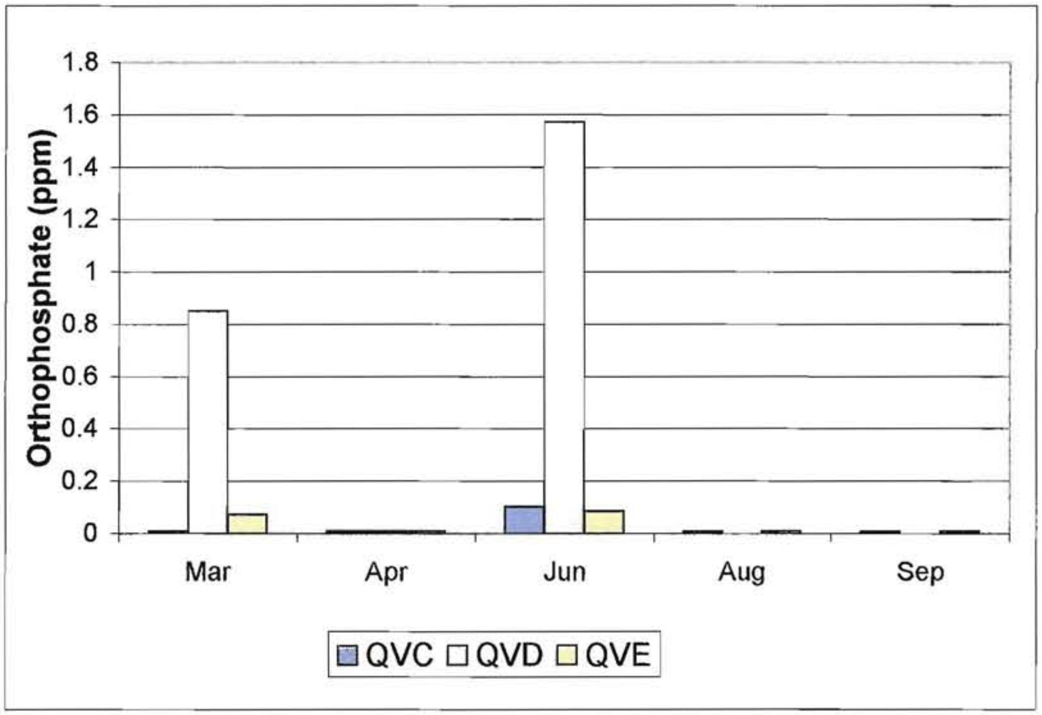


Figure 17. Concentrations of total phosphorus in storm event samples taken at the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997



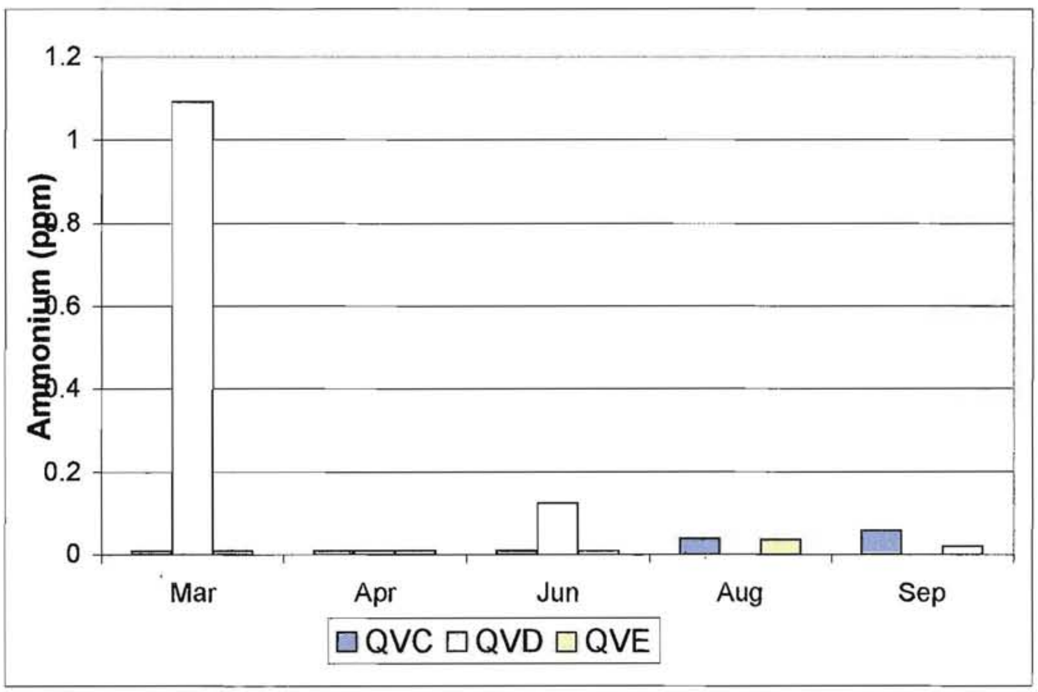


Figure 18. Concentrations of orthophosphate and ammonium in storm event samples taken from the dry pond (QVC, QVD, QVE), VT, 1997

OXYGEN DEMAND

Figures 19 and 20 show dissolved oxygen concentrations measured at all stations during baseflow and storm events, respectively. Dissolved oxygen (DO) concentrations of 5.0 mg/L should be the daily average for the mountainous regions of Virginia (State Water Control Board 1997), but levels should not be less than 4.0 mg/L. QVA and QVB show high dissolved oxygen concentration levels. These levels were especially high at QVB during the summer months showing perhaps the impact of the wet pond on increasing dissolved oxygen levels. QVC and QVE show lower dissolved oxygen levels, yet adequate, except for one sampling event in March when it reached 3 mg/L. Results from the storm event samples show a definite reduction in dissolved oxygen levels at all sites. However, the acceptable dissolved oxygen range was met, with the exception of site QVD in the June sample (3 mg/L).

Dissolved oxygen levels are important to fish, as it is their only source of oxygen. Decomposing organic matter utilizes dissolved oxygen and reduces that which is available for aquatic life. Most aquatic animals will thrive in water containing 6-10 mg/l of DO, while levels between 2 and 4 mg/l are considered medium to high pollution Dissolved oxygen levels at the storm management facility during 1997 remained in the acceptable range.

OIL AND GREASE

Runoff from parking lots and roads has the highest concentrations of hydrocarbon compounds, which are known to be toxic to aquatic life at low concentrations. Leakage of crankcase oil and other automobile lubricants on to roads and parking lots are the major source of this pollutant. Although hydrocarbons are immiscible in water and thus float, they also have a strong affinity for sediment particles. Their persistence in bottom sediments will adversely affect benthic macroinvertebrates. These compounds are best represented by the water quality parameter, total organic carbon (TOC).

Figures 21 and 22 give monthly and storm event results for TOC. Spikes in this parameter appear to be due to fecal organic matter input from site QVD and plant matter input towards the end of the growing season in September and October. The results during the storm event samples indicate reduction in TOC during the summer months due to the wet pond.

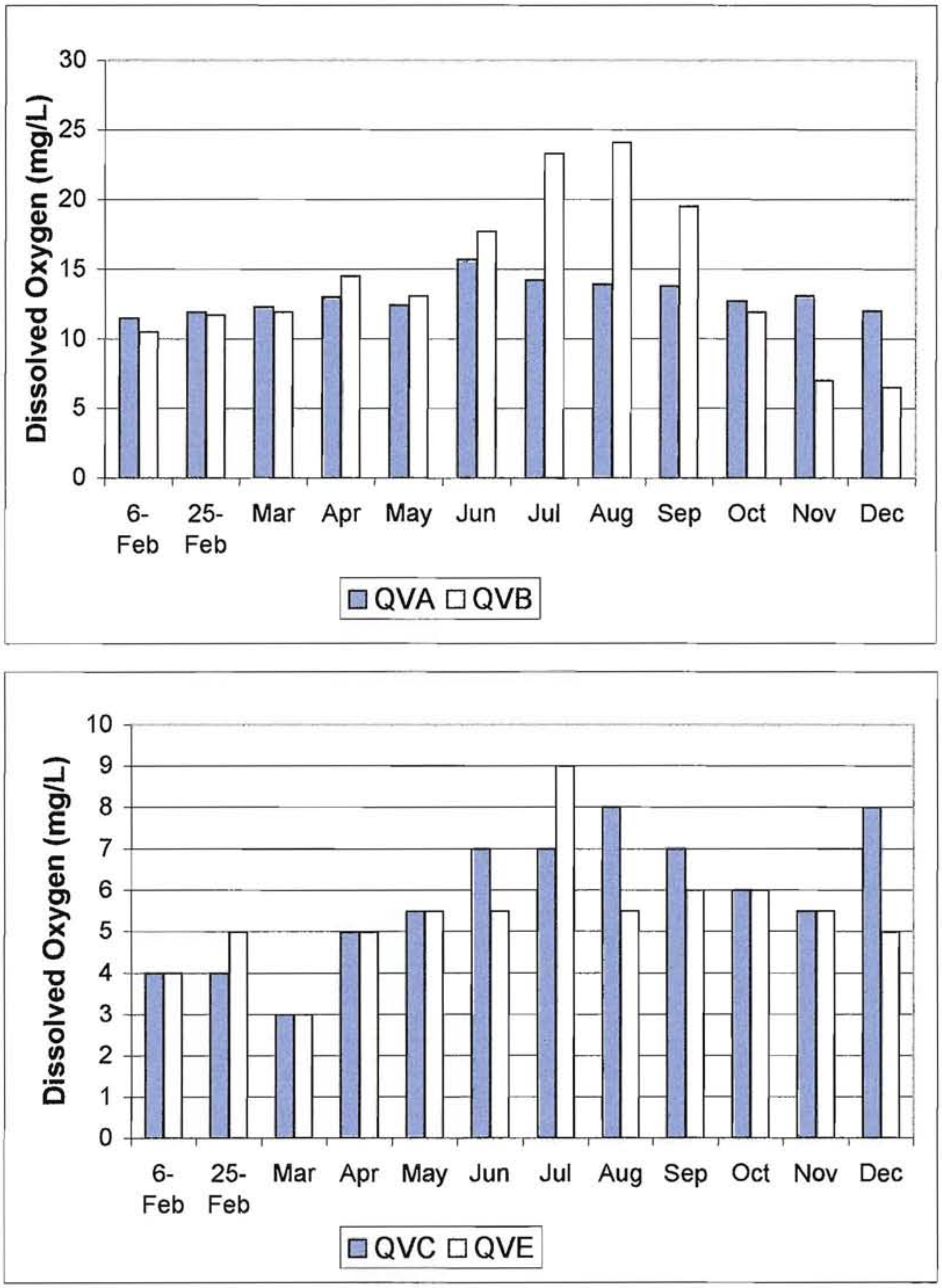
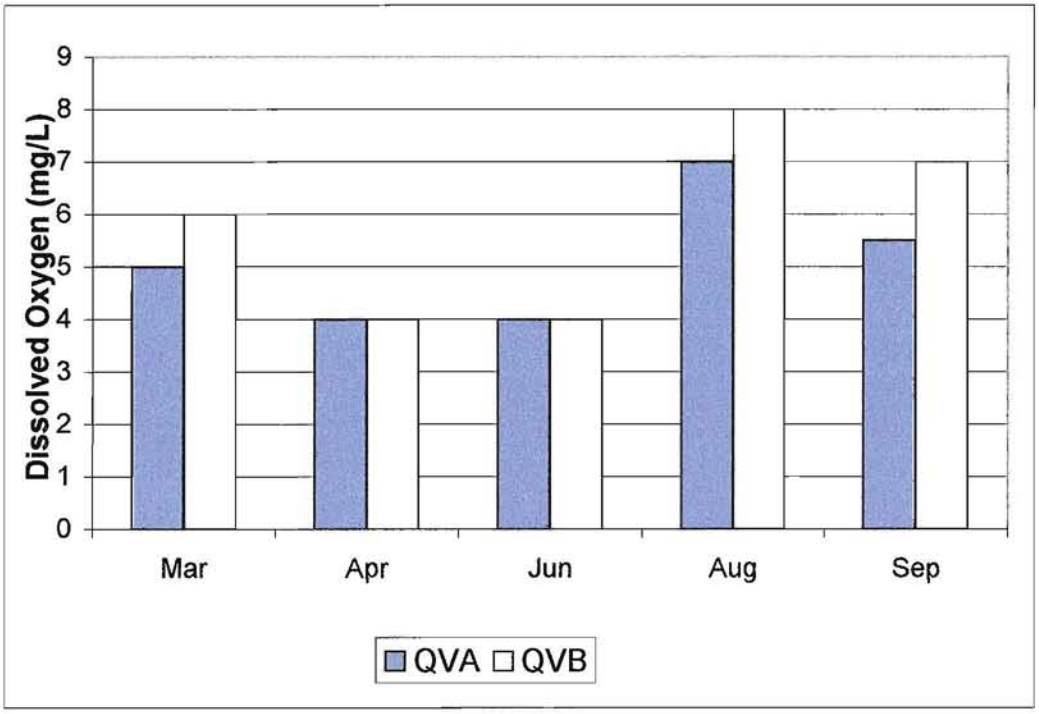


Figure 19. Concentrations of dissolved oxygen in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997



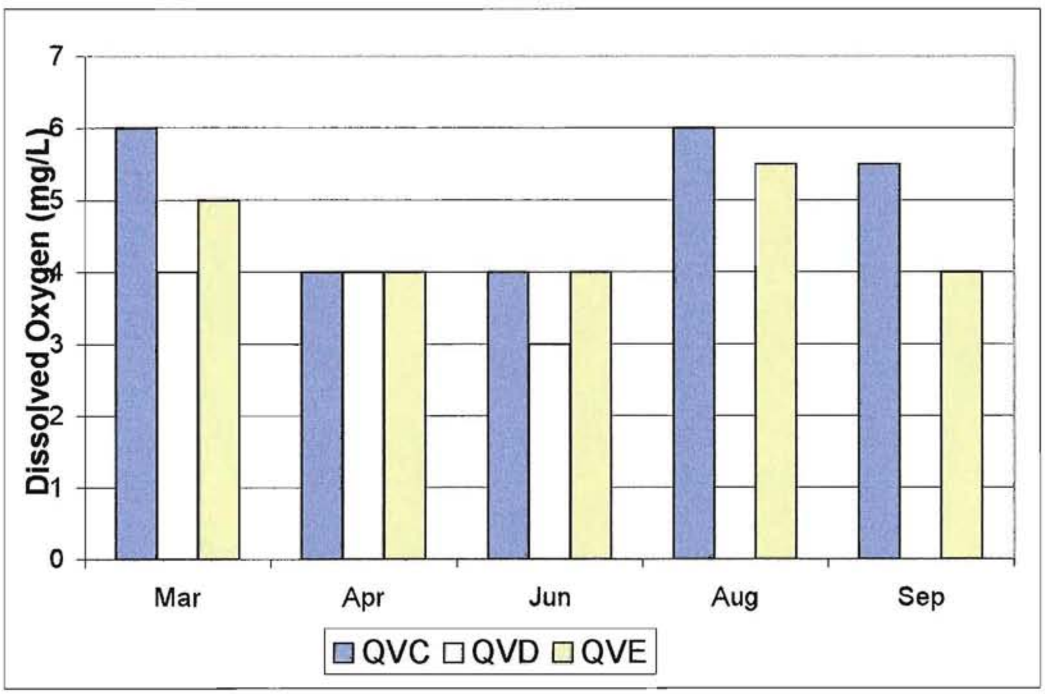


Figure 20. Concentrations of dissolved oxygen in storm event samples taken from the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997

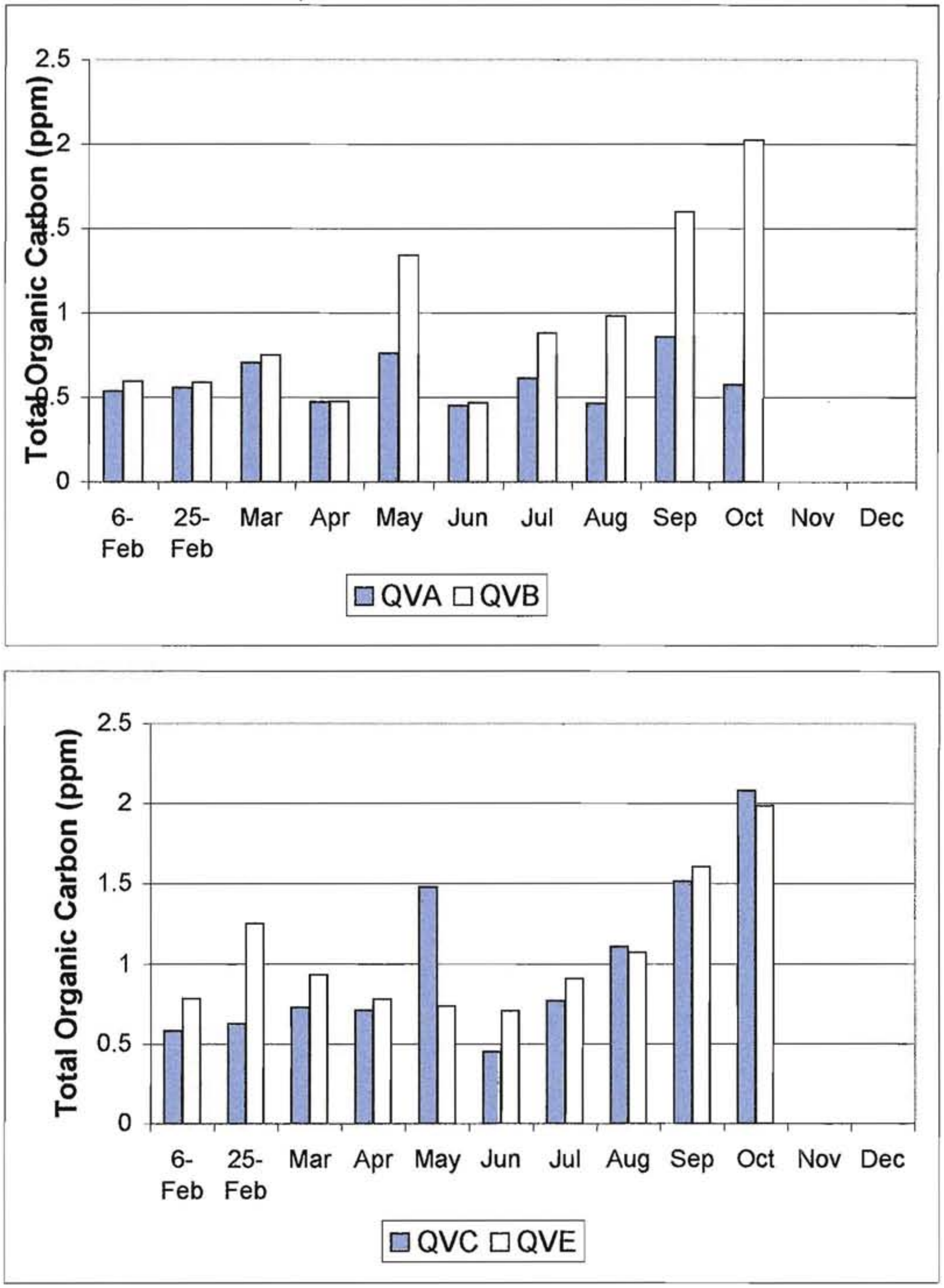
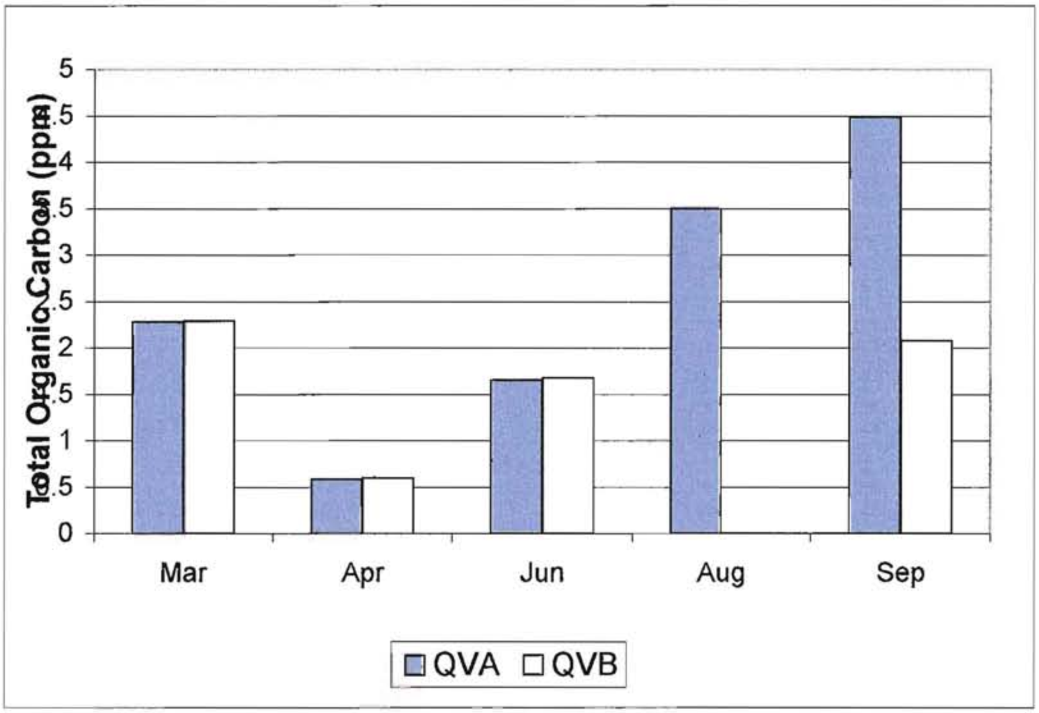


Figure 21. Concentrations of total organic carbon in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997



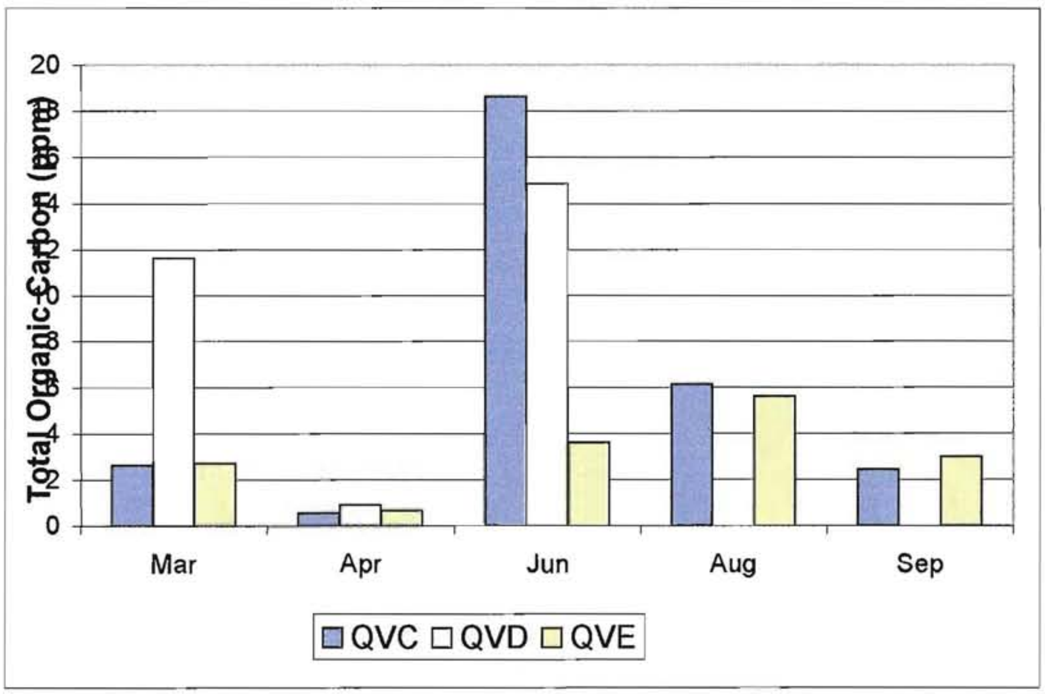


Figure 22. Concentrations of total organic carbon in storm event samples taken at the wet pond (QVA, QVB) and the dry pond (QVC, QVD, QVE), VT, 1997

TRACE METALS

Increased concentrations of trace metals are attributed to "leakage" from the urban landscape. They are primarily a concern to the community because of their potentially toxic effects on aquatic life, and their potential to contaminate supplies of drinking water. Adsorption of metals to sediment effectively reduces the concentration that is readily available for biological uptake. Another positive effect of particle settling is that urban runoff events typically occur over a shorter duration (2 to 8 hours) than the exposure intervals used in aquatic bioassay tests (24 hours to a week for chronic toxicity criteria) (Shueler 1987). Therefore, the soluble metals such as copper and zinc may be more threatening.

Copper concentrations measured at the stormwater management facility are shown in Figure 23. QVA and QVB show similar concentrations, but concentrations seem to increase from QVC to QVE (as the water moves through the quantity pond). Corn grown on the traditionally tilled fields surrounding the quantity pond may contribute copper from applied fertilizer. Peaks in concentration appear in the spring, which corresponds with fertilizer application.

Zinc concentrations are consistent from month to month, and show no decreasing or increasing trends in Figure 24. Figure 25 shows even less trend in lead results. Again, the dry detention basin may show higher lead concentrations at its outlet. Peaks of lead were seen in the fall.

Monthly samples of cadmium versus time are plotted in Figure 26. Concentrations are consistently low with the exception of the months of April, May, and June. The dry pond was completed mid-April. Excavation of the earth and rock to create the wet pond demanded a blasting program that began February 5, 1997 and ended August 6, 1997. The spikes appear to coincide with the most intense blasting periods. Also, tires are a primary source of cadmium, and the equipment used in construction (including blasting mats) may have contributed to these results.

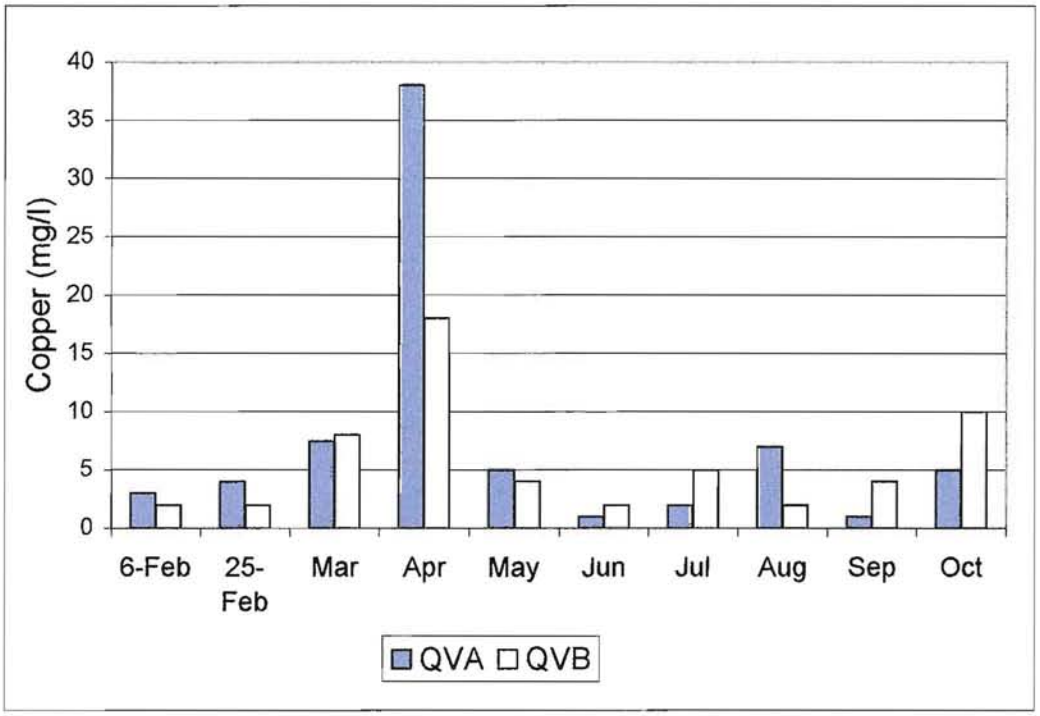
Oxidation-reduction reactions govern the solubility of trace metals in water. Organic content and pH create the environment for such reactions. Specifically, low pH increases solubility (Stumm and Morgan 1981). High organic matter, due to its high surface area to volume ratio, enrich storm water with more metals (Vestergaard 1979).

The U.S. Environmental Protection Agency has set two different standards. Maximum Contaminant Levels (MCLs) are standards that must be met by a utility providing drinking water. The second standard is the EPA trace metal criteria for urban runoff exposure, listed as the concentration causing mortality to the most sensitive individual of the most sensitive species when the species is subjected to short duration exposure (several hours once every several days). The range in values demonstrates the considerable scientific uncertainty regarding the chronic effects of trace metals on aquatic life. Table 8 is a summary of these comparisons, and shows that even the highest concentrations of the trace metals measured at the stormwater management facility satisfy both the EPA trace metal criteria and the drinking water standards. Therefore, detrimental effects due to these NPS pollutants do not appear to be of concern.

Table 8. Comparison of average concentrations exiting the wet pond detention system to U.S. EPA Standards*

Trace Metal	Peak Concentration (mg/l)	MCL for Drinking Water (mg/l)	U.S.EPA Trace Metal Criteria (mg/l)
Copper	0.004	1	20-80
Lead	0.008	0.05	150-850
Cadmium	0.005	0.005	3-20
Zinc	0.085	5	380-1200

*Values are taken from *Drinking Water Regulations and Health Advisories* from April 1992 and Schueler 1987.



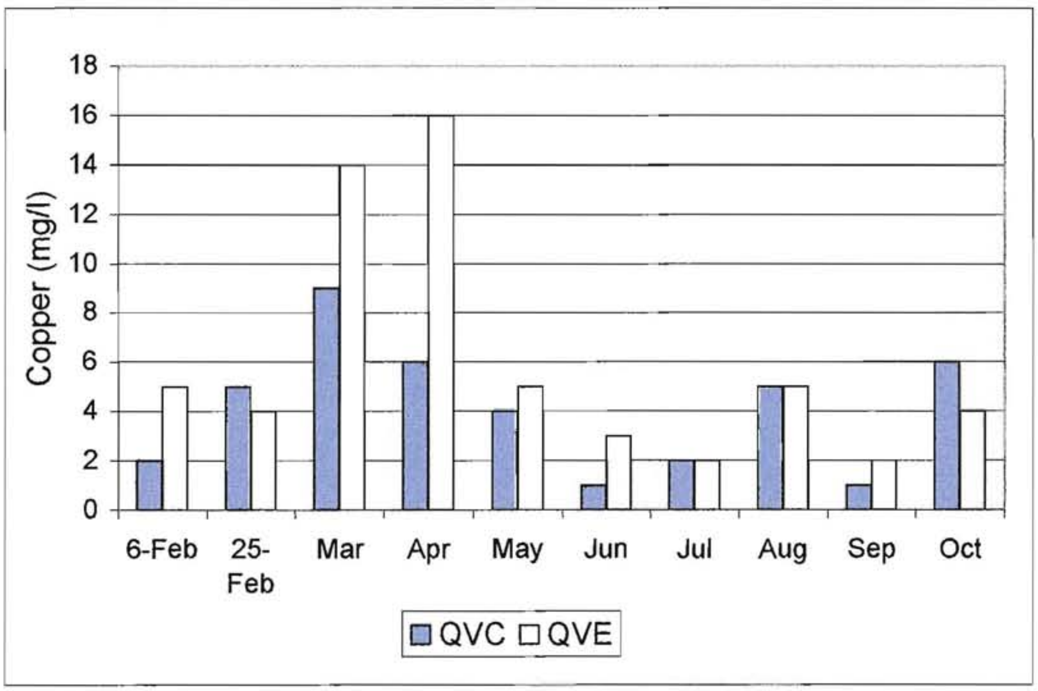
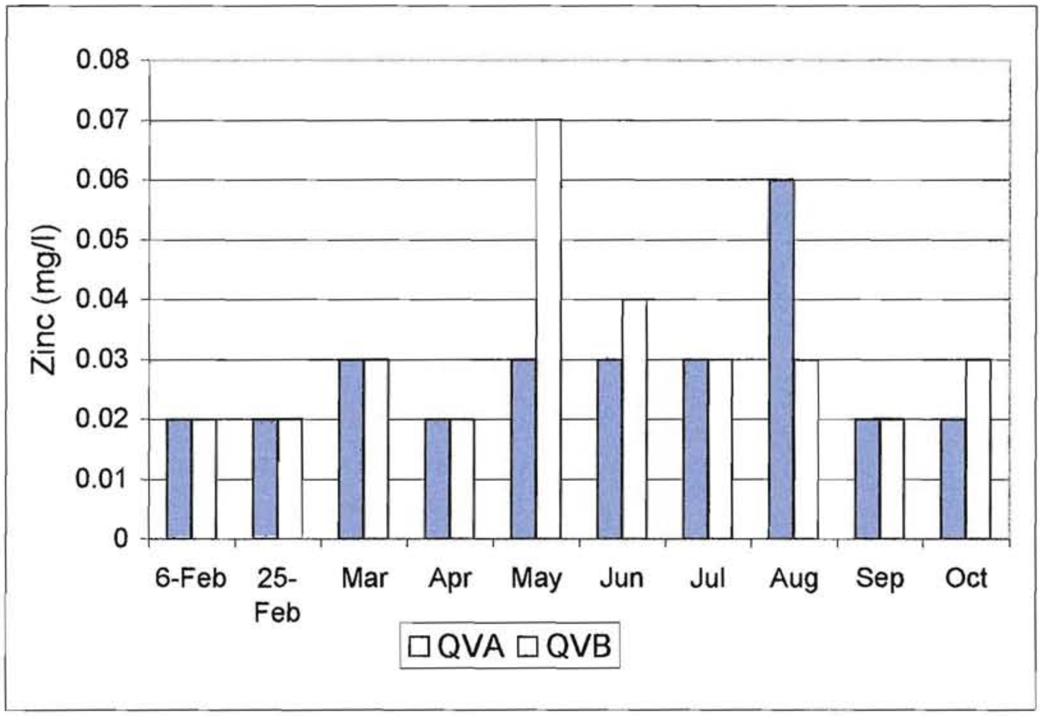


Figure 23. Concentration of copper in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997



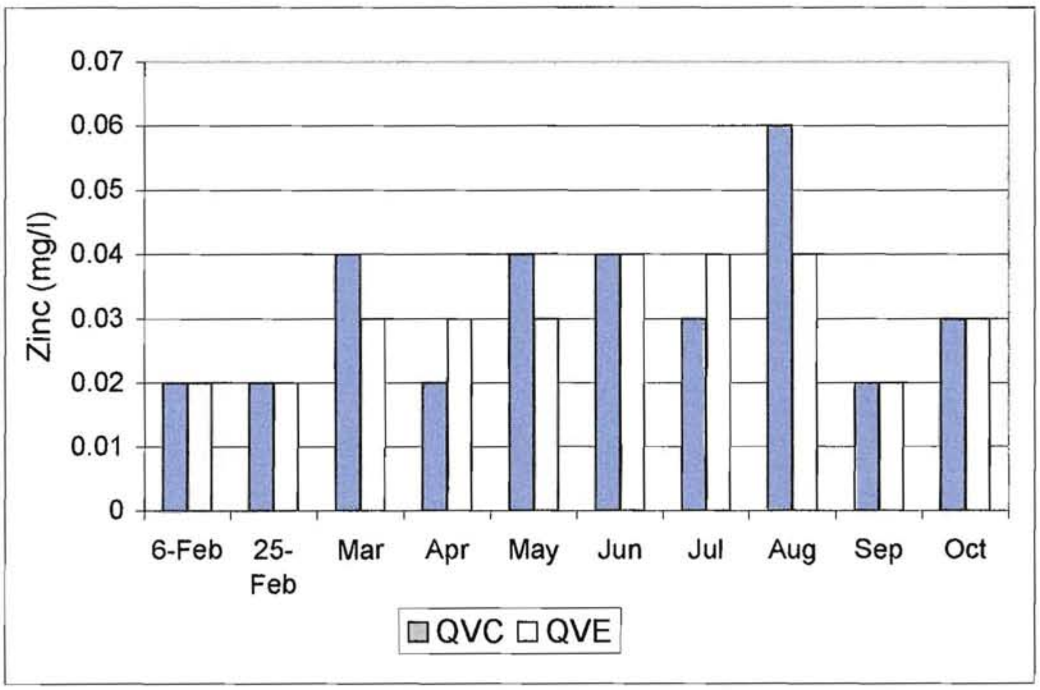
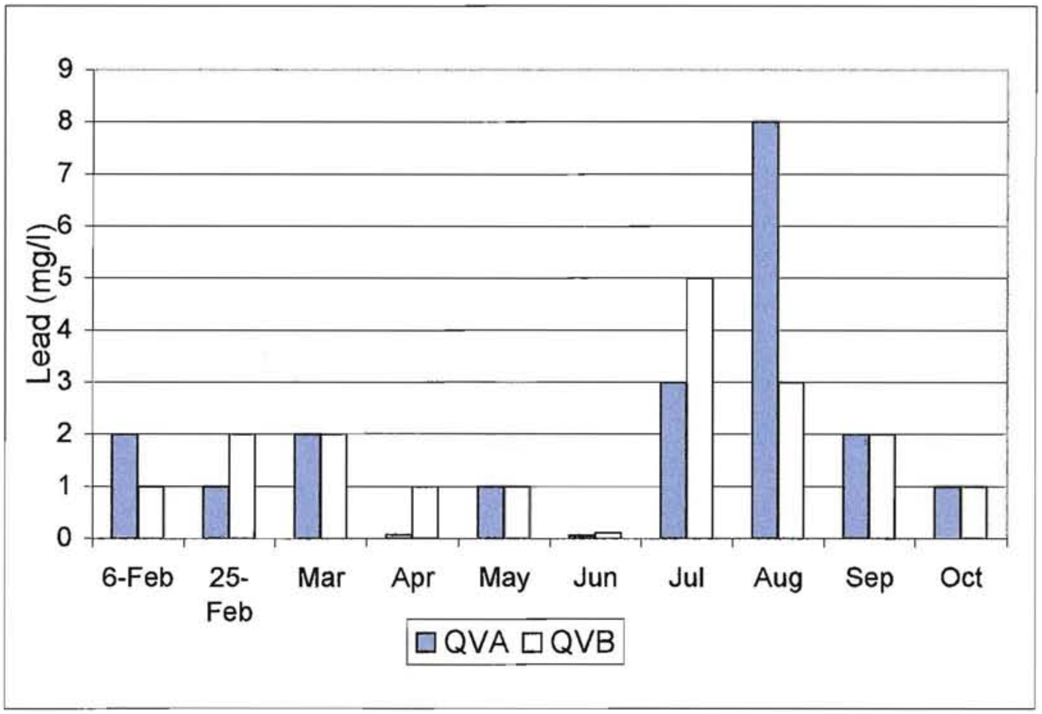


Figure 24. Concentration of zinc in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997



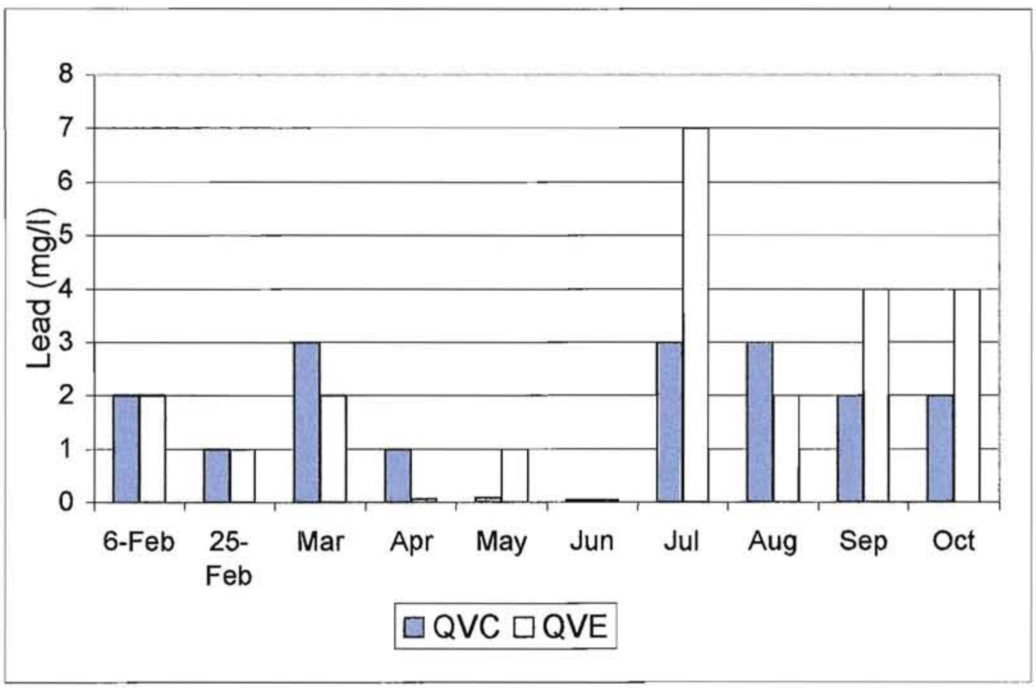


Figure 25. Concentration of lead in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997

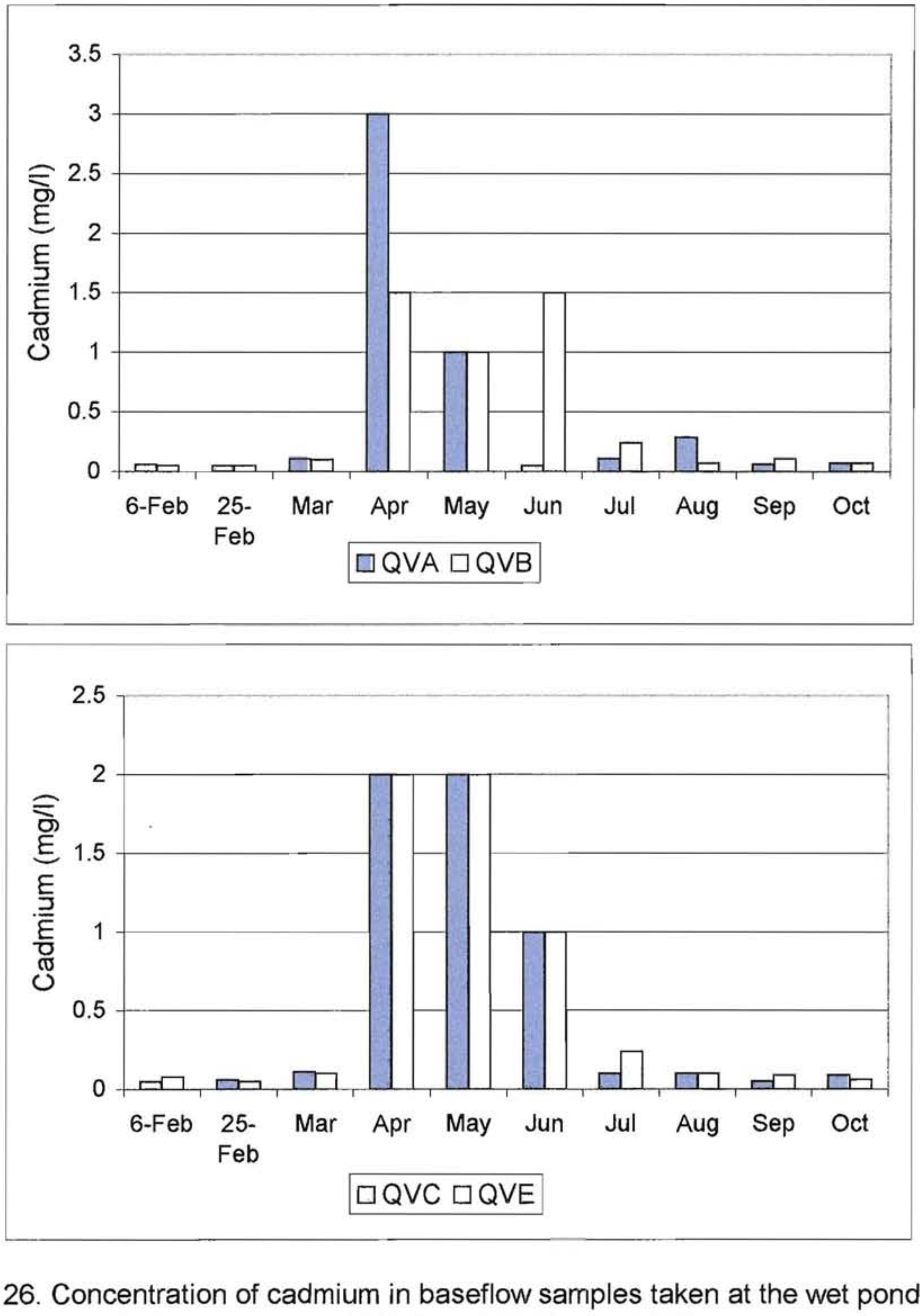


Figure 26. Concentration of cadmium in baseflow samples taken at the wet pond (QVA and QVB) and dry pond (QVC and QVE), VT, 1997

5.0 BENTHIC MACROINVERTEBRATE RESULTS AND DISCUSSION

HABITAT

Habitat quality assessments are presented in Tables 10, 11, and 12 for the three sampling dates, respectively. Habitat scores at all six study sites were low, but especially so at sites QVA, QVB, QVC, and QVE on the study stream. The maximum possible habitat score is 200, and relatively undisturbed streams of similar size in the Ridge and Valley ecoregion usually have habitat scores of at least 160. The most conspicuous problem with habitat quality in the study stream is the large amount of sediment that has accumulated in the riffles (see habitat measures 1, 2, 3, and 5 in Tables 10-12). In some cases, the coarse mineral substratum (cobble, pebble), which is preferred by most benthic macro-invertebrates, has been completely covered with sand and silt. In other cases, there are some cobbles and pebbles left exposed, but the base of this material has been tightly embedded in sand and silt. Poor habitat quality existed before the construction of the Virginia Tech Wet-Pond Detention Facility, but conditions worsened as a result of appreciable erosion during construction. Note in Tables 11 and 12 that the habitat scores at sites QVB and QVC decreased by 10 and by 6 at site QVE in April and August. This decrease was accounted for by habitat measures related to sedimentation (habitat measures 1, 2, 3, and 5). Field observations clearly documented that the sediment was coming from uncontrolled erosion related to construction, and this is substantiated by the fact that there was no increase in sedimentation at sites unaffected by construction. Habitat quality did not change at site QVA, or in Stroubles Creek, or CRC stream during April and August.

BENTHIC MACROINVERTEBRATES

Macroinvertebrate results are presented in Tables 13-18. All taxa collected and the numbers of each are presented in Table 13-18 for February, April, and August, respectively. Several conspicuous results are readily apparent in Tables 13-18. The total number of taxa collected in all streams, including the off-site streams, for all dates was very low (32). In other similar size streams in the Ridge and Valley ecoregion, Voshell usually finds two or three times as many taxa. Most of the organisms in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are sensitive to pollution and environmental stress. Hardly any taxa belonging to these three sensitive orders were collected at any of the sites in any of the streams, especially during February and April. Low numbers of a few taxa in these sensitive orders appeared in August, and the numbers were a bit higher in the study stream than the off-site streams. The few taxa that were consistently present included invertebrates other than insects, such as Amphipoda (scuds), Asellidae (sowbugs), and Oligochaeta (worms), and insects such as Chironomidae (midges) and Simuliidae (black flies). All of the taxa that were consistently present are either tolerant or facultative of pollution and environmental stress.

The metric values for all sites in February, April, and August are given in Tables 16-18, respectively. There was little difference among all sites and among sampling dates in February and April (Tables 16 and 17). At the sites affected by the Virginia Tech Wet-Pond Detention Facility (sites QVB, QVC, QVE), taxa richness increased by 2-3 times in August as compared to February and April. Taxa richness did not increase at site QVA in August but did increase by about the same relative amount at the off-site streams, Stroubles Creek, and the CRC stream. However, even the increased taxa richness in August falls below what would be expected in a relatively unimpaired stream in the Ridge and Valley ecoregion. Voshell has found that taxa richness (calculated at the same taxonomic level) averages 23 and ranges from 18 to 34 in similar-size streams in this area, if there is relatively little impairment from pollution or environmental stress. Therefore, even the highest taxa richness in this study (16 at Site E on August 29, 1997) was lower than the minimum value expected for this metric in streams with relatively little pollution or environmental stress.

For the other nine individual metrics that comprise the MAIS, there was also little difference among all sites and among sampling dates in February and April (Tables 16 and 17). What is most important about these results is that all metrics, which reflect very different aspects of community ecology, have values that strongly indicate impairment from pollution or environmental stress. There were some very slight improvements in these metrics in August, especially at sites QVB, QVC, and QVE (Table 18). Smith and Voshell (1997) statistically analyzed the usefulness of 69 metrics and determined that these 9 metrics were the most ecologically meaningful, and they had the greatest statistical discriminatory ability for assessing the biological condition of wadeable streams in the mid-Atlantic highlands. Recently, Voshell has been conducting studies on the effects of cattle grazing and watering in small streams in the Ridge and Valley ecoregion. As part of these studies, he has acquired data from five small streams that have relatively little impairment and represent reference, or best attainable, conditions. Expected values for the nine metrics in small streams with relatively little pollution or environmental stress are summarized in Table 9. There were several sampling dates for each stream that corresponded to the dates in this study.

Table 9. Voshell's reference data for five small streams in Virginia with little or no environmental impairment.

	Mean	Range
% 5 Dominant Taxa	< 76	58 - 91
Modified HBI	< 4.10	3.23 - 5.50
% Haptobenthos	> 70	52 - 95
EPT Index	> 13	9 - 18
# Ephemeroptera	> 4	3 - 6
% Ephemeroptera	> 22	7 - 42
Simpson Diversity Index	> 0.83	0.74 - 0.90
# Intolerant Taxa	> 18	14 - 24
% Scrapers	> 25	2 - 69

Values for five of the nine metrics (Modified HBI, % Haptobenthos, EPT Index, # Ephemeroptera, and # Intolerant Taxa) fell outside of the expected range of values at all sites on all dates. Values for the other four metrics (% 5 Dominant Taxa, % Ephemeroptera, Simpson Diversity Index, and % Scrapers) usually fell outside of the expected range of values, but at a few sites on a few dates values were barely within the expected range of values.

The last part of the assessment of biological condition involved categorization evaluation by the multimetric index called the Macroinvertebrate Aggregated Index for Streams (MAIS). The MAIS integrates values for the nine metrics listed above into a single numerical score between 0 and 18 and categorizes biological condition as Very Good, Good, Poor, or Very Poor. Very Good and Good are considered acceptable biological conditions, while Poor and Very Poor are considered unacceptable biological conditions (Smith and Voshell 1997). MAIS scores and biological condition categories for all sites in February, April, and August are presented at the bottom of Tables 15-17, respectively. MAIS scores for February and April were consistently very low at all sites, ranging from 0-4, which were all in the worst biological condition category, Very Poor. There was slight improvement at sites QVB and QVE and the CRC stream in August, ranging from 7-9, but these MAIS scores still reflect an unacceptable biological condition category of Poor. Smith and Voshell (1997) found that these criteria for biological condition categories had an error rate of only 10 percent. Voshell, in recent studies of cattle grazing mentioned above, found that the MAIS score for reference streams averaged 15 and ranged from 12-17. Because the highest MAIS score for any site in this study was 9, it is clear that all of the streams have seriously impaired biological conditions.

BENTHIC MACROINVERTEBRATE DISCUSSION

The most obvious reason for the seriously impaired biological conditions is poor habitat quality. Previous erosion and additional erosion during construction of the Virginia Tech Wet-Pond Detention Facility have introduced a tremendous amount of sediment into the study stream. Sedimentation has destroyed most of the coarse mineral substratum (cobble and pebble), which is the preferred habitat for most stream benthic macroinvertebrates. Benthic macroinvertebrates that require firm clean substratum (haptobenthos) are much less abundant in the study stream than in normal streams. Sediment also prevents algae from growing on stable rocks, thereby eliminating an important source of food for many benthic macroinvertebrates in streams. In the study stream, benthic macroinvertebrates that feed on algae (scrapers) are practically nonexistent. The sediment in the study stream probably was caused by many years of poor agricultural practices at Virginia Tech. Although at the present there is a good buffer strip of vegetation between the stream channel and the corn that is grown by traditional tillage methods, the sedimentation problem in the study stream is typical of streams where fields are plowed to the edge of the water or cattle are given complete access to the water. In addition, the sedimentation problem in the study steam was made worse by the construction of the Veterinary Medicine facility. Some of the storm water from the roads and parking lots of the facility is directed into culverts that empty onto an earthen bank. Eroded soils from the bank wash across the vegetated flood plain during heavy rains and enter the study stream. During construction of the Virginia Tech Wet-Pond Detention Facility very few sediment fences were used, and heavy equipment worked directly in the stream channel in many places.

Another problem with habitat in the study stream is the lack of shrubs and trees in the riparian area. Optimum biological conditions within the stream are achieved when there is partial shade to moderate temperatures and prevent blooms of nuisance algae. The leaves that drop into the stream from riparian shrubs and trees are another important source of food for some benthic macroinvertebrates. Benthic macroinvertebrates that feed on dead leaves (shredders) do not occur in the study stream.

The benthic macroinvertebrate community in the study stream appears to be too depauperate to be explained completely by poor habitat quality. There are many more benthic macroinvertebrate taxa that should be expected to occur in the sandy, silty areas that cover most of the bottom of the study stream. Exceptionally low taxa richness, such as occurs in the study stream, is usually caused by toxic substances. As described previously the study stream collects runoff from roads, parking lots, suburban neighborhoods, and land used for agricultural production. All of these are producers of potentially of toxic substances, both organic and inorganic, that could enter the study stream.

Table 10. Habitat assessment at study sites for Virginia Tech wet-pond detention facility on February 20, 1997.

Habitat Measures	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
1) Epifaunal substrate/ available cover (0-20)	11	8	8	11	13	11
2) Riffle quality (0-20)	13	8	8	11	14	13
3) Embeddedness (0-20)	10	5	5	7	10	13
4) Channel alteration (0-20)	11	11	11	11	11	13
5) Sediment deposition (0-20)	10	5	5	6	10	13
6) Frequency of riffles (or pools)/velocity-depth combinations (0-20)	11	9	9	11	11	11
7) Channel flow status (0-20)	16	16	16	16	16	16
8) Bank vegetative protection						
Left bank (0-10)	4	7	7	7	8	8
Right bank (0-10)	4	7	7	7	8	8
9) Bank stability						
Left bank (0-10)	7	8	8	8	8	8
Right bank (0-10)	7	8	8	8	8	8
10) Riparian vegetative zone stability						
Left bank (0-10)	1	5	5	5	5	8
Right bank (0-10)	1	5	5	5	8	8
Habitat Score (0-200)	106	102	102	113	130	138

Table 11. Habitat assessment at study sites for Virginia Tech wet-pond detention facility on April 29, 1997.

Habitat Measures	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
1) Epifaunal substrate/ available cover (0-20)	11	6	6	10	13	11
2) Riffle quality (0-20)	13	6	6	11	14	13
3) Embeddedness (0-20)	10	2	2	5	10	13
4) Channel alteration (0-20)	11	11	11	11	11	13
5) Sediment deposition (0-20)	10	2	2	3	10	13
6) Frequency of riffles (or pools)/velocity-depth combinations (0-20)	11	9	9	11	11	11
7) Channel flow status (0-20)	16	16	16	16	16	16
8) Bank vegetative protection						
Left bank (0-10)	4	7	7	7	8	8
Right bank (0-10)	4	7	7	7	8	8
9) Bank stability						
Left bank (0-10)	7	8	8	8	8	8
Right bank (0-10)	7	8	8	8	8	8
10) Riparian vegetative zone stability						
Left bank (0-10)	1	5	5	5	5	8
Right bank (0-10)	1	5	5	5	8	8
Habitat Score (0-200)	106	92	92	107	130	138

Table 12. Habitat assessment at study sites for Virginia Tech wet-pond detention facility on August 29, 1997.

Habitat Measures	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
1) Epifaunal substrate/ available cover (0-20)	11	6	6	10	13	11
2) Riffle quality (0-20)	13	6	6	11	14	13
3) Embeddedness (0-20)	10	2	2	5	10	13
4) Channel alteration (0-20)	11	11	11	11	11	13
5) Sediment deposition (0-20)	10	2	2	3	10	13
6) Frequency of riffles (or pools)/velocity-depth combinations (0-20)	11	9	9	11	11	11
7) Channel flow status (0-20)	16	16	16	16	16	16
8) Bank vegetative protection						
Left bank (0-10)	4	7	7	7	8	8
Right bank (0-10)	4	7	7	7	8	8
9) Bank stability						
Left bank (0-10)	7	8	8	8	8	8
Right bank (0-10)	7	8	8	8	8	8
10) Riparian vegetative zone stability						
Left bank (0-10)	1	5	5	5	5	8
Right bank (0-10)	1	5	5	5	8	8
Habitat Score (0-200)	106	92	92	107	130	138

Table 13. All benthic macroinvertebrate taxa and counts from samples at study sites for Virginia Tech wet-pond detention facility on February 20, 1997.

Taxa	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Other Invertebrates						
Amphipoda				41	11	
Asellidae		1	10	32		
Cambaridae			6	3		
Collembola	1					
Corbiculidae					28	
Oligochaeta	16		13			
Planariidae						
Planorbidae						
Pleuroceridae						
Ephemeroptera (Mayflies)						
Baetidae						1
Ephemerellidae						
Odonata (Damsel-,Dragonflies)						
Aeshnidae						
Calopterygidae						
Coenagrionidae						1
Plecoptea (Stoneflies)						
Nemouridae						
Hemiptera (True Bugs)						
Corixidae						
Gerridae						
Notonectidae						
Veliidae						
Coleoptera (Beetles)						
Dytiscidae		1	1	1		1
Elmidae	2		2	2		1
Haliplidae						
Trichoptera (Caddisflies)						
Hydropsychidae	2			1		
Hydroptilidae						
Diptera (True Flies)						
Ceratopogonidae						
Chironomidae	146	1180	144	87	163	211
Dixidae						
Muscidae						1
Simuliidae	3	10	7	12	31	8
Stratiomyidae						
Tabanidae						
Tipulidae			1	1		

Table 14. All benthic macroinvertebrate taxa and counts from samples at study sites for Virginia Tech wet-pond detention facility on April 29, 1997.

Taxa	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Other Invertebrates						
Amphipoda				37	6	
Asellidae		2	6	15		
Cambaridae	1					1
Collembola	1					1
Corbiculidae			1	2	20	
Oligochaeta	29	24	28	10	4	12
Planariidae						
Planorbidae					1	
Pleuroceridae						
Ephemeroptera (Mayflies)						
Baetidae			1			
Ephemerellidae						
Odonata (Damsel-,Dragonflies)						
Aeshnidae						1
Calopterygidae						4
Coenagrionidae						
Plecoptea (Stoneflies)						
Nemouridae						2
Hemiptera (True Bugs)						
Corixidae						
Gerridae						
Notonectidae						
Veliidae						
Coleoptera (Beetles)						
Dytiscidae	5	3	1	3	1	1
Elmidae	1				4	3
Haliplidae						
Trichoptera (Caddisflies)						
Hydropsychidae						
Hydroptilidae				1		
Diptera (True Flies)						
Ceratopogonidae						
Chironomidae	142	148	150	132	87	147
Dixidae						
Muscidae	3			1	1	3
Simuliidae	1	19	23	23	76	64
Stratiomyidae						
Tabanidae						
Tipulidae						

Table 15. All benthic macroinvertebrate taxa and counts from samples at study sites for Virginia Tech wet-pond detention facility on August 29, 1997.

Taxa	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Other Invertebrates						
Amphipoda			1	19	67	1
Asellidae	2				1	
Cambaridae		17	11	4		
Collembola		1				
Corbiculidae				1	47	3
Oligochaeta	15	7	17		8	50
Planariidae	7	15	11	12	60	21
Planorbidae						
Pleuroceridae		6		21		
Ephemeroptera (Mayflies)						
Baetidae		10	1	9		1
Ephemerellidae		8	1	2		
Odonata (Damsel-,Dragonflies)						
Aeshnidae						
Calopterygidae						
Coenagrionidae		5				2
Plecoptea (Stoneflies)						
Nemouridae						
Hemiptera (True Bugs)						
Corixidae			12			12
Gerridae		4	1		1	
Notonectidae				1		
Veliidae		2	1		3	
Coleoptera (Beetles)						
Dytiscidae	3	4	2			
Elmidae	1	1		1	8	16
Haliplidae						1
Trichoptera (Caddisflies)						
Hydropsychidae			1	27		
Hydroptilidae				1		
Diptera (True Flies)						
Ceratopogonidae						
Chironomidae	20	46	75	90	8	51
Dixidae				1	1	2
Muscidae	6			2		
Simuliidae		5	2	11	3	1
Stratiomyidae					2	1
Tabanidae		1				
Tipulidae				1		

Table 16. Benthic macroinvertebrate community metrics at study sites for Virginia Tech wet-pond detention facility on February 20, 1997.

Metrics	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Taxa Richness	6	5	8	9	5	7
% 5 Dominant Taxa	99.4	100.0	97.8	97.2	100.0	99.1
Modified HBI	6.17	6.00	6.18	6.53	6.05	6.01
% Haptobenthos	4.1	0.8	4.9	31.1	18.0	4.9
EPT Index	1	0	0	1	0	1
# Ephemeroptera	0	0	0	0	0	1
% Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.4
Simpson Diversity Index	0.25	0.02	0.38	0.68	0.48	0.11
# Intolerant Taxa	1	0	3	3	0	2
% Scrapers	1.2	0.0	1.1	1.1	0.0	0.4
Multimetric Index (MAIS) Categorization Evaluation						
MAIS Score	2	0	3	4	0	3
Biological Condition Category	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor

Table 17. Benthic macroinvertebrate community metrics at study sites for Virginia Tech wet-pond detention facility on April 29, 1997.

Metrics	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Taxa Richness	8	5	7	9	9	11
% 5 Dominant Taxa	98.4	100.0	99.0	96.9	96.5	96.2
Modified HBI	6.34	6.27	6.32	6.40	6.05	6.07
% Haptobenthos	1.1	9.7	11.4	27.2	43.0	29.3
EPT Index	0	0	1	1	0	1
# Ephemeroptera	0	0	1	0	0	0
% Ephemeroptera	0.0	0.0	0.5	0.0	0.0	0.0
Simpson Diversity Index	0.37	0.41	0.46	0.61	0.66	0.55
# Intolerant Taxa	2	0	1	0	1	4
% Scrapers	0.5	0.0	0.0	0.0	2.0	1.3
Multimetric Index (MAIS) Categorization Evaluation						
MAIS Score	3	0	3	1	2	3
Biological Condition Category	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor

Table 18. Benthic macroinvertebrate community metrics at study sites for Virginia Tech wet-pond detention facility on August 29, 1997.

Metrics	Study Stream Site A	Study Stream Site B	Study Stream Site C	Study Stream Site E	Off Site Stroubles Creek	Off Site CRC Stream
Taxa Richness	7	15	13	16	12	13
% 5 Dominant Taxa	94.4	72.7	92.6	83.3	90.9	92.6
Modified HBI	7.07	5.91	6.60	5.69	6.97	6.94
% Haptobenthos	1.9	26.5	4.4	45.3	37.8	14.2
EPT Index	0	2	3	4	0	1
# Ephemeroptera	0	2	2	2	0	1
% Ephemeroptera	0.0	13.6	1.5	5.4	0.0	0.6
Simpson Diversity Index	0.77	0.84	0.66	0.76	0.76	0.78
# Intolerant Taxa	1	5	3	7	2	3
% Scrapers	1.9	5.3	0.0	10.8	3.8	9.9
Multimetric Index (MAIS) Categorization Evaluation						
MAIS Score	3	9	5	9	4	7
Biological Condition Category	Very Poor	Poor	Very Poor	Poor	Very Poor	Poor

6.0 SUMMARY AND FUTURE RESEARCH PLANS

SUMMARY

Environmental factors potentially affecting the ability of ponds to perform as water quality improvement facilities have been examined for the wet pond detention facility handling the urban and agricultural runoff from the campus at Virginia Tech. Sediment from construction of the wet and dry ponds has been the primary pollutant to date. Further sampling, particularly automated sampling, should indicate improved pollutant removal results as the system stabilizes.

The biological condition of the study stream was severely impaired before construction of the Virginia Tech wet-pond detention facility and remains so after construction. The very poor biological condition is certainly caused by heavy sedimentation and probably by toxic substances, including metals. Successful functioning of the wet-pond detention facility should cause the study stream to recover below the lower pond (site QVE) and possibly below the upper pond (sites QVB and QVC). Results from August 29, 1997 hint that some slight recovery may have begun. However, recovery to good biological condition will be slow. This is especially true for the sedimentation problem. The study stream is small and has low gradient, therefore, it has little power to wash out the sediments that have already accumulated in the channel. Eventually, more loose, clean coarse mineral substratum will become available for colonization, and a more diverse benthic macroinvertebrate community will become established. In order for recovery to occur, it is essential that an adequate buffer strip of vegetation be consistently maintained. Recovery to good biological condition would be enhanced if shrubs and trees were established in the riparian zone.

The stormwater treatment facility at Virginia Tech should prove to be a highly effective Best Management Practice. Primary benefits of the wet pond are its capture of first flush pollutants, and its long hydraulic retention time which may promote pollutant degradation and transformation. The dry detention basin, on the other hand, ensures flood control and continued polishing of the water. The combination of the two ponds should show high pollutant removal efficiencies as further investigation continues.

FUTURE MONITORING PLANS

The ideal pollutant removal efficiency calculation would be performed on a specific unit volume of water as it moves through the stormwater management facility. Since it is impossible to label and trace a specific unit of water, we can only estimate pollutant removal efficiencies by assuming, and trying to assure, that every sample is representative of its position in the system. The problem with grab samples becomes readily apparent for a short-duration storm event. The grab sampling process takes two hours for a sampling team of two people. Sampling begins downstream, and by the time the inlet water is sampled at QVA, the storm and the visible sediment load may have dissipated. This creates inconsistencies in the data, and direct comparison of two sampling sites is impaired. For this reason, we have compared data only within the bounds of each pond (QVA and QVB for the wet pond; QVC, QVD, and QVE for the dry pond), and have not attempted to compare the inlet and outlet waters for the entire system. Continuous sampling with automated equipment will reduce error associated with sampling, and enable greater sample numbers to improve the data sets.

The monitoring system, including flow monitors and water quality samplers at four stations, was completed in May 1998. The major components of the weather station have been installed on top of the dam at the lower pond (see next section). All instruments will be tied to a common data logger for electronic data retrieval. Once sufficient data are collected, long-term pollutant loadings and their respective removal rates will be estimated. The long-term goal for this facility is to construct a bio-hydrology laboratory that may be used for research and instruction across the campus.

WEATHER STATION

Effective improvement of water quality parameters is directly related to the detention time of water in the system. Short detention times, due to large volumes of runoff produced by large storms (i.e. 20-year return period), lead to insufficient settling time. Because of this direct relationship between storm event and water quality, meteorological data is essential to the full understanding of the water quality data.

For this reason, a complete weather station has been installed at the lower detention pond. Equipment included in the station are: radiometer, pyranometer, wind anemometer, raingage, air/soil temperature probe, relative humidity, evaporation pan, soil/water temperature probe, and snow depth sensor. In the next phase of this project, these instruments will be tied to a data logger, accessible by an ethernet line for in-class and laboratory use.

SAMPLING EQUIPMENT

Automated equipment installed and working at each site increases the efficiency and consistency of water quality sampling and flow measurement. Velocity and discharge is now measured at four locations by ISCO 4150 Flow Logger systems. Also, a pressure transducer located at the sites will be used to measure water depth. These parameters will be recorded by Campbell Scientific Data loggers, which will permit the researchers to remain off-site and download the data at a later time. Four ISCO 3700 Water Quality samplers, programmed to extract samples at selected intervals, have been installed. Also, portable digital turbidometers will allow on site evaluation of suspended solids in the form of turbidity. Thus all weather, water quality samplers and flow loggers are operational as of September 1998. With additional funding support, it is anticipated that a period of sustained data collection and analysis can be initiated for full evaluation of pollutant removal performance at the regional facility.

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