POLECAT CREEK WATER QUALITY MONITORING
including:

Purchase and Installation of Equipment for Surface and Raingages,

Two Seasons of Trend Biological Monitoring

and

Freshwater Mussel Survey and Natural Heritage Survey

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Final Report

on

Installation of Monitoring Stations in Polecat Creek Watershed

by

Saied Mostaghimi and Phillip W. McClellan

The goal of the Polecat Creek Watershed Monitoring Project is to describe the efficacy of emerging landuse regulations and policies in protecting water quality during urban development activities. A water quality monitoring network was established, which consists of 5 runoff monitoring stations, 9 raingages and a complete weather station. The monitoring network was designed in order to evaluate the spatial contribution of nonpoint source pollutants originating from various major tributaries of the Polecat Creek.

The locations of all monitoring stations are indicated in Figure 1. A listing of equipment and instrumentation installed at each monitoring station is given in Table 1. A brief explanation of monitoring components is given in the following sections.

Runoff Monitoring Stations:

Each runoff monitoring station consists of a stilling well, intake pipes, water level recorders, a gauge house, and automatic water samplers. The runoff monitoring stations were located in straight, uniform reaches of streams, with smooth bed and banks of permanent nature, whenever possible. The stilling wells are located on one side of the stream, so that they do not interfere with the flow pattern.

In many cases, the stilling well is located at a minimum distance of 10 feet from the center of the stream. The sizes of the stilling wells were chosen, based on factors such as the required rigidity, height, type of material, and water level in the stream. Based on these factors, 24" diameter stilling wells were installed at QPA, QPB and QPC, and 48" stilling wells were used at QPD and QPE.

Two intake pipes of 3" diameter in size were installed at each of the stations. Although the minimum requirement is one pipe, the second intake pipe was installed, because one may become plugged. These pipes were installed at different elevations with provisions made for flushing out the possible accumulated silt in the stilling well. All seams were brazed and treated in order to make the stilling well watertight. The wells were placed on a concrete base, with the top of the base located a few inches below the lowest intake pipe. Detailed cross-sectional surveys of all sites were conducted prior to installation of the monitoring equipment (Figure 2). A schematic diagram of a typical installation of a stilling well and intake pipe is presented in Figure 3.

Each runoff monitoring site was equipped with a strip-chart, as well as the electronic stage sensors for continuous recording of the water level in the stream. In addition, a staff gage (non-recording) was installed at each site and is read regularly by the field observer. The schematics of a typical staff gage and its installation is presented in Figure 4. An instrument shelter (6'w x 8'l x 7'h) was installed at each of the monitoring stations, which houses the stage recorder, automatic water samplers and miscellaneous supplies. The information provided by Brakensiek et al (1979) for the design and installation of a shelter house, as well as the stilling wells, were used as a guideline in the design of these stations. Access to all shelter houses was provided by a walkway (catwalk). These walkways

would provide for servicing of the stations in all weather conditions. Safety and structural stability were the two main factors considered when designing these walkways. Diagrams of the site plan for QPA - QPE, which show the location of the gagehouse and catwalk are presented in Figures 5 - 9.

ISCO automatic water samplers are installed at each of the monitoring stations. These samplers are programmed to take composite water samples during storm events, based on the volume of the water flowing in the stream. CR10 data loggers are installed at each site (Figure 10) to control the samplers, as well as record the water level and the time of each sampling. In developing the sampling protocol, months of data were collected to determine the hydrologic response of each watershed. Shifts in the base flow associated with changes in the water table, possible beaver activities, as well as shifts due to precipitation events were observed. These shifts are significant when trying to identify the beginning and end of a runoff event. To account for the shifts, a digital filter, specifically a moving window average, is applied to the stage data. A four-hour window width is set for each watershed. The start of a runoff event is determined when the current stage value exceeds the average by a fixed amount. Once a runoff event is determined, 200 ml samples are collected with each passing of the set volume of flow. The set volume was determined by evaluating expected high flows, the water sampler sampling response time, and the capacity of samplers with regard to maximum number of samples (96). Table 2 shows the current setting for each watershed (note that these values will likely change as we are able to better describe the watersheds' hydrologic behavior). Samples are collected until the end of the runoff event is determined. The end of the event is identified when there is an increasing trend in the difference between the stage and the average stage, and the stage is less than the average. Figure 11 shows a typical hydrograph with runoff events

identified. It should be noted that for large storms the end of the runoff event is shifted toward the peak (Figure 11B). This is attributed to the filtering technique and the slow response of QPE. This shifting has not been shown to be a problem at the other gaging stations.

A comprehensive erosion control plan was developed and approved by the State of Virginia prior to construction of the monitoring stations. The procedures used for minimizing site disturbance and erosion during construction of gage houses are detailed in Figure 13.

Precipitation Monitoring Network:

A network of 9 precipitation gages were installed in Polcat Creek Watershed. These stations (PP1-PP9) are located throughout the watershed to enable an assessment of the spatial variability of precipitation. Tipping bucket raingages along with data loggers are located at each site. The schematic of a typical tipping bucket raingage is presented in figure 12. The raingages are powered by a 12 V, deep cycle battery and a solar panel installed at each site. The location of all raingage is indicated in Figure 1.

Weather Station:

A complete weather station was installed at the Waste Water Treatment Facility located in the Polcat Creek Watershed. The data collected at the weather station will greatly facilitate the interpretation of the water quality data being collected at various sites in the watershed. In addition, this information would be invaluable in the future modeling works in an effort to expand the results from

Polcat Creek Watershed to larger basins. The parameters collected at the weather station include:

- Precipitation
- Ambient Air Temperature
- Ambient Air Humidity
- Wind Speed and Direction
- Pan Evaporation
- Solar Radiation
- Soil Moisture (6" and 12" depths)
- Soil Temperature (6" and 12" depths)
- Snow Depth

QA/QC Plan:

A comprehensive quality assurance/quality control project plan was developed and submitted to the sponsor for review. All field installations were performed following standard procedures in order to provide data compatible with other similar projects. The QA/QC activities for the project is being closely followed in order to ensure proper data collection, handling and analysis.

Table 1. Polecat Creek Watershed monitoring sites.

Site Name	*Location*	*Equipment Description*
PP1	Smith sand and gravel quarry	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP2	Coleman farm	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP3	Caroline Co. Middle School	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP4	Smith farm	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP5	Lake Caroline	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP6	Lake Land 'Or	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP7	On cut over forest land off of Cedar Fork Road	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP8	Mount Olympus	Precipitation, one digital and one std. gage, solar panel and deep cycle battery.
PP9	Waste water treatment facility (the weather station)	Precipitation, one digital, one analog, one std. gage, one snow depth, and rain quality sampler, solar panel and deep cycle battery.
TP9	(the weather station)	Ambient air temperature, one analog and digital gage, and a max/min thermometer
HP9	(the weather station)	Ambient air humidity, one analog and one digital gage
DP9	(the weather station)	Wind direction, one digital gage
WP9	(the weather station)	Wind speed, one digital gage
EP9	(the weather station)	Pan evaporation, one analog and one digital gage
SP9	(the weather station)	Solar radiation, one digital gage
CP9	(the weather station)	Soil Moisture at .5 foot depth

Table 1 (cont.) Polecat Creek Watershed monitoring sites.

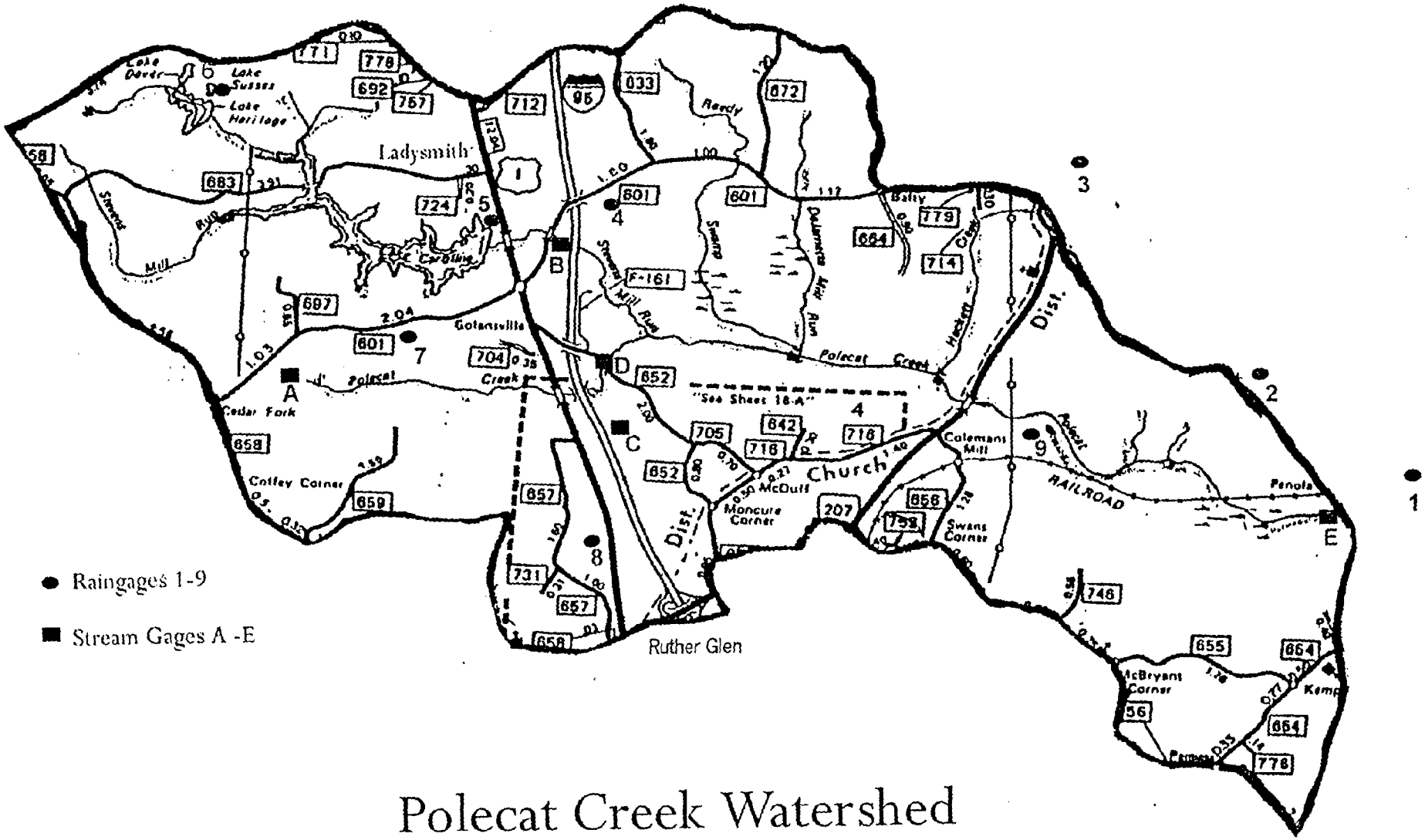
Site Name	*Location*	*Equipment Description*
CPA	(the weather station)	Soil Moisture at 1.0 foot depth
TP1	(the weather station)	Soil Temperature at .5 foot depth
TP2	(the weather station)	Soil Temperature at 1.0 foot depth
QPA	On Cedar Fork Road (rt. 601)	Stream stage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler), solar panel and deep cycle battery
QPB	Close to Smith farm, off of rt. 601, between US rt. 1 and US Interstate 95	Stream stage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler), solar panel and deep cycle battery
QPC	On Mr. Atkinson's farm close to interstate 95, accessed from rt. 652	Stream stage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler), solar panel and deep cycle battery
QPD	On Mr. Atkinson's farm off of rt. 652	Stream stage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler), solar panel and deep cycle battery
QPE	Watershed outlet, off of rt. 601	Stream stage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler), solar panel and deep cycle battery
LPA	Located at station QPA	Campbell Scientific model CR10 data logger, 2400 baud modem and telephone serviceand deep cycle battery
LPB	Located at station QPB	Campbell Scientific model CR10 data logger, 2400 baud modem and telephone serviceand deep cycle battery
LPC	Located at station QPC	Campbell Scientific model CR10 data logger, 2400 baud modem and telephone serviceand deep cycle battery
LPD	Located at station QPD	Campbell Scientific model CR10 data logger, 2400 baud modem and telephone serviceand deep cycle battery
LPE	Located at station QPE	Campbell Scientific model CR10 data logger, 2400 baud modem and telephone serviceand deep cycle battery

Table 1 (cont.) Polecat Creek Watershed monitoring sites.

Site Name	*Location*	*Equipment Description*
LPF	Located at the weather station	Campbell Scientific model 21X data logger, 2400 baud modem and telephone service, solar panel and deep cycle battery

Table 2. The Sampling Protocol for Various Runoff Stations

Station	Runoff Event Beginning Offset (feet)	Flow Volume per sample (cubic yards *1000)
QPA	0.05	2
QPB	0.05	3
QPC	0.05	2
QPD	0.05	2
QPE	0.05	90

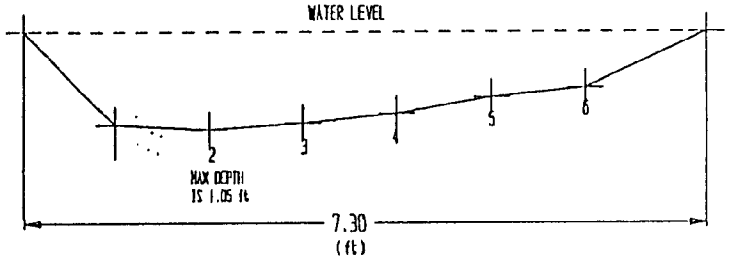


Polecat Creek Watershed

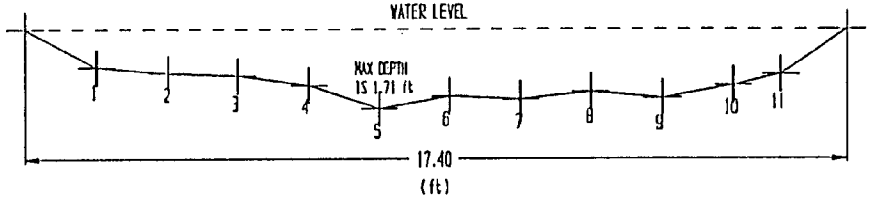
FIGURE 1

POLECAT CREEK STREAM BEDS

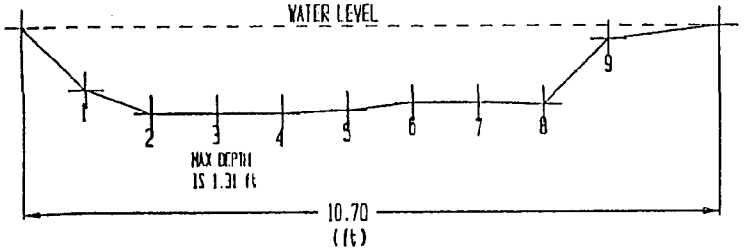
SITE: QPA



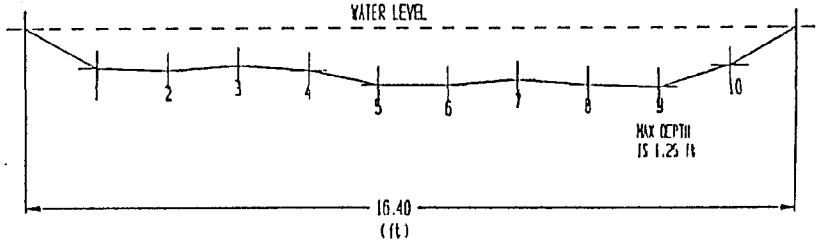
SITE: QPB



SITE: QPC

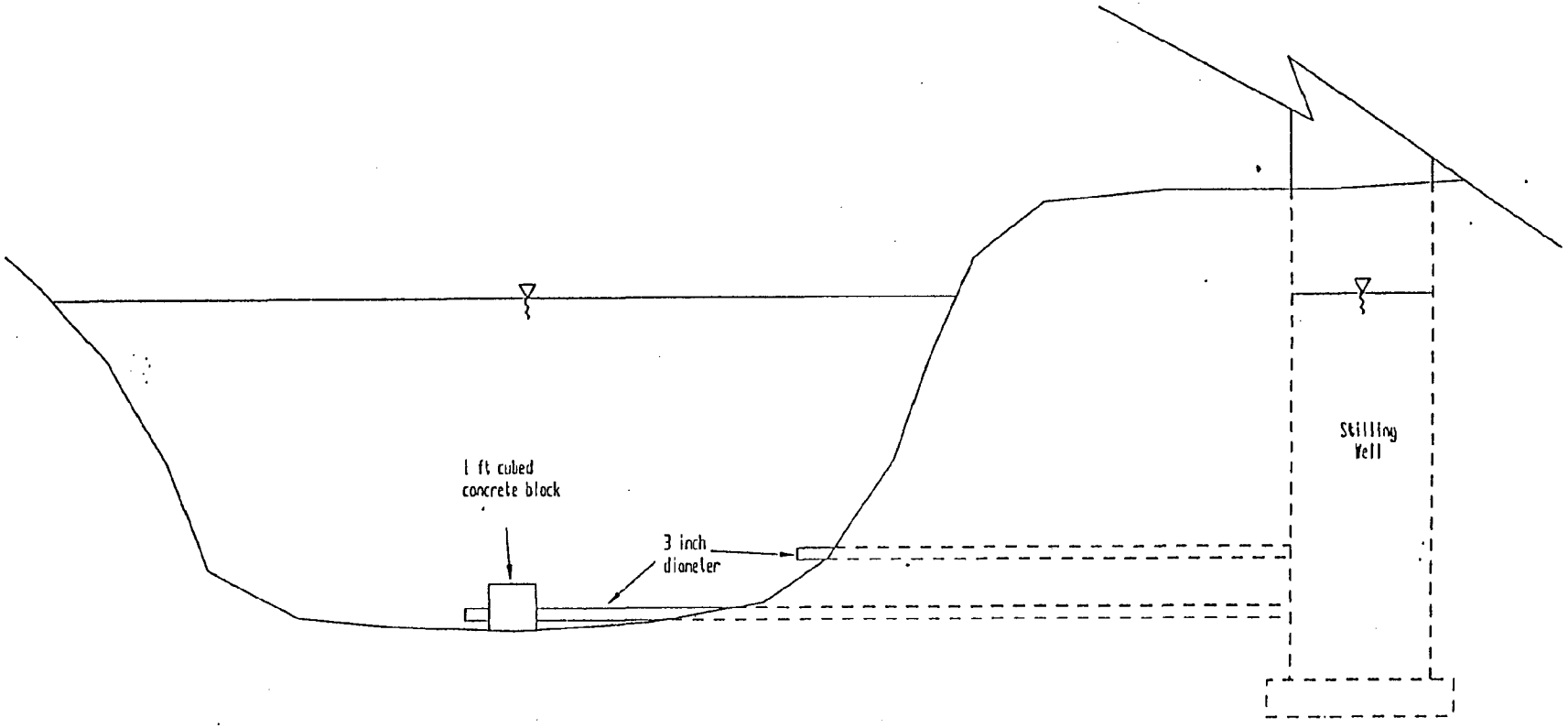


SITE: QPD



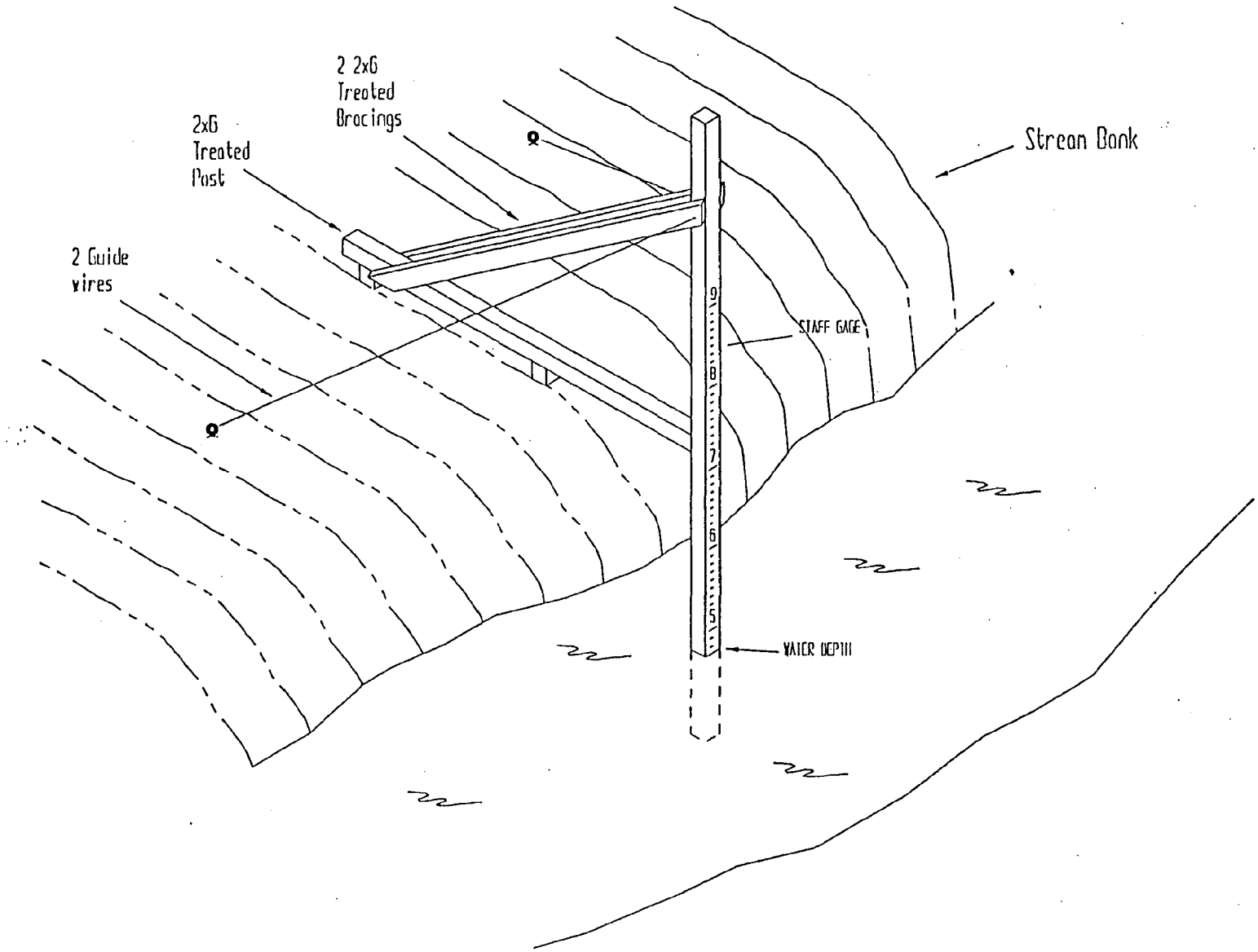
NOTE: NUMBERS AT POINTS ALONG STREAM BEDS REPRESENT THE DATA POINTS GIVEN IN TABLE 1.

FIGURE 2. Cross-Sections of Stream Beds.



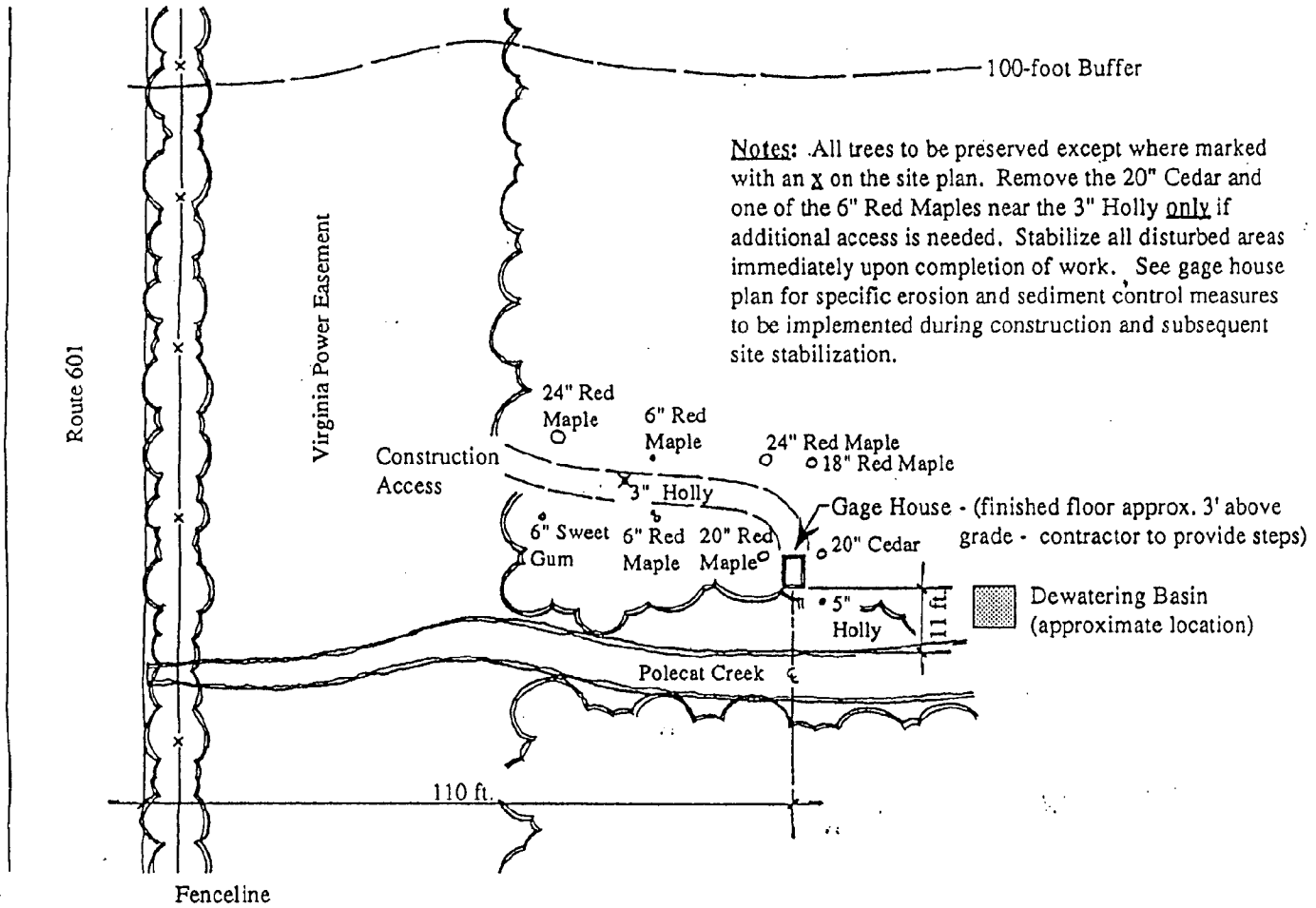
VA Tech Ag Engineering	TITLE: TYPICAL INSTALLATION FOR INTAKE PIPE	DATE: 5-11-94	REFERENCE NO.	PAGE 1 of 2

FIGURE 3



VA Tech Bio. Systens Engineering	TITLE: Staff Gage for Measuring Water Depth	DATE: 10-26-94	REFERENCE NO.	PAGE 1 of 1

FIGURE 4

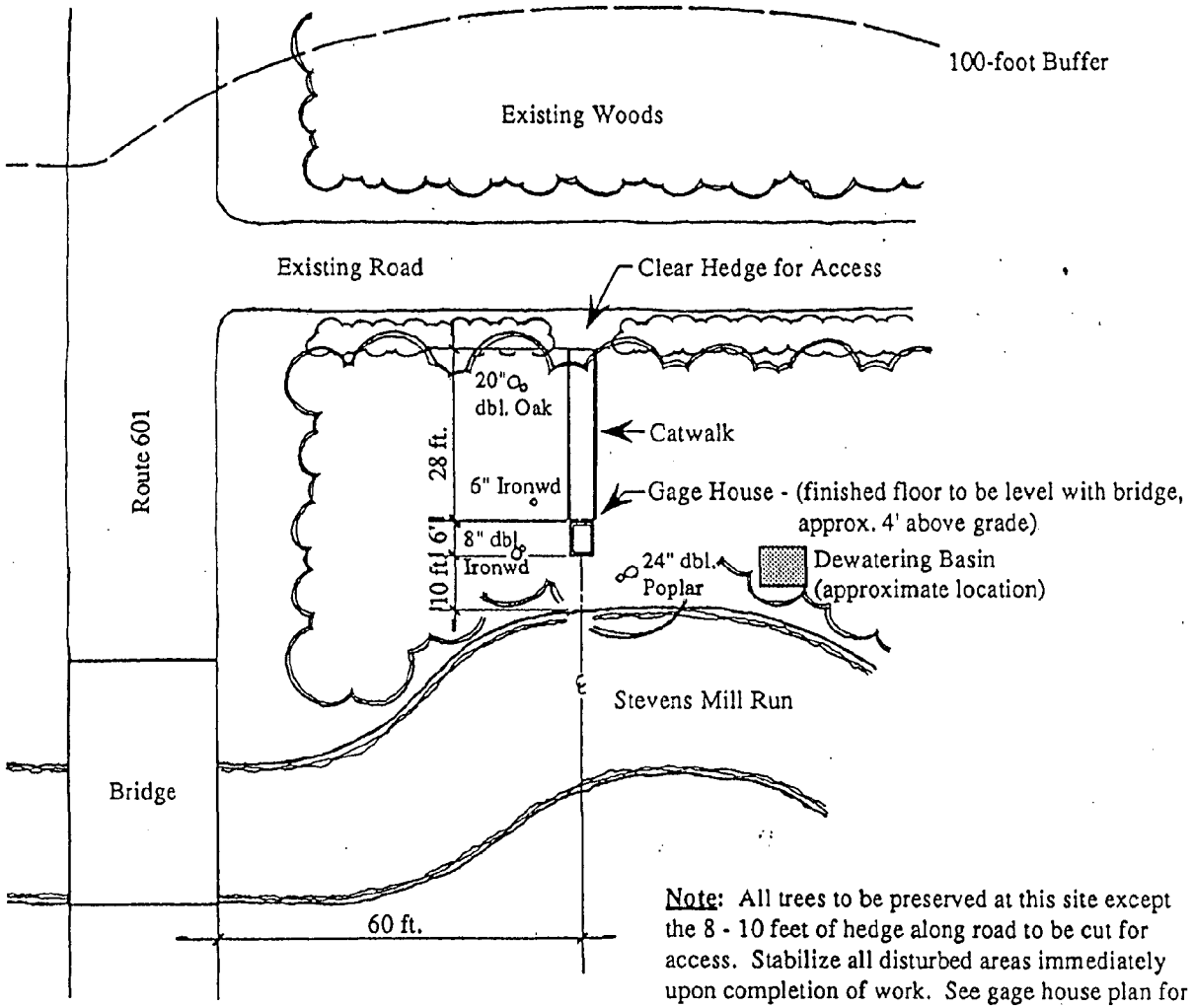


Polecat Creek Water Quality Monitoring Project

Station A - Site Plan Scale: 1" = 30'

30 15 0 30

FIGURE 5



Note: All trees to be preserved at this site except the 8 - 10 feet of hedge along road to be cut for access. Stabilize all disturbed areas immediately upon completion of work. See gage house plan for specific erosion and sediment control measures to be implemented during construction and subsequent site stabilization.

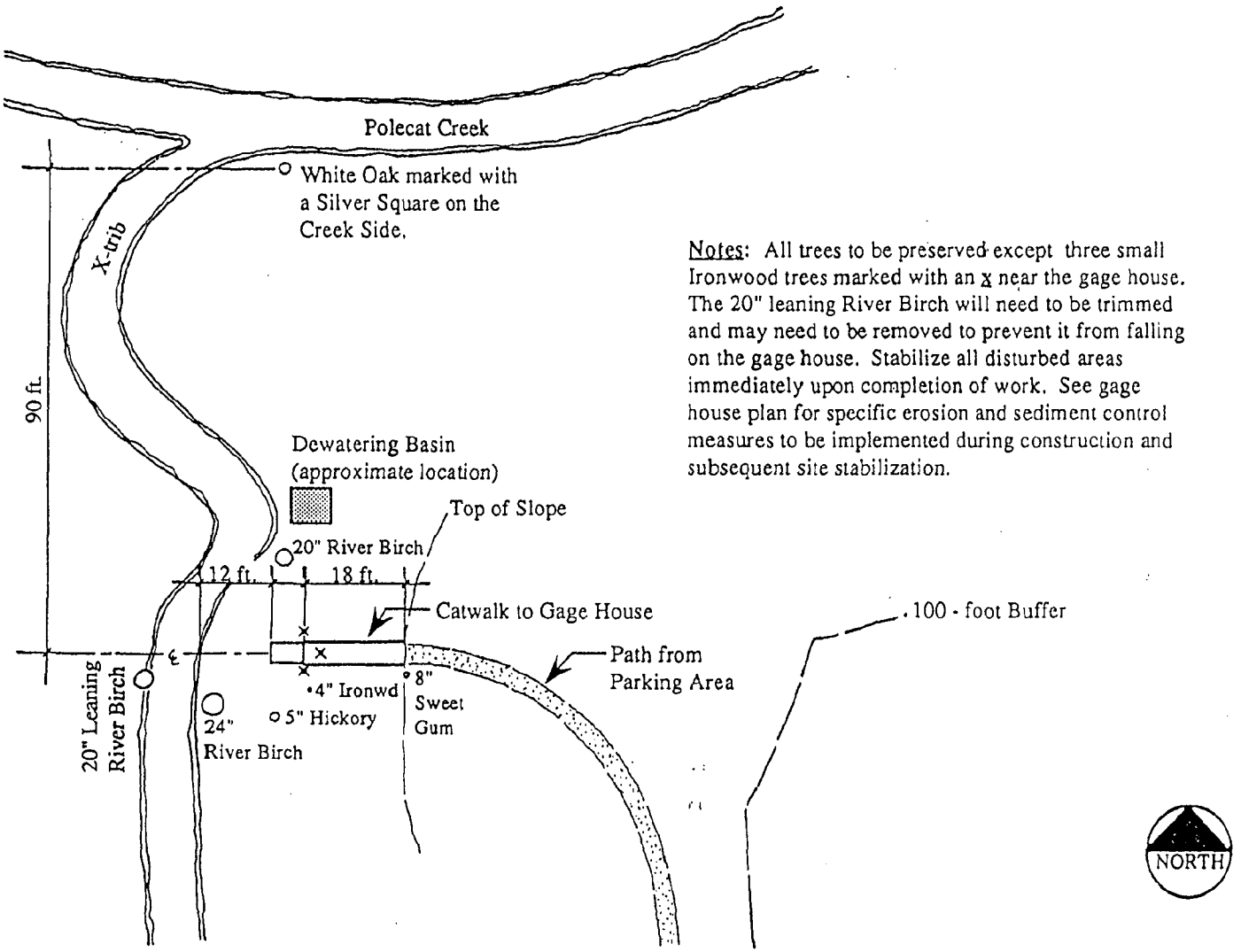
NORTH

Polecat Creek Water Quality Monitoring Project

Station B - Site Plan Scale: 1" = 30'

30 15 0 30

FIGURE 6



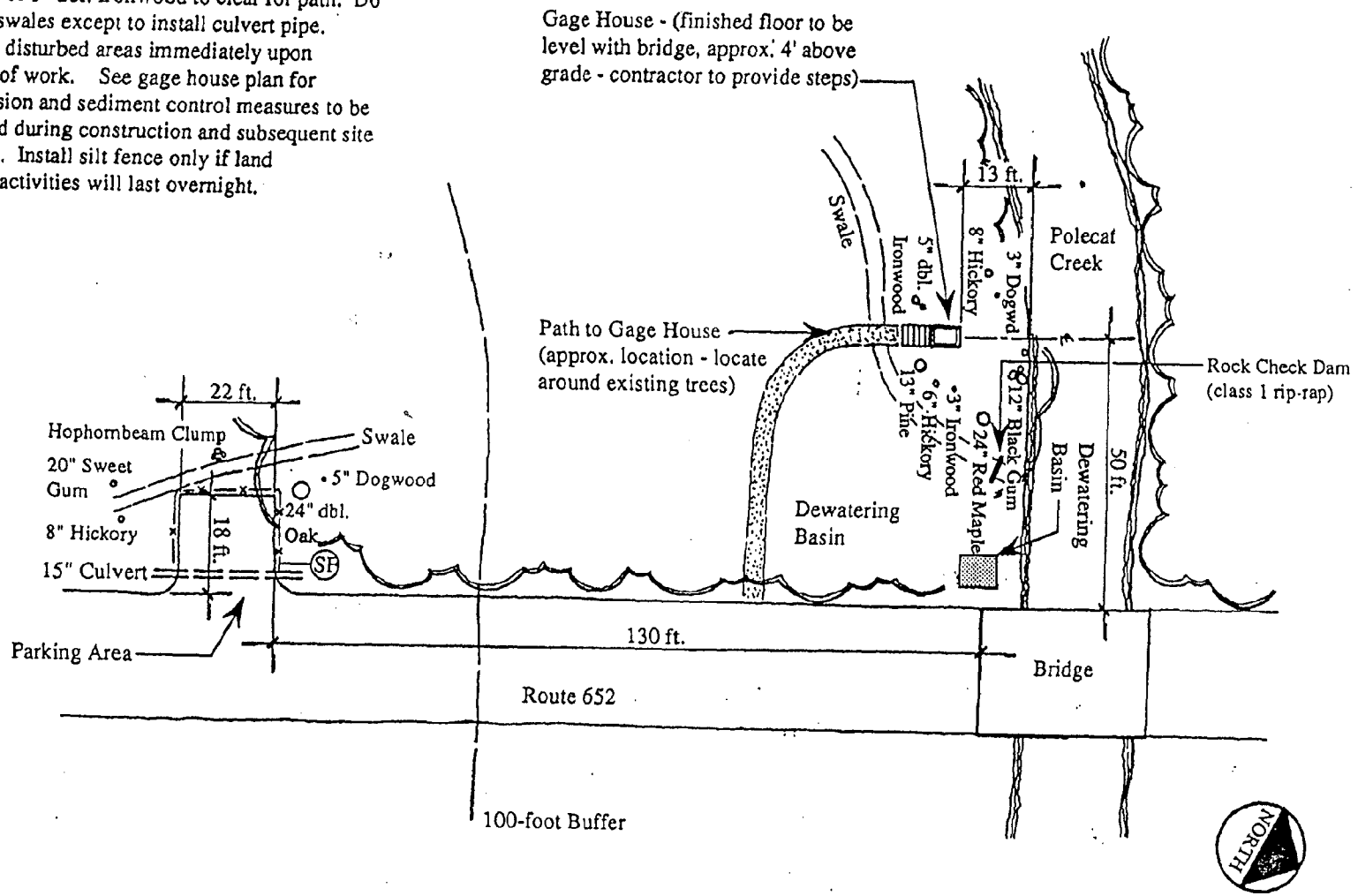
Notes: All trees to be preserved except three small Ironwood trees marked with an x near the gage house. The 20" leaning River Birch will need to be trimmed and may need to be removed to prevent it from falling on the gage house. Stabilize all disturbed areas immediately upon completion of work. See gage house plan for specific erosion and sediment control measures to be implemented during construction and subsequent site stabilization.

Polecat Creek Water Quality Monitoring Project
Station C - Site Plan Scale: 1" = 30'

30 15 0 30

FIGURE 7

Notes: All trees to be preserved at this site. Trim up lower limbs of 5" dbl. Ironwood to clear for path. Do not disturb swales except to install culvert pipe. Stabilize all disturbed areas immediately upon completion of work. See gage house plan for specific erosion and sediment control measures to be implemented during construction and subsequent site stabilization. Install silt fence only if land disturbance activities will last overnight.

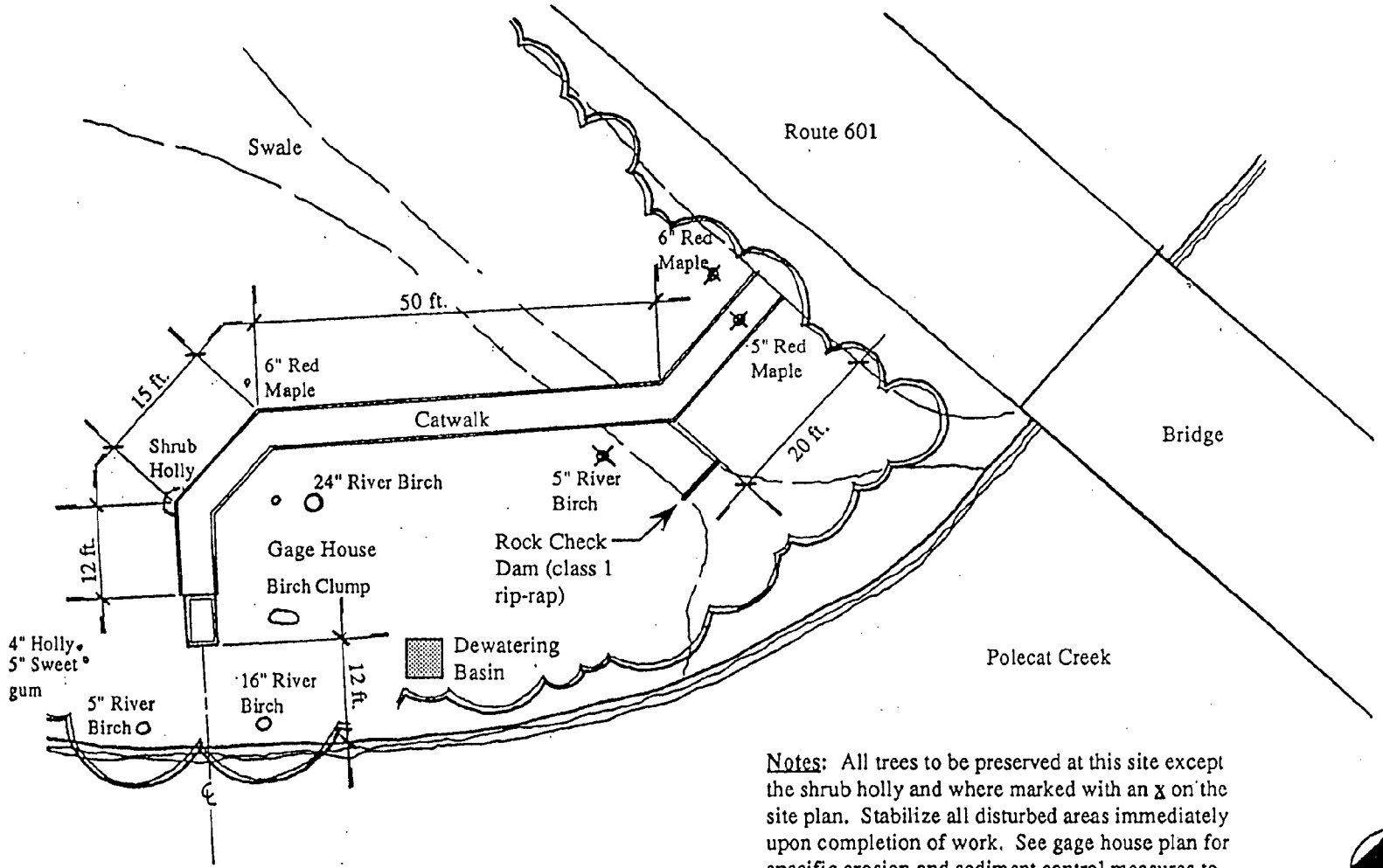


Polecat Creek Water Quality Monitoring Project

Station D - Site Plan Scale: 1" = 30'

30 15 0 30

FIGURE 8



Gage House location is approx. 90 ft. from the edge of Route 601 at the catwalk. Finished floor of gage house to be level with bridge, approx. 5' above grade.

Notes: All trees to be preserved at this site except the shrub holly and where marked with an x on the site plan. Stabilize all disturbed areas immediately upon completion of work. See gage house plan for specific erosion and sediment control measures to be implemented during stilling well and intake pipe construction and subsequent site stabilization.

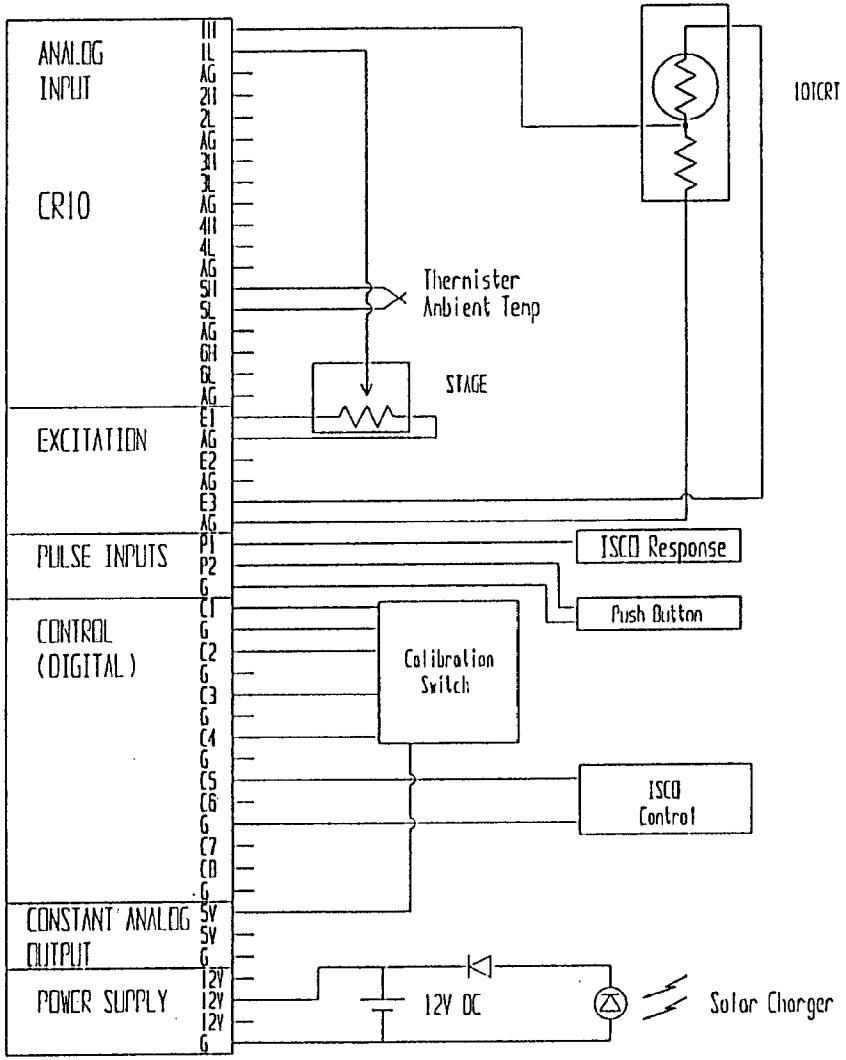
Polecat Creek Water Quality Monitoring Project

Station E - Site Plan Scale: 1" = 20'

20 10 0 20

FIGURE 9

Logger Code: LP2 Watershed: Polecat Creek Line: _____ File: LPILOG.PRI Pgnr: MP



VA Tech Bio. Systems Engineering	TITLE: Polecat Creek Gage Station Data Logger (CR10)	DATE:	REFERENCE NO. 5-9-94	PAGE 1 of 1

FIGURE 10

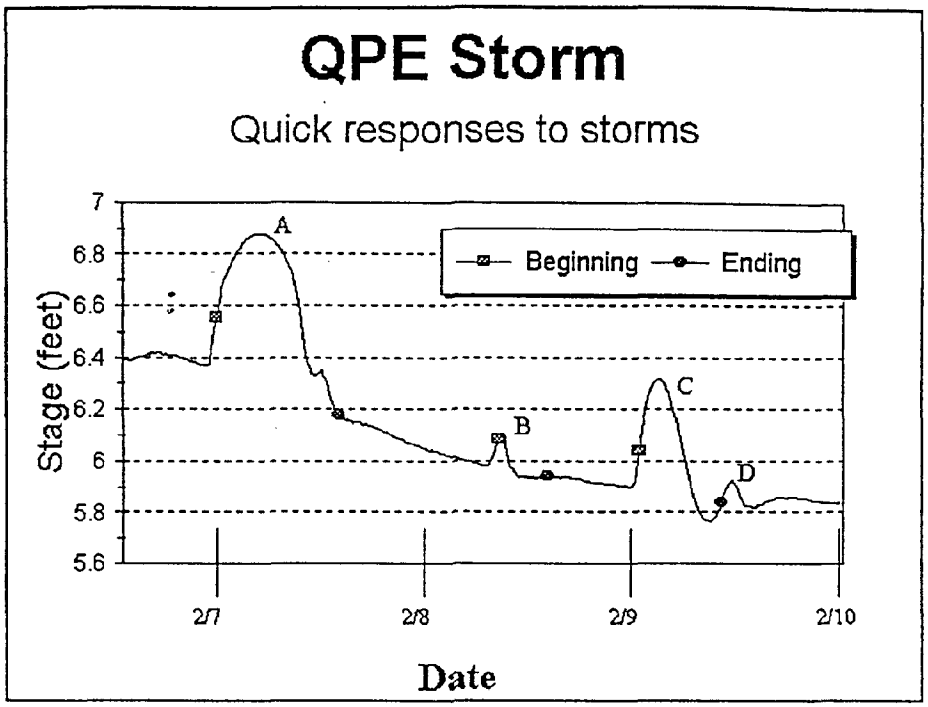


Figure 11A

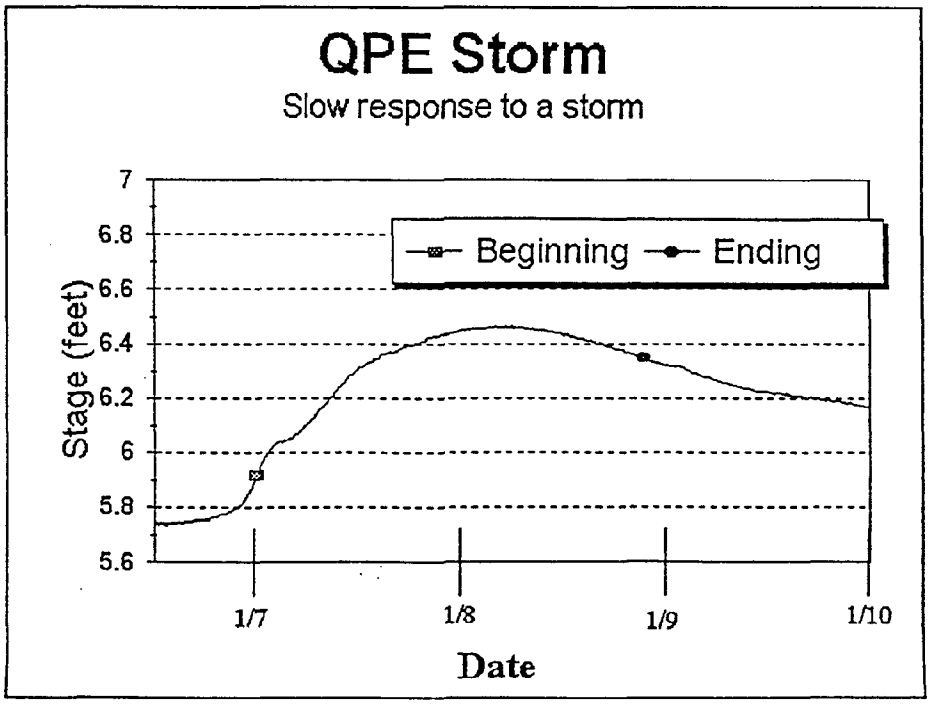
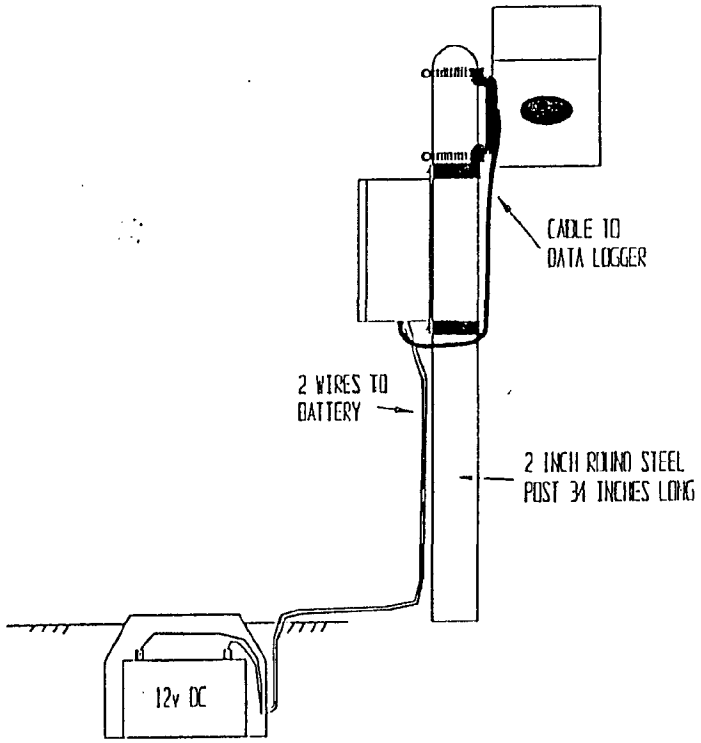
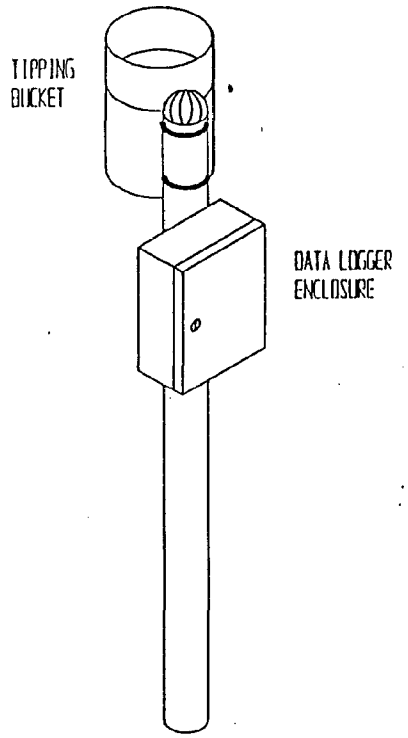


Figure 11B

TIPPING BUCKET RAINGAGE

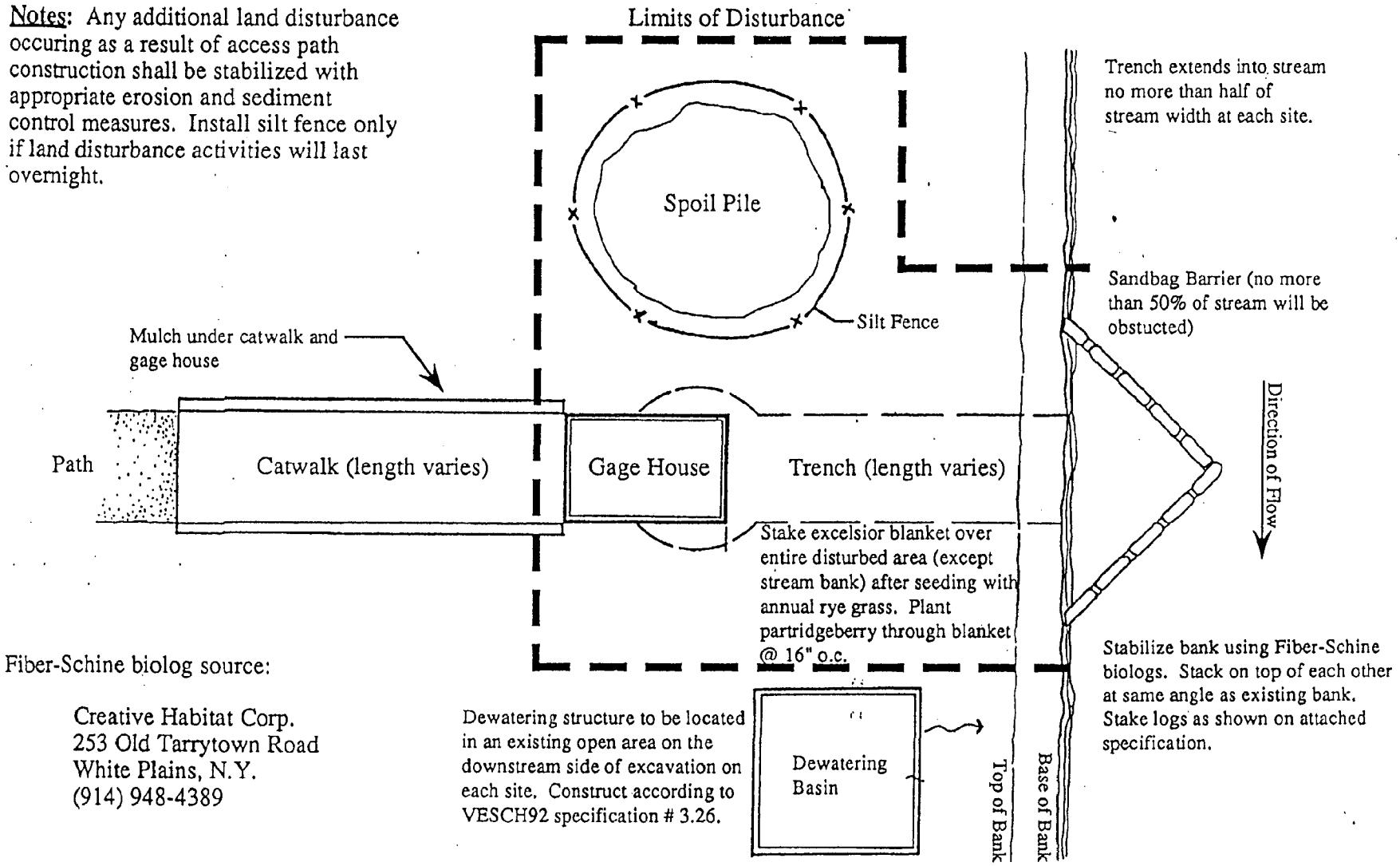




BOTH TIPPING BUCKET AND DATA LOGGER ENCLOSURE ARE ATTACHED USING U BOLTS.

VA Tech Ag Engineering	TITLE: TIPPING BUCKET RAINGAGE	DATE: 3-30-94	REFERENCE NO.	PAGE 1 of 2

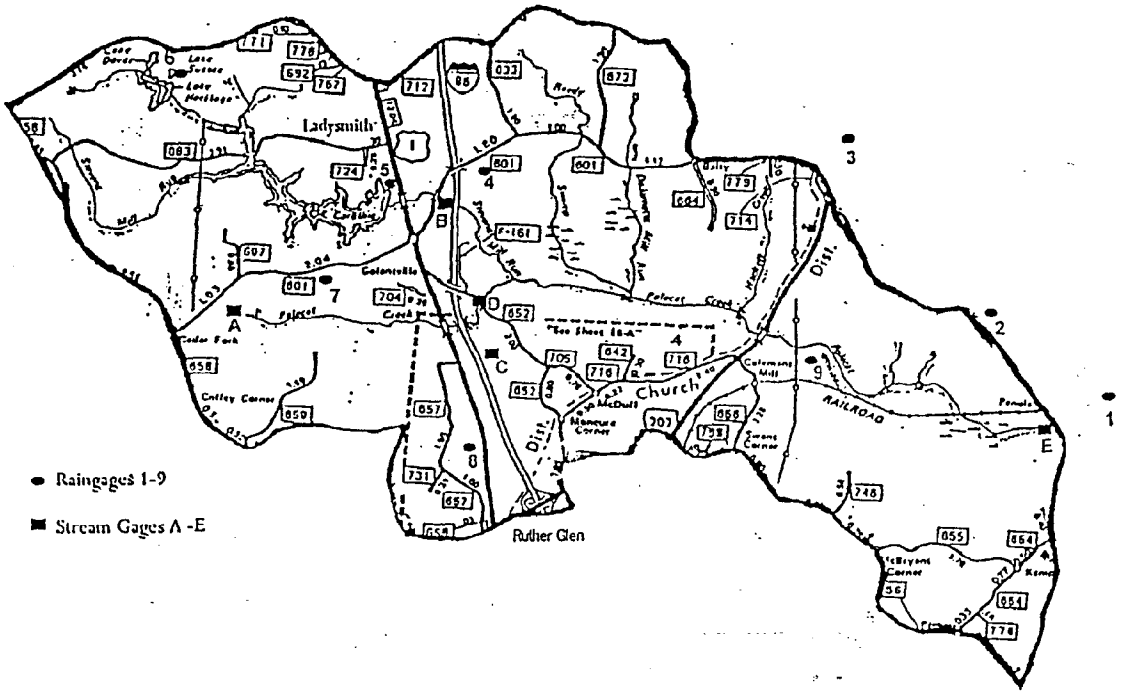
FIGURE 12



Polecat Creek Water Quality Monitoring Project

Gage House Plan Scale: 3/16" = 1'

FIGURE 13



WATERSHED/WATER QUALITY MONITORING FOR THE POLECAT CREEK WATERSHED

Semiannual Report
September - December,1994

Report No. P-94H2-9504

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Celebrating Our Department's 75th Anniversary
1920 - 1995

Data Report (September - December 1994)

Polecat Creek Watershed

A total of 207 mm of precipitation occurred on the Polecat Creek Watershed for the period between September - December 1994. A runoff/rainfall ratio of 0.18 was resulted at QOA (the watershed outlet) for this period. A summary of rainfall amounts, runoff volume and peak runoff rates for all monitoring stations for the reporting period is presented in Tables 1 and 2 .

Tables 3 through 12 summarize the sediment and nutrients concentrations and loading for all 5 stations in the watershed. The concentrations of sediment and nutrients at all stations were small and much lower than those from typical agricultural watersheds, such as Owl Run and Nomini Creek. Nitrate concentrations were always lower than the 10 ppm standard set by EPA for drinking water.

It should be noted that the values reported in Tables 1 - 12 may change when the runoff rating curves for the stations are finalized. Currently, 5 data points have been taken for runoff rate measurements at each station. Most of these data points were taken during low to medium flow rates. For the purpose of this report, the rating curves were extrapolated to determine the flow rates for all events which occurred during this reporting period. It also should be noted that the attached data tables follow the same format developed for the Owl Run and Nomini Creek

Watersheds, to facilitate the comparison among different watershed with different landuse activities. A copy of rating curves developed for various runoff stations is attached.

A monthly summary of precipitation, humidity, temperature and evaporation data collected at the weather station is presented in Table 13. Table 14 presents a summary of rainwater quality data collected from the watershed. It is interesting to note that nitrate concentrations in the rainwater are, in many instances, greater than those measured in the stream, indicating that the watershed acts as a filter to reduce selected pollutants concentrations.

Summaries of bacteriological data collected during the reporting period are presented in Table 15 - 18. The data are presented for fecal coliform, total coliform, and fecal streptococcus. Geometric and arithmetic means, as well as standard deviations are reported. In many instances, the bacteria count are lower than the health standards set by EPA. A ratio of fecal coliform to fecal streptococci (FC/FS) of greater than 0.7 is indicative of contamination by domestic waste, such as septic tanks. This ratio exceeded 0.7 in two instances at QOB. Closer examination of landuse activities in QOB subwatershed is recommended in order to assess the sources of contamination.

Table 1. Polecat Creek Watershed Storm Summary (Sep. - Dec., 1994).

Storm Dates	Avg. Rainfall (mm)	QPA Runoff (mm)	QPA Peak Runoff (mm/hr)	QPB Runoff (mm)	QPB Peak Runoff (mm/hr)	QPC Runoff (mm)	QPC Peak Runoff (mm/hr)
9/22 - 9/23	41.25	0.185	0.012	0.238	0.011	0.000	0.012
9/26 - 9/26	10.09	1.723	0.049	0.074	0.009	2.391	0.029
10/14 - 10/14	16.64	0.612	0.012	0.939	0.045	1.524	0.038
10/20 - 10/21	12.31	0.222	0.020	0.819	0.062	1.252	0.052
10/23 - 10/23	15.40	1.995	0.035	0.141	0.057	0.000	0.047
10/26 - 10/26	6.40	0.927	0.028	0.123	0.007	0.000	0.046
11/10 - 11/10	7.05	0.467	0.028	0.077	0.006	1.462	0.044
11/16 - 11/17	7.41	2.618	0.033	0.076	0.004	3.029	0.057
11/21 - 11/21	30.88	2.846	0.056	0.159	0.041	3.544	0.248
11/27 - 11/27	12.53	1.854	0.024	0.112	0.006	4.078	0.224
12/ 4 - 12/ 5	6.99	1.332	0.020	0.082	0.005	1.804	0.044
STORMS	168.69	14.782	0.056***	2.840	0.128***	19.085	0.248***
AMBIENT	38.147	19.927	0.007*	26.460	0.010*	53.499	0.021*
TOTAL	206.84	34.709	0.012**	29.300	0.011**	72.584	0.029**

*Average ambient flow
**Average 6-month flow
***Maximum peak runoff rate

Table 2. Polecat Creek Watershed Storm Summary (Sep. - Dec., 1994).

Storm Dates	Avg. Rainfall (mm)	QPD Runoff (mm)	QPD Peak Runoff (mm/hr)	QPE Runoff (mm)	QPE Peak Runoff (mm/hr)
9/22 - 9/23	41.25	6.976	0.150	2.054	0.031
9/26 - 9/26	10.09	1.191	0.089	1.206	0.019
10/14 - 10/14	16.64	1.563	0.079	1.889	0.028
10/20 - 10/21	12.31	0.000	0.079	0.726	0.024
10/23 - 10/23	15.40	0.647	0.057	1.960	0.032
10/26 - 10/26	6.40	0.503	0.016	5.276	0.047
11/10 - 11/10	7.05	0.566	0.011	2.377	0.042
11/16 - 11/17	7.41	1.443	0.025	0.413	0.028
11/21 - 11/21	30.88	2.688	0.142	4.284	0.069
11/27 - 11/27	12.53	2.097	0.069	1.561	0.024
12/ 4 - 12/ 5	6.99	1.043	0.021	1.064	0.023
STORMS	168.69	8.717	0.150***	22.811	0.069***
AMBIENT	38.147	67.159	0.023*	35.666	0.014*
TOTAL	206.84	85.875	0.030**	58.477	0.023**

*Average ambient flow
**Average 6-month flow
***Maximum peak runoff rate

Table 3. Nutrient Concentration from Polecat Creek Watershed (QPA), Sep. - Dec., 1994.

Storm	Runoff (1×10^6)	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	TN (ppm)	TKN filtered (ppm)	OP (ppm)	TP (ppm)	TP filtered (ppm)
9/22 - 9/23	0.6	0.006	0.086	0.050	0.397	0.447	0.411	0.000	0.047	0.000
9/26 - 9/26	5.4	0.007	0.000	0.146	0.000	0.146	0.000	0.003	0.045	0.000
10/14 - 10/14	2.1	0.007	0.000	0.146	0.000	0.146	0.000	0.003	0.045	0.000
10/20 - 10/21	0.9	0.007	0.000	0.146	0.000	0.146	0.000	0.003	0.045	0.000
10/23 - 10/23	6.4	0.008	0.000	0.140	0.000	0.140	0.000	0.000	0.065	0.000
10/26 - 10/26	3.3	0.008	0.000	0.140	0.000	0.140	0.000	0.000	0.065	0.000
11/10 - 11/10	3.6	0.003	0.099	0.285	0.050	0.335	0.000	0.000	0.026	0.000
11/16 - 11/17	10.1	0.055	0.000	0.000	3.857	3.857	0.000	0.000	0.235	0.000
11/21 - 11/21	9.5	0.004	0.045	0.055	2.018	2.073	0.000	0.000	0.016	0.000
11/27 - 11/27	6.0	0.000	0.015	0.041	1.366	1.407	0.897	0.001	0.000	0.000
12/ 4 - 12/ 5	4.2	0.001	0.030	0.045	1.018	1.063	1.712	0.000	0.000	0.000
Storm	51.9	0.014	0.020	0.088	1.366	1.454	0.246	0.001	0.070	0.000
Ambient	56.9	0.013	0.030	0.115	0.929	1.045	0.127	0.000	0.071	0.007
Total	108.7	0.014	0.025	0.102	1.138	1.240	0.184	0.000	0.070	0.004

Table 4. Nutrient Loading from Polecat Creek Watershed (QPA), Sep. - Oct., 1994.

Storm	TSS	NH_4	NO_3	TKN	TN	TKN filtered	OP	TP	TP filtered
					Kg				
9/22 - 9/23	3.3	0.05	0.03	0.23	0.26	0.24	0.00	0.03	0.00
9/26 - 9/26	37.7	0.00	0.79	0.00	0.79	0.00	0.02	0.24	0.00
10/14 - 10/14	14.4	0.00	0.30	0.00	0.30	0.00	0.01	0.09	0.00
10/20 - 10/21	6.4	0.00	0.13	0.00	0.13	0.00	0.00	0.04	0.00
10/23 - 10/23	50.9	0.00	0.89	0.00	0.89	0.00	0.00	0.41	0.00
10/26 - 10/26	26.1	0.00	0.46	0.00	0.46	0.00	0.00	0.21	0.00
11/10 - 11/10	11.5	0.35	1.02	0.18	1.20	0.00	0.00	0.09	0.00
11/16 - 11/17	554.4	0.00	0.00	38.88	38.88	0.00	0.00	2.37	0.00
11/21 - 11/21	35.9	0.42	0.52	19.12	19.64	0.00	0.00	0.15	0.00
11/27 - 11/27	0.0	0.09	0.24	8.19	8.43	5.37	0.01	0.00	0.00
12/ 4 - 12/ 5	4.2	0.12	0.19	4.24	4.43	7.13	0.00	0.00	0.00
Storm	744.8	1.0	4.6	70.8	75.4	12.7	0.0	3.6	0.0
Ambient	762.2	1.7	6.5	52.9	59.4	7.2	0.0	4.0	0.4
Total	1506.9	2.8	11.1	123.7	134.8	20.0	0.0	7.7	0.4

Table 5. Nutrient Concentration from Polecat Creek Watershed (QPB), Sep. - Dec., 1994.

Storm	Runoff (1×10^6)	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	TN (ppm)	TKN filtered (ppm)	OP (ppm)	TP (ppm)	TP filtered (ppm)
9/22 - 9/23	6.3	0.001	0.399	0.008	0.285	0.292	0.000	0.000	0.076	0.000
9/26 - 9/26	2.0	0.041	0.153	0.093	0.000	0.093	0.000	0.000	0.040	0.000
10/14 - 10/14	26.2	0.041	0.153	0.093	0.000	0.093	0.000	0.000	0.040	0.000
10/20 - 10/21	22.0	0.041	0.153	0.093	0.000	0.093	0.000	0.000	0.040	0.000
10/23 - 10/23	4.3	0.041	0.153	0.093	0.000	0.093	0.000	0.000	0.040	0.000
10/26 - 10/26	4.0	0.041	0.153	0.093	0.000	0.093	0.000	0.000	0.040	0.000
11/10 - 11/10	2.3	0.004	0.000	0.022	0.000	0.022	0.000	0.001	0.000	0.000
11/16 - 11/17	2.1	0.002	0.047	0.009	0.771	0.780	1.260	0.000	0.000	0.000
11/21 - 11/21	4.5	0.035	0.039	0.028	1.464	1.492	1.156	0.000	0.058	0.000
11/27 - 11/27	3.3	0.000	0.043	0.015	1.102	1.117	1.276	0.000	0.002	0.000
12/ 4 - 12/ 5	4.1	0.000	0.010	0.019	0.524	0.543	1.136	0.001	0.000	0.000
Storm	81.3	0.032	0.147	0.072	0.194	0.266	0.206	0.000	0.038	0.000
Ambient	698.3	0.029	0.109	0.069	0.088	0.157	0.120	0.000	0.034	0.014
Total	779.6	0.029	0.113	0.069	0.099	0.169	0.129	0.000	0.034	0.013

Table 6. Nutrient Loading from Polecat Creek Watershed (QPB), Sep. - Dec., 1994.

Storm	TSS	NH_4	NO_3	TKN	TN	TKN filtered	OP	TP	TP filtered
					Kg				
9/22 - 9/23	8.5	2.53	0.05	1.81	1.85	0.00	0.00	0.48	0.00
9/26 - 9/26	83.9	0.31	0.19	0.00	0.19	0.00	0.00	0.08	0.00
10/14 - 10/14	1076.1	4.02	2.44	0.00	2.44	0.00	0.00	1.05	0.00
10/20 - 10/21	901.4	3.36	2.04	0.00	2.04	0.00	0.00	0.88	0.00
10/23 - 10/23	175.5	0.65	0.40	0.00	0.40	0.00	0.00	0.17	0.00
10/26 - 10/26	165.4	0.62	0.38	0.00	0.38	0.00	0.00	0.16	0.00
11/10 - 11/10	9.3	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.00
11/16 - 11/17	4.1	0.10	0.02	1.59	1.61	2.59	0.00	0.00	0.00
11/21 - 11/21	157.0	0.18	0.13	6.59	6.71	5.20	0.00	0.26	0.00
11/27 - 11/27	0.0	0.14	0.05	3.66	3.71	4.24	0.00	0.01	0.00
12/ 4 - 12/ 5	0.0	0.04	0.08	2.17	2.25	4.70	0.00	0.00	0.00
Storm	2581.3	12.0	5.8	15.8	21.6	16.7	0.0	3.1	0.0
Ambient	19938.2	76.4	48.3	61.4	109.7	83.6	0.1	23.5	9.9
Total	22519.4	88.3	54.1	77.2	131.4	100.4	0.1	26.6	9.9

Table 7. Nutrient Concentration from Polecat Creek Watershed (QPC), Sep. - Dec., 1994.

Storm	Runoff ($l \times 10^6$)	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	TN (ppm)	TKN filtered (ppm)	OP (ppm)	TP (ppm)	TP filtered (ppm)
9/22 - 9/23	2.7	0.008	0.064	0.008	0.528	0.536	0.436	0.060	0.055	0.015
9/26 - 9/26	24.0	0.007	0.000	0.008	0.000	0.008	0.000	0.021	0.055	0.000
10/14 - 10/14	13.6	0.007	0.000	0.008	0.000	0.008	0.000	0.021	0.055	0.000
10/20 - 10/21	11.2	0.007	0.000	0.008	0.000	0.008	0.000	0.021	0.055	0.000
10/23 - 10/23	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/26 - 10/26	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11/10 - 11/10	13.1	0.005	0.000	0.056	0.059	0.115	0.716	0.004	0.020	0.000
11/16 - 11/17	27.3	0.000	0.020	0.000	1.388	1.388	1.630	0.034	0.025	0.000
11/21 - 11/21	31.7	0.008	0.021	0.032	1.073	1.105	2.304	0.027	0.038	0.065
11/27 - 11/27	36.4	0.005	0.047	0.090	0.032	0.122	0.083	0.037	0.001	0.003
12/ 4 - 12/ 5	16.8	0.003	0.000	0.093	0.000	0.093	0.000	0.106	0.000	0.000
Storm	176.7	0.005	0.017	0.040	0.425	0.465	0.741	0.035	0.028	0.012
Ambient	475.5	0.007	0.006	0.036	0.264	0.299	0.492	0.025	0.047	0.016
Total	652.1	0.006	0.009	0.037	0.308	0.344	0.559	0.027	0.042	0.015

Table 8. Nutrient Loading from Polecat Creek Watershed (QPC), Sep. - Dec., 1994.

Storm	TSS	NH_4	NO_3	TKN	TN	TKN filtered	OP	TP	TP filtered
					Kg				
9/22 - 9/23	21.3	0.17	0.02	1.40	1.43	1.16	0.16	0.15	0.04
9/26 - 9/26	168.0	0.00	0.19	0.00	0.19	0.00	0.50	1.32	0.00
10/14 - 10/14	95.2	0.00	0.11	0.00	0.11	0.00	0.29	0.75	0.00
10/20 - 10/21	78.3	0.00	0.09	0.00	0.09	0.00	0.23	0.62	0.00
10/23 - 10/23	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/26 - 10/26	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/10 - 11/10	65.3	0.00	0.73	0.77	1.50	9.35	0.05	0.26	0.00
11/16 - 11/17	0.0	0.55	0.00	37.83	37.83	44.42	0.93	0.68	0.00
11/21 - 11/21	253.9	0.67	1.01	33.98	34.99	72.95	0.86	1.20	2.04
11/27 - 11/27	179.7	1.70	3.28	1.16	4.44	3.04	1.34	0.04	0.09
12/ 4 - 12/ 5	50.5	0.00	1.57	0.00	1.57	0.00	1.78	0.00	0.00
Storm	912.1	3.1	7.0	75.1	82.1	130.9	6.1	5.0	2.2
Ambient	3131.7	2.9	16.9	125.4	142.3	233.7	11.7	22.1	7.8
Total	4043.8	6.0	23.9	200.6	224.5	364.6	17.9	27.2	10.0

Table 9. Nutrient Concentration from Polecat Creek Watershed (QPD), Sep. - Dec., 1994.

Storm	Runoff (1×10^6)	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	TN (ppm)	TKN filtered (ppm)	OP (ppm)	TP (ppm)	TP filtered (ppm)
9/22 - 9/23	185.2	0.013	0.017	0.016	0.355	0.371	0.051	0.028	0.046	0.009
9/26 - 9/26	32.1	0.000	0.000	0.005	0.059	0.064	0.248	0.010	0.030	0.000
10/14 - 10/14	41.1	0.000	0.000	0.005	0.059	0.064	0.248	0.010	0.030	0.000
10/20 - 10/21	37.0	0.000	0.000	0.005	0.059	0.064	0.248	0.010	0.030	0.000
10/23 - 10/23	16.9	0.006	0.000	0.006	0.825	0.831	0.000	0.013	0.075	0.000
10/26 - 10/26	14.3	0.006	0.000	0.006	0.825	0.831	0.000	0.013	0.075	0.000
11/10 - 11/10	15.2	0.006	0.000	0.009	0.000	0.009	0.000	0.091	0.097	0.055
11/16 - 11/17	37.9	0.009	0.000	0.000	0.001	0.001	0.000	0.040	0.000	0.000
11/21 - 11/21	70.1	0.013	0.003	0.007	0.392	0.400	0.064	0.025	0.052	0.015
11/27 - 11/27	57.1	0.000	0.050	0.009	0.466	0.475	0.773	0.023	0.071	0.001
12/ 4 - 12/ 5	29.1	0.000	0.045	0.019	0.845	0.864	0.512	0.018	0.065	0.000
Storm	536.0	0.007	0.014	0.010	0.330	0.340	0.187	0.025	0.047	0.007
Ambient	1703.6	0.002	0.004	0.026	0.331	0.357	0.357	0.014	0.138	0.138
Total	2239.7	0.004	0.007	0.022	0.331	0.353	0.317	0.016	0.116	0.107

Table 10. Nutrient Loading from Polecat Creek Watershed (QPD), Sep. - Dec., 1994.

Storm	TSS	NH_4	NO_3	TKN	TN	TKN filtered	OP	TP	TP filtered
					Kg				
9/22 - 9/23	2371.3	3.08	3.02	65.73	68.75	9.40	5.22	8.45	1.61
9/26 - 9/26	0.0	0.00	0.16	1.89	2.05	7.98	0.32	0.96	0.00
10/14 - 10/14	0.0	0.00	0.21	2.41	2.62	10.19	0.41	1.23	0.00
10/20 - 10/21	0.0	0.00	0.19	2.17	2.36	9.19	0.37	1.11	0.00
10/23 - 10/23	101.7	0.00	0.10	13.98	14.08	0.00	0.22	1.27	0.00
10/26 - 10/26	85.6	0.00	0.09	11.76	11.85	0.00	0.19	1.07	0.00
11/10 - 11/10	94.6	0.00	0.14	0.00	0.14	0.00	1.37	1.46	0.84
11/16 - 11/17	342.8	0.00	0.00	0.03	0.03	0.00	1.52	0.00	0.00
11/21 - 11/21	906.0	0.21	0.51	27.51	28.03	4.49	1.72	3.61	1.03
11/27 - 11/27	2.0	2.88	0.53	26.60	27.13	44.17	1.31	4.06	0.06
12/ 4 - 12/ 5	0.0	1.31	0.55	24.55	25.10	14.87	0.52	1.89	0.00
Storm	3904.0	7.5	5.5	176.6	182.1	100.3	13.2	25.1	3.5
Ambient	4096.2	7.6	44.7	563.6	608.3	608.8	23.1	234.9	235.7
Total	8000.3	15.1	50.2	740.2	790.4	709.1	36.2	260.1	239.2

Table 11. Nutrient Concentration from Polecat Creek Watershed (QPE), Sep. - Dec., 1994.

Storm	Runoff (1×10^6)	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	TN (ppm)	TKN filtered (ppm)	OP (ppm)	TP (ppm)	TP filtered (ppm)
9/22 - 9/23	248.1	0.006	0.033	0.042	0.118	0.160	0.092	0.067	0.049	0.064
9/26 - 9/26	149.8	0.000	0.000	0.030	0.000	0.030	0.000	0.071	0.050	0.035
10/14 - 10/14	228.9	0.000	0.000	0.030	0.000	0.030	0.000	0.071	0.050	0.035
10/20 - 10/21	141.7	0.001	0.000	0.036	0.000	0.036	0.000	0.057	0.083	0.014
10/23 - 10/23	237.0	0.002	0.000	0.040	0.000	0.040	0.000	0.047	0.105	0.000
10/26 - 10/26	647.4	0.001	0.000	0.048	0.000	0.048	0.000	0.051	0.113	0.039
11/10 - 11/10	287.3	0.044	0.000	0.029	0.803	0.833	0.445	0.029	0.176	0.021
11/16 - 11/17	65.5	0.048	0.000	0.030	1.668	1.698	0.749	0.041	0.215	0.000
11/21 - 11/21	519.9	0.025	0.000	0.047	1.752	1.799	0.344	0.032	0.166	0.002
11/27 - 11/27	189.1	0.000	0.025	0.156	1.425	1.581	0.416	0.069	0.095	0.067
12/ 4 - 12/ 5	153.3	0.003	0.016	0.091	0.768	0.858	0.167	0.077	0.088	0.066
Storm	2868.2	0.011	0.005	0.051	0.581	0.632	0.168	0.052	0.113	0.030
Ambient	4188.7	0.013	0.007	0.115	0.527	0.642	0.239	0.060	0.129	0.058
Total	7056.9	0.013	0.007	0.089	0.549	0.638	0.211	0.057	0.122	0.046

Table 12. Nutrient Loading from Polecat Creek Watershed (QPE), Sep. - Dec., 1994.

Storm	TSS	NH_4	NO_3	TKN	TN	TKN filtered	OP	TP	TP filtered
					Kg				
9/22 - 9/23	1474.3	8.08	10.43	29.30	39.73	22.82	16.74	12.18	15.99
9/26 - 9/26	0.0	0.00	4.50	0.00	4.50	0.00	10.64	7.49	5.24
10/14 - 10/14	0.0	0.00	6.87	0.00	6.87	0.00	16.26	11.45	8.01
10/20 - 10/21	170.1	0.00	5.10	0.00	5.10	0.00	8.02	11.76	1.98
10/23 - 10/23	473.9	0.00	9.48	0.00	9.48	0.00	11.14	24.88	0.00
10/26 - 10/26	795.7	0.00	31.39	0.00	31.39	0.00	32.92	72.97	24.96
11/10 - 11/10	12600.9	0.00	8.47	230.80	239.27	127.98	8.21	50.61	5.96
11/16 - 11/17	3144.5	0.00	1.97	109.27	111.24	49.09	2.69	14.08	0.00
11/21 - 11/21	13192.1	0.00	24.32	910.74	935.06	178.83	16.79	86.13	1.01
11/27 - 11/27	19.9	4.66	29.57	269.56	299.12	78.74	12.99	17.97	12.69
12/ 4 - 12/ 5	455.6	2.43	13.90	117.69	131.59	25.56	11.84	13.42	10.06
Storm	32327.0	15.2	146.0	1667.4	1813.3	483.0	148.2	322.9	85.9
Ambient	56155.6	30.8	481.2	2206.1	2687.3	1003.0	253.2	539.9	241.4
Total	88482.6	45.9	627.2	3873.4	4500.6	1486.0	401.4	862.9	327.3

Table 13. Polecat Creek Watershed Weather Parameters: Sep. - Dec., 1994.

Month	Precip.	Humidity, %			Temperature, C			Evaporation
	(mm)	avg.	min.	max.	ave.	min.	max.	(mm)
SEP	64.82	75.7	32.0	100.0	17.3	11.7	22.2	*
OCT	53.16	81.3	21.0	100.0	14.7	1.1	25.0	*
NOV	67.36	76.7	13.0	100.0	13.9	7.2	23.3	*
DEC	21.50	77.0	14.0	100.0	10.4	-6.1	20.6	*
SEP-DEC	206.84	62.1	13.0	100.0	14.1	6.1	25.0	*

* Evaporation pan winterized

Table 14. Rain Water Quality Data for Polecat Creek Watershed, (sampling station - PP9), Sep. - Dec., 1994.

Sample Collection Date	TSS (g/l)	NH_4 (ppm)	NO_3 (ppm)	TKN (ppm)	Filtered TKN (ppm)	TP (ppm)	OP (ppm)	Filtered TP (ppm)
9/13/94	0.003	0.038	0.083	0.9404	-	-	-	-
9/23/94	0.003	0.068	0.099	-	-	-	-	-
10/22/94	-	0.42	0.462	0.4417	-	0.135	-	-
10/28/94	-	0.162	0.4	1.5066	-	-	-	-
11/12/94	-	-	-	0.4416	-	0.055	-	-
11/21/94	0.003	0.201	0.378	0.3224	-	-	-	-
12/ 3/94	0.014	0.069	0.056	-	-	-	-	-
12/12/94	0.018	0.762	0.672	1.2139	0.6387	-	-	-
12/19/94	0.003	0.366	0.815	0.2648	0.4128	-	-	-

- = Non-Detectable

Table 15. Number of Fecal Coliforms and Fecal Streptococci per 100 ml of Water Sample, Sep. - Dec. 1994, (Polecat Creek Watershed).

	Site									
Date	QPA	QPB	QPC	QPD	QPE	QPA	QPB	QPC	QPD	QPE
	Fecal Coliform					Fecal Streptococci				
09/21/94	< 200	170*	20	< 200	40	230	172*	270	360	80
10/20/94	< 200	230*	40	80	< 20	54	45*	54	270	162
11/17/94	< 200	< 200	< 200	< 200	< 200	70	16	430	230	18
12/15/94	< 200	< 200	< 200	< 200	< 200	8	0	36	29	20

*FC/FS ratio exceeds 0.7 for these samples.

Table 16. Summary of fecal coliforms per 100 ml for all samples. Colony counts outside of the acceptable range are not included in these statistics. Polecat Creek Watershed, Sep. - Dec. 1994.

	Site				
	QPA	QPB	QPC	QPD	QPE
Geometric Mean	-	198	28	80	40
Arithmetic Mean	-	200	30	80	40
Standard Deviation	-	42	14	-	-
Sample Size	-	2	2	1	1

* Samples could not be collected.

- No quantitative data for determining means.

Table 17. Summary of fecal streptococci per 100 ml for all samples. Colony counts outside of the acceptable range are not included in these statistics. Polecat Creek Watershed, Sep. - Dec. 1994.

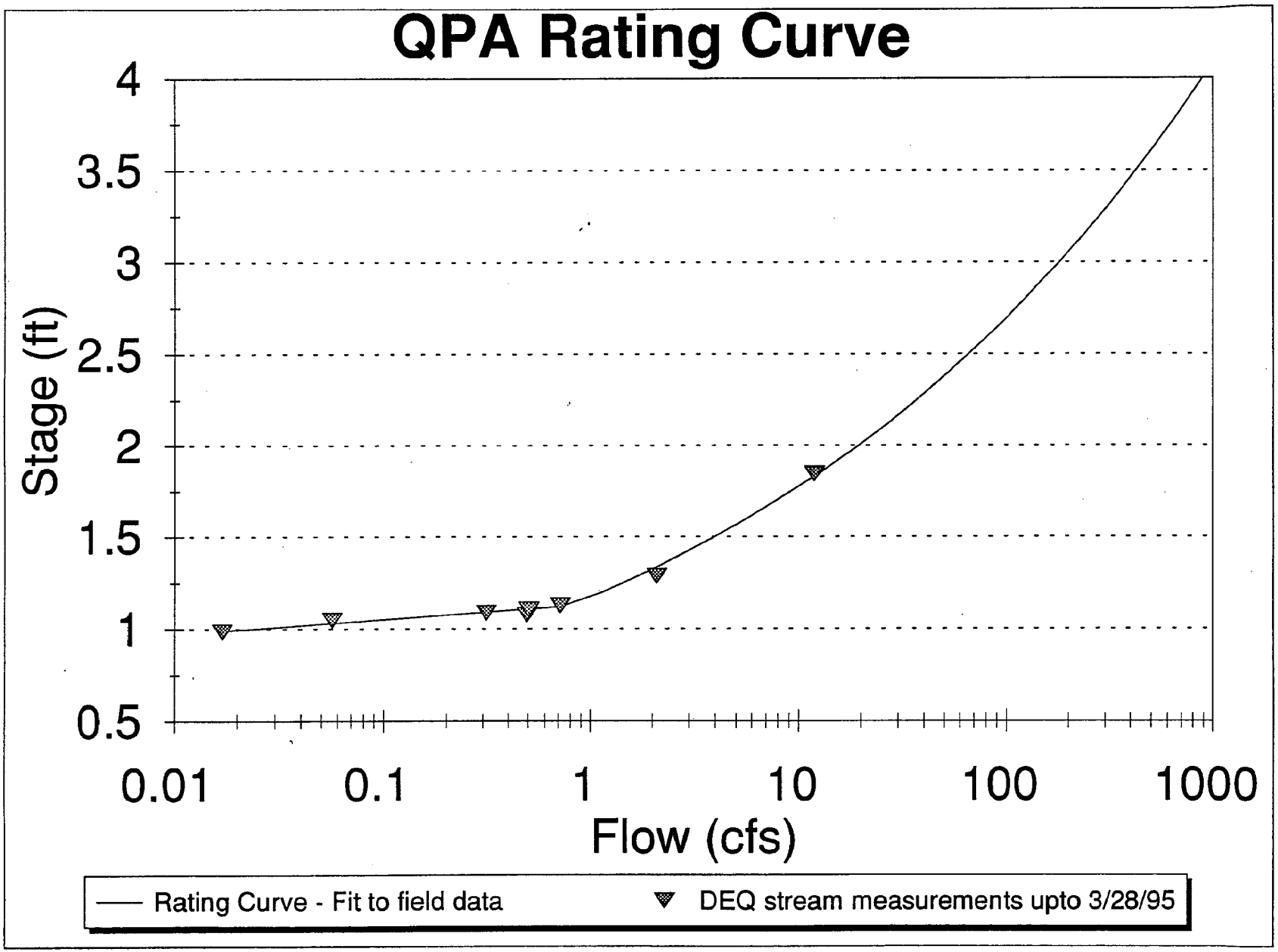
	Site				
	QPA	QPB	QPC	QPD	QPE
Geometric Mean	51	50	123	160	47
Arithmetic Mean	91	58	198	222	70
Standard Deviation	97	70	188	140	68
Sample Size	4	4	4	4	4

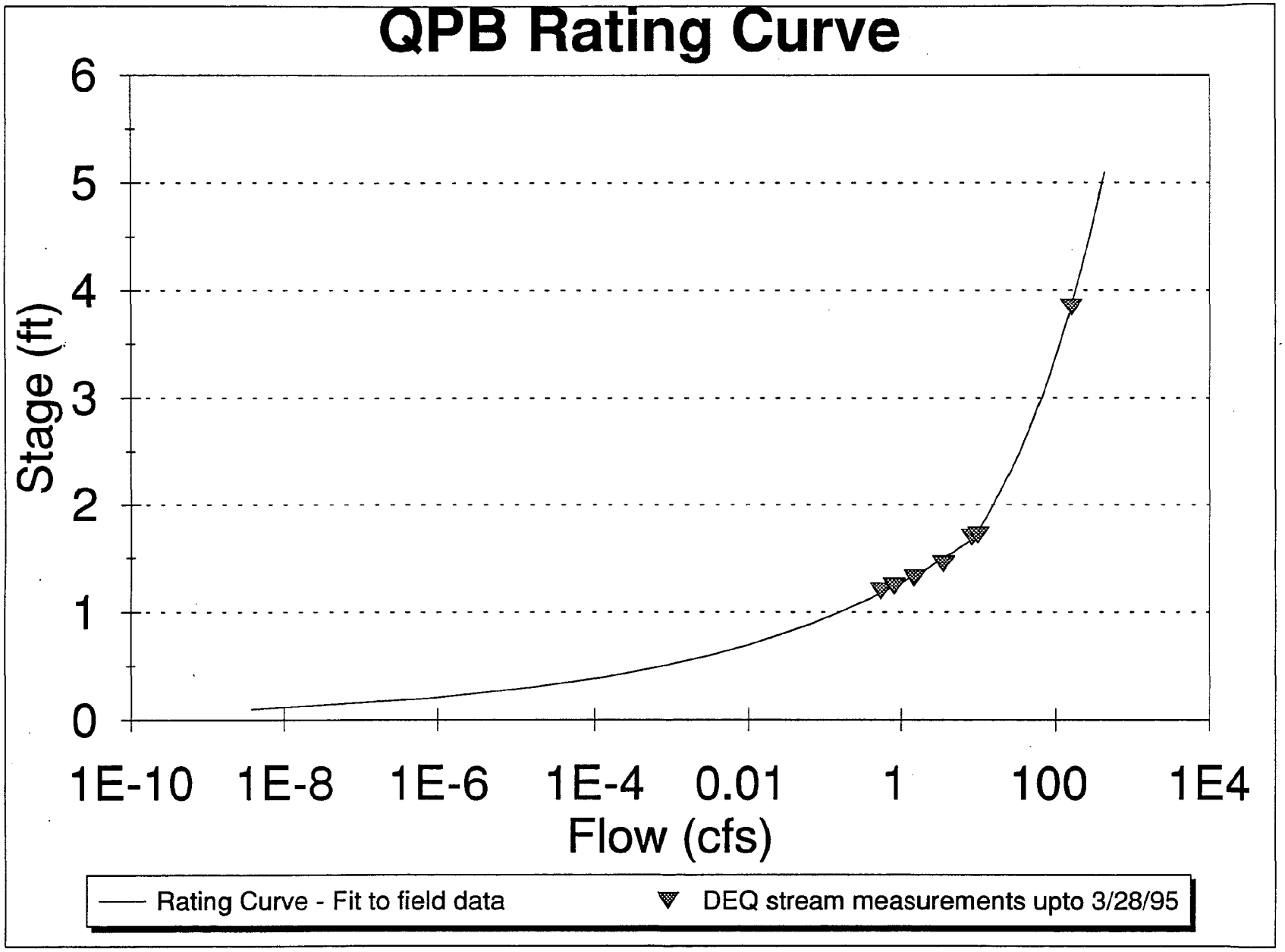
* Samples could not be collected.

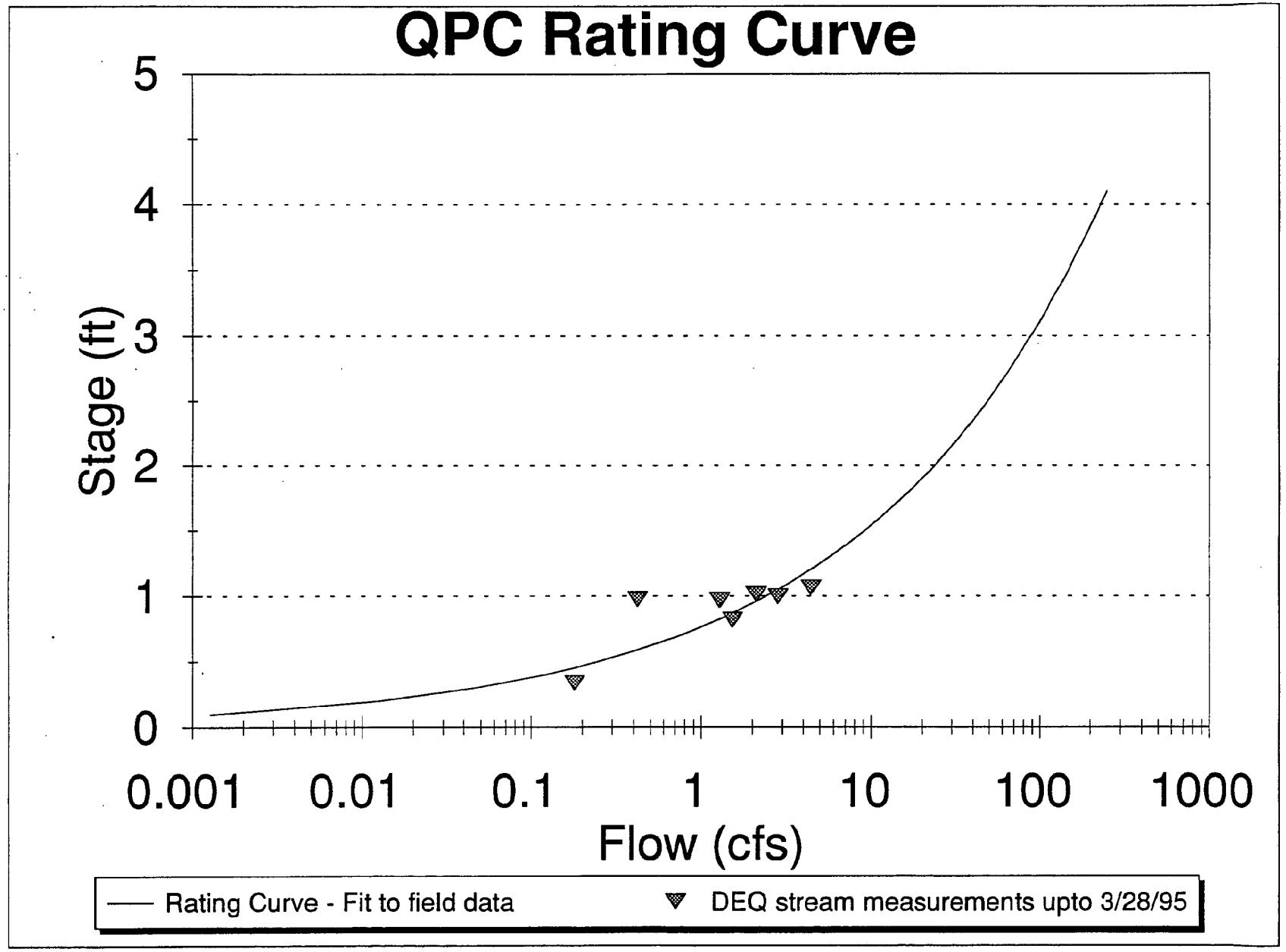
Table 18. Summary of total bacterial counts (x 10^5) per 100 ml for all samples. Colony counts outside of the acceptable range are not included in these statistics. Polecat Creek Watershed, Sep. - Dec. 1994.

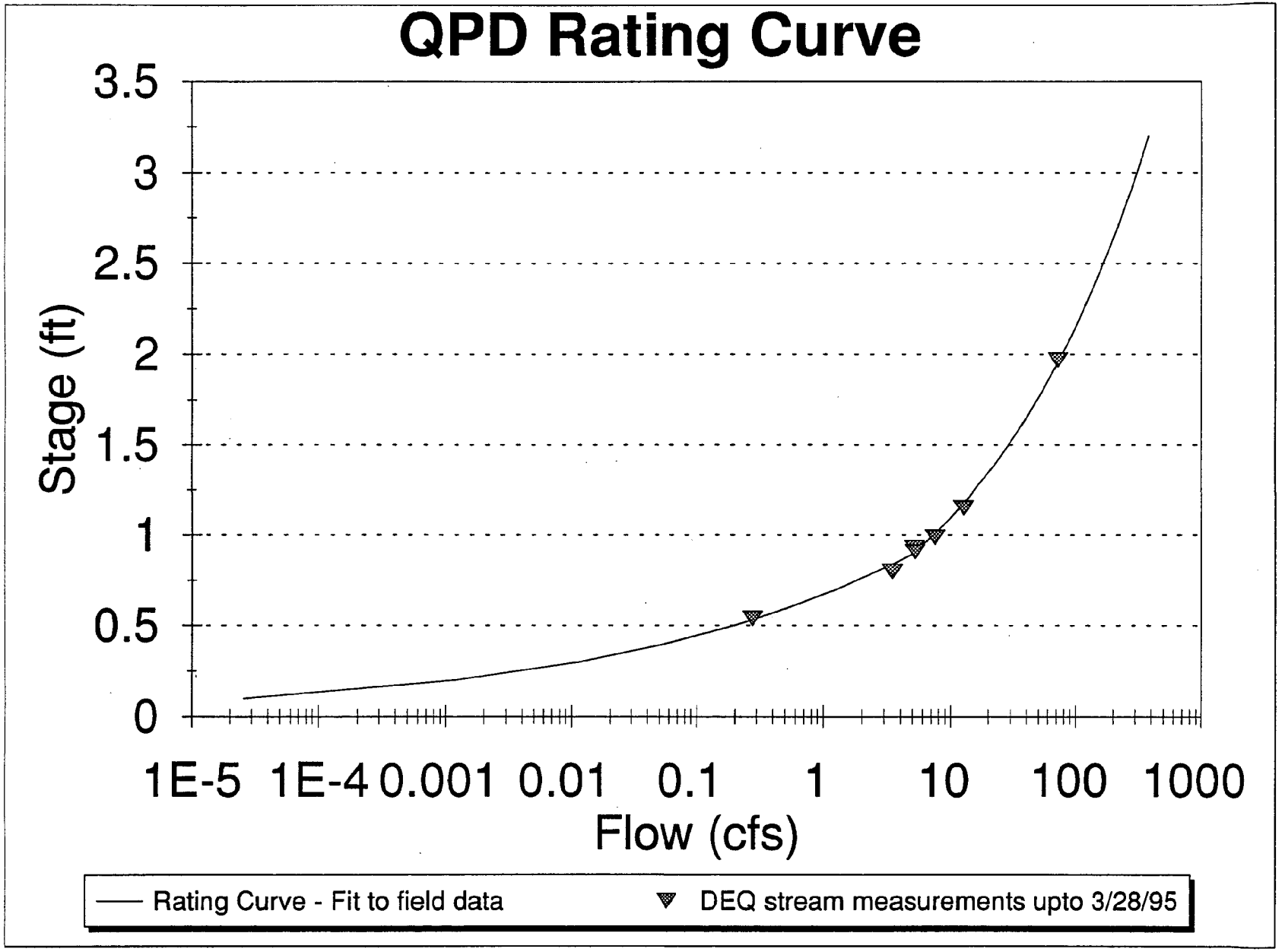
	Site				
	QPA	QPB	QPC	QPD	QPE
Geometric Mean	706	517	654	229	256
Arithmetic Mean	1000	1143	767	233	340
Standard Deviation	1039	1608	551	58	314
Sample Size	3	3	3	3	3

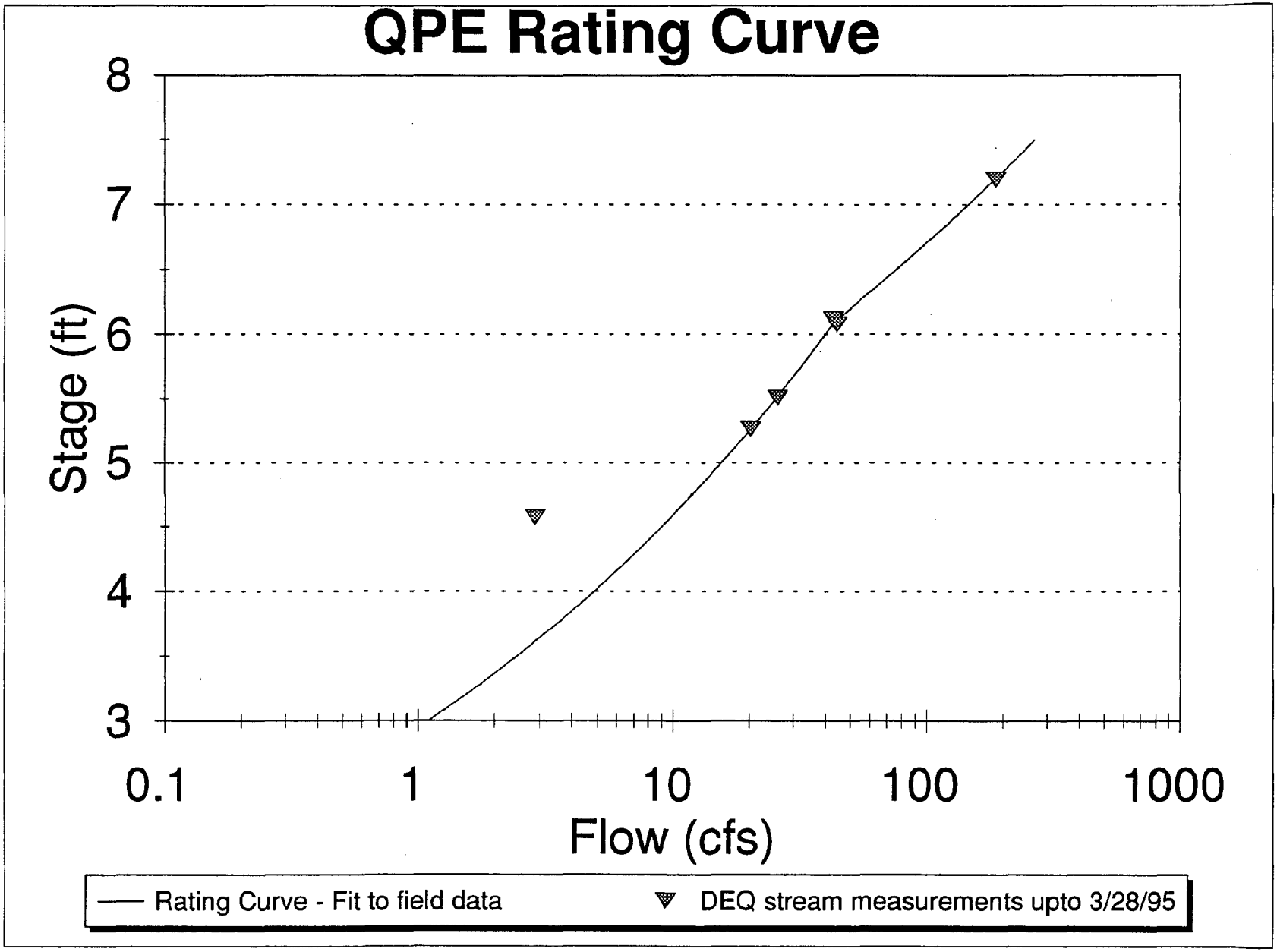
* Samples could not be collected.


QPA Rating Curve
Stage (ft)
4
3.5
3
2.5
2
1.5
1
0.5
0.01
0.1
1
10
100
1000
Flow (cfs)
Rating Curve - Fit to field data
DEQ stream measurements upto 3/28/95


QPB Rating Curve
Stage (ft)
6
5
4
3
2
1
0
1E-10
1E-8
1E-6
1E-4
0.01
1
100
1E4
Flow (cfs)
Rating Curve - Fit to field data
DEQ stream measurements upto 3/28/95


QPC Rating Curve
Stage (ft)
5
4
3
2
1
0
0.001
0.01
0.1
1
10
100
1000
Flow (cfs)
Rating Curve - Fit to field data
DEQ stream measurements upto 3/28/95


QPD Rating Curve
Stage (ft)
3.5
3
2.5
2
1.5
1
0.5
0
1E-5
1E-4
0.001
0.01
0.1
1
10
100
1000
Flow (cfs)
Rating Curve - Fit to field data
DEQ stream measurements upto 3/28/95


QPE Rating Curve
Stage (ft)
8
7
6
5
4
3
0.1
1
10
100
1000
Flow (cfs)
Rating Curve - Fit to field data
DEQ stream measurements upto 3/28/95

12.0 REPORTS TO MANAGEMENT

The Project Director will submit a Quarterly Report (January 15, April 15, July 15, and October 15) to the sponser. Each Quarterly Report will address the following topics:

- performance and system audits conducted
- evaluation of compliance with QA/QC Project Plan
- evaluation of data quality measurement trends
- identification of problems, needs, and recommendations for solutions.

Copies for Quarterly Report will be sent to the Grant Project Manager, the QA officer and Project Engineer/Manager. The final quarterly status report following completion of the project will provide a summary of the items listed above.

11.0 CORRECTIVE ACTION

If a calibration check shows that an equipment is not preforming within the accuracy stated in the objective, then a problem will be considered to exist. If the equipment should be repaired or recalibrated the field and laboratory personnel will be notified of any changes and will be provided a copy of the new calibration form and other information as necessary.

10.0 PROCEDURES USED TO DEVELOP ACCURACY AND PRECISION DATA

10.1 Field Data: Detail procedure and methods used to calculate precision and accuracy for field equipment is given in Appendix C.

10.2 Laboratory Data: The procedures for calculating and reporting precision and accuracy for laboratory data are given in Appendix D-13.

9.0 PREVENTATIVE MAINTENANCE

Preventative maintenance is described under section 4.0 of this report. Following is a list of field and laboratory equipment that would require preventative maintenance during the projects life:

Automatic Water Quality Samplers

Staff Gages

Rain Gages

Stage Recorders

Current Meter

Auto Analyzer

Laboratory Balances

Bloc Digester

Dattaloggers

TRACS 800

Drying Ovens

Stills

GC

8.0 AUDIT PROCEDURES

A system of semi-annual audits will be established to review and assess the ongoing quality assurance practices for compliance with the quality assurance program. These audits will be conducted by a committee whose members include the Laboratory Liaison Officer, Project Manager, Field Technician, and Project Quality Assurance Officer. This Committee will be responsible for verifying both compliance and performance and to identify discrepancies when they exist. During these initial audits control charts will be reviewed to assure that a) they are up-to-date and that control samples are being measured at the specified intervals in the lab, b) all field and laboratory equipment and instrumentation are checked and calibrated according to the specified procedures, c) a log book of problems encountered and the corrective actions taken is maintained, d) there is a high degree of cooperation between the various components of the project, e) uncertainty limits for all data is enforced, and f) all reports to the sponsoring agency are screened for QA aspects. The field and laboratory Quality Assurance Audit form (Appendix F) will be used by the Audit's Committee for internal audits to be conducted during June and December each year. The committee will report on the progress of the project and make recommendations for corrective actions as required.

7.0 INTERNAL QUALITY CONTROL

Internal quality control is an integral part of determining the quality of both field and laboratory data. Quality control check for field instrumentation are included in Section 6.0 of this report. The HAS data management system examines the important quality control checks.

The laboratory internal QC checks for the nutrient data and biological analysis are explained in Appendix D and Appendix E, respectively.

6.0 DATA REDUCTION, VALIDATION AND REPORTING

Data reduction, validation, and reporting procedures for this project will be according to the data management system, HAS, which was designed and adapted in the Water Quality Laboratory of the Biological Systems Engineering Department at Virginia Tech to manage hydrologic and water quality data from the watershed monitoring projects (Mostaghimi, 1989). A flow diagram of the data management system is given in Figure 6.1.

The Project Director will be responsible for submitting quarterly activity reports. A brief summary of activities including progress made, problems encountered, QC check, internal audit records, and steps taken to rectify the potential problems will be outlined in quarterly activity reports. Copies of these reports will be provided to other project investigators, laboratory , and field personnel.

on the data collected from other instruments located at the logger sited which is used for error checking.

Raw data are archived on the diskettes as well as on the Virginia Tech Biologial Systems Engineering Department Micro-Vax Mini Computer.

Data are transferred into the HAS data management system. At this point, the DOS filenames are converted to the mainframe file naming convention. For example above (QPA100188.007), the mainframe name would be "QPA1RAW88 L001007A" as discussed under section 10.2.2 of this report.

5.3.2 Field Transfer

- All electronic data collection devices not accessible by phone lines are serviced weekly by the Field Observers. Data from these devices are transferred to a portable computer and stored on diskettes. Diskettes are mailed to the Project Engineer at Virginia Tech on a weekly basis.
- Upon receiving diskettes, data is inventoried and the procedures outlined in the last two steps of section 5.3.1 are followed.

5.2 Bacteriological Samples: Bacteriological samples are collected on a monthly basis. Sample information is recorded on the field tracking form WQS-3 (Appendix A) and the information for all samples are logged into the HAS data management system

5.3 Electronic Data

5.3.1 Telecommunication Transfer:

Data recording devices accessible by telephone lines are transferred twice a week, to a personal computer at Virginia Tech. Immediately following data transfer, all output files are edited by a full screen editor for visual inspection and to verify the beginning and ending data collection dates. KEDIT, developed by Mansville Software (1987), is used for this process and was selected because it is compatible with the mainframe editor (XEDIT) used at Virginia Tech. The collection dates obtained during the editing step provide information for the naming convention used to properly identify the permanent output storage files form each site. The files are stored directly from KEDIT onto diskettes in a DOS sub-directory named Logger. An example of the DOS file naming convention used would be QPA100188.007 for a stream flow site on Polecat Creek Watershed. The '001' and '007' are the beginning and ending collection period Julian days, January 1 through January 7, respectively. The '88' is the collection year (1988) and the 'QPA' is location of the logger collection site. These permanent storage files are referred to as raw data logger files and the file naming convention is compatibile with the HAS system as the files are processed during the data reduction phase. The file name and date printed is recorded on form HD-5 (Appendix B).

After transfer and editing, a SPLIT program, part of the Campbell Scientific PC206 package (1986), is executed with each of the site storage files. This program scans and displays selective information from the logger data files. The main objective for executing this routine is to provide hardcopy of the water quality sample event dates and times that were sensed by the 21 x loggers. These sample events are needed to establish proper correspondence between stream flow measurements and water sampling during the data reduction phase. The hardcopy output also provides additional information

Upon sample delivery, laboratory personnel inventory them and sign off the tracking form. The discrepancies, if any, are noted and discussed with the Field Technician. The discrepancies are resolved by the Project Engineer in consultation with the Field Observer and Field Technician. Tracking sheets are separated by the laboratory manager by sites, each sample is assigned a separate laboratory number, and all samples are assigned a group number. All water samples have a letter prefix before their laboratory number. The samples are numbered by site and in numerical order by field number. The laboratory numbers are recorded on the log-in-sheets. If there are more than 120 samples in a shipment, the samples are separated into two groups. Group numbers consist of two letters (i.e., BA).

Samples are retrieved from the cooler and brought to the laboratory. The samples are separated by site and a laboratory number is recorded on the top and side of each sample. Samples are checked off on the log sheets as they are numbered. If there is more than 1 bottle for a sample (1 field number) a composite sample is needed. A portion from each bottle is added to a clean sample container, the laboratory number, site, and field number are recorded on the new bottle (Detail procedures are included in Appendix D-1)

Any sample irregularities are recorded in the laboratory log-in notebook. After all samples for each shipment have been logged in, the log sheets are assigned a laboratory delivery date and initialed by laboratory personnel. Copies of the original log sheets are made and the originals are passed on to the project engineer. At this time, sample problems are discussed with the Project Engineer, and all decisions on sample status are finalized. Sample numbers and reasons for non-analysis are recorded in the laboratory log-in notebook. After the samples are analyzed, they are stored in a walk-in cooler at 4°C for up to 6 months. The reason for such storage period is to enable the cross-checking of the information recorded on bottles with laboratory, log-in sheets, and electronically collected information (data loggers), if needed. After each semiannual report to the sponsor is completed, the samples are discarded. Sample custody procedures for water quality samples are discussed in detail in Appendix D-1. The tracking information for all samples are logged into the HAS data management system.

5.0 SAMPLE CUSTODY PROCEDURE

Sample custody procedures for various types of samples and data are described in this section. These procedures are designed to ensure accountability and sample custody responsibility so that there is a clear and documented method for the transfer of samples and data between the various laboratories involved in sample analysis.

5.1 Nutrient Water Samples:

All water quality samples are connected to data loggers which record the sampling time. The Field Observer, who lives on the watershed, visits all the monitoring stations within 24 hours after a rainstorm and:

- Removes all water quality samples collected within 24 hours of sampling time.
- Labels all samples using the Pre-prepared WQS-L labels (Appendix A).
- Completes field sheets. For nutrient samples, complete field tracking form WQS-1 (Appendix A).
- Transfer samples to the appropriate laboratories.

In situations where major storm events occur, the field observer immediately notifies the field technician who makes a trip solely for transporting the samples to Virginia Tech. Before shipping, all samples are inventoried and checked-off against the appropriate field tracking forms by the field technician. Appropriate actions are taken to resolve discrepancies between inventories and field tracking records by Field Observer and field technicians. All samples are packed in insulated coolers, iced down, and transported with the original copy of the field tracking form by surface transportation (usually by the University truck used by the field technician, in some cases, for example the biological samples, express overnight mail is used.) Nutrient samples and tracking forms are delivered to the Virginia Tech Water Quality Laboratory at 400 Seitz Hall in Blacksburg. Ms. Carol Ivey of the Water Quality Laboratory is responsible for inventorying and receiving nutrient samples.

Table 4.1 (Continued)

Fecal Coliform (MPN Tube)	Grab	Monthly	100 ml	Nalgene	Cool 4°C	24 hours
Total Coliform (MPN Tube)	Grab	Monthly	100 ml	Nalgene	Cool 4°C	24 hours
Fecal Streptococci (Membrane filtration)	Grab	Monthly	100 ml	Nalgene	Cool 4°C	24 hours

Table 4.1 **Sampling Method, Frequency, Preservation, and Holding Times**

Analytical Parameters	Collection Method	Collection Frequency	Volume Required	Container Type (polyethylene)	Preservation Method Immediately After Sampling	Maximum Holding Time Prior To Analysis
Ammonia	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	28 days
	Grab	Bi-weekly		Nalgene		
Nitrate & Nitrite	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	28 days
	Grab	Bi-weekly		Nalgene		
Nitrate	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	14 days
	Grab	Bi-weekly		Nalgene		48 hours
TKN	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	28 days
	Grab	Bi-weekly		Nalgene		
Orthophosphate	Automatic	Every 15 cm change in stage	500 ml	Isco	Filter, cool 4°C	14 days
	Grab	Bi-weekly		Nalgene		48 hours
Total-P	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	28 days
	Grab	Bi-weekly		Nalgene		
COD	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	28 days
	Grab	Bi-weekly		Nalgene		
TSS	Automatic	Every 15 cm change in stage	500 ml	Isco	Cool 4°C	14 days
	Grab	Bi-weekly		Nalgene		7 days

sampling and analyzed within 24 hours of sampling. The original copy of the field tracking form is shipped with samples to the laboratory personnel. Upon samples arrival, laboratory personnel will inventory them, assign lab number, and sign off the tracking form. Any discrepancies are discussed with the Field Observer. Appendix E details the field procedure for biological sampling and retrieval, and laboratory analysis developed for Nomini Creek and Owl Run watershed monitoring projects and will be adapted to this project (Mostaghimi, 1989).

4.4.3 Hydrologic Data: Stream water level recording charts are removed weekly by the Field Observer. The removal date and time and any equipment malfunctions are noted on each chart. Water quality samples identification (i.e. numbers) collected during that chart period is recorded on the back of the stream water level chart. All charts collected are mailed to the project manager.

4.5 Analytical Procedures: The analytical methods for nutrients and biological analysis are described in Appendix D, and E, respectively. These methods are based on the procedures listed in the US EPA Methods of the Examination of Water and Wastes and the Standard Methods for the Examination of Wastewater.

4.4 Sample Identification and Submission to Laboratory: Standard procedures developed for the Water Quality Laboratory in the Biological Systems Engineering Department at Virginia Tech will be followed. Methods for the calibration and maintenance of equipment used in the Water Quality Laboratory are documented in Appendix C. The purpose of these procedures are to define a regular schedule for equipment calibration and to instruct laboratory personnel in the correct maintenance of the laboratory instruments so that all tests can be preformed quickly and correctly. All calibration and maintenance operations are to be recorded in each piece of equipment's calibration/maintenance log book.

4.41 Nutrient, Sediment, and COD analysis: The Field Observer labels all samples using the pre-prepared labels and completes field log sheets (Appendix A) and stores all samples collected by the automated water samplers and delivers them to VPI&SU soon after their collection. Grab samples are collected on a weekly basis. Grab samples are placed in a cooler (4°C) immediately after collection and transported to the Water Quality Laboratory at Virginia Tech.

All collected samples are inventoried and checked-off against the appropriate field tracking forms by the Field Observer before being transferred to the Water Quality Laboratory. Appropriate action is taken to resolve discrepancies between inventories and field tracking records. All samples are packed in insulated coolers, iced down, and transported with the original copy of field tracking form by surface transportation to the Water Quality Laboratory, Biological Systems Engineering Department, Virginia Tech.

When samples arrive in the Water Quality Laboratory, they are logged in and assigned a laboratory number for sample tracking. The Allowable sample holding times, for nutrients, sediment, and COD are given in Table 4.1. Detailed information for nutrient analysis, data collection, reporting, and storage are given in Appendix D.

4.4.2 Bacteriological Samples: The Field Observer labels all samples using the pre-prepared labels. All samples are placed in an insulated container and transported to the laboratory immediately after

4.0 PROJECT OPERATING PROCEDURES

4.1 Field Sampling: Water will be sampled at all stations for sediment and nutrient analysis. Sampling for bacteria analysis will be conducted at all stations on a monthly basis. At all stations samples will be collected by both grab sampling and by automatic water samplers, on a weekly basis and during major rainfall events, for sediment and nutrient analysis.

At all stations two sampling schedules will be followed for sediment and nutrient measurement. The first sampling schedule will be initiated by the Field Observer on a weekly basis through the data loggers. The second sampling schedule will be based on the volume of water flowing in the stream during storm events. The data logger will be programmed to signal the automatic sampler to take a composite sample during each rainfall/runoff event. The sampling date and time and the corresponding stream stage is recorded by the data logger. The Field Observer will collect the samples within 24 hours of a storm event and send them to the appropriate laboratory at VPI&SU.

4.2 Sampling Containers, Preservation, and Holding Times: Standard procedures established for the Water Quality Laboratory in the Biological Systems Engineering at Virginia Tech (Mostaghimi, 1989) and approved by U.S. EPA will be followed for the proposed project. These procedures are outlined in Tables 4.1, and are presented in Appendix D.

4.3 Field Testing, Calibration, and Preventative Maintenance: Calibration and maintenance procedures for field equipment are explained in detail in Appendix C. In general, calibration is preformed on all equipment at installation time and every six months, thereafter. More frequent calibration may be performed if examination of data suggests an equipment malfunction. Equipment maintenance, on the other hand, is performed weekly by the field observer and monthly by the project personnel. Equipment are maintained at a level of or better that the stated QA accuracy (Table 3.1). Calibration and maintenance operations are recorded in a notebook.

Table 3.2 (Continued)

Fecal Strep (Membrane filtration)	0.0 colonies/100 ml	95% confidence limit	) 85%	1 dup. for each sample 1 blank per 5 samples	APHA 9230

* The QA protocol was designed as a minimum allowed QC procedures to follow based on the data quality objectives for this project. This plan was developed using the references listed below. Detection limits are lab values based on the height of recorder noise at maximum sensitivity. (Gas Chromatograph, Dr. H. McNair, 1985 ACS Shortcourse publication).

Handbook for Analytical Quality Control in Water and Wastewater Laboratories, USEPA, 1979.

Handbook of Quality Assurance for the Analytical Chemistry Laboratory, J. P. Dux (VNR Co. Inc.), 1986.

Quality Assurance of Chemical Measurements, J. K. Taylor (Lewis Publ. Inc.), 1987.

Table 3.2 Data Quality Standards for Laboratory Data.

Parameter	Detection Limit (mg/l)	Percent Recovery	Precision (mg/l)	QC Protocol*	Method
Ammonia (NH_3 - N)	0.01	98 - 102% recovery	± 0.06	1 dup. per 20 samples 1 EPA QA-QC standards per 40 samples 1 spike per 40 samples 1 blank run daily	EPA 350.1
Nitrate (NO_3 - N	0.05	96 - 100%	± 0.026	1 dup. per 20 samples 1 EPA QA-QC standards per 40 samples 1 spike per 40 samples 1 blank run daily	EPA 353.2
Orthophosphate (PO_4 - P)	0.01	89 - 94%	± 0.013	1 EPA QA-QC standards per 40 samples 1 spike per 40 samples 1 blank run daily	EPA 365.1
TKN	0.1	97 - 101%	± 0.126	1 dup. per 17.5 samples 2 EPA QA-QC standards per 35 samples 1 blank per 35 samples 1 spike per 35 samples	EPA 351.2
Total-P	0.05	91 - 94%	± 0.056	1 dup. per 17.5 samples 2 EPA QA-QC standards per 35 samples 1 blank per 35 samples 1 spike per 35 samples	EPA 365.1
Total Suspended Solids	0.02	± 5% relative error	± 0.74	1 dup. per 40 samples 1 blank per 40 samples 1 EPA standard per 200 samples	EPA 160.2
Hardness, total	0.1	95-100%	± 0.5	1 dup. per 40 samples	EPA 130.2
TOC (Carbon, total organic)	0.5	95-100 %	± 0.5	1 dup. per 40 samples	EPA Compatible Method
Fecal/Total Coliform (MPN Tube)	0.0 MPN/100ml	95% confidence limit	95%	1 dup. for each sample 1 blank per five samples	APHA 9221

Table 3.1 Data Quality Standards for Field Data.

Measurement Parameter	Accuracy	Precision	Completeness	Reference Used for Accuracy Calculations
Rainfall	4%	0.01 inch	80%	laboratory calibrated weights graduated pipette (with an equivalent 0.01" rainfall graduation)
Stage Stream	0.01 foot	0.005 foot	95%	land surveyor's level
Temperature Stream	2.0°C	0.1°C	80%	laboratory grade thermometer with 0.2°C resolution
Time Data Archival	10 minute	1 minute	95%	digital watch referenced to University mainframe clock and observed to be accurate within 1 minute per month
Time of Rainfall samples	10 minutes	1 minute	90%	same as above
Wet Weather Stream Samples	5 minutes	1 minute	90%	same as above

systems in order to ensure data comparability (Young, 1985; Mitchel, 1984, Beasley, 1985). Standard techniques recommended by Blakensiek et al. (1979) for the initiation and maintenance of hydrologic/water quality research project is followed. All data collected is reported in units consistent with other institutions reporting similar information to allow comparability of data bases among various organizations. The hydrologic/water quality data management system designed for the watershed will provide data that could be used by other researchers and organizations in evaluation of nonpoint source pollution control strategies.

3.4 Data Completeness: Data completeness goal, defined as the percent of valid data obtained from a monitoring station, compared to the amount that is expected to be obtained under normal situations are given in Table 3.1 and 3.2. If the completeness goal is not met, the missing data is either estimated form nearby stations, or by regression equations developed for some sites based on the historical data. In most cases, however, the data collected by the "backup" instrument is used to fill the data gap. When a decision is made to fill these gaps by estimating values (i.e. from closest alternate station or regression equations) such information will be tagged as estimated rather than observed in our data base management system.

3.0 QUALITY ASSURANCE OBJECTIVES

3.1 Data Accuracy and Precision: The purpose of the QA Plan for the Polecat Creek Watershed project is to provide data of known accuracy and precision. Standard techniques established for initiation and maintenance of hydrologic/water quality monitoring project were described in detail by Mostaghimi (1989) for the Nomini Creek watershed. The QA plan developed for the Nomini Creek watershed project, which was reviewed and approved by EPA, will be followed for the Polecat Creek project. Data Quality Standards for field and laboratory data are presented in Tables 3.1 and 3.2, respectively. The Quality Assurance Procedures are discussed in more detail in Appendix D. Accuracy is estimated by calculating the standard deviation of the differences between the measured and referenced values over a typical range of data (Appendix C). Table 3.1 indicates the reference used in evaluating precision values for various parameters. Precision is calculated in terms of the standard deviation for various measurements (Appendix C). The precision and accuracy of field data are determined on a semi-annual basis. When the established limits (QA/QC established values) are not met, the instrument is recalibrated according to the guidelines provided by the manufacturers and subsequent checks are made to ensure that the instrumentation is functioning properly.

3.2 Data Representative: Station QPE was established to describe the overall water quality draining the Polecat Creek Watershed. Stations QPA, QPB, QPC, and QPD were selected at the outlet of major tributaries in the watershed in order to evaluate the relative contributions of NPS pollutants originating from various areas within the Polecat Creek watershed. Once sufficient large numbers of biological and water chemistry samples are collected at these stations, multivariate analysis of the relationship between biological and chemical water quality will be preformed and predictive equations will be developed. Other sampling sites such as locations selected for precipitation, and raingages were chosen according to the guidelines provided by Brakensiek et al (1979) in order to adequately represent the spatial variability within the watershed.

3.3 Data Comparability: The monitoring strategy and analytical approach for the Polecat Creek Watershed were selected based on the investigator's experience in watershed/water quality monitoring

plan, b) ensure that all missing data is identified and replaced in accordance to procedures outlined in the QA plan, and c) to archive all data in accordance with the QA plan.

2.1 Responsibilities: Dr. Mostaghimi of the Department of Biological Systems Engineering, VPI&SU will serve as the Project Director and Quality Assurance Officer for the project. Dr. Mostaghimi is a specialist in the areas of nonpoint source pollution control, hydrology, and water quality engineering. He has authored over 220 technical publications related to various aspects of soil and water conservation engineering. He will be responsible for conducting quality assurance program and for taking or recommending corrective actions as required. Dr. Mostaghimi's other responsibilities will be: a) develop and implement quality control programs, including statistical procedures and techniques which will meet the desired quality standards, b) monitor quality assurance activities and determine conformance with policy and procedures and with sound practices, c) conduct system audits and make appropriate recommendations for corrective actions and improvements as may be necessary, and d) evaluate data quality and monitor other pertinent performance information.

P.W. McClellan and Mr. A.D. Davis of the Department of Biological Systems Engineering at VPI&SU will serve as the Quality Control Officers for the field data collection. Both Mr. McClellan and Mr. Davis will ensure the maximum integrity of all hydrologic and water quality data collected by following the procedures outlined in the QA/QC Plan for the project. Their specific responsibilities will be to ensure that: a) all field equipment is calibrated routinely, b) field technicians and field observers are trained on the proper procedures to be followed for sampling and recording, c) all field equipment calibrations, sample handling and shipping are documented and available to the QC officer for his review, d) all field data is transferred and validated according to procedures outlined in the QA plan, and e) all data is reduced according to the QA Plan and reported to the QA officer on a regular basis.

Mr P.W. McClellan and Mr. J.C. Carr of the Department of Biological Systems Engineering at VPI&SU will serve as the Quality Control Officers for data reduction and analysis. Both Mr. McClellan and Mr. Carr have extensive backgrounds in hydrologic data reduction and analysis. They are responsible for ensuring the integrity of all processed data. Their specific responsibilities will be to: a) ensure that all hydrologic data is processed in accordance to procedures outlined in the QA

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WATER QUALITY MONITORING (Nutrients/Bacterial)

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2.0 PROJECT ORGANIZATION AND RESPONSIBILITY

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1.7 Products Produced: Data summaries will be compiled and progress reports will be submitted to the Chesapeake Bay Local Assistance Department on a semi-annual basis. Intermediate findings will be presented through research reports and presentations will be made at professional meetings. A final report will be submitted within six months after the project's completion.

Maintenance of all monitoring stations and collection and shipment (delivery) of samples will be the responsibility of the Field Observer. The Field Observer will be trained and his/her specific responsibilities will be outlined in a comprehensive field manual. A complete description of sites' locations and the equipment in use at each of the sites is given in Table 3.1.

1.4 Schedule of Tasks:

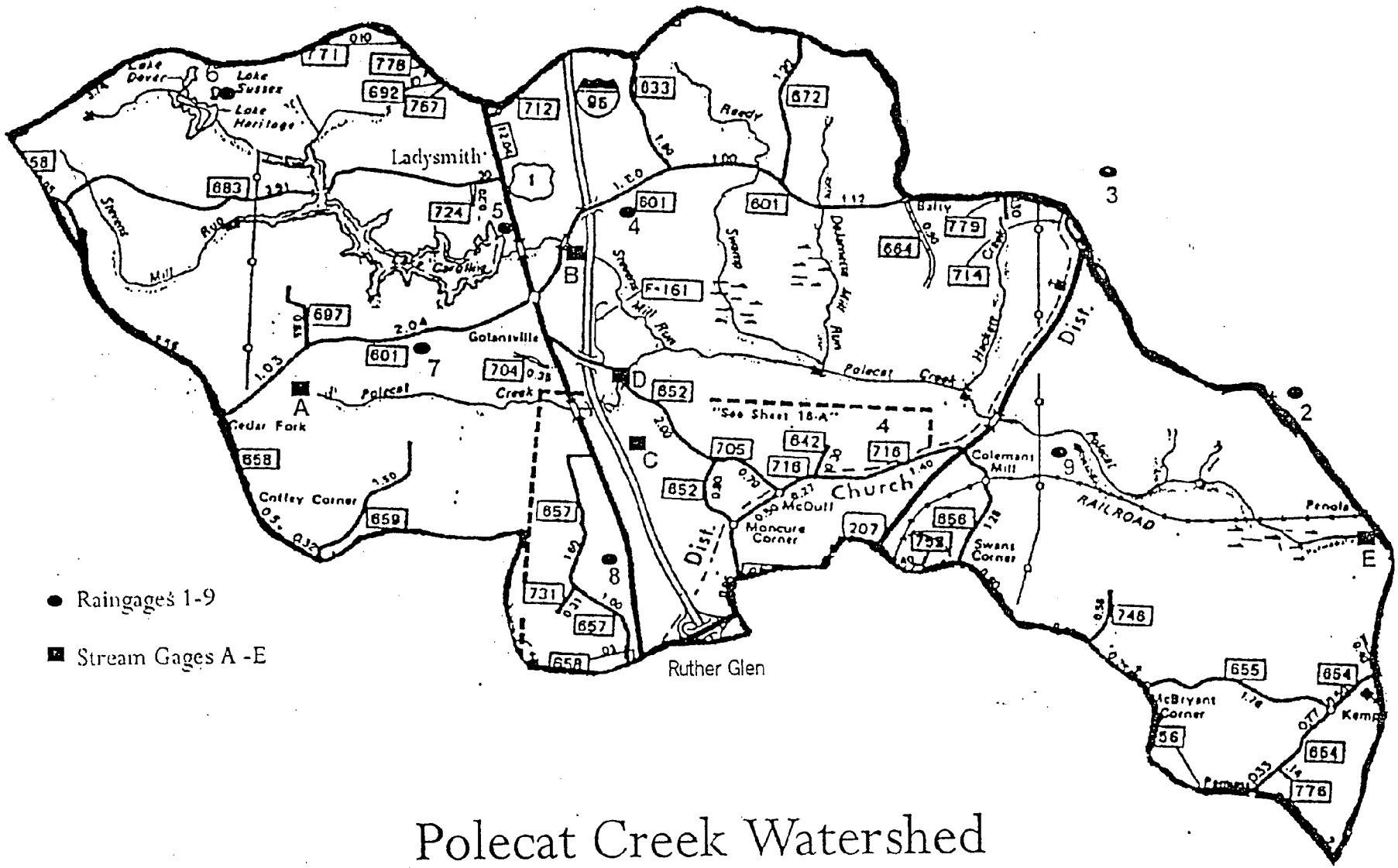
1.5 Data Evaluation: Water samples will be collected from each site,weekly and during each major storm event, with the exception of bacteria samples which will be collected once a month from all sites. A database management system developed at the Biological Systems Engineering Department will be used for storage, manipulation, and retrieval of the collected information. The system includes routines for error checking, data reduction, data summary, graphics and report generation. Interactive programming techniques is used to allow rapid access to any data type for selected time periods. The data collected from Polecat Creek Watershed will be organized in standard formats and archived for future use. Appropriate statistical procedures will be used to identify trends in the water quality data collected over the life of the project.

Table 1.1 (continued) Polecat Creek Watershed Monitoring Sites

Site Name	*Location*	*Equipment Description*
TP1	(the weather station)	Soil Temperature at 0.5 foot depth
TP2	(the weather station)	Soil Temperature at 1.0 foot depth
QPA	On Cedar Fork Road (Rt. 601)	Stream gage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler)
QPB	Close to Smith Farm, off of Rt. 601, between US Rt. 1 and US Interstate 95	Stream gage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler)
QPC	On Mr. Atkinson's Farm close to US Interstate 95, accessed from Rt. 652	Stream gage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler)
QPD	On Mr. Atkinson's Farm off of Rt. 652	Stream gage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler)
QPE	*Watershed outlet*, off of Rt. 601	Stream gage (one analog, one digital, one staff gage) and water quality sampling (one automatic water quality sampler)

Table 1.1. Polecat Creek Watershed Monitoring Sites

Site Name	*Location*	*Equipment Description*
PP1	Smith sand and gravel quarry	Precipitation, one digital and one standard gage
PP2	Coleman Farm	Precipitation, one digital and one standard gage
PP3	Caroline Co. Middle School	Precipitation, one digital and one standard gage
PP4	Smith Farm	Precipitation, one digital and one standard gage
PP5	Lake Caroline	Precipitation, one digital and one standard gage
PP6	Lake Land Or'	Precipitation, one digital and one standard gage
PP7	On cut over forest land off of Cedar Fork Road	Precipitation, one digital and one standard gage
PP8	Waste water treatment facility (the weather station)	Precipitation, one digital and one standard gage
PP9	(the weather station)	Precipitation, one digital, one analog, one standard gage, one snow depth, and rain quality sampler
TP9	(the weather station)	Ambient ait tempreture, one analog and digital gage, and a max/min thermometer
HP9	(the weather station)	Ambient air humidity, one analog and one digital gage
DP9	(the weather station)	Wind direction, one digital gage
WP9	(the weather station)	Wind speed, one digital gage
EP9	(the weather station)	Pan Evaporation, one analog and one digital gage
SP9	(the weather station)	Solar radiation, one digital gage
CP9	(the weather station)	Soil Moisture at 0.5 foot depth
CPA	(the weather station)	Soil Moisture at 1.0 foot depth



Polecat Creek Watershed

will be collected on a weekly basis. In addition, composite samples from storm events will also be collected from all stations. All samples will be analyzed for sediment and various forms of nutrient listed in the following paragraph. Samples will also be collected from all stations, on a monthly basis for analysis of bacteria.

The following analysis will be conducted on the samples collected form the watershed:

1. Total suspended solids
2. Nitrate and nitrite nitrogen
3. Total Kjeldahl nitrogen
5. Total nitrogen
6. Ortho-phosphorus
7. Total phosphorus
8. Carbon, total organic (TOC)
9. Hardness, total
10. Fecal coliform bacteria
11. Fecal streptococci bacteria
12. Total coliform bacteria
13. pH (field monitoring)
14. Dissolved Oxygen (field monitoring)
15. Temperature (field monitoring)
16. Conductivity (field monitoring)

Automatic water quality samplers will be installed at each runoff monitoring site to evaluate the NPS pollutant loadings during storm events. Cross-sectional survey of all sites will be performed and stream gauges (analog and digital) as well as staff gages will be installed to estimate the quantity of water flowing at all stations. The staff gages will be read by the Field Observer on weekly basis. Nine precipitation (rainguage) monitoring stations will also be installed at different locations within the watershed to monitor the rainfall amounts and intensity during the life of the project.

1.0 PROJECT DESCRIPTION

1.1 Need for Project: The Polecat Creek Watershed, located in south-central Caroline County of Virginia, was selected for this project due to its likely conversion from a rural watershed to predominantly urban watershed with in the next ten years. The 30,000 acre basin is located within the Interstate 95 corridor between Richmond, Virginia and Washington, D.C. as well as at headwaters of the Mattaponit River which is part of the York River system.

Currently, the predominant land cover in the watershed is forest, followed by open fields and pastureland, but two thirds of the watershed is designated a primary growth area in the Caroline County comprehensive plan. The Polecat Creek Watershed also includes some environmentally sensitive areas including wetlands and potential habitat for endangered species. Approximately, 2,433 acres of wetlands and waterbodies are located within the watershed, as well as 5,234 acres of Chesapeake Bay Preservation Areas (Resource Protection Areas) buffering the wetlands and waterbodies. The watershed presents the habitat requirements for three plant species listed by the U.S. Federal Government as threatened or endangered species. Therefore, there is a great need to describe the efficacy of existing and emerging land use regulations and policies in protecting adjacent water quality during urban development activities.

1.2 Objectives: The goal of the Polecat Creek Watershed monitoring project is to describe the efficacy of existing and emerging land use regulations and polices in protecting adjacent water quality during urban development activities. A nonpoint source monitoring system is designed and established in the watershed to facilitate the achievement of the above-stated goal.

1.3 Experimental Design: A nonpoint source monitoring program is established in the watershed. The system consists of 5 runoff, 9 rainfall and one weather monitoring station(s) and are described in Table 1.1. The location of various monitoring stations are indicated in Figure 1. The monitoring system is designed to identify spatial contribution of NPS pollutants from various tributaries within the Polecat Creek watershed. Automatic and Grab water quality samples from all 5 runoff stations

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QUALITY ASSURANCE/QUALITY CONTROL

PROJECT PLAN

for

POLECAT CREEK WATERSHED

MONITORING PROJECT

Prepared by

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Virginia Polytechnic Institute and State University

April 1995

POLECAT CREEK INVESTIGATION
BIOLOGICAL MONITORING

October 1, 1994 through March 30, 1995

Virginia Commonwealth University

Dr. Leonard Smock
Dr. Greg Garman
Mark King
Anne Wright

March 30, 1995

This project was funded, in part, by the Department of Environmental Quality's Coastal Resources Management Program through Grant #NA370A0360-01 of the National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the view of NOAA or any of its subagencies.

INTRODUCTION

This report details work conducted from October 1, 1994 through March 30, 1995 on the biomonitoring network of the Water Quality Monitoring Program designed by the Chesapeake Bay Local Assistance Department (CBLAD) for the Polecat Creek watershed. Quarterly samples will be continued through the spring and summer of 1995 under a 1994 NOAA Coastal Zone Management Program grant. The data presented in this report will be added to those additional data collected for an annual assessment of biotic integrity.

The objective of the work was to provide a biological assessment, utilizing macroinvertebrate and fish communities, as well as an assessment of channel and riparian habitat of existing water quality in streams throughout the watershed. Ultimately, the study will provide a data base to enable detection of changes in water quality brought about by changes in land use. Meeting these objectives will enhance our ability to determine the efficacy of landuse regulations designed to protect water quality from changes that might occur during and after altered land use in the watershed.

SITE DESCRIPTIONS

Trend monitoring sites (Table 1) exhibited physico-chemical characteristics that were typical of streams of the lower piedmont and upper coastal plain in the mid-Atlantic region (Smock and Gilinsky 1992; Garman and Nielson 1992). The substrate at most sites was a mixture of sand and gravel, with occasional cobble and bedrock in areas of moderate gradient. Sites ranged in size from first- (e.g. site A; YOP1A) to fourth-order (Mattaponi River, R;YOP4R). Two sites (Reedy Swamp, F; YOP2F and site W;YOP2W) exhibited extensive nontidal wetlands, and were selected to represent this potentially important habitat type. Reference sites (Table 1) were chosen to represent "least impaired" conditions (Karr et.al. 1986) across a range of stream orders, based on extensive field surveys for relatively undisturbed locations. In one case (site H: Higgins Stream), a suitable first-order reference stream could not be located within the York River drainage and a site in Surry County was selected.

In order to manipulate data within a computer database, each site was given a standardized, hierarchical code that uniquely identified collections. The first two characters identify the drainage name (e.g. YO=York rive

Table 1. Study site descriptions for biological/habitat trend monitoring and reference locations. The CBLAD and VCU site codes are provided in parentheses following the site name; interpretation of site codes is provided in the text.

Stream	Description
Monitoring Sites	
Polecat Creek (A; YOP1A)	at Rt. 601, south of Lake Caroline; first order
Stevens Mill Run (B; YOP2B)	at Rt. 601, outfall from Lake Caroline; second order
Unnamed tributary (C; YOP2C)	on Atkinson property and adjacent to I-95; second order
Polecat Creek (D; YOP3D)	at Rt. 652; third order
Polecat Creek (E; YOP5D)	at Rt. 601 near Penola, Virginia; third order
Reedy Swamp (F; YOP2F)	at Rt. 601, a tributary of Polecat Creek exhibiting extensive nontidal wetlands; second order
Mattaponi River (R; YOP4R)	at the confluence with Polecat Creek; fourth order
Reference Sites	
Higgins Stream (H; CHH1A)	southeast of Waverly, Surry County, Virginia; first order
Unnamed tributary (W; YOP2W)	at Rt. 658, north of Partlow, Virginia; second order stream exhibiting extensive nontidal wetlands; Spotsylvania County
South River (S; YOP2S)	at Rt. 603, second order
Matta River (M; YOP3M)	at Rt. 632, third order

drainage), the third character identifies the steam name within that drainage (e.g. YOP=Polecat Creek), and the fourth character indicates steam order (e.g. YOP1=1st order), and the final character provides the site name (e.g. YOP1A=site A of the Polecat Creek system). A date string (mm/dd/yy) follows the site designation and uniquely identifies an individual collection (e.g. YOP1A060294). Throughout the appendices, collections are identified by these codes.

BENTHIC MACROINVERTEBRATES

METHODS

Methodology for the analysis of benthic macroinvertebrate communities followed the procedure of the Environmental Protection Agency's Rapid Bioassessment Protocol III (RBP; Plafkin et al. 1989) with some enhancements. RBP III was chosen because its greater level of taxonomic resolution (genus versus family level) provides a better discrimination of degrees of water quality among sites.

The PRB III protocol calls for sampling benthic invertebrates in the most productive habitat in a set of streams. This usually is the riffle-run habitat. Not all of the streams in the Polecat Creek drainage, however, have a well developed riffle-run geomorphology. In such cases, the protocol and subsequent modifications for low-gradient streams suggest sampling submerged wood, which provides a stable substrate and often supports high invertebrate productivity (Benke et al. 1984, Smock et al. 1985). In order to provide the most complete biomonitoring data within the framework of the RBP protocol, we sampled both riffles-runs (hereafter referred to as the sediment) and submerged wood and analyzed the data from each separately. We thus have two independent estimates of water quality using benthic invertebrates.

Sampling Protocol

Sampling was conducted quarterly over the year, thereby providing a comprehensive seasonal baseline data set. Sampling of the sediment was accomplished with a net (mesh size = 425 μm) in both riffles, when present, and in cobble and pebble runs. The top layer of rocks was disturbed and large rocks were then rubbed by hand to remove closely attached organisms. All samples from the sediment at a given station were composited into one sample.

Wood samples consisted of invertebrates adhering to the surfaces of logs submerged in the stream. Logs that clearly had been only recently submerged were avoided. The surfaces of the logs were washed into a bucket and a visual examination for adhering organisms was made. All samples from individual logs at a given station were composited into one sample.

Sampling of coarse particulate organic matter (CPOM) is required for one of the RBP metrics. We sampled leaf packs in debris dams and on the sediment surface. Recently submerged leaves were avoided. During the summer, when leaf packs were rare, we sampled whatever aggregations of processed leaf litter were present.

All samples (sediment, wood and CPOM) were preserved in the field with isopropyl alcohol. Invertebrates were removed from the sample under a stereo-microscope after addition of Rose Bengal to facilitate the sorting process. The first 200 organisms randomly picked from the samples were identified and thus constituted the data base for calculating the metrics for a given station. Invertebrates in the CPOM samples were simply designated as shredders or non-shredders. All functional feeding group designations were made according to information in Merritt and Cummins (1984) and Pennak (1989).

There are no standard protocols for rapid bioassessment in wetlands using benthic invertebrates. Problems encountered in the bioassessment of wetlands include the lack of any tested metrics using invertebrates and the necessity for a standard habitat that is easily sampled but also is representative of substrates in the wetlands system.

We used an artificial substrate to provide a common substrate in both the reference and study wetlands. Since macrophytes are an important substrate for invertebrates in marsh wetlands, we used artificial macrophytes based on the design of Gilinsky (1984). They were constructed of braided polypropylene rope (6 mm diameter) that floats within the water column. Each substrate, consisting of 144 strands of 41 cm long rope attached to a base of netting, was held in the water column on a metal frame driven into the sediment. Four substrates were placed at each wetland site for several months prior to the initial sampling. The substrates were sampled by lifting them out of the water column, washing the rope strands into a bucket, passing the material through a sieve and preserving the sample. The substrate was then placed into the wetland for sampling the following quarter.

Data Analysis

The RBP III uses eight criteria for the analysis of stream condition at a site. All eight metrics were calculated for the sediment samples. Metric #8, which used the data from the CPOM samples, was not included in the analysis of the wood samples. Using those data for both the sediment and wood analyses would violate the assumption of independence of the data for future statistical analyses comparing the sediment and wood samples.

1. Taxa richness - the total number of taxa identified.
2. Modified Hilsenhoff Biotic Index (HBI) - provides a quantitative assessment of the tolerance of each invertebrate taxon to general water quality degradation.

$$HBI = \Sigma (x_i \, t_i/n)$$

where x_i = number of individuals of taxon i in a sample;

t_i = tolerance value for taxon t

n = total number of organisms in the sample.

The RBP document (Plafkin et al. 1989) provides tolerance values for some species, but they were derived for species in the western Great Lakes states and New York. To provide tolerance values that are regionally more accurate, we primarily used values developed and tested by the North Carolina Division of Environmental Management (Lenat 1993). Tolerance values for some taxa not listed by Lenat (1993) were taken form Plafkin et al. (1989); values for a few rare taxa for which no values have been published were estimated based on the PI's experience in using invertebrates for water quality assessment.

3. Ratio of scrapers to collector-filterers - the total number of individuals of taxa designated as scrapers divided by the total number of individuals of taxa designated as collector-filterers.

4. Ratio of EPT's to chironomids - the total number of individuals of taxa of Ephemeroptera (mayflies, Plecoptera (stoneflies) and Trichoptera (caddisflies) divided by the total number of Chironmidae.

5. Percent contribution of the dominant taxon - the number of individuals of the most abundant taxon divided by the total number of individuals.

6. EPT index - the total number of taxa of Ephemeroptera, Plecoptera and Tichoptera.

7. Community loss index - a measure of community similarity, measuring the difference in the taxonomic composition between the study station and the reference station:

$$\text{Community Loss Index} = \frac{b - a}{c}$$

where a = number of taxa common to both stations;

b = total number of taxa in the reference station sample;

c = total number of taxa in the test station sample.

8. Ration of shredders to total taxa - the number of shredders divided by the total number of individuals in the CPOM sample.

Following calculation of the eight metrics, a Biological Condition Score is assigned to each metric based on comparison of the metric score for the study station to that of the reference station (Table 3). Biological

Table 3. Biological condition scoring criteria for RBP III metrics (Plafkin et al. 1989).

	Metric	Biological Condition Scoring Criteria 6	4	2	0
1.	Taxa Richness[a]	>80%	60-80%	40-60%	<40%
2.	Hilsenhoff Biotic Index (modified)[a]	>85%	70-85%	50-70%	<50%
3.	Ration of Scrapers/Filterers Collectors[a,c]	>50%	35-50%	20-35%	<20%
4.	Ratio of EPT and Chironomid Abundances[a]	>75%	50-75%	25-50%	<25%
5.	% Contribution of Dominant Taxon[d]	<20%	20-30%	30-40%	>40%
6.	EPT Index[a]	>90%	80-90%	70-80%	>70%
7.	Community Loss Index[d]	<0.5	0.5-1.5	1.5-4.0	>4.0
8.	Ratio of Shredders/Total [a,c]	>50%	35-50%	20-35%	<20%

[a] Score is a ratio of study site to reference site X 100.

[b] Score is a ratio of reference site to study site X 100.

[c] Determination of Functional Feeding group is independent of taxonomic grouping.

[d] Scoring criteria evaluate actual percent contribution, not percent comparability to the reference station.

[e] Range of values obtained. A comparison to the reference station is incorporated in these indices.

Condition Scores for each metric are then summed and a Biological Condition Category is assigned for the study station based on the percent comparability with the reference station score (Table 4).

Only a subset of the eight metrics are appropriate for analysis of the data from the wetlands station: taxa a richness, percent contribution of dominant taxon, community loss index and the HBI. Those four metrics were sued to compare the study station to the reference wetlands station.

Quality Assurance

Quality assurance protocols followed those detailed by Tingler (1993). Appropriate chain of custody procedures were employed for the samples. All samples are permanently archived at the Aquatic Ecology Laboratory at Virginia Commonwealth University. All data were checked for transcriptional errors following their entry into the computer data base. Copies of the field and laboratory data sheets are archived in files at Virginia Commonwealth University. Replicate sampling and sample processing were conducted to check the accuracy of the field collection efforts. A 10% acceptance criteria was used for those samples. Data from the replicate sampling were used solely to meet quality assurance objectives; they are included in the archived data base but were not used as part of the metric assessment calculations. Additionally, a laboratory audit, with an acceptance criteria of 10%, was conducted on 5% of the benthic samples, thereby validating taxonomic identification and numbers of individuals in those samples.

Table 4. Bioassessment categories based on percent comparability of study stream to reference stream (Plafkin et al. 1989).

BIOASSESSMENT		
% Comparability to Reference Score [a]	Category	Attributes
>83%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure (composition and dominance) for stream size and habitat quality.
54 - 79%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms.
21 - 50%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17%	Severely impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

[a] Percentage values obtained that are intermediate to the above ranges will require subjective judgement as to the correct placement. Use of the habitat assessment and physicochemical data may be necessary to aid in the decision process.

STREAM FISH ASSESSMENTS

METHODS

Methodology for the analysis of stream communities generally followed the procedures of the Environmental Protection Agency's Rapid Bioassessment Protocol, and specifically the Index of Biotic Integrity (IBI; Karr 1981; Plafkin et al. 1989). Because of regional differences in fish assemblage structure and zoogeography, IBI metrics were modified to be most appropriate for the Polecat Creek watershed (York River drainage), but are equivalent in approach and design to those originally proposed by Karr (1981) and Karr et al (1989). The following fish community metrics and scoring criteria for the IBI were developed using a variety of sources, including distributional references (e.g. Hocutt et al 1986; Garman and Nielsen 1992; Jenkins and Burkhead 1994; Weaver and Garman 1994) and were reviewed by regional fishery biologists and ichthyologists:

Metric 1 Species richness Total number of native species in the sample, not including hybrids or introduced species. A total of 49 nonmigratory species and 13 diadromous/estuarine species are possible within the drainage; sampling by VCU has already collected 40 species from Polecat monitoring and reference sites. The number of introduced (i.e., non-native) species will be considered in another metric.

Score	1	2	5
1st/2nd order	≤4	5-7	≥8
3rd/4th order	≤8	9-11	≥12

Metric 2 Total individuals Total number of individuals in sample, expressed as catch per unit effort (CPUE), where effort is backpack electrofishing time (minutes).

Score	1	2	5
all orders	≤30	31-60	≥61

Metric 3 Darter species Total number of darter (Etheostoma & Percina spp. only for York drainage) species per sample. Four species are possible.

Score	1	2	5
1st/2nd order	0	1-2	≥3
3rd/4th order	1	2-3	4

Metric 4 Sunfish species Total number of centrarchid species, exclusive of Micropterus spp.; 12 species (native and introduced) possible from the York drainage.

Score	1	2	5
1st/2nd order	≤1	2-4	≥5
3rd/4th order	≤2	3-7	≥8

Metric 5 Sucker species Total number of catastomid species in the sample; four species possible form the York drainage.

Score	1	2	5
1st/2nd order	0	1-2	≥3
3rd/4th order	≤1	2-3	4

Metric 6 Intolerant species Total number of species, per sample classified as "intolerant" of degraded stream conditions. Intolerant species will include: Lampetra appendix, L. aepytera, northern hogsucker (Hypentelium nigricans), tadpole madtom, shield darter, stripeback darter.

Score	1	2	5
1st/2nd order	0	1-2	≥3
3rd/4th order	≤1	2-3	≥4

Metric 7 Tolerant species Percentage of individuals classified as "tolerant" of degraded conditions. This metric will use the relative abundance of a guild of species to replace "green sunfish" metric of Karr (1981), as suggested by Karr et al. (1986). Tolerant species will include: golden shiner, pumpkinseed sunfish, bluegill, creek chubsucker, brown bullhead, yellow bullhead, and tesselated darter.

Score	1	2	5
1st/4th order	<10	10-25	>25

Metric 8 Omnivorous species Percentage of individuals per sample classified as omnivorous; species will include: common carp (Cyprinus carpio), Nocomis spp., white sucker (Catastomous commersoni), channel catfish, and bluntnose minnow.

Score	1	2	5
1st/4th order	>45	20-45	<20

Metric 9 Insectivorous cyprinids Percentage of cyprinid individuals per sample classified as insectivorous; species will include: satinfin shiner, swallowtail shiner, common shiner, comely shiner, rosyface shiner, bridle shiner, rosyside dace.

Score	1	2	5
1st/4th order	<20	20-45	>45

Metric 10 Piscivores Percentage of individuals per sample classified as facultative piscivores (apex predators); species will include: redfin pickerel, chain pickerel, smallmouth bass, largemouth bass, black crappie.

Score	1	2	5
1st/4th order	<1	1-5	>5

Metric 11 Introduced species Percentage of individuals per sample classified as non-indigenous species. Hocutt and Wiley (1986) report 12 introduced species form the York drainage. This metric replaces the "hybrid" metric of Karr (1981) because hybrid identifications are often problematic, especially in the field. Moreover, the numerical dominance of exotic taxa in disturbed ecosystems is well-documented in the literature. Both the new "introduced" metric and the old "hybrid" metric influence the overall IBI score most significantly under "poor" and "fair" stream conditions.

Score	1	2	5
1st/4th order	>5	1-5	<1

Metric 12 Anomalies Percentage of individuals per sample exhibiting external parasites, infections, or skeletal abnormalities.

Score	1	2	5
1st/4th order	>5	2-5	<2

Stream fish communities were sampled by backpack and modified boat electrofishing during Fall 1995, following standard fisheries protocols. Fish were identified to species in the field by Mr. Mark King or Dr. Greg Garman; small voucher collections for each species were placed into VCU's Fish Collection. Data were entered into VCU's computer data base, which has been developed to calculate IBI metrics and scores for individual collections. All activities followed the Quality Assurance Project Plan prepared by CBLAD (Tingler 1994).

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APPENDIX A

Numbers of macroinvertebrates collected

Table 1. Numbers of individuals collected by substrate and season. FA= fall; WI= winter SP= spring; SU= summer.

STATION A

TAXON	SEDIMENT				WOOD			
	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.								
Leptophlebiidae								
Paraleptophlebia sp.	1							
Plecoptera								
Nemouridae								
Amphinemura wui								
Prostoia sp.								
Perlodidae (immature)	1							
Trichoptera								
Limnephilidae								
Pycnopsyche spp.								
Phryganeidae								
Ptilostomis sp.	1							
Polycentropodidae								
Polycentropus sp.								
Psychomyiidae								
Lype diversa								
Rhyacophilidae								
Rhyacophila sp.								
Lepidoptera	1							
Coleoptera								
Elmidae								
Dubiraphia sp.								
Megaloptera								
Sialidae								
Sialis sp.	1							

TAXON	SEDIMENT				WOOD			
	FA	WI	SP	SU	FA	WI	SP	SU
Diptera								
Chaoboridae								
Chaoborus sp.								
Chironomidae	143	36			123			
Ceratopogonidae	2							
Palpomyia spp.					3			
Culicidae								
Culex sp.								
Empididae	1							
Hemerodromia sp.								
Ephydridae								
Simuliidae		207						
Tabanidae								
Tabanus sp.	1							
Tipulidae								
Antocha sp.		2						
Limonia sp.	3							
Pilaria sp.								
Isopoda								
Asellidae								
Caecidotea sp.	2	5						
Amphipoda								
Gammaridae								
Gammarus sp.	4	10			3			
Decapoda								
Cambaridae	1							
Hydracarina	1							
Gastropoda								
Planorbidae								
Gyraulus sp.								
Bivalvia								
Sphaeriidae								
Pisidium sp.								
Annelida								
Oligochaetae	2	2						
Hirudinea					1			

Table 2. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

STATION B

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	1							
Ephemerellidae								
Eurylophella temporalis		1						
Heptageniidae								
Stenonema sp.	91	66			30	1		
Odonata								
Corduliidae								
Helocordula sp.								
Plecoptera								
Nemouridae								
Prostoia sp.	1							
Perlidae								
Perlesta sp.								
Perlodidae								
Isoperla spp.								
Taeniopterygidae								
Taeniopteryx spp.	4	1						
Trichoptera								
Hydropsychidae								
Chematopsyche sp.	12	13			40	1		
Hydropsyche sp.	8				6			
Hydroptilidae								
Hydroptila sp.								
Oxythira sp.						11		
Lepidostomatidae								
Lepidostoma sp.								
Philopotamidae								
Chimarra sp.	35	5			57			

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Tricoptera								
Polycentropodidae								
Polycentropus sp.						1		
Coleoptera								
Elmidae								
Ancyronyx sp.					1			
Dubiraphia sp.	1							
Macronychus glabratus		1			8			
Diptera								
Ceratopogonidae								
Culicoides sp.								
Chaoboridae		2						
Chaoborus punctapenni	2				1			
Chironomidae	46	35			27	89		
Empididae								
Hemerodromia sp.					2			
Simuliidae	10	55			4	4		
Tipulidae								
Tipula abdominalis	3	2			3			
Isopoda								
Asselidae								
Caecidotea sp.					1			
Amphipoda								
Gammaridae								
Gammarus sp.	2							
Decapoda								
Cambaridae	1							
Ostracoda								
Hydracarina	2							
Gastropoda								
Physidae								
Physa sp.								
Planordidae								
Gyraulus sp.					1			

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Bivalvia								
Sphaeriidae								
Pisidium sp.								
Sphaerium sp.		1						
Annelida					1			
Oligochaetae						4		

Table 3. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

STATION C

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Caenidae								
Caenis sp.								
Odonata								
Coenagrionidae								
Plecoptera								
Capniidae								
Allocapnia sp.	1							
Chloroperlidae								
Suwallia sp.								
Leuctridae								
Leuctra sp.								
Nemouridae								
Amphinemura wui								
Prostoia sp.	7							
Perlidae								
Eccoptura Xanthenes	1							
Perlodidae	1							
Isoperla spp.								
Taeniopterygidae								
Taeniopteryx sp.	2				1			
Trichoptera								
Hydropsychidae						11		
Chematopsyche sp.	11							
Hydroptilidae								
Hydroptila sp.								
Leptoceridae								
Ceraclea					1			
Nectopsyche sp.	1				1			
Polycentropodidae								
Polycentropus sp.								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Tricoptera								
Psychomyiidae								
Lype diversa						20		
Coleoptera								
Elmidae								
Ancyronyx sp.					2			
Macronychus glabratus					2	1		
Stenelmis sp.								
Megaloptera								
Sialidae								
Sialis sp.					1			
Diptera								
Ceratopogonidae								
Palpomyia spp.								
Chironomidae	119				146	167		
Empididae								
Simullidae						7		
Tipulidae								
Hexatoma sp.								
Tipula abdominalis	2				4			
Amphipoda								
Gammaridae								
Gammarus sp.	3				1	7		
Ostracoda								
Hydracarina	4							
Gastropoda								
Physidae								
Physa sp.						3		
Bivalvia								
Sphaeriidae								
Pisidium sp.	4					8		
Sphaerium sp.	1							
Unionidae								
Elliptio complanata								
Annelida								
Oligochaetae						1		
Nematoda								

Table 4. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

STATION D

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	5	10				2		
Pseudocloeon sp.						1		
Caenidae								
Caenis sp.	3							
Ephemerellidae								
Ephemerella sp.	22				9			
Eurylophella temporalis	11				12			
Seratella sp.								
Heptageniidae								
Stenonema modestum	1				1			
Leptophlebiidae								
Paraleptophlebia sp.								
Oligoneuridae								
Isonychia sp.		1						
Odonata								
Calopterygidae								
Calopteryx sp.		1						
Plecoptera								
Capniidae								
Allocapnia sp.					2			
Chloroperlidae								
Haploperla sp.	3							
Leuctridae								
Leuctra sp.								
Nemouridae								
Amphinemura wui								
Prostoia sp.								
Perlidae								
Eccoptura xanthenes	2	6						
Perlesta sp.								
Perlinella sp.	1							

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Plecoptera								
Perlodidae						2		
Clioperla clio		1						
Isoperla spp.		3				2		
Taeniopterygidae								
Taeniopteryx spp.	7	1				3		
Trichoptera								
Hydropsychidae								
Chematopsyche sp.	10	12						
Hydropsyche sp.	2	2						
Hydroptilidae								
Hydroptila sp.								
Lepidostomatidae								
Lepidostoma sp.								
Leptoceridae								
Ceraclea sp.	1				2			
Nectopsyche sp.					1			
Oecetis sp.		1						
Odontoceridae								
Psilotreta sp.	1							
Philopotamidae								
Chimarra sp.	1							
Polycentropodidae								
Nyctiophylax sp.					1	1		
Polycentropus sp.								
Psychomyiidae								
Lype diversa	1				21	10		
Rhyacophilidae								
Rhyacophila sp.		1						
Coleoptera								
Elmidae								
Ancyronyx variegatus					2			
Dubiraphia sp.	4							
Macronychus glabratus					5			
Stenelmis sp.								
Oulimnius sp.					1			

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Megaloptera								
Corydalidae								
Nigronia serricornis								
Sialidae								
Sialis sp.	1							
Diptera								
Ceratopogonidae								
Culicoides sp.	3							
Palpomyia spp.	7				1			
Chironomidae	81	16			195	62		
Empididae								
Simuliidae		226				126		
Tipulidae								
Antocha sp.								
Hexatoma sp.	1							
Tipula abdominalis						1		
Amphipoda								
Gammaridae								
Gammarus sp.	2	1			1	2		
Decapoda								
Ostracoda								
Hydracarina	3							
Gastropoda								
Planorbidae								
Gyraulus sp.					1			
Physidae								
Physa sp.					4	1		
Bivalvia								
Sphaeriidae								
Pisidium sp.								
Sphaerium sp.					1			

Table 5. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

STATION E

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	1							
Ephemerellidae								
Ephemerella sp.	1							
Eurylophella temporalis	1	2				1		
Heptageniidae								
Stenonema modestum								
Leptophlebiidae								
Leptophlebia sp.		5						
Paraleptophlebia sp.	7							
Odonata								
Coenagrionidae (immature)								
Plecoptera								
Nemouridae								
Nemoura sp.								
Prostoia sp.						1		
Perlidae								
Clioperla clio		1						
Taeniopterygidae								
Taeniopteryx spp.								
Trichoptera								
Hydropsychidae								
Chematopsyche sp.								
Hydropsyche sp.								
Hydroptilidae								
Hydroptila sp.								
Lepidostomatidae								
Lepidostoma sp.								
Leptoceridae								
Oecetis sp.					1			

TAXON	SEDIMENT				WOOD			
	FA	WI	SP	SU	FA	WI	SP	SU
Tricoptera								
Limnephilidae					1			
Pycnopsyche spp.								
Philopotamidae								
Chimarra sp.								
Polycentropodidae								
Neureclipsis sp.								
Nyctiophylax sp.						1		
Polycentropus sp.	5	3			1			
Psychomyiidae								
Lype diversa					5			
Coleoptera								
Dytiscidae								
Hydroporous sp.	10	7						
Elmidae								
Ancyronyx variegatus					4			
Duberaphia sp.	1							
Macronychus glabratus								
Stenelmis sp.	1				1			
Gyrinidae								
Dineutus sp.								
Gyrinis sp.								
Megaloptera								
Sialidae								
Sialis sp.		1						
Diptera								
Ceratopogonidae								
Culicoides sp.					2			
Palpomyia spp.	4				1	1		
Chironomidae	83	112			86	169		
Empididae								
Simuliidae		1			1	4		
Tabanidae								
Chrysops sp.					1			
Tabanus sp.		1						
Tipulidae								
Tipula abdominalis								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Isopoda								
Asellidae								
Caecidotea sp.	1	1						
Amphipoda								
Gammaridae								
Gammarus sp.		1			1			
Decapoda								
Cambaridae	1							
Hydracarina								
Gastropoda								
Physidae								
Physa sp.	1							
Bivalvia								
Sphaeriidae								
Sphaerium sp.	3							
Pisidium sp.		5						
Annelida	9							
Oligochaetae		2				7		

Table 6. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

SITE F

ARTIFICIAL SUBSTRATE

TAXON	FA	WI	SP	SU
Ephemeroptera				
Baetidae				
Baetis spp.		1		
Heptageniidae				
Stenonemo modestum		12		
Odonata				
Coenagrionidae				
Enallagma		1		
Plectoptera				
Nemouridae				
Prostoia sp.		1		
Perlodidae				
Clioperla clio		1		
Taeniopterygidae				
Taeniopteryx spp.		1		
Dytiscidae				
Laccornis sp				
Trichoptera				
Hydropsychidae				
Chematopsyche sp.		2		
Leptoceridae				
Ceraclea		1		
Phryganeidae				
Ptilostomis sp.		3		
Polycentropodidae				
Phylocentropus sp.	2			
Polycentropus sp.		1		
Megaloptera				
Sialidae				
Sialis sp.	3			

ARTIFICIAL SUBSTRATE

TAXON	FA	WI	SP	SU
Diptera				
Chironomidae	124	282		
Ceratopogonidae				
Culicoides sp.				
Palpomyia spp.	9			
Simuliidae		50		
Tipulidae				
Ormosia sp.				
Tipula sp.		1		
Isopoda				
Asellidae				
Caecidotea sp.				
Amphipoda				
Gammaridae				
Gammarus sp.	2	4		
Bivalvia				
Sphaeriidae				
Pisidium sp.				
Annelida	14			
Oligochaetae		9		

Table 7. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

SOUTH RIVER

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	29				6			
Caenidae								
Caenis sp.					1			
Ephemerellidae								
Ephemerella sp.	1							
Eurylophella temporalis					2			
Heptageniidae								
Stenacron interpunctatum					35			
Stenonema modestum	41				7	2		
Oligoneuridae								
Isonychia sp.								
Odonata								
Calopterygidae								
Calopteryx sp.					1			
Coenagrionidae								
Enallagma sp.	1				2			
Gomphidae								
Progomphus obscurus								
Plecoptera								
Capniidae								
Allocapnia sp.	26					1		
Chloroperlidae								
Leuctridae								
Leuctra sp.								
Nemouridae								
Amphinemura wui								
Prostoia sp.	1							

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Plecoptera								
Perlidae								
Beloneuria sp.								
Diploperla sp.	3							
Eccoptura xanthenes	2							
Taeniopterygidae								
Taeniopteryx spp.	1							
Hemiptera								
Corixidae								
Tricorixa sp.								
Trichoptera								
Hydropsychidae								
Chematopsyche sp.	21					1		
Leptocheridae								
Ocetis sp.					1			
Philopotamidae								
Chimarra sp.	25				1			
Polycentropodidae								
Nyctiophylax sp.					1			
Psychomyiidae								
Lype diversa					15	2		
Coleoptera								
Dryopidae								
Helichus sp.						1		
Dytiscidae								
Hydroporous sp.					2			
Elmidae								
Ancyronyx variegatus					4	1		
Dubiraphia sp.								
Macronychus glabratus					1	4		
Gyrinidae								
Gyrinus sp.					1			
Megaloptera								
Sialidae								
Sialis sp.								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Diptera								
Ceratopogonidae								
Culicoides sp.	2							
Palpomyia spp.	2				1			
Chironomidae	71				102	114		
Psychodidae								
Pericoma sp.								
Simuliidae	2					111		
Tipulidae								
Antocha sp.						3		
Dicranota sp.								
Hexatoma sp.	2							
Ormosia sp.								
Amphipoda								
Gammaridae								
Gammarus sp.					5			
Decapoda								
Cambaridae								
Hydracarina	1							
Gastropoda								
Planorbidae								
Gyraulus sp.					1			
Bivalvia								
Sphaeriidae								
Pisidium sp.					1	2		
Sphaerium sp.	1				1			
Annelida								
Oligochaetae						11		

Table 8. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

MATTA RIVER

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	1							
Baetiscidae								
Baetisca sp.	2							
Caenidae								
Caenis sp.	3				1			
Ephemerellidae								
Ephemerella sp.	31				48			
Eurylophella Temporalis					1			
Seratella sp.								
Heptageniidae								
Stenonema modestum	19				19			
Oligoneuridae								
Isonychia sp.	1							
Odonata								
Coenagrionidae								
Gomphidae								
Progomphus obscurus	1							
Plecoptera								
Leuctridae								
Leuctra sp.								
Nemouridae								
Amphinemura wui								
Prostoia sp.								
Perlidae								
Beloneuria sp.								
Clioperla Clio					1			
Isoperla spp.	2							
Taeniopterygidae								
Taeniopteryx spp.	5				13			

TAXON	SEDIMENT FA	SEDIMENT WI	SEDIMENT SP	SEDIMENT SU	WOOD FA	WOOD WI	WOOD SP	WOOD SU
Trichoptera								
Brachycentridae								
Brachycentrus sp.	1				38			
Hydropsychidae								
Chematopsyche sp.	2				11			
Hydropsyche sp.					1			
Macrostemum sp.	1							
Hydroptilidae								
Hydroptila sp.								
Leptoceridae								
Ceraclea sp.	2				1			
Ocetis sp.	1							
Lepidostomatidae								
Lepidostoma sp.								
Limnephilidae								
Pychnopsyche spp.	2							
Philopotamidae								
Chimarra sp.					1			
Polycentropodidae								
Nyctiophylax sp.								
Polycentropus sp.								
Psychomyiidae								
Lype diversa					6			
Coleoptera								
Dryopidae								
Helichus sp.	1							
Elmidae								
Ancyronyx variegatus					1			
Macronychus glabratus								
Megaloptera								
Corydalidae								
Corydalus sp.					1			
Sialidae								
Sialis sp.								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Diptera								
Ceratopogonidae								
Palpomyia spp.	1							
Chironomidae	16				57			
Empididae								
Hemerodromia sp.								
Simuliidae	2				1			
Tipulidae								
Tipula abdominalis								
Amphipoda								
Gammaridae								
Gammarus sp.								
Hydracarina	3				6			
Gastropoda								
Physidae								
Physa sp.								
Bivalvia								
Corbiculidae								
Corbicula fluminia	110				4			
Sphaeriidae								
Pisidium sp.	2							
Sphaerium sp.								
Annelida								

Table 9. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP=spring; SU= summer.

MATTAPONI RIVER

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Ephemeroptera								
Baetidae								
Baetis spp.	2	6			3	1		
Baetiscidae								
Baetisca sp.	7							
Ephemereilidae								
Ephemerella sp.	1	4						
Eurylophella temporalis		6			1	7		
Heptageniidae					3			
Stenonema modestum	6	2				5		
Leptophlebiidae								
Leptophlebia sp.		2						
Oligoneuridae								
Isonychia sp.								
Odonata								
Libellulidae								
Somatochlora sp.						1		
Plecoptera								
Capniidae								
Allocapnia sp.		3				1		
Nemouridae								
Prostoia sp.		7				12		
Perlidae					2			
Perlesta sp.								
Perlodidae								
Isoperla spp.		3				2		
Taeniopterygidae								
Taeniopteryx spp.	57	4			6	2		

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Trichoptera								
Brachycentridae								
Brachycentrus sp.								
Hydropsychidae								
Chematopsyche sp.	1				7			
Hydropsyche sp.					7			
Macrostemum sp.					1			
Hydroptilidae								
Hydroptila sp.								
Lepidostomatidae								
Lepidostoma sp.		1				1		
Leptoceridae								
Ceraclea sp.					1	1		
Nectopsyche sp.								
Oecetis sp.	1							
Limnephilidae								
Pycnopsyche spp.								
Philopotamidae								
Chimarra sp.	2				5			
Polycentropodidae								
Nyctiophylax sp.	1				1			
Polycentropus sp.								
Coleoptera								
Elmidae								
Macronychus glabratus	3				5	3		
Stenelmis sp.					5			
Gyrinidae								
Dineutus sp.								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Diptera								
Ceratopogonidae								
Palpomyia spp.								
Chironomidae	14	48			113	160		
Simuliidae	1	110						
Tipulidae								
Tipula abdominalis						1		
Isopoda								
Asellidae								
Caecidotea sp.						1		
Amphipoda								
Gammaridae								
Gammarus sp.								
Hydracarina	4	2			12	2		
Gastropoda								
Ancylidae								
Ferrissia sp.								
Lymnaeidae								
Lymnaea sp.	3							
Physidae								
Physa sp.								
Bivalvia								
Corbiculidae								
Corbicula sp.	76							
Sphaeriidae								
Pisidium sp.	1	9				2		
Sphaerium sp.	2							
Annelida	1							
Oligochaetae		5				5		
Hirudinea								

	SEDIMENT				WOOD			
TAXON	FA	WI	SP	SU	FA	WI	SP	SU
Turbellaria								
Planariidae								
Dugesia tigrina								

Table 10. Numbers of individuals collected by substrate and season. FA= fall; WI= winter; SP= spring; SU= summer.

WETLANDS REFERENCE SITE

ARTIFICIAL SUBSTRATE

TAXON	FA	WI	SP	SU
Ephemeroptera				
Baetidae				
Baetis spp.		4		
Centroptilum sp.				
Odonata				
Aeschnidae				
Epiaeschna sp.		1		
Corduliidae				
Epitheca sp.		3		
Coenagrionidae				
Enallagma sp.		1		
Hemiptera				
Belostomatidae				
Belostoma sp.		1		
Tricoptera				
Psychomyiidae				
Lype diversa		2		
Coleoptera				
Dytiscidae				
Hydroporous sp.		2		
Hydrophilidae				
Berosus sp.				
Diptera				
Chaoboridae				
Chaoborus punctapennis		2		
Chironomidae		260		
Ceratopogonidae				
Palpomyia spp.		5		
Tipulidae				
Antocha sp.		3		
Ormosia sp.				

ARTIFICIAL SUBSTRATE

TAXON	FA	WI	SP	SU
Isopoda				
Asellidae				
Caecidotea sp.		14		
Amphipoda				
Gammaridae				
Gammarus sp.		26		
Decapoda		1		
Gastropoda				
Lymnaeidae				
Lymnaea sp.		2		
Planorbidae				
Gyraulus sp.		1		
Bivalvia				
Sphaeriidae				
Pisidium sp.		3		
Annelida				
Oligochaetae		236		

APPENDIX B

Fish Community Metrics

PAGE NO. 1
PRODUCED ON: 04/27/95

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP4R101794

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	12	6.96	3	3	0	1	0.09	0.00	0.46	0.00	0.06	0.22	
SCORE:	5	5	3	3	1	1	1	5	5	1	1	1	32

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP3M101794

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	11	6.53	3	2	1	1	0.07	0.01	0.48	0.00	0.01	0.03	
SCORE:	3	5	3	1	1	1	1	5	5	1	5	3	34

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****

METRICS 1-12 REPORT FOR LOCATION CODE: YOP3E111494

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	9	1.06	2	0	0	0	0.29	0.06	0.06	0.12	0.00	0.12	
SCORE:	3	1	3	1	1	1	5	5	1	5	5	1	32

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP3D101994

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	11	2.99	2	3	1	0	0.39	0.12	0.05	0.02	0.24	0.10	
SCORE:	3	1	3	3	1	1	5	5	1	3	1	1	28

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP2W110494

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	4	5.01	1	1	0	0	0.58	0.00	0.00	0.00	0.01	0.01	
SCORE:	1	3	3	1	1	1	5	5	1	1	5	5	32

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP2S101794

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	13	14.4	2	3	2	0	0.55	0.06	0.25	0.01	0.05	0.10	
SCORE:	5	5	3	3	3	1	5	5	3	1	1	1	36

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP2F111494

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	6	1.32	1	3	1	0	0.50	0.00	0.00	0.00	0.00	0.44	
SCORE:	3	1	3	3	3	1	5	5	1	1	5	1	32

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PRODUCED ON: 04/27/95

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP2C101994

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	11	4.07	2	1	0	0	0.09	0.42	0.09	0.02	0.00	0.11	
SCORE:	5	3	3	1	1	1	1	3	1	3	5	1	28

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP2B100694

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	14	9.46	2	6	1	0	0.34	0.14	0.30	0.00	0.22	0.02	
SCORE:	5	5	3	5	3	1	5	5	3	1	1	5	42

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METRICS 1-12 REPORT FOR LOCATION CODE: YOP1A101994

****

	METRIC NUMBERS												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VALUE:	7	2.18	1	2	1	0	0.21	0.00	0.00	0.05	0.00	0.00	
SCORE:	3	1	3	3	3	1	3	5	1	5	5	5	38

APPENDIX C

Physico-chemical Data

COLLECTION LOCATION REPORT

LOCATION CODE	DRAINAGE	STREAM	ORDER	SITE CODE	DATE	TIME	EFFORT	TEMP	COND	pH	DO	HAB ASMT	INVERT SAMPLE	NOTES
CHH1A032594	CHOWAN	HIGGINS	1	A	03/25/94	1200	1522	12.00	0.00	0.00	0.00	.F.	X X X	VERY HIGH FLOW AND TURBIDITY AFTER A STORM EVENT.
CHH1A042994	CHOWAN	HIGGINS	1	A	04/29/94	1200	785	17.00	0.00	0.00	0.00	.F.	X X X	
CHH1A053094	CHOWAN	HIGGINS	1	A	05/30/94	1200	1057	15.00	0.00	0.00	0.00	.F.	X X X	
CHH1A061494	CHOWAN	HIGGINS	1	A	06/14/94	1200	782	19.00	0.00	0.00	0.00	.F.	X X X	Sampling done upstream of bridge.
CHH1A101593	CHONAN	HIGGINS	1	A	10/15/93	1200	1499	12.66	0.00	0.00	0.00	.F.	X X X	
YOP1A012694	YORK	POLECAT	1	A	01/26/94	1200	0	2.00	22.00	4.30	15.00	.T.		
YOP1A040594	YORK	POLECAT	1	A	04/05/94	1200	886	13.00	22.00	5.80	10.30	.T.	C K X	Site length = 124 paces.
YOP1A071493	YORK	POLECAT	1	A	07/14/93	1200	265	28.00	0.00	0.00	0.00	.F.	X X X	FLOW VERY LOW, ALMOST NONE. SHALLOW POOLS AND SLOW RIFFLES. OXIDE FLOC OVER MOST OF BOTTOM, SUGGESTING HYPOXIC CONDITIONS. ALL FISH OK- FEW JUVENILES-LGI,UPY. MOST BULLHEADS OF UNIFORM SIZE OF 6-8". VERY POOR PHYSIOCHEM. CONDITIONS.
YOP1A071594	YORK	POLECAT	1	A	07/15/94	1200	0	22.00	39.00	6.00	5.20	.T.		
YOP1A101994	YORK	POLECAT	1	A	10/19/94	1200	524	11.00	0.00	0.00	0.00	.F.	X X X	
YOP1A111093	YORK	POLECAT	1	A	11/10/93	1200	532	7.00	0.00	0.00	0.00	.F.	C K X	
YOP1A111893	YORK	POLECAT	1	A	11/18/93	1200	0	10.00	5.80	6.10	8.40	.T.	X X X	
YOP2B012694	YORK	POLECAT	2	B	01/26/94	1200	0	4.00	35.00	5.70	15.00	.T.		
YOP2B040594	YORK	POLECAT	2	B	04/05/94	1200	1136	16.00	37.00	7.10	10.60	.T.	X X X	69 PACES IN LENGHT
YOP2B071493	YORK	POLECAT	2	B	07/14/93	1200	442	0.00	0.00	0.00	0.00	.F.	X X X	
YOP2B071594	YORK	POLECAT	2	B	07/15/94	1200	0	25.00	80.00	6.40	6.80	.T.		
YOP2B100694	YORK	POLECAT	2	B	10/06/94	1200	780	18.00	4.00	6.85	0.00	.T.	X X X	
YOP2B111093	YORK	POLECAT	2	B	11/10/93	1200	592	0.00	0.00	0.00	0.00	.F.	C K X	
YOP2B111893	YORK	POLECAT	2	B	11/18/93	1200	0	12.00	61.00	6.10	9.10	.T.	X	

COLLECTION LOCATION REPORT

LOCATION CODE	DRAINAGE	STREAM	ORDER	SITE CODE	DATE	TIME	EFFORT	TEMP	COND	pH	DO	HAB ASMT	INVERT SAMPLE	NOTES
YOP2C020294	YORK	POLECAT	2	C	02/02/94	1200	0	2.00	80.00	6.40	16.40	.T.		
YOP2C040894	YORK	POLECAT	2	C	04/08/94	1200	935	11.00	40.00	5.70	9.90	.T.	X X X	95 PACES IN LENGTH
YOP2C071493	YORK	POLECAT	2	C	07/14/93	1200	461	0.00	0.00	0.00	0.00	.F.	X X X	
YOP2C072194	YORK	POLECAT	2	C	07/21/94	1200	0	26.00	81.00	6.40	7.50	.T.		
YOP2C101994	YORK	POLECAT	2	C	10/19/94	1200	810	12.00	0.00	0.00	0.00	.F.	X X X	
YOP2C111793	YORK	POLECAT	2	C	11/17/93	1200	626	14.00	0.00	0.00	0.00	.F.	C K X	
YOP2C111893	YORK	POLECAT	2	C	11/18/93	1200	0	11.00	89.00	6.10	8.40	.T.		
YOP2F020294	YORK	POLECAT	2	F	02/02/94	1200	0	0.00	22.00	5.30	15.50	.F.		
YOP2F050994	YORK	POLECAT	2	F	05/09/94	1200	787	0.00	0.00	0.00	0.00	.F.	X X X	11 SPACES SITE LENGTH, ARTIFICAL SUBSTRATE NOT REMOVED FOR SPRING SAMPLING
YOP2F071493	YORK	POLECAT	2	F	07/14/93	1200	155	0.00	0.00	0.00	0.00	.F.	X X X	TYPICAL WETLANDS W. ARUM sp. SOME FLOW THRU CHANNEL. LOW EF EFFICIENCY-LOTS-O-FISH. MANY YOY UPY & ASY. RECENTLY NUKED BEAVERS?
YOP2F072194	YORK	POLECAT	2	F	07/21/94	1200	673	25.00	35.00	5.80	1.20	.F.	X X X	
YOP2F111093	YORK	POLECAT	2	F	11/10/93	1200	369	10.00	0.00	0.00	0.00	.F.	X X X	
YOP2F111494	YORK	POLECAT	2	F	11/14/94	1200	819	0.00	0.00	0.00	0.00	.F.	X X X	
YOP2S020294	YORK	POLECAT	2	S	02/02/94	1200	0	1.00	28.00	6.80	16.20	.T.		
YOP2S040594	YORK	POLECAT	2	S	04/05/94	1200	1321	11.00	30.00	6.50	10.60	.T.	X X X	105 PACES
YOP2S072194	YORK	POLECAT	2	S	07/21/94	1200	0	24.00	81.00	6.40	7.40	.T.		
YOP2S072793	YORK	POLECAT	2	S	07/27/93	1200	608	21.00	0.00	0.00	0.00	.F.	X X X	
YOP2S101794	YORK	POLECAT	2	S	10/17/94	1200	479	10.00	0.00	0.00	0.00	.F.	X X X	
YOP2S111793	YORK	POLECAT	2	S	11/17/93	1200	510	14.00	0.00	0.00	0.00	.F.	C K X	
YOP2S120893	YORK	POLECAT	2	S	12/08/93	1200	0	7.00	38.00	7.80	13.40	.T.		

COLLECTION LOCATION REPORT

LOCATION CODE	DRAINAGE	STREAM	ORDER	SITE CODE	DATE	TIME	EFFORT	TEMP	COND	pH	DO	HAB ASMT	INVERT SAMPLE	NOTES
YOP2W051394	YORK	POLECAT	2	W	05/13/94	1200	539	18.00	0.00	0.00	0.00	.F.	X X X	ARTIFICAL SUBSTRATE NOT REMOVED FOR SPRING SAMPLING
YOP2W072194	YORK	POLECAT	2	W	07/21/94	1200	0	27.00	71.00	6.30	5.20	.F.		
YOP2W080994	YORK	POLECAT	2	W	08/09/94	1200	414	0.00	0.00	0.00	0.00	.F.	X X X	
YOP2W110494	YORK	POLECAT	2	W	11/04/94	1200	802	10.00	0.00	0.00	0.00	.F.	X X X	
YOP3D012694	YORK	POLECAT	3	D	01/26/94	1200	0	4.00	40.00	4.70	15.00	.T.	X X X	
YOP3D040894	YORK	POLECAT	3	D	04/08/94	1200	905	12.50	30.00	5.60	10.30	.T.	X X X	91 PACES REACH LENGHT
YOP3D071493	YORK	POLECAT	3	D	07/14/93	1200	474	0.00	0.00	0.00	0.00	.F.	X X X	FLOW VERY LOW. EXPOSED RIFFLES. LARGE LONG RUN/POOL. MISSED SEVERAL EOL'S IN THE ROCKS.
YOP3D071594	YORK	POLECAT	3	D	07/15/94	1200	0	25.00	80.00	6.70	8.00	.T.		
YOP3D101994	YORK	POLECAT	3	D	10/19/94	1200	824	12.00	0.00	0.00	0.00	.F.	X X X	
YOP3D111093	YORK	POLECAT	3	D	11/10/93	1200	652	7.00	0.00	0.00	0.00	.F.	C K X	
YOP3D111893	YORK	POLECAT	3	D	11/18/93	1200	0	11.00	72.00	6.10	10.10	.T.		METRIC #3 WAS CHANGED FROM POOL CHARACTERIZATION TO GLIDE CHARACTERIZATION
YOP3E020294	YORK	POLECAT	3	E	02/02/94	1200	0	3.00	41.00	6.80	16.40	.T.		
YOP3E040894	YORK	POLECAT	3	E	04/08/94	1200	913	14.00	35.00	5.80	9.60	.T.	X X X	
YOP3E071994	YORK	POLECAT	3	E	07/19/94	1200	0	25.00	65.00	6.30	6.90	.T.		
YOP3E072093	YORK	POLECAT	3	E	07/20/93	1200	1259	0.00	0.00	0.00	0.00	.F.	X X X	LOW BEAVER DAM HAD BEEN CONSTRUCTED UPSTREAM OF (~15M) STATE BRIDGE. LOW STREAM CONDITIONS PRESENT, MOST OF THE SITE COULD BE SHOCKED WITH CHEST WADERS @THESE WATER LEVELS.TWO DATA SHEETS; 926 CANOE AND 333 BACKPACK WHICH THE EFFORTS WERE ADDED TOGETHER.
YOP3E081194	YORK	POLECAT	3	E	08/11/94	1200	1247	0.00	0.00	0.00	0.00	.F.	X X X	
YOP3E111494	YORK	POLECAT	3	E	11/14/94	1200	960	0.00	0.00	0.00	0.00	.F.	X X X	

COLLECTION LOCATION REPORT

LOCATION CODE	DRAINAGE	STREAM	ORDER	SITE CODE	DATE	TIME	EFFORT	TEMP	COND	pH	DO	HAB ASMT	INVERT SAMPLE	NOTES
YOP3E111793	YORK	POLECAT	3	E	11/17/93	1200	611	14.00	0.00	0.00	0.00	.F.	C L X	
YOP3E111893	YORK	POLECAT	3	E	11/18/93	1200	0	11.80	65.00	6.30	8.60	.T.		
YOP3M020294	YORK	POLECAT	3	M	02/02/94	1200	0	2.00	28.00	7.00	16.60	.F.		
YOP3M040894	YORK	POLECAT	3	M	04/08/94	1200	787	13.00	30.00	6.20	9.30	.F.	X X X	106 PACES
YOP3M071994	YORK	POLECAT	3	M	07/19/94	1200	0	24.00	70.00	6.90	7.30	.T.		
YOP3M080994	YORK	POLECAT	3	M	08/09/94	1200	964	0.00	0.00	0.00	0.00	.F.	X X X	
YOP3M101794	YORK	POLECAT	3	M	10/17/94	1200	616	11.00	0.00	0.00	0.00	.F.	X X X	
YOP3M111793	YORK	POLECAT	3	M	11/17/93	1200	568	14.00	0.00	0.00	0.00	.T.	X X X	
YOP4R060794	YORK	POLECAT	4	R	06/07/94	1200	942	24.00	64.00	0.90	7.20	.T.	X X X	106 PACES
YOP4R060794	YORK	POLECAT	4	R	06/07/94	1200	0	24.00	64.00	6.90	7.20	.T.		
YOP4R071693	YORK	POLECAT	4	R	07/16/93	1200	804	27.00	0.00	0.00	0.00	.F.	X X X	
YOP4R071994	YORK	POLECAT	4	R	07/19/94	1200	0	26.00	62.00	6.90	7.60	.T.		
YOP4R081194	YORK	POLECAT	4	R	08/11/94	1200	1178	0.00	0.00	0.00	0.00	.F.	X X X	
YOP4R101794	YORK	POLECAT	4	R	10/17/94	1200	681	13.00	0.00	0.00	0.00	.F.	X X X	

COMMONWEALTH of VIRGINIA

A Natural Heritage Inventory of the Polecat Creek Watershed, Caroline County, Virginia and Preliminary Results of a Mark-Recapture Study

Final Report

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Division of Natural Heritiage
1500 East Main Street, Suite 312
Richmond, VA 23219
Telephone (804) 786-7951

Natural Heritage Technical Document #95-12, March 1995

DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL AND RECREATIONAL RESOURCES

A NATURAL HERITAGE INVENTORY OF THE POLECAT CREEK WATERSHED, CAROLINE COUNTY, VIRGINIA AND PRELIMINARY RESULTS OF A MARK-RECAPTURE STUDY OF *ELLIPTIO COMPLANATA*

FINAL REPORT

By:

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Prepared for:

Chesapeake Bay Local Assistance Department
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ACKNOWLEDGEMENTS

This Natural Heritage Inventory of the Polecat Creek watershed was accomplished through the funding, expertise, and assistance of numerous individuals other than the primary author. These contributions are recognized here.

This inventory was funded by the National Oceanic and Atmospheric Administration through the Coastal Program of the Department of Environmental Quality. Personnel with the Chesapeake Bay Local Assistance Department administered the contract, provided assistance in arranging access, and supplied information about natural resources and land use practices within the watershed. In particular, Jean Tingler, served as Polecat Creek project coordinator for this inventory and Darryl Glover assisted with various aspects of the project.

Natural Heritage Inventories conducted by the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DNH) are a group effort. DNH field biologists, including the author, planned and conducted all field work. Surveys were conducted by the following DNH personnel: Steven M. Roble, Allen J. Belden, Gary P. Fleming, William H. Moorhead, and Dirk J. Stevenson. Field zoologist Christopher S. Hobson served as project leader. Data Management staff, including Steve Carter-Lovejoy, Harold Evans, and Megan Rollins, assisted in this survey from start to finish, providing lists of potential rare species for the area in the initial stages, and processing data on the rare species and significant communities found at Polecat Creek. Caren A. Caljouw reviewed management and protection recommendations. Leslie D. Trew was responsible for the overall administration and coordination of the contract, while Patricia Jarrell handled financial affairs. Finally, Faye McKinney assisted by securing vehicles, coordinating itineraries, completing our travel expense reports, and assisting in many other administrative tasks.

We also thank Steven M. Roble, Gary P. Fleming, Leslie D. Trew, and Allen J. Belden for their assistance in reviewing portions of this manuscript.

Some of the information used in this report was compiled by Gary P. Fleming and Nancy Van Alstine for use in previous natural heritage inventory reports. The use of this information was extremely helpful in many ways and is greatly appreciated.

I. INTRODUCTION

INTRODUCTION TO THE INVENTORY PURPOSE, METHODS, AND PROCEDURES

In March, 1993, the Coastal Program of the Department of Environmental Quality contracted with the Chesapeake Bay Local Assistance Department (CBLAD) and the Department of Conservation and Recreation, Division of Natural Heritage (DCR-DNH) to conduct a natural heritage resource inventory and survey of freshwater mussels within the watershed of Polecat Creek, Caroline County, Virginia. Initially, this project included surveys for the federally endangered dwarf wedge mussel (*Alasmidonta heterodon*) at a proposed water quality monitoring station (site E) in compliance with United States Fish and Wildlife Service requirements for wetland permits. Four other proposed gauge station sites were surveyed during early 1994 by Phillip H. Stevenson (Stevenson, 1994). This portion of the project was completed during 1994. Additionally, three populations of the eastern elliptio (*Elliptio complanata*) were to be identified and marked so that the effects of nearby land development on the survival of these animals could be monitored during the ten year water quality monitoring project. This report includes results from the natural heritage resource inventory (Section I) and preliminary data from the mark-recapture study (Section II).

The Virginia Department of Conservation and Recreation's Division of Natural Heritage (DNH) is the state agency responsible by statutory authority under the Virginia Natural Area Preserves Act (Section 10.1-209 through 217, Code of Virginia) for inventory, database maintenance, protection, and management of Virginia's natural heritage resources. Such resources are defined as the habitats of rare, threatened, or endangered plant and animal species, rare or state significant communities, and other natural features. The Department of Conservation and Recreation - Division of Natural Heritage represents the first comprehensive attempt to identify the Commonwealth's most significant natural areas through ongoing scientific biological survey. Data gathered during this state-wide survey are assembled and managed through a sophisticated Biological and Conservation Data System (BCD) in which information on ecosystems and species, their biology, habitats, locations, conservation status, and management needs is continually updated and refined. The DNH is part of an international network of natural heritage programs, coordinated by The Nature Conservancy, which uses standardized inventory methodologies and BCD technology.

The intent of the Polecat Creek Natural Heritage Inventory is to verify and document the presence (or absence), distribution, and population status of specific elements of biological diversity: federally listed threatened or endangered species; proposed candidate species for federal listing; other rare plant and animal species monitored by DNH; and communities considered to be rare or exemplary by DNH. The practical goal of the inventory is to assist CBLAD personnel, private landowners, and local governments in decisions concerning land use, maintenance activities, public access, siting of facilities, and management of areas containing natural heritage resources.

DNH work on the inventory began during the spring of 1994 with a comprehensive review of existing information about the Polecat Creek watershed area. Field surveys were initiated in May, 1994 and continued through March, 1995. During this period DNH botanists, zoologists and community ecologists carried out surveys in areas determined to have potential for rare species and significant communities. Overall coordination of the project was through Jean Tingler of the Chesapeake Bay Local Assistance Department. A report summarizing the results of rare mussel surveys by DNH at gauging station E was completed during late 1994. All information collected during the project period is reported herein, and will be incorporated into the DNH Biological and Conservation Data System.

EXPLANATION OF THE NATURAL HERITAGE RANKING SYSTEM

Each of the significant natural features (species, community type, etc.) monitored by DNH is considered an element of natural diversity, or simply an **element**. Each element is assigned a rank that indicates its relative rarity on a five-point scale (1 = extremely rare; 5 = abundant; Table 1). The primary criterion for ranking elements is the number of occurrences, i.e. the number of known distinct localities or populations. Also of great importance is the number of individuals at each locality or, for highly mobile organisms, the total number of individuals. Other considerations include the condition of the occurrences, the number of protected occurrences, and threats. However, the emphasis remains on the number of occurrences, so that ranks essentially are an index of known biological rarity. These ranks are assigned both in terms of the element's rarity within Virginia (its State or S-rank) and the element's rarity over its entire range (its Global or G-rank). Subspecies and varieties are assigned a Taxonomic (T-) rank in addition to their G-rank. Taken together, these ranks give a concise picture of an element's rarity. For example, a designated rank of G5/S1 indicates an element which is abundant and secure range-wide, but extremely rare in Virginia. Ranks for community types are provisional, or in many cases lacking, due to ongoing efforts by the Natural Heritage network to classify community taxa. Rarity ranks used by DNH are not legal designations, and they are continuously updated to reflect new information.

Table 1. Definition of Natural Heritage state rarity ranks. Global ranks are similar, but refer to a species' range-wide status. Note that GA and GN are not used and GX means extinct. Sometimes ranks are combined (e.g. S1S2) to indicate intermediate or somewhat unclear status. Elements with uncertain taxonomic validity are denoted by the letter Q, after the global rank. Ranks for most community types have not been generated due to ongoing community classification efforts. These ranks should not be interpreted as legal designations.

S1	Extremely rare; usually 5 or fewer occurrences in the state; or may have a few remaining individuals; often especially vulnerable to extirpation.
S2	Very rare; usually between 5 and 20 occurrences; or few occurrences with many individuals; often susceptible to becoming endangered.
S3	Rare to uncommon; usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.
S4	Common; usually more than 100 occurrences, but may be fewer with many large populations; may be restricted to only a portion of the state; usually not susceptible to immediate threats.
S5	Very common; demonstrably secure under present conditions.
SA	Accidental in the state.
SH	Historically known from the state, but not verified for an extended period, usually more than 15 years; this rank is used primarily when inventory has been attempted recently.
SN	Regularly occurring migrants or transient species which are non-breeding, seasonal residents. (Note that congregation and staging areas are monitored separately).

Table 1. (continued)

SU Status uncertain, often because of low search effort or cryptic nature of the element.

SX Apparently extirpated from the state

The spot on the landscape that supports a natural heritage resource is an **element occurrence**. Occasionally, separate but nearby locations of a species or community element are treated as subpopulations (species) or sub-occurrences (community) of the same occurrence due to factors such as the probability of gene flow or hydrologic linkage. DNH has mapped over 7,400 element occurrences in Virginia. Information on the location and quality of these element occurrences is computerized within the Division's BCD system, and additional information is recorded on maps and in manual files.

In addition to ranking each element's rarity, each element occurrence is ranked to differentiate large, outstanding occurrences from small, vulnerable ones. In this way, protection efforts can be aimed not only at the rarest elements, but at the best examples of each. Species occurrences are ranked in terms of quality (size, vigor, etc.) of the population; the condition (pristine to disturbed) of the habitat; the viability of the population; and the defensibility (ease or difficulty of protecting) of the occurrence. Community occurrences are ranked according to their size and overall natural condition. These **element occurrence ranks** range from A (excellent) to D (poor). Sometimes these ranks are combined to indicate intermediate or somewhat unclear status, e.g. AB or CD, etc. In a few cases, especially those involving cryptic animal elements, field data may not be sufficient to reliably rank an occurrence. In such cases a rank of E (extant) may be given. Element occurrence ranks reflect the current condition of the species' population or community. A poorly-ranked element occurrence can, with time, become highly-ranked as a result of successful management or restoration.

Element ranks and element occurrence ranks form the basis for ranking the overall significance of sites. Site **biodiversity ranks** (B-ranks) are used to prioritize protection efforts, and are defined as follows:

B1 Outstanding Significance: only site known for an element; an excellent occurrence of a G1 species; or the world's best example of a community type.

B2 Very High Significance: excellent example of a rare community type; good occurrence of a G1 species; or excellent occurrence of a G2 or G3 species.

B3 High Significance: excellent example of any community type; good occurrence of a G3 species.

B4 Moderate Significance: good example of a community type; excellent or good occurrence of state-rare species.

B5 General Biodiversity Significance: good or marginal occurrence of a community type or state-rare species.

Note: sites supporting rare subspecies or varieties are considered slightly less significant than sites supporting similarly ranked species.

The U.S. Fish and Wildlife Service (USFWS) is responsible for the listing of endangered and threatened species under the Endangered Species Act of 1973, as amended. Federally listed species (including subspecific taxa) are afforded a degree of legal protection under the Act, and therefore sites supporting these species need to be highlighted. USFWS also maintains a review listing of potential candidate endangered and threatened taxa. Table 2 defines the various status categories used by USFWS and followed in this report. The status category of candidate species is based on the Service's current level of knowledge about the biological vulnerability of and threats to a species.

In Virginia, two acts have authorized the creation of official state endangered and threatened species lists. One act (section 29.1-563 through 570, Code of Virginia), administered by the Virginia Department of Game and Inland Fisheries (DGIF), authorizes listing of fish and wildlife species, not including insects. The Endangered Plant and Insect Species Act, (section 3.1-1020 through 1030, Code of Virginia), administered by the Virginia Department of Agriculture and Consumer Services (VDACS), allows for listing of plant and insect species. In general, these acts prohibit or regulate taking, possessing, buying, selling, transporting, exporting, or shipping of any endangered or threatened species appearing on the official lists. Species protected by these acts are indicated as either listed endangered (LE) or listed threatened (LT). Species under consideration for listing are indicated as candidates (C).

Table 2. U.S. Fish and Wildlife Service species status codes, with abbreviated definitions.

LE	Listed endangered
LT	Listed threatened
PE	Proposed to be listed as endangered
PT	Proposed to be listed as threatened
S	Synonyms
C1	Candidate, category 1: status data supports listing of taxon as endangered or threatened, but listing has been delayed by pending proposals of higher priority taxa.
C2	Candidate, category 2: evidence of vulnerability, but insufficient status data exists.
3A	Persuasive evidence exists that taxon is extinct.
3B	Name that does not represent a distinct taxon, according to recently published revisions and monographs.
3C	Taxon proven to be more abundant or widespread than previously believed and/or those that are not subject to any identifiable threat.

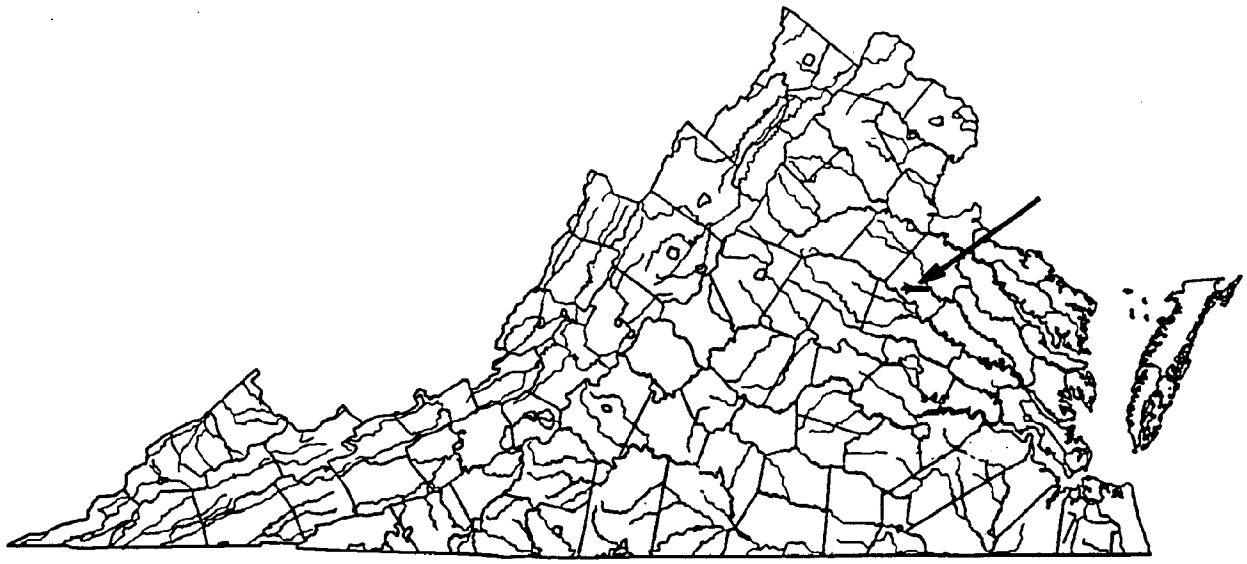
II. ENVIRONMENTAL CHARACTERISTICS OF THE POLECAT CREEK WATERSHED, CAROLINE COUNTY

A brief discussion of the general environmental characteristics of the Polecat Creek watershed is important for understanding the context in which significant natural communities and rare biota occur. Unless otherwise cited, county-wide statistics cited in this section are from Lillywhite and Niemann (1993) and Thompson (1991).

GENERAL LAND USE PATTERNS

Polecat Creek is located in south-central Caroline County, approximately 30 miles north of Richmond, and approximately 70 miles SSE of Washington D.C. (Fig 1). The headwaters originate in the Piedmont, flow across the fall zone into the Coastal Plain and converge with the Mattaponi River. The Mattaponi is a major tributary of the York River, which flows into the southern portion of the Chesapeake Bay.

Figure 1. Location of Polecat Creek watershed in Virginia



Caroline County is classified as 100% rural, with a total acreage of 342,695 and a population of 19,217 in 1990. Land use in the county as a whole is predominantly forestry-related, with forest lands comprising 76% of the total acreage. Only about 18% of the county's acreage is utilized for agriculture (D. Eastham, U.S. Soil Conservation Service, pers. comm. to Gary P. Fleming, 1994). The predominant land cover in the watershed is forest, followed by open fields and pastureland. The principal crops in the county are soybeans, wheat, barley, and corn, with a very small amount of grazing land included. The remaining 6% of the county consists of miscellaneous residential, developed, and open wetland areas. There are no major industries and, at present, only a limited amount of commercial and residential growth occurring around the towns of Bowling Green and Port Royal, located just NNE and NE of the drainage respectively. Significant urban development activity is expected in the area over the next ten years as a large portion of the Polecat Creek watershed is designated as primary growth area in the Caroline County comprehensive plan.

CLIMATE

The climate of the Polecat Creek area is classified as humid subtropical. This term denotes a seasonal temperature pattern with warm to hot summers and mild winters, along with sufficient precipitation to support forests (Woodward and Hoffman, 1991). The average growing season length in this region is approximately 180 days and the average annual precipitation is 42.69 inches (Hoppe and Jones, 1989).

PHYSIOGRAPHY, TOPOGRAPHY, AND GEOLOGY

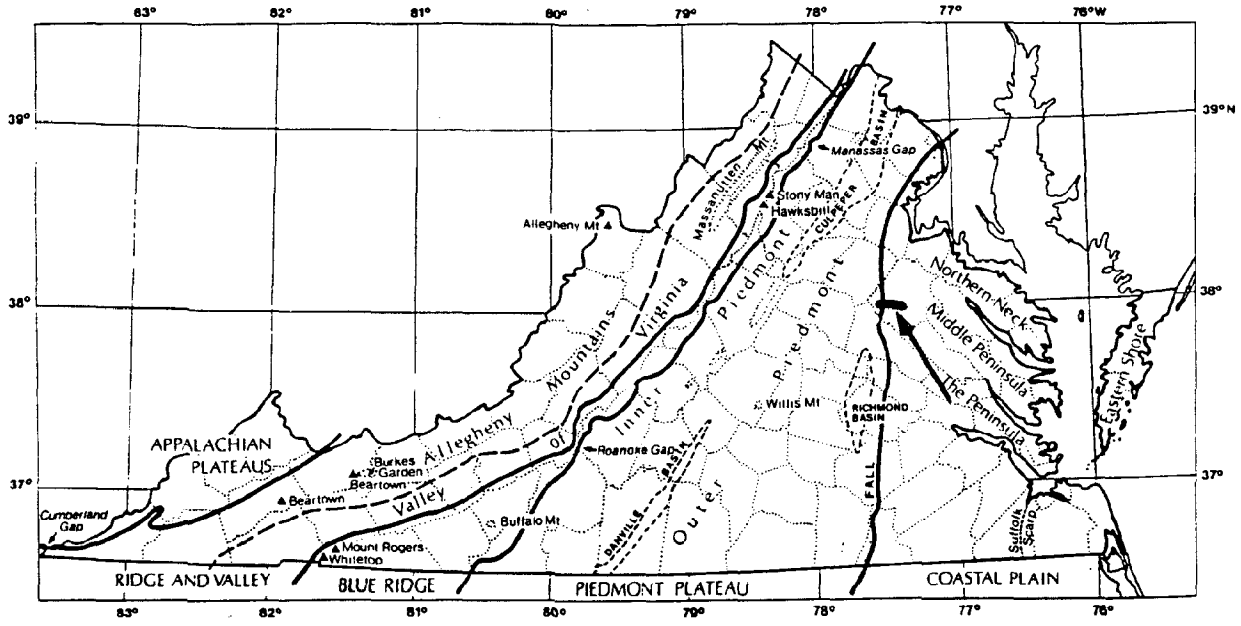
Western portions of the watershed including the headwaters, and several tributaries are located within the Piedmont physiographic province. Topography in this area can be described as hilly, with uplands dissected by deeply entrenched ravines caused by accelerated downcutting of streams. Although the overall character of this region is a gently sloping plain, relief is far from uniform. Soils found in this area are a complex of alluvial and fluvial deposits eroded from the Appalachian highlands to the west.

Eastern sections of the creek and several tributaries lie within the Coastal Plain physiographic province, the youngest of Virginia's ecoregions. The Coastal Plain is composed of unconsolidated sands, gravels, and clays eroded from the Appalachian highlands to the west and deposited along the continent margin as the Atlantic Ocean was formed. Over millions of years, changing sea levels, resulting from tectonic and climatic changes, have shaped a series of longitudinal, wave-cut terraces which characterize the province's current topography. North of the James River in Virginia, the Chesapeake Bay and the watersheds of four major rivers dissect the Coastal Plain into four peninsulas: the Eastern shore, the Northern Neck, the Middle Peninsula, and The Peninsula. The Polecat Creek watershed is considered to be in the extreme western portion of the Middle Peninsula.

The topography in the watershed is basically a rolling plain bisected by the fall zone between the Coastal Plain and Piedmont physiographic provinces; therefore, characteristics of both can be found. Elevations range from approximately 70 feet above sea level near the Polecat Creek convergence with the Mattaponi River, to approximately 300 feet above sea level near the western edge of the watershed. Although the plain slopes gradually from west to east, relief is far from uniform. Within the Piedmont sections of the watershed, stream dissection is more pronounced with some ravines deeply dissected and entrenched due to the accelerated downcutting of streams. These areas reveal a more pronounced transition into upland habitats than is seen in lower areas of the watershed. Portions of the stream within the Coastal Plain are comparatively more flat and with little topographic relief, creating a fairly mild transition from bottomland habitats into adjacent uplands. This area is characterized by bottomlands which are typically wide and flat allowing the stream to expand into these areas during periods of high water, at times creating large areas of flooded forest and marshy habitats.

Several major geological formations underlie this landscape (Mixon et. al., 1989). The Chesapeake Group (TC), which underlies much of the eastern portion of the watershed, consists of fine to coarse quartzose sand, silt, and clay deposited in shallow inner and middle shelf waters of the upper Pliocene and lower Miocene periods. Pliocene Sand and Gravel (TPSG) underlies higher topography, particularly drainage divides, in the western portions of the watershed. Lower Tertiary Deposits (TL) of glauconitic quartz sand and clay-silt underlies the broad, lower valleys and bottomlands within the watershed.
Alluvial deposits of the Quaternary and Tertiary periods are common in the central portion of the watershed. Western portions of the watershed are underlain by more resistant bedrock typical of the Piedmont. This region is primarily underlain by the porphyroblastic garnet-biotite gneiss (Ym) complex of late Precambrian or early Paleozoic periods (Rader and Evans 1993).

Figure 2. Physiographic context of Polecat Creek watershed.
(from Woodward and Hoffman, 1991 with copyright permission)



HYDROLOGY

Drainage patterns are more or less dendritic in the gentler topographic areas of the watershed, and distinctly of trellis form in the more deeply dissected areas. Lower elevation areas give way to slow moving backwaters, marshy areas and flooded pools. Major tributaries which drain the western portions of the watershed are Stevens Mill Run, Reedy Creek, De Jarnette Mill Run, and Hackett Creek. Major tributaries in the lower portions of the watershed include, Rafe Swamp, Saddle Swamp, and Millpond Swamp. Several of these tributaries are impounded forming ponds or lakes, most notably Lake Caroline along Stevens Mill Run.

Little published information is available on groundwater resources in Caroline County. In neighboring Essex County, well water supplies are obtained from several strata between depths of 50 and 140 feet (Hoppe and Jones, 1989). In areas near the Piedmont, at least some of the deeper water-bearing strata may be located in crystalline rocks which dip steeply under the narrow wedge of sediments deposited at the inner edge of the Coastal Plain. Sand and gravel aquifers within the wedge are generally confined

by strata of silt and clay of variable thickness and permeability. The uppermost aquifer, commonly referred to as the water table, is influenced by the local permeability of soils and by topography. The direction of flow within the water table aquifer is generally toward surface water drainage features.

SOILS

A comprehensive soil survey of Caroline County is currently underway by the U.S. Soil Conservation Service (SCS), but is not yet published (G. Ways, pers. comm.).

Soils within the watershed are generally moderate to strongly acidic in reactivity. Typic Hapludult soils predominate within the watershed, including the Remlik-Rumford units in upland habitats. Rumford series soils consist of very deep and somewhat excessively drained soils, formed in Coastal Plain sediments.

The major wetland soil units of the watershed are classified as Bibb-Chastain, Roanoke, Tomotley and Altavista (D. Eastman, pers. comm., 1995). Bibb soils are typically very deep, poorly drained soils, moderately permeable and formed in loamy alluvium on floodplains. The Chastain series consists of deep, poorly drained, nearly level soils that have a clayey subsoil, typically formed in clayey and loamy alluvium on the floodplains. Roanoke series soils consist of deep, poorly drained, nearly level soils that have a dominantly clayey subsoil; these soils are formed in alluvium, mostly on terraces. Soils of the Tomotley series are very deep, nearly level and poorly drained forming in moderately coarse textured to moderately fine textured, fluviomarine sediments on the intermediate terrace. The deep, moderately well drained soils of the Altavista series, are nearly level to gently sloping with a loamy subsoil; these soils are formed in loamy alluvium, mostly on terraces.

PRINCIPAL NATURAL COMMUNITY (ECOSYSTEM) TYPES

Although much altered by three centuries of human disturbance, temperate broadleaf deciduous forest is the predominant natural vegetation over much of Virginia and the eastern United States. Within the deciduous forest formation, four major vegetation regions recognized by Braun (1950) include portions of Virginia. The Polecat Creek watershed lies within the Oak-Pine region, which includes the state's southern Piedmont and the Coastal Plain north of the James River. To the west, including the state's northern Piedmont and Appalachian Mountains, is the Oak-Chestnut region, which is now modified by the near elimination of American chestnut (*Castanea dentata*) by disease. On the Coastal Plain south of the James River, the Southeastern Evergreen Forest region reaches its northern limits.

The Oak-Pine region is generally considered a transition zone where pines characteristic of the southeastern states become more common in oak (*Quercus* spp.)-dominated forests east of the Appalachians. Pine species, including Virginia or scrub pine (*Pinus virginiana*), shortleaf pine (*P. echinata*), and loblolly pine (*P. taeda*), are considered much more abundant today than in pre-settlement times, occurring prolifically in early successional communities of abandoned fields and clearcuts. Moreover, loblolly pine is one of the most valuable timber resources, and plantations of this species are a common and typical sight throughout much of the region. In the original forest, these species probably were scattered associates of oaks and other hardwoods, except in highly xeric habitats, areas of high fire incidence, and areas recovering from catastrophic disturbances (e.g. blow-downs), where they were more abundant and persistent. Small inclusions of mixed hardwoods, bottomland hardwoods, and other wetland communities are found along streams throughout the Oak-Pine region.

Although remnant hardwood stands in the region have undergone some successional modifications as a result of repeated cutting, they are considered somewhat stable – at least on the drier sites – due to vigorous sprout regeneration of dominant oaks. On the better upland sites, shade-intolerant species such

as tulip-poplar (*Liriodendron tulipifera*) may become dominant following cutting, while shade-tolerant beech (*Fagus grandifolia*) usually assumes increasing dominance in the prolonged absence of disturbance.

Within the Polecat Creek watershed, loblolly pine is abundant in monocultural plantings, while both loblolly and Virginia pines are dominant in natural early succession stands on many thousands of acres. Nevertheless, considerable upland areas and bottomlands remain forested in hardwoods, and among these, Natural Heritage ecologists have identified one exemplary mature bottomland hardwood stand. Vegetation within the watershed is decidedly southern in overall character, although representative species from both Coastal Plain and Piedmont habitats can be found. Northern species may occasionally occur in areas with cooler microclimates, such as steep-sided ravines. The watershed is typical of other areas within this region of Virginia.

Terrestrial (Upland) Communities:

Division of Natural Heritage ecologists recognize two broad types of more or less stable, upland forest vegetation within the watershed:

1. Oligotrophic Forest
2. Submesotrophic Forest

Oligotrophic forests occupy sites of low fertility and are characterized by an absence of nutrient-demanding species and the strong presence of members of the heath family. Submesotrophic forests are communities of only moderately infertile soil conditions, and are characterized by the presence of somewhat nutrient-demanding species.

Because of the sandy, nutrient-poor soils which are common in the watershed, oligotrophic forests are by far the most widespread of these community types. These are oak-dominated forests with a very low diversity of shrub and herbaceous species. Characteristic canopy trees are white oak (*Quercus alba*), southern red oak (*Q. falcata*), black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), hickories (*Carya* spp.), and some beech, often in mixture with Virginia and/or loblolly pines. Chestnut oak (*Q. montana*) often dominates on drier gravelly ridges and steep slopes. More or less dense strata of ericaceous (heath family) shrubs – mountain-laurel (*Kalmia latifolia*), black huckleberry (*Gaylussacia baccata*), blueberries (*Vaccinium* spp.) and, more locally, sheep-laurel (*Kalmia angustifolia*) -- are typical features of oligotrophic forests. Herbaceous growth is sparse, consisting of scattered pink ladyslipper (*Cypripedium acaule*), spotted wintergreen (*Chimaphila maculata*), trailing arbutus (*Epigaea repens*), poverty grass (*Danthonia spicata*), and a few other species. The exact floristic composition of these stands varies considerably with topography and soil conditions over the watershed and detailed plot sampling undoubtedly would delineate several well-defined associational segregates within the type.

Submesotrophic forest communities occur somewhat locally on ravine slopes and non-hydric ravine bottoms. Here, soil nutrient status is slightly enriched by colluvial processes and the prevalence of sandy loam and clay loam strata in the Remlick-Rumford series. The canopy association in these submesotrophic forests is usually dominated by white oak, beech, and tulip-tree. Northern red oak (*Quercus rubra*), southern red oak, black oak, hickories, and red maple (*Acer rubrum*) also are present in many stands. In the understory and shrub layers, ericaceous species may be thinly scattered or absent, while flowering dogwood (*Cornus florida*) and maple-leaved viburnum (*Viburnum acerifolium*) are usually common. Diagnostic herbaceous species include christmas fern (*Polystichum acrostichoides*), white wood aster (*Aster divaricatus*), naked-flowered tick-trefoil (*Desmodium nudiflorum*), violet wood sorrel (*Oxalis violacea*), wild comfrey (*Cynoglossum virginianum*), short-leaved bluegrass (*Poa cuspidata*), wedgegrass (*Sphenopholis nitida*), and spreading sedge (*Carex laxiculmis*).

No old growth upland forest was identified within the areas surveyed. This is not surprising, since mature stands which have escaped cutting (or at least extensive cutting) and the effects of beaver are decidedly rare in the Virginia Coastal Plain. On the other hand, thousands of acres of the watershed are representative of scrubby vegetation and secondary forest stands growing up on abandoned fields and clearcuts. The composition of these communities ranges from shrubby grasslands and pure stands of pine to variable mixtures of fast-growing, light-demanding deciduous tree sprouts, shrubs, and vines. Unless artificially maintained, such communities are temporary and will undergo rapid and inexorable development toward one of the more climax types of forest vegetation discussed above. Though valuable

for wildlife habitat, watercourse and wetland buffer, soil stabilization, and nature study, among other things, these communities are neither uncommon nor exceptional from a biological or ecological point of view, and they therefore cannot be considered significant from a natural heritage perspective.

Palustrine (Wetland) Communities:

It is clear from field surveys that wetlands of the Polecat Creek watershed are dynamic ecosystems comprising an often shifting mosaic of vegetation types and biota. In these habitats, the nature of soils, hydrologic regimes, vegetation communities, and species populations may be frequently altered in a given locality by unpredictable flooding, various natural and artificial impoundments, establishment and abandonment of beaver ponds, and so forth. Moreover, large-scale or catastrophic alterations to one portion of a watershed may have secondary impacts on adjacent, unaltered portions. More than any other factor, the extensive activities of beavers, often stimulated by the construction of culverted roadways across drainages, are responsible for the creation and maintenance of open wetland habitats. While beavers have always been members of this region's fauna, their populations have increased dramatically in recent decades and have led to widespread vegetational and hydrologic changes. However temporal they may be, active or abandoned beaver ponds can be considered "natural" habitats and sometimes support significant communities or rare species.

Within the Polecat Creek watershed's dynamically changing wetlands, the generalized (idealized) trend of vegetational development in seasonally to semipermanently flooded palustrine habitats is depicted in Table 3. A few species or genera typical of each successional stage are listed.

Table 3. Generalized Successional Development of Flooded Wetland

Emergent Aquatics	Freshwater (Nontidal) Marsh	Palustrine Scrub	Palustrine Forest
arrow-arum	sedge spp.	common alder	river birch
American bur-reed	rush spp.	black willow	sweetgum
cat-tail	grass spp.	red maple	red maple
			oaks (later stages)

Though it was beyond the scope of this survey to classify all wetlands in the survey area, several broad types of natural vegetated wetland communities were identified, in the course of field survey of accessible areas (refer to Appendix A for an explanation of the classification system used by Division of Natural Heritage ecologists). Field survey and analysis of secondary sources (aerial photographs, topographic maps, etc.) suggest that virtually all of the vegetated wetland communities in the watershed are one of the following types:

1. Eutrophic Seasonally Flooded Forest
2. Eutrophic Semipermanently Flooded Woodland
3. Eutrophic Semipermanently Flooded Scrub
4. Eutrophic Semipermanently Flooded Herbaceous Vegetation
5. Oligotrophic Saturated Forest
6. Oligotrophic Saturated Herbaceous Vegetation
7. Submergent/Floating-leaved Vegetation

Type 1, Eutrophic Seasonally Flooded Forest, is the natural climax community type that would occupy the majority of the bottomland sites outside the stream channel in the absence of disturbance by beaver and humans. Much of the bottomland presently supports early successional stages of this community type. The canopy is usually dominated by river birch (*Betula nigra*), sweet gum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*). As this community matures, certain oaks tend to become more prevalent, as evidenced by the scattered, old individuals of basket oak (*Quercus michauxii*) and willow oak (*Quercus phellos*). Heritage ecologists identified one significant occurrence of this community, in old growth condition, near the confluence of Polecat Creek and the Mattaponi River. Faunal associates of this community type are generally common and widespread species such as the swamp spreadwing (*Lestes vigilax*), green frog (*Rana clamitans*), eastern mud turtle (*Kinosternon subrubrum*), Carolina Wren (*Thyrothorus ludovicianus*), northern cricket frog (*Acris crepitans*), Wood Duck (*Aix sponsa*), and the swamp darner (*Epiaeschna heros*). In the vicinity of the significant community, the carpenter frog (*Rana virgatipes*), a watchlist species, is known historically, and was recorded further upstream in a similar community during 1994.

Types 2 through 4 above, and 7 in part, are open wetlands represented in the Polecat Creek watershed mostly by communities associated with beaver impoundments, and are seral stages dependent on beaver activity to prevent or reverse succession to forest, as discussed at the beginning of the section above.

Type 5 above, Oligotrophic Saturated Forest, is the prevalent wetland community in the watershed outside of the Polecat Creek bottomlands. It is one of the more interesting forested wetland community types

of the watershed, and is rarely, if ever, inundated by flooding. Commonly referred to as "seepage swamps", such communities occupy the bottoms of headwaters streams and their tributaries, where abundant groundwater seepage is the primary hydrological influence. Drainage in these habitats is typically diffuse with braided channels interlaced around saturated hummocks in a sandy or peaty substrate. Classified as oligotrophic saturated forest, the vegetation which occupies undisturbed habitats of this type is widely but somewhat locally distributed in the Coastal Plain. The dominant canopy species of this community type are red maple (*Acer rubrum*) and Blackgum (*Nyssa sylvatica*), with tulip-poplar (*Liriodendron tulipifera*) and loblolly pine (*Pinus taeda*) of occasional importance in the stand. Characteristic shrubs are sweetbay (*Magnolia virginiana*), sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), swamp azalea (*Rhododendron viscosum*), and possumhaw viburnum (*Viburnum nudum*). Herbaceous plants which could be considered "indicator" species of the community include skunk-cabbage (*Symplocarpus foetidus*), kidneyleaf grass-of-parnassus (*Parnassia asarifolia*), Collins' sedge (*Carex collinsii*), and twining bartonia (*Bartonia paniculata*). At ground level, sphagnum mosses (*Sphagnum* spp.) cover the hummocks with expansive mats. Oligotrophic saturated forests have become increasingly fragmented and threatened by the recent expansion of beaver populations in the upper portions of many drainages in Caroline County. Several rare odonates are typical of seepage swamp habitats including the gray petaltail (*Tachopteryx thoreyi*), sphagnum sprite (*Nehalennia gracilis*), and occasionally the seepage dancer (*Argia bipunctulata*). Other species which may be associated with this habitat include the spotted turtle (*Clemmys guttata*), four-toed salamander (*Hemidactylium scutatum*), northern dusky salamander (*Desmognathus fuscus*), and the erroneus biddie (*Cordulegaster erronea*).

The federally listed swamp-pink (*Helonias bullata*) has been found near the Polecat Creek watershed in this community type. Within the watershed, it was not found in those areas which could be accessed for this survey. However, one of the areas that could not be accessed for field survey, comprising the headwaters of Saddle Swamp near McBryant Corner, appears to have potential for this community type and *Helonias bullata*, based on map and aerial photograph analysis, and reconnaissance from public roads.

Type 6 above, Oligotrophic Saturated Herbaceous Vegetation, are open wetlands that are represented in this watershed only by communities created by beaver or man-made disturbances, such as old pond bottom wet meadows, and wet meadows maintained by mowing or grazing, in yards, pastures, and right-of-ways. In most cases the original natural climax vegetation in these areas was Oligotrophic Saturated Forest, or seepage swamp. Naturally open oligotrophic seepage communities are extremely rare, but a number of light-demanding rare plant species that are native to these communities can sometimes occur in artificially maintained open communities, depending in large part on the nature of the disturbance that is keeping these communities open. The two rare plants confirmed by this survey, *Juncus caesariensis* and *Sarracenia purpurea*, are found in this community type in a powerline right-of-way, which appears to be kept open by occassional "bushhogging". Also found in this community type was the seepage dancer (*Argia bipunctulata*), a denizen of sphagnous seeps with emergent vegetation. Other species such as the eastern red damsel (*Amphiagrion saucium*), the four-toed salamander, southern bog clubmoss (*Lycopodiella appressa*), and the citrine forktail (*Ischnura hastata*) can be found in these habitats.

Type 7, Submergent/Floating-leaved Vegetation, is the community type into which fall the perennial watercourses and shallow impoundments and portions of impoundments in the watershed. Within the drainage this habitat supports a variety of common and widespread species such as the eastern elliptio (*Elliptio complanata*), larvae of the fawn darner (*Boyeria vinosa*) and the common whitetail (*Libellula lydia*). Several rare or watchlist species are associated with this habitat including the least brook lamprey

(*Lampetra aepypetra*), mud sunfish (*Acantharcus pomotis*), squawfoot (*Strophitus undulatus*), and Georgia river cruiser (*Macromia illinoiensis georgina*), among others.

Lacustrine Communities:
Those portions of the impoundments in the watershed which are too deep to support vegetation fall into the Lacustrine System, which has not yet been subdivided in the current Division of Natural Heritage ecological classification. All occurrences of this community type in the watershed are man-made. The largest, and perhaps the only, occurrence is in Lake Caroline. There is a historic record for low water-milfoil (*Myriophyllum humile*) from Lake Caroline. However, the lake is currently thought to be too eutrophic for this species to occur.

Summary of Community Elements:
One community occurrence considered to be significant by Division of Natural Heritage ecologists was documented in the watershed: a stand of bottomland forest in old-growth condition, classified as Eutrophic Seasonally Flooded Forest. Refer to the Lower Polecat Creek site report for a complete description.

Summary of Plant and Animal Elements:
A total of two plant element occurrences and three animal element occurrences were documented in the watershed. All of the animals are members of the insect Order Odonata (dragonflies and damselflies). Summary lists are provided in Table 4, which includes all federal candidate species and other species monitored by DNH. Global and state ranks, and legal statuses are included. Several watchlist species were also recorded during this inventory, a summary is provided in Appendix B. A historic occurrence of low water-milfoil (*Myriophyllum humile*) is known from Lake Caroline, but is not included based on current conditions in the lake.

Table 4. SPECIES MONITORED BY VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION/DIVISION OF NATURAL HERITAGE FOUND WITHIN THE POLECAT CREEK WATERSHED DURING 1994-1995.

ELEMENT NAME	GLOBAL RARITY RANK	STATE RARITY RANK	USFWS STATUS	VA LEGAL STATUS	NUMBER OF OCCURRENCES
Plants:					
Juncus caesariensis New Jersey rush	G2	S2	C2	C	1
Sarracenia purpurea Northern pitcher plant	G5	S2S3			1
Animals:					
Argia bipunctulata seepage dancer	G4	S2S3			1
Macromia illinoiensis georgina Georgia river cruiser	G5T5	S1S2			1
Somatochlora filosa fine-lined emerald	G5	S2			1

III. MATERIALS AND METHODS

OVERVIEW OF NATURAL HERITAGE INVENTORY METHODOLOGY

Staff of the DCR-DNH conduct natural heritage inventories in a systematic and prioritized manner. In general, the most threatened geographic areas, habitats, and species receive inventory priority. Adequately funded inventories carried out over several months or even years, typically allow for very intensive sampling of potential habitats. This may be carried a step further if sampling is confined to a restricted geographic area providing for a more focused survey. Areas within the watershed to which access could be gained during the study period were surveyed. Unfortunately, several areas which held potential for rare species or exemplary communities were not surveyed during 1994-1995.

Natural heritage inventories usually are conducted in six basic stages:

1. Review of aerial photographs and maps. Aerial photographs of the entire survey area are reviewed in detail to identify potential natural areas to be studied in subsequent stages. When possible, both the oldest available photographs and the most recent ones are examined. Comparing these two sets of photographs helps determine how long forests and other vegetation types have been in their current condition. To aid in their interpretation, the photographs are cross-referenced with topographic, wetlands, and soils maps.

2. Review of existing information. Museum collections are visited by DNH staff, and specimen label information is recorded for rare species. Published and unpublished information on natural areas within the inventory area is collected and assimilated in conjunction with the review of aerial photographs. Maps of lands within the survey area are gathered, BCD databases are accessed, and the known distribution of natural heritage resources is examined. Local naturalists, soil conservationists, foresters, and college faculty often are consulted for additional information. During this stage, some potential natural areas are eliminated from further consideration while others are added.

3. Aerial reconnaissance. When possible, selected potential natural areas are studied in more detail by aerial reconnaissance using small aircraft.

4. Initial ground survey. Initial ground reconnaissance is conducted in targeted, high priority sites. During this stage, land use activities are assessed, conspicuous element occurrences are documented, and, if necessary, follow-up visits are planned.

5. Thorough inventory of the site. During this stage, detailed information is collected on the rare species and exemplary natural communities present at a site. Portions of a site not visited on foot are evaluated on the basis of aerial photographs and other information. The area of land needed to protect the special biological features is determined. Threats and past or present disturbances are also evaluated. Element occurrence data are transcribed onto DNH maps and entered into the BCD system. Throughout this stage of concentrated field inventory, continual communication between DNH project team members (botanists, zoologists, and ecologists) is emphasized to ensure that all significant natural areas are visited by appropriate specialists and that data are coordinated. In addition, some flexibility is built into the process so that priorities can be adjusted when unexpected elements are encountered.

6. Compilation of results and preparation of final report. As field work is completed, DNH biologists review the information gathered and rank sites according to their ecological significance. Maps are drawn showing preliminary conservation planning boundaries, and protection and management recommendations are written. These are combined with site reports and other required information in preparing a final report.

The materials and methodology employed by the major disciplines in carrying out the Polecat Creek inventory are summarized below:

BOTANICAL INVENTORY

For purposes of this study, rare plants are defined as the rarest known species in the Commonwealth. They include species with global ranks of G1, G2, and G3, and state ranks of S1, S2, S3, SH, SX, and SU. Data on species with state ranks of S1, S2 (or S2S3), SH, and SX are maintained in the BCD system and summarized annually on a master list of Virginia's rare plants. Species with state ranks of S3 and SU are not tracked using BCD, but maintained on a separate "watchlist." Only general information about watchlist species is recorded in the field and maintained in manual information files.

To initiate the inventory of rare plants within the Polecat Creek watershed, existing data on element occurrences within and near the area to be surveyed were obtained from the BCD database and reviewed. Additional information was gathered from botanical literature and from examination of collections at the following institutions: College of William and Mary, George Mason University, Longwood College, Lynchburg College, National Arboretum, Old Dominion University, University of Richmond, U.S. National Herbarium (Smithsonian Institution), University of North Carolina, Virginia Commonwealth University, and Virginia Polytechnic Institute and State University. This preliminary research indicated that three rare plants were known from the watershed, New Jersey rush (*Juncus caesariensis*), was known from a collection near Coleman's Mill Crossing within the Polecat Creek drainage. Low water-milfoil (*Myriophyllum humile*) was known from Lake Caroline which was briefly surveyed during 1993 by DNH botanists, and dwarf chinquapin oak (*Quercus prinoides*) is known from two sites along the drainage divide near Peatross, this species was not found within the watershed.

Information on the watershed landscape was gathered through examination of aerial photographs, geologic maps, and topographic maps. These sources were examined to delineate the distribution of plant habitats and to identify sites with high potential for rare species occurrences. Data compiled on the area's rare plants, along with information on the distribution of plant habitats, was used to formulate field plans and prioritize field investigations.

In early spring of 1994, DNH botanists met to develop field plans for the coming season. During planning meetings, aerial photographs were re-examined to ensure that those areas most likely to support rare plants were checked. During the field investigations, communication between field botanists, ecologists, zoologists, and CBLAD personnel ensured that new data were shared and that all significant rare plant habitats were investigated.

Botanical field work began in August 1994. Habitat for potential rare plant species within the watershed was surveyed during the appropriate season for the target species. Field botanist Allen J. Belden was responsible for the field work, with considerable contributions also coming from DNH ecologists Gary P. Fleming and William H. Moorhead. Jean Tingler, Polecat Creek project coordinator, provided much logistical assistance and contributed to some of the survey work.

During the botanical investigation, field data were recorded during each site survey and were coordinated with data collected from the same site by ecologists and zoologists. These data included the site location, directions, and a site description, as well as comments on land use, potential hazards, exotic flora and fauna, and off-site considerations. When rare plant occurrences were located, additional data were recorded, including the date(s) when the species was found, population boundaries and concentrations within those boundaries, approximate number of individuals, reproductive and phenological status, and species viability. Habitat factors such as moisture, light, and associated species, as well as any apparent immediate or long-term threats to the rare species population were also noted. Photographs were taken or voucher specimens were collected to verify the identity of all rare species, and each occurrence was ranked on the basis of all available data.

ZOOLOGICAL INVENTORY

For the purposes of this study, rare animals are defined as the rarest known species in the Commonwealth. They include species with global ranks of G1, G2, and G3, and state ranks of S1, S2, S3, SH, SX, and SU. Data on species with state ranks of S1, S2 (or S2S3), SH, and SX are maintained in the BCD system and summarized annually on a master list of Virginia's rare animals. Most species with state ranks of S3 and SU are not tracked using BCD, but maintained on a separate "watchlist." Only general information about watchlist species is recorded in the field and maintained in manual information files.

To initiate inventory of rare animals at Polecat Creek, existing data on element occurrences within and near the installation were obtained from the BCD database and reviewed. Additional information was gathered from zoological literature and from examination of selected collections at the following institutions: U.S. Museum of Natural History, the Carnegie Museum of Natural History, Lord Fairfax Community College, Eastern Mennonite College, Old Dominion University, Virginia Polytechnic Institute and State University, Virginia Commonwealth University, and the Virginia Museum of Natural History.

This preliminary research indicated that no rare animal occurrences were known from the Polecat Creek drainage. However, surveys conducted at Fort A.P. Hill, in Caroline County during 1992, 1993, and 1994 revealed several rare odonates (dragonflies and damselflies), one rare crustacean, and two amphibian species which could potentially occur within the drainage. Also, a number of DNH watchlist species are known from the vicinity of Polecat Creek including the carpenter frog (*Rana virgatipes*), rainbow snake (*Farancia erytrogramma*), mud sunfish (*Acantharcus pomotis*), American brook lamprey (*Lampetra appendix*) and several odonate species.

During the spring of 1994, aerial photographs and various map sources were consulted to determine the extent of potential rare animal habitats. Subsequently, a field plan, based on all of the available preliminary information, was developed to direct investigation of potential rare species habitats for all animal groups.

Field work was initiated in May, 1994 and continued through March, 1995. These investigations, which covered birds, mammals, amphibians, reptiles, fish, mussels, odonates (dragonflies and damselflies), butterflies, and other invertebrates, required repeated visits to several sites and potential habitats at different seasons. DNH zoologists Christopher S. Hobson, Dirk J. Stevenson, and Steven M. Roble were responsible for the work. Jean Tingler (CBLAD), Polecat Creek project coordinator, provided much logistical assistance and contributed to the survey work.

A variety of inventory and sampling methods were employed by the team's zoologists:

Sweep nets - lepidopterans, odonates, tiger beetles, and other flying invertebrates were sampled in terrestrial and aquatic habitats using sweep nets.

Dip nets - amphibians, fish, aquatic reptiles, and aquatic invertebrates were sampled using dip nets.

Hand collection - reptiles and amphibians, as well as some invertebrates, were collected by hand. Transects were walked through terrestrial habitats, where various cover objects were overturned in search of cryptic species.

Minnow traps - small fish, aquatic amphibians and reptiles, and aquatic invertebrates were sampled with minnow traps. Minnow traps were standard two-piece, dual-funnel, cage-type traps with small mesh.

Aquascope - mussel surveys were conducted using aquascopes made of 5-gallon buckets with see-through bottoms; these were used to see below the surface in riffle areas and deep or murky water. Mussels were removed from the substrate for identification and subsequently returned to the substrate in proper orientation. Shell material was collected by hand from muskrat middens, sand bars, and the stream bed when appropriate. Further information concerning mussel survey methods is provided in the accompanying mark-recapture project report.

Transects - transects were surveyed in various terrestrial and aquatic habitats for rare lepidopterans and odonates.

As in the botanical inventory, complete data were recorded for each site surveyed and additional data were recorded when rare animal occurrences were located. In cases where these sites were also visited by botanists and ecologists, the data were coordinated. All occurrences were ranked on the basis of available field data.

COMMUNITY INVENTORY

The need to protect rare species is generally well understood and appreciated, but the need to protect indigenous biotic communities sometimes requires explanation. Community classification, inventory, and protection should be regarded as an essential complement to rare species inventories. Communities represent functioning units of the landscape which:

1. support myriad life forms too cryptic or poorly known to be catalogued and prioritized individually;

2. provide the nurturing environment for both rare and common species;

3. contribute to the maintenance of larger ecosystems; and

4. possess unique intrinsic scientific, educational, and aesthetic values.

It is therefore important to locate, classify, and evaluate these communities as part of any comprehensive inventory of natural heritage resources.

For purposes of this study, significant communities are defined to include both outstanding examples of common community types (e.g. old-growth mixed hardwood forest) and all examples of rare community types (e.g. certain seepage-influenced, fire-maintained wetlands). Refer to Appendix A for the preliminary DNH classification of indigenous biotic communities.

Data collection began in early 1994 with a review of BCD database information and scientific literature. No existing information was available on natural communities of the Polecat Creek area, and rare species locations, which often indicate significant community occurrences, were also lacking. Therefore, staff ecologists relied heavily on aerial photographs, topographic maps, geologic maps, and soil surveys to identify potential sites for significant communities.

No previously documented significant communities were identified by this preliminary research, but large, tracts of bottomland forest and floodplain wetlands proved to be of interest.

Ecological field work began in August, 1994 and continued through March, 1995. During this period, sampling of high potential habitats was carried out in potentially significant areas of the watershed. As field work progressed and additional information became available, priorities and field plans were adjusted to ensure that all potential exemplary natural communities were surveyed.

Close communication was maintained with botanists and zoologists working on the project, and concurrent multidisciplinary investigation of highly significant sites was frequently arranged. Ecologist William H. Moorhead was responsible for most of the work, with contributions by field ecologist Gary P. Fleming and other DNH staff members. During the course of investigations, Jean Tingler of CBLAD provided additional community leads, helpful information on the land use history of potential sites, assistance with landowner contacts, and assistance in the field.

Complete standard information was collected from each site visited by ecologists and was coordinated with data collected by botanists and zoologists when necessary. When significant communities were located, additional data were collected on occurrence size, condition, boundaries, biotic and abiotic factors, floristics, evidence of disturbance, successional trends, and immediate or long-term threats. Community occurrences were ranked primarily by their quality and size.

INVENTORY RESULTS

The results of the field inventory (Section I) are presented in the following pages of this report. In part IV, site reports and maps for three areas determined to be conservation-worthy natural areas are presented. In part V, the overall findings of this inventory are summarized, and in part VI, preliminary protection and management recommendations are summarized.

As a result of this inventory, our knowledge of the fauna, flora and natural communities within the Polecat Creek watershed and surrounding areas has been increased significantly. Several new element occurrences were documented within the watershed including three animals, one plant, and one natural community as well as several watchlist species (Appendix B). The scope of this project gave insight into the overall character of the watershed; unfortunately, some of the best habitats, especially those with potential for swamp pink, were not accessible during the study period. Further survey within the

watershed is warranted to obtain a more thorough understanding of the potential and existing natural heritage resources.

IV. SITE REPORTS

INTRODUCTION TO THE SITE REPORTS

To facilitate management and enhance protection of biodiversity within the Polecat Creek drainage, boundaries have been provided for landscape units which merit practical and justifiable recommendation as conservation sites. A conservation site is a natural area that includes one or more element occurrences and has been assigned a biodiversity rank of at least B5. Reports follow for three conservation sites identified during the natural heritage resource inventory. The following standard reporting format is used for each conservation site identified within the survey area.

SITE NAME: Site names typically reflect a geographic locality and, in some cases, a prevalent landscape feature.

SIZE: The approximate acreage within the conservation planning boundary, as determined by planimeter, is given.

BIODIVERSITY RANK: The overall significance of the natural area, in terms of the rarity of natural heritage resources and the quality of their occurrences, is indicated. As described on page 4, these ranks range from B1 (very high significance) to B5 (general biodiversity significance).

LOCALITY: The county (or counties) containing the site is listed. All sites within the Polecat Creek drainage are in Caroline County.

QUADRANGLE: The name of the USGS 7.5' quadrangle map(s) that includes the site is listed.

QUADRANGLE CODE: The code used by DNH for the quadrangle is listed. The first five digits of the code represent latitude and longitude (in degrees) of the quadrangle.

LOCATION: Location of the site within the drainage and distance from some geographic landmark is given.

NATURAL HERITAGE RESOURCE SUMMARY TABLE: This field provides a synopsis of the natural heritage resources (rare species and significant communities), together with their status ranks (global, state, USFWS and Virginia legal) and element occurrence ranks.

SITE DESCRIPTION: A brief narrative describing the site, its significant elements, vegetation, habitat, and current land use is presented. The first reference to a species in a narrative is by scientific name, followed by common name in parentheses. Subsequent references to the same species are by common name only.

BOUNDARY JUSTIFICATION: The preliminary conservation planning boundary delineated in this report contains all known occurrences of natural heritage resources and adjacent lands required for their immediate protection. This information field explains the basis for the specific site boundaries.

THREATS: Threats to the site and its natural heritage resources are described. These may include both real, imminent threats and potential threats posed by types of land use activities or other factors that currently are not impacting the site.

MANAGEMENT RECOMMENDATIONS: This field is a summary of the major issues and factors that should be considered in management of the site for its biodiversity and natural heritage resource values. As a rule, generalized recommendations are provided based on potential threats identified during the survey work. The expertise of inventory biologists familiar with each site, as well as input from DNH natural areas program biologists has been utilized in preparing these recommendations. However, within the context of a relatively short-term (one year) inventory effort on large sites, it may be difficult to identify highly specific management strategies. In addition, the management needs of some natural heritage elements are so obscure that additional study by experts may be needed. In many cases, monitoring of natural heritage elements or site factors is recommended to determine the best long-term management practices. In all cases, if land use changes or specific high-impact actions are proposed within a site's boundary, consultation with DNH staff is recommended to assess impacts on the natural heritage resources.

PROTECTION RECOMMENDATIONS: A summary of the actions and priority needed to ensure long-term protection of the site and its elements is provided.

REFERENCES: Pertinent literature and sources cited within the site report are listed.

SITE MAP: The site map, drawn on a copy of the USGS 7.5' quad(s), shows the preliminary conservation planning boundary which contains all known element occurrences and the land determined to be important for long-term maintenance of the elements. The following factors are considered when drawing these boundaries:

- the extent of current and potential habitat for rare species and exemplary natural communities;

- species movement and migration corridors;

- maintenance of surface water quality within the site and the surrounding watershed;

- maintenance of the hydrologic integrity of groundwater resources;

- land intended to mitigate a wide variety of off-site impacts;

- land or activities necessary to preclude or minimize exotic species; and

- land necessary for management activities, e.g. prescribed burning.

The boundaries are intended for conservation planning purposes and, at the very least, should prevent inadvertent damage to the natural areas.

ELEMENT LOCATION MAPS: Maps showing the exact location of each element occurrence within a site are included following the Site Map. In the case of animal elements, which are often highly mobile organisms, the maps indicate where actual collections were made and/or specimens were observed. These location maps are intended to provide resource managers, and landowners with requisite site-specific information. However, since rare species are often sensitive to disturbance or may be sought out by collectors, we strongly recommend that this information not be shared with the general public or with persons not directly involved in the stewardship of these sites.

COLEMAN'S MILL BOG

SIZE: ca. 14.2 acres **BIODIVERSITY RANK:** B3

LOCALITY: Caroline County

QUADRANGLE: Ruther Glen **QUADRANGLE CODE:** 3707784

LOCATION: Acidic hillside seepages along a powerline right of way at the crossing of two unnamed tributaries of Polecat Creek, from 0.6 to 1.0 miles ESE of Coleman's Mill Crossing.

NATURAL HERITAGE RESOURCES SUMMARY TABLE

ELEMENT NAME	GLOBAL RARITY RANK	STATE RARITY RANK	USFWS STATUS	VA LEGAL STATUS	ELEMENT OCCURRENCE RANK
Plants:					
Juncus caesariensis New Jersey rush	G2	S2	C2	C	C
Sarracenia purpurea Northern pitcher-plant	G5	S2S3			BC
Animals:					
Argia bipunctulata seepage dancer	G4	S2S3			C

SITE DESCRIPTION: This site encompasses two small acidic hillside seepages near the head of an unnamed tributary of Polecat Creek. Crossing the seeps is a powerline right of way, which appears to be kept open by periodic bushhogging. Slopes within the site boundary have gentle to moderately steep inclinations. The substrate at this site ranges from sand to sandy muck.

Areas along the powerline right of way appear to be bushhogged on a rotational basis with more recently or thoroughly cut areas being dominated by light demanding herbs such as twisted yellow-eyed-grass (*Xyris torta*), tall nutrush (*Scleria triglomerata*), Canadian St. John's-wort (*Hypericum canadense*), Maryland meadow-beauty (*Rhexia mariana*), Virginia meadow-beauty (*R. virginica*), brownish beakrush (*Rhynchospora capitellata*), slender beakrush (*R. gracilenta*), bushy bluestem (*Andropogon glomerata*), hairy umbrella-sedge (*Fuirena squarrosa*), and southern bog clubmoss (*Lycopodiella appressa*). Those areas not recently cut or left uncut are dominated by woody species, including red maple (*Acer rubrum*), sweet-bay magnolia (*Magnolia virginiana*), sweet pepper-bush (*Clethra alnifolia*), and withe-rod (*Viburnum nudum*). Other rushes (*Juncus spp.*) which could be confused with *J. caesariensis* are present at this site, most notably Canada rush (*J. canadensis*) which is very similar morphologically. Mosses (*Sphagnum sp.*) and greenbriar (*Smilax sp.*) are also common at this site. Three watchlist plants were also

recorded from this area including thyme-leaf pinweed (*Lechea minor*), hairy pinweed (*Lechea mucronata*), and wild ipecac (*Euphorbia ipecacuanhae*).

Approximately 250-300 fertile ramets of New Jersey rush were seen in a ca. 6 x 30 m area. Fertile ramets were in bud, flower or early fruit. Many of the plants appeared to be quite small, possibly as a result of bushhogging earlier in the growing season. Two subpopulations of the northern pitcher plant were noted in the two adjacent seepage areas within the site. The northernmost subpopulation contained greater than 100 clumps within a ca. 0.5 acre area, including numerous ramets in flower or fruit. The southernmost subpopulation contains greater than 50 clumps within a ca. 6 x 12 m area, and only one flowering/fruiting ramet was seen.

Open sphagnous areas and wet depressions caused by the collection of water in natural depressions and on occasion tire tracks serve as breeding habitat for the state-rare seepage dancer (*Argia bipunctulata*). As many as 20 of these animals were seen during several site visits in 1994. This brightly colored yet inconspicuous damselfly is closely associated with open acidic seepage habitats and bogs usually with abundant sphagnum, thus it has a highly localized distribution throughout its range. Individuals of this species generally feed and travel among emergent vegetation and typically perch on vertical stems within open habitats (Dunkle, 1990). This species is known from several other acidic seepage habitats within Caroline County, Virginia.

BOUNDARY JUSTIFICATION: The boundary (Fig. 3) includes the catchment basin contributing to and including the acidic seepage habitats and a small downstream buffer. Open habitats containing both rare plant species and breeding habitat for the rare damselfly are included within the boundary.

THREATS: Threats to the long-term survival of the rare plant and animal species at this site include alteration of the local hydrology, possibly timber harvest directly upstream of the site (possibly contributing to siltation), and direct impacts to the wetlands from ditching, filling, and off-road vehicle use. Excessive flooding due to the accumulation of rocks, culverts or other such materials at vehicular stream crossings may negatively impact the rare species at this site. Both rare plant species are light demanding and require open habitats, and thus may be threatened by succession of woody vegetation and subsequent canopy closure.

MANAGEMENT RECOMMENDATIONS: Prescribed burning is the preferred method for maintaining the open character of this site and reducing competition from woody species, and should be carried out during the early growing season on a 2-3 year rotational basis. Alternative methods to prescribed burning include manual removal of vegetation, bushhogging, and herbicide applied directly to woody plant species. Herbicides should not be used in a generalized application at this site. Bushhogging should be done prior to the growing season to reduce negative impacts to the New Jersey rush and northern pitcher plant populations. A long-term monitoring plan should be implemented at this site including pre- and post-treatment census of rare plant populations.

If land use (particularly hydrological) or management practices change within the site boundary, consult with DNH staff to avoid negative impacts to the natural heritage resources. Periodic censusing of the rare odonate population at the site is recommended.

PROTECTION RECOMMENDATIONS: This site merits a high level of protection because of the presence of a globally rare federal candidate species and two state-rare species. Protection measures should include implementation of management recommendations and contacting landowners and land

managers within and adjacent to the site to educate them and work cooperatively toward a successful long-term management plan for the site.

REFERENCES:

Dunkle, Sidney W. 1990. Damselflies of Florida, Bermuda, and the Bahamas. Gainesville, Fla. - Washington, D.C.: Scientific Publishers.

Ware, Donna M.E. 1991. New Jersey Rush (*Juncus caesariensis*). pp. 85-86 in McDonald, J.N. and T. Skware, editors. Virginia's Endangered Species: Proceedings of a Symposium/coordinated by Karen Terwilliger. Blacksburg, Va.: The McDonald and Woodward Publishing Company.

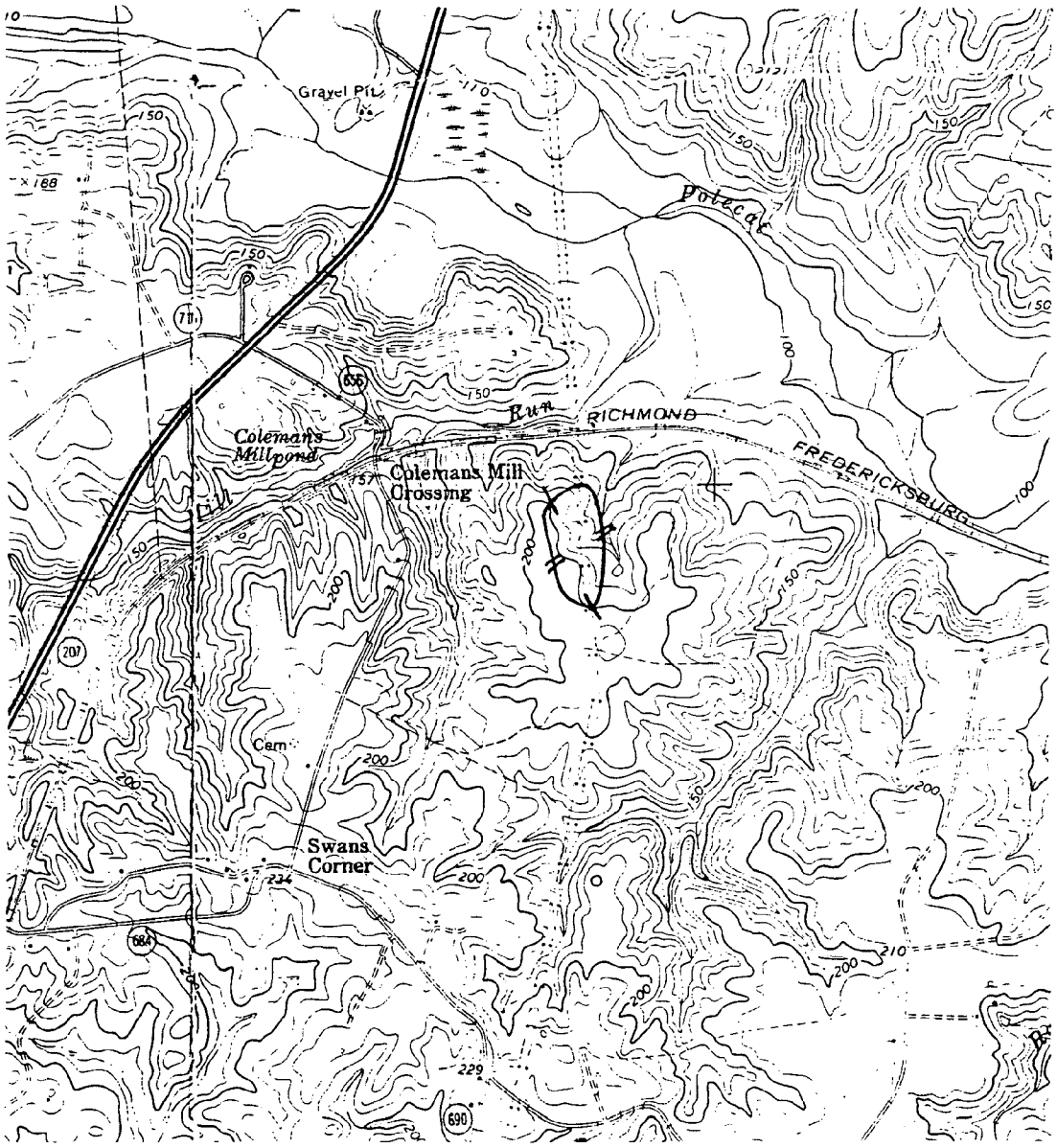


Figure 3. Coleman's Mill Bog
Conservation Planning Boundary
Ruther Glen USGS 7.5' Quad

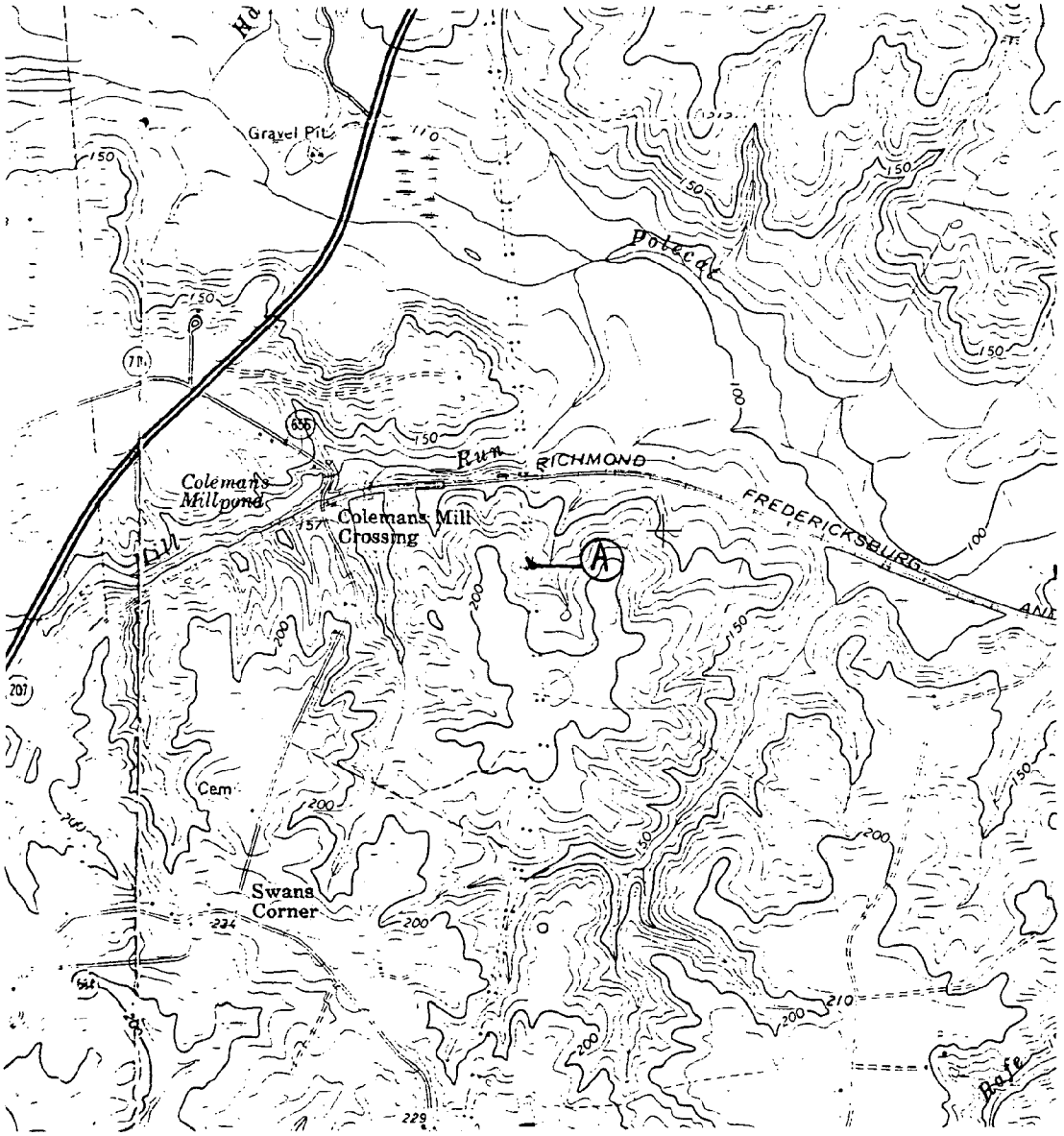


Figure 4. Coleman's Mill Bog
Location of *Juncus caesariensis*
Ruther Glen USGS 7.5' Quad
1 km

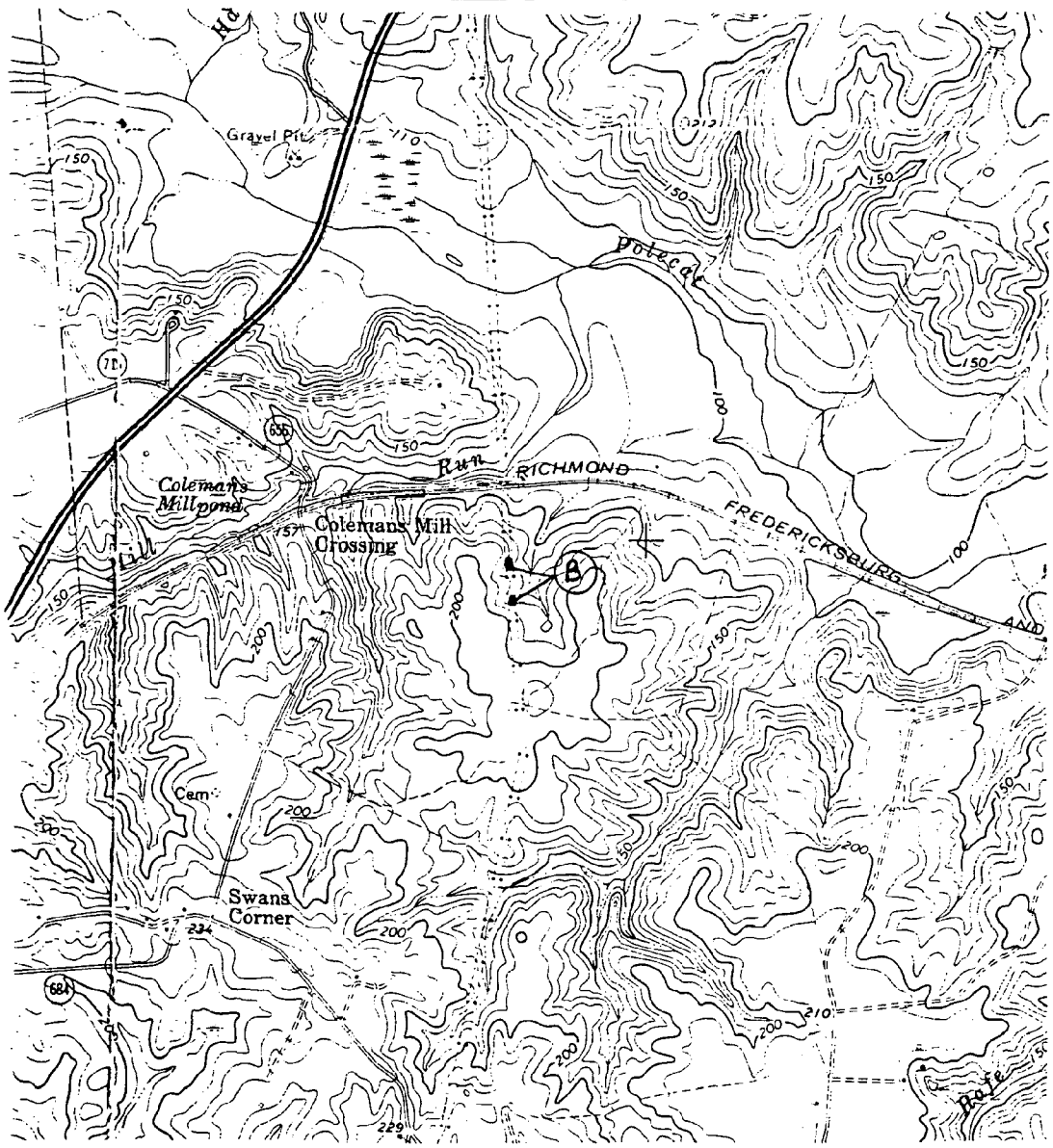


Figure 5. Coleman's Mill Bog
Location of *Sarracenia purpurea*
Ruther Glen USGS 7.5' Quad

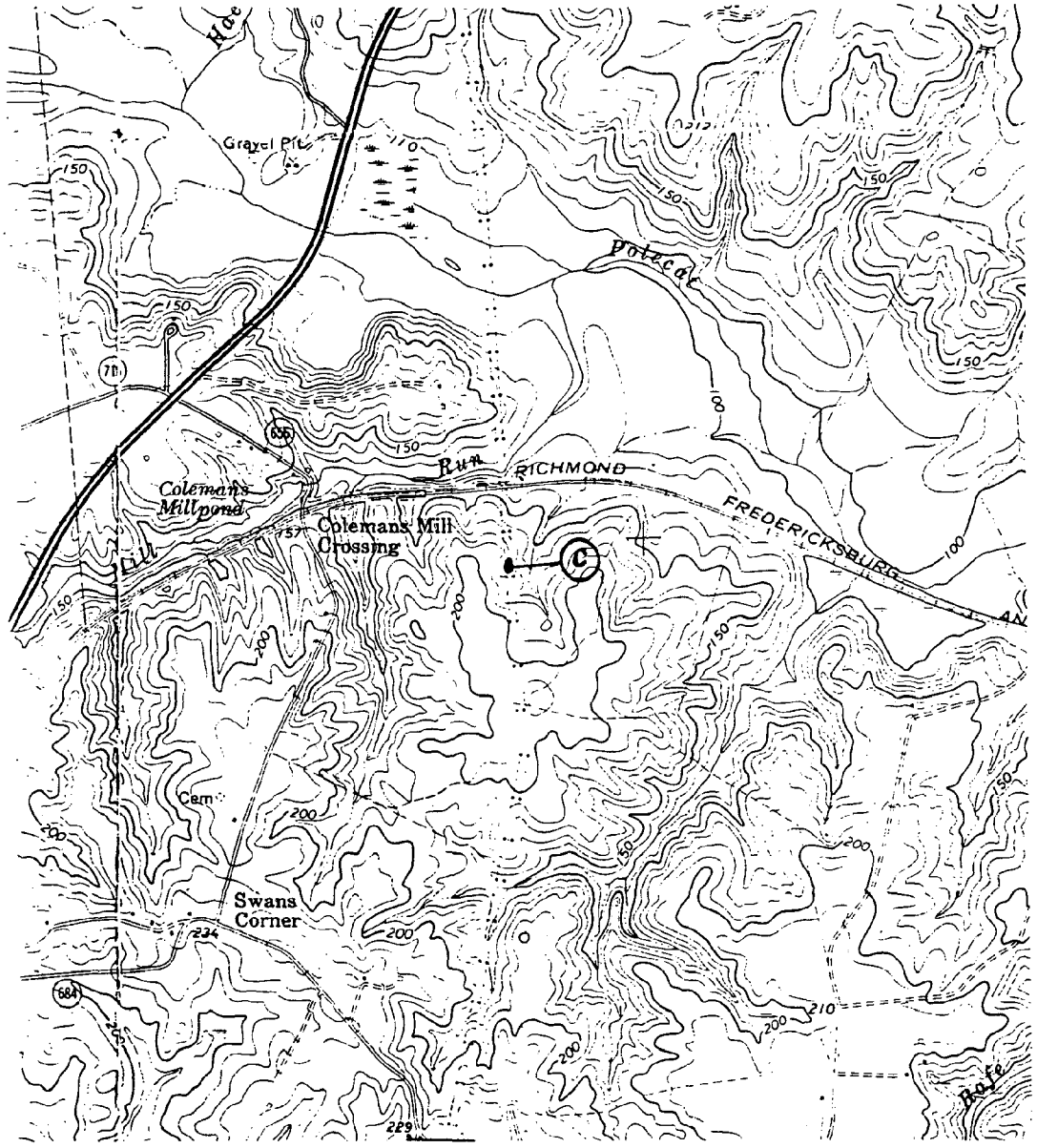


Figure 6. Coleman's Mill Bog
Location of *Argia bipunctulata*
Ruther Glen USGS 7.5' Quad

LOWER POLECAT CREEK

SIZE: ca. 32 acres **BIODIVERSITY RANK: B5**

LOCALITY: Caroline County

QUADRANGLE: Penola **QUADRANGLE CODE:** 3707783

LOCATION: Portion of Polecat Creek and adjacent bottomland and upland forest along the north bank, west and east of the Route 301 bridge. The area is approximately 2.5 km ESE of Penola.

ELEMENT NAME	GLOBAL RARITY RANK	STATE RARITY RANK	USFWS STATUS	VA LEGAL STATUS	ELEMENT OCCURRENCE RANK
Eutrophic seasonally flooded forest					CD

SITE DESCRIPTION: This site encompasses a section of bottomland along Polecat Creek, which supports a significant stand of mature basket oak-sweet gum (Quercus michauxii-Liquidambar styraciflua) forest, classified as eutrophic seasonally flooded forest. The significance of the stand is in its maturity, and the size of the canopy trees: 2.5 to 3 feet diameter, and many 100-120 feet tall. Generally in Virginia's Coastal Plain, few other bottomland sites have escaped both logging and beaver disturbance long enough to develop 150+ year old near-climax condition forest of the type found at this site. Other tree species within the stand include sycamore (*Platanus occidentalis*) and willow oak (*Quercus phellos*). Dominant species in the understory are red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), river birch (*Betula nigra*), American holly (*Ilex opaca*), and American hornbeam (*Carpinus caroliniana*). Herbaceous species in the stand include greater bladder sedge (*Carex intumescens*), wood-reed (*Cinna arundinacea*), starved aster (*Aster lateriflorus*), and Japanese honeysuckle (*Lonicera japonica*).

BOUNDARY JUSTIFICATION: Primary and secondary boundaries include adjacent bottomland corridor and a 100 foot buffer to protect the hydrologic regime associated with the community, and give some protection from wind damage. Recommended protection boundaries for this site are shown in Figure 7.

THREATS: Logging within or around the site boundary is considered the primary threat to the quality of this community. However, water quality and maintaining the current hydrological regime within the site should also be considered. Beavers are active within this portion of Polecat Creek and their expansion into this site should be considered a threat to the integrity of this community.

MANAGEMENT RECOMMENDATIONS: Work with landowners to develop a management plan which provides for the maintenance of this site, and protection of the exemplary natural community. Avoid timber harvest, and monitor the condition of the community periodically. Continue water quality monitoring within the drainage. Monitor beaver activity in the vicinity of this site and implement control measures if necessary.

PROTECTION RECOMMENDATIONS: This site warrants protection because of the exemplary stand of near-climax condition forest classified as eutrophic seasonally flooded forest. Work with landowners to avoid timber harvest or degradation of the site.

REFERENCES:

Hammerson, Geoffrey A. 1994. Beaver (Castor canadensis): Ecosystem Alterations, Management, and Monitoring. pp. 44-57 in Natural Areas Journal, Vol. 14, No.1. Natural Areas Association, Rockford, Illinois.

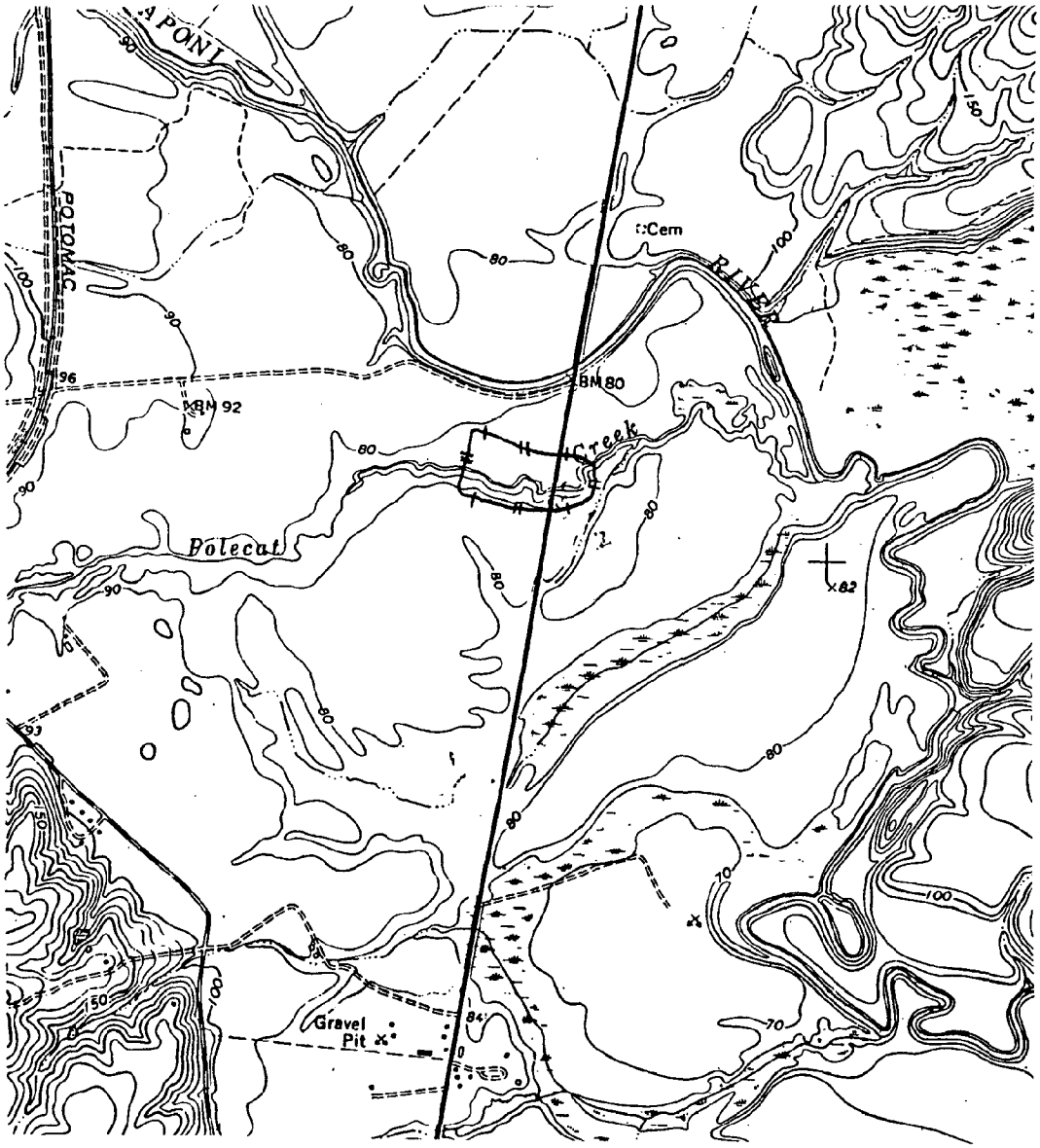


Figure 7. Lower Polecat Creek
Conservation Planning Boundary
Penola USGS 7.5' Quad

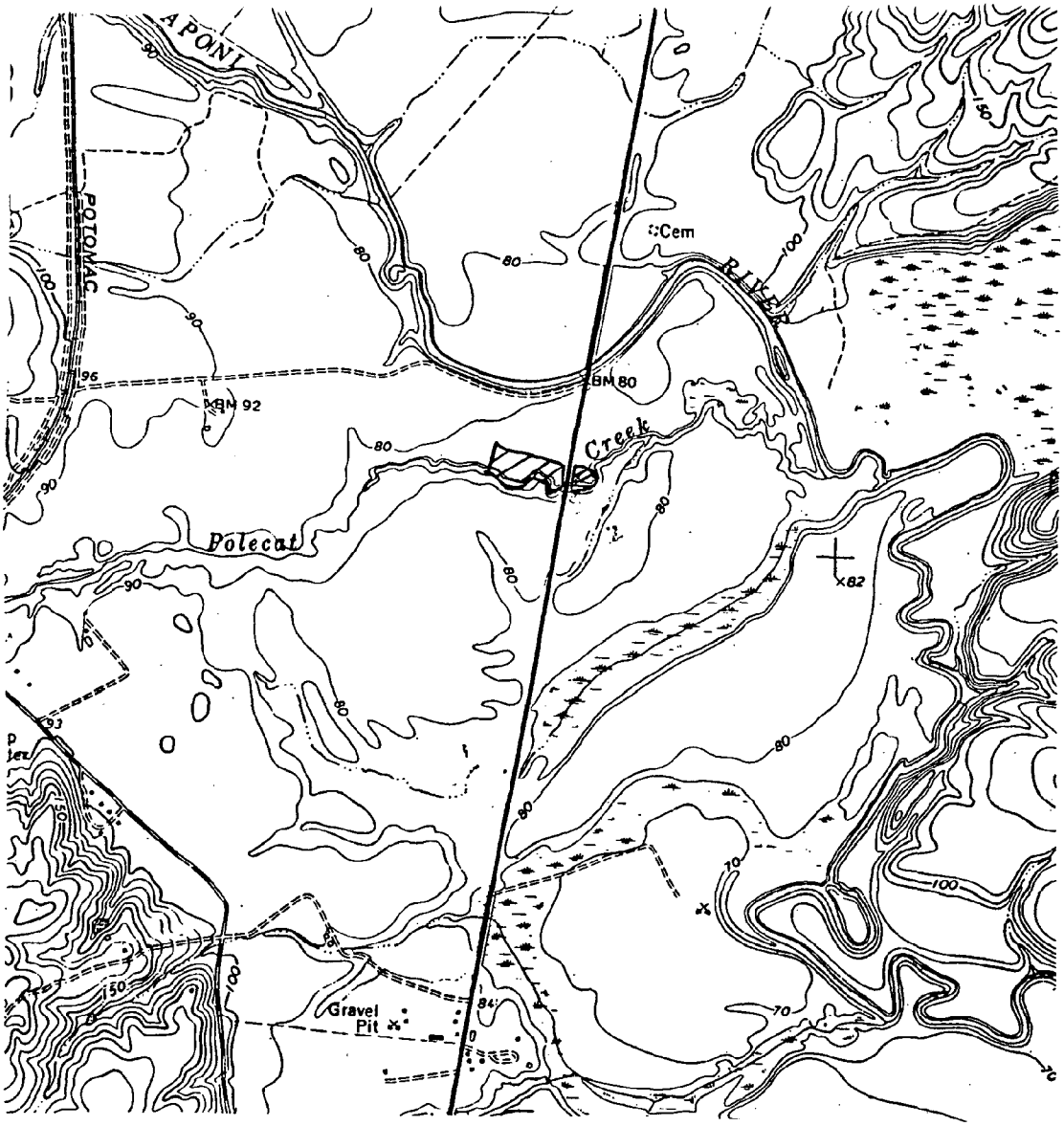


Figure 8. Lower Polecat Creek
Location of Eutrophic Seasonally Flooded Forest
Penola USGS 7.5' Quad

PENOLA BOTTOMLAND

SIZE: ca. 38 acres **BIODIVERSITY RANK:** B5

LOCALITY: Caroline County

QUADRANGLE: Penola **QUADRANGLE CODE:** 3707783

LOCATION: Approximately 0.4 to 1.0 km SSW to WSW of Penola along Polecat Creek. Site begins upstream of county route 601 bridge and extends downstream of the bridge approximately 0.4 km

NATURAL HERITAGE RESOURCES SUMMARY TABLE

ELEMENT NAME	GLOBAL RARITY RANK	STATE RARITY RANK	USFWS STATUS	VA LEGAL STATUS	ELEMENT OCCURRENCE RANK
ANIMALS:					
Macromia illinoiensis georgina Georgia river cruiser	G5T5	S2			C
Somatochlora filosa fine-lined emerald	G5	S2			C

SITE DESCRIPTION: The site consists of a portion of Polecat Creek east and west of the Route 601 bridge near Penola, Virginia. Much of the area is second or third growth bottomland forest with some older, more mature trees scattered throughout. Backwaters and flooded forested depressions were encountered primarily on the south side of the creek within the site. Emergent vegetation was abundant in backwaters and open stretches of the creek in the downstream portion of the site. Substrate within the site consists of sand and sandy mud, and the creek bed was primarily sand with detritus accumulations and slower moving sections holding a mucky substrate. Uplands bordering the site have canopy dominants of river birch (*Betula nigra*), sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and green ash (*Fraxinus pennsylvanica*) with some scattered loblolly pine (*Pinus taeda*) and Virginia pine (*Pinus virginiana*). Catbriar (*Smilax rotundifolia*) was noted as an important component of the shrub layer, while wood-reed (*Cinna arundinacea*) and sedges in the genus *Carex* were dominant in the herbaceous layer.

BOUNDARY JUSTIFICATION: Primary and secondary boundaries include a portion of bottomland and adjacent upland habitat downstream of the Route 601 bridge, and a small portion of bottomland upstream of the bridge. This boundary includes a recommended buffer zone to protect water quality and maintain current habitat within the site. Figure 9 shows the recommended conservation boundary for this site.

THREATS: Disturbance of the hydrologic regime within or surrounding the site may have negative impacts on natural heritage resources. Beaver populations within the drainage may alter the hydrology of the area, significantly impacting aquatic habitats used by rare odonates present at this site. Water quality is considered the most important factor in maintaining populations of rare odonates within the site.

Although not currently a threat within the Polecat Creek drainage, the spread of the gypsy moth (*Lymantria dispar*) and consequent use of pesticides containing chitin inhibitors (notably Dimilin) may pose a threat to the long-term survival of these species.

MANAGEMENT RECOMMENDATIONS: Periodic census of the odonate populations at this site is recommended to determine status and abundance. Monitor beaver activities within the area and implement control measures if necessary. Continue to monitor water quality in Polecat Creek and work with landowners to ensure maintenance of the forest cover and hydrologic regime within the site. If the gypsy moth becomes a factor in the drainage, the use of Dimilin should be discouraged within or upstream of the site.

PROTECTION RECOMMENDATIONS: Work with landowners to secure protection for the species at this site and develop a long term management plan which will ensure the species' survival. Implement management recommendations noted above, and consult with DNH regarding changes in land use or management practices.

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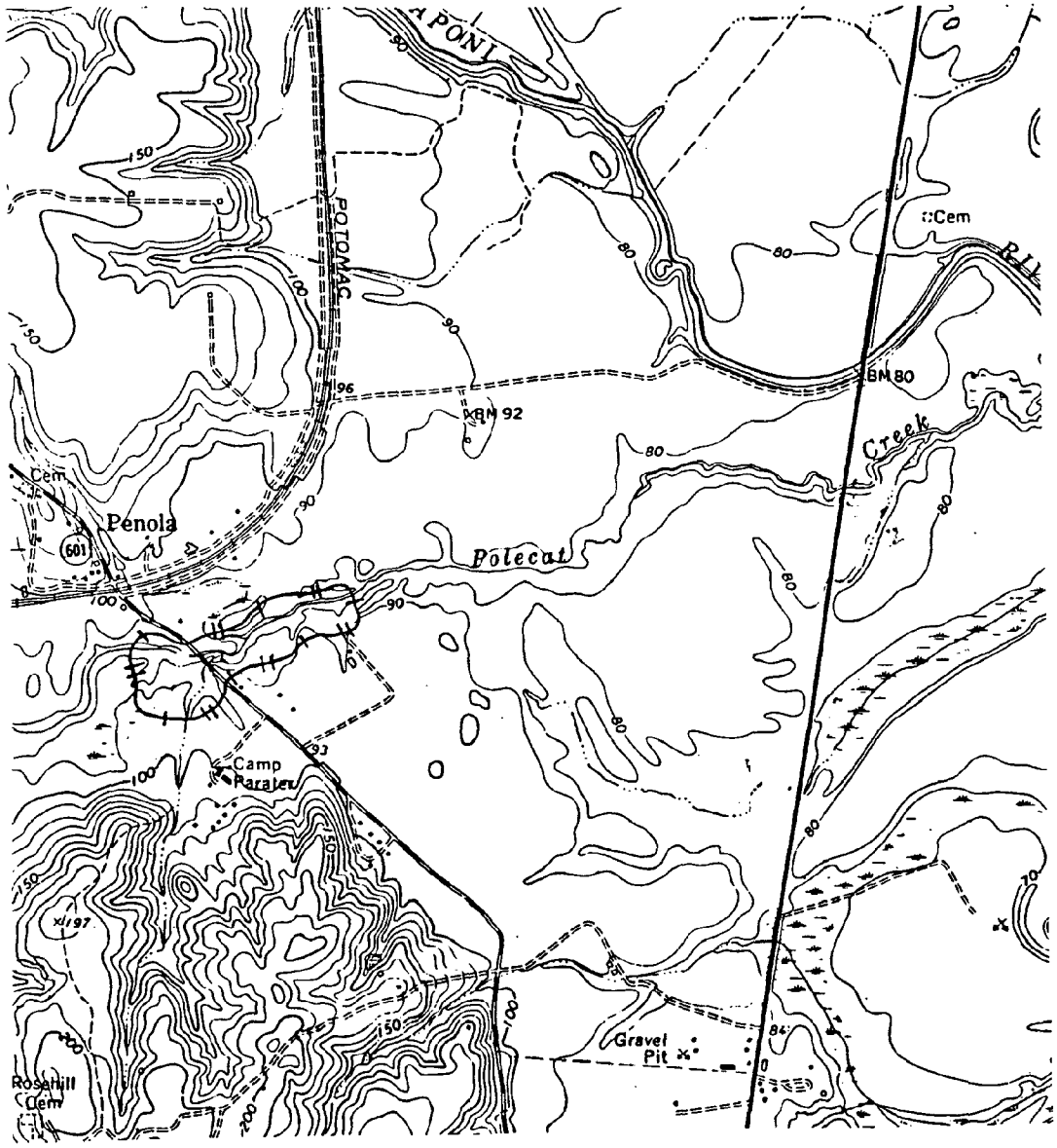

Figure 9. Penola bottomland
Conservation Planning Boundary
Penola USGS 7.5' Quad

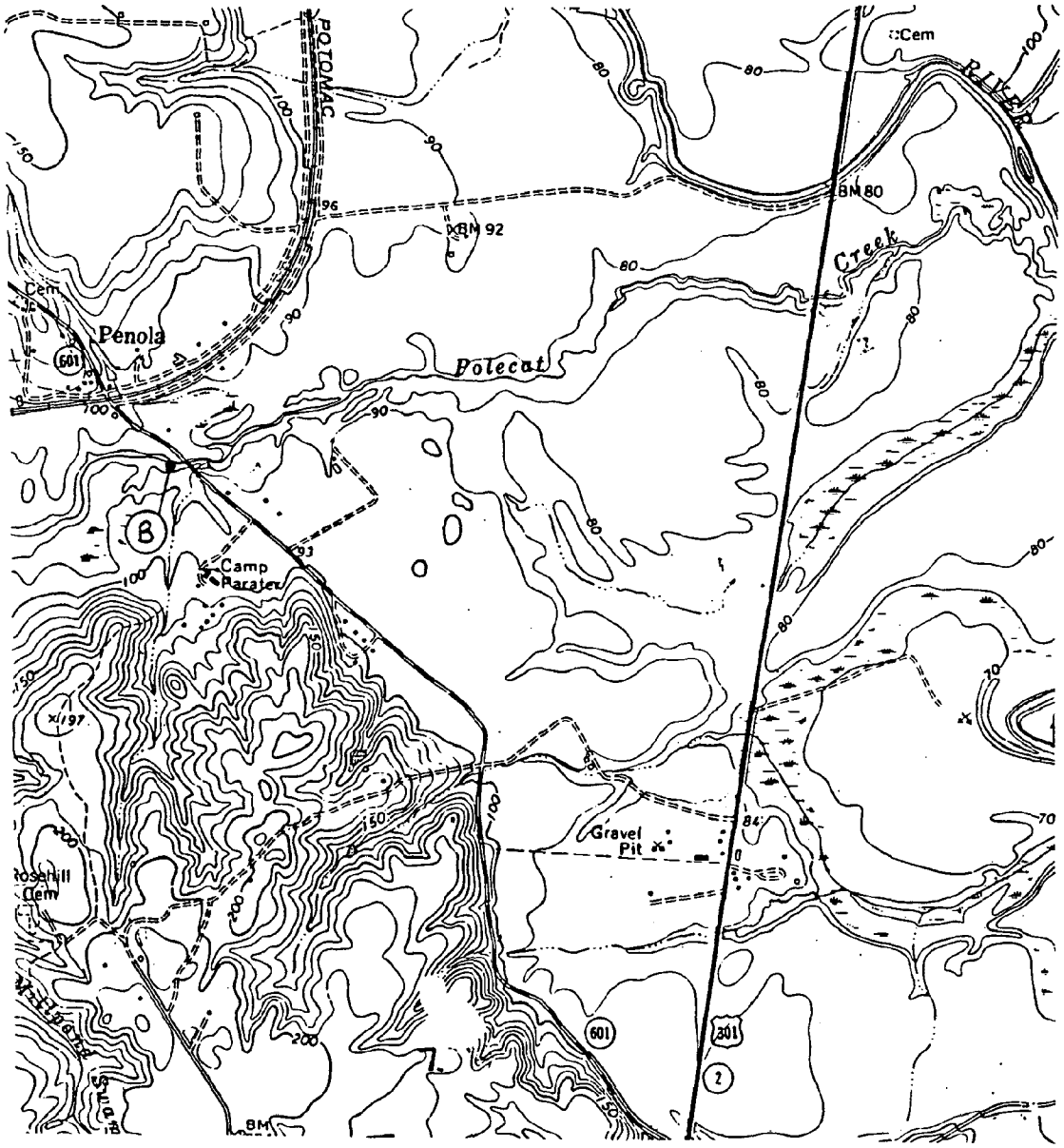

Figure 10. Penola bottomland
Location of *Macromia illinoiensis georgina*
Penola USGS 7.5' Quad

1 Km

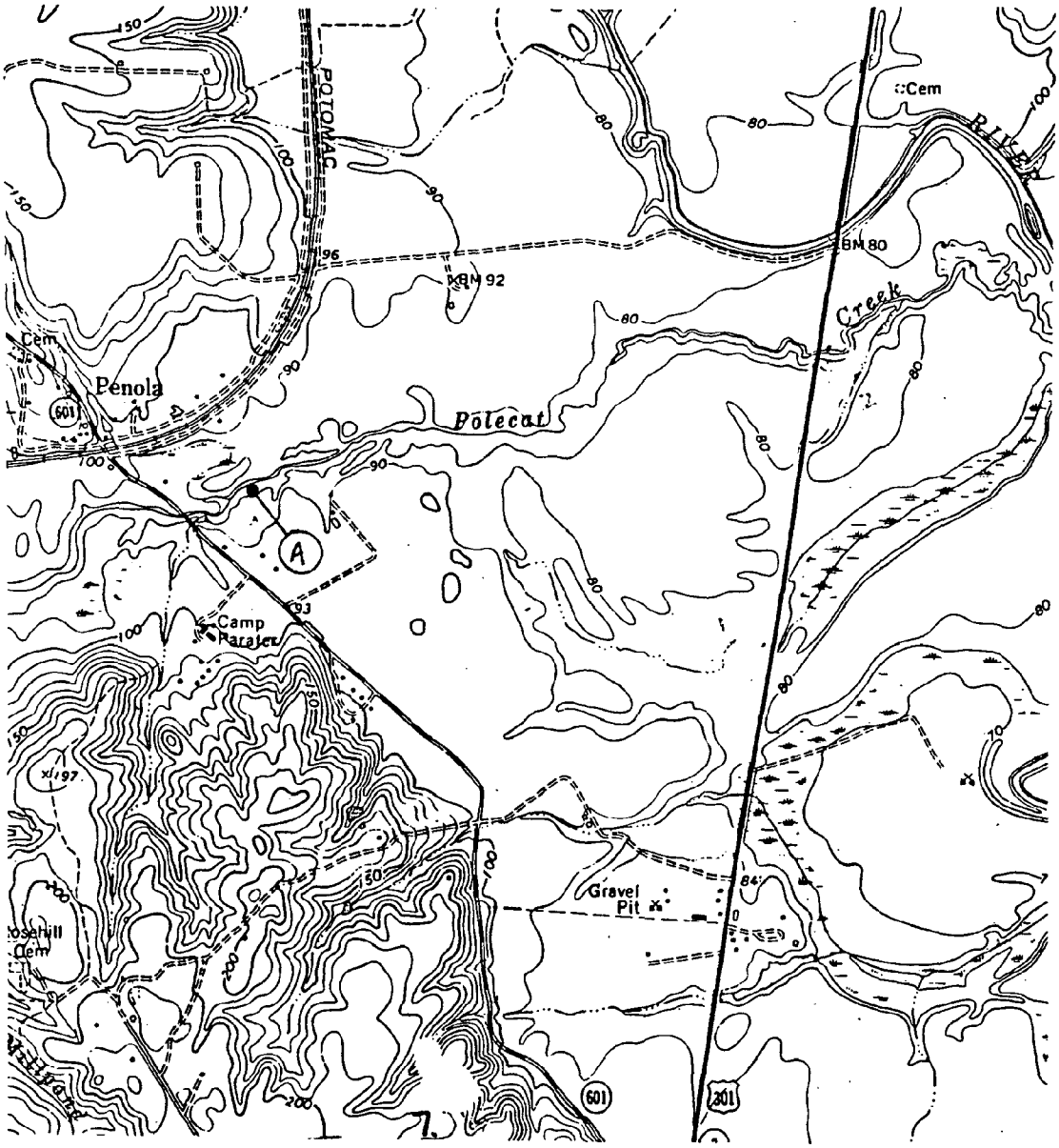

Figure 11. Penola bottomland
Location of *Somatochlora filosa*
Penola USGS 7.5' Quad

V. SUMMARY OF FINDINGS

A total of six element occurrences were found within the Polecat Creek drainage in the course of the Natural Heritage Inventory. These included one globally rare plant, a state rare plant, three state rare odonates (dragonflies and damselflies), and one natural community. A historic occurrence of low water-milfoil (*Myriophyllum humile*) is known from Lake Caroline. The lake was briefly surveyed in 1993, and is currently thought to be too eutrophic to support a population of this species. However, this species could potentially occur as a remnant population in areas of the lake which have not been heavily eutrophied (e.g. stream input areas). Dwarf chinquapin oak (Quercus prinoides) is known from the drainage divide near Petross, but was not encountered in those areas surveyed in 1994 and 1995.

As a result of the Natural Heritage Inventory of the Polecat Creek drainage, three conservation sites were proposed to protect the rare species and significant communities within them. Two rare plants (Juncus caesariensis, Sarracenia purpurea) and one rare odonate (*Argia bipunctulata*) were documented at the Coleman's Mill Bog Conservation Site. Two rare odonates (*Macromia illinoiensis georgina, Somatochlora filosa*) were documented from the Penola Bottomland Conservation Site. One exemplary natural community (eutrophic seasonally flooded forest) was documented at the Lower Polecat Creek conservation site.

In addition, several watchlist species were recorded from various areas within the Polecat Creek watershed. Appendix B summarizes watchlist species found during this inventory.

VI. SUMMARY OF PROTECTION AND MANAGEMENT RECOMMENDATIONS

Six natural heritage element occurrences were documented within the Polecat Creek watershed. For the most part, the protection and management activities required to maintain the viability of these occurrences should have little significant impact on the overall land use within the watershed. Through careful planning and early consultation with DNH staff when specific actions are proposed, most potential conflicts can be avoided or resolved.

Potential threats to element occurrences, along with site-specific protection and management recommendations, are detailed for each of the three conservation sites described in this report. The conservation planning boundary drawn for each site should alert resource managers, landowners and planning agencies to the need for special planning when certain types of potentially threatening actions are proposed within these areas. Additional management activities needed to control biotic threats (e.g. beavers, gypsy moth) or to maintain habitat conditions (e.g. prescribed burning) are outlined when appropriate.

All of the rare species and the exemplary community listed in this report are associated with wetland habitats (streams, seeps) fed by somewhat nutrient-poor groundwater seepage and streams. In most cases, maintenance of requisite habitat conditions requires protection of upslope hydrologic recharge zones and sufficient buffer to ensure the quality and quantity of both groundwater seepage and surface water. These considerations are strongly reflected in the conservation planning boundary location and specific recommendations for most of the sites.

In this section, protection and management recommendations are summarized on an element-by-element basis. As a rule, recommendations are based on actual and potential threats identified during the survey work. It may be difficult, however, to identify highly specific management strategies because of time constraints and the focus on inventory during this type of study. In the case of a few natural heritage resources, management needs may be so obscure or complex that additional research is needed. In many cases, monitoring of element occurrences is recommended to determine the best long-term management practices. In all cases, if land use changes or specific high-impact actions are proposed within a site's boundary, consultation with DNH staff is recommended to assess impacts on the natural heritage resources.

COMMUNITIES:

Element name: Eutrophic Seasonally Flooded Forest

One occurrence of this exemplary community was documented within the watershed, at the Lower Polecat Creek conservation site. The significance of the stand is in its maturity, and the size of the canopy trees: 2.5 to 3 feet diameter, and many 100-120 feet tall. Generally in Virginia's Coastal Plain, few other bottomland sites have escaped both logging and beaver disturbance long enough to develop 150+ year old near-climax condition forest of the type found at this site. Management recommendations include working with landowners to develop a management plan which provides for the maintenance of this site, and protection of the exemplary natural community. Avoid timber harvest, and monitor the condition of the community periodically. Continue water quality monitoring within the drainage. Monitor beaver activity in the vicinity of this site and implement control measures if necessary.

PLANTS:

Element name: ***Juncus caesariensis***
Common name: New Jersey rush
Global/state ranks: G2/S2
Legal status: federal and state candidate for listing

This globally rare species has a limited and irregular range in boggy habitats from New Jersey to Virginia, with outlying disjunctions in Nova Scotia and the mountains of North Carolina. One occurrence was reverified within the watershed during this inventory. This plant is a light-demanding species which requires open, usually sphagnous, groundwater-saturated habitats. This occurrence is interesting because of its location within a powerline right of way, and because management needs may be somewhat different from other sites where this species occurs. Flooding from blockages at vehicular road crossings, and direct disturbance of individual plants are considered the main threats at this site. Secondary threats include hydrologic perturbations from upslope timber harvests and road construction. Protection and management needs include the removal of debris obstructing the flow of seepages within the powerline right of way; and avoidance of timber harvests, road construction, and other activities which could adversely affect the hydrologic stability of the habitat. Monitoring of this species before and after treatment is recommended to determine the effectiveness of management techniques.

Element name: ***Sarracenia purpurea***
Common name: northern pitcher-plant
Global/state ranks: G5/S2S3

This species is a characteristic plant of bogs in southern Canada and the north-central and northeastern United States, extending south along the Coastal Plain to Louisiana. The plants of Caroline County, Virginia belong to var. *purpurea*, the northern phase of the species, which reaches its southernmost limits in Virginia. One occurrence has been documented within the watershed at the Coleman's Mill Bog conservation site. Prescribed burning is the recommended method of management at this site, although other methods such as manual removal of woody vegetation (possibly with direct application of herbicides to woody species) and bushhogging may be used as secondary management methods. In addition, upslope timber harvests, road construction (especially across the seepage habitat), and other potential sources of hydrologic perturbation should be avoided. Further monitoring of this species (pre- and post-treatment) is recommended to ensure the survival of this population, and monitor success of management practices.

ANIMALS:

Element name: ***Argia bipunctulata***
Common name: seepage dancer
Global/state ranks: G4S2

One occurrence of this damselfly (ca. 20 individuals) was documented within the watershed, in the Coleman's Mill Bog conservation site. The seepage dancer is locally distributed within a wide range which includes much of the southeastern United States. Protection and management of this species' open, seepage-influenced habitat at Coleman's Mill Bog should include the avoidance of upslope timber harvests, road construction, and other hydrologic perturbations. Open conditions at the site appear to be

maintained, at least in the past, by periodic bushhogging of the site. Baseline monitoring of the population and vegetation management of this site are recommended to ensure long-term survival of this population.

Element name: ***Macromia illinoiensis georgina***
Common name: Georgia river cruiser
Global/state ranks: G5T5/S1S2

One occurrence of this dragonfly (a single teneral male) was documented within the watershed, in the Penola Bottomland conservation site. This species is fairly common throughout its range. However, the subspecies *M. i. georgina* is relatively uncommon in Virginia, occupying medium to large, generally slow-moving streams and rivers in Virginia's Coastal Plain and southern Piedmont. Protection and management recommendations for this species include maintaining water quality within the drainage, and monitoring of the population to determine status and abundance.

Element name: ***Somatochlora filosa***
Common name: fine-lined emerald
Global/state ranks: G5/S2

One occurrence of this dragonfly (a single adult male) was documented within the watershed, in the Penola Bottomland conservation site. This species is rare in Virginia, and occurs primarily within the southeastern portion of the state. This occurrence represents the northernmost known locality for this species in Virginia. Dunkle (1989) reports that this species breeds in sheet flow swamp thickets and backwaters of slow-moving streams. The habitat where this species was documented is a slow-moving portion of Polecat Creek with abundant emergent vegetation, in proximity to backwater pools and flooded forested depressions. Although no evidence of reproduction was documented, the habitat at the collection site appears to be similar to breeding habitats at other locations in Virginia where this species has been documented. Protection and management recommendations include periodic census of odonate populations to determine presence/absence, number of individuals, etc.; continue water quality monitoring and work toward a long-term management plan for the site at which this species occurs.

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SECTION II. A MARK RECAPTURE STUDY OF ELLIPTIO COMPLANATA

INTRODUCTION

The Polecat Creek drainage encompasses approximately 30,000 acres in south-central Caroline County, Virginia. As part of a combined inventory and monitoring project, DCR-DNH was contracted by CBLAD to identify and mark three populations of the eastern elliptio (*Elliptio complanata*) within the watershed. Initially, populations were identified at three distinct sites (gauge stations B,D,E) within the watershed. Unfortunately, the site located furthest downstream (site E) was inundated and subsequently destroyed by beaver activity during the Fall of 1994. Consequently, only two sites (sites B and D) were marked for future study.

Prior to this study, only one mussel species was reported from the watershed. Stevenson (1994) found *Elliptio complanata* at three of four proposed gauging station sites that he surveyed (Stevenson, 1994). Of particular interest is the absence of the introduced asian clam (*Corbicula fluminea*). This species is well established in other tributaries of the Mattaponi River. The federally endangered dwarf wedgemussel (*Alasmidonta heterodon*) has been found in the Mattaponi River drainage, and although potential habitat for the species exists in Polecat Creek and its tributaries, this species has not been recorded here. Stevenson (1994) reported that favorable conditions for several other species including the triangle floater (*Alasmidonta undulata*), yellow lance (*Elliptio lanceolata*), and squawfoot (*Strophitus undulatus*) exist within the watershed, although they were not recorded during his surveys.

Polecat Creek and its tributaries lie partly within the Piedmont and partly within the Coastal Plain. Substrates and soils characteristic of both regions can be found within the watershed. Stevenson (1994) speculated that this geographic location may be a cause for the lack of several species which tend to occur in the Piedmont. In western portions of the watershed, stream habitats typify those of the Piedmont with generally more coarse substrates and higher flow rates. In eastern portions of the watershed, stream habitats are more Coastal Plain in character with more sandy substrates, and slower moving water.

Water quality within Polecat Creek seems to be fairly good, with clear to moderately turbid waters depending on nutrient input, siltation, and recharge rates. The water is often tea-colored, due to excessive amounts of tannins from decaying vegetation. Several tributaries of Polecat Creek, including Stevens Mill Run, seem to have slightly more turbid waters, and typically are silt-laden even in areas with moderately high flow rates. Beaver populations, which seem to be quite vigorous, also impact water quality and flow rates, sometimes directly affecting mussel populations. With increased beaver activity, silt loads and flow rates are expected to fluctuate greatly. Toxic spills, including petroleum products, have been documented within the watershed particularly in proximity to Interstate 95. These inputs may drastically impact mussel and fish populations in the short-term, and with repeated spills, long-term affects can be expected.

A major portion of the Polecat Creek watershed is designated as primary growth area in the Caroline County comprehensive plan. Significant urban development activity is expected in the area within the next ten years. Monitoring water quality and the effects of urban development on populations of freshwater mussels is a primary objective of this mark-recapture study, and with data collected from water quality monitoring stations at five sites within the drainage, the effects of toxic spills, increased sediment loads, and other by-products of urbanization can be monitored closely.

This report summarizes the preliminary results, materials and methods used, descriptions of study sites, and comparison of preliminary results with those of other researchers.

MATERIALS AND METHODS

Populations of freshwater mussels were identified at two distinct sites (gauging stations B and D) within the watershed. These sites were chosen based on the presence of mussels reported during previous surveys (Stevenson, 1994), and available natural or man-made barriers effectively isolating these populations for study.

Site B consisted of an approximately section of Stevens Mill Run which began approximately 13 meters downstream of the County Route 601 bridge and continued to the second of two bedrock ledges approximately 90 meters downstream.

Site D consisted of an approximately 750 meter section of Polecat Creek from Interstate 95 downstream to a bedrock ledge 10 meters upstream of the County Route 652 bridge.

The primary survey method employed was aquascoping using five gallon buckets with clear plexiglass bottoms. Mussels were easily observed in the substrate using this technique. Handpicking and searching sandbars for discarded and dead shells were additional techniques used to locate specimens where applicable. Another technique which was not used during these surveys is searching muskrat middens. No muskrat middens were observed along those areas of the streams surveyed. Each site was thoroughly and systematically searched over four consecutive days.

All individual mussels observed were removed from the substrate, cleaned, dried and uniquely marked using individually numbered, plasticized paper tags. All tags were fixed to the right valve of the shell (anterior end) using Superglue brand adhesive; some individuals were double-tagged on opposite sides of the shell at site B. Once the adhesive had dried, mussels were returned to the approximate vicinity of their capture and placed in the proper orientation in the substrate. Mussels spent a maximum of 1.5 hours out of the water while allowing the glue to completely set.

Dial calipers were used to record measurements of shell length, height and width for each individual animal (see Figure 12 for measurements taken). Data on sex, age and reproductive condition were not recorded for individuals marked during this survey. Size data collected for all mussels is presented in Appendix C.

SITE DESCRIPTIONS

The survey area at site B provided a variety of suitable habitats for mussels including riffle, run, and pool areas with sand and gravel substrates interspersed with cobble and some bedrock. Stevens Mill Run at this site is a moderately small stream, from four to seven meters wide, and ranging from 0.1 - 1.0 meters in depth. Run type habitats were of moderate depths and typically held sand or gravel substrates. Riffle habitats were more shallow, and substrates were typically a sand and gravel mixture. Pool habitats were generally deeper and held primarily sand and cobble substrates with higher sediment loads. Water quality at this site was good, but somewhat more turbid and with a higher sediment load than the Polecat Creek site.

The survey area at site D provided similar habitats to those at site B, although this site contained comparatively larger quantities of these habitats. Polecat Creek within this site was approximately four to eight meters wide with depths ranging from approximately 0.1 m to nearly one meter in the deepest pools. Riffle habitats were generally shallow and contained mostly gravel and sand substrates. However,

those areas of riffle in the downstream sections of the site were noticeably more rocky with a greater component of cobble interspersed with pockets of sand and gravel. Riffle habitats occurring where bedrock protruded from the banks were somewhat deeper than others. Run type habitats, found primarily in the middle stretches of the site, were of moderate depths and generally had sand, gravel or mixed sand/gravel substrates. Pool habitats were relatively common in areas where beaver had impounded the stream. Substrates in these areas were silty or sandy in composition. Several small stretches of generally unsuitable habitat had bedrock or clay substrates. Water quality was noticeably better at this site than at site B with clear to slightly turbid water, except in those areas impacted by beaver.

RESULTS AND DISCUSSION

A total of 356 eastern elliptio was captured and marked at site B. Mussel densities were extremely high at this site compared to site D; all individuals were captured in an approximately 90 meter section of the Stevens Mill Run. Additionally, two species of native freshwater mussels previously unrecorded from the watershed were encountered at this site, including one adult squawfoot (*Strophitus undulatus*), and 11 eastern floater (*Pyganadon cataracta*). Several recaptures of elliptio marked during fall 1994 were recorded at site B during further survey efforts in mid March, 1995. Of 83 individuals marked during 1994, 38 were recaptured during March, 1995. Recapture data is provided in Appendix C.

For analysis, all eastern elliptio were placed into size classes based on their length measurement. The smallest numbers of individuals fell into the 20-40 and 100-115 mm size classes with four each. Intermediate size classes of 40-55, 55-70, and 85-100 mm contained 19, 87, and 54 individuals, respectively. The largest number of individuals (188) fell into the 70-85 mm size class. Fifty-three percent of the population at this site was in the 70-85 mm size class. This suggests that the population is made up of primarily moderate-sized adult animals with relatively few juveniles and large adults. The size frequency distribution of the Stevens Mill Run population of eastern elliptio is presented in Figures 13 and 14.

The density of mussels observed in Stevens Mill Run greatly exceeds that reported by Stevenson (1994), and includes two additional species not found by him. Stevenson (1994) reported a total number of 32 live mussels and 7 dead shells (all eastern elliptio) within a 600 m survey area which includes the entirety of our survey area, and a considerable amount of habitat both upstream and downstream of the area surveyed for this report. Differences in reported mussel density at this site may be attributable to the timing of surveys and total search effort. Stevenson (1994) conducted intensive surveys (107 minutes survey time) during early February, a period during which many mussels may have receded into the substrate or may have been concealed by leaf pack. Our surveys were considerably more time-consuming and intensive, and were conducted mostly during mid-March, when mussels may have been more active and several fairly recent rain events had flushed most of the leaf pack from the substrate.

A total of 473 eastern elliptio was captured and marked at site D. Density of mussels at this site was much less than at site B considering the greater length of the survey area and availability of habitat. All individuals were eastern elliptio, and were distributed patchily throughout the habitat, with several areas containing high densities while others produced very low densities. Mussels were most common at this site in the middle reaches of the survey area in deeper riffles and rocky or gravelly and moderately deep run habitats. Areas with predominantly cobble or mixed cobble/sand/gravel substrates were the least productive, and those areas with clay or bedrock substrates were only slightly more productive.

Size classes used for analysis of this population were comparable to those used for site B, with slightly

different distributions of individuals within them. The largest number of individuals (220) fell into the 55-70 mm class, while the smallest numbers of individuals were in the 20-40 and 100-115 mm classes with one and two individuals, respectively. Intermediate size classes of 40-55, 70-85, and 85-100 mm held 56, 167, and 27 individuals, respectively. Forty-seven percent of the population was in the 55-70 mm size class as opposed to 24% in this class at site B. This distribution within size classes is somewhat different than in the population at site B. The large number of individuals in the 55-70 mm size class suggests a slightly younger overall population at this site, but may reflect environmental differences between the sites such as food availability or water chemistry. It is possible that growth rates are different between the two sites. However, this cannot be ascertained without age data. The size-frequency distribution of the Polecat Creek population of eastern elliptio is presented in Figures 13 and 14.

The density of mussels reported from survey site D are also not consistent with those reported by Stevenson (1994), who found only 132 individuals in 153 minutes of searching within a much greater survey area (1020 m). Our survey area is totally within the area surveyed by Stevenson. Furthermore, most of the mussels that he observed were found in the furthest downstream section of his survey area, most of which is below the County Route 652 bridge (not included in our site). Our survey showed that most of the mussels were found in the middle reaches of the site, well upstream of the bridge. Again, the discrepancy could lie in the factors associated with different survey periods and total amount of survey effort as mentioned for the previous site.

SUMMARY

Two populations of the eastern elliptio were identified and marked at two sites within the Polecat Creek watershed. Several recaptures of elliptio marked during Fall 1994 were recorded at site B during further survey efforts in late winter 1995. Three species were identified at site B, two of which had not been previously documented within the watershed (*Strophitus undulatus*, *Pyganadon cataracta*). A total of 356 individual elliptio was captured and individually tagged at site B, with the largest percentage of the population (53%) in the 70-85 mm class size. At site D, a total of 473 elliptio was captured and individually tagged. The largest percentage of this population (47%) fell in the 55-70 mm size class, possibly indicating a younger population than at site B. Mussel densities for both sites were considerably greater than those reported by Stevenson (1994). Several environmental or biological factors could explain these discrepancies in reported mussel densities.

Individually tagged mussels will be used to monitor overall population trends over the next ten years to determine the effects of urbanization on the survival of these mussels. Further survey within the watershed may reveal the presence of other species of mussels or new populations of species documented here.

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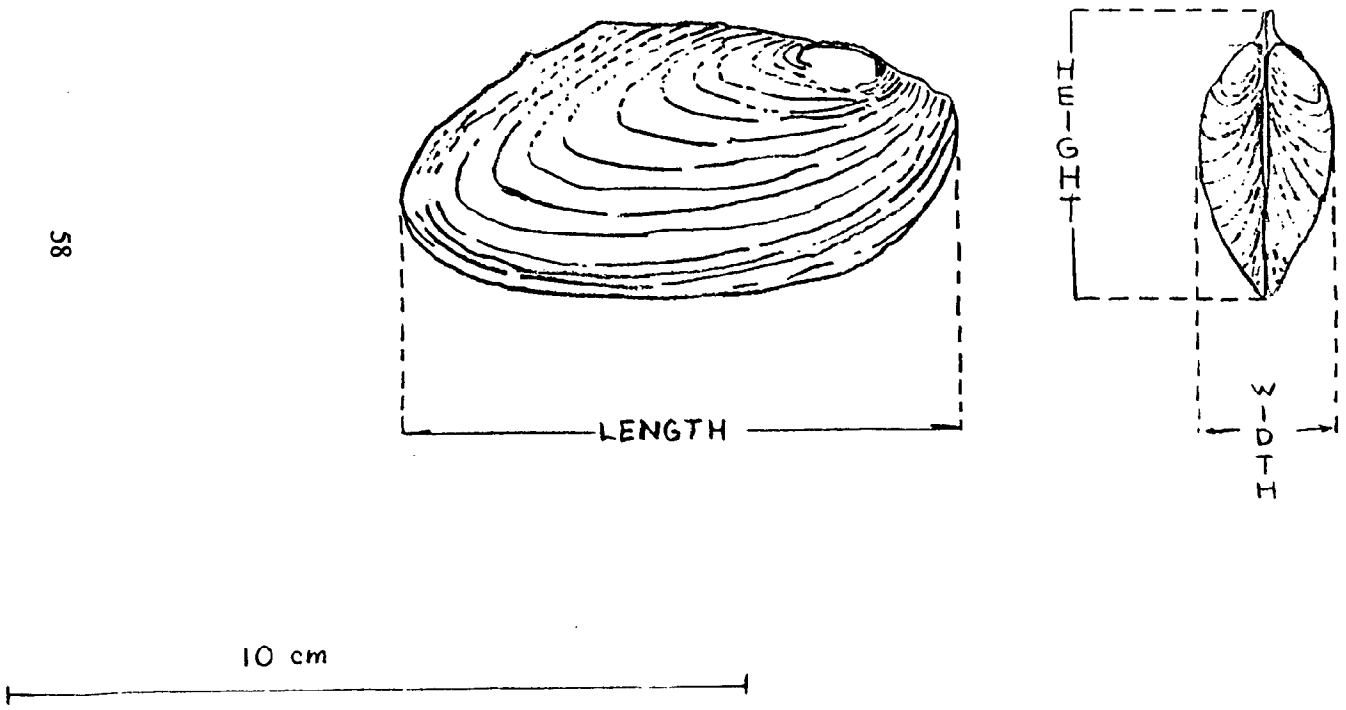


Figure 12. Size measurements taken on *Elliptio complanata*

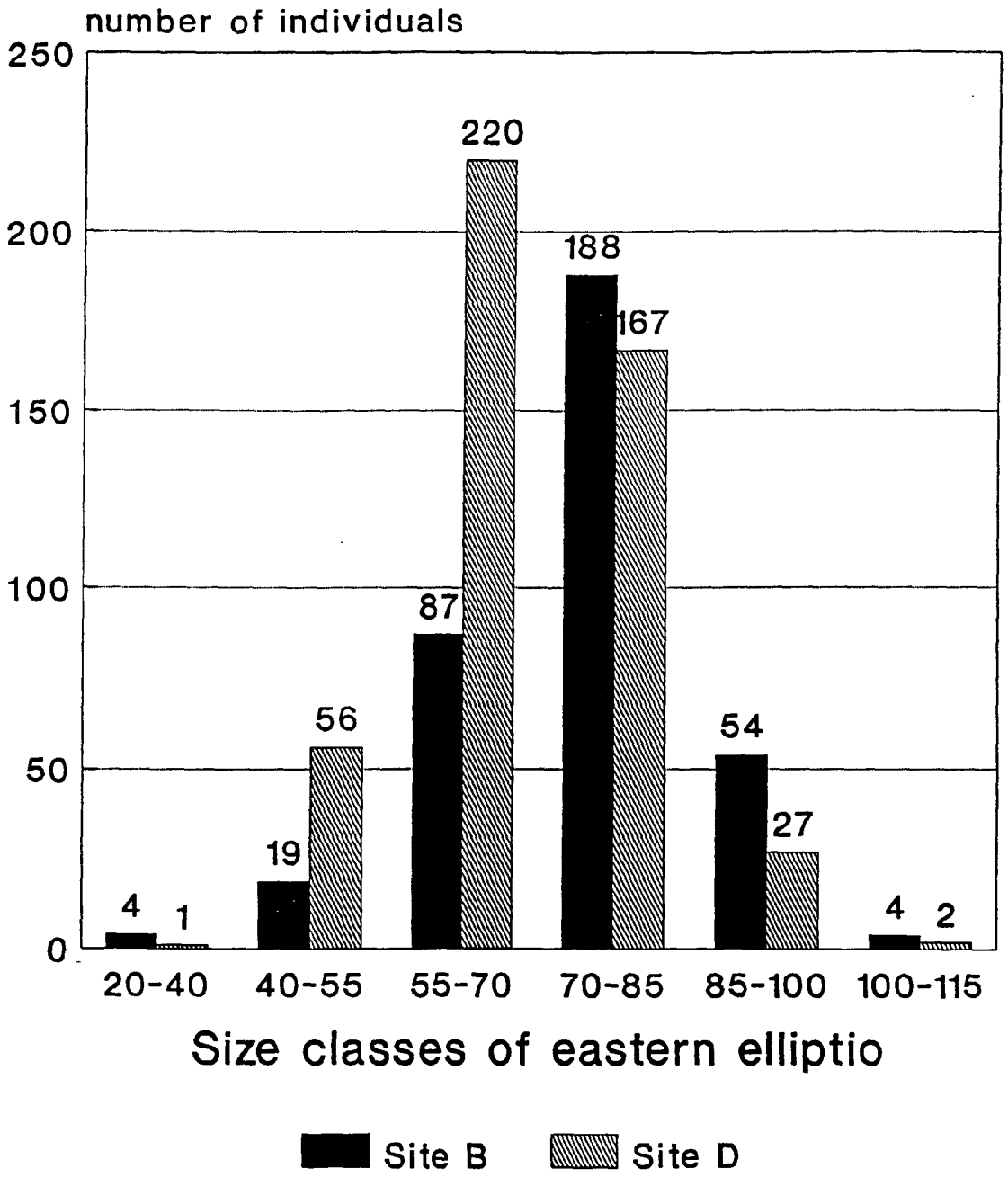
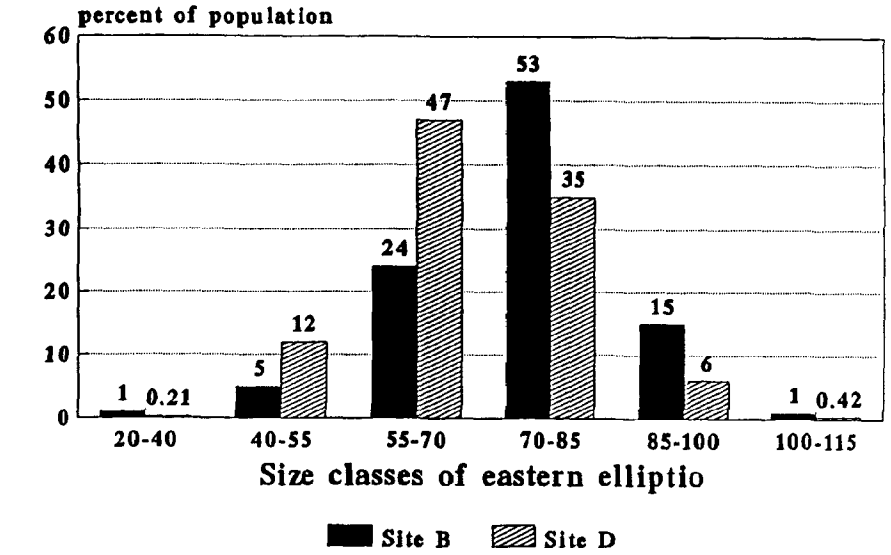
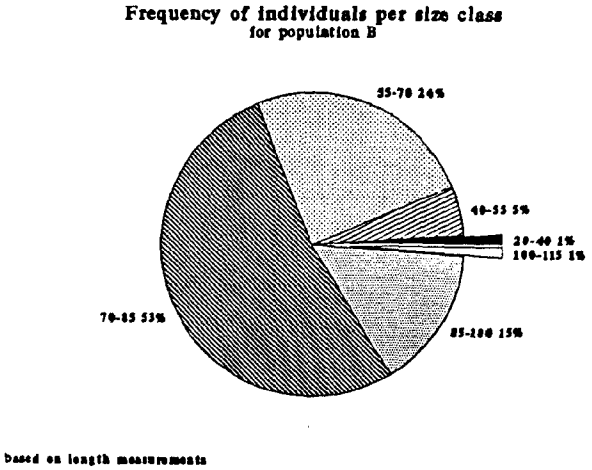


Figure 13. Frequency distribution histogram for sites B and D -- total # of individuals





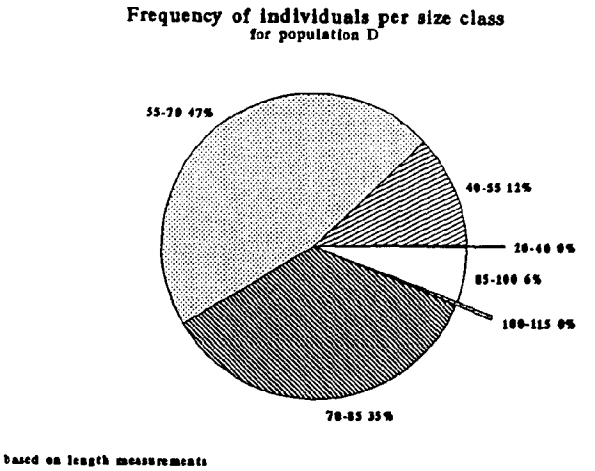


Figure 14. Frequency distribution histogram and pie charts for sites B and D -- percent of population per size class

APPENDIX A

A CLASSIFICATION OF VIRGINIA'S INDIGENOUS BIOTIC COMMUNITIES: VEGETATED TERRESTRIAL, PALUSTRINE, AND ESTUARINE COMMUNITY CLASSES

by

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Natural Heritage Technical Report # 92-21

May 1, 1992

CONTENTS

INTRODUCTION:

The goal of this work is to create a framework for understanding and classifying Virginia's indigenous biotic communities. Achieving this goal has direct bearing on the success of the Division of Natural Heritage whose mission is to document the status, distribution, and ecology of native species and their habitats in the Commonwealth, protect these living resources by way of a system of natural area preserves, and provide information and technical advice to individuals, organizations, and agencies. Community classification and inventory represents a "coarse-filter" approach to biological conservation which secures the protection of a vast number of cryptic or poorly known species. Also, it brings needed attention to the aesthetic, scientific, and ecosystem function values of natural communities. The present draft of the classification deals with communities supporting vascular plant species within the Terrestrial, Palustrine and Estuarine Systems. It supplants appropriate sections of an earlier Division of Natural Heritage classification (Rawinski, 1990).

CLASSIFICATION PRINCIPLES AND METHODS:

A classification system is an organized form of cataloging based on fixed principles. Community classifications vary widely, largely because principles vary in accord with classification purposes. The ultimate purpose of this effort is to name, describe, and differentiate Associations - the basic systematic units. Unfortunately, these units have not yet been identified because of insufficient information. However, the upper levels of a hierarchy, described here, will help partition the great diversity of the natural world into logical units; this in turn will help us identify and understand relationships among the Associations. The hierarchical levels within the final draft of the Virginia classification will likely be:

SYSTEM
  CLASS
    ALLIANCE
      ASSOCIATION
        SUBASSOCIATION.

Communities of life are inextricably associated with the physical environment, and ignoring edaphic-ecological factors when constructing a "community" classification is difficult. When classifications use biotic and abiotic factors to differentiate the basic systematic units (e.g. Reschke, 1990; Schafale and Weakley, 1990), these units are best characterized as "ecosystems", or "ecosystem units". In the Virginia classification, the basic systematic units - the Associations - will be differentiated entirely on the basis of their biological characteristics, with edaphic-ecological factors used in a complementary manner. Consequently, this draft of the Virginia community classification does not require any prior formal or ad hoc classification of physiographic region, landform, or habitat. It also avoids the use of terms such as bog, marsh, and fen in community names because such terms tend to vary in meaning, or reflect an ecosystem or landform approach to classification. Judging by my use of edaphic-ecological terms in Class names, one might assume

that an ecosystem or landform approach was used; this is not the case. Each Class was defined on the basis of a specified floristic composition. Ideally the Classes should have been named using a few diagnostic plant taxa, but because each Class encompassed many different kinds of vegetation, this was not possible.

Unavoidably, this classification focuses on vegetation, but it should not be viewed as simply a plant community classification. Among all forms of life, vascular plants are the easiest to work with because they are large and conspicuous, immotile, and superbly reflect subtle environmental conditions and site history. Classifying plant communities is therefore the key to describing and delimiting a full range of habitats utilized by animal and microbial life, at least within the vegetated Terrestrial, Palustrine, and Estuarine Systems. Principles of vegetation classification, namely those articulated by Westhoff and van der Maarel (1973) in their discussion of the Braun-Blanquet approach to community classification, are followed in the Virginia classification:

- "Plant communities are conceived as types of vegetation, recognized by their floristic composition. The full species compositions of communities better express their relationships to one another and environment than any other characteristic.

- Amongst the species that make up the floristic composition of a community, some are more sensitive expressions of a given relationship than others. For practical classification (and indication of environment) the approach seeks to use those species whose ecological relationships make them most effective indicators; these are diagnostic species (character-species, differential-species, and constant companions).

- Diagnostic species are used to organize communities into a hierarchical classification of which the association is the basic unit. The vast information with which phytosociologists deal must, of necessity, be thus organized; and the hierarchy is not merely necessary but invaluable for the understanding and communication of community relationships that it makes possible."

Character-species are more or less restricted to the stands of a given abstract community type, and therefore characterize it and indicate its environment (Westhoff and van der Maarel, 1973). These species may be used to identify syntaxa (named communities) within several levels of a classification hierarchy, from Subassociation to Class. Use of character-species is an extremely powerful tool in community classification, but very few plant species show strong fidelity to a given syntaxon, and this fact has seemed to hinder efforts to apply the Braun-Blanquet classification approach in eastern United States where the influential work of Whittaker (1953, 1962) and others emphasized continuous change in community composition along environmental gradients, resulting from the individualistic nature of species populations.

Continuous compositional change along environmental gradients does not, however, preclude the use of the Braun-Blanquet classification approach, and in fact continuous and predictable compositional change can be used to great

advantage. As long as species response along environmental and community gradients is reasonably well understood, character-species and certain differential-species may be used to classify communities. Differential-species are usually used to define only lower syntaxa (Westhoff and van der Maarel, 1973), but I have broadened their use and meaning to define Class-level syntaxa. To reflect the broadened application of the differential-species concept, I refer to these species as "conditional character-species". These plants closely resemble true character-species in their ability to identify various syntaxa, but their diagnostic ability is conditional on the absence of certain other species. Referring to these plants as "conditional character-species" and arranging them in a sequence reflecting a community gradient bring a more intuitive level of understanding to the classification approach, and facilitate the production of dichotomous keys.

The Terrestrial System:

To generate Classes within the Terrestrial System, trophic (nutrient) regime was identified as a major environmental gradient affecting floristic composition and community gradients. Five trophic regime descriptors were selected:

1) eutrophic
2) permesotrophic
3) mesotrophic
4) submesotrophic, and
5) oligotrophic.

Using floras, published and unpublished community literature, specimen label data, plot data, personal knowledge of plant habitat preference, and interviews with a number of botanists, I first generated a list of those plants restricted to the richest soil environments. These are true character-species and they are, almost without exception, instantly diagnostic of eutrophic communities. This method of selecting diagnostic species was very similar to that used by Reed (1988) who reviewed many floras and consulted with experts to generate lists of plant species diagnostic of wetland conditions. When the eutrophic indicators are not present in a given stand, other plants, the "conditional character-species", may become diagnostic of permesotrophic communities. These species have diagnostic qualities only when the eutrophic indicators are absent. Note that permesotrophic indicators may occur within eutrophic communities, but eutrophic indicators cannot occur in permesotrophic communities; the response of species populations along this community gradient is therefore unidirectional.

In the absence of both eutrophic and permesotrophic indicators, other plants become diagnostic of mesotrophic communities. Similarly, in the absence of eutrophic, permesotrophic, and mesotrophic indicators, certain plants become diagnostic of submesotrophic communities. Stands lacking the eutrophic, permesotrophic, mesotrophic, and submesotrophic indicators are classified as oligotrophic if any of the oligotrophic indicators are present. Finally, anomalous stands lacking the oligotrophic indicators may be assigned to a given class using other factors, e.g. soils, or simply called "unclassified".

Superimposed on the above trophic regime gradient is a light regime gradient. For this reason the mesotrophic, submesotrophic, and oligotrophic indicators were arranged by their relative shade tolerance. Stands containing only shade tolerant species will likely be forests, while stands supporting moderately shade tolerant or shade intolerant species will likely be woodland, scrub, or herbaceous-dominated types. The exception to this rule is applied to a short-term successional stage of vegetation resulting from infrequent or unusual episodes of disturbance. For example, a blown-down forest now dominated by blackberry should still be classified as forest despite the absence of trees. While this may seem awkward, it is a pragmatic solution to a difficult classification problem. Open-canopy vegetation maintained over the long-term through frequent disturbance (e.g. frequent fire, seasonal flood scour, repeated exposure to severe winds) should be regarded as distinct structural-floristic Classes. Implicit in the distinction between infrequent and frequent disturbance is the notion that the history of frequent disturbance has allowed light-demanding plants to persist at the site over a long period of time. There will certainly be instances in which disturbance factors cannot readily be characterized as infrequent or frequent, and in these cases I recommend the recognition of distinct structural-floristic Classes; this is a conservative measure that ensures that poorly known or problematic communities are not dismissed as seral stages. Users of this classification should be aware that the shade tolerant plants identified in the lists can occur in semi-forested and non-forested communities, but the shade intolerant plants will rarely, if ever, be found in forests. This implies another unidirectional gradient.

Eutrophic and permesotrophic woodland, scrub, and herbaceous vegetation will most often be the result of infrequent disturbance, such as blow-down. No light-demanding plants faithful to these nutrient regimes could be identified. Open canopy eutrophic and permesotrophic communities are therefore not recognized as distinct Classes at the present time, but rather as seral stages of the forests. If future field work documents naturally occurring open canopy eutrophic and permesotrophic communities in Virginia, the classification can be adjusted accordingly.

Lists of character-species and conditional character-species were derived from the Atlas of the Virginia Flora (Harvill et al., 1986), but nomenclature followed Kartesz and Kartesz (1980). A species was selected for a list only if its habitat preference was reasonably well known, and if it had distinct diagnostic value for the purpose of the classification. Approximately 900 diagnostic species were selected. Species of wide ecological tolerance, such as those growing in both upland and wetland soils, were generally excluded from consideration; they did not meet fidelity criteria at the System level. Some of the excluded species will, however, have diagnostic value in differentiating the lower syntaxa when these are classified in the future.

The Estuarine System:

Halophytes were used to define vegetated classes within the Estuarine System. A very few of the species also occur in inland saline wetlands; such wetlands should be classified within the Palustrine System for the time being and regarded as a rare, or anomalous condition.

The Palustrine System:

Classes within the Palustrine System were identified through the character-species/conditional character-species approach. I have not supplied detailed instructions for separating the Palustrine System from the Terrestrial because in most cases this difference will be readily apparent. However, when dealing with problematic transitional zones, I refer the user to Reed's (1988) list of plant species that occur in Northeastern wetlands. Only those plants with indicator status of Obligate or Facultative Wetland should be regarded as diagnostic of the Palustrine System, for the purpose of the Virginia classification. If necessary, other factors such as soils or flooding regime may also be used to assign stands to the Palustrine System. The Palustrine System of the Virginia classification has a broader definition than that used in Cowardin et al. (1979). The Virginia definition includes all freshwater (to oligohaline) wetland and aquatic environments supporting non-halophytic vascular plant life, thereby encompassing parts of Cowardin's Lacustrine, Riverine, and Estuarine Systems. Note that the Cowardin definition of the Estuarine System relies upon an average salinity measure (0.5 ppt.), and not halophytic plants, to define the upstream or landward limit of the System. Determining this salinity measure in the field is difficult, and as a consequence, some wetlands classified within Cowardin's Estuarine System support non-halophytic vegetation.

Hydrologic regime was identified as a major factor influencing floristic composition at the Class level. Four hydrologic regime descriptors were subsequently identified:

1) saturated,
2) seasonally flooded,
3) semipermanently flooded (including permanently flooded environments supporting emergents), and
4) permanently flooded (lacking emergents).

These descriptors were derived from Cowardin et al. (1979), but I've given numbers 2 and 3 broader meaning. Number 2 encompasses Cowardin's temporarily flooded category, while number 3 includes the intermittently exposed category and any permanently flooded environments supporting emergent vegetation. This was done out of practical necessity; too often the Cowardin hydrologic regime categories cannot be recognized in the field. Description number 4 also deviates from the Cowardin definition in the sense that it is exclusively reserved for those permanently flooded environments lacking emergents, i.e. communities composed entirely of submergents and/or floating-leaved species.

Plant species indicative of trophic regime were also used to generate Classes within the Palustrine System. Unlike the Terrestrial System, where five trophic regime levels were identified, only two trophic regime levels were selected for use in the Palustrine System. This difference in approach seemed unavoidable, given the fact that fewer plant species were strictly diagnostic of trophic regime within the Palustrine System. The two trophic regime descriptors were:

1) oligotrophic, and
2) eutrophic.

Note that the each of the above terms now connotes a relatively wide range of fertility conditions; use of these terms in the Terrestrial System is much mor restrictive. While this might cause some confusion, it maintains a level of nomenclatural continuity between Systems.

Lists of character-species and conditional character-species serve to identify and differentiate Classes within the Palustrine System. As with the Terrestrial System, some of the lists are subdivided into shade tolerant, moderately shade tolerant, and shade intolerant species to aid in distinguishing the various structural types.

Keys to the Classes of the Terrestrial, Estuarine, and Palustrine Systems were developed. The character-species and conditional character-species that need to be examined when using the keys are given in appendices.

CONCLUDING REMARKS:

Character-species and conditional character-species play an important role in the classification of Virginia's indigenous vegetation. Relatively large lists of these species have been generated, and most stands of natural vegetation can be readily classified to the level of Class using this approach. The basic requirement is that a reasonably complete species list from a representative sample of the vegetation is collected and interpreted using the keys. Recommended plot size for forests and woodlands is 400 sq. m., and for scrub and herbaceous communities, 100 sq. m. As stand data sets accumulate and are analyzed, the Associations should become apparent.

The lists of character-species and conditional character-species serve another important purpose. They give an indication of the classification and inventory work which lies ahead. Each listed species needs to be observed in the field, and recorded as a component of a given community. This will ensure complete coverage of the final draft classification. Refinements and suggestions are definitely needed, and in fact, I eagerly await word of any unusual communities that aren't readily classified under the present system. Natural vegetation is exceedingly complex and trying to make sense of it using feeble human constructs will no doubt be a long, frustrating, and humbling endeavor.

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A KEY TO VEGETATED TERRESTRIAL COMMUNITY CLASSES
(Note: All Class names are understood to represent the Terrestrial System).

a. Eutrophic character-species (Appendix T1) present. . . . . [EUTROPHIC FOREST]
a. Eutrophic character-species absent.

b. Permesotrophic conditional character-species (Appendix T2) present. . . . [PERMESOTROPHIC FOREST]
b. Permesotrophic conditional character-species absent.

c. Mesotrophic conditional character-species (Appendix T3) present.

d. Moderately shade tolerant or shade intolerant species (Appendices T3, T4, & T5) present and conspicuous; woodland, scrub and herbaceous communities.

e. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [MESOTROPHIC WOODLAND]
e. Trees absent or cover less than 5% of the area.

f. Woody species between 1 and 6 m tall (scrub) cover more than 5% of the area. . . . . [MESOTROPHIC SCRUB]
f. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . . [MESOTROPHIC HERBACEOUS VEGETATION]

d. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . . [MESOTROPHIC FOREST]

c. Mesotrophic conditional character-species absent.

g. Submesotrophic conditional character-species (Appendix T4) present.

h. Moderately shade tolerant or shade intolerant species (Appendices T4 & T5) present and conspicuous; woodland, scrub and herbaceous communities.

i. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [SUBMESOTROPHIC WOODLAND]
i. Trees absent or cover less than 5% of the area.

j. Woody species between 1 and 6 m tall (scrub) cover more than 5% of the area. . . . . [SUBMESOTROPHIC SCRUB]
j. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . . [SUBMESOTROPHIC HERBACEOUS VEGETATION]

h. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . . [SUBMESOTROPHIC FOREST]

g. Submesotrophic conditional character-species absent.

k. Oligotrophic conditional character-species (Appendix T5) present.

l. Moderately shade tolerant or shade intolerant species present and conspicuous; woodland, scrub and herbaceous communities.

m. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [OLIGOTROPHIC WOODLAND]
m. Trees absent or cover less than 5% of the area.

n. Woody species between 1 and 6 m tall (scrub) cover more than 5% of the area. . . . . [OLIGOTROPHIC SCRUB]
n. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . . [OLIGOTROPHIC HERBACEOUS VEGETATION]

l. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . . [OLIGOTROPHIC FOREST]

k. Oligotrophic indicators absent. Use other factors (e.g. soils) to assign the stand to one of the above classes. If this isn't possible, refer to the stand as: . . . . . [UNCLASSIFIED TERRESTRIAL COMMUNITY]

A KEY TO VEGETATED ESTUARINE COMMUNITY CLASSES

a. Estuarine character-species (Appendix E1) present.

b. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [ESTUARINE SCRUB]

b. Scrub vegetation absent or cover less than 5% of the area.

c. Herbaceous species other than submergents present. . . . . [ESTUARINE HERBACEOUS VEGETATION]

c. The only vascular plants present are submergents such as Ruppia maritima and Zostera marina. . . . . [ESTUARINE SUBMERGENT VEGETATION]

a. Estuarine character-species absent. Consider whether the stand could be classified using the Palustrine System key, or refer to the stand as: . . . . . [UNCLASSIFIED ESTUARINE COMMUNITY]

KEYS TO THE VEGETATED PALUSTRINE COMMUNITY CLASSES

(Note: All Class names are understood to represent the Palustrine System. Also, use of the terms, eutrophic and o' [redacted]rop is in the broad sense, each term encompassing roughly half of the range of community trophic conditions).

Character-species indicating saturated, eutrophic conditions (Appendix P1) present.	EUTROPHIC SATURATED Key P1
Conditional character-species indicating saturated, oligotrophic conditions (Appendix P2) present.	OLIGOTROPHIC SATURATED Key P2
Conditional character-species indicating semipermanently flooded, eutrophic conditions (Appendix P3) present.	EUTROPHIC SEMIPERMANENTLY FLOODED Key P3
Conditional character-species indicating semipermanently flooded, oligotrophic conditions (Appendix P4) present.	OLIGOTROPHIC SEMIPERMANENTLY FLOODED Key P4
Conditional character-species indicating seasonally flooded, eutrophic conditions (Appendix P5) present.	EUTROPHIC SEASONALLY FLOODED Key P5
Conditional character-species indicating seasonally flooded, oligotrophic conditions (Appendix P6) present.	OLIGOTROPHIC SEASONALLY FLOODED Key P6
Conditional character-species indicating permanently flooded conditions (Appendix P7) present (submergent/floating-leaved vegetation).	[SUBMERGENT/FLOATING-LEAVED VEGETATION]
None of the above species present. Use other factors to assign the stand to a Class. If this isn't possible, refer to the stand as:	[UNCLASSIFIED PALUSTRINE COMMUNITY]

Key P1: Eutrophic Saturated

a. Moderately shade tolerant or shade intolerant species (Appendices P1 & P2) present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [EUTROPHIC SATURATED WOODLAND]

b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [EUTROPHIC SATURATED SCRUB]

c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . . [EUTROPHIC SATURATED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [EUTROPHIC SATURATED FOREST]

Key P2: Oligotrophic Saturated

a. Moderately shade tolerant or shade intolerant species present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [OLIGOTROPHIC SATURATED WOODLAND]

b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [OLIGOTROPHIC SATURATED SCRUB]

c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . . [OLIGOTROPHIC SATURATED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [OLIGOTROPHIC SATURATED FOREST]

Key P3: Eutrophic Semipermanently Flooded

a. Moderately shade tolerant or shade intolerant species (Appendices P3 & P4) present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [EUTROPHIC SEMIPERMANENTLY FLOODED WOODLAND]

b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [EUTROPHIC SEMIPERMANENTLY FLOODED SCRUB]

c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . [EUTROPHIC SEMIPERMANENTLY FLOODED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [EUTROPHIC SEMIPERMANENTLY FLOODED FOREST]

Key P4: Oligotrophic Semipermanently Flooded

a. Moderately shade tolerant or shade intolerant species present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [OLIGOTROPHIC SEMIPERMANENTLY FLOODED WOODLAND]
b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [OLIGOTROPHIC SEMIPERMANENTLY FLOODED SCRUB]
c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . [OLIGOTROPHIC SEMIPERMANENTLY FLOODED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [OLIGOTROPHIC SEMIPERMANENTLY FLOODED FOREST]

Key P5: Eutrophic Seasonally Flooded

a. Moderately shade tolerant or shade intolerant species (Appendices P5 & P6) present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [EUTROPHIC SEASONALLY FLOODED WOODLAND]
b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [EUTROPHIC SEASONALLY FLOODED SCRUB]
c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . [EUTROPHIC SEASONALLY FLOODED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [EUTROPHIC SEASONALLY FLOODED FOREST]

Key P6: Oligotrophic Seasonally Flooded

a. Moderately shade tolerant or shade intolerant species present and conspicuous; woodland, scrub, and herbaceous communities.

b. Trees present (covering at least 5% of the area), but significant gaps exist among tree crowns. . . . . [OLIGOTROPHIC SEASONALLY FLOODED WOODLAND]
b. Trees absent or cover less than 5% of the area.

c. Woody species between 1 and 6 m. tall (scrub) cover more than 5% of the area. . . . . [OLIGOTROPHIC SEASONALLY FLOODED SCRUB]
c. Scrub vegetation absent or covers less than 5% of the area; herbaceous species prevalent. . . . [OLIGOTROPHIC SEASONALLY FLOODED HERBACEOUS VEGETATION]

a. Moderately shade tolerant or shade intolerant species absent or inconspicuous; trees form a more or less continuous cover; forest. . [OLIGOTROPHIC SEASONALLY FLOODED FOREST]

Appendix T1 Character-species of the eutrophic forest class

SHADE TOLERANT

Acer nigrum
Blephila ciliata
Carex albursina
Carex careyana
Carex hitchcockiana
Carex plantaginea
Diplazium pycnocarpon
Dryopteris goldiana
Erigenia bulbosa
Erythronium albidum
Floerkea proserpinacoides
Hydrophyllum macrophyllum
Jeffersonia diphylla
Matteuccia struthiopteris
Meehania cordata
Mertensia virginica
Milium effusum
Phacelia bipinnatifida
Smilacina stellata
Trillium cernuum
Trillium sessile
Uvularia grandiflora

Appendix T2 Conditional character-species of the permesotrophic forest class

SHADE TOLERANT

Allium tricoccum
Carex pedunculata
Carex sparganioides
Caulophyllum thalictroides
Chaerophyllum procumbens
Delphinium tricorne
Diarrhena americana
Dicentra canadensis
Dicentra cucullaria
Disporum maculatum
Gymnocladus dioica
Hepatica nobilis v. acuta
Hybanthus concolor
Hydrastis canadensis
Hydrophyllum canadense
Panax quinquefolius
Phlox divaricata
Phlox stolonifera
Polemonium reptans
Schizachne purpurascens
Trillium grandiflorum
Viola canadensis
Viola rostrata
Viola striata

Appendix T3 Conditional character-species of mesotrophic classes

SHADE TOLERANT

Acer floridanum
Aconitum reclinatum
Actaea pachypoda
Adiantum pedatum
Allium canadense
Aplectrum hyemale
Aralia racemosa
Aristolochia macrophylla
Asarum canadense
Asimina triloba
Astilbe biternata
Botrychium virginianum
Carex amphibola
Carex gracillima
Carex jamesii
Cimicifuga americana
Cimicifuga racemosa
Claytonia caroliniana
Claytonia virginica
Collinsonia canadensis
Cryptotaenia canadensis
Dentaria diphylla
Dentaria laciniata
Deparia acrostichoides
Desmodium cuspidatum
Desmodium glutinosum
Diphylleia cymosa
Dirca palustris
Dryopteris celsa
Festuca obtusa
Fraxinus quadrangulata
Galearis spectabilis
Geranium maculatum
Helianthus decapetalus
Hepatica nobilis v. obtusa
Hydrophyllum virginianum
Hystrix patula
Impatiens pallida
Laportea canadensis
Magnolia tripetala
Menispermum canadense
Mitella diphylla
Monarda clinopodia
Osmorhiza claytoni
Osmorhiza longistylis
Penstemon laevigatus
Polymnia canadensis
Polymnia uvedalia
Rubus odoratus
Rudbeckia laciniata
Sanguinaria canadensis
Sanicula canadensis
Sanicula gregaria
Sanicula marilandica
Solidago flexicaulis
Staphylea trifolia
Thalictrum coriaceum
Thalictrum dioicum
Thelypteris hexagonoptera
Tilia heterophylla
Trillium sulcatum
Triosteum angustifolium
Triosteum aurantiacum
Triosteum perfoliatum

MODERATELY SHADE TOLERANT

Adlumia fungosa
Astragalus canadensis
Baptisia australis
Blephilia hirsuta
Camassia scilloides
Campanula americana
Carex oligocarpa
Cassia marilandica
Clematis occidentalis
Eupatorium sessilifolium
Hackelia virginiana
Hexalectris spicata
Lathyrus venosus
Liatris spicata
Onosmodium hispidissimum
Oryzopsis racemosa
Pycnanthemum incanum
Salvia urticifolia
Silphium terebinthinaceum
Solidago rigida
Uniola latifolia
Zanthoxylum americanum

Appendix T4 Conditional character-species of submesotrophic classes

SHADE TOLERANT

Acer saccharum
Ageratina altissima
Anemone lancifolia
Anemone virginiana
Angelica triquinata
Antennaria plantaginifolia
Arabis canadensis
Arabis laevigata
Arisaema triphyllum
Asclepias exaltata
Asclepias quadrifolia
Asplenium resiliens
Aster macrophyllus
Athyrium asplenioides
Betula papyrifera
Brachyelytrum erectum
Callicarpa americana
Calycanthus floridus
Carex aestivalis
Carex digitalis
Carex laxiculmis
Carex laxiflora
Carex nigromarginata
Carex platyphylla
Carex virescens
Carex willdenowii
Carpinus caroliniana
Carya cordiformis
Chrysogonum virginianum
Clintonia umbellulata
Conopholis americana
Coreopsis auriculata
Cornus alternifolia
Cunilla origanoides
Cymophyllus fraseri
Cynoglossum virginianum
Dentaria heterophylla
Desmodium nudiflorum
Desmodium pauciflorum
Desmodium rotundifolium
Dichanthelium latifolium
Dioscorea villosa
Disporum lanuginosum
Galium circaezans
Galium concinnum
Galium latifolium
Hedyotis purpurea
Heracleum lanatum
Hieracium paniculatum
Hydrangea arborescens
Ligusticum canadense
Liparis liliifolia
Lonicera canadensis
Luzula acuminata
Magnolia acuminata
Obolaria virginica
Ostrya virginiana
Oxalis violacea
Phryma leptostachya
Platanthera orbiculata
Platanthera viridis v. bracteata
Poa cuspidata
Podophyllum peltatum
Polygonatum biflorum
Polygonatum pubescens
Polystichum acrostichoides
Prenanthes alba
Pyrularia pubera
Scirpus verecundus
Sedum ternatum
Senecio obovatus
Silene stellata
Smilacina racemosa
Solidago arguta
Solidago caesia
Solidago curtisii
Sphenopholis nitida
Stellaria pubera
Styrax americana
Taenidia integerrima
Taxus canadensis
Thalictrum thalictroides
Thaspium barbinode
Thaspium trifoliatum
Tiarella cordifolia
Uvularia perfoliata
Viburnum acerifolium
Viola hastata
Viola rotundifolia
Viola triloba

MODERATELY SHADE TOLERANT

Agropyron trachycaulum
Aquilegia canadensis
Arabis patens
Aster infirmus
Aster oblongifolius
Aureolaria flava
Berberis canadensis
Bouteloua curtipendula
Bromus pubescens
Carex cephalophora
Carex eburnea
Carex meadii
Celastrus scandens
Clematis viorna
Cornus rugosa
Cuscuta coryli
Cystopteris fragilis
Echinacea laevigata
Fragaria vesca
Helianthus divaricatus
Helianthus strumosus
Lithospermum canescens
Lonicera dioica
Muhlenbergia sobolifera
Muhlenbergia tenuifolia
Myosotis verna
Parthenium auriculatum
Passiflora lutea
Pellaea atropurpurea
Penstemon calycosus
Penstemon hirsutus
Phacelia dubia
Polygala senega
Ranunculus fascicularis
Ranunculus micranthus
Rhamnus caroliniana
Rudbeckia triloba
Silene virginica
Silphium trifoliatum
Solidago ulmifolia
Tradescantia ohiensis
Viburnum rafinesquianum
Woodsia obtusa
Zizia aptera

SHADE INTOLERANT

Aster grandiflorus
Atriplex arenaria
Buchnera americana
Cakile edentula
Castilleja coccinea
Cirsium virginianum
Coreopsis tripteris
Eryngium yuccifolium
Helianthus angustifolius
Helianthus atrorubens
Polygonum glaucum
Psoralea psoralioides
Salsola kali
Sporobolus asper

Appendix T5 Conditional character-species of oligotrophic classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
[illegible]cer pensylvanicum	Ageratina aromatica	
[illegible]mianthium muscaetoxicum	Allium cernuum	
Antennaria virginica	Angelica venenosa	
Asimina parviflora	Arabis serotina	Agrostis elliottiana
Aster acuminatus	Aristida lanosa	Ammophila breviligulata
Aster divaricatus	Aster linariifolius	Anaphalis margaritacea
Betula lenta	Aster undulatus	Andropogon gerardii
Buckleya distichophylla	Aureolaria laevigata	Arabis lyrata
Carex brunnescens	Aureolaria pedicularia	Aralia hispida
Carex debilis	Baptisia tinctoria	Arctostaphylos uva-ursi
Carex pensylvanica	Calamagrostis porteri	Aristida curtissii
Carya glabra	Calystegia spithamaea	Aristida dichotoma
Castanea dentata	Campanula divaricata	Aristida purpurascens
Castanea pumila	Carex emmonsii	Aristida tuberculosa
Chamaelirium luteum	Carex polymorpha	Asclepias amplexicaulis
Chimaphila maculata	Carex umbellata	Asclepias verticillata
Chimaphila umbellata	Carya pallida	Asplenium montanum
Clethra acuminata	Centrosema virginianum	Aster spectabilis
Clintonia borealis	Cheilanthes lanosa	Bulbostylis capillaris
Comandra umbellata	Chrysopsis gossypina	Bulbostylis ciliatifolia
Convallaria montana	Clematis albicoma	Carex silicea
Corallorhiza odontorhiza	Clematis ochroleuca	Carphephorus bellidifolius
Coreopsis major	Clematis viticaulis	Carphephorus tomentosus
Cypripedium acaule	Cnidoscolus stimulosus	Cenchrus tribuloides
Deschampsia flexuosa	Comptonia peregrina	Cirsium horridulum
Draba ramosissima	Coreopsis verticillata	Corydalis sempervirens
Dryopteris campyloptera	Danthonia compressa	Cyperus granitophilus
Dryopteris marginalis	Desmodium paniculatum	Cyperus grayi
Epigaea repens	Dicentra eximia	Danthonia sericea
Galax urceolata	Diervilla lonicera	Danthonia spicata
Gaultheria procumbens	Eriogonum alleni	Desmodium sessilifolium
Goodyera pubescens	Euphorbia ipecacuanhae	Desmodium strictum
Gymnocarpium dryopteris	Galactia regularis	Diamorpha smallii
Hamamelis virginiana	Gaylussacia dumosa	Eragrostis hirsuta
Hexastylis virginica	Gymnopogon ambiguus	Eragrostis refracta
Ilex vomitoria	Helianthemum canadense	Eragrostis spectabilis
Isotria medeoloides	Heuchera americana	Euphorbia ammannioides
Isotria verticillata	Iris verna	Euphorbia polygonifolia
Lycopodium annotinum	Kuhnia eupatorioides	Festuca octoflora
Lycopodium clavatum	Liatris graminifolia	Haplopappus divaricatus
Lycopodium digitatum	Lilium philadelphicum	Helianthemum bicknellii
Lycopodium obscurum	Lupinus perennis	Helianthus hirsutus
Lycopodium obscurum v. dendroideum	Lycopodium prophilum	Hudsonia tomentosa
Lycopodium tristachym	Lycopodium selago	Isanthus brachiatus
Lysimachia quadrifolia	Ophioglossum engelmannii	Juncus secundus
Malaxis unifolia	Paronychia canadensis	Juniperus communis
Medeola virginiana	Paxistima canbyi	Krigia biflora
Melampyrum lineare	Pinus echinata	Krigia montana
Melanthium hybridum	Pinus palustris	Krigia virginica
Menziesia pilosa	Pinus pungens	Lechea maritima
Oxalis acetosella	Pinus virginiana	Lechea racemulosa
Oxydendrum arboreum	Pityopsis graminifolia	Lechea villosa
Pieris floribunda	Polygonum cilinode	Leptoloma cognatum
Polypodium virginianum	Prenanthes roanensis	Liatris aspera
Prenanthes trifoliata	Pseudotaenidia montana	Liatris turgida
Pteridium aquilinum	Pyxidanthera barbulata	Manfreda virginica
Quercus coccinea	Quercus ilicifolia	Minuartia glabra
Quercus marilandica	Quercus incana	Minuartia groenlandica
Quercus montana	Quercus laevis	Minuartia michauxii
Quercus velutina	Quercus margarettae	Minuartia patula
Rhododendron calendulaceum	Quercus virginiana	Muhlenbergia capillaris
Rhododendron periclymenoides	Rhus aromatica	Muhlenbergia cuspidata
Rhododendron prinophyllum	Saxifraga michauxii	Oenothera humifusa
Sassafras albidum	Sedum telephioides	Opuntia humifusa
Symplocos tinctoria	Selaginella rupestris	Panicum amarulum
Tipularia discolor	Senecio antennariifolius	Panicum amarum
Trillium undulatum	Senecio pauperculus	Panicum flexile
Tsuga caroliniana	Silene caroliniana	Paronychia argyrocoma
Uvularia pudica	Smilax tamnoides	Paronychia fastigiata
Uvularia sessilifolia	Solidago bicolor	Paronychia riparia
Vaccinium arboreum	Solidago odora	Polygala verticillata
Vaccinium elliottii	Solidago roanensis	Polygonella articulata
Vaccinium erythrocarpum	Sorbus americana	Polygonella polygama
Vaccinium stamineum	Spiraea betulifolia ssp. corymbosa	Portulaca smallii
Vaccinium tenellum	Sporobolus clandestinus	Potentilla tridentata
Viburnum tenendides	Stipa avenacea	Ruellia humilis
	Stylosanthes biflora	Sali[illegible]rifolia
	Tephrosia virginiana	Schizachyrium scoparium
	Tradescantia rosea v. graminea	Scutellaria parvula
	Trifolium virginicum	Silphium compositum
	Vaccinium angustifolium	Sisyrinchium albidum
	Vaccinium crassifolium	Solidago racemosa
	Vaccinium myrtilloides	Solidago spathulata ssp. randii
	Viburnum rufidulum	Spiranthes tuberosa
	Viola pedata	Sporobolus vaginiflorus
	Woodsia ilvensis	Stipulicida setacea
	Woodsia scopulina	Stylisma humistrata
	Xerophyllum asphodeloides	Talinum teretifolium
	Zigadenus glaucus	Triplasis purpurea
	Zigadenus leimanthoides	Uniola paniculata
		Zanthoxylum clava-herculis

Appendix E1 Character-species of vegetated classes within the estuarine system

Agalinis maritima
Aster tenuifolius
Borrichia frutescens
Distichlis spicata
Fimbristylis castanea
Iva frutescens
Juncus gerardii
Juncus roemerianus
Kosteletzkya virginica
Lythrum lineare
Puccinellia fasciculata
Ruppia maritima
Salicornia bigelovii
Salicornia europea
Salicornia virginica
Scirpus maritimus
Scirpus robustus
Sesuvium maritimum
Spartina alterniflora
Spartina cynosuroides
Spartina patens
Spergularia marina
Suaeda linearis
Suaeda maritima
Zostera marina

Appendix P1 Character-species of eutrophic saturated classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
	Caltha palustris	Acorus calamus
Carex scabrata	Carex stipata	Carex lacustris
Hexastylis lewisii	Carex trichocarpa	Carex lanuginosa
Ranunculus septentrionalis	Iris versicolor	Carex tetanica
	Lobelia siphilitica	Cyperus haspan
	Myosotis laxa	Eleocharis rostellata
	Veronica americana	Juncus balticus
	Veronica anagallis-aquatica	Lathyrus palustris
		Lysimachia quadriflora
		Lythrum alatum
		Mentha arvensis
		Pedicularis lanceolata
		Sabatia dodecandra

Appendix P2 Conditional character-species of oligotrophic saturated classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
Cardamine bulbosa	Alnus incana ssp. rugosa	Aletris aurea
Cardamine rotundifolia	Asclepias rubra	Calamagrostis cinnoides
Carex collinsii	Aster radula	Calopogon tuberosus
Carex laevivaginata	Campanula aparinoides	Carex buxbaumii
Carex leptalea	Carex atlantica	Carex conoidea
Carex prasina	Carex bullata	Carex hystericina
Carex styloflexa	Carex trisperma	Carex interior
Chamaecyparis thyoides	Carex venusta	Carex prairea
Chrysosplenium americanum	Chelone cuthbertii	Centella asiatica
Cyrilla racemiflora	Cirsium muticum	Cladium mariscoides
Dalibarda repens	Conioselinum chinense	Cleistes divaricata
Fraxinus nigra	Cypripedium reginae	Dichromena colorata
Hedyotis michauxii	Drosera rotundifolia	Drosera brevifolia
Helonias bullata	Eleocharis tortilis	Drosera capillaris
Listera smallii	Equisetum sylvaticum	Epilobium leptophyllum
Lyonia lucida	Parnassia grandifolia	Equisetum fluviatile
Ophioglossum vulgatum	Platanthera ciliaris	Eriocaulon decangulare
Parnassia asarifolia	Poa palustris	Eriophorum virginicum
Platanthera clavellata	Rhamnus alnifolia	Eryngium aquaticum
Platanthera psycodes	Sanguisorba canadensis	Filipendula rubra
Poa paludigena	Sarracenia purpurea	Fimbristylis puberula
Saxifraga micranthidifolia	Selaginella apoda	Iris prismatica
Saxifraga pensylvanica	Solidago uliginosa	Juncus abortivus
Solidago patula	Sphenopholis pensylvanica	Juncus nodosus
Symplocarpus foetidus	Zenobia pulverulenta	Juncus pelocarpus
Thalictrum clavatum		Lilium catesbaei
Thelypteris simulata		Lobelia georgiana
Toxicodendron vernix		Lycopodium alopecuroides
Veratrum viride		Lycopodium appressum
Viburnum nudum		Lycopodium inundatum
Viola walteri		Menyanthes trifoliata
		Muhlenbergia glomerata
		Nasturtium officinale
		Platanthera blephariglottis
		Platanthera cristata
		Pogonia ophioglossoides
		Polygala cruciata
		Rhynchospora alba
		Rhynchospora capillacea
		Sabatia calycina
		Sarracenia flava
		Scirpus expansus
		Scleria reticularis
		Scleria verticillata
		Sclerolepis uniflora
		Tofieldia glutinosa
		Tofieldia racemosa
		Utricularia cornuta
		Utricularia juncea
		Xyris ambigua
		Xyris difformis
		Xyris jupicai
		Xyris torta
		Zigadenus densus
		Zigadenus glaberrimus

Appendix P3 Conditional character-species of eutrophic semipermanently flooded classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
Cardamine longii	Azola caroliniana	Aeschynomene virginica
Fraxinus caroliniana	Carex decomposita	Amaranthus cannabinus
Nyssa aquatica	Carex hyalinolepis	Asclepias lanceolata
Peltandra virginica	Echinodorus cordifolius	Aster subulatus
Ranunculus flabellaris	Heteranthera reniformis	Bacopa inominita
Ranunculus laxicaulis	Hydrocotyle ranunculoides	Bidens coronata
Rumex verticillatus	Limnobium spongia	Carex alata
Triadenum walteri	Pontederia cordata	Carex torta
	Ranunculus sceleratus	Cladium jamaicense
	Sium suave	Cyperus brevifolioides
		Echinochloa walteri
		Elatine minima
		Elatine triandra
		Eleocharis halophila
		Eriocaulon parkeri
		Isoetes riparia
		Juncus acuminatus
		Justicia americana
		Lemna trisulca
		Lilaeopsis carolinensis
		Lilaeopsis chinensis
		Lobelia elongata
		Nelumbo lutea
		Nuphar luteum ssp. sagittifolium
		Physostegia purpurea
		Sacciolepis striata
		Sagittaria calycina v. spongiosa
		Sagittaria rigida
		Sagittaria subulata
		Scirpus acutus
		Sparganium eurycarpum
		Spirodella polyrhiza
		Wolfiella gladiata
		Zizania aquatica

Appendix P4 Conditional character-species of oligotrophic semipermanently flooded classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
Itea virginica	Carex comosa	Bidens laevis
Taxodium distichum	Hottonia inflata	Brasenia schreberi
	Hydrocotyle umbellata	Carex canescens
	Hydrocotyle verticillata	Dulichium arundinaceum
	Orontium aquaticum	Eleocharis equisetoides
		Eleocharis quadrangulata
		Eleocharis robbinsii
		Eriocaulon septangulare
		Glyceria acutiflora
		Glyceria septentrionalis
		Isoetes engelmannii
		Panicum hemitomon
		Polygonum amphibium
		Polygonum hydropiperoides
		Sagittaria graminea
		Scirpus ancistrochaetus
		Scirpus subterminalis
		Scirpus tabernaemontanii
		Scirpus torreyi

Appendix P5 Conditional character-species of eutrophic seasonally flooded classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
Arisaema dracontium	Carex gigantea	Axonopus furcatus
Carex crus-corvi	Hibiscus moscheutos	Cyperus erythrorhizos
Carex frankii	Justicia ovata v. lanceolata	Cyperus filicinus
Carex grayi	Penthorum sedoides	Cyperus strigosus
Carex oxylepis	Salix caroliniana	Eclipta alba
Carex squarrosa	Salix nigra	Eragrostis frankii
Carex typhina		Eragrostis hypnoides
Carya aquatica		Glyceria grandis
Commelina virginica		Juncus torreyi
Cornus foemina		Lippia lanceolata
Mimulus alatus		Phalaris arundinacea
Populus heterophylla		Rorippa palustris
Quercus bicolor		Scirpus atrovirens
Quercus lyrata		Scirpus fluviatilis
Saururus cernuus		Scirpus pendulus
Scirpus divaricatus		

Appendix P6 Conditional character-species of oligotrophic seasonally flooded classes

SHADE TOLERANT	MODERATELY SHADE TOLERANT	SHADE INTOLERANT
Carex crinita	Carex glaucescens	Boltonia asteroides
Carex louisianica	Carex joori	Calamagrostis canadensis
Carex lupulina	Carex walteriana	Carex albolutescens
Cinna arundinacea	Glyceria melicaria	Carex barrattii
Cornus amomum	Iris virginica	Cyperus dentatus
Quercus palustris	Juncus effusus	Drosera intermedia
	Scirpus cyperinus	Eleocharis baldwinii
		Eleocharis flavescens
		Eleocharis melanocarpa
		Eleocharis tricostata
		Eleocharis tuberculosa
		Erigeron vernus
		Eupatorium leucolepis
		Eupatorium recurvans
		Fimbristylis annua
		Fimbristylis autumnalis
		Fuirena pumila
		Glyceria canadensis v. laxa
		Helenium virginicum
		Juncus brevicaudatus
		Juncus caesariensis
		Juncus canadensis
		Juncus repens
		Juncus scirpoides
		Lachnocaulon anceps
		Lindernia anagallidea
		Lipocarpha maculata
		Lobelia puberula
		Ludwigia brevipes
		Ludwigia sphaerocarpa
		Lysimachia hybrida
		Panicum rigidulum
		Proserpinaca palustris
		Proserpinaca pectinata
		Pycnanthemum flexuosum
		Rhynchospora caduca
		Rhynchospora cephalantha
		Rhynchospora corniculata
		Rhynchospora macrostachya
		Scirpus purshianus

Appendix P7 Conditional character-species of the submergent/floating-leaved class

Cabomba caroliniana
Callitriche heterophylla
Ceratophyllum demersum
Ceratophyllum muricatum
Elodea canadensis
Elodea nuttallii
Heteranthera dubia
Myriophyllum heterophyllum
Myriophyllum humile
Myriophyllum spicatum
Najas flexilis
Najas gracillima
Najas guadalupensis
Nymphoides aquatica
Podostemon ceratophyllum
Potamogeton crispus
Potamogeton diversifolius
Potamogeton epihydrus
Potamogeton foliosus
Potamogeton illinoensis
Potamogeton nodosus
Potamogeton oakesianus
Potamogeton pectinatus
Potamogeton perfoliatus
[illegible]eton pulcher
[illegible]eton pusillus
[illegible]mogeton spirilus
Potamogeton tennesseensis
Potamogeton zosteriformis
Utricularia biflora
[illegible]ularia fibrosa
[illegible]icularia inflata
Utricularia purpurea
Utricularia radiata
Utricularia vulgaris
Vallisneria americana
Zannichellia palustris

APPENDIX B

List of watchlist species recorded during 1994-1995 at Polecat Creek.

Scientific name	Common name
Plants:	
Lechea minor	thyme-leaf pinweed
Lechea mucronata	hairy pinweed
Euphorbia ipecacuanhae	wild ipecac
Utricularia geminiscapa	hidden-fruited bladderwort
Animals:	
Acantharcus pomotis	mud sunfish
Calopteryx dimidiata	sparkling jewelwing
Lampetra aepypetra	least brook lamprey
Lestes inaequalis	elegant spreadwing
Lestes vigilax	swamp spreadwing
Rana virgatipes	carpenter frog
Strophitus undulatus	squawfoot

APPENDIX C

Appendix 3. Data collected from mussels at sites B and D, by species.

Pyganadon cataracta (n = 11)

Identification #	Length mm	Height mm	Width mm
B008	58.5	30.6	21.3
B024	60.5	34.0	22.7
B034	61.7	33.7	20.3
B039	64.6	35.2	22.4
B042	62.6	36.3	22.5
B069	91.5	47.3	32.6
B099	77.5	43.7	28.7
B104	58.9	34.5	22.0
B119	73.7	42.5	26.5
B125	108.0	55.4	39.5
B250	30.1	17.7	11.5

Strophitus undulatus (n = 1)

Identification #	Length mm	Height mm	Width mm
B171	67.5	39.9	26.5

Elliptio complanata from site D (Gauging station D, Polecat Creek).

Identification #	Length mm	Height mm	Width mm
D001	92.0	47.9	31.6
D002	91.8	52.1	26.3
D003	82.2	45.2	23.5
D004	89.4	45.2	23.5
D005	70.7	36.8	20.2
D006	77.1	41.4	23.4
D007	72.9	40.4	21.5
D008	71.0	38.2	21.0
D009	69.7	35.6	19.3
D010	58.8	30.6	14.4
D011	73.5	41.7	20.3
D012	59.3	30.2	15.2
D013	51.6	27.7	13.2
D014	56.2	30.2	16.3
D015	49.0	25.4	13.4
D016	58.0	28.3	15.2
D017	41.4	20.4	11.3
D018	40.1	21.2	10.4
D019	69.6	59.0	20.6
D020	65.4	35.1	19.7
D021	66.1	37.3	18.3
D022	76.8	42.0	23.1
D023	64.5	37.8	18.0
D024	63.8	35.4	17.6
D025	64.8	35.7	19.8
D026	66.7	37.8	19.2
D027	55.1	29.3	13.8
D028	75.1	42.1	20.4
D029	68.4	35.8	21.3
D030	54.1	29.2	15.7
D031	80.1	44.7	21.0
D032	71.3	38.5	21.5
D033	65.2	33.1	16.8
D034	83.8	49.9	28.3
D035	59.7	28.7	14.5
D036	55.5	28.7	14.0
D037	67.2	36.3	19.5
D038	92.8	51.5	29.4
D039	58.2	29.4	15.2
D040	64.2	36.5	17.9
D041	60.0	33.6	17.4
D042	60.8	35.6	17.3
D043	71.3	38.3	21.5
D044	54.1	28.3	13.8
D045	75.1	42.9	20.8
D046	59.1	32.1	18.3
D047	66.9	37.1	20.9

Site D (cont'd)

D048	70.3	38.8	19.7
D049	83.4	49.0	26.7
D050	88.1	50.6	27.9
D051	76.1	40.6	22.4
D052	55.0	28.7	13.5
D053	70.8	37.1	18.8
D054	72.7	38.5	19.7
D055	63.8	35.2	17.5
D056	74.3	38.8	22.1
D057	65.7	37.2	18.0
D058	64.9	37.1	19.0
D059	71.1	40.3	21.1
D060	75.7	49.0	20.0
D061	67.0	36.7	20.4
D062	58.6	33.0	17.6
D063	73.3	39.0	21.4
D064	70.2	38.2	20.7
D065	67.7	36.1	20.1
D066	71.6	41.2	20.2
D067	78.2	43.7	23.2
D068	71.0	41.5	21.8
D069	80.0	46.9	26.1
D070	81.6	46.1	25.4
D071	71.4	42.5	20.9
D072	71.4	39.6	21.7
D073	62.4	35.2	19.2
D074	75.4	41.1	20.5
D075	75.5	40.2	19.5
D076	78.9	43.9	22.1
D077	74.0	40.0	22.0
D078	87.7	46.3	22.8
D079	56.3	30.3	14.5
D080	67.4	37.6	19.3
D081	69.2	37.8	20.2
D082	68.8	37.3	18.5
D083	54.1	29.4	15.8
D084	72.6	40.0	23.0
D085	73.5	38.0	19.0
D086	69.5	39.5	20.0
D087	75.0	40.3	20.3
D088	67.3	38.2	20.4
D089	69.1	38.3	21.2
D090	68.6	36.5	17.3
D091	52.8	28.1	13.9
D092	75.3	41.3	21.3
D093	60.6	34.0	17.2
D094	64.8	36.7	19.8
D095	82.2	44.0	22.0
D096	92.8	50.2	26.4
D097	64.7	35.4	19.5
D098	64.8	36.9	18.9
D099	67.3	35.9	19.4

Site D (cont'd)

D100	64.3	37.3	21.2
D101	90.0	50.7	28.3
D102	91.3	51.8	28.1
D103	70.5	38.2	19.4
D104	66.2	36.3	19.0
D105	62.5	35.5	18.5
D106	71.6	37.5	18.9
D107	66.2	37.2	19.2
D108	67.4	36.7	18.5
D109	63.3	33.9	16.0
D110	84.5	46.3	27.0
D111	74.9	42.3	24.1
D112	111.6	62.9	31.5
D113	84.4	49.2	27.7
D114	59.5	33.8	16.2
D115	70.0	40.7	23.3
D116	53.0	29.8	15.4
D117	59.5	29.7	14.9
D118	71.9	40.0	21.8
D119	72.3	37.5	20.0
D120	82.0	44.7	22.6
D121	88.2	49.8	23.2
D122	75.5	39.1	20.0
D123	81.0	46.4	24.4
D124	73.5	41.5	20.7
D125	72.2	41.2	20.4
D126	72.6	37.9	19.1
D127	69.0	38.9	19.0
D128	69.2	38.7	19.7
D129	73.0	39.8	20.4
D130	73.9	40.6	21.4
D131	62.4	35.6	18.5
D132	61.5	32.2	16.4
D133	78.5	42.1	21.2
D134	50.0	27.5	13.8
D135	76.7	40.2	23.2
D136	69.2	35.8	19.5
D137	74.9	39.3	20.0
D138	71.2	37.5	18.8
D139	72.1	37.8	19.7
D140	76.3	40.9	21.4
D141	76.1	41.5	24.0
D142	65.8	36.1	19.7
D143	65.6	36.0	18.3
D144	73.1	38.7	20.3
D145	75.8	41.3	21.9
D146	71.3	39.7	21.2
D147	71.4	38.6	20.4
D148	89.9	51.2	27.1
D149	83.5	47.0	25.2
D150	53.4	28.2	14.0
D151	65.5	35.6	19.4

Site D (cont'd)

D152	66.2	35.7	19.3
D153	84.0	44.5	26.8
D154	46.2	26.3	13.3
D155	56.6	29.6	14.6
D156	39.6	22.4	12.0
D157	54.0	27.7	14.3
D158	50.7	27.3	14.2
D159	53.0	32.3	14.9
D160	60.6	32.3	14.9
D161	62.8	33.9	16.2
D162	64.5	34.5	18.9
D163	62.8	34.3	17.6
D164	67.3	37.9	19.5
D165	69.5	36.7	17.6
D166	61.7	33.6	14.6
D167	69.2	36.6	21.3
D168	68.5	37.2	18.8
D169	69.7	39.2	20.3
D170	76.3	43.1	24.5
D171	70.4	37.0	19.8
D172	84.1	46.5	28.2
D173	72.0	41.0	22.2
D174	79.5	43.0	24.7
D175	79.4	46.3	25.3
D176	86.5	47.9	26.2
D177	71.5	39.2	19.9
D178	87.1	49.7	22.9
D179	67.8	39.2	20.5
D180	55.0	28.8	14.4
D181	63.8	34.5	14.7
D182	71.4	40.0	19.6
D183	78.7	43.4	25.5
D184	57.0	28.7	14.7
D185	81.5	46.9	25.7
D186	68.7	37.5	19.9
D187	79.5	44.3	22.6
D188	65.8	37.2	16.2
D189	82.0	47.5	21.3
D190	50.8	27.7	15.2
D191	62.7	33.1	16.0
D192	70.0	36.9	19.5
D193	69.5	38.0	19.4
D194	75.7	41.5	20.9
D195	83.5	47.5	26.0
D196	67.4	37.4	19.4
D197	78.7	47.0	24.2
D198	78.5	41.7	23.0
D199	87.6	50.0	27.5
D200	58.6	32.1	15.5
D201	67.1	38.2	19.3
D202	68.6	37.1	19.9
D203	71.9	40.3	19.4

Site D (cont'd)

D204	70.2	36.5	19.6
D205	69.5	40.0	17.7
D206	70.3	42.7	20.6
D207	52.4	28.3	14.5
D208	57.7	30.1	13.2
D209	90.7	46.2	26.1
D210	70.9	37.6	20.7
D211	74.4	41.8	21.0
D212	67.3	39.1	20.4
D213	66.2	36.8	19.4
D214	63.3	35.5	19.0
D215	47.7	26.8	12.8
D216	46.5	24.2	12.4
D217	61.2	32.8	18.1
D218	72.2	37.3	20.9
D219	67.5	38.0	19.8
D220	50.9	25.9	13.7
D221	70.3	39.1	19.2
D222	62.1	34.0	17.9
D223	74.2	40.4	21.5
D224	78.0	43.6	20.7
D225	75.7	42.0	19.4
D226	72.7	40.2	21.7
D227	65.6	37.0	16.6
D228	66.2	38.8	20.5
D229	65.7	35.7	18.2
D230	73.7	41.1	21.2
D231	61.9	33.4	16.0
D232	81.0	47.1	25.2
D233	56.0	28.7	12.9
D234	62.1	34.1	18.5
D235	58.8	32.3	16.6
D236	92.4	49.8	26.3
D237	47.5	23.7	12.2
D238	52.2	29.4	13.7
D239	63.2	33.5	18.0
D240	69.1	38.0	20.1
D241	65.1	34.2	17.7
D242	66.0	33.9	18.2
D243	70.2	39.3	20.3
D244	53.1	29.0	16.2
D245	76.9	42.1	21.1
D246	74.4	40.6	20.0
D247	88.7	49.5	25.7
D248	49.9	28.2	12.8
D249	72.2	37.2	18.2
D250	70.6	36.2	16.7
D251	75.7	41.7	20.2
D252	54.2	28.5	14.7
D253	74.7	37.8	20.6
D254	69.3	38.1	20.7
D255	56.8	28.8	14.9

Site D (cont'd)

D256	61.1	33.3	15.2
D257	69.3	37.3	19.5
D258	79.4	42.3	21.0
D259	76.4	43.1	22.8
D260	62.7	33.9	16.8
D261	68.1	36.3	19.5
D262	51.0	28.2	13.1
D263	71.6	40.2	20.5
D264	71.7	39.2	19.5
D265	65.3	38.0	19.2
D266	60.2	33.5	18.3
D267	48.6	26.1	12.0
D268	73.2	41.7	20.5
D269	76.3	43.1	24.9
D270	47.1	26.6	13.5
D271	51.9	26.9	13.8
D272	65.8	34.5	17.3
D273	71.3	35.7	20.0
D274	91.7	53.6	27.3
D275	77.8	44.4	21.2
D276	56.2	29.1	15.1
D277	61.1	33.5	18.4
D278	67.8	35.7	20.5
D279	63.3	33.8	18.2
D280	65.5	36.0	17.0
D281	63.4	33.5	14.9
D282	80.5	43.9	25.7
D283	73.7	40.1	20.4
D284	70.8	38.5	21.0
D285	54.7	30.2	15.6
D286	52.6	27.8	14.3
D287	71.8	38.7	18.5
D288	66.0	34.7	19.1
D289	66.3	38.6	22.3
D290	74.8	42.3	22.1
D291	72.9	41.5	22.5
D292	65.8	36.8	20.3
D293	63.2	33.9	18.6
D294	70.6	37.7	19.2
D295	56.5	28.2	16.1
D296	71.0	39.0	22.7
D297	52.3	39.4	14.5
D298	50.2	27.3	14.1
D299	73.7	39.9	20.7
D300	48.4	25.5	13.0
D301	59.5	32.4	16.7
D302	48.5	26.4	13.0
D303	60.0	33.8	17.0
D304	48.7	25.5	12.1
D305	60.7	35.2	17.9
D306	65.5	37.0	20.6
D307	73.6	38.9	19.2

Site D (cont'd)

D308	85.2	49.7	24.7
D309	83.3	45.2	22.5
D310	72.5	39.2	18.6
D311	67.5	34.4	18.5
D312	66.3	35.5	19.3
D313	61.2	32.8	18.0
D314	63.3	34.0	19.1
D315	49.5	26.5	13.5
D316	53.5	28.8	13.4
D317	67.2	36.5	20.7
D318	67.8	34.6	20.5
D319	61.0	32.6	16.3
D320	51.7	26.8	13.5
D321	53.6	29.5	13.4
D322	61.8	33.0	20.2
D323	69.2	35.8	20.5
D324	63.5	35.5	18.3
D325	no measurements taken on this animal		
D326	61.3	33.3	18.9
D327	69.6	36.9	20.0
D328	68.7	37.3	19.1
D329	75.2	39.7	20.5
D330	75.4	40.0	21.5
D331	43.9	23.1	12.2
D332	57.9	30.0	14.7
D333	56.5	31.1	15.3
D334	55.8	29.0	15.2
D335	56.3	31.2	15.3
D336	58.0	32.0	16.2
D337	55.5	29.5	14.1
D338	57.8	31.2	14.5
D339	71.2	39.0	20.7
D340	70.5	37.6	22.5
D341	48.8	24.5	13.0
D342	66.5	34.0	15.7
D343	68.5	36.7	18.6
D344	93.5	52.7	27.8
D345	70.8	38.9	19.5
D346	67.0	36.5	18.6
D347	69.3	36.9	21.1
D348	68.9	39.8	21.9
D349	67.5	35.3	20.0
D350	59.8	32.1	16.6
D351	64.5	37.5	20.2
D352	72.5	39.0	20.9
D353	68.7	38.0	19.5
D354	63.3	36.0	19.7
D355	46.2	25.1	11.5
D356	88.2	47.0	24.3
D357	64.3	34.1	19.9
D358	75.7	39.9	21.0
D359	78.7	44.8	28.0

Site D (cont'd)

D360	59.5	32.7	18.3
D361	46.5	26.7	11.4
D362	79.2	43.9	19.8
D363	83.7	45.8	24.5
D364	85.4	50.5	25.4
D365	72.8	39.3	21.5
D366	80.6	43.7	24.8
D367	66.2	36.3	15.5
D368	44.5	23.8	12.0
D369	66.1	36.1	18.2
D370	77.6	41.5	22.9
D371	63.5	33.7	17.5
D372	66.8	37.1	17.6
D373	109.6	59.0	30.6
D374	88.7	50.5	31.7
D375	90.2	49.4	24.5
D376	70.1	39.3	18.7
D377	50.5	26.1	13.2
D378	78.6	45.3	28.3
D379	55.9	30.0	15.3
D380	58.2	30.3	15.2
D381	67.6	37.2	18.1
D382	95.8	58.2	29.7
D383	69.0	39.3	20.6
D384	63.0	32.8	17.6
D386	70.6	37.4	20.2
D387	78.0	44.6	25.0
D388	55.5	30.9	15.4
D389	59.0	32.5	17.0
D390	78.0	42.8	22.4
D391	63.5	35.2	19.4
D392	41.6	22.3	10.9
D393	70.7	39.3	21.3
D394	51.1	28.4	13.2
D395	73.2	38.3	19.2
D396	62.4	33.8	17.1
D397	58.5	29.3	13.7
D398	67.6	39.3	18.5
D399	69.6	38.2	19.3
D400	83.0	51.0	26.0
D401	67.7	38.9	20.4
D402	65.8	35.4	18.0
D403	58.5	31.0	14.5
D404	62.0	33.1	15.9
D405	68.9	38.3	19.2
D406	62.5	34.8	18.0
D407	47.8	25.4	13.2
D408	50.1	27.9	14.1
D409	69.7	38.1	20.5
D410	77.7	45.0	24.1
D411	70.5	38.0	19.5
D412	55.9	28.2	14.1

Site D (cont'd)

D413	80.6	42.6	19.2
D414	67.9	36.8	19.0
D415	56.1	31.2	15.0
D416	76.3	41.3	20.4
D417	66.4	36.3	18.1
D419	68.7	37.2	19.9
D420	64.3	34.1	15.3
D421	71.7	38.2	18.5
D422	65.6	35.7	18.1
D423	65.5	36.5	19.0
D424	50.9	27.8	15.0
D426	55.2	31.7	16.3
D427	73.4	39.5	15.9
D428	84.7	48.0	27.5
D429	67.4	38.3	18.5
D430	60.4	33.3	17.3
D431	48.7	26.1	12.8
D432	63.7	37.5	19.6
D433	66.9	36.8	19.5
D434	71.6	41.4	20.2
D435	59.4	33.4	19.0
D436	62.4	34.4	17.1
D437	74.9	41.5	20.0
D438	55.4	31.1	16.0
D439	59.9	34.2	19.2
D440	86.0	49.0	27.5
D441	80.8	46.6	24.3
D442	72.4	40.2	20.0
D443	71.8	39.2	20.2
D444	62.4	33.9	16.4
D445	56.8	30.9	14.7
D446	59.1	30.9	14.8
D447	68.2	37.7	21.0
D448	68.6	38.7	20.3
D449	70.9	37.8	20.6
D450	63.8	34.5	18.0
D451	52.8	28.5	13.0
D452	49.0	25.6	12.7
D453	73.1	42.5	21.8
D454	73.3	39.2	22.2
D455	76.3	39.5	20.5
D456	56.7	31.1	15.8
D457	53.2	30.3	14.6
D458	56.2	32.8	17.0
D459	82.6	46.9	23.4
D460	66.2	34.0	16.9
D461	64.0	35.4	20.3
D462	77.4	41.7	20.4
D463	66.3	38.3	21.1
D464	86.5	49.1	27.0
D465	61.2	34.8	18.9
D466	68.8	38.9	20.4

Site D (cont'd)

D467	63.1	35.0	15.5
D468	76.9	43.6	26.4
D469	47.4	24.0	12.3
D471	69.0	42.5	22.7
D472	67.3	35.5	17.5
D473	66.1	37.1	20.1
D474	61.4	36.7	18.0
D479	80.2	46.8	27.4
D480	72.7	39.6	22.9
D481	58.2	31.5	14.7
D482	56.4	33.5	18.1

Total number marked at site D = 473

***Elliptio complanata* from site B (Gauging station B, Stevens Mill Run).**

Identification #	Length mm	Height mm	Width mm
B001	73.4	41.3	23.5
B002	64.0	34.8	18.3
B003	79.5	45.2	24.9
B004	81.1	44.8	23.8
B005	79.1	43.7	25.8
B006	104.7	60.9	29.8
B007	85.4	46.8	28.1
B009	80.6	44.7	25.9
B010	75.0	42.7	24.2
B011	61.5	35.4	19.3
B012	57.7	32.0	16.4
B013	76.3	42.1	24.0
B014	72.9	42.8	24.9
B015	61.0	33.9	18.7
B016	81.2	45.7	25.3
B017	80.1	45.5	26.4
B018	67.0	38.7	22.6
B019	87.5	45.1	24.5
B020	71.2	40.6	19.6
B021	84.7	49.2	26.7
B022	72.1	40.6	20.9
B023	50.6	26.9	13.7
B025	85.6	47.7	28.7
B026	86.5	47.2	25.7
B027	74.3	43.8	23.9
B028	73.1	42.7	22.6
B029	71.1	39.1	23.4
B030	67.2	38.6	19.6
B031	84.7	48.1	27.5

Site B (cont'd)

B032	78.3	44.0	25.5
B033	67.5	40.4	21.3
B035	77.9	43.4	23.1
B036	98.6	54.2	26.9
B037	57.6	32.4	18.7
B038	80.0	43.6	25.6
B040	87.9	47.5	25.4
B041	79.3	44.3	24.2
B043	76.3	41.3	24.9
B044	71.4	42.1	22.1
B045	72.3	42.5	21.5
B046	75.6	42.3	20.6
B047	77.8	43.9	26.3
B048	69.3	37.7	20.1
B049	95.0	50.9	27.5
B050	55.0	28.5	15.4
B051	83.8	45.9	26.8
B052	71.3	40.2	23.1
B053	79.4	46.0	27.0
B054	85.7	47.5	27.4
B055	89.2	48.5	29.8
B056	68.3	41.4	21.6
B057	76.8	44.1	22.9
B058	82.5	43.4	21.6
B059	81.0	46.4	25.0
B060	75.6	40.2	23.6
B061	39.1	21.3	11.7
B062	88.4	49.1	26.9
B063	87.3	50.5	28.2
B064	94.6	51.5	27.7
B065	77.8	45.3	24.9
B066	67.9	41.3	21.5
B067	78.4	43.0	25.2
B068	84.5	46.6	29.1
B070	90.1	49.4	26.1
B071	76.2	41.1	26.1
B072	88.0	50.0	27.8
B073	92.7	50.4	27.2
B074	107.6	58.4	30.7
B075	85.7	50.4	25.7
B076	91.7	50.3	27.0
B077	77.6	44.1	23.7
B078	90.4	50.5	25.7
B079	57.3	32.2	15.5
B080	98.3	52.5	31.2
B081	83.6	45.2	25.3
B082	67.2	38.5	21.5
B083	68.1	39.1	19.6
B084	85.8	47.3	23.9
B085	81.0	46.4	24.5
B086	61.4	34.4	18.2
B087	74.7	41.6	20.3

Site B (cont'd)

B088	93.3	52.8	26.0
B089	69.1	38.1	18.7
B090	73.3	40.0	23.6
B091	77.8	45.3	22.5
B092	73.5	42.1	19.8
B093	71.6	39.7	23.2
B094	78.9	47.2	26.5
B095	72.6	41.3	25.7
B096	74.4	42.0	24.9
B097	85.0	46.8	27.7
B098	77.2	42.3	21.6
B100	73.6	43.5	23.6
B101	65.7	36.6	19.5
B102	60.6	34.6	20.2
B103	64.6	35.8	18.4
B105	58.8	30.8	15.5
B106	79.2	43.0	25.7
B107	72.4	41.2	22.7
B108	57.5	34.6	18.8
B109	54.8	31.4	18.4
B110	86.0	45.3	25.8
B111	78.9	44.5	23.3
B112	89.0	51.4	27.5
B113	83.1	48.8	28.3
B114	73.7	41.7	23.2
B115	62.7	35.8	16.0
B116	76.0	42.9	23.3
B117	63.0	36.0	19.0
B118	72.0	38.1	23.0
B120	61.3	34.0	20.2
B121	53.5	27.7	14.2
B122	84.0	44.7	23.4
B123	73.3	43.6	21.0
B124	70.3	42.6	24.9
B126	82.3	46.2	21.6
B127	77.0	42.5	24.0
B128	75.5	40.7	21.3
B129	74.8	41.7	24.4
B130	61.8	33.8	18.3
B131	68.7	40.0	21.0
B132	79.8	44.8	20.8
B133	68.3	37.6	20.7
B134	69.4	39.4	23.1
B135	68.2	38.0	19.6
B136	63.0	33.7	18.3
B137	74.3	41.5	21.3
B138	71.9	41.4	21.3
B139	52.5	27.2	14.0
B140	47.8	27.8	14.2
B141	77.2	41.8	22.4
B142	84.8	47.0	24.7
B143	96.5	49.8	28.0

Site B (cont'd)

B144	69.4	37.9	23.6
B145	69.7	43.0	20.2
B146	73.5	41.7	23.4
B147	78.6	42.1	23.5
B148	82.1	46.5	27.8
B149	71.0	37.9	19.8
B150	75.4	41.8	23.7
B151	87.7	49.0	25.4
B152	72.0	40.2	22.1
B153	89.3	50.6	23.4
B154	79.1	43.1	23.8
B155	58.7	33.1	17.7
B156	70.7	40.3	23.3
B157	74.2	43.7	23.0
B158	67.5	39.5	20.4
B159	90.2	48.6	27.7
B160	65.3	34.8	19.9
B161	78.3	43.7	21.6
B162	49.6	29.1	14.1
B163	48.9	27.8	13.9
B164	60.5	31.9	18.8
B165	71.1	39.4	23.9
B166	65.3	36.2	16.9
B167	94.5	51.2	26.2
B168	80.7	44.0	26.1
B169	82.9	46.5	23.4
B170	83.1	46.0	27.0
B172	66.4	37.7	16.2
B173	83.2	47.4	25.1
B174	78.6	41.2	23.6
B175	68.7	40.1	22.5
B176	62.5	33.5	60.2
B177	63.3	37.1	20.1
B178	54.6	31.5	16.0
B179	70.6	39.2	21.5
B180	61.6	35.2	17.0
B181	49.8	28.6	14.0
B182	55.1	30.4	16.8
B183	90.1	53.3	28.6
B184	84.0	46.5	23.7
B185	84.8	43.8	27.0
B186	102.6	56.8	27.4
B187	71.2	38.6	20.4
B188	79.2	44.0	25.2
B189	84.3	50.0	25.5
B190	78.0	43.8	23.7
B191	94.1	52.4	31.1
B192	76.6	45.0	25.4
B193	79.1	46.4	24.6
B194	73.8	41.2	24.4
B195	69.4	38.5	19.5
B196	59.8	29.9	16.6

Site B (cont'd)

B197	87.4	46.0	27.4
B198	61.3	33.9	18.6
B199	57.5	32.4	16.3
B200	80.5	43.3	26.7
B201	79.9	44.4	26.2
B202	81.0	47.4	22.0
B203	81.5	44.8	23.8
B204	90.3	48.2	27.5
B205	76.7	42.8	21.9
B206	82.6	44.8	25.4
B207	76.6	42.2	23.0
B208	70.1	41.5	22.3
B209	84.4	49.4	27.2
B210	64.4	35.6	20.7
B211	76.9	43.1	23.3
B212	75.8	43.1	23.5
B213	82.2	47.0	22.0
B214	67.5	37.0	22.0
B215	80.0	45.8	26.4
B216	59.2	33.5	18.1
B217	84.2	47.0	27.0
B218	82.2	46.2	26.9
B219	72.2	40.5	21.9
B220	73.2	40.5	20.7
B221	74.1	40.2	18.5
B222	60.8	35.9	20.5
B223	56.5	30.5	16.3
B224	86.8	50.2	27.2
B225	71.7	42.5	23.7
B226	83.5	48.3	26.8
B227	68.5	37.2	20.4
B228	60.8	32.0	21.9
B229	75.0	41.2	25.2
B230	55.4	31.1	15.1
B231	78.3	43.5	23.8
B232	66.8	38.2	20.3
B233	73.5	42.5	24.7
B234	77.0	43.5	25.0
B235	68.0	40.0	19.5
B236	66.2	37.3	17.4
B237	82.3	47.3	22.2
B238	74.3	43.1	24.6
B239	77.2	42.8	23.4
B240	82.2	43.1	23.6
B241	78.8	43.4	25.3
B242	83.1	45.8	27.0
B243	59.9	36.8	20.5
B244	55.8	30.5	13.7
B245	83.5	44.9	25.2
B246	78.9	45.7	23.6
B247	79.2	43.9	25.4
B248	57.2	29.9	13.2

Site B (cont'd)

B249	40.5	20.7	11.6
B251	23.8	13.0	5.4
B252	20.7	11.7	5.5
B253	79.6	45.5	22.6
B254	87.5	48.6	25.0
B255	93.2	50.9	32.1
B256	96.6	53.2	28.1
B257	75.9	43.1	22.1
B258	98.4	57.6	28.2
B259	51.3	34.5	17.4
B260	74.0	42.8	23.2
B261	76.8	42.8	25.5
B262	54.7	30.1	17.0
B263	62.7	36.6	18.2
B264	55.0	29.8	16.0
B265	92.6	51.5	28.2
B266	77.5	45.4	27.9
B267	107.6	59.7	31.5
B268	81.5	45.1	21.5
B269	78.9	46.0	25.9
B270	67.3	38.3	21.5
B271	92.0	49.4	30.1
B272	66.9	38.8	19.9
B273	88.2	49.9	24.2
B274	72.1	41.7	24.7
B275	74.5	42.1	25.0
B276	74.8	39.9	23.3
B277	60.2	34.5	19.6
B278	72.7	41.3	24.8
B279	69.7	40.1	21.8
B280	71.2	38.2	20.5
B281	99.1	57.8	29.7
B282	71.1	38.2	20.7
B283	81.3	45.6	25.8
B284	84.3	45.9	22.3
B285	53.8	30.1	15.3
B286	84.0	43.9	26.6
B287	76.0	43.4	25.3
B288	74.7	41.8	23.4
B289	98.6	52.6	26.3
B290	81.5	48.1	25.3
B291	81.2	44.5	23.2
B292	70.7	39.4	20.7
B293	73.8	39.3	25.7
B294	56.5	31.3	15.3
B295	83.1	46.2	22.7
B296	83.1	47.6	27.3
B297	63.0	35.9	20.8
B298	72.6	42.7	23.0
B299	69.8	40.7	21.4
B300	64.1	36.6	18.0
B301	70.3	38.4	20.1

Site B (cont'd)

B302	51.9	27.6	14.8
B303	88.0	50.4	26.6
B304	81.1	46.6	25.1
B305	67.8	38.3	17.8
B306	52.0	27.7	13.2
B307	69.5	38.8	21.9
B308	63.9	35.6	16.2
B309	78.4	43.5	24.9
B310	65.8	38.1	17.5
B311	49.5	28.8	14.4
B312	72.2	44.5	22.6
B313	30.9	17.6	10.8
B314	73.1	39.2	23.8
B315	82.5	46.3	28.6
B316	78.6	43.5	25.8
B317	80.5	44.6	22.8
B318	78.1	43.2	21.7
B319	78.2	43.4	25.8
B320	87.3	46.8	26.1
B321	89.9	49.5	29.0
B322	88.1	50.4	23.3
B323	80.7	41.9	25.3
B324	67.1	36.4	14.8
B325	69.7	36.3	17.1
B326	89.1	51.2	25.9
B327	69.9	40.9	22.1
B328	85.1	49.1	24.9
B329	86.4	47.3	28.5
B330	90.7	53.3	31.5
B331	67.7	37.8	24.0
B332	77.2	46.2	24.7
B333	64.5	38.2	21.9
B334	81.2	44.9	25.5
B335	62.5	33.5	not meas.
B336	78.9	43.8	26.2
B337	61.0	34.2	17.7
B338	78.2	43.3	24.6
B339	51.9	29.4	13.6
B340	58.7	32.6	15.8
B341	58.5	34.0	15.3
B342	70.0	41.5	24.5
B343	75.8	43.6	24.7
B344	58.7	31.3	14.9
B345	84.0	46.7	23.0
B346	77.9	43.4	21.5
B347	86.7	50.9	28.5
B348	81.5	48.7	26.1
B349	84.7	45.4	26.2
B350	73.1	41.8	21.5
B351	81.0	46.7	26.4
B352	84.0	51.0	24.8
B353	54.5	30.6	17.2

Site B (cont'd)

B354	76.6	42.3	25.1
B355	72.9	42.0	20.2
B356	84.9	47.7	29.1
B357	81.1	44.0	23.8
B358	71.0	43.0	22.7
B359	72.7	40.5	22.8
B360	87.6	45.4	25.2
B361	81.4	47.2	26.3
B362	79.5	45.0	26.5
B363	80.6	46.4	26.3
B364	78.1	42.4	23.0
B365	48.1	25.4	11.8
B366	66.5	36.5	20.1
B367	83.9	45.8	26.7
B368	97.9	51.6	27.6

number 296 was triple-tagged.
number 312 and numbers 314-368 above were double-tagged.

Total number marked at site B = 356

Recaptures recorded during 1995 from site B (with date of recapture).

Mussel Number	Date Recaptured
B002	3/15
B004	3/15
B006	3/15
B007	3/15
B008	3/15
B011	3/15
B012	3/17
B013	3/16
B014	3/16
B016	3/15
B017	3/15
B019	3/15
B020	3/15
B025	3/15
B028	3/15
B029	3/15
B030	3/15
B037	3/15
B038	3/15
B051	3/15
B040	3/16
B042*	3/16
B043	3/16
B047	3/16

Recaptures (cont'd)

B049	3/16
B054	3/16
B055	3/16
B056	3/16
B058	3/16
B059	3/16
B060	3/16
B062	3/16
B064	3/16
B067	3/16
B068	3/16
B073	3/16
B076	3/16
B077	3/16

* =*Pyganadon cataracta*

Total number of recaptures = 38

Date 5/04/95

Grant: NOAA CZM 10/01/93 Principal Task: Gage

		Grant Funds	State Funds	In Kind
Contractual	Allocated	66,934.00	52,707.00	0.00
	Spent	66,934.00	60,032.88	
	Remaining	0.00	(7,325.88)	0.00
Equipment	Allocated	0.00	100.00	0.00
	Spent		100.00	
	Remaining	0.00	0.00	0.00
Fringe	Allocated	755.00	0.00	4,978.00
	Spent	755.00		3,502.79
	Remaining	0.00	0.00	1,475.21
Personnel	Allocated	5,993.00	0.00	15,311.00
	Spent	5,993.00	.51	14,561.74
	Remaining	0.00	(.51)	749.26
Travel	Allocated	0.00	600.00	0.00
	Spent		600.00	
	Remaining	0.00	0.00	0.00

NOAA CZM 10/01/93

Expenditure Date	Recipient	Expenditure	Expenditure Description	Funding Source	Overall Allocation
12-Oct-94	VPI&SU	$11,631.00	Install Gages	Grant	Contractual
21-Nov-94	VPI&SU	$38,369.00	Install Gages	Grant	Contractual
12-Dec-94	VCU	$2,644.46	Biomonitoring 10/1/94 through 3/30/95	Grant	Contractual
18-Jan-95	VCU	$7,018.06	Biomonitoring	Grant	Contractual
30-Mar-95	VCU	$7,080.54	Biomonitoring 10/1/94 through 3/30/95	Grant	Contractual
30-Mar-95	VPI&SU	$190.94	Gage Monitoring (Jan'95 - Mar'95)	Grant	Contractual
30-Mar-95	DNH	$755.00	Final Report Mussel Surveys	Grant	Fringe
16-Nov-94	Div. Natural Heritage	$2,652.51	Mussel Survey - Personnel billed to Contractual	Grant	Personnel
29-Mar-95	DNH Reimbursement	$3,341.00	Final Report Mussel Surveys	Grant	Personnel
05-Apr-95	CBLAD	($0.51)	Adjustment to DNH Personnel Expenses	Grant	Personnel
		$73,682.00			
26-Mar-94	C.W. Jackson Hauling	$566.82	Repairs to Mr. Atkinson's driveway at Gage Site C	State	Contractual
28-Apr-94	VPI&SU	$38,369.48	Purchase Gage Equipment and Supplies	State	Contractual
15-Nov-94	VCU	$787.86	Biomonitoring	State	Contractual
22-Nov-94	VPI&SU	$1,133.52	Install Gages	State	Contractual
08-Dec-94	VPI&SU	$12,822.00	Gage Monitoring	State	Contractual
17-Jan-95	VCU	$1,919.14	Biomonitoring	State	Contractual
31-Mar-95	VPI&SU	$4,434.06	Gage Monitoring (Jan'95 - Mar'95)	State	Contractual
29-Mar-95	Div Natural Heritage	$100.00	Equipment reimbursement	State	Equipment
04-Apr-95	CBLAD	$0.51	Adjustment to DHN Personnel Expenses	State	Personnel
30-Mar-95	Div Natural Heritage	$600.00	Travel Reimbursement	State	Travel
		$60,733.39			

NOAA CZM 10/01/93

In Kind Expenditures

Position	Time Period Ends	Overall Allocation	DOLLARS
EE Fringe	30-Jun-94	Fringe	$15.93
SEN Fringe	30-Jun-94	Fringe	$39.04
EE Fringe	30-Sep-94	Fringe	$42.48
SEN Fringe	30-Sep-94	Fringe	$39.04
CE Fringe	31-Dec-94	Fringe	$378.00
DNH Eco Fri	31-Dec-94	Fringe	$385.60
DNH Zoo Fri	31-Dec-94	Fringe	$822.40
EE Fringe	31-Dec-94	Fringe	$185.26
SEC Fringe	31-Dec-94	Fringe	$72.48
SEN Fringe	31-Dec-94	Fringe	$554.40
CE Fringe	30-Mar-95	Fringe	$270.00
EE Fringe	30-Mar-95	Fringe	$174.64
SEC Fringe	30-Mar-95	Fringe	$48.32
SEN Fringe	30-Mar-95	Fringe	$475.20
			$3,502.79
EE Salary	30-Jun-94	Personnel	$208.04
SEN Salary	30-Jun-94	Personnel	$132.00
EE Salary	30-Sep-94	Personnel	$554.76
SEN Salary	30-Sep-94	Personnel	$132.00
CE Salary	31-Dec-94	Personnel	$1,259.44
DNH Zoo Per	31-Dec-94	Personnel	$2,740.00
EE Salary	31-Dec-94	Personnel	$2,471.18
SEC Salary	31-Dec-94	Personnel	$241.92
SEN Salary	31-Dec-94	Personnel	$1,848.00
CE Salary	30-Mar-95	Personnel	$899.60
EE Salary	30-Mar-95	Personnel	$2,329.52
SEC Salary	30-Mar-95	Personnel	$161.28
SEN Salary	30-Mar-95	Personnel	$1,584.00
			$14,561.74

INTERAGENCY TRANSFER INVOICE

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY VIRGINIA TECH OFFICE OF SPONSORED PROGRAMS	CODE 230 208	AGENCY FISCAL OFFICER CHESAPEAKE BAY LOCAL ASS'T DEP	CODE
ADDRESS 340 BURRUSS HALL BLACKSBURG, VIRGINIA 24061-0249		ADDRESS 805 EAST BROAD ST., SUITE 701 RICHMOND, VIRGINIA 23219	
INV # 0072 437952-0320	DATE 10/12/94	SHIPPED TO	
APPROVED BY (Whitestone (703)231-7387		AGENCY REFERENCE NO.	

DATE OF DELIVERY	DESCRIPTION OF ARTICLES OR SERVICES	UNITY	UNIT	UNIT PRICE	AMOUNT
7/1/94 THROUGH 9/30/94	TRANSFER FUNDS FOR POLECAT CREEK WATERSHED PROJECT.				20,022.00

NOTE

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT

I certify that this goods or is in agreement with the merchandise or service for which payment is being made, and that computations and coding on the voucher are correct and discounts taken are proper.

Initial [illegible]

VOUCHER #	DATE
930191	10/28/94
SHEET 1	20,022 00
SHEET 2	
SHEET 3	
SHEET 4	
TOTAL	20,022 00

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FY	PROGRAM	SUB	FTE	OBJ	REV SOURCE	AMOUNT	PROJECT	TK	PH
136	230		03	02	95					06050	20,022.00			

COST CODE	AGENC	PSD	AGY. REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REF DOC NUMBER	SX
			437952							

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGNCY	GLA	FUND	DET	FY	PROGRAM	SUB	FTE	OBJ.	REV. SOURCE	AMOUNT	PROJECT	TK	PH
380	408		100	00	95	503	02		1244		11631.00	40002		

COST CODE	FIPS	PSD	AGY. REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REF DOC NUMBER	SX

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXP. DISTRIBUTION SHEETS ARE ATTACHED

SUPPLIED BY: CREDIT	CODE:	SUPPLIED TO: CHARGE	CODE:
VIRGINIA TECH OFFICE OF SPONSORED PROGRAMS 340 BURRUSS HALL BLACKSBURG, VIRGINIA 24061-0249	208	**CHES. BAY LOCAL ASS'T.** 805 EAST BROAD STREET, SUITE 701 RICHMOND, VIRGINIA 23129 ATTENTION: JEAN TINGLER	

INVOICE DATE	INVOICE #	STATUS	SHIP TO:	
11/21/94	0109		AGENCY REF:	

DATE OF DELIVERY	DESCRIPTION OF ARTICLES OR SERVICES	TOTAL AMT	
4/1/94 THROUGH 9/30/94	FINAL BILLING FOR DESIGN AND IMPLEMENTATION OF A WATER QUALITY MONITORING SYSTEM FOR POLECAT CREEK WATERSHED - 94-408-04 **CREDIT: 437880-0320**	$39,502.52	

NOTE: SEC. 9 OF THE COMMONWEALTH OF VA ACCOUNTING POLICY & PROCEDURE MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR THIS DOCUMENT	I CERTIFY THAT THIS VOUCHER IS IN AGREEMENT WITH THE MERCHANDISE OR SERVICE FOR WHICH PAYMENT IS BEING MADE AND FURTHER, THAT COMPUTATIONS AND CODING ON THE VOUCHER ARE CORRECT AND DISCOUNTS TAKEN ARE PROPER. INITIAL:	VOUCHER	DATE	SUBMITTED BY:
				O. Terry **ODETTA TERRY** RESEARCH ADMIN. PHONE: **(703) 231-9387**
		SHEET 1		
		SHEET 2		
		SHEET 3		
		SHEET 4		
		TOTAL	$39,502.52	**(703) 231-4822**

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND			PROGRAM				REV	AMOUNT	PROJECT		
			FUND	DET	FY	PROG	SUB	ELE	OBJ	SOURCE		PROJ	TK	PH
136	208		03	02	95					06050	$39,502.52			

COST CODE	RIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM/DD/YY	REFERENCE DOC NUMBER	REFERENCE DOC SX
			437 880					

DESCRIPTION	CURRENT DOCUMENT NUMBER	CURRENT DOCUMENT SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND			PROGRAM				REV	AMOUNT	PROJECT		
			FUND	DET	FY	PROG	SUB	ELE	OBJ	SOURCE		PROJ	TK	PH
380	408		10	60	95	50302					~~$38,502.52~~ 38	40002		

COST CODE	RIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM/DD/YY	REFERENCE DOC NUMBER	REFERENCE DOC SX

DESCRIPTION	CURRENT DOCUMENT NUMBER	CURRENT DOCUMENT SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

CHECK BOX IF DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

38,369.00 pay with 1993 Comp Take Funds

1,133.52 pay with State Bonical Funds Jean Tingler

of Virginia

DISTRIBUTION CONTINUATION SHEET

NAME CBLAD (408)

VOUCHER ____________ DATE ____________ (MM DD YY)

AGENCY	GLA	FUND: FUND	FUND: DET	FFY	PROGRAM: PROG	PROGRAM: SUB	PROGRAM: ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT: PROJECT	PROJECT: TK	PROJECT: PH
408		01	00	95	503	02		1344		1,133.52			

FIPS	PSD	AGENCY REFERENCE	INVOICE: DATE	INVOICE: NUMBER	DUE DATE: MM	DUE DATE: DD	DUE DATE: YY	REFERENCE DOC: NUMBER	REFERENCE DOC: SX	√

DESCRIPTION	CURRENT DOCUMENT: NUMBER	CURRENT DOCUMENT: SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND: FUND	FUND: DET	FFY	PROGRAM: PROG	PROGRAM: SUB	PROGRAM: ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT: PROJECT	PROJECT: TK	PROJECT: PH
380	408		10	00	95	503	02		1344		38,369.00	40002		

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE: DATE	INVOICE: NUMBER	DUE DATE: MM	DUE DATE: DD	DUE DATE: YY	REFERENCE DOC: NUMBER	REFERENCE DOC: SX	√

DESCRIPTION	CURRENT DOCUMENT: NUMBER	CURRENT DOCUMENT: SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND: FUND	FUND: DET	FFY	PROGRAM: PROG	PROGRAM: SUB	PROGRAM: ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT: PROJECT	PROJECT: TK	PROJECT: PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE: DATE	INVOICE: NUMBER	DUE DATE: MM	DUE DATE: DD	DUE DATE: YY	REFERENCE DOC: NUMBER	REFERENCE DOC: SX	√

DESCRIPTION	CURRENT DOCUMENT: NUMBER	CURRENT DOCUMENT: SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND: FUND	FUND: DET	FFY	PROGRAM: PROG	PROGRAM: SUB	PROGRAM: ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT: PROJECT	PROJECT: TK	PROJECT: PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE: DATE	INVOICE: NUMBER	DUE DATE: MM	DUE DATE: DD	DUE DATE: YY	REFERENCE DOC: NUMBER	REFERENCE DOC: SX	√

DESCRIPTION	CURRENT DOCUMENT: NUMBER	CURRENT DOCUMENT: SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND: FUND	FUND: DET	FFY	PROGRAM: PROG	PROGRAM: SUB	PROGRAM: ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT: PROJECT	PROJECT: TK	PROJECT: PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE: DATE	INVOICE: NUMBER	DUE DATE: MM	DUE DATE: DD	DUE DATE: YY	REFERENCE DOC: NUMBER	REFERENCE DOC: SX	√

DESCRIPTION	CURRENT DOCUMENT: NUMBER	CURRENT DOCUMENT: SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

☐ CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

DA-02-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

*121294-378GC

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY VA Commonwealth University Grants and Contracts Accounting	CODE 236	AGENCY Chesapeake Local Assistance Dept. Fiscal Office	CODE 408
ADDRESS Box 843039 Richmond, Va 23284-3039		ADDRESS 701 E. Broad Street, Suite 701 Richmond, Va 23219	
INVOICE NUMBER #2	DATE (MM/DD/YY) 121294	SHIPPED TO Attn: Jean Tingler	
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Month Ending 11/30/94	To request payment in accordance with the contract between Chesapeake Bay Local Assistance and VCU for the project entitled "Local-Term Biological Characterization of Water Quality of Polecat Creek..." under the direction of Dr(s) Greg C. Garman and Len Smock. 0-38022-4213				2,644.46

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

initial JP

VOUCHER NUMBER 950334	DATE (MM/DD/YY) 011795
TOTAL THIS SHEET	2,644 46
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
136	236		03	02	95					06050	2 644 46			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	√

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
380	408		01	00	95	503	02		1244		2 644 46			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	√
611					1						

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

12-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

*011795- 451GC

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY	VA Commonwealth University Grants and Contracts Accounting — CODE 236	AGENCY	Chesapeake Local Assistance Dept. Fiscal Office — CODE 408
ADDRESS	Box 843039 Richmond, VA 23284-3039	ADDRESS	701 E. Broad Street, Suite 701 Richmond, VA 23219
INVOICE NUMBER	#3	DATE (MM/DD/YY)	1-17-95
		SHIPPED TO	Attn: Jean Tingler
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1/1/94 Office ~~Hing~~ thru 12/31/94	To request payment in accordance with the contract between Chesapeake Bay Local Assistance and VCU for the project entitled "Local-Term Biological Characterization of Water Quality of Polecat Creek..." under the direction of Dr(s) Greg C. Garman and Len Smock. 11/1/94 Thru 12/31/94 Received a separate billing for the month of Oct, 1994, in the amt of 787.36 0-38022-4213				8937.14 ~~9,725.00~~

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

initial JP - 1/17

VOUCHER NUMBER	DATE (MM/DD/YY)
15c473	030195
TOTAL THIS SHEET	8937.14 -9,725.00
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
136	236		03	02	95					06050	~~9,725.00~~ 8937.14			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
380	408		01	00	95	503	12		1244		1,717.14			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓
611											

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

PLEASE RETURN YELLOW COPY TO:
VCU GENERAL ACCOUNTING
BOX 843037
RICHMOND, VIRGINIA 23284-3037

DA-02-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

*040595- 679 GC

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY VA Commonwealth University Grants and Contracts Accounting	CODE 236	AGENCY Chesapeake Local Assistance Dept. Fiscal Office	CODE 406
ADDRESS Box 843039 Richmond, VA 23284-3039		ADDRESS 701 E. Broad Street, Suite 701 Richmond, VA 23219	
INVOICE NUMBER: #4	DATE (MM/DD/YY): 4-5-95	SHIPPED TO: Attn: Jean Tingler	
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Quarter Ending 03/31/95	To request payment in accordance with the contract between Chesapeake Bay Local Assistance and VCU for the project entitled "Local-Term Biological Characterization of Water Quality of Pole Cat Creek" under the direction of Dr(s) Greg C. Garman and Len Smock. 0-38022-4213				7,080.54

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

initial JP

VOUCHER NUMBER	DATE (MM/DD/YY)
TOTAL THIS SHEET	7,080 54
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FPY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
136	236		03	02	95					06050	7 080 54			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND	DET	FPY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

INTERAGENCY TRANSFER INVOICE

FYI

COPY

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY	CODE	AGENCY	CODE
Chesapeake Bay Local Assistance Department	408	Department of Enviornmental Quality	440
ADDRESS		ADDRESS	
805 E. Broad St., Ste 701 Richmond, VA 23219		P O Box 10150 Richmond, VA 23219	
INVOICE NUMBER	DATE (MM/DD/YY)	SHIPPED TO	
#95010	4/7/95		
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
10/01/94- 03/31/95	To request funds for expenditures incurred under the VCRMP Grant #NA37OZ03601, Task #9 CZM 1993 FEO FUNDS DNH SALARY $3341.00 AND DNH FRINGE + 755.00 $4096.00		-		4,096.00

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

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initial _____

VOUCHER NUMBER	DATE (MM/DD/YY)
TOTAL THIS SHEET	4,096 00
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	4,096 00

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
182 ~~821~~	408		10	00	95	503	02				4 096 99	40002		

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

DA 02-039 (REV 7/88)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

SUPPLIED BY: CREDIT			SUPPLIED TO: CHARGE		
AGENCY	DNR/DIVISION OF NATURAL HERITAGE	CODE 199	AGENCY	CHESAPEAKE BAY LOCAL ASSISTANCE DEPT	CODE 408
ADDRESS	P. O. Box 721, Financial Mgt Sect Richmond, Virginia 23219		ADDRESS	805 East BroadStreet, Suite 701 Richmond, Virginia 23219	
INVOICE NUMBER	H0074-S	DATE (MM/DD/YY) 11/16/94	SHIPPED TO		
REQUISITION NUMBER			AGENCY REFERENCE NO.		

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	Polecat Creek Water Quality Monitoring Project Freshwater Mussel Surveys through September, 1994				$2652.51

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

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Initial _____

VOUCHER NUMBER	DATE (MM/DD/YY)
950227	112294
TOTAL THIS SHEET	
TOTAL SHEET 2	2652 51
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	2652 51

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
136	199		02	00	95	503	17			02600	2652 51	7776		

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOCUMENT NUMBER	BSX
637			H0074-S	11/16/94						

DESCRIPTION	CURRENT DOCUMENT NUMBER	BSX	SUBSIDIARY ACCOUNT	MULTI PURPOSE
Polecat Creek				

C. W. Jackson Hauling, Inc.
ICC - 183693
P.O. Box 469
Milford, VA 22514

HAULING INVOICE 03-26-94 21049

TO:

CHESAPEAKE BAY LOCAL ASST.
805 E. BROAD ST. SUITE 701
RICHMOND, VA 23219

PLEASE REMIT TO:

C. W. Jackson Hauling, Inc.
ICC - 183693
P.O. Box 469
Milford, VA 22514

CUSTOMER NO. 1685 PAGE NUMBER 1 PHONE: 804-225-3440

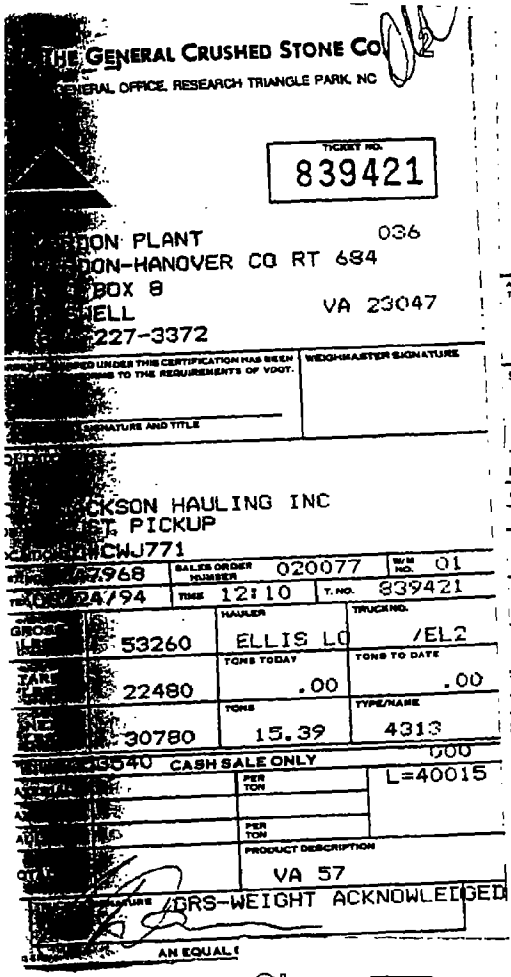
TRIP	DATE	TICKET	PICKUP LOCATION	DESTINATION	DRIVER	QUANTITY	RATE	TOTAL
415	03-24-94	839352	GEN. CRUSH/DOSWELL,V	ATKINSON - A940065	ELLIS B. LOVING	15.65	3.02	47.26
414	03-24-94	839365	GEN. CRUSH/DOSWELL,V	ATKINSON - A940065	ELLIS B. LOVING	15.61	3.02	47.14
412	03-24-94	839391	GEN. CRUSH/DOSWELL,V	ATKINSON - A940065	ELLIS B. LOVING	15.42	3.02	46.57
413	03-24-94	839421	GEN. CRUSH/DOSWELL,V	ATKINSON - A940065	ELLIS B. LOVING	15.39	3.02	46.48
	03-24-94		-- Daily Total --			62.07	----------	187.45
				ATKINSON - A940065	---- Job Total ----------	62.07	----------	187.45

TOTAL TICKETS 4 62.07 TOTAL DUE 187.45

TRIP	DATE	TICKET	PICKUP LOCATION	DESTINATION	MATERIAL	QUANTITY	RATE	AMOUNT	TAX	TOTAL
415	03-24-94	839352	GEN. CRUSH/DOSWELL	ATKINSON - A940065	GVA4-A	15.65	5.70	89.20	4.01	93.21
414	03-24-94	839365	GEN. CRUSH/DOSWELL	ATKINSON - A940065	GVA4-A	15.61	5.70	88.98	4.00	92.98
412	03-24-94	839391	GEN. CRUSH/DOSWELL	ATKINSON - A940065	GVA57	15.42	6.00	92.52	4.16	96.68
413	03-24-94	839421	GEN. CRUSH/DOSWELL	ATKINSON - A940065	GVA57	15.39	6.00	92.34	4.16	96.50
					TOTAL TICKETS 4	62.07		363.04	16.33	379.37

INVOICE SUMMARY

FOR HAULING	AMOUNT	187.45
FOR MATERIAL	AMOUNT	379.37
---) PLEASE PAY THIS AMOUNT ---) FOR HAULING + MATERIAL	TOTAL DUE	566.82



THE GENERAL CRUSHED STONE Co
GENERAL OFFICE, RESEARCH TRIANGLE PARK, NC

TICKET NO. 839421

DON PLANT 036
DON-HANOVER CO RT 684
BOX 8
ELL VA 23047
227-3372

AGGREGATE SHIPPED UNDER THIS CERTIFICATION HAS BEEN TESTED AND CONFORMS TO THE REQUIREMENTS OF VDOT. | WEIGHMASTER SIGNATURE
SIGNATURE AND TITLE

CKSON HAULING INC
ST PICKUP
#CWJ771
7968 SALES ORDER NUMBER 020077 W/M NO. 01
24/94 TIME 12:10 T. NO. 839421

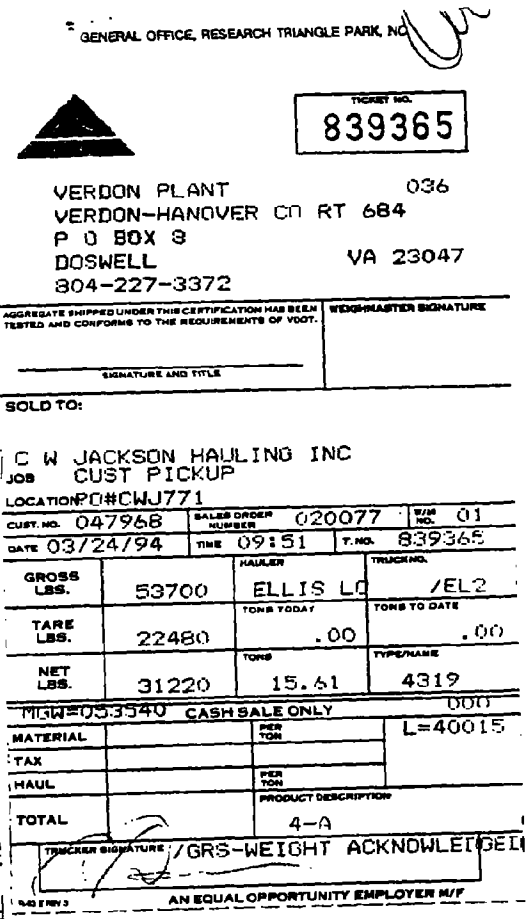
		HAULER	TRUCK NO.
GROSS LBS.	53260	ELLIS LC	/EL2
TARE LBS.	22480	TONS TODAY .00	TONS TO DATE .00
NET LBS.	30780	TONS 15.39	TYPE/NAME 4313

3540 CASH SALE ONLY 000

		PER TON	
			L=40015
		PER TON	
		PRODUCT DESCRIPTION	
	VA 57		

/GRS-WEIGHT ACKNOWLEDGED

AN EQUAL



GENERAL OFFICE, RESEARCH TRIANGLE PARK, NC

TICKET NO. 839365

VERDON PLANT 036
VERDON-HANOVER CO RT 684
P O BOX 8
DOSWELL VA 23047
804-227-3372

AGGREGATE SHIPPED UNDER THIS CERTIFICATION HAS BEEN TESTED AND CONFORMS TO THE REQUIREMENTS OF VDOT. | WEIGHMASTER SIGNATURE
SIGNATURE AND TITLE

SOLD TO:

C W JACKSON HAULING INC
JOB CUST PICKUP
LOCATION PO#CWJ771
CUST. NO. 047968 SALES ORDER NUMBER 020077 W/M NO. 01
DATE 03/24/94 TIME 09:51 T. NO. 839365

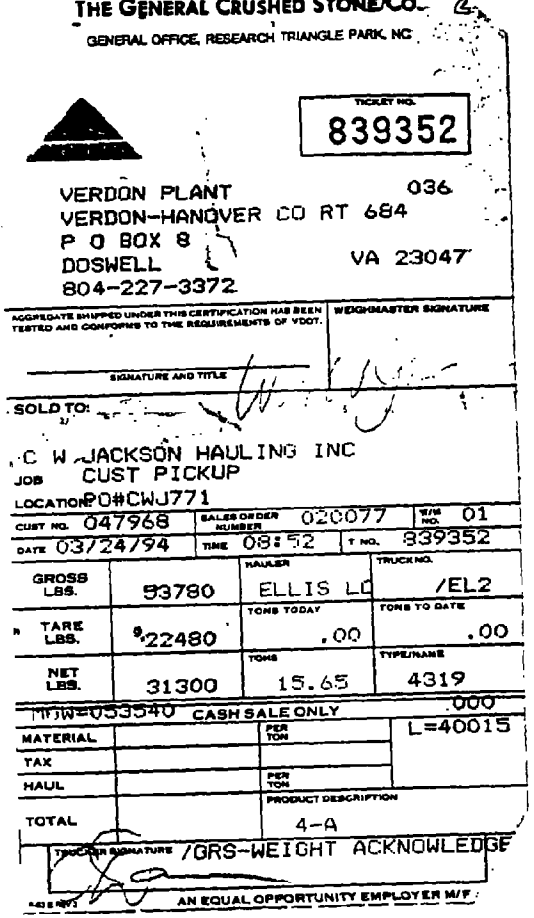
		HAULER	TRUCK NO.
GROSS LBS.	53700	ELLIS LC	/EL2
TARE LBS.	22480	TONS TODAY .00	TONS TO DATE .00
NET LBS.	31220	TONS 15.61	TYPE/NAME 4319

MIW=053540 CASH SALE ONLY 000

		PER TON	
MATERIAL			L=40015
TAX		PER TON	
HAUL		PRODUCT DESCRIPTION	
TOTAL	4-A		

TRUCKER SIGNATURE /GRS-WEIGHT ACKNOWLEDGED

AN EQUAL OPPORTUNITY EMPLOYER M/F



THE GENERAL CRUSHED STONE/CO.
GENERAL OFFICE, RESEARCH TRIANGLE PARK, NC

TICKET NO. 839352

VERDON PLANT 036
VERDON-HANOVER CO RT 684
P O BOX 8
DOSWELL VA 23047
804-227-3372

AGGREGATE SHIPPED UNDER THIS CERTIFICATION HAS BEEN TESTED AND CONFORMS TO THE REQUIREMENTS OF VDOT. | WEIGHMASTER SIGNATURE
SIGNATURE AND TITLE

SOLD TO:

C W JACKSON HAULING INC
JOB CUST PICKUP
LOCATION PO#CWJ771
CUST. NO. 047968 SALES ORDER NUMBER 020077 W/M NO. 01
DATE 03/24/94 TIME 08:52 T. NO. 839352

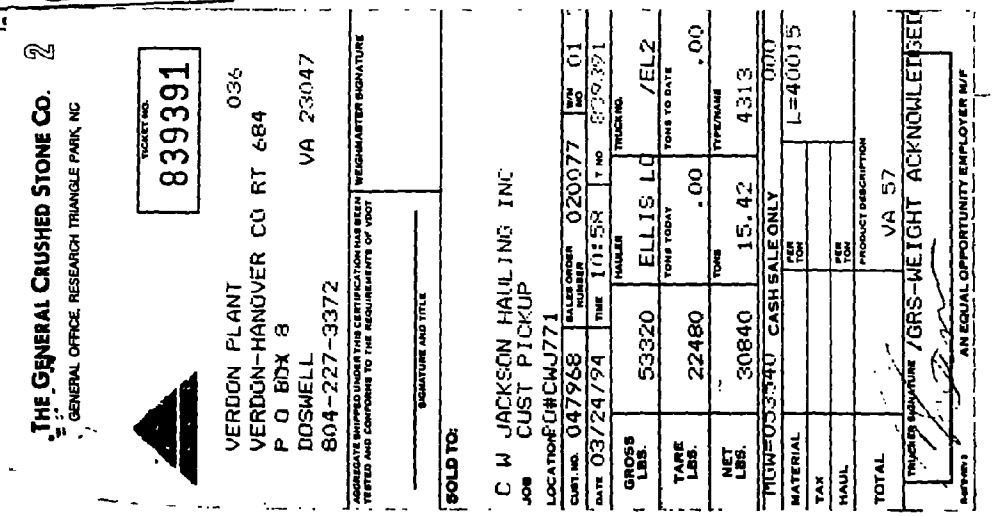
		HAULER	TRUCK NO.
GROSS LBS.	53780	ELLIS LC	/EL2
TARE LBS.	22480	TONS TODAY .00	TONS TO DATE .00
NET LBS.	31300	TONS 15.65	TYPE/NAME 4319

MIW=053540 CASH SALE ONLY 000

		PER TON	
MATERIAL			L=40015
TAX		PER TON	
HAUL		PRODUCT DESCRIPTION	
TOTAL	4-A		

TRUCKER SIGNATURE /GRS-WEIGHT ACKNOWLEDGE

AN EQUAL OPPORTUNITY EMPLOYER M/F



THE GENERAL CRUSHED STONE CO.
GENERAL OFFICE, RESEARCH TRIANGLE PARK, NC

TICKET NO. 839391

VERDON PLANT 036
VERDON-HANOVER CO RT 684
P O BOX 8
DOSWELL VA 23047
804-227-3372

AGGREGATE SHIPPED UNDER THIS CERTIFICATION HAS BEEN TESTED AND CONFORMS TO THE REQUIREMENTS OF VDOT. | WEIGHMASTER SIGNATURE
SIGNATURE AND TITLE

SOLD TO:

C W JACKSON HAULING INC
JOB CUST PICKUP
LOCATION PO#CWJ771
CUST. NO. 047968 SALES ORDER NUMBER 020077 W/M NO. 01
DATE 03/24/94 TIME 10:58 T. NO. 839391

		HAULER	TRUCK NO.
GROSS LBS.	53320	ELLIS LC	/EL2
TARE LBS.	22480	TONS TODAY .00	TONS TO DATE .00
NET LBS.	30840	TONS 15.42	TYPE/NAME 4313

MIW=053540 CASH SALE ONLY 000

		PER TON	
MATERIAL			L=40015
TAX		PER TON	
HAUL		PRODUCT DESCRIPTION	
TOTAL	VA 57		

TRUCKER SIGNATURE /GRS-WEIGHT ACKNOWLEDGED

AN EQUAL OPPORTUNITY EMPLOYER M/F

Orig mailed w/ $50,000

RECEIVED
MAY 2 1994
Chesapeake Bay
Local Assistance
Dept.

INTERAGENCY TRANSFER INVOICE

SUPPLIED BY: CREDIT		SUPPLIED TO: CREDIT	
AGENCY VIRGINIA TECH OFFICE OF SPONSORED PROGRAMS	CODE 230	AGENCY MS. JEAN TINGLER CHESAPEAKE BAY LOCAL ASS'T	CODE
ADDRESS 340 BURRUSS HALL BLACKSBURG, VIRGINIA 24061-0249		ADDRESS DEPT., 805 EAST BROAD STREET, SUITE 701, RICHMOND, VIRGINIA 23219	
INV # 0386 437880-0320	DATE 4/28/94	SHIPPED TO	
APPROVED BY: Odetta Seay (703) 231-9380		AGENCY REFERENCE NO.	

DATE OF DELIVERY	DESCRIPTION OF ARTICLES OR SERVICES	QNTY	UNIT	UNIT PRICE	AMOUNT
1/1/94 THROUGH 3/31/94	TRANSFER FUNDS FOR DESIGN AND IMPLEMENTATION OF A WATER QUALITY MONITORING SYSTEM FOR POLECAT CREEK WATERSHED #004				38,369.48

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

Initial_____

VOUCHER #	DATE	
SHEET 1	38,369	48
SHEET 2		
SHEET 3		
SHEET 4		
TOTAL	38,369	48

TRANSFER DISTRIBUTION

TRANS	AGNCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJ.	REV. SOURCE	AMOUNT	PROJECT PROJ	TK	PH
136	230		03	02	94					06050	38,369.48			

COST CODE	AGENC	PSD	AGY. REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REF DOC NUMBER	SX
			437880							

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGNCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJ.	REV. SOURCE	AMOUNT	PROJECT PROJ	TK	PH
350	408		01	010	94	523	02		1244		38369.48			

COST CODE	FIPS	PSD	AGY. REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REF DOC NUMBER	SX
611										

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXP. DISTRIBUTION SHEETS ARE ATTACHED

DA-02-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

State funds

111594-3346a

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY VA Commonwealth University Grants and Contracts Accounting	CODE 236	AGENCY Chesapeake Local Assistance Dept. Fiscal Office	CODE 408
ADDRESS Box 843039 Richmond, VA 23284-3039		ADDRESS 701 E. Broad Street, Suite 701 Richmond, VA 23219	
INVOICE NUMBER #1	DATE (MM/DD/YY) 11-15-94	SHIPPED TO Attn: Jean Tingler	
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Month Ending 10/31/94	To request payment in accordance with the contract between Chesapeake Bay Local Assistance and VCU for the project entitled "Local-Term Biological Characterization of Water Quality of Polecat Creek..." under the direction of Dr(s) Greg C. Garman and Len Smock. 0-38022-4213				787.86

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

Initial UP

VOUCHER NUMBER	DATE (MM/DD/YY)
950238	12/06/94
TOTAL THIS SHEET	787 86
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	787 86

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
136	236		03	02	95					06050	787 86			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

DBL PEC

TRANS	AGENCY	GLA	FUND	DET	FFY	PROG	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
380	408		01	00	95	503	02		1214		787 86			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX
611										

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

SUPPLIED BY: CREDIT			SUPPLIED TO: CHARGE	
VIRGINIA TECH		CODE:	**CHESAPEAKE BAY LOCAL**	CODE:
OFFICE OF SPONSORED PROGRAMS	208		805 EAST BROAD STREET, SUITE 701	
340 BURRUSS HALL			RICHMOND, VIRGINIA 23219	
BLACKSBURG, VIRGINIA 24061-0249			ATTENTION: FISCAL OFFICER	
INVOICE DATE	INVOICE #	STATUS	SHIP TO:	
12/15/94	0114		AGENCY REF:	

DATE OF DELIVERY	DESCRIPTION OF ARTICLES OR SERVICES	TOTAL AMT	
10/1/94 THROUGH 12/31/94	TRANSFER FUNDS FOR 95-408-001- POLECAT CREEK WATERSHED PROJECT **CREDIT: 437952-0320**	$20,022.00	

NOTE: SEC. 9 OF THE COMMONWEALTH OF VA. ACCOUNTING POLICY & PROCEDURE MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR THIS DOCUMENT	I CERTIFY THAT THIS VOUCHER IS IN AGREEMENT WITH THE MERCHANDISE OR SERVICE FOR WHICH PAYMENT IS BEING MADE; AND FURTHER, THAT COMPUTATIONS AND CODING ON THE VOUCHER ARE CORRECT AND DISCOUNTS TAKEN ARE PROPER. INITIAL:	VOUCHER	DATE	SUBMITTED BY:	
				O Terry	
		SHEET 1		ODETTA TERRY	
		SHEET 2		RESEARCH ADMIN.	
		SHEET 3		PHONE:	
		SHEET 4		(703) 231-9387	
		TOTAL	$20,022.00	(703) 231-4822	

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND			PROGRAM			OBJ	REV SOURCE	AMOUNT	PROJECT		
			FUND	DET	FY	PROG	SUB	ELE				PROJ	TK	PH
136	208		03	02	95					06050	$20,022.00			

COST CODE	FPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM/DD/YY	REFERENCE DOC NUMBER	REFERENCE DOC SX
			437952					

DESCRIPTION	CURRENT DOCUMENT NUMBER	CURRENT DOCUMENT SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND			PROGRAM			OBJ	REV SOURCE	AMOUNT	PROJECT		
			FUND	DET	FY	PROG	SUB	ELE				PROJ	TK	PH
380	468		01	00	95	503	03		1344		$20,022.00			

COST CODE	FPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM/DD/YY	REFERENCE DOC NUMBER	REFERENCE DOC SX
611								

DESCRIPTION	CURRENT DOCUMENT NUMBER	CURRENT DOCUMENT SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

CHECK BOX IF DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

7,200 on the Analyses

#12,822 on Monitoring

State General Funds — Jean Tinglen

DA-02-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY	CODE	AGENCY	CODE
Dept. of Environmental Quality	440	Chesapeake Bay Local Assistance Dept.	408
ADDRESS		ADDRESS	
629 E. Main St., 3rd Flr, Richmond, VA		805 E. Broad St., Suite 701, Richmond, VA	
INVOICE NUMBER	DATE (MM/DD/YY)	SHIPPED TO	
44095-010	4/18/95		
REQUISITION NUMBER		AGENCY REFERENCE NO.	
		94-408-06	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	Costs incurred with the Polecat Creek Watershed Project for the period Jan. 1 - March 31, 1995 PAY w/ #191 FED CEA '93 FUNDS #4434 STATE FUNDS DG				4625.

NOTE:

SECTION 9 OF THE COMMONWEALTH OF VIRGINIA ACCOUNTING POLICIES AND PROCEDURES MANUAL LISTS TRANSACTION CODES AUTHORIZED FOR USE ON THIS DOCUMENT.

I certify that this voucher is in agreement with the merchandise or service for which payment is being made; and further, that computations and coding on the voucher are correct and discounts taken are proper.

Initial _____

VOUCHER NUMBER	DATE (MM/DD/YY)
TOTAL THIS SHEET	4,625 00
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	4,625 00

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROGRAM	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
180	440		01	00	95	514	07		1123		4 625 00			

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓
608											

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE

TRANS	AGENCY	GLA	FUND	DET	FFY	PROGRAM	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED

DA-02-039 (REV. 7/86)
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ACCOUNTS

INTERAGENCY TRANSFER INVOICE

SUPPLIED BY: CREDIT		SUPPLIED TO: CHARGE	
AGENCY	CODE	AGENCY	CODE
DCR/ Division of Natural Heritage	199	Chesapeake Bay Local Assistance Dept	
ADDRESS		ADDRESS	
1500 E. Main Street, Suite 312 Richmond, Virginia 23219		804 E. Broad Street, Suite 701 Richmond, Virginia 23219	
INVOICE NUMBER	DATE (MM/DD/YY)	SHIPPED TO	
H-0156	4/13/95		
REQUISITION NUMBER		AGENCY REFERENCE NO.	

DATE OF DELIVERY OR SERVICE	DESCRIPTION OF ARTICLES OR SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	Expenses for State Match Funds Polecat Creek Water Quality Monitoring Project OK - CZM 1993 $600 TRAVEL REIMBURSEMENTS $100 EQUIPMENT "				700.00

NOTE:

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initial _____

VOUCHER NUMBER	DATE (MM/DD/YY)
TOTAL THIS SHEET	700 00
TOTAL SHEET 2	
TOTAL SHEET 3	
TOTAL SHEET 4	
AMOUNT CERTIFIED FOR PAYMENT	700 00

TRANSFER DISTRIBUTION

TRANS	AGENCY	GLA	FUND	DET	FFY	PROGRAM	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
	199		02	00	95	5037			1284		600.00	71753		

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓
637											

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE
Polecat Creek				

TRANS	AGENCY	GLA	FUND	DET	FFY	PROGRAM	SUB	ELE	OBJECT	REVENUE SOURCE	AMOUNT	PROJECT	TK	PH
	199		02	00	95	5037			1343		100.00	71753		

COST CODE	FIPS	PSD	AGENCY REFERENCE	INVOICE DATE	INVOICE NUMBER	DUE DATE MM	DD	YY	REFERENCE DOC NUMBER	SX	✓
637											

DESCRIPTION	CURRENT DOCUMENT NUMBER	SX	SUBSIDIARY ACCOUNT	MULTI-PURPOSE	CHECK IF EXPENDITURE DISTRIBUTION CONTINUATION SHEETS ARE ATTACHED
Polecat Creek					

ADMINISTRATION
NATURAL HERITAGE
PLANNING AND RECREATION RESOURCES
SOIL AND WATER CONSERVATION
STATE PARKS

COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION

DIVISION OF NATURAL HERITAGE

Main Street Station, 1500 East Main Street — Suite 312

TDD (804) 786-2121 Richmond, Virginia 23219 (804) 786-7951 FAX: (804) 371-2674

April 13, 1995

Mr. Darryl M. Glover
Senior Environmental Engineer
Chesapeake Bay Local Assistance Department
805 E. Broad Street, Suite 701
Richmond, Virginia 23219

Dear Mr. Glover:

Enclosed is the State Match information for the Polecat Creek Water Quality Monitoring Project.

DNH State Zoologist	20 days @ $137	$2,740
Fringe State Zoologist	30% of $2,740	822
Fringe State Ecologist	19$ of $2,025	385
	Total DNH State Match Funds	3,947

If you need any further information, do not hesitate to call me.

Sincerely,

Pat Jarrell
Financial Administrator

pj