Environmental Report
Operating License Stage

Limerick Generating Station

Units 1 & 2

PHILADELPHIA ELECTRIC COMPANY

Vol. 4

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ENVIRONMENTAL EFFECTS OF ACCIDENTS

7.1 STATION ACCIDENTS INVOLVING RADIOACTIVITY

The purpose of this section is to consider the potential radiological effects on the environment of accidental events and to compare these potential effects with those of normal station operation and natural background radiation. Radiological effects that result from normal station operation are discussed in Section 5.2, and natural background radiation is discussed in Section 6.4.

A detailed accident and safety analysis is a normal part of the design and licensing of each power station. The results of this analysis are presented to the NRC in the form of safety analysis reports (SARs). These reports contain detailed descriptions of the facility and station site, as well as a highly conservative analysis of the effects of normal and abnormal plant conditions. In addition to the analysis presented in the SAR, further examination of the environmental effects of normal and abnormal station conditions, based upon realistic parameters, is required to be presented in this Environmental Report. An assessment of the risks associated with the Limerick plant from accidents more severe than included in the design bases for the station was undertaken and is required to be presented in Section 7.1.4.

There are two main aspects of station safety: prevention of station accidents, and containment of radioactivity in the event of an accident. Prevention of station accidents begins with conservative design of the reactor and its control system, and conservative engineering of the reactor installation. Starting with this base, the designer seeks to anticipate the possible sources of malfunction, and to make provisions for mitigating their effects in the design. A strict quality assurance program ensures high component and system reliability.

Radioactive materials produced in the core of the reactor are contained within the station by a number of successive barriers that are incorporated in the station design. These barriers are the fuel material, zircaloy fuel cladding, the steel wall of the reactor vessel, and the primary and secondary containment systems. Containment of radioactivity in the event of an accident also involves the incorporation of engineered safety features (ESF) in the station design, such as radiation shields, emergency cooling systems, and air filtration systems.

In considering the environmental effects of postulated station accidents, several important distinctions must be made from other station environmental effects. The estimated effects are potential rather than certain. As a result of measures taken, or prevention of accident through design, manufacture, and operation, occurrences of accidental events in operating nuclear power plants have been rare. The improbability of accidental events in operating nuclear plants has been maintained at this low level through design review, operating limits, and quality assurance procedures. Therefore, the environmental effects of these potential events must be considered in conjunction with their probability of occurrence.

7.1.1 APPROACH TO THE ANALYSIS OF CLASS 1-8 ACCIDENTS

In the Federal Register of June 13, 1980 (45FR 40101), the Nuclear Regulatory Commission published a statement of interim policy regarding accident considerations. This statement withdrew the proposed annex to Appendix D of 10CFR50 and suspended the rulemaking procedures associated with it. It also put forward the Commission's interim policy that "...Environmental Impact Statements shall include consideration of the site-specific environmental impacts attributable to accident sequences that can result in inadequate cooling of the reactor fuel and in melting of the reactor core. In this regard, attention shall be given both to the probability of occurrence of such releases and to the environmental consequences of such releases."

Accordingly, Section 7.1.4 describes an analysis of the public risk associated with these severe accidents.

Although, as is described above, the proposed annex was subsequently withdrawn, the information for accidents formerly designated as Class 1-8 is given in Sections 7.1.1 to 7.1.3. The public risk associated with these accidents is summarized in Section 7.1.3.9.

The occurrence of abnormal station conditions and accidental events must be considered in design, licensing, and operation of nuclear power plants. In technical terms, an accident is an unexpected chain of events (i.e., a process rather than a single event). In SARs, the basic events involved in various possible station accidents are identified and studied with regard to the adequacy of the performance of the engineered safety features (ESF). In addition, the potential radiological effects of station accidents are analyzed by the evaluation of physical factors involved in each chain of events that might result in radiation exposures to humans. These factors include the meteorological conditions existing at the time of the accident, radionuclide uptake rates, and exposure times and distances, as well as the many factors that depend upon station design and the mode of operation. In these analyses, the factors affecting the consequences of each accident are identified and evaluated, and uncertainties in their values are discussed. Because some degree of uncertainty always exists in the prediction of these factors, it has become general practice in SARs to assume conservative values in making calculated estimates of radiation doses.

As a result of the highly conservative analysis, the radiation exposure levels calculated in SARs are not actually expected to be reached, even if the event initiating the accident occurs. In fact, the calculated exposures resulting from a DBA are generally far in excess of what would be expected, and do not provide a realistic means of assessing the radiological effects of postulated station accidents. In the analyses presented here, the radiation exposures associated with station accidents have been analyzed on a more realistic basis, as specified in the proposed annex to Appendix D of 10 CFR Part 50, which is referenced by NRC Regulatory Guide 4.2, Rev. 2 (Ref 7.1-1). In many cases, the assumptions are still conservative in that the most probable assumptions would result in even lower radiation exposure.

The effectiveness of measures that have been taken for accident prevention is judged by the frequency at which the accident occurs; that is, the accident probability. The effectiveness of the measures taken in containment of radioactivity can be judged by the calculated values of the radiological exposures associated with each accident. As discussed in the Federal Register (36 FR 22851) for the proposed annex to Appendix D of 10 CFR Part 50, the determination of the environmental impact of potential accidents requires the consideration of both the potential exposures, and the probabilities of receiving these exposures.

The environmental impact of the postulated accidents is evaluated for eight accident classes identified in Table 7.1-1. These classes are defined in the proposed annex to Appendix D of 10 CFR Part 50.

7.1.2 MODELS AND DATA USED TO EVALUATE THE ENVIRONMENTAL CONSEQUENCES OF CLASS 1-8 ACCIDENTS

Maximum individual dose estimates are based upon a receptor located at the exclusion area boundary. Man-rem dose estimates are based upon the year 2000 population projections. The population distribution as a function of distance and sector for the year 2000 has been estimated, and presented in Section 2.1. The total population dose was determined by taking the product of the dose and the number of people receiving that dose in an area segment defined by a 22.5° sector, at a particular distance from the station, and summing the product of each 22.5° sector for a distance out to 50 miles from the station.

7.1.2.1 Radiation Dose Models and Data for Class 1-8 Accidents

The models used are based upon NRC Regulatory Guides 1.3 (Ref 7.1-2) and 1.25 (Ref 7.1-3). The following assumptions are basic to both the model for the whole-body dose due to immersion in a cloud of radioactivity, and the model for the thyroid dose due to inhalation of radioactivity:

a. Direct radiation from the station is negligible compared to whole-body radiation due to immersion in the cloud of radioactivity.

b. All radioactive releases are treated as ground level releases, regardless of the point of discharge.

c. Continuous release atmospheric dispersion factors are applicable, and cloud depletion due to ground deposition is assumed to be insignificant.

d. The dose receptor is a standard man, as defined by the International Commission on Radiological Protection (ICRP) (Ref 7.1-4).

For all distances and time periods, the semi-infinite cloud model is used to calculate the whole-body dose. The procedure results in population exposures that are conservative.

The semi-infinite, whole-body gamma dose is given by the following equation from TID-24190 (Ref 7.1-5):

$$rD_{\infty} = (0.25)\ (X/Q) \sum_{i=1}^{N} (Q_i)(E_i) \qquad (7.1\text{-}1)$$

where:

- rD_{∞} = gamma dose from semi-infinite cloud (rad)
- X/Q = atmospheric dilution factor ($sec/meter^3$)
- N = number of isotopes
- Qi = source strength for isotope i (curies)
- Ei = average gamma energy for isotope i (MeV/dis)

The thyroid dose for a given time period is obtained from the following equation:

$$D = (X/Q)(BR) \sum_{i=1}^{N} (Q_i)(DCF_i) \qquad (7.1\text{-}2)$$

where:

- D = thyroid inhalation dose (rem)
- X/Q = atmospheric dilution factor ($sec/meter^3$)
- BR = breathing rate ($meter^3/sec$)
- N = number of isotopes
- Qi = total activity of iodine isotope i released (curies)
- DCFi = dose conversion factor for iodine isotope i (rem/curies inhaled)

Table 7.1-2 lists the physical data for the radiation dose models. The half-life values were taken from the Meek and Rider Report (Ref 7.1-6), and are in general agreement with those in TID-14844 (Ref 7.1-7) and ORNL-2127 (Ref 7.1-8). The values for the gamma energies are those given in the Table of Isotopes (Ref 7.1-9). The thyroid dose conversion factors are taken from the ICRP Committee II Report (Ref 7.1-10), and the breathing rates used in the calculations of inhalation doses are based upon the average daily breathing rates assumed in the ICRP Report, which are also used in the NRC Regulatory Guide 1.3 (Ref 7.1-2).

7.1.2.2 Source Term Models and Data for Class 1-8 Accidents

It is the purpose of this section to provide the general information used for accident evaluations.

The inventories of radioactive materials in the fuel pellets and fuel rod gap spaces in the reactor core depend upon the following:

a. Core power

b. Plant capacity factor

c. Temperature distribution in the pellets

d. Length of operating time prior to the accident or shutdown

e. Diffusion rates of radioisotopes through the fuel pellet materials.

Fission product inventories for the core and gap are based upon operation at 3458 MWt for 1000 days. Activity inventories for the total core, total gap, and gap of one fuel rod are given in Table 7.1-3. Reactor coolant concentrations are given in Table 7.1-4. These coolant concentrations were calculated using the methodology of NUREG-0016 (Ref 7.1-11).

7.1.2.3 Atmospheric Diffusion Estimates for Class 1-8 Accidents

Estimates of atmospheric diffusion (X/Q) have been made at the exclusion area boundary, the outer boundary of the low population zone (LPZ), and at 0.5, 1.5, 2.5, 3.5, 4.5, 7.5, 15, 25, 35, and 45 miles for each sector. These estimates have been made for periods of 2, 8, and 16 hours, and 3 and 26 days following a postulated accident. The sector-dependent model in Draft Regulatory Guide 1.145 (Ref 7.1-12) has been used.

The calculation procedure used to determine X/Q for the appropriate time periods following a postulated accident is described in Draft Regulatory Guide 1.145. The diffusion model presented in this guide is used to determine X/Q values for the first 2 hours following the accident. X/Q values for longer time periods are determined by logarithmic interpolation between the 2-hour accident value and the annual X/Q at each receptor point.

The annual X/Q values have been calculated using the model described in Regulatory Guide 1.111 (Ref 7.1-13). The Limerick emission has been classified as a low-level release, according to the criteria of Draft Regulatory Guide 1.145. This requires that the source be treated as ground level. This assumption has also been made in the annual X/Q calculations.

Meteorological data from Limerick Weather Station No. 1, from January 1972 through December 1974, have been used in the diffusion calculations. Lapse rate wind distributions have been computed using wind speed and direction from the 30-foot level, and temperature difference from the 266-26 foot height interval. The lapse rate, wind speed, and wind direction categories are consistent with the recommendations of Regulatory Guide 1.23 (Ref 7.1-14). The wind distribution used to calculate the 2-hour accident X/Q values has been normalized by directional sector, in accordance with Draft Regulatory Guide 1.145. This distribution is shown in Table 2.3.2-2. In each sector, the total frequency of wind speed and stability categories equals 100%. The stability classes designated as 1 through 7 in this distribution refer to the Pasquill classes A through G. A wind distribution computed in the standard manner is shown in Table 2.3.2-42. This distribution was used to calculate the annual X/Q values used in the logarithmic interpolation scheme.

The dispersion parameters developed by Pasquill (Ref 7.1-15) and Gifford (Ref 7.1-16) have been used in the accident calculations. Analytical approximations to these curves, developed by Eimutis and Konicek (Ref 7.1-17), have been used for sigma-y. The approximations of Busse and Zimmerman (Ref 7.1-18) have been used for sigma-z. A building wake correction of 2298m² was used. This is equal to one-half the minimum cross-sectional area of the reactor turbine enclosure complex.

The effective probability level is an adjustment necessary to equate the directionally dependent approach of Draft Regulatory Guide 1.XXX with the 50th percentile criterion previously employed by the NRC in the directionally independent model. This parameter is calculated as follows:

$$Pe = \frac{P(N/n)}{S} \qquad (7.1\text{-}3)$$

where:

Pe = effective probability level

P = desired probability level (50%)
N = total number of hours having valid wind and stability data in the period of record
n = total number of hours having valid wind and stability data in the directional sector of interest
S = total number of directional sectors (16)

The effective probability levels calculated for each sector at the Limerick Generating Station are listed in Table 7.1-5.

Cumulative frequency distributions of X/Q for the first 2 hours following a postulated accident were computed for distances of interest in each sector. These distributions were then plotted on a log probability scale. In each plot, the data points were enveloped by a fitting function, as described by Markee and Levine (Ref 7.1-19). The accident X/Q values in each directional sector were then obtained from the intersection of this function and the effective probability level.

Accident X/Q values for periods of 8 and 16 hours and 3 and 26 days following the accident have been determined by logarithmic interpolation between the maximum 2-hour and the maximum annual X/Q at each distance. A complete summation of the estimated X/Q values for the entire duration of the postulated accident is given in Table 7.1-6 for distances up to 50 miles for each sector.

7.1.3 CLASS 1-8 ACCIDENT ANALYSIS

In the following subsections, postulated accidents are identified and analyzed, and their radiological consequences are estimated.

7.1.3.1 Class 1 - Trivial Accidents Inside Primary Containment

Class 1 accidents are postulated as the release of small quantities of radioactive material inside the primary containment. The various mechanisms by which this may occur include small spills and small leaks from equipment and valve packing. A low level of continuous leakage from components such as valve packing stems, pump seals, and flanges, etc, is expected. Radioactivity release events of this class are considered as part of normal operating conditions, and analyzed along with radioactivity releases due to normal operation in Sections 3.5 and 5.2.

7.1.3.2 Class 2 - Small Releases Outside Primary Containment

Class 2 events are postulated as the release of small quantities of radioactive material outside the primary containment. These include small spills and leaks from equipment outside the primary containment. A low level of continuous leakage from components such as valve packing stems, pump seals, and flanges, etc, is expected. Radioactivity release events of this class are considered to be minor perturbations of normal operating conditions, and analyzed as "miscellaneous leakages," along with radioactivity releases due to normal operation in Sections 3.5 and 5.2.

The events in Classes 1 and 2 represent occurrences that are anticipated during station operation. Their consequences, which are small, are considered within the framework of routine effluents from the station.

7.1.3.3 Class 3 - Radwaste System Failure

Class 3 accidents are postulated to involve the release of radioactivity to the environment through a failure, or malfunction, in the radwaste systems.

The most serious radiological consequences will be caused by a release from the waste sludge tank in the solid radwaste system, or from the charcoal delay tank in the offgas treatment system. A number of combinations of inadvertent operator errors and equipment malfunctions, or failures, could be identified that might result in a release of some or all of the radioactivity stored in the waste sludge tank and the offgas treatment system charcoal delay tank. Iodine isotopes in the liquid tank are assumed to become partially airborne after its failure. In general, the amounts of radioactivity that could be released by any such combination of events are limited in the following ways:

Station Feature	Function
Limits on reactor coolant activity	Restricts total curies present in radwaste system tanks
Radiation monitors	Allow early detection of radioactivity releases,

	allowing operator action to terminate release
Limits on tank size	Restricts total curies present in any one tank
Isolation valves	Allow operator to terminate radioactivity releases
Interlock procedures	Reduce probability of inadvertent releases
Charcoal filters	Delay tanks are continuously vented to limit the accumulation of gases

Three releases of different types have been analyzed to cover the range of postulated events.

7.1.3.3.1 Class 3.1 - Equipment Leakage or Malfunction

The accident postulated is a failure of equipment in the liquid radwaste system that would cause the sudden release to the radwaste enclosure of 25% of the average inventory contained in the waste sludge tank. This tank is considered because its failure would result in the largest amount of radioactivity (iodine) released from the radwaste enclosure by the failure of any one tank. The radioactivity of the liquid released is based on the normal accumulation of liquid radwaste over a 6-day period.

The parameters and assumptions used in this analysis are as follows:

a. Twenty-five percent of the average inventory of accumulated liquid waste will be spilled.

b. An iodine partition factor of 0.01 is used for analysis.

c. Noble gas release as a result of the accident is negligible.

d. There is no liquid released to the environment.

e. Meteorology for less than 8 hours is used because the release from this accident is expected to last for less than 8 hours.

The radioactivity released to the environment is given in Table 7.1-7.

7.1.3.3.2 Class 3.2 - Offgas Treatment System Failure

The offgas treatment system has been incorporated in the station design to reduce the gaseous radwaste release from the station. It is assumed that, within this system, the first charcoal delay tank failure would result in the most significant whole-body dose. The analysis of this event is based on the following assumptions:

a. Source term: an offgas release rate of 60,000 microcuries/sec after 30 minutes decay, and maximum accumulated activity in the first charcoal delay tank based on 22.5 days buildup time for xenon and 0.98 days buildup time for krypton.

b. Release of 100% of the noble gas activity contained in the first charcoal delay tank. The iodine releases are negligible.

c. Meteorology for less than 8 hours is used because the release from this accident is expected to last for less than 8 hours.

The radioactivity released to the environment is given in Table 7.1-8.

7.1.3.3.3 Class 3.3 - Release of Waste Sludge Tank Contents

This accident is defined to be the sudden release of 100% of the average inventory contained in the waste sludge tank. Other assumptions used in evaluating the consequences of this accident are identical to those used in the Class 3.1 accident. The radioactivity released to the environment is given in Table 7.1-9.

In making an assessment of the probability of releases of this type, it is not possible to establish precise numerical values. Events in Class 3 are not anticipated during station operation.

7.1.3.4 Class 4 - Fission Products to Primary System (BWR)

Class 4 accidents are postulated as those events that release radioactivity from the fuel into the primary system.

To demonstrate the potential environmental consequences of these events, two situations are postulated and evaluated:

a. Fuel cladding defects

b. Off-design transients that induce fuel failures above those expected (such as flow blockage and flux maldistributions).

7.1.3.4.1 Class 4.1 - Fuel Cladding Defects

Releases from these events are included and evaluated under routine releases in accordance with 10 CFR Part 50, Appendix I, and included in the routine radioactive discharge discussed in Section 5.2.

7.1.3.4.2 Class 4.2 - Off-Design Transients That Induce Fuel Failures Above Those Expected (Such as Flow Blockage and Flux Maldistributions)

This accident is assumed to induce fuel failures to the core above those normally expected. The following assumptions are postulated for an off-design transient:

a. A release into the reactor coolant of 0.02% of the core inventory of noble gases and 0.02% of the core inventory of halogens.

b. One percent of the halogens and 100% of the noble gases in the reactor coolant are released into the steam.

c. If the radioactivity release from the core is high, the radiation monitors in the main steam line will initiate MSIV closure. MSIV closure will result in the release of radioactivity to the turbine enclosure by condenser leakage, and then to the atmosphere. If the radioactivity level is not high enough to trip the MSL monitor, the inventory released from the core will be processed through the offgas treatment system, from which the eventual release of radioactivity yields a lower exclusion area boundary (EAB) whole-body gamma dose than that from condenser leakage. The more conservative case (radioactivity released through condenser leakage) is used in this accident analysis.

d. Radioactivity is carried over to the condenser, where 10% of the halogens and 100% of the noble gases are available for leakage from the condenser to the environment at 0.5% per day of condenser volume for the course of the accident (24 hours).

e. Meteorology used is for a 24-hour accident.

The radioactivity released to the environs for the duration of the accident is given in Table 7.1-10.

7.1.3.5 Class 5 - Fission Products to Primary and Secondary Systems (PWR)

Analysis of a Class 5 accident is not applicable because the reactor is a BWR.

7.1.3.6 Class 6 - Refueling Accidents

Class 6 accidents are postulated to include refueling accidents inside the refueling area. Following the accident, radioactive material is released to the environs from the refueling area via the standby gas treatment system. It should be noted that the refueling area will be automatically isolated on detection of high radiation levels in the ventilation exhaust air from the refueling area.

To demonstrate the potential environmental consequences of this type of accident, two refueling accidents are postulated and evaluated:

a. Fuel assembly drop

b. Heavy object drop onto fuel in core.

7.1.3.6.1 Class 6.1 - Fuel Assembly Drop

A fuel assembly drop is postulated to occur as a result of the mishandling of a spent fuel assembly. The accident is assumed to result in damage to one row of fuel rods in the assembly. The subsequent release of radioactivity from the damaged fuel assembly will bubble through the water covering the assembly, where most of the radioactive iodine will be entrained. The following assumptions are postulated for a fuel assembly drop accident:

a. The gap activity (noble gases and halogens) in one row of fuel rods is released into the water. (Gap activity is 1% of total activity in a rod.)

b. There is a one-week decay time before the accident occurs.

c. Iodine decontamination factor in water is 500. Noble gases are not retained by water.

d. Fission products released to the refueling area atmosphere are mixed by the reactor enclosure recirculation system. Part of the recirculated flow is exhausted to the environment via the standby gas treatment system.

e. The filter efficiency for iodines of the standby gas treatment system is 99%, that of the reactor enclosure recirculation and filtration system is 95%.

f. Meteorology for less than 8 hours is used because the release from this accident is expected to last for less than 8 hours.

The activity contained in the fuel rod gap, and that released from the refueling area is a result of this accident, is given in Table 7.1-11.

7.1.3.6.2 Class 6.2 - Heavy Object Drop onto Fuel in Core

This accident is assumed to result in damage to an average fuel assembly. The same assumptions as used in the fuel assembly drop accident apply, except that 100 hours of decay time is assumed before the object drop occurs. The radioactivity released to the pool water, and from the refueling area as a result of this accident, is given Table 7.1-12.

7.1.3.7 Class 7 - Spent Fuel Handling Accidents

Class 7 accidents are postulated to include spent fuel handling accidents in the refueling area. Following accidents in the refueling area, evacuation and isolation of the area will be initiated by high radiation alarms. The normal HVAC system in the area will be automatically isolated. The refueling area atmosphere will then be treated by the reactor enclosure recirculation system and the standby gas treatment system before release to the environs. To demonstrate the potential environmental consequences of this type of accident, three spent fuel handling accidents are postulated and evaluated:

a. Fuel assembly drop in fuel storage pool

b. Heavy object drop onto fuel rack

c. Fuel cask drop.

7.1.3.7.1 Class 7.1 - Fuel Assembly Drop in Fuel Storage Pool

This accident is defined as the mishandling of a spent fuel assembly and assumes the same radioactivity release as postulated for a Class 6.1 accident. The assumptions used in evaluating this accident, as well as the resultant offsite doses, are identical to those in Class 6.1 (Section 7.1.3.6.1).

7.1.3.7.2 Class 7.2 - Heavy Object Drop Onto Fuel Racks

This accident assumes a release of radioactivity from a damaged fuel assembly, similar to that postulated for the Class 6.2 accident, except that a 30-day decay period before the accident occurs is assumed. Other assumptions used are identical to those in Class 6.2 (Section 7.1.3.6.2). Table 7.1-13 lists the activity release from the fuel assembly to the spent fuel pool and the activity released to the environment.

7.1.3.7.3 Class 7.3 - Fuel Cask Drop

The spent fuel cask will be equipped with redundant sets of lifting lugs and yokes compatible with the reactor enclosure crane main hook, thus preventing a cask drop due to a single failure. Therefore, the spent fuel cask drop is not considered to be a credible accident, and no analysis was performed. FSAR Section 9.1.5 describes the reactor enclosure crane and the interlocks that prevent moving the spent fuel cask over the fuel pool.

During fuel handling operations in the reactor enclosure, there exists the remote possibility that one or more fuel assemblies will sustain some mechanical damage. There exists an even more remote possibility that this damage will be severe enough to breach the cladding and release some of the radioactive fission products contained therein. Accidents in Classes 6 and 7 are of similar or lower probability than accidents in Classes 3 and 4, but are still possible.

7.1.3.8 Class 8 - Accident Initiation Events Considered for Design Basis Evaluation in the Safety Analysis Report

Class 8 accidents include the loss-of-coolant accident (small and large pipe breaks), reactivity excursion accident, and steam line break accident.

7.1.3.8.1 Class 8.1 - Loss-of-Coolant Accidents (LOCA)

A LOCA is defined as a loss of reactor coolant due to a sudden circumferential rupture of a reactor coolant system pipe, or any line connected to that system, inside containment.

To demonstrate the potential environmental consequences of this type of accident, two LOCAs are postulated and evaluated:

a. Small pipe break (6 inches or less)

b. Large pipe break.

7.1.3.8.1.1 Small Pipe Break (6 inches or less)

The following assumptions and parameters are postulated for evaluating the environmental consequences of a LOCA for a small pipe break (6 inches or less):

a. Source term: The average radioactivity inventory in the primary coolant is released to the primary containment.

b. A reduction factor of 0.2 is used in the source term for the effects of plateout and the decontamination factor in the pool.

c. The effects of radiological decay during holdup in the containment are taken into account.

d. The free iodine and noble gases leak from the primary containment to the reactor enclosure at a rate of 0.5% of the contained volume per day.

e. Fifty percent mixing in the reactor enclosure.

f. Negative pressure in the reactor enclosure is maintained for the duration of the accident, and whatever is leaked from the enclosure is released through the SGTS.

g. The SGTS exhausts a portion of the air from the reactor enclosure recirculation and filtration system. Charcoal filter efficiency for the standby gas treatment filters is 99% for iodines, and that for the reactor enclosure filtration system is 95%.

h. The breathing rate for persons offsite is 3.47×10^{-4} meters^3/sec for the first 8 hours. From 8 to 24 hours following the accident, the breathing rate is 1.75×10^{-4} meters^3/sec. Thereafter, the rate is 2.32×10^{-4} meters^3/sec.

i. Meteorology for both short time (<8 hours) and longer time (8 hours to 30 days) releases is used for this accident.

The release as a function of time from this accident is given in Table 7.1-14.

7.1.3.8.1.2 Large Pipe Break

The large pipe break LOCA is assumed to be a sudden circumferential break of a recirculation line, permitting the discharge of coolant into the primary containment from both sides of the break. The assumptions and parameters postulated for evaluating the environmental conseuqences of this accident are identical to those assumed for the LOCA small pipe break, with the following exceptions:

a. Source Term: The average radioactivity inventory in the reactor coolant is released to the containment, plus a release into the coolant of 0.2% of the core inventory of halogens and noble gases.

b. Fission product inventories in the core are calculated at the end of core life (1000 days), assuming fuel power operation at 3458 MWt.

The release as a function of time is given in Table 7.1-15.

7.1.3.8.1.3 Class 8.1(a), Break in Instrument Line From Primary System That Penetrates the Containment

This accident is postulated to involve lines outside the primary containment that are not provided with isolation capacity inside the primary containment.

The following assumptions are used for a primary system instrument line break accident:

a. The average radioactivity inventory in the primary coolant is based on an offgas release rate of 60,000 microcuries/sec after 30 minutes delay.

b. Total mass release through the failed line is 25,000 lb.

c. The charcoal filter efficiency for the SGTS is 99% for iodine, and that for the reactor enclosure filtration system is 95%.

d. A reduction factor of 0.1 in the source term is assumed from combined plateout and building mixing.

e. Meteorology for less than 8 hours is used for this accident.

The activity releases from this accident are given in Table 7.1-16.

7.1.3.8.2 Class 8.2 - Control Rod Accidents

7.1.3.8.2.1 Class 8.2(a), Rod Ejection Accident (PWR)

This class of accident is not applicable for this analysis.

7.1.3.8.2.2 Class 8.2(b), Rod Drop Accident (BWR)

A rod drop accident is defined as the complete (but not necessarily sudden) rupture, breakage, or disconnection of a random fully-inserted control rod drive from its cruciform control blade, at or near the coupling, in such a way that the blade becomes stuck at its location (fully inserted). This assumption sets up a condition where, if the drive were withdrawn, the stuck blade could later fall from the core, causing a reactivity excursion accident. The following assumptions are postulated for a rod drop accident:

a. There is a release into the coolant of 0.025% of the core inventory of noble gases and 0.025% of the core inventory of halogens.

b. One percent of the halogens and 100% of the noble gases in the reactor coolant are released into the condenser.

c. A high radiation signal in the main steam lines will automatically close the MSIVs and trip and mechanical vacuum pump. Activity in the turbine-condenser offgas systems will leak to the turbine enclosure, and then to the atmosphere.

d. Radioactivity is carried over to the condenser, where 10% of the halogens and 100% of the noble gases are available for leakage from the condenser at 0.5% of the condenser volume per day for the course of the accident (24 hours).

e. Meteorology used is for a 24-hour accident.

The activity released to the environs, as a function of time for the duration of the rod drop accident, is given in Table 7.1-17.

7.1.3.8.3 Class 8.3 - Steam Line Break Accidents

7.1.3.8.3.1 Class 8.3(a), Steam Line Breaks (PWR)

This class of accident is not applicable for this analysis.

7.1.3.8.3.2 Class 8.3(b), Steam Line Breaks (BWR)

A steam line break accident is a circumferential break of a main steam line outside primary containment.

To demonstrate the potential environmental consequences of this type of accident, two steam line break accidents are postulated and evaluated:

a. Small pipe break (of 0.25 ft^2)

b. Large pipe break.

For these postulated breaks, considering the most probable operating conditions prior to the break and using realistic assumptions, the calculated two-phase mixture level in the reactor pressure vessel does not reach the steam line before isolation is complete. Therefore, only steam will issue from these breaks for the entire transient.

<u>Small Pipe Break (of 0.25 ft^2):</u> The following assumptions and parameters are postulated for evaluating the environmental consequences of a main steam line break accident for a small pipe break:

a. The primary coolant activity is based on an offgas release rate of 60,000 microcuries/sec after 30 minutes delay.

b. It is assumed that the main steam line will release coolant for 5 seconds after the isolation signal is received.

c. The total amount of steam escaping from the break is 2750 lb. This quantity is the sum of a steam loss for two time periods, a 0.5-second duration prior to reactor trip, and a 5-second duration to complete closure of the MSIVs.

d. Iodine in the fluid released to the atmosphere is at one-tenth the primary system liquid concentration.

e. Fifty percent of the iodines and 100% of the noble gas in the fluid exiting through the break are assumed to be released to the atmosphere.

f. Meteorology for less than 8 hours is used because the release from this accident is expected to last for less than 8 hours.

The total activity released to the environs is given in Table 7.1-18.

Large Pipe Breaks: The assumptions and parameters postulated for evaluating the environmental consequences of a main steam line break accident for a large pipe break are identical to those given for a small pipe break, with the exception that the total amount of steam escaping from the break is 36,000 pounds. This quantity is the sum of a steam loss for two time periods, a 0.5-second duration prior to reactor trip, and a 5-second duration to complete closure of the MSIVs.

The total activity released to the environs is given in Table 7.1-19.

In making an assessment of the probability of the occurrence of typical events considered as DBAs in the FSAR, a firm numerical estimate is not possible because of the extreme rarity of such events. Quality assurance for design, manufacture, and operation, and highly conservative design considerations combine to produce piping and vessels with an extremely low probability of failure. Therefore, when the consequences are weighted by probabilities, the environmental risk is low.

7.1.3.9 Summary of Environmental Consequences and Public Risk of Class 1-8 Accidents

In the preceding discussion, a number of postulated accidents have been identified and analyzed. These selected events cover the full range of accident analyses formerly required in the NRC guidelines. The resulting estimates of potential station EAB doses as a result of each postulated accident, along with an assessment of the likelihood of each event, are listed in Table 7.1-20.

In the column giving the general assessment of the likelihood of these events and conditions, several categories have been used. Those events that could be expected to occur at frequencies of from once per station lifetime to as often as once per year are classified "occasional". Those events or conditions that would be expected to occur at frequencies less than once per station lifetime are classified "rare". Finally, there are a number of events that are considered unlikely, with projected probabilities much less than once per station lifetime. These events have been classified "extremely rare".

Table 7.1-21 shows the estimated integrated exposure from each postulated accident to the population within 50 miles of the station. When considered with the probability of occurrence, the annual potential radiation exposure of the population from all the postulated accidents is a small fraction of the exposure from natural background radiation and, in fact, is well within naturally occurring variations in the natural background.

From the results in the accident analysis, several specific conclusions can be reached concerning offsite doses:

a. The radiation exposures that would result from the occurrence of accidents are generally lower than those expected from normal operation, and much lower than that from natural background radiation.

b. The population exposure from possible station accidents is negligible when compared to the population exposure received from just the variation in natural background radiation, which overshadows the potential population exposure from any accident considered.

c. Most of the radiation dose levels are so low as to be undetectable, even with the most sensitive modern radiation detection instruments.

d. When these potential exposures are considered in conjunction with their predicated frequencies of occurrence, it is judged that Class 1-8 accidents are small contributors to public risk. This judgment is based on the Reactor Safety Study (Ref. 7.1-20) and a published risk assessment of Class 3-8 accidents (Ref. 7.1-21). The Class 3-8 study estimated risk to the public using methodology that is similar to that used in the RSS. The results of the study showed that Class 3-8 accidents are small contributors to public risk relative to postulated more severe accidents.

7.1.4 APPROACH TO THE ANALYSIS OF SEVERE ACCIDENTS

This analysis is being provided at the request of the NRC staff (EROL Questions E450.1, E450.2, E450.3 and E450.4) to help provide a response to the Statement of Interim Policy on severe accident considerations published by the NRC in the Federal Register on June 13, 1980 (45FR40101).

The analysis uses a comprehensive probabilistic risk assessment of the radiological consequences of accidents at the Limerick site. The assessment includes consideration of both internal and external initiators and specifically includes contributions from internal events, earthquakes, and fires. Internal and external flood, transportation, tornado, and turbine missile initiators were found to be noncontributors to risk. The analysis involves highly improbable sequences of failures that are more severe than those postulated for the design basis for protective systems and engineered safety features. The analysis treats the frequency of occurrence of these events in a systematic fashion and includes an assessment of uncertainty in the frequencies, the phenomenological analysis, and the consequence analysis. The focus of the presentation in this section is on the median results for the radiological consequences of the postulated events.

The fire analysis consists of an estimate of the frequencies of fires in various rooms in the plant and models the effects of fires on various safety-related systems. The seismic analysis consists of a detailed study of the predicted characteristics of earthquakes at the Limerick site and of the response of structures and systems. The earthquakes predicted to cause accidents at the Limerick plant that are significant contributors to public risk are highly improbable and of a severity that has not occurred in the Limerick area in historical times. Given the occurrence of such an earthquake, it is highly likely that the public consequences of the earthquake itself directly on the surrounding area would be considerably more severe than the consequences of a seismically-induced accident at the plant.

Section 7.1.4.1 contains descriptions of the models and data employed in the analysis. Section 7.1.4.2 explains how the analysis was performed. The results are presented in Section 7.1.4.3. Section 7.1.4.4 contains conclusions.

7.1.4.1 Models and Data

Section 7.1.4.1.1 describes the fission product source terms and their associated frequencies. Section 7.1.4.1.2 contains a brief outline of the consequence model (the CRAC2 code) and the necessary input data. Section 7.1.4.1.3 discusses the uncertainty analysis.

7.1.4.1.1 Source Term Description and Associated Frequencies

The magnitude and frequency of fission product source terms used in this assessment are given in Tables 7.1-22 and 7.1-23, respectively. Source term is defined in this section to mean the magnitude of the release of fission products to the atmosphere, together with associated characteristics such as the time of release, warning time, duration of release, and rate of release of heat. These source terms have been selected to characterize the release anticipated from the various events analyzed in this section. These source terms tend to be conservative estimates that, for example, exclude deposition in the primary system and in the reactor enclosure. Detailed descriptions and the basis for selection of these source terms is given in the Limerick Generating Station Severe Accident Risk Assessment (Ref. 7.1-22).

a. OXRE -- This source term includes the releases due to oxidation reactions that occur as a result of an in-vessel or ex-vessel steam explosion, or a hydrogen explosion following core melt. Fire is the most important contributor to this source term, contributing 55 percent of the point estimate frequency of 1.3×10^{-7} per year.

b. OPREL -- This source term is dominated by gross rupture of the containment, either as a result of the buildup of noncondensable gases or a hydrogen burn, following loss of coolant inventory, core melt and vessel rupture. Again, fires contribute most significantly to the point estimate frequency, given 55 percent of the total of 2.0×10^{-5} per year.

c. C4γ -- This source term is for an ATWS sequence ending in gross rupture of the drywell. Seismic and internal initiators are roughly equal contributors, and the total point estimate frequency is 1.3×10^{-7} per reactor year.

d. C4γ' -- This source term is for an ATWS sequence ending in gross rupture of the wetwell, without loss of the suppression pool. Seismic and internal initiators are roughly equal contributors, and the total point estimate frequency is 1.1×10^{-7} per reactor year.

e. C4γ" -- This source term is for an ATWS sequence ending in gross rupture of the wetwell, with loss of the suppression pool. Seismic and internal initators are roughly equal contributors, and the total point estimate frequency is 1.3×10^{-8} per reactor year.

f. C123γ" -- This source term is for those sequences other than C4γ" that result in a gross rupture of the containment in the wetwell with loss of the suppression pool. It has a total point estimate frequency of 1.0×10^{-6} per year, to which fires contribute 58 percent.

g. LEAK1 -- This source term is for core melt sequences in which the containment leaks relatively slowly without operation of the standby gas treatment system (SGTS). The leakage sizes are smaller than for the γ failure modes and preclude gross rupture. These sequences are small contributors to public risk. The most important initiator is fire, and the total point estimate frequency is 3.2×10^{-6} per year.

h. LEAK2 -- This source term is for core melt sequences that are similar to those in LEAK1 except that the SGTS is operating effectively. The most important initiator is fire, and the total point estimate frequency is 1.8×10^{-5} per reactor year.

i. RB -- This source term includes the releases that result from the collapse of the reactor enclosure as a result of an earthquake. This leads to failure of the RHR heat exchanger lateral supports, which is assumed to lead to failure of the attached piping leading from the suppression pool. The pool will drain down to the pipe, leading to an open containment while the core melts. However, the suppression pool is still available for fission product scrubbing of the melt release of fission products.

j. VR -- This is a source term for the case in which the reactor vessel fails, and the containment fails shortly thereafter.

For internal events, this source term is caused by a spontaneous vessel rupture that can cause immediate containment failure. In this case, VR has a predicted point estimate frequency of 1.4×10^{-8} per reactor year.

For earthquakes, this source term is dominated by events in which there is failure of the vessel upper lateral supports, causing rupture of the four main steam lines while collapse of the reactor enclosure breaks pipework connected to the suppression pool (as in the case of source term RB). In this seismic case, VR has a predicted point estimate frequency of 3.7×10^{-7} per reactor year.

k. VRH20 -- This source term is also for the case in which the reactor vessel fails, and the containment fails shortly thereafter. The only difference between this source term and VR is that, in the case of VRH20, sufficient water is assumed to remain in the bottom of the vessel so that fission products are driven rapidly out into the atmosphere when molten core falls and causes the generation of steam. In the case of VR, the vessel is assumed to be completely dry, and it takes a relatively long time to drive the fission products out into the atmosphere. For spontaneous (internal) vessel rupture, VRH20 has a point estimate frequency of 1.4×10^{-8} per reactor year. In the seismic case, VRH20 has a point estimate frequency of 4.1×10^{-8} per reactor year.

The derivation of the point estimate frequencies is presented in Reference 7.1-22 and a discussion of the methods employed in the uncertainty evaluation of frequency is given in Section 7.1.4.1.3.1.

7.1.4.1.2 Consequence Model

The CRAC2 code was used to generate the complementary cumulative distribution functions (CCDFs) that are the final product of the analysis (Figures 7.1-2 to 7.1-6). The code is discussed in the PRA Procedures Guide (Ref. 7.1-23). A schematic outline of CRAC2 is given in Figure 7.1-1. Reference 7.1-23 should be consulted for discussion of such topics as exposure pathways, dosimetric and health effects models, and protective actions. Those parts of the input data or the coding that were modified to take account of Limerick specific features are discussed below.

7.1.4.1.2.1 Curies of Fission Products and Actinides in the Core at the Initiation of the Accident

The amounts (curies) of each radionuclide released to the atmosphere for each accident sequence or release category is obtained by multiplying the release fractions specified in the definition of the source term (Table 7.1-22) by the amounts that would be present in the core at the time of the hypothetical accident. These amounts are shown in Table 7.1-24 for the Limerick reactor.

7.1.4.1.2.2 Meteorological Data

The CRAC2 input data file for Limerick contains five years of consecutive hourly values of wind speed, wind direction, stability class, and precipitation intensity. These were processed from measurements taken at the Limerick site during the years 1972 to 1976.

These five years of data were processed by CRAC2 using the bin sampling technique. This required a minor code modification to enable CRAC2 to sample from the entire five years of data. The sampling techniques used by CRAC2 are described in Reference 7.1-23. The use of five years of data and the improved sampling techniques of CRAC2 yield a more complete and representative sample than has been possible using the "stratified sampling" techniques of CRAC. The data are consistent with those used and presented elsewhere in the EROL.

7.1.4.1.2.3 Population Distributions

The population distribution around the site has been assigned to a grid consisting of 16 sectors, the first of which is centered on due north, the second on 22-1/2 degrees east of north, etc. There are also 34 radial intervals (Table 7.1-24) that contain the predicted permanent resident population for the year 2000.

The population within 50 miles was taken from Tables 2.1-5 and 2.1-12 and assigned to the finer CRAC2 grid by ratioing by area. In the 50 to 500 mile range, 1980 U.S. census data were used on a county-by-county basis, and 1981 Canadian census data were used in census tracts, which are comparable in size to U.S. counties. The population within counties or tracts was again assigned to the CRAC2 population grid by ratioing by area. Extrapolation to the year 2000 was done by using regional growth rates from the

Census Department's Bureau of Economic Affairs, for the USA, and similar regional growth rates for Canada.

7.1.4.1.2.4 Evacuation Modeling and Other Protective Measures

The site-specific offsite emergency response plans are not complete at this time. Certain features of these plans, however, are considered to be sufficiently defined so as to be used in this analysis (e.g., 360-degree evacuation of the EPZ). These features were combined with a generic evacuation model, which was developed at Sandia Laboratories, on the basis of U.S. evacuation experience. It is described in the PRA Procedures Guide. This evacuation model is used with three alternative evacuation scenarios; 1-, 3- or 5-hour delay times with relative probabilities of 30, 40 and 30 percent, and a subsequent evacuation speed of 10 mph (4.5 m/sec). This is considered to be a "best estimate" model.

The source terms considered in Tables 7.1-22 and 7.1-23 include some with contributions from earthquakes. For evacuation for these sequences, the model was modified to incorporate a 3-hour delay for the whole population and an effective evacuation speed of 0.5 m/sec.

The "best estimate" model also includes an estimate of the response of people beyond the EPZ in the range 10 to 25 miles. They are assumed to continue their normal activities for 12 hours after the passage of the cloud, at which time they are rapidly relocated. In the event of an earthquake, this period is assumed to be 24 hours. Equivalent reductions in predicted dose could be achieved by other countermeasures such as assuming that people shelter in their basements or large buildings for a day or two before relocating; that is, significant reductions in predicted dose could be achieved by a choice of simple countermeasures. The outer limit of 25 miles is chosen because, in general, calculations with CRAC2 show that, even with conservative fission product source terms, life-threatening acute doses are rarely predicted beyond this distance, even in the most adverse of weather conditions.

7.1.4.1.2.5 Economic Costs

The necessary input to the calculation of economic costs in CRAC2 includes several unit costs such as the cost of evacuating or relocating a person and the cost of decontaminating an acre of farm land or developed land. These costs are given in Reference

7.1-20 and have been updated to 1980 to allow for inflation. In addition, land use statistics, farm land values, farm product values, dairy production, and growing season information are required by CRAC2. These statistics are provided on a county-wide basis within 50 miles and on a state-wide basis for larger distances. The various economic inputs are tabulated in Reference 7.1-22.

7.1.4.1.3 Uncertainty

Reference 7.1-23 lists 51 modeling assumptions or parameter variations to which the complementary cumulative distribution functions (CCDFs) may be sensitive. However, an uncertainty analysis taking account of all 51 parameters would be prohibitively time consuming. Instead, four major sources of uncertainty were chose; (a) the frequencies of the source terms given in Table 7.1-23; (b) the magnitude and associated characteristics of the source terms; (c) the evacuation and sheltering modeling; and (d) the modeling of health effects.

Consideration of this limited set of uncertainties is sufficient to establish plausible bounds on the CCDFs; that is, more detailed uncertainty analysis would not be expected to produce results that are likely to lie outside the bounds established by the more limited uncertainty analysis. Justification for this view is given in Reference 7.1-22.

7.1.4.1.3.1 Uncertainty in Frequencies

Probability distributions on the frequencies of the source terms contributing to the various results were constructed. For accident sequences originating from internal and seismic initiating events, distributions were obtained by propagating uncertainties on input parameters to the fault tree and event tree analyses through the algebraic expressions for accident class frequencies in terms of those parameters, using Monte Carlo methods. The distributions on the input parameters were assigned in a manner that follows currently accepted practice as described, for example, in Reference 7.1-23. For initiating events originating from fires in the plant, the probability distribution on accident class frequency was constructed on the basis of a sensitivity analysis of the more important assumptions and parameters. They are discussed in detail and documented in Reference 7.1-22.

7.1.4.1.3.2 Uncertainty in Source Terms

One of the greatest sources of uncertainty in the CCDFs is the magnitude of the source terms. Sensitivity studies have been carried out to determine the effect of a range of source term magnitudes and times of release for: (a) VR and VRH20; (b) C4γ, C4γ' and C4γ" (both seismic and internal); (c) OPREL (latent effects only); and (d) RB. These source terms were chosen because, on the basis of runs of CRAC2 carried out with the source terms and point estimate frequencies given in Table 7.1-23, it was established that they represent the major contributors to public risk. Details of these sensitivity studies and their effect on the CCDFs are provided in Reference 7.1-22.

7.1.4.1.3.3 Uncertainty in Evacuation and Sheltering

The CCDF for early fatalities is particularly sensitive to the choice of evacuation delay time (Ref. 7.1-23). Sensitivity studies were carried out in which they delay time was varied from 1 to 5 hours. The evacuation velocity was varied from 2.5 to 10 mph. For seismically initiated sequences, it was assumed for the sensitivity study that evacuation assumptions would be unaffected.

The 10 to 25 mile sheltering assumptions were changed to simulate sheltering in basements for 24 hours, followed by rapid relocation. In addition, the outer 25 mile radius was changed to 50 miles.

The effect that these variations have on CCDFs is described in Reference 7.1-22.

7.1.4.1.3.4 Uncertainty in Health Effects Modeling

For early fatalities, Reference 7.1-20 provides dose-response relationships for minimal, supportive, and heroic medical treatment. In the sensitivity analysis, each of these was chosen in turn. The standard dose-response relationship used for latent cancers in CRAC2, the central estimate, was varied to allow the simple linear dose-response relationship. The effect that these variations have on the CCDFs is described in Reference 7.1-22.

7.1.4.2 Analysis

The first step in the analysis was to use the point estimate source terms and point estimate frequencies in Tables 7.1-22 and 7.1-23, respectively, in CRAC2 and to produce a single CCDF for each health or economic effect. This single CCDF is called "point estimate" because it is obtained using single or point estimates of each of the important input parameters. For each health or economic effect, the significant contributors to risk, determined by comparing the size of each contributor to the area under the point estimate CCDFs, were (a) VR and VRH20; (b) RB; (c) C4γ, C4γ' and C4γ"; and (d) OPREL (latent effects only).

In the second step, an uncertainty analysis of the frequency of each source term was carried out as described in Section 7.1.4.1.3.1.

The third step was to establish a range of conditional CCDFs for each source term and each of the health or economic effects that are being considered. Upper and lower estimates on this range were taken as upper and lower percentiles on a lognormal distribution. The upper percentiles were chosen as the 95th or 99th, depending on how likely the estimates are expected to be, and the lower estimate was chosen to be the 5th percentile. This is sufficent to fix the two independent parameters in the lognormal distribution.

The fourth step was to use this lognormal distribution in combination with the uncertainty distribution on frequencies to given an overall uncertainty distribution on the CCDFs. The uncertainty distributions are presented in Reference 7.1-22.

The final step was to extract from the uncertainty distribution the medians that are presented in Section 7.1.4.3.

7.1.4.3 Results

The results of the analysis are given in Figures 7.1-2 to 7.1-7 and in Table 7.1-26. These results give the total contribution from all source terms for seismic, internal, and fire initiators. The CCDFs for individual source terms, as well as upper and lower estimates and point estimates, are given in Reference 7.1-22. All of the results presented here are median CCDFs.

7.1.4.3.1 CCDFs

Figure 7.1-2 contains the median CCDF for the number of people receiving a bone marrow dose in excess of 200 rems from early exposure. (Early exposure is confined to that portion of the radiation dose that is accumulated within 7 days, due to inhalation of radioactive materials, cloudshine and groundshine.) This level of dose roughly corresponds to a need for hospital treatment.

Figure 7.1-3 shows the median CCDF for the total population exposure in person-rems for the population out to 500 miles (that is, the probability per reactor year that the total population exposure will equal or exceed the values given). The figure also gives a similar CCDF for the population within 50 miles.

Figure 7.1-4 shows the median CCDF for acute fatalities, representing radiation injuries that would produce fatalities within about one year after exposure.

Figure 7.1-5 gives the median CCDFs for latent cancer fatalities. CCDFs for the total population and the population within 80 km (50 miles) are shown separately, and the latent cancers have been subdivided into that attributable to exposures of the thyroid and all other organs.

Figure 7.1-6 shows the CCDF for ex-plant costs in 1980 dollars. In general, these costs are dominated by decontamination of urban or agriculatural land. Additional economic costs include decontamination of the facility itself and the cost of replacement power. These impacts are discussed in Section 7.1.4.3.2.

7.1.4.3.2 Risk Considerations

The foregoing discussions have dealt with both the frequency (or likelihood of occurrence) of accidents and their impacts (or consequences). Because the ranges of both factors are broad, it is also useful to combine them to obtain average measures of environmental risk. Such averages can be particularly useful as an aid to the comparison of radiological risks associated with accidental releases, or those arising from other accidents.

A common way in which this combination of factors is used to estimate risk is to multiply the frequencies by the consequences. The resultant risk is then expressed as the number of consequence expected per unit time. Table 7.1-26 shows average values of risk associated with population dose, acute fatalities, latent fatalities, and costs for protective actions and decontamination. These average values are obtained by summing the frequency multiplied by the consequences over the entire range of the median CCDFs. They are equal to the areas under the corresponding CCDFs. Because the probabilities are on a per-reactor-year basis, the averages shown are also on a per-reactor-year basis.

The acute fatality risk of 4.1×10^{-5} deaths per reactor year at the median level may be put into perspective by noting that 60 fatalities from motor vheicle accidents, 24 from falls, 8 from burns, and 3 from firearms are likely to occur each year within 10 miles of the plant. These figures are based on U.S. averages.

The individual risk of acute fatality as a function of distance is displayed on Figure 7.1-7. The risk to the average individual living within one mile of the site boundary is 2.2×10^{-9} per reactor year. This risk is small. For comparison, the following risks of fatality per year to an individual living in the United States may be noted; 2.2×10^{-4} per year from automobile accidents and 1.2×10^{-5} per year from firearms.

The average population exposure is 70 person-rem per reactor year. This value may be compared with the annual average population exposures from routine operation given in Tables 5.2-15 and 5.2-17.

The average number of latent cancer fatalities (summing those due to thyroid dose and those in all other organs) within the population to 500 miles is 0.013 per reactor year. The equivalent average latent cancer fatalities for the population within 50 miles is 0.008 per reactor year. These figures may be put in perspective by noting that, in the population of 8,100,000 that is predicted to live within 50 miles of the Limerick reactor in the year 2000, there will be about 20,000 cancer fatalities per year from all causes. This figure was obtained by multiplying the figure for the population within 50 miles by 2.5×10^{-3}, which, according to the Statistical Abstract of the United States, is the chance per year that an individual will die of cancer.

The ex-plant economic risk, in 1980 dollars, associated with the Limerick Generating Station is predicated to be $6,000 per reactor year at the median level. This figure is small compared with the estimated property damage caused by other accidents within 50 miles of the Limerick site (e.g., of the order of $10 million per year for automobile accidents. This figure is based on U.S. average statistics).

There are other economic impacts and risks that are not included in the calculations discussed above. These costs would be for decontamination and repair or replacement of the facility, and for replacement power. Experience with such costs is currently being accumulated as a result of the Three Mile Island accident.

It is already clear that such costs can equal or exceed the original capital cost. The cost for decontamination and restoration is in the region of $2 billion. Replacement power costs for two units at the Limerick site are estimated at $580 million per year. If it is assumed that both units on the site are out of operation for 8 years, the total cost of the accident would be $6.64 billion. The accident sequences considered in this report and shown in Table 7.1-22 would all lead to core melt and would in turn lead to costs of the size described above. The predicted median frequency of core melt is 3.0×10^{-5} per year so that the economic risk due to the accident sequences considered in this report is predicted to be $200,000 per year. This estimate is in 1980 dollars.

7.1.4.4 Conclusions

The previous sections consider the potential environmental impacts of severe accidents at the Limerick facility. These have covered a broad spectrum of hypothetical accidental releases and a range of possible health and economic impacts. The comparisons in the section on risk considerations show that the public risk associated with these impacts is small.

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TABLE 7.1-1

CLASSIFICATION OF POSTULATED INCIDENTS

ACCIDENT CLASS	INCIDENT DESCRIPTION	EXAMPLE(S)
1	Trivial incidents inside containment	Small spills; small leaks
2	Small releases outside containment	Small spills, and small leaks from equipment and valve packing
3	Radwaste system failure	Equipment leakage or malfunction; release of waste gas or liquid
4	Fission products to primary system (BWR)	Fuel cladding failures during normal operations; off-design transients that induce fuel failures above those expected
5	Fission products to primary and secondary systems (PWR)	Not applicable
6	Refueling accidents	Fuel assembly drop; heavy object drop onto fuel in core
7	Spent fuel handling accidents	Fuel assembly drop in fuel storage pool; heavy object drop onto fuel rack; fuel cask drop
8	Accident initiation events considered in design basis evaluation in the safety analysis report	Loss of coolant accidents; rod drop accident - reactivity excursion; steamline breaks

TABLE 7.1-2

PHYSICAL DATA FOR RADIATION DOSE MODELS

ISOTOPE	DECAY CONSTANT (hr^{-1})	GAMMA ENERGY (MeV/dis)	THYROID DOSE CONVERSION FACTOR (rem/curie INHALED)
I-131	3.59×10^{-3}	3.71×10^{-1}	$1.48 \times 10^{+6}$
I-132	3.07×10^{-1}	$2.40 \times 10^{+0}$	$5.25 \times 10^{+4}$
I-133	3.41×10^{-2}	4.77×10^{-1}	$4.00 \times 10^{+5}$
I-134	8.00×10^{-1}	$1.94 \times 10^{+0}$	$2.50 \times 10^{+4}$
I-135	1.07×10^{-1}	$1.77 \times 10^{+0}$	$1.24 \times 10^{+5}$
Xe-131m	2.45×10^{-3}	3.30×10^{-3}	-
Xe-133	5.48×10^{-3}	3.00×10^{-2}	-
Xe-133m	1.28×10^{-2}	3.26×10^{-2}	-
Xe-135	7.58×10^{-2}	2.46×10^{-1}	-
Xe-135m	$2.66 \times 10^{+0}$	4.22×10^{-1}	-
Xe-137	$1.07 \times 10^{+1}$	1.50×10^{-1}	-
Xe-138	$2.38 \times 10^{+0}$	$2.87 \times 10^{+0}$	-
Kr-83m	3.73×10^{-1}	8.00×10^{-4}	-
Kr-85	7.35×10^{-6}	2.10×10^{-3}	-
Kr-85m	1.58×10^{-1}	1.51×10^{-1}	-
Kr-87	5.47×10^{-1}	$1.37 \times 10^{+0}$	-
Kr-88	2.48×10^{-1}	$1.75 \times 10^{+0}$	-

BREATHING RATES

Time Period (hours)	Breathing Rates ($meter^3/sec$)
0 to 8	3.47×10^{-4}
8 to 24	1.75×10^{-4}
24 to 720	2.32×10^{-4}

TABLE 7.1-3

FISSION PRODUCT INVENTORIES IN THE FUEL (curies)

ISOTOPE	CORE[1]	GAP[2]	GAP RADIOACTIVITY PER ROD[3]
I-131	$8.57\times10^{+7}$	$8.57\times10^{+5}$	$1.81\times10^{+1}$
I-132	$1.28\times10^{+8}$	$1.28\times10^{+6}$	$2.70\times10^{+1}$
I-133	$1.97\times10^{+8}$	$1.97\times10^{+6}$	$4.16\times10^{+1}$
I-134	$2.30\times10^{+8}$	$2.30\times10^{+6}$	$4.86\times10^{+1}$
I-135	$1.80\times10^{+8}$	$1.80\times10^{+6}$	$3.80\times10^{+1}$
Kr-83m	$1.53\times10^{+7}$	$1.53\times10^{+5}$	$3.23\times10^{+0}$
Kr-85m	$3.83\times10^{+7}$	$3.83\times10^{+5}$	$8.09\times10^{+0}$
Kr-85	$1.30\times10^{+6}$	$1.30\times10^{+4}$	2.74×10^{-1}
Kr-87	$7.37\times10^{+7}$	$7.37\times10^{+5}$	$1.56\times10^{+1}$
Kr-88	$1.03\times10^{+8}$	$1.03\times10^{+6}$	$2.17\times10^{+1}$
Kr-89	$1.35\times10^{+8}$	$1.35\times10^{+6}$	$2.85\times10^{+1}$
Xe-131m	$6.48\times10^{+5}$	$6.48\times10^{+3}$	1.37×10^{-1}
Xe-133m	$5.01\times10^{+6}$	$5.01\times10^{+4}$	$1.06\times10^{+0}$
Xe-133	$1.97\times10^{+8}$	$1.97\times10^{+6}$	$4.16\times10^{+1}$
Xe-135m	$5.30\times10^{+7}$	$5.30\times10^{+5}$	$1.12\times10^{\ 1}$
Xe-135	$1.86\times10^{+8}$	$1.86\times10^{+6}$	$3.93\times10^{+1}$
Xe-137	$1.77\times10^{+8}$	$1.77\times10^{+6}$	$3.74\times10^{+1}$
Xe-138	$1.74\times10^{+8}$	$1.74\times10^{+6}$	$3.67\times10^{+1}$

(1) Based upon operating power of 3458 MWt.

(2) Equal to 1% of the total core inventory (Regulatory Guide 4.2).

(3) Based on 764 fuel assemblies in the core, and 62 rods per assembly.

TABLE 7.1-4

EQUILIBRIUM PRIMARY
COOLANT RADIOACTIVITY(1)

ISOTOPE	HALOGENS CONCENTRATION(2) microcurie/gm	NOBLE GAS RELEASE RATE microcurie/sec(t=0)
I-131	5.0×10^{-3}	-
I-132	3.0×10^{-2}	-
I-133	2.0×10^{-2}	-
I-134	5.0×10^{-2}	-
I-135	2.0×10^{-2}	-
Kr-83m	-	$2.08 \times 10^{+3}$
Kr-85m	-	$3.59 \times 10^{+3}$
Kr-85	-	$1.13 \times 10^{+1}$
Kr-87	-	$1.25 \times 10^{+4}$
Kr-88	-	$1.25 \times 10^{+4}$
Kr-89	-	$7.75 \times 10^{+4}$
Xe-131m	-	$8.88 \times 10^{+0}$
Xe-133m	-	$1.70 \times 10^{+2}$
Xe-133	-	$4.91 \times 10^{+3}$
Xe-135m	-	$1.59 \times 10^{+4}$
Xe-135	-	$1.36 \times 10^{+4}$
Xe-137	-	$8.88 \times 10^{+4}$
Xe-138	-	$5.29 \times 10^{+4}$

(1) Based upon an average offgas release rate of 60,000 microcuries/sec after 30 minutes delay.

(2) Based upon reactor coolant water mass of 1.724×10^{8} gms.

TABLE 7.1-5

EFFECTIVE PROBABILITY LEVELS FOR FIFTY PERCENTILE X/Q[1]

Sector	Effective Probability Level
SSW	80.0
SW	81.0
WSW	52.0
W	39.0
WNW	66.0
NW	75.0
NNW	65.0
N	47.0
NNE	53.0
NE	75.0
ENE	64.0
E	39.0
ESE	22.0
SE	31.0
SSE	55.0
S	64.0

[1] Calculated using 1972-1974 Tower No. 1, 30-foot lapse rate wind distribution.

TABLE 7.1-6

FIFTY PERCENTILE ATMOSPHERIC DIFFUSION FACTORS - X/Q (sec/m^3)

DISTANCE 731 METERS (0.45 mi)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
SSW	4.5x10-5	2.8x10-5	2.3x10-5	1.4x10-5	7.2x10-6	3.2x10-6
SW	5.6x10-5	3.4x10-5	2.7x10-5	1.7x10-5	8.1x10-6	3.4x10-6
WSW	8.8x10-5	5.3x10-5	4.2x10-5	2.5x10-5	1.2x10-5	4.7x10-6
W	1.1x10-4	6.7x10-5	5.3x10-5	3.2x10-5	1.5x10-5	6.1x10-6
WNW	7.5x10-5	4.6x10-5	3.6x10-5	2.2x10-5	1.0x10-5	4.0x10-6
NW	6.3x10-5	4.0x10-5	3.2x10-5	1.9x10-5	9.3x10-6	3.7x10-6
NNW	6.9x10-5	3.6x10-5	3.4x10-5	2.0x10-5	9.5x10-6	3.8x10-6
N	8.4x10-5	5.2x10-5	4.1x10-5	2.4x10-5	1.2x10-5	4.6x10-6
NNE	6.1x10-5	3.8x10-5	3.0x10-5	1.8x10-5	9.0x10-6	3.7x10-6
NE	4.3x10-5	2.8x10-5	2.3x10-5	1.4x10-5	7.2x10-6	3.1x10-6
ENE	5.1x10-5	3.4x10-5	2.7x10-5	1.7x10-5	8.3x10-6	3.5x10-6
E	7.9x10-5	6.1x10-5	4.0x10-5	2.5x10-5	1.2x10-5	5.0x10-6
ESE	1.2x10-4	7.3x10-5	5.8x10-5	3.6x10-5	1.8x10-5	7.3x10-6
SE	1.0x10-4	6.3x10-5	5.0x10-5	2.9x10-5	1.4x10-5	5.6x10-6
SSE	6.2x10-5	3.8x10-5	3.1x10-5	2.9x10-5	9.2x10-6	3.8x10-6
S	6.2x10-5	3.8x10-5	3.1x10-5	2.9x10-5	9.0x10-6	3.6x10-6

DISTANCE 805 METERS (0.5 mi)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
SSW	4.3x10-5	2.7x10-5	2.2x10-5	1.4x10-5	6.6x10-6	2.8x10-6
SW	4.7x10-5	2.9x10-5	2.3x10-5	1.4x10-5	7.0x10-6	2.9x10-6
WSW	7.5x10-5	4.7x10-5	3.7x10-5	2.2x10-5	1.1x10-5	4.1x10-6
W	9.5x10-5	5.8x10-5	4.6x10-5	2.8x10-5	1.3x10-5	5.3x10-6
WNW	6.4x10-5	4.0x10-5	3.2x10-5	1.9x10-5	8.8x10-6	3.5x10-6
NW	5.8x10-5	3.4x10-5	2.7x10-5	1.6x10-5	7.7x10-6	3.2x10-6
NNW	6.4x10-5	3.9x10-5	3.1x10-5	1.8x10-5	8.3x10-6	3.3x10-6
N	7.6x10-5	4.7x10-5	3.7x10-5	2.2x10-5	1.0x10-5	4.0x10-6
NNE	5.7x10-5	3.5x10-5	2.8x10-5	1.7x10-5	7.9x10-6	3.2x10-6
NE	4.0x10-5	2.6x10-5	2.1x10-5	1.3x10-5	6.4x10-6	2.7x10-6
ENE	4.6x10-5	2.9x10-5	2.4x10-5	1.4x10-5	7.1x10-6	3.0x10-6
E	7.2x10-5	4.7x10-5	3.7x10-5	2.2x10-5	1.1x10-5	4.3x10-6
ESE	1.1x10-4	6.8x10-5	5.4x10-5	3.2x10-5	1.6x10-5	6.3x10-6
SE	8.9x10-5	5.4x10-5	4.3x10-5	2.6x10-5	1.2x10-5	4.9x10-6
SSE	5.7x10-5	3.4x10-5	2.8x10-5	1.7x10-5	8.0x10-6	3.3x10-6
S	5.6x10-5	3.4x10-5	2.7x10-5	1.7x10-5	7.9x10-6	3.2x10-6

TABLE 7.1-6 (Cont'd)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
			DISTANCE 2043 METERS (1.3 mi)			
SSW	1.2x10-5	7.3x10-6	5.9x10-6	3.5x10-6	1.7x10-6	7.2x10-7
SW	1.3x10-5	8.0x10-6	6.5x10-6	3.9x10-6	1.9x10-6	7.6x10-7
WSW	2.2x10-5	1.3x10-5	1.0x10-5	6.0x10-6	2.8x10-6	1.1x10-6
W	2.9x10-5	1.7x10-5	1.3x10-5	7.8x10-6	3.6x10-6	1.4x10-6
WNW	1.8x10-5	1.1x10-5	8.5x10-6	5.0x10-6	2.3x10-6	9.0x10-7
NW	1.7x10-5	1.0x10-5	7.8x10-6	4.6x10-6	2.2x10-6	8.5x10-7
NNW	1.8x10-5	1.1x10-5	8.5x10-6	4.9x10-6	2.3x10-6	8.7x10-7
N	2.3x10-5	1.3x10-5	1.1x10-5	6.2x10-6	2.8x10-6	1.1x10-6
NNE	1.7x10-5	1.0x10-5	8.0x10-6	4.6x10-6	2.1x10-6	8.4x10-7
NE	1.1x10-5	6.8x10-5	5.4x10-6	3.4x10-6	1.6x10-6	7.1x10-7
ENE	1.3x10-5	8.0x10-6	6.4x10-6	3.9x10-6	1.9x10-6	7.8x10-7
E	2.2x10-5	1.4x10-5	1.1x10-5	6.3x10-6	2.9x10-6	1.1x10-6
ESE	3.3x10-5	2.0x10-5	1.6x10-5	9.0x10-6	4.2x10-6	1.6x10-6
SE	2.8x10-5	1.7x10-5	1.3x10-5	7.5x10-6	3.4x10-6	1.3x10-6
SSE	1.6x10-5	9.8x10-6	7.7x10-6	4.6x10-6	2.2x10-6	8.6x10-7
S	1.7x10-5	1.0x10-5	7.8x10-6	4.5x10-6	2.1x10-6	8.1x10-7
			DISTANCE 2415 METERS (1.5 mi)			
SSW	1.0x10-5	6.2x10-6	4.8x10-6	2.9x10-6	1.4x10-6	5.7x10-7
SW	1.1x10-5	6.8x10-6	5.4x10-6	3.2x10-6	1.5x10-6	6.0x10-7
WSW	2.0x10-5	1.2x10-5	9.0x10-6	5.1x10-6	2.3x10-6	8.3x10-7
W	2.5x10-5	1.5x10-5	1.2x10-5	6.5x10-6	2.9x10-6	1.1x10-6
WNW	1.7x10-5	9.9x10-6	7.5x10-6	4.3x10-6	1.9x10-6	7.2x10-7
NW	1.5x10-5	9.0x10-6	7.0x10-6	4.0x10-6	1.8x10-6	6.7x10-7
NNW	1.8x10-5	1.1x10-5	8.0x10-6	4.4x10-6	1.9x10-6	6.9x10-7
N	2.1x10-5	1.3x10-5	9.5x10-6	5.3x10-6	2.3x10-6	8.3x10-7
NNE	1.5x10-5	9.0x10-6	6.9x10-6	3.9x10-6	1.7x10-6	6.6x10-7
NE	1.1x10-5	6.7x10-6	5.3x10-6	3.1x10-6	1.4x10-6	5.6x10-7
ENE	1.1x10-5	6.9x10-6	5.4x10-6	3.2x10-6	1.5x10-6	6.2x10-7
E	1.9x10-5	1.1x10-5	8.7x10-6	5.0x10-6	2.3x10-6	8.7x10-7
ESE	2.9x10-5	1.7x10-5	1.3x10-5	7.5x10-6	3.5x10-6	1.3x10-6
SE	2.5x10-5	1.5x10-5	1.1x10-5	6.3x10-6	2.7x10-6	1.0x10-6
SSE	1.5x10-5	9.0x10-6	7.0x10-6	4.0x10-6	1.8x10-6	6.8x10-7
S	1.5x10-5	8.9x10-6	6.8x10-6	3.8x10-6	1.7x10-6	6.4x10-7

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
			DISTANCE 4025 METERS (2.5 mi)			
SSW	4.7x10-6	2.7x10-6	2.3x10-6	1.4x10-6	6.6x10-7	2.7x10-7
SW	5.8x10-6	3.6x10-6	2.8x10-6	1.6x10-6	7.5x10-7	2.9x10-7
WSW	1.1x10-5	6.3x10-6	4.8x10-6	2.6x10-6	1.1x10-6	3.9x10-7
W	1.5x10-5	8.7x10-6	6.5x10-6	3.6x10-6	1.5x10-6	5.2x10-7
WNW	8.3x10-6	4.8x10-6	3.6x10-6	2.1x10-6	9.4x10-7	3.4x10-7
NW	7.2x10-6	4.3x10-6	3.3x10-6	1.9x10-6	8.5x10-7	3.2x10-7
NNW	8.5x10-6	4.2x10-6	3.3x10-6	1.9x10-6	8.5x10-7	3.3x10-7
N	1.2x10-5	6.7x10-6	5.1x10-6	2.8x10-6	1.2x10-6	4.0x10-7
NNE	7.3x10-6	4.4x10-6	3.4x10-6	1.9x10-6	8.5x10-7	3.1x10-7
NE	4.3x10-6	2.7x10-6	2.1x10-6	1.3x10-6	6.5x10-7	2.7x10-7
ENE	5.5x10-6	3.4x10-6	2.7x10-6	1.6x10-6	7.4x10-7	2.9x10-7
E	1.1x10-5	6.5x10-6	4.9x10-6	2.7x10-6	1.2x10-6	4.2x10-7
ESE	1.8x10-5	1.0x10-5	7.7x10-6	4.2x10-6	1.8x10-6	6.1x10-7
SE	1.5x10-5	8.5x10-6	6.4x10-6	3.4x10-6	1.4x10-6	4.8x10-7
SSE	7.5x10-6	4.4x10-6	3.4x10-6	1.9x10-6	8.7x10-7	3.3x10-7
S	6.9x10-6	4.2x10-6	3.2x10-6	1.8x10-6	8.2x10-7	3.1x10-7
			DISTANCE 5634 METERS (3.5 mi)			
SSW	2.9x10-6	1.8x10-6	1.4x10-6	8.4x10-7	4.1x10-7	1.7x10-7
SW	3.4x10-6	2.1x10-6	1.6x10-6	9.5x10-7	4.5x10-7	1.8x10-7
WSW	7.2x10-6	4.0x10-6	3.0x10-6	1.7x10-6	7.0x10-7	2.4x10-7
W	8.7x10-6	5.0x10-6	3.8x10-6	2.1x10-6	9.0x10-7	3.2x10-7
WNW	5.6x10-6	3.2x10-6	2.9x10-6	1.4x10-6	5.9x10-7	2.1x10-7
NW	4.9x10-6	2.8x10-6	2.2x10-6	1.2x10-6	5.5x10-7	2.0x10-7
NNW	5.6x10-6	3.2x10-6	2.5x10-6	1.3x10-6	5.7x10-7	2.0x10-7
N	7.7x10-6	4.4x10-6	3.2x10-6	1.7x10-6	7.0x10-7	2.4x10-7
NNE	4.8x10-6	2.8x10-6	2.2x10-6	1.2x10-6	5.3x10-7	1.9x10-7
NE	3.1x10-6	1.9x10-6	1.5x10-6	9.0x10-7	4.3x10-7	1.7x10-7
ENE	3.7x10-6	2.2x10-6	1.7x10-6	1.0x10-6	4.7x10-7	1.8x10-7
E	7.4x10-6	4.3x10-6	3.2x10-6	1.8x10-6	7.6x10-7	2.6x10-7
ESE	1.2x10-5	6.7x10-6	5.1x10-6	2.7x10-6	1.1x10-6	3.8x10-7
SE	9.4x10-6	5.3x10-6	4.0x10-6	2.2x10-6	9.0x10-7	3.0x10-7
SSE	4.8x10-6	2.8x10-6	2.2x10-6	1.2x10-6	5.4x10-7	2.0x10-7
S	4.3x10-6	2.6x10-6	2.0x10-6	1.1x10-6	5.1x10-7	1.9x10-7

TABLE 7.1-6 (Cont'd)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
			DISTANCE 7244 METERS (4.5 mi)			
SSW	2.1x10-6	1.3x10-6	1.0x10-6	6.2x10-7	2.9x10-7	1.2x10-7
SW	2.4x10-6	1.5x10-6	1.2x10-6	6.9x10-7	3.3x10-7	1.3x10-7
WSW	4.9x10-6	2.8x10-6	2.1x10-6	1.2x10-6	4.8x10-7	1.7x10-7
W	6.9x10-6	3.9x10-6	2.9x10-6	1.6x10-6	6.6x10-7	2.3x10-7
WNW	4.0x10-6	2.3x10-6	1.7x10-6	9.5x10-7	4.1x10-7	1.5x10-7
NW	3.3x10-6	1.9x10-6	1.5x10-6	8.4x10-7	3.7x10-7	1.4x10-7
NNW	3.7x10-6	2.2x10-6	1.7x10-6	9.4x10-7	4.2x10-7	1.5x10-7
N	4.9x10-6	2.8x10-6	2.1x10-6	1.2x10-6	5.0x10-7	1.7x10-7
NNE	3.3x10-6	1.9x10-6	1.5x10-6	8.4x10-7	3.8x10-7	1.4x10-7
NE	1.9x10-6	1.2x10-6	9.6x10-7	5.8x10-7	2.9x10-7	1.2x10-7
ENE	2.3x10-6	1.4x10-6	1.1x10-6	6.7x10-7	3.2x10-7	1.3x10-7
E	5.0x10-6	2.9x10-6	2.2x10-6	1.2x10-6	5.2x10-7	1.8x10-7
ESE	7.8x10-6	4.4x10-6	3.4x10-6	1.8x10-6	7.8x10-7	2.7x10-7
SE	7.0x10-6	4.0x10-6	3.0x10-6	1.6x10-6	6.4x10-7	2.1x10-7
SSE	3.3x10-6	2.0x10-6	1.5x10-6	8.5x10-7	3.8x10-7	1.4x10-7
S	3.0x10-6	1.8x10-6	1.4x10-6	8.0x10-7	3.6x10-7	1.4x10-7
			DISTANCE 12073 METERS (7.5 mi)			
SSW	1.1x10-6	6.8x10-7	5.4x10-7	3.2x10-7	1.5x10-7	6.2x10-8
SW	9.2x10-7	6.0x10-7	4.8x10-7	3.0x10-7	1.5x10-7	6.5x10-8
WSW	3.1x10-6	1.7x10-6	1.3x10-6	6.7x10-7	2.7x10-7	8.7x10-8
W	4.5x10-6	2.5x10-6	1.8x10-6	9.3x10-7	3.8x10-7	1.1x10-7
WNW	2.4x10-6	1.4x10-6	1.1x10-6	5.6x10-7	2.3x10-7	7.8x10-8
NW	1.7x10-6	1.0x10-6	7.8x10-7	4.4x10-7	1.9x10-7	7.3x10-8
NNW	2.0x10-6	1.2x10-6	8.7x10-7	4.8x10-7	2.1x10-7	7.3x10-8
N	2.7x10-6	1.5x10-6	1.2x10-6	6.0x10-7	2.5x10-7	8.6x10-8
NNE	1.8x10-6	1.0x10-6	7.8x10-7	4.4x10-7	1.8x10-7	6.8x10-8
NE	9.6x10-7	6.1x10-7	4.8x10-7	2.9x10-7	1.4x10-7	6.0x10-8
ENE	1.3x10-6	8.0x10-7	6.3x10-7	3.6x10-7	1.7x10-7	6.5x10-8
E	2.6x10-6	1.5x10-6	1.1x10-6	6.1x10-7	2.6x10-7	9.2x10-8
ESE	4.7x10-6	2.7x10-6	2.0x10-6	1.0x10-6	4.2x10-7	1.4x10-7
SE	3.7x10-6	2.1x10-6	1.5x10-6	8.2x10-7	3.4x10-7	1.1x10-7
SSE	1.8x10-6	1.1x10-6	8.0x10-7	4.6x10-7	2.0x10-7	7.3x10-8
S	1.7x10-6	1.0x10-6	7.7x10-7	4.3x10-7	1.9x10-7	6.9x10-8

TABLE 7.1-6 (Cont'd)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
			DISTANCE 24146 METERS (15.0 mi)			
SSW	3.9x10-7	2.5x10-7	2.0x1-7	1.2x10-7	5.8x10-8	2.4x10-8
SW	4.5x10-7	2.8x10-7	2.2x10-7	1.3x10-7	6.3x10-8	2.5x10-8
WSW	1.1x10-6	6.2x10-7	4.8x10-7	2.5x10-7	1.0x10-7	3.4x10-8
W	1.8x10-6	9.7x10-7	7.2x10-7	3.8x10-7	1.4x10-7	4.4x10-8
WNW	8.6x10-7	4.9x10-7	3.7x10-7	2.0x10-7	8.5x10-8	3.0x10-8
NW	6.7x10-7	4.0x10-7	3.1x10-7	1.8x10-7	7.8x10-8	2.8x10-9
NNW	7.8x10-7	4.6x10-7	3.5x10-7	1.9x10-7	8.0x10-8	2.8x10-8
N	1.1x10-6	6.2x10-7	4.6x10-7	2.5x10-7	1.0x10-7	3.3x10-8
NNE	6.1x10-7	3.6x10-7	2.8x10-7	1.6x10-7	6.9x10-8	2.6x10-8
E	3.2x10-7	2.1x10-7	1.7x10-7	1.1x10-7	5.5x10-8	2.4x10-8
ENE	4.2x10-7	2.7x10-7	2.1x10-7	1.2x10-7	6.0x10-8	2.5x10-8
E	1.1x10-6	6.2x10-7	4.7x10-7	2.6x10-7	1.1x10-7	3.6x10-8
ESE	2.1x10-6	1.1x10-6	8.5x10-7	4.4x10-7	1.6x10-7	5.3x10-8
SE	1.7x10-6	9.2x10-7	6.9x10-7	3.5x10-7	1.3x10-7	4.2x10-8
SSE	7.6x10-7	4.4x10-7	3.3x10-7	1.8x10-7	7.8x10-8	2.8x10-8
S	5.8x10-7	3.5x10-7	2.7x10-7	1.5x10-7	7.0x10-8	2.7x10-8
			DISTANCE 40244 METERS (25 mi)			
SSW	1.6x10-7	1.1x10-7	8.5x10-8	5.3x10-8	2.7x10-8	1.2x10-8
SW	2.0x10-7	1.3x10-7	1.0x10-7	6.3x10-8	3.1x10-8	1.3x10-8
WSW	5.1x10-7	2.9x10-7	2.2x10-7	1.2x10-7	5.0x10-8	1.7x10-8
W	7.8x10-7	4.3x10-7	3.2x10-7	1.7x10-7	6.7x10-8	2.2x10-8
WNW	3.9x10-7	2.3x10-7	1.8x10-7	9.7x10-8	4.3x10-8	1.5x10-8
NW	3.1x10-7	1.9x10-7	1.5x10-7	8.3x10-8	3.7x10-8	1.4x10-8
NNW	4.1x10-7	2.3x10-7	1.8x10-7	9.5x10-8	4.0x10-8	1.4x10-8
N	5.3x10-7	3.0x10-7	2.3x10-7	1.2x10-7	4.9x10-8	1.6x10-8
NNE	3.1x10-7	1.8x10-7	1.4x10-7	8.0x10-8	3.6x10-8	1.3x10-8
NE	1.6x10-7	1.1x10-7	8.5x10-8	5.3x10-8	2.7x10-8	1.2x10-8
ENE	2.1x10-7	1.3x10-7	1.0x10-7	6.4x10-8	3.1x10-8	1.3x10-8
E	5.1x10-7	3.0x10-7	2.2x10-7	1.2x10-7	5.2x10-8	1.8x10-8
ESE	9.4x10-7	5.3x10-7	3.9x10-7	2.0x10-7	8.0x10-8	2.6x10-8
SE	7.1x10-7	4.1x10-7	3.0x10-7	1.6x10-7	6.5x10-8	2.1x10-8
SSE	3.3x10-7	1.9x10-7	1.5x10-7	8.5x10-8	3.8x10-8	1.4x10-8
S	2.8x10-7	1.7x10-7	1.3x10-7	7.5x10-8	3.4x10-8	1.3x10-8

TABLE 7.1-6 (Cont'd)

Sector	2 Hour	8 Hour	16 Hour	72 Hour	624 Hour	Annual
			DISTANCE 56341 METERS (35 mi)			
SSW	9.8x10-8	6.4x10-8	5.2x10-8	3.3x10-8	1.7x10-8	7.6x10-9
SW	1.7x10-7	1.0x10-7	7.8x10-8	4.6x10-8	2.1x10-8	8.0x10-9
WSW	3.4x10-7	1.9x10-7	1.4x10-7	7.7x10-8	3.2x10-8	1.1x10-8
W	5.3x10-7	3.0x10-7	2.3x10-7	1.3x10-7	5.4x10-8	1.4x10-8
WNW	2.5x10-7	1.3x10-7	1.0x10-7	5.9x10-8	2.6x10-8	9.6x10-9
NW	2.1x10-7	1.3x10-7	9.5x10-8	5.4x10-8	2.4x10-8	9.0x10-9
NNW	2.5x10-7	1.4x10-7	1.1x10-7	6.0x10-8	2.5x10-8	8.8x10-9
N	3.3x10-7	1.5x10-7	1.1x10-7	6.3x10-8	2.7x10-8	1.0x10-8
NNE	2.1x10-7	1.3x10-7	9.5x10-8	5.3x10-8	2.3x10-8	8.1x10-9
NE	1.1x10-7	7.2x10-8	5.7x10-8	3.5x10-8	1.7x10-8	7.4x10-9
ENE	1.3x10-7	8.3x10-8	6.6x10-8	4.0x10-8	1.9x10-8	8.0x10-9
E	3.2x10-7	1.8x10-7	1.4x10-7	7.5x10-8	3.2x10-8	1.1x10-8
ESE	6.4x10-7	3.0x10-7	2.3x10-7	1.2x10-7	5.1x10-8	1.7x10-8
SE	4.8x10-7	2.7x10-7	2.0x10-7	1.0x10-7	4.0x10-8	1.3x10-8
SSE	2.2x10-7	1.3x10-7	1.0x10-7	5.5x10-8	2.4x10-8	8.9x10-8
S	1.9x10-7	1.2x10-7	9.0x10-8	5.0x10-8	2.3x10-8	8.4x10-9
			DISTANCE 72439 METERS (45 mi)			
SSW	7.8x10-8	4.9x10-8	4.0x10-8	2.4x10-8	1.2x10-8	5.4x10-9
SW	1.1x10-7	7.0x10-8	5.4x10-8	3.2x10-8	1.4x10-8	5.7x10-9
WSW	2.4x10-7	1.3x10-7	1.0x10-7	5.4x10-8	2.2x10-8	7.5x10-9
W	3.8x10-7	2.1x10-7	1.5x10-7	7.9x10-8	3.0x10-8	9.8x10-9
WNW	1.8x10-7	1.1x10-7	8.0x10-8	4.4x10-8	1.9x10-8	6.8x10-9
NW	1.7x10-7	9.8x10-8	7.5x10-8	4.1x10-8	1.8x10-8	6.3x10-9
NNW	1.8x10-7	1.0x10-7	7.7x10-8	4.2x10-8	1.8x10-8	6.2x10-9
N	3.2x10-7	1.7x10-7	1.3x10-7	6.3x10-8	2.4x10-8	7.2x10-9
NNE	1.5x10-7	8.7x10-8	6.7x10-8	3.6x10-8	1.6x10-8	5.7x10-9
NE	7.2x10-8	4.6x10-8	3.8x10-8	2.3x10-8	1.2x10-8	5.2x10-9
ENE	1.1x10-7	6.7x10-8	5.2x10-8	3.0x10-8	1.4x10-8	5.7x10-9
E	2.4x10-7	1.4x10-7	1.0x10-7	5.6x10-8	2.3x10-8	8.1x10-9
ESE	4.6x10-7	2.6x10-7	1.9x10-7	9.7x10-8	3.8x10-8	1.2x10-8
SE	3.0x10-7	1.7x10-7	1.3x10-7	6.7x10-8	2.8x10-8	9.4x10-9
SSE	1.6x10-7	9.0x10-8	7.0x10-8	3.9x10-8	1.7x10-8	6.3x10-9
S	1.3x10-7	7.7x10-8	6.0x10-8	3.4x10-8	1.6x10-8	6.0x10-9

TABLE 7.1-7

CLASS 3.1 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT
OF EQUIPMENT LEAKAGE OR MALFUNCTION
(WASTE SLUDGE TANK)

ISOTOPE	RADIOACTIVITY RELEASED TO THE ENVIRONMENT (curies)
I-131	3.85×10^{-3}
I-132	9.58×10^{-6}
I-133	9.18×10^{-4}
I-134	1.05×10^{-8}
I-135	1.48×10^{-4}

TABLE 7.1-8

CLASS 3.2 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF THE FIRST CHARCOAL BED FAILURE IN THE OFFGAS TREATMENT SYSTEM

ISOTOPE	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
Kr-83m	1.90×10^{1}
Kr-85m	4.10×10^{1}
Kr-85	1.02
Kr-87	7.50×10^{1}
Kr-88	1.70×10^{2}
Kr-89	5.57
Xe-131m	9.53
Xe-133m	4.73×10^{1}
Xe-133	3.11×10^{3}
Xe-135m	1.60×10^{1}
Xe-135	6.46×10^{2}
Xe-137	1.01×10^{1}
Xe-138	6.22×10^{1}

TABLE 7.1-9

CLASS 3.3 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF GROSS EQUIPMENT FAILURE
(WASTE SLUDGE TANK)

ISOTOPE	RADIOACTIVITY RELEASED TO THE ENVIRONMENT (curies)
I-131	1.54×10^{-2}
I-132	3.83×10^{-5}
I-133	3.67×10^{-3}
I-134	4.19×10^{-8}
I-135	5.91×10^{-4}

TABLE 7.1-10

CLASS 4.2 ACCIDENT

RADIOACTIVITY RELEASED AS A
RESULT OF AN OFF-DESIGN TRANSIENT ACCIDENT

	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)	
ISOTOPE	0-8 hours	8-24 hours
I-131	2.81×10^{-2}	5.36×10^{-2}
I-132	1.59×10^{-2}	1.48×10^{-3}
I-133	5.74×10^{-2}	7.68×10^{-2}
I-134	1.20×10^{-2}	1.99×10^{-5}
I-135	4.02×10^{-2}	2.42×10^{-2}
Kr-83m	$1.62 \times 10^{+0}$	8.64×10^{-2}
Kr-85m	$7.25 \times 10^{+0}$	$2.64 \times 10^{+0}$
Kr-85	4.33×10^{-1}	8.64×10^{-1}
Kr-87	$5.52 \times 10^{+0}$	7.02×10^{-2}
Kr-88	$1.49 \times 10^{+1}$	$2.34 \times 10^{+0}$
Xe-131m	2.14×10^{-1}	4.15×10^{-1}
Xe-133m	$1.58 \times 10^{+0}$	$2.71 \times 10^{+0}$
Xe-133	$6.42 \times 10^{+1}$	$1.20 \times 10^{+2}$
Xe-135m	8.28×10^{-1}	4.54×10^{-10}
Xe-135	$4.64 \times 10^{+1}$	$3.90 \times 10^{+1}$
Xe-137	6.92×10^{-1}	0
Xe-138	$3.05 \times 10^{+0}$	1.69×10^{-8}

TABLE 7.1-11

CLASS 6.1 ACCIDENT

RADIOACTIVITY RELEASED AS A
RESULT OF A FUEL ASSEMBLY DROP ACCIDENT

ISOTOPE	GAP RADIOACTIVITY RELEASED TO POOL WATER (curies)	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	$7.92 \times 10^{+1}$	2.68×10^{-6}
I-133	$1.30 \times 10^{+0}$	4.30×10^{-8}
Kr-85	$2.20 \times 10^{+0}$	6.23×10^{-1}
Xe-131m	7.26×10^{-1}	2.04×10^{-1}
Xe-133m	$1.02 \times 10^{+0}$	2.75×10^{-1}
Xe-133	$1.33 \times 10^{+2}$	$3.69 \times 10^{+1}$
Xe-135	1.01×10^{-3}	2.18×10^{-4}

TABLE 7.1-12

CLASS 6.2 ACCIDENT

RADIOACTIVITY RELEASED AS A
RESULT OF A HEAVY OBJECT DROP ONTO FUEL IN CORE

ISOTOPE	GAP RADIOACTIVITY RELEASED TO POOL WATER (curies)	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	$7.84 \times 10^{+2}$	2.66×10^{-5}
I-133	$9.52 \times 10^{+1}$	3.15×10^{-6}
I-135	7.92×10^{-2}	2.47×10^{-9}
Kr-85m	6.88×10^{-5}	1.15×10^{-5}
Kr-85	$1.70 \times 10^{+1}$	$4.82 \times 10^{+0}$
Xe-131m	$6.64 \times 10^{+0}$	$1.86 \times 10^{+0}$
Xe-133m	$1.86 \times 10^{+1}$	$5.02 \times 10^{+0}$
Xe-133	$1.49 \times 10^{+3}$	$4.14 \times 10^{+2}$
Xe-135	$1.31 \times 10^{+0}$	2.83×10^{-1}

TABLE 7.1-13

CLASS 7.2 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF A HEAVY OBJECT DROP ONTO FUEL RACK

ISOTOPE	RADIOACTIVITY RELEASED TO SPENT FUEL POOL (curies)	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	$8.46 \times 10^{+1}$	2.87×10^{-6}
Kr-85	$1.69 \times 10^{+1}$	$4.79 \times 10^{+0}$
Xe-131m	$1.45 \times 10^{+0}$	4.07×10^{-1}
Xe-133m	7.53×10^{-3}	2.03×10^{-3}
Xe-133	$4.99 \times 10^{+1}$	$1.39 \times 10^{+1}$

TABLE 7.1-14

CLASS 8.1 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF
LOSS-OF-COOLANT ACCIDENT - SMALL PIPE BREAK

	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)			
ISOTOPE	0-8 hrs	8-24 hrs	24-96 hrs	96-720 hrs
I-131	1.14×10^{-9}	2.77×10^{-9}	1.06×10^{-8}	3.05×10^{-8}
I-132	2.06×10^{-9}	3.05×10^{-10}	2.27×10^{-12}	0
I-133	3.99×10^{-9}	6.88×10^{-9}	8.61×10^{-9}	7.93×10^{-10}
I-134	9.76×10^{-10}	3.80×10^{-12}	1.06×10^{-17}	0
I-135	2.95×10^{-19}	2.50×10^{-9}	5.85×10^{-10}	3.29×10^{-13}
Kr-83m	2.38×10^{-5}	4.56×10^{-6}	1.80×10^{-8}	4.47×10^{-20}
Kr-85m	9.98×10^{-5}	1.06×10^{-4}	1.31×10^{-5}	1.69×10^{-10}
Kr-85	6.79×10^{-7}	3.60×10^{-6}	2.19×10^{-5}	1.80×10^{-4}
Kr-87	7.96×10^{-5}	4.42×10^{-6}	1.11×10^{-9}	0
Kr-88	2.34×10^{-4}	1.16×10^{-4}	3.31×10^{-6}	6.62×10^{-14}
Xe-131m	5.29×10^{-7}	2.72×10^{-6}	1.49×10^{-5}	5.87×10^{-5}
Xe-133m	9.56×10^{-6}	4.38×10^{-5}	1.57×10^{-4}	1.05×10^{-4}
Xe-133	2.87×10^{-4}	1.43×10^{-3}	6.88×10^{-3}	1.36×10^{-2}
Xe-135	5.58×10^{-4}	1.30×10^{-3}	7.50×10^{-4}	3.37×10^{-6}
Xe-135m	5.02×10^{-6}	4.56×10^{-14}	0	0
Xe-137	1.80×10^{-6}	0	0	0
Xe-138	2.10×10^{-5}	1.73×10^{-12}	0	0

TABLE 7.1-15

CLASS 8.1 ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF
LOSS-OF-COOLANT ACCIDENT - LARGE PIPE BREAK

	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)			
ISOTOPE	0-8 hrs	8-24 hrs	24-96 hrs	96-720 hrs
I-131	1.55×10^{-4}	3.75×10^{-4}	1.43×10^{-3}	4.14×10^{-3}
I-132	6.99×10^{-5}	1.03×10^{-5}	7.71×10^{-8}	1.96×10^{-17}
I-133	3.11×10^{-4}	5.37×10^{-4}	6.72×10^{-4}	6.19×10^{-5}
I-134	3.56×10^{-5}	1.39×10^{-7}	3.86×10^{-13}	0
I-135	2.10×10^{-4}	1.78×10^{-4}	4.17×10^{-5}	2.34×10^{-8}
Kr-83m	$2.62 \times 10^{+0}$	5.02×10^{-1}	1.98×10^{-3}	4.93×10^{-15}
Kr-85m	$1.60 \times 10^{+1}$	$1.70 \times 10^{+1}$	$2.10 \times 10^{+0}$	2.70×10^{-5}
Kr-85	$1.17 \times 10^{+0}$	$6.19 \times 10^{+0}$	$3.77 \times 10^{+1}$	$3.11 \times 10^{+2}$
Kr-87	$7.01 \times 10^{+0}$	3.89×10^{-1}	9.77×10^{-5}	0
Kr-88	$2.89 \times 10^{+1}$	$1.43 \times 10^{+1}$	4.09×10^{-1}	8.17×10^{-9}
Xe-131m	5.77×10^{-1}	$2.97 \times 10^{+0}$	$1.63 \times 10^{+1}$	$6.41 \times 10^{+1}$
Xe-133m	$4.21 \times 10^{+0}$	$1.93 \times 10^{+1}$	$6.94 \times 10^{+1}$	$4.62 \times 10^{+1}$
Xe-133	$1.72 \times 10^{+2}$	$8.57 \times 10^{+2}$	$4.13 \times 10^{+3}$	$8.14 \times 10^{+3}$
Xe-135	$1.14 \times 10^{+2}$	$2.65 \times 10^{+2}$	$1.53 \times 10^{+2}$	6.90×10^{-1}
Xe-135m	2.51×10^{-1}	2.28×10^{-9}	0	0
Xe-137	5.37×10^{-2}	0	0	0
Xe-138	$1.03 \times 10^{+0}$	8.54×10^{-8}	0	0

TABLE 7.1-16

CLASS 8.1(a) ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF A PRIMARY SYSTEM INSTRUMENT LINE BREAK ACCIDENT

ISOTOPE	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	1.85×10^{-7}
I-132	7.54×10^{-7}
I-133	7.06×10^{-7}
I-134	8.25×10^{-7}
I-135	6.40×10^{-7}
Kr-83m	1.21×10^{-3}
Kr-85m	3.58×10^{-3}
Kr-85	1.93×10^{-5}
Kr-87	5.25×10^{-3}
Kr-88	9.71×10^{-3}
Xe-131m	1.50×10^{-5}
Xe-133m	2.76×10^{-4}
Xe-133	8.19×10^{-3}
Xe-135m	1.47×10^{-3}
Xe-135	1.76×10^{-2}
Xe-137	2.08×10^{-3}
Xe-138	5.48×10^{-3}

TABLE 7.1-17

CLASS 8.2(b) ACCIDENT

RADIOACTIVITY RELEASED AS A
RESULT OF A ROD DROP ACCIDENT

	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)	
ISOTOPE	0-8 hrs	8-24 hrs
I-131	3.51×10^{-2}	6.71×10^{-2}
I-132	1.99×10^{-2}	1.85×10^{-3}
I-133	7.18×10^{-2}	9.61×10^{-2}
I-134	1.50×10^{-2}	2.49×10^{-5}
I-135	5.09×10^{-2}	3.18×10^{-2}
Kr-83m	$2.03 \times 10^{+0}$	1.08×10^{-1}
Kr-85m	$9.07 \times 10^{+0}$	$3.30 \times 10^{+0}$
Kr-85	5.41×10^{-1}	$1.08 \times 10^{+0}$
Kr-87	$6.92 \times 10^{+0}$	8.79×10^{-2}
Kr-88	$1.87 \times 10^{+1}$	$2.93 \times 10^{+0}$
Xe-131m	2.67×10^{-1}	5.18×10^{-1}
Xe-133m	$1.98 \times 10^{+0}$	$3.39 \times 10^{+0}$
Xe-133	$8.03 \times 10^{+1}$	$1.50 \times 10^{+2}$
Xe-135m	$1.04 \times 10^{+0}$	5.70×10^{-10}
Xe-135	$5.81 \times 10^{+1}$	$4.88 \times 10^{+1}$
Xe-137	8.66×10^{-1}	0
Xe-138	$3.81 \times 10^{+0}$	2.12×10^{-8}

TABLE 7.1-18

CLASS 8.3(b) ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF A
STEAM LINE BREAK ACCIDENT - SMALL PIPE BREAK

ISOTOPE	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	1.25×10^{-5}
I-132	7.48×10^{-5}
I-133	5.00×10^{-5}
I-134	1.25×10^{-4}
I-135	5.00×10^{-5}
Kr-83m	1.37×10^{-3}
Kr-85m	2.37×10^{-3}
Kr-85	7.48×10^{-6}
Kr-87	8.23×10^{-3}
Kr-88	8.23×10^{-3}
Xe-131m	5.86×10^{-6}
Xe-133m	1.12×10^{-4}
Xe-133	3.24×10^{-3}
Xe-135m	1.05×10^{-2}
Xe-135	8.98×10^{-3}
Xe-137	5.86×10^{-2}
Xe-138	3.49×10^{-2}

TABLE 7.1-19

CLASS 8.3(b) ACCIDENT

RADIOACTIVITY RELEASED AS A RESULT OF A
STEAM LINE BREAK ACCIDENT - LARGE PIPE BREAK

ISOTOPE	RADIOACTIVITY RELEASED TO ENVIRONMENT (curies)
I-131	8.15×10^{-4}
I-132	4.90×10^{-3}
I-133	3.27×10^{-3}
I-134	8.15×10^{-3}
I-135	3.27×10^{-3}
Kr-83m	1.80×10^{-2}
Kr-85m	3.10×10^{-2}
Kr-85	9.80×10^{-5}
Kr-87	1.08×10^{-1}
Kr-88	1.08×10^{-1}
Xe-131m	7.67×10^{-5}
Xe-133m	1.47×10^{-3}
Xe-133	4.25×10^{-2}
Xe-135m	1.18×10^{-1}
Xe-135	1.37×10^{-1}
Xe-137	7.67×10^{-1}
Xe-138	4.57×10^{-1}

TABLE 7.1-20

SUMMARY OF MAXIMUM EXCLUSION AREA BOUNDARY DOSES RESULTING FROM ACCIDENTS

ACCIDENT CLASS	DESCRIPTION	THYROID DOSE (millirem)	WHOLE-BODY GAMMA DOSE (millirem)	GENERAL ASSESSMENT OF LIKELIHOOD
1.0	TRIVIAL ACCIDENTS INSIDE CONTAINMENT	(1)	(1)	occasional
2.0	SMALL RELEASES OUTSIDE CONTAINMENT	(1)	(1)	occasional
3.0	RADWASTE SYSTEM FAILURE			
3.1	Equipment Leakage or Malfunction	18.8	0.00911	rare
3.2	Release from offgas treatment system first charcoal delay tank rupture	Negligible	22	rare
3.3	Release of waste sludge tank contents	75.2	0.0364	rare
4.0	FISSION PRODUCTS TO PRIMARY SYSTEM (BWR)			
4.1	Fuel Cladding Defects	(1)	(1)	occasional
4.2	Off-Design Transients that Induce Fuel Failures Above Those Expected	2.94	1.33	rare

TABLE 7.1-20 (Cont'd)

ACCIDENT CLASS	DESCRIPTION	THYROID DOSE (millirem)	WHOLE-BODY GAMMA DOSE (millirem)	GENERAL ASSESSMENT OF LIKELIHOOD
5.0	FISSION PRODUCTS TO PRIMARY AND SECONDARY SYSTEM (PWR)	----------Not Applicable-----------		
6.0	REFUELING ACCIDENTS			
6.1	Fuel Assembly Drop	0.000101	0.0204	rare
6.2	Heavy Object Drop Over Fuel in Core	0.00103	0.231	rare
7.0	SPENT FUEL HANDLING ACCIDENTS			
7.1	Fuel Assembly Drop in Fuel Storage Pool	0.000101	0.0204	rare
7.2	Heavy Object Drop onto Fuel Rack	0.000108	0.0078	rare
7.3	Fuel Cask Drop	----------Not Applicable-----------		
8.0	ACCIDENT INITIATION EVENTS CONSIDERED IN FSAR			
8.1	LOSS-OF-COOLANT ACCIDENTS			
	Small Pipe Break			Extremely rare
		5.19×10^{-7}	1.76×10^{-5}	
	Large Pipe Break			Extremely rare
		6.35×10^{-2}	6.14	

TABLE 7.1-20 (Cont'd)

ACCIDENT CLASS	DESCRIPTION	THYROID DOSE (millirem)	WHOLE-BODY GAMMA DOSE (millirem)	GENERAL ASSESSMENT OF LIKELIHOOD
8.1(a)	Break in Instrument Line from Primary System that Penetrates the Containment	1.76×10^{-5}	8.99×10^{-4}	rare
8.2	CONTROL ROD ACCIDENTS			
8.2(a)	Rod Ejection Accident (PWR)	----------Not Applicable-----------		
8.2(b)	Rod Drop Accident (BWR)	3.68	1.67	Extremely rare
8.3	STEAMLINE BREAK ACCIDENTS			
8.3(a)	Steamline Breaks (PWR)	----------Not Applicable-----------		
8.3	STEAMLINE Breaks (BWR)			
	Small Break	0.00131	0.0047	Extremely rare
	Large Break	0.0856	0.0621	Extremely rare

(1) Incidents included and evaluated under routine radioactive releases are contained in Section 5.2.

TABLE 7.1-21 (Page 1 of 2)

SUMMARY OF POPULATION DOSES RESULTING FROM ACCIDENTS

ACCIDENT CLASS		DESCRIPTION	YEAR 2000 POPULATION DOSE WITHIN 50 MILES (man-rem)
1.0		TRIVIAL ACCIDENTS INSIDE CONTAINMENT	(1)
2.0		SMALL RELEASES OUTSIDE CONTAINMENT	(1)
3.0		RADWASTE SYSTEM FAILURE	
	3.1	Equipment Leakage or Malfunction	0.373
	3.2	Offgas Treatment System First Charcoal Delay Tank Rupture	8.8×10^{-1}
	3.3	Waste Sludge Tank Failure	1.49
4.0		FISSION PRODUCTS TO PRIMARY SYSTEM (BWR)	
	4.1	Fuel Cladding Defects	(1)
	4.2	Off-Design Transients that Induce Fuel Failures Above Those Expected	53.9
5.0		FISSION PRODUCTS TO PRIMARY AND SECONDARY SYSTEM (PWR)	not applicable
6.0		REFUELING ACCIDENTS	
	6.1	Fuel Assembly Drop	0.834
	6.2	Heavy Object Drop Over Fuel in Core	9.45
7.0		SPENT FUEL HANDLING ACCIDENTS	
	7.1	Fuel Assembly Drop in Fuel Storage Pool	0.834
	7.2	Heavy Object Drop Onto Fuel Rack	0.319
	7.3	Fuel Cask Drop	not applicable

TABLE 7.1-21 (Cont'd)

ACCIDENT CLASS	DESCRIPTION	YEAR 2000 POPULATION DOSE WITHIN 50 MILES (man-rem)
8.0	ACCIDENT INITIATION EVENTS CONSIDERED IN FSAR	
8.1	Loss-of-Coolant Accidents	
	Small Pipe Break	0.00106
	Large Pipe Break	222
8.1(a)	Break in Instrument Line From Primary System That Penetrates the Containment	0.0368
8.2	CONTROL ROD ACCIDENTS	
8.2(a)	Rod Ejection Accident (PWR)	not applicable
8.2(b)	Rod Drop Accident (BWR)	67.4
8.3	STEAMLINE BREAK ACCIDENTS	
8.3(a)	Steamline Breaks (PWR)	not applicable
8.3(b)	Steamline Breaks (BWR)	
	Small Break	0.192
	Large Break	2.54

(1) Incidents included and evaluated under routine radioactive releases are contained in Section 5.2.

TABLE 7.1-22

SOURCE TERM CHARACTERISTICS - POINT ESTIMATE[1]

CRAC 2 Input GROUP	T_r [2] (hr)	T_d [3] (hr)	T_w [4] (hr)	h[5] (m)	Q[6] (cal/sec)	XE	QI	I_2	Cs	Te	Sr	Ru	La
						RADIONUCLIDE RELEASE FRACTIONS							
OXRE	4.0	0.5	3.0	27	8.4(6)[7]	1.0	3(-4)	0.20	0.06	0.50	0.007	0.40	1.0(-5)
OPREL	7.0	2.0	6.0	27	8.4(6)	1.0	3(-4)	0.11	0.09	0.016	0.01	3(-3)	3 (-4)
C4γ	1.5	2.0	1.0	27	7.0(4)	1.0	3(-4)	0.261	0.202	0.434	0.029	0.095	5.2(-3)
C4γ'	1.5	2.0	1.0	27	7.0(4)	1.0	3(-4)	0.07	0.09	0.20	0.016	0.008	5.0(-3)
C4γ"	1.5	2.0	1.0	10	7.0(4)	1.0	3(-4)	0.73	0.70	0.55	0.09	0.12	7.0(-3)
C123γ"	7.0	2.0	6.0	10	7.0(4)	1.0	3(-4)	0.13	0.17	0.50	0.02	0.08	6.2(-3)
LEAK 1	7.0	2.0	6.0	27	7.0(4)	0.73	3(-4)	1.9(-2)	9.8(-3)	4.6(-2)	1.6(-3)	3.2(-3)	5.8(-4)
LEAK 2	7.0	2.0	6.0	27	7.0(4)	0.73	3(-4)	2.7(-3)	9.8(-5)	4.6(-4)	1.6(-5)	3.2(-5)	5.8(-6)
RB[8]	1.5	3.0	1.5	10	8.4(6)	1.0	3(-4)	0.05	0.09	0.09	4.0(-3)	0.02	5.0(-3)
VR[9]	0.25	3.5	0.25	10	1.4(4)	1.0	3(-4)	0.1	0.33	0.33	0.15	0.04	0.02
VRH20[10]	0.34	0.65	0.34	10	2(6)	1.0	3(-4)	0.5	0.73	0.75	0.35	0.07	0.05

[1] The final CCDFs given in Figures 7.1-2 through 7.2-6 are medians and are obtained from an uncertainty analysis on the source term characteristics.
[2] T_r = time of release
[3] T_d = duration or release
[4] T_w = warning time
[5] h = height of release
[6] Q = rate of release of energy
[7] 8.4(6) = 8.4×10^6
[8] Reactor building failure
[9] Vessel rupture without water in vessel
[10] Vessel rupture with water in vessel

TABLE 7.1-23

FREQUENCIES OF TABLE 7.1-22 SOURCE TERMS

CRAC 2 INPUT GROUP	POINT ESTIMATE (YR^{-1})			MEDIAN (YR^{-1})		
	INTERNAL	SEISMIC	FIRE	INTERNAL	SEISMIC	FIRE
OXRE	4.4(-8)	1.3(-8)	6.9(-8)	3.3(-8)	7.5(-10)	2.6(-8)
OPREL	7.0(-6)	2.0(-6)	1.1(-5)	5.3(-6)	1.2(-7)	4.2(-6)
C4γ	6.4(-8)	6.3(-8)	0	6.4(-8)	2.0(-9)	0
C4γ'	5.6(-8)	5.6(-8)	0	5.6(-8)	9.0(-10)	0
C4γ"	6.4(-9)	6.3(-9)	0	6.2(-9)	1.0(-10)	0
C123γ"	3.6(-7)	1.0(-7)	5.8(-7)	2.8(-7)	6.3(-9)	2.2(-7)
LEAK 1	1.1(-6)	3.3(-7)	1.8(-6)	8.8(-7)	2.0(-8)	6.8(-7)
LEAK 2	6.1(-6)	1.7(-6)	9.9(-6)	4.6(-6)	1.1(-7)	3.7(-6)
RB	0	1.2(-6)	0	0	7.6(-9)	0
VR	1.4(-8)	3.7(-7)	0	5.0(-9)	<1(-10)	0
VRH20	1.4(-8)	4.1(-8)	0	5.0(-9)	<1(-10)	0

TABLE 7.1-24 (Cont'd) (Page 2 of 2)

Group/radionuclide	Radioactive inventory (million of Curies)	Half-life (days)
COBALT AND NOBLE METALS		
Cobalt-58	0.0	71.0
Cobalt-60	0.0	1,920
Molybdenum-99	166	2.80
Technitium-99m	143	0.25
Ruthenium-103	114	39.5
Ruthenium-105	67	0.185
Ruthenium-106	42	366
Rhodium-105	60	1.5
RARE EARTHS, REFRACTORY OXIDES AND TRANSURANICS		
Yttrium-90	504	2.67
Yttrium-91	127	59.0
Zirconium-95	152	65.2
Zirconium-97	156	0.71
Niobium-95	145	35.0
Lanthanum-140	166	1.67
Cerium-141	151	32.3
Cerium-143	148	1.38
Cerium-144	90	284
Praseodymium-143	147	13.7
Neodymium-147	61	11.1
Neptunium-239	1,670	2.35
Plutonium-238	0.036	32,500
Plutonium-239	0.02	8.9×10^6
Plutonium-240	0.024	2.5×10^6
Plutonium-241	5.5	5,350
Americium-241	0.0034	1.6×10^5
Curium-242	1.1	163
Curium-244	0.013	6,630

5.04 Table E.8 : GE error in CRAC.

Note: The above grouping of radionuclides corresponds to that in the Reactor Safety Study

TABLE 7.1-24

ACTIVITY IN THE LIMERICK REACTOR

CORE AT 3293 MWt

Group/radionuclide	Radioactive inventory (million of Curies)	Half-life (days)
NOBLE GASES		
Krypton-85	0.57	3,950
Krypton-85m	28	0.183
Krypton-87	55	0.0528
Krypton-88	77	0.117
Xenon-133	184	5.28
Xenon-135	34	0.384
IODINES		
Iodine-131	83	8.05
Iodine-132	128	0.0958
Iodine-133	183	0.875
Iodine-134	202	0.0366
Iodine-135	172	0.280
ALKALI METALS		
Rubidium-86	0.061	18.7
Cesium-134	5.7	750
Cesium-136	1.9	13.0
Cesium-137	5.6	11,000
TELLURIUM-ANTIMONY		
Tellurium-127	5.8	0.391
Tellurium-127m	0.79	109
Tellurium-129	21.8	0.048
Tellurium-129m	5.8	34.0
Tellurium-131m	11.4	1.25
Tellurium-132	122	3.25
Antimony-127	6.0	3.88
Antimony-129	23.2	0.179
AKALINE EARTHS		
Strontium-89	102	52.1
Strontium-90	4.8	10,300
Strontium-91	130	0.403
Barium-140	163	12.8

TABLE 7.1-25

PERMANENT RESIDENT POPULATION FOR THE LIMERICK SITE

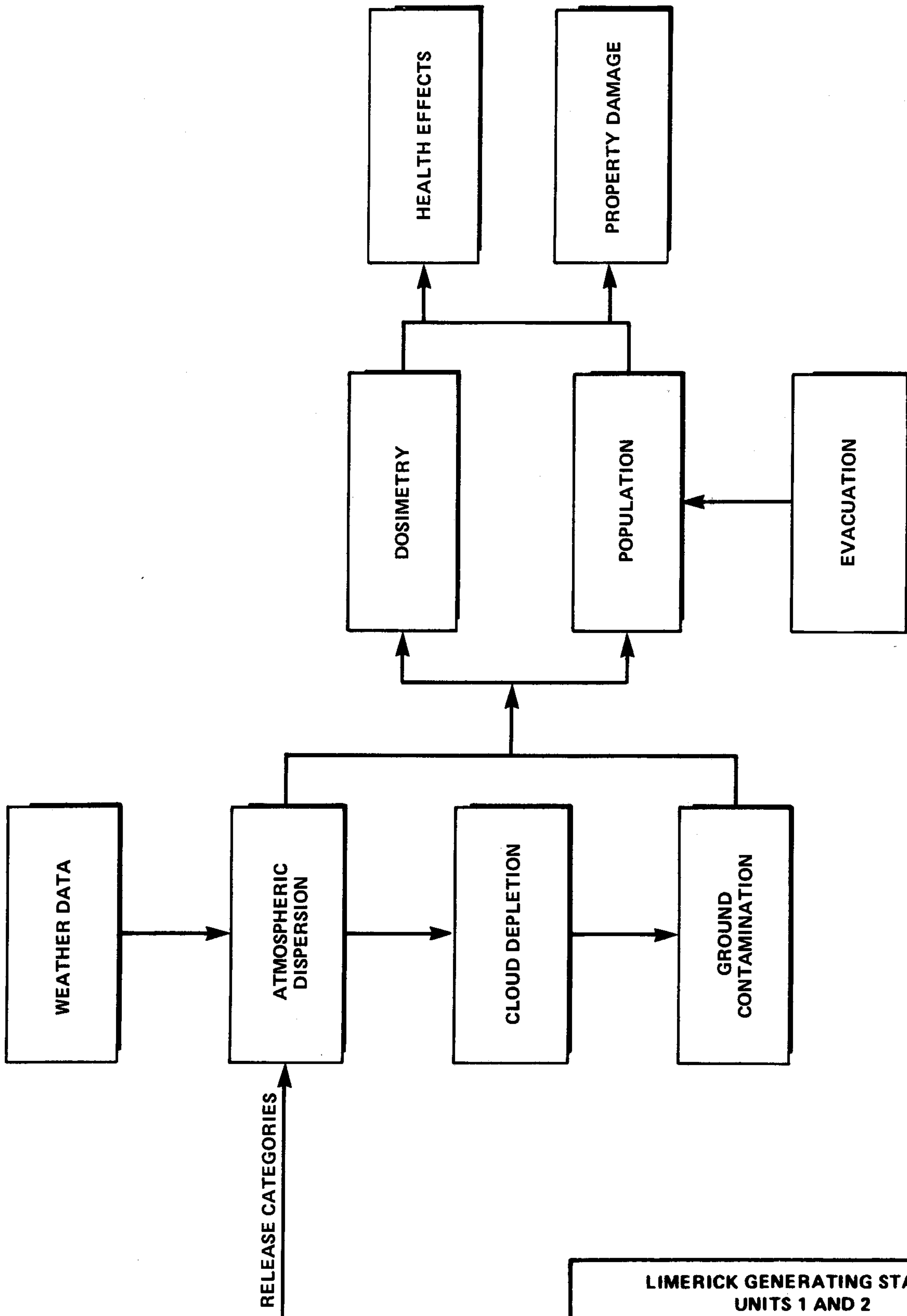
Sector (miles)	Direction N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0-0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5-1.0	61	141	27	32	23	73	0	18	5	0	88	67	65	10	24	11
1.0-1.5	308	110	40	38	60	70	222	204	259	305	123	136	33	45	199	317
1.5-2.0	432	153	55	53	84	97	311	286	362	427	173	190	46	63	278	444
2.0-2.5	243	151	128	159	183	192	675	949	175	207	117	339	715	2,083	1,537	565
2.5-3.0	297	184	157	194	223	234	826	1,160	213	254	142	414	874	2,546	1,878	690
3.0-3.5	316	214	191	218	281	172	2,622	2,669	50	232	208	293	740	7,310	4,029	572
3.5-4.0	365	246	220	252	325	199	3,025	3,079	57	268	239	339	853	8,435	4,648	661
4.0-4.5	472	92	187	109	227	198	745	1,126	253	168	200	713	1,197	2,232	960	434
4.5-5.0	527	102	210	121	253	221	833	1,258	283	187	223	796	1,337	2,494	1,073	486
5-6	1,306	585	559	345	2,248	2,692	598	5,913	944	472	745	261	60	1,724	164	1,032
6-7	1,544	691	660	407	2,657	3,182	707	6,989	1,115	558	880	309	70	2,038	193	1,219
7-8.5	2,761	1,236	1,181	729	4,751	5,691	1,264	12,499	1,995	998	1,574	552	126	3,645	346	2,181
8.5-10	3,295	1,476	1,410	870	5,671	6,792	1,508	14,918	2,381	1,191	1,879	659	150	4,550	413	2,603
10-12.5	1,280	4,739	6,146	9,828	12,472	31,605	21,922	7,194	17,907	8,376	1,211	2,068	737	24,907	1,578	1,986
12.5-15	1,565	5,792	7,512	12,012	15,243	38,629	26,794	8,792	21,887	10,237	1,481	2,528	901	30,442	1,928	2,428
15-17.5	1,850	6,845	8,877	14,197	18,014	45,652	31,666	10,391	25,866	12,098	1,750	2,987	1,065	35,976	2,279	2,869
17.5-20	2,134	7,897	10,243	16,381	20,786	52,675	36,537	11,990	29,846	13,960	2,019	3,447	1,229	41,511	2,629	3,310
20-25	20,829	97,040	10,711	27,827	63,046	336,450	563,411	121,367	17,609	17,078	23,839	10,670	8,012	34,626	8,212	7,096
25-30	25,457	118,604	13,091	34,010	77,056	411,217	688,613	148,337	21,523	20,873	29,137	13,041	9,793	42,320	10,037	8,673
30-35	21,716	85,094	14,733	11,780	122,464	324,681	336,351	16,314	202,552	24,450	6,281	34,785	23,142	9,433	6,615	2,663
35-40	25,057	98,186	16,999	13,592	141,305	374,632	388,097	18,823	233,714	28,212	7,247	40,136	26,705	10,884	7,632	3,072
40-45	11,888	17,743	24,911	18,800	225,218	49,936	67,649	13,997	11,762	32,128	9,777	71,801	37,361	12,542	24,250	13,994
45-50	13,286	19,831	27,841	21,011	251,715	55,811	75,607	15,643	13,146	35,907	10,927	80,248	41,756	14,017	27,103	15,640
50-55	6.886	32,970	30,854	53,592	187,792	49,511	161,447	30,528	53,899	8,247	27,223	34,766	32,841	22,307	20,197	22,346
55-60	17,057	16,913	64,100	105,293	174,828	59,913	102,131	39,055	68,362	9,516	42,384	36,859	44,757	31,575	23,085	45,025
60-65	30,623	17,742	66,292	171,163	162,803	72,760	47,391	34,900	53,574	9,185	50,422	43,002	49,577	45,230	19,869	47,911
65-70	35,151	15,206	62,170	272,858	160,844	78,672	55,195	32,108	18,030	5,570	40,968	58,190	46,595	42,210	21,365	39,144
70-85	155,810	36,828	296,821	2,001,226	351,491	177,523	128,551	69,479	57,227	22,168	730,546	206,022	116,878	74,437	72,049	141,117
85-100	114,867	53,596	456,449	6,070,038	0	0	0	27,737	61,571	43,637	942,506	101,937	110,012	41,030	59,928	20,755
100-150	271,093	258,729	1,244,443	5,114,585	0	0	0	8,231	209,523	362,873	2,739,529	1,062,112	238,115	295,032	140,775	182,565
150-200	482,802	568,895	1,353,835	1,802,514	0	0	0	0	52,287	166,772	329,908	287,951	520,317	164,714	142,422	324,640
200-350	1,650,580	1,194,147	3,569,922	4,813,485	0	0	0	0	542,893	3,071,062	1,879,393	1,030,760	4,504,704	5,425,319	6,677,693	2,105,064
350-500	818,581	5,136,991	949,375	0	0	0	0	0	31,959	2,036,392	4,558,303	2,849,465	6,044,539	9,035,347	504,911	306,549

TABLE 7.1-26

AVERAGE VALUES OF ENVIRONMENTAL RISKS

DUE TO ACCIDENTS PER REACTOR-YEAR

Environmental Risk	Average/RY (Median)
Population exposure	
Person-rems within 50 miles	40
Total person-rems	70
Acute fatalities	4.1×10^{-5}
Latent cancer fatalities	
All organs excluding thyroid	0.012
Thyroid only	0.001
Cost of protective actions and decontamination	$6,000



LIMERICK GENERATING STATION
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SCHEMATIC OUTLINE OF
CONSEQUENCE MODEL

FIGURE 7.1-1

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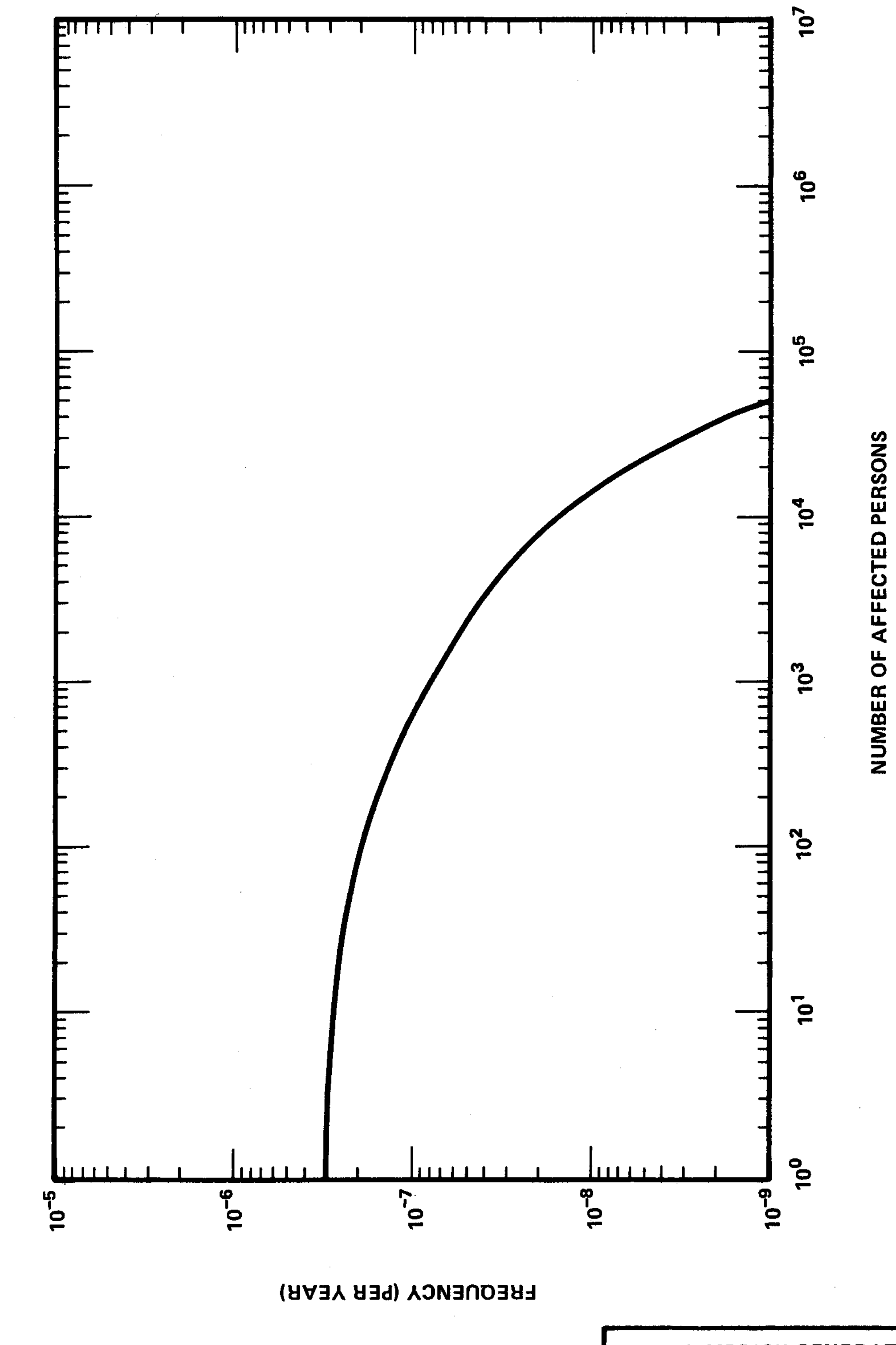

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MEDIAN CCDF OF
BONE MARROW DOSE
GREATER THAN 200 REM

FIGURE 7.1-2

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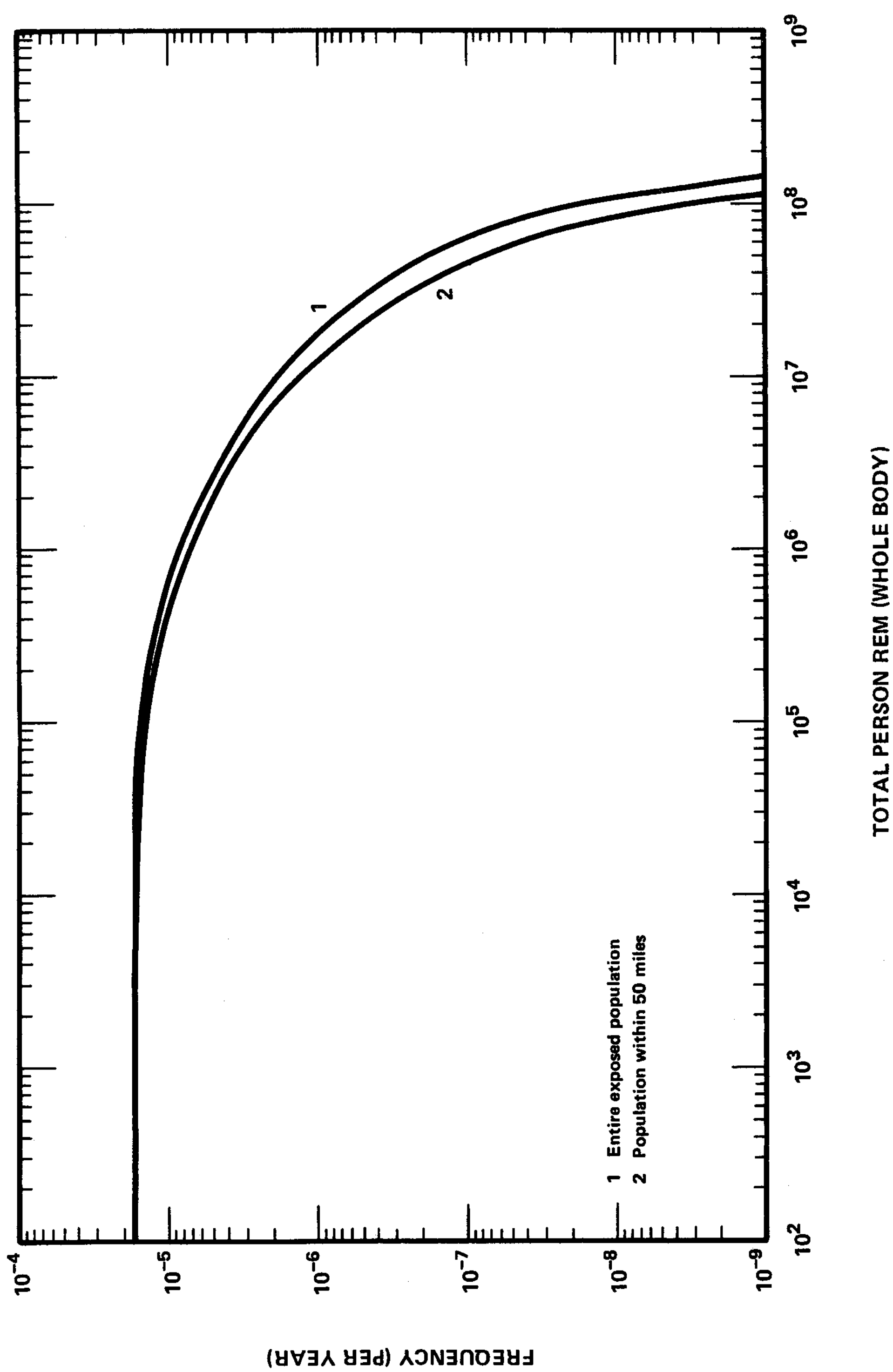

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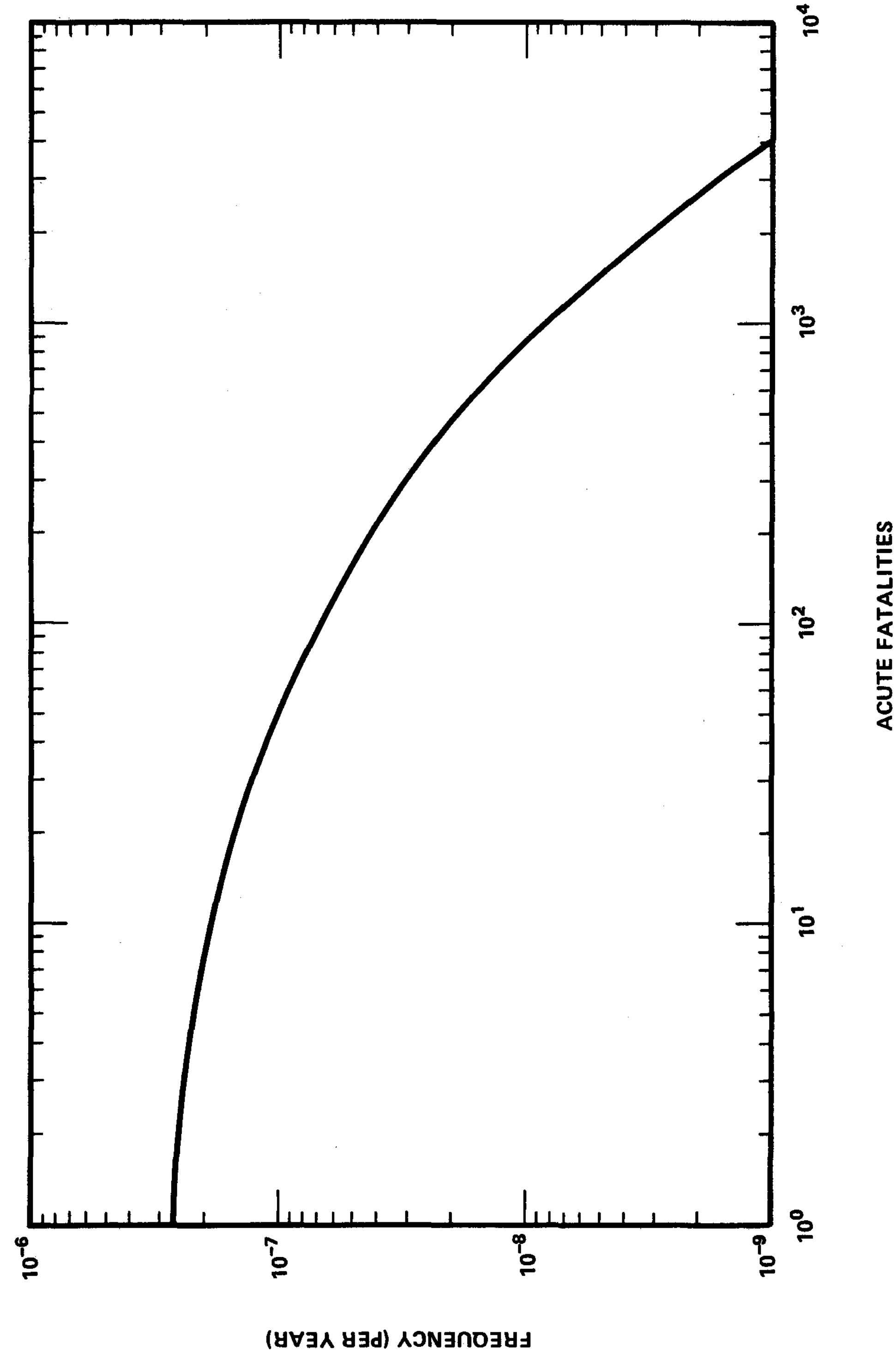
MEDIAN CCDF OF
POPULATION EXPOSURES

FIGURE 7.1-3

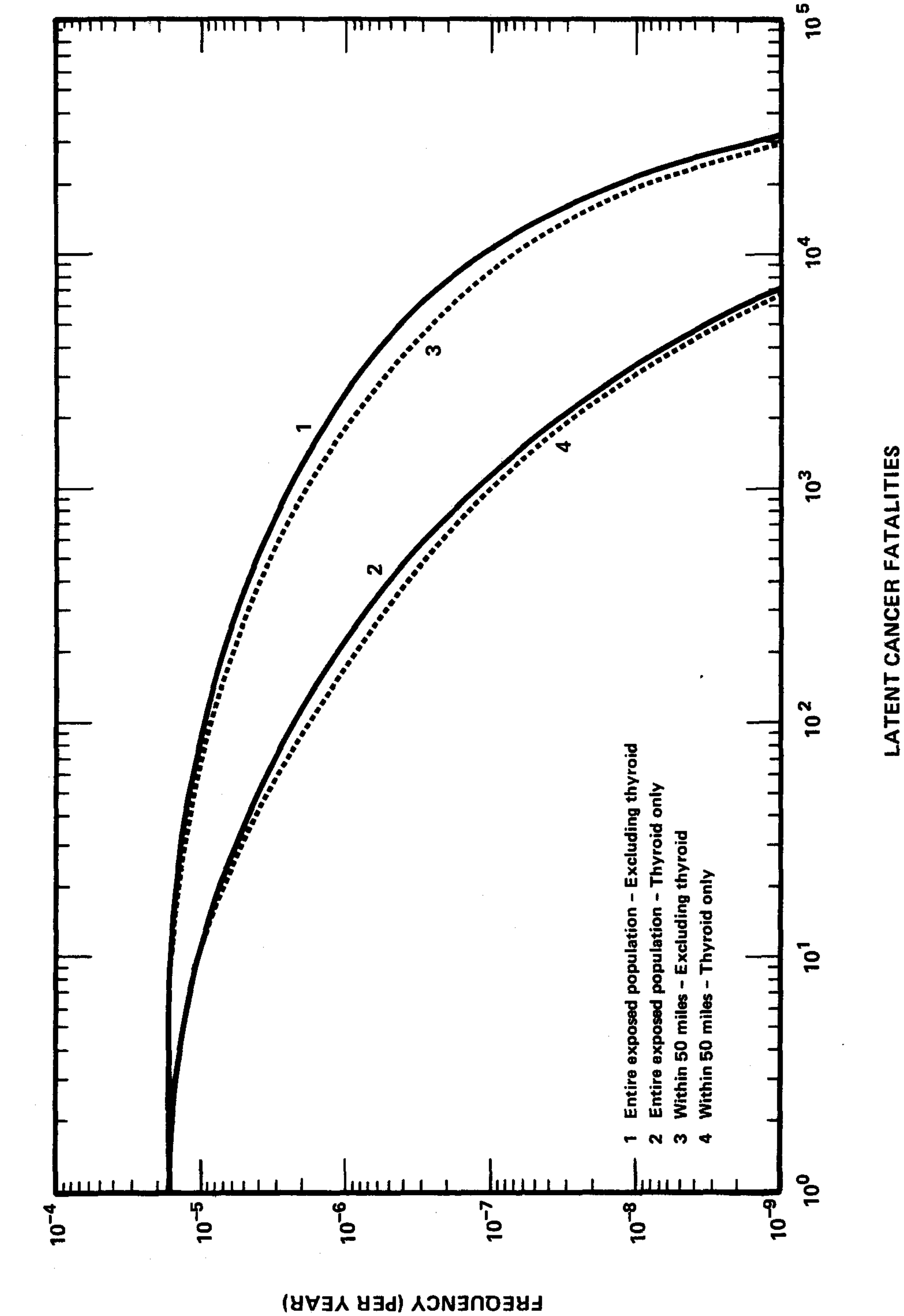
REV. 12, 04/83



LIMERICK GENERATING STATION
UNITS 1 AND 2
ENVIRONMENTAL REPORT

MEDIAN CCDF OF
ACUTE FATALITIES

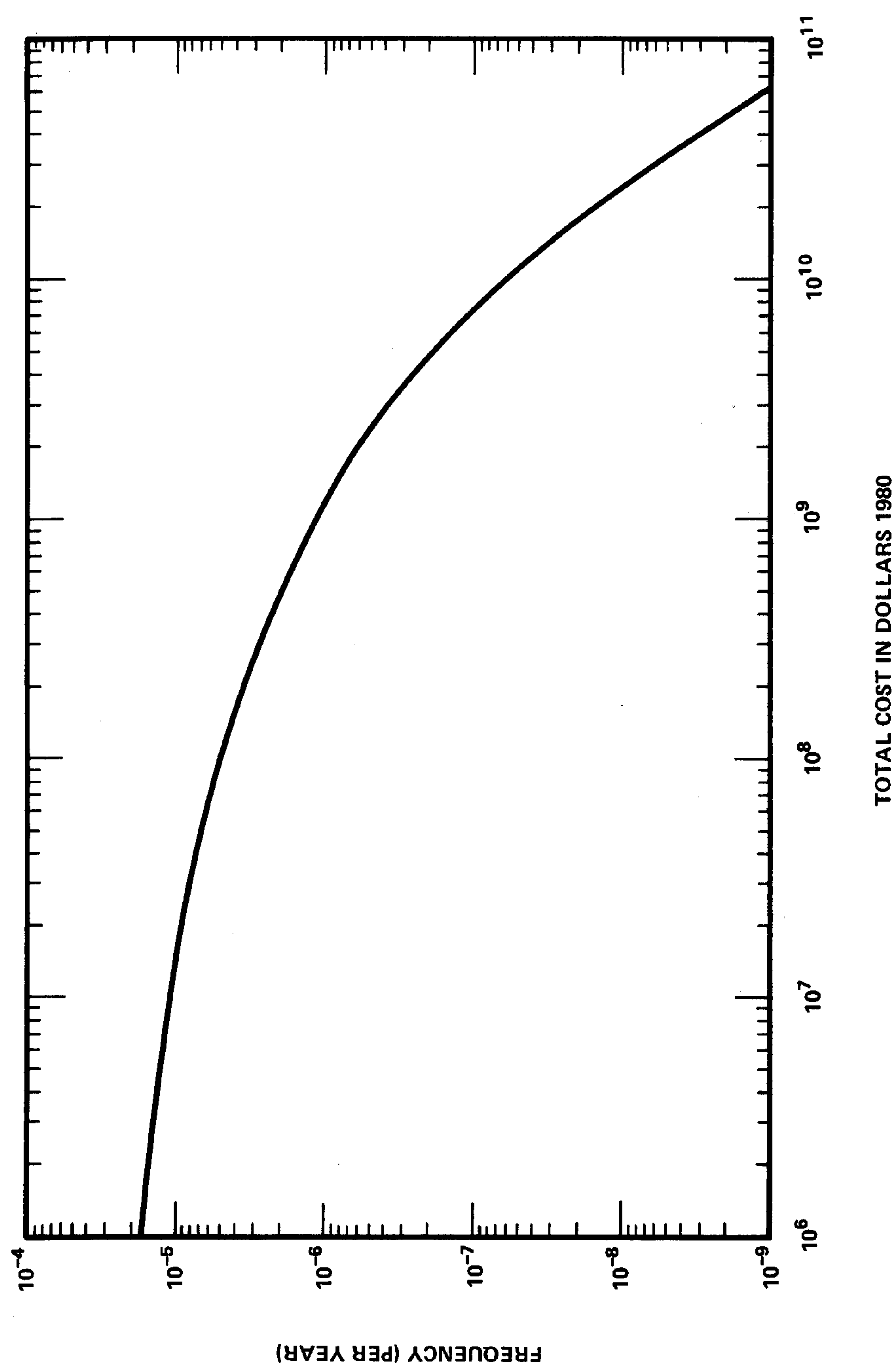
FIGURE 7.1-4 REV. 12, 04/83



LIMERICK GENERATING STATION
UNITS 1 AND 2
ENVIRONMENTAL REPORT

MEDIAN CCDF OF LATENT CANCER FATALITIES

FIGURE 7.1-5 REV. 12, 04/83



LIMERICK GENERATING STATION
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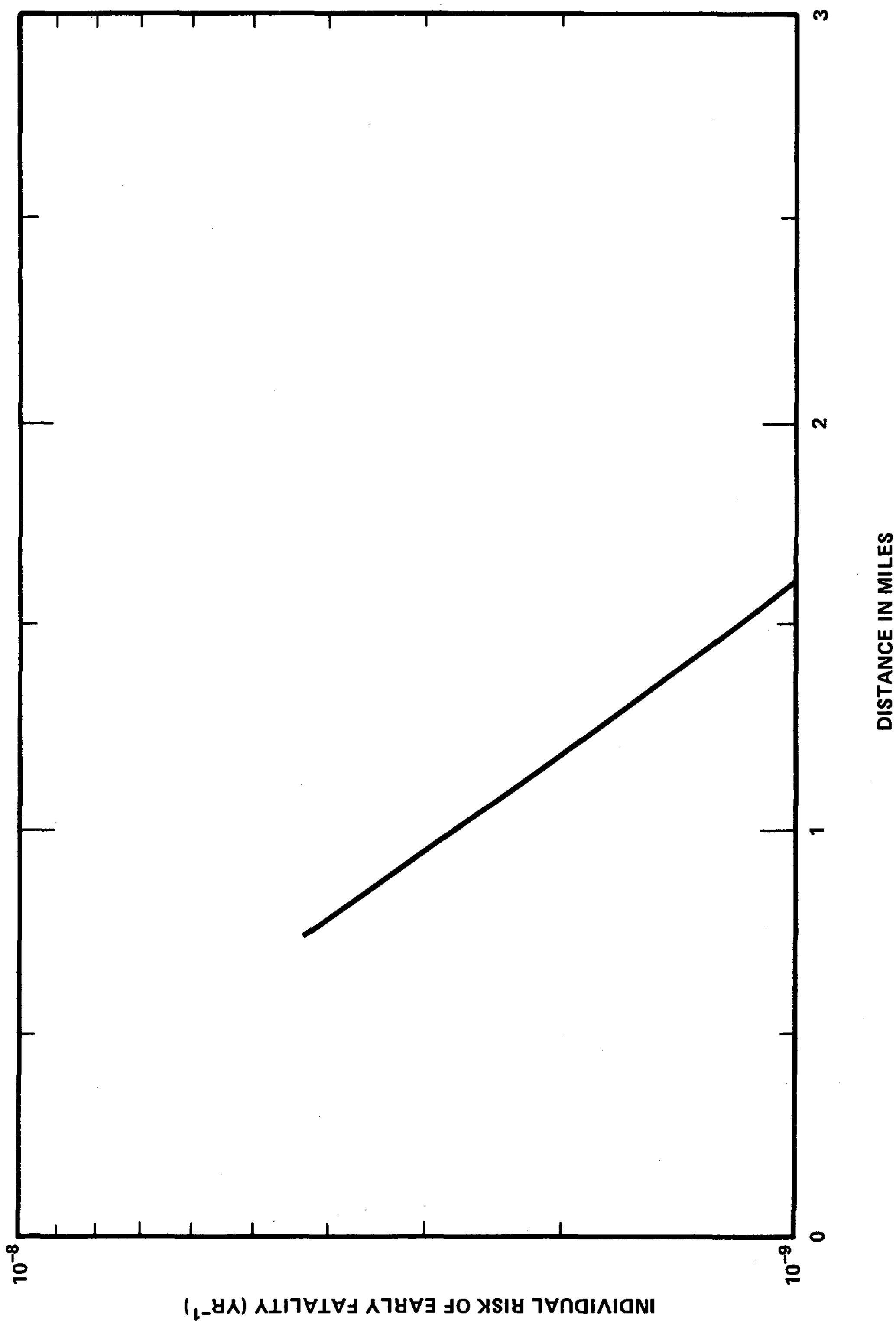
MEDIAN CCDF OF
EX - PLANT COSTS

FIGURE 7.1-6

REV. 12, 04/83



LIMERICK GENERATING STATION
UNITS 1 AND 2
ENVIRONMENTAL REPORT

MEDIAN INDIVIDUAL RISK OF EARLY FATALITY AS A FUNCTION OF DISTANCE

FIGURE 7.1-7 **REV. 12, 04/83**

7.2 TRANSPORTATION ACCIDENTS INVOLVING RADIOACTIVITY

The transportation of fuel and waste to and from Limerick Generating Station is within the scope of Paragraph (g) of 10 CFR 51.20. The environmental risks from accidents involving the transportation of radioactive materials to and from each unit are as set forth in Summary Table S-4 of 10 CFR 51, shown as Table 7.2-1 in this section.

In accordance with Regulatory Guide 4.2 and 10 CFR 51, no further discussion is necessary.

TABLE 7.2-1

SUMMARY TABLE S-4 - ENVIRONMENTAL IMPACT OF TRANSPORTATION OF FUEL AND WASTE TO AND FROM ONE LIGHT-WATER-COOLED NUCLEAR POWER REACTOR[1]

NORMAL CONDITIONS OF TRANSPORT

	Environmental impact
Heat (per irradiated fuel cask in transit)	250,000 Btu/hr
Weight (governed by Federal or State restrictions)	73,000 lbs per truck; 100 tons per cask per rail car.
Traffic density:	
Truck	Less than 1 per day.
Rail	Less than 3 per month.

Exposed population	Estimated number of persons exposed	Range of doses to individuals[2] (per reactor year)	Cumulative doses to exposed population (per reactor year)[3]
Transportation workers	200	0.01 to 300 millirem	4 man-rem.
General public:			
Onlookers	1,100	0.003 to 1.3 millirem	3 man-rem.
Along Route	600,000	0.0001 to 0.06 millirem	

ACCIDENTS IN TRANSPORT

	Environmental risk
Radiological effects	Small[4].
Common (nonradiological) causes	1 fatal injury in 100 reactor years: nonfatal injury in 10 reactor years; $475 property damage per reactor year.

[1]Data supporting this table are given in the Commission's "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants" WASH-1238, December 1972, and Supp. I NUREG-75/038, April 1975.

[2]The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural baground and medical exposures should be limited to 5,00 millirem per year for individuals as a result of occpational expossure and should be limited to dose to individuals due to average natural background radiation is about 140 millirem per year.

[3]Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people were to receive a dose of 0.5 rem (500 millirem), or if 2 people were to receive rem (500 millirem) each, the total man-rem dose in each case would be 1 man-rem.

[4]Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multireactor site.

7.3 OTHER ACCIDENTS

This section discusses the measures employed for the prevention of significant environmental effects resulting from nonradiological accidents. The accidents considered are those concerned with the storage and use of oil, condensate water, acid, caustic, alum, and chlorine, and other compressed gases.

7.3.1 STORAGE AND USE OF OIL

Five 150 gpm oil interceptors are installed in yard areas to intercept accidental oil spills near the points of oil storage and use. Each interceptor has a sediment bucket, baffle, surface oil draw-off tube, bottom-connected water outlet, and an inlet flow control to achieve maximum efficiency. The interceptor operates by gravity with the light oil rising to the surface slightly above the operating water level. The oil drains through a stationary draw-off tube into a 500 gallon waste oil storage tank associated with each interceptor. The oil interceptors and waste oil storage tanks are located in concrete pits. Effluent from the oil interceptors, as well as other normal waste drainage, is routed to the holding pond via two parallel 750 gpm oil separators.

Two parallel 750 gpm gravity differential oil separators, located immediately upstream of the holding pond, treat all flows entering the holding pond except for floor drainage from the holding pond treatment enclosure. These oil separators each have an oil capacity of 8000 gallons as well as an oil drain line to a common 6000 gallon underground storage tank. The oil-free water drains to the holding pond.

Outdoor diked areas south of the Unit 2 reactor enclosure contain several aboveground tanks which include one 200,000 gallon residual (No. 6) fuel oil storage tank, and one 50,000 gallon diesel (No. 2) fuel oil storage tank. To prevent water pollution from a tank leak or rupture, the storage tanks are installed on impervious asphalt bases and enclosed within earthen dikes capable of containing 110% of the contents of the largest tank. The enclosed areas around the tanks are sloped to catch basins, which can be drained by gravity through normally closed manually-operated valves and then through an oil interceptor to the holding pond via the oil separators. Rainwater that collects within the enclosed area is drained under operator supervision.

Eight underground diesel oil storage tanks (each with a capacity of 41,500 gallons) are located south of the Unit 1 reactor enclosure. To prevent water pollution from a tank leak or rupture, the storage tanks are encased with a lean mixture of cement and sand that is contained within an impervious membrane.

Two outdoor oil unloading areas, one for the aboveground tanks and one for the underground tanks, are paved depressions that can contain at least 7000 gallons. Each depression is drained by a catch basin leading to an isolation valve, which can be closed during truck unloading operations to prevent possible water pollution from an oil unloading accident. The isolation valves are normally left open allowing rainwater to drain through oil interceptors to the holding pond via the oil separators.

Thirteen oil-filled outdoor transformers are located north of the turbine enclosures. The transformer oil contains approximately 0.2% by weight of di-tertiary butyl para cresol. There are four main transformers for Unit 1, each containing 7880 gallons; three main transformers for Unit 2, each containing 10,600 gallons; one auxiliary transformer for each unit containing 4740 gallons; one safeguard transformer for each unit containing 3550 gallons; and one circulating water pump structure service transformer for each unit containing 1310 gallons. To prevent water pollution from a transformer leak or rupture, the outdoor transformers are located on concrete slabs with curbs. Drains in the slabs will convey rainwater, or fire deluge water in the case of a fire, through an oil interceptor to the holding pond via the oil separators.

To prevent water pollution from a leak or rupture of indoor piping, tanks, and transformers, various floor drains (exclusive of the oily waste system in the turbine enclosures) are routed through oil interceptors to the holding pond via the oil separators. Floor drainage from the auxiliary boiler enclosure and the lube oil storage enclosure is routed through an oil interceptor to the holding pond via the oil separators. Floor drainage from the eight diesel-generator enclosures (each of which contains an 825 gallon diesel oil day tank and a 250 gallon lube oil makeup tank within curbed areas) is routed through an oil interceptor to the holding pond via the oil separators. The drainage from the fuel oil transfer enclosure and from pits and trenches containing oil pumps, piping, and valves is routed through an oil interceptor to the holding pond via the oil separators. Floor drainage from the circulating water pump structure (which contains a 550 gallon diesel oil tank, within a curbed area, for the diesel engine-driven fire pump) is routed through an oil interceptor to the holding point via the oil separators.

Each turbine enclosure contains three 16,000 gallon lube oil storage tanks, an 11,200 gallon main turbine lube oil reservoir, an 1100 gallon M-G set fluid drive (lube oil), three 1000 gallon reactor feed pump turbine lube oil reservoirs, a generator hydrogen seal oil tank holding approximately 530 gallons, and a turbine electro-hydraulic control (EHC) reservoir holding 800 gallons of fire resistant hydraulic fluid consisting of straight triaryl phosphate ester which is heavier than water. These oil containers are located within curbed areas which are drained through oily waste plumbing to the oily waste sump. Oily waste from each turbine enclosure oily waste sump passes through an oil interceptor. Samples are collected from the tanks and monitored for radioactivity. If no measurable amounts of activity are found, the tank contents will be pumped into a truck and delivered to the auxiliary boiler fuel oil tank. If no measurable amounts of activity are found in the oil free water, the water is then pumped to the holding pond. While the potential for radioactive contamination is low, provisions are made so that contaminated oil can be transferred to suitable containers and solidified for disposal. Likewise, contaminated water shall be processed, used in conjunction with other radioactive waste in solidification or processed through the radwaste system.

7.3.2 STORAGE OF CONDENSATE AND REFUELING WATER

An outdoor diked area south of the Unit 2 reactor enclosure contains one above ground 200,000 gallon condensate storage tank. A common outdoor diked area west of the Unit 1 reactor enclosure contains another above-ground 200,000 gallon condensate storage tank and an above ground 550,000 gallon refueling water storage tank. To prevent water pollution from a tank leak or rupture, the storage tanks are installed on impervious asphalt bases within earth dikes capable of containing 110% of the contents of the largest tank. The enclosed areas around the tanks are sloped to catch basins, which can be drained by gravity through normally closed manually-operated valves to either the radwaste system or to the holding pond. Rainwater that collects within the enclosed areas will be drained under operator supervision.

7.3.3 STORAGE AND USE OF ACID AND CAUSTIC

A 4000 gallon sulfuric acid storage tank and a 4000 gallon sodium hydroxide storage tank are located inside of the water treatment enclosure within areas that are surfaced and curbed to contain 110% of the capacity of the tanks. The water treatment enclosure also contains a 200 gallon caustic tank, a 200 gallon alum tank, a 100 gallon hypochlorite tank, a 50 gallon chlorine solution tank, a 56 gallon caustic day tank, and a 33 gallon acid day tank, all of which are located in areas that drain to a 2100 gallon chemical waste sump. The acid and caustic waste in the chemical waste sump (resulting from accidental spills, leaks, and tank ruptures as well as from normal regeneration of the demineralizers) will be pumped to either of two 15,000 gallon neutralizing tanks for pH adjustment before being routed through the waste water settling basins. Other floor drainage in the water treatment enclosure is routed through waste water settling basins to the holding pond. The neutralizing tanks are located outside in a surfaced and curbed area which drains to the holding pond.

Two 10,000 gallon storage tanks provide the sulfuric acid which is used to maintain a nearly neutral pH of the circulating water and service water in the cooling towers. The storage tanks have no drain connections and are located inside of enclosures which are surfaced and curbed to contain 110% of the capacity of the tanks. Four 50 gallon acid feed tanks provide acid to the circulating water from the storage tanks. The feed tanks are located at the cooling tower basin and inside enclosures which are surfaced and curbed to contain at least 110% of tank capacity. The acid piping is contained within concrete trenches which drain to sumps for transfer to the holding pond, cooling tower basins, or portable tankage.

Water treatment chemicals are also stored in the holding pond treatment enclosure. Dry alum and sodium hydroxide are stored in bags on pallets. Sulfuric acid and polyelectrolytes are stored in drums no larger than 55 gallons. The chemicals are mixed in four 210 gallon solution tanks when needed. Floor drains in the holding pond treatment enclosure are routed to the holding pond.

7.3.4 STORAGE AND USE OF CHLORINE

Liquid chlorine is supplied to the chlorination equipment from a single-unit railroad tank car equipped with excess-flow valves designed to close when the flowrate of liquid chlorine exceeds about 7000 lbs per hour. A separate rail siding used only for chlorine tank cars is provided with de-rails, signs and safety equipment recommended by the Chlorine Institute for unloading chlorine. Gas masks are provided in convenient locations to facilitate expeditious corrective action in the event of a chlorine leak. Chlorine detectors alarm the presence of chlorine in the chlorine storage area.

Piping from tank cars to chlorine evaporators is run to chlorine equipment located in a separate room in the circulating water pump structure. Liquid chlorine evaporators and vacuum type gas chlorinators are provided for operation and control of the chlorine system. Chlorine gas lines from the chlorinators are operated under vacuum to the point of use areas to minimize the leakage potential of chlorine gas and concentrated chlorine solutions.

7.3.5 STORAGE AND USE OF COMPRESSED GASES

Carbon dioxide is stored as a bulk liquid in three refrigerated tanks. The tanks are provided with high and low pressure alarms. These alarms detect loss of refrigeration or tank leakage.

Carbon dioxide is used for purging the generator hydrogen system, and as part of the fire protection system.

Hydrogen is stored onsite in a battery of high pressure containers (bottles). Each bottle is equipped with a pressure relief device and is mounted in a rack to restrain its movement. The bottles are individually valved to a withdrawal (transfer) manifold which is equipped with relief valves. The hydrogen storage area at the station is located remote from the main building.

Hydrogen is used to cool the generator.

No adverse environmental effects are anticipated from the storage of compressed gases.

7.3.6 SUMMARY

To prevent water pollution from a leak or rupture of oil and chemicals, potential spill areas are either drained to the turbine enclosure oily waste system or drained through oil separators to the holding pond. The holding pond effluent is continuously monitored, while discharging, for pH and turbidity, and the effluent is automatically stopped if excessively acid, alkaline, or turbid water is detected. The holding pond water is then treated using a portable oil skimmer, disposable oil sorbents, acid, caustic, alum, or polyelectrolytes as necessary until the water is suitable for discharge. Due to the protection provided by the oil separators, the large reserve capacity of the holding pond, and the standby treatment available at the holding pond, it is concluded that accidental spills of oil and chemicals would not cause significant environmental effects.

CHAPTER 8

ECONOMIC AND SOCIAL EFFECTS OF STATION CONSTRUCTION AND OPERATION

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CHAPTER 8

TABLES

CHAPTER 8

ECONOMIC AND SOCIAL EFFECTS OF STATION CONSTRUCTION AND OPERATION

Construction and operation of the Limerick Station affects both the social and economic conditions of residents of Montgomery, Berks and Chester counties, Pennsylvania, and to a lesser degree the entire nation. This chapter assesses both the beneficial and adverse effects of operation of the Limerick Station, and where possible, places a monetary value upon them. All monetary values are expressed in 1990 dollar values unless otherwise noted.

8.1 BENEFITS

8.1.1 PRIMARY BENEFITS

Limerick Station is a nominal 2110 MWe (net) two-unit station. Unit 1 is scheduled for commercial operation in 1985 and Unit 2 in 1988. The net average annual energy generation of the station, calculated at a 70% capacity factor, is 12.9 billion kWh.

The energy delivered by the station is divided into four categories--residential, small commercial and industrial, large commercial and industrial, and other. System losses reduce the net annual energy delivered to customers to 12 billion kWh. The 1990 demand for electrical energy is expected to be distributed to the Applicant's customers as shown on the following summary:

	Million kWh
Small Commercial and Industrial	1440
Large Commercial and Industrial	6480
Residential	3600
Other	480
Total	12000

The price of electricity is the basis used to determine the station output's value to society since it reflects the value that users place on electricity. However, this market price provides only the minimum value of the output, since many customers are prepared to pay more for electricity than they are actually being charged. The average price for electricity in 1990 is estimated to be approximately 12.9 cents per kWh for all users described above.

The value of station output in its first full year of two-unit operation is therefore $1.55 billion. This aggregate value is based on the value of sales to all users: residential, commercial, and industrial.

It would be impractical to enumerate the specific uses of electricity and evaluate how these contribute to a rising quality of life at home and at work. One illustration which may be worth noting in this context is the use of household appliances. The Applicant's projections show that between 1982 and 1992, the saturation ratio (number of appliances as percent of total residential customers) of clothes dryers will rise from 44% to 50%; dishwashers from 37% to 39%; and freezers from 30% to 35%. Clearly, many families that do not use these and other appliances can be expected to acquire them as they seek to improve their living standards. An analysis of the sources of growth in electricity usage reveals that the rate of growth of residential usage is substantially faster in low income sections of the City of Philadelphia than the higher income sections of the City and in the suburban areas served by the Applicant.

The importance of Limerick Station in providing an adequate and reliable power supply for the Applicant and for the Pennsylvania-New Jersey-Maryland (PJM) Interconnection is discussed in Chapter 1. That discussion describes capacity reserve conditions based on current demand projections. Chapter 1 indicates that benefits from the Limerick Station capacity are substantial. For example, if Limerick Station were delayed one year, to 1986-89, the Applicant's energy costs will increase $400 million. If delayed two years, to 1987-90, energy costs would increase $830 million.

Operation of Limerick Station will provide substantial savings of oil. The value of nuclear capacity has become increasingly evident in the recent past as a result of imported oil price increases, embargoes, natural gas shortages and coal strikes.

No sale of steam or other products or services from the station is currently anticipated.

8.1.2 OTHER SOCIAL AND ECONOMIC BENEFITS

8.1.2.1 Tax Revenues

When completed and operational, the station will provide added tax revenues to state, federal and local governments. While tax revenues are treated as benefits in this discussion, it is recognized that such revenues are essentially transfer payments. For this analysis, taxes are apportioned on the basis of current rates and corporate financing plans and reflect the values of: (a) stock allocated to finance the station, (b) projected net income allocated to the station, (c) anticipated gross receipts allocated to the energy sales, made possible by station output, and (d) the value of that portion of the station applicable to realty taxes. All monetary values are expressed in 1990 dollars and assume two unit operation. It is of course recognized that these values are, at best, only estimates of what may actually occur. Changes in tax laws, for example, could produce results that differ substantially from today's estimated values.

8.1.2.1.1 State Taxes

a. Capital Stock Tax

This is a 1% annual tax on the value of capital stock of corporations which are incorporated in the Commonwealth of Pennsylvania. The tax is levied against all outstanding stock of all classes, common and preferred. The average annual capital stock tax is estimated to be approximately $26 million.

b. Corporate Net Income Tax

Pennsylvania levies an annual corporate net income tax which is an excise or privilege tax levied against all corporations "doing business" in Pennsylvania or "having capital or property employed" in the state. The tax rate is 10.5% of net income allocated to Pennsylvania, which in the Applicant's case is all its net taxable income.

The average annual corporate net income tax is projected to be approximately $35 million.

c. Gross Receipts Tax

Public utility corporations doing business in Pennsylvania are subject to a 4.5% tax on the gross receipts from utility services rendered. In the Applicant's case the tax is levied on gross receipts from energy sales.

The average annual gross receipts tax is estimated to be about $70 million.

d. Public Utility Realty Tax

Public utilities do not pay local property taxes in Pennsylvania. The Commonwealth of Pennsylvania levies a public utility realty tax in lieu of local property taxes, and redistributes this tax according to a specified formula. The public utility realty tax is 3% of the state's taxable value of public utility realty.

The public utilities realty tax average annual liability for Limerick Station is estimated to be approximately $27 million.

e. Total State Tax

The average annual state tax liability attributable to Limerick Station is estimated to be approximately $158 million.

8.1.2.1.2 Federal Income Tax

The Applicant will incur a federal income tax liability for income increases resulting from the Limerick Station contribution to energy sales. The federal income tax, as well as the previously discussed state income tax, was developed based on the Applicant's projected rate of return, after taxes, on invested capital necessary to cover costs of equity capital (recognizing effects of investment tax credit and tax basis depreciation deductions). The analysis assumes that energy sales will cover debt service, operating costs and the projected rate of return on invested capital.

The average annual federal income tax is estimated to be $144 million.

8.1.2.1.3 Miscellaneous Taxes

Local governments and school districts levy various personal and wage taxes on residents and persons who work within their jurisdictions. Most of the operating staff of Limerick Station will reside near the station and thus contribute to these tax revenues. Because of the fluid nature of these taxes their value to the local governments have not been estimated. However, many taxing bodies levy a 1% earned income (wage) tax. Based on Subsection 8.1.2.2 this could produce approximately $440,000 annually.

The Commonwealth of Pennsylvania levies a 2.2% earned income tax on residents and employees in Pennsylvania. This tax (based on projected 1987 operating salaries) would be approximately $968,000 annually.

8.1.2.2 <u>Payrolls and Employment</u>

Expenditures for the operation of the station represent an addition to the national as well as regional income.

Approximately 724 people are expected to staff the Limerick Station. The annual payroll in 1990 dollars, for the operating staff, is expected to be about $44 million.

Because the bulk of the operating labor force for the station is drawn from the local area, the impact is and continues to be on regional employment.

8.1.2.3 Incremental Increase in Regional Product

The incremental increase in regional product due to operation of Limerick Station is the value of the electric energy produced by the station less the personal income that would have been produced by the family units that previously resided in the area required for station construction and operation. The value of this personal income is estimated to be less than $1 million annually. This loss in regional product is considered to be negligible compared to the value of the electrical energy. The incremental increase in regional product is therefore, equal to the value of the electrical energy produced.

8.1.2.4 Public Parks and/or Recreational Areas

Recreation potential of the floodplain area adjacent to the station site is determined by its physical features, together with planned station uses on the site and existing industrial activity in the surrounding community.

The river is relatively shallow at the site and the use of motorboats is dependent on the river level. Canoes and other similar craft are more likely to be used under the existing conditions.

8.1.2.5 Improvement of Local Roads and Transportation Facilities

Two existing township roads were rehabilitated by the Applicant in connection with plant construction. A 2-1/2 mile section of Longview Road was relocated and repaved. Evergreen Road, the main access to the plant, was upgraded for approximately one mile.

8.1.2.6 Research and Environmental Monitoring

A number of environmental baseline studies and monitoring programs are being conducted by the Applicant. These include the water chemistry, thermal data, and aquatic and terrestrial biological monitoring programs. These efforts provide meaningful information for use in assessing environmental changes imposed on the local area by operation of the Limerick Station. To the extent these programs contribute to a better understanding and prediction of environmental interrelationships, they are considered research efforts. In addition, since the detailed documentation developed on the species and abundance of local terrestrial and aquatic organisms serves to strengthen the store of scientific information concerning the area, the programs under which this information was developed can also be defined as research. The Applicant has estimated that in excess of $5.5 million has been spent for research at the Limerick Station as of December 31, 1982.

8.1.2.7 Educational Center

The Applicant constructed an "Energy Information Center" as part of the overall nuclear education program. Located on Longview Road just southeast of Limerick Station, the center offers formal programs and provides exhibit material for visitors. The center includes energy conservation information in addition to current information relevant to nuclear issues.

8.1.2.8 Annual Savings of Oil for Power Generation

Operation of Limerick Station provides a substantial contribution to the national interest by reducing the need for consuming large amounts of oil. Operation of the Limerick Station is expected to replace fossil fuel equivalent to about 20 million barrels of oil per year on the PJM interconnection.

8.2 COSTS

8.2.1 INTERNAL COSTS

Costs are expressed in 1990 dollars, with the exception of capital dollars. Capital dollars are actual and proposed expenditures expressed in the year the expenditure would occur.

Following are the primary internal costs associated with the operation of the station:

a. The site of approximately 595 acres contains about 87 acres for the station and environs with the remainder open area.

b. The cost of land acquisition and improvements and facility construction associated with the station amounts to about $5.82 billion. Table 8.2-1, Cost Information for Limerick Station, shows construction cost details. The levelized annual carrying charges on the capital cost are estimated to be $1.129 million.

   The cost to complete both Limerick units was estimated at $2.2 billion on December 31, 1982. On a cost to complete basis the annual carrying charges are $427 million. The cost to complete estimate does not include AFUDC on money spent prior to December 31, 1982.

c. Recognizing the requirements of the Delaware River Basin Commission (DRBC) that compensation (augmentation) is required for consumptive water use at the Limerick Station at designated low flow periods, the Applicant is actively pursuing alternatives to provide the required augmentation to low flow. Typical projected costs for this augmentation are conservatively estimated at about $13 million annually.

d. The capital cost of the bulk power transmission system including switchyards associated with Limerick Station is about $91 million. The estimated annual carrying charges on this capital cost is $17.7 million.

e. The annual fuel costs for Limerick are estimated to be $130 million. This is a 10-year levelized estimate of fuel costs for two-unit operation. Table 8.2-2, Estimated Costs of Electrical Energy Generation, shows a breakdown of these costs in mills/kWh.

f. The annual operating and maintenance costs are estimated to be $140 million.

g. Station decommissioning alternatives are discussed in detail in Section 5.8. Because of the uncertainty surrounding regulatory requirements no commitment by the Applicant to any alternative can be made at this time. However projected decommissioning costs in 1990 dollars range from $13 million to about $160 million. The annual cost for the $160 million scenario is estimated to be $31 million.

h. To the extent that needs can be anticipated, research and development costs associated with potential improvement of the facility and its operation and maintenance are inherently included in the cost of the station in (b) above. Also included in the station costs are the Applicant's overhead costs, which include the costs of the environmental studies.

The total primary internal costs for the station, exclusive of fees to the NRC, are estimated to be $1.46 billion annually on a total cost basis and $759 million annually on a cost to complete basis.

8.2.2 EXTERNAL COSTS

Temporary external costs associated with the operation of the station are discussed below.

No shortages of housing are anticipated as a result of operation of the Limerick Station. The number of permanent employees for operation of the station is approximately equal to the number of non-manual employees that had been transferred to the area by the architect/engineer/constructor. The permanent staff is expected to have no measurable impact on housing, health, and school facilities. Whatever modest increase in services that might be required by the permanent staff is more than offset by taxes paid to local municipalities.

Station operation has no impact on local water and sewer facilities. A permanent sewage treatment plant has been constructed, and the effluent from this plant is piped to the nearby Schuylkill River. The domestic water supply for the station is from the river.

Operation of the station is not expected to have any material adverse effects on recreational, aesthetic, or scenic values, and will not degrade or restrict access to areas of historic or cultural interest. While it is obvious that because of the station, aesthetic, scenic and other changes occur, it is the view of the Applicant that, on balance, these changes are within acceptable limits.

The operation of Limerick Station, apart from its contribution to adequate regional electrical supply, is not expected to influence the industrial development of the area.

Overall, the Applicant believes that the economic and social benefits associated with the operation of the station will be substantial at the local, regional and national levels, while the external social and economic costs will be minimal.

TABLE 8.2-1

COST INFORMATION FOR LIMERICK GENERATING STATION

1. Applied interest rate during construction	7.0-10.0%/year
2. Length of construction workweek	40 hr/wk
3. Estimated site labor requirement	26.7 manhours/kWe
4. Average site labor pay rate (including fringe benefits) Effective at month and year of start of construction	11.32/hr
5. Escalation rates	
Site labor	7%/year
Materials	7%/year
Composite rate	7%/year

POWER STATION COST
THOUSAND DOLLARS

Direct Costs	Unit 1	Unit 2
a. Land and land rights	6,000	-
b. Structures and site facilities	253,000	262,000
c. Reactor plant equipment	336,000	349,000
d. Turbine plant equipment not including heat rejection systems	99,000	104,000
e. Heat rejection system	51,000	52,000
f. Electric plant equipment	52,000	54,000
g. Miscellaneous equipment	51,000	53,000
h. Contingency allowance	80,000	115,000
Subtotal	928,000	989,000
Indirect Costs		
a. Construction facilities, equipment and services	162,000	178,000
b. Engineering and construction management	490,000	523,000
c. Other costs	132,000	102,000

TABLE 8.2-1 (Cont'd)

d. Interest during construction	965,000	1,349,000
Subtotal	1,749,000	2,152,000
Unit cost	2,677,000	3,141,000
Station cost	5,818,000	

TABLE 8.2-2

ESTIMATED COST OF ELECTRICAL ENERGY GENERATION

Fuel Cycle Costs [1]	Unit 1 (mills/kWh)	Unit 2 (mills/kWh)
Cost of U_3O_8	3.32	5.71
Cost of Conversion	0.25	0.34
Cost of Enrichment	3.16	3.76
Cost of Fabrication	1.37	1.59
Cost of Processing Spent Fuel[2]	-	-
Cost of Waste Disposal[2]	-	-
Credit for Plutonium or U-233[2]	-	-
Total	8.10	11.40
Cost of Operation and Maintenance[3]	10.9	10.9

[1] Fuel cycle cost are levelized for 10 years
[2] Not applicable because fuel costs are calculated on the basis of zero-net salvage. The 1 mill/kWh disposal charge of the Nuclear Waste Policy Act of 1982 has not been included.
[3] 70% capacity factor

CHAPTER 9

ALTERNATIVE ENERGY SOURCES AND SITES

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CHAPTER 9

ALTERNATE ENERGY SOURCES AND SITES

Alternate Energy Sources and Sites were discussed in Section 8.1 and 8.2 of the Environmental Report - Construction Permit Stage and Chapter 10 of the Final Environmental Statement. The subject of alternate sites is not discussed further, in accordance with 10 CFR 51 and Regulatory Guide 4.2. In early 1983, construction of Unit 1 and common was 83% complete; Unit 2 was 30% complete. The only alternative to completing construction of Units 1 and 2, with commercial operation scheduled for 1985 and 1988, respectively, considered worthy of examination at this time is to cease construction and restore site to pre-construction appearance.

9.1 TERMINATE CONSTRUCTION AND RESTORE SITE

9.1.1 REPLACEMENT OF REQUIRED CAPACITY

As stated in Chapter 1 long term capacity purchases are not feasible to meet the Applicant's requirements.

When Limerick 1 and 2 are placed in service 1272 MW of oil fired capacity will be retired. This will reduce the Applicant's oil consumption in accordance with current national energy policy. The Applicant estimates that retirement of these oil fired units will save 7.4 million barrels of oil per year and air pollution will be reduced by 24,420 tons SO_x and 9,320 tons NO_x per year.

Delaying the retirement of older oil-fired units is not considered practical. When the Limerick units are placed in service 796 MWe of oil-fired intermediate steam capacity will be retired. The average age of this equipment will be 40 years in 1988. This equipment is old and ready for retirement. Maintenance problems compounded by metal fatigue problems would increase the forced outage rates of these units such that they would not be capable of being base loaded units.

When Limerick Unit 1 is placed in service, 476 MWe of oil-fired peaking combustion turbine capacity will be retired. This equipment was installed in the late 1960's. The combustion turbines to be retired are characterized by high heat rates, high fuel costs, and abnormally high maintenance costs. These units were not designed for base load operation and their high forced outage rates preclude their use as base load units.

9.1.2 COSTS ASSOCIATED WITH TERMINATING LIMERICK GENERATING STATION

The following costs are associated with terminating the construction of the Limerick Generating Station:

a. As of March 1983, the sunk capital cost of the Limerick project was about $2.7 billion. The annual revenue requirement associated with amortizing this investment over a 20 year period would amount to about $540 million per year. This annual amount assumes the accounting for the sunk capital would be treated as an in-service plant in all aspects, including return of capital on a straight line basis, return on capital not recovered, taxes based on tax depreciation at a normal 1.5% Declining Balance/Straight Line (DB/SL) basis over an Accelerated Cost Recovery System (ACRS) life of 16 years and retention of the investment tax credit. The Applicant's projected lack of taxable income in the near future would preclude it from using any potential tax loss that might result from such a termination.

b. The estimated capital cost to restore the site to its pre-construction appearances is about $200 million. The annual revenue requirement associated with amortizing this investment over a 20 year period would amount to about $40 million per year. This annual amount assumes the accounting for the sunk capital would be treated as an in-service plant in all aspects, including return of capital on a straight line basis, return on capital not recovered, taxes based on tax depreciation at a normal 1.5 DB/SL basis over an ACRS life of 16 years and retention of the investment tax credit. The Applicant's projected lack of taxable income in the near future would preclude it from using any potential tax loss that might result from such a termination.

9.2 CONCLUSIONS

The completion of Limerick is the preferred course of action. The adverse consequences of termination of construction are (1) an increase in customer costs, (2) a failure to pursue the national energy policy of reducing oil usage and (3) a generating capacity deficit which cannot be reliably supplied by older marginal steam units.

CHAPTER 10

STATION DESIGN ALTERNATIVES

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STATION DESIGN ALTERNATIVES

10.1 ALTERNATIVE CIRCULATING SYSTEMS (Exclusive of Intake and Discharge)

The circulating water systems and the associated natural draft cooling towers for the Limerick Generating Station are described in Section 3.4. Alternatives to the natural draft cooling towers are discussed in Section 8.4.1 of the Environmental Report-Construction Permit Stage, and Section 11.1 of the Final Environmental Statement. In accordance with 10 CFR 51 and NRC Regulatory Guide 4.2, no further discussion of circulating system alternatives is necessary.

10.2 ALTERNATIVE INTAKE SYSTEMS

10.2.1 SCHUYLKILL RIVER INTAKE STRUCTURE

The intake system for the LGS is described in Section 3.4. The Schuylkill River intake structure is being constructed under Corps of Engineers Permit No. NAPOP-N-00-888, and Pennsylvania Department of Environmental Resources Water Obstruction Permit No. 19616. The adverse environmental effects on the Schuylkill River intake have been found to be minimal, as discussed in Section 5.1.3.

10.2.2 PERKIOMEN INTAKE STRUCTURE

Alternative designs considered for the Perkiomen Creek Intake structure included a man-made infiltration gallery consisting of buried perforated-pipe, natural infiltration galleries, several schemes of shoreline intakes with traveling water screens, and an inshore pump structure with submerged stationary wedge-wire screens.

The buried perforated-pipe intake structure was discounted during the conceptual design phase. It was determined that siltation would affect the efficiency of the intake. In addition, the efficiency of the perforated-pipe intake was determined to be unreliable during seasonal low flows.

Similarly, the natural infiltration gallery concept was discounted during the preliminary design phase. The permeability of the natural soils is not sufficient to transmit the required quantity of water to the gallery under the existing head conditions.

Several schemes utilizing the conventional vertical traveling screen were investigated thoroughly. The primary arrangement utilized a structure with an onshore intake bay. The intake bay consisted of the following: floating trash boom, trash rack, and vertical traveling screen. The face of the traveling screen was placed flush with the normal shoreline. A fish bypass in advance of the traveling screen was provided.

The width of the intake, size of traveling screen, and screen mesh openings were designed to maintain a maximum intake velocity approaching the face of the screen of 0.5 fps at low water. The combination of low intake velocity and fish bypass would provide a means of egress for small fish.

The selected intake design consists of an on-shore pumping station that is gravity fed by three intake lines supplied by intake wedge-wire screens located in the surface water source.

Openings in the intake screens are oblong, with a 2-mm clear opening. Inlet velocities through the screen openings are designed for 0.5 fps maximum. The potential angle of safety, or escape from the screen approach, is almost 360 degrees.

The screens are located sufficiently high above the bottom of the stream to minimize effects on bottom-dwelling organisms. The screens are located near the mid-channel area, away from the near-shore, shallow water zones where aquatic life is most abundant, and where much of the aquatic reproduction occurs.

The adverse environmental effects of the Perkiomen Creek intake have been found to be minimal, as discussed in Section 5.1.3.

The intake structure is described in section 3.4 and shown in Figures 3.4-11 through 3.4-15.

10.3 ALTERNATIVE DISCHARGE SYSTEMS

The diffuser discharge system for the Limerick Generating Station is described in Section 3.4, and the environmental effects associated with the discharge are discussed in Chapter 5 of this report. Additionally, information was provided in Section 11.3 of the Final Environmental Statement. The diffuser is being constructed under U.S. Army Corps of Engineers Permit No. NAPOP-N-00-888, Pennsylvania Department of Environmental Resources Water Obstruction Permit No. 19616, and Delaware River Basin Commission (DRBC) Water Use Approval No. D-69-210CP (Final). The discharge system will not cause the Schuylkill River water temperature to be raised more than 5°F outside of, or exceed a rate of change greater than 2°F per hour at the boundary of, a mixing zone equal to one-half of the river width and 3500 feet in length as specified by the DRBC. In accordance with 10 CFR 51 and NRC Regulatory Guide 4.2, no further discussion of discharge system alternatives is necessary.

10.4 ALTERNATIVE CHEMICAL WASTE SYSTEMS

The chemical waste system for the Limerick Generating Station is described in Section 3.6. The system will produce an effluent meeting U.S. Environmental Protection Agency standards (40 CFR 423). Additional discussion of alternatives is provided in Section 11.4 of the Final Environmental Statement. In accordance with 10 CFR 51 and NRC Regulatory Guide 4.2, no further discussion of chemical waste system alternatives is necessary.

10.5 BIOCIDE TREATMENT ALTERNATIVES

The biocide treatment system for the Limerick Generating Station is described in Section 3.6. The system will produce an effluent meeting U.S. Environmental Protection Agency standards (40 CFR 423). Additional discussion of alternatives is provided in Section 11.5 of the Final Environmental Statement. In accordance with 10 CFR 51 and Regulatory Guide 4.2, no further discussion of biocide treatment alternatives is necessary.

10.6 ALTERNATIVE SANITARY WASTE SYSTEMS

The sanitary waste system for the Limerick Generating Station is described in Section 3.7. The system has been installed and is being operated in accordance with U.S. Environmental Protection Agency NPDES Permit No. PA 0024414 and Water Quality Management Permit No. 4672437 issued by the Pennsylvania Department of Environmental Resources. No discussion of sanitary system alternatives is necessary.

10.7 ALTERNATIVE LIQUID RADWASTE SYSTEMS

The liquid radwaste system is described in Section 3.5. Alternatives were discussed in Section 8.4.3.1 of the Environmental Report-Construction Permit Stage and Section 11.7 of the Final Environmental Statement. No further consideration has been done to formulating liquid radwaste system design since analysis indicates that liquid radioactive effluents from Limerick will be within the "as low as reasonably achievable" numerical guides for design objectives and limiting conditions of operation set forth in Appendix I of 10 CFR 50 and will satisfy the guides for design objectives proposed in the concluding statement of position of the Regulatory Staff in Docket RM-50-2.

10.8 ALTERNATIVE GASEOUS RADWASTE SYSTEMS

The gaseous radwaste system is described in Section 3.5. No further consideration has been given to formulating alternative gaseous radwaste system designs since analysis indicates that gaseous radioactive effluents from LGS will be within the "as low as reasonably achievable" numerical guides for design objectives and limiting conditions of operation set forth in Appendix I of 10 CFR 50 and will satisfy the guides for design objectives proposed in the Concluding Statement of Position of the Regulatory Staff in Docket RM-50-2.

10.9 ALTERNATIVE TRANSMISSION FACILITIES

As discussed in sections 3.2 and 5.4 of the Environmental Report - Construction Permit Stage and section 3.7 of the Final Environmental Statement, transmission requirements were a significant factor in the selection of the Limerick Site, because the necessary rights-of-way were already established. In section 3.7 of the Final Environmental Statement, the NRC Staff concurred with the Applicant in finding "...that grouped systems within fewer transmission corridors, rather than a growth in the number of corridors, are a better approach to land planning".

Consistant with the finding, the routing of transmission facilities not previously described was selected so as to utilize existing rights-of-way exclusively. Specifically, the Cromby to North Wales and Cromby to Plymouth Meeting 230 kV lines described in section 3.9 of this report will be constructed entirely on previously existing transmission line and railroad rights-of-way. Alternative routings for these lines would require the acquisition of new private rights-of-way with attendant adverse environmental impacts, and are therefore not evaluated further.

CHAPTER 11

SUMMARY BENEFIT - COST ANALYSIS

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SUMMARY BENEFIT-COST ANALYSIS

The importance of the Limerick Generating Station (LGS) in providing an economic and reliable power supply for the Applicant and the PJM Interconnection was demonstrated in Chapter 1. The economic and social effects of station construction and operation were discussed in Chapter 8. Other benefit-cost information has been provided throughout this report. It is the purpose of this chapter to summarize and weigh the overall benefits and costs of operating the completed station. This final balancing must, of necessity, be qualitative, since it is not possible to quantify all of the station's benefits and costs in comparable units of measure. All monetary values are expressed in 1990 dollar values unless otherwise noted.

11.1 BENEFITS

11.1.1 DIRECT BENEFITS

The primary benefits resulting from operation of LGS are those inherent in the value of the generated electricity which will be delivered to meet customer needs. The station will provide an average annual generation of 12.9 billion kWh based on a 70% capacity factor for the 2110 MWe station. Distribution of the energy based on projected 1990 demand is: 3.6 billion kWh - Residential, 7.92 billion kWh - Commercial and Industrial, 0.48 billion kWh - Other and 0.9 billion kWh - System Use and Losses. As noted previously, the actual value of this energy cannot be readily monetized, since its true worth relates to customer needs, safety, convenience, etc., that it provides. Based on an average $0.129 per kWh for all users, the value of station output in its first full year of two-unit operation is $1.55 billion.

As discussed in Chapter 1, delays from current in-service schedules for the station are likely to add substantially to the Applicant's overall cost of service. For example, if both the units were delayed one year, the Applicant's cost of energy is estimated to increase by about $320 million, and plant cost is estimated to increase by about $650 million. Furthermore, it has also been noted that station operation will conserve oil.

11.1.2 INDIRECT BENEFITS

The indirect benefits to be realized from the construction of LGS include over $460 million paid annually in taxes (essentially transfer payments) to the state and federal governments.

Operating staff for LGS is projected to about 724 persons with an expected average annual payroll of $44 million. The bulk of these employees will be drawn from the local area thus enhancing the local economy.

11.2 COSTS INCURRED

The costs of the project include economic costs, in terms of dollars, and environmental costs, expressed in a variety of units. As detailed in Chapter 8, the total station primary internal costs are estimated to be approximately $1.46 billion annually on a total cost basis and $759 million annually on a cost to complete basis.

The environmental effects are discussed below with respect to the three major divisions of the biosphere: the aquatic, atmospheric and terrestrial regions. The environmental impact (costs) must be considered for both absolute magnitude and degree of importance. In the following discussions of environmental costs, an attempt has been made to evaluate these factors.

11.2.1 AQUATIC

The aquatic environmental effect of the station includes the effect on surface waters and on ground water. In both instances the physical effects of the station water intake and the chemical, radiological, thermal and physical effects of liquid discharges must be considered.

11.2.1.1 Surface Water

Water for cooling and domestic used for LGS is withdrawn from the Schuylkill River and Perkiomen Creek.

The cooling water for the station is passed through the condensers into cooling towers where rejected heat is dissipated. Make-up for water lost by evaporation, drift and blowdown is withdrawn from the Schuylkill River and Perkiomen Creek in accordance with Docket Decision D-69-210 (final) issued by the Delaware River Basin Commission on November 5, 1975.

The cooling tower blowdown is returned to the Schuylkill River. The blowdown is treated and monitored to maintain chlorine residuals and dissolved solid concentrations within the applicable water quality standards of the Commonwealth of Pennsylvania.

Liquid radioactive wastes are treated in a separate system. The calculated exposure from LGS are well within limits of Appendix I to 10 CFR 50.

Domestic water is supplied via the clarified and domestic water systems. Appropriate treatment and storage is provided.

The station is served by a sewage treatment plant. The effluent from the treatment plant is discharged to the Schuylkill River.

Intake structures are located on the Schuylkill River, and Perkiomen Creek. Water intake velocity is limited to minimize the effect on the biota.

The discharge into the Schuylkill River will be by means of a diffuser pipe located at the river bottom.

11.2.1.2 Groundwater

The operation of LGS will have no adverse effect on groundwater. The wells supplying water for the construction of the station will be capped subsequent to station operation.

11.2.2 ATMOSPHERIC

The atmospheric environment is affected by the routine operation of LGS through discharge of gaseous effluents from the station and the evaporation of water and drift from the cooling towers.

Gaseous releases from the station are from vents located on the reactor enclosure roof. The gaseous radwaste system monitors, processes and controls the release of radioactive gases from the station. The estimated individual and population ingestion exposures resulting from the release of radioactive nuclides to the atmosphere and direct radiation from radioactive materials at LGS are discussed in Section 5.2. These exposures are based on conservative models and consequently reflect maximum potential exposure rather than that which might be expected. The calculated exposures from LGS are well within limits of Appendix I to 10 CFR 50.

The cooling tower effluent carries moisture due to evaporation of the circulating water and entrained water droplets (drift). The effluent forms a plume, visible at times, as it drifts away from the towers. The cooling tower plume is emitted at about 500 feet above the ground, therefore, the plume should not cause any impact on surface conditions, i.e., fogging, icing, etc.

The plume should have little or no impact on aircraft operations in the vicinity. Dissolved solids contained in the drift will settle to the ground under the plume. Annual salt deposition rates due to cooling tower operation have been calculated and shown to be well below natural deposition rates in the Limerick region. Thus, the impact of these salts both on and off-site is considered insignificant.

11.2.3 TERRESTRIAL

The LGS site occupies approximately 595 acres. Approximately 87 acres have been disturbed by facilities which occupy the site. While some existing flora and fauna have been displaced no permanent effect on either is anticipated. No unusual or endangered species are known to exist in the area. The flora and fauna of wooded open areas will be preserved as is consistent with use.

11.3 CONCLUSIONS

It is the considered judgment of the Applicant that, within the the limits of todays's fuel and technology constraints, the aggregate benefits derived from operation of LGS will substantially exceed the combined economic and environmental costs of its construction and operation. This has resulted from a balancing of environmental and economic costs which in the view of the Applicant properly reflects both the importance of environmental protection and the basic societal judgment that adequate supplies of relatively economic electricity must be maintained.

It is the belief of the Applicant that the operation of LGS as designed satisfies all applicable benefit-cost criteria and that the benefits to be derived far outweight the economic and environmental costs involved.

Table 11.3-1 provides a summary of the primary benefits and costs of operating LGS.

TABLE 11.3-1

SUMMARY BENEFITS-COSTS; LIMERICK GENERATING STATION

	Item	Benefits[1]	Reference
1.	Expected Average Annual Generation and Approximate Value	12.9 billion kWh $1.5 billion[2]	Section 8.1
2.	Proportional Distribution of Electric Energy (1990)	66% Industrial and Commercial 30% Residential 4% Other 100% Total	Section 8.1
3.	Average Annual Federal and State Taxes	$460 million	Section 8.1
4.	Direct Station Employment	724	Section 8.1
5.	Public Facilities	An Energy Information Center is provided	Sections 2.1, 8.1
6.	Annual Savings of Equivalent Oil for Power Generation	20 million barrels	Section 8.1
7.	Average Annual Federal and State Taxes	$460 million	Section 8.1

	Item	Costs	Reference
1.	Total Capital Cost (Land and Station)	$5,820 million	Section 8.2
2.	Capital Cost to Complete	$2,200 million	Section 8.2
3.	Capital Cost (Associated Transmission System)	$91 million	Section 8.2
4.	Decommissioning Cost[3]	$160 million	Section 8.2
5.	10-Year Levelized Annual Fuel Cost	$130 million	Section 8.2
6.	Annual Operation and Maintenance Cost	$140 million	Section 8.2
7.	Annual Low Flow Augmentation Cost	$13 million	Section 8.2

Item	Costs	Reference
8. Aquatic Costs		
a. Surface Water • Average Consumptive Use	32.8 MGD	Section 3.3
b. Ground Water	0.0 MGD	Section 2.4
c. Biota		
Impingement and Entrainment		Section 5.1
• Phytoplankton	Minimal	
• Zooplankton	Minimal	
• Meroplankton	Minimal	
• Larval Fish	Minimal	
d. Radioactive Releases - Liquid Effluents		Section 5.2
• Biota other than man		Table 5.2-10

SPECIES	mrad/yr/2 units INTERNAL	EXTERNAL
Fish	5.9	0.014
Invertebrates	39.0	1.1
Aquatic Plants and Algae	18.0	0.017
Muskrat	28.0	3.2
Raccoon	1.1	2.4
Heron	99.0	2.1
Duck	26.0	4.8

• Individual Man	mrem/yr/2 units Total Body	Any Organ	Table 5.2-18
Liquid Effluents	1.02 (Adult)	1.78 (Adult-bone)	

Item	Costs	Reference
9. Atmospheric Costs		
a. Radioactive Releases-Gaseous Effluents		
• Biota other than man		

SPECIES	mrad/yr/2 units INTERNAL	EXTERNAL	Table 5.2-10
Raccoon	0.0	1.3	
Heron	0.0	1.3	
Duck	0.0	1.3	
Terrestrial Vegetation	0.38	1.6	
Squirrel	1.4	1.9	
Robin	0.0	1.9	
Mockingbird	0.0	2.5	
Deer	2.3	1.2	

Item	Costs	Reference
• Individual Man	--/yr/2 units	Table 5.2-18
1) Noble gases		
Gamma Dose in Air	0.86 mrad	
Beta Dose in Air	0.59 mrad	
Total Body Dose	0.46 mrem	
Skin Dose	0.90 mrem	
2) Radioiodines and Particulates Any Organ (all pathways)	10.55 mrem (Infant-thyroid)	
b. Cooling Towers		
• Evaporation	32.4 MGD	Section 3.3
• Drift	0.4 MGD	Section 3.3
• Salt Deposition	Variable with distance, sector	Section 5.1.4

10.	Terrestrial		
a.	Site	595 acres	Section 2.1
b.	Station Facilities	87 acres	Section 2.1

(1) Monetized benefits - costs in 1990 dollars, unless otherwise noted.
(2) First year of 2-unit operation (1989)
(3) Based on projected costs for prompt removal/dismantling; 1990 dollars.

CHAPTER 12

ENVIRONMENTAL APPROVALS AND CONSULTATIONS

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ENVIRONMENTAL APPROVALS AND CONSULTATION

12.1 PERMITS

12.1.1 FEDERAL PERMITS

The following is a listing of the Federal permits and their status for Limerick Generating Station:

Permit	Agency	Status
1. Nuclear Plant Construction-Unit 1	U.S. Nuclear Regulatory Commission (NRC)	Received
2. Nuclear Plant Construction-Unit 2	NRC	Received
3. Nuclear Plant Operating License	NRC	Not Received
4. Special Nuclear Material License	NRC	Not Received
5. By-Product Material License	NRC	Not Received
6. Dredging and Encroachments Schuylkill River Intake Facilities and Discharge Diffuser	U.S. Army Corps of Engineers (COE)	Received
7. NPDES for Construction Discharges	U.S. Environmental Protection Agency (EPA)	Received
8. No Hazard to Air Navigation Determination	Federal Aviation Administration (FAA)	Received

12.1.2 STATE PERMITS

The following is a listing of the State permits and their status for Limerick Generating Station:

Permit	Agency	Status
1. 401 Water Quality Certification - Construction Permits and Operating License - Units 1 and 2 - (NRC)	Department of Environmental Resources (DER)	Received
2. Deleted		
3. 401 Water Quality Certification - Dredging and Encroachments Permit - Schuylkill River Facilities- (COE)	DER	Received
4. 401 Water Quality Certification - NPDES Permit for Construction Discharges - (EPA)	DER	Received
5. Industrial Waste Discharge Permit	DER	Received
6. NPDES Permit for Plant Operating Discharges	DER	Not Received
7. Sanitary Waste Discharge Permit	DER	Received
8. Air Pollution Permit for Auxiliary Boilers	DER	Received
9. Air Pollution Permit for Construction of BWR's	DER	Received
10. Air Pollution Permit for Concrete Batch Plant	DER	Received
11. Air Pollution Permit for Concrete Batch Plant Boiler	DER	Received
12. Intake and Discharge Structure for Schuylkill River Facilities	DER	Received

	Permit	Agency	Status
13.	Intake Structure for Perkiomen Creek Facilities	DER	Received
14.	Dredging and Encroachments Permit - Possum Hollow Creek	DER	Received
15.	Water Obstruction-Electrical Conduit - Possum Hollow Creek	DER	Received
16.	Water Obstruction - Culvert - Possum Hollow Creek	DER	Received
17.	Water Obstruction - Culvert - Brook Evans Creek	DER	Received
18.	Plan Approval - Temporary Construction Buildings	Department of Labor & Industry (DL&I)	Received
19.	Plan Approval - Turbine, Reactor, Control and Radwaste Buildings	DL&I	Received
20.	Plan Approval - Sewage Treatment Building	DL&I	Received
21.	Plan Approval - Circulating Water Pump and Water Treatment Buildings	DL&I	Received
22.	Plan Approval - Auxiliary Boiler and Lube Oil Storage Building	DL&I	Received
23.	Plan Approval - Schuylkill River Pumphouse	DL&I	Received
24.	Plan Approval - Diesel Generator Building	DL&I	Not Received
25.	Plan Approval - Spray Pond Pumphouse	DL&I	Not Received
26.	Plan Approval - Administration Building	DL&I	Received
27.	Plan Approval - Perkiomen Creek Pumphouse	DL&I	Received

	Permit	Agency	Status
28.	Flammable Liquids Storage and Handling for Eight Underground Fuel Oil Tanks	State Police	Received
29.	Flammable Liquids Storage and Handling for Two Above Ground Fuel Oil Tanks	State Police	Received
30.	Flammable Liquids Storage and Handling for Temporary Above Ground Fuel Oil Tank	State Police	Received
31.	Highway Crossing Permit - Perkiomen Creek Pipeline	Pennsylvania Department of Transportation (PennDOT)	Not Received
32.	Railroad Crossing Agreement - Schuylkill River Cased Pipes	Conrail (Reading Div.)	Received
33.	Railroad Crossing Agreement - Schuylkill Road at Grade	Conrail	Received
34.	Deleted		
35.	Certificate of Necessity	Public Utility Commission (PUC)	Received
36.	Notification of Airway Obstruction	Bureau of Aviation	Received
37.	52 PA Code CH57 Transmission Siting Permit for Limerick to Cromby, 220-60 (230 kV) line	Public Utility Commission (PUC)	Not Received
38.	52 PA Code CH57 Transmission Siting Permit for Limerick to Cromby, 220-61 (230kV) line	Public Utility Commission (PUC)	Not Received
39.	52 PA Code CH57 Transmission Siting Permit for Cromby to Plymouth Meeting, 220-63 (230 kV) line	Public Utility Commission (PUC)	Not Received

12.1.3 LOCAL PERMITS

The following is a listing of Local permits and their status for Limerick Generating Station:

Permit	Agency	Status
1. Building Permits	Limerick Township	Received

12.1.4 INTERSTATE PROJECT APPROVALS

The following is a listing of Interstate Project approvals and their status for Limerick Generating Station:

Permit	Agency	Status
1. Approval for Surface Water Use	Delaware River Basin Commission (DRBC)	Received

12.2 LAWS AND ORDINANCES FOR TRANSMISSION LINES

The laws and ordinances for the transmission lines are listed in Section 12.1, PERMITS.

12.3 WATER QUALITY CERTIFICATION

Water quality certification under Section 401 of the Federal Water Pollution Control Act, as amended, has been requested and received for each of the Federal permits received thus far, and are listed in Section 12.1, PERMITS. Water quality certification for the remaining Federal permits or licenses will be requested from the Pennsylvania Department of Environmental Resources (DER) at the time of submittal of the application.

The DER has received authority to administer the National Pollutant Discharge Elimination System (NPDES) program in Pennsylvania. The Applicant will submit a NPDES permit application for the plant operating discharges to the DER. Because of the DER now having this authority, the water quality certification will not be required for issuance of the NPDES permit.

12.4 ADDITIONAL CONSULTATION

A listing of Federal, State, local and regional planning authorities that were contacted or consulted is as follows:

12.4.1 FEDERAL AUTHORITIES

Department of Agriculture
Department of Health, Education and Welfare
Department of Housing and Urban Development
Department of the Interior
Federal Aviation Administration
U. S. Army Corps of Engineers
U. S. Environmental Protection Agency
U. S. Food and Drug Administration
U. S. Nuclear Regulatory Commission

12.4.2 STATE AUTHORITIES

Conrail
Pennsylvania Bureau of Aviation
Pennsylvania Department of Environmental Resources
Pennsylvania Department of Health
Pennsylvania Department of Labor and Industry
Pennsylvania Department of Transportation
Pennsylvania Environmental Council
Pennsylvania Environmental Quality Board
Pennsylvania Fish Commission
Pennsylvania Game Commission
Pennsylvania Legislative Committee on Conservation
Pennsylvania Public Utility Commission
Pennsylvania State Planning Board
Pennsylvania State Police

12.4.3 REGIONAL AUTHORITIES

Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Environmental Information and Planning Center
Green Valleys Association
Neshaminy Water Resources Authority
Perkiomen Valley Watershed Association

12.4.4 LOCAL AUTHORITIES

Borough of Norristown
Bucks County Division of Natural Resources
Bucks County Planning Commission
Chester County Commissioners
Chester County Department of Health
Chester County Water Resources Authorities

East Coventry Township Supervisors
Limerick Township Planning Commission
Limerick Township Supervisors
Limerick Township Zoning Officer
Lower Pottsgrove Planning Commission
Lower Pottsgrove Township Supervisors
Montgomery County Commissioners
Montgomery County Planning Commission
Philadelphia Air Management Service
Philadelphia Civil Defense
Philadelphia Department of Public Health
Philadelphia Water Department

CHAPTER 13

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REFERENCES FOR THE ENVIRONMENTAL REPORT - OPERATING LICENSE STAGE

13.0 REFERENCES FOR THE EROL

All references are sited at the end of the respective sections.

APPENDIX A

ENVIRONMENTAL TECHNICAL SPECIFICATIONS

APPENDIX A

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FIGURE

1. DEFINITIONS, ABBREVIATIONS, AND SYMBOLS

Frequently used terms, abbreviations, and symbols are explicitly defined so that a uniform interpretaion of these specifications may be achieved.

1.1 DEFINITIONS

Accuracy: The deviation of the mean result obtained by a particular method from the value accepted as true.

Annually: Once each calendar year, at intervals of approximately 12 calendar months, plus or minus 30 days.

Bimonthly: Once every 2 months, plus or minus 30 days.

Biweekly: Once every 2 weeks, plus or minus 7 days.

Calibration: The adjustment, as necessary, of an instrument output so that it responds with the necessary range and accuracy to a known value of the parameter that the instrument monitors.

Combined Chlorine: The chlorine that reacts with ammonia or other nitrogen compounds in water.

Commercial Operation: The date that the Applicant accepts the unit from the architect engineer.

Composite Sample: A combination of individual samples collected at regular intervals during a specified period of time. Either the volume of each individual sample is proportional to the flow rate discharge at the time of sampling, or the number of equal volume samples is proportional to the time period used to produce the composite.

Environmental Deviation: An environmental deviation is said to occur whenever a protection limit or reporting level is exceeded, or whenever, in the opinion of the plant superintendent, an unusual event involving a significant environmental impact has occurred.

Free Chlorine: Chlorine that remains in the water as molecular chlorine, hypochlorous acid, or hypochlorite ion after water has been treated with chlorine.

Functional Test: The verification of instrument operability by performing all specified functions using the parameter(s) that the instrument sensor or device monitors.

Grab Sample: A single sample that is collected in less than 15 minutes.

Instrument Calibration: An instrument calibration means the adjustment of an instrument signal output so that it corresponds, within acceptable range and accuracy, to a known value(s) of the parameter that the instrument monitors.

Monitoring Requirement: The method, frequency, location, accuracy, and sensitivity of the measurement of a given parameter.

Monthly: Once each calendar month, at intervals of approximately 30 days, plus or minus 15 days.

Normal Power Operation: Plant operation between 2 and 100% of rated thermal power in a nonemergency situation, using normal operating procedures.

Normal Power Increase or Decrease: The increase or decrease in plant power as the result of scheduled plant startup or shutdown, or changes in electrical load while at normal power operation.

NPDES Permit: The National Pollutant Discharge Elimination System Permit, to be issued by the Environmental Protection Agency to the Applicant. This permit will authorize the Applicant to discharge controlled wastewater from Limerick Generating Station into the waters of the Commonwealth of Pennsylvania.

Precision: The reproducibility of measurements within a data set; that is, the scatter or dispersion of a set about its central value (mean).

Protection Limit: A numerical limit on a plant effluent or operating parameter that, when not exceeded, should not result in an unacceptable environmental impact.

Quarterly: Once in each 3-month period of a calendar year beginning in January, at intervals of approximately 13 weeks, plus or minus 4 weeks.

Rated Thermal Power: Rated thermal power refers to operation at a reactor power of 3293 MWt.

Report Level: The numerical level of an environmental parameter, below which the environmental impact is considered reasonable on the basis of available information.

Semimonthly: Twice each calendar month, at intervals of approximately 15 days, plus or minus 7 days.

Special Study Program: An environmental study program designed to evaluate the impact of plant operation on the environmental parameter.

Total Residual Chlorine: The sum of the free chlorine and the combined chlorine.

Weekly: Once in each calendar week, at intervals of approximately 7 days, plus or minus 3 days.

1.2 ABBREVIATIONS

BWR: Boiling Water Reactor

10 CFR Part 50: Code of Federal Regulations;
Title 10 - Atomic Energy
Part 50 - Licensing of Production and Utilization Facilities

FSAR: Final Safety Analysis Report

IRC: Independent Review Committee

LGS: Limerick Generation Station

NEPA: National Environmental Policy Act

MPC: Maximum Permissible Concentration

MSL: Mean Sea Level

NRB: Nuclear Review Board

NRC: Nuclear Regulatory Commission

POR: Plant Operations Review

PMF: Probable Maximum Flood

PSAR: Preliminary Safety Analysis Report

USGS: United States Geological Survey

WSP: Water Supply Paper (USGS)

1.3 SYMBOLS

Btu/hr: Heat transfer rate, British thermal units per hour

°C: Temperature, degrees Celsius

cfs: Water flow, cubic feet per second

°F: Temperature, degrees Fahrenheit

ft^3: Volume, cubic feet

fps: Speed, feet per second

fpm: Speed, feet per minute

gpd: Liquid flow, gallons per day

gpm: Liquid flow, gallons per minute

lb/day: Weight flow rate, pounds per day

m/sec: Speed, meters per second

mg/liter: Concentration, milligrams per liter

Mgd: Liquid flow, million gallons per day

mph: Speed, miles per hour

MWt: Power, megawatts of thermal power

2. LIMITING CONDITION FOR OPERATION

2.1 NONRADIOLOGICAL LIMITS

Not Applicable.

3. NONRADIOLOGICAL MONITORING

a. Initiation and Duration of Monitoring Programs

The aquatic environmental monitoring program described in this section will commence at the onset of commercial operation, except as specified under each program. It will continue until modified or terminated, normally 2 years after commercial operation of Unit 2, as provided in these ETS.

b. Delays in Sample Collection

If sample collection cannot be undertaken on the scheduled date, due to unusual conditions such as equipment failure, or an act of nature (meteorological and/or hydrological) that prevents the sample from being obtained or analyzed, the factual basis will be recorded, and collections will commence on the first practical date following the scheduled date.

3.1 ABIOTIC

3.1.1 THERMAL CHARACTERISTICS OF COOLING WATER DISCHARGE

3.1.1.1 Monitoring Requirement and Bases

Will be conducted as required by the NPDES Permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.1.1.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES Permit.

3.1.2 pH

3.1.2.1 Monitoring Requirement and Bases

Will be conducted as required by the NPDES Permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.1.2.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES Permit.

3.1.3 BIOCIDE

3.1.3.1 Monitoring Requirement and Bases

Will be conducted as required by the NPDES Permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.1.3.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES Permit.

3.1.4 OTHER CHEMICALS THAT MAY AFFECT WATER QUALITY

3.1.4.1 Monitoring Requirements and Bases

Will be conducted as required by the NPDES permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.1.4.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES.

3.2 AQUATIC

3.2.1 CREEL SURVEY

3.2.1.1 Monitoring Requirement

Creel surveys of the Schuylkill River, Perkiomen Creek, and East Branch of the Perkiomen Creek are to be conducted to estimate the fishing pressure, harvest, and number of people utilizing these river bodies for recreational activities.

Data collection and analysis will be performed in accordance with the procedure prepared by the Applicant as per Section 5.6.

The monitoring program commences at commercial operation of Unit 1, and terminates either 1 year after the commencement of commercial operation of Unit 2, or 4 years after the start of commercial operation of Unit 1, whichever comes first.

3.2.1.2 Bases

Impacts to the fishes community in the above river bodies may result from the mechanical, thermal, and biological effects of LGS and water diversion operation. The aquatic impacts of LGS operation are expected to be minor, and to be restricted to a small area downriver of the diffuser discharge on the Schuylkill River, and downriver of the Perkiomen intake. Diversion will affect all of the East Branch Perkiomen Creek to varying degrees. The detection of plant-induced impacts requires rigorous sampling, which includes adequate frequency of sampling, as well as a reasonably good predictive relationship between control and affected areas. The comparison of angling effort will provide a relative indication of the magnitude of diversion effects.

The data from baseline programs support the position that the baseline programs, which utilize sample sizes so as not to impact the river bodies, can at best only detect changes of great magnitude. Thus, comparison of angling mortality with average daily impingement and entrainment losses will provide a relative indicator of the magnitude of plant effects.

3.2.1.3 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported with the impingement (Section 3.2.3) and entrainment (Section 3.2.4) programs as required by the NPDES.

3.2.2 FISHERIES

3.2.2.1 Monitoring Requirement

Collections are to be made at control and affected stations on the Schuylkill River, Perkiomen Creek, and at affected stations on East Branch of the Perkiomen Creek. These collections will provide estimates of species composition, distribution, and abundance. Length-weight-age relationships for a selected species, all as related to the operational period.

Collection and analyses will be performed in accordance with the procedures prepared by the Applicant as per Section 5.6.

This monitoring program commences at commercial operation of Unit 1, and terminates either 1 year after the start of commercial operation of Unit 2, or 5 years after the start of commercial operation of Unit 1, whichever comes first.

3.2.2.2 Bases

Impacts to the fishes in the above river bodies may result from the mechanical, thermal, and biological effects of LGS and water diversion operation. The aquatic impacts of LGS operation are expected to be minor and restricted to a small area near the intake structure and the diffuser discharge on the Schuylkill River, and near of the Perkiomen intake. The detection of small plant-induced impacts requires rigorous sampling, which includes adequate frequency of sampling, as well as a reasonably good predictive relationship between control and affected areas. Diversion will affect the East Branch Perkiomen Creek to varying degrees.

The comparison of relative abundance, species composition, length-weight-age relationships between the preoperational and postoperational years will provide an indication of the magnitude of effects due to LGS and diversion operation.

3.2.2.3 Action

Description of the program, summarized results and analyses, and interpretation of the analyses are to be reported on an annual basis.

3.2.3 IMPINGEMENT OF ORGANISMS

3.2.3.1 Monitoring Requirement and Bases

Will be conducted as required by the NPDES Permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.2.3.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES Permit.

3.2.4 ENTRAINMENT OF LARVAL FISH

3.2.4.1 Monitoring Requirement and Bases

Will be conducted as required by the NPDES Permit to be issued under Section 402 of PL-92-500, Federal Water Pollution Control Act Amendments of 1972.

3.2.4.2 Action

The results of the monitoring conducted under this program are to be summarized, analyzed, interpreted, and reported as required by the NPDES Permit.

4. SPECIAL STUDIES

Special studies will be conducted as required by the NPDES Permit to be issued under Section 402 of PL 92-500, Federal Water Pollution Control Act Amendments of 1972.

5. ADMINISTRATIVE CONTROL

The administrative and management controls established by the Applicant to implement the environmental technical specifications are described in this section. Included are the assignment of responsibilities, organizational structure, operating procedures, review and audit functions, reporting specifications, and record retention.

5.1 REPONSIBILITY AND ORGANIZATION

a. The plant superintendent is responsible for the operation of the facility, and to ensure that the facility operates within the limits set forth in the environmental technical specifications.

b. In all matters pertaining to operation of the facility, and to the environmental technical specifications, the plant superintendent shall report to, and consult with the Superintendent, Nuclear Section of the Generation Division or, in his absence, to the superintendent, Fossil and Hydro Section of the Generation Division. The management organization is shown in Figure A 5-1.

5.2 STATE AND FEDERAL PERMIT AND CERTIFICATES

Section 401 of the Federal Water Pollution Control Act requires any Applicant for a federal license or permit to conduct any activity that may result in any discharge into navigable waters to provide the licensing agency with a certification from the state having jurisdiction that the discharge will comply with applicable provisions of Sections 301, 302, 306, and 307 of the FWPCA. Section 401 further requires that any certification provided under this section will set forth any effluent limitations, and other limitations and monitoring requirements necessary to ensure that any Applicant for federal license or permit will comply with the applicable limitations. Accordingly, the Applicant will comply with the requirements set forth in the Section 401 certification. Subsequent revisions to the certifications are accommodated in accordance with the provisions of Section 5.8.2.

5.3 REVIEW AND AUDIT

Committees for review and audit of plant operations are described below.

In addition to the responsibilities specified in Appendix A to the Operating License, the committees will have the following responsibilities concerning the environmental impact of the plant:

a. Plant Operations Review Committee (PORC)

   1. Review proposed onsite tests and experiments and results thereof, when such tests have environmental significance.

   2. Review proposed changes to the environmental technical specifications.

   3. Review operating instructions as specified in Section 5.5.

   4. Review environmental deviations as specified in Section 5.4.

b. Nuclear Review Board (NRB)

1. Review proposed changes to the environmental technical specifications.

2. Review proposed changes or modifications to plant systems, or equipment that may affect the environmental impact of the plant.

3. Review all reported environmental deviations.

c. Independent Review Committee

An Independent Review Committee (IRC) will review the following aspects pertaining to the environmental impact of the station:

1. Objectives, effectiveness, and results from the environmental monitoring programs, prior to submittal to the NRC.

2. Proposed changes to the environmental technical specifications, and the evaluated impact of the changes.

3. Proposed changes or modifications to station systems, or equipment to determine the environmental impact of the changes.

4. Proposed written procedures and changes as described in Section 5.6, and proposed changes thereto, that affect the environmental impact of the station.

5.4 ACTION TO BE TAKEN IF A PROTECTION LIMIT OR REPORT LEVEL IS EXCEEDED, OR IF HARMFUL EFFECTS ARE DETECTED

a. For the purpose of this specification, an environmental deviation is defined as stated in Section 1.1.

b. Any environmental deviation shall be reported to the superintendent, Nuclear Section of the Generation Division or, in his absence, to the superintendent, Fossil and Hydro Section of the Generation Division, and reviewed by the PORC. This committee shall prepare a separate report for each environmental deviation. This report will include an evaluation of the cause of the deviation, extent and magnitude of the impact, and recommendations for appropriate action to prevent or reduce the probability of such a deviation.

c. Copies of all such reports will be submitted to the superintendent, Nuclear Section of the Generating Division, and to the chairman of the NRB for review and approval of any recommendations.

d. The superintendent, Nuclear Section of the Generation Division will report the circumstances of any environmental deviation to the NRC, as specified in Section 5.7.2.

e. If harmful effects or evidence of irreversible damage not considered in the Final Environmental Statement are detected by the monitoring programs, the licensee will provide to the NRC staff an analysis of the problem and a plan of action to be taken to eliminate, or significantly reduce the detrimental effects or damage.

5.5 UNIT OPERATING PROCEDURES

a. Plant personnel will have instructions available for use in operation of the plant components and systems that could have an impact on the environment.

b. Instructions and appropriate checkoff lists will be provided for the following:

   1. Normal startup operation and shutdown of systems and components involving the environmental aspects of the plant.

   2. Actions to be taken to correct specific and potential malfunctions of systems or components involving the environmental aspects of the plant.

   3. Surveillance and testing requirements of environmental monitoring equipment associated with the monitoring required by these ETS.

c. All instructions described under 5.5.a and 5.5.b and changes thereto, will be reviewed and approved by the plant superintendent prior to implementation.

d. Temporary changes to instructions that do not change the intent of the original instruction may be made, provided such changes are approved by the shift superintendent and at least one other member of the plant staff knowledgeable in the areas(s) affected by the procedure. Such changes will be documented and subsequently reviewed by the plant superintendent.

5.6 ENVIRONMENTAL PROGRAM DESCRIPTION DOCUMENT

The Applicant will prepare an environmental program description document describing the programs that are required by these ETS. These program descriptions will be submitted to the NRC after approval of these ETS, and subsequent modifications to these programs will be made by the Applicant in conformance with Section 5.6.3.

5.6.1 PROCEDURES

Detailed written procedures, including applicable checklists and instructions, will be prepared and followed for activities involved in carrying out the ETS. Procedures will include purpose(s), objective(s), program duration, experimental design, milestone (to indicate objectives have been fulfilled, are being fulfilled, or cannot be fulfilled), sampling, data processing including storage, instrument calibration, measurements, analyses, rationale for interpreting analyses, and actions to be taken when limits (where appropriate) are exceeded.

5.6.2 PROGRAM RESULTS

Procedures will be established to ensure that the nonradiological program results are accomplished, including analytical measurements. The procedures will document the program in policy directive, designate a responsible organization or individuals, include purchased services (e.g., contractual laboratory or other contract services), provide for audits of results and procedures by Applicant personnel or designated personnel, and systems to identify and correct deficiencies, investigate anomalous or suspect results, and review and evaluate program results and reports.

Procedures will be established, as required by the NPDES Permit, to ensure the quality of nonradiological program results.

5.6.3 CONSISTENCY WITH INITIALLY APPROVED PROGRAMS

Modifications to, or changes in the initially approved programs, developed in accordance with Section 5.6, will be governed by the need to maintain consistency with previously used programs so that direct comparisons of data are technically valid. Such modifications or changes will be justified and, as appropriate, supported by comparative sampling programs (or studies) demonstrating the comparability of results, or provide a basis for making adjustments that permit direct comparisons.

5.7 PLANT REPORTING REQUIREMENTS

5.7.1 ROUTINE REPORTS

In addition to the environmental monitoring information, required by Appendix A to the Operating License, the following information will be submitted in an annual report:

a. Records of special study programs data, and analysis thereof

b. Record of changes to the plant that affect the environmental impact of the facility, and

c. Records of changes to environmental permits and certificates.

5.7.2 NONROUTINE REPORTS

a. Environmental Deviation Reports

In the event of an environmental deviation, as defined in the environmental technical specifications, notification will be made within 24 hours by telephone or telegraph to the Director of the NRC Regional Inspection and Enforcement Office. A written report will follow within 10 days to the Director, Office of Nuclear Reactor Regulation (copy to the Director of Regional Inspection and Enforcement Office).

The written report on an environmental deviation and, to the extent possible, the preliminary telephone and telegraph notification, should: (a) describe, analyze, and evaluate implications, (b) indicate the cause of the occurrence, and (c) indicate the corrective action (including any significant changes made in procedures) taken to preclude repetition of the occurrence, and to prevent a similar occurrence involving similar components or systems.

b. Reporting of Changes to the Plant or Permits

A written report, including an evaluation of the environmental impact resulting from a change, will be forwarded to the Director, Office of Nuclear Reactor Regulation (copy to the Director of the Regional Inspection and Enforcement Office) in the event of:

1. Changes to the plant that affect the environmental impact evaluation contained in the Environmental Report or the Environmental Statement. This requirement does not preclude making changes, on

short notice, that are minor in terms of environmental impact.

2. Changes or additions to permits and certificates required by federal, state, local, and regional authorities for the protection of the environment. When submittals of changes are made to the concerned agency, a copy will be submitted to the NRC.

3. Request for changes in environmental technical specifications.

5.8 CHANGES IN ENVIRONMENTAL TECHNICAL SPECIFICATIONS AND PERMITS

5.8.1 CHANGES IN ENVIRONMENTAL TECHNICAL SPECIFICATIONS

Requests for changes in environmental technical specifications will be submitted to the NRC for review and authorization, per 10 CFR 50.90. The request will include an evaluation of the environmental impact of the proposed change, and a supporting justification.

5.8.2 CHANGES IN PERMITS AND CERTIFICATIONS

Changes or additions to required federal, state, local, and regional authority permits and certificates for the protection of the environment will be reported to the NRC within 30 days of issuance.

5.9 RECORDS RETENTION

5.9.1 RECORDS RETAINED FOR 5 YEARS

Records and/or logs relative to the following items, as they impact the environment, will be kept in a manner convenient for review, and will be retained for 5 years, unless a longer period is required by applicable regulations:

a. Records of principal maintenance activities of equipment pertaining to environmental impact.

b. Records of environmental deviations.

c. Records of periodic checks, inspections, and/or calibrations performed to verify that environmental surveillance requirements are being met.

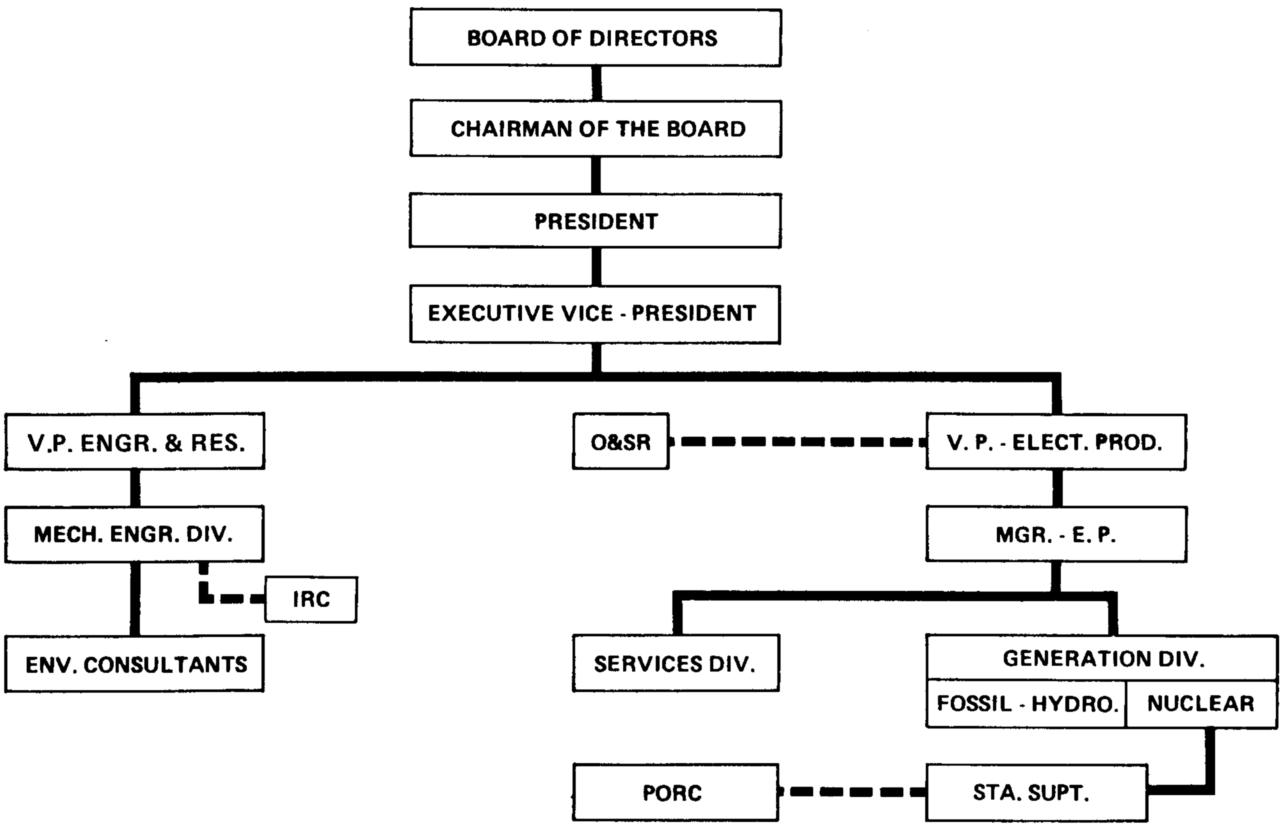
d. Records of any special study programs specified in Section 4 of this Appendix.

e. Records of changes made to operating procedures, equipment, permits, and certificates.

5.9.2 RECORDS RETAINED FOR THE LIFE OF THE CORPORATION

The following records and/or logs will be retained for the life of the corporation:

a. Records of offsite environmental monitoring surveys.



LIMERICK GENERATING STATION
UNITS 1 AND 2
ENVIRONMENTAL REPORT

ADMINISTRATIVE CONTROL

FIGURE A5-1

QUESTION E100.1

In addition to other requested information, provide a summary and brief discussion, in table form, by section, of differences between currently projected environmental effects (including those that would degrade and those that would enhance environmental conditions) and the effects discussed in the environmental report and environmental hearings associated with the construction permit review. On a similar basis, indicate changes in plant or plant component design, location or operation that have been made or planned since the construction permit review.

RESPONSE

Table E100.1-1 lists plant differences that have been made or planned between the ERCP and the EROL which could be significant relative to environmental impact. Changes in plant or plant component design, location, or operation that have been made or planned since the construction permit review are summarized in FSAR Table 1.3-8.

TABLE E100.1-1

SIGNIFICANT ENVIRONMENTAL EFFECT CHANGES FROM ERCP TO EROL

ITEM	CHANGE	REASON	EROL SECTION IN WHICH SUBJECT IS DISCUSSED
Spray pond	Spray pond constructed	Ensure adequate supply of emergency cooling water	4.1.2, 5.1.2, 5.1.4.3, 5.3.2, 6.1.2.1
Radiological monitors	Upgraded instrumentation	Provide greater sensitivity and broader range	6.1.5.2
Transmission lines	230 kv lines from Cromby to North Wales and from Cromby to Plymouth Meeting will be constructed	Improved transmission reliability	3.9, 10.9
Gaseous waste management system	Changed offgas treatment system	Increased reliability and maintainability	3.5.3

QUESTION E100.2

Provide a copy of the Environmental Report, with amendments, submitted to the Delaware River Basin Commission addressing the Point Pleasant Diversion, Bradshaw Reservoir, and associated water transmission facility.

RESPONSE

Two Environmental Reports addressing the diversion system were submitted to the Delaware River Basin Commission (DRBC). One report addressed the Point Pleasant Pumping Station, Combined Transmission Main, and public water supply components and was submitted February, 1979, by Neshaminy Water Resources Authority (NWRA). The NWRA has provided counsel for the regulatory staff with copies of all NWRA applications to the DRBC. The second report, submitted July, 1979, by Philadelphia Electric Company, addressed Bradshaw Reservoir, the transmission main to the East Branch Perkiomen Creek, and the East Branch and Main Stems of Perkiomen Creek. This report is provided as Exhibit E100.2-1.

ENVIRONMENTAL REPORT

BRADSHAW RESERVOIR, TRANSMISSION MAIN,
EAST BRANCH PERKIOMEN, AND PERKIOMEN CREEKS

JULY, 1979

****

PHILADELPHIA ELECTRIC COMPANY

EXHIBIT E1002-1

BRADSHAW RESERVOIR, TRANSMISSION MAIN, EAST BRANCH PERKIOMEN, AND PERKIOMEN CREEKS

ENVIRONMENTAL REPORT

S U M M A R Y

This Report provides information on the Philadelphia Electric Company (PECO) portion of the Neshaminy Water Resources Authority Water Supply Project (Point Pleasant Diversion); specifically, the Bradshaw Reservoir and the transmission main from the Reservoir to the East Branch of the Perkiomen Creek. The PECO portion of the Point Pleasant Diversion Plan was reviewed by the DRBC as part of its review of the inclusion of the Point Pleasant Diversion Plan in the DRBC's Comprehensive Plan. A Final Environmental Impact Statement was prepared by the DRBC in February, 1973, in connection with its Comprehensive Plan review. The PECO portion of the Point Pleasant Diversion Plan was also reviewed by DRBC in connection with Section 3.8 approval of PECo's Limerick Generating Station (Docket No. D-69-210-CP).

This Report provides information supplementing the analyses contained in the DRBC Final Environmental Impact Statement (EIS) on the Point Pleasant Diversion Plan, Bucks and Montgomery Counties, dated February, 1973. The information in this Report is presented topically in areas where either additional supportive information or clarification appeared appropriate. In areas not specifically discussed herein, it was not considered necessary to provide additional information or clarification since no significant changes in these areas have occurred since the original report. Our evaluation of the information contained in the 1973 DRBC EIS together with the supplemental information provided herein indicates that the supplemental information has no signficant impact on the conclusions stated in the 1973 EIS.

The following sections are included in this report:

SECTION I - PROJECT DESCRIPTION - BRADSHAW RESERVOIR

The Bradshaw Reservoir was evaluated in the 1973 DRBC EIS. The references and conclusions regarding the reservoir are still valid with the following exception. The reservoir size has been increased from 46 MGD to 70 MGD. The increased size provides for an adequate operating capacity, emergency storage and space for silt buildup. The information presented in this Section provides a more complete description of the facility and discusses alternatives considered specifically for the reservoir.

SECTION II - PROJECT DESCRIPTION - PERKIOMEN TRANSMISSION MAIN

The Perkiomen Transmission Main and the environmental impacts associated with it were included in the 1973 DRBC EIS. The main was described as one of the facilities comprising the proposed action. The environmental impacts of this main were reviewed together with the impacts of the other proposed pipelines. The references and conclusions regarding the transmission main are still valid. The information presented in this Section is intended to provide a more complete description and to discuss alternatives considered specifically for the route of the transmission main.

SECTION III - ALTERNATIVES TO PROPOSED PLAN

Alternatives to the proposed plan to supply water to the Limerick Generating Station were discussed in the 1973 DRBC EIS. The conclusions reached in connection with each of the five alternatives covered in the 1973 DRBC EIS are still valid. The material presented in this Section, in addition to expanding on several of the previous alternatives, describes seven pipeline alternatives which were considered to supply only PECO's water requirements.

SECTION IV FLOWS

Supplemental flow and meteorological data from 1974 to 1977 were evaluated and summarized. The information is shown in Table 1 of Section IV. Also included is a summary of the estimated augmentation and flow, by months, if the diversion had been in operation during this same time period. The estimated number of weeks of simulated augmentation is less than the number of weeks of withdrawal at the Perkiomen intake since augmentation was assumed to be curtailed if Perkiomen natural flow exceeded 450 cfs in order that natural flooding not be aggravated. Detailed supplemental flow information compiled by E. H. Bourquard Associates is also presented in Section IV.

SECTION V - WATER QUALITY

The general conclusions of the 1973 DRBC EIS regarding water quality remain valid. Table 3 (Page 17) of the 1973 DRBC EIS presented basic water quality information. This table was composed to present data to characterize the water quality of each of the Diversion component streams. It is based on data collected in 1967 and 1968 by Broadfoot et al. Comparison of the data with more recent data indicates that the medians are similar but the extremes are different. The extremes are different because data were collected over a longer period of record and at more frequent intervals and thus, include a greater variety of physical conditions. Additional data from four stations show that East Branch Perkiomen Creek quality varies from source to mouth. The upstream reach has water quality similar to that of the Delaware, the middle reach is organically and inorganically enriched, and the lower reach is recovering from degradation.

Supplementary water quality information is presented in Section V.

SECTION VI - WATER TEMPERATURE

Supplementary water temperature information is presented in Section VI.

SECTION VII - AQUATIC BIOLOGY

In general, the conclusions and predictions of the 1973 DRBC EIS remain essentially correct.

Increased flow will provide a relative improvement in aquatic life. The increased flow will not improve fish production uniformly since some areas are already quite productive. In addition, increased flow will likely enhance the aesthetics of fishing sites.

There will be some loss of aquatic life. However, the loss will not be significant, and the overall creek is expected to improve with time.

The results of an extensive aquatic biology program by RMC - Ecological Division are presented in Section VII.

SECTION VIII - TERRESTRIAL BIOLOGY

The site of the Bradshaw Reservoir and three alternate pipeline routes were surveyed by RMC - Ecological Division in April, 1979. The results of that survey are presented in Section VII.

Section IX - HISTORICAL AND ARCHEOLOGICAL INFORMATION

The possibility that places of historical or archeological importance would be disturbed by the proposed action was considered in the 1973 DRBC EIS. The conclusion was that the Bradshaw Reservoir and the Perkiomen Transmission Main would not affect any properties of significance. This conclusion is still valid. The information presented in this Appendix supplements previously submitted information and details a study and investigation conducted in 1978.

SECTION I

BRADSHAW RESERVOIR

Bradshaw Reservoir

General Although final design work such as the preparation of detailed construction drawings and specifications has not been completed, design has progressed sufficiently to provide information adequate to define the purpose, location, external appearance, approximate size and anticipated effects of the proposed Bradshaw Reservoir.

Purpose The Bradshaw Reservoir is the final point of discharge for the combined quantity of water pumped from the Delaware River by and through the combined facilities consisting of the Point Pleasant intake, the pumping station, and the combined transmission main. At this reservoir the water will be divided and flow either by gravity to the North Branch of the Neshaminy Creek or under pump pressure to the East Branch of the Perkiomen Creek.

The two main purposes of the reservoir are the distribution of the water to the counties and to Philadelphia Electric Company (PECo.) and the accommodation of the different pumping rates of the Point Pleasant pumping station and the Bradshaw pumps.

The distribution of the water pumped from the Delaware River to the reservoir will vary greatly over the life of the project. During the initial few years of operation, approximately 75% of the water pumped to meet the forecasted water needs (63 MGD maximum) will be delivered to the East Branch of the Perkiomen Creek for use by PECo. As the years pass, the growing population will require additional water so that by year 2010 the water supply needs of the public may be expected to exceed PECo. needs. In 2010, slightly over 51% of the maximum forecasted water (95 MGD) delivered to the reservoir will be routed to the North Branch of the Neshaminy Creek. It is planned to use the gated gravity outlet and the multiple pumps installed at the Bradshaw Reservoir to make the distribution of the combined inflow to the reservoir.

The accommodation or balancing of the different discharge flow rates at Point Pleasant and at Bradshaw will be satisfied by providing a volume in the reservoir between pre-established elevations suitable for storing water when the inflow exceeds outflow and capable of supplying water for short time periods when outflow is greater than inflow.

Two other purposes of the reservoir which may prove very beneficial are the emergency water supply provided and the silt settling basin effect. Sufficient water storage capacity will be provided to enable PECo.'s maximum flow requirement to be met for one day. This emergency storage would be used in the event of the unavailability of the Point Pleasant facilities for this period of time. The settling basin effect results from the relatively long detention time for stored water. Most of the suspended material in the water pumped from the Delaware River, which includes silts and clays, should settle out in the reservoir. During periods when pumpage is limited to the minimum flow requirements of the East Branch of the Perkiomen Creek, the theoretical detention time will be in excess of two days.

<u>Location</u> The Bradshaw Reservoir is to be located in Plumstead Township, Bucks County, Pennsylvania, at the intersection of Bradshaw and Myers Roads. The site is about 2.5 miles southwest of the Point Pleasant Pumping Station and the Delaware River. The reservoir is near the drainage divide between the North Branch of the Neshaminy Creek and the South Branch of Geddes Run. It will occupy a minimum of land, about 28 acres, and will have no drainage area. It will not significantly reduce the natural flow or runoff to either stream.

<u>Description of Project</u>

The Bradshaw Reservoir will be created in an open area by the construction of compacted earthen dikes (Figure No. 1). The dikes will form a square reservoir about 900 feet on a side. The project will be essentially a balanced cut and fill type operation. The area to be the reservoir bottom will be excavated down to such an elevation that the removed impervious material will be sufficient to form the required dikes. The bottom of the reservoir will be a minimum of either 3 feet of existing impervious material or 2 feet of a compacted material supplied to the site from an external source. The dikes will be made by compacting the excavated material and will vary in height from about 5 feet to 20 feet due to the existing contours of the existing ground. The sloping faces of the dikes will be gentle with a rise of 1 foot in a horizontal run of 2.75 feet and 3 feet for the outside and waterside slopes respectively. The outside surface will be evenly graded and seeded with a grass or appropriate ground cover to provide for erosion protection. The waterside surface will be faced with stone riprap to mitigate erosion due to the fluctuating water levels.

Control of the quality of all materials will be closely monitored as will the compaction methods used during construction so that the water tightness of the reservoir will be assured.

Built into the western dike of the reservoir there will be a structure (Figure No. 2) which will contain the gated outlet feeding the gravity transmission main leading to the North Branch of the Neshaminy Creek. The structure also will house five 11.5 MGD electric motor driven, vertical turbine-type pumps, one of which will be considered a spare. These pumps will deliver PECo.'s needs to the East Branch of the Perkiomen Creek. Vertical pumps were selected over centrifugal pumps because of their compact design and non-priming characteristic. The pumps are identical to each other to simplify operation and reduce spare part inventories. Four pumps will carry the maximum demand, and partial loads will be pumped efficiently with a reduced number of pumps. Removable trash racks will be installed at the entrance to the structure to prevent any debris that may have gotten into the reservoir from fouling the pumps or being passed to either of the creeks supplied. A slot in the structure will be provided for the installation of stop logs so that dewatering can be accomplished if maintenance is required.

High water level in the reservoir, which can occur due to pumping at Point Pleasant or excessive rainfall, will be controlled in several ways. Redundant automatic controls will be provided to shutdown any operating supply pumps when a predetermined high water level occurs. Signals will be included to inform the pumping station operators of reservoir elevations so that they may take early action prior to automatic shutdown to regulate pumping rates. To lower reservoir water levels and accommodate excessive rainfall, water will be withdrawn by opening the gated outlet to the gravity main feeding the Neshaminy Creek or by starting the Bradshaw pumps to deliver water to the Perkiomen Creek.

A fence will surround the reservoir property to prohibit unauthorized access and the unused area of the property will be landscaped in a manner compatible with the surrounding area.

<u>Size</u>

The capacity of the Bradshaw Reservoir will be approximately 70 million gallons (MG). The reservoir was sized to meet minimum operating requirements, to provide a limited amount of storage for emergencies and to accommodate silt buildup. The capacity breakdown is as follows:

18 MG for operating capacity
46 MG for emergency storage
6 MG for silt buildup
70 MG total capacity

The operating capacity is the equivalent of one day's minimum pumping rate (27 cfs) as established in the Delaware River Basin Commission's docket proceedings for the protection of aquatic life in the Perkiomen Creek and its East Branch throughout the normal low flow season. The emergency storage is sufficient to supply the maximum one day requirement of PECo. for power purposes (65 cfs). The capacity reserved for silt buildup amounts to a depth of $1\frac{1}{2}$ feet. Based on the results of water sample tests taken from the Delaware River at Point Pleasant and USGS water quality records at Morrisville, it is expected to be more than 25 years before silt settling out in the reservoir will reach this depth.

The reservoir is approximately 900 feet square and has a water surface of about 18 acres.

Alternatives to Specific Facility Proposed

Alternatives to the overall water supply system proposed in this application are presented in Section III. It is the purpose at this point to provide an analysis of alternatives for only the specific component of the system herein described, the Bradshaw Reservoir.

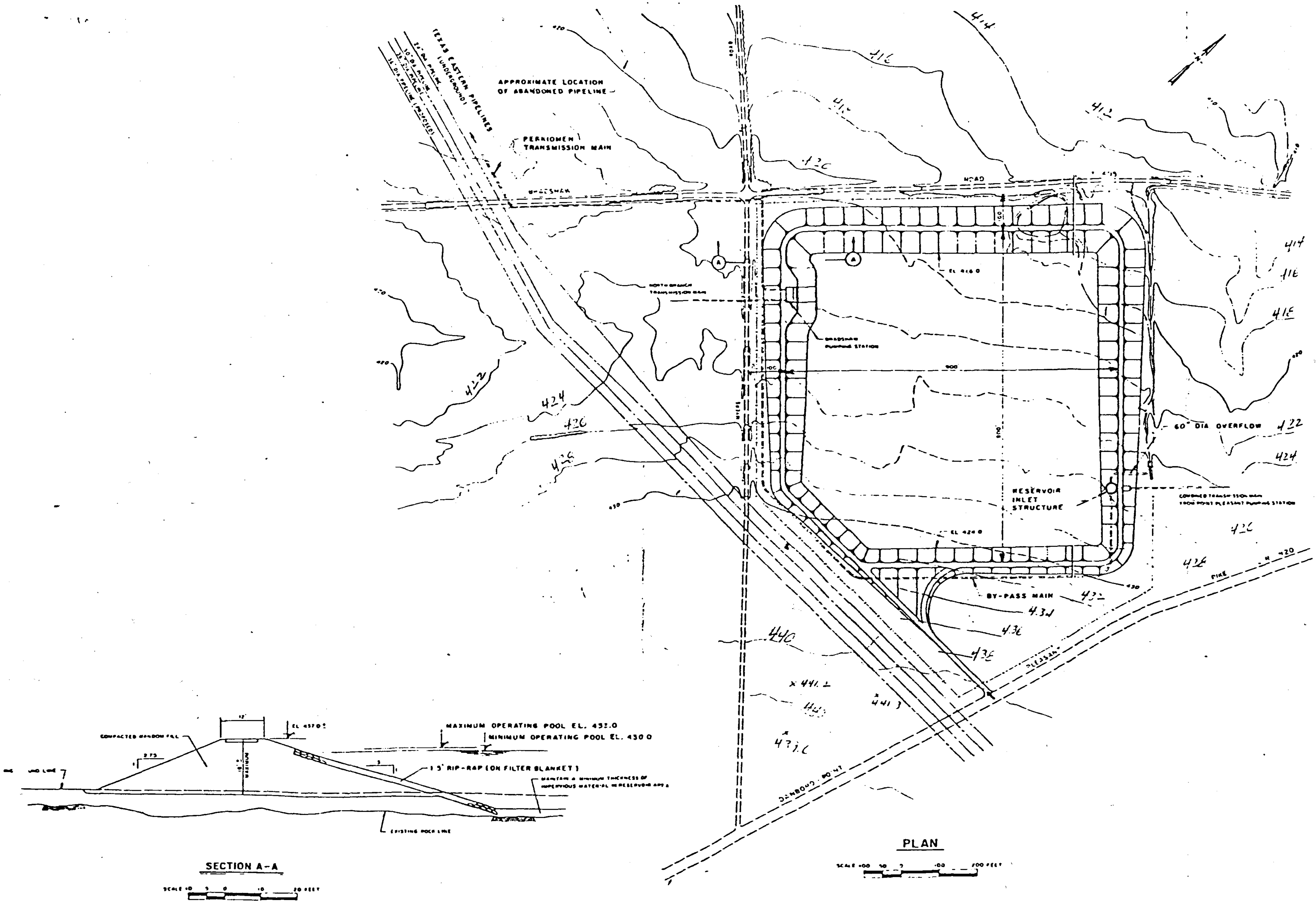
The first alternatives considered were reservoirs at other sites. Like the Bradshaw Reservoir site, two alternative sites were considered along the Neshaminy Water Resources Authority's 3½ mile pipeline route from the Point Pleasant pumping station to the North Branch of the Neshaminy Creek. The Bradshaw Reservoir is located on the high ground where the pipeline crosses from one watershed to another, the alternative sites would be on each side of the watershed divide, on existing streams at lower elevations. One alternative reservoir was on the headwater of a tributary of Geddes Run and the other reservoir was on the headwater of the North Branch of the Neshaminy Creek. Each of these two alternatives would be created by the construction of a dam, complete with spillway and outlet works, across an existing stream. The perimeter of each reservoir would be established by the existing terrain and consequently would be irregular in shape requiring the use of a greater land area than required by the Bradshaw Reservoir. The Geddes location would require about 40 acres, the North Branch site would exceed 50 acres, while the Bradshaw Reservoir will occupy about 28 acres. Since the water level in any reservoir constructed will rise and fall regularly, it will not be suitable for recreation and the public will be prohibited from using it for reasons of safety (Figure No. 3).

The alternative reservoirs, since they would be located on existing streams, would be subject to siltation and pollution due to the water runoff from the surrounding drainage area. Later transfer of this water to another watershed, whether it is the Neshaminy or the Perkiomen, would have a detrimental effect. The Bradshaw Reservoir will not have a drainage area of its own and so will not be polluted or silted by local runoff, thus minimizing detrimental environmental effects.

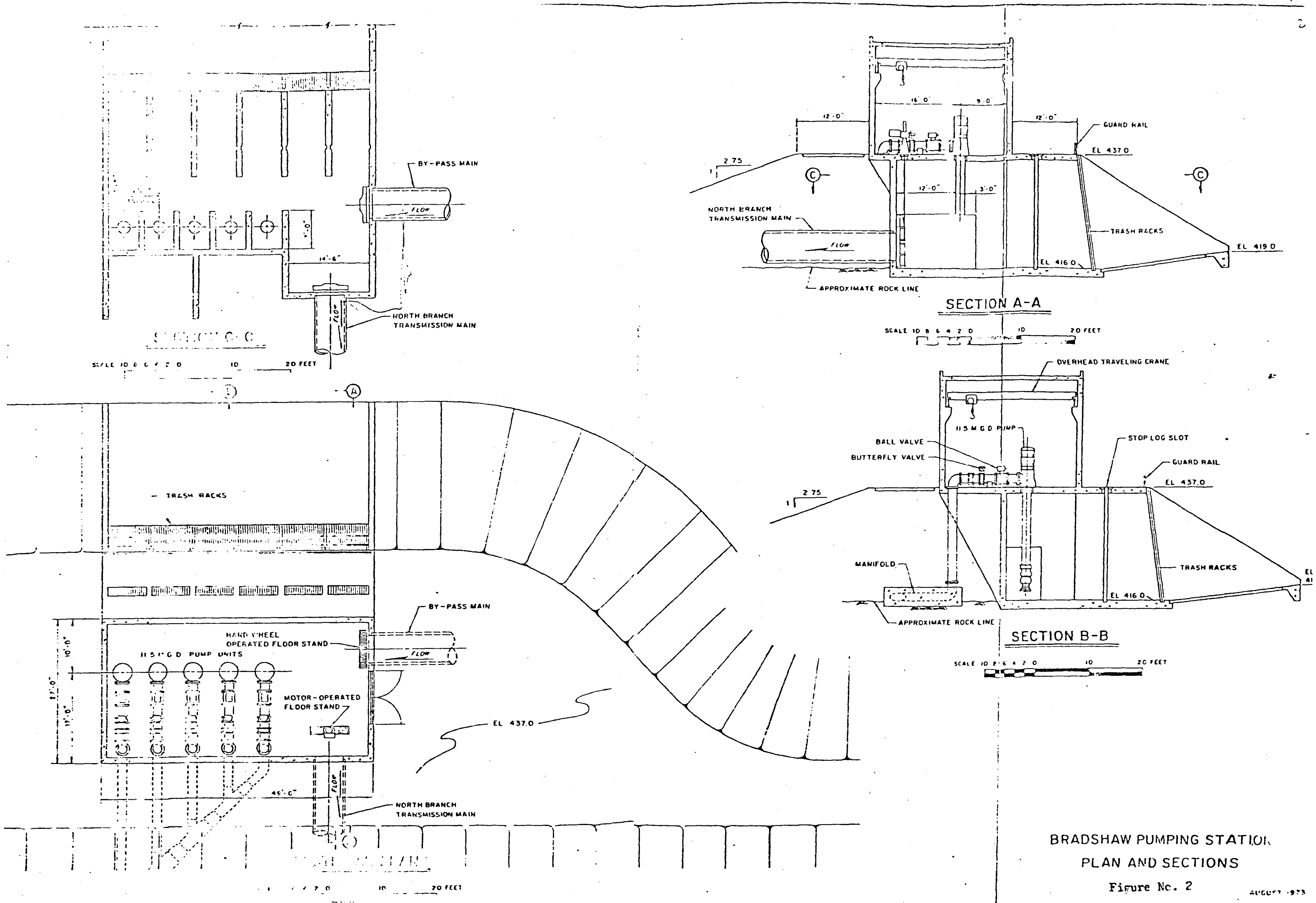
A further objection to the use of either low level, reservoir alternative is the added cost necessary to deliver the water to the counties or to PECo. A reservoir on the tributary to Geddes Run would require the installation of pumps to deliver water to the North Branch of the Neshaminy Creek or the costly excavation of a deep trench to continue to use gravity flow since the terminal points would be separated by the watershed divide. A reservoir on the North Branch of Neshaminy Creek would significantly increase the pumping head to the East Branch of the Perkiomen Creek thus raising the system operating costs.

A final alternative was considered which assumed no reservoir at all. This would be possible, but a bifurcation or a tee connection would be required in the large, 66 inch diameter combined transmission main extending from Point Pleasant. The distribution of water to the Neshaminy and to the Perkiomen watersheds would be controlled by the use of gates or valves. The added equipment, necessary if the reservoir is eliminated, would increase the system complexity, increase equipment maintenance and reduce the reliability of the water supply. A further, significant objection to the elimination of any reservoir is the loss of the one day emergency water storage. The added assurance of continued water supply provided by the storage in a reservoir is beneficial.

The alternatives to the Bradshaw Reservoir do not have any recognized advantages and, as indicated in the foregoing discussion, have environmentally less desirable features, so the decision was made to incorporate the Bradshaw Reservoir in the proposed water supply system.



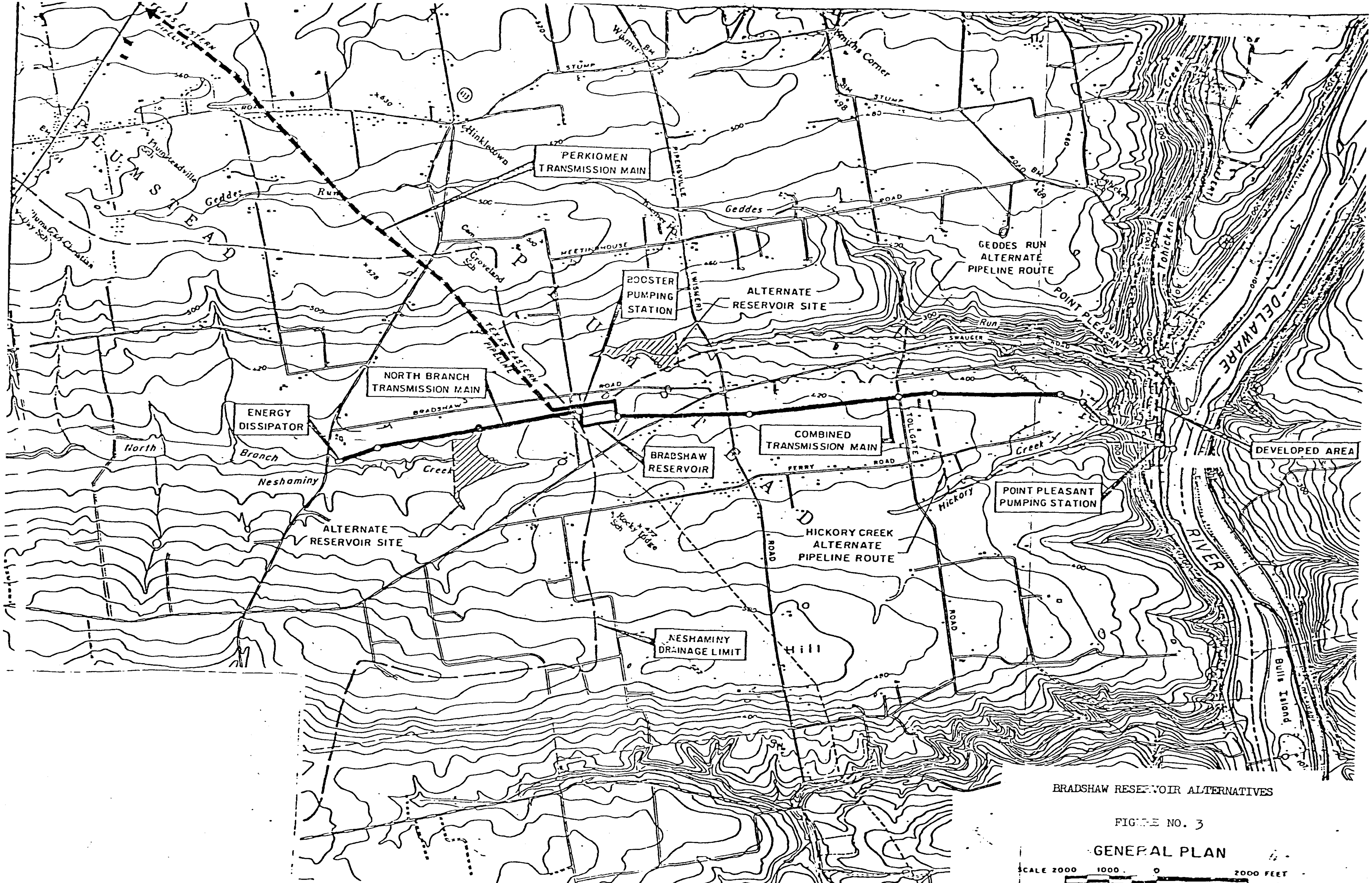
BRADSHAW RESERVOIR
PLAN AND SECTION
Figure No.[illegible]



BRADSHAW PUMPING STATION
PLAN AND SECTIONS

Figure No. 2

AUGUST 1973



BRADSHAW RESERVOIR ALTERNATIVES

FIGURE NO. 3

GENERAL PLAN

MARCH 1977

SECTION II

PERKIOMEN TRANSMISSION MAIN

Perkiomen Transmission Main

General Although final design work such as the preparation of detailed construction drawings and specifications has not been completed, design has progressed sufficiently to provide information adequate to define the purpose, location, external appearance, approximate size and anticipated effects of the proposed Perkiomen Transmission Main.

Purpose The Perkiomen Transmission Main is the connecting link of the proposed system for transporting Delaware River water from the Bradshaw Reservoir to the East Branch of the Perkiomen Creek for Power Company use. Its purpose is solely to convey water in a safe, economical manner with minimum effect on the environment.

Location The Perkiomen Transmission Main (Figure No. 1) is an underground pipeline extending due west almost 7 miles from its inlet at the Bradshaw Reservoir to its outlet into the East Branch of the Perkiomen Creek. The main is parallel to and forms a common pipeline corridor with an existing pipeline right-of-way of the Texas Eastern Transmission Corporation. The initial 40% of the main is in Plumstead Township and the remaining 60% is in Bedminster Township, both townships being political subdivisions of Bucks County, Pennsylvania. The main will not cross any significant streams or rivers. The only major road crossing is U. S. Highway No. 611 which the main crosses about 0.7 miles north of Plumsteadville. The outlet will discharge into the creek about 0.4 miles upstream from the Elephant Road crossing.

Description of Project

The Perkiomen Transmission Main design proposes a reinforced concrete pressure pipe having an inside diameter of 42 inches. The main is to be buried with a minimum depth of cover of 3 feet for its entire 35,400 foot (6.7 miles) length. To avoid deep trench excavations, the pipeline grade will generally follow the ground surface. The minimum soil cover will provide protection from external loading and frost action. At all road and stream crossings, the main will be installed in a steel casing or encased in additional concrete. Air relief control and blow-off valves will be provided where needed along the main. These will be enclosed in reinforced concrete vaults. Surge control equipment will also be provided as required.

No water treatment facilities are proposed in connection with the transfer of water from the Delaware River through the transmission main to the East Branch of the Perkiomen Creek. Studies have shown the waters to be compatible.

An impact type energy dissipator will be constructed at the outlet end of the main for water velocity reduction to minimize possible erosion of the creek bed and side slopes (Figure No. 2). The energy dissipator will be a reinforced concrete box into which the water discharges. The discharge will be directed at a concrete baffle so the velocity energy will be exhausted in the box before the water flows out into a spur channel off the East Branch of the Perkiomen Creek. The spur channel will be riprapped on the sides and the bottom to further dissipate the water energy and to resist erosion. The dissipator itself will be about 15 feet long, 11 feet wide, and extend almost 12 feet below existing grade to establish a firm foundation.

Studies which are presently underway indicate that the pipe material could be coated steel or reinforced fiberglass and that a more economical size might be 48 inches inside diameter. The ultimate decision on these items will depend in part on material costs and construction labor costs at the time of bidding the work.

Alternatives

Consideration was given to three alternative routes (Figure No. 3) for the Perkiomen Transmission Main before the selection of the proposed route (Line B) was made. The three routes all began at the same point but differed slightly in their paths and discharge points.

The three routes were originally called Lines A, B, and C and can be described as follows:

Line "A". This route was developed as the most feasible route on the basis of preliminary hydraulic design and construction cost estimates. It generally represents the shortest distance between the Bradshaw Reservoir site and the East Branch, yet takes into account the topographic features of the area and construction factors that might be encountered. With the possible exception of ease of right-of-way acquisition, this route was found to combine the best of all features in the preliminary examinations.

Line "B". This route extends along an existing pipeline right-of-way of the Texas Eastern Transmission Corporation which runs nearly parallel to and at a distance of approximately 2000 feet south of the above mentioned Line "A". The Texas Eastern right-of-way is 125 feet wide, sufficient to install four pipelines at 25-foot spacing. Three pipes, a 24-inch, 30-inch, and 36-inch, have already been installed, and installation of the fourth pipe of 42-inch diameter is scheduled for the near future.

A pipeline along this route would be about the same length as Line "A". Although such a line would be located on higher ground than Line "A" and thus would have higher pumping costs, its location adjacent to an existing pipeline, forming a common pipeline corridor, will minimize detrimental environmental and land use effects.

Line "C". This route, which would utilize the abandoned Tuscarora pipeline right-of-way, would have a pipeline length about 2400 feet longer and a static pumping head about 15 feet greater than Line "A". The sole advantage of this route appeared to be less difficult problems in connection with right-of-way acquisition. The Buckeye Pipeline Company and the Humble Oil Company were contacted to determine the present status of the right-of-way along Line "C". It became evident that renegotiations would probably be necessary with each property owner and so the right-of-way situation thus appears complex. Any advantage this route might have had disappeared.

Other features regarding the three routes were reviewed and found to be quite similar. All lines pass through soil with nearly the same properties. The geological formations are nearly identical, so no severe excavation problems are expected on any route.

The total area required for right-of-way would be similar for all routes. Esthetically there should be no significant difference between routes since after construction the right-of-way will be graded and reseeded so that it will essentially be returned to the natural condition. Finally a review was made of the area involved to determine the presence of any historic or archeological features of importance. The routes were considered equally acceptable by this review. (See Section IX.)

Line "B" was selected from the alternatives as the best route to develop primarily because the acquisition of the right-of-way would have the least impact on the public since it would utilize an existing pipeline corridor.

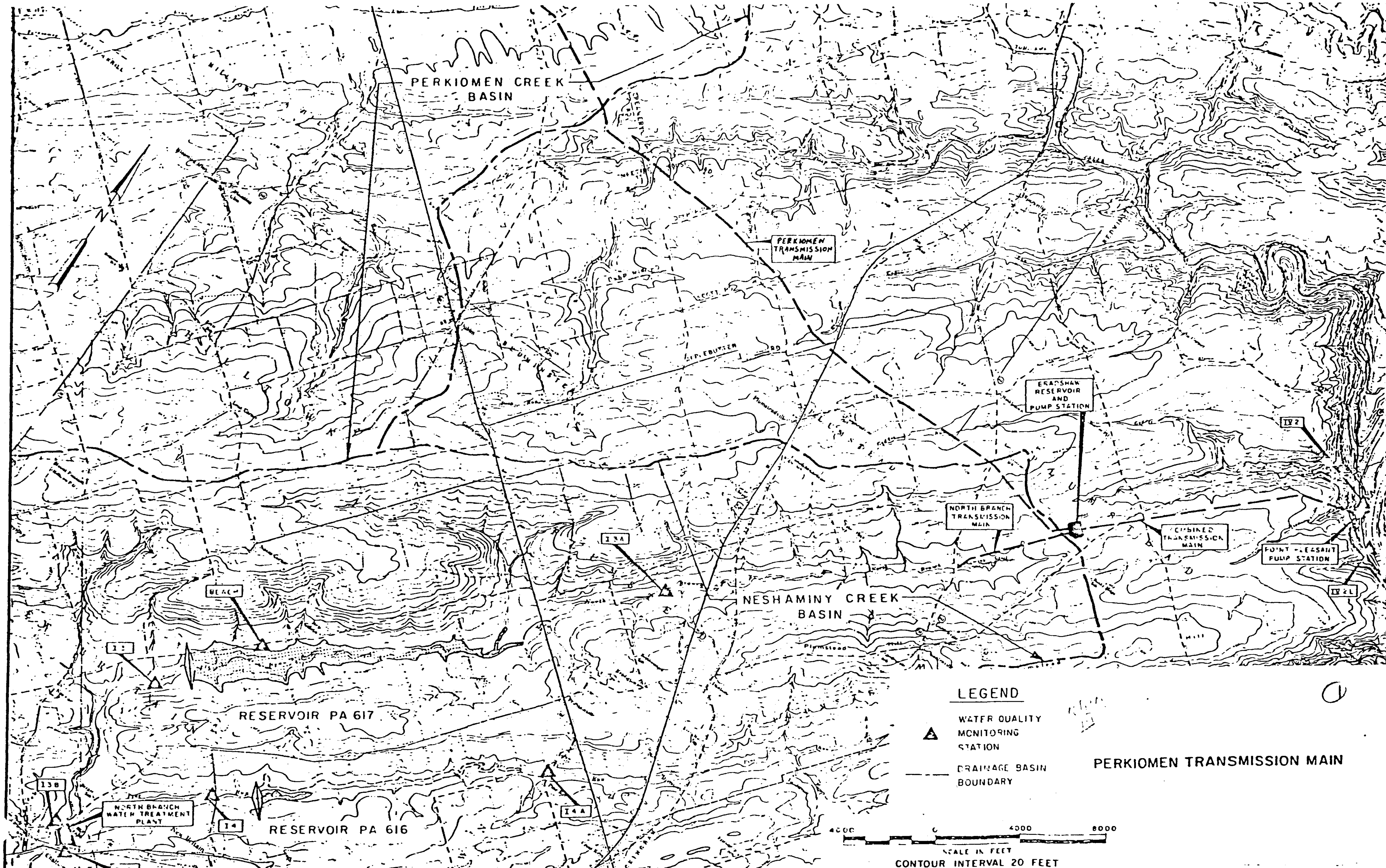

PERKIOMEN CREEK BASIN
PERKIOMEN TRANSMISSION MAIN
BRADSHAW RESERVOIR AND PUMP STATION
IV2
NORTH BRANCH TRANSMISSION MAIN
COMBINED TRANSMISSION MAIN
POINT PLEASANT PUMP STATION
IV2L
I3A
BEACH
NESHAMINY CREEK BASIN
RESERVOIR PA 617
RESERVOIR PA 616
I3B
NORTH BRANCH WATER TREATMENT PLANT
I4
I4A
LEGEND
WATER QUALITY MONITORING STATION
DRAINAGE BASIN BOUNDARY
PERKIOMEN TRANSMISSION MAIN
4000 0 4000 8000
SCALE IN FEET
CONTOUR INTERVAL 20 FEET

Figure No.1

Alternatives to Proposed Plan

A number of alternatives to the proposed water supply system for the Limerick Generating Station have been considered. The proposed plan is based upon others delivering Delaware River water to the Bradshaw Reservoir, a facility to be built, owned and operated by PECo., and the subsequent pumping of the water by PECo. through its own transmission main to the East Branch of the Perkiomen Creek.

The alternatives investigated include: four different pipelines originating at different points on the Delaware River but each delivering water to the East Branch of the Perkiomen Creek, two different pipelines originating at the Delaware River and following different routes to a booster pumping station on the Perkiomen Creek near Graterford, a pipeline from the Philadelphia Northeast Sewage Treatment Plant to a booster pumping station on the Perkiomen Creek near Graterford, reservoirs in the Schuylkill River Basin and groundwater underlying the area near the generating station.

Several significant differences exist between the alternatives as a group and the proposed plan. Under the proposed plan others will construct a new intake/pumping station capable of delivering sufficient water to meet future public water supply requirements and to supply the needs of the Limerick Generating Station. The alternatives assume PECo. would act alone and construct facilities to supply only its own needs. These facilities would not be readily expandable in the future to serve the public. There would be no Bradshaw Reservoir constructed as part of any of the alternative plans.

Pipelines from Delaware River to East Branch Perkiomen

Alternative A - A pipeline, approximately 9.2 miles long and 42 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River, north of Tohickon Creek near Walls Island (about River Mile 160), to the East Branch of the Perkiomen Creek near Elephant Road.

Alternative B - A pipeline, approximately 9.1 miles long and 42 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River at Point Pleasant (about River Mile 157) to the East Branch of the Perkiomen Creek near Elephant Road. This alternative is similar to the proposed joint Point Pleasant proposal which would serve the water needs of both Bucks and Montgomery Counties and PECo., but it would be sized to meet only the PECo. requirements. The transmission main would follow the proposed route of the combined main and the main to the East Branch of the Perkiomen. There would be no Bradshaw Reservoir.

Alternative C - A pipeline, approximately 12.8 miles long and 48 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River near Hendrick Island (about River Mile 153) to the East Branch of the Perkiomen Creek near Elephant Road.

Alternative D - A pipeline, approximately 14.8 miles long and 48 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River north of New Hope (about River Mile 150) to the East Branch of the Perkiomen Creek near Elephant Road.

Pipelines from Delaware River to Graterford

Alternative E - A pipeline, approximately 34.8 miles long and 54 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River north of New Hope (about River Mile 150) at the site of the 500 KV electric transmission line river crossing to a booster pumping station on the Perkiomen Creek near Graterford.

Alternative F - A pipeline, approximately 32.8 miles long and 54 inches in diameter, would convey water inland from an intake/pumping station located on the Delaware River north of New Hope (about River Mile 149.5) at the site of the 220 KV electric transmission line river crossing to a booster pumping station on the Perkiomen Creek near Graterford.

Pipeline from Sewage Treatment Plant to Graterford

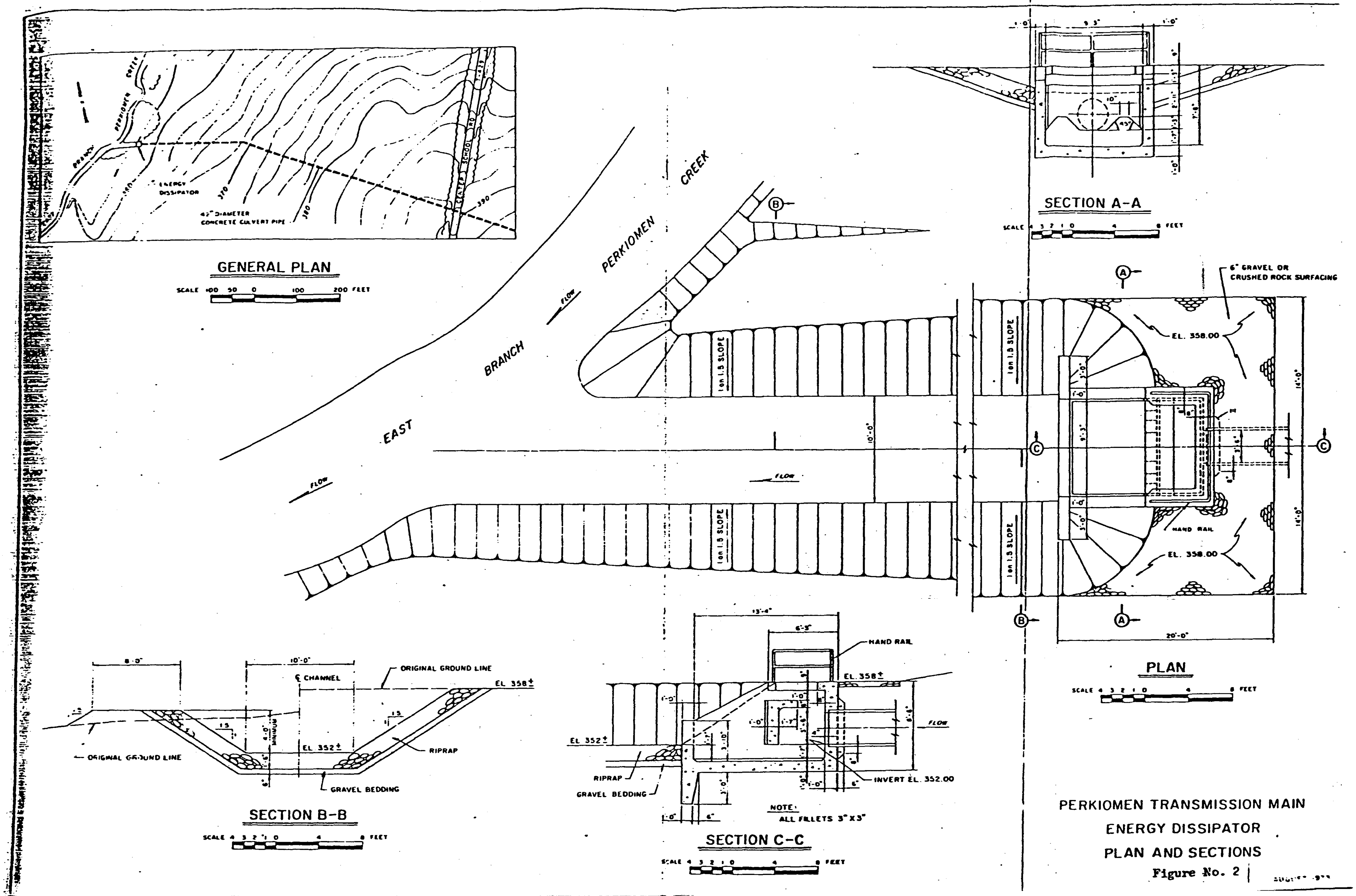
Alternative G - A pipeline, approximately 48 miles long and 60 inches in diameter, would convey the effluent from the City of Philadelphia Northeast Sewage Treatment Plant (about River Mile 104) to a booster pumping station on the Perkiomen Creek near Graterford. The pipeline would go north from the treatment plant approximately 8 miles through a heavily developed area of the city, turn northwest and parallel Route 63 to the pumping station.

Analysis of Pipeline Alternatives

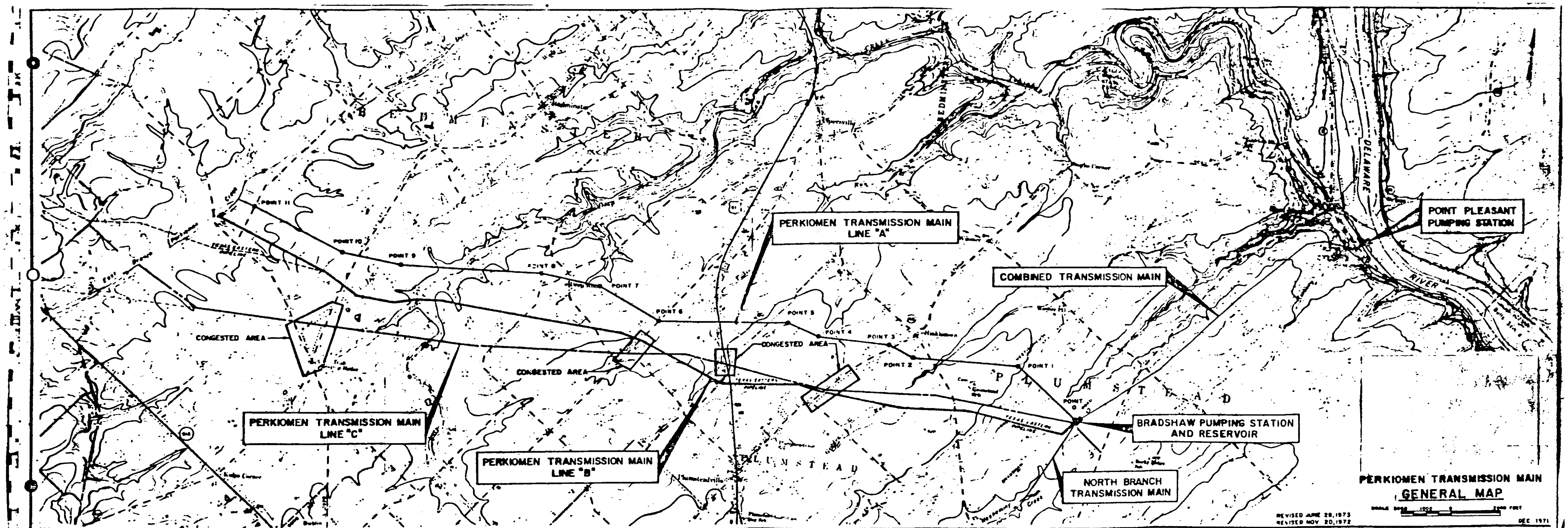
The cost, environmental impact, and land use impact of an underground pipeline are closely related to the pipeline length and the population density along the right-of-way.

Alternatives A, B, C, and D are similar in environmental effect and cost in that they withdraw water from the same reach of the Delaware River; pass through a primarily rural area with scattered suburban developments; and discharge water at the same point into the East Branch of the Perkiomen Creek. Pipeline B is slightly more attractive than Alternative A since it would parallel the Texas Eastern Transmission Corporation right-of-way, minimizing the environmental and land use effects by using the common corridor principle. Pipeline B is preferred over Alternatives C and D since it is shorter, thus less costly and requires less land.

Alternatives E, F, and G would have significantly greater impacts than Alternatives A, B, C, and D. Alternatives E, F, and G are considerably longer thus increasing the environmental impacts, occupying more land area and raising the costs. Alternative G would have significant adverse effects due to its passing through the densely populated Northeast Philadelphia and suburban areas of Lower Bucks and Montgomery Counties. In addition, these latter alternatives will not utilize the East Branch of the Perkiomen Creek and will not benefit the East Branch by providing a substantial minimum flow of water during the low flow period of the year. Since Alternatives E, F, and G are clearly less preferable than the others, the additional environmental problems and costs associated with these alternatives, particularly with the sewage treatment plant effluent, as a makeup water source have not been evaluated.



PERKIOMEN TRANSMISSION MAIN
ENERGY DISSIPATOR
PLAN AND SECTIONS
Figure No. 2



PERKIOMEN TRANSMISSION MAIN
LINE "A"
POINT PLEASANT
PUMPING STATION
COMBINED TRANSMISSION MAIN
DELAWARE
RIVER
POINT 11
POINT 10
POINT 9
POINT 8
POINT 7
POINT 6
POINT 5
POINT 4
POINT 3
POINT 2
POINT 1
POINT 0
CONGESTED AREA
CONGESTED AREA
CONGESTED AREA
P L U M S T E A D
PLUMSTEAD
BRADSHAW PUMPING STATION
AND RESERVOIR
NORTH BRANCH
TRANSMISSION MAIN
PERKIOMEN TRANSMISSION MAIN
LINE "C"
PERKIOMEN TRANSMISSION MAIN
LINE "B"
PERKIOMEN TRANSMISSION MAIN
GENERAL MAP
REVISED JUNE 28, 1973
REVISED NOV. 20, 1972
DEC. 1971

Figure No. 3

SECTION III

ALTERNATIVES TO PROPOSED PLAN

Alternative B, which would serve alone and which is indicated above to be the most desirable of the alternative pipelines, and separate facilities to supply Bucks County were compared with the proposed joint water supply facilities in the Feasibility Study prepared by E. H. Bourquard Associates in 1970. This study, done for the DRBC, Bucks County and PECo., was referenced in the 1973 DRBC EIS. The comparison indicated that the joint facilities would result in annual cost savings of more than 20% for Bucks County and 10% for PECo. as well as providing advantages in operating flexibility and reliability. Since the joint project also requires 2 fewer miles of total right-of-way than the combined individual facilities, the proposed project is superior to the most preferred alternate pipeline route.

Reservoir Alternatives in the Schuylkill River Basin

Existing or Planned DRBC Reservoir - No existing reservoir in the Schuylkill River Basin has sufficient storage available for use as a water source for Limerick. Storage in the Blue Marsh Reservoir, recently constructed by the U.S. Army Corps of Engineers, has been assigned to other uses. Planned reservoirs will not be available in time to meet Limerick Generating Station needs.

Company Owned Reservoir in the Schuylkill Basin - A number of potential reservoir sites have been identified in the Schuylkill Basin as a result of map and field studies by the Corps of Engineers and utility company consultants. Ten of these sites received extensive preliminary reviews, and the two most promising sites were the subject of detailed engineering and environmental study.

Analysis of Reservoir Alternative - A reservoir would have a greater environmental impact than the proposed pipeline system. At the most environmentally acceptable Schuylkill Basin site, about 2000 acres of land would have to be purchased and relocation of more than 60 households would be required to allow reservoir construction and operation. About 770 acres of land would be inundated or covered by embankments. The cost of a reservoir is also significantly higher than the proposed pipeline system.

Groundwater Alternative

The groundwater resources in much of Montgomery County are already used at or in excess of their drought recharge capability. The use of groundwater for makeup to Limerick Generating Station, therefore, is not feasible. As evidence of the critical nature of groundwater supplies, it only needs to be noted that the recent studies of the DRBC indicate problems in sustaining adequate yields to meet current demands. The problem is so critical that public hearings have recently been held to receive comments on proposed regulations to protect groundwater sources.

Summary

The proposed joint water supply system, designed to supply the needs of Bucks and Montgomery Counties and PECo., is considerably less environmentally harmful, requires less land and results in lower costs than any of the alternatives studies. When compared to the pipeline alternatives, it results in only one intake/pumping station on the Delaware River to serve several users rather than a series of stations, each having a single purpose. A new reservoir in the Schuylkill River Basin would have a greater environmental impact, larger land use, and higher cost than the proposed pipeline system. The use of groundwater or existing reservoirs is not feasible since insufficient supplies of water to meet PECo. needs are available.

SECTION IV

FLOWS

Flow Information

A report entitled "Investigation of the Effect of Proposed Pumpages on Stream Flows of East Branch Perkiomen Creek and North Branch Neshaminy Creek" by E. H. Bourquard Associates, Inc., dated July 8, 1970, was included in the 1973 DRBC EIS as Appendix 8. Subsequent to the preparation of the report, changes were made in the proposed pumping rates to the East Branch Perkiomen Creek. Therefore, a thorough review has been made to determine what effects would result from the changes. A discussion of this review is presented below, and the portions of the original report referring to the East Branch Perkiomen Creek are updated accordingly. Paragraph headings are as used in the original report.

Introduction. No change.

Purpose of Investigation. No change.

Perkiomen Creek. For this update, the East Branch Perkiomen Creek channel was re-examined on March 26, 1979, by Robert E. Steacy, Senior Hydraulic Engineer of this office, and A. Richard Diederich, Civil Engineer, of Philadelphia Electric. Each of the 15 stream channel sites was visited, pictures were taken, and the descriptive comments made regarding any changes since the 1970 and 1972 investigations. A copy of these comments is attached hereto. At each site, new estimates were made of typical channel bottom widths and of Manning "n" values.

Re-examination of the East Branch revealed only minor changes in channel alignments and sections since the prior examinations. The only construction change was replacement of the steel truss bridge at Elephant Road with a new single-span reinforced concrete structure. Also, the stream channel was widened and reshaped in the vicinity of the new bridge.

Neshaminy Creek. Updated in NWSS EIR.

Method of Investigation. The same method of investigation was employed. However, the Perkiomen Creek computations were redone, using a programable calculator and revised values of channel flow, channel width, and Manning's "n". The changes in channel flows resulted from the reduction in the estimated average rate of pumping into Perkiomen Creek, and from usage of a more recent analysis of low flows. As mentioned previously, the revised channel widths and "n" values were from a field examination of the East Branch on March 26, 1979. The new flood flow computations took into account overbank flow but channel velocites are used for the comparison with the originally estimated velocities.

Selected Low, Median and Flood Flows. Same procedure was followed as for the original computations, except that the low and median flows were recomputed using a publication with a more recent analysis of stream flows, namely, PaDER's Water Resources Bulletin No. 12, "Low Flow Characteristics of Pennsylvania Streams" 1977. The flood flows of the original computations were not revised.

Low Flows. Revised per PaDER Water Resources Bulletin No. 12.

Median Flow. Revised per PaDER Water Resources Bulletin No. 12.

Average Stream Flow. Not considered meaningful so was not used.

One Year Flood. No change.

Mean Annual Flood. No change.

Five Year and Fifty Year Floods. No change.

Delaware River Pumpage. The average rate of pumping Delaware River water into the East Branch of Perkiomen Creek was estimated to be 35 MGD (54 cfs) in the original Study. With the more recent stream flow analyses of the Schuylkill River and Perkiomen Creek, the average pumping rate is now estimated at 22.3 MGD (34 cfs), not including water losses in transit. This rate was used in the revised computations. The maximum Perkiomen Creek pumping rate of 42 MGD (65 cfs) remains the same.

Findings on Perkiomen Creek. Tables Nos. 1 and 2, attached, show the values of discharges (Q), flow depths (D), and flow velocities (V), which were developed in the original Study and used to evaluate the effects of the various flows on the East Branch stream channel. These are listed under the "Orig." column for the 7-Day, 2-Year low flow and the median flow, each for three conditions: (1) no pumpage from the Delaware River, (2) pumping at the estimated average rate, and (3) pumping at the maximum anticipated rate. All of these values have been recomputed to reflect changes in estimated pumpages and in stream channel characteristics; the revised values are shown on Tables Nos. 1 and 2 under the "New" column.

Table No. 3 shows the effects on flood flow characteristics for the original and the revised estimates of stream channel characteristics. A major change from the original hydraulic computations was taking of overbank flow into account; this had not been done in the original computations.

Low Flow Periods. With a lower average pumping rate and some revision of stream channel characteristics, there are minor changes in depths and velocities at the various channel sites. However, these changes are insignificant and do not alter the original findings regarding the effects of pumpages during low flow periods.

Median Stream Flow. There were no appreciable changes as a result of the updated pumping rates and stream channel characteristics. The only major change was in the period when a minimum pumpage of 27 cfs is to be maintained into the East Branch. Originally, it had been assumed to be year-around. The present concept is to maintain this minimum from the first day each year that the Schuylkill River and Perkiomen Creek are unable to supply the cooling water needs of the Limerick Plant to the day in late fall and early winter when the two streams are able to supply these needs on a continuing basis. Analyses of stream flow data indicate that, with this criteria, the minimum pumpage rate of 27 cfs will be maintained from mid-April to mid-November under average stream flow conditions. During this period, pumpages into the East Branch would be halted whenever floods occurred on this stream.

Flood Flows. The primary purpose of presenting data on the various flood flows was to show that the stream channel is subject to much greater flow rates, depths and velocities by natural flood flows than by the proposed pumpages from the Delaware River. This was emphasized by giving the ratio of the flow rates, depths and velocities of the flood flows to these same features of the pumpages during low flow periods, and with median flow. Now that the estimated average pumpage rate has been reduced from 54 cfs to 34 cfs, these ratios are greater than those originally calculated. Accordingly, the effects of the pumpages on the stream channel should be even less than had been originally anticipated.

Findings of Neshaminy Creek. The latest findings on Neshaminy Creek are presented in the NWSS EIR of 1979, and are not duplicated here.

Operation of Pumping Station. No change.

General Conclusions. No change. Elimination of the 27 cfs minimum pumpage rate into the East Branch of Perkiomen Creek during the late winter and early spring period is not expected to adversely affect the ecology of this stream. It is during this period when natural stream flows are greatest and the needs of the stream biota are at a minimum.

TABLE 1

SIMULATION OF
ESTIMATED WEEKLY WATER WITHDRAWALS DURING TWO UNIT,
FULL POWER GENERATION,
1974–1977[1]

Month	Total Weeks	WEEKS WATER WITHDRAWN FROM Schuylkill	Perkiomen	Delaware	Estimated Withdrawal From Delaware, CFS
January	16	16	0	0	0
February	16	16	0	0	0
March	17	17	0	0	0
April	19	18	0	1	43.5
May	16	6	4	6	23.8
June	17	3	0	14	46.2
July	19	0	3	16	39.4
August	16	0	0	16	45.1
September	20	0	3	17	40.7
October	16	3	3	10	27.6
November	16	12	1	3	37.5
December	20	20	0	0	0
TOTAL =	208	111	14	83	
% of Total	100%	53%	7%	40%	
Mean, Weeks/Year		28	3	21	

[1]Based on weekly means of 1) daily Perkiomen Creek flows (Graterford), 2) daily Schuylkill River flows and temperatures (Pottstown), and 3) hourly meteorology from LGS Tower No. 1. Concentration factor equals 3.34 and drift equals 0.017 percent of circulating water and service water flows.

COMPARISON OF ORIGINAL AND NEW STREAM FLOW DATA

Stream Channel Site No.	7 Day - 2 Year Low Flow in East Branch Perkiomen Creek with:																	
	No Pumpage						Average Pumpage						Maximum Pumpage					
	Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps	
	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New
1	1.06	1.24	0.06	0.09	0.19	0.20	55.0	35.2	0.59	0.66	0.98	0.81	66.1	66.2	0.65	0.89	1.07	1.13
2	1.03	1.20	0.05	0.05	0.22	0.17	55.0	35.2	0.51	0.37	1.14	0.71	66.1	66.2	0.56	0.49	1.24	0.99
3	0.95	1.11	0.04	0.05	0.28	0.25	55.0	35.1	0.43	0.37	1.49	1.05	66.0	66.1	0.48	0.50	1.60	1.46
4	0.92	1.07	0.04	0.05	0.22	0.22	55.0	35.1	0.40	0.35	1.34	0.94	66.0	66.1	0.45	0.48	1.43	1.31
5	0.86	1.00	0.03	0.04	0.22	0.19	55.0	35.0	0.36	0.31	1.15	0.82	65.9	66.0	0.40	0.42	1.24	1.15
6	0.77	0.90	0.04	0.04	0.21	0.18	54.8	34.9	0.44	0.31	1.32	0.82	65.8	65.9	0.49	0.42	1.42	1.15
7	0.71	0.83	0.04	0.05	0.19	0.19	54.8	34.8	0.48	0.46	1.19	0.89	65.8	65.8	0.53	0.62	1.29	1.24
8	0.65	0.76	0.05	0.06	0.17	0.16	54.7	34.8	0.61	0.51	1.18	0.80	65.7	65.8	0.68	0.69	1.27	1.12
9	0.52	0.61	0.03	0.06	0.21	0.23	54.6	34.6	0.47	0.60	1.40	1.25	65.6	65.6	0.52	0.82	1.52	1.74
10	0.40	0.46	0.03	0.06	0.17	0.20	54.4	34.5	0.54	0.72	1.31	1.19	65.4	65.5	0.61	0.98	1.39	1.65
10A	0.32	0.38	0.03	0.06	0.17	0.21	54.3	34.4	0.60	0.84	1.40	1.30	65.3	65.4	0.67	1.14	1.50	1.80
11	0.29	0.34	0.04	0.05	0.19	0.19	54.3	34.3	0.83	0.76	1.71	1.22	65.3	65.3	0.93	1.03	1.82	1.70
12	0.17	0.20	0.03	0.05	0.14	0.18	54.2	34.2	0.79	0.96	1.66	1.40	65.2	65.2	0.88	1.30	1.79	1.93
13	0.11	0.13	0.02	0.03	0.13	0.16	54.1	34.1	0.65	0.70	2.00	1.56	65.1	65.1	0.74	0.95	2.14	2.17
14	0.05	0.05	0.01	0.02	0.15	0.17	54.1	34.0	0.71	0.95	2.45	2.18	65.1	65.0	0.79	1.28	2.64	3.00
Average	0.59	0.69	0.04	0.05	0.19	0.19	54.6	34.7	0.56	0.59	1.45	1.13	65.6	65.7	0.63	0.80	1.56	1.57

Notes:

1. Original (Orig.) data are from Report dated July 8, 1970, titled "Investigation of the Effects of Proposed Pumpages on Stream Flows of East Branch Perkiomen Creek and North Branch of Neshaminy Creek".
2. New (New) data are from computations made in April 1979 using updated basic information.

TABLE NO. 1

COMPARISON OF ORIGINAL AND NEW STREAM FLOW DATA

Stream Channel Site No.	Median Stream Flow in East Branch Perkiomen Creek with:																	
	No Pumpage						Average Pumpage						Maximum Pumpage					
	Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps	
	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New
1	31.9	33.6	0.42	0.69	0.80	0.74	85.9	67.6	0.76	0.90	1.19	1.13	96.9	98.6	0.82	1.13	1.24	1.31
2	30.8	32.5	0.36	0.37	0.90	0.64	84.8	66.5	0.65	0.49	1.37	0.99	95.8	97.5	0.70	0.62	1.44	1.15
3	28.6	30.2	0.29	0.36	1.16	0.92	82.6	64.2	0.54	0.49	1.78	1.44	93.6	95.2	0.59	0.62	1.85	1.68
4	27.5	29.1	0.27	0.34	1.00	0.82	81.5	63.1	0.51	0.46	1.56	1.29	92.5	94.1	0.55	0.59	1.64	1.51
5	25.6	27.1	0.23	0.29	0.84	0.69	79.6	61.1	0.44	0.40	1.36	1.11	90.6	92.1	0.48	0.52	1.42	1.31
6	23.2	24.5	0.26	0.27	0.95	0.67	77.2	58.5	0.53	0.39	1.54	1.09	88.2	89.5	0.58	0.51	1.60	1.30
7	21.3	22.5	0.27	0.38	0.83	0.70	75.3	56.5	0.58	0.56	1.35	1.17	86.3	87.5	0.63	0.73	1.43	1.39
8	19.4	20.5	0.33	0.40	0.78	0.61	73.4	54.5	0.73	0.62	1.32	1.04	84.4	85.5	0.79	0.81	1.40	1.24
9	15.7	16.5	0.23	0.41	0.83	0.87	69.7	50.5	0.54	0.70	1.56	1.57	80.7	81.5	0.59	0.93	1.65	1.89
10	11.9	12.5	0.22	0.42	0.71	0.74	65.9	46.5	0.61	0.80	1.40	1.45	76.9	77.5	0.67	1.08	1.49	1.76
10A	9.7	10.3	0.22	0.44	0.69	0.76	63.7	44.3	0.61	0.91	1.49	1.56	74.7	75.3	0.73	1.24	1.57	1.90
11	8.6	9.1	0.28	0.36	0.82	0.68	62.6	43.1	0.90	0.80	1.81	1.45	73.6	74.1	1.00	1.11	1.91	1.78
12	5.1	5.4	0.20	0.34	0.64	0.64	59.1	39.4	0.83	0.97	1.73	1.60	70.1	70.4	0.92	1.07	1.84	1.74
13	3.2	3.4	0.13	0.19	0.62	0.60	57.2	37.4	0.69	0.69	2.02	1.76	68.2	68.4	0.76	0.98	2.18	2.21
14	1.4	1.4	0.08	0.15	0.56	0.61	55.4	35.4	0.72	0.90	2.47	2.41	66.4	66.4	0.80	1.30	2.66	3.02
Average	17.6	18.6	0.25	0.36	0.81	0.71	71.6	52.6	0.64	0.67	1.60	1.40	82.6	83.6	0.71	0.88	1.69	1.68

Notes:

1. Original (Orig.) data are from Report dated July 8, 1970, titled "Investigation of the Effects of Proposed Pumpages on Stream Flows of East Branch Perkiomen Creek and North Branch of Neshaminy Creek".
2. New (New) data are from computations made in April 1979 using updated basic information.

COMPARISONS OF ORIGINAL AND NEW STREAM FLOW DATA

FLOOD FLOWS IN EAST BRANCH PERKIOMEN CREEK

Stream Channel Site No.	One-Year Flood						Mean Annual Flood						5-Year Flood						50-Year Flood					
	Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps		Q in cfs		D in ft.		V in fps	
	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New	Orig.	New
1	1,470	NO CHANGE	4.2	5.5	3.5	3.6	4,200	NO CHANGE	7.8	9.0	5.1	5.2	6,132	NO CHANGE	9.7	11.0	5.9	6.0	12,600	NO CHANGE	14.7	15.6	7.4	7.3
2	1,400		3.5	3.0	4.1	3.3	4,000		6.5	5.3	5.9	5.2	5,840		8.1	6.6	6.8	6.1	12,000		12.4	9.1	8.7	7.5
3	1,295		2.8	2.9	5.2	4.7	3,700		5.2	4.9	7.6	7.0	5,402		6.6	6.2	8.7	8.4	11,100		10.1	9.2	11.1	10.7
4	1,260		2.6	2.4	4.6	4.2	3,600		4.8	4.6	6.8	6.3	5,254		6.1	5.8	7.8	7.6	10,800		9.3	8.5	10.1	9.7
5	1,225		2.3	2.4	4.0	3.7	3,500		4.2	3.9	6.0	5.3	5,110		5.3	4.9	6.9	6.4	10,500		8.2	7.3	9.0	8.3
6	1,155		2.7	2.3	4.4	3.6	3,300		5.0	4.0	6.5	5.6	4,818		6.3	4.9	7.4	6.5	9,900		9.6	7.0	9.6	8.2
7	1,050		2.8	3.2	3.8	3.7	3,000		5.2	5.2	5.6	5.4	4,380		6.5	6.3	6.4	6.3	9,000		10.0	9.1	8.3	8.0
8	945		3.3	3.4	3.5	3.2	2,700		6.2	5.6	5.2	4.7	3,942		7.7	6.7	5.9	5.3	8,100		11.8	9.3	7.5	6.6
9	805		2.3	3.6	4.0	4.5	2,300		4.4	5.5	5.9	6.3	3,358		5.5	6.5	6.9	7.0	6,900		8.4	8.7	8.8	8.6
10	682		2.5	3.9	3.5	3.9	1,950		4.6	6.1	5.1	5.4	2,847		5.7	7.1	5.9	6.1	5,850		8.8	9.5	7.6	7.4
10A	578		2.5	4.1	3.5	3.9	1,650		4.6	5.8	5.1	5.1	2,409		5.7	6.9	5.9	5.8	4,950		8.8	8.9	9.4	6.9
11	490		3.1	3.3	3.8	3.6	1,400		5.6	4.7	5.5	4.7	2,044		7.0	5.4	6.2	5.2	4,200		10.5	7.1	7.7	6.2
12	338		2.4	3.4	3.3	3.5	965		4.4	4.9	4.8	4.6	1,409		5.4	5.6	5.4	5.0	2,895		8.3	7.3	6.8	6.0
13	238		1.6	2.0	3.5	3.8	680		3.0	3.2	5.1	5.0	993		3.8	3.5	5.9	5.3	2,040		5.7	4.8	7.5	6.7
14	112		1.1	1.7	3.3	3.7	320		2.0	2.6	4.8	5.1	467		2.6	3.2	5.5	5.7	960		3.9	4.1	7.0	6.6
Average	870		2.6	3.2	3.9	3.8	2,484		4.9	5.0	5.7	5.4	3,627		6.1	6.0	6.5	6.2	7,453		9.4	8.4	8.4	7.6

Notes: 1. Original (Orig.) data are from Report dated July 8, 1970, titled "Investigation of the Effects of Proposed Pumpages on Stream Flows of East Branch Perkiomen Creek and North Branch of Neshaminy Creek".

2. New (New) data are from computations made in April 1979 using updated basic information.

TABLE NO. 3

SECTION V

WATER QUALITY

Perkiomen Creek Water Quality

Water quality studies of the Perkiomen Creek were initiated in May, 1974. Table 1 is a summary of Perkiomen Creek water quality data covering 1975 through 1977. These data were collected at P14390 (See Table 2 for description of sampling locations). The data are reflective of a moderately hard warmwater stream that receives moderate amounts of pollution. The mainstem Perkiomen Creek has an ionic base which fluctuates between sulfate and carbonate, and like the Schuylkill contains high concentrations of major cations and anions. The major cations and anions are at their highest concentrations July through November (Table 1). All transition series elements are found in low concentrations (Table 1).

Perkiomen East Branch - Water Quality

Water quality studies of the East Branch were initiated in May, 1974. While data were collected at four stations, only two, the upper E32300, and the lower, E2800, will be used in this discussion. Table 3 is a summary of water quality data from E32300 covering the period 1975 through 1977, and Table 2.4-9 is a summary of data from E2800 covering the same period. The water quality of the East Branch ranges from good at E32300 to highly degraded at E2800. This shift in quality is a result of allochthonous inputs from source to mouth. The ionic base of the Upper East Branch is carbonate and shifts to sulfate in the lower reaches. The East Branch has high concentrations of major cations and anions in the middly and lower reaches (Table 4); especially July through November when flow becomes intermittent. The lower reaches also have high concentrations of the ions considered essential plant nutrients and of certain transition series elements (i.e. iron, manganese, zinc, copper, and chromium). The quality of the Upper East Branch is not unlike that of the Delaware River at Point Pleasant while the quality of the Lower East Branch is similar to that of the Schuylkill.

Delaware River - Water Quality

Water quality studies of the Delaware River were initiated in May, 1974. The water quality of the Delaware (1975 through 1977) is summarized in Table 4. Data in this table was collected at A11263 and depict a moderately hard warmwater stream with a carbonate ionic base. The quality of Delaware water is relatively good in that it is well buffered and does not contain excessively high concentrations of major cations and anions or ions considered essential plant nutrients (Table 4). Lead and zinc are the only transition series elements present in significant quantities. While temporal changes in Delaware water quality do occur, they are not as severe as the shifts on smaller streams because of the greater flow.

TABLE 1 • SUMMARY OF PERKIOMEN CREEK WATER QUALITY 1975 THROUGH 1978

STATION P 14390

PARAMETER	DEC, JAN, FEB MIN	MED	MAX	MAR, APR, MAY MIN	MED	MAX	JUN, JUL, AUG MIN	MED	MAX	SEP, OCT, NOV MIN	MED	MAX
TEMPERATURE (C)	0.0	0.5	5.0	0.0	10.0	26.0	16.0	22.5	29.0	2.0	13.0	22.0
DISSOLVED OXYGEN (MG/L)	11.0	13.0	15.6	8.0	12.1	17.0	5.0	7.7	10.4	7.4	10.4	14.4
BIOCHEMICAL OXYGEN DEMAND (MG/L)	0.1	1.2	2.9	0.1	1.7	6.5	0.4	1.7	5.0	0.0	1.1	4.6
TOTAL ORGANIC CARBON (MG/L)	0.0	4.1	44.4	0.0	7.8	15.3	0.0	9.2	27.1	0.0	3.7	17.7
FLOW (CMS)	3	9	42	4	8	108	2	7	14	2	4	92
PH	7.34	7.59	8.62	7.24	7.77	9.54	7.43	8.04	8.61	7.39	7.94	9.03
TOTAL INORGANIC CARBON (MG/L)	31.9	52.5	81.4	24.4	39.7	58.1	7.2	60.9	79.5	35.0	68.0	92.8
TOTAL ALKALINITY (MG/L)	29.4	49.6	78.4	21.9	39.4	58.1	6.6	62.2	78.6	32.2	66.6	91.8
FREE CARBON DIOXIDE (MG/L)	0.0	2.0	5.0	0.0	1.0	3.0	0.0	1.0	4.4	0.0	1.5	3.5
TOTAL HARDNESS (MG/L)	57.0	80.0	129.3	49.4	73.7	96.2	67.3	86.0	106.4	48.8	102.0	120.7
SPECIFIC CONDUCTANCE (USM/CM)	167	215	339	136	194	288	180	247	336	155	277	332
TURBIDITY (JTU)	2.4	5.7	210.0	2.8	6.0	312.0	2.3	5.5	296.0	0.9	4.2	70.0
TOTAL SUSPENDED SOLIDS (MG/L)	0	6	251	0	7	717	0	9	274	0	6	69
TOTAL DISSOLVED SOLIDS (MG/L)	61	147	224	0	135	190	79	174	466	132	189	310
CHLORIDE (MG/L)	12.40	24.70	46.69	8.86	17.00	40.10	14.60	21.23	50.30	12.10	26.60	37.97
FLUORIDE (MG/L)	0.00	0.14	0.55	0.04	0.11	0.50	0.02	0.21	0.51	0.00	0.21	0.31
SULFATE (MG/L)	18.7	32.2	48.0	19.3	27.5	38.0	18.7	30.1	53.6	22.1	32.9	71.9
SODIUM (MG/L)	7.67	10.50	22.80	6.89	9.37	17.42	7.41	13.34	19.95	5.46	10.67	19.05
POTASSIUM (MG/L)	1.73	2.94	5.30	1.44	2.38	5.26	2.21	4.39	12.99	2.37	5.68	11.70
CALCIUM (MG/L)	13.30	19.21	34.61	12.93	18.04	28.40	16.19	23.45	39.90	12.97	24.26	37.90
MAGNESIUM (MG/L)	5.78	8.21	12.53	5.10	7.16	10.31	6.23	8.60	10.57	5.05	9.13	14.80
AMMONIA-NITROGEN (MG/L)	0.00	0.15	0.89	0.00	0.02	0.19	0.00	0.01	0.20	0.00	0.02	0.11
NITRITE NITROGEN (MG/L)	0.02	0.02	0.05	0.02	0.03	0.06	0.01	0.02	0.11	0.00	0.02	0.09
NITRATE NITROGEN (MG/L)	0.75	1.74	3.14	0.47	1.30	2.00	0.28	0.83	2.75	0.00	1.04	2.07
TOTAL PHOSPHATE PHOSPHORUS (MG/L)	0.06	0.12	0.24	0.05	0.09	0.61	0.09	0.17	0.94	0.07	0.15	0.35
ORTHO PHOSPHATE PHOSPHORUS (MG/L)	0.05	0.08	0.18	0.02	0.07	0.17	0.04	0.12	0.23	0.06	0.15	0.31
ARSENIC (MG/L)	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000
BERYLLIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BORON (MG/L)	0.00	0.17	0.59	0.06	0.15	0.24	0.00	0.12	0.41	0.00	0.16	0.31
CADMIUM (MG/L)	0.000	0.000	0.002	0.000	0.000	0.005	0.000	0.000	0.004	0.000	0.000	0.009
CHROMIUM (MG/L)	0.000	0.002	0.005	0.000	0.001	0.014	0.000	0.001	0.010	0.000	0.002	0.007
COPPER (MG/L)	0.003	0.008	0.017	0.001	0.007	0.033	0.003	0.007	0.122	0.000	0.007	0.012
IRON (MG/L)	0.090	0.269	2.814	0.091	0.270	8.988	0.089	0.280	7.487	0.102	0.277	1.119
LEAD (MG/L)	0.000	0.001	0.012	0.000	0.001	0.027	0.000	0.002	0.079	0.000	0.001	0.012
MANGANESE (MG/L)	0.004	0.054	0.197	0.012	0.042	0.444	0.000	0.063	0.272	0.005	0.029	0.272
NICKEL (MG/L)	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
SELENIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ZINC (MG/L)	0.000	0.012	0.119	0.000	0.010	0.076	0.000	0.012	0.092	0.000	0.006	0.045
MERCURY (UG/L)	0.000	0.000	0.905	0.000	0.000	0.300	0.000	0.000	0.400	0.000	0.000	0.500
COBALT (MG/L)	0.000	0.000	0.003	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 2 - SAMPLING LOCATIONS

STATION	LOCATION
P14390*	Perkiomen - Graterford Intake
E32300	East Branch - Headwaters
E2800	East Branch - Mouth
A11263	Delaware River - Point Pleasant Intake

* River meter

TABLE 3 . SUMMARY OF EAST BRANCH PERKIOMEN CREEK WATER QUALITY 1975 THROUGH 1978

STATION E 52300

PARAMETER	DEC, JAN, FEB MIN	MED	MAX	MAR, APR, MAY MIN	MED	MAX	JUN, JUL, AUG MIN	MED	MAX	SEP, OCT, NOV MIN	MED	MAX
TEMPERATURE (C)	0.0	0.0	3.5	0.0	9.0	23.0	15.0	21.5	27.5	0.5	12.0	20.0
DISSOLVED OXYGEN (MG/L)	9.2	12.8	14.2	6.6	10.6	13.6	4.9	6.9	9.8	5.0	9.0	12.8
BIOCHEMICAL OXYGEN DEMAND (MG/L)	0.0	0.8	5.2	0.0	1.1	5.7	0.2	1.6	4.3	0.0	1.4	6.3
TOTAL ORGANIC CARBON (MG/L)	0.0	0.1	14.9	0.0	7.4	11.8	0.0	8.6	93.4	0.0	3.5	29.1
FLOW (CMS)	0.15	0.48	3.23	0.01	0.34	2.08	0.00	0.11	0.91	0.00	0.07	2.53
PH	7.11	7.25	7.84	6.94	7.47	8.26	7.30	7.63	7.98	6.97	7.46	8.19
TOTAL INORGANIC CARBON (MG/L)	21.0	40.4	74.6	16.3	34.3	66.5	29.9	71.1	98.0	21.7	61.7	105.4
TOTAL ALKALINITY (MG/L)	18.0	35.4	72.4	13.0	32.0	60.9	28.9	69.8	93.0	19.8	62.4	95.7
FREE CARBON DIOXIDE (MG/L)	1.0	2.5	5.0	0.7	2.2	6.0	0.4	3.0	57.0	0.8	3.5	5.3
TOTAL HARDNESS (MG/L)	49.6	80.1	134.5	38.7	67.8	97.9	62.0	97.4	121.4	36.5	92.7	142.0
SPECIFIC CONDUCTANCE (USM/CM)	144	197	495	99	190	297	187	266	327	122	244	361
TURBIDITY (JTU)	2.4	6.5	200.0	3.2	6.5	276.0	1.7	5.3	50.0	1.2	4.7	110.0
TOTAL SUSPENDED SOLIDS (MG/L)	0	5	350	1	6	552	0	7	31	0	5	185
TOTAL DISSOLVED SOLIDS (MG/L)	89	141	294	0	119	250	124	183	241	120	182	261
CHLORIDE (MG/L)	11.70	20.66	109.40	7.80	17.01	35.70	9.51	25.50	47.38	7.90	24.88	41.47
FLUORIDE (MG/L)	0.00	0.01	0.40	0.00	0.02	0.11	0.00	0.10	0.46	0.00	0.10	0.21
SULFATE (MG/L)	20.6	35.8	69.0	20.3	31.0	40.1	24.9	32.3	38.6	21.5	34.8	82.1
SODIUM (MG/L)	7.28	9.85	57.21	5.12	9.22	18.31	8.27	14.10	28.80	4.27	10.71	18.05
POTASSIUM (MG/L)	1.53	2.16	3.80	1.33	1.89	3.16	1.91	2.86	5.45	1.76	2.99	47.91
CALCIUM (MG/L)	10.26	15.44	28.68	7.97	16.20	23.10	13.60	21.80	35.50	9.50	20.80	31.13
MAGNESIUM (MG/L)	5.65	9.88	15.94	4.57	8.70	12.35	8.00	11.25	14.73	4.67	12.04	16.14
AMMONIA-NITROGEN (MG/L)	0.00	0.00	0.14	0.00	0.01	0.15	0.00	0.00	0.14	0.00	0.00	0.06
NITRITE NITROGEN (MG/L)	0.00	0.01	0.04	0.00	0.01	0.08	0.00	0.01	0.40	0.00	0.01	0.09
NITRATE NITROGEN (MG/L)	0.42	1.82	4.08	0.00	1.20	2.57	0.00	0.15	1.55	0.00	0.42	2.78
TOTAL PHOSPHATE PHOSPHORUS (MG/L)	0.01	0.04	0.25	0.01	0.04	0.46	0.02	0.04	0.25	0.00	0.04	0.38
ORTHO PHOSPHATE PHOSPHORUS (MG/L)	0.00	0.02	0.09	0.00	0.03	0.08	0.00	0.02	0.07	0.00	0.02	0.18
ARSENIC (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BERYLLIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BORON (MG/L)	0.00	0.11	0.23	0.06	0.10	0.26	0.00	0.09	0.44	0.02	0.12	0.24
CADMIUM (MG/L)	0.000	0.000	0.001	0.000	0.000	0.005	0.000	0.000	0.005	0.000	0.000	0.004
CHROMIUM (MG/L)	0.000	0.001	0.005	0.000	0.001	0.008	0.000	0.001	0.004	0.000	0.001	0.006
COPPER (MG/L)	0.002	0.007	0.080	0.000	0.007	0.024	0.002	0.006	0.018	0.000	0.005	0.026
IRON (MG/L)	0.047	0.240	3.441	0.066	0.224	8.375	0.108	0.250	0.831	0.050	0.234	2.104
LEAD (MG/L)	0.000	0.001	0.134	0.000	0.002	0.025	0.000	0.003	0.009	0.000	0.001	0.012
MANGANESE (MG/L)	0.021	0.051	0.300	0.000	0.035	0.347	0.012	0.049	0.252	0.005	0.032	0.442
NICKEL (MG/L)	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.01
SELENIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ZINC (MG/L)	0.000	0.012	0.050	0.000	0.010	0.410	0.000	0.008	0.032	0.000	0.008	0.046
MERCURY (UG/L)	0.000	0.000	1.990	0.000	0.000	0.500	0.000	0.000	20.000	0.000	0.000	4.900
COBALT (MG/L)	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 4 • SUMMARY OF EAST BRANCH PERKIOMEN CREEK WATER QUALITY 1975 THROUGH 1978

STATION E 2800

PARAMETER	DEC, JAN, FEB MIN	DEC, JAN, FEB MED	DEC, JAN, FEB MAX	MAR, APR, MAY MIN	MAR, APR, MAY MED	MAR, APR, MAY MAX	JUN, JUL, AUG MIN	JUN, JUL, AUG MED	JUN, JUL, AUG MAX	SEP, OCT, NOV MIN	SEP, OCT, NOV MED	SEP, OCT, NOV MAX
TEMPERATURE (C)	0.0	0.0	5.5	0.0	10.0	26.0	15.5	22.5	28.0	1.0	12.0	21.0
DISSOLVED OXYGEN (MG/L)	9.6	12.7	15.8	8.8	11.8	18.8	4.0	8.0	11.1	7.2	10.0	15.0
BIOCHEMICAL OXYGEN DEMAND (MG/L)	0.2	1.2	3.2	0.5	1.4	8.7	0.3	1.4	4.0	0.0	1.1	6.3
TOTAL ORGANIC CARBON (MG/L)	0.0	2.4	98.6	0.0	8.0	15.8	0.0	11.6	17.6	0.0	4.6	21.9
FLOW (CMS)	0.41	1.80	12.13	0.20	1.17	5.88	0.00	0.28	1.47	0.00	0.29	3.20
PH	7.34	7.51	8.60	7.24	7.84	9.80	7.63	8.15	8.87	7.32	8.03	8.79
TOTAL INORGANIC CARBON (MG/L)	27.9	63.0	144.3	13.9	46.8	83.2	46.4	87.7	136.4	35.6	80.1	149.8
TOTAL ALKALINITY (MG/L)	24.0	60.4	132.1	12.3	48.3	83.2	44.1	88.4	133.1	32.2	87.4	148.3
FREE CARBON DIOXIDE (MG/L)	0.0	2.0	8.3	0.0	1.0	3.0	0.0	1.0	6.0	0.0	1.9	7.5
TOTAL HARDNESS (MG/L)	65.5	109.4	194.5	42.9	90.0	148.6	65.8	134.9	222.8	56.0	140.0	232.9
SPECIFIC CONDUCTANCE (USM/CM)	188	324	684	148	279	555	193	428	892	171	444	731
TURBIDITY (JTU)	2.0	6.7	210.0	1.6	4.9	284.0	1.1	4.0	140.0	0.7	3.4	105.0
TOTAL SUSPENDED SOLIDS (MG/L)	0	4	331	0	3	707	0	7	157	0	4	149
TOTAL DISSOLVED SOLIDS (MG/L)	107	205	460	45	177	341	149	280	380	169	297	458
CHLORIDE (MG/L)	19.14	40.80	103.00	14.20	32.30	87.20	10.01	56.18	79.70	22.50	50.90	105.70
FLUORIDE (MG/L)	0.00	0.07	0.45	0.00	0.09	0.21	0.03	0.19	0.41	0.00	0.17	0.34
SULFATE (MG/L)	24.6	47.0	99.9	19.3	38.7	64.0	22.1	55.0	118.7	34.1	61.5	813.6
SODIUM (MG/L)	10.19	23.55	48.57	8.78	18.20	46.59	11.20	38.13	62.04	9.38	22.60	73.82
POTASSIUM (MG/L)	1.84	3.13	6.53	1.90	2.93	5.06	3.08	5.14	8.15	2.69	4.90	8.02
CALCIUM (MG/L)	12.82	22.84	47.38	11.88	21.52	35.99	16.10	31.74	82.60	12.97	30.80	47.60
MAGNESIUM (MG/L)	7.62	12.20	21.84	4.63	9.88	16.10	7.10	12.58	18.01	5.74	14.67	22.00
AMMONIA-NITROGEN (MG/L)	0.00	0.28	3.98	0.60	0.07	0.75	0.00	0.00	0.62	0.00	0.02	0.15
NITRITE NITROGEN (MG/L)	0.01	0.04	0.30	0.02	0.03	0.26	0.00	0.02	0.17	0.00	0.02	0.11
NITRATE NITROGEN (MG/L)	1.44	2.94	4.30	0.22	1.87	3.63	0.00	0.79	2.38	0.00	1.76	3.67
TOTAL PHOSPHATE PHOSPHORUS (MG/L)	0.08	0.42	2.04	0.07	0.32	1.00	0.25	0.72	1.72	0.25	0.55	1.64
ORTHO PHOSPHATE PHOSPHORUS (MG/L)	0.05	0.33	1.87	0.11	0.23	0.71	0.14	0.57	1.60	0.23	0.45	1.32
ARSENIC (MG/L)	0.000	0.000	0.003	0.000	0.000	0.006	0.000	0.000	0.007	0.000	0.000	0.006
BERYLLIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BORON (MG/L)	0.00	0.19	0.56	0.10	0.18	0.27	0.07	0.23	1.73	0.00	0.18	0.50
CADMIUM (MG/L)	0.000	0.002	0.006	0.000	0.001	0.004	0.000	0.002	0.009	0.000	0.001	0.013
CHROMIUM (MG/L)	0.000	0.006	0.020	0.001	0.003	0.037	0.000	0.003	0.011	0.000	0.004	0.068
COPPER (MG/L)	0.003	0.009	0.024	0.005	0.012	0.109	0.004	0.009	0.447	0.001	0.009	0.021
IRON (MG/L)	0.010	0.187	2.971	0.000	0.147	8.808	0.005	0.227	3.698	0.006	0.125	1.787
LEAD (MG/L)	0.000	0.001	0.010	0.000	0.001	0.027	0.000	0.003	0.060	0.000	0.001	0.016
MANGANESE (MG/L)	0.004	0.042	0.197	0.000	0.028	0.507	0.000	0.047	0.250	0.000	0.023	0.321
NICKEL (MG/L)	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.25	0.00	0.00	0.02
SELENIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ZINC (MG/L)	0.000	0.018	0.057	0.000	0.010	0.092	0.000	0.014	0.340	0.000	0.009	0.046
MERCURY (UG/L)	0.000	0.000	1.500	0.000	0.000	0.400	0.000	0.000	0.700	0.000	0.000	0.500
COBALT (MG/L)	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5 . SUMMARY OF DELAWARE RIVER WATER QUALITY 1975 THROUGH 1978

STATION A 11263

PARAMETER	DEC, JAN, FEB MIN	MED	MAX	MAR, APR, MAY MIN	MED	MAX	JUN, JUL, AUG MIN	MED	MAX	SEP, OCT, NOV MIN	MED	MAX
TEMPERATURE (C)	0.0	1.0	4.5	0.0	9.5	22.5	17.0	23.0	29.0	2.0	13.0	24.0
DISSOLVED OXYGEN (MG/L)	11.4	12.6	14.4	7.6	10.4	13.0	6.2	7.5	13.8	7.0	9.4	12.4
BIOCHEMICAL OXYGEN DEMAND (MG/L)	0.0	1.0	5.5	0.3	1.3	5.2	0.3	2.0	5.0	0.0	1.2	4.0
TOTAL ORGANIC CARBON (MG/L)	0.0	2.1	19.2	0.0	7.2	13.7	0.0	7.9	31.0	0.0	3.6	12.9
FLOW (CMS)	156	277	1862	264	419	841	132	226	541	98	268	741
PH	7.27	7.58	7.89	7.31	7.53	7.97	7.52	7.85	9.22	7.26	7.52	8.42
TOTAL INORGANIC CARBON (MG/L)	25.5	40.6	57.8	15.6	27.6	47.7	27.1	49.3	61.4	22.6	41.4	66.0
TOTAL ALKALINITY (MG/L)	23.4	38.4	54.0	14.3	26.3	45.9	26.1	47.4	60.3	11.4	38.8	62.5
FREE CARBON DIOXIDE (MG/L)	0.5	1.5	5.0	0.5	1.3	3.5	0.0	1.5	7.0	0.0	2.0	4.3
TOTAL HARDNESS (MG/L)	36.6	58.9	74.5	35.4	49.4	76.4	45.4	70.1	85.0	31.4	50.9	88.4
SPECIFIC CONDUCTANCE (USM/CM)	89	155	216	92	127	205	122	181	235	100	143	226
TURBIDITY (JTU)	2.0	3.4	21.0	1.7	4.8	68.0	1.1	4.2	35.0	0.5	3.5	43.0
TOTAL SUSPENDED SOLIDS (MG/L)	0	4	54	0	9	99	0	7	93	0	8	86
TOTAL DISSOLVED SOLIDS (MG/L)	47	100	166	0	97	133	91	117	160	66	108	317
CHLORIDE (MG/L)	7.44	11.34	22.21	4.90	9.07	26.79	7.01	11.70	18.77	1.00	11.62	32.07
FLUORIDE (MG/L)	0.00	0.01	0.47	0.00	0.03	0.10	0.00	0.10	0.64	0.00	0.07	0.26
SULFATE (MG/L)	12.3	21.1	35.8	14.6	20.0	28.5	14.1	27.3	31.5	7.8	21.8	38.5
SODIUM (MG/L)	3.44	6.50	10.74	3.29	5.47	8.32	4.99	7.05	19.29	3.05	5.06	10.34
POTASSIUM (MG/L)	1.07	1.44	2.10	0.93	1.26	2.06	1.23	1.63	2.71	1.18	1.71	3.09
CALCIUM (MG/L)	8.93	14.01	18.81	9.34	12.35	19.16	10.68	17.99	31.90	7.51	13.64	22.00
MAGNESIUM (MG/L)	3.31	5.75	7.16	2.67	4.74	7.49	3.40	6.99	9.41	2.55	5.18	9.20
AMMONIA-NITROGEN (MG/L)	0.07	0.26	0.55	0.00	0.10	1.00	0.00	0.03	0.18	0.00	0.06	0.29
NITRITE NITROGEN (MG/L)	0.01	0.02	0.04	0.01	0.02	0.05	0.02	0.04	0.08	0.01	0.04	0.07
NITRATE NITROGEN (MG/L)	0.59	0.89	1.52	0.32	0.64	1.21	0.38	0.96	1.35	0.11	0.75	1.54
TOTAL PHOSPHATE PHOSPHORUS (MG/L)	0.05	0.09	0.13	0.04	0.07	0.17	0.06	0.12	0.27	0.05	0.13	0.28
ORTHO PHOSPHATE PHOSPHORUS (MG/L)	0.02	0.06	0.23	0.01	0.04	0.09	0.02	0.06	0.13	0.03	0.07	0.17
ARSENIC (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BERYLLIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BORON (MG/L)	0.00	0.11	0.56	0.03	0.08	0.21	0.00	0.08	0.26	0.00	0.08	0.20
CADMIUM (MG/L)	0.000	0.000	0.003	0.000	0.000	0.003	0.000	0.000	0.010	0.000	0.000	0.003
CHROMIUM (MG/L)	0.000	0.001	0.005	0.000	0.001	0.004	0.000	0.001	0.011	0.000	0.002	0.006
COPPER (MG/L)	0.003	0.006	0.067	0.001	0.006	0.024	0.001	0.008	0.027	0.000	0.007	0.021
IRON (MG/L)	0.080	0.218	1.962	0.080	0.261	2.064	0.073	0.267	1.900	0.050	0.259	2.996
LEAD (MG/L)	0.000	0.001	0.006	0.000	0.002	0.010	0.000	0.004	0.020	0.000	0.002	0.012
MANGANESE (MG/L)	0.005	0.049	0.330	0.027	0.066	0.151	0.031	0.073	0.256	0.005	0.051	0.483
NICKEL (MG/L)	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.06
SELENIUM (MG/L)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ZINC (MG/L)	0.027	0.060	0.153	0.019	0.034	0.072	0.004	0.028	0.096	0.008	0.032	0.215
MERCURY (UG/L)	0.000	0.000	0.300	0.000	0.000	0.400	0.000	0.000	0.400	0.000	0.000	0.400
COBALT (MG/L)	0.000	0.000	0.003	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000

SECTION VI

WATER TEMPERATURE

WATER TEMPERATURE OF THE DELAWARE RIVER, EAST BRANCH OF THE PERKIOMEN CREEK AND THE PERKIOMEN CREEK

Supplementary Materials Prepared for the Delaware River Basin Commission

Hourly water temperature readings have been obtained from four thermographs located along the Limerick water transfer route. The thermograph referred to as TEMP_5 in the attached tables is located on the Delaware River near the Point Pleasant water transfer intake, Temp_4 is on the East Branch of the Perkiomen upstream of the Bucks Road bridge near the inflow point of the transfer pipeline, Temp_3 is located on the East Branch beneath the Garges Road bridge and Temp_2 is on the main stem Perkiomen Creek at the site of the Graterford intake.

The attached tables are analyses of data recorded from July 31, 1974 to June 2, 1977 and are based on daily average temperatures.

Table 1 gives the N size, mean, standard deviation, minimum value and maximum value for all years combined and for each year individually for the months of diversion, May--October. A Duncan's multiple range test for difference between location means showed that for all years combined the mean temperatures for the Delaware River, lower East Branch and Perkiomen locations were not significantly different. Table 2 shows the same statistics as Table 1, except that the period of interest is January--December. Table 3 presents the monthly means for all years combined.

THERMOGRAPH TEMP_2 IS ON
THE PERKIOMEN, TEMP_3 AND TEMP_4 ARE ON THE EAST BRANCH
AND TEMP_5 IS ON THE DELAWARE
MAY-OCTOBER, 1974-1977

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	450	20.64	4.45	6.85	28.62
TEMP_3	463	19.35	5.01	5.45	29.05
TEMP_4	279	16.77	4.47	4.57	25.00
TEMP_5	396	18.99	4.99	6.72	26.59

YEAR=74

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	68	21.93	3.83	11.67	27.22
TEMP_3	93	18.19	6.07	5.96	27.29
TEMP_4	52	16.25	3.96	8.99	23.32
TEMP_5	93	18.83	5.97	7.88	26.59

YEAR=75

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	165	20.61	4.16	9.57	28.62
TEMP_3	181	20.09	4.30	7.81	29.05
TEMP_4	68	16.20	3.94	6.05	24.1[illegible]
TEMP_5	97	18.75	4.44	11.08	25.40

YEAR=76

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	184	20.41	4.95	6.85	27.33
TEMP_3	156	19.20	5.22	5.45	27.77
TEMP_4	126	17.16	5.10	4.57	25.00
TEMP_5	173	19.31	4.91	6.72	26.27

YEAR=77

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	33	19.35	3.45	12.74	24.02
TEMP_3	33	19.18	3.62	12.24	24.20
TEMP_4	33	17.29	3.47	9.93	22.07
TEMP_5	33	18.50	3.84	12.84	23.97

TABLE 2

THERMOGRAPH TEMP_2 IS ON
THE PERKIOMEN, TEMP_3 AND TEMP_4 ARE ON THE EAST BRANCH
AND TEMP_5 IS ON THE DELAWARE
1974-1977

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	946	12.41	9.06	0.00	28.62
TEMP_3	1009	11.72	8.70	0.02	29.05
TEMP_4	816	8.91	7.45	0.02	25.00
TEMP_5	694	11.50	8.17	0.23	26.59

YEAR=74

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	123	14.14	9.33	1.28	27.22
TEMP_3	154	12.84	8.52	0.25	27.29
TEMP_4	113	10.05	7.32	0.65	25.32
TEMP_5	154	13.71	8.17	1.93	26.59

YEAR=75

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	326	13.06	8.75	0.00	28.62
TEMP_3	365	12.57	8.57	0.10	29.05
TEMP_4	237	8.02	6.62	0.11	24.14
TEMP_5	219	11.86	7.44	0.37	25.40

YEAR=76

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	361	12.77	9.26	0.27	27.35
TEMP_3	333	11.51	8.96	0.02	27.77
TEMP_4	302	9.63	8.12	0.02	25.00
TEMP_5	357	11.91	8.58	0.23	26.27

YEAR=77

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	136	8.36	8.07	0.02	24.02
TEMP_3	157	9.10	8.08	0.03	24.20
TEMP_4	164	8.07	7.22	0.07	22.07
TEMP_5	164	8.07	7.14	0.33	23.97

THERMOGRAPH MP_2 IS ON
THE PERKIOMEN, TEMP_3 AND TEMP_4 ARE ON THE EAST BRANCH
AND TEMP_5 IS ON THE DELAWARE
1974-1977
MONTH=1

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	94	1.08	1.25	0.02	6.34
TEMP_3	94	1.05	1.42	0.06	7.22
TEMP_4	94	0.90	1.31	0.05	6.20
TEMP_5	85	1.25	1.06	0.37	5.07
MONTH=2					
TEMP_2	82	1.80	1.80	0.00	6.60
TEMP_3	83	1.81	2.23	0.03	7.52
TEMP_4	83	1.37	1.85	0.02	8.06
TEMP_5	57	2.56	1.69	0.33	6.74
MONTH=3					
TEMP_2	60	7.18	2.91	1.77	14.07
TEMP_3	85	6.70	3.23	1.25	15.77
TEMP_4	76	5.84	3.44	0.92	16.65
TEMP_5	71	5.81	2.14	1.75	10.81
MONTH=4					
TEMP_2	82	11.77	4.09	4.21	21.78
TEMP_3	101	12.68	4.30	3.80	22.80
TEMP_4	101	11.46	4.27	3.13	21.53
TEMP_5	101	11.12	3.89	3.26	20.30
MONTH=5					
TEMP_2	94	18.59	3.18	11.91	24.02
TEMP_3	94	18.43	3.24	11.72	24.20
TEMP_4	85	16.38	3.07	9.93	22.07
TEMP_5	85	16.73	3.19	12.12	23.97
MONTH=6					
TEMP_2	63	22.25	3.03	16.26	27.35
TEMP_3	61	22.46	2.97	17.06	27.77
TEMP_4	33	21.09	2.95	14.34	25.00
TEMP_5	27	21.97	2.22	17.67	25.18
MONTH=7					
TEMP_2	62	24.44	1.30	21.04	27.22
TEMP_3	36	24.22	1.47	20.73	27.29
TEMP_4	34	21.67	1.25	19.00	23.62
TEMP_5	61	23.55	1.19	20.04	26.59

TABLE 3 (Continued)

THERMOGRAPH : MP_2 IS ON
THE PERKIOMEN, TEMP_3 AND TEMP_4 ARE ON THE EAST BRANCH
AND TEMP_5 IS ON THE DELAWARE
1974-1977

MONTH=6

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	94	24.57	1.42	20.71	28.62
TEMP_3	94	23.98	1.77	19.11	29.03
TEMP_4	15	21.69	1.79	17.40	24.14
TEMP_5	69	24.38	1.40	20.90	26.27

MONTH=9

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	69	20.05	2.14	15.15	25.62
TEMP_3	85	18.75	2.45	12.87	24.94
TEMP_4	19	18.16	2.93	12.45	22.86
TEMP_5	61	19.72	2.18	15.50	24.62

MONTH=10

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	68	13.65	2.78	6.85	18.36
TEMP_3	93	12.20	3.13	5.45	18.35
TEMP_4	93	12.73	3.05	4.57	17.74
TEMP_5	93	12.73	2.77	6.72	17.49

MONTH=11

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
IP_2	85	7.08	3.65	1.62	15.83
TEMP_3	90	6.58	4.34	0.25	16.17
TEMP_4	90	6.87	4.70	0.89	18.47
TEMP_5	91	7.85	3.41	2.36	14.36

MONTH=12

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TEMP_2	93	2.26	1.76	0.14	7.48
TEMP_3	93	1.91	1.82	0.02	7.38
TEMP_4	93	1.87	1.72	0.11	7.63
TEMP_5	93	2.76	1.65	0.23	6.97

SECTION VII

AQUATIC BIOLOGY

PERKIOMEN CREEK

PERKIOMEN CREEK

Perkiomen Creek is located in the Triassic Lowland section of the Piedmont physiographic province, a rich farming area of rolling hills. It is a major Schuylkill tributary in this province and drains 938 km² of Lehigh, Berks, Bucks, and Montgomery counties.

The aquatic community of the Perkiomen Creek system has been influenced by man's long history of activities in the watershed. Water quality and flows have been altered, habitat changed or eliminated, and the species complex directly manipulated. Although these activities have probably reduced diversity somewhat, the community remains relatively stable and healthy.

The creek downstream of the East Branch confluence will be impacted by water diversion; water withdrawal will occur at Graterford. The Perkiomen Creek study area includes that stretch from Spring Mount Road bridge downstream to below U.S. 113 bridge (Fig. 1). Sample stations are designated by common name and by the letter 'P' followed by a number which indicates distance in meters from the mouth of the Creek. Where stations include several meters of stream, site numbers designate the downstream end of the station. A sampling history by program is given in Tables 1 and 2.

No major population centers occur within its relatively rural watershed which contains a number of small boroughs. Most surrounding land is residential or used for agriculture. Low base flows and frequent spates characterize an extremely variable flow regime. Spring flows are generally high due to snow melt and precipitation; late summer and early autumn flows are very low but subject to rapid fluctuation due to local thunderstorms.

Water quality near Graterford is relatively good with nutrient loading being the most serious stress. Nutrients enter the stream from both point and nonpoint sources and from Green Lane Reservoir. Primary point sources are municipal sewage treatment plants. Nonpoint source nutrients originate from on-site sewage treatment facilities and from agricultural runoff. Green Lane Reservoir also receives point and nonpoint source nutrients. Of 17 Pennsylvania lakes inventoried by the EPA's National Eutrophication Survey in 1973 and 1974, Green Lane was found to be most eutrophic (DVRPC and Chester-Betz Engineers

1977). Water released from the hypolimnion during summer stratification is anoxic and highly enriched with nutrients.

Phytoplankton

A qualitative study of phytoplankton in 1974 yielded 54 taxa (Table 3). Diatoms were represented by 22 genera and were found throughout the year. Green and blue-green algae were represented by 25 and 6 genera, respectively, and were found predominantly in summer and early fall. Seasonal succession of these three groups in Perkiomen Creek followed seasonal changes in water temperature.

The benthic diatom *Navicula* was the most common phytoplankter and occurred throughout the year; it was particularly abundant in winter. The planktonic diatom *Melosira* was abundant in late summer. Three genera (*Ankistrodesmus*, *Scenedesmus*, *Pediastrum*) of green algae were abundant phytoplankters; all were present in low numbers in winter and spring, and increased in summer. *Anabaena* was the only abundant genus of blue-green algae and was most common in summer.

In general, phytoplankton densities in Perkiomen Creek appeared to be low, and most abundant phytoplankters were of periphytic origin. For these reasons Perkiomen Creek was considered to be an area of low potential impact for phytoplankton.

Periphyton

Periphyton, an important primary producer in Perkiomen Creek, was studied from July through December 1973. Taxonomic composition was very similar to that in the East Branch and was almost exclusively diatoms. Maximum standing crop biomass (106 mg dry wt/dm^2) and production rate (8 mg dry wt/dm^2/day) were recorded in October; lowest values for both parameters occurred in December (Table 4).

Macrophytes

Macrophytes were not studied on Perkiomen Creek. Qualitative observations indicated that macrophytes were not common and they were therefore considered to be of low potential impact.

Zooplankton

Zooplankton was not studied in Perkiomen Creek because it was considered to be of low potential impact. Studies conducted in other temperate small streams have shown that zooplankton is typically low in density.

Macroinvertebrates

Benthic macroinvertebrates play an important functional role in most lotic ecosystems by converting allochthonous and autochthonous materials into temporary storage within their own tissue, thus ultimately becoming an essential component in the food web. Macroinvertebrates also shred coarse organic material (e.g., leaves) into finer particles that can be utilized by smaller macroinvertebrates.

A pilot study was conducted on Perkiomen Creek and East Branch Perkiomen Creek from June 1970 through December 1971. Data collected during this period were used to develop experimental design for a preoperational quantitative program which began in January, 1972, and was continued in 1973, 1974, and 1976. Only the riffle biotope was sampled quantitatively; it was common in the creeks and invertebrate diversity and production are typically highest in this habitat type. Pilot study data, because qualitative, were used only in the compilation of a species list.

Two locations were sampled on Perkiomen Creek (Spring Mount - P22000, above the East Branch confluence; Rahns - P13600, below), and six on East Branch Perkiomen Creek (Elephant - E36725, Branch - E32200, Sellersville - E26700, Cathill - E23000, Moyer - E12500, WaWa - E5600). For a summary of East Branch Perkiomen Creek macroinvertebrate sample history see Tables 1 & 2 in the following section on the East Branch.

SPECIES INVENTORY

A species list (Table 5) of macroinvertebrates collected by all methods (i.e., benthos quantitative and qualitative, drift; see references above) indicated that both creeks were characterized by a diverse macroinvertebrate assemblage. Representatives of all major orders of aquatic insects were collected between June 1970 and December 1976, as were planarians, annelids, isopods, amphipods, decapods, molluscs, and others. The more diverse groups were Arthropoda (82% of total taxa, primarily insects 96%), Annelida (8%; leeches 48%, worms 32%), and Mollusca (6%; snails 58%, clams 42%). The more diverse insect orders were Diptera, Coleoptera, Trichoptera, and Ephemeroptera. Diptera was represented by the greatest number of families and one family, Chironomidae, contained the greatest number of genera. Of the 301 taxa collected, 15 were considered abundant, 65 common, 97 uncommon, and 124 rare.

COMMUNITY DESCRIPTION

Based on quantitative sampling of the riffle biotope it was apparent that longitudinal changes in macrobenthos on East Branch Perkiomen Creek were strongly influenced by intermittent flow in the headwaters and degraded water quality in the middle section. Benthic invertebrates exhibited a high degree of resiliency in response to short-term phenomena such as spates and localized channelization. There were no major anthropogenic stresses operating on that section of Perkiomen Creek included in the study area and diversity (richness) was greater here than on the East Branch.

Faunal patterns, with few exceptions, were relatively constant as relative abundance data showed little variation among years. All forms of feeding mechanisms were represented among the dominant invertebrates as were primary, secondary, and tertiary consumers. Macrobenthos communities in both creeks were diverse and productive.

Standing Crop Numbers and Biomass

For both Creeks numerical and biomass standing crop data were highly variable among sites in the same month, and among months within year for the same site. When data from all months were combined and averaged by year, spatial trends in abundance were apparent (Table 6). Intermittent flow and degraded water quality reduced standing crop numbers on the upper (Elephant 4-yr mean, 5736 organisms/m²; Branch 8339/m²) and middle East Branch (Sellersville 8277/m², Cathill 6578/m²), respectively. Recovery, in terms of increased density, was evident in the lower section

(Moyer 14,925/m², WaWa 23,781/m²). Standing crops on Perkiomen Creek averaged 14,996/m² at Spring Mount upstream of the confluence and 12,906/m² at Rahns downstream of the confluence. Spatial trends in biomass density on both Creeks were like those for numbers; biomass at Cathill was particularly low in 1973 and 1974 due to the preponderance of small-size chironomid larvae.

In general Perkiomen Creek stations (Table 6) and the East Branch, all stations combined (Tables 7 and 8), showed an increase in bethic density in all consecutive sample years. The marked increase in mean density on the East Branch between 1974 and 1976 was due largely to the increase in the fingernail clam Sphaerium rhomboideum at WaWa. Although 1972 was the year of Tropical Storm Agnes (greatest flood of record), invertebrate density was reduced below normal only in June and there was little effect on the annual mean.

Within-year trends in total standing crop largely reflected the population dynamics of dominant organisms described below under 'Important Species'. In general total numbers and biomass were greatest in fall (Table 9).

Richness

Taxonomic diversity, richness component, of riffle benthos was high in both creeks throughout the year. On East Branch Perkiomen Creek annual diversity (Table 6) was highest at upstream stations (Elephant 4-yr mean, 59 taxa; Branch 55), decreased at Sellersville (52), and reached a low midpoint on the Creek at Cathill (32). Diversity then increased with increasing distance downstream (Moyer 46, WaWa 47) but did not recover to levels found in the headwaters.

High richness at Elephant was due in large part to intermittent flow which typically occurred in late summer and fall. Surface flow often ceased during this period and riffle habitat was replaced temporarily by isolated pools maintained by subsurface percolation. This change to pool habitat, still effectively sampled, was accompanied by an invasion of 'quiet water' species, primarily of the groups Hemiptera and Coleoptera. The relatively large fluctuations in total taxa collected between years at Elephant and perhaps Branch may have been related to the intensity and duration of discontinuous flow.

Diversity at Sellersville was below that at Branch but was still relatively high. This station was sporadically subjected to storm sewer discharge from two pipes under the Main Street Bridge. Quantitative sampling transected the entire channel directly downstream of the bridge at this site and both affected and unaffected areas were sampled. The relatively high diversity here may not indicate an entirely healthy environment but rather a diverse set of water quality conditions.

The reduction in benthic richness at Cathill was due to the station's continual exposure to the Sellersville Borough sewage treatment plant effluent, A zone of recovery extended the remaining length of Creek.

The annual total number of taxa collected on the East Branch, all stations combined, decreased slightly from 1972 to 1974 but increased to a maximum in 1976 (Table 7). This variability reflected (1) annual variation in the intensity of perturbations already discussed (i.e., intermittency, effluent degraded water quality), as well as short term stresses such as spates at all stations, stormwater input at Sellersville, channelization at Branch in June 1974, etc., (2) decrease in sample size from 5 to 4 replicates in July 1973; in general more uncommon taxa are collected as 'n' increases, and (3) absence of sampling in winter 1974. The June 1972 flood had little effect on annual diversity.

Benthic diversity was greater on Perkiomen Creek than on the East Branch, and slightly greater above the confluence (Spring Mount 68) than below it (Rahns 63) (Table 6). Flow at Spring Mount was near torrential, substrate was mixed rubble and supported an epilithic algal community for much of the year. Flow at Rahns was more laminar and the compacted sand-gravel substrate (overlain by few large rocks) was susceptible to scouring during high water periods.

Similarity Between Stations

Monthly computation of Morisita's index of overlap provided a single value denoting benthic community similarity between selected pairs of stations in terms of taxonomic composition and abundance; the higher the value (range 0-1) the more similar. Yearly means were determined by averaging all monthly values within the year. Similarity between adjacent sites on East Branch Perkiomen Creek, excluding Chironomidae, ranged from lows of 0.426 and 0.431 (4-yr means) between Elephant, Branch, Cathill and Moyer respectively, to 0.675 between Moyer and WaWa (Table 6). Mean index values for the East Branch, all stations combined, were very similar in all years but 1976. Monthly variability was high. Similarity between the two Perkiomen Creek stations was higher (0.727) than that for any East Branch pair.

In addition to computing Morisita's index of overlap between adjacent stations, all East Branch sites were compared individually with Moyer station. The East Branch shows pronounced longitudinal differences in macrobenthos due primarily to intermittent flow in the headwaters and degraded water quality midpoint on the Creek. Moyer is considered on the basis of flow regime, substrate composition, faunal assemblage, and magnitude of stress to be the site which presently is most indicative of what more (in terms of length of stream) benthos may be like after Diversion. East Branch pairings with Moyer gave the following 4-yr mean values, in decreasing order; WaWa (0.675, most similar), Branch (0.598), Sellersville (0.493), Cathill (0.425), and Elephant (0.367, least similar). It is expected that similarity between stations will increase following Diversion as flow and water quality conditions become more similar throughout the Creek.

Overlap values which included Chironomidae (not shown) were higher in all instances due to the abundance of this group at all sites. These values overestimated similarity in one sense because the taxonomic composition of Chironomidae was known to differ, in some cases markedly, between stations.

IMPORTANT SPECIES

Within-year and between-year trends in standing crop largely reflected the population dynamics of dominant organisms. Dominant species (taxa in this case since not all macroinvertebrates were identified to species) are defined as those organisms, collected in quantitative benthic samples, which comprised 2% or greater of the total number or biomass for the station and year under consideration. Because of their high relative and absolute abundance, they were largely responsible for biotic interactions within the community and hence were considered 'important' to existing community structure, function, and stability. Dominant (important) taxa were selected for each station, as well as for the East Branch all stations combined, because benthic communities differed along the Creeks and a gradational spatial response to Diversion is anticipated.

Taxa meeting this criterion were (1) numbers only - Caenis sp., Tricorythodes sp., Perlesta placida, and Leucotrichia pictipes, (2) biomass only - Erpobdella punctata, Cambarus bartoni, Orconectes limosus, Argia spp., Corydalus cornutus, and Tipula spp., and (3) numbers and biomass - Dugesia spp., Oligochaeta, Ephemerella spp., Baetis spp., Stenonema spp., Allocapnia spp., Corixidae, Psephenus herricki, Stenelmis spp., Chimarra spp., Cheumatopsyche spp., Hydropsyche spp., Simuliidae, Chironomidae, Physa acuta, and Sphaerium spp. These 26 taxa represented 19% of the total number (139) of taxa collected in quantitative benthic samples during the 4-yr study period.

The temporal (Table 9) and spatial (numbers, Table 10; biomass, Table 11) distribution of these taxa during the 4-yr study period are discussed in phylogenetic order below.

Dugesia spp.: Two species of this flatworm were found in the Creeks, D. dorotocephala and D. tigrina, with the former by far the more abundant. D. dorotocephala is eurythermic, tolerant of moderate organic pollution, and has an ecological preference for headwaters. D. tigrina is a eurythermic species occurring in the lower stretches of rivers. Both species are carnivorous and feed on living, dead, or crushed animal matter.

In the creeks Dugesia (primarily D. dorotocephala) was present in all months but attained maximum densities in August through November. It was dominant at Branch, Sellersville, Moyer, and WaWa (the station of maximum numbers and biomass) and essentially absent at Cathill. D. tigrina was found in Perkiomen Creek and was dominant at Spring Mount.

Oligochaeta: Four families comprised the majority of numbers or biomass of benthic oligochaetes; Lumbriculidae, Naididae, Tubificidae, and Lumbricidae. The first three are strictly aquatic whereas Lumbricidae is almost entirely terrestrial. Lumbricids were taken in samples from all stations only occasionally but their relatively large size made them important contributors to total worm biomass.

Lumbriculids were common at all stations except Elephant and Cathill and their density appeared to be inversely correlated with tubificid density. Two types were encountered, one with simple setae (common) and one with bifid setae (rare). This family was more abundant on Perkiomen Creek than on the East Branch. They are intermediate in size between Lumbricidae and Tubificidae.

Naididae was found principally at Sellersville and to a lesser extent Cathill. Species identified were Ophidonais serpentina, Nais communis, Pristina breviseta, and P. foreli. These worms were periodically abundant in benthic samples but because of their small size (about 3 mm) contributed little to standing crop biomass.

Tubificids ('sludge-worms') were found at all stations but occurred in greatest abundance at Sellersville and Cathill. Species identified were Limnodrilus hoffmeisteri, L. claparedianus, Branchiura sowerbyi, Peloscolex ferox (Elephant station only), and Aulodrilus limnobius. Increased numbers of tubificids in the vicinity of organic effluents is well documented and can be attributed mainly to the adaptation of the respiratory physiology of the worms to very low oxygen concentrations or even anaerobic conditions. Some tubificids (including L. hoffmeisteri) have high tolerance limits for lead and zinc in solution. Riffle is not optimum habitat for either Tubificidae or Naididae since both prefer fine sediments in which to burrow and feed.

In the Creeks, oligochaetes were dominant at all sites but WaWa and reached maximum densities at Sellersville. They were collected year-round and there were no obvious seasonal trends in abundance. Except for day-active Naididae, oligochaetes were not often collected in drift. As a group oligochaetes are sediment ingestors deriving most if not all of their nutrition from bacteria.

Erpobdella punctata: This is one of the most commonly encountered and widely distributed species of freshwater leeches in North America. It is both predator (primarily oligochaetes and insect larvae) and scavenger. This leech is associated with polluted conditions. It was found in low numbers at all stations and was dominant in terms of biomass only at Sellersville. Individuals were present year-round with highest numbers present in summer and fall.

Cambarus bartoni and *Orconectes limosus*: Crayfish are principally omnivorous scavengers, seldom predaceous. They were most numerous and most often collected at Elephant station and were taken sporadically and in low numbers at other stations. Only 1, 2, and 3 individuals were collected at Cathill, WaWa, and Rahns stations, respectively, in the study period. *C. bartoni* was the abundant species in the upper 10 km of East Branch Perkiomen Creek whereas *O. limosus* was essentially the only species inhabiting riffle habitat in the lower 26 km and on Perkiomen Creek. Crayfish were not abundant numerically but were often important contributors to biomass, particularly at upper East Branch stations.

Discontinuous flow was less severe in 1973 and 1974 and this may account for the higher crayfish densities in these years at Elephant station. The sampling method provided reliable estimates of crayfish density in riffle habitat; crayfish prefer to secrete themselves during the day under stones, and stones of applicable size were routinely included within the sampling unit.

Caenis sp.: No key to the immatures of this mayfly genus exists but only one species appeared to be present. *Caenis* appears to be more tolerant of low dissolved oxygen concentration than any other mayfly. Like *Tricorythodes* its preferred habitat is those areas of streams which have greatly reduced current or no current, so their abundance in the Creeks is probably greatest in non-riffle habitat. Feeding habits of nymphs are like those of *Tricorythodes*. *Caenis* was found at all stations but was dominant only at Branch. Maximum densities occurred in September through November.

Tricorythodes sp.: No key to the immatures of this mayfly genus exists but only one species appeared to be present. Nymphs are fairly common among gravel in permanent streams. Nymphs are detritivore-herbivore (active scrapers). *Tricorythodes* was a night-active drifter. It was rarely collected on the East Branch but was numerous on Perkiomen Creek, particularly at Rahns. Generally it was found only in June through October and was most abundant in September.

Ephemerella spp.: Three species of this mayfly were found in the Creeks but only *E. deficiens* was common. It is associated with vegetation in rocky, swift, unpolluted streams. Nymphs are herbivorous. Rarely taken on the East Branch, Ephemerella was dominant at both Perkiomen Creek stations. It was present in all months but attained highest densities in May and July through December.

Baetis spp.: At least five species of Baetis mayflies were found in the Creeks. The only numerous species keyed to B. intercalaris in Burks (1953). Baetis is common in shallow running water under stones or among debris or emergent vegetation along the banks of brooks or creeks. With few exceptions nymphs are herbivores or scavengers, living on vegetable detritus and minute aquatic organisms, principally diatoms. Baetis spp. were dominant at all stations except Elephant and Cathill (essentially absent), and Moyer. Maximum densities occurred in May through September. Baetis spp. were commonly collected in drift samples and were night-active.

Stenonema spp.: Eight species of Stenonema mayflies were found, three of which were commonly collected: Stenonema (=Stenacron) interpunctatum at Elephant, and S. nepotellum and S. rubrum on Perkiomen Creek. The S. (=Stenacron) interpunctatum complex is at present only superficially known and contains several subspecies; ours appears to be S. (=Stenacron) interpunctatum heterotarsale. All three species are considered facultative and herbivorous. Maximum densities occurred in fall. Stenonema was common in drift and night-active.

Argia spp.: No regional key to species based on the immature stage is available, but apparently at least two species of this damselfly were present, one of which was rare. The common species keyed to A. apicalis in Walker (1953). The carnivorous nymphs occur commonly in streams where they cling to rocks and debris in the current. Argia was collected at all stations and was dominant at Branch (numbers and biomass). Maximum densities occurred in fall.

Allocapnia spp.: Several species of Allocapnia were recorded from the Creeks but the common one was A. vivipara, found in greatest numbers at Elephant. It is a small, dark, brachypterous stonefly that emerges in mid-winter (hence the common name 'winter' stoneflies). It can be abundant in temporary streams, and feeds (chewing) on detritus and algae and is most abundant in allochthonous debris. Allocapnia was found in the upper East Branch and on Perkiomen Creek. Greatest densities occurred at Elephant in November through February. Nymphs were uncommon in April through October.

Perlesta placida: This stonefly has a wide tolerance for different types of streams, including intermittent ones. It is also one of the few stoneflies that emerges in mid and late summer. It is strictly carnivorous (chewing) and feeds principally on Chironomidae, Ephemeroptera, and other insects. P. placida was found in the upper East Branch and on Perkiomen Creek. Greatest densities were at Elephant in April through June. Nymphs were essentially absent the rest of the year.

Corixidae: The preferred lotic habitat of corixids, or 'water boatmen', is pools and quiet regions of streams. They were collected in high numbers in quantitative samples only at Elephant during extremely low flow periods when riffle habitat was temporarily replaced by standing water. All instars of Sigara modesta were often abundant in these pools coexisting with small numbers of Trichocorixa calva, a species with which it is commonly found. As herbivores corixids are unique among aquatic Hemiptera.

Corydalus cornutus: C. cornutus (adult commonly called the 'dobsonfly', larva the 'hellgrammite') is associated with larger components of substrate in riffle-run areas of well aerated streams. The larva is large (to 80 mm) and an active macropredator that feeds mainly on Simuliidae, Hydropsychidae, and Chironomidae. It was rare in East Branch Perkiomen Creek but dominant (biomass) in Perkiomen Creek. Numerical densities were similar and low throughout the year.

Psephenus herricki: Larvae of this beetle, known as 'water pennies' because of their flat and highly streamlined form, are aquatic and actively feed on algae and microcrustaceans. They exhibit a very strong positive thigmotaxis and prefer riffle habitat. It was collected at all stations in the study period but was most numerous in the lower East Branch and at Rahns (station of maximum density) on Perkiomen Creek. Maximum larval densities occurred in October and December and adults were collected incidentally in June through September.

Stenelmis spp.: Three species of this beetle were found in the Creeks but only one was abundant, probably *S. crenata*. *Stenelmis* is common in gravel substrate of streams, and both larvae and adults are aquatic herbivores. Adults, unlike larvae, showed a propensity to drift and exhibited a nocturnal behavioral periodicity. *S. crenata* has been recorded as tolerant of chlorides but sensitive to sewage and phosphate wastes.

Stenelmis was abundant in the creeks and was dominant at all but Cathill and Spring Mount. Larvae were present in high densities Arpil through November. Adults, like larvae, were collected year-round but were most numerous in June through November.

Chimarra spp.: Two species of this caddisfly occurred in the Creeks; *C. aterrima* was rare and *C. obscura* was abundant. *C. obscura* is the most widely distributed of the genus. It inhabits flowing water and constructs, on the undersides of rocks in riffles, fixed retreats that consist of elongate, saclike capture nets in which the larvae dwell and trap drifting food particles, generally smaller-sized particles than co-existing Hydropsychidae (e.g., *Cheumatopsyche* and *Hydropsyche*).

Chimarra was abundant in the Creeks and was dominant at most stations. It was uncommon at Elephant and Cathill. Larvae were most numerous in late summer and fall; pupae were collected from April through December and peak numbers occurred in July through September. At least some instars drifted and exhibited a nocturnal periodicity.

Cheumatopsyche spp. and *Hydropsyche* spp.: These two closely related genera of net-building caddisflies (family Hydropsychidae) are perhaps the most abundant and widespread caddisfly genera. The two genera are easily separable except for very early instars. Each genus in the Creeks contained multiple species. No key to larval *Cheumatopsyche* is available but adults of at least three species (*C. analis*, *C. sordida*, *C. campyla*) were taken in a light trap collection at Spring Mount.

Seven species of *Hydropsyche* occurred in the Creeks, based largely on the key to larvae by Ross (1944) and determinations by the Applicant's consultant which were based mainly on larval head capsule color patterns. Common species were 'A', 'C', and 'E'. Species 'A' larvae were largest and found principally in the lower East Branch and Perkiomen Creek. Species 'C' was numerous on both Creeks. Species 'E' was restricted primarily to Sellersville and Cathill.

The larvae are omnivorous and can be found in almost every stream that is not severely polluted. Here they build loose stone retreats and capture nets where current speed is suitable for efficient food (seston) gathering. Both genera were commonly collected in drift samples and exhibited an increase in density during darkness.

Although closely related the two genera exhibit differences in tolerance to organic enrichment and intermittent flow as evidenced by their contrasting spatial patterns in East Branch Perkiomen Creek. Cheumatopsyche was dominant at all stations in relatively high numbers whereas Hydropsyche was abundant at most stations but essentially absent from Elephant (discontinuous flow) and Sellersville and Cathill (degraded water quality). On East Branch Perkiomen Creek Hydropsyche outnumbered Cheumatopsyche only at WaWa. In Perkiomen Creek annual mean standing crop of Cheumatopsyche was roughly twice that of Hydropsyche. Cheumatopsyche in this system clearly had the competitive advantage. Larvae of both genera were most abundant in summer and fall and pupae were present from April through October.

Leucotrichia pictipes: L. pictipes is an easily recognizable, fast-water micro-caddisfly intolerant of organic pollution. Its case adheres tightly to the upper surface of stones and for this reason its numbers are certainly underestimated. It actively feeds on surrounding algae and associated detritus. It was essentially absent from upper and middle East Branch Perkiomen Creek, dominant in the lower East Branch (Moyer and WaWa), and common but not dominant on Perkiomen Creek. Highest larval numbers occurred in late summer and fall.

Tipula spp.: This is the largest cranefly genus and several species were collected in the Creeks. No key to the immatures is available. The only commonly encountered species was quite large (up to 70 mm extended) and on this basis was provisionally called T. abdominalis. It was collected most frequently in the upper East Branch. Preferred habitat is submerged vegetative matter in riffles, runs, or pools. They are detritivorous. Numerical densities were low and greatest in winter.

Simuliidae: Two genera of blackflies were identified from the Creeks, *Prosimulium* (rare) and *Simulium* (abundant). It is difficult to key larval *Simulium* to species but on the basis of pupae, *S. vittatum* was the most common species in the Creeks and is also one of the most common species in the U.S. Blackfly larvae are found in the shallows of streams where current is swift, their cephalic fans screening passing water for food particles. Some species of *Simulium* are very tolerant of organic pollution and can become abundant in partially polluted streams.

Simuliidae was abundant in the Creeks and was dominant at all stations. Larval standing crops were high throughout the year with peaks in May, September, and November. Pupae, also present in all months, were most numerous in May and June. Larvae were often abundant in drift and exhibited a nocturnal periodicity.

Chironomidae: The true midges were the most abundant and diverse group of invertebrates in the Creeks, comprising at least 37 genera (Table 5). Midge larvae and pupae were abundant at all stations throughout the 4-yr study period. Larvae often represented the highest percentage of total aquatic drift but did not exhibit any periodicity at the family level.

Four midge taxa were dominant in the Creeks; *Cricotopus* spp. (subfamily Orthocladiinae), *Polypedilum* spp. and Tanytarsini (subfamily Chironominae), and Pentaneurini (subfamily Tanypodinae). Larvae of the tribe Pentaneurini do not build cases and are predaceous; other insect larvae form a large portion of their diet. They were numerous in the upper East Branch, peaked in abundance at Cathill, and were much reduced in number farther downstream and in Perkiomen Creek.

Larvae of Tanytarsini (*Micropsectra* and *Tanytarsus*) were found at all stations in varying numbers but were present in maximum densities at Spring Mount where near torrential flow and rubble substrate were evidently conducive to the support of large populations. Larvae of stream species characteristically construct a fixed case and net that strains food particles from the current.

Two species of Polypedilum were found in the Creeks, P. fallax and P. illinoense. P. fallax was rare. The genus was found at all stations but maximum numbers occurred in the lower East Branch in summer. Larvae construct flimsy tubes, and food is derived from seston caught on temporary nets extending across the lumen of the tube or from actively grazing sediment. Other important taxa in the tribe Chironomini were Chironomus spp., Dicrotendipes sp., Microtendipes tarsalis, and Stictochironomus sp. Chironomini was not abundant on Perkiomen Creek.

Cricotopus spp. dominated the chironomid community at all but Elephant station and were most abundant at Spring Mount. Several species of this genus were recognized but only two could be identified with any degree of certainty, C. bicinctus and C. sp. 1 (Roback 1957). Roback (1957) found C. bicinctus to be the most common Cricotopus species in southeast Pennsylvania. It has been collected from intermittent streams and is particularly resistent to organic enrichment, low dissolved oxygen concentration, and at least some heavy metals.

Most Orthocladiinae are either algal or algal-detrital feeders, and larvae probably seek out and ingest their food directly from the substrate on which they live. In general the subfamily is more abundant in colder months. Cardiocladius obscurus was present in relatively high numbers at WaWa, Spring Mount, and Ramns. From field observation Orthocladius rivulorum was at times present in large numbers at Spring Mount inhabiting flexible tubes attached at one end to substrate surfaces.

In 1974 chironomid diversity was highest at Elephant probably because this station displayed the most varied flow conditions which ranged from intermittent (static) to flood. Fewest taxa were collected at WaWa.

Physa acuta: Physa snails collected from all stations on one date in 1977 were identified as P. acuta by William J. Clench (pers. comm.). The Applicant's consultant has often observed this snail out of water on rocks near the air-water interface although it probably cannot tolerate drying. Like most Physa species it is tolerant of organic enrichment and, by use of atmospheric oxygen for respiration, can exist in anaerobic waters for extended periods.

Physa is a scavenger and essentially omnivorous. The coating of living algae which covers most submerged surfaces forms the chief food, but dead plant and animal material is frequently ingested.

P. acuta was collected from all stations in the study period but was most numerous in the middle East Branch where on some occasions it was extremely abundant on all types of substrate. It was present in all months but reached maximum densities in late summer and fall.

Sphaerium spp.: At least two species of *Sphaerium* (fingernail clams) were found in the Creeks, *S. striatinum* and *S. rhomboideum*. The former was common at Sellersville, the latter abundant at WaWa. The family is considered to be tolerant of polluted conditions. *Sphaerium* was collected year-round and was present in greatest density (due to high numbers of young) in late summer and fall. *Sphaerium* spp. are sessile and utilize as a food source organic seston, filtered from the water brought in through the incurrent siphon.

DRIFT

Macroinvertebrate drift refers to the downstream transport of benthic macroinvertebrates in freshwater streams. Stream drift is utilized as a food source by many fishes and may play an important role in recolonization of depopulated areas and redistribution of benthos.

A pilot 24-h drift study was conducted on Perkiomen Creek at Graterford in August 1972, following which studies were conducted concurrently on the East Branch and Perkiomen Creeks once per month, April through October 1973 and April through September 1974. Study periods corresponded to the period when flow augmentation may have been required during plant operation. Concurrent sampling allowed a comparative assessment of drift between Creeks.

Aquatic drift densities on both creeks were variable over the study period and ranged from 471 to 11,012 animals/1000 m^3 on East Branch Perkiomen Creek and 321 to 11,492/1000 m^3 on Perkiomen Creek (Table 12). Although mean monthly numerical drift densities averaged 412% greater on Perkiomen Creek in the 13-mo study period, they were often similar to those recorded on the East Branch. Biomass (mg dry wt/1000m³) ranged from 22 to 453 and from 43 to 629 on East Branch and Perkiomen Creek, respectively. Monthly biomass densities were often similar between Creeks and averaged 14% greater in Perkiomen Creek. Mean monthly drift densities, numbers and biomass, were significantly ($P \leq 0.10$) correlated (Spearman's rank correlation coefficient) between streams. Total drift per unit time was consistently greater on Perkiomen Creek due to greater velocity (2.0-3.7 times greater on Perkiomen Creek) and discharge.

Drift densities varied, sometimes markedly, from month to month on the same Creek, and appeared to fluctuate in response to short-term phenomena which essentially precluded extrapolation of results to the entire month or even several days.

Sixty-one and 92 taxa were collected in drift samples from East Branch Perkiomen Creek and Perkiomen Creek, respectively, in the study period. When drift studies were combined by year within Creek it was evident that chironomid larvae and pupae dominated drift numerically in both Creeks (Table 12), followed by Baetis, Hydropsyche, and Cheumatopsyche. These organisms were also relatively abundant in most months. Naididae was dominant on Perkiomen Creek but was taken in high numbers only in May 1974.

More taxa were collected in Perkiomen Creek samples in all months. This reflected the greater benthic richness of Perkiomen Creek and the higher velocities which resulted in the chance capture of more organisms uncommon in the drift over an equal sampling period.

Generally the aquatic component accounted for the greatest percentage of total drift; emergent drifters were the next most numerous. Input from strictly terrestrial sources was smallest although certain insects were occasionally abundant.

Based on monthly estimates in 1973 the proportion of benthos in the drift ranged from 0.0009 to 0.0099% on the East Branch and 0.0020 to 0.1316% on Perkiomen Creek. Higher percentages would be expected at certain times in the life histories of individual populations. For example, a high proportion of pupal Cricotopus (midge) may be in the water column prior to eclosion.

Mean monthly densities of aquatic drifters per 1000 m³ in Perkiomen Creek were compared with benthic densities per

m^2 at Rahns (790 m downstream) in corresponding months. Although benthos, like drift, was dominated by Diptera and Trichoptera there was no clear or consistent proportional relationship between benthic standing crop and drift density. Note that benthic values were based on riffle habitat whereas drift organisms originated primarily from run habitat.

Sampling every 2 h provided data on diel periodicity of aquatic drift. Total densities varied markedly, but somewhat predictably over a 24-h period. Maximum densities (numbers and biomass) in both Creeks occurred after sunset since most drifters exhibited a nocturnal behavioral periodicity (Table 13), a phenomenon apparently unaffected by dissolved oxygen concentration, water temperature, or velocity as measured in this study. This relationship between invertebrate drift and changes in light intensity has been well documented (Waters 1972).

Dominant drift organisms (Table 12) that did not display a behavioral nocturnal drift were Chironomidae (no apparent periodicity) and Naididae (day-active). Chironomids as a group rarely exhibit a diel periodicity. This is not surprising since these insects are commonly diverse in lotic systems and their treatment at the family level may obscure any discrete but overlapping periodicities that may otherwise be evident at the genus or species level. Chironomidae was the most diverse family in the study area, comprising at least 37 genera. The number of taxa which drifted was also greatest during darkness (Table 13).

Fish

The fish community of Perkiomen Creek was typical of those found in other lotic systems of similar size in southeastern Pennsylvania. In general the fish fauna ranged from minnows, important as both primary consumers and forage for top-level carnivores, to the pike and sunfish families which are sociologically important for recreation and ecologically significant as key predators. With few exceptions the species were indigenous and reproduced locally.

Historically man has influenced the fish community of Perkiomen Creek by altering water quality, changing morphology and flow patterns with dams and reservoirs, and introducing or maintaining species by stocking. Operation of LGS may affect the existing fish community due to Diversion and water withdrawal (entrainment and impingement). In order to evaluate these impacts the fish community has been intensively sampled primarily by seine and electrofishing for 7 years.

SPECIES INVENTORY

A list of species collected from the Creek from 1970 through 1976 is presented in Table 14. Qualitative abundance was established by subjective comparison of recent catch statistics. Eight families including 40 species were inventoried as well as hybrids of Esocidae, Cyprinidae, and within-genus Lepomis. This was a relatively large number of species considering the limited area sampled and the historic and geologic factors that have reduced the number of species in mid-Atlantic streams. None of the species in Perkiomen Creek is considered commercially valuable, or rare or endangered by either Federal or State regulatory agencies. The American eel is the only true migratory species. Brook trout cannot maintain itself in Perkiomen Creek due to high water temperature, but has often been stocked in downstream tributaries by the Pennsylvania Fish Commission. Muskellunge was also stocked although the capture of one young individual in 1977 indicated limited natural reproduction had occurred.

COMMUNITY DESCRIPTION

Larval Fish

Larval fish drift in the area of the proposed Graterford intake (P14390) on Perkiomen Creek was investigated from 1973 through 1975. Larvae inhabiting the shoreline were studied using traps in 1975. Relative abundance of drifting larvae was similar among years (Table 15). Carp and minnows were first and second in abundance, respectively, while Lepomis spp. was usually third and white sucker fourth. With exception of carp, relative abundance of shoreline larvae was similar to that of drifting larvae; minnows were most abundant followed by white sucker and Lepomis spp. (Table 16).

Spawning extended from March through August. Larval drift densities were low through April, peaked in late May or early June, peaked slightly again in early July or August, and decreased through September. These variations were caused by species-specific spawning periods (Table 17). The perch family and white sucker spawned primarily in May. Two peak spawnings (early and mid-summer) occurred for both *Notropis* spp. and *Lepomis* spp. Spawning times varied somewhat among years due to environmental conditions.

Diel fluctuation in drift occurred regularly in Perkiomen Creek. Most larvae were collected between sunset and sunrise, and peak densities usually occurred between 2200 and 0400 h.

A horizontal gradient in abundance of drifting larvae was present in 1974 and 1975 with highest densities usually occurring near shore (Table 18). Horizontal distribution of individual taxa is discussed in following sections. Total drift density did not vary between channels in 1975 although differences did occur for some taxa (Table 19).

Minnows and Young

Twenty-nine species and *Lepomis* hybrids were collected by seine in 1975 and 1976 (Table 20). Most were minnows and young of larger species. The most abundant species (1975 and 1976 combined) were spotfin shiner (69% of total catch), spottail shiner (10%), satinfin shiner (4%), comely shiner (3%), and white sucker (3%). Each of the remaining species comprised less than 2% of total. Relative abundance of dominant species varied between 1975 and 1976. Minnows and young were generally more abundant in 1976 than in 1975. Within-year catches were highest in summer and fall months reflecting the appearance of young-of-year fishes (Table 22).

Redbreast sunfish and green sunfish dominated the electrofishing catch in 1975 and 1976; relative abundance of young sunfish was similar between years (Table 21).

Spotfin shiner was the most numerous species in each site for both years combined (Table 20). Relative abundance of other dominant species (spottail shiner, satinfin shiner, comely shiner, white sucker) varied little among sites. Total mean catch per net sweep was similar among sites.

Relative abundance of young sunfish was significantly correlated among sites in both years.

The number of species captured per seine collection was used as an index of species diversity. Diversity was significantly greater in 1976 than in 1975 and significantly greater in summer and fall than in winter and spring due to the appearance of young-of-year fishes during the former period (Tables 20 and 22). Spatial variability in diversity was due primarily to a signficantly greater number of species at P13580.

Adults

Twenty-one species of large fish were collected by electrofishing in 1974, 1975, and 1976 (Table 23). Esocid, Cyprinid, and Lepomis hybrids were also captured. Large fish populations were relatively stable in Perkiomen Creek as total catch was similar at the same site among years, and catch of the 16 most abundant species was significantly correlated among years and among sites. Redbreast sunfish was the dominant species at all sites in all years, comprising 49% of the total catch. White sucker (12%) and smallmouth bass (11%) were the next most abundant species followed by pumpkinseed, carp, green sunfish, and rock bass (each about 5% of total).

IMPORTANT SPECIES

Important fishes selected for Perkiomen Creek together with applicable criteria are presented in Table 24. Generally this diverse group includes the more sensitive fish of direct use to man and species important to the structure and function of the ecosystem. Those chosen are also likely to be affected by operation of Graterford intake. The local biology of important species is described below.

American Shad: American shad (*Alosa sapidissima*) was not found in Perkiomen Creek and its introduction is dependent on results of the Pennsylvania Fish Commission's program to provide fish passage-ways at dams downriver of LGS.

Muskellunge: Young muskellunge (*Esox masquinongy*) and its sterile hybrid with the northern pike (*Esox lucius*) were uncommon in Perkiomen Creek. Three individuals were taken in three annual electrofishing surveys at four sites (Table 23). Monthly electrofishing yielded four in 1977. No young were taken by seine in monthly sampling in 1975 and 1976; however one small (30 mm TL) individual captured in May 1977 indicated that limited natural reproduction had occurred in the Creek. Adults were also uncommon. One immature adult was captured in 1976 and one large (330 mm FL) individual was captured on three separate occasions in 1977. Populations have been primarily maintained by Pennsylvania Fish Commission stocking programs.

Carp: Spawning of carp (*Cyprinus carpio*) in Perkiomen Creek took place in May of both 1974 and 1975 at temperatures of 18 to 24 C. Abundance of drifting carp larvae varied somewhat among 1973, 1974, and 1975 although it was always the most abundant species (Table 15). Mean drift densities were 0.1126 individuals/m³ (50% of total drift) in 1973, 0.4328 individuals/m³ (80%) in 1974, and 0.1269 individuals/m³ (46%) in 1975. It ranked fifth in abundance of trap catches of shoreline larvae (Table 16). Maximum drift densities shifted from July in 1973 to May in 1974 and 1975 (Table 17). Carp frequently drifted during the day in May, but was always more numerous at night. Carp was generally more abundant in drift near mid-stream than near shore (Table 18). Post-larvae and juveniles inhabited sheltered areas of quiet water.

Numerically carp comprised a relatively small percentage of the electrofishing catch in all years (1974-1976) at all sites. Adult carp ranged from 1% of total catch at P14160 in 1975 to 9% at P20000 in 1976. Differences in relative abundance were slight at the same site among years. Carp was more abundant upstream of the intake site at P20000 (131 fish/ha) and P14390 (67), due primarily to abundance of preferred habitat (Table 26).

Carp was an important contributor to biomass at all sites and dominated at P14390 in 1974 and 1976. It ranked second at other sites where its abundance was estimated. Biomass estimates varied both temporally and spatially in the same manner as numerical estimates. Maximum length of carp collected in Perkiomen Creek was 680 mm FL. A recreational fishery for carp exists on Perkiomen Creek because of the fish's size and fighting ability.

Comely Shiner: In late July 1975 and 1976 young comely shiner (Notropis amoenus) appeared in seine catches from quiet, sheltered backwater areas downstream of runs and riffles. It ranked fourth in overall abundance in Perkiomen Creek seine catches (Table 20) and temporal and spatial variation was not significant. Total mean catch per net sweep increased slightly from 398 in 1975 to 437 in 1976.

The longest comely shiner collected was 85 mm FL. The length-weight relationship was significantly different between 1975 and 1976, and among sites. Fish were heavier in 1975 than 1976 (Table 28). Fish gained proportionately more weight per unit increase in length in an upstream direction.

Spottail Shiner: Spawning of this species (Notropis hudsonius) in Perkiomen Creek occurred from May through June in 1974 and 1975. Larvae were identified in drift. Spottail shiner ranked second in overall abundance in seine catches (Table 20). Adults were most often collected in slow-moving water over gravel shoals. Total mean catch per net sweep was significantly greater in 1976 (2444) than 1975 (189) and catches were highest in early summer when young appeared (Table 22). Distribution of individuals was more clumped in winter, but spatial variation of catch among sites was not significant.

Maximum length was 97 mm FL. The spottail shiner length-weight relationship was significantly different between years and among sites. Increase in weight with length was greater in 1975 than 1976 (Table 28). Faster growth in 1975 may have been due to reduced competition within the smaller population.

Spotfin Shiner: Based on larval collections spotfin shiner (Notropis spilopterus) spawned in mid-August 1974 and July through August 1975 at temperatures between 26 and 29 C It was the dominant species taken by seine comprising 69% of the total catch for 1975 and 1976 combined (Table 20). It appeared to have stable populations in Perkiomen Creek with no significant variation between years or among sites. Spotfin shiner total mean catch of spotfin shiner per net sweep was, however, significantly higher in late summer and fall than at other times (Table 22). Length-weight relationships were similar between years but significantly different among sites (Table 28).

White Sucker: White sucker (<u>Catostomus commersoni</u>) spawned early since drifting larvae were collected only in May. Larvae frequently drifted during the day but were always more numerous at night. Densities of drifting larvae were similar among years (1973-1975) (Table 15). White sucker usually ranked fourth in abundance and ranged from 1% of catch in 1974 to 5% in 1973. It ranked second in abundance (8%) in shoreline trap catches in 1975. In 1975 drifting larvae at P14390 were more abundant in the east rather than west channel

Seine catch of young white sucker increased from 6 individuals per net sweep in 1975 to 811 individuals per net sweep in 1976 (Table 20). Largest catches occurred at the extreme upstream and downstream seine sites in 1975 and 1976 combined. Mean catch per net sweep was 11 at P13580, 14 at P19775, and progressively declined from each extreme to 1 at P14455.

White sucker was the second most abundant large fish in Perkiomen Creek (Table 23). Differences in abundance between years was variable depending on site. Estimates at P14390 were not statistically different between 1974 and 1976, but estimates were higher in 1976 than in 1974 at P14020 and P14200 (Table 26). Spatial variation was also inconsistent. All three sites in 1974 had similar estimates of abundance. In 1976 abundance was less at P14390 and P14020 (139 and 258 fish/ha, respectively) than at P20000 and P14200 (314 and 334 fish/ha).

White sucker was the most important contributor to biomass at all sites except P14390 where it was exceeded by carp. Spatial and temporal trends were similar for biomass and number estimates . Most growth occurred in the first year of life (Table 29). White sucker at P14020 was significantly smaller at age II than individuals at other sites. No general trend in growth pattern was evident for length of white sucker in the area of Perkiomen Creek studied. A significant difference in length-weight regression coefficients existed among four sites in 1976. Fish gained proportionately more weight per unit increase in length in a downstream direction (Table 30).

Redbreast Sunfish: Larvae grouped as <u>Lepomis</u> spp. were third in overall drift abundance. The majority were probably redbreast sunfish because this species is the dominant adult in Perkiomen Creek, and most larval sunfish collected in 1975 were identified as this species. <u>Lepomis</u>

spp. comprised a consistent percentage of drift catch from 1973 to 1975 (4-8%). Composition of trap samples of shoreline larvae was similar (Table 16). Peak drift densities of <u>Lepomis</u> occurred in July 1973, mid-June 1974, and late June 1975. Larval sunfish were generally more abundant in samples taken closer to shore in 1975.

Redbreast sunfish young ranked eighth in overall abundance in the seine catch. Annual variation in abundance was not great; total mean catch per net sweep increased from 86 (1% of total catch) in 1975 to 181 (1%) in 1976 (Table 20). Electrofishing estimates of redbreast sunfish exhibited a similar trend (Table 21). Spatial variation among the six seine sites was slight. Redbreast sunfish comprised 1% of total catch at sites P14130 and P19775 and averaged 2% at all other sites. Electrofishing estimates varied from 24 fish per 20 m of shoreline at P14225 to 75 fish per 20 m at P14690 in 1976. (Table 25)

Redbreast sunfish was consistently the most abundant large fish in Perkiomen Creek (Table 23). It ranged from 36% of total catch at P20000 to 61% at P14200 in 1976. Annual variation for the total population was slight. Although estimates of age I were significantly lower in 1976 compared to 1974 at most sites, estimates of older age-groups were always similar (Table 27). Estimates by age group revealed that 1975 was a relatively weak year-class compared to 1973. Spatial variation in number of fish per hectare was great (Table 26). Site P14200 had the greatest density of redbreast sunfish both years (2026/ha in 1974, 1397/ha in 1976) followed by P14020 (897, 511), P20000 (415 in 1976), and P14390 (437, 338).

Maximum age in 1973 was V (Table 29). Greatest growth in length occurred in the second year. In 1976 temporal and spatial variation was evident among lengths at annulus. Fish were generally smaller at each annulus at P20000, larger at P14390, and approximately equal at P14020 and P14200.

Smallmouth Bass: Smallmouth bass (<u>Micropterus dolomieui</u>) larvae (unlike juveniles) rarely occurred in Perkiomen Creek drift. Young bass were relatively low in abundance (1% of total seine catch) although they comprised the second most abundant member of the sunfish family. Abundance varied annually, increasing from 27 fish per net sweep in 1975 (2% of total) to 142 (1%) in 1976. This species was more abundant at P14320, P20500, and P19775 where it accounted for roughly 2% of total catch. At other sites it averaged 1% of total.

Smallmouth bass was the third most abundant large fish (11% of total) based on 3 yr of electrofishing in Perkiomen Creek. Relative abundance remained constant within site between years. Population estimates were similar between 1975 and 1976 at P14200 but different between 1974 and 1976 at P14390. Estimates of abundance were larger at downstream sites. In 1976 site P14200 contained 203 fish per ha compared to 84 fish per ha at P14390.

Smallmouth bass ranked fourth in biomass at sites where abundance of all important species could be estimated. Biomass was greatest at sites where numerical abundance was greatest. Bass appeared to weigh less in 1975 than 1976 due to smaller size structure of the population. Individuals ranged up to 469 mm FL. An age and growth study in 1973 revealed that the oldest specimen was age III (Table 29). Most growth (39% of total) occurred in the first year of life. The 1970 year-class exhibited the highest growth rate. Significant spatial variation occurred for fish length at each annulus. Age structure indicated dominant age-groups I and II and a weak age-group III. Smallmouth bass was actively sought by fishermen in Perkiomen Creek.

Shield Darter: Peak spawning of shield darter (Percina peltata) occurred in May. Larval catches were consistently low in drift and trap samples. Number per m^3 ranged from 0.2% of total in 1974 to 1.0% in 1973 and 1975. Shield darters drifted during the day but were more numerous at night. Spatial distribution across the stream was fairly consistent (Table 18). Shield darter comprised 1% of the total seine catch in 1975 and 1976. Total mean catch per net sweep showed little temporal or spatial variation.

TABLE 1

NUMBER OF SAMPLES BY YEAR, PROGRAM, AND SITE COLLECTED FROM PERKIOMEN CREEK, 1972-1977.*

Program/Sites	1972	1973	1974	1975	1976	1977
Water Quality						
P18700	-	-	-	-	-	24
P14390	-	-	14	24	24	24
Phytoplankton						
P14390	-	-	11	-	-	-
Periphyton						
P14390	-	14	-	-	-	-
Benthic Macroinvertebrates						
P22000	12	12	9	-	11	-
P13600	10	12	9	-	11	-
Macroinvertebrate Drift						
P14390	12	84	72	-	-	-
Larval Fish Drift						
P14390	-	479	514	504	-	-
Larval Fish Trap						
P14390	-	-	-	84	-	-
Seine						
P19775	-	-	-	11	11	-
P16500	-	-	-	11	11	-
P14455	-	-	-	10	10	-
P14320	-	-	-	10	11	-
P14130	-	-	-	11	11	-
P13580	-	-	-	11	11	-
Small Fish Population Estimates						
P14830	-	-	-	-	3	-
P14690	-	-	-	3	3	-
P14585	-	-	-	3	-	-
P14225	-	-	-	3	3	-
P14210	-	-	-	3	3	-

TABLE 1 (Cont'd) (Page 2 of 2)

Program/Sites	1972	1973	1974	1975	1976	1977
Large Fish Population Estimates						
P20000	-	-	-	-	4	-
P19765	-	-	-	-	2	-
P14390	-	-	5	-	5	-
P14160	-	-	3	2	3	-
P14020	-	-	2	-	2	-
Age and Growth						
P20000						
White sucker	-	-	-	49	-	-
Redbreast sunfish	-	-	-	64	-	-
P19860						
Redbreast sunfish	-	51	-	-	-	-
Green sunfish	-	30	-	-	-	-
Smallmouth bass	-	9	-	-	-	-
P17400						
Redbreast sunfish	-	50	-	-	-	-
Smallmouth bass	-	28	-	-	-	-
P14390						
White sucker	-	-	-	33	-	-
Redbreast sunfish	-	53	-	65	-	-
Green sunfish	-	32	-	-	-	-
Smallmouth bass	-	40	-	-	-	-
P14160						
White sucker	-	-	-	46	-	-
Redbreast sunfish	-	-	-	64	-	-
P14020						
White sucker	-	-	-	36	-	-
Redbreast sunfish	-	-	-	56	-	-
P13580						
Redbreast sunfish	-	77	-	-	-	-
Green sunfish	-	41	-	-	-	-
Smallmouth bass	-	5	-	-	-	-

[1] See footnotes in Table 2.2.2-1 for definition of what constitutes one sample.

TABLE 2

NUMBER OF SAMPLES BY MONTH, PROGRAM, AND YEAR COLLECTED FROM PERKIOMEN CREEK, 1972-1977.[1,2]

Program/Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Quality												
1974	-	-	-	-	-	2	2	2	2	2	2	2
1975	2	2	2	2	2	2	2	2	2	2	2	2
1976	2	2	2	2	2	2	2	2	2	2	2	2
1977	4	4	4	4	4	4	4	4	4	4	4	4
Phytoplankton												
1974	1	1	1	1	1	-	1	1	1	1	1	1
Periphyton												
1973	-	-	-	-	-	-	-	4	3	4	2	2
Benthic Macroinvertebrates												
1972	1	2	2	2	2	2	2	2	2	2	2	1
1973	2	2	2	2	2	2	2	2	2	2	2	2
1974	-	-	-	2	2	2	2	2	2	2	2	2
1976	-	2	2	2	2	2	2	2	2	2	2	2
Macroinvertebrate Drift												
1972	-	-	-	-	-	-	-	12	-	-	-	-
1973	-	-	-	12	12	12	12	12	12	-	-	-
1974	-	-	-	12	12	12	12	12	12	-	-	-
Larval Fish Drift												
1973	-	-	-	48	26	120	95	96	24	-	-	-
1974	-	-	-	47	144	114	104	105	-	-	-	-
1975	-	-	-	-	144	72	144	144	-	-	-	-
Larval Fish Trap												
1975	-	-	-	-	24	12	24	24	-	-	-	-
Seine												
1975	-	4	6	6	6	6	6	6	6	6	6	6
1976	-	6	6	6	6	6	6	6	6	6	6	5

[1]See footnotes in Table 2.2.2-1 for definition of what constitutes one sample.
[2]Number of samples for Small Fish Population Estimate, Large Fish Population Estimate, and Age and Growth programs was not included because only annual data was utilized.

Table 3

MONTHLY QUALITATIVE LISTING OF PHYTOPLANKTON GENERA COLLECTED AT P14390 IN PERKIOMEN CREEK IN 1974.
VALUES ARE RECORDED AS FOLLOWS: X = PRESENT, C = COMMON, A = ABUNDANT.

	25 Jan	14 Feb	14 Mar	18 Apr	23 May	11 Jul	29 Aug	20 Sep	18 Oct	21 Nov	12 Dec
Chlorophyta											
Eudorina			X	X		X					
Pleodorina							C				
Volvox		X									
Chlorococcum							X	X	X	X	
Ankistrodesmus					X	X	C	C	C	X	X
Kirchneriella						X	X	X	X		
Selenastrum						X	X	X		X	X
Oocystis											X
Coelastrum						X	X	X		X	
Scenedesmus					X	X	A	C	X	X	X
Hydrodictyon	X										
Pediastrum	X	X	X	X	X	X	C	X	X		
Ulothrix	X	X	X								
Microspora									X		
Stigeoclonium	X		X	X	X						
Oedogonium				X	X						
Cladophora	X										
Mougeotia									X	X	X
Spirogyra	X		X	X	X						
Closterium				X	X		X	X	X	X	X
Cosmarium					X	X	X	X	X		
Desmidium									X		X
Staurastrum	X				X	X	X	X	X	X	X
Unknown - Flagellated		X	X	X	X		X		X	X	
Euglenophyta											
Euglena		X	X								
Pyrrhophyta											
Ceratium				X							
Bacillariophyta											
Dinobryon				X							
Mallomonas									X	X	X
Synura	X	X		X							
Coscinodiscus		X		X		X					
Cyclotella			X		X	X	X	X	C	X	X
Melosira	X	X	X	X	X	X	A	C	C	X	X
Stephanodiscus										A	X
Asterionella	X	X	X	X	X					X	X
Diatoma	X		X		X	X			X	X	X
Fragilaria	X	X	X	X	X	X	X	X	X	X	C

	25 Jan	14 Feb	19 Mar	18 Apr	23 May	31 Jul	29 Aug	20 Sep	18 Oct	21 Nov	12 Dec
Bacillariophyta (cont.)											
Meridion	x	x	x	x	x				x		
Opephora										x	
Synedra	x	x	x	x	x	x	x	x	x		x
Tabellaria		x	x		x						
Cocconeis						x	x	x	x		x
Gyrosigma				x		x	x		x		
Navicula	x	x	x	x	x	x	C	x	A	A	A
Gomphonema	x	x	x	x	x						
Cymbella		x	x	x	x	x	x	x	x	x	
Nitzschia	x	x	x	x	x	x	x	x	C	x	x
Rhoicosphenia									x		
Surirella	x	x						x			x
Cyanophyta											
Coelosphaerium							x				
Merismopedia		x					x				
Microcystis		x									
Oscillatoria	x	x	x	x	x	x	x	x	x		
Anabaena							A				x
Stichosiphon									x		

TABLE 4

PERIPHYTON PRODUCTION LISTED AS TOTAL BIOMASS (STANDING CROP) MG/DM² AND TOTAL PRODUCTIVITY RATES MG/DM²/DAY. VALUES (ASH-FREE DRY WEIGHTS) ARE LISTED FOR STATION 214390, PERKIOMEN CREEK, DURING 1973.

Date	Exposure Time (days)	Mean Ash-Free Wt. (mg/dm²)	Accumulation (mg)	Production (mg/dm²/day⁻¹)
17 Aug	10	58.7	-	
24 Aug	17	80.9	22.2	3.17
31 Aug	24	73.0	- 7.9	-1.13
7 Sep	7	74.2	-	
14 Sep	14	98.3	24.1	3.44
21 Sep	21	23.8	-74.5	-10.64
5 Oct	7	34.5	-	
12 Oct	14	90.7	56.2	8.03
19 Oct	21	105.7	15.0	2.14
26 Oct	7	18.1	-	
2 Nov	14	12.6	- 5.5	-0.79
9 Nov	21	29.8	17.2	2.46
12 Dec	12	4.2	-	
19 Dec	19	3.2	- 1.0	-0.14

SPECIES LIST AND RELATIVE QUALITATIVE ABUNDANCE OF MACROINVERTEBRATES COLLECTED BY ALL METHODS FROM ALL HABITATS IN EAST BRANCH PERKIOMEN CREEK AND PERKIOMEN CREEK, 1970-1976.*,**

PORIFERA
Spongillidae (U,28)
COELENTERATA
Hydra sp. (C,12)
PLATYHELMINTHES
Plagiostomidae
Hydrolimax grisea (U,21)
Planariidae
Dugesia dorotocephala (A,21)
D. tigrina (U,21)
NEMERTEA
Prostoma graecense (C,15)
NEMATODA (U,12)
BRYOZOA
Plumatella repens (C,12)
ANNELIDA
Oligochaeta
Lumbricidae (U,2)
Tubificidae
Limnodrilus hoffmeisteri (C,2)
L. claparedianus (U,2)
Branchiura sowerbyi (U,2)
Peloscolex ferox (U,2)
Aulodrilus limnobius (U,2)
Aeolosomatidae (U,2)
Naididae
Ophidonais serpentina (U,18)
Nais communis (U,18)
Pristina breviseta (U,18)
P. forelli (U,18)
Lumbriculidae (A,2)
Branchiobdellidae (U,2)
Hirudinea
Glossiphoniidae
Helobdella stagnalis (U,32)
H. lineata (R,32)
H. elongata (R,32)
Placobdella ornata (R,32)
P. parasitica (U,32)
Actinobdella triannulata (R,32)
Batracobdella phalera (R,32)
Piscicolidae
Piscicolaria reducta (R,24)
Piscicola milneri (R,24)
Erpobdellidae
Erpobdella punctata (C,32)
Hirudinidae
Haemopis marmorata (R,32)
Macrobdella decora (R,32)
ARTHROPODA
Isopoda
Asellidae
Asellus communis (C,38)
A. stygius (R,28)

ARTHROPODA (cont.)
Amphipoda
Talitridae
Hyalella azteca (U,28)
Gammaridae
Gammarus fasciatus (U,28)
Crangonyx gracilis (R,28)
Stygonectes sp. (R,19)
Decapoda
Cambaridae
Cambarus bartoni (C,28)
Orconectes limosus (C,28)
Hydracarina (C,28)
Collembola
Isotomidae
Isotoma sp. (C,28)
Isotomurus palustris (C,28)
Poduridae
Hypogastrura sp. (U,28)
Sminthuridae (U,28)
Ephemeroptera
Ephemeridae
Ephemera simulans (R,6)
Caenidae
Caenis sp. (C,12)
Tricorythidae
Tricorythodes sp. (C,12)
Ephemerellidae
Ephemerella deficiens (C,6)
E. attenuata (U,6)
E. dorothea (U,6)
Leptophlebiidae
Paraleptophlebia praepedita (U,6)
Choroterpes basalis (U,6)
Baetidae
Baetis intercalaris (A,6)
B. frondalis (R,6)
B. flavistriga (R,6)
B. cingulatus (U,6)
B. pluto (R,6)
Callibaetis fluctuans (R,6)
Ameletus lineatus (R,6)
Pseudocloeon myrsum (C,6)
P. punctiventris (U,6)
Heterocloeon curiosum (C,6)
Cloeon alamance (U,6)
Centroptilum sp. (R,6)
Siphlonuridae
Siphlonurus sp. (R,6)
Isonychia sp. (C,6)
Heptageniidae
Heptagenia sp. (R,6)
Stenonema (=Stenacron) (U,22)
interpunctatum heterotarsale

ARTHROPODA (cont.)
Ephemeroptera (cont.)
Heptageniidae (cont.)
Stenonema fuscum (R,22)
S. nepotellum (C,22)
S. rubromaculatum (R,22)
S. rubrum (C,22)
S. vicarium (R,22)
S. tripunctatum (U,22)
S. smithae (R,22)
Odonata
Gomphidae
Gomphus quadricolor (R,26)
Lanthus albistylus (U,26)
Libellulidae
Plathemis lydia (C,26)
Leucorrhinia sp. (R,12)
Perithemis sp. (R,26)
Libellula sp. (R,26)
Macromiidae
Macromia alleghaniensis (C,26)
Corduliidae
Epicordulia princeps (R,26)
Neurocordulia obsoleta (R,12)
Calopterygidae
Calopteryx sp. (R,12)
Coenagrionidae
Argia spp. (C,12)
Enallagma spp. (R,12)
Ischnura spp. (U,12)
Aeschnidae
Basiaeschna janata (R,28)
Aeschna sp. (U,12)
Anax junius (U,26)
Plecoptera
Taeniopterygidae
Strophopteryx fasciata (R,35)
Taeniopteryx nivalis (C,35)
Capniidae
Allocapnia vivipara (C,35)
A. pygmaea (U,35)
A. rickeri (U,35)
Nemouridae
Amphinemura delosa (C,35)
Perlidae
Neoperla clymene (U,35)
Phasganophora capitata (R,35)
Perlesta placida (C,35)
Acroneuria abnormis (R,35)
Leuctridae
Leuctra sp. (R,35)
Perlodidae
Isoperla bilineata (U,35)
Chloroperlidae (R,35)

TABLE 5 (Cont'd)

ARTHROPODA
- Hemiptera
  - Gerridae
    - *Gerris remigis* (C,7)
    - *Metrobates anomalus* (C,7)
    - *Rheumatobates rileyi* (C,7)
    - *Trepobates subnitidus* (C,7)
  - Veliidae
    - *Rhagovelia* sp. (C,28)
    - *Microvelia* sp. (A,28)
  - Corixidae
    - *Trichocorixa calva* (U,40)
    - *Sigara modesta* (C,17)
    - *Palmacorixa* sp. (R,28)
  - Saldidae
    - *Pentacora* sp. (U,37)
    - *Saldula* sp. (U,37)
  - Notonectidae
    - *Notonecta* sp. (R,28)
  - Belostomatidae
    - *Belostoma* sp. (R,37)
- Megaloptera
  - Sialidae
    - *Sialis* sp. (C,28)
  - Corydalidae
    - *Corydalus cornutus* (C,28)
    - *Nigronia serricornis* (R,27)
- Coleoptera
  - Haliplidae
    - *Peltodytes duodecimpunctatus* (U,1)
    - *P. muticus* (R,1)
    - *Haliplus fasciatus* (R,1)
  - Dytiscidae
    - *Ilybius* sp. (R,11)
    - *Bidessus affinis* (R,11)
    - *Agabus gagates* (C,11)
    - *Hydroporus consimilis* (C,11)
    - *H.* sp. A (R,39)
    - *Hydrovatus* sp. (R,28)
    - *Laccophilus proximus* (C,11)
    - *Copelatus glyphicus* (R,11)
  - Gyrinidae
    - *Gyrinus analis* (R,11)
    - *Dineutus hornii* (R,11)
  - Hydrophilidae
    - *Berosus peregrinus* (C,11)
    - *B. striatus* (U,11)
    - *Enochrus pygmaeus* (C,11)
    - *E. perplexus* (U,11)
    - *E. cinctus* (C,25)
    - *Helophorus lacustris* (U,11)
    - *Laccobius agilis* (C,11)
    - *Paracymus subcupreus* (C,11)
    - *Tropisternus glaber* (U,11)

ARTHROPODA (cont.)
- Coleoptera (cont.)
  - Hydrophilidae (cont.)
    - *T. lateralis* (C,11)
    - *Anacaena limbata* (C,11)
    - *Sphaeridium* spp. (U,37)
    - *Hydrobius melaenum* (R,11)
  - Hydraenidae
    - *Hydraena* sp. (U,37)
    - *Ochthebius* sp. (U,37)
  - Hydroscaphidae
    - *Hydroscapha natans* (R,37)
  - Psephenidae
    - *Psephenus herricki* (C,3)
  - Eubriidae
    - *Ectopria nervosa* (U,3)
  - Dryopidae
    - *Helichus* sp. (U,3)
  - Elmidae
    - *Ancyronyx variegata* (R,33)
    - *Dubiraphia vittata* (C,3)
    - *D. bivittata* (U,3)
    - *D. quadrinotata* (R,3)
    - *Microcylloepus pusillus* (C,33)
    - *Optioservus trivittatus* (C,3)
    - *O. ovalis* (R,3)
    - *Stenelmis crenata* (A,3)
    - *S.* sp. B (R,39)
    - *Macronychus glabratus* (R,33)
    - *Oulimnius latiusculus* (R,33)
  - Chrysomelidae
    - *Galerucella nymphaeae* (U,11)
    - *Donacia piscatrix* (R,11)
- Neuroptera
  - Sisyridae
    - *Climacia areolaris* (U,28)
- Trichoptera
  - Glossosomatidae
    - *Glossosoma* sp. (R,31)
  - Rhyacophilidae
    - *Protoptila* sp. (R,31)
  - Philopotamidae
    - *Chimarra obscura* (A,31)
    - *C. aterrima* (U,31)
    - *Wormaldia moesta* (U,31)
  - Psychomyiidae
    - *Nyctiophylax vestitus* (R,14)
    - *N.* sp. A (R,14)
    - *Polycentropus* sp. (U,14)
    - *Neureclipsis* sp. (U,14)
  - Phryganeidae
    - *Ptilostomis* sp. (R,31)
  - Limnephilidae
    - *Neophylax* sp. (R,13)

ARTHROPODA (cont.)
- Trichoptera (cont.)
  - Leptoceridae
    - *Ceraclea transversa* (R,29)
    - *C.* sp. A (U,39)
    - *Oecetis* spp. (U,31)
    - *Mystacides sepulchralis* (R,31)
    - *Triaenodes* sp. (R,31)
  - Hydropsychidae
    - *Cheumatopsyche* spp. (A,31)
    - *Hydropsyche betteni* (U,31)
    - *H. phalerata* (R,31)
    - *H.* sp. A (C,39)
    - *H.* sp. B (R,39)
    - *H.* sp. C (A,39)
    - *H.* sp. D (U,39)
    - *H.* sp. E (C,39)
    - *Macronema zebratum* (C,31)
    - *Diplectrona modesta* (R,31)
  - Hydroptilidae
    - *Hydroptila ajax* (U,31)
    - *H. consimilis* (C,31)
    - *H. spatulata* (C,31)
    - *H. armata* (U,31)
    - *H. waubesiana* (R,31)
    - *Leucotrichia pictipes* (A,31)
    - *Agraylea* sp. (R,31)
    - *Oxyethira* sp. (R,12)
- Lepidoptera
  - Pyralididae
    - *Parargyractis* sp. (C,37)
- Diptera
  - Tipulidae
    - *Limnophila* sp. (R,37)
    - *Helius* sp. (R,37)
    - *Dicranota* sp. (R,37)
    - *Erioptera* sp. (U,37)
    - *Antocha* sp. (U,37)
    - *Pseudolimnophila* sp. (U,20)
    - *Limonia* sp. (R,37)
    - *Paradelphomyia* sp. (R,37)
    - *Dolichopeza* sp. (R,37)
    - *Tipula* spp. (U,37)
  - Simuliidae
    - *Simulium vittatum* (A,34)
    - *Prosimulium* sp. (U,37)
  - Chironomidae
    - *Psectrotanypus dyari* (R,30)
    - *Tanypus* sp. (R,23)
    - *Procladius riparius* (U,30)
    - *Ablabesmyia auriensis* (U,30)
    - Pentaneurini spp. (A,23)
    - Tanytarsini (A) including
    - *Micropsectra gmundensis* (20)

ARTHROPODA (cont.)
- Diptera (cont.)
  - Chironomidae (cont.)
    - *Tanytarsus exigua* (30)
    - *T. guerla* (30), and
    - *T. glabrescens* (30)
    - *Pseudochironomus fulviventris* (R,30)
    - *Chironomus* spp. (C,23)
    - *Cryptochironomus fulvus* (U,30)
    - *C. norax* (U,10)
    - *C. blarina* (U,10)
    - *Endochironomus* sp. (U,23)
    - *Tribelos* sp. (U,23)
    - *Dicrotendipes modestus* (U,30)
    - *Glyptotendipes* sp. (U,23)
    - *Polypedilum illinoense* (A,30)
    - *P. fallax* (R,20)
    - *Paracladopelma* sp. (R,23)
    - *Microtendipes tarsalis* (C,30)
    - *Paralauterborniella* sp. (R,23)
    - *Paratendipes* sp. (U,23)
    - *Stictochironomus* sp. (U,23)
    - *Stenochironomus* sp. (U,23)
    - *Parachironomus* sp. (U,23)
    - *Phaenopsectra* sp. (U,23)
    - *Xenochironomus xenolabis* (R,30)
    - *Diamesa nivoriunda* (U,30)
    - *Cardiocladius obscurus* (C,30)
    - *Cricotopus bicinctus* (A,30)
    - *C.* sp. 1 (R,30)
    - Other *Cricotopus* spp. (C,23)
    - *Orthocladius rivulorum* (U,30)
    - *Eukiefferiella* spp. (U,23)
    - *Trichocladius* sp. (U,23)
    - *Diplocladius cultriger* (U,30)
    - *Psectrocladius* sp. (U,23)
    - *Brillia* sp. (R,23)
    - *Metriocnemus* sp. (R,23)
    - *Corynoneura xena* (R,30)

ARTHROPODA (cont.)
- Diptera (cont.)
  - Chironomidae (cont.)
    - *Heterotrissocladius* sp. (U,23)
    - *Thienemanniella* sp. (R,23)
  - Psychodidae
    - *Psychoda* sp. (U,20)
    - *Pericoma* sp. (R,20)
    - *Telmatoscopus* sp. (R,20)
  - Heleidae
    - *Palpomyia* spp. (C,37)
    - *Dasyhelea* sp. (R,37)
    - *Atrichopogon peregrinus* (R,36)
    - *A.* sp. A (R,39)
    - *A.* sp. B (R,39)
    - *Stilobezzia* sp. (R,36)
    - *Culicoides* sp. (R,36)
  - Empididae
    - *Clinocera* sp. (U,37)
    - *Hemerodromia* sp. (C,37)
  - Ephydridae
    - *Brachydeutera argentata* (R,37)
    - *Scatella-Neoscatella* sp. (R,37)
  - Culicidae
    - *Chaoborus* sp. (R,37)
    - *Anopheles* sp. (R,20)
  - Muscidae
    - *Lispe* sp. (R,20)
  - Mycetophilidae (R,20)
  - Dolichopodidae
    - *Aphrosylus* sp. (R,20)
  - Tabanidae
    - *Chrysops* sp. (U,20)
    - *Tabanus* sp. (R,20)
  - Sciomyzidae
    - *Dictya* sp. (R,37)
  - Stratiomyidae (R,37)
  - Rhagionidae
    - *Atherix variegata* (R,37)

ARTHROPODA (cont.)
- Hymenoptera
  - Diapriidae
    - *Trichopria* sp. (R,37)
  - Mymaridae
    - *Caraphractus* sp. (U,37)

MOLLUSCA
- Gastropoda
  - Physidae
    - *Physa acuta* (A,9)
  - Lymnaeidae
    - *Lymnaea humilis* (C,16)
  - Planorbidae
    - *Gyraulus parvus* (C,16)
    - *Helisoma trivolvis* (R,16)
    - *H. anceps* (R,16)
  - Ancylidae
    - *Ferrissia tarda* (A,16)
  - Viviparidae
    - *Campeloma decisa* (R,16)
  - Pleuroceridae
    - *Goniobasis virginica* (R,16)
  - Hydrobiidae
    - *Amnicola limosa* (U,16)
  - Valvatidae
    - *Valvata piscinalis* (R,16)
- Pelecypoda
  - Sphaeriidae
    - *Musculium securis* (R,5)
    - *Sphaerium rhomboideum* (C,5)
    - *S. striatinum* (R,5)
    - *Pisidium* spp. (C,5)
  - Unionidae
    - *Anodonta cataracta* (U,8)
    - *A. imbecillis* (R,8)
    - *Elliptio complanatus* (R,8)
    - *Ligumia nasuta* (R,8)

*A = abundant, C = common, U = uncommon, R = rare.

**Numbers refer to the taxonomic references listed below. For complete citation see the Literature Cited section.

1. Brigham (1972)
2. Brinkhurst (1972)
3. Brown (1972)
4. Burch (1975a)
5. Burch (1975b)
6. Burks (1953)
7. Calabrese (Pers. Comm.)
8. Clarke and Berg (1959)
9. Clench (Pers. Comm.)
10. Curry (1958)
11. Dillon and Dillon (1961)
12. Edmunson (1959)
13. Flint (1960)
14. Flint (1964)
15. Gibson and Moore (1976)
16. Harman and Berg (1971)
17. Hilsenhoff (1970)
18. Hiltunen (1973)
19. Holsinger (1972)
20. Johannsen (1934-37)
21. Kenk (Pers. Comm.)
22. Lewis (1974)
23. Mason (1973)
24. Meyer (1946)
25. Miller (Pers. Comm.)
26. Needham and Westfall (1955)
27. Neunzig (1966)
28. Pennak (1953)
29. Resh (1976)
30. Roback (1957)
31. Ross (1944)
32. Sawyer (1972)
33. Sinclair (1964)
34. Stone (1964)
35. Surdick and Kim (1976)
36. Thomsen (1937)
37. Usinger (1956)
38. Williams (1970)
39. Consultant's designator
40. Bobb (1974)

TABLE 6

SELECTED MEASUREMENTS FOR TOTAL MACROBENTHOS IN THE RIFFLE BIOTOPE OF PERKIOMEN CREEK AND EAST BRANCH PERKIOMEN CREEK (1972-1976).

STATION	1972 NO./ SQ.MET.	WT./ SQ.MET.	TOTAL TAXA	MORISITAS INDEX OF OVERLAP ADJACENT STATIONS	MORISITAS INDEX OF OVERLAP WITH MOYER STATION	1973 NO./ SQ.MET.	WT./ SQ.MET.	TOTAL TAXA	MORISITAS INDEX OF OVERLAP ADJACENT STATIONS	MORISITAS INDEX OF OVERLAP WITH MOYER STATION
EAST BRANCH										
ELEPHANT	4716.7	-	51		0.838	5771.9	2.4953	58		0.349
				0.535					0.475	
BRANCH	6599.8	-	61		0.556	11371.0	1.5017	55		0.597
				0.594					0.555	
SELLERSVILLE	5958.6	-	43		0.539	5906.1	1.6511	54		0.442
				0.592					0.672	
CATRILL	6499.2	-	28		0.462	2751.7	0.3097	25		0.513
				0.462					0.513	
MOYER	7545.2	-	42		N/A	7836.1	1.9451	42		N/A
				0.785					0.701	
MANA	12497.7	-	46		0.785	11706.7	3.6821	50		0.701
				0.640					0.602	
PERKIOMEN										
RAHNS	11980.4	-	61		0.566	10599.6	4.0538	65		0.498
				0.691					0.742	
SPRING MOUNT	8261.3	-	67		0.714	14301.1	4.2128	73		0.651

TABLE 6 (CON'T)

STATION	1974 NO./ SQ.MET.	WT./ SQ.MET.	TOTAL TAXA	MORISITAS INDEX OF OVERLAP ADJACENT STATIONS	MORISITAS INDEX OF OVERLAP WITH MOYER STATION	1976 NO./ SQ.MET.	WT./ SQ.MET.	TOTAL TAXA	MORISITAS INDEX OF OVERLAP ADJACENT STATIONS	MORISITAS INDEX OF OVERLAP WITH MOYER STATION
EAST BRANCH										
ELEPHANT	6066.7	2.3133	64		0.400	6390.5	1.7840	63		0.282
				0.413					0.100	
BRANCH	7444.4	2.2460	49		0.576	7941.8	2.6347	54		0.663
				0.669					0.348	
SELLERSVILLE	8669.2	2.2199	53		0.489	12493.2	4.7003	58		0.502
				0.685					0.270	
CATHILL	5300.6	0.9791	28		0.478	11753.4	3.3642	45		0.249
				0.478					0.249	
MOYER	13071.9	5.7547	44		N/A	30445.6	7.6905	54		N/A
				0.543					0.670	
WAWA	20354.7	6.1566	44		0.543	50565.2	14.4593	49		0.670
				0.440					0.490	
PERKIOMEN										
NANNS	11413.9	3.0759	61		0.495	17612.5	4.4454	65		0.518
				0.744					0.731	
SPRING MOUNT	16010.9	3.5074	71		0.718	21404.5	5.1368	61		0.689

BIOMASS IS EXPRESSED AS G DRY WEIGHT
MORISITAS INDEX OF OVERLAP, A MEASURE OF BENTHIC COMMUNITY SIMILARITY BETWEEN STATIONS, WAS COMPUTED EXCLUDING CHIRONOMIDAE

TABLE 7

MEAN DENSITY (NO./SQ. MET.), PERCENT COMPOSITION (%), AND FREQUENCY OF OCCURRENCE (FO %) OF BENTHIC MACROINVERTEBRATES WHICH IN ANY YEAR COMPRISED 2% OR GREATER OF THE TOTAL NUMBER COLLECTED IN QUANTITATIVE SAMPLES (1972-1976) FROM THE RIFFLE BIOTOPE OF EAST BRANCH PERKIOMEN CREEK, ALL STATIONS COMBINED.

TAXON	1972 NO./ SQ.MET.	%	FO %	1973 NO./ SQ.MET.	%	FO %	1974 NO./ SQ.MET.	%	FO %	1976 NO./ SQ.MET.	%	FO %
DUGESIA SPP.	99.3	*	37.4	39.9	*	31.5	379.2	3.7	51.9	1133.6	5.6	63.2
BAETIS SPP.	181.1	2.5	36.5	197.3	2.6	37.1	205.6	*	54.6	289.4	*	44.4
STENELMIS SPP.	282.2	3.8	68.7	318.7	4.2	72.9	676.9	6.6	88.9	2373.4	11.8	93.1
CHIMARRA SPP.	697.9	9.5	48.1	571.1	7.5	50.2	1005.4	9.8	71.3	1836.1	9.1	68.2
CHEUMATOPSYCHE SPP.	1360.0	18.5	84.1	1047.4	13.8	78.2	1912.1	18.6	96.3	2053.7	10.2	90.4
HYDROPSYCHE SPP.	420.8	5.7	47.0	362.0	4.8	42.7	967.7	9.4	62.0	888.7	4.4	55.9
SIMULIIDAE	525.8	7.2	77.7	415.6	5.5	71.8	390.0	3.8	69.4	640.7	3.2	75.5
CHIRONOMIDAE	3195.2	43.5	93.9	4148.7	54.7	99.7	3289.7	32.0	100.0	5505.0	27.4	96.9
SPHAERIUM SPP.	13.0	*	22.0	4.5	*	15.6	647.9	6.3	35.2	3973.6	19.8	51.3
ALL OTHERS	562.6	7.7	88.1	482.2	6.4	96.0	811.5	7.9	94.0	1393.2	6.9	95.8
TOTAL NUMBER	7337.8			7587.4			10285.9			20087.4		
TOTAL TAXA	89			85			83			98		

* = LESS THAN 2.0%

a.

TABLE 8

MEAN DENSITY (MG/SQ. MET.), PERCENT COMPOSITION (%), AND FREQUENCY OF OCCURRENCE (FO %) OF BENTHIC MACROINVERTEBRATES WHICH IN 1973 OR 1974 COMPRISED 2% OR GREATER OF THE TOTAL DRY WEIGHT BIOMASS COLLECTED IN QUANTITATIVE SAMPLES FROM THE RIFFLE BIOTOPE OF EAST BRANCH PERKIOMEN CREEK, ALL STATIONS COMBINED.

TAXON	1973 MG/ SQ.MET.	%	FO %	1974 MG/ SQ.MET.	%	FO %
DUGESIA SPP.	20.9	*	31.5	169.1	5.2	51.9
OLIGOCHAETA	59.0	3.1	62.3	67.1	2.1	63.9
CAMBARUS BARTONI	236.5	12.3	6.2	207.6	6.3	6.5
ORCONECTES LIMOSUS	178.1	9.2	8.9	240.3	7.3	3.2
STENELMIS SPP.	69.2	3.6	72.9	170.4	5.2	88.9
CHIMARRA SPP.	158.6	8.2	50.2	320.6	9.8	71.3
CHEUMATOPSYCHE SPP.	384.4	20.0	78.2	678.7	20.7	96.3
HYDROPSYCHE SPP.	373.1	19.4	42.7	721.1	22.0	62.0
SIMULIIDAE	56.8	2.9	73.8	36.6	*	69.4
CHIRONOMIDAE	216.3	11.2	99.7	262.5	8.0	100.0
SPHAERIUM SPP.	3.0	*	15.6	146.1	4.5	35.2
ALL OTHERS	168.9	8.8	89.4	258.0	7.9	95.4
TOTAL	1925.6			3278.3		

* = LESS THAN 2.0%

MEAN TOTAL BIOMASS IN 1976 WAS 5790.0

TABLE 10

SPATIAL DISTRIBUTION, BY STATION BY YEAR, OF IMPORTANT BENTHIC MACROINVERTEBRATES COLLECTED IN QUANTITATIVE SAMPLES (1972-1976) FROM THE RIFFLE BIOTOPE OF EAST BRANCH PERKIOMEN CREEK AND PERKIOMEN CREEK. MEAN DENSITY (NO./SQ.MET.), PERCENT COMPOSITION (%), AND FREQUENCY OF OCCURRENCE (FO %) ARE TABULATED.

	ELEPHANT NO./SQ.MET.	%	FO %	BRANCH NO./SQ.MET.	%	FO %	SELLERSVILLE NO./SQ.MET.	%	FO %	CATHELL NO./SQ.MET.	%	FO %
DUGESIA SPP.												
1972	*	*	3.3	106.6	2.8	60.0	13.4	*	33.3	*	*	2.2
1973	3.3	*	13.7	43.0	*	37.0	1.4	*	11.1	-	-	-
1974	13.9	*	50.0	15.0	*	33.3	56.7	*	41.7	-	-	-
1976	7.1	*	26.8	130.7	*	68.2	417.0	3.3	84.1	2.3	*	13.6
MEAN	5.2			102.1			109.6			*		
OLIGOCHAETA												
1972	15.6	*	31.7	58.4	*	73.3	403.4	6.8	85.0	43.0	*	62.2
1973	50.8	*	68.6	76.9	*	57.4	515.9	8.6	83.3	59.7	2.2	66.7
1974	128.9	2.1	72.2	112.8	*	52.8	597.2	6.9	83.3	33.6	*	47.2
1976	95.4	*	63.4	50.9	*	54.5	671.4	5.4	90.9	142.7	*	72.7
MEAN	66.4			71.9			531.5			70.7		
ERPOBDELLA PUNCTATA												
1972	*	*	5.0	2.3	*	15.0	5.6	*	26.7	-	-	-
1973	*	*	5.9	*	*	3.7	10.8	*	33.3	-	-	-
1974	3.9	*	10.6	2.2	*	11.1	11.4	*	52.8	-	-	-
1976	-	-	-	1.4	*	9.1	46.1	*	70.5	2.7	*	13.6
MEAN	1.1			1.6			17.3			*		
CAMBARUS BARTONI												
1972	1.1	*	10.0	*	*	3.3	*	*	1.7	-	-	-
1973	5.1	*	31.4	*	*	3.7	*	*	3.7	-	-	-
1974	6.9	*	36.1	-	-	-	*	*	2.8	-	-	-
1976	2.0	*	14.6	1.4	*	13.6	-	-	-	*	*	2.3
MEAN	3.5			*			*			*		
ORCONECTES LIMOSUS												
1972	*	*	3.3	*	*	6.7	*	*	1.7	-	-	-
1973	*	*	2.0	-	-	-	*	*	1.9	-	-	-
1974	*	*	5.6	-	-	-	*	*	2.8	-	-	-
1976	-	-	-	*	*	2.3	*	*	6.8	-	-	-
MEAN	*			*			*			-	-	-
CAENIS SP.												
1972	56.3	*	26.7	300.2	4.5	81.7	62.5	*	66.7	*	*	6.7
1973	44.6	*	58.8	388.1	3.9	79.6	33.5	*	61.1	-	-	-
1974	49.4	*	83.3	465.3	6.3	75.0	81.9	*	77.8	*	*	2.8
1976	33.4	*	51.2	214.3	2.7	75.0	140.7	*	84.1	*	*	4.5
MEAN	46.8			315.8			75.8			*		
TRICORYTHODES SP.												
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	*	*	1.9	*	*	1.9	-	-	-
1974	-	-	-	*	*	2.8	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-
MEAN	-	-	-	*			*			-	-	-

TABLE 10 (CONTINUED)

		ELEPHANT NO./ SQ.MET.	%	FO %	BRANCH NO./ SQ.MET.	%	FO %	SELLERSVILLE NO./ SQ.MET.	%	FO %	CATHILL NO./ SQ.MET.	%	FO %
EPHEMERELLA SPP.													
	1972	-	-	-	-	-	-	*	*	1.7	-	-	-
	1973	*	*	3.9	-	-	-	*	*	1.9	-	-	-
	1974	1.4	*	2.8	-	-	-	-	-	-	-	-	-
	1976	-	-	-	-	-	-	*	*	2.3	-	-	-
	MEAN	*			-	-	-	*			-	-	-
BAETIS SPP.													
	1972	75.8	*	30.0	628.3	9.5	50.0	36.0	*	45.0	1.4	*	11.1
	1973	58.2	*	33.3	510.2	4.5	59.1	46.8	*	50.0	*	*	3.7
	1974	10.8	*	30.6	483.6	6.5	75.0	243.3	2.8	86.1	2.2	*	16.7
	1976	40.7	*	41.5	447.3	5.5	54.5	49.1	*	45.5	8.2	*	18.2
	MEAN	50.9			523.5			80.5			2.9		
STENONEMA SPP.													
	1972	7.0	*	8.3	12.5	*	31.7	6.1	*	30.0	-	-	-
	1973	14.4	*	35.3	26.9	*	44.4	5.8	*	24.1	-	-	-
	1974	72.8	*	91.7	3.3	*	22.2	18.9	*	47.2	-	-	-
	1976	82.0	*	53.7	10.5	*	29.5	5.0	*	27.3	*	*	2.3
	MEAN	37.9			14.4			8.1			*		
ARGIA SPP.													
	1972	*	*	1.7	37.6	*	33.3	7.0	*	20.3	*	*	2.2
	1973	*	*	7.8	42.2	*	51.9	7.6	*	35.2	*	*	7.4
	1974	*	*	5.6	9.2	*	30.6	20.6	*	55.6	2.2	*	8.3
	1976	*	*	2.4	10.0	*	56.8	15.7	*	56.8	6.8	*	30.6
	MEAN	*			27.4			11.6			2.4		
ALLOCAPNIA SPP.													
	1972	335.7	7.1	41.7	3.0	*	15.0	-	-	-	*	*	2.2
	1973	173.7	3.0	45.1	12.7	*	31.5	2.8	*	18.5	-	-	-
	1974	510.3	8.4	38.9	6.7	*	22.2	5.6	*	22.2	-	-	-
	1976	144.4	2.3	31.7	12.5	*	22.7	5.7	*	18.2	*	*	2.3
	MEAN	203.5			8.6			3.1			*		
PERLESTA PLACIDA													
	1972	115.4	2.4	16.7	9.3	*	8.3	1.1	*	6.7	-	-	-
	1973	147.4	2.6	29.4	22.1	*	24.1	6.0	*	16.7	*	*	1.9
	1974	125.8	2.1	30.6	26.4	*	22.2	3.3	*	13.9	-	-	-
	1976	12.4	*	7.3	27.5	*	11.4	4.5	*	9.1	-	-	-
	MEAN	103.6			20.2			3.6			*		
CORIXIDAE													
	1972	*	*	5.0	-	-	-	-	-	-	-	-	-
	1973	43.4	*	33.3	1.8	*	3.7	*	*	1.9	-	-	-
	1974	161.4	2.7	52.8	*	*	2.8	-	-	-	-	-	-
	1976	142.4	2.2	41.5	*	*	4.5	1.4	*	2.3	-	-	-
	MEAN	74.0			*			*			-	-	-

TABLE 10 (CONTINUED)

		ELEPHANT NO./ SQ.MET.	%	FO %	BRANCH NO./ SQ.MET.	%	FO %	SELLERSVILLE NO./ SQ.MET.	%	FO %	CATHILL NO./ SQ.MET.	%	FO %
CORYDALUS CORNUTUS													
	1972	-	-	-	-	-	-	-	-	-	-	-	-
	1973	-	-	-	-	-	-	-	-	-	-	-	-
	1974	-	-	-	-	-	-	*	*	5.6	-	-	-
	1976	-	-	-	-	-	-	-	-	-	-	-	-
	MEAN	-	-	-	-	-	-	*			-	-	-
PSEPHENUS HERRICKI													
	1972	-	-	-	3.9	*	20.0	-	-	-	*	*	2.2
	1973	*	*	7.8	9.4	*	33.3	*	*	3.7	*	*	1.9
	1974	1.4	*	11.1	18.9	*	41.7	1.7	*	16.7	*	*	2.0
	1976	2.4	*	22.0	65.9	*	68.2	23.0	*	16.4	1.1	*	9.1
	MEAN	*			22.3			5.6			*		
STENELMIS SPP.													
	1972	107.0	2.3	70.0	174.9	2.7	71.7	82.1	*	61.7	29.9	*	55.6
	1973	81.2	*	86.3	186.2	*	74.1	69.1	*	70.4	13.9	*	46.3
	1974	149.2	2.5	86.1	112.8	*	86.1	349.7	4.0	94.4	21.9	*	69.4
	1976	140.2	2.2	82.9	363.2	4.6	79.5	1360.5	10.9	97.7	50.6	*	97.7
	MEAN	115.3			209.2			418.1			30.5		
CHIMARRA SPP.													
	1972	*	*	3.3	283.0	4.3	60.0	40.1	*	48.3	6.2	*	24.4
	1973	12.2	*	19.6	397.1	3.5	55.6	58.5	*	40.7	*	*	7.4
	1974	9.4	*	36.1	747.5	10.0	83.3	276.1	3.2	83.3	5.6	*	27.8
	1976	35.1	*	31.7	671.1	8.5	86.4	54.5	*	72.7	3.6	*	15.9
	MEAN	13.1			489.0			92.3			3.8		
CHEUMATOPSYCHE SPP.													
	1972	1123.1	23.8	66.7	592.3	9.0	93.3	731.7	12.3	85.0	1408.6	21.7	80.0
	1973	162.0	2.8	62.7	1052.0	9.3	60.5	476.7	8.0	79.6	183.6	6.7	72.2
	1974	662.8	10.9	88.9	1732.8	23.3	91.7	1763.9	20.3	100.0	1412.2	24.7	97.2
	1976	187.8	2.9	58.5	1753.0	22.1	90.9	969.3	7.8	97.7	553.4	4.7	93.2
	MEAN	570.3			1195.1			906.2			809.4		
HYDROPSYCHE SPP.													
	1972	25.8	*	31.7	136.2	2.1	55.0	*	*	8.3	*	*	2.2
	1973	*	*	5.9	156.1	*	55.6	5.2	*	18.5	*	*	1.9
	1974	4.4	*	13.9	624.2	8.4	83.3	10.8	*	61.1	4.4	*	13.9
	1976	*	*	4.9	581.8	7.3	77.3	3.9	*	22.7	7.5	*	27.3
	MEAN	9.4			333.4			4.6			2.9		
LEUCOTRICHIA PICTIPES													
	1972	-	-	-	*	*	1.7	-	-	-	-	-	-
	1973	-	-	-	*	*	1.9	-	-	-	-	-	-
	1974	-	-	-	-	-	-	1.1	*	8.3	*	*	8.3
	1976	-	-	-	*	*	4.5	-	-	-	2.0	*	9.1
	MEAN	-	-	-	*			*			*		

TABLE 10 (CONTINUED)

		ELEPHANT NO./ SQ.MET.	%	FO %	BRANCH NO./ SQ.MET.	%	FO %	SELLERSVILLE NO./ SQ.MET.	%	FO %	CATHILL NO./ SQ.MET.	%	FO %
TIPULA SPP.													
	1972	1.8	•	8.3	3.2	•	15.0	•	•	3.3	-	-	-
	1973	5.1	•	29.4	1.4	•	9.3	-	-	-	•	•	1.9
	1974	3.3	•	27.8	-	-	-	•	•	2.8	•	•	5.6
	1976	11.2	•	36.6	3.2	•	22.7	•	•	4.5	•	•	4.5
	MEAN	5.0			2.1			•			•		
SIMULIIDAE													
	1972	574.4	12.2	55.0	564.0	8.5	80.0	252.7	4.2	85.0	1365.6	21.0	88.9
	1973	170.6	3.0	58.8	713.1	6.3	79.6	584.8	9.8	85.2	192.8	7.0	55.6
	1974	173.9	2.9	44.4	476.4	6.4	86.1	941.7	10.9	75.0	269.2	5.1	83.3
	1976	116.6	2.1	36.6	770.9	9.7	77.3	246.6	•	81.8	1900.0	16.9	93.2
	MEAN	292.7			636.2			471.6			944.2		
CHIRONOMIDAE													
	1972	2192.8	46.5	75.0	3302.0	50.0	100.0	3831.0	64.3	100.0	3572.0	55.0	100.0
	1973	4488.0	77.8	100.0	7516.1	66.1	100.0	4006.0	66.9	100.0	2289.9	81.2	100.0
	1974	3706.9	61.1	100.0	2486.4	33.4	100.0	3790.3	43.7	100.0	3640.0	60.6	100.0
	1976	5007.3	78.4	90.2	2565.9	32.3	90.9	4126.8	33.0	100.0	7678.2	65.3	100.0
	MEAN	3719.2			4156.7			3939.2			4200.3		
PHYSA ACUTA													
	1972	8.8	•	28.3	5.2	•	25.0	261.1	4.4	46.7	20.0	•	20.0
	1973	29.5	•	35.3	5.4	•	13.0	31.3	•	53.7	2.2	•	9.3
	1974	8.9	•	38.9	9.2	•	47.2	80.3	•	72.2	4.2	•	16.7
	1976	42.7	•	39.0	9.1	•	29.5	910.0	7.3	77.3	1156.4	9.8	65.9
	MEAN	21.8			6.9			310.7			291.0		
SPHAERIUM SPP.													
	1972	5.6	•	23.3	5.6	•	25.0	11.1	•	21.7	-	-	-
	1973	2.1	•	17.6	3.0	•	20.4	2.8	•	20.4	-	-	-
	1974	10.3	•	27.8	1.1	•	8.3	96.4	•	69.4	-	-	-
	1976	5.9	•	22.0	8.9	•	34.1	2659.8	21.3	90.9	•	•	4.5
	MEAN	5.6			4.8			625.3			•		
ALL OTHERS													
	1972	67.4	•	61.7	289.8	4.4	95.0	211.8	3.6	90.0	49.7	•	62.2
	1973	268.7	4.7	98.0	206.3	•	96.3	118.9	•	90.7	6.8	•	33.3
	1974	249.2	4.1	100.0	110.3	•	88.9	316.9	3.7	97.2	11.1	•	44.4
	1976	260.7	4.1	87.8	240.9	3.0	90.9	780.2	6.2	100.0	119.3	•	77.3
	MEAN	199.0			222.1			334.4			51.0		

TABLE 10 (CONTINUED)

		MOYER NO./ SQ.MET.	%	FO %	WAWA NO./ SQ.MET.	%	FO %	SPRING MOUNT NO./ SQ.MET.	%	FO %	BAHNS NO./ SQ.MET.	%	FO %
DUGESIA SPP.													
	1972	191.6	2.5	60.0	178.9	*	61.7	89.2	*	71.7	163.9	*	54.0
	1973	107.3	*	51.9	82.2	*	74.1	225.8	*	53.7	75.3	*	46.3
	1974	781.7	5.6	86.1	1407.8	6.9	100.0	106.4	*	69.4	166.9	*	80.6
	1976	3229.1	10.6	93.2	2938.4	5.8	90.9	731.1	3.4	77.3	190.5	*	79.5
	MEAN	966.5			1005.9			290.9			144.8		
OLIGOCHAETA													
	1972	29.9	*	53.3	61.1	*	50.0	36.9	*	63.3	101.7	*	64.0
	1973	21.7	*	46.3	38.8	*	51.9	39.4	*	63.0	55.2	*	61.1
	1974	46.1	*	77.8	41.1	*	50.0	80.9	*	80.6	116.9	*	77.8
	1976	18.6	*	63.6	39.3	*	38.6	26.6	*	54.5	81.0	*	79.5
	MEAN	28.1			46.3			44.9			90.2		
ERPOBDELLA PUNCTATA													
	1972	1.4	*	11.7	4.1	*	21.7	1.8	*	10.0	*	*	2.0
	1973	*	*	3.7	2.8	*	16.7	*	*	5.6	3.2	*	24.1
	1974	2.5	*	19.4	8.1	*	41.7	*	*	2.8	2.5	*	13.9
	1976	4.5	*	22.7	9.3	*	31.8	*	*	2.3	1.0	*	15.9
	MEAN	2.0			5.7			*			1.9		
CAMBARUS BARTONI													
	1972	-	-	-	-	-	-	-	-	-	-	-	-
	1973	-	-	-	-	-	-	-	-	-	-	-	-
	1974	-	-	-	-	-	-	-	-	-	-	-	-
	1976	*	*	6.8	-	-	-	-	-	-	-	-	-
	MEAN	*			-	-	-	-	-	-	-	-	-
ORCONECTES LIMOSUS													
	1972	*	*	6.7	*	*	3.3	*	*	3.3	*	*	2.0
	1973	*	*	1.9	-	-	-	*	*	3.7	-	-	-
	1974	1.1	*	11.1	-	-	-	*	*	2.8	*	*	2.8
	1976	*	*	4.5	-	-	-	-	-	-	*	*	2.3
	MEAN	*			*			*			*		
CAENIS SP.													
	1972	1.3	*	10.0	24.7	*	51.7	4.1	*	13.3	11.4	*	30.0
	1973	*	*	7.4	3.2	*	20.4	0.4	*	25.9	64.7	*	55.6
	1974	2.2	*	13.9	12.2	*	22.2	1.1	*	2.8	27.5	*	30.9
	1976	54.5	*	52.3	12.7	*	38.6	-	-	-	26.4	*	43.2
	MEAN	13.4			13.7			3.8			33.8		
TRICORYTHODES SP.													
	1972	*	*	1.7	15.2	*	10.3	41.7	*	20.0	324.3	2.7	44.0
	1973	-	-	-	*	*	5.6	4.2	*	11.1	11.4	*	16.7
	1974	-	-	-	*	*	5.6	15.0	*	30.6	10.0	*	36.1
	1976	*	*	2.3	22.5	*	15.9	10.4	*	25.0	65.7	*	34.1
	MEAN	*			10.1			21.6			104.3		

TABLE 10 (CONTINUED)

		MOYER NO./ SQ.MET.	%	FO %	WAWA NO./ SQ.MET.	%	FO %	SPRING MOUNT NO./ SQ.MET.	%	FO %	BARNS NO./ SQ.MET.	%	FO %
EPHEMERELLA SPP.													
	1972	-	-	-	-	-	-	140.1	*	60.0	649.7	5.4	54.0
	1973	*	*	1.9	1.4	*	7.4	929.9	6.5	90.7	520.3	4.9	85.2
	1974	*	*	2.8	*	*	3.8	1541.4	9.6	100.0	449.2	3.9	91.7
	1976	*	*	4.5	12.3	*	22.7	2631.6	12.3	86.4	511.8	2.9	79.5
	MEAN	*			3.2			1185.1			519.5		
BAETIS SPP.													
	1972	51.1	*	30.0	249.3	*	46.7	361.5	4.4	45.0	759.4	6.3	58.0
	1973	97.4	*	27.8	463.2	4.0	48.1	665.7	4.7	57.4	704.9	7.4	61.1
	1974	106.4	*	58.3	387.2	*	61.1	823.9	5.1	81.3	716.9	6.3	72.2
	1976	531.6	*	52.3	642.7	*	54.5	1345.5	6.3	63.6	1100.0	7.9	59.1
	MEAN	183.2			423.6			755.1			900.9		
STENONEMA SPP.													
	1972	-	-	-	*	*	3.3	366.5	4.4	83.3	371.8	3.1	66.0
	1973	*	*	5.6	6.8	*	18.5	656.1	4.6	100.0	460.4	4.3	85.2
	1974	-	-	-	*	*	2.8	675.8	4.2	100.0	229.2	2.0	94.4
	1976	26.6	*	40.9	3.0	*	18.2	505.0	2.4	97.7	355.2	2.0	97.7
	MEAN	6.2			2.7			535.9			365.9		
ARGIA SPP.													
	1972	-	-	-	18.5	*	33.7	*	*	5.0	32.0	*	28.0
	1973	8.0	*	24.1	9.2	*	33.1	11.0	*	31.5	20.9	*	37.0
	1974	66.1	*	66.7	23.1	*	61.1	28.9	*	58.3	10.0	*	36.1
	1976	47.7	*	95.5	18.2	*	61.4	21.1	*	40.9	29.1	*	36.4
	MEAN	25.3			16.7			13.5			23.9		
ALLOCAPNIA SPP.													
	1972	*	*	1.7	*	*	1.7	41.0	*	26.7	14.0	*	22.0
	1973	-	-	-	*	*	1.9	17.3	*	16.7	43.6	*	40.7
	1974	*	*	2.8	*	*	2.8	20.6	*	19.4	58.6	*	33.3
	1976	-	-	-	*	*	2.3	8.9	*	18.2	81.6	*	25.0
	MEAN	*			*			23.3			48.1		
PERLESTA PLACIDA													
	1972	-	-	-	-	-	-	8.1	*	8.3	1.3	*	6.0
	1973	-	-	-	-	-	-	6.2	*	14.8	10.2	*	11.1
	1974	-	-	-	*	*	2.8	33.1	*	30.6	11.1	*	22.2
	1976	*	*	4.5	*	*	2.3	57.5	*	15.9	1.8	*	9.1
	MEAN	*			*			23.4			5.9		
CORIXIDAE													
	1972	-	-	-	-	-	-	-	-	-	-	-	-
	1973	-	-	-	*	*	1.9	-	-	-	-	-	-
	1974	-	-	-	-	-	-	-	-	-	-	-	-
	1976	*	*	2.3	-	-	-	-	-	-	-	-	-
	MEAN	*			*			-	-	-	-	-	-

TABLE 10 (CONTINUED)

	MOYER NO./ SQ.MET.	%	FO %	WAWA NO./ SQ.MET.	%	FO %	SPRING MOUNT NO./ SQ.MET.	%	FO %	RAHNS NO./ SQ.MET.	%	FO %
CORYDALUS CORNUTUS												
1972	*	*	1.7	-	-	-	*	*	6.7	*	*	4.0
1973	*	*	7.4	*	*	3.7	2.6	*	16.7	2.4	*	14.8
1974	*	*	8.3	-	-	-	4.2	*	25.0	1.4	*	5.6
1976	3.9	*	27.3	2.3	*	15.9	5.7	*	38.6	5.0	*	40.9
MEAN	1.3			*			3.0			2.3		
PSEPHENUS HERRICKI												
1972	19.3	*	33.3	18.5	*	63.3	3.6	*	20.0	24.5	*	60.0
1973	10.2	*	37.0	47.6	*	81.5	8.8	*	40.7	101.6	*	83.3
1974	69.4	*	50.0	117.2	*	83.3	11.7	*	55.6	112.5	*	86.1
1976	96.8	*	86.4	263.0	*	100.0	22.7	*	52.3	549.1	3.1	93.2
MEAN	41.6			100.3			10.9			189.8		
STENELMIS SPP.												
1972	504.7	4.7	73.3	731.5	5.9	85.0	24.2	*	65.0	404.9	3.4	98.0
1973	370.0	4.7	77.8	1178.4	10.1	83.3	38.8	*	77.8	632.8	6.0	90.7
1974	715.8	5.2	97.2	2711.7	13.3	100.0	100.6	*	97.2	636.4	5.6	94.4
1976	4469.1	16.0	100.0	7296.6	14.4	100.0	382.5	*	95.5	783.0	4.4	100.0
MEAN	1496.2			2712.4			123.7			607.5		
CHIMARRA SPP.												
1972	975.4	12.9	60.0	2708.6	21.7	95.0	138.0	*	76.7	287.3	2.4	50.0
1973	485.1	6.2	79.6	2442.1	20.9	96.3	79.3	*	81.5	609.1	5.7	83.3
1974	1634.7	11.8	97.2	3359.2	16.5	100.0	73.6	*	80.6	440.0	3.8	88.9
1976	4720.5	15.5	100.0	5409.1	10.7	100.0	1427.0	6.7	93.2	2235.5	12.7	97.7
MEAN	1810.7			3367.6			402.1			877.5		
CHEUMATOPSYCHE SPP.												
1972	2360.0	31.3	90.0	1956.6	15.7	96.7	1255.2	15.2	96.7	2191.4	18.3	96.0
1973	2724.6	34.8	88.9	1636.2	14.0	96.3	1322.6	9.2	100.0	2007.0	18.9	100.0
1974	4470.9	32.3	100.0	1522.2	7.5	100.0	1817.8	11.5	100.0	2515.8	22.2	100.0
1976	5719.1	18.8	100.0	2992.5	5.9	100.0	2669.8	12.5	100.0	2557.7	14.5	100.0
MEAN	3621.1			2021.8			1702.9			2292.3		
HYDROPSYCHE SPP.												
1972	1270.9	16.9	83.3	977.4	7.8	98.3	800.5	10.8	91.7	1067.1	8.9	90.0
1973	664.9	8.5	79.6	1325.0	11.3	92.6	922.5	6.5	100.0	1264.0	11.9	98.1
1974	2109.7	15.2	100.0	3052.8	15.0	100.0	659.2	4.1	100.0	952.8	8.3	100.0
1976	1771.4	5.8	100.0	2906.4	5.7	100.0	1102.5	5.2	97.7	1476.4	8.4	100.0
MEAN	1371.8			1896.8			904.0			1200.4		
LEUCOTRICHIA PICTIPES												
1972	80.1	*	33.3	211.0	*	38.3	78.7	*	36.7	114.2	*	38.0
1973	27.9	*	35.2	35.8	*	31.5	26.9	*	48.1	27.1	*	33.3
1974	154.7	2.6	61.1	434.2	2.1	61.1	126.1	*	66.7	117.0	*	61.1
1976	476.1	*	80.6	942.1	*	84.1	130.7	*	63.6	116.6	*	45.5
MEAN	206.3			376.3			84.9			95.1		

TABLE 10 (CONTINUED)

		MOYER NO./ SQ.MET.	%	FO %	WAWA NO./ SQ.MET.	%	FO %	SPRING MOUNT NO./ SQ.MET.	%	FO %	RAHNS NO./ SQ.MET.	%	FO %
TIPULA SPP.													
	1972	*	*	3.3	*	*	1.7	*	*	1.7	*	*	2.0
	1973	*	*	3.7	-	-	-	*	*	5.6	*	*	7.4
	1974	-	-	-	-	-	-	*	*	5.6	-	-	-
	1976	*	*	6.8	-	-	-	*	*	9.1	*	*	6.0
	MEAN	*			*			*			*		
SIMULIIDAE													
	1972	350.4	4.8	83.3	249.5	*	85.0	1241.0	15.0	98.3	1207.7	10.7	78.0
	1973	330.9	4.2	85.2	487.9	4.2	77.8	1135.4	7.9	94.4	702.0	7.4	96.3
	1974	219.2	*	63.9	259.4	*	63.9	2131.9	13.3	100.0	1085.6	16.5	97.2
	1976	319.5	*	81.8	348.4	*	79.5	1416.8	6.6	97.7	2040.9	11.6	97.7
	MEAN	316.1			340.1			1416.8			1418.3		
CHIRONOMIDAE													
	1972	1516.3	20.1	100.0	4851.1	38.8	98.3	2900.9	35.1	96.7	3405.2	28.4	100.0
	1973	2769.4	35.3	98.1	3041.7	32.8	100.0	7200.7	50.4	100.0	2552.0	24.1	100.0
	1974	3004.7	21.7	100.0	3109.7	15.3	100.0	6548.1	40.9	100.0	2112.2	20.4	100.0
	1976	7561.4	24.8	100.0	6054.3	12.0	100.0	7114.3	33.2	100.0	4403.4	25.5	100.0
	MEAN	3512.0			4519.9			5732.4			3202.7		
PHYSA ACUTA													
	1972	10.0	*	20.0	*	*	6.7	78.9	*	58.3	8.6	*	24.0
	1973	47.2	*	42.6	*	*	3.7	44.2	*	50.0	7.4	*	35.2
	1974	11.6	*	38.9	*	*	2.8	81.9	*	72.2	3.9	*	27.8
	1976	29.5	*	38.6	2.3	*	11.4	178.0	*	77.3	9.1	*	29.5
	MEAN	25.5			*			92.6			7.4		
SPHAERIUM SPP.													
	1972	10.6	*	28.3	41.8	*	28.3	17.0	*	46.7	70.5	*	30.0
	1973	4.8	*	5.6	13.9	*	29.6	12.1	*	40.7	12.7	*	25.9
	1974	2.5	*	19.4	3776.9	18.6	86.1	8.1	*	33.3	100.3	*	66.7
	1976	510.2	*	63.6	20385.9	40.3	90.9	175.0	*	72.7	93.2	*	65.9
	MEAN	120.8			5341.3			49.8			66.4		
ALL OTHERS													
	1972	154.7	2.0	75.0	176.0	*	75.0	540.1	6.5	100.0	668.4	5.6	98.0
	1973	163.3	2.1	90.7	88.8	*	83.3	933.7	6.5	100.0	550.8	5.2	98.1
	1974	261.1	*	88.9	130.0	*	94.4	1017.8	6.4	100.0	406.4	4.3	100.0
	1976	430.7	*	100.0	263.4	*	97.7	1432.7	6.7	100.0	510.2	2.9	97.7
	MEAN	219.4			163.0			940.8			562.3		

* = LESS THAN 1/SQ.MET. OR LESS THAN 2.0%
EPHORDILLA PUNCTATA, CAMBARUS BARTONI, ORCONECTES LIMOSUS, ARGIA SPP., CORYDALUS CORNUTUS, AND TIPULA SPP. WERE DOMINANT ONLY AS BIOMASS (SEE TABLE 2.2.2.2-11).

TABLE 11

SPATIAL DISTRIBUTION, BY STATION BY YEAR, OF IMPORTANT BENTHIC MACROINVERTEBRATES COLLECTED IN QUANTITATIVE SAMPLES (1973, 1974) FROM THE RIFFLE BIOTOPE OF EAST BRANCH PERKIOMEN CREEK AND PERKIOMEN CREEK. MEAN DENSITY (MG DRY WT/SQ. MET.) AND PERCENT COMPOSITION (%) ARE TABULATED.

		ELEPHANT MG/ SQ. MET.	%	BRANCH MG/ SQ. MET.	%	SELLERSVILLE MG/ SQ. MET.	%	CATHILL MG/ SQ. MET.	%
DUGESIA SPP.									
	1973	+	+	15.3	+	+	+	-	-
	1974	5.6	+	4.4	+	23.5	+	-	-
	MEAN	2.9		10.9		9.5		-	-
OLIGOCHAETA									
	1973	56.7	2.3	54.7	3.6	115.3	7.0	9.8	3.2
	1974	33.3	+	54.7	2.4	84.6	3.8	15.2	+
	MEAN	47.0		54.7		103.0		12.0	
ERPOBDELLA PUNCTATA									
	1973	12.7	+	1.7	+	43.6	2.6	-	-
	1974	14.9	+	2.4	+	117.6	5.3	-	-
	MEAN	13.6		2.0		73.2		-	-
CAMBARUS BARTONI									
	1973	891.4	35.7	202.6	13.5	361.5	21.9	-	-
	1974	797.0	34.5	-	-	448.5	20.2	-	-
	MEAN	852.3		121.6		396.3		-	-
ORCONECTES LIMOSUS									
	1973	554.2	22.2	-	-	484.9	29.4	-	-
	1974	71.7	3.1	-	-	314.4	14.2	-	-
	MEAN	354.6		-	-	416.7		-	-
CAENIS SP.									
	1973	4.1	+	11.4	+	2.9	+	-	-
	1974	7.9	+	21.4	+	8.3	+	+	+
	MEAN	5.7		15.4		5.1		+	
TRICORYTHODES SP.									
	1973	-	-	+	+	+	+	-	-
	1974	-	-	+	+	-	-	-	-
	MEAN	-	-	+		+		-	-
EPHEMERELLA SPP.									
	1973	+	+	-	-	+	+	-	-
	1974	+	+	-	-	-	-	-	-
	MEAN	+		-	-	+		-	-
BAETIS SPP.									
	1973	5.4	+	34.1	2.3	2.7	+	+	+
	1974	1.6	+	34.0	+	12.1	+	+	+
	MEAN	3.8		34.1		6.5		+	
STENONEMA SPP.									
	1973	4.8	+	12.5	+	1.5	+	-	-
	1974	40.9	2.1	+	+	4.4	+	-	-
	MEAN	23.0		7.7		2.7		-	-

TABLE 11 (CONTINUED)

		ELEPHANT MG/ SQ.MET.	%	BRANCH MG/ SQ.MET.	%	SELLERSVILLE MG/ SQ.MET.	%	CATHILL MG/ SQ.MET.	%
ARGIA SPP.									
	1973	+	+	70.0	4.7	10.4	+	+	+
	1974	1.9	+	9.6	+	25.0	+	+	+
	MEAN	+		45.8		16.2		+	
ALLOCAPNIA SPP.									
	1973	22.8	+	1.5	+	+	+	-	-
	1974	77.6	3.4	+	+	+	+	-	-
	MEAN	45.5		1.1		+		-	-
PERLESTA PLACIDA									
	1973	43.5	+	7.6	+	3.8	+	+	+
	1974	31.6	+	33.7	+	1.1	+	-	-
	MEAN	38.5		18.0		2.7		+	
CORIXIDAE									
	1973	39.0	+	+	+	+	+	-	-
	1974	99.6	4.3	+	+	-	-	-	-
	MEAN	64.1		+		+		-	-
CORYDALUS CORNUTUS									
	1973	-	-	-	-	-	-	-	-
	1974	-	-	-	-	1.2	+	-	-
	MEAN	-	-	-	-	+		-	+
PSEPHENUS HERRICKI									
	1973	+	+	8.4	+	+	+	+	+
	1974	1.8	+	7.7	+	1.5	+	+	+
	MEAN	+		8.1		+		+	
STENELMIS SPP.									
	1973	24.5	+	55.1	3.7	18.3	+	5.7	+
	1974	42.2	+	32.1	+	65.1	2.9	7.5	+
	MEAN	31.8		45.9		37.0		6.4	
CHIMARRA SPP.									
	1973	+	+	83.0	5.5	13.2	+	+	+
	1974	1.9	+	320.1	14.3	88.7	4.0	+	+
	MEAN	1.1		177.8		43.4		+	
CHEUMATOPSYCHE SPP.									
	1973	97.9	3.9	419.7	27.9	197.1	11.9	107.9	38.8
	1974	359.2	15.5	813.6	36.2	561.0	25.3	689.1	70.4
	MEAN	206.0		577.4		342.7		340.4	
HYDROPSYCHE SPP.									
	1973	+	+	108.1	12.5	7.3	+	+	+
	1974	+	+	477.8	21.3	18.3	+	5.6	+
	MEAN	+		304.0		11.7		2.2	

TABLE 11 (CONTINUED)

		ELEPHANT MG/ SQ.MET.	%	BRANCH MG/ SQ.MET.	%	SELLERSVILLE MG/ SQ.MET.	%	CATHILL MG/ SQ.MET.	%
LEUCOTRICHIA PICTIPES									
	1973	-	-	+	+	-	-	-	-
	1974	-	-	-	-	+	+	+	+
	MEAN	-		+		+		+	
TIPULA SPP.									
	1973	99.3	4.0	43.4	2.9	-	-	8.1	2.6
	1974	117.7	5.1	-	-	1.6	+	11.1	+
	MEAN	106.9		26.0		+		9.3	
SIMULIIDAE									
	1973	15.5	+	70.8	4.7	76.4	4.6	40.6	13.1
	1974	19.2	+	71.4	3.2	52.3	2.4	35.1	3.6
	MEAN	17.0		71.1		66.8		38.4	
CHIRONOMIDAE									
	1973	457.4	18.3	178.8	11.9	216.3	13.1	133.0	42.9
	1974	404.8	21.0	305.8	13.6	205.4	9.3	205.9	21.8
	MEAN	468.7		229.6		212.0		162.2	
PHYSA ACUTA									
	1973	110.8	4.4	5.1	+	45.6	2.8	3.5	+
	1974	13.3	+	9.5	+	48.9	2.2	6.6	+
	MEAN	70.4		6.9		46.9		4.7	
SPHAERIUM SPP.									
	1973	+	+	4.3	+	+	+	-	-
	1974	+	+	+	+	28.7	+	-	-
	MEAN	+		2.7		11.9		-	-
ALL OTHERS									
	1973	52.2	2.1	33.0	2.2	48.0	2.9	+	+
	1974	80.1	3.5	45.9	2.0	107.4	4.8	+	+
	MEAN	63.8		38.1		71.8		+	

TABLE 11 (CONTINUED)

		MOYER MG/ SQ.MET.	%	WAWA MG/ SQ.MET.	%	SPRING MOUNT MG/ SQ.MET.	%	RAHNS MG/ SQ.MET.	%
DUGESIA SPP.									
	1973	60.5	3.1	47.4	*	28.7	*	24.9	*
	1974	362.6	6.3	610.8	10.1	31.0	*	38.0	*
	MEAN	181.3		275.9		29.6		30.1	
OLIGOCHAETA									
	1973	106.0	5.4	16.0	*	100.0	2.4	87.6	2.2
	1974	126.6	2.2	89.3	*	42.8	*	75.2	2.4
	MEAN	114.2		45.3		77.1		82.6	
ERPOBDELLA PUNCTATA									
	1973	3.8	*	41.0	*	13.5	*	38.3	*
	1974	16.6	*	68.3	*	*	*	47.8	*
	MEAN	8.9		51.9		8.1		42.1	
ORCONECTES LIMOSUS									
	1973	50.1	2.6	-	-	173.8	4.1	-	-
	1974	1055.7	18.3	-	-	1.6	*	*	*
	MEAN	452.4		-	-	104.9		*	
CAENIS SP.									
	1973	*	*	*	*	*	*	2.5	*
	1974	*	*	*	*	*	*	*	*
	MEAN	*		*		*		1.9	
TRICORYTHODES SP.									
	1973	-	-	*	*	*	*	1.5	*
	1974	-	-	*	*	1.5	*	*	*
	MEAN	-	-	*		*		1.1	
EPHEMERELLA SPP.									
	1973	*	*	*	*	82.6	*	33.0	*
	1974	*	*	*	*	264.1	7.5	33.7	*
	MEAN	*		*		155.2		33.3	
BAETIS SPP.									
	1973	5.0	*	15.9	*	36.7	*	52.7	*
	1974	8.0	*	28.9	*	65.7	*	57.2	*
	MEAN	6.2		21.1		48.3		54.5	
STENONEMA SPP.									
	1973	*	*	*	*	247.7	5.9	54.4	*
	1974	-	-	*	*	213.1	6.1	55.9	*
	MEAN	*		*		231.9		55.0	
ARGIA SPP.									
	1973	4.1	*	14.2	*	5.6	*	12.3	*
	1974	65.7	*	46.7	*	34.7	*	11.3	*
	MEAN	28.7		27.2		17.1		11.9	

TABLE 11 (CONTINUED)

		MOYER MG/ SQ.MET.	%	WAWA MG/ SQ.MET.	%	SPRING MOUNT MG/ SQ.MET.	%	BAHNS MG/ SQ.MET.	%
ALLOCAPNIA SPP.									
	1973	-	-	+	+	+	+	4.1	+
	1974	+	+	+	+	2.2	+	3.9	+
	MEAN	+		+		1.1		4.0	
PERLESTA PLACIDA									
	1973	-	-	-	-	3.4	+	+	+
	1974	-	-	+	+	21.9	+	4.1	+
	MEAN	-	-	+		10.8		2.0	
CORIXIDAE									
	1973	-	-	+	+	-	-	-	-
	1974	-	-	-	-	-	-	-	-
	MEAN	-	-	+		-	-	-	-
CORYDALUS CORNUTUS									
	1973	2.2	+	17.4	+	615.3	14.6	142.0	3.5
	1974	7.1	+	-	-	400.4	11.4	129.6	4.2
	MEAN	4.1		10.4		529.3		137.0	
PSEPHENUS HERRICKI									
	1973	5.5	+	35.1	+	8.6	+	30.5	+
	1974	36.6	+	112.6	+	11.0	+	85.3	2.8
	MEAN	18.0		66.1		9.5		52.4	
STENELMIS SPP.									
	1973	75.3	3.9	233.7	6.3	12.4	+	113.2	2.8
	1974	210.7	3.7	664.7	10.8	41.2	+	184.3	6.0
	MEAN	129.5		406.1		23.9		141.7	
CHIMARRA SPP.									
	1973	184.0	9.5	662.1	18.0	24.6	+	187.7	4.6
	1974	659.7	11.5	852.5	13.8	23.5	+	147.2	4.8
	MEAN	374.2		738.3		24.2		171.5	
CHEUMATOPSYCHE SPP.									
	1973	779.6	40.1	688.3	18.7	683.7	16.2	1146.9	28.3
	1974	1328.5	23.1	320.6	5.2	539.3	15.4	800.3	26.0
	MEAN	999.2		541.2		626.0		1008.2	
HYDROPSYCHE SPP.									
	1973	406.8	20.9	1615.0	43.9	1058.0	25.1	1646.0	40.6
	1974	1609.3	28.0	2215.1	36.0	873.4	24.9	831.2	27.0
	MEAN	887.8		1855.0		983.8		1320.1	
LEUCOTRICHIA PICTIPES									
	1973	1.7	+	1.4	+	1.8	+	+	+
	1974	18.9	+	25.4	+	4.5	+	7.4	+
	MEAN	8.6		11.0		2.9		3.3	

TABLE 11 (CONTINUED)

		MOYER NO/ SQ.MET.	%	WAWA NO/ SQ.MET.	%	SPRING MOUNT NO/ SQ.MET.	%	BAUMS NO/ SQ.MET.	%
TIPULA SPP.									
	1973	12.4	*	-	-	31.0	*	52.0	*
	1974	-	-	-	-	30.3	*	-	-
	MEAN	7.5		-	-	31.2		31.2	
SIMULIIDAE									
	1973	58.3	3.0	76.6	2.1	308.0	7.3	69.7	*
	1974	19.4	*	22.0	*	175.3	5.0	237.1	7.7
	MEAN	42.8		54.8		255.4		136.7	
CHIRONOMIDAE									
	1973	131.1	6.7	194.7	5.3	491.4	11.7	185.3	4.6
	1974	160.3	2.8	212.6	3.5	436.5	12.4	162.7	5.3
	MEAN	142.8		201.9		469.4		176.2	
PHYSA ACUTA									
	1973	42.5	2.2	*	*	24.6	*	8.9	*
	1974	13.4	*	2.5	*	41.9	*	2.3	*
	MEAN	30.9		1.0		31.5		6.3	
SPHAERIUM SPP.									
	1973	*	*	11.8	*	11.9	*	3.0	*
	1974	*	*	846.0	13.7	1.9	*	49.0	*
	MEAN	*		345.5		7.9		21.4	
ALL OTHERS									
	1973	14.9	*	10.3	*	246.5	5.9	156.0	3.8
	1974	54.9	*	29.2	*	250.6	7.1	110.2	3.6
	MEAN	30.9		17.9		240.1		137.7	

* = LESS THAN 1 NO/SQ.MET. OR LESS THAN 2.0%
CAENIS SPP., TRICORYTHODES SP., PERLESTA PLACIDA, AND LEUCOTRICHIA PICTIPES WERE DOMINANT ONLY NUMERICALLY (SEE TABLE 2.2.2.2-10).

TABLE 12

SUMMARY TABLE OF AQUATIC MACROINVERTEBRATE DRIFT AS MEASURED FOR EACH MONTHLY 24-H STUDY IN EAST BRANCH PERKIOMEN CREEK AND PERKIOMEN CREEK. MONTHLY VALUES FOR INDIVIDUAL TAXA REPRESENT PERCENT OF TOTAL DRIFT.

	1973	1974							
	Aug	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean
East Branch Perkiomen Creek									
Dominant[a] taxa									
Baetis spp.	-	Absent	9.4	9.8	4.6	41.8	7.1	2.2	9.0
Coenagrionidae	-	Absent	Absent	[b]	Absent	Absent	2.7	Absent	[b]
Stenelmis spp.	-	4.0	4.6	7.6	8.1	1.1	1.0	Absent	5.7
Chimarra spp.	-	28.9	Absent	[b]	[b]	Absent	1.0	Absent	4.3
Cheumatopsyche spp.	-	4.0	[b]	18.7	29.9	3.2	10.1	2.2	13.4
Hydropsyche spp.	-	3.2	[b]	49.8	8.1	Absent	9.6	Absent	25.0
Chironomidae	-	35.6	72.9	7.3	43.1	51.7	64.7	84.4	31.6
Total percent	-	75.7	87.9	94.2	94.3	98.3	94.2	88.8	91.1
Total number/1000 m³	-	386	530	1921	902	689	1897	418	927
All taxa									
Total number ± SE/1000 m³	-	510±107	603±92	2039±799	957±282	697±263	1912±485	471±164	1019±157
Total biomass (mg dry wt) ± SE/1000 m³	-	71±19	74±15	352±148	192±50	57±38	223±107	80±30	148±28
Total taxa	-	19	13	16	12	5	10	7	12
Velocity (m/s)	-	0.125	0.116	0.110	0.052	0.037	0.034	0.030	0.072
Perkiomen Creek									
Dominant[a] taxa									
Naididae	-	0	0	0	0	0	0	0	Absent
Gammarus fasciatus	-	[b]	Absent	[b]	[b]	1.4	[b]	[b]	[b]
Tricorythodes sp.	-	Absent	Absent	6.7	3.4	1.0	[b]	1.0	3.4
Baetis spp.	-	Absent	17.5	7.0	[b]	33.2	18.1	3.1	6.1
Cheumatopsyche spp.	-	5.3	[b]	13.9	4.5	12.2	3.6	[b]	6.4
Simuliidae	-	[b]	3.4	4.9	[b]	[b]	[b]	2.4	1.6
Chironomidae	-	50.9	67.9	52.9	85.9	40.9	70.1	79.5	73.2
Heleidae	-	Absent	Absent	Absent	[b]	[b]	[b]	Absent	[b]
Total percent	-	56.4	88.8	35.3	95.8	89.7	93.8	87.0	91.7
Total number/1000 m³	-	181	625	3358	10,126	1285	2807	592	2550
All taxa									
Total number ± SE/1000 m³	1991±539	321±60	704±204	2765±701	10570±2294	1433±495	2991±1107	680±140	2781±520
Total biomass (mg dry wt) ± SE/1000 m³	82±20	69±23	69±17	275±145	482±114	134±45	201±63	98±39	190±32
Total taxa	20	14	19	31	37	25	26	20	27
Velocity (m/s)	0.146	0.360	0.238	0.244	0.171	0.101	0.116	0.110	0.191

[a] Taxa which comprised ≥2% of the total number in either 1973 or 1974. Numerous other taxa were dominant in individual months.
[b] Drifting, but at levels below 2% of total.

TABLE 12 (Cont'd)

	1974						
	Apr	May	Jun	Jul	Aug	Sep	Mean
East Branch Perkiomen Creek							
Dominant[1] taxa							
Baetis spp.	+[2]	36.6	23.9	4.7	[illegible]	16.3	20.6
Coenagrionidae	Absent	Absent	1.3	+	7.1	1.0	2.0
Stenelmis spp.	5.7	2.5	1.3	10.3	+	1.0	1.7
Chimarra spp.	2.1	+	+	Absent	Absent	1.0	+
Cheumatopsyche spp.	+	Absent	4.4	3.2	3.5	6.0	+
Hydropsyche spp.	2.0	26.9	9.1	1.1	2.2	7.0	14.3
Chironomidae	77.7	32.6	48.1	45.0	57.7	44.3	47.2
Total percent	88.5	99.1	91.6	95.3	[illegible]	90.0	98.8
Total number/1000 m^3	1077	5272	459	1267	[illegible]	453	2979
All taxa							
Total number ± SE/1000 m^3	1217±189	5320±2001	533±132	1495±551	11012±1697	562±91	3355±717
Total biomass (mg dry wt) ± SE/1000 m^3	130±55	348±187	22±5	384±345	453±156	42±10	220±72
Total taxa	19	20	16	17	29	19	20
Velocity (m/s)	0.116	0.090	0.150	0.037	0.014	0.049	0.079
Perkiomen Creek							
Dominant[1] taxa							
Naididae	2.9	48.3	+	+	+	Absent	13.1
Gammarus fasciatus	Absent	Absent	1.4	+	9.4	2.2	2.3
Tricorythodes sp.	Absent	Absent	+	+	2.1	+	+
Baetis spp.	1.9	4.5	31.5	2.2	18.2	11.5	9.0
Cheumatopsyche spp.	1.4	+	7.8	1.5	41.1	8.4	10.3
Simuliidae	20.0	+	10.9	1.0	1.1	2.1	2.5
Chironomidae	56.7	43.6	31.9	78.4	11.3	50.5	48.7
Heleidae	Absent	+	+	10.4	+	Absent	3.3
Total percent	82.9	97.9	85.0	94.5	85.9	75.0	89.4
Total number/1000 m^3	610	9511	1047	10860	6112	2784	5101
All taxa							
Total number ± SE/1000 m^3	736±97	9715±807	1232±169	11492±4155	7149±2912	1712±1036	5706±976
Total biomass (mg dry wt) ± SE/1000 m^3	43±15	251±46	86±29	629±244	431±171	152±50	275±56
Total taxa	30	23	23	47	41	35	34
Velocity (m/s)	0.322	0.138	0.247	0.111	0.117	0.170	0.191

TABLE 13

DIEL PERIODICITY OF AQUATIC DRIFT ON EAST BRANCH PERKIOMEN CREEK AND PERKIOMEN CREEK EXPRESSED AS PERCENT OF THE 24-H TOTAL, ALL DRIFT STUDIES COMBINED. FOR EXAMPLE, HIGHEST (19.1%) NUMERIC DRIFT DENSITIES ON PERKIOMEN CREEK GENERALLY OCCURRED NEAR 2200 H.

	1000	1200	1400	1600	1800	2000	2200	2400	0200	0400	0600	0800
Numbers												
East Branch	2.8	2.7	5.3	4.8	3.7	5.0	23.7	14.1	23.7	9.3	2.5	2.5
Perkiomen	3.6	3.0	3.9	4.7	4.4	6.5	19.1	15.4	17.3	14.3	5.0	2.6
Biomass												
East Branch	2.3	2.0	3.0	4.3	3.0	4.3	32.2	15.0	23.1	8.0	2.3	1.7
Perkiomen	1.2	1.1	2.8	3.1	4.1	7.2	21.2	23.1	17.1	14.7	3.1	1.1
Taxa												
East Branch	8.0	7.2	7.4	7.7	8.0	8.0	12.3	12.3	12.0	8.3	5.4	3.2
Perkiomen	5.0	5.4	6.8	8.4	8.0	9.9	10.9	12.2	10.9	10.6	7.0	5.0

TABLE 14

FISHES COLLECTED IN PERKIOMEN CREEK BY ALL GEARS DURING THE PERIOD JUNE 1970 THROUGH DECEMBER 1976. NOMENCLATURE IS FROM BAILEY (1960).

Common Name	Scientific Name	Relative Abundance
Freshwater eel family	Anguillidae	
American eel	Anguilla rostrata (Lesueur)	Rare
Trout family	Salmonidae	
Brook trout	Salvelinus fontinalis (Mitchell)	Rare
Pike family	Esocidae	
Redfin pickerel	Esox americanus americanus Gmelin	Uncommon
Muskellunge	Esox masquinongy Mitchill	Uncommon
Minnow family	Cyprinidae	
Goldfish	Carassius auratus (Linnaeus)	Common
Carp	Cyprinus carpio Linnaeus	Common
Carp x Goldfish hybrid		Uncommon
Cutlips minnow	Exoglossum maxillingua (Lesueur)	Common
Golden shiner	Notemigonus crysoleucas (Mitchill)	Uncommon
Comely shiner	Notropis amoenus (Abbott)	Abundant
Satinfin shiner	Notropis analostanus (Girard)	Abundant
Bridle shiner	Notropis bifrenatus (Cope)	Rare
Common shiner	Notropis cornutus (Mitchill)	Common
Spottail shiner	Notropis hudsonius (Clinton)	Abundant
Swallowtail shiner	Notropis procne (Cope)	Common
Spotfin shiner	Notropis spilopterus (Cope)	Abundant
Bluntnose minnow	Pimephales notatus (Rafinesque)	Common
Fathead minnow	Pimephales promelas Rafinesque	Rare
Blacknose dace	Rhinichthys atratulus (Hermann)	Common
Longnose dace	Rhinichthys cataractae (Valenciennes)	Common
Creek chub	Semotilus atromaculatus (Mitchill)	Uncommon
Fallfish	Semotilus corporalis (Mitchill)	Common
Sucker family	Catostomidae	
White sucker	Catostomus commersoni (Lacepede)	Abundant
Creek chubsucker	Erimyzon oblongus (Mitchill)	Uncommon

TABLE 14 (Continued)

Common Name	Scientific Name	Relative Abundance
Freshwater catfish family	Ictaluridae	
White catfish	*Ictalurus catus* (Linnaeus)	Rare
Yellow bullhead	*Ictalurus natalis* (Lesueur)	Common
Brown bullhead	*Ictalurus nebulosus* (Lesueur)	Uncommon
Channel catfish	*Ictalurus punctatus* (Rafinesque)	Rare
Margined madtom	*Noturus insignis* (Richardson)	Uncommon
Killifish family	Cyrinodontidae	
Banded killifish	*Fundulus diaphanus* (Lesueur)	Common
Mummichog	*Fundulus heteroclitus* (Linnaeus)	Rare*
Sunfish family	Centrarchidae	
Rock bass	*Ambloplites rupestris* (Rafinesque)	Common
Redbreast sunfish	*Lepomis auritus* (Linnaeus)	Abundant
Green sunfish	*Lepomis cyanellus* Rafinesque	Common
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)	Common
Bluegill	*Lepomis macrochirus* Rafinesque	Common
Sunfish hybrid	*Lepomis* hybrid	Uncommon
Smallmouth bass	*Micropterus dolomieui* Lacepede	Common
Largemouth bass	*Micropterus salmoides* (Lacepede)	Uncommon
White crappie	*Pomoxis annularis* Rafinesque	Rare
Black crappie	*Pomoxis nigromaculatus* (Lesueur)	Rare
Perch family	Percidae	
Tessellated darter	*Etheostoma olmstedi* Storer	Common
Shield darter	*Percina peltata* (Stauffer)	Uncommon

*Possible bait release

TABLE 15

MEAN DENSITY AND RELATIVE ABUNDANCE OF DRIFTING LARVAL FISH COLLECTED FROM PERKIOMEN CREEK AT P14390, MAY-AUGUST IN 1973, 1974, AND 1975.

TAXA	1973 NO./ CU.MET.	%	1974 NO./ CU.MET.	%	1975 NO./ CU.MET.	%
MINNOWS	0.08028	36.0	0.06707	12.4	0.09465	34.5
CARP	0.11250	50.5	0.43283	79.9	0.12685	46.3
WHITE SUCKER	0.01196	5.4	0.00775	1.4	0.01815	6.6
YELLOW BULLHEAD	0.00185	0.8	0.00223	0.4	0.00108	0.4
BANDED KILLIFISH	-	-	0.00012	0.0	-	-
LEPOMIS SUNFISH	0.00923	4.1	0.03007	5.6	0.02096	7.6
TESSELLATED DARTER	0.00461	2.1	0.00047	0.1	0.00972	3.5
SHIELD DARTER	0.00231	1.0	0.00117	0.2	0.00281	1.0
TOTAL	0.22285		0.54171		0.27424	

TABLE 16

TOTAL CATCH AND RELATIVE ABUNDANCE OF LARVAL FISH COLLECTED BY TRAP NET FROM PERKIOMEN CREEK SHORELINE P14390, MAY-AUGUST IN 1975.

TAXA	TOTAL CATCH	% CATCH
MINNOWS	1270	83.0
CARP	18	1.2
WHITE SUCKER	116	7.6
LEPOMIS SUNFISH	94	6.1
TESSELLATED DARTER	29	1.9
SHIELD DARTER	1	0.2
TOTAL	1530	

TABLE 17

DAILY MEAN DENSITY (NO./CU.MET.) OF DRIFTING LARVAL FISH
COLLECTED FROM PERKIOMEN CREEK AT P14390, MAY-AUGUST, 1974 AND 1975.

1974

TAXA	08MAY	15MAY	20MAY	30MAY	05JUN	11JUN	27JUN	02JUL	08JUL	16JUL	24JUL	29JUL	05AUG	13AUG	22AUG	27AUG
MINNOWS	0.003	0.001	0.557	0.032	0.039	0.060	0.029	0.027	0.142	0.059	0.089	0.037	0.094	0.042	0.037	0.020
CARP	0.003	-	7.304	0.659	0.011	0.127	-	-	0.003	0.006	0.006	0.003	0.057	-	-	-
WHITE SUCKER	0.024	0.043	-	0.003	-	-	-	-	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	0.003	-	0.038	0.006	-	-	-	-	-	-
ROCK BASS	-	-	-	0.006	0.006	0.007	-	-	0.005	-	-	-	-	-	-	-
LEPOMIS SUNFISH	-	-	0.002	0.002	0.022	0.300	0.025	-	0.025	0.019	0.039	0.118	0.035	-	-	-
TESSELLATED DARTER	0.002	0.002	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-
SHIELD DARTER	0.009	0.002	0.002	0.002	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 17 (CON'T)

1975

TAXA	12MAY	27MAY	17JUN	01JUL	29JUL	12AUG	26AUG
MINNOWS	0.002	0.055	0.006	0.036	0.069	0.016	0.003
CARP	-	0.316	-	0.000	0.001	-	-
WHITE SUCKER	0.155	0.011	-	-	-	-	-
YELLOW BULLHEAD	-	-	0.000	0.003	-	-	-
ROCK BASS	-	-	-	0.011	-	-	-
LEPOMIS SUNFISH	-	0.004	0.000	0.078	0.016	0.001	-
TESSELLATED DARTER	0.021	0.010	0.002	-	-	-	-
SHIELD DARTER	0.019	0.001	-	-	-	-	-

TABLE 18

HORIZONTAL VARIATION IN DENSITY OF LARVAL FISH
COLLECTED FROM THE PERKIOMEN CREEK AT P14390 IN 1975.

TAXA	NET 1 NO./CU.MET.	NET 2 NO./CU.MET.	NET 3 NO./CU.MET.	NET 4 NO./CU.MET.	NET 5 NO./CU.MET.	NET 6 NO./CU.MET.
MINNOWS	0.0584	0.0498	0.0481	0.0512	0.0098	0.0448
CARP	0.1494	0.1908	0.2549	0.2636	0.0366	0.0616
WHITE SUCKER	0.0361	0.0420	0.0408	0.0415	0.0850	0.1473
YELLOW BULLHEAD	0.0017	0.0009	0.0019	0.0010	0.0000	0.0026
ROCK BASS	0.0042	0.0067	0.0068	0.0024	0.0066	0.0216
LEPOMIS SUNFISH	0.0234	0.0138	0.0094	0.0097	0.0038	0.0396
TESSELLATED DARTER	0.0113	0.0160	0.0134	0.0204	0.0082	0.0075
SHIELD DARTER	0.0120	0.0092	0.0091	0.0109	0.0092	0.0068

TABLE 19

MEAN DRIFT DENSITY OF LARVAL FISH IN THE EAST
AND WEST CHANNELS OF PERKIOMEN CREEK AT P14390 IN 1975.

TAXA	EAST CHANNEL NO./CU.MET.	WEST CHANNEL NO./CU.MET.
MINNOWS	0.0286	0.0521
CARP	0.0508	0.2103
WHITE SUCKER	0.1117	0.0404
YELLOW BULLHEAD	0.0011	0.0014
ROCK BASS	0.0161	0.0050
LEPOMIS SUNFISH	0.0217	0.0146
TESSELLATED DARTER	0.0080	0.0150
SHIELD DARTER	0.0002	0.0106

TABLE 20

ANNUAL AND SPATIAL VARIATION IN MEAN CATCH PER UNIT EFFORT (C/F), AND RELATIVE ABUNDANCE OF FISHES COLLECTED BY SEINE FROM THE PERKIOMEN CREEK IN 1975 AND 1976.

SPECIES	1975 P19775 C/F	%	1976 P19775 C/F	%	1975 P16500 C/F	%	1976 P16500 C/F	%	1975 P14455 C/F	%	1976 P14455 C/F	%	1975 P14320 C/F	%	1976 P14320 C/F
AMERICAN EEL	-	-	0.10	0.1	-	-	-	-	-	-	-	-	-	-	-
CUTLIPS MINNOW	-	-	1.23	0.8	0.09	0.1	0.88	0.5	-	-	-	-	-	-	-
GOLDEN SHINER	-	-	0.18	0.1	0.08	0.1	-	-	-	-	1.60	0.3	-	-	0.11
COMELY SHINER	25.70	25.2	3.59	2.2	2.90	4.1	2.67	1.7	1.92	1.4	20.49	4.0	3.64	2.5	5.39
SATINFIN SHINER	1.06	1.0	2.96	1.8	7.44	10.5	18.68	11.6	0.65	0.5	1.89	0.4	3.76	2.6	7.95
COMMON SHINER	1.97	1.9	4.00	2.4	0.61	0.9	3.13	1.9	1.62	1.2	0.60	0.1	0.86	0.6	0.61
SPOTTAIL SHINER	2.27	2.2	26.68	16.3	0.48	0.7	44.94	27.8	3.39	2.5	80.60	15.7	2.09	1.5	27.01
SWALLOWTAIL SHINER	9.48	9.3	4.06	2.5	1.68	2.4	4.51	2.8	1.82	1.4	6.74	1.3	54.24	37.7	1.30
SPOTFIN SHINER	56.60	55.4	71.18	43.4	53.12	74.8	66.35	41.1	115.33	85.7	360.72	70.4	71.09	49.4	222.34
BLUNTNOSE MINNOW	0.10	0.1	0.10	0.1	0.47	0.7	0.56	0.3	1.03	0.8	8.60	1.7	0.36	0.2	0.13
BLACKNOSE DACE	-	-	0.43	0.3	0.30	0.4	1.06	0.7	-	-	-	-	-	-	0.26
LONGNOSE DACE	0.09	0.9	5.23	3.2	0.10	0.1	0.65	0.4	-	-	-	-	-	-	-
CREEK CHUB	-	-	0.39	0.2	-	-	0.30	0.2	-	-	-	-	-	-	-
FALLFISH	1.79	1.8	0.26	0.2	0.20	0.3	0.48	0.3	-	-	-	-	0.14	0.1	-
WHITE SUCKER	-	-	26.88	16.4	0.30	0.4	7.92	4.9	-	-	1.60	0.3	0.14	0.1	4.96
YELLOW BULLHEAD	-	-	0.10	0.1	-	-	0.09	0.1	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	0.08	0.1	-	-	-	-	-	-	-	-	-	-	-
MARGINED MADTOM	-	-	-	-	-	-	0.08	0.0	-	-	-	-	-	-	-
BANDED KILLIFISH	0.27	0.3	0.51	0.3	0.39	0.6	1.59	1.0	-	-	0.34	0.1	0.80	0.6	0.50
ROCK BASS	0.12	0.1	0.26	0.2	0.20	0.3	0.09	0.1	-	-	0.40	0.1	0.50	0.4	-
REDBREAST SUNFISH	-	-	0.81	0.5	2.05	2.9	1.72	1.1	3.22	2.4	9.77	1.9	2.73	1.9	2.31
GREEN SUNFISH	0.09	0.1	-	-	-	-	0.20	0.1	0.81	0.6	4.80	0.9	-	-	0.76
PUMPKINSEED	-	-	-	-	-	-	-	-	2.05	1.5	6.17	1.2	0.45	0.3	0.49
BLUEGILL	0.12	0.1	0.09	0.1	0.29	0.4	-	-	2.30	1.7	2.97	0.6	1.72	1.2	-
LEPOMIS HYBRID	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	0.12	0.1	4.52	2.8	0.29	0.4	4.92	3.0	0.14	0.1	3.60	0.7	1.24	0.9	7.27
LARGEMOUTH BASS	0.09	0.1	0.61	0.4	-	-	-	-	-	-	-	-	-	-	0.30
WHITE CRAPPIE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TESSELLATED DARTER	1.07	1.0	9.52	5.8	-	-	0.33	0.2	0.22	0.2	1.20	0.2	0.14	0.1	0.59
SHIELD DARTER	0.12	0.1	0.17	0.1	-	-	0.25	0.2	-	-	0.20	0.0	-	-	-

TABLE 20 (CONTINUED)

SPECIES	%	1975 P14130 C/F	%	1976 P14130 C/F	%	1975 P13580 C/F	%	1976 P13580 C/F	%	1975 MEAN C/F	%	1976 MEAN C/F	%	COMBINED YEARS MEAN C/F	%
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-	-	0.02	0.0	0.01	0.[illegible]
CUTLIPS MINNOW	-	0.21	0.3	-	-	0.22	0.2	0.63	0.2	0.09	0.1	0.46	0.2	0.20	0.1
GOLDEN SHINER	0.0	-	-	0.34	0.1	0.40	0.3	0.39	0.1	0.08	0.1	0.42	0.2	0.25	0.1
COMELY SHINER	1.9	0.57	0.7	6.23	2.3	2.16	1.7	3.23	1.0	6.25	5.7	6.73	2.4	6.49	3.[illegible]
SATINFIN SHINER	2.8	11.22	13.4	13.98	5.2	9.58	7.6	7.56	2.4	5.73	5.2	8.94	3.2	7.33	3.[illegible]
COMMON SHINER	0.2	5.03	6.0	2.63	1.0	8.05	6.4	2.71	0.9	3.08	2.8	2.31	0.8	2.69	1.[illegible]
SPOTTAIL SHINER	9.0	4.11	4.9	24.98	9.3	5.17	4.1	24.50	7.8	2.92	2.7	37.60	13.4	20.26	10.[illegible]
SWALLOWTAIL SHINER	0.5	0.54	0.6	1.92	0.7	2.11	1.7	1.99	0.6	11.13	10.2	3.37	1.2	7.25	3.[illegible]
SPOTFIN SHINER	70.7	59.30	70.6	197.47	73.7	91.62	73.0	212.41	67.6	73.93	67.7	185.76	66.3	129.84	66.[illegible]
BLUNTNOSE MINNOW	0.0	-	-	0.47	0.2	1.29	1.0	9.31	3.0	0.57	0.5	3.11	1.1	1.84	0.[illegible]
BLACKNOSE DACE	0.1	-	-	4.66	1.7	0.53	0.4	1.93	0.6	0.14	0.1	1.42	0.5	0.70	0.[illegible]
LONGNOSE DACE	-	-	-	1.36	0.5	-	-	0.23	0.1	0.17	0.2	1.26	0.5	0.72	0.[illegible]
CREEK CHUB	-	-	-	-	-	-	-	0.37	0.1			0.18	0.1	0.09	0.[illegible]
FALLFISH	-	0.48	0.6	0.34	0.1	0.22	0.2	0.34	0.1	0.49	0.4	0.24	0.1	0.36	0.[illegible]
WHITE SUCKER	1.8	0.11	0.1	10.68	4.0	-	-	21.80	6.9	0.09	0.1	12.47	4.4	6.28	3.2
YELLOW BULLHEAD	-	-	-	-	-	-	-	2.23	0.7	-	-	0.41	0.1	0.21	0.[illegible]
BROWN BULLHEAD	-	-	-	-	-	-	-	-	-	-	-	0.01	0.0	0.01	0.[illegible]
MARGINED MADTOM	-	-	-	0.11	0.0	-	-	-		-	-	0.03	0.0	0.02	0.[illegible]
BANDED KILLIFISH	0.2	0.97	1.2	1.08	0.4	1.21	1.0	2.89	0.9	0.61	0.6	1.17	0.4	0.89	0.[illegible]
ROCK BASS	-	-	-	-	-	0.09	0.1	0.08	0.0	0.15	0.1	0.13	0.0	0.14	0.[illegible]
REDBREAST SUNFISH	0.3	0.45	0.5	0.45	0.2	1.27	1.0	4.39	1.4	1.58	1.4	3.14	1.1	2.36	1.[illegible]
GREEN SUNFISH	0.1	-	-	-	-	0.47	0.4	3.45	1.1	0.22	0.2	1.40	0.5	0.81	0.[illegible]
PUMPKINSEED	0.2	-	-	-	-	0.22	0.2	4.39	1.4	0.43	0.4	1.77	0.6	1.10	0.[illegible]
BLUEGILL	-	-	-	-	-	-	-	0.92	0.3	0.70	0.6	0.63	0.2	0.66	0.[illegible]
LEPOMIS HYBRID	-	0.10	0.1	-	-	0.11	0.1	-		0.04	0.0			0.02	0.[illegible]
SMALLMOUTH BASS	2.6	0.42	0.5	0.57	0.2	0.43	0.3	1.50	0.5	0.43	0.4	3.75	1.3	2.09	1.1
LARGEMOUTH BASS	0.1	-	-	-	-	-	-	0.16	0.1	0.02	0.0	0.10	0.1	0.10	0.1
WHITE CRAPPIE	-	-	-	-	-	-	-	0.00	0.0	-		0.01	0.0	0.01	0.[illegible]
TESSELLATED DARTER	0.2	0.13	0.4	0.73	0.3	0.39	0.3	6.25	2.0	0.36	0.3	3.13	1.1	1.75	0.[illegible]
SHIELD DARTER	-	0.09	0.1	-	-	-	-	0.42	0.1	0.04	0.0	0.17	0.1	0.10	0.[illegible]

TABLE 21

ANNUAL VARIATION AND FREQUENCY OF OCCURRENCE (FO) IN AGE 0 SUNFISH SPECIES COMPOSITION COLLECTED BY ELECTROFISHING IN PERKIOMEN CREEK (ALL SITES COMBINED) IN 1975 AND 1976.

SPECIES	1975 TOTAL CATCH	% TOTAL	FO (%)	1976 TOTAL CATCH	% TOTAL	FO (%)	GRAND TOTAL CATCH	% TOTAL
ROCK BASS	4	3.5	25.0	14	4.9	50.0	18	4.5
REDBREAST SUNFISH	64	56.6	100.0	197	69.6	100.0	261	65.9
GREEN SUNFISH	41	36.3	83.3	36	12.7	58.3	77	19.4
PUMPKINSEED	-	-	-	34	12.0	50.0	34	8.6
SMALLMOUTH BASS	4	3.5	25.0	2	0.7	8.3	6	1.5
TOTAL	113			283			396	

TABLE 22

MONTHLY VARIATION IN MEAN CATCH PER UNIT EFFORT OF FISHES COLLECTED BY SEINE FROM PERKIOMEN CREEK (ALL SITES COMBINED) IN 1975 AND 1976.

SPECIES	FEB 1975	1976	MAR 1975	1976	APR 1975	1976	MAY 1975	1976	JUN 1975	1976	JUL 1975	1976
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-	-	0.19
CUTLIPS MINNOW	-	-	-	-	-	-	0.20	-	0.41	1.04	0.16	2.11
GOLDEN SHINER	0.21	-	0.15	-	0.20	0.14	-	2.57	0.20	-	0.17	0.67
COMELY SHINER	30.44	1.07	0.35	1.67	17.03	2.21	7.05	4.39	1.51	0.14	2.01	4.24
SATINFIN SHINER	1.29	0.81	3.64	0.47	2.39	11.34	2.82	11.42	2.05	2.77	4.38	4.96
COMMON SHINER	1.41	-	0.17	-	8.26	-	2.92	-	5.75	7.31	9.50	8.40
SPOTTAIL SHINER	0.75	0.24	3.08	-	4.45	-	5.58	0.21	7.61	225.33	5.78	47.31
SWALLOWTAIL SHINER	2.19	0.36	0.28	0.13	2.02	0.42	87.54	3.46	0.57	3.64	-	0.46
SPOTFIN SHINER	52.22	2.65	18.24	2.20	99.75	14.20	131.20	71.04	52.80	64.86	17.00	59.24
BLUNTNOSE MINNOW	0.61	-	0.99	-	1.55	0.14	0.87	0.28	-	0.56	-	2.00
BLACKNOSE DACE	-	-	-	-	0.56	3.10	-	1.98	0.81	3.09	0.17	2.43
LONGNOSE DACE	-	-	-	-	0.33	0.15	1.07	0.30	0.22	8.45	-	1.46
CREEK CHUB	-	-	-	-	-	-	-	-	-	0.15	-	1.32
FALLFISH	0.25	0.26	0.33	-	1.54	-	1.09	-	1.04	1.02	0.65	0.63
WHITE SUCKER	-	-	-	-	-	-	0.56	83.81	0.45	40.69	-	6.00
YELLOW BULLHEAD	-	-	-	-	-	-	-	-	-	-	-	3.54
BROWN BULLHEAD	-	-	-	-	-	-	-	-	-	-	-	-
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	-	-	-
BANDED KILLIFISH	0.11	0.45	1.64	0.41	2.92	0.21	0.61	0.60	-	1.20	-	1.51
ROCK BASS	-	-	-	-	-	-	0.41	0.14	0.24	0.15	0.19	-
REDBREAST SUNFISH		-	-	-	0.48	1.11	1.61	0.56	1.17	1.25	0.14	0.10
GREEN SUNFISH	0.25	-	-	-	-	-	0.56	-	0.20	0.20	0.24	1.08
PUMPKINSEED	-	-	-	0.28	0.28	-	0.20	0.14	2.29	0.47	0.37	1.04
BLUEGILL	-	-	-	-	-	0.28	-	-	2.02	-	1.38	2.29
LEPOMIS HYBRID	-	-	-	-	-	-	0.20	-	-	-	-	-
SMALLMOUTH BASS	-	-	0.24	-	-	-	0.82	-	0.65	30.47	0.37	6.02
LARGEMOUTH BASS	0.25	-	-	-	-	-	-	0.14	-	-	-	1.67
WHITE CRAPPIE	-	-	-	-	-	-	-	-	-	-	-	-
TESSELLATED DARTER	0.21	-	0.92	0.33	0.57	0.59	0.20	-	0.79	14.91	-	8.76
SHIELD DARTER	-	-	-	-	-	0.11	-	0.33	0.22	0.06	-	0.35

TABLE 22 (CON'T)

	AUG 1975	1976	SEP 1975	1976	OCT 1975	1976	NOV 1975	1976	DEC 1975	1976
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-
CUTLIPS MINNOW	0.19	1.04	-	0.67	-	0.17	-	-	-	-
GOLDEN SHINER	-	0.42	-	0.15	-	0.21	-	0.42	-	-
COMELY SHINER	2.00	9.10	4.49	16.54	2.28	18.69	0.89	12.70	2.68	2.12
SATINFIN SHINER	6.26	11.59	9.85	10.26	5.93	15.05	8.60	16.37	14.31	11.83
COMMON SHINER	1.08	3.42	0.83	2.59	0.61	0.50	-	0.85	-	1.91
SPOTTAIL SHINER	1.33	24.69	1.00	49.40	1.52	30.17	0.19	14.24	0.17	15.76
SWALLOWTAIL SHINER	2.79	3.32	3.44	9.93	0.97	10.34	1.92	3.59	17.78	0.88
SPOTFIN SHINER	66.73	187.98	101.62	426.96	60.60	631.47	59.56	502.87	66.17	48.92
BLUNTNOSE MINNOW	0.20	0.50	0.64	7.71	-	7.92	0.30	14.45	1.06	0.17
BLACKNOSE DACE	-	2.76	-	0.87	-	0.42	-	0.76	-	-
LONGNOSE DACE	-	0.79	-	0.58	-	1.51	0.19	0.46	-	-
CREEK CHUB	-	0.19	-	0.15	-	-	-	0.14	-	-
FALLFISH	0.37	-	-	0.19	-	0.51	-	-	-	-
WHITE SUCKER	-	2.53	-	0.30	-	0.76	-	0.14	-	-
YELLOW BULLHEAD	-	0.72	-	0.19	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	0.15	-	-
MARGINED MADTOM	-	-	-	0.21	-	0.14	-	-	-	-
BANDED KILLIFISH	0.32	1.76	0.49	1.62	0.21	1.49	-	2.24	0.17	1.19
ROCK BASS	-	0.50	0.58	-	0.19	0.33	-	0.33	-	-
REDBREAST SUNFISH	2.11	13.46	6.72	6.57	0.42	2.64	1.76	-	-	-
GREEN SUNFISH	0.16	9.54	0.50	1.16	0.56	1.51	-	0.81	-	-
PUMPKINSEED	0.14	1.41	0.11	4.76	-	8.10	0.67	2.01	0.20	-
BLUEGILL	0.52	1.33	1.42	-	0.83	2.89	1.00	-	0.28	-
LEPOMIS HYBRID	0.19	-	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	1.58	2.96	0.38	0.97	0.21	0.15	0.39	-	-	-
LARGEMOUTH BASS	-	-	-	-	-	0.15	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	0.15	-	-	-	-
TESSELLATED DARTER	0.35	1.85	-	2.80	-	2.01	0.71	1.57	0.19	1.12
SHIELD DARTER	-	-	-	0.19	-	-	-	-	0.17	-

TABLE 23

TOTAL CATCH AND RELATIVE ABUNDANCE OF FISHES COLLECTED BY ELECTROFISHING FROM PERKIOMEN CREEK IN 1974, 1975, AND 1976.

SPECIES	1974 P14190 NO.	%	P14160 NO.	%	P14020 NO.	%	1975 P14160 NO.	%	1976 P20000 NO.	%	P14390 NO.	%	P14160 NO.	%	P14020 NO.	%	TOTAL NO.	TOTAL %
AMERICAN EEL	7	0.3	2	0.3	1	0.1	4	0.4	7	0.6	9	0.4	5	0.7	2	0.3	37	0.4
MUSKELLUNGE	-	*	-	*	1	0.1	-	*	2	0.2	-	*	-	*	-	*	3	0.0
GOLDFISH	13	0.6	-	*	-	*	-	*	4	0.4	17	0.7	-	*	-	*	34	0.4
CARP	137	6.2	18	2.4	42	6.1	11	1.1	105	9.2	104	4.4	13	1.7	34	5.4	464	4.9
GOLDEN SHINER	-	*	-	*	-	*	3	0.3	-	*	-	*	-	*	-	*	3	0.0
FALLFISH	1	*	-	*	-	*	7	0.7	-	*	-	*	-	*	-	*	8	0.1
MINNOW HYBRID	6	0.3	-	*	4	0.6	2	0.2	3	0.3	-	*	-	*	-	*	15	0.2
WHITE SUCKER	241	10.8	50	6.6	59	8.5	101	10.0	272	23.9	215	9.1	123	16.4	99	15.8	1160	12.1
WHITE CATFISH	-	*	-	*	-	*	-	*	1	0.1	-	*	-	*	-	*	1	0.0
YELLOW BULLHEAD	68	3.1	17	2.2	9	1.3	30	3.0	33	2.9	43	1.9	11	1.5	4	0.6	215	2.2
BROWN BULLHEAD	34	1.5	2	0.3	5	0.7	1	0.1	6	0.5	19	0.8	1	0.1	1	0.2	69	0.7
CHANNEL CATFISH	-	*	-	*	-	*	-	*	1	0.1	1	*	-	*	-	*	2	0.0
MARGINED MADTOM	5	0.2	2	0.3	-	*	1	0.1	1	0.1	6	0.3	-	*	-	*	15	0.2
ROCK BASS	89	4.0	36	4.8	26	3.8	65	6.5	67	5.9	99	4.2	33	4.4	29	4.6	443	4.6
REDBREAST SUNFISH	993	44.7	507	67.1	333	48.1	510	50.7	403	35.4	1172	49.6	458	60.9	275	43.9	4656	48.7
GREEN SUNFISH	127	5.7	19	2.5	48	6.9	30	3.0	36	3.2	116	4.9	22	2.9	27	4.3	425	4.4
PUMPKINSEED	130	5.9	13	1.7	37	5.3	59	5.9	43	3.8	164	6.9	12	1.6	47	7.5	505	5.3
BLUEGILL	89	4.0	8	1.1	12	1.7	91	9.0	35	3.1	49	2.1	3	0.4	26	4.2	313	3.3
LEPOMIS HYBRID	24	1.1	2	0.3	3	0.4	3	0.3	7	0.6	23	1.0	9	1.2	3	0.5	74	0.8
SMALLMOUTH BASS	254	11.4	79	10.4	108	15.6	87	8.6	90	7.9	324	13.7	62	8.2	78	12.5	1082	11.3
LARGEMOUTH BASS	5	0.2	1	0.1	5	0.7	1	0.1	8	0.7	2	0.1	-	*	1	0.2	23	0.2
WHITE CRAPPIE	-	*	-	*	-	*	-	*	4	0.4	-	*	-	*	-	*	4	0.0
BLACK CRAPPIE	-	*	-	*	-	*	-	*	5	0.4	-	*	-	*	-	*	5	0.1
	2222		756		693		1006		1139		2361		752		626		9556	

* = LESS THAN 0.1%

TABLE 24

CRITERIA FOR DETERMINATION OF IMPORTANT FISHES OF PERKIOMEN CREEK.

Common Name	IMPORTANCE				LINK TO PLANT				
					DIRECT		INDIRECT		
	Commercial	Recreational	Ecological	Abundant	Susceptible to Impingement	Susceptible to Entrainment	Altered Habitat	Altered Food Supply	Altered Competitive Relationships
American shad[1]	X	X	X		X	X			
Muskellunge[2]		X			X			X	X
Carp[2,3,4]		X	X	X	X	X			
Comely shiner[5]			X	X	X	X	X		
Spottail shiner[3,4,5]			X	X	X	X			
Spotfin shiner[3,4,5]			X	X	X	X			
White sucker[2,3,4,5,6]		X	X	X	X	X		X	X
Redbreast sunfish[2,3,4,5,6,7]		X	X	X	X	X		X	X
Smallmouth bass[2,5,6,7]		X	X	X	X			X	X
Shield darter[3,4,5]			X		X	X		X	X

[1]Importance dependent on results of Pennsylvania Fish Commission program to provide fishways at dams downriver of LGS.
[2]Species sampled by large fish population estimate program.
[3]Species sampled by larval fish drift program.
[4]Species sampled by larval fish trap net program.
[5]Species sampled by seine program.
[6]Species sampled by age and growth program.
[7]Species sampled by small fish population estimate program.

TABLE 25

ANNUAL AND SPATIAL VARIATION IN REDBREAST SUNFISH POPULATION ESTIMATES AT FOUR SITES ON PERKIOMEN CREEK IN 1975 AND 1976.

Site	1975[1] N/20 m	1976 N/20 m
P14830	-	53
P14690	-	75
P14225	-	24
P14210	-	49
Streamwide estimate	81	185

[1]Too few specimens were captured in 1975 to provide reliable estimates within site.

TABLE 26

POPULATION ESTIMATES (N PER HECTARE) AND ESTIMATED BIOMASS (W PER HECTARE) OF LARGE FISHES COLLECTED BY ELECTROFISHING FROM FOUR SITES ON PERSIMMON CREEK IN 1974, 1975, AND 1976.

Species	Year	P20000 N/ha	P20000 W/ha (kg)	P14190 N/ha	P14190 W/ha (kg)	P14160 N/ha	P14160 W/ha (kg)	P14020 N/ha	P14020 W/ha (kg)
Redbreast sunfish	1974	-	-	437	20.9	1622	55.3	897	-
	1975	-	-	-	-	1479	46.5	-	-
	1976	415	14.5	338	18.7	1397	54.3	511	25.8
Carp	1974	-	-	110	208.0	41	90.1	-	-
	1975	-	-	-	-	-	-	-	-
	1976	131	160.0	67	95.0	-	-	-	-
White sucker	1974	-	-	154	80.4	174	149.0	137	-
	1975	-	-	-	-	451	110.0	-	-
	1976	314	175.0	139	58.1	334	90.8	258	67.6
Green sunfish	1974	-	-	87	2.12	-	-	-	-
	1975	-	-	-	-	-	-	-	-
	1976	18[1]	0.743	36	1.21	-	-	-	-
Smallmouth bass	1974	-	-	53	5.69	-	-	-	-
	1975	-	-	-	-	210	7.72	-	-
	1976	29[2]	2.717	84	7.29	163	12.4	-	-

[1] Represents fish considered to be >age 1.
[2] Represents fish considered to be age 2.

TABLE 27

POPULATION ESTIMATES BY AGE-GROUP FOR REDBREAST SUNFISH COLLECTED FROM FOUR SITES ON PERKIOMEN CREEK IN 1974, 1975, AND 1976.

Site	Age-Group	YEAR 1974	1975	1976
P20000	I	-	-	350
	II	-	-	156
	>II	-	-	169
	Total	-	-	676
P14390	I	734	-	247
	II	519	-	580
	>II	578	-	591
	Total	1831	-	1418
P14160	I	438	360	313
	II	406	403	397
	>II	177	137	167
	Total	9[illegible]6	908	857
P14020	I	214	-	85
	II	332	-	174
	>II	165	-	143
	Total	674	-	384

TABLE 28

LENGTH-WEIGHT RELATIONSHIPS ($\ln W = a + b \ln L$) OF IMPORTANT SPECIES COLLECTED BY SEINE FROM PERKIOMEN CREEK IN 1975 AND 1976.

Species	Site/Year	a	b
Comely shiner	P19775	-12.57	3.23
	P16500	-11.83	3.05
	P14455	-11.52	2.96
	P14320	-11.19	2.92
	P14130	-10.84	2.78
	P13580	-10.95	2.82
	1975	-12.00	3.09
	1976	-11.05	2.85
Spottail shiner	P19775	-11.63	3.04
	P16500	-11.75	3.09
	P14455	-11.82	3.08
	P14320	-12.43	3.25
	P14130	-9.94	2.83
	P13580	-11.58	3.03
	1975	-12.87	3.37
	1976	-11.09	2.91
Spotfin shiner	P19775	-12.03	3.12
	P16500	-11.93	3.11
	P14455	-12.18	3.17
	P14320	-12.43	3.28
	P14130	-12.49	3.26
	P13580	-12.10	3.16
	1975	-12.39	3.27
	1976	-12.09	3.16

TABLE 29

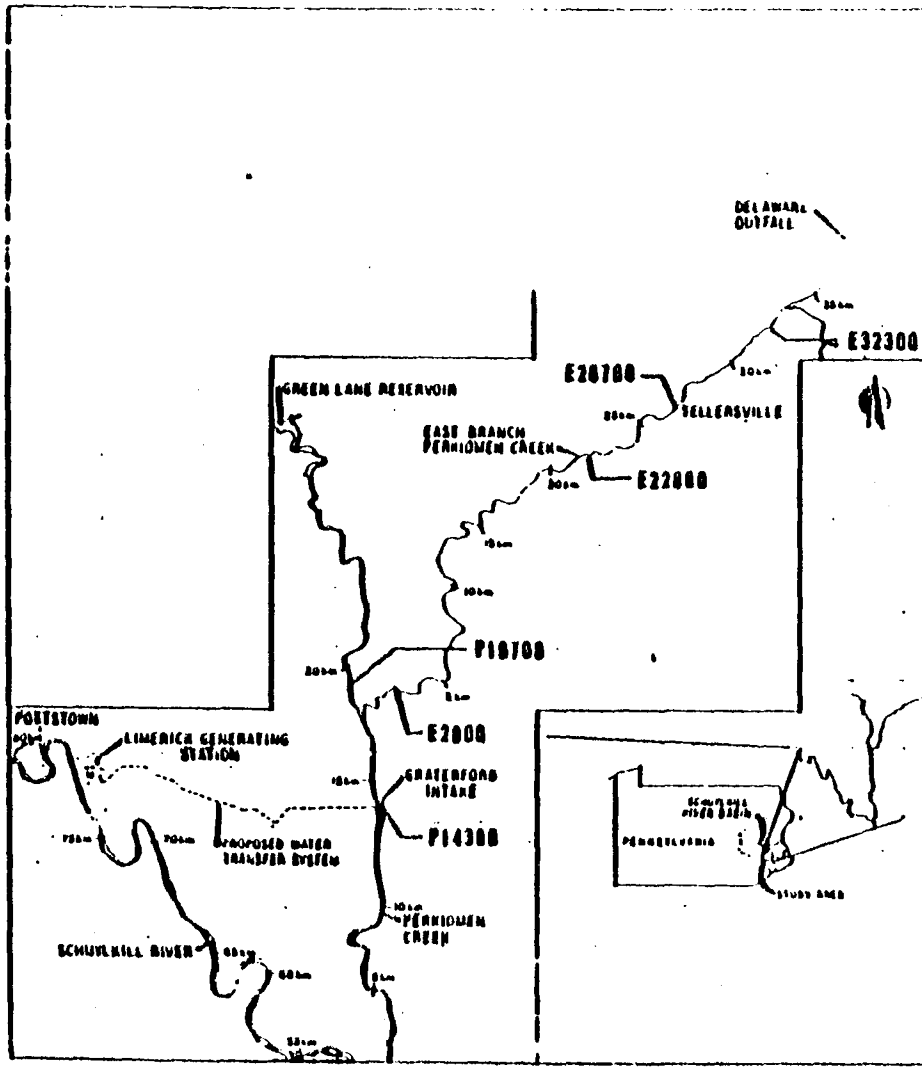
MEAN CALCULATED LENGTHS AT ANNULUS FOR REDBREAST SUNFISH, WHITE SUCKER, AND SMALLMOUTH BASS COLLECTED FROM PERKIOMEN CREEK IN 1973 AND 1976.

Species	Year	Site	No. of Fish	Weighted Mean Length (mm FL) at Annulus I	II	III	IV	V
Redbreast sunfish	1973	Streamwide	209	41	90	127	150	166
Redbreast sunfish	1976	P20000	64	35	76	117	147	-
		P14390	63	43	88	130	156	-
		P14160	62	37	85	122	-	-
		P14020	55	39	86	125	145	-
	Population Mean			38	84	124	149	-
White sucker	1976	P20000	41	113	213	291	-	-
		P14390	31	111	213	293	-	-
		P14160	43	107	206	259	-	-
		P14020	34	98	178	263	-	-
	Population Mean			107	203	277	-	-
Smallmouth bass	1973	Streamwide	76	83	159	213	-	-

TABLE 30

LENGTH-WEIGHT RELATIONSHIPS ($\ln W = a + b \ln L$) OF WHITE SUCKER COLLECTED BY ELECTROFISHING AT FOUR SITES ON PERKIOMEN CREEK IN 1976.

Site	a	b
P20000	-10.11	2.81
P14390	-10.72	2.91
P14160	-11.25	3.01
P14020	-11.71	3.09



PHILADELPHIA ELECTRIC COMPANY
LIMERICK GENERATING STATION
UNITS 1 AND 2
ENVIRONMENTAL REPORT

PERKIOMEN CREEK, EAST BRANCH
PERKIOMEN CREEK AND DELAWARE RIVER
WATER QUALITY SAMPLING SITES.

FIGURE 1 JUNE, 1970

EAST BRANCH PERKIOMEN CREEK

East Branch Perkiomen Creek

East Branch Perkiomen Creek is a warmwater stream which drains 158 km³ of the Piedmont physiographic province in southeastern Pennsylvania. It flows southwest approximately 39 km from its source in Bedminster Township to its confluence with Perkiomen Creek just below Schwenksville, Pennsylvania. The Creek has a low gradient (1.9 m/km) and consists of riffle and run habitats with few natural pools. Several small man-made impoundments are located in the lower half. The stream supports a diverse and productive flora and fauna.

Because the entire Creek will be used for Diversion, the East Branch Perkiomen Creek study area includes the Creek from just upstream of Elephant Road bridge downstream to the confluence. Sample stations are designated by common name and by the letter 'E' followed by a number which indicates distance in meters from the mouth of the Creek. Where stations include several meters of stream, site numbers designate the downstream end of the station. A sampling history by program is given in Tables 1 and 2.

East Branch Perkiomen Creek is a major tributary to Perkiomen Creek. Much of the watershed is used for agriculture but land is increasingly being developed for residential use. The major population concentration occurs midpoint on the Creek at Sellersville-Perkasie.

Low natural base flows and frequent localized storms produce an extremely variable flow regime. Spring flows are generally high due to snow melt and precipitation, and spates occur throughout the year. As summer approaches flows become lower and in late summer and fall surface flow in upper reaches often ceases. Riffle habitat is much reduced or eliminated in about one-third of the stream length and the Creek becomes a series of pools or quiescent reaches connected by subsurface percolation. Several low dams are present.

Anthropogenic stresses from nonpoint source runoff is a problem, particularly in the headwaters where most of the surrounding land is used for agriculture. Runoff from farmland carries a heavy load of nutrients. Stormwater and sewage enter the East Branch via storm drains under the Route 309 bridge in Sellersville. This enriched discharge is most persistent during periods of heavy rainfall when the

Sellersville-Perkasie Sewage Treatment Plant capacity is exceeded.

The greatest point source stress is the Sellersville-Perkasie Sewage Treatment Plant effluent which enters the creek about 3 km upstream of Cathill Road (E23000, about midpoint on the creek). The effluent contains very high levels of chlorine, nutrients, and heavy metals. Residual chlorine has its greatest effect in the immediate vicinity of the outfall. Chlorine rapidly diffuses into the atmosphere and decays as a result of photochemical reactions. However since the effluent is highly enriched with nitrogenous compounds, chloramines are formed as a result of chlorination and these may persist in the stream. The stimulating effect of nutrients on aquatic plant growth can produce marked diel fluctuations in dissolved oxygen (DO). Several 24-h DO studies showed that a critical DO depression (<2mg/l; the Commonwealth's minimum criterion is 4.0) and extreme diel fluctuation occurred downstream of the effluent. Heavy metals such as cadmium, chromium, copper, and zinc are concentrated in the effluent. All the above described factors produce a stressed community downstream of the outfall.

Tributary Indian Creek (which enters the East Branch near meter 6900) may also stress the East Branch. It receives effluents from the Telford Borough and Lower Salford Township Sewage Treatment Plants, and a number of food-processing industries. The primary stress created by Indian Creek is nutrient loading, and it appears that this creek may periodically degrade lower East Branch water quality.

Phytoplankton

Phytoplankton was not studied in East Branch Perkiomen Creek because it was considered to be of low potential impact. Studies conducted in other shallow, temperate headwater streams have indicated that phytoplankton is typically low in density and essentially of periphytic origin.

Periphyton

Periphyton is a seasonally important primary producer in East Branch Perkiomen Creek and was studied in 1973 and 1974. Periphytic algae were almost exclusively diatoms and only the common genera were recorded. These were Navicula, Melosira, Synedra, Nitzschia, and Cocconeis. Local biology and habitat requirements for these algae have already been described and seasonal changes in the taxonomic composition of periphyton were similar to those observed in the Schuylkill River.

Periphyton standing crop biomass in the East Branch was highly variable and apparently responsive to a number of environmental factors. Biomass was maximum in April through October under conditions of relatively stable low flow and high temperature (Table 3). Highest biomass occurred in August of both years (1973, 48 mg/dm^2; 1974, 106 mg/dm^2). Biomass was low from January through March and November through December due to increased velocities and lower temperature. This seasonal pattern of periphyton productivity is typical of lotic systems in temperate regions.

Periphyton in the upper East Branch (E32115, E26867) was more susceptible to scouring during increased flow than periphyton in the lower section (E2800). During periods of low flow E32115 and E26867 exhibited higher periphyton biomass than E2800, probably because the shallower water allowed more light to reach the periphyton community.

Macrophytes Zooplankton and Macroinvertebrates

Refer to Perkiomen Creek section for a discussion of these biotic components.

Fish

The fish community of East Branch Perkiomen Creek consisted of warmwater species typical of small lotic systems in southeast Pennsylvania (Mihursky 1962). In general the fish fauna included minnows and suckers, important as food convertors and forage, and freshwater catfish, pike, and sunfish, important ecologically at higher trophic levels and sociologically as pan and sport fishes. Most species were indigenous and reproduced locally.

To some extent fish distribution in the East Branch reflected longitudinal zonation typical of lotic systems. However characteristic distributions were modified somewhat by major point-source domestic and industrial discharge and the presence of several small impoundments.

SPECIES INVENTORY

Nine families including 23 genera and 40 species were collected (Table 4) as well as hybrids of both the minnow and carp family and the genus *Lepomis*. No species were commercially valuable or considered threatened or endangered by Federal or state regulatory agencies. The American eel was the only true migratory (catadromous) species.

Qualitative abundance was established within family or among related families by subjective comparison of recent catch statistics. Species designated rare or uncommon were low in abundance and significant alteration of their environment could result in a change in distribution or possible extirpation. Brook trout, a coldwater fish, was occasionally stocked in the Creek by the Pennsylvania Fish Commission but did not sustain itself. A single muskellunge captured near the mouth of the Creek was assumed to have originated from Perkiomen Creek where muskellunge has been stocked.

COMMUNITY DESCRIPTION

Larval Fish

Larval fish drift at E2650 was investigated in 1973 and 1974 using drift nets. Data collected from this site were representative only of the lower East Branch. Relative abundance of dominant taxa (comprising >90% of the total identified catch) varied between years (Table 5). In 1973 white sucker and yellow bullhead were first and third in abundance, respectively, whereas *Lepomis* spp. were first and white sucker third in 1974. Unidentified minnows (mostly *Notropis* spp.) ranked second in both years.

Spawning extended primarily from May through August. Density of drifting larvae varied during this period as a result of species-specific peak spawns (Table 6). White sucker and tessellated darter spawned primarily from late April to early May, while yellow bullhead spawned in early June. Two peak spawning periods for both *Notropis* spp. and *Lepomis* spp. were observed; one in early June and one from July to early August. Few (26) drifting eggs were taken because most East Branch fishes lay demersal eggs.

Diel fluctuation in drift occurred regularly. Most larvae were collected between sunset and sunrise. Peak densities usually occurred between 2600 and 0200 h.

Minnows and Young

In 1975 and 1976, 30 species and *Lepomis* and *Notropis* hybrids were collected by seine from lotic sites in East Branch Perkiomen Creek (Table 7). Most were minnows and young-of-year pan and sport fishes. The few adult pan and sport fishes which were included did not affect results.

Total abundance of minnows and young (total mean catch per effort) did not differ between years. Dominant species, based on 1975 and 1976 seine data combined, were spotfin shiner (54% of total), bluntnose minnow, banded killifish, tessellated darter (each 6%), and common shiner (5%). All other species individually comprised less than 5% of the total mean catch per effort. Relative abundance of the more numerous species varied between 1975 and 1976. In 1975 spotfin shiner, comely shiner, swallowtail shiner, common shiner, and satinfin shiner dominated the catch, while in 1976 spotfin shiner, tessellated darter, banded killifish, bluntnose minnow, and white sucker (young) were most numerous.

A general decrease in total mean catch per effort was noted from upstream to downstream areas. The depression in abundance at E26980 and subsequent recovery (increase) at E12440 probably indicated effects of the Sellersville Municipal Sewage Treatment Plant.

Spotfin shiner was the most numerous species in each site, and abundance of dominant species was quite variable among sites. Variation in spatial relative abundance was indicative of species zonation. Bridle shiner, common shiner, spottail shiner, swallowtail shiner, spotfin shiner, bluntnose minnow, creek chubsucker, and Lepomis hybrid were common in the upstream section of the East Branch. Goldfish, golden shiner, and creek chub were established primarily in the middle reaches, and carp, cutlips minnow, satinfin shiner, longnose dace, fallfish, and margined madtom were more prevalent downstream. Other species were generally distributed throughout the Creek. Species segregation occurred as a result of longitudinal changes in habitat and water quality.

The number of species per collection was used as a general index of diversity. This parameter also indicated a pattern of longitudinal zonation in the Creek. Number of species increased from headwaters to about midpoint in the stream, then decreased downstream toward the confluence. Usually the number of species increases downstream as a result of increased habitat heterogeneity. Lower diversity in the downstream reaches of the East Branch may have reflected degraded water quality downstream of Sellersville and sampling method bias toward smaller (i.e., upstream) stream size.

Adults

Lotic Sites: Eighteen species of large fish (defined as all members >50 mm FL of the pike, sucker, freshwater catfish, and sunfish families and goldfish and carp) were collected from lotic sites by DC electrofishing in 1973 and 1975. Also collected were goldfish x carp and Lepomis hybrids. White sucker, green sunfish, yellow bullhead, and redbreast sunfish dominated in both years (Table 8), and comprised 25, 23, 19, and 15%, respectively, of the total estimated streamwide number.

Relative abundance of the 14 most abundant species remained essentially the same between 1973 and 1975 at each site, but often varied between sites in each year. The four dominant species were generally important throughout the stream and comprised from 50 to 91% of the large fish community at each site. Pumpkinseed and Lepomis hybrid composed only 4 and 3% of total, respectively, but were important at E36020. Other locally important species were redfin pickerel (E36020), bluegill (E30540), and smallmouth bass and margined madtom (E1550). Species zonation was likely due to habitat variety and water quality differences as mentioned previously.

Results of biomass analyses were very similar to those based on population estimates. White sucker (46% of total estimated biomass), yellow bullhead (13%), carp (11%), redbreast sunfish (9%), and green sunfish (8%) comprised the majority of biomass (Table 8). No other species composed more than 5% of the total, but the following fishes made significant contributions at specific locations and times: pumpkinseed (E36020, 1975), Lepomis hybrid (E36020, both years), creek chubsucker (E36020, 1973), redfin pickerel (E36020, 1975), chain pickerel (E36020, 1975), brown bullhead (E26240, 1975), and smallmouth bass (E1550, 1975).

Lentic Sites: Sixteen species and carp x goldfish and Lepomis hybrids were collected in spring 1974 and fall 1975 at Fretz (E15500) and WaWa (E5650) reservoirs (Table 9). Percent composition of total catch was used to evaluate community structure because unbiased population estimates could not be calculated for each species. Green sunfish was the most abundant species in both reservoirs in 1974 and 1975. White sucker, pumpkinseed, and bluegill followed green sunfish in order of overall abundance from the two sites. Bluegill was more numerous in Fretz than WaWa, while pumpkinseed was more numerous in WaWa, probably because of habitat differences. Yellow bullhead was relatively abundant in WaWa where, during low flows, the site was more characteristic of lotic habitat. Brown bullhead was more common in Fretz which was typically lentic.

Studies of fishes in the East Branch identified the presence of large numbers of hybrid sunfish (offspring of interspecific matings within the genus Lepomis), particularly in the headwaters Hybrid sunfish ranked sixth among large fish in streamwide abundance and ninth in streamwide biomass for 1973 and 1975 combined. Hybrids often comprised more than 25% of the total sunfish population in headwater sites (>40% at E36020). Abundance declined somewhat steadily downstream where they composed 5-10% of total.

The high incidence of hybrid sunfish in the East Branch was unusual. Hybrids commonly occur in habitat suitable for compatible sunfishes; however they commonly comprise only a very small percentage of the total sunfish population (Bailey and Lagler 1938, Birdsong and Yerger 1967). Hybrids were rare or nonexistant in several sites on nearby Tohickon and Neshaminy Creeks which have habitats similar to those in the upper East Branch. Hybrids were also uncommon in the

Schuylkill River and Perkiomen Creek study areas. Hybridization in the East Branch was most likely due to crowding in isolated pools during the spawning season when flow in the upstream reaches was often intermittent.

IMPORTANT SPECIES

A relatively large number of species were selected because effects of diversion on fishes of East Branch Perkiomen Creek are expected to be diverse and spatially variable due to the variety of habitats and presence of existing stresses. Important species were chosen to represent three general ecological niches present in the Creek, and taxa of sociological importance (Table 10). These fishes will also most likely be affected by changes in the physical and chemical nature of the Creek caused by Diversion. The local biology of important species is described below.

Redfin Pickerel: Redfin pickerel (*Esox americanus*) was common only in the headwaters often being found in isolated shallow pools with no flow and heavy aquatic vegetation. The species was most numerous at E36020 (62 individuals/500 m of stream) and showed a decreasing trend in abundance downstream (Table 11). Only one specimen was taken from the two impoundments sampled (Table 12). Populations increased dramatically from 1973 to 1975, especially at E36020 where numbers almost doubled. Variations in biomass were similar to those in abundance.

Maximum age was 4-5 yr but most specimens were age I (Table 15). Maximum length was 309 mm FL. Greatest (48%) growth in length occurred in the first year of life. The length-weight relationship of 32 specimens was $\ln W = -10.17 + 2.67 \ln FL$. Although this species is a common game fish, angling for redfin pickerel in the East Branch was virtually nonexistent because of small adult size.

Satinfin Shiner: Satinfin shiner (*Notropis analostanus*) was common in East Branch Perkiomen Creek, preferring habitat with fast current and bedrock substrate. Streamwide abundance based on seine collections decreased from a mean catch per unit effort of 106 in 1975 to 63.9 in 1976, and it ranked eighth in overall abundance (Table 7). This species was most important in downstream reaches, comprising 18, 23, and 10% of total mean catch per unit effort at E1890, E5475, and E12440, respectively.

Common Shiner: Common shiner (*Notropis cornutus*) spawned from June through July (Gerlach 1979). The occurrence of two peak larval drift periods, one in June and July, may have indicated intermittent or multiple spawning. Mean daily larval drift density in 1974 ranged from 0.007 larvae/m³ in mid-June to 0.012 larvae/m³ in late July. Common shiner ranked fourth in overall seine catch. Mean catch per unit effort increased from 119 in 1975 to 141 in 1976. Variation in abundance among sites was significant, this species being more prevalent in upstream reaches where it comprised 4 and 8% of total at E32170 and E29810, respectively. Abundance was lowest at E26980, probably due to degraded water quality downstream of Sellersville. Length-weight relationships of common shiner differed significantly between 975 and 1976 as well as among sites (Table 13). Individuals at E29810 grew slower in weight per unit length relative to other sites.

Spotfin Shiner: Larval drift densities of spotfin shiner (*Notropis spilopterus*) in the East Branch were highest in July and August in 1974. This species ranked first in overall seine catch Mean catch per unit effort decreased from 1870 in 1975 to 849 in 1976. Variation among sites was significant, the species being more prevalent in upstream reaches where it comprised 55 and 56% of total at E29810 and E32170, respectively. Abundance did not decrease sharply downstream of Sellersville indicating that this species was tolerant of degraded water quality. Length-weight relationships varied significantly between 1975 and 1976 as well as among sites. The high regression coefficients at E12440 and E26980 (downstream of and in Sellersville, respectively) was again indicative of this species' tolerance of poor water quality.

White Sucker: White sucker generally spawned in May in 1973 and 1974, earlier than most important species in the East Branch, and had a relatively short spawning period. Abundance of larvae in drift varied between 1975 and 1974 (Table 5). In 1973 white sucker mean drift density was 0.1234 individuals/m³ (60% of total drift), but in 1974 declined to 0.1032 (26%). Maximum drift densities occurred in early May in both 1973 and 1974, and declined to negligible levels by early June (Table 6). White sucker always drifted at a greater rate during the night, reaching peak densities between 2600 and 0400 h.

White sucker young in the seine catch ranked sixth in overall abundance. Variation in abundance between 1975 and 1976 was high with mean catch per unit effort increasing from 29 in 1975 to 154 in 1976. Variation was high among upstream seine sites but comparatively low among downstream sites. White sucker dominated at E29810 and E1890 where it comprised 8 and 20% of total mean catch, respectively. Abundance of young was low at sites near Sellersville but increased from E12440 downstream to E1890.

White sucker was overall the most abundant adult fish collected by electrofishing (Table 11). Streamwide abundance decreased from a mean of 605 individuals/500 m in 1973 to 525 in 1975. Abundance was lowest in upstream and downstream reaches and peaked just downstream of Sellersville. While the area downstream of Sellersville was not prime spawning or nursery habitat, adults apparently moved into the region to benefit indirectly from the organic enrichment here.

White sucker was the most important contributor to streamwide biomass (mean, 47 kg/500 m), and dominated every site except E1550. Streamwide biomass increased from 1973 to 1975 even though numerical abundance declined. This was not an unusual short-term trend for a relatively long-lived species.

Estimated abundance of adult white sucker in Fretz reservoir (E15500) decreased from 1149 to 546 specimens from May 1974 to October 1975, while population levels in WaWa (E5650) during the same period remained essentially stable (Table 12). This species was slightly more numerous in WaWa than Fretz. Biomass was also somewhat higher in WaWa in 1975.

White suckers collected upstream and downstream of Sellersville exhibited fairly stable growth in length from 1968 to 1973 (Table 16). No significant difference in growth for combined stations upstream and downstream of Sellersville was observed, but fish collected downstream were consistently larger at each annulus for all year-classes than upstream. Specimens were not aged past their fourth year because of scale inconsistencies. Maximum length at capture was 344 mm FL.

Analysis of covariance indicated significantly different length-weight regressions among populations of white sucker collected at five sites in 1973 (Table 14). Generally individuals upstream gained proportionately more weight per unit increase in length than those downstream.

Yellow Bullhead: Yellow bullhead (*Ictalurus natalis*) spawned in June and July 1973 and June 1974. Because of nesting behavior and parental care of yellow bullhead larvae rarely occurred in drift. In 1973 mean drift density was 0.0184 individuals/m^3 (9% of total drift), but declined to 0.0090 individuals/m^3 (2%) in 1974 (Table 5). Peak densities occurred in late June of 1973 and 1974 (Table 6). This species always drifted at a greater rate during the night, reaching peak densities between 2600 and 0200 h.

Yellow bullhead young were not abundant in the seine catch and comprised less than 1% of total mean catch per unit effort in 1975 and 1% in 1976. Young were more prevalent upstream of Sellersville but generally comprised less than 1% of total mean catch in this area.

Yellow bullhead was overall the third most abundant adult fish collected by electrofishing. Streamwide abundance increased from a mean of 317 individuals/500 m in 1973 to 563 in 1975. The adults were generally more numerous downstream of Sellersville. The apparent contradiction between these and seine results was likely due to the fact that the seine is not an effective gear for sampling young in larger downstream areas.

Yellow bullhead adults were also the third most important contributors to streamwide biomass with a mean of 12 kg/500 m Generally annual and site variation in this parameter was similar to that of estimated abundance. However biomass was much higher at E1550 where abundance was lower, indicating that many of these fish were larger and older. This may have been a reason for the decline in abundance noted at E1550 from 1973 to 1975.

Abundance of adults increased in both Fretz and WaWa reservoirs from May 1974 to October 1975. This was likely the result of successful spawns in 1973 and 1974 because abundance varied similarly in lotic regions during the same general period. Both abundance and biomass were higher in WaWa due to this species' apparent preference for the habitat in this reservoir. The longest yellow bullhead collected from East Branch Perkiomen Creek was 295 mm FL. This species was an important pan fish in the East Branch.

Redbreast Sunfish: (*Lepomis auritus*). Sunfish larvae were only identified to genus (*Lepomis* spp.). Spawning of redbreast sunfish, green sunfish, pumpkinseed, and bluegill in the occurred from June through August in 1973 and 1974 *Lepomis* spp. larvae comprised only 6% (.0128 individuals/m^3) of East Branch drift in 1973, but increased to 37% (.1469 individuals/m^3) in 1974 (Table 5). Peak densities occurred in late July in 1973 and mid-June and late July in 1974.

Redbreast sunfish young ranked tenth in overall abundance in the seine catch. Annual variation in streamwide abundance was moderate with mean catch per unit effort increasing from 14 (<1% of total mean catch) in 1975 to 37 (2%) in 1976. Young were most abundant at E29810 and E32170 where they comprised 1 and 2% of total, respectively. Abundance was lowest near Sellersville (E26630 and E26980) but higher downstream of the treatment plant.

Redbreast sunfish was the fourth most abundant adult fish collected by electrofishing Streamwide abundance increased from 257 fish/500 m in 1973 to 436 in 1975, probably as a result of populations recovering from severe flooding in June 1972. Abundance generally increased from an upstream to downstream direction except for a depression downstream of Sellersville. Recovery from effects of Sellersville was evident at E12040.

Adult redbreast sunfish was also the fourth most important contributor to streamwide biomass with a mean of 10 kg/500 m. Annual and site trends in biomass were similar to those of estimated abundance.

Redbreast sunfish abundance increased in both Fretz and WaWa from May 1974 to October 1975, probably as a result of a successful spawn in 1974. Redbreast sunfish was much more numerous in WaWa reservior than Fretz.

Growth in length often varied significantly by year-class and location (Table 17). Growth rates were generally lower at E36020 and increased downstream. Reduced habitat due to intermittent conditions and competition may have been responsible for poor growth at E36020. High growth rates downstream were probably due to greater habitat variety and space associated with increasing stream size.

Comparisons of length-weight regressions (Table 14) among sites indicated that average fish weight was similar at E12040, E30540, and E36020 in both 1973 and 1975. At E36020 fish collected in 1975 were heavier than those captured in 1973.

Stable age structures were observed at E12040 and E36020 in 1973 and E12040 and E1550 in 1975. With minor exceptions number of fish in each consecutive age-group decreased. Low abundance of age I fish caused slightly upset age structures at E30540, E26240, and E1550 in 1973 and E36020, E30540, and E26240 in 1975.

Green Sunfish: Green sunfish (Lepomis cyanellus) young ranked eleventh in overall abundance in the seine catch. The mean catch per unit effort increased from 4.6 (<1% of total) in 1975 to 33.7 (2%) in 1976. The species was somewhat more prevalent in the middle and upstream sections of the Creek.

Green sunfish was the second most abundant adult fish collected by electrofishing. Downstream of Sellersville there was an increase in abundance from 1973 to 1975. This was primarily due to increases in the abundance of fish 51 to 90 mm FL, which indicated a good 1974 spawn. Upstream of Sellersville there was also an increase in abundance of this size group, but it was offset by a decline in the number of fish greater than 90 mm FL.

The distribution of adult green sunfish was different from that of redbreast sunfish. Green sunfish reached peak abundance downstream of Sellersville and gradually decreased in abundance to the confluence. This suggested that green sunfish had a greater tolerance for the degraded water quality downstream of Sellersville. However where conditions were suitable for redbreast sunfish, green sunfish may have been at a competitive disadvantage.

Green sunfish was the fifth greatest contributor to streamwide biomass (mean, 7.7 kg/500 m) Temporal and spatial variation in biomass was similar to that of abundance. The decline of larger older fish upstream of Sellersville was also demonstrated by rather large decreases in biomass.

Green sunfish decreased in abundance at both Fretz and WaWa reservoirs from May 1974 to October 1975. In 1975 spatial differences in abundance and biomass were slight.

Food habits of 14 green sunfish from the Schuylkill River indicated chironomid larvae and pupae, cladocera, cyclopoids, algae, and other plant material were popular food items.

Growth in length of green sunfish in 1973 and 1975 was consistent among year-classes and sites (Table 18). Rates of growth in weight were similar between years at E36020, E26240, and E1550. Average weights of fish upstream of Sellersville were greater than those downstream.

Stable age structures were observed at E36020 and E1550 in 1973 and at all five sites sampled in 1975. Absence of age I fish caused slightly upset structures at E30540, E26240, and E12040 in 1973. Improvement of age structures in 1975 probably reflected recovery from the June 1972 flood.

Pumpkinseed: (Lepomis gibbosus). Refer to redbreast sunfish (above) for information on spawning periods and larval drift. Pumpkinseed young were low in streamwide abundance and comprised less than 1% of total mean catch per unit effort. Annual variation in abundance was high with mean catch per unit effort increasing from 2.5 (<1% of total) in 1975 to 26.1 (1%) in 1976. Abundance of young was highest in the mid and upstream regions of the Creek but was low at E26980 downstream of Sellersville.

Pumpkinseed was the fifth most abundant adult fish collected by electrofishing. Streamwide abundance differed slightly between 1973 and 1975, increasing from 83 to 86 fish/500 m, due primarily to a rise in abundance at E12040 and E1550. This species exhibited a streamwide pattern of abundance similar to that of redfin pickerel. Both species prefer lentic habitat or the quiet water of small streams, which was generally available only in the upstream area of the Creek.

Pumpkinseed ranked ninth in streamwide biomass (mean, 1.4 kg/500 m). Annual and site trends in this parameter were the same as those for abundance.

Pumpkinseed decreased in abundance in Fretz reservoir but increased in WaWa from May 1974 to October 1975 . Abundance and biomass were highest in Fretz due to this species' apparent preference for the habitat there.

Smallmouth Bass: *Micropterus dolomieui*) Smallmouth bass young were low in streamwide abundance, comprising less than 1% of the total mean seine catch per unit-effort. Annual variation was negligible with mean catch per unit effort increasing slightly from 1.5 in 1975 to 1.9 in 1976. Young were prevalent only at E1890 and E32170. None was caught immediately downstream of Sellersville (E26980) in 1975 or 1976.

Smallmouth bass was the eighth most abundant adult fish encountered by electrofishing. Streamwide abundance increased from 28 to 55 specimens/500 m from 1973 to 1975, primarily as a result of a two-fold increase in number at E1550. Habitat preferred by smallmouth bass was prevalent from Sellersville downstream to the stream mouth. However this species was abundant only at the extreme downstream reach (E1550). Degraded water quality downstream of Sellersville apparently inhibited smallmouth bass production at E26240 and E12040. Smallmouth bass was the sixth greatest contributor to community biomass (mean, 2.5 kg/500 m). Biomass was also highest at E1550.

Smallmouth bass comprised only a small portion of the adult fish population in Fretz and WaWa reservoirs. Estimated abundance decreased slightly in both impoundments from May 1974 to October 1975.

Tessellated Darter: (*Etheostoma olmstedi*) Larvae were collected infrequently in drift; at mean densities of 0.0021 individuals/m^3 in 1973 and 0.0001 in 1974, it comprised 1.0 and less than 0.1% of total drift, respectively. Peak drift occurred in early May 1973 (0.010 individuals/m^3) and mid-May 1974 (0.002).

Tessellated darter was relatively numerous and comprised 5.8% of the total mean catch per unit effort in East Branch seine collections. Annual variation was high and mean catch per unit effort increased from 48.1 (2% of total) in 1975 to 242.7 (11%) in 1976. Streamwide variation in abundance was also high with the species being most prevalent in the upstream reaches of the Creek. Abundance was low downstream of Sellersville, an indication of this species' intolerance of poor water quality.

TABLE 1

NUMBER OF SAMPLES BY YEAR, PROGRAM, AND SITE COLLECTED FROM EAST BRANCH PERKIOMEN CREEK, 1972-1977.[a]

Program/Sites	1972	1973	1974	1975	1976	1977
Water Quality						
A11263	-	-	14	24	24	24
E12300	-	-	14	24	24	24
E26700	-	-	14	24	24	24
E22880	-	-	14	24	24	24
E2800	-	-	14	24	24	24
Periphyton						
E32115	-	-	29	-	-	-
E22867	-	-	26	-	-	-
E8350	-	14	-	-	-	-
E2800	-	14	26	-	-	-
Benthic Macroinvertebrates						
E36725	9	12	9	-	10	-
E32200	12	12	9	-	10	-
E26700	12	12	9	-	11	-
E23000	9	12	9	-	11	-
E12500	12	12	9	-	11	-
E5600	12	12	9	-	11	-
Macroinvertebrate Drift						
E2230	-	84	69	-	-	-
Larval Fish Drift						
E2650	-	136	56	-	-	-
Seine						
E36690	-	-	-	10	10	-
E32170	-	-	-	11	10	-
E29010	-	-	-	11	10	-
E26630	-	-	-	11	10	-
E22980	-	-	-	11	10	-
E12440	-	-	-	11	10	-
E5475	-	-	-	11	10	-
E1890	-	-	-	11	10	-
Large Fish Population Estimates						
E36020	-	2	-	2	-	-
E30540	-	2	-	2	-	-
E22240	-	2	-	2	-	-
E15500	-	-	2	2	-	-
E12040	-	2	-	2	-	-
E5650	-	-	2	2	-	-
E1550	-	2	-	2	-	-

TABLE 1 (Continued)

(Page 2 of 3)

Program/Sites	1972	1973	1974	1975	1976	1977
Age and Growth						
F10235*						
Redfin pickerel	-	-	2	-	-	-
E36700						
Redbreast sunfish	-	1	-	-	-	-
E36020						
Redfin pickerel	-	24	-	-	-	-
White sucker	-	31	-	-	-	-
Redbreast sunfish	-	46	-	29	-	-
Green sunfish	-	50	-	36	-	-
E34350						
Redbreast sunfish	-	36	-	-	-	-
Green sunfish	-	46	-	-	-	-
E34250						
Redbreast sunfish	-	8	-	-	-	-
E32300						
Redbreast sunfish	-	33	-	-	-	-
Green sunfish	-	31	-	-	-	-
E32200						
Redbreast sunfish	-	11	-	-	-	-
Green sunfish	-	2	-	-	-	-
E31290						
Redfin pickerel	-	1	-	-	-	-
E30940						
Redbreast sunfish	-	39	-	-	-	-
Green sunfish	-	22	-	-	-	-
E30540						
Redfin pickerel	-	11	-	-	-	-
White sucker	-	40	-	-	-	-
Redbreast sunfish	-	56	-	56	-	-
Green sunfish	-	35	-	39	-	-
E26700						
Green sunfish	-	2	-	-	-	-
E22240						
Redfin pickerel	-	1	-	-	-	-
White sucker	-	20	-	-	-	-
Redbreast sunfish	-	14	-	24	-	-
Green sunfish	-	67	-	50	-	-
E18400						
Redbreast sunfish	-	5	-	-	-	-
Green sunfish	-	16	-	-	-	-
E18340						
Redbreast sunfish	-	2	-	-	-	-
Green sunfish	-	31	-	-	-	-
E12040						
White sucker	-	20	-	-	-	-
Redbreast sunfish	-	35	-	46	-	-
Green sunfish	-	60	-	36	-	-

TABLE 1 (Continued)

(Page 3 of 3)

Program/Sites	1972	1973	1974	1975	1976	1977
Age and Growth (cont.)						
E10700						
Redbreast sunfish	-	19	-	-	-	-
Green sunfish	-	55	-	-	-	-
E8500						
Redbreast sunfish	-	34	-	-	-	-
Green sunfish	-	40	-	-	-	-
E7100						
White sucker	-	25	-	-	-	-
Redbreast sunfish	-	17	-	-	-	-
Green sunfish	-	34	-	-	-	-
E2100						
Redbreast sunfish	-	37	-	-	-	-
Green sunfish	-	25	-	-	-	-
E1550						
White sucker	-	26	-	-	-	-
Redbreast sunfish	-	56	-	55	-	-
Green sunfish	-	32	-	43	-	-

[a]See footnotes in Table 2.2.2-1 for definition of what constitutes one sample.
[b]Culvert Creek, a tributary of East Branch Perkiomen Creek.
Collection site approximately 235 m from East Branch confluence.

TABLE 2

NUMBER OF SAMPLES BY MONTH, PROGRAM, AND YEAR COLLECTED FROM EAST BRANCH PERKIOMEN CREEK, 1972-1977.[1,2]

Program/Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water Quality												
1974	-	-	-	-	-	10	10	10	10	10	10	10
1975	10	10	10	10	10	10	10	10	10	10	10	10
1976	10	10	10	10	10	10	10	10	10	10	10	10
1977	10	10	10	10	10	10	10	10	10	10	10	10
Periphyton												
1973	-	-	-	-	-	-	-	6	6	8	4	4
1974	-	12	6	5	15	3	-	8	9	9	9	5
Benthic Macroinvertebrates												
1972	5	5	5	6	6	6	6	5	5	5	6	6
1973	6	6	6	6	6	6	6	6	6	6	6	6
1974	-	-	-	6	6	6	6	6	6	6	6	6
1976	-	6	6	6	6	6	6	6	4	6	6	6
Macroinvertebrate Drift												
1973	-	-	-	12	12	12	12	12	12	-	-	-
1974	-	-	-	12	12	12	9	12	-	-	-	-
Larval Fish Drift												
1973	-	-	-	24	24	28	24	24	12	-	-	-
1974	-	-	-	6	14	12	14	10	-	-	-	-
Seine												
1975	-	7	8	8	8	8	8	8	8	8	8	8
1976	-	8	8	8	8	8	8	8	8	8	8	-

[1]See footnotes in Table 2.2.2-1 for definition of what constitutes one sample.
[2]Number of samples for Small Fish Population Estimate, Large Fish Population Estimate, and Age and Growth programs was not included because only annual data was utilized.

TABLE 3

PERIPHYTON STANDING CROP BIOMASS (MG/DM²) ASH-FREE DRY WEIGHT AND PRODUCTIVITY RATES (MG/DM²/DAY) ASH-FREE DRY WEIGHT BY STATION IN EAST BRANCH PERKIOMEN CREEK, 1973 AND 1974.

Date	Days[1]	E32115 SC	E32115 PR	E22867[2] SC	E22867[2] PR	E8350[3] SC	E8350[3] PR	E2600[4] SC	E2600[4] PR
17 Aug 73	10	17.9	-[5]			14.0	-		
24 Aug	17	39.7	3.11			19.3	0.76		
31 Aug	24	48.4	1.24			42.0	3.24		
7 Sep	7	14.1	-			10.8	-		
14 Sep	14	18.4	0.59			21.4	1.51		
21 Sep	21	11.8	-0.94			23.9	0.16		
5 Oct	7	11.8	-			4.9	-		
12 Oct	14	42.0	4.31			10.5	0.80		
19 Oct	21	48.1	0.87			17.9	1.06		
26 Oct	7	14.4	-			3.4	-		
2 Nov	14	14.5	0.01			6.3	0.41		
9 Nov	21	17.8	0.47			8.4	0.30		
12 Dec	12	3.3	-			3.0	-		
19 Dec	19	3.3	0.00			2.6	-0.06		
1 Feb 74	7	4.0	0.57	2.0	0.29			4.3	0.61
7 Feb	14	6.8	0.20	3.4	0.10			5.2	0.06
14 Feb	21	13.8	0.33	3.9	0.02			7.4	0.10
21 Feb	28	15.0	0.04	3.3	-0.20			8.6	0.04
14 Mar	7	3.3	0.47	4.0	0.57			5.4	0.77
21 Mar	14	4.0	0.05	4.1	0.01			7.5	0.15
18 Apr	7	4.1	0.58	3.7	0.53			5.3	0.76
24 Apr	14	20.8	1.19	ns[6]	ns			81.5	5.44
2 May	7	25.9	3.70	42.6	6/09			14.5	2.07
9 May	14	32.7	0.88	40.2	-0.17			49.8	2.52
16 May	21	19.2	-0.64	27.5	-0.60			36.6	-0.63
23 May	7	7.4	1.05	15.7	2.24			18.0	2.57
31 May	14	19.7	0.60	28.4	0.95			30.5	0.89
6 Jun	21	35.2	0.74	62.0	1.60			45.3	0.70
8 Aug	7	59.1	8.44	43.4	6.20			ns	ns
15 Aug	14	19.7	-2.81	77.3	2.42			49.5	3.54
23 Aug	22	106.3	4.22	55.5	-0.99			22.8	-1.27
12 Sep	7	13.4	1.91	13.0	1.86			12.5	1.78
20 Sep	15	18.5	0.34	18.6	0.37			44.4	2.13
26 Sep	21	27.9	0.85	27.2	0.41			37.9	-0.31
10 Oct	7	5.1	0.73	ns	ns			4.5	0.64
18 Oct	(8)[7] 15	8.7	0.31	3.3	0.41			7.7	0.23
24 Oct	(14) 21	14.2	0.21	17.7	1.03			4.4	-0.16
31 Oct	(21)	ns	ns	23.3	0.27			ns	ns
14 Nov	7	3.3	0.47	4.8	0.69			1.9	0.27
21 Nov	14	8.0	0.34	9.1	0.31			3.8	0.14
28 Nov	21	15.1	0.36	19.3	0.51			5.4	0.08
12 Dec	7	0.60	0.09	0.20	0.03			0.20	0.03
19 Dec	14	0.80	0.01	ns	ns			ns	ns
27 Dec	21	2.50	0.08	ns	ns			ns	ns

[1]This represents the actual number of days that the artificial plates are exposed to periphyton colonization.
[2]Station E22867 was not sampled in 1973.
[3]Station E8350 was sampled only in 1973.
[4]Station E2600 was not sampled in 1973.
[5]No values were calculated for periphyton productivity rates for any station in 1973 due to low growth rates during the first 7 days of colonization.
[6]ns indicates that no samples were collected on that date.
[7]The numbers in parenthesis indicate the number of days of exposure for the artificial [illegible] E22867 only.

TABLE 4

FISHES COLLECTED IN THE EAST BRANCH PERKIOMEN CREEK BY ALL GEARS DURING THE PERIOD JUNE 1970 THROUGH DECEMBER 1976. NOMENCLATURE IS FROM BAILEY (1960).

Common Name	Scientific Name	Relative Abundance
Freshwater eel family	Anguillidae	
American eel	*Anguilla rostrata* (Lesueur)	Uncommon
Trout family	Salmonidae	
Brook trout	*Salvelinus fontinalis* (Mitchill)	Occur only when stocked
Pike family	Esocidae	
Redfin pickerel	*Esox americanus americanus* Gmelin	Common
Muskellunge	*Esox masquinongy* Mitchill	Rare
Chain pickerel	*Esox niger* Lesueur	Rare
Minnow family	Cyprinidae	
Goldfish	*Carassius auratus* (Linnaeus)	Common
Carp	*Cyprinus carpio* Linnaeus	Common
Carp x Goldfish hybrid		Rare
Cutlips minnow	*Exoglossum maxillingua* (Lesueur)	Abundant
Golden shiner	*Notemigonus crysoleucas* (Mitchill)	Abundant
Comely shiner	*Notropis amoenus* (Abbot	Abundant
Satinfin shiner	*Notropis analostanus* (Girard)	Abundant
Bridle shiner	*Notropis bifrenatus* (Cope)	Uncommon
Common shiner	*Notropis cornutus* (Mitchill)	Abundant
Spottail shiner	*Notropis hudsonius* (Clinton)	Common
Swallowtail shiner	*Notropis procne* (Cope)	Abundant
Spotfin shiner	*Notropis spilopterus* (Cope)	Abundant
Bluntnose minnow	*Pimephales notatus* (Rafinesque)	Abundant
Fathead minnow	*Pimephales promelas* Rafinesque	Rare
Blacknose dace	*Rhinichthys atratulus* (Hermann)	Abundant
Longnose dace	*Rhinichthys cataractae* (Valenciennes)	Abundant
Creek chub	*Semotilus atromaculatus* (Mitchill)	Uncommon
Fallfish	*Semotilus corporalis* (Mitchill)	Uncommon
Minnow hybrid		Rare

TABLE 4 (Continued)

(Page 2 of 2)

Common Name	Scientific Name	Relative Abundance
Sucker family	Catostomidae	
White sucker	*Catostomus commersoni* (Lacepede)	Abundant
Creek chubsucker	*Erimyzon oblongus* (Mitchill)	Common
Freshwater catfish family	Ictaluridae	
White catfish	*Ictalurus catus* (Linnaeus)	Rare
Yellow bullhead	*Ictalurus natalis* (Lesueur)	Abundant'
Brown bullhead	*Ictalurus nebulosus* (Lesueur)	Common
Margined madtom	*Noturus insignis* (Richardson)	Common
Killifish family	Cyprinodontidae	
Banded killifish	*Fundulus diaphanus* (Lesueur)	Abundant
Sunfish family	Centrarchidae	
Rock bass	*Ambloplites rupestris* (Rafinesque)	Common
Redbreast sunfish	*Lepomis auritus* (Linnaeus)	Abundant
Green sunfish	*Lepomis cyanellus* Rafinesque	Abundant
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)	Abundant
Bluegill	*Lepomis macrochirus* Rafinesque	Common
Sunfish hybrid	*Lepomis* hybrid	Abundant
Smallmouth bass	*Micropterus dolomieui* Lacepede	Common
Largemouth bass	*Micropterus salmoides* (Lacepede)	Common
White crappie	*Pomoxis annularis* Rafinesque	Rare
Perch family	Percidae	
Tessellated darter	*Etheostoma olmstedi* Storer	Abundant
Yellow perch	*Perca flavescens* (Mitchill)	Rare
Shield darter	*Percina peltata* (Stauffer)	Uncommon

TABLE 6

MEAN DAILY DRIFT DENSITY (NO./CU.MRT) FOR SELECTED LARVAL FISH
COLLECTED FROM EAST BRANCH PERKIOMEN CREEK AT R2650, 1973 AND 1974.

1973

TAXA	17APR	01MAY	15MAY	04JUN	26JUN	09JUL	23JUL	06AUG	23AUG	04SEP
MINNOWS	-	0.008	0.017	0.082	0.025	0.031	0.120	0.287	0.024	-
WHITE SUCKER	-	0.353	0.289	0.030	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	0.075	0.034	0.029	-	-	-
LEPOMIS SUNFISH	-	-	-	-	0.001	-	0.220	0.004	-	-
TESSELLATED DARTER	-	0.010	-	-	-	-	-	-	-	-

1974

TAXA	02MAY	08MAY	15MAY	20MAY	30MAY	05JUN	11JUN	19JUN	27JUN	08JUL	16JUL	24JUL	29JUL	06AUG	13AUG	22AUG	27AUG
MINNOWS	-	0.002	0.042	0.449	0.184	0.052	0.135	0.159	5.372	0.039	0.015	0.111	0.120	0.094	0.220	0.052	0.081
CARP	0.006	0.009	-	0.420	0.001	-	-	-	-	-	-	-	0.002	0.011	-	-	0.007
COMMON SHINER	-	-	-	-	-	-	-	0.007	-	-	0.010	-	0.012	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	0.001	-	0.028	-	-	-	-	-	-	-	-	-	-
WHITE SUCKER	0.230	1.200	0.106	0.107	0.022	0.021	-	-	-	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	0.114	0.206	0.018	0.015	-	-	-	-	-	-
ROCK BASS	-	-	-	-	0.003	-	-	-	-	-	-	0.072	0.009	-	-	-	-
LEPOMIS SUNFISH	-	-	-	-	-	0.388	2.169	0.002	0.037	0.092	-	0.420	0.095	0.067	0.001	0.003	-
TESSELLATED DARTER	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 7

MEAN CATCH PER UNIT EFFORT (C/F) AND RELATIVE ABUNDANCE OF FISH SPECIES
COLLECTED BY SEINE FROM EAST BRANCH PERKIOMEN CREEK IN 1975 AND 1976.

SPECIES	1975 E36690 C/F	%	1976 E36690 C/F	%	1975 E32170 C/F	%	1976 E32170 C/F	%	1975 E29810 C/F	%	1976 E29810 C/F	%	1975 E26630 C/F	%	1976 E26630 C/F
REDFIN PICKEREL	0.74	1.6	0.47	1.4	-	-	-	-	-	-	0.19	0.0	0.17	0.1	-
GOLDFISH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CARP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CUTLIPS MINNOW	-	-	-	-	-	-	-	-	-	-	-	-	0.12	0.1	0.66
GOLDEN SHINER	0.23	0.5	4.19	13.0	1.36	0.1	5.24	0.7	0.98	0.2	1.50	0.3	3.12	1.3	1.96
COMELY SHINER	4.24	9.0	1.74	5.4	79.84	7.2	8.84	1.2	12.26	2.5	4.59	0.8	12.76	4.8	2.65
SATINFIN SHINER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.40
BRIDLE SHINER	-	-	-	-	1.16	0.1	-	-	0.40	0.1	-	-	-	-	-
COMMON SHINER	3.77	8.0	3.37	10.4	15.47	1.4	65.56	9.1	49.97	10.3	30.64	5.6	14.01	5.3	9.61
SPOTTAIL SHINER	0.08	0.2	-	-	2.16	0.2	7.36	1.0	2.05	0.4	9.64	1.8	0.89	0.3	0.05
SWALLOWTAIL SHINER	0.49	1.0	0.46	1.4	72.74	6.6	69.17	9.6	39.58	8.2	14.52	2.6	10.03	4.1	14.01
SPOTFIN SHINER	28.14	59.7	1.43	4.4	775.43	70.4	238.42	33.2	329.97	68.3	224.41	40.8	194.98	73.9	154.00
BLUNTNOSE MINNOW	0.46	1.0	3.13	9.7	71.01	6.4	141.18	19.7	8.92	1.8	39.30	7.1	5.10	1.9	6.17
BLACKNOSE DACE	-	-	-	-	1.09	0.1	13.50	1.9	1.86	0.4	42.35	7.7	5.05	1.9	41.75
LONGNOSE DACE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.58
FALLFISH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MINNOW HYBRID	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17
WHITE SUCKER	1.17	2.5	0.79	2.4	11.93	1.1	13.55	1.9	4.39	0.9	78.14	14.2	0.40	0.2	6.30
CREEK CHUBSUCKER	0.49	1.0	1.13	3.5	0.39	0.0	0.44	0.1	0.20	0.0	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	0.13	0.0	0.67	0.1	-	-	1.69	0.3	-	-	0.20
BROWN BULLHEAD	-	-	0.19	0.6	-	-	0.44	0.1	-	-	-	-	-	-	-
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BANDED KILLIFISH	-	-	-	-	37.28	3.4	38.95	5.4	10.13	2.1	27.52	5.0	4.07	1.5	47.05
REDBREAST SUNFISH	1.00	2.1	0.80	2.5	7.82	0.7	24.61	3.4	3.79	0.8	9.27	1.7	1.11	0.4	0.41
GREEN SUNFISH	0.53	1.1	5.89	18.2	0.11	0.0	11.21	1.6	-	-	0.93	0.2	0.80	0.3	10.81
PUMPKINSEED	0.67	1.4	1.21	3.7	0.91	0.1	4.03	0.6	0.22	0.0	-	-	1.18	0.4	13.10
BLUEGILL	1.06	2.3	0.18	0.5	1.00	0.1	5.50	0.8	1.46	0.3	0.19	0.0	0.13	0.1	4.05
LEPOMIS HYBRID	1.60	3.4	5.13	15.9	0.23	0.0	2.15	0.3	-	-	-	-	0.20	0.1	1.22
SMALLMOUTH BASS	-	-	-	-	1.00	0.1	0.22	0.0	0.13	0.0	-	-	-	-	0.12
LARGEMOUTH BASS	0.41	0.9	0.09	0.3	0.93	0.1	-	-	0.51	0.1	-	-	0.44	0.2	1.41
TESSELLATED DARTER	2.00	4.1	2.15	6.6	19.63	1.8	66.27	9.2	16.15	3.3	65.21	11.9	8.04	3.0	102.49

TABLE 7 (Continued)

%	1975 E22980 C/F	%	1976 E22980 C/F	%	1975 E12440 C/F	%	1976 E12440 C/F	%	1975 E5475 C/F	%	1976 E5475 C/F	%	1975 E1890 C/F	%	1976 E1890 C/F	%
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	0.31	0.2	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	0.08	0.0	-	-	-	-	0.09	0.1	-	-
0.2	0.71	0.3	0.53	0.3	2.31	1.4	6.11	2.7	1.56	0.6	1.45	1.0	1.11	0.8	1.73	2.0
0.5	1.73	0.7	11.85	6.2	0.05	0.0	0.45	0.2	-	-	0.12	0.1	-	-	-	-
0.6	1.04	0.4	0.46	0.2	25.95	15.7	12.28	5.3	4.96	1.9	2.06	1.4	4.07	3.1	1.31	1.6
0.1	-	-	-	-	14.85	9.0	26.76	11.6	67.33	26.1	22.83	15.5	23.90	18.1	13.91	16.5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.3	2.06	0.9	1.94	1.0	8.28	5.0	15.02	6.5	18.50	7.2	13.67	9.3	5.35	4.1	4.46	5.3
0.2	0.11	0.0	-	-	0.18	0.1	0.85	0.4	0.41	0.2	0.85	0.6	0.11	0.1	1.04	1.2
3.3	4.41	1.9	2.92	1.5	2.11	1.3	1.33	0.6	2.63	1.0	2.05	1.4	0.35	0.3	0.09	0.1
36.5	203.25	86.1	64.49	31.9	96.00	58.1	105.32	45.7	148.45	57.6	62.60	42.5	78.94	59.8	23.70	28.1
1.5	4.00	2.1	1.60	0.8	1.76	1.1	2.89	1.3	5.47	2.1	0.80	0.5	0.28	0.2	0.46	0.5
9.9	2.07	0.9	2.36	1.2	1.33	0.8	10.11	4.4	2.15	0.8	4.90	3.3	0.90	0.7	2.36	2.0
-	0.45	0.2	0.09	0.0	3.25	2.0	9.21	4.0	0.74	0.3	7.34	5.0	0.90	0.7	4.00	4.7
0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.1	-	-
0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.5	0.57	0.2	5.10	2.7	-	-	13.90	6.0	-	-	15.58	10.6	10.57	8.0	24.45	28.9
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.1	-	-	0.36	0.2	0.06	0.0	0.29	0.1	-	-	0.49	0.3	-	-	0.22	0.3
-	-	-	0.15	0.1	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	0.08	0.1	0.08	0.1	-	-
11.1	9.60	4.1	91.05	47.8	6.68	4.0	9.25	4.0	3.70	1.4	2.87	2.0	4.41	3.3	0.73	0.9
0.1	0.22	0.1	0.33	0.2	0.57	0.3	1.49	0.6	0.69	0.3	2.50	1.7	0.55	0.4	3.79	4.5
2.6	2.47	1.0	5.01	2.6	0.77	0.5	4.06	1.8	0.50	0.2	1.49	1.0	0.20	0.2	0.77	0.9
3.2	0.19	0.1	1.12	0.6	0.06	0.0	3.65	1.6	-	-	0.63	0.4	-	-	-	-
1.0	0.11	0.1	0.50	0.3	0.12	0.1	4.50	2.0	0.08	0.0	0.17	0.1	-	-	-	-
0.3	0.79	0.3	0.30	0.2	0.12	0.1	0.34	0.1	-	-	0.17	0.1	-	-	-	-
0.0	-	-	-	-	0.13	0.1	-	-	-	-	0.24	0.2	0.19	0.1	1.27	1.5
0.3	0.11	0.0	-	-	-	-	0.31	0.1	-	-	-	-	-	-	-	-
24.2	1.07	0.5	-	-	0.52	0.3	2.45	1.1	0.48	0.2	4.32	2.9	-	-	0.22	0.3

TABLE 7 (Continued)

1975 MEAN C/F	%	1976 MEAN C/F	%	COMBINED YEARS MEAN C/F	%
0.11	0.0	0.08	0.0	0.09	0.0
-	-	0.04	0.0	0.02	0.0
0.01	0.0	0.01	0.0	0.01	0.0
0.76	0.2	1.33	0.4	1.04	0.3
0.97	0.3	3.15	1.0	2.06	0.6
18.30	5.9	4.27	1.4	11.29	3.5
13.41	4.0	8.09	2.7	10.75	3.4
0.20	0.1	-	-	0.10	0.0
14.80	4.4	18.22	6.1	16.51	5.2
0.76	0.2	2.61	0.9	1.68	0.5
16.83	5.0	13.21	4.4	15.01	4.7
214.24	69.1	110.76	36.9	172.50	53.9
12.37	3.6	24.71	8.2	18.54	5.8
1.43	0.5	14.96	4.9	8.34	2.6
0.68	0.2	2.61	0.9	1.64	0.5
-	-	0.45	0.2	0.23	0.1
0.01	0.0	-	-	0.01	0.0
-	-	0.02	0.0	0.01	0.0
1.66	1.1	19.90	6.6	11.02	3.7
0.13	0.0	0.19	0.1	0.16	0.1
0.02	0.0	0.50	0.2	0.26	0.1
-	-	0.10	0.0	0.05	0.0
0.01	0.0	0.01	0.0	0.01	0.0
9.61	2.8	27.52	9.2	18.56	5.8
1.98	0.6	5.46	1.8	3.72	1.2
0.68	0.2	5.01	1.7	2.85	0.9
0.40	0.1	3.02	1.0	1.71	0.5
0.52	0.3	1.91	0.6	1.21	0.4
0.35	0.1	1.11	0.4	0.73	0.2
0.18	0.1	0.23	0.1	0.21	0.1
0.30	0.1	0.21	0.1	0.26	0.1
6.04	1.9	30.75	10.2	18.39	5.8

TABLE d

RELATIVE ABUNDANCE (%N) AND BIOMASS (%W) OF FISHES COLLECTED BY ELECTROFISHING FROM LOTIC SITES, EAST BRANCH PERKIOMEN CREEK, 1973 AND 1975.

	E16020				E30540				E22240			
	1973		1975		1973		1975		1973		1975	
Species	% N	% W	% N	% W	% N	% W	% N	% W	% N	% W	% N	% W
Redfin pickerel	3.0	3.1	7.0	6.1	0.1	1.2	0.6	0.9	<0.1	<0.1	0.3	0.0
Chain pickerel	0.0	0.0	0.6	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goldfish	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.3	4.1	0.2	0.8
Carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.9	<0.1	0.5
Carp x goldfish hybrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golden shiner	2.0	0.9	0.0	0.0	1.9	0.8	1.6	0.7	0.3	0.1	0.1	<0.1
White sucker	17.4	36.7	14.6	39.5	24.6	45.1	20.7	41.9	51.6	72.6	33.3	66.6
Creek chubsucker	5.0	6.6	3.8	3.4	0.1	0.7	2.2	2.8	0.2	0.2	0.1	0.2
White catfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow bullhead	10.3	3.5	5.8	6.5	5.8	10.6	25.5	11.7	6.5	5.7	11.4	11.7
Brown bullhead	1.6	2.2	2.1	1.3	2.4	4.6	0.9	1.7	1.6	1.7	2.0	5.1
Margined madtom	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Rock bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Redbreast sunfish	13.3	8.0	12.4	7.4	11.1	21.4	22.2	20.9	0.7	11.3	3.3	2.0
Green sunfish	12.8	18.6	12.1	5.6	13.9	7.3	6.2	5.1	31.6	11.0	43.7	11.5
Pumpkinseed	13.8	7.0	11.1	5.3	8.0	3.9	3.1	1.9	2.5	1.5	3.6	0.8
Bluegill	1.9	0.8	5.3	2.1	3.2	0.7	10.4	3.7	1.2	0.1	0.4	0.1
Lepomis hybrid	14.8	10.5	19.4	10.5	2.9	1.6	2.6	2.3	1.2	0.8	1.2	0.3
Smallmouth bass	1.2	0.4	0.0	0.0	1.3	1.2	0.7	1.7	<0.1	<0.1	0.2	0.1
Largemouth bass	2.7	1.4	5.8	2.7	1.5	0.9	3.5	2.8	0.2	<0.1	0.2	<0.1

	E12040				E1550				Sites Combined				Years Combined	
	1973		1975		1973		1975		1973		1975			
Species	% N	% W	% N	% W	% N	% W	% N	% W	% N	% W	% N	% W	% N	% W
Redfin pickerel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.7	0.5	0.6	0.5
Chain pickerel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.5	<0.1	0.3
Goldfish	0.6	1.8	0.3	3.5	5.0	4.6	0.7	2.1	1.2	3.0	0.2	1.3	0.6	2.1
Carp	0.0	0.0	0.1	1.4	0.1	31.8	4.4	35.8	0.5	11.4	0.7	11.4	0.6	11.4
Carp x goldfish hybrid	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.0	<0.1	0.6	<0.1	0.1
Golden shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.7	0.2	0.5	0.1	0.6	0.1
White sucker	27.0	54.6	14.3	27.1	13.4	29.3	6.8	23.9	32.1	48.7	20.1	44.3	25.1	46.3
Creek chubsucker	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.5	0.7	0.9	0.7	0.9	0.7
White catfish	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	<0.1	<0.1
Yellow bullhead	18.5	24.4	37.6	34.2	22.6	15.1	13.2	10.1	16.0	11.9	21.2	13.2	19.0	12.6
Brown bullhead	0.1	0.6	0.0	0.8	0.6	0.4	0.7	1.3	1.3	1.6	1.0	3.1	1.2	2.4
Margined madtom	0.0	0.0	0.4	0.2	7.7	0.7	7.5	0.3	1.0	0.2	1.2	0.1	1.1	0.2
Rock bass	0.0	0.0	0.0	0.0	2.9	1.5	1.1	0.7	0.4	0.5	0.2	0.2	0.1	0.3
Redbreast sunfish	7.5	4.4	10.1	15.4	28.7	10.6	37.9	15.0	13.4	7.9	15.8	10.6	14.8	9.4
Green sunfish	24.5	12.4	33.5	15.2	8.3	0.9	12.8	1.6	21.4	7.9	24.1	7.5	23.1	7.6
Pumpkinseed	0.7	0.7	1.8	0.8	0.7	0.2	1.9	0.8	4.6	1.7	1.3	1.2	3.8	1.4
Bluegill	0.5	<0.1	0.0	0.0	0.4	<0.1	2.5	0.6	1.4	0.2	3.7	0.9	2.7	0.6
Lepomis hybrid	0.2	0.2	0.9	0.3	0.0	0.0	0.7	0.4	2.7	1.3	2.7	1.2	2.7	1.2
Smallmouth bass	0.3	0.1	0.9	1.2	6.5	4.5	8.9	6.6	1.3	1.8	1.8	2.5	1.6	2.2
Largemouth bass	0.1	1.0	0.1	0.1	0.1	0.1	0.8	0.1	3.7	0.4	1.5	0.6	1.2	0.5

TABLE 9

RELATIVE ABUNDANCE (% TOTAL CATCH) OF ALL SPECIES COLLECTED BY ELECTROFISHING FROM FRETZ (E15500) AND NAVA (E5650) RESERVOIRS, EAST BRANCH PERKIOMEN CREEK IN 1974 AND 1975.

SPECIES	15500 1974 %	1975 %	5650 1974 %	1975 %	TOTAL %
AMERICAN EEL	0.1	-	-	-	0.01
REDFIN PICKEREL	-	0.0	-	-	0.01
GOLDFISH	5.5	1.0	1.1	0.3	1.87
CARP	0.6	1.0	2.4	3.0	1.69
GOLDEN SHINER	1.9	0.5	0.1	0.1	0.60
MINNOW HYBRID	0.1	-	0.4	0.1	0.14
WHITE SUCKER	23.1	13.0	16.2	6.9	14.97
CREEK CHUBSUCKER	0.6	0.1	0.1	-	0.22
WHITE CATFISH	-	-	0.1	-	0.01
YELLOW BULLHEAD	1.4	6.6	18.5	18.9	11.09
BROWN BULLHEAD	3.8	5.1	1.0	2.1	3.31
REDBREAST SUNFISH	0.7	3.5	8.9	20.7	7.94
GREEN SUNFISH	31.3	20.6	38.3	36.6	33.34
PUMPKINSEED	21.8	15.4	6.7	7.7	12.97
BLUEGILL	1.4	19.0	0.1	0.6	6.41
LEPOMIS HYBRID	4.5	3.3	4.2	2.5	3.61
SMALLMOUTH BASS	0.9	0.6	0.3	0.2	0.51
LARGEMOUTH BASS	2.3	1.4	0.7	0.5	1.24
YELLOW PERCH	0.1	-	-	-	0.01

TABLE 10

CRITERIA FOR DETERMINATION OF IMPORTANT FISHES OF EAST BRANCH PERKIOMEN CREEK.

	IMPORTANCE			LINK TO PLANT (DIVERSION)		
Common Name	Recreational	Ecological	Abundant	Altered Habitat	Altered Food Supply	Altered Competitive Relationships
Redfin pickerel[1,2]		X		X		
Satinfin shiner[3]		X	X	X		X
Common shiner[3]		X	X	X		X
Spotfin shiner[3]		X	X	X		X
White sucker[1,2,4]	X	X	X	X	X	
Yellow bullhead[1,2]	X	X	X	X		
Redbreast sunfish[1,2,4]	X	X	X	X		X
Green sunfish[1,2,4]		X	X	X		X
Pumpkinseed[1,2]		X	X	X		X
Smallmouth bass[1,2]	X	X		X		
Tessellated darter[3]		X	X	X		

[1]Species sampled by large fish catch per unit effort program.
[2]Species sampled by large fish population estimate program.
[3]Species sampled by seine program.
[4]Species sampled by age and growth program.

TABLE 11

POPULATION ESTIMATES (N PER 500M STREAM LENGTH) AND ESTIMATED BIOMASS (W IN KG PER 500M STREAM LENGTH) OF SELECTED SPECIES COLLECTED BY ELECTROFISHING FROM LOTIC SITES, EAST BRANCH PERKIOMEN CREEK, 1973 AND 1975.

		E36020		E30540		E22240		E12040		E1550		Sites Combined	
Species	Year	N/500m	W/500m	N/500m	W/500m	N/500m	W/500m	N/500m	W/500m	N/500m	W/500m	N/500m	W/500m
Redfin pickerel	1973	36	1.05	13	0.11	1	0.03	0	0.00	0	0.00	9	0.36
	1975	62	1.84	21	0.71	0	0.00	0	0.00	0	0.00	17	0.51
White sucker	1973	185	12.65	390	25.91	1661	100.86	586	35.40	203	47.54	605	44.47
	1975	130	11.81	676	31.44	1202	37.54	457	15.19	162	48.31	525	48.94
Yellow bullhead	1973	110	1.20	91	6.07	208	7.85	833	15.82	343	28.48	317	11.88
	1975	52	1.95	835	8.89	413	10.94	1199	19.16	115	20.51	563	12.29
Redbreast sunfish	1973	142	2.76	524	12.20	23	0.41	161	2.83	435	20.09	257	7.67
	1975	111	2.22	725	15.80	118	4.21	321	8.63	907	30.27	436	12.24
Green sunfish	1973	136	6.48	220	4.20	1018	15.34	530	7.92	125	1.76	406	7.12
	1975	108	1.68	202	3.84	1586	23.84	1069	8.53	107	3.17	654	8.21
Pumpkinseed	1973	147	2.43	126	2.22	112	2.14	16	0.02	12	0.46	83	1.45
	1975	99	1.57	100	1.47	129	1.57	57	0.42	47	1.57	86	1.32
Smallmouth bass	1973	13	0.13	20	0.60	1	0.02	6	0.08	98	8.56	28	1.89
	1975	0	0.00	24	1.31	7	0.25	30	0.69	213	13.43	55	3.14

Table 12

POPULATION ESTIMATES (N) AND ESTIMATED BIOMASS (W) OF SELECTED SPECIES COLLECTED BY ELECTROFISHING FROM LENTIC SITES, EAST BRANCH PERKIOMEN CREEK, IN 1974 and 1975.

Species	Year	E15500		E5650		Sites Combined	
		N	W (kg)	N	W (kg)	N	W (kg)
Redfin pickerel	1974	0	-	0	-	0	-
	1975	1	-	0	-	1	-
White sucker	1974	1149	-	687	-	1836	-
	1975	576	98.53	654	122.29	1230	220.82
Yellow bullhead	1974	64	-	789	-	853	-
	1975	539	47.72	1433	104.68	1972	152.40
Redbreast sunfish	1974	11	-	230	-	241	-
	1975	113	2.95	827	23.52	940	26.47
Green sunfish	1974	1107	-	1180	-	2287	-
	1975	847	20.96	869	25.50	1716	46.46
Pumpkinseed	1974	931	-	160	-	1091	-
	1975	540	20.42	247	7.15	787	27.57
Smallmouth bass	1974	22	-	7	-	29	-
	1975	14	-	6	-	20	-

TABLE 13

LENGTH-WEIGHT RELATIONSHIPS ($\ln W = a+b \ln L$) OF SELECTED SPECIES COLLECTED BY SEINE FROM EAST BRANCH PERKIOMEN CREEK IN 1975 and 1976.

Species	Site/Year	a	b
Common shiner	E36690	-12.93	3.40
	E32170	-12.63	3.33
	E29810	-11.94	3.17
	E26630	-12.76	3.38
	E22980	-11.94	3.18
	E12440	-12.37	3.27
	E5475	-12.61	3.33
	E1890	-12.31	3.25
	1975	-12.67	3.34
	1976	-12.16	3.23
Spotfin shiner	E36690	-11.98	3.13
	E32170	-12.14	3.17
	E29810	-12.29	3.21
	E26630	-12.31	3.22
	E22980	-12.51	3.28
	E12840	-11.82	3.09
	E5475	-12.27	3.21
	E1890	-11.97	3.12
	1975	-12.28	3.20
	1976	-12.00	3.14

TABLE 14

LENGTH-WEIGHT RELATIONSHIPS (ln W = a+b ln L) OF SELECTED SPECIES
COLLECTED BY ELECTROFISHING FROM LOTIC SITES, EAST BRANCH PERKIOMEN CREEK,
IN 1973 AND 1975.

Species	Site	1973 a	1973 b	1975 a	1975 b
White sucker	E36020	-12.76	3.27		
	E30540	-11.59	3.05		
	E22240	-11.47	3.01		
	E12040	-10.86	2.92		
	E1550	-11.37	3.02		
Redbreast sunfish	E36020	-11.92	3.24	-10.81	3.01
	E30540	-11.05	3.06	-10.77	3.01
	E22240	-10.29	2.92	-12.20	3.11
	E12040	-11.70	3.20	-11.14	3.09
	E1550	-10.98	3.05	-11.00	3.06
Green sunfish	E36020	-11.01	3.05	-11.68	3.21
	E30540	-12.81	3.42	-11.40	3.14
	E22240	-11.40	3.12	-11.29	3.12
	E12040	-13.29	3.53	-11.95	3.25
	E1550	-12.20	3.30	-11.11	3.04

TABLE 15

MEAN CALCULATED LENGTHS AT ANNULUS FOR REDFIN PICKEREL COLLECTED AT FIVE SITES ON THE EAST BRANCH PERKIOMEN CREEK IN 1973 AND 1975.

Age-Group	No. of Fish	Mean Calculated Length (mm FL) at Annulus I	II	III	IV	V
I	12	126				
II	6	117	170			
III	3	132	184	210		
IV	2	132	178	201	234	
V	1	94	149	178	205	2[illegible]
Total	24	24	12	6	3	1
Grand Average						
Length		124	173	202	224	25[illegible]
Increment		124	49	29	22	[illegible]
% Total Growth		48.1	19.0	11.2	8.[illegible]	11.2

TABLE 16

MEAN CALCULATED LENGTHS AT ANNULUS FOR WHITE SUCKER COLLECTED BY ELECTROFISHING UPSTREAM AND DOWNSTREAM OF SELLERSVILLE, EAST BRANCH PERKIOMEN CREEK, IN 1973.

Age-Group	Year-Class	Location	No. of Fish	Mean Calculated Length (mm FL) at Annulus I	II	III	IV
I	1973	Upstream	7	63			
		Downstream	24	95			
II	1971	Upstream	19	79	143		
		Downstream	26	91	158		
III	1970	Upstream	22	78	133	194	
		Downstream	28	81	139	197	
IV	1969	Upstream	6	74	118	177	213
		Downstream	6	76	136	195	244
Total No. Fish		Upstream	54	54	47	28	6
		Downstream	84	84	60	34	6
Weighted Mean FL		Upstream		76	135	190	213
		Downstream		89	147	197	244
Increment		Upstream		76	59	55	23
		Downstream		89	59	50	47
% Total Growth		Upstream		15.7	27.7	25.8	10.8
		Downstream		36.1	24.2	20.5	19.2

TABLE 17

MEAN CALCULATED LENGTHS AT ANNULUS FOR REDBREAST SUNFISH COLLECTED BY ELECTROFISHING FROM LOTIC SITES, EAST BRANCH PERKIOMEN CREEK, IN 1973 AND 1975.

Site	Year	No. of Fish	Weighted Mean Length (mm FL) at Annulus I	II	III	IV	V
E36020	1973	84	32	66	94	118	143
	1975	27	23	58	90		
E30540	1973	118	34	65	74	116	119
	1975	54	32	64	97	114	
E22240	1973	10	30	70			
	1975	28	33	89	104		
E12040	1973	79	37	86	122	148	166
	1975	46	31	80	119		
E1550	1973	90	41	94	129		
	1975	55	33	85	133		

TABLE 18

MEAN CALCULATED LENGTHS AT ANNULUS FOR GREEN SUNFISH COLLECTED BY ELECTROFISHING FROM LOTIC SITES, EAST BRANCH PERKIOMEN CREEK, IN 1973 AND 1975.

Site	Year	No. of Fish	Weighted Mean Length (mm FL) at Annulus I	II	III	IV
E36020	1973	87	38	76	108	138
	1975	35	28	69		
E30540	1973	79	38	75	106	
	1975	37	40	80		
E22240	1973	103	36	77	111	
	1975	47	33	75	103	
E12040	1973	149	37	77	112	133
	1975	30	35	71	108	
E1550	1973	62	37	77	118	
	1975	36	32	78	107	

SECTION VIII

TERRESTRIAL BIOLOGY

PERKIOMEN DIVERSION PIPELINE & BRADSHAW RESERVOIR

TERRESTRIAL ECOLOGY

The following information is the result of an April, 1979 inspection by an EMC - Ecological Division terrestrial biologist.

Pipeline Routes

Visual inspection was made of most of each route from road crossings and by walking through many of the wooded portions of the routes.

From the standpoint of adverse impacts to terrestrial plants and animals all three routes are essentially similar. Construction of Line B (as per Perkiomen Transmission Main General Map, Figure No. 3) will probably cause the least disturbance to present plant and animal communities because it parallels the existing Texas Eastern Pipeline for most of its length. No rare, threatened, or endangered plant or animal species on the preferred or either of the alternative routes were observed.

Most of each of the three routes was composed of pasture, crop fields, and suburban lawns. The remainder of each was wooded. The species composition of all the woodlots inspected was remarkably similar. All were dominated by oaks and hickories of several species and red maple. The understory was sparse and open; poison ivy was ubiquitous. The woodlots through which the the pipeline routes pass are typical of other wooded areas in the immediate vicinity. No unique or critical habitats along these pipeline routes were observed. Many of the woodlots inspected had small trash dumps in them.

In summary, the terrestrial flora and fauna of the three routes for the Perkiomen Diversion Pipeline are very similar to that of the rest of Upper Bucks County. None of the routes, to our knowledge, pass through or contain any critical plant or animal habitats.

The discharge sites for each route (A, B, C) are very similar. The banks of the East Branch Perkiomen are composed of a thick shrub and tree cover which contains red maple, silver maple (A. sacchariunum), and several species of dogwood and virurnum. These shrubs serve to stabilize the creek, and an effort should be made to protect these shrubs during construction. There was no unique or critical habitat apparent at or near the discharge sites.

Bradshaw Reservoir

The Bradshaw Reservoir site is composed of a crop field which contained corn stubble at the time of the inspection and a small woodlot. The woodlot was typical of those observed in the area and was composed mainly of Pin Oak (Quercus palustris) and Red Maple (Acer rubrum). There was a small shallow pond in the woodlot which will probably be contained in the reservoir. Many trees in this woodlot had been recently cut down and removed, probably for firewood.

SECTION IX

HISTORICAL AND ARCHEOLOGICAL INFORMATION

Historic and Archaeological Report

General A detailed study and field investigation was conducted by local archaeologists in late 1978 to determine if the construction of the proposed facilities would destroy or encroach on any items of archaeologic value. This study was made to supplement investigations previously conducted by others and reported in the DRBC's Environmental Impact Statement of February, 1973.

Location The field investigation was conducted on the site of the Bradshaw Reservoir and along the entire route of the Perkiomen Transmission Main. Field locations were relatively easy to establish since the reservoir property is bounded by two improved township roads and the main runs parallel to the Texas Eastern right-of-way.

Description of Study

The archaeologists first conducted a literature search to develop the history of the area. Several books have been written concerning the early Indian tribes in Bucks County and about local historic places. Following this effort, a field inspection trip was made during which numerous test pits were dug and many shovel tests made. Test pit excavations were from 3 to 5 feet on a side and from 1 to 2 feet deep. A shovel test was made by digging a hole about 1 foot deep and only 1¼ feet long by 3/4 feet wide. In addition to fresh excavations, existing pits and cuts for roads were carefully inspected.

Findings Bradshaw Reservoir - There is nothing in the reservoir area that would be eligible for nomination to the Historic Register. Much of the area currently is used for farming, and a corn crop was growing at the time of the investigation. A stand of pine trees, surrounded by dense undergrowth, covers a portion of the site. The test pit opened revealed no cultural materials below the surface.

Perkiomen Transmission Main - The route of the main is generally plowed cornfields, open woodlands, and medium to medium-high grass.

The first mile of the route between the Bradshaw Reservoir and Durham Road (PA 413) was walked, but neither visual observation nor shovel tests disclosed any significant cultural materials.

Over the next 1.75 miles, between roads PA 413 and US 611, the remains of a stone field wall and an abandoned well were found. Both appear to have been constructed of plated, shale-like stones seen quite commonly in this area. No artifacts or other standing features were noted in this area.

The main next extends about 1 mile from US 611 to the north branch of Cabin Run. Again no artifacts or features of importance were noted. Two local residents did mention finding a few arrowheads 20 to 30 years ago, but none have been reported found since that time. Because of this report, a test pit was opened and shovel tests made; but all results were negative.

The next mile between Scott Road and Deep Run revealed nothing of interest. The area has been used recently for dumping of both construction materials and domestic debris.

The remaining distance to the East Branch of the Perkiomen was walked and searched. However, results were the same; no artifacts or features of importance or historical interest were found. The owner of land on which shovel tests were conducted claimed there once was a small town called Jacobstown, but nothing is now visible.

Conclusion

No historic or archaeologic properties will be effected by the proposed construction based on information obtained during the subject study. To supplement the study, a surveillance program will be implemented during ground clearing and excavating to assure that any features of historic or archaeologic value, which were not discovered during the initial search, will not be destroyed.