

- (12) Hilderbrand, S.G., R.R. Turner, D. Wright, A.T. Szluka, B. Tschantz, and S. Tam, Analysis of Environmental Issues Related to Small-scale Hydroelectric Development III: Water Level Fluctuations, Oak Ridge, TN, 1980, Environmental Sciences Division, Oak Ridge National Laboratory, Publication No. 1591.
- (13) Turbak, S.C. D.R. Reichle, and C.R. Shriver, Analysis of Environmental Issues Related to Small-scale Hydroelectric Development IV: Fish Mortality Resulting from Turbine Passage, Oak Ridge, TN, 1981, Environmental Sciences Division, Oak Ridge National Laboratory, Publication No. 1597.
- (14) Loar, J.M. and M.J. Sale, Analysis of Environmental Issues Related to Small-scale hydroelectric Development V: Instream Flow Needs for Fishery Resources, Oak Ridge, TN, 1981, Environmental Sciences Division, Oak Ridge National Laboratory, Publication No. 1829.
- (15) Cada, G.F., K.D. Kamar, J.A. Solomon, and S.G. Hilderbrand, Analysis of Environmental Issues Related to Small-scale Hydroelectric Development VI: Dissolved Oxygen Concentration below Operating Dams, Oak Ridge, TN, 1982, Environmental Sciences Division, Oak Ridge National Laboratory, Publication No. 1828.
- (16) Hynes, H.B.N, The Ecology of Running Water, Toronto, Canada, 1970, University of Toronto Press, 555 pp.
- (17) Weisberg, S.B., K.A. Rose, B.S. Clevenger and J.O. Smith, Inventory of Maryland Dams of Hydropower Resources, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, and Dam Safety Division of Maryland Department of Natural Resources, 1985.
- (18) Chesapeake Bay, Maryland, Routine Chemical, Physical, and Bacteriological Studies, I., 1969, prepared for Baltimore Gas and Electric Company, Baltimore, MD, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1970.
- (19) Chesapeake Bay, Maryland, Routine Chemical, Physical, and Bacteriological Studies, II., 1969, prepared for Baltimore Gas and Electric Company, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1970.
- (20) A Chemical, Bacteriological, and Physical Study on the Chesapeake Bay in the Vicinity of Calvert Cliffs, Maryland, February 1970 - December 1970, prepared for Baltimore Gas and Electric Company, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1972.
- (21) A Chemical, Bacteriological, and Physical Study on the Chesapeake Bay in the Vicinity of Calvert Cliffs, Maryland, January 1971 - December 1971, prepared for Baltimore Gas and Electric Company, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1972.

- (22) Semi-Annual Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1974.
- (23) Semi-Annual Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1975.
- (24) Semi-Annual Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1976.
- (25) Semi-Annual Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1977.
- (26) Non-Radiological Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, January-December 1977, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1978.
- (27) Non-Radiological Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, January-December 1978, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1979.
- (28) Non-Radiological Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, January-December 1979, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1980.
- (29) Summary of Findings: Calvert Cliffs Nuclear Power Plant Aquatic Monitoring Program (Vol I - text, 90 pp.; Vol. II - technical appendices, 280 pp.), prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-CC-80-2, 1980.
- (30) Non-Radiological Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, January-December 1980, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1981.

- (31) Non-Radiological Environmental Monitoring Report, Calvert Cliffs Nuclear Power Plant, January-December 1981, prepared for Nuclear Regulatory Commission, by Baltimore Gas and Electric Company, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1982.
- (32) Holland, A.F., M.H. Heigel, A.T. Shaughnessy, C.F. Stroup, and E.A. Ross, Long-term benthic monitoring programs near the Morgantown and Calvert Cliffs Power Plants - Third Annual Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, PPSP-CC-85-1, 1985.
- (33) Bongers, L.H., T.T. Polgar, A.J. Lippson, G.M. Krainak, R.L. Morgan, A.F. Holland, and W.A. Richkus. The Impact of the Morgantown Power Plant on the Potomac Estuary: An Interpretive Summary of the 1972-1973 Investigations, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, PPSP-MP-15, 1975.
- (34) Morgantown Station and the Potomac Estuary: A316 Environmental Demonstration, prepared for Potomac Electric Power Company, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1977.
- (35) Mihursky, J.H., Patuxent Thermal Studies - Summary and Recommendations, Solomons, MD, 1969, University of Maryland, Chesapeake Biological Laboratory.
- (36) Impact Assessment Report: Chalk Point Steam Electric Station Aquatic Monitoring Program, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (37) Otto, R.G., Chalk Point Station 316 Demonstration Summary: An Assessment of Impacts Associated with Open-cycle Condenser Cooling Conducted in Compliance with COMAR 10.50.01.13, prepared for the Potomac Electric Power Company, by R.G. Otto Assoc., Baltimore, MD, 1983.
- (38) Chalk Point Station 316 Demonstration. Technical Reports. Vol.I-IV, prepared for Potomac Electric Power Company, by Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, 1983.
- (39) Plankton Studies Conducted at H. A. Wagner Generating Station, July-September 1980, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Normandeau Associates, Boston, MA, 1981.
- (40) A.13 Demonstration in Support of the Application for Alternate Effluent Limitations, Southwest Resource Recovery Facility (Baltimore BRESO). Prepared for Rust International Corp., by Ecological Analysts, Inc., Sparks, MD, 1983.

- (41) Power Plant Site Evaluation: Brandon Shores Site, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by the Johns Hopkins University, Applied Physics Laboratory, Baltimore, MD, JHU-PPSE-1-2, 1972.
- (42) Morgan, R. P., III, Steam Electric Station Effects Upon Primary Productivity in the Patuxent River Estuary, Solomons, MD, 1968, University of Maryland, Chesapeake Biological Laboratory, NRI Ref. No. 69-27.
- (43) Morgan, R.P., III, J.A. Mihursky, S.S. Herman, C.I. Gibson, and A.J. McErlean, Patuxent Thermal Studies - Supplementary Report - Phytoplankton Studies, Solomons, MD, 1969. University of Maryland, Chesapeake Biological Laboratory, Ref. No. 69-6.
- (44) Morgan, R.P., III and R.G. Stross, Destruction of Phytoplankton in the Cooling Water Supply of a S.E.S., Chesapeake Science, Vol. 10, 1969, pp. 165-171.
- (45) Hamilton, D.A., Jr., D.A. Flemer, C.W. Keefe, and J.A. Mihursky, Power Plants: Effects of Chlorination on Estuarine Primary Production, Science, Vol. 169, 1970, pp. 197-198.
- (46) Flemer, D.A. and J.A. Sherk, Jr. The Effects of Steam Electric Station Operation on Entrained Phytoplankton, Hydrobiologia, Vol. 55, 1977, pp. 33-44.
- (47) Heinle, D.R., Effects of Passage Through Power Plant Cooling Systems on the Estuarine Copepod, Eurytemora affinis. Marine Biology, Vol. 31, 1976, pp. 235-247.
- (48) Holland, A.F., N.K. Mountford, M.H. Hiegel, D. Cargo, and J.A. Mihursky, Results of Benthic Studies at Calvert Cliffs, Final Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, and the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, PPSP-MP-28 and UMCEES 179-119-CBL, 1979.
- (49) Holland, A.F. and M.H. Hiegel, Results of Benthic Studies at Chalk Point: Final Report to the Maryland Power Plant Siting Program, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-CP-81-1, 1981.
- (50) Heck, K. and M. Hirshfield, Benthic and Fish Studies to Assess Thermal Impacts of the H. A. Wagner Steam Electric Station, Patapsco River, Maryland 1980-1981, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1982.

- (51) Mihursky, J.A., K.V. Wood, S. Kerig, and E.M. Setzler-Hamilton, Chalk Point Steam Electric Station Studies; Patuxent Estuary Studies: Ichthyoplankton Population Studies, 1979. Final Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, UMCEES 80-39-CBL, 1980.
- (52) Loos, J.J., Distributions of Pelagic Life Stages of Bay Anchovy, Silversides, and Naked Goby in the Patuxent River, Prepared for the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Co., Washington, D.C, 1983.
- (53) Summers, J.K. and A.F. Holland, Preliminary Projections of the Effects of Plant Operations at Chalk Point on Spawning and Nursery Areas of Consequence of Representative Important Species, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (54) Edinger, J.E. and E.M. Buchak, Estimates of Bay Anchovy Entrainment by Chalk Point Power Plant Using 1982 Fish Surveys, prepared for Potomac Electric Power Company, by J.E. Edinger Associates, Inc., Philadelphia, PA, 1983.
- (55) Polgar, T.T., J.K. Summers, and M.S. Haire, Evaluation of the Effects of the Morgantown SES Cooling System on Spawning and Nursery Areas of Representative Species, Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-MP-27, 1979.
- (56) Impact Assessment Report: C. P. Crane Steam Electric Station Aquatic Monitoring Program, prepared for Maryland Department of Natural Resources, Power Plant siting Program, by Martin Marietta Environmental Center, Baltimore, MD, 1983.
- (57) Dovel, W.L. Fish Eggs and Larvae In: Gross Physical and Biological Effects of Overboard Spoil Disposal in Upper Chesapeake Bay. Prepared for U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife by University of Maryland, Chesapeake Biological Laboratory. NRI Special Report No. 3. 1970.
- (58) Ecological Studies at the H. A. Wagner Plant. Prepared for Baltimore Gas and Electric Company, by Lawler, Matusky and Skelly Engineers, Pearl River, NY, 1980.
- (59) Gould Street Power Plant Impingement, Entrainment, and Hydrothermal Studies - Final Report, prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1979.
- (60) Riverside Power Plant Impingement, Entrainment and Hydrothermal Studies. Final Report. Prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1980.

- (61) Koo, T.S.Y., Ed., A Biological Study of Baltimore Harbor, prepared by Center for Environmental and Estuarine Studies, University of Maryland, Chesapeake Biological Laboratory, Solomons, MD, CEES Special Report No. 6, 1975.
- (62) Hirshfield, M.F., J.H. Hixon, and E.S. Perry, Chalk Point Auxiliary Pump Study 1981, prepared for the Maryland Department of Natural Resources, Power Plant Siting Program, by the Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, Report No. 82-3F, 1982.
- (63) Estimates of Impingement and Auxiliary Tempering Pump Entrainment at the Chalk Point Station, prepared by Potomac Electric Power Company, Environmental Affairs Group, Water and Land Use Department, Washington, DC, 1983.
- (64) Mortality of Impinged Blue Crabs, Callinectes sapidus Rathbun, after Return to the Discharge Canal at the Morgantown Steam Electric Station, prepared for Potomac Electric Power Company, by the Environmental Affairs Group, Washington, DC, 1982.
- (65) Alternate Intake Designs for Reducing Fish Impingement Losses at Morgantown Steam Electric Station, prepared for Potomac Electric Power Company, by Stone and Webster Engineering Corporation, Boston, MA, Ref. No. 13804-W(B)-1. 1981.
- (66) Assessment of Compliance for the Chalk Point Steam Electric Generating Station with Mixing Zone Criteria in COMAR 10.50.01.13E(1), prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (67) Holland, A.F. and G.F. Johnson, Analysis of 1980-1981 Finfish Data Collected Near the Chalk Point SES, prepared for the Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-CP-82-1, 1982.
- (68) Moore, C.J. and C.M. Frisbie, A Winter Sport Fishing Survey in a Warm Water Discharge of a Steam Electric Station on the Patuxent River, Maryland, Chesapeake Science, Vol. 13, 1972, pp. 110-115.
- (69) Moore, C.J., G.A. Stevens, A.J. McErlean, and H.H. Zion, A Sport Fishing Survey in the Vicinity of a Steam Electric Station on the Patuxent Estuary, Maryland, Chesapeake Science, Vol. 14, 1973, pp. 160-170.
- (70) Homer, M., P.W. Jones, R. Bradford, Jr., and J.A. Mihursky, Fish Community Studies in the Patuxent Estuary, 1978- 1979: Final Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, 1979.

- (71) Homer, M., P.W. Jones, R. Bradford, J.M. Scoville, and J.A. Mihursky, Patuxent Estuary Fish Survey: Cooperative PPSP/WRA Project, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, UMCEES-79-207-CBL, 1979.
- (72) Homer, M., P.W. Jones, R. Bradford, J.M. Scoville, D. Morck, N. Kaumeyer, L. Hoddaway, and D. Elam, Demersal Fish Food Habits Studies Near the Chalk Point Power Plant, Patuxent Estuary, Maryland, 1978-1979, prepared for the Maryland Department of Natural Resources, Power Plant Siting Program, by the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, UMCEES-80-32-CBL, 1980.
- (73) Homer, M., N. Caplins, and J.A. Mihursky, Condition Factors and Length/weight Regressions Associated with Certain Fish Species Near the Chalk Point Power Plant, Patuxent Estuary, Maryland-1978-1979, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, UMCEES-80-91-CBL, 1980.
- (74) Souza, P.A., T.T. Polgar, R.E. Miller, and A.F. Holland, Results of Blue Crab Studies at Chalk Point: Final Report to the Maryland Power Plant Siting Program, prepared for Maryland Department of Natural Resources, Power Plant siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-CP-80-10, 1980.
- (75) Abbe, G.R. and C.W. Hart, Jr., Growth and Mortality of Tray-held Oysters in the Patuxent River, MD, Proc. Nat. Shellfish. Assoc., Vol. 64, 1974, p. 1.
- (76) The Effects of Condenser Replacement at the Chalk Point SES on Nearby Tray-held Oysters, May-December 1982, prepared for Potomac Electric Power Company, by Benedict Estuarine Research Laboratory, Academy of Natural Science of Philadelphia, Benedict, MD, ANSP Report No. 85-3, 1983.
- (77) Roosenburg, W.H., Greening and Copper Accumulation in the American Oyster, *Cassostrea virginica*, in the Vicinity of Steam Electric Generating Station, Chesapeake Science, Vol. 10, 1969, pp. 241-252.
- (78) Eaton, A., and C. Chamberlin, Copper Cycling in the Patuxent River Estuary and Condenser Microfouling Studies, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by The Johns Hopkins University, Baltimore, MD, PPRP-53, 1982.
- (79) Phelps, H., Copper and Zinc Concentrations in Oysters from Selected Locations on the Chesapeake Bay, Summary Report 1979-1977, prepared for NASA (Grant NGR 09-050-019) by University of the District of Columbia, 1979.

- (80) Holland, A.F., N.K. Mountford, M. Hiegel, K. Kaumeyer, D. Cargo, and J.A. Mihursky. Results of Benthic Studies at Calvert Cliffs. Annual Report on August 1976 through May 1977 Data. Prepared for Maryland Department of Natural Resources, Power Plant Siting Program by Martin Marietta Environmental Center, Baltimore, MD, and University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. PPSP Ref. No. CC-78-2.
- (81) A.13 Demonstration in Support of the Application for Alternate Effluent Limitations for the Baltimore Gas and Electric Company, C.P. Crane Power Plant, prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1981.
- (82) Sellner, K.G., L.A. Lyons, R.K. Mahoney, M.M. Olson, and E.S. Penny, Phytoplankton Studies and Nutrient Concentrations in the Vicinity of the C.P. Crane Generating Station, July 1979 through March 1980, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1980.
- (83) Grant, G.C. and S.P. Berkowitz, An Environmental Assessment of the Summer Plankton in the Vicinity of the C.P. Crane Generating Station, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1979.
- (84) Grant, G.C. and S.P. Berkowitz, An Analysis of the Phyto-plankton, Microzooplankton, and Mesozooplankton Populations in the Vicinity of the C.P. Crane Generating Station during the Spring Months of 1979, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1979.
- (85) Grant, G.C., C.J. Womack, and J.E. Olney, Zooplankton of the Waters Adjacent to the C.P. Crane Generating Station, Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1980.
- (86) Otto, R.G., M. VanDeusen, and L.S. Kaufman, Prediction of Biological Impacts Associated with Expansion of Vienna Steam Electric Station, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by The Johns Hopkins University, Chesapeake Bay Institute, Baltimore, MD, PPSE 9-11, 1980.
- (87) Vienna Power Station-Prediction of Aquatic Impacts of Proposed Cooling Water Intake, A Section 316(b) Demonstration, prepared by Delmarva Power and Light Company, Salisbury, MD, 1982.
- (88) Portner, E.M. and L.C. Kohlenstein, Prediction of Entrainment and Impingement Impact for Striped Bass Eggs and Larvae by the Proposed Vienna Unit No. 9, Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by the Johns Hopkins University, Applied Physics Laboratory, PPSE-8-1, 1979.

- (89) Possum Point Power Station Aquatic Monitoring Studies, Prepared for Virginia Electric Power Company, by Ecological Analysts Inc., Sparks, MD, 1979.
- (90) Impingement and Entrainment Studies, prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1979.
- (91) Impingement Abundance and Viability Studies, prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Sparks, MD, 1981.
- (92) Carter, H.H. and R.J. Regier, The Distribution of Excess Temperature from the Vienna Generation Station on the Nanticoke River, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by The Johns Hopkins University, Chesapeake Bay Institute, Baltimore, MD, Technical Report 90, 1975.
- (93) Physical Impact Evaluation of the Discharge of Heated Water from the C.P. Crane Generating Station, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Aquatec, Inc., South Burlington, VT, 1978.
- (94) An Environmental Assessment and Ecological Survey of the Aquatic Biota, C.P. Crane Power Plant, 1978-1980, prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1981.
- (95) Zubkoff, P.L., A Preliminary Study of Community Oxygen Metabolism in the Vicinity of the C.P. Crane Electric Power Generating Station. Final Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1980.
- (96) An Environmental Assessment and Ecological Survey of the Aquatic Biota, C.P. Crane Power Plant, January-December 1979. Prepared for Baltimore Gas and Electric Company, by Ecological Analysts, Inc., Sparks, MD, 1980.
- (97) Harris, R.L., J.R. Banacki, and R.A. Jordan, Trace Metals in Sediment and in Tissues of the Brackish Water Clam, Rangia cuneata, September 1979: Part II of C.P. Crane Power Station Benthos Study Interim Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1980.
- (98) Nichols, B.L., R.R. Anderson, W.C. Banta, E.J. Forman, and S.H. Boutwell, Evaluation of the Effects of the Thermal Discharge on the Submerged Aquatic Vegetation and Associated Fauna in the Vicinity of the C.P. Crane Generating Station-Final Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Scientific Applications, Inc., McLean, VA, 1979.
- (99) Nichols, B.L. and R.R. Anderson, Evaluation of the Effects of Thermal Discharge on Submerged Aquatic Vegetation Growth, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by NTSC Technical Services, Ltd., Vienna, VA, 1980.

- (100) Jordan, R.A., C.E. Sutton, and P.A. Goodwin, A Survey of the Late Summer Benthic Community in the Vicinity of C.P. Crane Generating Station, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1979.
- (101) Jordan, R.A., C.E. Sutton, and P.A. Goodwin, Benthic Macroinvertebrate Population Distribution in Relation to the C.P. Crane Power Plant Thermal Discharge, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Virginia Institute of Marine Science, Gloucester Point, VA, 1980.
- (102) Jordan, R.A. and C.E. Sutton, Oligohaline Benthic Invertebrate Communities at Two Chesapeake Bay Power Plants, Estuaries, Vol. 7, 1984, pp. 192-214.
- (103) Shaughnessy, A.T., Population Structure and Dynamics of the Brackish-water Clam, Rangia cuneata, in Upper Chesapeake Bay in the Vicinity of C.P. Crane Power Plant, Baltimore County, Maryland, Masters thesis, Towson State University, Towson, MD, 1983.
- (104) Evaluation of C.P. Crane Generating Station Thermal Discharge Effects on the Finfish Community, Summer 1980, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Texas Instruments, Dallas, TX, 1981.
- (105) Evaluation of C.P. Crane Generating Station Thermal Discharge Effects on the Finfish Community, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Texas Instruments, Dallas, TX, 1981.
- (106) Power Plant Site Evaluation: Aquatic Biology. Final Report: Dickerson Site, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Ecological Analysts, Inc., Towson, MD, 1974.
- (107) A 316 Demonstration in Support of the Application for Alternate Effluent Limitations for the Potomac Electric Power Company, Dickerson Steam Electric Station, prepared for Potomac Electric Power Company, by the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, 1979 (Revised 1981).
- (108) Impact Assessment Report: R. Paul Smith Steam Electric Station Aquatic Monitoring Program, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, 1981.
- (109) R. Paul Smith Power Station Thermal Discharge and Impingement/Entrainment Studies, Volumes I and II, prepared for Potomac Edison Power Company by Energy Impact Associates, Inc., Pittsburg, PA, 1980.

- (110) Vannote, R.L. and B.N. Sweeney, Long-term Monitoring Studies in the Freshwater Portion of the Potomac River, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Stroud Water Research Center of the Academy of Natural Sciences of Philadelphia, PA, 1985.
- (111) Long-term Fisheries Monitoring in the Vicinity of the Dickerson Steam Electric Station, prepared for Potomac Electric Power Company, by Environmental Affairs Water and Land Use Department, Washington, DC, 1981.
- (112) Long-term Fisheries Monitoring in the Vicinity of the Dickerson Station, prepared for Potomac Electric Power Company, by Environmental Affairs Water and Land Use Department, Washington, DC, 1984.
- (113) Power Plant Site Evaluation Aquatic Biology, Perryman Site, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Ecological Analysts, Inc., Towson, MD, 1974.
- (114) Power Plant Site Evaluation Interim Report, Perryman Site, Biota of the Bush River, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Applied Physics Laboratory, The Johns Hopkins University, Baltimore, MD, 1973.
- (115) Limited Early Site Review, Perryman Site Suitability Report, prepared for Baltimore Gas and Electric Company, by Dames and Moore, Inc., 1976.
- (116) Aquatic Ecological Study of the Proposed Perryman Power Plant Site, prepared for Baltimore Gas and Electric Company, by RMC-Environmental Services, Muddy Run, PA, 1984.
- (117) Janicki, A.J., F. Jacobs, W.H. Burton, and R.A. Cummins, The Upper Bay Network: A Study of the Plankton Resources of the Upper Chesapeake Bay, Volume I, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1984.
- (118) Burton, W.H., F. Jacobs, A.F. Holland, and R.A. Cummins, Bush River Ichthyoplankton Distributions Near the Proposed Perryman Site, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD 1985.
- (119) Jacobs, F., and W. Richkus, Potential Aquatic Impacts of Various Intake/Discharge Options for the Proposed Perryman Power Plant, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1984.
- (120) Dwyer, R., K. Rose, R. Ross, Evaluation of Models for Assessing Power Plant Impacts on the Water Quality of the Bush River Estuary, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1984.

- (121) Nutrient, Oxygen, and Productivity Survey of the Bush River Estuary, prepared for Martin Marietta Environmental Systems, by University of Maryland Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, 1984.
- (122) Chesapeake Bay: A Framework For Action, U.S. Environmental Protection Agency, Chesapeake Bay Program, Annapolis, MD, 1983.
- (123) Summers, K., SNAC Analyses for Proposed Perryman Site, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (124) Weisberg, S.B., W.H. Burton, E.A. Ross, and F. Jacobs, The Effects of Screen Slot Size, Screen Diameter, and Through-slot Velocity on Entrainment of Estuarine Ichthyoplankton Through Wedge-wire Screens, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, PPSP-CP-84-1, 1984.
- (125) Bush River Water Quality Completion Report, prepared for Harford County, Maryland, by CH2M Hill, 1983.
- (126) Mansutti, R. and H. Kolb, A Historical Review of the Shad Fisheries of North America, prepared for Maryland Department of Research and Education, by the University of Maryland, Chesapeake Biological Laboratory, Publication No. 97, 1953.
- (127) Pavol, K.W. and R.M. Davis, Life History and Management of the Smallmouth Bass in the Susquehanna River Below Conowingo Dam, Report F-29-R to the State of Maryland Wildlife Administration, 1982.
- (128) Davis, J.C., Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review, Journal of Fisheries Research Board of Canada, Vol, 32, 1975, pp. 2295-2332.
- (129) Weisberg, S.B. and A.J. Janicki, The Effects of an Interim Minimum Flow from the Conowingo Dam on Fish Feeding and Benthos in the Susquehanna River, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (130) Walburg, C.H. and R.P. Nichols, Biology and Management of the American Shad and Status of the Fisheries, Atlantic Coast of the United States 1960-1967, prepared by U.S. Fish and Wildlife Service, Atlanta, GA, Special Scientific Report Fish. No. 550, 1967.
- (131) Dwyer, R.L., and M.A. Turner, A Simulation Model of River Flow and DO Dynamics Downstream of Conowingo Dam, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center, Baltimore, MD, PPSP-UBLS-82-3, 1982.

- (132) Summers, J.K., Conowingo Reservoir Ecosystem Simulation Model, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1984.
- (133) Dwyer, R.L., and M.A. Turner. 1982. Simulation of River Flow and DO Dynamics Affected by Peaking Discharges from a Hydroelectric Dam. Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1982.
- (134) Dwyer, R.L., and M.A. Turner, Simulations of the Effects of Minimum Discharge Schedules on the DO of Conowingo Dam Discharge, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (135) Moffit, C., and B.E. Kynard, Connecticut River Basin Anadromous Fish Studies - 1 March 1980 - 28 February 1981, prepared by Massachusetts Cooperative Fish Research Unit, University of Massachusetts, Amherst, MA, Project No. AFS-4-R-20, 1981.
- (136) Bowman, M.L., and S.B. Weisberg, Use of Multiple Unequally-Sized Turbines to Reduce Flow Fluctuations Below Hydroelectric Dams, paper presented at the Small Hydro/Fisheries Symposium, Denver, CO, 1985.
- (137) Energy and Environmental Management: An Assessment of Turbine-Related Fish Mortality at Dam Number 4 on the Potomac River, prepared for Potomac Edison Company, by Energy and Environmental Management, Inc., Murrysville, PA, 1983.
- (138) Diaz-Tous, I.A. and M.J. Miller, Condenser Macrofouling Control -- the State-of-the-Art. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art, Diaz-Tous, I.A., M.J. Miller, and Y.G. Mussalli, Eds., Palo Alto, CA, 1983, Electric Power Research Institute.
- (139) Weisberg, S.B., C.F. Stroup, A.F. Holland, and E.A. Ross, Biofouling Potential on Fine Mesh Wedge-wire Screens and a Test of Some Mechanisms of Biofouling Control, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Systems, Columbia, MD, PPSP-CP-84-3, 1984.
- (140) Abbe, G.R., Substrate Studies. In: Morgantown Station and the Potomac River Estuary: A 316 Environmental Demonstration, prepared for Potomac Electric Power Company, by Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, 1977.
- (141) Andrews, J.D., Fouling Organisms of Chesapeake Bay: Interim Report XVII of the Inshore Survey Program, prepared by the Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, MD, Ref. No. 53-3, 1953.

- (142) Mattice, J.S., Freshwater Macrofouling and Control with Emphasis on Corbulica. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art, Diaz-Tous, I.A., M.J. Miller, and Y.G. Mussalli Eds., Palo Alto, CA, 1983, Electric Power Research Institute.
- (143) Brungs, W.A., Effects of Wastewater and Cooling Water Chlorination on Aquatic Life, prepared for U.S. Environmental Protection Agency, EPA Ecological Research Series, EPA-600-3-76-098, 1976.
- (144) Bongers, L.H., T.P. O'Connor, and D.T. Burton, Bromine Chloride - an Alternative to Chlorine for Fouling Control in Condenser Cooling Systems, prepared for U.S. Environmental Protection Agency, by Martin Marietta Environmental Center, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, EPA-600-17-77-053, 1977.
- (145) Liden, L.H., D.T. Burton, L.H. Bongers, and A.F. Holland, The Effects of Chlorobrominated and Chlorinated Cooling Waters on Estuarine Organisms, Journal of Water Pollution Control Federation, Vol. 52, 1980, pp. 173-182.
- (146) Roberts, M.H., Jr., R.J. Diaz, M.E. Bender, and R.J. Huggett, Acute Toxicity of Chlorine to Selected Estuarine Species, Journal of Fisheries Research Board of Canada, Vol. 32, 1975, pp. 2525-2528.
- (147) Breisch, L.L., D.A. Wright, and D.M. Powell, Chlorine and the Chesapeake Bay, College Park, MD, 1984, University of Maryland Sea Grant, UM-SG-TS-84-02.
- (148) Sugam, R., and G.R. Helz, The Chemistry of Chlorine on Estuarine Waters, prepared for the Maryland Department of Natural Resources, Power Plant Siting Program, by the University of Maryland, Chemistry Department, College Park, MD, PPRP-26, 1977.
- (149) Helz, G.R., The Non-Oxidative Decay Products of Chlorine, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by the University of Maryland Chemistry Department, College Park, MD, 1981.
- (150) Mangum, D.C., and W.F. McIlhenny, Control of Marine Fouling in Intake Systems-A comparison of Ozone and Chlorine. In: Aquatic Applications of Ozone, proceedings of International Ozone Institute Workshop Series, 1974, pp. 138-153.
- (151) Hall, L.W., Jr., D.T. Burton, W.C. Graves, and S.T. Margrey, The Effects of Dechlorinated Industrial Effluent on Striped Bass (*Morone saxatilis*) Ichthyoplankton, prepared for Department of Natural Resources, Power Plant Siting Program, by Academy of Natural Sciences of Philadelphia, Philadelphia, PA, PPSP-MP-33, 1981.

- (152) Taylor, R.J., and L.B. Richardson, Ultrasonics as an Alternative to Biocides Program Report, prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD, PPRP-82, 1981.
- (153) Johnson, G., J. Foertch, M. Keser, and M.B. Johnson, Thermal Backwash as a Method of Macrofouling Control at Millstone Nuclear Power Station, Waterford, Connecticut, U.S.A., In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the Art, Diaz-Tous, I.A., M.J. Miller and Y.G. Mussalli Eds., Palo Alto, CA, 1983, Electric Power Research Institute.
- (154) Nauman, J.W., and R.L. Cory, Thermal Additions and Epifaunal Organisms at Chalk Point, Maryland, Chesapeake Science, Vol. 10, 1969, pp. 218-226.
- (155) Gitlitz, M.H., Recent Developments in Marine Antifouling Coatings, Journal of Coatings Technology, Vol. 53, 1981, pp. 46-52.
- (156) Hall, C.H., R.L. Martin, R.E. Hillman, Antifouling Coatings: Potential for Controlling Macrofouling in Operational Power Plants. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art, Diaz-Tous, I.A., M.J. Miller, and Y.G. Mussalli, Eds., Palo Alto, CA, 1983, Electric Power Research Institute.
- (157) Beaumont, A.R., and M.D. Budd, High Mortality of the Larvae of the Common Mussel at Low Concentrations of Tributyltin, Marine Pollution Bulletin, Vol. 15, 1984, pp. 402-405.
- (158) Waldock, M.J. and J.E. Thain, Shell Thickening in Crassostrea gigas: Organotin Antifouling or Sediment Induced, Marine Pollution Bulletin, Vol. 14, 1983, pp. 411-415.
- (159) Jeff Waxman, Consolidated Edison Company of New York, Telephone conversation, A.F. Holland, 1984.
- (160) Cannon, J.B., G.F. Cada, K.K. Campbell, D.W. Lee, and A.T. Szluha, Fish Protection at Steam-Electric Power Plants: Alternative Screening Devices, prepared for U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, by Oak Ridge National Laboratory, Oak Ridge, TN, 1979.
- (161) Tatham, T.R., D.L. Thomas, and G.J. Miller, Survival of Fishes and Macroinvertebrates Impinged at Oyster Creek Generating Stations. In: Fourth National Workshop on Entrainment and Impingement, L.D. Jensen, Ed., Melville, NY, 1977, E.A. Communications.
- (162) Newman, E.N., T.P. Mainz, and L. Liebenstein, Evaluation of Barrier Nets to Reduce Fish Impingement, prepared for the Workshop on Advanced Intake Technology, 1981.

- (163) Haymes, G.T. and D.H. Patrick, Alternative Fish Protective Techniques: Pneumatic Guns and Rope Nets, prepared by Ontario Hydro Biological Research Section, Chemical Research Department, Toronto, Ontario, 1984.
- (164) Otto, R.G., T.I. Hiebert and V.R. Kranz, The Effectiveness of a Remote Profile-wire Screen Intake Module in Reducing the Entrainment of Fish Eggs and Larvae. In: Advanced Intake Technology for Power Plant Cooling Water Systems, Proceedings of the Workshop of Advanced Intake Technology, P.B. Dorn and J.T. Johnson, Eds., San Diego, CA, 1981, pp. 47-56.
- (165) Hanson, B.N., W.H. Bason, B.E. Beitz and K.E. Charles, A Practical Intake Screen Which Substantially Reduced the Entrainment of Early Life Stages of Fish. In: Fourth National Workshop on Entrainment and Impingement. L.D. Jensen, Ed., Melville, NY, Ecological Analysts, Inc., pp. 392-407.
- (166) Wietz, D.H., Problems Associated with the Installation of Fish Barrier Nets at the Morgantown Generating Station, prepared by Potomac Electric Power Company, Washington, DC, 1982.
- (167) Evaluating the Effectiveness of Outages Objective I Report. Review of Statistical Estimators for Biological Parameters of Outage Assessment Measures, prepared for Consolidated Edison Company of New York, by Martin Marietta Environmental Systems, Columbia, MD, 1985.
- (168) Hudson River Ecological Study in the Area of Indian Point-1981 Annual Report, prepared for Consolidated Edison Company of New York, Inc., and New York Power Authority, by Consolidated Edison Company of New York, Inc., New York, NY, 1982.
- (169) Boesch, D.F. and R. Rosenberg. Response to Stress in Marine Benthic Communities. In: Stress Effects on Natural Ecosystems. G.W. Barrett and R. Rosenberg, Eds. John Wiley and Sons, New York. pp. 179-200.
- (170) Holland, A.F., Long-term Variations of Macrobenthos in a Mesohaline Region of Chesapeake Bay, Estuaries, Vol 8, 1985, pp. 37-45.

CHAPTER V

RADIOLOGICAL IMPACT

Nuclear power plants in the United States are licensed and regulated by the U.S. Nuclear Regulatory Commission. Conditions imposed in the operating licenses for each plant permit the routine discharge of low levels of radioactivity to the environment. These releases must be within the guidelines of the federal regulations contained in 10 CFR 50 Appendix I, and are restricted by limits on the radiation doses received offsite by a hypothetical maximum exposed individual (Table V-1). Annual total body doses cannot exceed 3 mrem per reactor for the aqueous pathway and 5 mrem per reactor for the atmospheric pathway. Aqueous pathway doses are received through ingestion of radioactivity in water and seafood, and exposure to contaminated water and sediments. Atmospheric pathway doses result from inhalation of, and direct exposure to, gaseous and particulate radioactivity in the passing plume and ingestion of radionuclides deposited on, or assimilated by, terrestrial vegetation and animals.

Calvert Cliffs on the Chesapeake Bay is the only nuclear power plant in Maryland. However, Peach Bottom and Three Mile Island on the Susquehanna River in Pennsylvania have the potential for impact on Maryland. This chapter presents the Power Plant Siting Program's (PPSP) evaluation of the environmental impact on Maryland of radioactivity released by these plants during 1983-1984. This assessment is based on results of surveillance programs and radioecological studies conducted by PPSP as well as the individual utilities, and the Maryland Department of Health and Mental Hygiene (DHMH). Included are discussions of the radioactivity discharged by each plant and the actual distribution of radionuclides in the environment. Doses to man via the atmospheric and aqueous release pathways are calculated. Comparisons with natural background doses, operating license restrictions, and environmental radionuclide concentrations present the previous reporting periods are made where appropriate. A brief discussion of nuclear waste disposal for each plant is also included.

A. Calvert Cliffs Nuclear Power Plant

The Calvert Cliffs Nuclear Power Plant, owned and operated by the Baltimore Gas and Electric Company (BG&E), is the only nuclear power plant located in Maryland. Each of its two units is a pressurized water reactor, each having a maximum dependable capacity of 890 MWe.

Unit 1 of the Calvert Cliffs nuclear power plant, placed in commercial service on May 8, 1975, had as of the end of 1984 produced 54,043,380 MWh gross of electrical energy. Unit 2, placed in commercial service April 1, 1977, had as of the end of 1984 produced 45,658,203 MWh gross. Since the beginning of commercial operation, Units 1 and 2 had (by the end of 1984) achieved cumulative unit capacity factors of 74.6% and 78.1%, respectively.

Table V-1. 10 CFR 50 Appendix I Guidelines: Limiting Conditions for Operation of Light-Water-Cooled Nuclear Power Reactors to Keep Radioactivity in Effluents to Unrestricted Areas as Low as is Reasonable Achievable.

Type of Dose	Design Objectives(a)	Point of Dose Evaluation
<u>Liquid Effluents</u>		
Dose to whole body from all pathways	3 mrem/yr per unit	Location of the highest dose offsite(b)
Dose to any organ	10 mrem/yr per unit	Same as above
<u>Gaseous Effluents(c)</u>		
Gamma dose in air	10 mrad/yr per unit	Location of the highest dose offsite (d)
Beta dose in air	20 mrad/yr per unit	Same as above
Dose to whole body	5 mrem/yr per unit	Location of the highest dose offsite (b)
Dose to skin	15 mrem/yr per unit	Same as above
<u>Radioiodines and Particulates (e)</u>		
<u>Released to the Atmosphere</u>		
Dose to any organ from all pathways	15 mrem/yr per unit	Location of the highest dose offsite (f)

- (a) Evaluated for a maximum exposed individual.
- (b) Evaluated at a location that is anticipated to be occupied during plant lifetime, or with respect to such potential land and water usage and food pathways as could actually exist during the term of plant operation.
- (c) Calculated only for noble gases.
- (d) Evaluated at a location that could be occupied during the term of plant operations.
- (e) Doses due to carbon-14 and tritium intake from terrestrial food chains are included in this category.
- (f) Evaluated at a location where an exposure pathway and dose receptor actually exist at the time of licensing. However, if the applicant determines design objectives with respect to radioactive iodine on the basis of existing conditions and if potential changes in land and water usage and food pathways could result in exposures in excess of the guideline values given above, the applicant should provide reasonable assurance that a monitoring and surveillance program will be performed to determine: (1) the quantities of radioactive iodine actually released to the atmosphere and deposited relative to those estimated in the determination of design objectives; (2) whether changes in land and water usage and food pathways which would result in individual exposures greater than originally estimated have occurred; and (3) the content of radioactive iodine in foods involved in the changes, if they occur.

Releases to the Environment

Radionuclides discharged to the atmosphere and Chesapeake Bay by Calvert Cliffs during 1983-1984 as reported by BG&E are given in Tables V-2 and V-3. Noble gases, which are not of significant environmental concern, comprise virtually 100% of the atmospheric releases.

Environmental Monitoring Programs

BG&E, DHMH, and PPSP each conduct routine radiological monitoring programs designed to define the environmental impact of the releases described above. The BG&E program is structured to conform to environmental surveillance requirements imposed in its NRC operating license. The DHMH performs assurance monitoring to provide an independent confirmation of the utility program. The program conducted by PPSP is focused primarily on the aqueous pathway impact, and is designed to define the areal and trophic-level distribution and concentration of power plant radionuclides in the Calvert Cliffs vicinity of Chesapeake Bay. Descriptions of these monitoring programs can be found in CEIR IV (1).

Atmospheric and Terrestrial Radionuclide Distributions

The Chinese weapons test of October 15, 1980 resulted in elevated levels of radioactivity detected in atmospheric and terrestrial samples collected through most of 1981 as reported in CEIR IV (1); no evidence of the test was found in 1982. Atmospheric and terrestrial radionuclide concentrations for 1983-1984 reflect the decrease in weapons test fallout since the 1981-1982 reporting period.

• Atmospheric

Inspection of radionuclide concentrations in air particulate, air iodine, and precipitation samples for 1983-1984 indicates no discernible Calvert Cliffs increment to atmospheric radioactivity.

Beta activity in atmospheric particulates was detected (typical values between 0.5-2.5 fCi/m³) over the two year period, with the range of values lower than for previous reporting periods, suggesting an apparent decrease in atmospheric fallout from past weapons testing (2,3). No measurable concentration of power plant radionuclides was detected; Cs-137 was detected on several occasions, but at levels near the threshold of detection, to a maximum of 3.1 ± 0.7 fCi/m³ (2,3,8). Beryllium-7, a naturally occurring cosmogenic radionuclide, was detected in most samples to a maximum of 370 ± 30 fCi/m (2,3,8). Sporadic detection of Sr-90 occurred at levels near detection threshold (<0.5 fCi/m³) to a maximum of 0.7 ± 0.3 fCi/m³. Sr-89 was not detected. No radioactive iodine was detected (<12 fCi/m³) in the atmosphere during the 1983-1984 reporting period (2,3,8).

Table V-2. Total Curies of Radionuclides Released to the Atmosphere by the Calvert Cliffs Nuclear Power Plant, 1983, 1984 as Reported by BG&E (4-7).

Radionuclide	1983	1984
<u>Summary</u>		
Tritium	41.54	2.63
Fission and Activation Gases	9390.97	3795.41
Halogens	0.21	0.15
Particulates	0.52	0.20
Total Curies	9433.24	3798.39
<u>Fission and Activation Gases</u>		
Ar-41	0.506	0.1725
Kr-85	2.980	5.345
Kr-85m	7.678	0.60032
Kr-87	0.2300	0.011517
Kr-88	0.9970	0.14060
Xe-131m	51.28	17.9700
Xe-133	9161.03690	3493.000
Xe-133m	37.9100	80.959
Xe-135	128.3400	57.00
Xe-135m	0.00	140.220000
<u>Halogens</u>		
Br-82	0.000036	0.000148
I-131	0.095168	0.059438
I-132	0.027000	0.001246
I-133	0.076780	0.070233
I-134	0.00	0.000003
I-135	0.006658	0.015154
<u>Particulates</u>		
Co-58	0.000019	0.000024
Rb-88	0.297700	0.046390
Sr-89	0.000120	0.00
Sr-90	0.000000	0.000003
Cs-134	0.002700	0.000007
Cs-137	0.004530	0.000048
Cs-138	0.006851	0.000359
Ba-140	0.000000	0.000191
La-140	0.000000	0.000377

Table V-3. Total Curies of Radionuclides Released as Liquid Effluent by the Calvert Cliffs Nuclear Power Plant, 1983, 1984 as Reported by BG&E (4-7).

Radionuclide	1983	1984
<u>Summary</u>		
Tritium	755.90	787.00
Dissolved Noble Gases	2.26	0.26
Halogens	0.39	0.13
Other	1.84	1.50
Total Curies	760.39	788.89
<u>Noble Gases</u>		
Kr-85	0.082	0.00
Kr-85m	0.000077	0.00
Xe-133	2.17	0.25316
Xe-133m	0.001606	0.00214
Xe-135	0.009148	0.003936
<u>Halogens</u>		
I-131	0.3327	0.0903
I-132	0.00	0.000785
I-133	0.05816	0.04133

Table V-3 Cont'd.

Radionuclide	1983	1984
<u>Other</u>		
Na-24	0.006385	0.001569
Cr-51	0.07256	0.1230
Mn-54	0.01471	0.01531
Fe-59	0.00	0.00071
Co-57	0.000728	0.000116
Co-58	0.6049	0.5647
Co-60	0.08008	0.1001
Sr-89	0.0036	0.00590
Sr-90	0.000747	0.00135
Zr-95	0.013864	0.03021
Zr-97	0.000261	0.00105
Nb-95	0.029393	0.05447
Nb-97	0.002102	0.02085
Mo-99	0.00787	0.001240
Ru-103	0.00193	0.00535
Ag-110m	0.07740	0.09525
Sn-113	0.000963	0.004164
Cs-134	0.18131	0.1045
Cs-136	0.000938	0.00
Cs-137	0.3149	0.2433
Sb-122	0.013597	0.000080
Sb-124	0.07347	0.00207
Sb-125	0.32790	0.069043
Te-132	0.00	0.000426
Ba-140	0.001790	0.000751
La-140	0.00465	0.00021
Ce-141	0.00	0.003510
Ce-144	0.000684	0.05377

During 1983-1984 beta emitters were detected in precipitation, following a pattern similar to atmospheric particulates with the range of values (maximum 12.8 ± 0.8 pCi/l) less than those in previous reporting periods (2,3,8), again suggesting a decrease in atmospheric weapons test fallout. Although tritium was not detected in precipitation (<140 pCi/l) by BG&E (2,3), DHMH reported fallout attributable levels of tritium on several occasions (maximum of 500 ± 300 pCi/l) (8). No measurable concentrations of any plant related fission or activation products were detected. Naturally occurring Be-7 was detected in most samples to a maximum of 170 ± 40 pCi/l (2,3,8). There was no detectable presence of Sr-89 (<10 pCi/l) or Sr-90 (<0.7 pCi/l) in precipitation samples during the 1983-1984 reporting period (2,3).

. Terrestrial

Concentrations of radionuclides in terrestrial media (crop, soil, and vegetation samples) for 1983-1984 do not indicate any atmospheric plant increment from Calvert Cliffs. Crop samples from near and farfield stations contained measurable concentrations of Cs-137. Radiostrontium analyses of vegetation revealed no detectable Sr-89 (<35 pCi/kg wet). However, Sr-90 was detected in the majority of vegetation samples, ranging from 6 to a maximum of 780 pCi/kg wet in tobacco (2,3). The distribution and levels of Sr-90 and Cs-137 for vegetation sampled from onsite and farfield farms coupled with the absence of Sr-89, indicates these concentrations are the result of weapons testing and not Calvert Cliffs.

Aquatic Radionuclide Distributions

Radionuclides attributable to both releases by Calvert Cliffs as well as weapons test fallout have been detected in the Chesapeake Bay system. Very low levels of Cs-137, Zr/Nb-95, Ce-141, and Ce-144 were detected in sediments during 1983 and 1984. Although Calvert Cliffs contributes small quantities of these nuclides, a comparison of concentrations in the nearfield with those remote locations indicates that historic weapons test fallout is the more likely source.

The routine release of tritium by Calvert Cliffs may occasionally produce concentrations in nearfield Bay water which exceed levels attributable to weapons testing. Dilution and dispersion reduce these concentrations to ambient levels in a short time. During 1983, Calvert Cliffs released a total of about 756 Ci of tritium to the Bay, and 787 Ci in 1984 (2,3). Monthly grab samples by BG&E showed only fallout-attributable tritium levels. (maximum 301 ± 117 pCi/l) (2, 3). Quarterly grab samples by DHMH in 1983-1984 indicated a slight plant-attributable tritium increment in August 1984 (100 ± 400 pCi/l) (8). Because tritium is not bioaccumulated and release quantities are relatively low, no adverse environmental impact has resulted.

Calvert Cliffs also releases small quantities of bioaccumulable radionuclides to the Bay. Through food chain transport and bioconcentration, upper trophic levels, including man, may ultimately receive a dose increment attributable to plant operation. Bioaccumulable

radionuclides detected in the Bay environment attributed solely to Calvert Cliffs during 1983-1984 included Co-58, Co-60, Zn-65, and Ag-110m (2,3,9). Table V-4 lists maximum concentrations of Calvert Cliffs-attributed radionuclides detected in Bay samples by the PPSP program.

- Sediments

Co-58 and Co-60 were consistently detected in Bay sediments in the Calvert Cliffs area, primarily associated with silt and clay particles. Variations in these radionuclide concentrations occur over time as a result of physical processes which disperse sediment particles, as well as chemical and biological processes which may partition environmental radionuclide concentrations. The dispersion of radiocobalt-labelled sediment particles has resulted in a slight expansion down-bay of the area where both Co-58 and Co-60 can be detected in sediments. Low levels of radiocobalt have been detected consistently in sediments along the Western Shore as far as 3 miles to the south. Hydrodynamic dispersion, nuclide decay, and particle dilution appears to have reduced concentrations to sporadically-detectable levels beyond this point. A slight increase in the concentration of Co-60 but not Co-58 is apparent within the sampling grid, a function of the longer half-life of Co-60 (5.3 yrs) relative to Co-58 (71 days).

- Biota

No Calvert Cliffs radionuclides were detected in any edible finfish collected during 1983-1984 by either BG&E or PPSP. Ag-110m was the only Calvert Cliffs radionuclide detected in forage finfish, and occurred on a single occasion, at one extremely low level, and only in Menhaden (Table V-4). Co-58, Co-60, and Ag-110m were detected in nearfield epifauna samples collected from panels emplaced at 3 month exposure intervals. Co-60 and Ag-110m concentrations were consistently higher for the July-September exposure period during both 1983 and 1984. No plant related nuclides were detected in farfield epifauna samples. Low levels of Ag-110m were also detected in nearfield blue crab meat on one occasion in 1983 and in both nearfield and farfield blue crab meat and shell twice in 1984 (Table V-4). The occurrence of Ag-110m in farfield blue crab (which are mobile organisms) and not in farfield epifauna (which are sessile organisms) suggests that blue crabs are exposed to Ag-110m during transit through the nearfield location as they migrate to other areas of the Bay.

Plant related radionuclides were detected in macro-algae and grass shrimp, which was not the case for the 1981-1982 reporting period (1). Co-58 was detected in *Enteromorpha* sp. on a single occasion in 1983 and in *Ulva* sp. on a single occasion in 1984. Ag-110m was detected in both *Enteromorpha* sp. and *Ulva* sp. in 1984 (Table V-4). Ag-110m was also detected in grass shrimp once in 1983 and twice in 1984 (Table V-4).

Of biota harvested for human consumption in the Calvert Cliffs area, oysters are the principal indicators of radiological impact because they are non-mobile and possess an ability to concentrate metals, including radionuclides. Oysters have consistently contained Ag-110m and have sporadically contained low levels of power-plant related Co-58.

Table V-4. Maximum Concentrations of Calvert Cliffs - Related Radionuclides in Samples Associated with the Chesapeake Bay for the Period 1983-1984, PPSP Monitoring Program (9). Counting Uncertainty at 95% Confidence Level.

Sample Type	Radionuclide Concentration (pCi/kg wet) (a)											
	Co-58			Co-60			Zn-65			Ag-110m		
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984
Seaduck (Flesh)	<13	<12	<14	<14	<14	<14	<28	<28	<17	<17	<17	<17
Edible Finfish (Flesh)	<12	<10	<10	<8	<8	<8	<20	<20	<12	<12	<10	<10
Forage Finfish (Whole)	<12	<8	<15	<8	<8	<8	<30	<30	<20	<20	2+2	2+2
Oyster Meat	10+5	21+4	1+2	<8	67+13	21+8	420+16	250+10	10+5	10+5	6+5	6+5
Crab Meat	<15	<15	<12	<8	<12	<12	<12	<12	15+7	15+7	56+19	38+11
Crab Shell	<30	<20	<14	<10	<40	<16	<25	<25	46+18	46+18	6+4	6+4
Grass Shrimp	<20	<20	<25	<15	<30	<20	<30	<30	8+9	8+9	307+89	307+89
Epifauna	2192+428	2344+153	661+244	351+76	<200	<100	339+250	339+250	31+9(b)	31+9(b)	8+5(c)	8+5(c)
Macro Algae	(b) 109+12 (c) 16+6											
Bay Sediment	233+59	91+47	213+31	173+21	<30	<30	39+17	39+17	58+25	58+25	12+8	12+8
Clay	87+21	70+18	50+10	52+8	<30	<30	24+37	24+37				
Sand												

(a) Crab shell and sediment concentrations are pCi/kg dry weight; epifauna concentrations are pCi/kg ash weight.

(b) *Enteromorpha* sp.

(c) *Ulva* sp.

Ag-110m was consistently detected in 1) oysters located on natural bars in the plant discharge, 2) bar oysters sampled quarterly from Camp Canoy by BG&E (maximum 535 ± 30 pCi/kg wet) (2,3), and 3) oysters immersed quarterly in trays located in the plant discharge vicinity (1 ± 3 to 119 ± 11 pCi/kg wet). Maximum concentrations for natural bar oysters collected by PPSP in Table V-4.

Levels of Zn-65 released by Calvert Cliffs during 1983 & 1984 are too low to be detectable by BG&E in sampling the discharge prior to release. Due to an ability to concentrate the metal, low but detectable concentrations of Zn-65 were observed sporadically in both natural bar and tray oysters sampled by PPSP (Table V-4).

Radioisotopes of strontium are reasonably mobile in aquatic ecosystems and may ultimately deposit in calcium-bearing bones and shells. Because of the potential for bioaccumulation in lower and higher trophic levels (including man), PPSP performs radiostrontium analyses on a variety of biota. Low levels of Sr-90 have been observed in edible finfish flesh (2 ± 6 pCi/kg wet), oyster meat (2 ± 1 pCi/kg wet), and grass shrimp (12 ± 3 pCi/kg wet). BG&E detected Sr-90 in edible finfish flesh and bone to a maximum of 15 ± 6 pCi/kg wet (2,3) for the 1983-1984 reporting period. Strontium-89 was not detected by PPSP or BG&E. There is no discernible Sr-89 increment from Calvert Cliffs; detected Sr-90 concentrations are likely residuals from weapons test fallout.

Radiation Dose to Man

Estimates of the dose commitments¹ to individuals consuming seafood (oysters) harvested in the vicinity of Calvert Cliffs have been calculated using the maximum radionuclide concentrations detected in shellfish taken from this area (Table V-5). Calculated dose commitments to adults, teenagers and children are given. Table V-6 contains a comparison of doses calculated for this reporting period with those of the previous reporting period (1). These doses are trivial and represent small fractions of those permitted under Calvert Cliffs' operating license (see Table V-1).

Conclusion

No radioactivity detected by monitoring of the atmospheric pathway during 1983-1984 is attributed to plant operation. Discharges via the aqueous pathway have produced detectable radionuclide concentrations in the Chesapeake Bay ecosystem. Sediments have contained low levels of Co-58 and Co-60. The range of concentrations varies over time, and no significant build-up is apparent in the nearfield. The down-bay migration of radiocobalt-labelled sediments has produced an area of radiocobalt detectability during this reporting period which extends to approximately 3 miles south of the plant.

¹The dose commitment from the ingestion of a given quantity of some radionuclide is the total dose that will be received by the individual before removal by radioactive decay. These estimates employ Regulatory Guide 1.109 dose conversions (10).

Table V-5. Maximum Dose Commitment (in mrem) to an individual Consuming Oysters (a) Exclusively from the Vicinity of the Calvert Cliffs Nuclear Power Plant (Utilizing Maximum Radionuclide Concentrations Given for 1983-1984 in Table V-4).

Age Group		Adult	Teen	Child
Quantity of Oysters Consumed(b)		5 kg/yr	3.8 kg/yr	1.7 kg/yr
Total	Co-58	.000179	.000179	.000198
Body Dose	Co-60	.000024	.000025	.000031
	Zn-65	.002345	.002379	.002588
Dose	Ag-110m	.000185	.000188	.000208
	-----	-----	-----	-----
	TOTAL	.002733	.002771	.003025
Bone Dose	Co-58	(c)	(c)	(c)
	Co-60	(c)	(c)	(c)
Dose	Zn-65	.001608	.001469	.001562
	Ag-110m	.000336	.000327	.000385
	-----	-----	-----	-----
	TOTAL	.001944	.001796	.001947
Liver Dose	Co-58	.000074	.000078	.000065
	Co-60	.000011	.000011	.000011
Dose	Zn-65	.005159	.005100	.004161
	Ag-110m	.000311	.000310	.000260
	-----	-----	-----	-----
	TOTAL	.005555	.005499	.004497
Kidney Dose	Co-58	(c)	(c)	(c)
	Co-60	(c)	(c)	(c)
Dose	Zn-65	.003350	.003264	.002622
	Ag-110m	.000611	.000591	.000484
	-----	-----	-----	-----
	TOTAL	.003961	.003855	.003106
GI-LLI Dose (d)	Co-58	.001586	.001072	.000378
	Co-60	.000200	.000146	.000059
Dose	Zn-65	.003250	.002160	.000731
	Ag-110m	.126840	.086982	.030916
	-----	-----	-----	-----
	TOTAL	.131876	.09036	.032084

- (a) No power-plant radioactivity has been detected in edible finfish
- (b) Recommended consumption valves from Reg guide 1.109.
- (c) Dose/concentration conversion factors not available.
- (d) Gastrointestinal tract - lower large intestine.

Table V-6. Comparison of 1981-1982 and 1983-1984 Dose Commitments (in mrem) to an Individual Consuming Oysters Exclusively from the Calvert Cliffs Vicinity (a).

	1981-1982			1983-1984		
	Adult	Teen	Child	Adult	Teen	Child
Total Body	0.003	0.003	0.004	0.003	0.003	0.003
Bone	0.003	0.002	0.002	0.002	0.002	0.002
Liver	0.011	0.011	0.007	0.006	0.006	0.004
Kidney	0.005	0.005	0.003	0.004	0.004	0.003
GI-LLI	0.247	0.165	0.062	0.132	0.090	0.032

(a) PPSP derived data

Radionuclides attributed to aqueous releases by Calvert Cliffs have been detected at low levels in some sampled Bay biota, including forage finfish, oysters, crabs, algae, and epifauna. The maximum detected concentrations would produce radiation doses to the various organisms which are still orders of magnitude lower than doses resulting from the naturally radioactive sources present in the Bay environment.

Employing the maximum detected concentration in seafood (oysters), the estimated maximum dose as from seafood consumption would be 0.13 mrem to an adult's gastrointestinal tract. This is well within 10 CFR 50 Appendix I design criteria limiting a maximum exposed individual to 3 mrem annually per reactor for the aqueous pathway.

B. Peach Bottom Atomic Power Station

The Peach Bottom Atomic Power Station, owned and operated by the Philadelphia Electric Company (PECO), is located in Pennsylvania approximately three miles north of the Pennsylvania-Maryland border on the Susquehanna River. Although outside Maryland, it has an impact potential because of its proximity and the fact that radioactivity is discharged to the Susquehanna River. The plant operates two boiling water reactors, each with a maximum dependable capacity of 1098 MWe.

Unit 2, placed in commercial service in July 1974, had produced 58,718,660 MWh gross of electrical energy as of the end of 1984. Unit 3, placed in commercial service in December 1974, had produced 60,507,540 MWh gross. Since the beginning of commercial operation, Units 2 and 3 have achieved cumulative capacity factors of 63.9% and 58.2% respectively.

Releases to the Environment

Quantities of radionuclides released to the environment by the Peach Bottom Atomic Power Station during 1983 and 1984 are presented in tables V-7 and V-8. The radionuclide inventory discharged to the atmosphere (Table V-7) is comprised almost exclusively of the relatively short-lived and chemically inert noble gas radionuclides of xenon and krypton. Very low levels of radioiodine are also released, of which I-131 (half life 8 1/2 days) is most important because of its potential to provide a radiation dose to the thyroid. Although very low levels of this nuclide were released during the reporting period, offsite monitoring by PECO contractors detected I-131 in milk on several occasions.

Quantities of radionuclides released to the Susquehanna River (Conowingo Pond) during the subject period are given in Table V-8. Of this inventory, more than 85% is tritium. Present in the Susquehanna as tritiated water, it is not bioaccumuable and of little environmental concern. During the subject period, less than 3 curies of bioaccumuable radionuclides were released via the aqueous pathway. Of these, only I-131, Co-60, Zn-65, Cs-134, and Cs-137 were detected in biota and sediments collected from the Susquehanna and Upper Chesapeake Bay.

Because both PBAPS units were not operating for significant portions of the reporting period, the aqueous release inventory of these bioaccumuable radionuclides for 1983-1984 was lower than for the prior (1981-1982) reporting period. Notably, the release of Zn-65 during 1982 was almost 2 curies as compared with less than 1 curie of this nuclide for 1983 and 1984 combined.

Release quantities of radionuclides detected in aqueous pathway monitoring during 1983 and 1984 are compared with aqueous release quantities from prior reporting periods in Table V-9.

Table V-7. Total Curies of Radionuclides Released to the Atmosphere by the Peach Bottom Atomic Power Station, 1983, 1984, as Reported by PECO (12-15).

Radionuclide	1983	1984
<u>Summary</u>		
Tritium	15.29	26.18
Fission and Activation Gases	33661.24	80843.53
Halogens	1.34	1.33
Particulates	<u>0.10</u>	<u>0.18</u>
Total Curies	33677.97	80871.22
<u>Fission and Activation Gases</u>		
Ar-41	4.91	0.00
Kr-85m	501.62	131.96
Kr-87	60.17	264.22
Kr-88	392.56	298.24
Xe-131m	0.00	283.70
Xe-133	21591.45	74514.00
Xe-133m	512.90	1604.10
Xe-135	10461.90	2641.90
Xe-135m	122.55	592.41
Xe-138	13.18	513.00
<u>Halogens</u>		
I-131	0.038611	0.09326
I-133	0.8783	0.78955
I-135	0.4273	0.4509

Table V-7 Cont.d

Radionuclide	1983	1984
<u>Particulates</u>		
Na-24	0.000387	0.001300
Co-58	0.000062	0.000026
Co-60	0.000336	0.000186
Cu-64	0.000000	0.001990
Zn-65	0.002102	0.001455
Rb-88	0.006723	0.000000
Rb-89	0.000455	0.000000
Sr-89	0.001331	0.003625
Sr-90	0.000117	0.000111
Sr-91	0.001424	0.001198
Y-91m	0.007960	0.007533
Tc-99m	0.000097	0.000076
Cd-109	0.000259	0.000086
Cs-134	0.000654	0.001436
Cs-137	0.000775	0.001585
Cs-138	0.060759	0.144750
Ba-139	0.017080	0.010687
Ba-140	0.001553	0.001137
La-140	0.001062	0.000883

Table V-8. Total Curies of Radionuclides Released as Liquid Effluent by the Peach Bottom Atomic Power Plant, 1983, 1984 as Reported by PECO (12-15).

Radionuclide	1983	1984
<u>Summary</u>		
Tritium	20.24	35.82
Dissolved Noble Gases	0.26	4.88
Halogens	0.18	0.29
Other	<u>1.91</u>	<u>1.04</u>
Total Curies	22.59	42.03
Kr-85m	0.002407	0.075700
Kr-87	0.000000	0.029630
Kr-88	0.000000	1.703800
Xe-131m	0.004571	0.055121
Xe-133	0.175480	1.425238
Xe-133m	0.000377	0.042516
Xe-135	0.066496	1.508529
Xe-135m	0.014876	0.041945
I-131	0.133409	0.141411
I-132	0.001974	0.002366
I-133	0.038298	0.119783
I-134	0.000515	0.000000
I-135	0.007469	0.023796
Na-24	0.215319	0.172646
P-32	0.144050	0.019544
Cr-51	0.011779	0.005827
Mn-54	0.002879	0.015609
Mn-56	0.000373	0.001829
Fe-55	0.058749	0.023858
Co-58	0.017243	0.004558
Co-60	0.156490	0.112434
Ni-63	0.061589	0.007334
Cu-64	0.006760	0.000000
Zn-65	0.785820	0.210714
Sr-89	0.003682	0.044945
Sr-90	0.000406	0.001964
Sr-91	0.000000	0.000404
Sr-92	0.001502	0.000706
Y-91m	0.001412	0.001036
Nb-95	0.000650	0.000689
Mo-99	0.000000	0.002180
Tc-99m	0.013805	0.012340
Cd-109	0.006960	0.003050
Ag-110m	0.002418	0.001290

Table V-8 (cont'd)

Radionuclides	1983	1984
<u>Other</u>		
Sn-113	0.000000	0.000746
Sb-124	0.000235	0.000286
Sb-125	0.000000	0.001120
Te-132	0.000000	0.000149
Cs-134	0.147172	0.164410
Cs-136	0.000000	0.007370
Cs-137	0.256160	0.211329
Ba-140	0.001360	0.001909
La-140	0.003894	0.005564
Ce-144	0.000000	0.003150
Np-239	0.000000	0.000924

Table V-9. Comparison of Annual Release Quantities (in Curies) of Radionuclides Which Have Been Detected in the Aqueous Environment. (1, 12-15)

Radionuclide	<u>Curies Released</u>					
	1979	1980	1981	1982	1983	1984
I-131	0.96	0.06	0.05	0.15	0.13	0.14
Co-60	0.16	0.16	0.13	0.65	0.16	0.11
Zn-65	0.46	0.31	0.29	1.96	0.79	0.21
Cs-134	3.92	0.57	0.10	0.46	0.15	0.16
Cs-137	3.26	0.70	0.17	0.65	0.26	0.21

Environmental Monitoring Programs

PECO, DHMH, and PPSP conduct separate monitoring programs, each designed with distinct emphases to assess the radiological impact of the Peach Bottom plant. The PECO program is defined by NRC operating license requirements. Their contractors analyze samples of air, precipitation, terrestrial vegetation, soil, and milk and monitor ambient radiation dose levels in addressing atmospheric pathway impact. The DHMH analyzes Conowingo Pond water and air particulates from the vicinity.

To address aquatic pathway environmental impact, PECO contractors and PPSP analyze sediments and a variety of aquatic biota. PECO surveillance is restricted to the Conowingo Pond. PPSP programs focus on this aquatic pathway as it represents the greatest potential environmental impact in Maryland, conducting monitoring and research programs which address aquatic impact in the Conowingo Pond, the lower Susquehanna River and the Chesapeake Bay (Figure V-1).

Atmospheric and Terrestrial Radionuclide Distributions

Other than natural radionuclides and weapons-test fallout levels of Cs-137, I-131 and Cs-134 were the only radionuclides evident in atmospheric and terrestrial monitoring. In 1983 a slight concentration of I-131 was detected on one occasion in milk from three of eight regional farms monitored weekly from Spring through Fall. The highest concentration recorded was 4.4 ± 0.4 pCi/l.

In 1984 very low levels of I-131 were again evident in milk from two of eight farms monitored. Detectable concentrations occurred at a nearfield farm on 9/17/84 and persisted through 10/29/84. The maximum recorded I-131 concentration was 0.43 ± 0.04 pCi/l. At a slightly more distant farm, I-131 was evident in milk from 10/8/84 to 10/29/84 with a maximum recorded concentration of 0.11 ± 0.04 pCi/l (16-19). Their detection at these low levels provides an indication of the efficacy of the milk surveillance program. As a basis for the determination of radiological impact however, the milk monitoring grid may not provide an accurate estimator. It is noted that sampling stations are distributed to the west of the PBAPS site (16-19). Since an annual wind rose for this vicinity indicates essentially a 360° downwind direction at 312 ft (the height of the release stack) (11), potential detection of a PBAPS I-131 increment in the milkshed is only partially represented, thus the PBAPS radiological impact via the atmospheric-pasture-milk pathway may be underestimated. While these detectable levels are attributed to slightly elevated releases of I-131 by PBAPS in September and October (15), they may simply reflect a higher incidence of easterly winds (blowing toward monitoring stations) during those months.

In addition to the I-131 concentrations previously described, Cs-134 was detected in milk (5 ± 5 pCi/l) on a single sampling occasion at a concentration barely above the analytical detection limit (16-19). This concentration is not environmentally significant, and may in fact be an analytical artifact. It is noteworthy that atmospheric releases of Cs-134

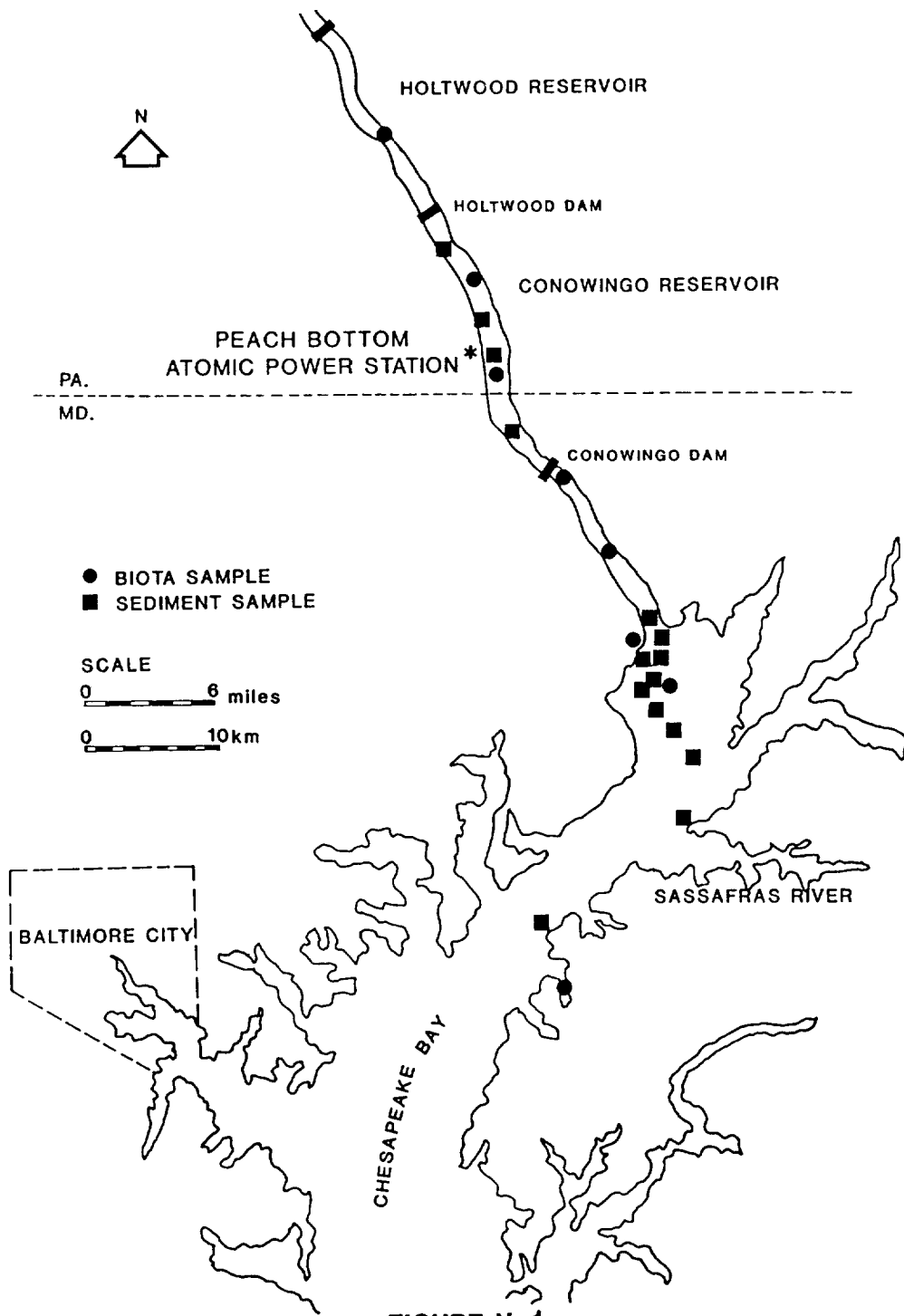


FIGURE V-1
PPSP SUSQUEHANNA RIVER/UPPER BAY SAMPLING LOCATIONS

during 1983-84 were orders of magnitude lower than in 1981-82, and that I-131 releases during 1983 resembled those of the prior two years, but were three times those annual values in 1984.

Aquatic Radionuclide Distributions

As indicated in Table V-10, low levels of radionuclides attributed to aquatic releases by PBAPS have been detected in a variety of monitored environmental media (20).

. Biota

During 1983-1984, radionuclides detected in finfish by PPSP and attributed to aqueous releases by PBAPS included Co-60, Zn-65, Cs-134 and Cs-137 (20). I-131, which is a PBAPS release product, was also detected on several occasions. However detection of this nuclide upstream of PBAPS (20) as well indicates an additional source, probably a medical facility. As in prior reporting years, concentrations of all these nuclides were highest in finfish collected from the Conowingo Pond, and also consistently detectable in collections from the Conowingo Dam tailrace. Edible finfish species with detectable concentrations of these nuclides included channel catfish, carp, hybrid (striped x white) bass, walleye, white perch, and smallmouth and largemouth bass. Generally, concentrations of these nuclides in the finfish analyzed were lower in this reporting period (1983-1984) than previously (1981-82), reflecting the relatively lower concentrations released by PBAPS. This fact also indicates that although these nuclides are bioaccumulated, physical nuclide decay, as well as chemical exchange and depuration mechanics discourage long term accumulation.

Low levels of Zn-65 and Cs-134 were detected in submerged aquatic vegetation collected from the lower Susquehanna during the prior reporting years, but neither these nor any other PBAPS nuclides were detected in 1983-1984.

PPSP conducts a caging program in which crayfish and freshwater mussels are submerged within and above the influence of PBAPS releases. Removed for analysis monthly, they provide an indication of bioavailability of PBAPS radionuclides. Radionuclides attributed to aqueous releases by PBAPS detected in mussels caged in the Conowingo Pond included Co-60, Zn-65, and Cs-134. Concentrations of all these nuclides were much lower than recorded during 1982, again reflective of the comparatively lower concentrations of these radionuclides in PBAPS releases during 1983 and 1984. A low level of Zn-65 was occasionally detectable in mussels resident on the Susquehanna Flats at levels an order of magnitude or more lower than concentrations in the Conowingo Pond as in prior years. This is primarily the result of Zn-65 "holdup" in the Pond and subsequent nuclide decay as well as downstream dilution.

The crayfish caging study was initiated in 1983, so a comparison with the prior reporting period is not possible. During 1983, crayfish immersed in Conowingo Pond contained the same PBAPS radionuclides as mussels; however, at slightly higher concentrations with respect to radio-cobalt and radio-cesium (Table V-10). While mussels appear to be better indicator

Table V-10. Maximum Concentrations of Radionuclides Attributed to Peach Bottom Atomic Power Station in Various Aquatic Biota for the Period 1983-1984 as Determined through PPSP Monitoring program (20). Counting Uncertainty at 95% Confidence Level.

Media	Radionuclide Concentration (pCi/kg, wet) (a)			
	Co-60	Zn-65	Cs-134	Cs-137 (b)
EDIBLE FINFISH (Flesh)				
Holtwood	<10	<20	<14	6 ± 6
Conowingo Pond	<10	82 ± 21	94 ± 15	288 ± 20
Conowingo Dam Tailrace	<10	21 ± 11	53 ± 17	81 ± 11
Susquehanna Flats	<10	<60	<27	22 ± 19
FORAGE FINFISH (Whole)				
Holtwood	<10	<20	<10	14 ± 3
Conowingo Pond	19 ± 5	639 ± 200	51 ± 6	76 ± 15
Conowingo Dam Tailrace	<7	59 ± 11	49 ± 5	70 ± 7
CRAYFISH				
Holtwood Reservoir	<25	<50	<25	<30
Conowingo Pond	7 ± 15	106 ± 66	81 ± 44	94 ± 48
MUSSELS (<u>Elliptio complanata</u>)				
Holtwood Reservoir	<15	<30	<20	2 ± 8
Conowingo Pond	2 ± 2	269 ± 32	10 ± 7	11 ± 7
Susquehanna Flats	<15	13 ± 9	<7	1 ± 2
SUBMERGED AQUATIC VEGETATION (<u>M. spicatum</u>)				
Susquehanna Flats	<8	<8	<4	35 ± 7
SEDIMENT				
Holtwood	0	0	0	334 ± 12
Conowingo Pond	988 ± 18	837 ± 67	308 ± 20	1163 ± 40
Susquehanna Flats	28 ± 12	45 ± 22	57 ± 11	383 ± 13

(a) Sediment concentrations are pCi/kg dry weight.

(b) Primarily attributable to weapons testing fallout; however where Cs-134 was also present, a power plant produced Cs-137 increment is also indicated.

organisms for Zn-65 availability, crayfish are better accumulators and indicators of cobalt, cesium and iodine. No PBAPS attributable radionuclides were detected in crayfish during 1984, again the result of reduced release concentrations. Other than a trace of Cs-137 attributed to weapons testing, no manmade radionuclides have been detected in crayfish caged in the Holtwood Reservoir upstream of PBAPS.

- Sediments

During 1983-1984, radionuclides attributed to PBAPS detected in sediments included Co-60, Zn-65, Cs-134, and Cs-137¹. In 1981-1982, these same radionuclides were also present at slightly lower levels. The relatively higher release concentrations of these radionuclides in 1982 accounts for the increase in sediment concentrations in 1983. These same radionuclides were evident in sediments collected on the Susquehanna Flats; however, at concentrations reduced by an order of magnitude or more. Dilution and dispersion of suspended matter coupled with the migration of bottom sediments distribute this PBAPS radioactivity such that it is generally undetectable in sediments south of the Sassafrass River mouth.

Radiation Dose To Man

Releases of radioactivity to the atmosphere by PBAPS during 1983 and 1984 resulted in the occasional presence of low levels of I-131 in cows milk. During 1983, the highest recorded concentration was 4.4 pCi/l. As this concentration was detected on only one weekly sampling, an entire year's consumption of milk at this concentration would result in an annual maximum hypothetical dose to an infant thyroid of only 0.4 mrem. During 1984, I-131 was detected in cows milk more frequently, but at lower levels than in 1983, producing an estimated annual maximum hypothetical dose of only 0.11 mrem to an infant thyroid.

For the aqueous pathway, the annual total body dose associated with consumption of drinking water was calculated for an individual consuming two liters of water from the Conowingo Pond containing radionuclides in concentrations derived from the release quantities given in table V-8. Concentrations of tritium, Zn-65, Cs-134 and Cs-137 are estimated to produce a plant-related annual total body dose increment to an adult of only 0.01 mrem under average (36,000 cfs) river flow conditions. In actuality, however, processing the water for human consumption would remove almost all of the cesium and zinc. A dose from PBAPS released tritium is estimated to be 0.0007 mrem. By way of comparison, a drinking water dose attributable to tritium from weapons testing would be about 35 times greater.

¹As noted in the previous table, Cs-137 is introduced into the environment not only by power plants, but also by fallout from nuclear weapons testing. Cs-134, however, is introduced into the environment exclusively as a result of power plant operation, and its presence implies that at least some percentage of the Cs-137 was contributed by the power plant. Because the two isotopes behave identically in the environment, the power plant Cs-137 increment may be estimated from the ratio of Cs-137 to Cs-134 in the plant discharge.

The maximum annual hypothetical radiation dose to individuals consuming finfish caught exclusively in the Conowingo Pond utilizing the maximum recorded concentration of PBAPS-related radionuclides as determined from PPSP monitoring would be 0.59 mrem to the total body.¹ The highest calculated dose commitment would be 0.87 mrem to a teenager liver. Table V-11 summarizes dose commitments to a maximum exposed individual.

The plant attributable total body dose increment associated with the aqueous pathway is calculated to be less than 1 mrem per year. By comparison, that attributable to the ingestion of natural radioactivity is estimated to be about 21 mrem per year.

Conclusion

Atmospheric releases of I-131 produced relatively low but detectable concentrations of this nuclide in cows milk collected from farms in the PBAPS vicinity during the 1983, 1984 period. The maximum hypothetical dose for 1983 is estimated to be 0.4 mrem to an infant thyroid, or 1.3% of the allowable limit (10 CFR 50, Appendix I), and for 1984, 0.11 mrem, or 0.4% of the limit. Other than possibly a trace concentration of Cs-134 in cows milk, no other atmospherically released radionuclides were detected in the environment during the subject period.

Aqueous releases of radioactivity by PBAPS have consistently produced detectable concentrations of Zn-65, Cs-134, and Cs-137 in sediments and biota of the Conowingo Pond, lower Susquehanna River, and Upper Chesapeake Bay. Maximum concentrations for the subject period occurred in the Conowingo Pond. The maximum hypothetical annual dose resulting from the ingestion of finfish containing the maximum radionuclide concentrations for this period is estimated to be less than 1 mrem to a teenager's liver. This represents about 4 percent of the 10 CFR 50 design objective. The maximum annual total body dose from finfish consumption is estimated to be 0.6 mrem to an adult, which represents about 10% of the design criteria.

The dose increment resulting from operation of PBAPS is within 10 CFR 50 Appendix I criteria (Table V-1). An assessment of these exposure levels is given some perspective by a comparison with doses from natural radiation, which in this vicinity averages about 100 mrem per year to the total body and internal organs.

¹These dose estimates assume that the maximum radionuclide concentrations occur in all consumed finfish for the annual consumption estimate, and that all Cs-137 is due to PBAPS (some fraction is due to weapons test fallout). These dose commitments are therefore overestimates of the actual PBAPS contribution.

Table V-11. Maximum Dose commitment (a) (in mrem) for an Individual Consuming Finfish Affected by PBAPS Effluents Exclusively (Based on Radionuclide Concentrations Given in Table V-10). Calculations Based Upon Conversion Factors of USNRC Reg. Guide 1.109.

	Adult	Teen	Child
Consumption:			
Finfish	21 kg/yr	16 kg/yr	6.9 kg/yr
Total Body Dose:			
Zn-65	0.01	0.01	0.01
Cs-134	0.24	0.14	0/05
Cs-137	<u>0.34</u>	<u>0.19</u>	<u>0.07</u>
TOTAL	0.59	0.34	0.13
Bone Dose:			
Zn-65	0.01	0.01	0.01
Cs-134	0.12	0.13	0.15
Cs-137	<u>0.38</u>	<u>0.41</u>	<u>0.51</u>
TOTAL:	0.51	0.55	0.67
Liver Dose:			
Zn-65	0.03	0.03	0.02
Cs-134	0.29	0.30	0.25
Cs-137	<u>0.52</u>	<u>0.54</u>	<u>0.49</u>
TOTAL	0.84	0.87	0.76
Kidney Dose:			
Zn-65	0.02	0.02	0.01
Cs-134	0.10	0.09	0.08
Cs-137	<u>0.18</u>	<u>0.19</u>	<u>0.16</u>
TOTAL	0.30	0.30	0.25
GI Tract Dose:			
Zn-65	0.02	0.01	0.00
Cs-134	0.00	0.00	0.00
Cs-137	<u>0.01</u>	<u>0.01</u>	<u>0.00</u>
TOTAL	0.04	0.02	0.01

(a) The dose commitment from ingestion of a given quantity of a radionuclide is the total dose that will be received by the individual before the radioactive material is removed from the body by excretion and/or radioactive decay.

C. Three Mile Island Nuclear Station

The Three Mile Island Nuclear Station (TMINS), owned jointly by Metropolitan Edison Co., Pennsylvania Electric Co. and Jersey Central Power and Light Co., is operated by the General Public Utilities Nuclear Corporation (GPUN). The plant is situated on an island in the Susquehanna River approximately 8 miles southeast of Harrisburg, Pennsylvania. This location is approximately 30 air miles and 42 river miles from the Maryland border. Each of the two units is a pressurized water reactor with a maximum dependable capacity of 840 MWe. Neither unit has been in operation since the Unit 2 accident of March 28, 1979.⁴

Unit 1 of the TMINS, placed in commercial service on September 2, 1974, has produced 25,484,330 MWh of gross electrical energy. Unit 2, placed in commercial service on December 30, 1978 and in operation for only 95 full power days prior to the accident, has produced 2,125,528 MWh of gross electrical energy.

Releases to the Environment

Radionuclides discharged to the atmosphere and the Susquehanna River during the 1983-84 period are presented in tables V-12 and V-13. Because neither unit was in operation during this time, release quantities are extremely small.

Atmospheric and Terrestrial Radionuclide Distributions

Monitoring in the plant vicinity by the utility, the Pennsylvania DER and the EPA has revealed no detectable radioactivity in the atmospheric or terrestrial environment which is attributed to TMINS with the possible exception of an extremely low concentration of Co-60 detected by the utility on a single occasion in 1983 in an airborne particulate sample.

Aquatic Radionuclide Distributions

Monitoring of river water, biota and sediments in the vicinity of the plant has indicated low but detectable concentrations of TMINS-related radionuclides in nearfield sediments, including Co-60 and Cs-134 (21,22). Other than weapons test fallout attributable levels of Cs-137 no other man-made radionuclides were detected with the exception of I-131 in river water. Due to the occasional detection of this nuclide upstream of the plant as well as from downstream stations, the presence of this radionuclide is attributed to upstream medical facility discharges.

⁴The NRC voted to allow Unit 1 to restart in May 1985. A U.S. Circuit Court of Appeals stay of the order was lifted by the U.S. Supreme Court, and the unit returned to service on October 3, 1985.

Table V-12. Total Gaseous Releases (Curies) From The Three Mile Island Nuclear Station (23-26).

Radionuclide	Unit 1		Unit 2		Total	
	1983	1984	1983	1984	1983	1984
H-3	0.00075	0.00005	48.7	14.3	48.70075	14.30005
Kr-85	20.1	0.3622	209.64	246.51	229.74	246.8722
Sr-90	0.00001	--	--	0.0000002	0.00001	0.0000002
Cs-134	--	--		0.00000001	--	0.00000001
Cs-137	0.00006	--	0.0000004	0.0000045	0.0000604	0.0000045

Table V-13. Total Liquid Releases (Curies) from the Three Mile Island Nuclear Station (23-26).

Radionuclide	Unit 1		Unit 2		Total	
	1983	1984	1983	1984	1983	1984
H-3	3.09	1.725	0.00038	0.000156	3.09038	1.725156
Sr-90	0.00059	0.00163	0.000002	--	0.000592	0.00163
Cs-134	0.00552	0.00246	--	0.000007	0.00552	0.002467
Cs-137	0.04805	0.02170	0.00006	0.000276	0.04811	0.021976
Co-60	0.01682	0.00276	--	--	0.01682	0.00276
Mn-54	0.00003	--	--	--	0.00003	--
Fe-55	0.00933	0.00519	--	--	0.00933	0.00519
Sb-125	0.00052	0.0003	--	--	0.00052	0.0003
Ag-110M	0.00006	--	--	--	0.00006	--
Ru-106	0.00021	--	--	--	0.00021	--

(1) Assumes all unidentified beta emitters are Sr-90.

Monitoring by PPSP of biota and sediments in the Holtwood Reservoir (an impoundment of the Susquehanna River downstream of TMINS but upstream of PBAPS) has revealed only natural and weapons test radioactivity, again with the exception of low levels of I-131, detected on occasion in Holtwood crayfish. PPSP monitoring in the lower Susquehanna River and Upper Chesapeake Bay have periodically revealed low levels of I-131 in sediments, aquatic vegetation, crayfish, and mussels.

Conclusion

The ongoing cleanup of TMINS Unit 2 and the maintenance of Unit 1 have resulted in releases of extremely low levels of radioactivity to the environment during 1983 and 1984. While low levels of plant attributable radioactivity was detected in the nearfield aquatic environment, these concentrations are likely the result of pre-accident operation. No TMINS attributable radioactivity was detected in Maryland during this subject period (1983, 1984) or previously (1,20).

D. Radioactive Waste Disposal

The operation of a nuclear power plant results in the generation of two types of radioactive waste requiring offsite disposal: low-level and spent fuel. Low level radioactive wastes (LLW) are characterized by relatively low concentrations of radioisotopes, and include such items as contaminated protective clothing and equipment. Spent fuel is nuclear fuel which has completed its useful life.

The passage in 1980 of the Low-Level Radioactive Waste Policy Act granted individual states the authority to form regional compacts to provide for the establishment of regional facilities for the disposal of LLW. As of January 1, 1986, any compact region may restrict the use of LLW disposal sites to wastes generated within the region. This is significant in that it will essentially close the three existing disposal sites (located in Washington, Nevada and South Carolina) to wastes generated outside the compact regions in which they are located. Unfortunately, since the passage of the Act, no compacts have been ratified by Congress. Therefore, virtually no progress has been made in identifying new sites for LLW disposal, and the addition of new sites to relieve the burden on those presently operating is still several years away. Legislation to permit non-compact states to continue using existing sites after January 1, 1986 is expected in the near future. Maryland is a member of the Northeast Compact, and has negotiated with other potential compact regions, most recently the Appalachian.

All LLW generated at the Calvert Cliffs Nuclear Power Plant and Peach Bottom Atomic Power Station was shipped to either Barnwell, South Carolina or Hanford, Washington (volumes and activity levels of waste shipped are

given in Tables V-14 and V-15). LLW generated at the Three Mile Island Nuclear Station was shipped to Hanford, Washington (Table V-16). In addition, TMINS shipped several EPICOR-II prefilters and SDS liners offsite during 1983, 1984. These were shipped to DOE facilities in Hanford or Richland, Washington.

Table V-14. Low-Level Solid Waste Shipped Offsite for Disposal from CCNPP as reported by BG&E (4-7).

Type of Waste	1983		1984	
	Volume (m ³)	Activity (Ci)	Volume (m ³)	Activity (Ci)
Spent resin, filter sludge, evaporator bottoms, etc.	28.5	106	32.2	798
Dry compressor waste, contaminated equipment, etc.	477	1.35	491.7	21.8
Irradiated components, control rods, etc.	-	-	4.44	36,900

Table V-15. Low-Level Solid Waste Shipped Offsite for Disposal from PBAPS as reported by PECO (12-15).

	1983	1984
Volume (ft ³)	94,700	79,910
Activity (Ci)	22,420	92,200
Number of Shipments	337	254

Table V-16. Low-Level Solid Waste Shipped Offsite for Disposal from TMINS-Unit 2 as reported by GPU Nuclear (23-26)

Type of Waste	1983		1984	
	Volume (m ³)	Activity (Ci)	Volume (m ³)	Activity (Ci)
Spent resins, filter sludge, evaporator bottoms, etc.	227.9	4.96E+8	68.3	9881
Dry compressible waste, contaminated equipment, etc.	311.6	13.14	183.6	1.55
Number of Shipments	93		27	

Table V-17. Capacity of Spent Fuel Pools and Amount of Fuel Actually Stored (in Fuel Assemblies)

	Calvert Cliffs	Peach Bottom	
	Both Units	Unit 2	Unit 3
Licensed Capacity	1830	2816	2816
Spent Fuel Assemblies in Storage	868	1462(a)	1212(b)

(a) 58 fuel rods also in storage

(b) 6 fuel rods also in storage

The Nuclear Waste Policy Act of 1982 established federal responsibility for disposal of radioactive waste and spent fuel, as well as establishing a schedule for siting permanent disposal facilities. Under the provisions of the Act, the U.S. Department of Energy (DOE) must, by January 1, 1985, recommend to the President three sites for characterization for the first repository. The President must recommend to Congress a site for the first repository by March 31, 1987. The deadline for DOE to begin disposing of spent fuel is January 31, 1998.

The Act also provides for utilities to be able to ship spent fuel offsite prior to the availability of permanent disposal sites. It is the responsibility of nuclear power plant operators to provide for storage of spent fuel until permanent disposal sites are available. The Act does however permit away-from-reactor (AFR) storage (of up to a total of 1900 metric tons in federal facilities) if necessary to prevent disruption of operation at nuclear power plants. Reactor operators will be required to demonstrate that they cannot reasonably provide the onsite storage necessary for ensuring continued operation prior to being permitted to utilize federal AFR facilities.

It is expected that the implementation of the Act will ultimately relieve nuclear power plant operators of the burden of storing spent fuel onsite. Virtually all spent fuel generated at nuclear power plants across the country is presently stored onsite in spent fuel storage pools. These spent fuel pools were not designed for indefinite storage, but rather to temporarily store spent fuel for "cool-down," pending its shipment offsite. For this reason, spent fuel pools were constructed with limited capacities.

The limited capacities of spent fuel pools at Calvert Cliffs and Peach Bottom⁵ could eventually compromise continued operation. Although both plants have expanded original spent fuel pool capacity by reracking, present capacities will be exhausted in a few years. Assuming present licensed capacity, and retaining the capacity to discharge one full core, the projected date of the last refueling that can be discharged to the spent fuel pool at Calvert Cliffs is April 1991. Peach Bottom has the ability to store fuel onsite until March 1991 for Unit 2, and March 1992 for Unit 3. The licensed capacities of the spent fuel pools is compared to the fuel assemblies actually stored there in Table V-17.

⁵Three Mile Island is not considered here because neither unit is presently operating.

REFERENCES - CHAPTER V

- (1) Power Plant Cumulative Environmental Impact Report, Maryland Power Plant Siting Program, PPSP-CEIR-IV. Jan. 1984.
- (2) Radiological Environmental Monitoring Program Annual Report for the Calvert Cliffs Nuclear Power Plant, Jan 1 - Dec 31, 1983. Baltimore Gas & Electric Co., Baltimore, Md. March 1984.
- (3) Radiological Environmental Monitoring Program Annual Report for the Calvert Cliffs Nuclear Power Plant, Jan. 1 - Dec. 31, 1984. Baltimore Gas and Electric Co., Baltimore, Maryland. March 1985.
- (4) Semi-annual Effluent Release Report for Calvert Cliffs, Jan. 1981 - May 1983. Baltimore Gas and Electric Co., Baltimore, Md. 1983.
- (5) Semi-annual Effluent Release Report for Calvert Cliffs, June 1981 - Dec. 1983. Baltimore Gas and Electric Co., Baltimore, Md. 1984.
- (6) Semi-annual Effluent Release Report for Calvert Cliffs, Jan 1982 - May 1984. Baltimore Gas and Electric Co., Baltimore, Md. 1984.
- (7) Semi-annual Effluent Release Report for Calvert Cliffs, June 1982-Dec 1984. Baltimore Gas and Electric Co., Baltimore, Md. 1985.
- (8) Quarterly Environmental Radiological Monitoring Data, Maryland Department of Health and Mental Hygiene, Division of Radiation Control, Baltimore, Md. 1984.
- (9) McLean, R.I., S.L. Domotor and T.E. Magette, Radionuclide Concentrations in the Vicinity of the Calvert Cliffs Nuclear Power Plant, 1983, 1984. (Unpublished) Maryland Power Plant Siting Program, Annapolis, Md. 1985.
- (10) Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, Regulatory Guide 1.109, Revision 1, US Nuclear Regulatory Commission, Washington, D.C., October 1977.
- (11) Peach Bottom FEIS
- (12) Semi-annual Effluent Release Reports for the Peach Bottom Atomic Power Station, Units 2 and 3, Jan. 1, 1983 - May 31, 1983, Philadelphia Electric Co., Philadelphia, Pa. 1984.
- (13) Semi-annual Effluent Release Reports for the Peach Bottom Atomic Power Station, Units 2 and 3, June 1, 1983 - Dec. 31, 1983, Philadelphia Electric Co., Philadelphia, Pa. 1984.
- (14) Semi-annual Effluent Release Reports for the Peach Bottom Atomic Power Station, Units 2 and 3, Jan. 1, 1984 - May 31, 1984. Philadelphia Electric Co., Philadelphia, Pa. 1984.

- (15) Semi-annual Effluent Release Reports for the Peach Bottom Atomic Power Station, Units 2 and 3, June 1, 1984 - Dec. 31, 1984. Philadelphia Electric Co., Philadelphia, Pa. 1985
- (16) Peach Bottom Atomic Power Station, Radiological Regional Environmental Monitoring Program Report Number 17, Jan. 1, 1983 - Dec. 31, 1983. Radiation Management Corporation, Philadelphia, Pa. 1984.
- (17) Peach Bottom Atomic Power Station, Radiological Regional Environmental Monitoring Program Report Number 18, Jan. 1, 1984 - Dec. 31, 1984. Radiation Management Corporation, Philadelphia, Pa. 1985.
- (18) Peach Bottom Atomic Power Station Environs Radiation Monitoring Program, Jan. 1, 1983 - Dec. 31, 1983. Chemical Waste Management, Inc., Natick, Ma. 1984.
- (19) Peach Bottom Atomic Power Station Environs Radiation Monitoring Program, Jan. 1, 1984 - Dec. 31, 1984. Chemical Waste Management Corporation, Natick, Ma. 1985.
- (20) McLean, R.I., and S.L. Domotor, Radionuclide Concentrations in the Vicinity of PBAPs. 1983, 1984. (Unpublished) Maryland Power Plant Siting Program, Annapolis, Md. 1984.
- (21) 1983 Radiological Environmental Monitoring Report for Three Mile Island Nuclear Generating Station. GPU Nuclear Corporation, Middletown, Pa. 1982.
- (22) 1984 Radiological Environmental Monitoring Report for Three Mile Island Nuclear Generating Station. GPU Nuclear Corporation, Middletown, Pa. 1983.
- (23) Three Mile Island Nuclear Generating Station, Units 1 and 2, Radioactive Effluent Release Report, Jan. 1983 - June 1983. GPU Nuclear Corp., Middletown, Pa. August 1983.
- (24) Three Mile Island Nuclear Generating Station, Units 1 and 2, Radioactive Effluent Release Report, July 1983 - Dec. 1983. GPU Nuclear Corp., Middletown, Pa, March 1984.
- (25) Three Mile Island Nuclear Generating Station, Units 1 and 2, Radioactive Effluent Release Report, Jan. 1984 - June 1984. GPU Nuclear Corp., Middletown, Pa. August 1984.
- (26) Three Mile Island Nuclear Generating Station, Units 1 and 2, Radioactive Effluent Release Report, July 1983 - Dec. 1984. GPU Nuclear Corp., Middletown, Pa. March 1985.

CHAPTER VI

GROUND WATER IMPACT

Power plant operations can affect the quantity and quality of ground water resources. In addition to the large quantity of surface water used by utilities for condenser cooling, high quality fresh water is needed for boiler makeup, pump cooling, sanitary water supplies, and pollution control equipment. Power plants that do not have access to abundant sources of fresh surface water depend upon ground water to meet their requirements. The consumption of ground water by power plants is of concern because it can reduce the availability of ground water supplies and influence the movement of contaminants in ground water. Ground water contamination can result from the storage of coal, landfilling of combustion by-products, and other routine utility operations.

Studies conducted by the Power Plant Siting Program (PPSP) have indicated that some minor ground water contamination has occurred at abandoned and currently operating coal ash sites in Maryland. Several of these studies are discussed in the 1984 CEIR, Chapter VII, Coal Ash Management (1). Similarly, the impact of utility ground water withdrawals in Maryland was discussed in Chapter VIII of the 1984 CEIR. The conclusion from the PPSP studies is that the present rate of ground water usage by Maryland power plants does not pose a significant, long-term problem.

The purpose of this chapter is to present an overview of the hydrogeologic conditions in Maryland, a discussion of the present utility ground water consumption and its impacts, and a summary of potential sources of ground water contamination from power plant operations.

A. Geology and Ground Water Occurrence in Maryland

The occurrence of ground water in an area depends largely on the physical character, distribution, and structure of bedrock and unconsolidated earth materials. Since these factors also strongly affect the physiography (configuration of the land surface) of a region, the physiographic divisions or provinces in the State correspond roughly to areas where ground water conditions are similar. Thus the availability of adequate ground water contamination from the construction and operation of a power plant may be predicted to a certain extent from the physiographic area under consideration.

The United States can be divided into 34 natural regions called physiographic provinces. Each has a unique structural framework which gives rise to distinctive landforms, climate, vegetation, slopes, soils -- all of which directly or indirectly control the occurrence and usage of ground water. Figure VI-1 shows the boundaries of the five physiographic provinces

which occur in Maryland and the location of all operating power plants and ash sites. They are, from southeast to northwest: Atlantic Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateaus (2).

Atlantic Coastal Plain Province

The majority of Maryland's power plants and ash sites are located in the Atlantic Coastal Plain Physiographic Province. It makes up more than sixty percent of the state's land area, including all of the Eastern Shore and an area approximately ten to forty miles wide extending from southwest to northeast along the western shore to the Chesapeake Bay. All four power plants that withdraw significant amounts of ground water -- Chalk Point, Morgantown, Vienna and Calvert Cliffs -- are located within the Coastal Plain.

The Coastal Plain province is characterized by the presence of interbedded deposits of sand, silt, clay, and gravel. These deposits were laid down on metamorphic basement rocks of schist, gneiss, and metagabbroic rocks. The erosional surface on the basement rocks slopes toward the southeast, so that each successive sedimentary deposit on the basement rock dips gently toward the southeast and thickens in that direction.

Ground water sources supply much of the water used in the Coastal Plain, as the vast network of unconsolidated sand aquifers underlying this province yields large quantities of water. Surface water sources are used less because many of the streams have insufficient flow or are too brackish or saline (3).

Figure VI-2 is a generalized regional geologic cross section identified as D-D' on Figure VI-1. It shows the relationship of the Coastal Plain deposits to the underlying basement rock, the thickening of the Coastal Plain formations toward the southeast, and the gentle dip of the Coastal Plain formations. The dip results in the formations' cropping out in narrow northeast-trending subparallel bands where they are exposed at the surface. As a result, ground water in the province is found in both unconfined (water table) and confined (artesian) aquifers, or water-bearing units. Unconfined aquifers occur where coarse-grained deposits (sand and gravel) are present at the surface and are recharged directly by infiltration of precipitation or seepage from surface water bodies such as streams, lakes, and ponds. Confined aquifers in the Coastal Plain are separated above and below by layers (strata) of fine-grained deposits (silt and clay) which isolate the water-bearing unit from direct recharge. Confined aquifers are recharged where the confined layer extends to the surface or where it is in contact with other overlying coarse-grained deposits which receive and transmit recharge downward to the confined aquifer. A schematic diagram showing the occurrence of ground water and the nature of confined and unconfined aquifers in the Coastal Plain of Maryland is presented as Figure VI-3.

The Coastal Plain's unconsolidated sand and gravel deposits can often provide relatively large quantities of water to wells less than 300 feet deep. Individual yields may be as high as 2,000 gallons per minute where the

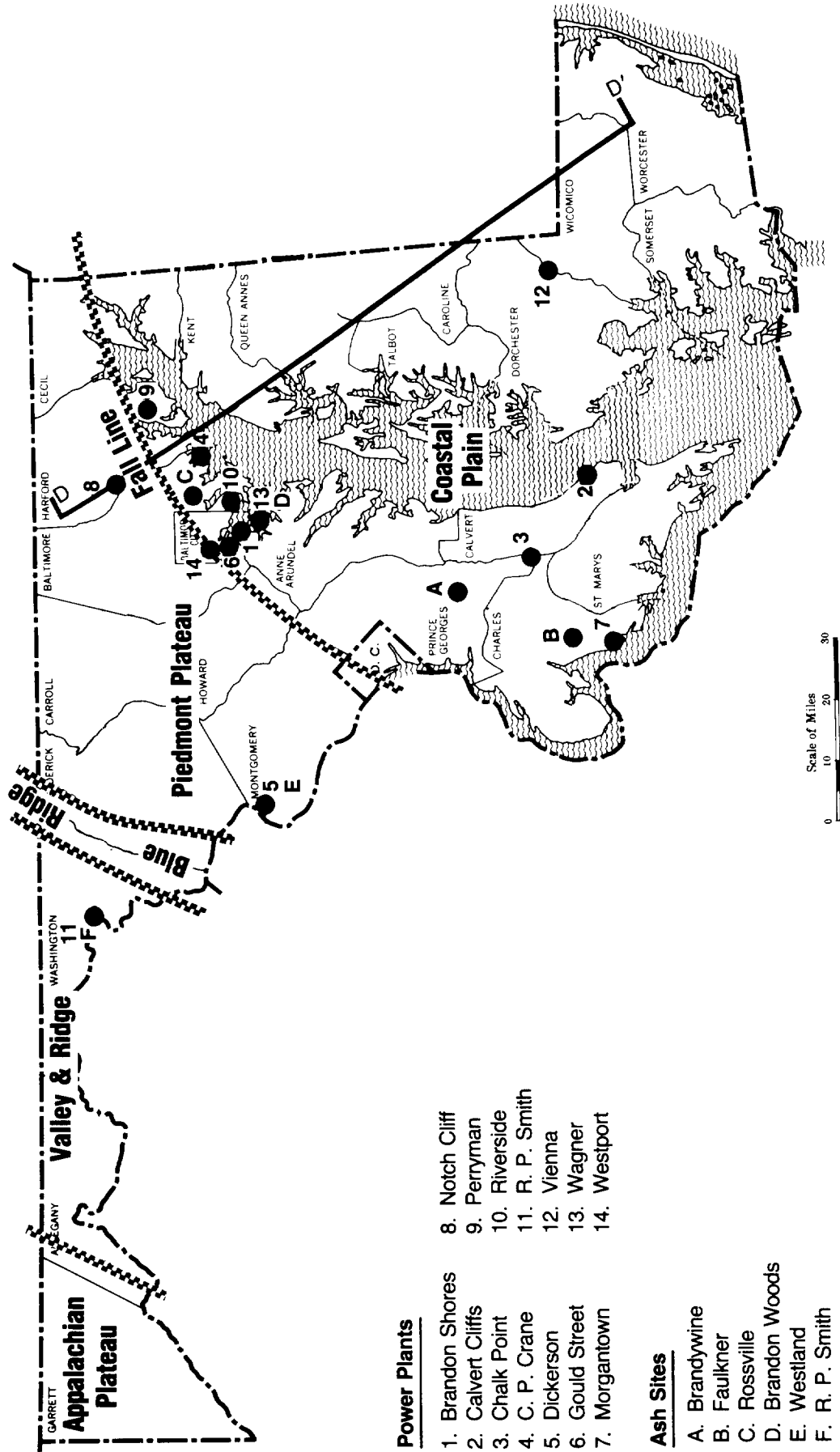
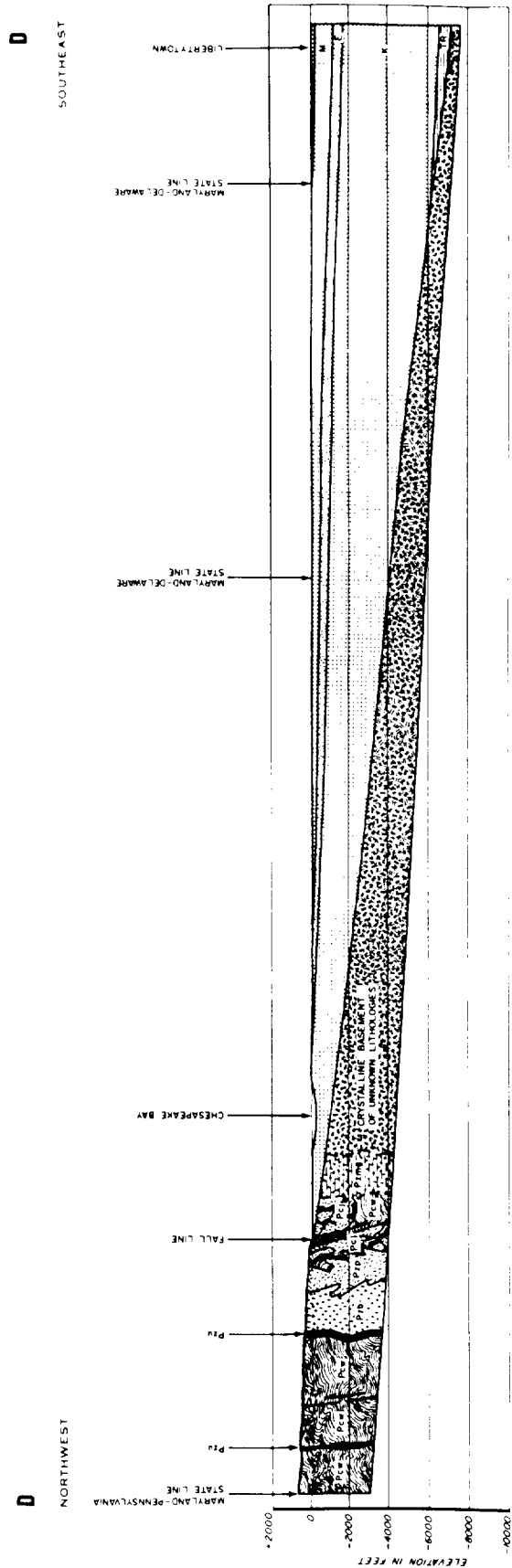


Figure VI-1. Locations of Existing Maryland Power Plants And Ash Sites In Relation To Physiographic Provinces



SYMBOL	DESCRIPTION	AGE	AGE
M	CLAY, SILT, SAND, AND GRAVEL	MIOCENE	CLAYMATEL REENS
E	CLAY, SILT, SAND, AND GRAVEL	Eocene	MELAGARRO
K	CLAY, SILT, SAND, AND GRAVEL	CRETACEOUS	JAMES R. W. GREEN
TR	CONGLOMERATE, SANDS, AND CONGLOMERATES	TERTIARY	WISSARDICKEN FORMATION
Pp	PURE LITHOLOGICAL UNITS	PALEOGENE	WELL-SHOWN CONGLOMERATE SECTION
P	BALTIMORE CARRO	PALEOZOIC	TABLE SHOWING DIRECTION OF MOVEMENT

Figure VI-2. Generalized Cross Section (D-D') of Coastal Plain Physiographic Province

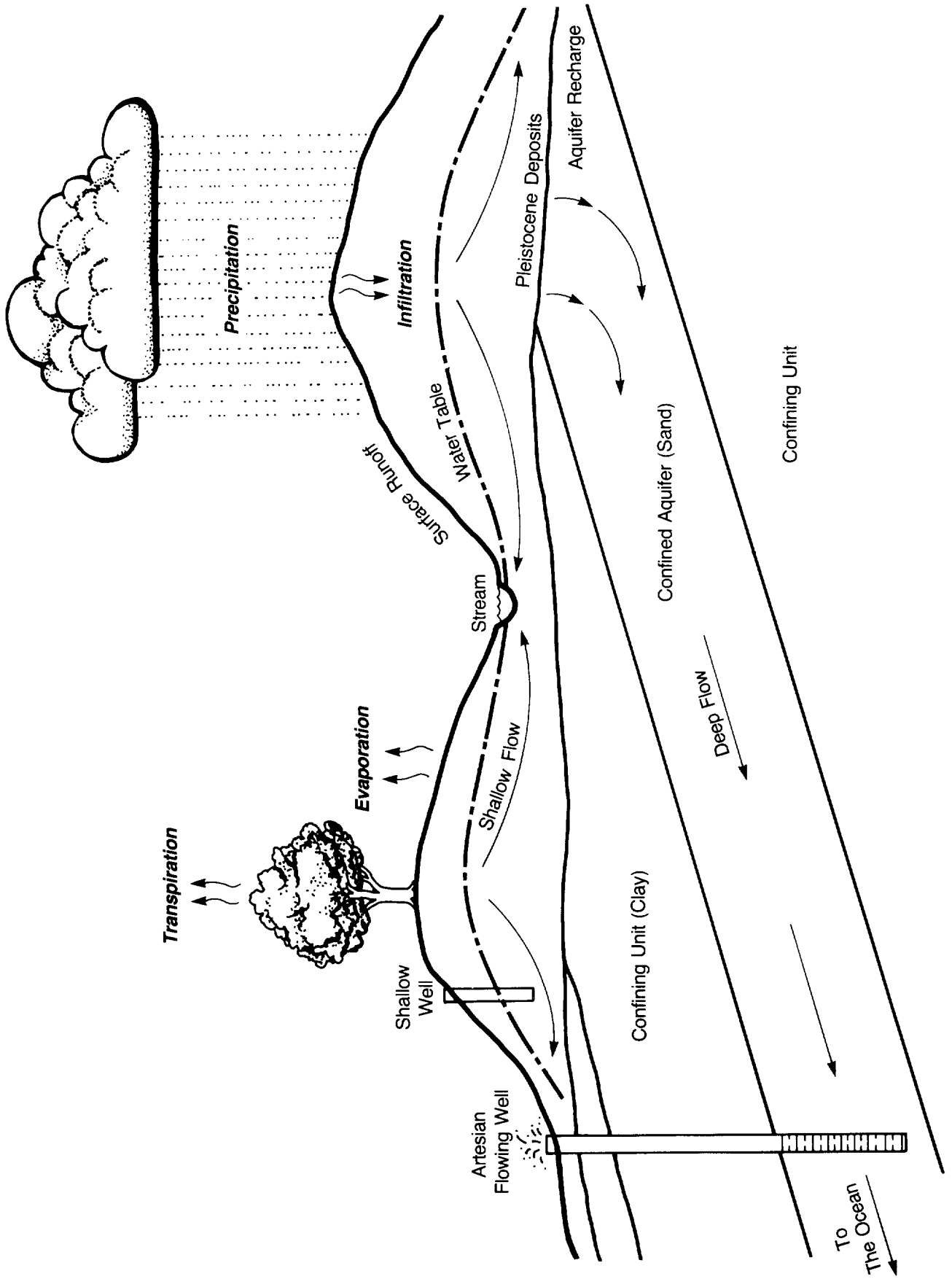


Figure VI-3. The Hydrologic Cycle in the Coastal Plain of Maryland

thickest coarse-grained deposits occur at or near the surface. However, in some areas, these surficial deposits are thin and provide relatively small yields to shallow Maryland wells (3). Deeper wells produce ground water from confined artesian aquifers which extent to depths as great as 1,300 feet and yield more than 1,400 gallons per minute to pumping wells.

There are four major Southern Maryland aquifers in the Atlantic Coastal Plain which are important sources of ground water for power plants:

1. Pleistocene aquifer -- unconfined surficial aquifer. A principal source of ground water at the Vienna power plant.
2. The Aquia aquifer -- an important aquifer in portions of the Maryland Coastal Plain. In some areas, this formation is too clayey to be used as an aquifer. The Calvert Cliffs plant withdraws ground water from this aquifer.
3. The Magothy aquifer -- this aquifer supplies ground water to the Chalk Point power plant.
4. The Potomac Group (including the Patapsco) -- a widely used aquifer in Maryland's Coastal Plain. It supplies water to the Morgantown and Chalk Point power plants.

Piedmont Province

The Piedmont Physiographic Province, in west-central Maryland, is bordered by the Atlantic Coastal Plain on the southeast and the Blue Ridge Province on the northwest. Approximately 20 to 50 miles wide, its low, rolling topography is characterized by ridges and valleys ranging from approximately 50 to 300 feet high. The Dickerson coal-fired power plant, the Westland ash site, and the Notch Cliff gas turbines are located within this province. However, none of these sites utilize significant quantities of ground water.

The Piedmont's geologic structure is extremely complex, consisting of folded and faulted metamorphic rocks ranging in age from Precambrian (greater than 600 million years old) to Triassic (245 million years old). Ground water occurs in the lower portions of the saprolite, a thick mantle of residual soils, most often immediately above the bedrock surface and within fractures in the bedrock itself. In the rock, zones of secondary permeability occur along faults, joints, and other fractures which are most abundant near the rock surface. Because the ground water is concentrated in these zones, the orientation of the fractures and the nature of their interconnections has a strong control on the occurrence and movement of ground water within the rock. Recharge is through direct infiltration of precipitation where the bedrock is exposed or from overburden deposits.

In general, wells developed in the Piedmont yield low to moderate quantities of water commonly ranging up to 50 gallons per minute with a maximum expected yield of 400 gallons per minute. Aquifers within this

province are not specifically named but are identified by the formation in which they occur. Ground water quality is generally good, but some local areas have high iron content or hardness (3).

Blue Ridge Province

The Blue Ridge Physiographic Province is a topographically high ridge or pair of ridges extending north-northeastward across western Maryland between Hagerstown and Frederick. Its rocks are much more resistant to the weathering and erosion than the rocks of the surrounding provinces, with the result that the ridge stands as much as 400 feet above surrounding areas. There are no operating power plants or ash sites in the Blue Ridge Province of Maryland.

As in the Piedmont Province, ground water in the Blue Ridge occurs in zones of secondary porosity, namely faults and other fractures in the bedrock, which are found mostly near the surface. Its aquifers too are not specifically named. Due to the Blue Ridge's greater elevation and relief, erosion has removed most of the thick residual solids of the type that characterize the Piedmont Province. Ground water yields are very low, with wells typically yielding less than fifty gallons per minute. The ground water in the Blue Ridge is generally of good quality (3).

Ridge and Valley Province

The Ridge and Valley Province lies to the west of the Blue Ridge and east of the Appalachian Plateaus. The province is characterized by northeast-trending subparallel ridges and valleys caused by the differential resistance to the erosion of folded sedimentary rocks. The upturned edges of more resistant formations occur as ridges, and less resistant formations as valleys. The R. P. Smith power plant and ash site are located with the Ridge and Valley Province.

Ground water in the Ridge and Valley Province occurs along zones of secondary porosity (fractures and faults), most often in sandstone and limestone. Aquifers within the province are not specifically named. Lesser amounts of ground water are locally produced from fractured shale and siltstone formations. Recharge to the ground water is by precipitation and infiltration from surface streams. The ground water table in this province often occurs at considerable depths, especially in limestone bedrock areas where ground water can be drained off through well-developed systems of solution cavities. Average well yields in the area are on the order of 125 gallons per minute, although maximum yields of up to 1,000 gallons per minute have been reported. The quality of ground water is usually good but varies considerably depending on the type of bedrock in which the water is found.

Appalachian Plateaus Province

The Appalachian Plateaus Province is situated in the extreme western portion of Maryland near the West Virginia border. The Maryland portion of the province is approximately sixty miles wide and is characterized by the presence of the Allegheny Plateau section. Folded sandstones, shales, and conglomerates with some interbedded coals occur in ridges and valleys formed by erosion of the mildly folded rocks. Ground water quality and availability is similar to that described in the Ridge and Valley Province. There are no operating power plants or active ash sites located within this province.

B. Ground Water Withdrawal

This discussion of ground water withdrawal augments and updates data presented in Chapter VIII of the 1984 CEIR (1). Where appropriate, ground water pumpage and water level drawdown data from earlier years are presented and updated with data for 1983 and 1984 in order to provide a complete record of changes and trends over time.

Power plants require large volumes of surface water for condenser cooling -- water that is returned for the most part to the source water body. However, an operating power plant also needs high quality fresh water for boiler makeup, pump cooling, sanitary water supplies, and for the operation of pollution control equipment. A 2,000-megawatt fossil-fueled power plant can use as much as 1.6 million gallons per day (mgd) of fresh water (not including once-through condenser cooling water).

Depending on its location, a Maryland power plant draws its high quality fresh water from one of the following four sources (4):

1. Non-tidal rivers -- Non-tidal river water can be purified and utilized for various plant process.
2. Municipal water supply -- Large cities such as Baltimore and Washington, D.C. often provide industrial-quality water for use in power plants.
3. Brackish surface water -- Surface water from tidal streams and estuaries can be utilized for plant purposes after suitable treatment for lowering of salinity.
4. Ground water -- Power plants not located near abundant sources of surface water must depend on ground water to meet all fresh water needs.

The withdrawal of large amounts of ground water for plant purposes can lower the water table below the intakes of nearby existing wells, leaving them with little or no water available for withdrawal. Figure VI-4 shows diagrammatically the cone of depression around a large-volume pumping well and

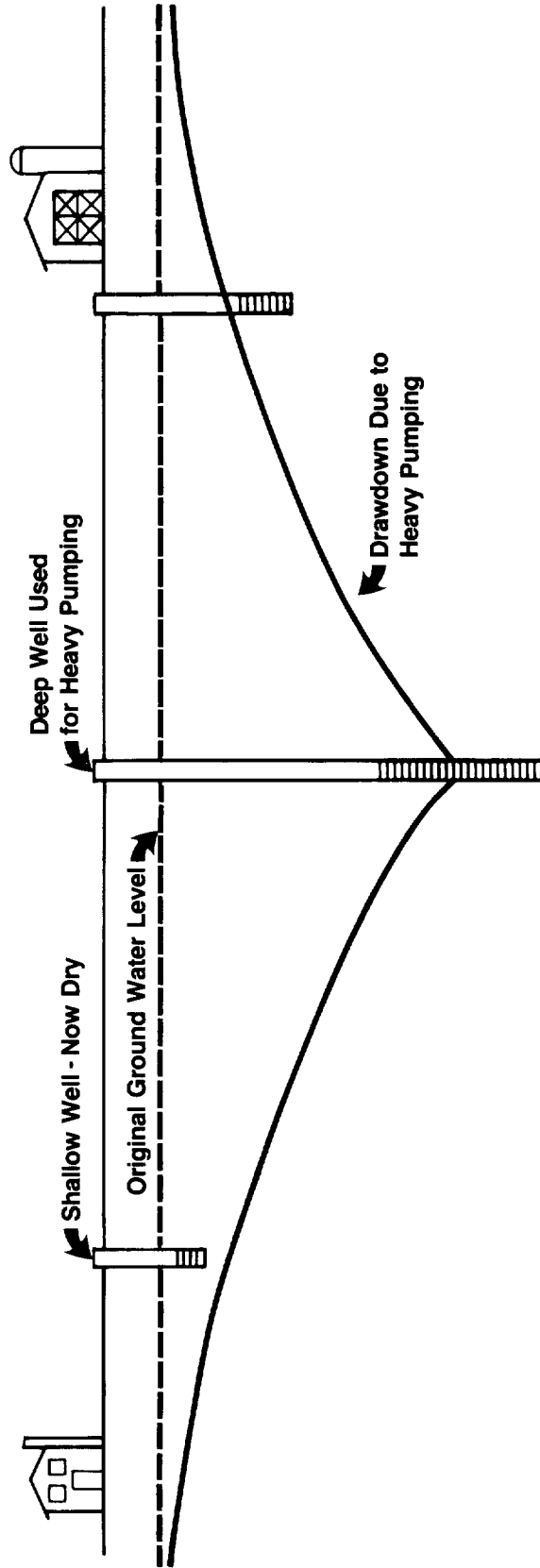


Figure VI-4 . Impact of Pumping on Local Ground Water Levels

its potential effect on nearby industrial and domestic wells. This condition can be corrected by eliminating or reducing plant pumpage or by deepening the existing wells where hydrogeological conditions allow.

The large-scale withdrawal of ground water and the resultant lowering of water levels may also exacerbate the effects, and alter the distribution, of contaminated ground water in a region. Ground water withdrawal can increase horizontal and/or vertical migration rates in the area of influence of the pumping well by changing or even reversing ground water gradients. In either case, contamination could be drawn toward the pumping wells. Similarly, in areas such as Maryland's Coastal Plain, ground water withdrawal can draw brackish or saline ground water landward within aquifers (saltwater intrusion). In addition, leakage of saline ground water through confining layers can be induced from overlying or underlying brackish aquifers or from saline surface water in estuaries.

Neither of these potential problems have been observed in the vicinity of power plants in Maryland. Lowered ground water levels have not as yet dried up wells of nearby small users, nor has there been any indication that pumpage has caused saltwater intrusion.

Four power plants in Maryland---Calvert Cliffs, Vienna, Morgantown, and Chalk Point---all located within the Coastal Plain Physiographic Province, use significant quantities of ground water. In 1984, the ground water withdrawal by these plants totaled approximately 2 mgd, which is approximately one percent of the total amount of ground water withdrawn in Maryland (4). Their locations, the aquifers they draw from, and their impact on ground water resources are discussed below:

- o The Calvert Cliffs Nuclear Power Plant, located on the western shore of the Chesapeake Bay, utilizes water drawn from the Aquia aquifer. During 1983 and 1984 the plant used an average of approximately 278,000 gallons per day (gpd) from three wells averaging 620 feet in depth. This withdrawal rate was well below the permitted appropriation of 450,000 gpd.

Data presented in Figure VI-5 show monthly pumpage from the Aquifer and water levels measured in observation wells. Water levels shown on the graph were made in well CA-Ed27 until 1983 when the well was destroyed. Readings made in 1984 were made in well CA-Ed47 which was constructed to replace well CA-Ed27. The relatively large range of fluctuations of reading from well CA-Ed27 probably resulted from its close proximity to the production wells. Observation well CA-Ed47 was constructed at a location away from the center of the well field. Figure VI-6 shows the potentiometric levels in the Aquia aquifer in Southern Maryland as of September 1984. Figure VI-7 shows changes in potentiometric levels in the Aquia aquifer between 1982 and 1984. These figures indicate a continued gradual

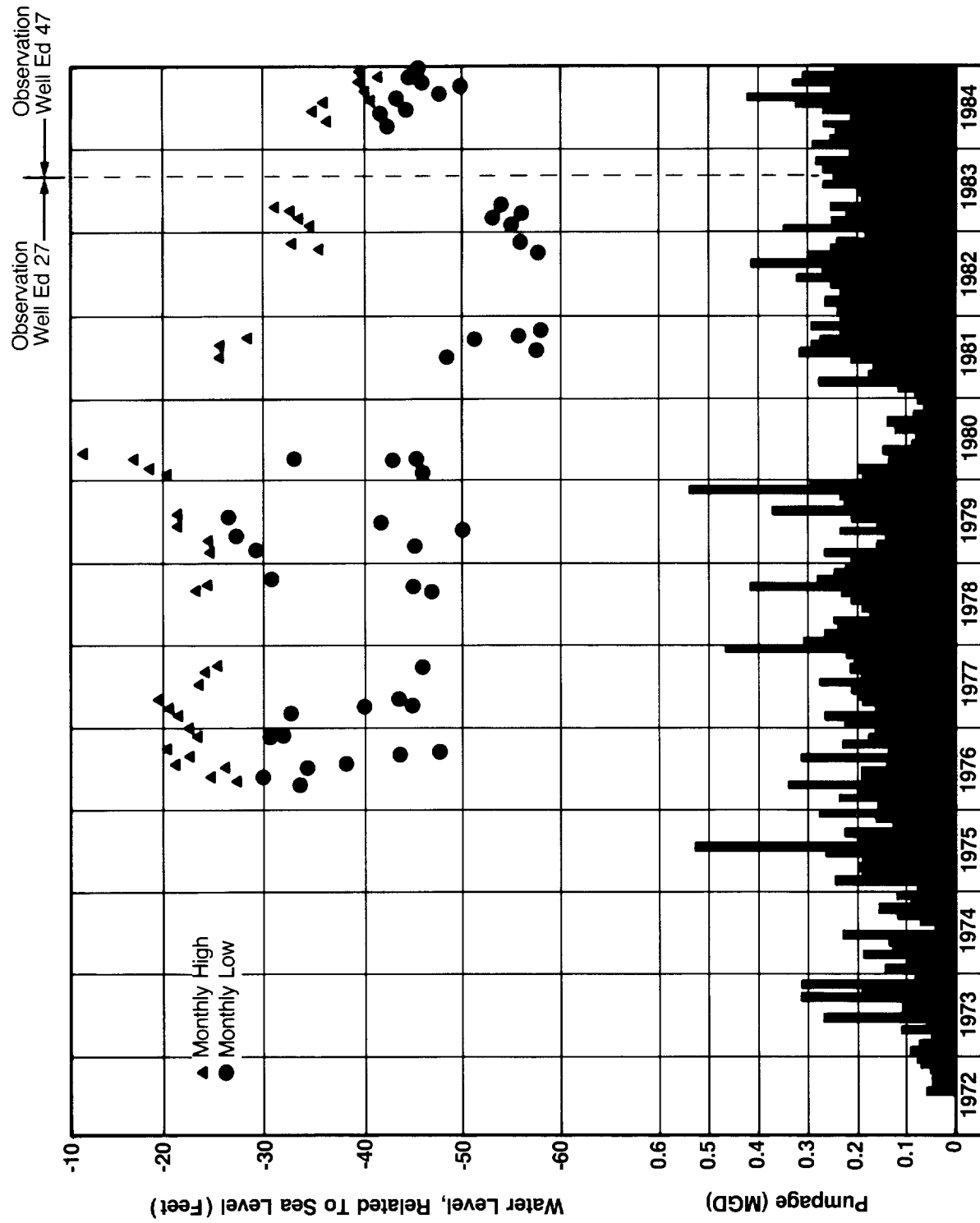


Figure VI-5. Ground Water Pumpage And Water Levels At The Calvert Cliffs Power Plant From First Operation Through 1984

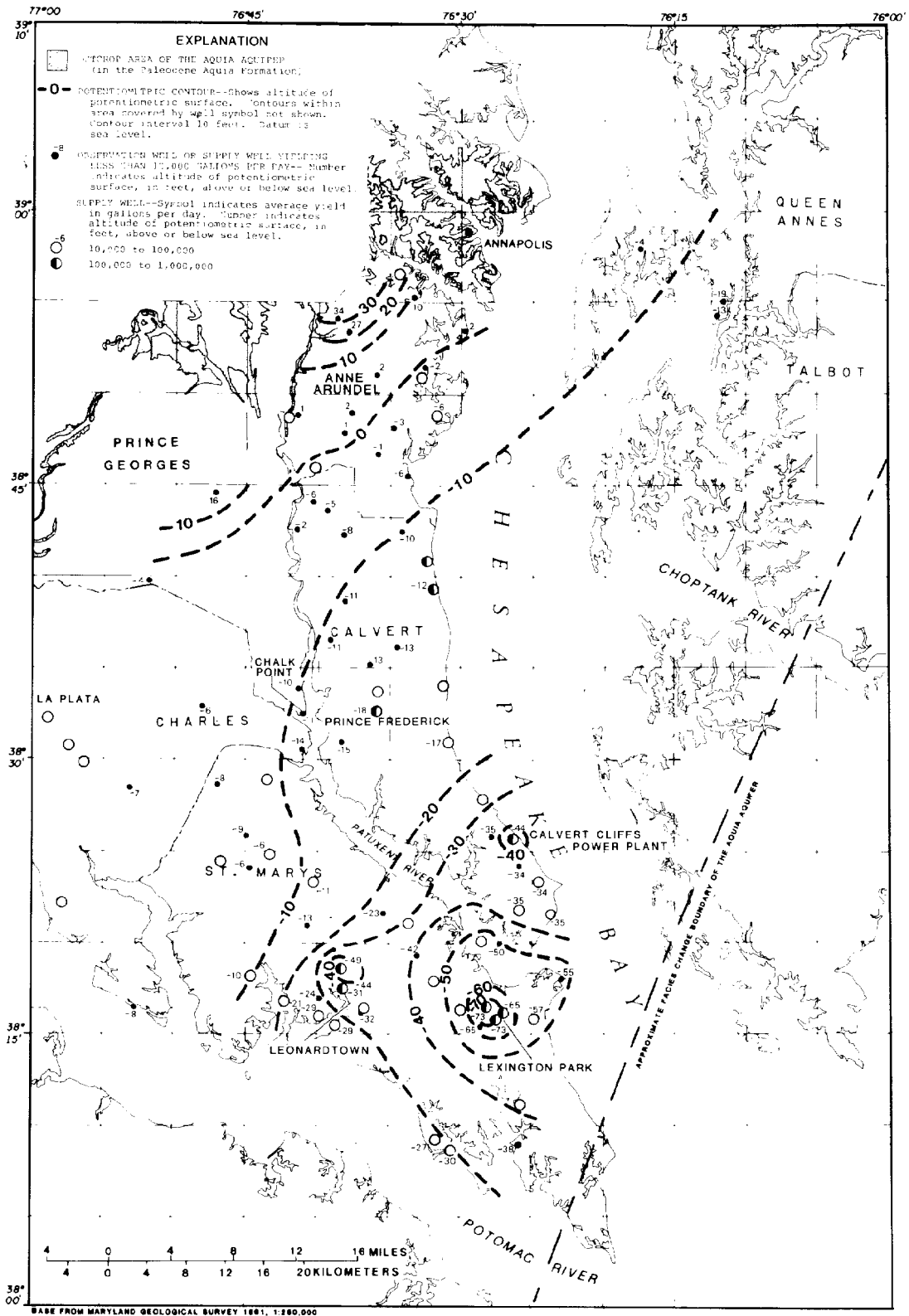


Figure VI-6. The Potentiometric Surface of the Aquia Aquifer in Southern Maryland, September 1984

Prepared by: Frederick K. Mack, Judith C. Wheeler, Stephen E. Curtin, and David C. Andreasen
 in Cooperation With: MARYLAND GEOLOGICAL SURVEY AND MARYLAND ENERGY ADMINISTRATION
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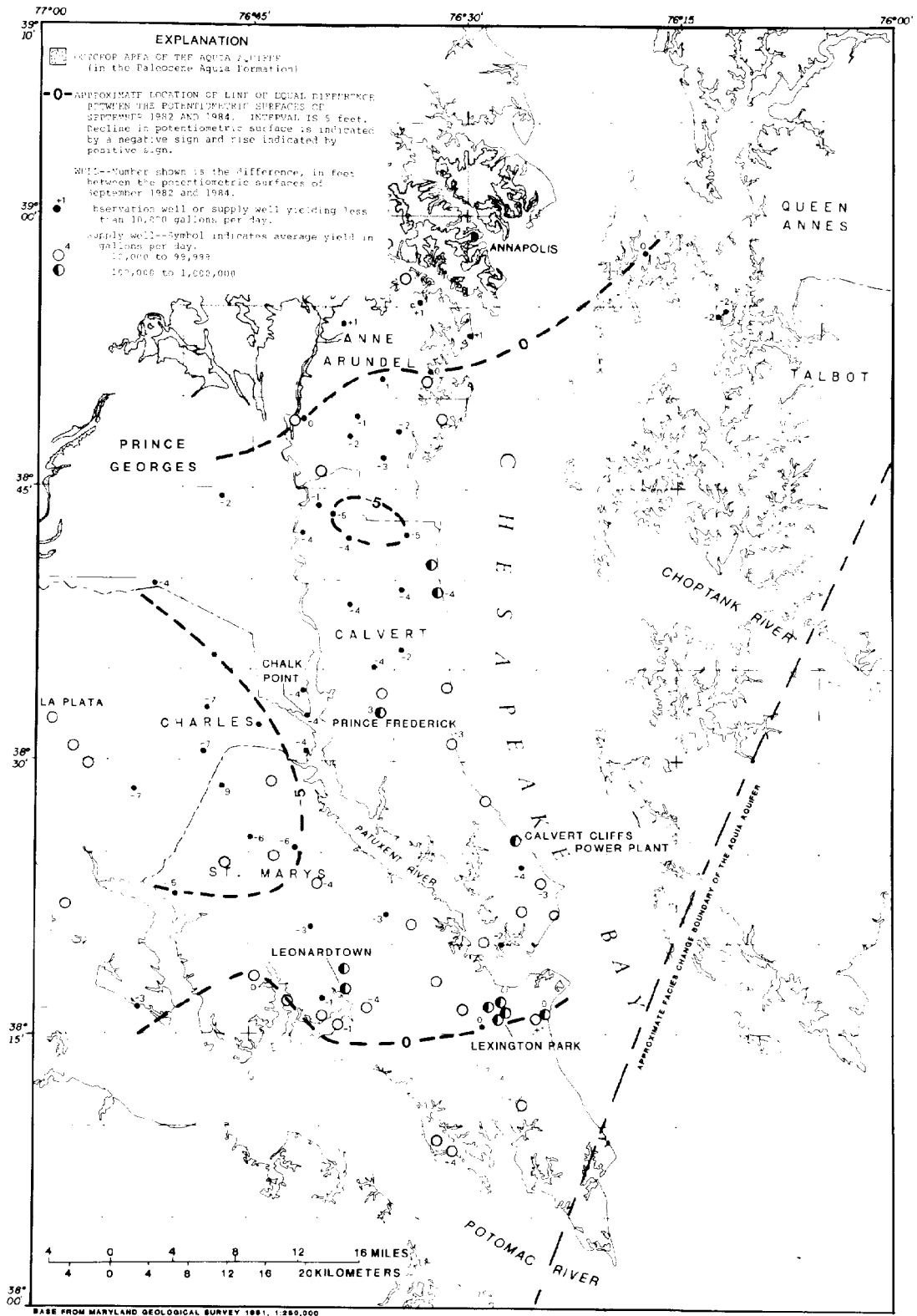


Figure VI-7. The Difference Between the Potentiometric Surfaces of the Aquia Aquifer of September 1982 and September 1984 in Southern Maryland

Prepared by: Frederick K. Mack, Judith C. Wheeler, Stephen E. Curtin, and David C. Andreasen
 In Cooperation With: MARYLAND GEOLOGICAL SURVEY AND MARYLAND ENERGY ADMINISTRATION
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lowering of the ground water surface between 1982 and 1984. In the area of the Calvert Cliffs plant, water levels continued to drop but to a lesser degree than during the period 1979 to 1982. In September 1984, potentiometric levels measured in monitoring wells near the plant ranged from 34 to 44 feet below sea level, a drop of approximately 4 feet since September 1982 (Figure VI-7).

- o The Vienna power plant is located on the Nanticoke River. While this plant once obtained ground water from the Federalsburg aquifer, all withdrawals since 1979 have been from the Pleistocene aquifer (Figure VI-8). The Vienna plant relies upon one major production well for most of its ground water. This well is screened at 54 feet. A second standby well is approximately 310 feet in depth. Since average ground water pumpage allowed under existing permits is 100,000 gpd, these withdrawals, averaging approximately 30,000 gpd, are well within permitted limits. During 1983, 10,340,140 gallons of ground water were pumped for plant purposes and in 1984, ground water withdrawal was 11,721,550 gallons.

Reduced pumping rates at Vienna resulted from the retirement of Units 5 through 7 in 1980. Ground water use is expected to increase with the planned start-up of Nanticoke Unit 1, also located at this site, in the mid-1990s. Operation of the new unit will require approximately 390,000 gpd of water. Additional supplies will come from the existing aquifer sources, which are considered adequate.

- o The Morgantown plant is located on the Potomac River. In 1983 and 1984, Morgantown pumped an average of approximately 657,000 gpd from the Patapsco aquifer. Pumpage was 226,388,827 gallons in 1983 and 253,363,341 gallons during 1984.

Morgantown obtains ground water from four wells averaging 1,100 feet in depth. Pumpage rates and water level data from plant production and observation wells are presented in Figure VI-9. Measurements indicate that the range of water levels in 1983 and 1984 was similar to the range for the period from 1979 to 1980. No long-term trend in water levels in the monitoring wells is evident from these measurements.

- o The Chalk Point power plant is located on the Patuxent River. It withdraws ground water from one well that is 1,066 feet in depth in the Patapsco aquifer and from five wells that average 615 feet in depth in the Magothy aquifer. Chalk Point pumped an

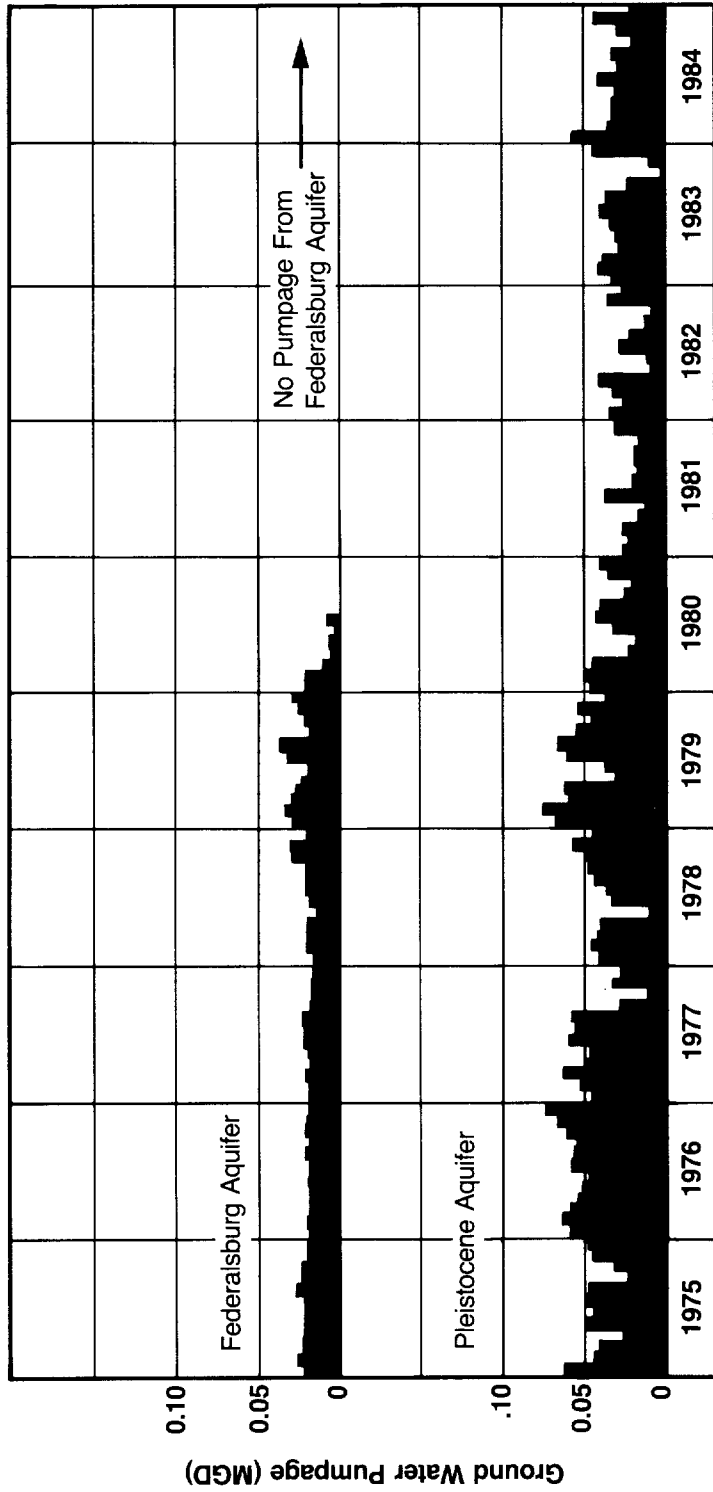


Figure VI-8 . Ground Water Pumpage At The Vienna Power Plant, By Aquifer, From 1975 To 1984

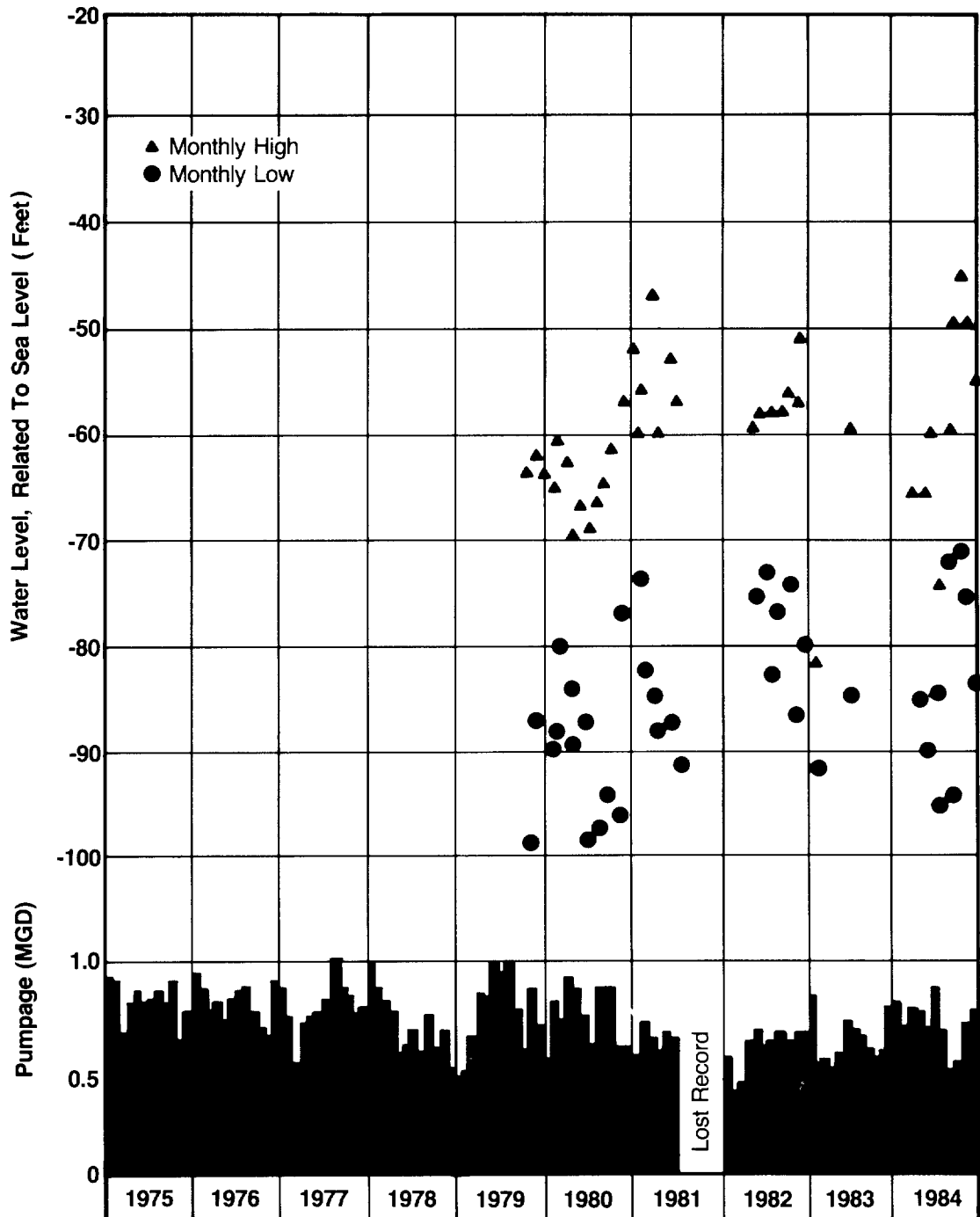


Figure VI-9. Ground Water Pumpage And Water Levels In Observation Well At The Morgantown Power Plant From 1975 Through 1984

average of 1,112,085 gpd in 1983 and 990,546 gpd in 1984 from these two aquifers. The total pumpage for 1983 and 1984 was 405,910,993 gallons and 362,40,015 gallons, respectively. There are no large ground water users near the plant.

Figure VI-10 shows the Chalk Point pumpage record and water level data for the Patapsco aquifer. As can be seen from Figure VI-10, both pumpage and ground water levels remained essentially constant in 1983 and 1984. Pumpage and water levels have not changed substantially since 1981 (1). Figure VI-11 also shows pumpage (although average pumpage per month rather than daily rates) and water levels for the Patapsco aquifer. These water level measurements are taken in the production well, while those for Figure VI-10 were taken from a separate observation well.

Water level data from a production well is generally less informative than that taken from a separate observation well. This is because water levels fluctuate dramatically due to the effects of pumping. This is obvious from Figure VI-11 which illustrates very different levels when the pump is on than when it is off.

Because these water level measurements are so strongly affected by pumping, a single outlying water level measurement may be more indicative of a short term increase in pumping than a significant change in the aquifer water level. This is likely the case with the 1984 value showing an aquifer level of -110 feet. These water level data are nonetheless useful for showing long term trends in aquifer water levels.

The water level data in Figure VI-11 are particularly important in understanding the effect of Chalk Point on the Patapsco aquifer. This is because the observation well which provided the data for Figure VI-10 (PG-Hf 40) is actually screened at 850 feet while the production well is screened at 1000 feet. While both wells are in the Patapsco aquifer, and observation well PG-Hf 40 at least indirectly measures the effects of Chalk Point pumpage, there is likely some separation between the two sands in which these wells are screened.

Figure VI-10 also shows the pumpage from the Magothy aquifer, as well as water levels in that aquifer. Water levels in the Magothy declined during the period from June 1983 through January 1984, but rebounded during 1984. At least some of this recovery is attributable to slightly lower pumpage rates during 1984. The water levels in the Magothy aquifer appear to have stabilized in the 1980s after declining since plant startup in 1963 (Figure VI-12). These water levels are closely related to changes in pumpage.

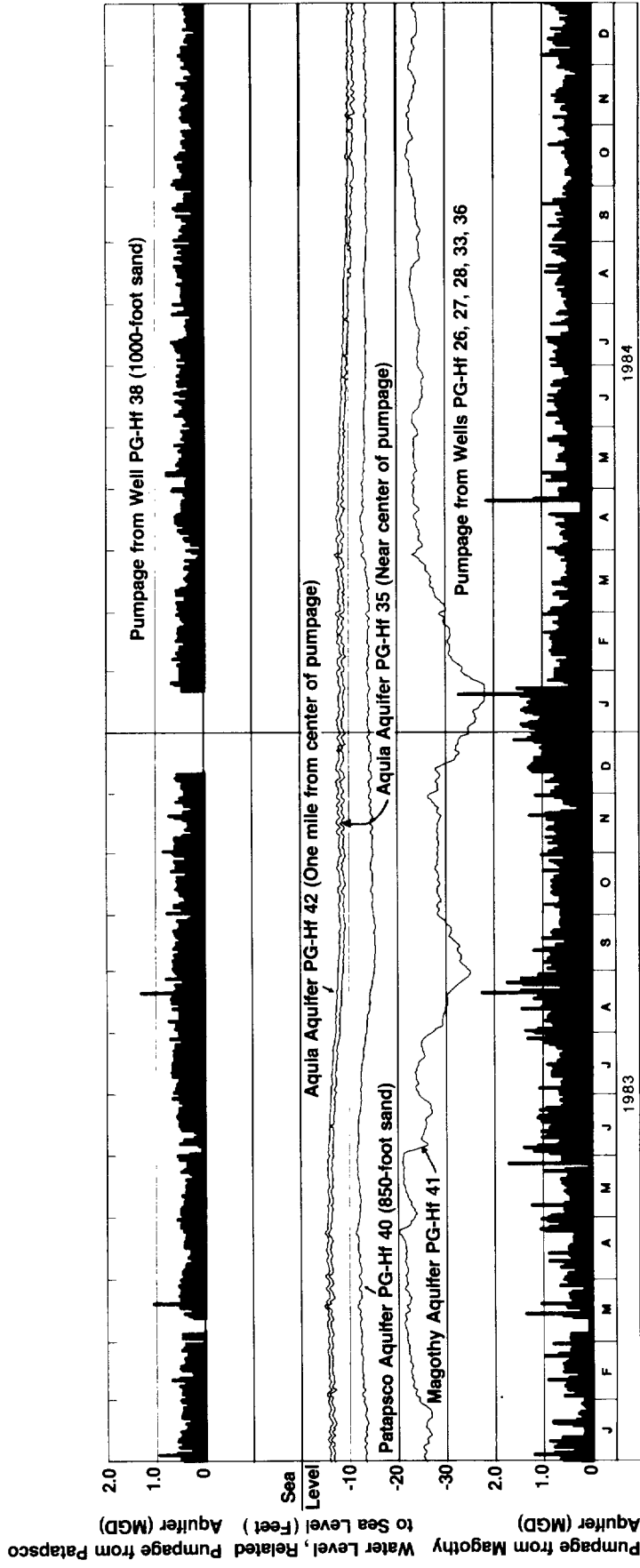


Figure VI-10 . Daily Water Levels and Pumpage Record for Chalk Point (October 1981-December 1984)

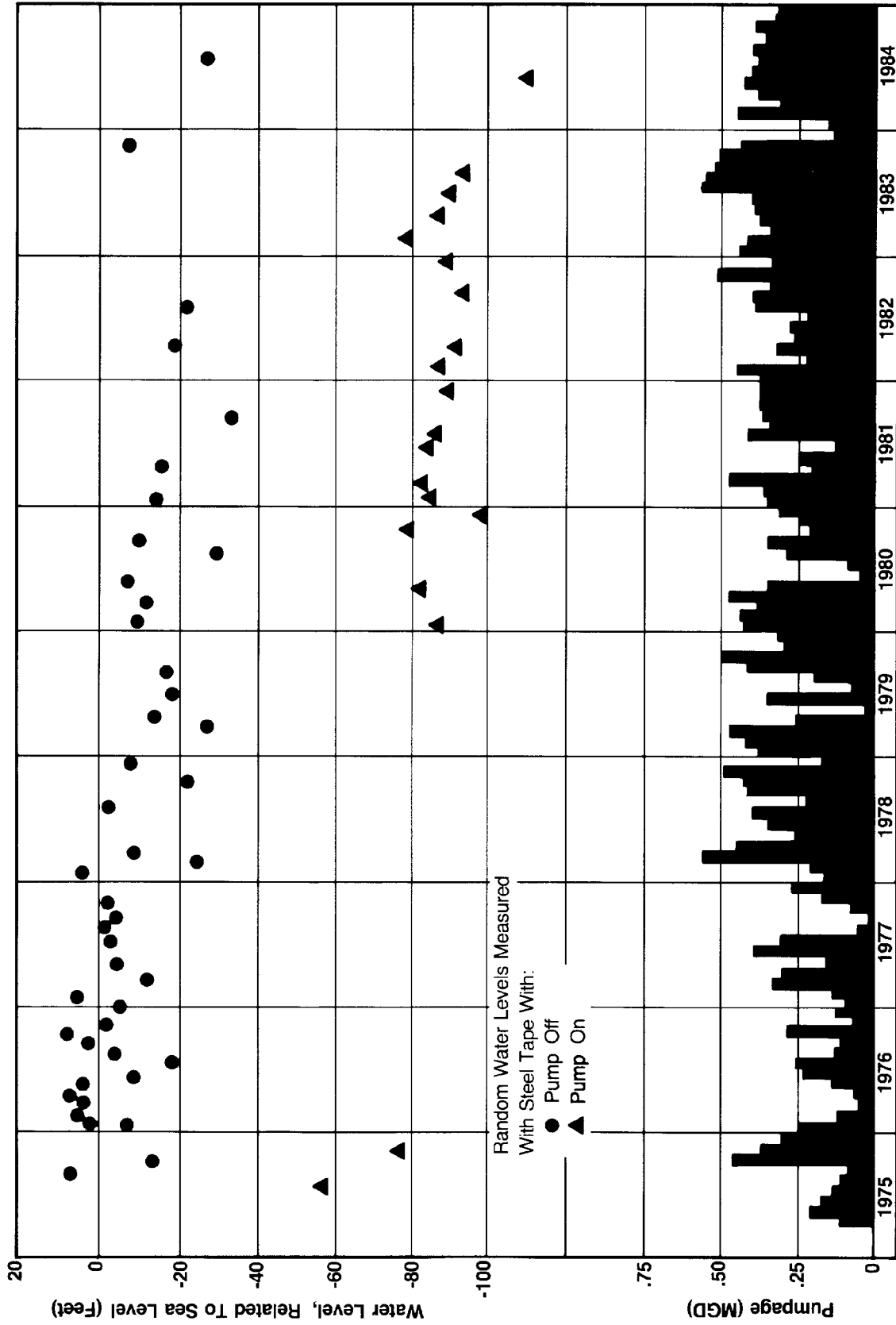


Figure VI-11. Ground Water Pumpage and Water Levels as Measured in Production Well PG-Hf 38 for the Patapsco Aquifer at the Chalk Point Power Plant

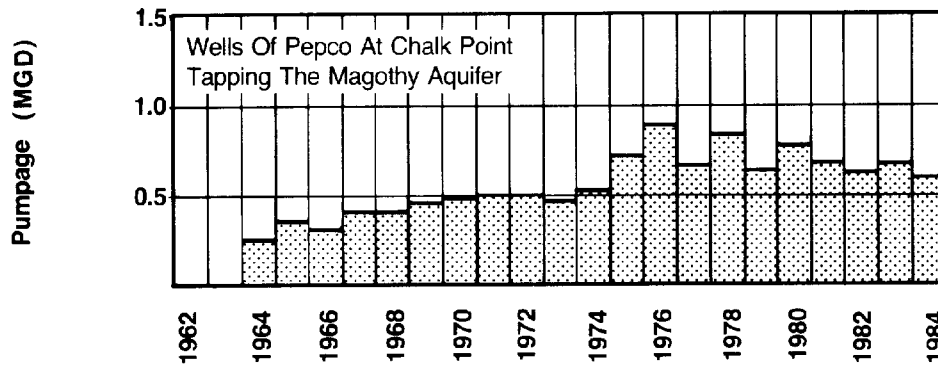
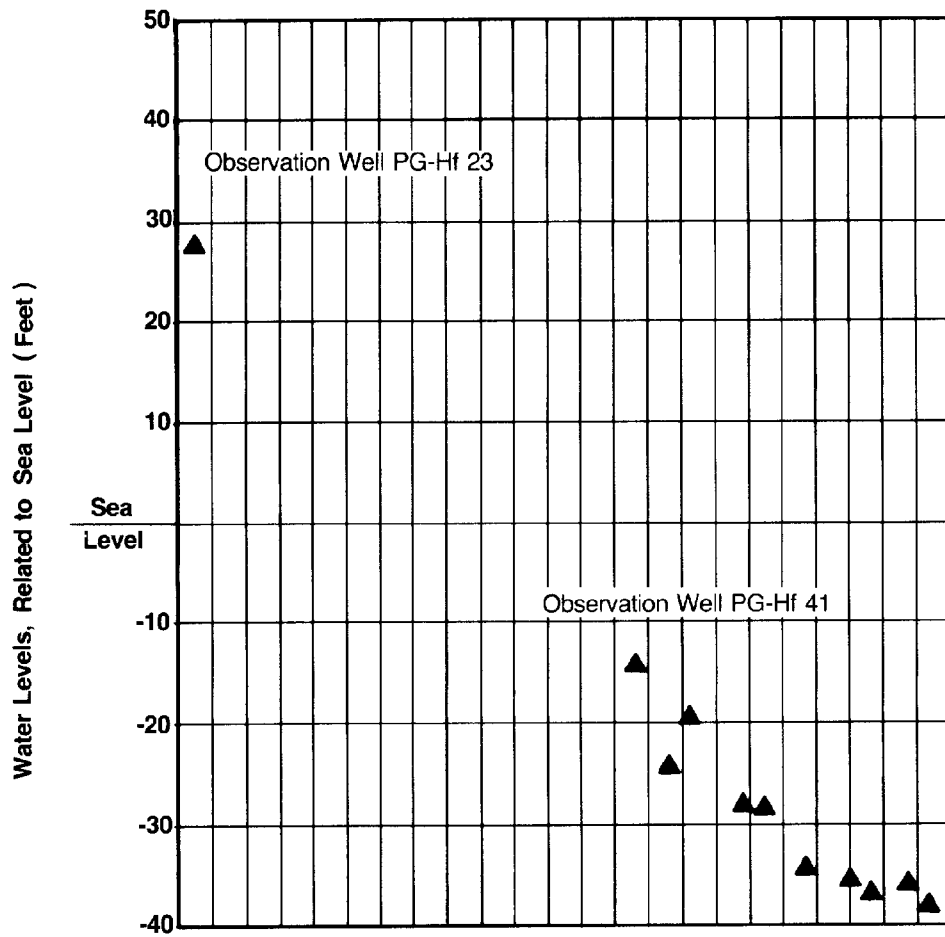


Figure VI-12. Relationship Between Annual Low Water Levels And Average Annual Pumpage At Chalk Point (1962-1984)

Figure VI-13 shows the potentiometric surface of the Magothy aquifer as of September 1984. Changes in the potentiometric surface from 1982 to 1984 are shown in Figure VI-14. This figure confirms the indications given by the water level data from Figure VI-12 that water levels in the Magothy have stabilized. There has actually been a net rise in water levels at Chalk Point from 1982 to 1984.

Figure VI-10 also shows water levels for the Aquia aquifer as measured in two observation wells. These wells are monitored because of concern that Chalk Point pumpage was responsible for water level declines in the Aquia (even though Chalk Point withdraws ground water from the Patapsco and Magothy aquifers). Although there are slight declines in the Aquia water levels, these do not correlate with fluctuations in pumpage from the Magothy. (A similar situation - moderate declines in Aquia water levels uncorrelated to pumping activity at Chalk Point - was observed in 1981 and 1982.) This indicates that the Aquia and Magothy are separated by effective confining beds.

To date, there has been no indication that ground water pumpage at those four power plants has had adverse effects on nearby ground water users. Lowered ground water levels has not as yet dried up wells in the vicinity of the plants, nor has there been any indication that pumpage has caused saltwater intrusion.

C. Ground Water Contamination

Dynamics of Ground Water Contamination

Ground water contamination occurs when materials containing pollutants come into contact with soil materials at the land surface and are then mobilized by contact with water -- usually through precipitation. The percolating ground water carries the contaminants downward to the water table, impairing water quality in the aquifer. This process is illustrated in Figure VI-15.

Once a contaminant enters the aquifer, a three-dimensional plume of contamination expands vertically and laterally in the directions of ground water flow. Once contaminated, an aquifer may be very difficult to clean, forcing the development of alternate water supplies or installation of treatment systems to reduce the amount of contamination prior to water use.

Dilution and attenuation of contaminants can mask or inhibit the migration of a contaminant plume. The chemistry of fossil fuels and their combustion by-products (ash) are sufficiently similar to allow broad grouping into two major categories of concern when discussing attenuation of contaminants through interaction with natural subsurface materials. Cationic (positive-charged) trace elements, in particular heavy metals (cadmium, mercury, lead, etc.), are of primary concern. Elements

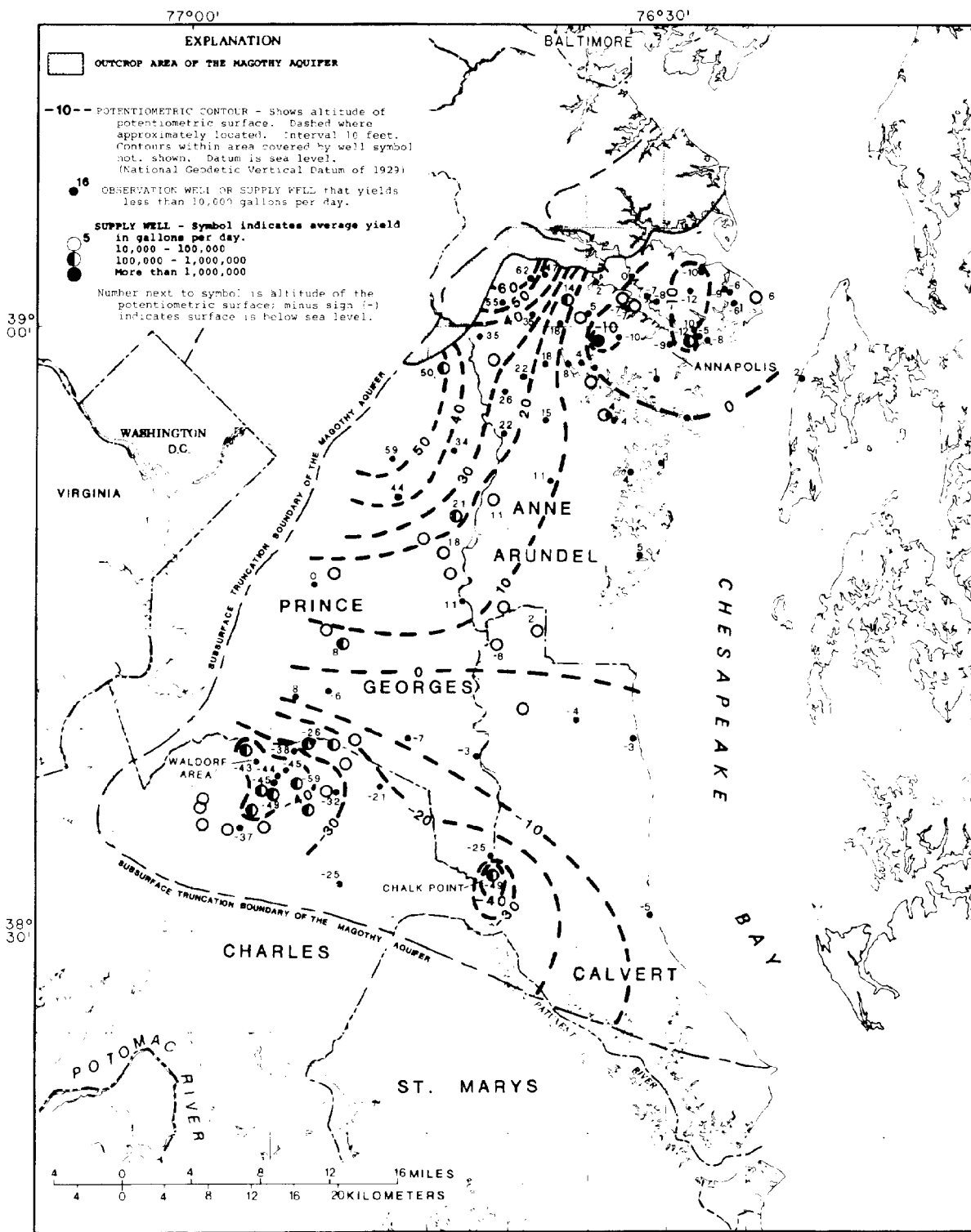


Figure VI-13. The Potentiometric Surface of the Magothy Aquifer in Southern Maryland, September 1984

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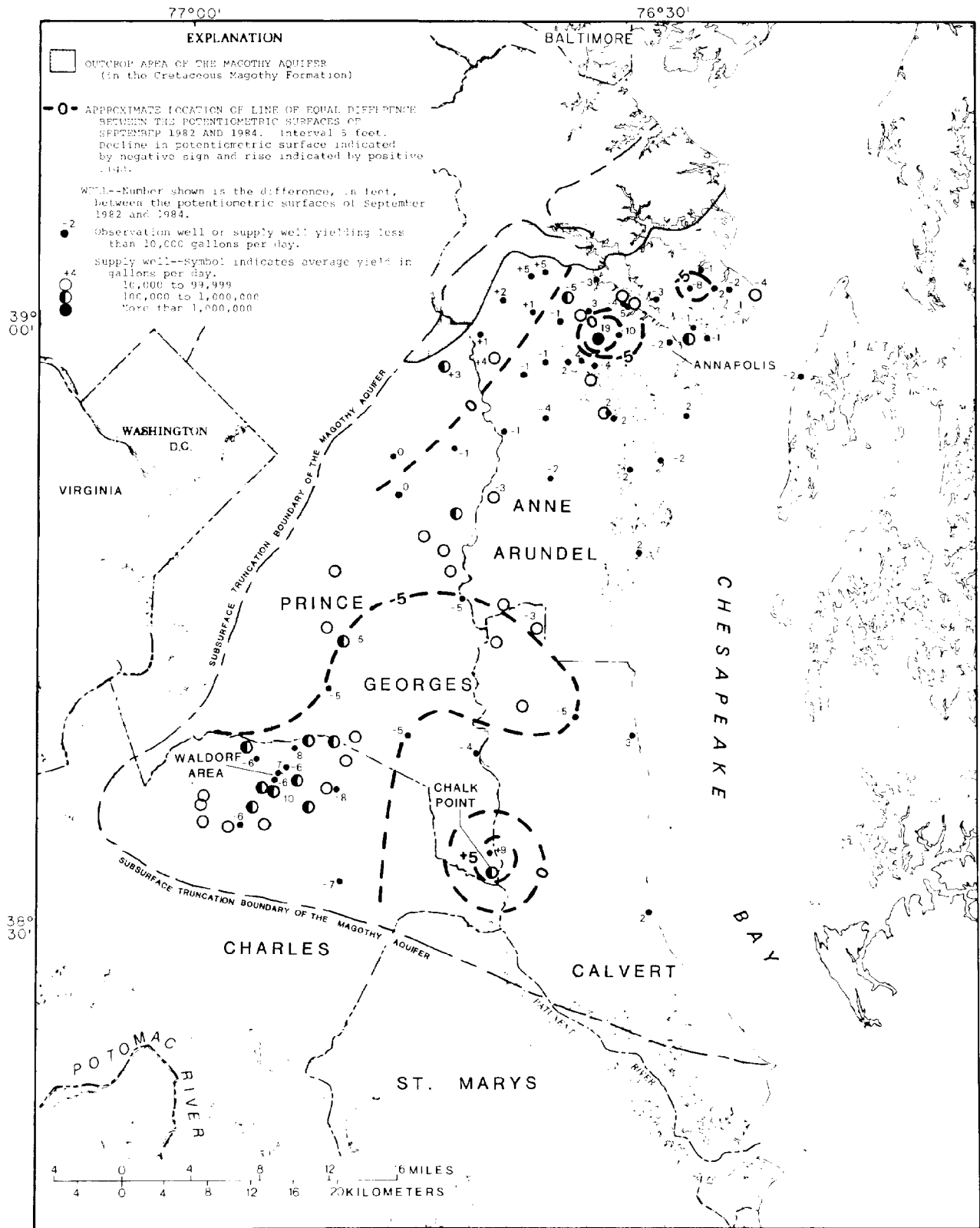


Figure VI-14. The Difference Between the Potentiometric Surfaces of the Magothy Aquifer of September 1982 and September 1984 in Southern Maryland

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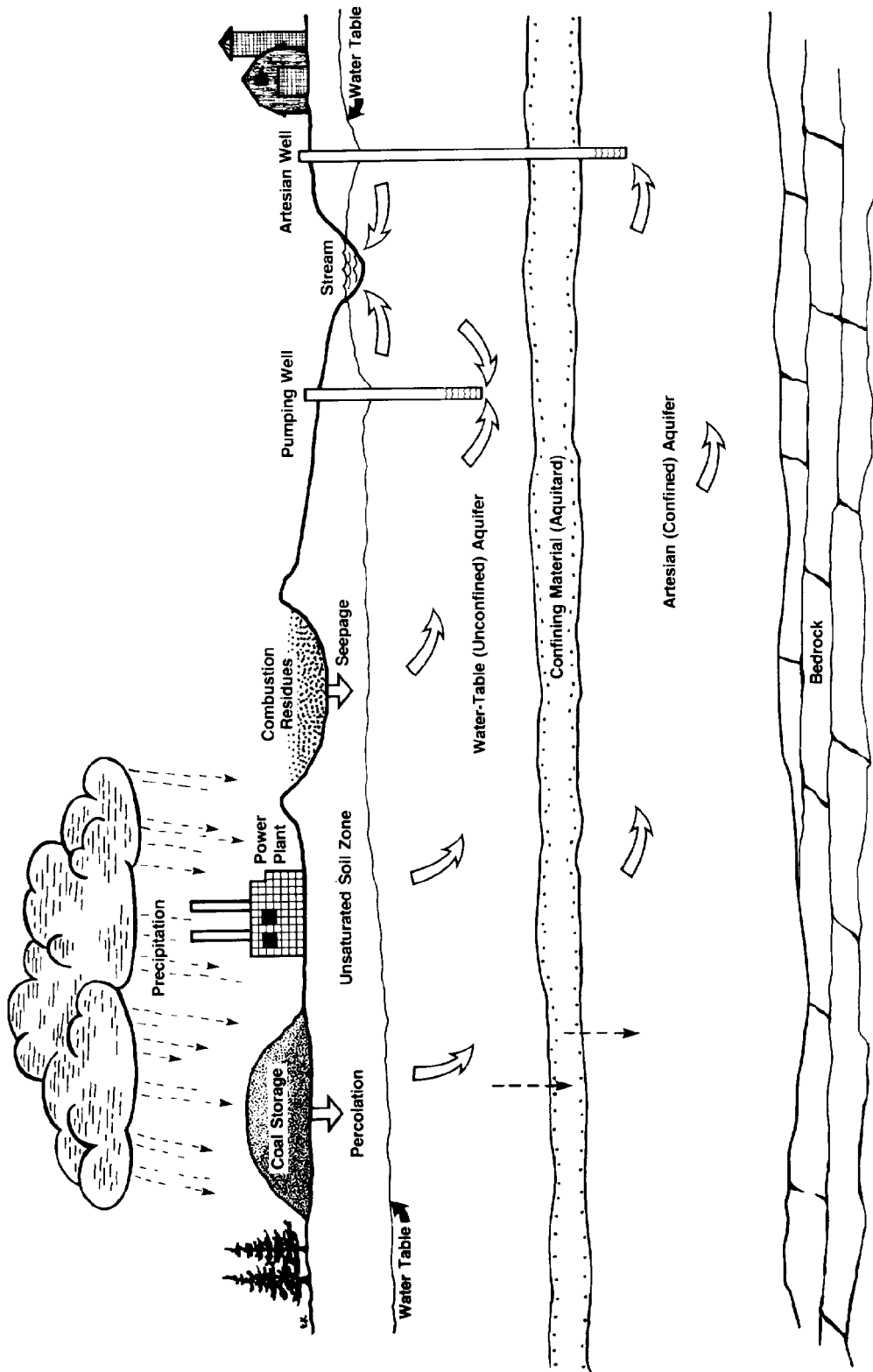


Figure VI-15. Potential Pathways Of Coal & Coal Combustion By-Product Leachates

characterized by anionic (negative-charged) speciation under typical field conditions warrant separate treatment from heavy metals because their environmental behavior is different (5).

The National Research Council has compiled a list of cationic trace elements resulting from coal resource development, which are often present at coal storage or ash sites in concentrations sufficient to warrant investigation (6). From this list, the elements of greatest concern are the transition elements or heavy metals which can be toxic to many biological systems even in dilute solutions. These elements are:

- cadmium
- mercury
- lead
- nickel
- chromium
- vanadium

Besides the potentially toxic cationic heavy metals, a group of trace elements characterized by anionic speciation under conditions commonly found in coal ash landfills are of environmental concern. This group includes:

- arsenic
- selenium
- molybdenum
- boron
- fluorine

Because of their chemical nature, potential toxicity, and significant concentration in fuel and combustion by-products, three of these elements --arsenic, selenium, and molybdenum -- are considered by the National Research Council to be among the group of elements of greatest concern in coal resource development and coal combustion.

Coal Pile Leachate

Both active and reserve coal pile areas are maintained at a typical coal-fired power plant. The active storage piles maintain enough coal for the continuous operation of the power plant between coal shipments. The reserve pile provides a buffer against interruptions of scheduled coal shipments.

The leachates and runoff generated by coal storage piles vary considerably in chemical character, and their effects can be similar to that of acid mine drainage. The acidic solutions are created when pyrite in stockpiled coal oxidizes to iron sulfate under the aerobic conditions of storage. The effects of coal pile acid leachate and runoff are more severe with high-sulfur coals (7). However, all Maryland coal-fired power plants use low-sulfur coal with a sulfur content of three percent or less.

In addition to having potentially high acidic levels, coal pile runoff and leachate may also contain trace metals. The trace elements present in coal pile runoff and leachate include: arsenic, beryllium, cadmium, chromium, cobalt, copper, manganese, mercury, nickel, selenium, and zinc. Table VI-1 presents the ranges of concentrations.

Table VI-1 Constituents of Coal Pile Runoff

	<u>Range (mg/l)</u> (except for pH)	
<u>Conventional Measures of Pollution</u>		
pH	2.10	- 6.60
Total Suspended Solids	22.00	- 610.00
Total Dissolved Solids	720.00	- 28,970.00
Turbidity	2.77	- 505.00
Total Hardness	130.00	- 1,851.00
<u>Major Chemical Constituents</u>		
Ammonia	0.00	- 1.77
Nitrite	0.30	- 1.90
Phosphorous	0.20	- 1.20
Sulfate	130.00	- 20,000.00
Chloride	3.60	- 481.00
Aluminum	66.00	- 1,200.00
Iron	0.06	- 4,700.00
Manganese	90.00	- 180.00
Sodium	160.00	- 1,260.00
<u>Trace Element Constituents</u>		
Arsenic	0.005	- 0.60
Beryllium	<0.01	- 0.07
Cadmium	<0.001	- 0.003
Chromium	0.00	- 16.00
Cobalt	0.025	- 0.90
Copper	0.01	- 3.90
Magnesium	0.00	- 174.00
Mercury	<0.0002	- 0.007
Nickel	0.24	- 0.75
Selenium	<0.001	- 0.03
Zinc	0.006	- 12.50

(Reference 7)

Little information is available concerning the impact of coal pile leachate and runoff on surface water and ground water quality in Maryland. Surface water discharges from coal piles are regulated under each plant's NPDES permit and must be monitored for pH and total suspended solids levels. Coal piles in Maryland are not specifically designed to prevent ground water contamination, i.e., coal piles are not lined, nor is ground water downgradient of coal piles monitored. To date, the impact of present coal pile management practices on Maryland's ground water quality has not been investigated.

Coal Combustion By-Products

Coal combustion by-products include:

- Fly ash
- Bottom ash
- Boiler slag
- Flue gas desulfurization (FGD) sludge

Currently, the seven coal-fired plants operating in Maryland together produce about one million tons of ash per year. Some ash is sold, but most is landfilled at sites owned by the utilities (8). The names and locations of the ash sites presently operating in Maryland are presented in Figure VI-1.

All of the ashes produced in Maryland plants have similar chemical characteristics. Ash from eastern United States coals consists primarily of aluminum silicate with lesser proportions of lime, iron, magnesium, sulfur trioxide, sodium and potassium oxides, and carbon. Fly ash and bottom ash have similar chemical compositions, but bottom ash tends to have a lower carbon content. Coal ash may also contain trace amounts of arsenic, barium, cadmium, lead, mercury, chromium, and selenium.

The Power Plant Siting Program has conducted environmental assessments at presently operating and closed ash sites to evaluate the effectiveness of their design and operation in protecting the environment. The results of several of these studies were reported in the 1984 CEIR (1). All studies conducted since the last CEIR was written (9, 10, 11), as well as earlier studies, show that environmental impacts attributable to the ash sites are minimal. The findings of all environmental investigations of ash sites conducted by PPSP are summarized in Reference 12.

FGD sludge is generated by desulfurization scrubbers installed in power plant emission stacks. While there are no scrubbers presently operating in Maryland, their use can be anticipated in the future. However, since FGD sludge often makes up the largest volume of solid waste at coal-fired power plants that use SO₂ scrubbers, it will be briefly discussed. The sludge's predominant constituents are calcium sulfate, calcium sulfite, sodium chloride, and magnesium chloride, and the sludge frequently contains detectable amounts of trace metals (13).

FGD sludges are not a major source of leachable toxic trace elements; hence few leaching experiments have been conducted. Results on leachates from lime sludge and calcium-based dry scrubber sludges show that the

concentrations of silver, chromium, mercury, lead, and selenium are below detection limits (13). However, because of the high concentrations of sulfates in FGD sludge, leachate concentrations of total dissolved solids can be quite high, reaching levels greater than 1,000 mg/l. Some trace element concentrations of FGD sludges are listed in Table VI-2.

Table VI-2 Trace Elements in Wet FGD Sludge

Element	<u>Sludge Solids</u>		<u>Sludge Liquor</u>	
	Median Conc. (mg/kg)	Range (mg/kg)	Median Conc. (mg/l)	Range (mg/l)
Arsenic	12	0.8-52	0.03	¼0.0004-0.06
Boron	140	42-530	14.9	2.1-76
Cadmium	10.6	0.06-25	0.02	0.002-0.12
Chromium	15.	1.6-180	0.02	¼0.0002-0.25
Copper	17.5	6-340	0.03	0.0045-0.53
Fluoride	625.	266-1017	2.3	0.2-63
Mercury	0.4	0.005-6	0.005	0.00006-0.10
Lead	2.4	0.25-290	0.03	¼0.005-0.50
Selenium	5.0	2-60	0.18	0.003-1.9

Fuel Oil and Oil Ash

Very little information is available regarding the impact of fuel oil and oil ash on Maryland's surface and ground water resources. For this reason, the discussion presented here will focus on the potential impacts associated with the two substances. Fuel oil can pose a threat to ground water during transportation to the plant or while stored at the plant. It is transported to plants via pipelines, tank trucks, barges, ships, or rail cars. Accidents, such as valve miscues, loading/unloading spillage, and equipment leaks, are all potential routes to contamination. Once delivered, the oil is stored in above-ground or buried tanks, either of which may leak over time.

The ash by-products of oil burning plants can have chemical characteristics different from coal ash. An oil-burning plant produces less than one percent of the ash produced by a comparably sized coal-fired plant. Most of the ash is bottom ash. The composition of oil ash is extremely variable due to the compositional differences in oil, but it is chiefly composed of metal oxides and partially oxidized carbon compounds. Several elements present in trace quantities in coal ash, such as copper, nickel, vanadium and zinc, may comprise a large part of oil ash (13). To date, no significant problems associated with fuel oil or oil ash have been identified at Maryland power plants.

Other Wastes

Power plant maintenance also generates wastes. Heat transfer surfaces are periodically cleaned to maintain the efficiency of a plant. These surfaces include:

- Boiler
- Boiler fireside
- Air preheater
- Stack
- Cooling tower basin
- Miscellaneous small equipment

Strong chemicals are usually used to remove deposits formed on surfaces. Sometimes the surfaces are actually cleaned to bare metal, producing trace metals such as iron, copper, nickel, zinc, and chromium in the cleaning solution (14). These waters are often considered "hazardous" as defined by the Resource Conservation and Recovery Act. Manifest records for hazardous waste from the electric power industry reveal that several categories of waste comprise the bulk of the listed material:

- Oily wastes
- Spent acids
- Halogenated and non-halogenated organics
- Heavy metals
- PCBs
- Boiler wash

Hazardous wastes are subject to strict on-site storage, transportation, and disposal requirements. Maryland utilities comply with all applicable hazardous waste regulations.

REFERENCES - CHAPTER VI

- (1) Power Plant Siting Program, Maryland Department of Natural Resources. Power Plant Cumulative Environmental Impact Report (PPSP CEIR-4). Annapolis, Maryland 1984.
- (2) Thornbury, W. D. Regional Geomorphology of the United States. John Wiley and Sons, Inc., New York. 609 pp 1965.
- (3) Todd, D. K. Ground-Water Resources of the United States. Premier Press, Berkeley, California. 747 pp. 1983.
- (4) Wheeler, J. C. Water Use in Maryland. U.S. Geological Survey, Maryland Geological Survey, and Maryland Water Resources Administration. 1983.
- (5) Liberti, M.R. and H.A. Elliott. Attenuation of Leachates from Coal and Coal Combustion By-Products by Maryland Soils. Environmental Resources Management. PPSP-85-1. July 1985.
- (6) NRC. 1980. Trace-Element Geochemistry of Coal Resource Development Related to Environmental Quality and Health. National Research Council. National Academy Press, Washington, D.C.
- (7) Davis, C. D. and W. J. Boegly. Coal Pile Leachate Quality. J. Environ. Eng. Div. ACSE. 107:EE2. 1981.
- (8) Simek, E. M., C. P. Demeter and P. N. Klose. Coal Ash Deposition in Maryland 1950 through 1980. Environmental Resources Management. PPSP-MP-41.
- (9) Simek, E. M. and J. E. Veith. Geotechnical Evaluations of Two Older Ash Disposal Sites. Environmental Resources Management and Soil Engineers, Inc. PPSP-MP-53. 1984.
- (10) Klose, P. N. and G. T. Potera. Biological Impact Studies of the Faulkner Ash Site. Environmental Resources Management. PPSP-MP-56 1984.
- (11) ERM. Environmental Aspects of the Brandywine Ash Site. Environmental Resources Management. PPSP-MP-54. 1984.
- (12) Simek, E. M. Coal Ash Management in Maryland. Environmental Resources Management. PPSP-MP-55. 1984.
- (13) EPRI. Physical-Chemical Characteristics of Utility Solid Wastes. Prepared by Tetra Tech, Inc., Lafayette, California. EA-3236. 1983.
- (14) EPRI. The Impacts of RCRA (PL 94-580) on Utility Solid Wastes. Prepared by Fred C. Hart Associates, Inc. New York. EPRI FP-878. 1978.

CHAPTER VII

ACID DEPOSITION

In the last few years, there has been increasing public concern over the possible ecological and economic implications of acidic deposition. This chapter of the CEIR summarizes the atmospheric processes leading to acid deposition and the possible effects of this deposition on ecological systems. It also describes the major legislative proposals introduced at the federal level that are aimed at reducing acid deposition.

The EPA and 10 other federal agencies are currently funding the comprehensive National Acid Precipitation Assessment Program (NAPAP). This program has two goals. The first is to establish the relationship between emissions of SO₂ (and other pollutants) and the deposition of acid materials on "sensitive receptors". The second is to assess environmental effects that may be attributable to such acidic depositions. Preliminary assessments will be completed in 1986 and 1987, and a final NAPAP report is to be issued in 1989. Maryland has many concerns which are unique to the Chesapeake Bay region and are not being addressed in studies supported by other programs such as NAPAP. Therefore, the State is supporting additional studies to address these issues.

The deposition of acidic materials, loosely termed "acid rain," includes dry deposition of atmospheric gases and particulate materials, as well as wet deposition of acidic materials formed in clouds, dew, and fogs, and scavenged from the atmosphere during the precipitation process. Although attention in the press has focused on wet deposition (acid rain), studies of the effects of acidic deposition on sensitive ecosystems and materials have clearly shown that the full deposition process--including both wet and dry deposition--contributes to any changes that may occur.

The acidity of precipitation is normally measured on the pH scale, where a pH of 7.0 is neutral and a pH of 6.0 is ten times more acidic than a pH of 7.0. Early estimates of the natural acidity of precipitation (as measured by pH) were based solely on the equilibrium of carbon dioxide in the atmosphere with "pure" water. This equilibrium pH value is about 5.6. However, more recent studies in remote sections of the world (1) suggest that the pH of rain not affected by anthropogenic emissions is closer to 5.0 than to 5.6.

As discussed later in this chapter, the mean annual pH of precipitation in Maryland is about 4.0. Thus, precipitation in Maryland is roughly 10-40 times as acidic as natural rain (pH 5-5.6). This acidity is consistent with averages for the northeastern United States.

Studies of effects to ecological systems and materials in other areas of the country have indicated that changes are occurring to certain sensitive resources such as lakes and forests (2). Western Maryland has been characterized as sensitive due to its geology and the nature of its soils (3). However, few studies have been conducted in this region and effects in either its terrestrial or aquatic habitats have not been documented. Perturbations caused by coal mining activities in this area make the task of discerning acid

deposition effects difficult. It appears that other sensitive receptors in Maryland include the watersheds of the coastal plain streams. Typically, soils of this region are naturally acidic and offer only moderate buffering capacity. In areas where the soil does offer buffering capacity, certain land use practices (e.g., ditching to accelerate runoff) can be detrimental if they reduce the time of contact of acidic rainwaters with the soils.

A. Atmospheric Processes, Emissions, and Deposition

Acidic sulfates and nitric acid are formed by the oxidation of sulfur and nitrogen compounds released to the atmosphere by natural and anthropogenic sources. Global sulfur emissions appear to be about equally divided between natural sources (such as volcanoes) and man-made sources (4); however, in eastern North America, anthropogenic emissions exceed natural ones by a factor of ten (5).

Power plants are among the major emitters of sulfur and nitrogen oxides, the anthropogenic emissions thought to be principally responsible for high rainwater acidity in Eastern North America. Power plant emissions account for about two-thirds of total sulfur oxide emissions and one-third of total nitrogen oxide emissions in this region. Furthermore, since power plants often have taller stacks than industrial plants, their emissions may travel farther and hence participate more fully in the oxidation reactions that lead to production of highly acidic materials in the atmosphere (6). In addition, studies conducted near power plants (7-12) indicate the potential for increased wet and dry acidic deposition near such facilities.

The mechanisms leading to formation of acidic precipitation events have recently been reviewed by the EPA (13) and the National Academy of Sciences (6). Oxidation of both sulfur and nitrogen oxides is accelerated in the presence of photochemically formed ozone and certain catalysts present in the atmospheric aerosol. Oxidation of sulfur dioxide in cloud water is rapid, and is an important source of rainwater sulfuric acid. Nitrogen compounds appear to compete with sulfur dioxide for oxidizing materials, and some investigators have claimed that high concentrations of nitrogen oxides may reduce the rate of sulfur oxidation in the atmosphere (13). Because of the complexity of the interconnected reactions that lead to sulfuric and nitric acid formation in the atmosphere and in clouds, wet deposition of these materials may not be proportional to emissions (6). Rather, a non-linear (i.e., nonproportional) relationship may exist so that reductions in emissions may not produce commensurate reductions in wet deposition of acidic materials at downwind receptors (13). However, all anthropogenic sulfur and nitrogen oxide emissions are eventually deposited to the ecosystem by either wet or dry deposition. Thus deposition rates of, for example, anthropogenic sulfur must be linearly related to emissions if a sufficiently large geographical area (such as eastern North America) and sufficiently long time period (such as a year) are considered (6). Present models of transport, transformation, and deposition process are unable to accurately determine the linearity of these processes on more than an extremely gross scale.

The implications of these relationships strongly affect the success of any strategy or program to protect sensitive ecosystems. While a general national program to reduce emissions of acid deposition precursors such as sulfur oxides and nitrogen oxides may successfully reduce average annual deposition over a large area, the program may not appear to be effective at a specific location or time. Development of an effective model to allow such projections is a high priority for NAPAP (2).

There has been concern that occurrence of acidic precipitation is becoming both more intense and more widespread. Cogbill and Likens (14) and Likens and Butler (15) presented a comparison of data from 1965 and 1973 purporting to show a significant increase in rainwater acidity on the Eastern seaboard, particularly in southerly sections. Their conclusions were based on a comparison of data collected at a number of stations by several different collection and analytical schemes. The basis for this analysis was later examined by Hansen et al. (16). These authors conclude that the reported trends for most of the Cogbill and Likens sites are less than the uncertainties introduced into the data by the diversity of analytical techniques employed in the data collection programs. However, some decrease in pH values may be documentable in a region extending from Alabama eastward to Florida. Examination of data from several long-established networks, such as the Hubbard Brook study in New Hampshire, indicates that no substantial change in rainwater pH had occurred during the 1965-1973 study period. Hansen et al. (16) conclude that existing data are not adequate to demonstrate substantial trends in rainwater acidity in the northeastern United States.

While it has been known for some time that major sources of both sulfur and nitrogen oxides occur to the west and north of Maryland, the extent to which these emissions lead to deposition in the State is unknown. In the five state region (West Virginia, Virginia, Pennsylvania, Delaware, and Maryland), Maryland clearly contributes only a small percentage of the overall emissions (Figure VII-1). The major emitters in Pennsylvania and West Virginia are located directly in the path of storms which frequently track across the midwest to the East Coast. Emissions from these sources are expected to contribute strongly to the acidity of Maryland's precipitation. Figure VII-2 presents the same data shown in Figure VII-1 on an emission density basis--tons of pollutants per square mile--so that the total emissions are not biased by the size of the state. On this basis, Maryland's contribution is much larger, but it is still less than any other state in the region except Virginia.

Figure VII-3 shows actual and projected sulfur dioxide emissions from Maryland electric utilities and other sources for 1974-1984, 1990, and 1995. Within Maryland, about two-thirds (220,000 tons) of the 1980-1984 average sulfur oxide emissions came from power plants (See also Table III-1, p. III-3). Utility emissions are expected to increase to about 300,000 tons by 1990, representing about three-fourths of total sulfur dioxide emissions at that time.

Figure VII-4 presents actual and projected sulfur dioxide emissions by utility. At present, the majority of utility emissions in Maryland come from facilities owned by PEPCO. The emission increases projected for 1990 and 1995 will be primarily due to capacity additions and coal conversions at plants owned by BG&E. In comparison, the two largest non-utility sources, Westvaco

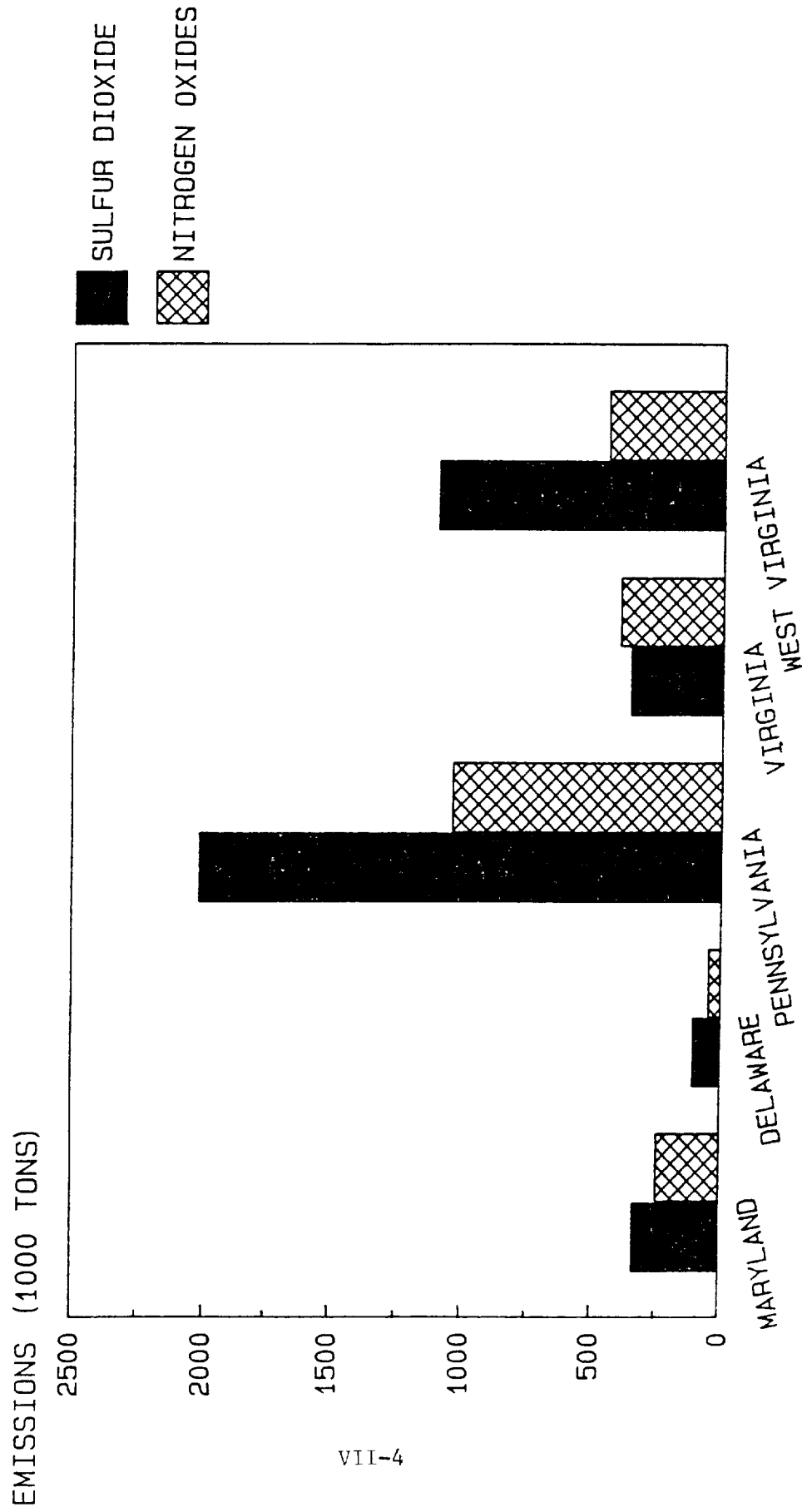


Figure VII-1. Total sulfur dioxide and nitrogen oxide emissions in 1980 (data from Ref. 18)

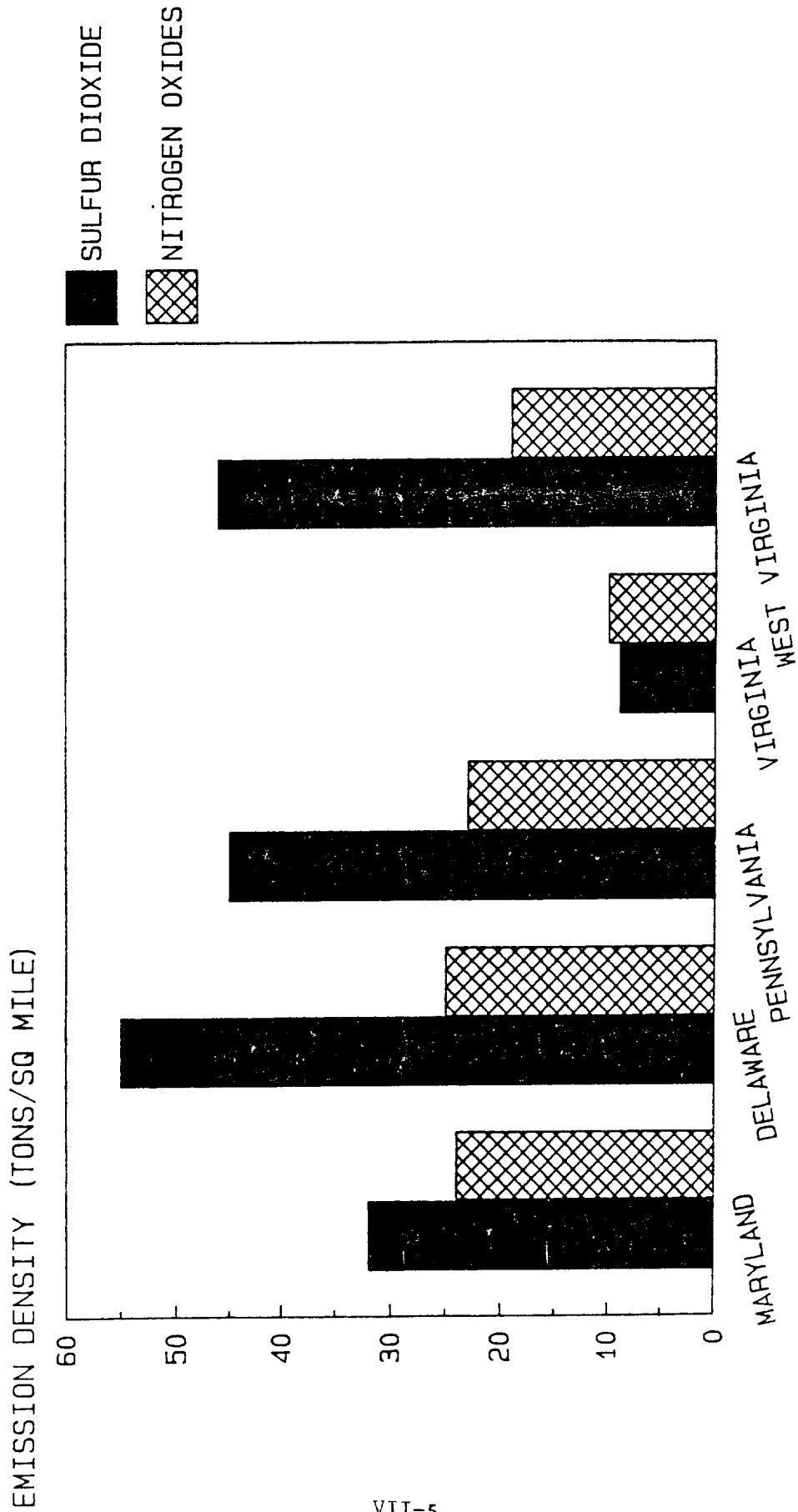


Figure VII-2. Sulfur dioxide and nitrogen oxide emission densities in 1980 (data from Ref. 18)

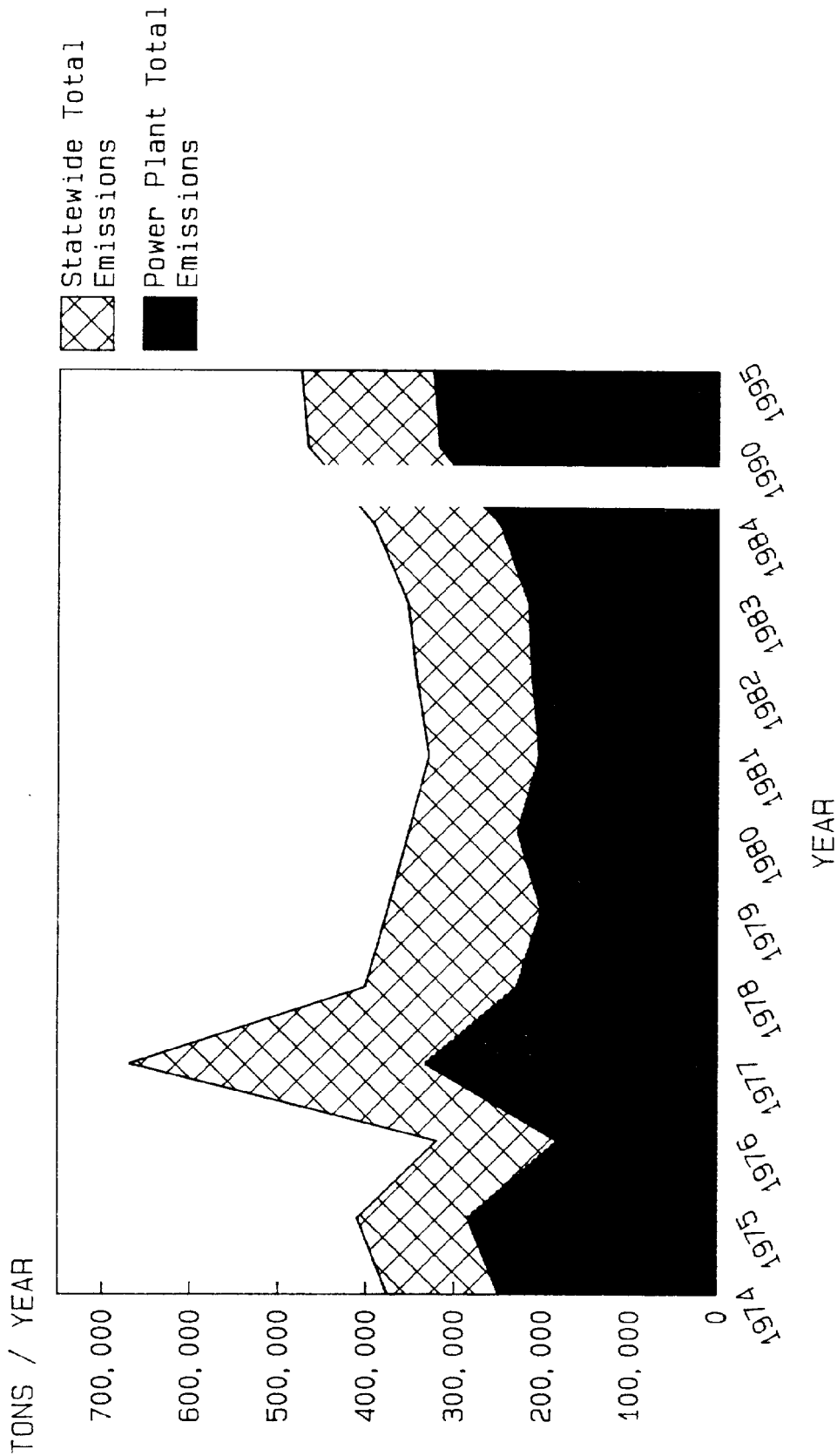


Figure VII-3. Statewide and power plant emissions of sulfur dioxide. Reported emissions from ref. 19-25. Projected emissions from ref. 26.

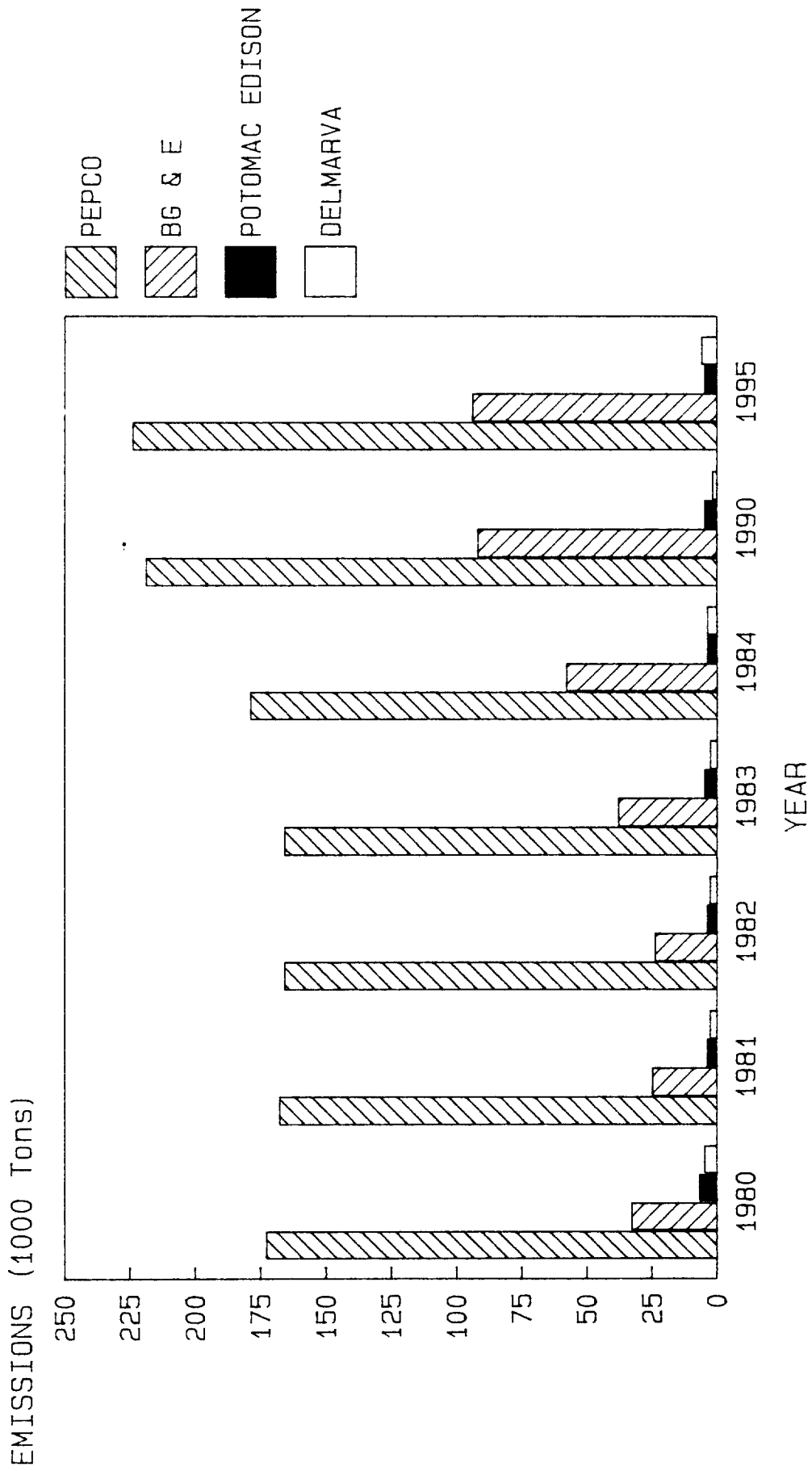


Figure VII-4. Total power plant emissions of sulfur dioxide, by utility company. Reported emissions from ref. 19-25. Projected emissions from ref. 26.

and Bethlehem Steel, jointly emitted 25,000 tons of sulfur oxides during 1980. Sulfur-emitting sources are highly concentrated in the Baltimore-Washington corridor: in 1981, four counties--Charles, Baltimore, Prince Georges, and Montgomery --produced 76 percent of the total sulfur emissions (17).

Figure VII-5 shows actual and projected nitrogen oxide emissions for Maryland. Overall, total nitrogen oxide emissions fell slightly between 1980 and 1983 and are projected to increase back to 1981 levels by the mid-1990s. Although utility nitrogen oxide contributions are expected to almost double by 1995, this increase is partially balanced by a projected 60 percent decline in highway nitrogen oxide emissions. Figure VII-6 shows actual and projected nitrogen oxide emissions for Maryland by utility. Trends for nitrogen oxide emissions are similar to those discussed above for sulfur dioxide emissions.

The relative contribution of in-state versus out-of-state sources of acid deposition precursors to the acidity of Maryland's rainfall is the subject of current PPSP studies. Results from four long-range transport models have been applied to estimate the sources of deposition in the Maryland region. These models indicate that approximately 60-80 percent of the statewide deposition of sulfur is from out-of-state sources (27). It should be noted that the spatial distribution of in-state deposition is not described by these models. Preliminary assessments indicate that much of the deposition from out-of-state sources may occur in the western and central portion of the State. The ratio of in-state to out-of-state caused deposition is likely to be higher for eastern Maryland due to major emissions sources (e.g., power plants and transportation) in the Baltimore-Washington corridor. PPSP is currently evaluating in-state deposition patterns using existing deposition data collected in and near Maryland.

B. General Deposition Monitoring Studies

As a result of the growth in interest in measuring acid deposition and controlling emitting sources that contribute to rainwater acidity, several state and federal programs have been established to collect and analyze rainwater in Maryland (see Figure VII-7). Several of these programs are aimed at analyzing trends in acid deposition, others are aimed at studying sources and mechanisms leading to acid rainwater, and still others are concerned with observing effects of acidic rain events. An earlier examination of the data collected at these sites (28) concluded that the annual average pH for rainfall at rural sites is about 4.0 with no obvious spatial or temporal pattern. Individual storms can vary by up to 1 pH unit from the average. As mentioned above, a major effort is now underway to examine the patterns of deposition of hydrogen ion, sulfate, and nitrate as measured by these stations.

Each deposition measurement program has established sample collection and analysis protocols appropriate to its stated objective. For instance, programs concerned with the relationship between acidic precipitation and local stream chemistry conduct event-based sampling, whereas trend monitoring programs collect samples weekly. Event-based sampling is particularly critical for programs designed to examine episodic changes in stream chemistry which may be influenced by precipitation. This diversity of protocols, although necessary,

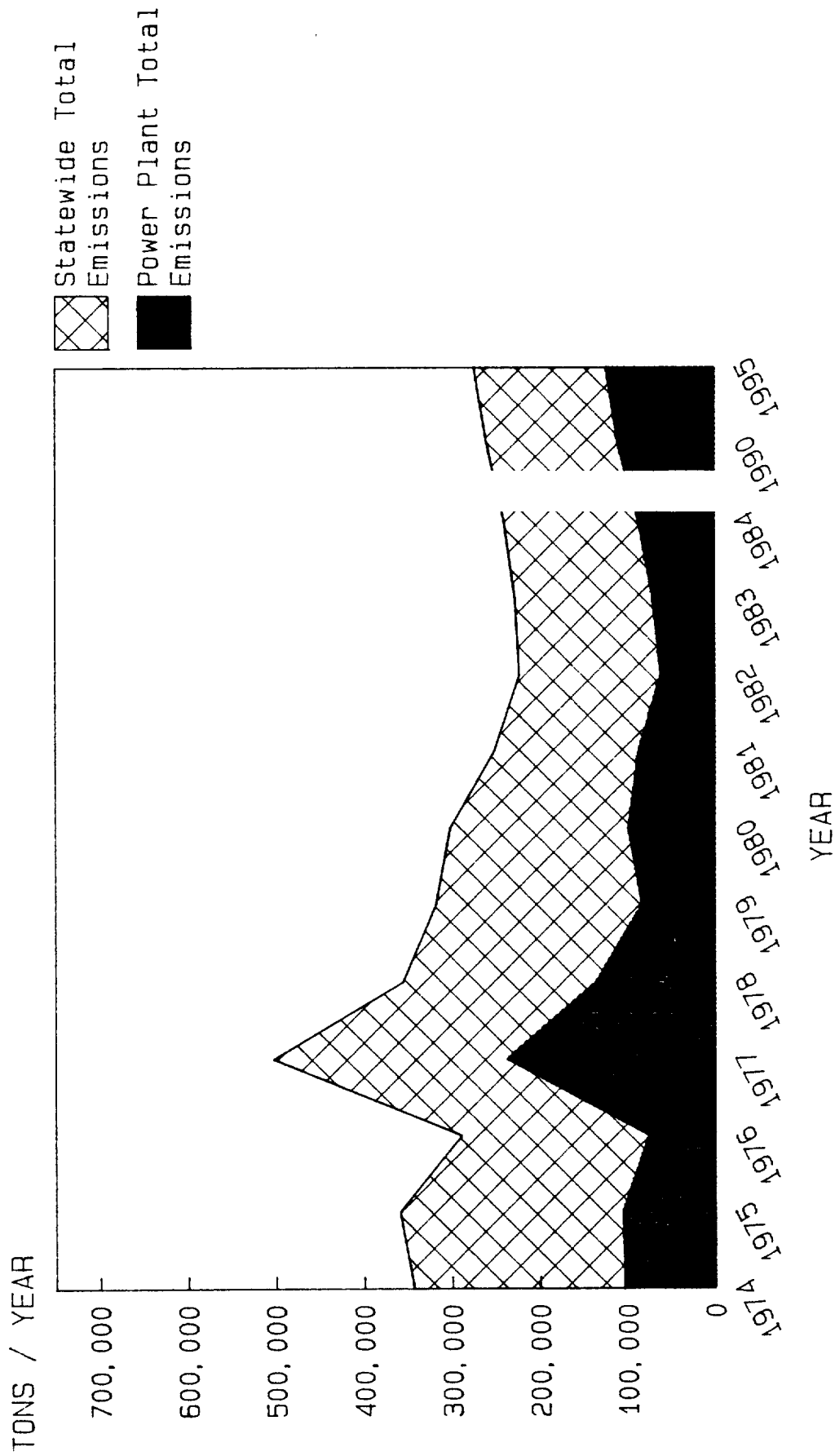


Figure VII-5. Statewide and power plant emissions of nitrogen oxides. Reported emissions from ref. 19-25. Projected emissions from ref. 26.

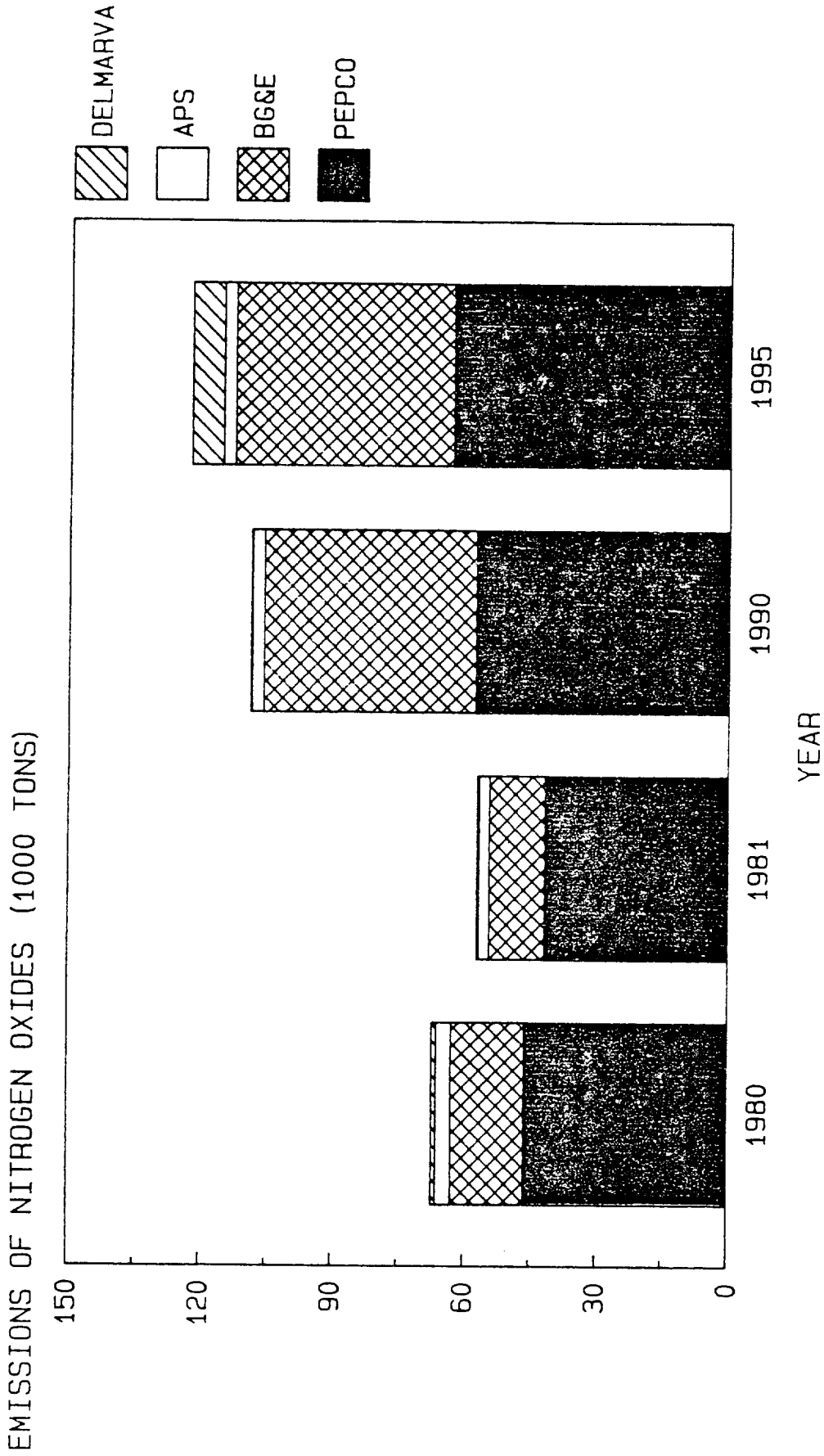


Figure VII-6 Actual and projected utility nitrogen dioxide emissions for Maryland (data from Ref. 26)

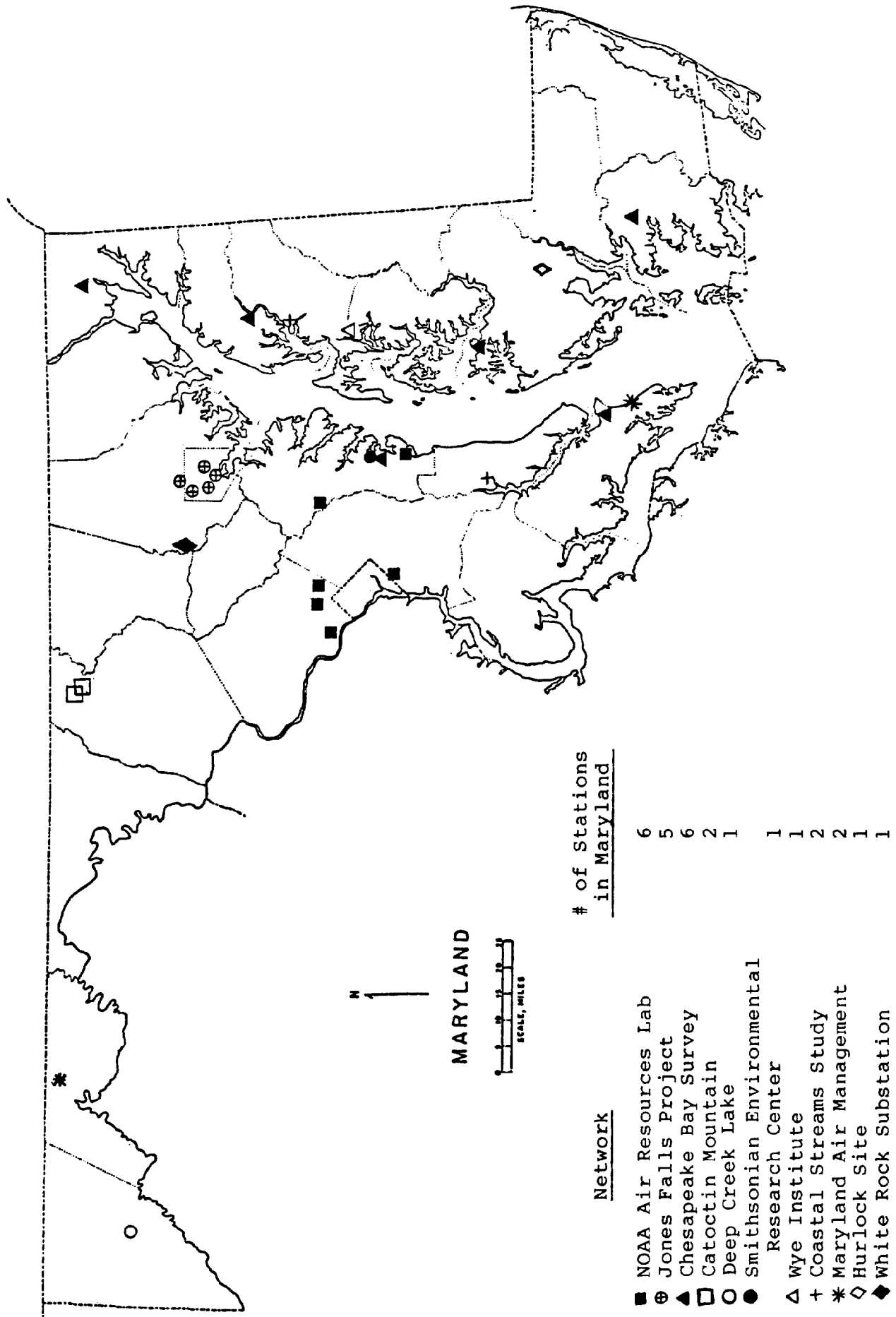


Figure VII-7. Precipitation Chemistry Monitoring Station Locations

prevents simple comparison and integration of results from neighboring programs. Such integration might lead to new insights into the nature and sources of acidic deposition in the State. Perceiving the advantages of producing a common, Statewide database, members of the acid deposition measurement community in Maryland have agreed to implement a minimum list of common procedures in all studies to allow data comparisons to be made at the Statewide level (29). A brief description of the deposition monitoring programs conducted in Maryland is given below.

National Oceanographic and Atmospheric Administration (NOAA) Network

Since 1975, staff of NOAA have operated a wet deposition monitoring network at their homes around the Washington metropolitan area. A total of 10 sites have been used, with 6-8 sites active at any one time. The program was reduced to one site in 1981 (30).

Two results of these observations have been reported. First, pH of the precipitation is generally lower in the summer months. Second, there was a general increase in precipitation pH from 4.0 to 4.4 in the Washington, D.C. area through the period 1974-1981. However, a change in the method of measuring pH occurred during this period, bringing to question the validity of the apparent increase.

White Rock Substation (BG&E) Site

Baltimore Gas and Electric Company operates a National Atmospheric Deposition Program (NADP) site at its substation on White Rock Road in Carroll County. Primary samples are collected on a weekly basis and submitted to NADP (31). A secondary set of event samples is also collected to allow comparisons of event-sampling to weekly sampling for the site. The site has been in full operation since October 1984.

Coastal Streams Acidification Study

This study, which was conducted by the Academy of Natural Sciences of Philadelphia (ANSP) under funding from the Maryland Power Plant Siting Program (PPSP), was designed to examine the potential effects of acid deposition on the water quality of small, freshwater tributaries to Chesapeake Bay. These streams have been used for spawning by fish such as herring, alewife, and white and yellow perch. Precipitation was collected on an event basis at two sites, one near Lyons Creek in southern Anne Arundel County and one near Chestertown for the period May 1984 - June 1985 (32). It is anticipated that at least one of these sites will be reactivated during Spring 1986. Results for the period of Spring 1984 indicated a volume-weighted mean pH of 4.2.

Deep Creek Lake Studies

Between September 1980 and August 1984, the Maryland Power Plant Siting Program, Garrett Community College, the U.S. Geological Survey, and Martin Marietta Corporation conducted a study of acidic deposition and its effects on water quality at Deep Creek Lake, Maryland (33-36).

The results of these three years of study are:

- Precipitation at Deep Creek Lake is as acidic as that anywhere in the United States. Annual volume-weighted mean field pH values of precipitation were 3.9, 3.9, and 4.0 for the first three years of the study (35).
- The predominant ion in precipitation is sulfate. Concentrations of hydrogen and sulfate ion are highly correlated in samples collected under comparable conditions (35). Both sulfate and hydrogen ion content of rain are greater in summer than in other seasons.
- About 47 percent of the sulfate deposition at Deep Creek Lake occurs in precipitation associated with northwesterly wind directions (36). Trajectory analysis of precipitation events from the first two years of the study indicates that more than 95 percent of the sulfate deposited at Deep Creek Lake came from areas to the southwest, west, or northwest of the site (37), indicating a source origin outside of Maryland.
- Organic acids may contribute up to 40 percent of the total acid in selected events (33).
- Acid input from streams draining geologically acidic areas in the basin is approximately equal to the direct input of rainwater falling on the lake's surface. Other streams entering the lake are neutral or basic, indicating that soils and rocks of the watershed effectively buffer acid input from precipitation.
- Lake water ionic composition has not changed during the four years of the study. Major sources of buffering for the lake include limestone outcroppings in the basin and under the lake and bottom sediments in Cherry Creek Cove of Deep Creek Lake.

The study team concluded that although precipitation provides large amounts of hydrogen ion input to the lake annually, limestone outcroppings in the watershed prevent any near-term danger of acidification.

Maryland Air Management Administration (MAMA) Stations

As part of a national network of precipitation stations, EPA has sponsored two stations within Maryland. The two stations, which have been operation by MAMA since October 1984, are located in Rocky Gap State Park, Allegheny County, and at the Elms Environmental Education Center in St. Mary's County. These locations were selected to complement existing NADP sites at Wye Institute and in surrounding states. Precipitation is collected on a weekly basis at both of these sites (38).

Chesapeake Bay Aerial Precipitation Survey

The Chesapeake Bay Aerial Precipitation Survey (39) was conducted by the Maryland Geological Survey during 1980-1981 as part of the Chesapeake Bay program. Six sites were located around the Bay. Because of below-normal precipitation for the year, only 20 samples were collected. This number is sufficient only to characterize general precipitation in the Bay region during

the study year. Field pH measurements ranged from 3.83 to 4.9 for individual events with an average of 4.0. Sulfate concentrations increased as wind shifted from north, through east, to west.

Jones Falls Network

As part of the Jones Falls Urban Runoff Project conducted by the Baltimore Regional Planning Council under EPA sponsorship, five precipitation monitoring sites were operated in the Baltimore urban area on an event basis during 1980-1981. This monitoring program terminated with completion of the project in 1981. Annual average pH was about 3.9.

Smithsonian Environmental Research Center

The Smithsonian Environmental Research Center is conducting a long-term study of the effects of various factor on the Rhode River estuary south of Annapolis. An important component of the study is the measurement of precipitation chemistry. Precipitation has been collected and analyzed at this site since 1974, providing the longest continuous record of precipitation chemistry in Maryland at the present time. Wet precipitation sample collection started in 1981; prior to that time, only bulk samples were collected.

Volume-weighted mean pH showed a steadily decreasing trend over the period 1974-1981 (40). Since the early 1980s, the annual pH has fluctuated between 3.8 and 4.0 with no discernible trend (41).

Catoctin Mountain Studies

Personnel of the U.S. Geological Survey (USGS) are conducting a study relating acidic rain events to stream pH and aluminum values for first-order streams in the Catoctin Mountains of Maryland. Precipitation samples have been collected at these sites since 1982 (42). Annual volume-weighted mean pH has ranged from 3.9-4.2 during this period.

Hurlock Site

As part of the PPSP co-funded study by USGS of groundwater quality on the Eastern Shore, the USGS collected precipitation samples on a weekly basis at Hurlock, Dorchester County, from April 1984 to July 1984. The volume-weighted mean pH for this period was 4.4 (43).

Wye Institute Site

The University of Maryland Agricultural Extension Service has operated, under Federal sponsorship, a precipitation monitor at the Wye Institute as part of the National Acid Deposition Program. The monitor, which collects precipitation on a weekly basis, has operated since March 1983. The annual volume-weighted mean pH for the first year was about 4.2. For Spring 1984, the volume-weighted mean pH was 4.3.

All the monitoring programs conducted to date show that the annual volume-weighted mean pH of precipitation in the State is generally in the range 3.9-4.2, which is consistent with measurements in the northeastern United States. Precipitation pH from individual storms can vary by up to 1 unit from

the average. To date, there has been no published examination of the detailed patterns of deposition within the State, although work on this topic is presently being supported by PPSP. An analysis of deposition patterns from data collected in Spring 1984 is expected to be completed during 1986.

Storm trajectory analysis conducted for storms recorded at the Deep Creek Lake site showed that storms tracking from the Midwest appear to contribute the lowest pH and highest sulfate concentrations to wet deposition in that portion of the State (37). A similar analysis is being supported by PPSP for data collected under the Coastal Streams Acidification Study described above.

C. Effects

The effects of acid deposition have generally been classified as affecting four types of systems:

- Aquatic
- Terrestrial
- Materials
- Human Health.

Aquatic

Increased inputs of acidic materials via atmospheric deposition have been implicated in the acidification of surface waters. The response of surface waters to these acid inputs is determined in part by:

- The amount of deposition
- The availability of exchangeable soil base cations in the watershed
- The sulfur retention capacity of the watershed
- The types and degree of biological transformations (e.g., sulfate reduction) in the body of water.

Acidification can have dramatic effects on the chemical and biological characteristics of surface waters. Plankton communities of acidic lakes are typically less diverse, (i.e., with fewer species) than those found in non-acidified lakes, indicating a loss of community vitality; however, the abundance and biomass of those species present does not seem to be adversely affected by acidification (44-47). Benthic invertebrate communities in acidic lakes and streams also are less diverse; taxonomic groups such as molluscs and amphipods are especially acid-sensitive (48,49). Decomposition of organic materials is retarded in acidic waters, with a shift from bacterial pathways to decomposition by fungi and yeasts (50).

The aquatic effect that typically receives the greatest attention is the decline of fish populations with increased acidification (51,52). It has yet to be determined how many lakes or streams have been impacted, either in the United States in general, or Maryland in particular. Three mechanisms by which acidification may affect fish populations have been suggested (53):

- Fish kills during episodic acidification
- Reproductive failure
- Decreased food availability and/or quality.

Acidified waters frequently contain elevated concentrations of trace metals (especially aluminum) since high acidity enhances the solubility of metals. These concentrations can adversely affect the survival of the susceptible early life stages of particular fishes (54). At low pH levels in particular, the response mechanisms to elevated aluminum concentrations can include altered osmoregulation and reduced oxygen uptake and transport because of gill damage (55).

Terrestrial

Because of their economic importance forested and agricultural environments have received the greatest attention with regards to potential impacts on terrestrial ecosystems, Acid deposition can damage terrestrial vegetation in several ways. Direct foliar damage and reduced plant growth can be caused by the acidic components of both wet and dry deposition (56). Photooxidants (e.g., ozone) have also been implicated as a cause of severe foliar damage (57, 58). The types of foliar damage most often observed include chlorophyll degradation, accelerated weathering of cuticular wax, necrotic lesions, and gall formation (59). The extent of the damage is largely species specific, depending upon not only the concentration and amount of the pollutant, but also on its contact time. Contact time is clearly dependent upon leaf morphology, which determines the wettability of the leaf surface (59).

While no studies have been conducted in Maryland, results of laboratory and field experiments concerning foliar and growth effects caused by acid deposition in other areas can reasonably be applied to the vegetation typically found in Maryland. The Maryland Interagency Working Group (28) identified tobacco, corn, and soybeans as the agricultural crops that may potentially be impacted by acid deposition. Laboratory (60) and field-grown (61) soybeans have shown reduced growth and increased necrosis and chlorosis when exposed to gaseous sulfur dioxide. However, exposure to simulated acid precipitation apparently stimulated the photosynthetic rates of soybeans with no effect on its yield (61). Nutrient losses have been observed in laboratory-grown tobacco leaves exposed to simulated acid rain (62). Chronic exposures of tobacco leaves to sulfur dioxide and ozone have been observed to cause reduced growth, with the net effect of the combined exposure being equal to the additive effects of the single pollutant (63). However, other studies using tobacco grown under controlled environments showed no effect on either tobacco growth or on yield (64). No apparent reduction in growth or yield have been observed in either field or laboratory-grown corn exposed to acid precipitation (64).

The effects of acid deposition on forest vegetation (trees) can be both direct and indirect. Direct foliar damage has been observed in Scots pine (65) and poplar trees (66). However, indirect effects may have a greater impact on tree growth and forest productivity. Soil acidification, with resulting mobilization of aluminum, has been implicated in the die-back of spruce, beech, and fir forests in Germany (67). However, several other factors (such as disease, ozone exposure, pathogens and drought) have also been identified as possible causes for the recent die-backs in the high elevations of the northeastern United States in addition to acid deposition (68). Soil acidification depends largely on soil capacities for anion adsorption and base saturation. Many questions regarding these soil properties must be addressed before soil acidification effects can be understood. Indirect effects via accelerated cation leaching have also been hypothesized as resulting from deposition of acidic materials. Such a process could result in reduced nutrient availability and eventually reduced tree growth. Direct evidence of increased leaching of Ca, Mg, and K from the Rhode River, MD, watershed has been observed by Correll et al. (40). The degree of the losses depended upon the magnitude of disturbance in the various portions of this watershed. Any long-term effects on vegetative growth in this system obviously depend upon the pool of available nutrients and their rate of replacement. Correll et al. (40) concluded that the size of the available pool is such that significant effects could be expected in a few decades.

Materials Damage

Materials damage caused by acidic atmospheric pollutants has also recently become a concern. Perhaps the best example of damage directly related to acidic deposition is erosion of ancient statuary of marble or limestone (69). Other structures, including buildings, have also been affected. However, metallic and painted surfaces are likely to suffer the most costly damage because they require increased maintenance, more frequent replacement, or substitution with more expensive materials that are less susceptible to damage. Urban structures within Maryland are the most likely candidates for damage due to acid deposition. Identifying the effects of locally-generated acidic materials will be extremely difficult. A NAPAP-sponsored national assessment of the materials damage caused by acid deposition is expected to be completed 1986. Results of this study will provide an indication of the potential for materials damage in Maryland.

Human Health

To date, no direct effects on human health of acid deposition have been documented, although research continues on the effects of inhaling sulfate particles and aerosols. Indirect human health effects (e.g., food chain accumulation of metals and contamination of drinking water) are also being investigated. Although some studies have shown that metal mobilization and bioaccumulation in the food chain (e.g., fish) is occurring, they have not conclusively linked these phenomena to acid deposition as a sole cause (70). No human health effects have been documented as resulting from metal mobilization and bioaccumulation caused by acid deposition. Studies of contamination of drinking water supplies have suggested that increasing corrosivity is the most significant potential impact. A study of cistern systems in Western Pennsylvania showed that heavy metals (e.g., lead, cadmium) which were atmospherically deposited accumulated in the sediments at the bottom of

cisterns and that these metals could appear in the drinking water when conditions allow the suspension of the sediment (70). Studies of a similar nature have not been conducted in Maryland.

D. Studies in Maryland

In March 1983, a State Interagency Working Group was convened to assess the impact of acid deposition on Maryland resources. Members of the working group represented the Maryland Departments of Agriculture, Economic and Community Development, Health and Mental Hygiene, Natural Resources, State Planning, and Transportation. The group reviewed available data on rainwater acidity in the state, on groundwater composition, and on sensitive receptors. The major conclusions of the group's report (28) were:

- Maryland's rainfall is as acidic as anywhere in the United States. During the past 9 years, reported mean annual pH values at Maryland rainwater measurement sites ranged from 3.5 to 4.5. For rural stations, the mean annual average pH was about 4.0.
- No direct adverse effects of acid deposition on the resources of the state could be documented; however, additional field investigations were needed to rule out damage to sensitive resources such as anadromous fish.
- Headwater streams in western Maryland and on the coastal plain may be sensitive to acid deposition.
- Aluminum concentrations and pH values for headwaters of some Chesapeake Bay tributaries were in a range that has been shown to cause deleterious effects to fishes. However, the species of fish tested were not those commonly found in the Chesapeake Bay region (e.g., striped bass, herring, white perch).

The working group recommended additional studies: to evaluate the nature and amount of acidic materials deposited in Maryland, to identify and evaluate the sensitivity of Maryland resources, and to measure the water quality of headwater streams.

Studies currently underway, or recently completed, in Maryland are located primarily in the Coastal Plain and fall into three general categories: watershed; biotoxicity; and remedial action. The State funded projects are directed toward concerns unique to Maryland that are not being addressed by other programs such as NAPAP. These projects are in response to recommendations set forth in the report of the Interagency Working Group on Acid Deposition (28). Several Federally funded projects are also directed toward those recommendations.

Watershed Studies

A major program funded by NAPAP is the National Surface Water Survey (NSWS), which is quantifying the current surface water chemistry in areas of the United States likely to be sensitive to acid deposition (2). The first

phase of the survey began in 1984 with the National Lake Survey, in which nearly 4000 lakes in the northeastern, southern, northern midwest and far west regions of the country were sampled. No lakes in Maryland were included in the survey. The second phase of the NSWS is the National Stream Survey, which is to begin in early 1986. More than 20 Maryland streams have tentatively been selected for inclusion in the stream survey. The latter phases of the NSWS will involve establishing a long-term surface water monitoring network that will allow detection and measurement of chemical and biological trends related to acid deposition. This goal reflects one of the Interagency Working Group's recommendations; however, it is much too early to know if any long-term NSWS monitoring stations would be located in Maryland.

Several watershed studies have been completed or are underway in Maryland's Coastal Plain. The first of these was a coastal stream pilot survey in 1983 funded by PPSP. The objective of this study was to evaluate the potential impact of acid deposition on the water quality of spawning areas for species such as American shad, blueback herring, alewife, white perch and yellow perch. The survey consisted of weekly sampling during March and April of 23 small freshwater tributaries to Chesapeake Bay. These streams are more likely to be impacted by acid deposition than are larger rivers downstream which serve as spawning habitat for striped bass. The typical pH for these small freshwater streams would be 6.5 to 7.0 without acidic input. However, over the two-month sampling period, each of the 23 streams exhibited pulses of pH less than 6.0 at least once during periods of high rainfall. In 14 of the streams, pH values as low as 5.5 were observed, and, most strikingly, in 6 streams, pH values of 4.5 - 4.9 were detected (71,72). The lower levels of pH have been observed to cause almost complete mortality in freshwater fish species (51-55).

Because of the concerns raised by the survey results, a second PPSP -funded study was planned and initiated in 1984. The Coastal Streams Acidification Study, conducted by the Academy of Natural Sciences of Philadelphia (ANSP), was designed to determine the potential role of acidic deposition in changes in the chemistry of anadromous fish spawning streams. Estimates of the loading via atmospheric deposition of acidic materials were made and attempts will be made to determine whether this loading is sufficiently large to explain the episodic pH fluctuations observed in the study streams. Alternative hypotheses for the episodic pH fluctuations will also be considered. To this end, examination of other potential sources of acidity (such as farming practices) in the watersheds will be conducted.

Sampling was conducted on three watersheds chosen from the initial group of 23 streams sampled in 1983. The watersheds chosen were:

- Lyons Creek in Anne Arundel County
- Morgan Creek in Kent County
- Granny Finley Branch in Queen Anne's County.

Lyons Creek was chosen because of the episodic acidic conditions observed during the 1983 survey. Morgan Creek exhibited periods of high total dissolved aluminum concentrations in 1983 and was chosen due to the potential impact of aluminum toxicity on the early life stages of fishes spawning in this stream.

Granny Finley Branch exhibited neither acidic conditions nor elevated aluminum concentrations and was chosen as a control stream. Preliminary analyses of the ANSP study results are underway. It appears that the responses of these streams to precipitation events are variable and likely to depend, in part, on the meteorological and chemical characteristics of the precipitation events. In-depth analyses of the results will be concluded in 1986.

PPSP has also co-funded a study by the U.S. Geological Survey of the potential effects of acid deposition on groundwater quality on Maryland's Eastern Shore. Study elements included sampling of precipitation surface water and groundwater to determine if acid deposition was affecting the Columbia Aquifer, a major drinking water supply on Maryland's Eastern Shore. The study results show that the chemistry of surface and groundwater differs substantially from that of the precipitation which falls in the region (43). Of particular importance is the conclusion that groundwaters do not contain the high dissolved aluminum concentrations that were observed in surface waters.

The U.S. Geological Survey is conducting a study relating acidic rain events to stream pH and aluminum values for first-order streams in the Catoctin Mountains of Maryland, which lie in the Blue Ridge physiographic province. Precipitation samples are collected on an event basis. Interim results (42) indicate that the rainfall is buffered through chemical reactions with minerals in the bedrock and that no deleterious effects would be expected for the local aquatic populations. Studies to identify this reaction mechanism are ongoing.

The Deep Creek Lake study (33-36) funded by PPSP was the major project related to acid deposition conducted thus far in Maryland's Allegheny Plateau region. An important objective of the study was to determine the effect of acid deposition on the water chemistry of the lake. The lake receives relatively large amounts of acid from atmospheric and geologic inputs, but the lake water chemistry showed no trend over four years of study. A companion study co-funded by PPSP and USGS showed that limestone outcroppings provide significant amounts of buffering to the lake (73). It is now thought that the lake is not in danger of near-term acidification.

Biotoxicity Studies

PPSP sponsored an Applied Physics Laboratory field and laboratory study in spring 1985 of the effects of low pH and various dissolved aluminum concentrations on the survival of blueback herring. In the lab, eggs and yolk-sac larvae were exposed to both constant and varying conditions of pH and aluminum. In the field, these life stages were exposed to ambient conditions in Lyons Creek using both in-situ test chambers and a flow-through field laboratory. The laboratory results suggest that blueback herring early life stages are very sensitive to changes in pH and dissolved aluminum conditions, with yolk-sac larvae being more sensitive than eggs. These results predicted that conditions which had been observed in Lyons Creek by ANSP in 1984 could have resulted in high mortality of yolk-sac larvae. The field results neither verified nor refuted these predictions since toxic pH and dissolved aluminum conditions did not occur in Lyons Creek during spring 1985 because of the lack of significant rainfall and run-off events in the period (74). Further studies are planned to define the critical pH below which survival is unlikely and to determine if such conditions can be observed in field bioassay experiments.

The U.S. Fish and Wildlife Service sponsored biotoxicity studies in 1984 and 1985 as part of its Emergency Striped Bass Study. Results from in-situ studies on the Nanticoke and Choptank rivers in 1984 suggest that low pH and elevated dissolved aluminum concentrations may be important causes of mortality of striped bass early life stages (75). Laboratory studies indicated that inorganic contaminants may also contribute to striped bass larval mortality under the low pH conditions encountered in the Nanticoke and Choptank Rivers (76).

Remedial Action Studies

While the relative role of acid deposition and soil in the acidification of surface waters is as yet undefined, a number of countries have developed operational or experimental programs for the mitigation of acidification effects (77). The most common mode of mitigation is the application of a neutralizing agent to terrestrial and aquatic systems. Sweden and Norway have initiated the larger mitigation programs, most likely because the majority of the sulfur and nitrogen deposited in these countries is generated outside of their borders, thereby giving them no option for emission controls.

Although liming terrestrial systems has been conducted in Scandinavia, liming of aquatic systems to mitigate acidic conditions is more common. The overall objective of the mitigation programs is to maintain water quality (especially pH) in the optimum range for growth and reproduction of certain fish population. Depending on the current status of the fish populations, the mitigation programs have been implemented to either restore or protect valuable fisheries resources.

As a participant in the NAPAP studies the U.S. Fish and Wildlife Service is responsible for the development of mitigation techniques for restoring or protecting acid lakes, streams, and groundwater in the United States. To date, the major results of this program have been the establishment of federal-state cooperative projects in which field tests of selected mitigation strategies for lakes and streams will be implemented. Also, handbooks have been completed and include standardized methods for sampling of biological chemical parameters in mitigation projects, site selection, engineering evaluation of mitigation techniques, and dosage models for lakes and streams. Mitigation research in the private sector includes, most importantly, the EPRI-sponsored Lake Acidification Mitigation Project in which several acidic lakes in the Adirondacks are being chemically neutralized by the addition of calcium carbonate.

An experimental stream acidification mitigation project has been very recently initiated in Maryland. Sponsored by the Maryland Tidewater Administration with cooperation from the private sector, this project will entail the deployment of automated stream dosing devices on two coastal streams near Annapolis. The objectives of this project are to assess the impact of acidic spring streamflow on yellow perch spawning and recruitment, and to evaluate the benefits to the water quality and biota in these two streams of neutralizing acidic events.

Another mitigation project, the Mystic Harbor Agricultural Liming Study, funded by PPSP, is currently being conducted near Ocean City, Maryland. This project's objective is to examine quantitatively the effects of the

interactions of acid precipitation and agricultural soil amendments (primarily lime) on the water quality of surface runoff and soil interflow. This project takes advantage of the availability of previously characterized test plots that are hydraulically separated and have been under some cultivation in the recent past. Additions of limestone and agricultural fertilizers have been made to two test plots, in the same amounts as would be recommended to farmers having similar soils. The water quality of surface runoff and soil water from these two test plots will be compared to those from two contiguous control plots. In addition, water quality under vegetated and non-vegetated conditions will be compared. This project will be completed in 1986.

E. Acid Deposition Control Legislation

During the 97th and 98th Congresses, 15 proposals were introduced to amend the Clean Air Act to control acid deposition. The stated goal of all the control legislation is to reduce acid deposition to a level that protects areas perceived as sensitive. Generally, the bills attempt to achieve approximately 50 percent reduction in deposition rates by requiring 8-12 million ton reduction in sulfur dioxide emission over a period of 10-12 years. Control of nitrogen oxides through legislation has been less consistent; some bills imposed strong controls on present and future emissions while others completely ignored control strategies for NO_x. Some bills allowed substitution of nitrogen oxide reductions for sulfur dioxide reductions in a ratio of 2 to 1.

Diverse control strategies are proposed by the various bills to achieve the prescribed reductions in emissions. Often the strategies reflect efforts on the part of the sponsor to mitigate potential adverse impacts of the legislation itself, such as reduced employment in coal supply activities, increased electric rates, or decreased economic growth. The bills also differ significantly in their treatment of compliance and allowable increases in emissions after a reduction has been achieved (26, 18).

Under one commonly assumed scenario, Maryland's share of a national sulfur dioxide reduction program of 12 million tons (the maximum amount now under consideration) would be about 125,000 tons. Apportioning this reduction among sources in the State is generally not specified in the legislation, although it is reasonable to assume that a large portion of Maryland's share would be provided by utility sources. An additional complication is that many electric utilities that serve Maryland supply electricity to Maryland from facilities located in other states.

In order to obtain an estimate of the costs to Maryland of an acid rain control strategy, a hypothetical scenario was established (26) based on a synthesis of the legislation described above. The following assumptions were made:

- National legislation would be passed requiring a 12 million ton reduction from 1980 emission levels. The bill would not include an emission cap.
- Only reductions in sulfur dioxide would be required.

- Maryland's share of this reduction would be 125,000 tons based on the State's relative contribution of sulfur dioxide emissions to the total sulfur dioxide emissions in the control region.
- All reductions in Maryland would come from utilities and be allocated to them according to their emissions in excess of a 1.2 lb SO₂/MMBtu rate.

Details on the assumptions concerning out-of-state controls and financing are contained in reference 26.

Each of Maryland's utilities was requested to design a program to meet its allocated emissions target. For Maryland plants, they were free to choose the technology to be employed to meet the reduction at individual plants. For this preliminary study, the utilities attempted to minimize their individual system-wide costs based on the engineering and environmental costs associated with each facility. However, the control plans and underlying assumptions, although reasonable, do not necessarily represent the lowest or highest cost or optimum programs for the individual utilities or for the State of Maryland.

For all utilities combined, the total 15-year system-wide costs were 3.8 billion dollars; annual average costs were 256 million dollars (stated in 1985 dollars). The costs varied substantially by utility (Table VII-1). Costs for PEPCO, the utility required to achieve the largest reduction, were greatest at 2.2 billion dollars for 15 years. Delmarva Power and Light's (DP&L) costs were the lowest, approximately 200 million dollars total.

Table VII-1. Total system-wide costs of the sulfur dioxide reduction program (in millions of 1985 dollars)

Utility	Total 15 Year Cost	Average Annual Cost
Baltimore Gas & Electric	\$ 834	\$ 56
Delmarva Power & Light	199	13
Potomac Edison	634	42
Potomac Electric Power Company	<u>2,173</u>	<u>145</u>
Total all utilities	\$3,840	\$256

Reference:26

In this study compliance was defined as the difference between actual 1980 emissions and projected emission using 1980 plant-use statistics and the projected new lower emission rates, a method used frequently in the legislation introduced during the 97th and 98th Congresses. It must be noted that when

compliance is defined in this way, PEPCO did not achieve its targeted reduction; the costs discussed above more closely corresponds to their share of a 10 million ton nationwide reduction plan.

Because it was assumed that all costs would eventually be borne by each utility's ratepayers, a rough estimate was made of the expected change in a typical customer's electric bill. To do this, an average surcharge resulting from emission compliance was first computed by dividing annual costs by projected kilowatt-hour (kWh) sales for each year (Table VII-2). This computation assumes the charge would be uniformly distributed over all rate classes (residential, commercial, industrial), a reasonable first approximation in the absence of information concerning how such costs would actually be allocated. An assumed monthly residential electrical use of 750 kWh was then multiplied by the surcharge to determine the increase in a residential customer's monthly bill. Based on this calculation, BG&E and DP&L customers' bills would increase by an average of 1-2 dollars per month, PE customers by 3 dollars per month, and PEPCO customers' by 5 dollars per month. These figures represent approximately a 3, 2, 7, and 10 percent increase in an average electric bill for each utility, respectively. First-year costs would be about double the average costs (Table VII-2) and would equal, for example, about 100 dollars in the first year for a PEPCO customer.

Table VII-2. Average monthly surcharge to finance a sulfur dioxide reduction program

Utility	First Year Surcharge (mills/kWh)	Average Surcharge (over 15 years) (mills/kWh)
Baltimore Gas & Electric	4.1	2.1
Delmarva Power & Light	2.4	1.3
Potomac Edison	7.1	3.8
Potomac Electric Power Company	11.0	6.5

NOTE: These surcharges are computed by dividing revenue requirements by projected energy sales, assuming a uniform surcharge over all rate classes.

Reference: 26

In the process of estimating the costs of an acid rain control program, a number of issues were identified that would require resolution before any control program could be implemented. These issues fell into two general categories--those concerned with the development and implementation of a specific state reduction plan, and those specific to utility power plant

operations. Because these issues affect both the distribution of economic costs and the long-term operation of utility systems, it is important that they be carefully considered in development of any implementation program.

F. Conclusions

It is clear that rainfall in Maryland is acidic; however, the sources contributing to this acidity have yet to be fully determined. Preliminary analyses suggest that the sources of acidity measured in Western Maryland lie to the west and northwest of the State. Analyses to determine detailed deposition patterns across the State are underway; these analyses will also attempt to determine source regions for deposition in the central and eastern sections of Maryland. Monitoring programs are in place to measure deposition in Maryland relative to the surrounding region.

National studies sponsored by NAPAP have shown both potential and actual damage to aquatic and forest ecosystems and materials. Acid deposition has been strongly implicated in aquatic ecosystem damage; other factors may play a more important role in damage to forests and materials. A preliminary assessment of the causes and consequences of this damage is expected to be published by NAPAP in 1986.

Numerous studies of the effects of acid deposition on Maryland's resources have been completed or are underway. Deep Creek Lake seems to be protected from near-term acidification due to limestone outcroppings in the watershed and under the lake. Studies in several small watersheds in the Catoctin Mountains suggest that rainfall is buffered by bedrock minerals in those watersheds and that no deleterious effects would be expected for the local aquatic populations. Studies in the Coastal Plain have shown that groundwater used for drinking water supplies is not affected (over the short-term) by acid deposition, but that chemistry of freshwater tributaries may be. A pilot survey in 1983 showed stream water conditions (low pH and high dissolved aluminum) in the anadromous fish spawning habitat that might be deleterious to early life stages of species such as American shad, blueback herring, alewife, white perch, and yellow perch. Preliminary results from a more detailed study in 1984-85 suggest that these stream chemistry conditions, and their pattern, are influenced by rainfall meteorology and chemistry.

Concern has been raised at the state and federal levels about the impact of acid deposition-induced changes in surface water quality on the spawning and early life stages of anadromous fish. Studies of blueback herring and striped bass in Maryland have been completed or are under way. The results show that the early life stages of these species are very sensitive to low pH and high dissolved aluminum and that rapid changes in these parameters may cause even greater mortality than static conditions. Such episodic changes have been observed in the field. Thus it appears that the earlier expressions of concern were justified.

Two liming projects are under way in Maryland. One of these is designed to assess the impact of water quality conditions in the spring on yellow perch spawning and recruitment, and to evaluate the benefits of stream liming to

water quality and biota. Another project, near Ocean City, is examining the effects of agricultural soil amendments on the water quality of surface runoff and soil interflow produced by acid precipitation.

Numerous bills have been introduced in the Congress to amend the Clean Air Act to control acid deposition. The bills generally attempt to achieve an approximately 50 percent reduction in deposition rates by requiring an 8-12 million ton reduction in sulfur dioxide emissions over a 10-12 year period. Costs to Maryland of a hypothetical control scenario have been estimated. For Maryland's four major utilities, the total estimated 15 year cost of a 12 million ton national reduction was 3.8 billion dollars.

REFERENCES - CHAPTER VII

- (1) Harding, D., and J.M. Miller. The Influence on Rain Chemistry of the Hawaiian Volcano Kilauea. J. of Geophysical Research, Vol. 87, No. C2, 20 February 1982, pp. 1225-1230.
- (2) National Acid Precipitation Assessment Program: Annual Report, 1984. Interagency Task Force on Acid Precipitation, Washington, DC, 1985.
- (3) Omernik, J.M. Total Alkalinity of Surface Waters. U.S. Environmental Protection Agency, 1982.
- (4) Kellogg, W.W., R.D. Cadle, E.R. Allen, A.L. Lazrus, and E.A. Martell. The Sulfur Cycle. Science, Vol. 175, 1972, pp. 587-596.
- (5) Galloway, J.N., and D.M. Whelpdale. An Atmospheric Sulfur Budget for Eastern North America. Atmos. Environ., Vol. 14, 1980, pp. 409-417.
- (6) Acid Deposition Atmospheric Processes in Eastern North America. Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation, National Academy of Sciences, Washington, DC, 1983, National Academy Press.
- (7) Li, T.Y., and H.E. Landsberg. Rainwater pH Close to a Major Power Plant. Atmos. Environ., Vol. 9, 1976, pp. 81-88.
- (8) Anderson, D.E. Continuous Measurement of pH Using an Automatic Precipitation Collector and Analyzer. University of Maryland Meteorology Program, University of Maryland, Publication No. 78-178, 1978.
- (9) Li, T.Y. Continuous Records of Precipitation pH Close to a Major Power Plant. University of Maryland, Institute for Physical Science and Technology, Technical Note BN 841, 1976.
- (10) Patrinos, A.A.N., M.J. Dana, and R.E. Saylor. Wetfall Chemistry Studies Around a Large Coal - Fired Power Plant in the Southeastern United States. Paper presented at American Chemical Society Meeting, Las Vegas, NV, 1982.
- (11) Hutcheson, M.R., and F.P. Hall, Jr. Sulfate Washout from a Coal-Fired Power Plant Plume. Atmos. Environ., Vol. 8, 1974, pp. 23-28.
- (12) Granat, L., and H. Rodhe. A Study of Fallout by Precipitation Around an Oil-Fired Power Plant. Atmos. Environ. Vol. 7, 1973, pp. 781-782.
- (13) The Acidic Deposition Phenomenon and Its Effects; Critical Assessment Review Papers, Volume I: Atmospheric Sciences. U.S. Environmental Protection Agency, Office of Research and Development, EPA-600/8-83-016A, May 1983.
- (14) Cogbill, C.V., and G.E. Likens. Acid Precipitation in the Northeastern United States. Water Resources Research, Vol. 10, No. 6, December 1974, pp. 1133-1137.

- (15) Likens, G.E., and T.J. Butler. Recent Acidification of Precipitation in North America. Atmos. Environ., Vol. 15, 1981, pp. 1103-1109.
- (16) Hansen, D.A., G.M. Hidy, and G.J. Stensland. Examination of the Basis for Trend Interpretation of Historical Rain Chemistry in the Eastern United States. Environmental Research and Technology, Inc., Westlake Village, CA, ERT P-A097, February 1981.
- (17) Campbell, S., and M. Arlauskas. Comparison of Sulfur and Nitrogen Oxide Emission Rates with Wet Deposition Rates in the State of Maryland. Prepared by Martin Marietta Environmental Center for the Maryland Power Plant Siting Program, PPSP-MP-45, April 1983.
- (18) Acid Rain and Transported Air Pollutants: Implications for Public Policy. U.S. Congress, Office of Technology Assessment, OTA-O-204, June 1984.
- (19) Maryland. Annual. Maryland air quality data reports, State of Maryland, Department of Health and Mental Hygiene, Bureau of Air Quality and Noise Control, Baltimore, MD.
- (20) Maryland. 1977a. 1976 Emissions inventory report, State of Maryland, Department of Health and Mental Hygiene, Bureau of Air Quality and Noise Control, Baltimore, MD. BAQNC-TM 76-09 (1976) and 77-21 (1977).
- (21) Maryland. 1977b. Fuels and emissions totals for state, State of Maryland, Department of Health and Mental Hygiene, Air Management Administration, Baltimore, MD.
- (22) Maryland. 1978. Fuels and emissions totals for state, State of Maryland, Department of Health and Mental Hygiene, Air Management Administration, Baltimore, MD.
- (23) Maryland. 1980. Fuels and emissions totals for state, State of Maryland, Department of Health and Mental Hygiene, Air Management Administration, Baltimore, MD.
- (24) Maryland. 1982. 1979 Emissions and fuels use report, State of Maryland, Department of Health and Mental Hygiene, Air Management Administration, Baltimore, MD AMA-TM 82-06.
- (25) Paine, A. 1986. Personal communication between A. Paine, Maryland Air Management Administration, and R. DiMartino, Martin Marietta Environmental Systems, 8 January 1986.
- (26) Kete, N., R. Roig and D.H. Brown. 1985. Acid Rain Control Legislation: Costs to Maryland Electric Utilities and Implementation Issues. Prepared for the Maryland Power Plant Siting Program.
- (27) Corio, L. 1985. Review of long-range transport models for application to estimate impacts in Maryland from sources located outside of Maryland. Martin Marietta Environmental Systems, Columbia, MD, Technical memorandum. Ref. No. 3704-607.

- (28) The Potential Effects of Acid Deposition in Maryland: Report of the Maryland Interagency Working Group on Acid Deposition. State of Maryland, Office of Environmental Programs, Department of Health and Mental Hygiene, January 1984.
- (29) Workshop on Data Compatibility. Conducted in Baltimore, MD, by Martin Marietta Environmental Systems for the State of Maryland and National Bureau of Standards, August 29, 1984.
- (30) Miller, J.M., D.H. Pack, and K. Telegados. 1983. The pH of Precipitation in the Washington, D.C. Area: 1975-1981. National Oceanic and Atmospheric Administration, Air Resources Laboratory.
- (31) Lodge, J. 1985. Telephone conversation with R. Roig, Martin Marietta Environmental Systems, 10 July 1985.
- (32) Academy of Natural Sciences of Philadelphia. 1986. Effects of Acid Deposition on Maryland Coastal Plain Streams. Prepared for Maryland Power Plant Siting Program.
- (33) Ferrier, M.D. Assessment of Acid Inputs to Deep Creek Lake, Garret County, Maryland: Third Annual Report. Prepared by Garrett Community College for the Maryland Power Plant Siting Program, PPSP-AD-8, 1984.
- (34) Scott, H., S. Campbell, and M. Giuliano. An Assessment of the Chemical Composition of Rain and Surface Water Samples Collected at Deep Creek Lake, Garrett County, Maryland: First Annual Report. Prepared by Martin Marietta Environmental Center for the Maryland Power Plant Siting Program, PPSP-MP-39, 1982.
- (35) Campbell, S., H. Scott, and J. Ondov. Chemical Composition of Precipitation and Watershed Samples Collected at Deep Creek Lake, Garret County, Maryland: Third Annual Report. Prepared by Martin Marietta Environmental Systems for the Maryland Power Plant Siting Program, PPSP-AD-9, August, 1984.
- (36) Campbell, S. Chemical Composition of Precipitation and Watershed Samples Collected at Deep Creek Lake, Garrett County, MD: Fourth Annual Report. Prepared by Martin Marietta Environmental Systems for the Maryland Power Plant Siting Program, July 1985.
- (37) Pfeffer, N., S. Campbell, and L. Corio. Analysis of Air Mass Trajectories Associated with Rain Events at Deep Creek Lake, Maryland, 1981-1982. Prepared by Martin Marietta Environmental Systems for the Maryland Power Plant Siting Program, PPSP-AD-11, May 1985.
- (38) Andrew, D. 1985. Telephone conversation with R. Roig, Martin Marietta Environmental Systems.

- (39) Conkwright, R.D., J.M. Hill and M.V. Chattey. 1982. Chesapeake Bay Aerial Precipitation Survey: Wetfall Precipitation Chemistry Basic Data Report. Prepared by the Maryland Geological Survey for the U.S. Environmental Protection Agency.
- (40) Correll, D.L., N.M. Goff, and W.T. Peterjohn. 1984. Ion balances between precipitation inputs and Rhode River watershed discharges. In: Geological Aspects of Acid Deposition, pp. 55-76. O. Bricker, ed. Stoneham, MA: Butterworth Publishers.
- (41) Correll, D.L. 1985. Telephone conversation with R. Roig, Martin Marietta Environmental Systems.
- (42) Katz, B. 1985. Telephone conversation between B. Katz, U.S. Geological Survey, and R. Roig, Martin Marietta Environmental Systems, 16 August 1985.
- (43) Bachman, L.J., and B.G. Katz. Draft. Relationship between precipitation quality, shallow groundwater geochemistry, and dissolved aluminum in eastern Maryland. Prepared by the U.S. Geological Survey for the Maryland Power Plant Siting Program.
- (44) Yan, N.D., and P. M. Stokes. The Effects of pH on Lake Water Chemistry and Phytoplankton in a LaCloche Mountain Lake. Water Pollution Research, Vol. 11, 1976, pp. 127-137.
- (45) Almer, B., W. Dickson, C. Ekstrom, E. Hornstrom, and V. Miller. Effects of Acidification on Swedish Lakes. Ambio, Vol. 3, 1974, pp. 30-36.
- (46) Confer, J., T. Kaaret, and G. Likens. Zooplankton Diversity and Biomass in Recently Acidified Lakes. Canadian Journal of Fisheries and Aquatic Sciences, Vol. 40, 1983, pp. 36-42.
- (47) Sprules, W.G. Midsummer Crustacean Zooplankton Communities in Acid-stressed Lakes. Journal of the Fisheries Research Board of Canada, Vol. 32, 1975, pp. 389-395.
- (48) Singer, R. Ed. Effects of Acidic Precipitation on Benthos. Proceedings of a Regional Symposium on Benthic Biology, North American Benthological Society, Hamilton, NY, 1981, p. 156.
- (49) Okland, J., and K.A. Okland. pH Level and Food Organisms for Studies of 1000 Lakes in Norway. Proceedings of the International Conference on the Ecological Impact of Acid Precipitation, D. Drablos and A. Tollan, eds., SNSF Project, As-NHL, Norway, 1980, pp. 326-327.
- (50) Francis, A.J., H.L. Quinby, and G.R. Hendrey. Effect of Lake pH on Microbial Decomposition of Allochthonous Litter. In: Early Biotic Responses to Advancing Lake Acidification. G.R. Hendrey, ed., Stoneham, MA, 1984, Butterworth Publishers, pp. 1-22.

- (51) Schofield, C.L. Historical Fisheries Changes in the United States Related to Decreases in Surface Water pH. In: Acid Rain/Fisheries. T.A. Haines and R.E. Johnson, eds., 1982, American Fisheries Society, Bethesda, MD, pp. 57-68.
- (52) Harvey, H.H., and C. Lee. Historical Fisheries Changes Related to Surface Water pH Changes in Canada. In: Acid Rain/Fisheries. T.A. Haines and R.E. Johnson, eds., 1982, American Fisheries Society, Bethesda, MD, pp. 45-56.
- (53) Harvey, H.H. Population Responses of Fish in Acidified Waters. In: Acid Rain/Fisheries. T.A. Haines and R.E. Johnson, eds., 1982, American Fisheries Society, Bethesda, MD. pp. 227-244.
- (54) Baker, J.P., and C.L. Schofield. Aluminum Toxicity to Fish as Related to Acid Precipitation and Adirondack Surface Water Quality. Proceedings of the International Conference on the Ecological Impact of Acid Precipitation, D. Drablos and A. Tollan, eds., SNSF Project, As-NHL, Norway, 1980, pp. 292-293.
- (55) Wood, C.M., and D.G. McDonald. Physiological Mechanisms of Acid Toxicity to Fish. In: Acid Rain/Fisheries. T.A. Haines and R.E. Johnson, eds., 1982, American Fisheries Society, Bethesda, MD, pp. 197-226.
- (56) Evans, L.S. Biological Effects of Acidity on Vegetation: A Review. Environmental and Experimental Botany, Vol. 22, 1982, pp. 155-169.
- (57) Shriner, D.S. Interactions Between Acidic Precipitation and SO₂ or O₃: Effects on Plant Response. Phytopathology News, Vol. 12, 1978, p. 152.
- (58) Troiano, J., L. Colavito, L. Heller, and D.C. McCune. Effect of Simulated Acid Rain and Photochemical Oxidant on Seed Development in Soybeans. Phytopathology, Vol. 71, 1981, p. 565.
- (59) Shriner, D.S. Plant Response to Acidic Deposition. In: The Acidic Deposition Phenomenon and Its Effects, Critical Assessment Review Papers. Vol. II. Effects Sciences, EPA-600/8-83-016B, 1983, pp. 3-5 to 3-10.
- (60) Evans, L.S., and K.F. Lewin. Growth, Development, and Yield Responses of Pinto Beans and Soybeans to Hydrogen Ion Concentrations of Simulated Acidic Rain. Environmental and Experimental Botany, Vol. 21, 1981, pp. 103-114.
- (61) Irving, P.M., and J.E. Miller. Response of Field-grown Soybeans to Acid Precipitation Alone and in Combination with Sulfur Dioxide. Proceedings of the International Conference on the Ecological Impact of Acid Precipitation, D. Drablos and A. Tollan, eds., SNSF Project, As-NHL, Norway, 1980, pp. 170-171.
- (62) Fairfax, J.A.W., and N.W. Lepp. Effect of Simulated Acid Rain on Cation Loss from Leaves. Nature, Vol. 255, 1976, pp. 324-325.

- (63) Tingley, D.T., and R.A. Reinert. Effect of Ozone and Sulfur Dioxide, Singly and in Combination, on Plant Growth. Environmental Pollution, Vol. 2, 1975, pp. 117-125.
- (64) Irving, P.M. Crops. In: The Acidic Deposition Phenomenon and Its Effects, Critical Assessment Review Papers, Vol. II. Effects Sciences, EPA-600/8-83-016B, 1983, pp. 3-42 to 3-64.
- (65) Cape, J.N., I.A. Nicholson, J.W. Kinnaird, and I.S. Peterson. Influence of a Polluted Atmosphere on Cuticle Degradation in Scots Pine (Pinus sylvestris). Proceedings of the International Conference on the Ecological Impact of Acid Precipitation, D. Drablos and A. Tollan, eds., SNSF Project, As-NHL, Norway, 1980, p. 146.
- (66) Evans, L.S., N.F. Gmur, and C.F. DaCosta. Foliar Response of Six Clones of Hybrid Poplar to Simulated Acid Rain. Phytopathology, Vol. 68, 1978, pp. 847-856.
- (67) Ulrich, B. Dangers for the Forest Ecosystem due to Acid Precipitation; Necessary Counter measures: Soil Liming and Exhaust Gas Purification. U.S. Environmental Protection Agency Translation TR-82-0111. EPA/NCSU Acid Precipitation Program, North Carolina State University, Raleigh, N.C.
- (68) McLaughlin, S.B., D.J. Raynal, and A.H. Johnson. Forests. In: The Acidic Deposition Phenomenon and Its Effects, Critical Assessment Review Papers, Vol. II. Effects Sciences, EPA-600/8-83-016B, 1983, pp. 3-27 to 3-42.
- (69) Yocum, J.E., and N.S. Baer. Effects on Materials. In: The Acidic Deposition Phenomenon and Its Effects, Critical Assessment Review Papers, Vol. II. Effects Sciences, EPA-600/8-83-016B, 1983, pp. 7-1 to 7-49.
- (70) Indirect Effects on Health In: The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers, Vol. II. Effects Sciences, EPA-600/8-83-0166F, 1984.
- (71) Survey of Water Quality and Flow in Maryland Coastal Zone Streams: A Data Report. Prepared by Ecological Analysts, Inc., for Maryland Power Plant Siting Program, Report No. PPSP-50, 1983.
- (72) Janicki, A., and R. Cummins. An Analysis of Survey Data on the Chemistry of Twenty-three Streams in the Chesapeake Bay Watershed: Some Implications of the Impact of Acid Deposition. Prepared by Martin Marietta Environmental Center for the Maryland Power Plant Siting Program, Department of Natural Resources, Ref. No. MP-83-51, 1983.
- (73) Hodges, A.L. In preparation. Estimated Average Annual Alkalinity of Six Streams Entering Deep Creek Lake, Garrett County, Maryland. Prepared by the U.S. Geological Survey. Open-File Report 85-197.

- (74) Klauda, R.J. and R.E. Palmer. In preparation. Laboratory and Field Bioassay Experiments on Blueback Herring from Maryland Coastal Plain Streams. Prepared by the Johns Hopkins University, Applied Physics Laboratory for the Maryland Power Plant Siting Program.
- (75) Hall, L.W. Jr., A.E. Pinkney, and L.O. Horseman. 198. Mortality of striped bass larvae in relation to contaminants and water quality in a Chesapeake Bay tributary. Trans. Amer. Fish. Soc. 114:861-868.
- (76) Palawski, D., J.B. Hunn and F.J. Dwyer. 1985. Sensitivity of Young Striped Bass to Organic and Inorganic Contaminants in Fresh and Saline Waters. Trans. Amer. Fish. Soc. 114:748-753.
- (77) Fraser, J.E., and D.L. Britt. 1983. Liming to mitigate surface water acidification: International programs, strategies, and economic considerations. In: Lake Restoration, Protection and Management. North American Lake Management Society, U.S. EPA 440/5-83-001.

