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THE ANACOSTIA RIVER, ECOLOGICAL IMBALANCE OF AN URBAN STREAM VALLEY

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> "A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it." [1]

INTRODUCTION

The Anacostia River, a branch of the Potomac, flows in the eastern part of the District of Columbia, and in adjacent suburban Prince George's and Montgomery Counties. It is in many ways a prototype of the urban stream showing severe ecological imbalances resulting from intensive and unplanned land use and the general impact of technology.

In a real sense too the Anacostia is a "peoples river" in that the 993,000 inhabitants of its basin (Jaworski, Clark, and Feigner, 1970) largely have low to intermediate incomes and a low degree of mobility so that they depend critically on the river for recreation and general environmental quality. It is thus an area in which environmental and social problems meet.

Except for certain headwater tributaries the ecological state of the Anacostia is a dismal one. Although the basin is not heavily industrialized it is affected by a wide variety of biological, chemical and physical pollution. Many headwater and interstream areas are eroding at catastrophic rates, and are loosing their remaining top soil and vegetative cover because of unplanned land development. Even within the public parks we see much evidence of poor watershed management practices, as is illustrated by purposeful and unnecessary removal of indigenous ground cover, which is best adapted to prevailing conditions, so that rapid run-off and erosion result. We find that the pollution and other problems of the Anacostia can be resolved into the following fundamental points:

1. The critical dependence of the environmental quality of water, land, and air on the presence of natural areas, that is, on areas that possess undisturbed top soil and indigenous vegetative ground cover.

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[1] Justice Oliver Wendell Holmes, U.S. Supreme Court decision in New Jersey vs New York et al re diverting water from the Delaware River. 282 US 336, 342. (Grover and Harrington, 1943.)

2. The direct or indirect relation between most forms of pollution and ecological imbalance and the inefficient transportation system centered on the automobile.

3. The piecemeal and narrow planning and execution of public and private agencies in relation to land and water use. This point is particularly well-illustrated by the hydrologic practices of the public agencies.

This paper is a preliminary report of an investigation now in progress. Although considerable attention has recently been given to biological (sewage) pollution ("Potomac water Quality," 1969; Jaworski et al., 1970) in the Anacostia basin, it is our objective here to pinpoint sources of less well known physical and chemical pollutants and poor land use and hydrologic practices. We also offer suggestions for further pollution documentation and remedies which may be undertaken by private and public agencies. It is our feeling that the emerging picture of the deteriorating environment in the Anacostia Valley and some remedies we suggest will have meaning for other urban rivers.

PHYSICAL SETTING

The Anacostia Basin, a 184 mi^2 (477 km^2) area, lies on the boundary between two physiographic provinces, the deeply weathered crystalline piedmont to the northwest and the semiconsolidated coastal plain sedimentary region to the east. The main stem and the major tributaries are associated with Quaternary stream channel deposits of the Wicomico formation upstream and with the recent alluvium deposits of the Pamlico formation in the estuary region. Much of the latter deposit resulted from the historic agricultural and urban erosion period, including the present; it also includes some artificial fill (Cooke and Cloos, 1951).

Although the main stem lies on these geologically young formations the latter lie astride the approximate boundary of the Cretaceous Patuxent and Patapsco[2] formation, the oldest coastal plain sediments in the area. It may be of some signifiance that this region is also part of the intake area for the ground water in the Patuxent formation, which is an important aquifer for western Maryland. Because most of the coastal plain sediments exclusive of the aquifers are semiconsolidated silts and clays, they are subject to rapid erosion where exposed and engender locally poor drainage conditions (Cooke and Cloos, 1951).

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[2] Including Arundel Clay at the base.

The main stem of the Anacostia and its major tributaries are characterized by well defined flood plains which consist of silts, sands and gravels. Field observations show that originally these flood plains were covered with lush forest typical of the eastern hardwood zone. Exceptions are areas of flood plain which originally consisted of open water but are now covered by the Pamlico formation. Only human activity has prevented afforestation of these areas. It is apparent that the original flood plain forests played an important role not only in the regional ecological scheme but also as a regulator of climate (Reifsnyder and Lull, 1965) and in the regimen of the stream itself. In particular, the flood plain vegetation acted as a trap for sediments transported during floods through the resistance it created which slowed the water enough to bring about deposition. As a result the waters flowed more slowly to the Potomac estuary than at the present time and much soil which might otherwise have been lost to the sea was trapped for the enrichment of the region. It is interesting that these flood plain soils are today being exploited as a source for top soil in urban residential development. However, greatly increased erosion rates of the agricultural and urban period have swamped the flood plains with the same sterile subsoils which also are clogging the estuary. In this great volume of sediments such topsoils as are still available for erosion are lost by dilution.

The hydrologic and other physical characteristics of the Anacostia basin depend greatly on climatic factors. Because the regional rainfall is in excess of 40 inches (1.02 meters) per year and because much of this precipitation falls in summer thunderstorms, the discharge in cubic feet per second of streams as well as their erosion-sedimentation capabilities vary widely in time (Darling, 1962). For example at the gauging station of the Northeast Branch at Riverdale the discharge has been known to vary by a factor of 2000 in forty-eight hours.

The generally humid climate also favors acid soil conditions and pH values as low as 5.0 have been measured by the authors. It is significant that certain heavy metal pollutants, characteristic of urban areas are soluble in acid waters. This is especially true of lead (Garrels and Christ, 1964) and of cadmium (Musgrave, 1966). It is interesting in this regard that the waters of the Patuxent aquifer in western Maryland show characteristically low pH values in the upper Anacostia Basin (Mack, 1966). It may be that this reflects a close chemical communication with the surface in this area.

PHYSICAL AND CHEMICAL POLLUTANTS OF THE ANACOSTIA RIVER

The pollutants of the Anacostia River may be classified as physical, chemical and biological, although obviously many pollutants contain components of two or three of these classes. Thus for example biological constituents of sewage are degraded into, and coexist with, inorganic phosphates, nitrates and carbonates.

Biological pollutants from sewage have received extensive study and documentation (Jaworski et al., 1970); however we shall not be primarily concerned with these biological pollutants here since our objective is to draw attention to the less well known but perhaps equally important physical and chemical pollutants.

Pollutants may also be classified as to source. The chief sources are (1) sewage disposal, (2) eroding land, (3) industry, and (4) general technological installations including the countless private appurtenances to our culture. The last source in particular has been little appreciated until recently and its magnitude is still largely unknown.

The major physical pollutant of the Anacostia Basin in terms of total mass is silt from eroding land. It has been estimated (Jaworski, et al., 1970) that the silt contribution of the entire Anacostia watershed is 114,000 tons per year or an average of 620 tons mi^{-2} yr^{-1} (239 tons km^{-2} yr^{-1}). However, the Northeast and Northwest branches yield 1,060 and 1,850 tons mi^{-2} yr^{-1} (409 and 714 tons km^{-2} yr^{-1}) respectively ("Potomac River water Quality," 1969). Since most of the Anacostia Basin is covered either by vegetation or by urban developments such as streets and buildings most of this silt must come from areas or eroding vegetation-free land. According to U. S. Department of Interior study ("The cost of clean water and its economic impact," 1969) the sediment yield from areas of new construction (such as highway sites) was found to be 10 times greater than that of cultivated land, 200 times greater than that of grass areas, and 2000 times greater than that of forest areas, depending upon the rainfall, the land slope and the exposure of the bank. In one particular case, that of the Scott Run watershed in Fairfax County, Virginia, it was found that sediment was produced at a rate of some 89,000 tons mi^{-2} yr^{-1} (34,363 tons km^{-2} yr^{-1}).

As an illustration of erosion from a highly exposed area of high relief in the Anacostia Basin we may refer to the "Greenbelt" area on the Indian Creek watershed and lying mostly within the municipality of Greenbelt, Maryland. The area in question lies just north of Greenbelt Road and extends north along the edge of the Indian Creek flood plain. Clay fill obtained from this area and deposited on the Indian Creek flood plain is also included. The areas in question are almost completely bare of vegetation and largely consist of unconsolidated clays and silts of Patapsco (including the Arundel clay) formation. Bare clay hills between 50 and 100 ft (15 and 30 meters) in height show gullies more than 6 ft (2 meters) deep (Fig. 1). Examination of the basin and the U. S. Geological survey map (1965) indicates that perhaps less than 2 percent of the basin of the Northeast Branch of the Anacostia consists of land as exposed to erosion as this. If we assume the 2 percent figure we may estimate the yearly erosion rate as follows: Since the drainage area of the Northeast Branch has an average yearly erosion rate of 1,000 tons mi^{-2} we adopt this figure. We may also assume that the land other than the Greenbelt type erodes at a rate between grass and forest land but more like grassland. To be on the conservative side we may assume a rate of erosion of 1/500 the rate of the Greenbelt area. Then if B is the erosion rate of Greenbelt type land in tons $\text{mi}^{-2}\ \text{yr}^{-1}$, we have

$$\frac{B}{500}\ (0.98) + B(0.02) = 1,000 \text{ tons mi}^{-2}\text{yr}^{-1}$$

or

$$B = 45,537 \text{ tons mi}^{-2}\text{yr}^{-1}$$

$$= (17,582 \text{ tons km}^{-2}\text{yr}^{-1})$$

This figure is of the same order of magnitude as that of the Virginia land referred to earlier. Since the area of the Greenbelt exposure is about 1/5 mi^2 the above figure indicates that the Greenbelt area alone could contribute of the order of 10,000 tons or about 8,000 cubic yards yr^{-1} of silt to the Anacostia River and the estuary.

In the case of the Greenbelt area most of the silt is eroded and transported during times of heavy rains during which it finds its way down storm drains to Indian Creek. At such times Indian Creek and the entire Anacostia "run red" with the characteristic red clay. At such times also the large volume of silt and clay swamps the many other pollutants which are so apparent during low and average flow.

Many of the most common types of physical and chemical pollutants from industrial sources are those emanating either directly from the automobile or related commerce. Examples are the conspicuous debris emanating from concrete, asphalt and sand and gravel production for highways. One of the largest sources of this type of pollution on the Anacostia is the sand and gravel industry at Branchville. This industry is located on the flood plain of Indian Creek immediately to the west of the Greenbelt area previously referred to. The physical pollutants from this source include sand and gravel wash ("Potomac Water Quality," 1969) spoiled batches of concrete, waste lumber frequently coated with concrete, asphalt, metallic junk, and other material (Figs. 2 and 3). Debris of this type may be traced all along Indian Creek and the Northeast Branch into the mainstream of the Anacostia at Bladensburg and beyond. Large fragments of concrete (Fig. 4) may be seen along the banks. It is likely that these are transported during flood stage through the mechanism and drag of buoyant and drag forces exerted by turbulent and high density silt-laden waters at such times.

The capacity of the Anacostia and its tributaries to transport debris is deceptive if observations are confined to times of low or normal flow conditions. The average discharge of the Northeast Branch gauging station at Riverdale, Maryland for the last thirty some years was observed to be 76.0 cfs (2.2 cubic meters per second) ("Water Resources Data for Maryland and Delaware," 1968). However the minimum and maximum discharges observed during this time were 1.4 cfs (0.04 cms) and 10,500 cfs (297 cms) respectively. The minimum discharge, which occurred on Sept. 11, 1966 was followed by a 3,300 cfs (93 cms) discharge less than 48 hours later ("Water Resources Data for Maryland and Delaware," 1966). Such large variations in discharge correspond to increases in mean velocity by many factors, at the Riverdale Station.[3] Velocities at localized points within the channel would be increased even more. How these velocity changes effect the transporting power with respect to solid debris may be estimated by considering that the tractive and drag forces on such debris is comprised of components which are proportional to the velocity on one hand and proportional to the square of the velocity on the other (Bruun and Lackey, 1962). Since the tractive force is proportional to the particle diameter of the particle which can just be moved, and since the mass of a particle is proportional to the cube of its diameter, the velocity squared component indicates that the mass of a particle which can be transported may at times vary as the sixth power of the velocity. Although this is the theoretical maximum in transporting power it does show what is possible with a given increase in velocity. Thus for example, if the velocity were increased by a factor of 10 the mass moved might be increased by as much as 10^6.

Of course much of the solid industrial waste does not move directly downstream but is deposited on the flood plain where it creates local pollution problems. Where concrete is deposited on the flood plain before it sets, as in many instances at the Branchville location (Fig. 5), it impares the water absorbing capacity of the soil and brings about more rapid run-off into the stream. Also in this case the cement particles are loosened by acid leaching (as we show later) and transported directly into the stream. This illustrates the point that flood plains which have been denuded of vegetation contribute debris to their streams by surface wash even when no flooding as such occurs. These processes may be observed at work along Indian Creek during rainy weather.

In addition to the industrial sources cited above there are also innumerable sources of solid waste pollution in the Anacostia Basin that are related either to the day to day commerce or to the ordinary habits of the populace. As an illustration of commercial solid waste pollution we may again draw attention to the eroding Greenbelt area and its surroundings. At this location we have observed a variety of metallic junk mixed with the same silt deposits which find their way down storm drains into Indian Creek (Fig. 6). Omnipresent components of this

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[3] George Comer, personal communication.

junk are toxic substances such as the lead in discarded battery cases. This material accompanies the silt into Indian Creek through the storm drains as does the dissolved matter derived from it by contact with the acid waters. It is apparent that by the principles of hydrology all these materials are eventually carried down river and are either deposited on the flood plains or in the estuary. The extent to which these disolved materials may enter the aquifer of the Patuxent formation is unknown at present.

It is an important point, alluded to above, that the solid debris from industrial and commercial activities has effects far beyond its unsightliness and mechanical effects such as obstruction of navigation. By its decay and dissolution noxious chemicals may be released and find their way into drinking water and biological food chains. Even concrete which is sometimes regarded as chemically inert may have a significant effects on the pH of natural waters. Our observations show that when large volumes of concrete are in contact with relatively small amounts of water natural pH values of 5.5 may be raised to 7.5 or more. We find that although $Ca(OH)_2$ (calcium hydroxide) is a prominent component of cement, its distinctive x-ray pattern is usually missing from concrete debris which has been in contact with natural waters. It is well known that $Ca(OH)_2$ reacts with acid waters and makes them more alkaline. Similarly it has recently been shown (Gustafson, 1970) that such toxic organic compounds as polychlorinated biphenyls (PCB's) emanate from decaying solid wastes which contain plastics. It has been demonstrated that these compounds are highly concentrated from natural waters by marine food chains.

Another highly toxic constituent of solid wastes is cadmium. Lagerwerff and Specht (1970) found that this metal is present in certain automobile tires as concentrations ranging from 20-90 ppm. According to their experiments, conducted in part within the Anacostia Basin, Cd-bearing particles from this source contaminate the soil and are concentrated along highways. It is well known that because of chemical similarities to zinc, cadmium is always associated with the latter metal. If this seems likely that, because of the propensity for cadmium to go into solution in acid waters, considerable amounts of the metal must find their way into the Anacostia River from the large population of cars within the basin.

In addition to the chemical pollutants which pass into aqueous solution from the solid state, there are also many chemicals which enter the stream directly as soluble liquids or as immisible liquids which float on the water surface or which form emulsions. Like dissolved matter such liquids are not greatly restricted by physical barriers but pass directly downstream with the water. Perhaps the best examples of such substances are petroleum products, which enter the Anacostia River from industries, commercial centers and general human activities. As in the case of many other pollutants we find that most petroleum products stem either directly or indirectly from the automobile. Thus the waters of Indian Creek shown an enhanced oil slick in passing through the Branchville sand and gravel works. Our investigations show that this oil comes at least in part from waste oil which is deposited on the flood plain in the form of discarded oil containers, oily rags used in wiping machinery and similar materials. Examples of commercial sources of oil pollution are to be found on Greenbelt Road where service station operators dispose of waste oil directly down storm drains leading to Indian Creek. In addition to such willful acts, much oil pollution also stems from the accumulated drippings from private and public vehicles on highways and in extensive parking lots, such as those of the Greenbelt shopping areas. Oil from these sources may be observed emerging from a storm drain on the south side of Greenbelt Road just to the east of Indian Creek. This oil forms prominent slicks during times of low or moderate water flow and has conspicuously stained the concrete of the drain (Fig. 7).

The oil pollution which emanates from the above sources along Indian Creek may be traced downstream, along the Northeast Branch, and along the Anacostia at Bladensburg, Maryland and beyond. In time of low to moderate water flow a strong odor of hydrocarbons may be detected and continuous oil slicks are present along the bank (Fig. 8). These oil slicks are so continuous that they apparently exclude the bank as a habitat for frogs, since none were ever observed by us. However the Anacostia River at Bladensburg does have a number of species of fish that are able to survive the multiple pollutants. Among these are catfish which are sought by the local inhabitants for food.

Because of widespread use of pesticides in the urban and suburban region of the basin, residues of the latter of necessity reach the river. A test conducted during August 5 to 11, 1969 detected no chlorinated hydrocarbon pesticides in the Blue Plains Sewage disposal effluent (Jaworski, 1969). The detection limits for most of these compounds is in the range of 5 to 25 nanograms liter^{-1} (pp 10^{12}). However quantities of DDT in this range are readily concentrated in aquatic food chains and have been shown to be toxic to brine shrimp (Harrison, Lauck, Mitchell, Parkhurst, Tracy, Watts and Yannacone, 1970). It is obvious that the question of pesticides in urban streams requires reevaluation at lower detection limits.

HYDROLOGIC PRACTICES, PRIVATE AND PUBLIC

Although streams in the Anacostia Basin are naturally flashy, this characteristic has been greatly increased by the large areas covered by pavement and buildings as well as a storm drain system which is designed to speed run-off. Although reforestation consequent to the decline of agriculture has somewhat compensated these effects of urbanization, it is perhaps significant that the lowest discharge in 29 years at the Riverdale gauging station occurred in 1966. Little effort has been made to protect some critical steep interstream areas and flood plains which have recently become subject to stripping of their natural vegetation. For example the flow of Indian Creek and its natural flood plain have been constricted and otherwise encroached upon both by the pollutants referred to earlier and by fill materials south of Greenbelt Road. On other parts of the flood plain of the Northeast Branch downstream from Riverdale there is no flood plain forest on the recently deposited Pamlico formation. Even on public park land adjacent to this flood plain the natural understory and ground cover have been destroyed and the area reseeded to grass so that the areas are subject to excessively fast run-off and erosion (Fig. 9). This results from the unsuitability of grass as ground cover when compared to indigeous vegetation. It is interesting that in many instances, such as that illustrated in Fig. 9, run-off is facilitated by public agencies even in areas where there are no adverse effects of local flooding. This shows what a deeply ingrained part of public policy is the rapid evacuation of water.

It is interesting to compare run-off from the three following classes of ground cover: 1) The ordinary grass sod referred to earlier, 2) Indigenous forest ground cover and 3) Managed vegetative ground cover with water holding properties comparable to indigenous ground cover. While it is true that water loss through transpiration effects is less for grass than for the forest ground cover, it must be kept in mind that far more water is retained by the forest ground cover than by the grass which replaces it. Thus forest land is more efficient than sod in recharging the ground water which feeds streams. Consequently the indigenous vegetation is a better stream flow regulator than is ordinary sod. Furthermore, the transpired water of forests makes a notable contribution in moderating summer temperatures (Reifsnyder and Lull 1965).

Although examples of the third class of ground cover may be found which approximate the water holding capacity of forest ground cover these will require continuous maintenance. As for the case of ordinary grass, such forms of ground cover represent imposed environmental modifications characterized by a higher energy flux than the indigenous vegetation. If this energy of maintenance, consisting of fertilization, mowing etc. is withheld the area spontaneously reverts to the indigenous type. Furthermore since the high energy flux is dissipated by pollutants (Mueller, 1971) all ground cover forms other than indigenous ground cover add to the pollution load of a watershed. Consequently indigenous ground covers have a distinct advantage from an overall environmental standpoint.

A factor which further increases the rate of run-off is the practice of the public agencies in straightening and paving tributary streams and ditches which lead into the Anacostia. As an example we may consider the ditch east of Riverdale, Maryland (Fig. 10) which has a gradient of the order of 100 ft. per mile (19 meters per kilometer). Although such stream modifications have been introduced to alleviate local flooding they can result in unforeseen effects downstream. Thus we need only consider that when water attains high velocities on a resistant (paved) bed it acquires a large potential to do erosive work. Although the kinetic energy engendered does no work while the water flows on the paved bed, it does when the rapidly moving water reaches the main stream with silty banks and bed such as characterize the Anacostia. The result is that the banks and bed are rapidly eroded and the material is transported downstream and deposited in the estuary. The effects of such erosion may be seen in numerous caving banks along the stream (Fig. 11). Thus what is gained in flood protection upstream may be more than compensated for by increased erosion rates in the main stream and consequent silting of the channel and estuary. It is interesting that because of such hydrologic practices silting of the channel and estuary would continue even if all erosion upstream could be halted.

Temporarily solving a local flooding problem by concreting to increase the volume and speed of the runoff can also create downstream flooding problems. At times the increased flow can not be contained at the next bend in the stream and paving, flood control relief will telegraph a similar problem further downstream. The end result of this procedure turns a watershed holding system into a water release, flushing system.

ECONOMIC FACTORS

It is axiomatic that pollution abatement is highly dependent on economics. The studies reported here indicate that significant abatement of water pollution will be expensive. For example, greatly reducing industrial pollution will entail effectively separating cumbersome cleansing and waste disposal processes and the streams on which they depend. Similarly the prevention of oil pollution from motor vehicles will require either leak-proof cars or grease traps in storm drains which will be effective in a variety of weather conditions. In the existing economic system the logical source of funds for pollution abatement is in the cost of the goods and services responsible for pollution. In this context it is important to establish the cost to the public which results from the existence of specific pollution sources. This is a difficult task for pollutants such as oil, toxic chemicals and concrete since few measures are as yet being taken to abate them and many of their deliterious effects are of such a subtle character that they are only beginning to be recognized. There have, however, been expenditures for certain types of pollution abatement for some time.

For example, besides the large sums of money that are spent for construction of stream projects, a continuing cost is being incurred for sediment removal. The Army Corps of Engineers maintains the flood control and navigation channel in the Anacostia River from the foot of 15th Street, S. E., Washington, D. C. to the vicinity of Bladensburg, Maryland. Since channel construction in 1959 the following maintenance sums have been spent to remove sediments.

Table 1
Volume and Cost of Sediment Removal on the Anacostia
(Reynolds, 1971)

Fiscal Year	Cubic Yards Removed	Cost
1961	116,700	$132,703
1964	100,247	$ 95,900
1967	135,256	$136,375
1970	83,300	$ 84,139

We have seen that the sediment source in southwestern Greenbelt is estimated to contribute of the order of 10,000 tons of sediment to the Anacostia each year. In terms of the cost of removal shown in Table 1, sediments from this source cost the public of the order of $10,000 per year.

SUMMARY AND CONCLUSIONS

It is apparent that the Anacostia River Valley is out of balance with respect to stresses placed upon it by ungoverned technological expansion. Symptoms of this imbalance are widespread biological, chemical and physical pollution as well as destructive land use and hydrologic practices. As a result the regimen of the river is in continuous transition and its great potential as an environmental asset is being lost to the nearly one million inhabitants of the Basin. Instead it has become an enormous burden and threat to the health and well-being of these inhabitants. There is no question but that the environmental deterioration will lead to high tax burdens for years to come.

As a result of our preliminary study we make the following recommendations so that immediate remedial action can be undertaken:

(a) That a comprehensive ecological study of the basin be undertaken.

(b) That a program of afforestation and establishment of indigeous ground cover on flood plains be undertaken.

(c) That a program of soil stabilization and land reclamation be undertaken for eroding areas.

(d) That critical headwater areas which have been denuded of vegetation or converted to sod be replanted to indigenous vegetation or carefully planned alternatives.

(e) That means be sought to prevent automotive oil from reaching the river. This might involve vehicle inspection to prevent leaks and the installation of oil traps in storm drains.

(f) That means be sought to slow run-off by modification of the storm drain systems.

(g) That the river be continuously monitored for a variety of chemical pollutants including heavy metals and organic compounds.

(h) That a study be undertaken to determine the potential for pollution of coastal plain aquifers.

We urge particularly that the recommendations be coordinated with those set forth in the excellent studies by J. H. Cumberland (1965) and the U. S. Department of Interior ("The Potomac - A Model Estuary," 1970).

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Figure 1a. Eroding coastal plain sediments consisting largely of clay and silt. Much of this material has been disturbed by heavy equipment and large quantities of it have been removed and dumped on the nearby Indian Creek flood plain.

Figure 15 Eroding coastal plain sediments consisting largely of clay and silt Much of this material has been disturbed by heavy equipment and large quantities of it have been removed and dumped on the nearby Indian Creek flood plain.

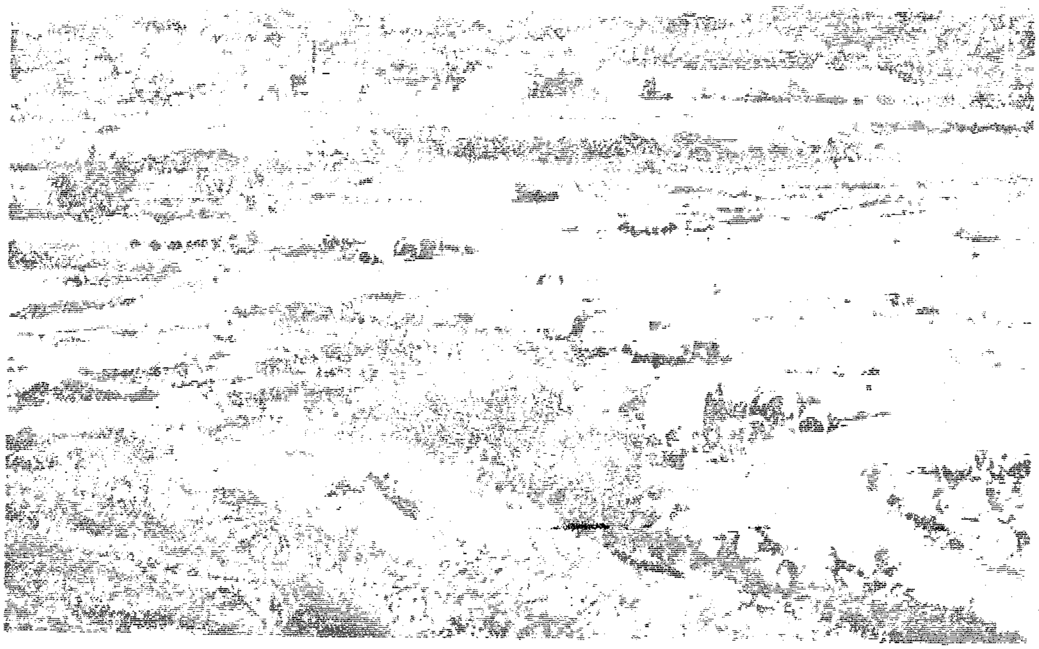

Figure 2. Panorama of the Indian Creek flood plain at the Branchville sand and gravel industrial site. Buildings of the operation are at the upper left. Note variety of dumped debris and "roads" constructed from waste concrete.

Figure 3. Close-up of debris on Indian Creek flood plain at the Branchville site immediately to the north of the area shown in Fig. 2. The debris consists of a variety of junk and includes a considerable quantity of oil containers and oily rags.

Figure 4a. A panorama of the Anacostia River Channel opposite the Prince George's Marina. Large fragments of rubble, consisting in part of concrete blocks are deposited on the mud flats.

Figure 4b. A panorama of the Anacostia River Channel opposite the Prince George's Marina. Small concrete fragments are scattered along the stream banks and on the flood plain.

Figure 5. A steep sided pile of spoiled concrete on the Indian Creek flood plain at the Branchville industrial site.

Figure 6. Silt and debris wash around a storm drain at Greenbelt, Maryland. A large proportion of silt from the eroding sediments at this site finds its way down the storm drain. Much metallic junk and other debris is also washed into these drains.

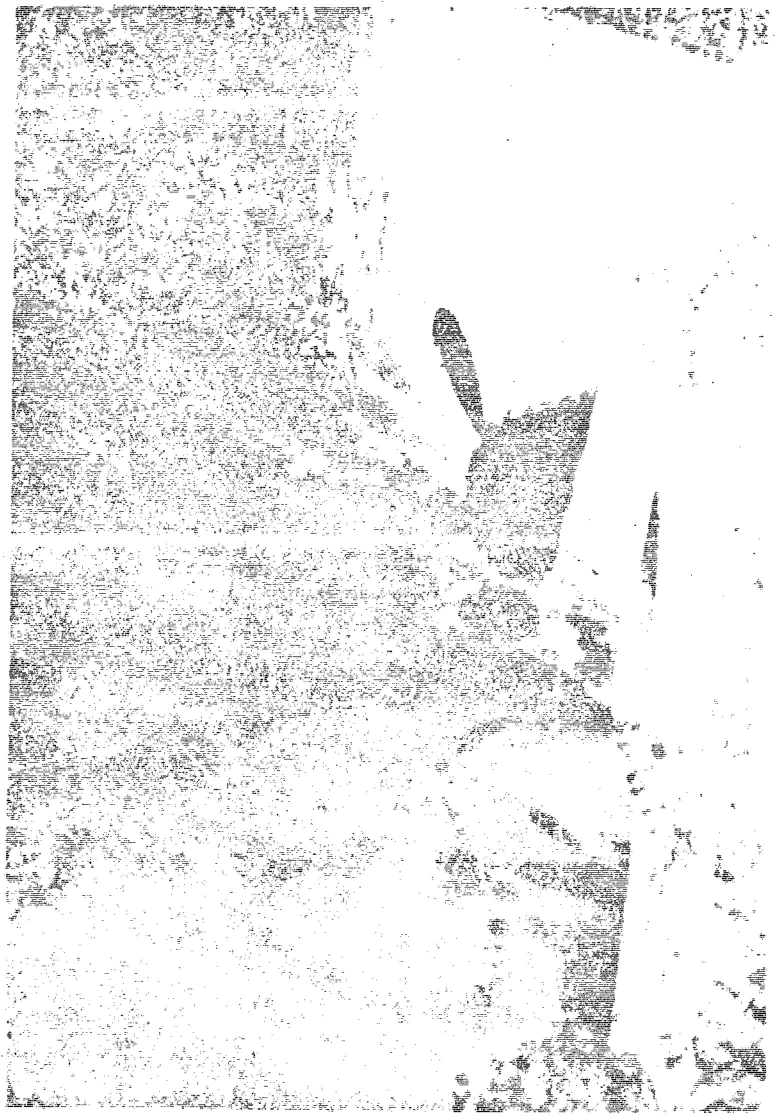

Figure 7. Storm drain outlet in ditch leading to Indian Creek on the south side of Greenbelt Road. Note heavy oil slick on the water. The vegetation and concrete are heavily oil stained.

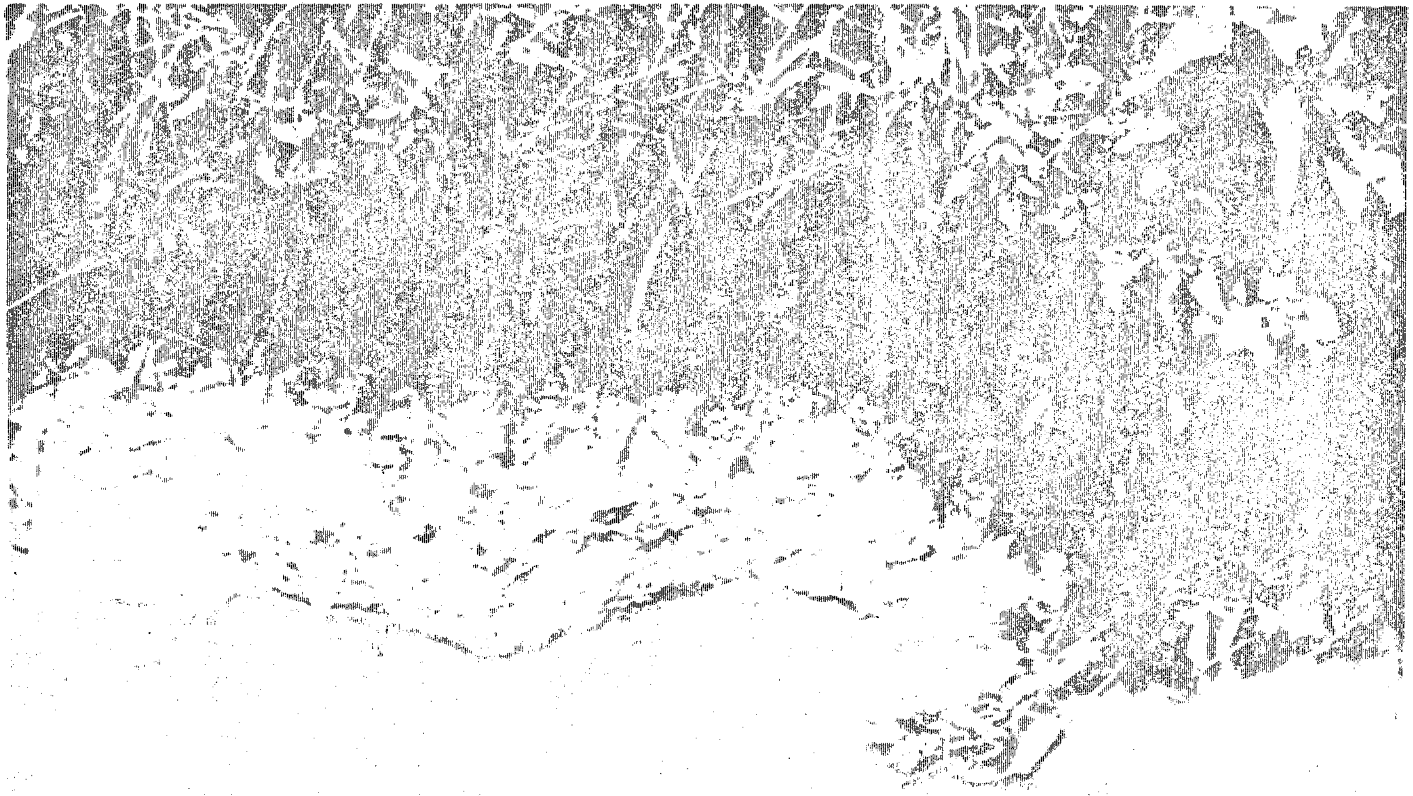

Figure 8. Oil slick on bank along the Northeast Branch of the Anacostia River near Bladensburg, Maryland. The oil thickly coats the bank mud and extends onto the water.

Figure 9. Flood plain along the Northeast Branch of the Anacostia River south of Riverdale, Maryland. The grass covered surface is subject to erosion from sheet wash.

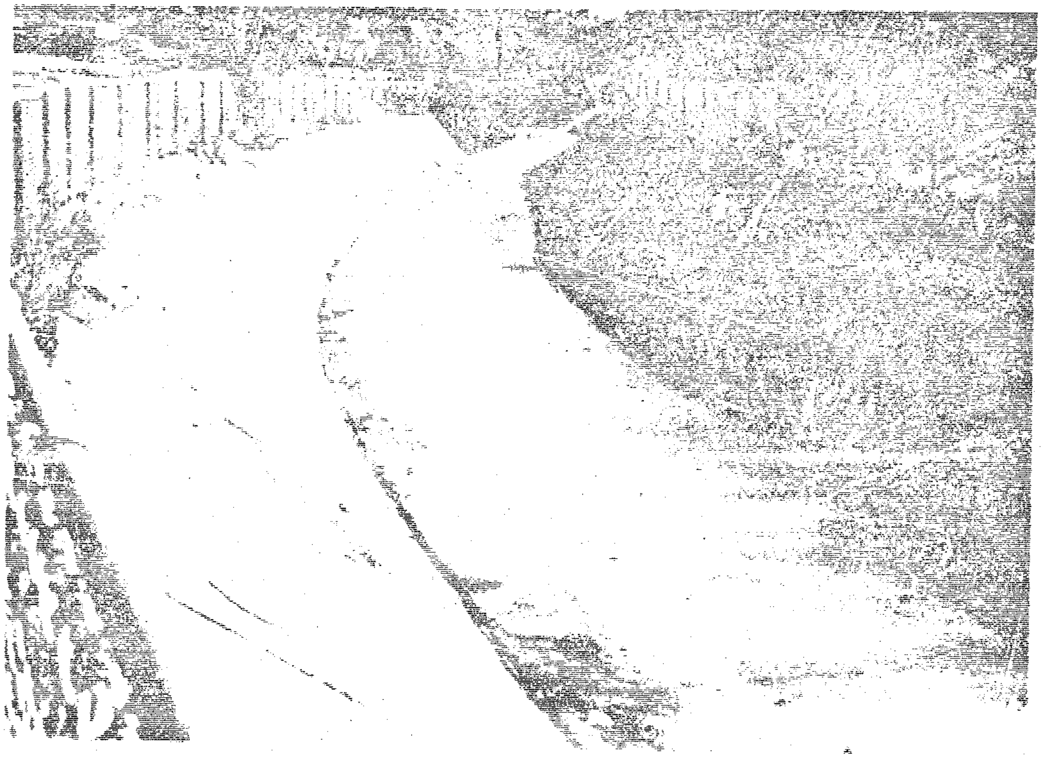

Figure 10. Paved ditch at the site of an intermittent branch of the Anacostia River east of Riverdale, Maryland. Run-off in such ditches attains high velocities and great potential for erosion downstream.

Figure 11. Typical caving banks along the Northeast Branch of the Anacostic River south of Riverdale, Maryland. Such caving results largely from rapid run-off upstream and is aggrevated by the paving of stream beds and ditches.