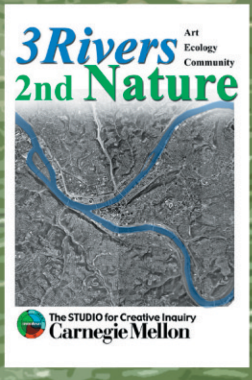

3R2N Terrestrial Report: Allegheny River
Phase 3 - 2002
Riverbank Geology

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I. Abstract

The intent of the 3R2N terrestrial study is to describe and document conditions of riverbank geology, accessibility, preservation, and restoration potential along the Allegheny River in Pools 1, 2, 3, and 4, Allegheny County, Pennsylvania. Data collected during the 2002 field season includes bank and berm slopes, heights, material types and grain sizes, material conditions, accessibility potential, and floodplain identification. Data was collected along $1/10^{th}$ mile sections of each bank, which were identified in the field with a Global Positioning Receiver (GPS). This data was entered into a database for later GIS and ARCINFO analysis. Riverbank access was graded into three categories, and mapped with ARCVUE computer software. Preservation data was also graded into three categories, and mapped. The data from the access and preservation maps was filtered through a Boolean truth chart, and riverbank sections worthy of restoration were identified, graded, and mapped. Riverbank grain sizes and materials distribution were plotted for each pool, and the resulting trends discussed.

II. Geological Setting

A. Geological Time

In order to present a geological history of the Allegheny River, the rocks through which it flows, and the ages of the materials transported by the river, a discussion of the amount of time is presented, using the geological time scale used today (fig. 1). This time scale is divided into Eras and Periods. The bedrock layers exposed in the Allegheny River valley from Freeport, Pennsylvania (Pool 4) to downtown Pittsburgh (Pool 1) are from the Pennsylvanian Period, in Paleozoic Era (meaning "old life") dating from about 300 million (ma) years ago. If one were to drill a hole in Pittsburgh, down through 16,000 feet of sedimentary layers, much older rocks will be found, from the Precambrian Era, about 1,200 ma (million years ago). These ancient crystalline rocks (non-sedimentary) are exposed on the surface about 150 miles north of Toronto, Ontario, Canada, and in the Philadelphia area in Pennsylvania. The simplified geological time scale (fig. 1) illustrates the Eras and Periods. The sedimentary beds exposed in the Allegheny River valley are shown in the local stratigraphic rock column, which shows an expanded portion of the Pennsylvanian Period (fig. 2), and range from the middle Conemaugh Group (all of the Glenshaw Formation, and most of the Casselman Formation) and the upper portion of the Allegheny Group.

B. Geological Time and a Geological History of the Allegheny River

The present-day Allegheny River flows southward from New York and Pennsylvania, to its confluence with the Ohio and Monongahela Rivers at Pittsburgh, Pennsylvania. It is slowly eroding and downcutting through the bedrock of the Pittsburgh region, which consists of flat-lying sedimentary beds of shale, sandstone, limestone, clay stone, and coal that were originally deposited during the Pennsylvanian Period of geological time (about 300 million years ago). These bedrock layers can be seen from certain points along the Allegheny River today (fig. 3). During this time of rock formation, the river drainage system and topography were totally different from that seen today; the ancestral rivers flowed west into a shallow sea that covered Western Pennsylvania and Eastern Ohio. The climate was tropical, as the equator was very close to the Pittsburgh area due to continental drift. Figure 4 is a paleogeographic map of Pennsylvania, as of about 300 million years ago. The climatic environment at this time in Pennsylvania's history was similar to that of the Amazon River delta in Brazil; the climate was very hot and steamy, with high amounts of rainfall. This type of climate in the ancestral Western Pennsylvania area was due to its proximity to the earth's equator; processes of continental drift have moved the North American continent northward about 45° latitude. Plants grew quickly in this environment; and then decayed, and formed thick layers of organic matter that was later was compressed and changed to coal. Huge insects lived in this environment, with some dragonfly species having a wingspan of over thirty inches. The rivers that drained this ancestral landscape flowed from east to west, into the shallow sea that covered much of Western Pennsylvania and Ohio at that time; the beds and channels of these old rivers have no relationship to those of the rivers now seen in the region. The sources for these ancestral rivers were in the mountains to the east, which predated the Appalachians.

The history of the Allegheny River as we know it today probably began back at the beginning of the Cenozoic Era, about sixty million years ago (Wagner, 1970). During this time, Western Pennsylvania was a broad, flat plain similar to those now seen in the mid-western United States. There was probably very little topographic relief, and there was little elevation difference between the tops of any hills and the water levels of the Allegheny. The topog+raphic relief in Pittsburgh is now nearly 700 feet, as the level of the water in the Allegheny at the Point is 710 feet above sea level, and the tops of the highest hills are almost 1400 feet above sea level.

During the late Cenozoic era (about five million years ago) geological processes slowly uplifted the Pittsburgh area, increasing the slope of the Allegheny River, allowing it to start downcutting erosion. The erosional style during the early Cenozoic Era was one of sidecutting, with large river meander loops. As the Allegheny flowed faster due to uplifted land, and a greater downslope river gradient (with a larger resulting erosive capability), the river's course straightened out somewhat and sideways erosion was abandoned to greater downward erosion. Deep valleys were then cut, about 400 feet below the elevation of the plain formed during the early Cenozoic Era. If one looks out at the Pittsburgh landscape from a high point (such as the USX Tower downtown) one can see that all the hilltops are level, and represent the remnants of this old plain (fig. 5). The downcutting action of the Allegheny continued until the river's water level was about 200 above that seen today.

There was a temporary hiatus of the downward erosion of the Allegheny, and this was affected by the advance of the great ice sheets that covered Northwestern Pennsylvania during the "ice ages." There were four ice sheet advances during this time period, but the next to the last ice advance radically changed the courses of some of our rivers.

The Allegheny River has not always flowed south, emptying into the Ohio River, with the Monongahela. Before the third ice advance, the Ohio River originally flowed north into Lake Erie, in the valley of the present-day Beaver River. The ice sheet advance dammed the north-flowing Ohio River, and water impounded behind it forming a large valley-fill lake. This lake, called "Lake Monongahela," probably formed between 750,000 and 970,000 years ago (Marine and Donahue, 2000). Thick deposits of sand, mud, gravel, and cobbles can be seen in certain places within Pittsburgh, at about 920 feet above sea level; this deposit is known as the "Carmichaels Formation," or the "Parker Strath" (Wagner, 1970). These unconsolidated sediments represent material deposited by the Allegheny and Monongahela Rivers when they were impounded by glacial ice to the north. Figure 6 represents these terrace deposits and abandoned loops in the Pittsburgh area, and figure 7 shows these deposits in Allegheny County. Marine and Donahue (2000) have found evidence for this lake as far south as present-day West Virginia. The Cathedral of Learning (University of Pittsburgh) and the Carnegie Museum of Natural History both rest on the Carmichaels Formation deposits. Sometime during this high water event, the southern portion of the Ohio River eroded through its divide, and started to flow southward.

Before the advance of the glacial ice, there were three ancestral rivers that combined to form the Allegheny River as we know it today. Figure 8, showing the pre-glacial river drainage of Western Pennsylvania, has the “Upper Allegheny” River flowing northwestward from northern Pennsylvania into New York, and into the ancestral Lake Erie basin. The “Middle Allegheny” River flowed southwestward from Tidioute, PA., and then turning northwest into the Lake Erie basin. Much of this “Middle Allegheny” river moved in the bed of present French Creek. The “Lower Allegheny” River followed the present-day bed closely, with a confluence at the site of Pittsburgh, with the Monongahela. The resulting ancestral Ohio River flowed northward into the Lake Erie basin. This river followed the bed of the present-day Beaver River for a short distance.

As the glacial ice finally retreated, the old Ohio River divide was eroded through, and all the water from the Allegheny flowed southward to the Mississippi River, as it does presently. Lake Monongahela drained, and the river started again on its downcutting action. There was a fourth ice advance that deposited a blanket of unconsolidated glacial till in the northern portions of the Allegheny River drainage basin and much of this material was deposited in the Allegheny riverbed, due to outwashing from the surrounding hills. One of the major differences between the Allegheny and Monongahela riverbank and bottom materials is the introduction of glacial alluvium, which the Monongahela lacks. Downcutting remains the major erosional style of the Allegheny, even though there is still some meandering and sidecutting. The water level of the Allegheny dropped about 200 feet, since the third ice advance; this may give an idea of how slow erosional processes are on a major waterway.

Figure 9 is a map of the present drainage patterns in Western Pennsylvania, showing also the furthest advance of glacial ice.

III. Data Aquisition and Analysis

A. Field Methods

The field work for Year 3 of the project was confined to Pools 1, 2, 3, and 4 of the Allegheny River, from Freeport, PA, to the point at Pittsburgh, PA. Pool 1 of the Allegheny River starts at Pittsburgh, and ends at Lock and Dam #2, in Highland Park; Pool 2 starts at Lock and Dam #2 in Highland Park and ends at Acmetonia, PA. Pool 3 starts at Lock and Dam #3 at Acmetonia and ends at Lock and Dam #4 at Natrona, PA. Pool 4 covers the Allegheny River from Natrona, PA to Lock and Dam #5, at Schenley, PA, just upriver from Freeport, PA. Schenley, PA is near the confluence of the Allegheny and Kiskiminetas Rivers.

Both banks of the Allegheny River (and the banks of the islands) were divided into 1/10th mile sections. These section's start and stop points were programmed in to a GPS (Global Positioning System) receiver unit as latitude and longitude points. This GPS receiver was used aboard the field vessel to determine each section's starting and ending point.

The geology and geometry of the riverbank and/or berm was described for each 1/10th mile section. If a berm was present in a section, its slope was reported (in degrees) and the average grain size distribution data was recorded. A modified version of the Wentworth-Udden scale of grain sizes was used to report data for this study (Boggs, 1987):

Boulder Size	› 256 mm.	
Cobble Size	› 64 mm.,	‹ 256 mm.
Pebble Size	› 4 mm.,	‹ 64 mm.
Coarse Sand Size	› 1 mm.,	‹ 4 mm.
Sand Size	› 1/16 mm.,	‹ 1 mm.
Silt Size	› 1/256 mm.,	‹ 1/16 mm.
Clay Size		‹ 1/256 mm.

Along with the grain size distribution data, and the berm slope in degrees, the percentages of natural and manmade materials were recorded for each section. Manmade materials include slag, cement, steel, wooden bulkheads, gabion, stone block, rubble, and "other."

Natural materials (if not moved and deposited by human operations) were classified as bedrock, boulders, cobbles, gravel, sand, mud, and "other." Driftwood piles and other garbage that deposited or dumped on the berm were not included in any of the geological descriptions.

The descriptions for the riverbanks were described using the same procedure as the berm; the bank slope was reported in degrees, the grain size distribution of the bank materials was determined, and the percentages of the natural and manmade materials was recorded for each 1/10th mile bank section.

The condition of the berm and bank materials was reported as "consolidated" or "unconsolidated." An example of a consolidated bank would be a steel bulkhead, or a stone block wall. Unconsolidated natural bank and berm materials include sand, gravel, cobbles, silt, and mud. Manmade materials can also be unconsolidated, including slag piles, and coal mine waste dumps.

Along with the berm and bank slope steepness number (in degrees), four categories of steepness were recorded. The first, "vertical," implies a 90° "slope." A "steep" bank or berm is one that has a slope greater than 45°, but is not vertical. A "moderate" slope is less than 45°, but greater than 22°; and a "slight" bank or berm slope is less than or equal to 22°.

The bank and berm slopes were measured using a wooden Jacob's Staff, and a geological compass that has a built-in clinometer. The Jacob's Staff was placed parallel with the slope to be measured, and the compass was placed on the staff, and an angle in degrees was then recorded. Most berm slopes were less than 25°, and bank slopes usually were greater than 45°. The bank height measurements were determined by line-of-sight from the opposite bank, or the middle of the river, using an object with a known height (such as a building, or a railroad freight car) for comparison. Bank heights were also determined by climbing the bank, noting its slope, and estimating height using simple trigonometric relationships.

Bank and berm accessibility was reported as "easy," "moderate," and "no access." Easy access (from the water side of the bank and/or berm) usually had a berm with a slope of less than 22°, and a material grain size distribution that allowed easy landing from a boat. Large boulders inhibit access, as does thick, soft deposits of mud and silt. The berms that had the easiest access had a large amount of sand, coarse sand, and pebble sized material, and a small amount of cobble sized grains. Steep banks with no berms (and bank slopes greater than 45°) generally had more difficult access, and a vertical wall or bulkhead was classified "no access."

Grain size distributions for the bank and berm materials were measured by picking one spot of the bank or berm (about 1 meter square) if the rest of the 1/10th mile section had similar material characteristics. If the grain size of the bank and/or berm material changed significantly in one section, then an overall size distribution average was reported. Banks that were covered by dense vegetation were sampled with a shovel to determine materials and grain size ranges. Berm and bank areas that appeared to be in a natural state were sampled, and the material was sieved to determine grain size distribution ranges.

B. Access Descriptions

Figures 10, 11, and 12 show riverbanks that are vertical, and have consolidated materials that are manmade. These banks are classified under the "no access" category. Figure 10 is a high cement dock, now inactive, that was once used by PPG Industries, near Glassmere, PA. This wall is over twenty-five feet high. Figure 11 is a steel bulkhead used as a dock for Allegheny Ludlum Steel Co. in Natrona, PA. These walls are over twenty feet high. The third photograph (fig. 12) is an example of a vertical high wall built from large interlocking cement blocks, used as a barge loading dock. Many industrial sites along the Allegheny River utilized an unsaleable waste product as a building aggregate, increasing the amount of level land above high flood stage.

Other areas of "no access" include the riverfront adjacent to lock and dam structures, and portions of the bank blocked by shipping activity.

Figures 13, 14, 15, and 16 are areas that have difficult, but possible access. There is a lack of berm in these examples, the grain sizes of the bank materials are very coarse (boulder sizes), and the bank slope is steep, prohibiting easy landing from the water. Figure 13 is a portion of bank where large boulders of natural bedrock have slid down the bank, and lie at the water's edge making access very difficult. Figure 14 depicts a similar situation as in figure 13, but the boulders were placed by man, as a bank stabilization tool. Figure 15 is a portion of the left bank of the Allegheny River just below Lock and Dam #4, at Natrona, Pa.; the bank has been stabilized with boulder to cobble sized stones, set in an orderly fashion. The dam highwalls upriver are vertical, or "no access" areas. Figure 16 is a steep bank built up using industrial waste, including slag and coal mine refuse. The bank is steep, there is no berm, and boat landing is difficult here, classifying this as a "moderate" to "difficult" access area.

Figures 17, 18, 19, 20, 21, 22, and 23 all show bank and berm conditions along the Allegheny River that have "easy" access conditions. Figure 17 is a photograph of a wide berm, with a slight low bank in the background. This is "easy" access, but not ideal access, as the berm has a high concentration of silt and mud, making a boat landing slightly unpleasant, due to soft conditions. Figure 18 has ideal accessibility; the berm slope is slight, and the materials consist of sand and course sand, making boat landing easy and pleasant. The low bank (about twelve feet high) is also very sandy, and this is a typical low floodplain deposit, usually seen on the inside of river bends. This is also known as a "point bar" deposit. The berm shown in figure 19 is of coarser material than in the previous two photographs; most of the material is pebble size, with about 20% of the berm as cobble size grains. This berm has easy access, as landing here was not difficult or unpleasant, due to lack of soft mud and silt. Figures 20 and 21 also show easy access, which are both in more natural settings; in both cases, the bank heights are low, and the berm is wide with a slight slope. Figures 22 and 23 are examples of easy access, but these areas are less aesthically pleasing, as the berm and bank materials consist of industrial waste products. The ease of landing a small boat at these sites is not hampered, however.

C. Bank and Berm Materials: Man-made

Man-made bank and berm conditions were observed during the 2002 field season on the Allegheny River. Unconsolidated man-made bank and berm materials include steel mill slag, coal mine refuse piles, cement plant waste material, boulders dumped along the bank to stabilize erosion, and material dumped as fill for railroad and highway rights-of-way. Consolidated man-made materials include cement docks and bulkheads, stone and brick walls, structures at water level (fig. 24), steel and wood retaining walls, dumped cement, and solidified slag. Other man-made materials that do not fall into the above categories include odd trash dumped along the riverbank, and occasional wrecks (fig. 25). Examples of consolidated man-made bank materials are cement walls, steel piling walls, and cement block walls (fig. 10, 11, and 12). Figure 26 shows a mixture of man-made materials: the railroad line is built on introduced fill, including slag and natural material. The berm, along the water's edge, has been covered with introduced boulder sized natural material (sandstone) to control erosion.

D. Bank and Berm Materials: Natural

The majority of the banks and berms along the Allegheny River consist of natural materials. These materials are all unconsolidated, except for one exposure of natural bedrock near Lock and Dam #4. Natural materials include boulders, cobbles, pebbles, sand. silt, and mud. The boulders, cobbles, and pebbles are from local sources, as a product of normal weathering, or introduced, from the outwash of glacial materials transported by ice. Some of the introduced materials have been brought in from sources over 1000 kilometers to the north, from Canada.

Local natural bank and berm materials are similar to those found in the Monongahela River; the parent rocks which they have weathered from consist of sandstone, shale, limestone, and a small amount of coal. The local bedrock in the Allegheny River basin is similar to that of the Monongahela River watershed, except for a lesser amount of coal. Figure 27 shows large natural boulders of local sandstone that have slid down to the water's edge.

Figures 28 and 29 are photographs of a large gravel bank on the north side of Jack's Island. This bank is about 10 feet high, and consists mostly of cobble sized material, with a lesser amount of pebble and sand sized grains. Much of this material has been introduced to the area, from transport by glacial ice. Much of the exotic material is from the Canadian Shield, which is made up of pre-Cambrian rock, ranging in age from 1.2 to 2.6 billion years old. A one meter square was imposed on a flat portion of this gravel bank, and a cobble count performed; the results are as follows:

Local sedimentary material (sandstone, shale, etc.)	67%
Exotic sedimentary material (sandstone, limestone, etc.)	14%
Exotic metamorphic material (gneiss, quartzite, etc.)	17%
Exotic igneous material (granite, gabbro, etc.)	2%

The exotic sedimentary cobbles were identified by fossil content and species; this percentage could be higher, if ambiguities in field identification were eliminated. Most fossils collected from introduced sedimentary rocks were of Silurian age (fig. 1, Geological Time Scale) and these rocks are exposed on the surface in the Buffalo, New York area, but deeply buried in the Pittsburgh region. Since there are no surface exposures of metamorphic or igneous rocks within the Allegheny River drainage basin, these cobbles are definitely of exotic origin, even though they were transported and deposited by natural processes. Metamorphic rocks occur about 16,000 feet down in the Pittsburgh area.

Figures 30 and 31 show a berm and bank, respectively, that have a slightly finer grain size distribution that at Jack's Island. Most of the gravel here is pebble size, with some larger cobbles included, and a greater amount of sand. The berm has a shallow slope (allowing good access) and the bank is not too steep to easily walk up, allowing fine access to the road above. The materials here are mostly of local origin; about 15% of the pebbles and cobbles are exotic. A few fragments of man-made introduced material can be seen in figure 30, in the form of coal, bricks, and cement blocks. The natural grains (pebble and cobble sizes) are well rounded, implying a certain amount of transportation (by water and ice) from the original source. By contrast, most larger sized grains in the Monongahela River are more angular in shape, inferring shorter movement distance from their source.

Figure 19 is a shallow angled berm, with a large sand percentage. This bimodal grain size distribution is common along the Allegheny River, with berm areas that consist of cobbles and sand only. The cobbles here are very well rounded, and appear to have been transported a long distance. This berm is composed of over 50% exotic (natural) cobbles, with over 30% of the cobbles igneous and metamorphic rocks. Access is clearly easy here, as the berm slope is slight, and the shore is sandy, permitting easy small boat landing.

A berm that grades downstream from cobble to pebble to sand sized grains is shown in figure 32. This berm is on the southeast bank of Jack's Island, just above Lock and Dam #4. The photo is facing downstream, with the dam top on the horizon. As the grain size fines downstream, the angle of repose changes; the cobbles can support a steeper angle, and the sandier berm a lesser slope. Access is easy on the downstream portion of the island, and is a little more difficult upstream; many islands in the Allegheny River are coarser grained on the upstream end, and fine downstream. The lithological makeup of the cobbles and pebbles is similar to that in figures 28 and 29.

Figure 20 shows a sandy berm (with a small amount of mud) along with a bank that is mostly mud. This is a good example of a low floodplain that is about ten feet high above water level, and is probably underwater once every five years. The berm is mostly sand, with some pebble sized grains, mixed with mud. Access is good here, as boat landing is easy. Figure 17 is a berm that is about 50% sand and 50% mud; access is also easy here, if one steps from their boat onto the sandy areas, and avoids the mud. In this specific locality, mud has been deposited on top of the sand layer, from a flooding event. Figure 33 is a berm that is 100% mud; access is unpleasant here, as one will sink quickly in the mud when stepping from a boat.

A small stream delta into the Allegheny River is shown in figure 34. This particular stream is Chartier's Run, on the southeast bank of the Allegheny, in Pool 4. The Allegheny is flowing from left to right in this photo. In this case, the coarser material is on the upstream side of the delta, and the finer material is downstream. This is due to the slowing action of the delta deposits during flooding events, where finer grained material drops out of a moving river when slowed. The initial impact of moving floodwater on the delta (just before it slows down) is to remove fine grained sediments on the upstream side. This is also true for many of the Allegheny River islands, where the upstream end is being eroded, and the downstream end is a site for sediment deposition. The islands very slowly migrate downstream from these erosion and deposition processes.

IV. Results and Discussion

A. Data Analysis

The data from each 1/10th mile section of Pools 1, 2, 3, and 4 of the Allegheny River was entered into a computer database, to be used in conjunction with the GIS and ARCINFO mapping programs. The three major areas of inquiry using the geological dataset and the computer mapping programs are:

1) Describing which sections of the riverbank have easy, moderate, and no access
2) Determining which riverbank sections are the best preserved, or which are closest to "pristine" condition, with minimum anthropogenic influence
3) Using datasets generated from sections one and two to find riverbank sections that are worthy of restoration and/or other improvements

B. Access

Three different grades of river access were generated : easy, moderate, and difficult/vertical access. Each of these grades was determined in the field by estimating the difficulty one would have landing a boat from the water onto the shoreline in question, using a sixteen foot powerboat as the standard. In many areas, a smaller boat, such as a canoe, would be able to access a particular shoreline more easily than a larger powerboat. Conversely, many of the shorelines that have an "easy" or "moderate" access label could not be used by larger commercial craft. Some of the "vertical" or "no access" cases are unusable by pleasure craft, but are suited more for large commercial freight carriers.

Several variables were used to determine these access categories; examples include water depth as the shoreline is approached (for a sixteen foot boat with a half foot loaded draft, and a jet type outboard motor), the amount of restrictive vegetation, bank height and steepness, the width of the berm, if present, and the competence of the berm or bank material where one actually steps from the boat onto the shore. Plate 1 is a map of Pools 1 through 4 on the Allegheny River that illustrates the three grades of general access.

C. Preservation

Three different grades of riverbank preservation were created, with the idea of determining which sections were best preserved in their natural state. There are no high banks which are still in their natural condition, (as perhaps would have been seen before European settlement in the Pittsburgh area). All the high banks have been extensively modified, especially by railroad building activity over the past 150 years. Much material was imported as fill, to raise track beds above the floodplain level. The Allegheny River had railroads along its banks and still does, although to a lesser extent than when Pittsburgh was an industrial center.

The riverbank areas that are in their natural state are those that have their materials reworked by flooding action. The low lying banks and berms are affected by periodic floods to a greater extent than the higher ones; since there is constant dynamic change from erosion and deposition of material, these low sections represent the most "natural" portions of the riverbank.

To determine which areas qualify as best preserved, the height and frequency of flooding along the Allegheny River has to be taken into account. The typical one-year (annual) flooding event has a water level height range of zero to 6 feet (US Army Corps of Engineers, 1987). The two-year floods have average water levels up to 9 feet above normal pool elevation, and the five-year flood has an average crest of 13 feet above pool. Any banks or berms below these elevations will have their materials and geometries reworked and changed due to the erosive and depositional action of the water. Hence, these low-lying portions of the banks can be interpreted as the closest to natural state.

Another criteria used to determine preservation is the amount of manmade material present. If there is a smaller manmade material percentage in the bank or berm makeup, this can be interpreted as existing closer to a natural state.

The three grades of riverbank/berm preservation and their criteria for selection are:

Preservation Value	Physical Condition	Material Condition
Best -	0 - 6' above pool,	100% natural
Moderate -	0 - 6' above pool,	5 0 - 100% natural
Poor -	6 - 15' above pool,	50 - 100% natural

These data operators were entered into the ARCINFO computer mapping program, and a map of the riverbank section's preservation potentials were plotted (plate 5).

D. Restoration

The restoration potential is contingent on bank height (and potential floodplain affect) as well as soil composition. As depicted in the table below, restoration values have been identified by physical condition in relationship to the material condition of the banks. A third element, access to the site from both land-based communities and water-use communities has not been considered in the current study.

Restoration Value	Physical Condition	Material Condition
Best -	0 - 6' above pool,	50-100% manmade
Moderate -	6 - 15' above pool,	0-50% manmade
Poor -	15 - 30' above pool,	0-50% manmade

For example, a physical condition of 0 - 6' above pool places the bank in relationship to the one-year flood pattern. Combined with a natural/ manmade soil mix of 50% or greater manmade soils the restoration potential is high. Meaning that restoring the riverbanks to natural state is very possible as the physical and material conditions are in place to support native plant materials. This is the condition for our best restoration scenario. The moderate scenario, assumes the same bank heights of 6 - 15' above pool with 0 - 50% man-made bank materials. The physical condition is in place for a natural system restoration. The relatively good material condition of the banks can be amended. The lowest restoration value represents a physical condition of 15 - 30' above pool with 0 - 50% manmade material. Although there is still potential for restoration, proximity to public access, use or contiguous existing habitat would come into play when making a decision to restore.

Figures 35 is a map of the Year 3 study area, showing the riverbank sections that have the different grades of access. Figure 36 is the same area as figure 35, with the riverbank sections that are candidates for preservation. Figure 37 shows the riverbank restoration potential for the same area and figure 38 shows the floodplains that are effected by the one year flood, with a maximun height of six feet above pool level. All of the above maps were generated from field data, and filtered using GIS and ARCINFO computer programs. Additional information gathered this way can be applied to any portion of the study area, at many scales.

E. Riverbank Grain Size and Material Type Trends

Grain size attributes are important descriptive properties of riverbanks. Riverbank morphology can be predicted based on grain size measurements and material makeup. Grain size can also predict river hydrological dynamics; erosional cutbanks versus depositional sand bar banks. This prediction holds true for natural or man-made materials. Grain size distribution trends in a riverbank also reflect watershed drainage, which depends on land use, geology, and climatic factors.

Figures 41 - 44 are pie charts that show natural materials and grain sizes for Pools 1, 2, 3, and 4 of the Allegheny River. Grain size trends for man-made materials are not relevant, as they were not deposited through long-term natural geological processes. In general, there is a trend of coarser grains along the upstream direction. This is true for most rivers and streams, especially if material was added to the system, as seen in the Allegheny River, resulting from glacial outwash deposit erosion and transportation. Pool 1 has 78% mud, Pool 2, 48%, Pool 3, 47%, and Pool 4 at only 24%. The amount of sand increases upstream, and the cobble/gravel amounts increase upstream, except for Pool 3. This is due to a smaller number of islands, as most of the cobble and gravel sized material is exposed along island shores. Figure 45 is a chart showing the average percentages of natural materials for all of the Allegheny River, Pools 1, 2, 3, and 4.

Figures 45, 47, 48, and 49 are charts showing percentages of man-made riverbank material in Pools 1, 2, 3, and 4 of the Allegheny River. In general, there is an increase of historical heavy industry (particularly steelmaking) along an upstream direction. The only major steelmakers in Pool 2 were Edgewater Steel, and Woodings-Verona Toolworks, both now defunct. Allegheny Ludlum Steel is still active in pool 4. These riverbank industries can be correlated to the amount of slag found as bank material; Pool 1 has only 3% slag, where Pools 2, 3, and 4 have 19%, 24%, and 45% respectively.

The amount of rubble and fill is fairly consistent over the study area, except in Pool 1, where there was a greater amount of fill dumped over time to increase land area in and near the City of Pittsburgh. Pools 2, 3, and 4 have about the same amount of rubble and fill, due to railroad construction along both riverbanks. The amount of concrete (used for retaining walls and freight docks) is about the same for Pools 1, 2, and 3; there is a lesser amount in Pool 4, as there is only one major dock (at the Allegheny Ludlum Steel Company).

A general decrease of man-made bank materials can be traced along the upstream direction (fig. 50 - 53). Pool 4 reverses the trend somewhat, again due to steelmaking activity there. Even though there is a slight increase of industrial activity in the upstream portions of the study area, the impact of the City of Pittsburgh and other historical building activities downstream result in the trends seen in the chart figures. Figure 54 is a chart with the total average amount of natural vs. man-made material percentages for the whole study area, with 45% natural bank materials and 55% man-made material. The techniques used for grain size and material data analysis can be applied down to the 1/10th mile bank section scale, if more detail is needed.

F. Comparison: Allegheny and Monongahela Rivers

Using the material and grain size charts from the previous year's study, differences between the Allegheny and Monongahela Rivers can be illustrated. There is a greater concentration of man-made materials (73% man-made and 27% natural) in the Monongahela's banks compared with the Allegheny River (55% man-made, 45% natural). Reasons for these differences will be discussed below. The average grain size of natural materials in the Monongahela River decreases upstream, in contrast with the Allegheny River, where the grain sizes of natural materials increases upstream. The reason for these differences can be explained by the extra glacial outwash material introduced in to the Allegheny River watershed at the end of the Ice Age.

Two major comparisons between the Allegheny and Monongahela Rivers will be presented: 1) using natural materials and morphology as a basis, and 2) the amount of industrial impact on both rivers.

As stated earlier in this report, the materials seen in the riverbanks and bottoms differ greatly between the Allegheny and Monongahela Rivers. The materials found in the Monongahela river valleys are all derived from the Monongahela drainage basin, while the Allegheny has a large influx of exotic material, due to the last two glacial ice advances during the Pleistocene epoch. The lithological differences in the natural materials in both rivers has been discussed; igneous and metamorphic rocks that do not occur in the Allegheny River watershed are present in the banks and berms, and these grains show evidence of long transportation by water and ice, as they are well-rounded in shape. These exotic cobbles and pebbles usually have a greater trend to a more spherical shape (sphericity), as the nature of these harder rocks does not allow easy breakage along bedding planes. Large well-rounded cobbles of sandstone are sometimes (but rarely) seen in the Monongahela River, but these sporadic clasts were probably transported by water from West Virginia. There are only one or two layers of competent, massive sandstone that would act as a source rock for these grains, which explains their rarity in the Monongahela. Also, the distance of transportation is shorter than that of the Allegheny; longer transport distances result in more well-rounded grains. Most of the natural bedrock in the Monongahela watershed is too incompetent to stand up to long river transport. Most of the cobble and pebble sized clasts in the Monongahela have poor sphericity, as the local rocks break easily along their bedding planes, resulting in flatter grains, that are “pancake” shaped.

Another major difference in natural materials between the Allegheny and Monongahela Rivers, apart from lithology, is the amount of material in each river valley, usually referred to as the sediment load. There is a limit to how much sediment a river can carry; when that limit is reached, the morphology of the river changes greatly. A river that has a small sediment load has one channel in its valley; as the sediment load is increased, islands start to form, dividing the channel somewhat. If there is even more sediment load, the river changes its shape to a braided stream, with amastomizing channels, separated by many small islands. Many river deltas have this shape. Generally, for a given amount of sedimentary load, rivers with smaller gradients will tend to have a braided shape, due to the sediment load dropping out of the water, from lower water velocity. The upper reaches of the Allegheny (outside of the study area) tend more to a true braided morphology, as there is less water to remove the sediments present. A good example of this can be seen in Port Allegany, PA.

The Allegheny River has a slightly steeper gradient than the Monongahela, but the sediment load is much greater, from the influx of glacial alluvium. The load is greater than the river can easily carry, and island formation results.

Lithology and the amount of natural materials are different between the Allegheny and Monongahela Rivers; this is why one sees no large islands or gravel banks in the Monongahela River. Figure 38 shows four cross-sections of the Allegheny River; note the large amount of glacially derived alluvium in each case. Figure 55 is a map of the gravel resources in Pennsylvania, showing the glaciated areas, along with major streams that carry glacial outwash.

A second major comparison between the Allegheny and Monongahela Rivers is the amount and type if industrial impact each river experienced.

The main factor influencing industrial site placement in the Pittsburgh area is the proximity to coal resources, especially those mined from the ten-foot thick Pittsburgh Seam. The Pittsburgh Seam is present in the Monongahela valley, but mostly absent from the Allegheny valley. Since the amount of coal needed for the steelmaking industry is large, and transportation costs are high for such a great amount of bulk, most of the steelmaking activity was built in the Monongahela valley. Figure 56 is a map of Allegheny County, showing where the Pittsburgh Seam occurs. Northward, in the Allegheny valley, this seam has been eroded away. Except for the Upper Freeport Coal, (which is much thinner than the Pittsburgh Coal) there are comparatively fewer coal resources available in the Allegheny valley, compared with the Monongahela valley. Hence, the impact of industry is less in the Allegheny than the Monongahela. Present day evidence for this are fewer slag piles, abandoned barge docks, etc. During the height of industrial activity in Pittsburgh, there was a much greater amount of coal shipped on the Monongahela. Figure 57, which is an old chart showing river transportation tonnage broken down by each commodity (in 1925) clearly indicate where the greater amount of coal was shipped. Conversely, the Allegheny moved a larger tonnage of gravel, for reasons already explained.

V. References

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VI. Appendix A
Figures

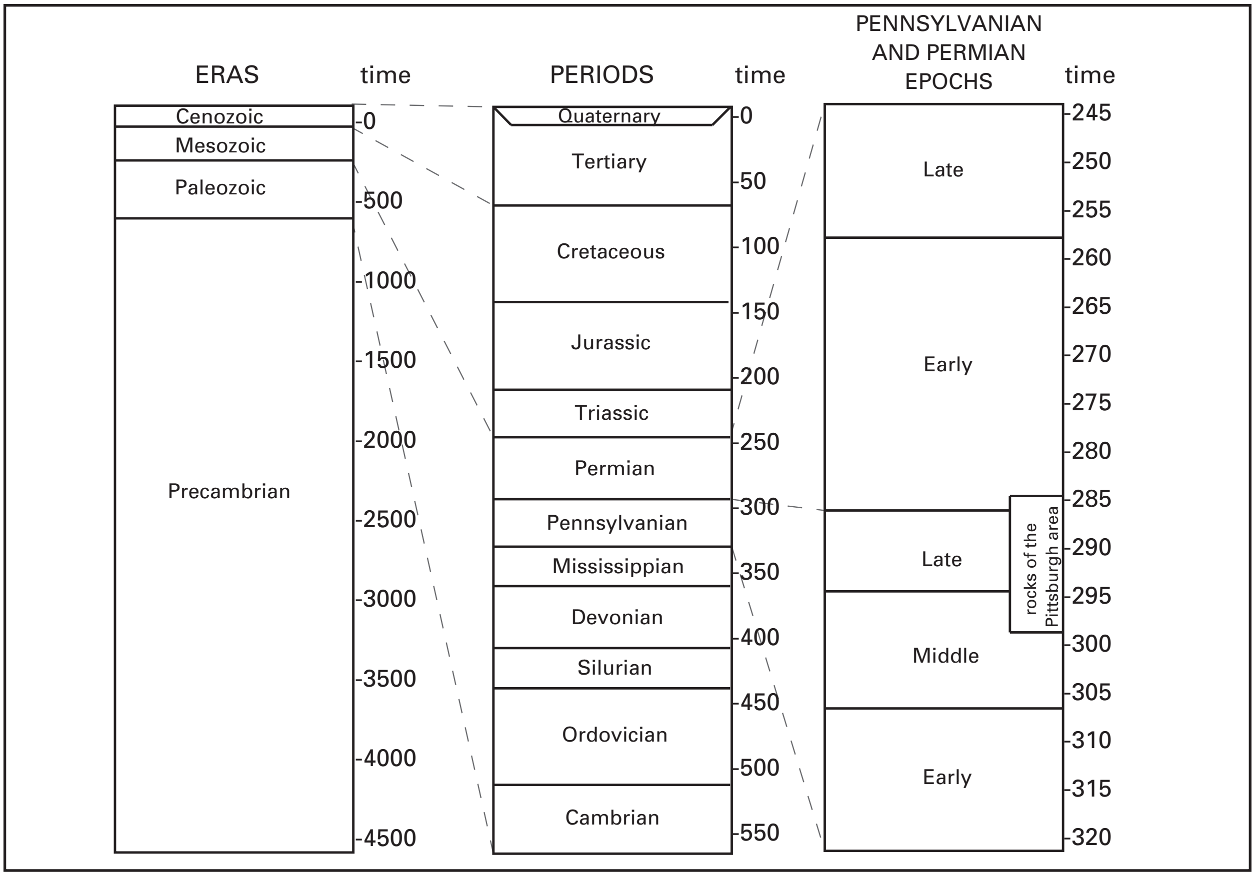

Fig. 1. Simplified geological time scale, showing the relationships between eras, periods, and epochs. The rocks of the Pittsburgh area were deposited mainly during the Late Pennsylvanian. Time is shown in millions of years.

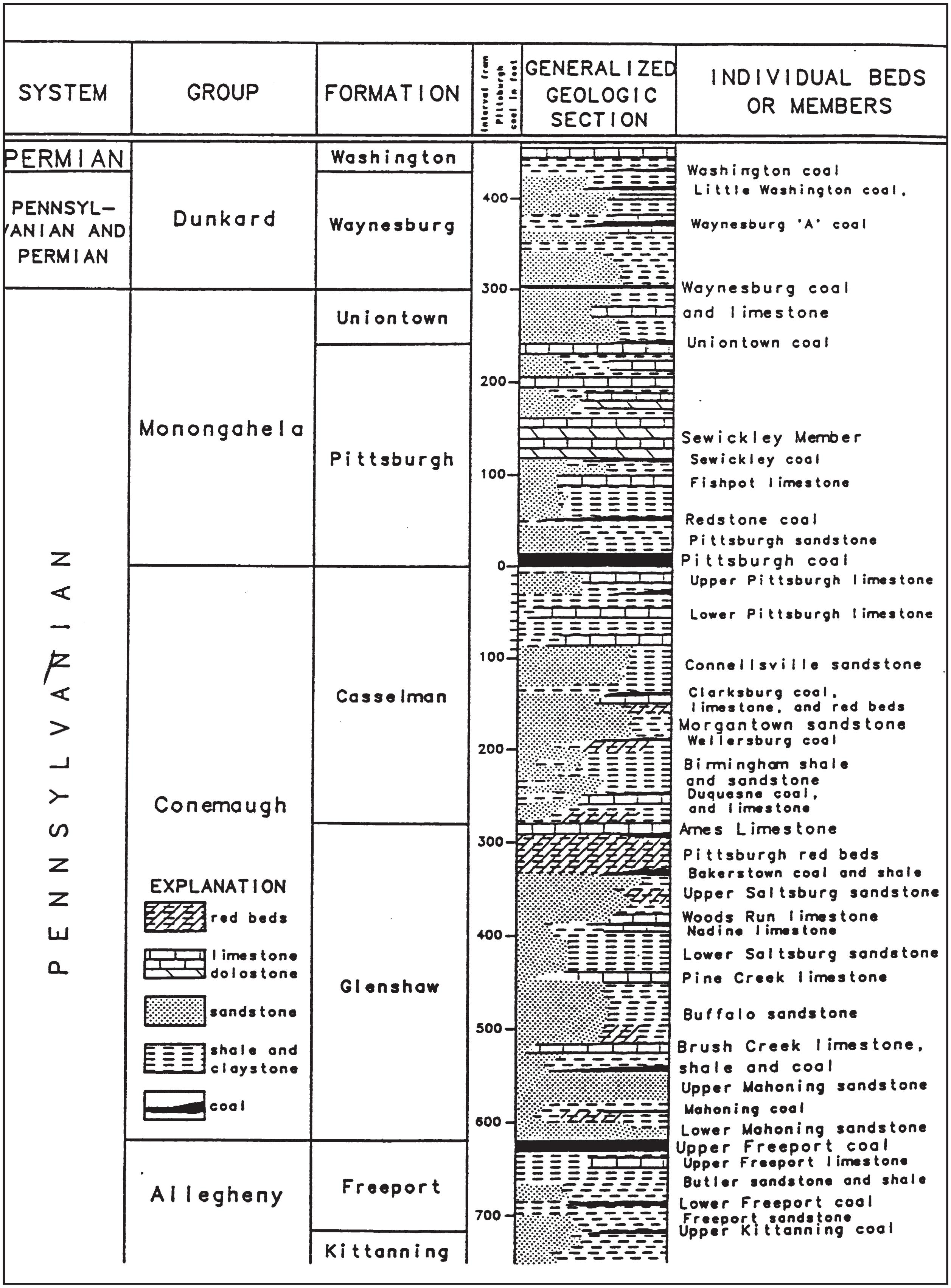

Fig. 2. Expanded portion of the Pennsylvanian Period

Fig. 3. Bedrock layers as currently seen from the Allegheny River

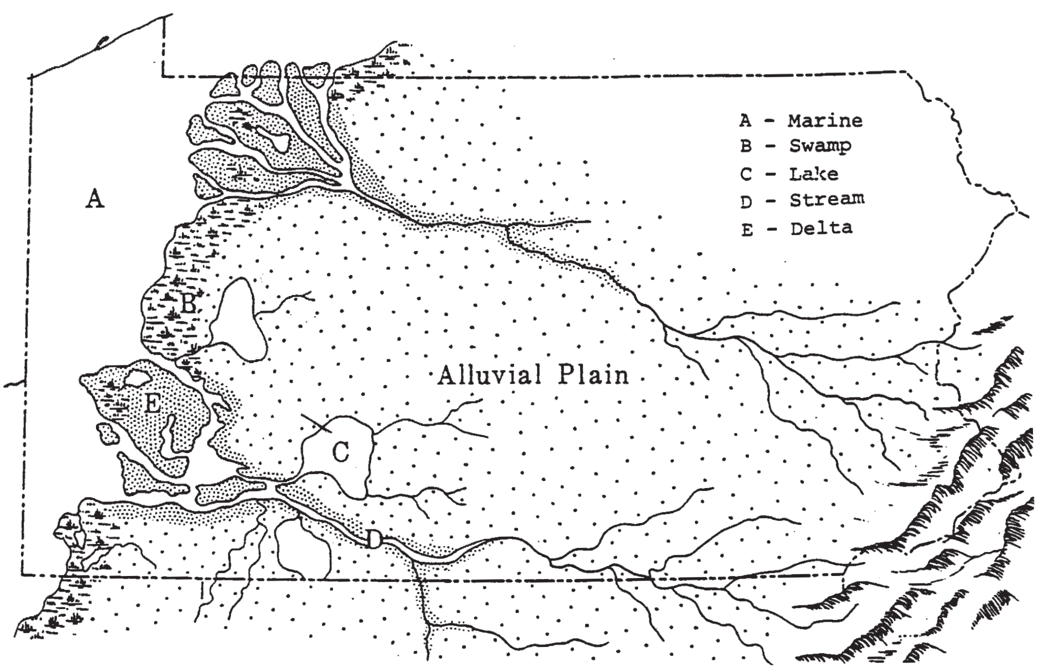

Fig. 4. Paleogeographic map of Pennsylvania, 300 millions years ago

Fig. 5. Downtown Pittsburgh

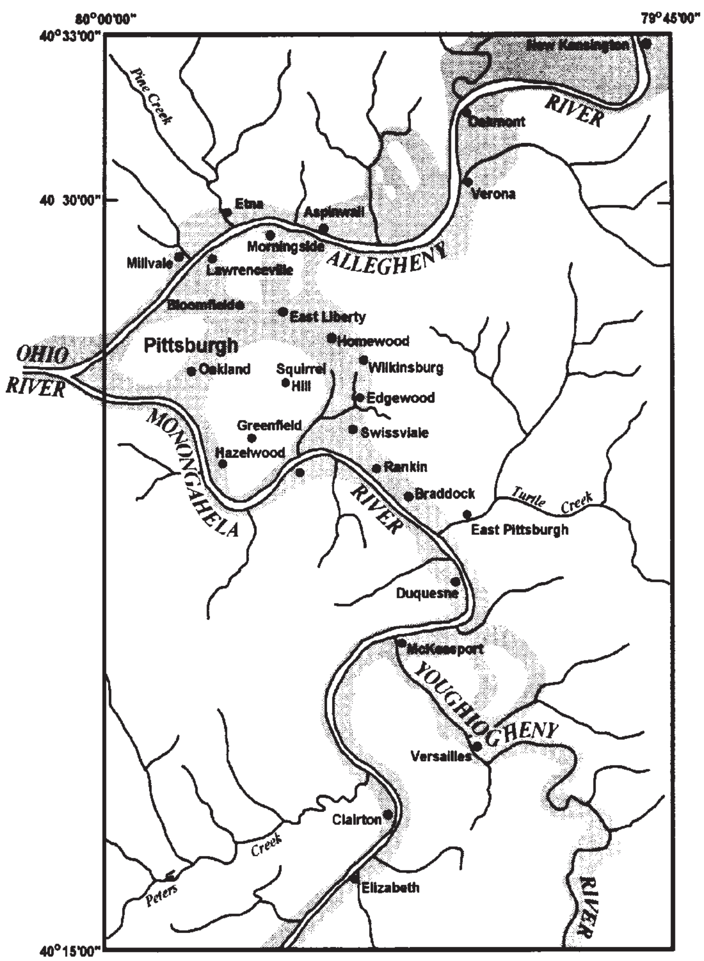

Fig. 6. Terrace deposits and abandoned loops in the Pittsburgh area

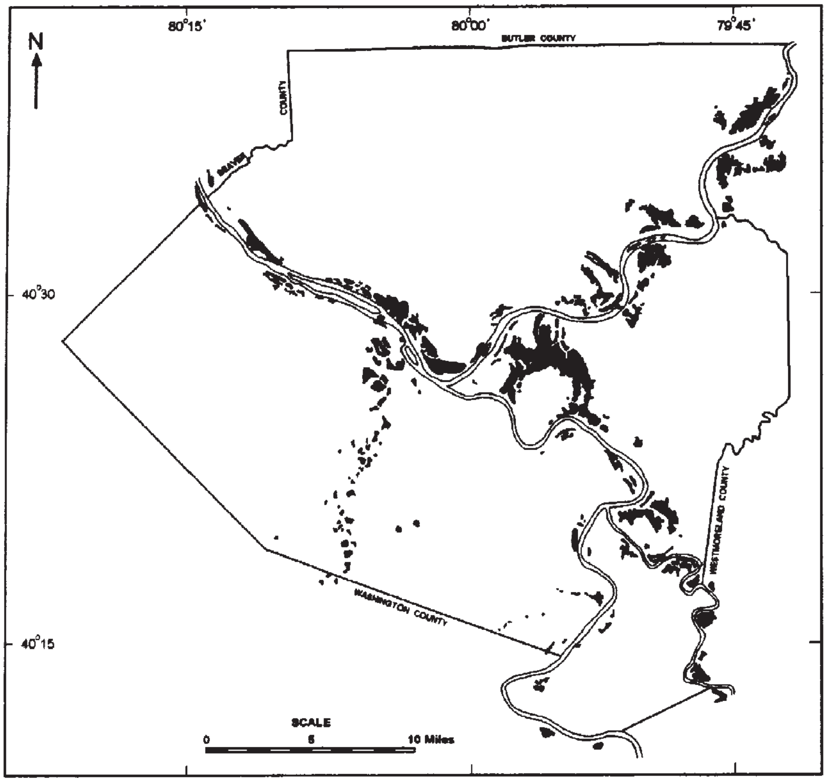

Fig. 7. Deposits in Allegheny County

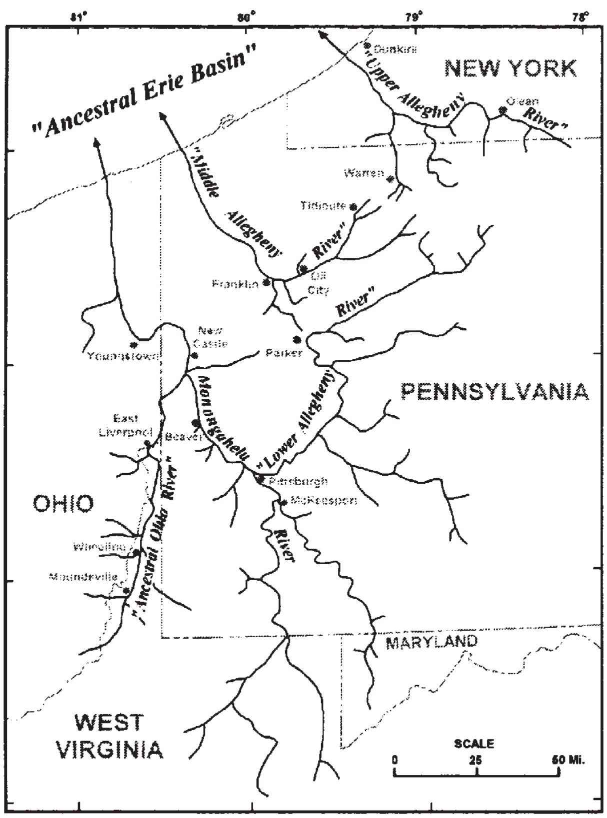

Fig. 8. Pre-glacial river drainage of Western Pennsylvania

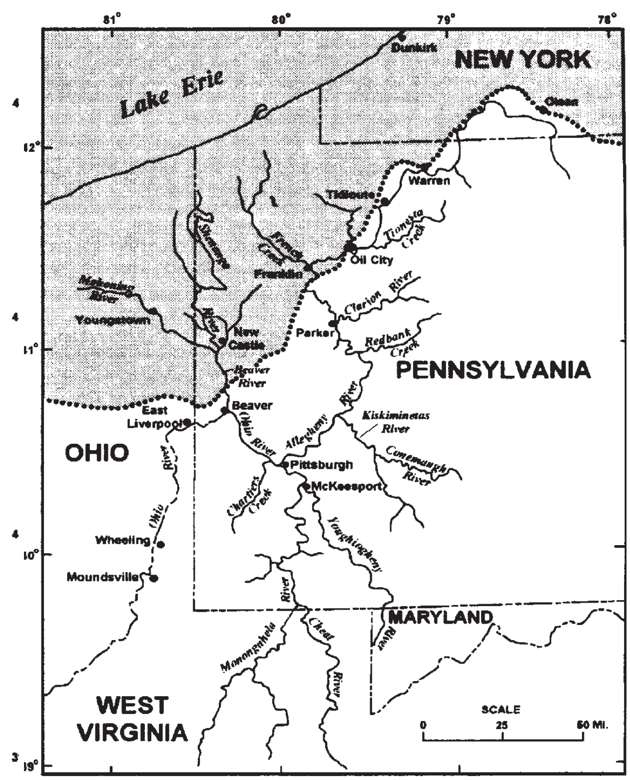

Fig. 9. Present drainage patterns in Western Pennsylvania

Fig. 10. Vertical riverbank, consolidated manmade materials

Fig. 11. Vertical riverbank, consolidated manmade materials

Fig. 12. Vertical riverbank, consolidated manmade materials

Fig. 13. Natural bedrock

Fig. 14. Edge access difficult

Fig. 15. Stablized bank

Fig. 16. Moderate to difficult access

Fig. 17. Wide berm

Fig. 18. Ideal accessibility

Fig. 19. Coarse material, shallow angled berm

Fig. 20. Easy access, natural setting, sandy berm

Fig. 21. Easy access, nautral setting

Fig. 22. Easy acces, non-aesthetically pleasing

Fig. 23. Easy access, non-aesthetically pleasing

Fig. 24. Water level structure

Fig. 25. Wreck

Fig. 26. Mix of man-made materials

Fig. 27. Large boulder

Fig. 28. Large gravel bank

Fig. 29. Large gravel bank

Fig. 31. Introduced material, bank

Fig. 30. Introduced material, berm

Fig. 32. Berm gradation

Fig. 33. 100% mud, poor access

Fig. 34. Small stream delta

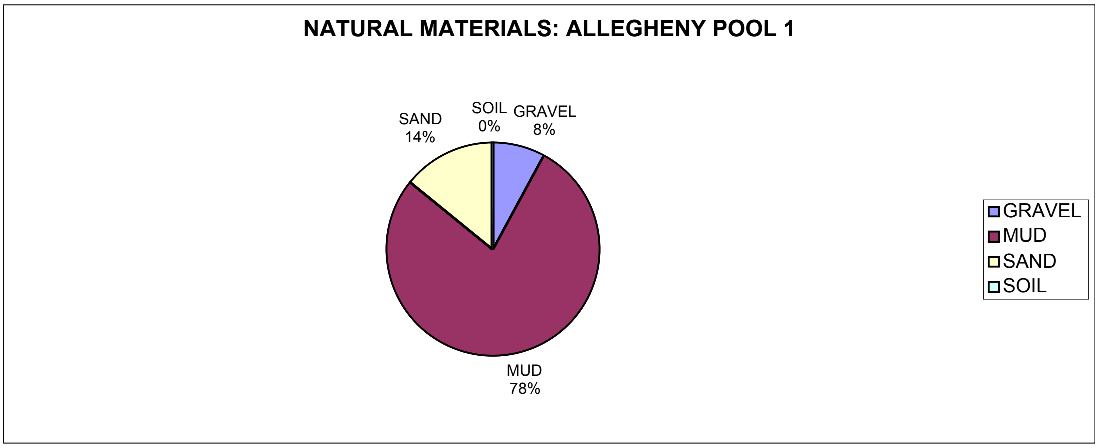

Fig. 41

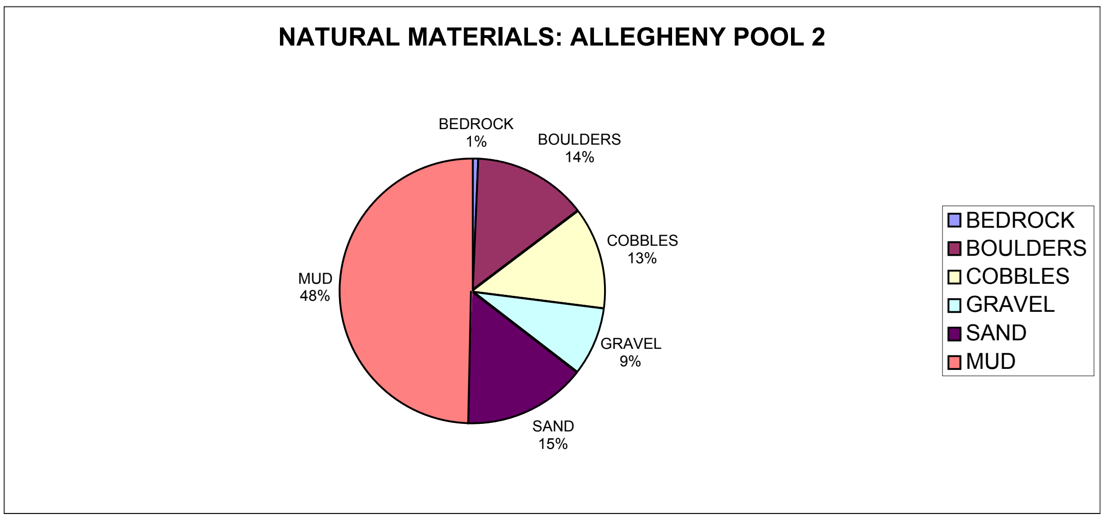

Fig. 42

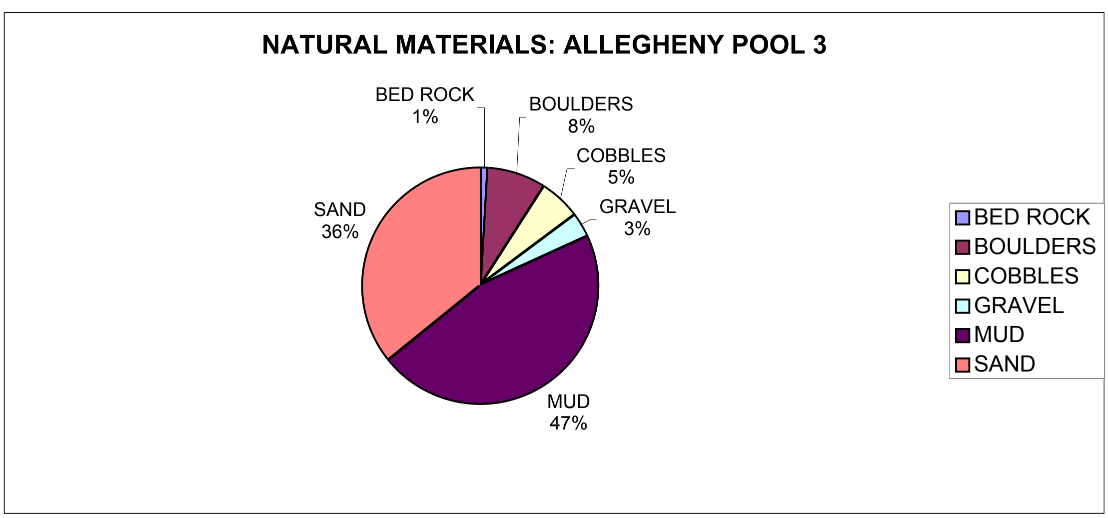

Fig. 43

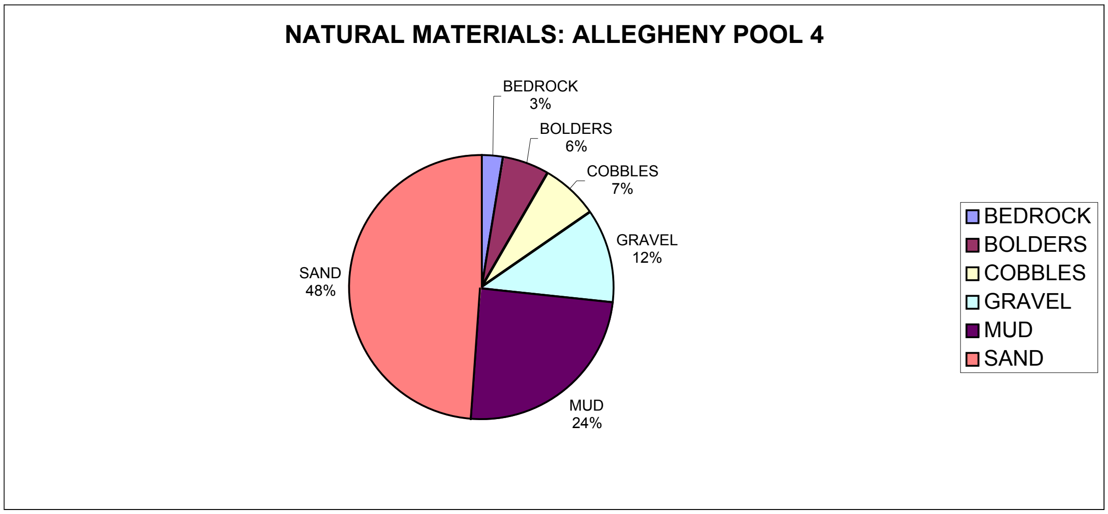

Fig. 44

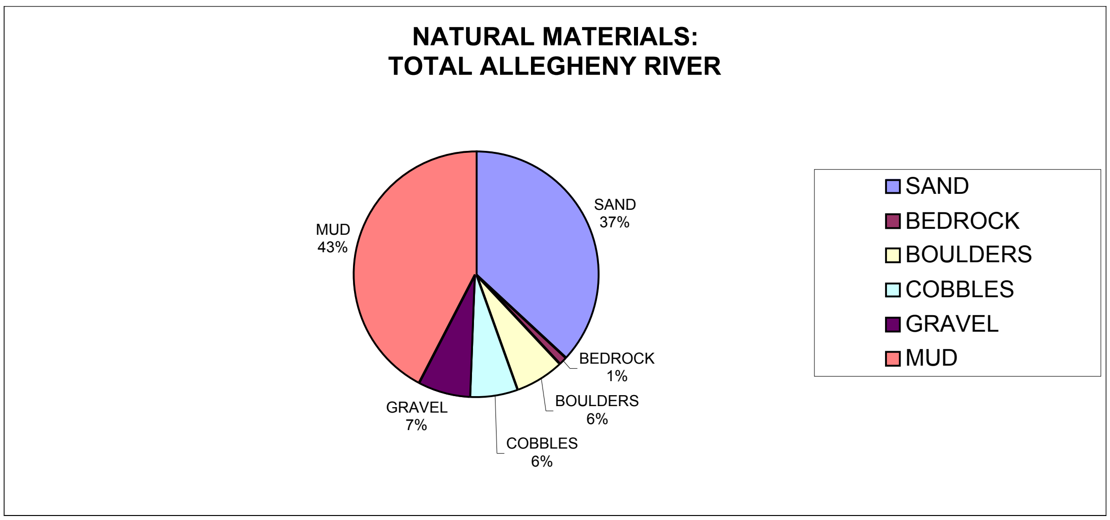

Fig. 45

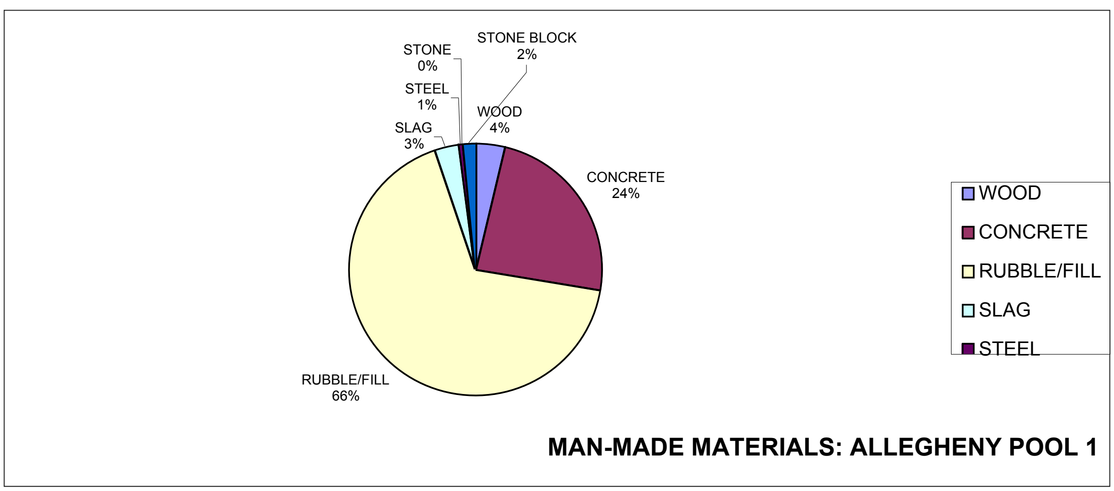

Fig. 46

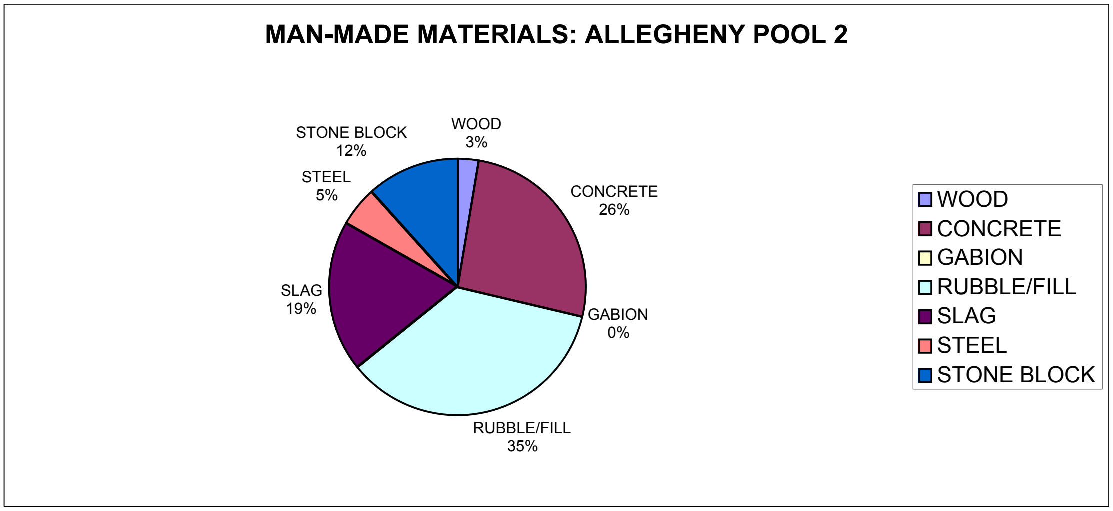

Fig. 47

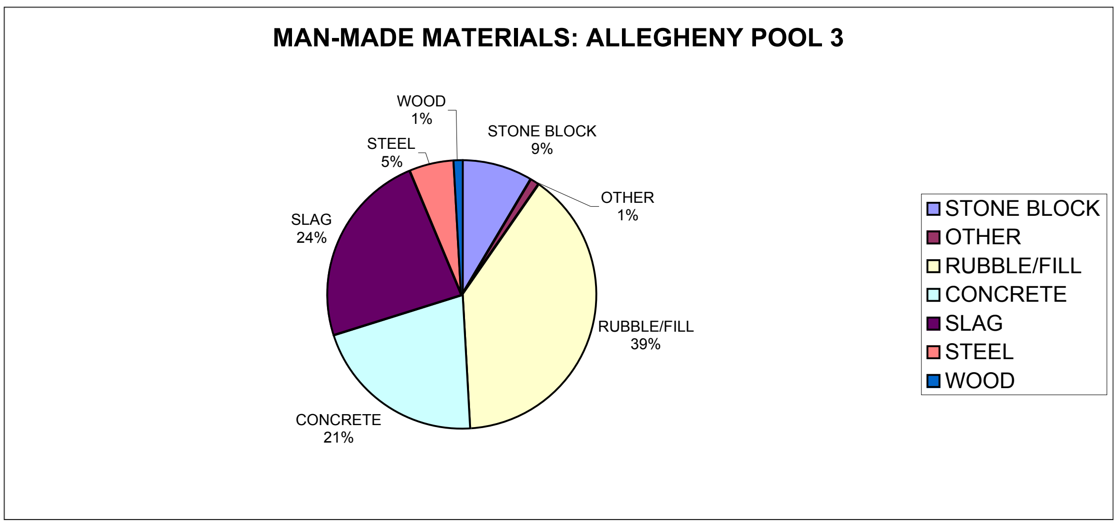

Fig. 48

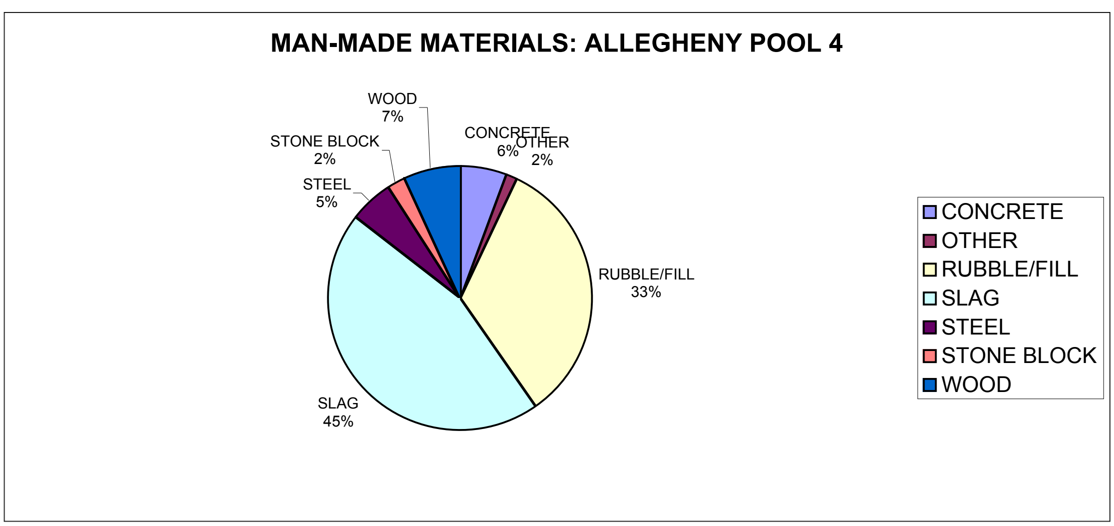

Fig. 49

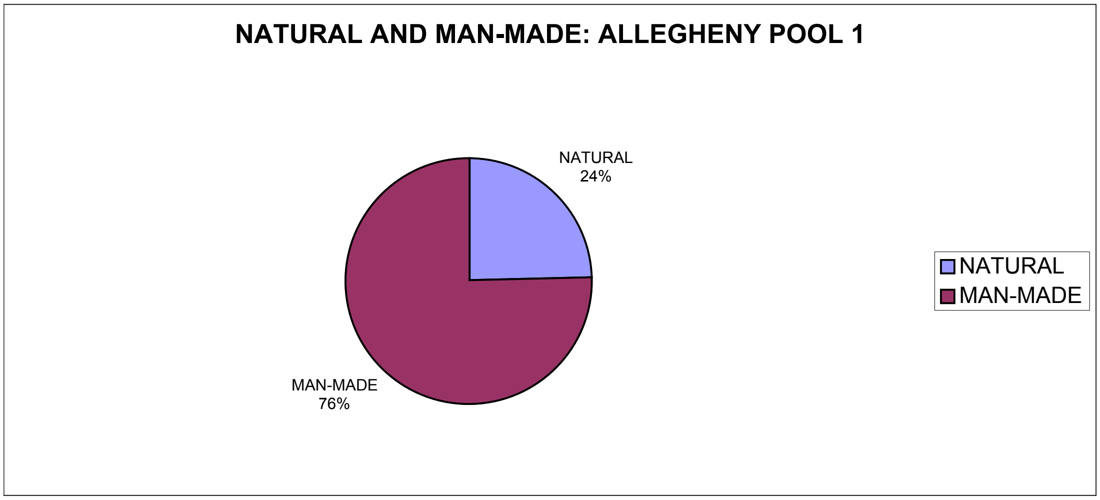

Fig. 50

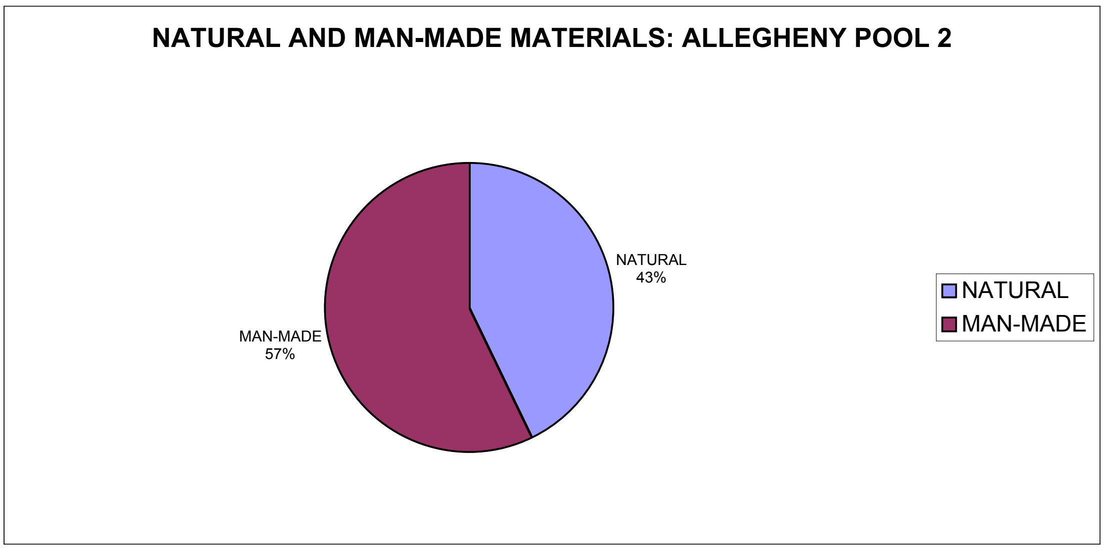

Fig. 51

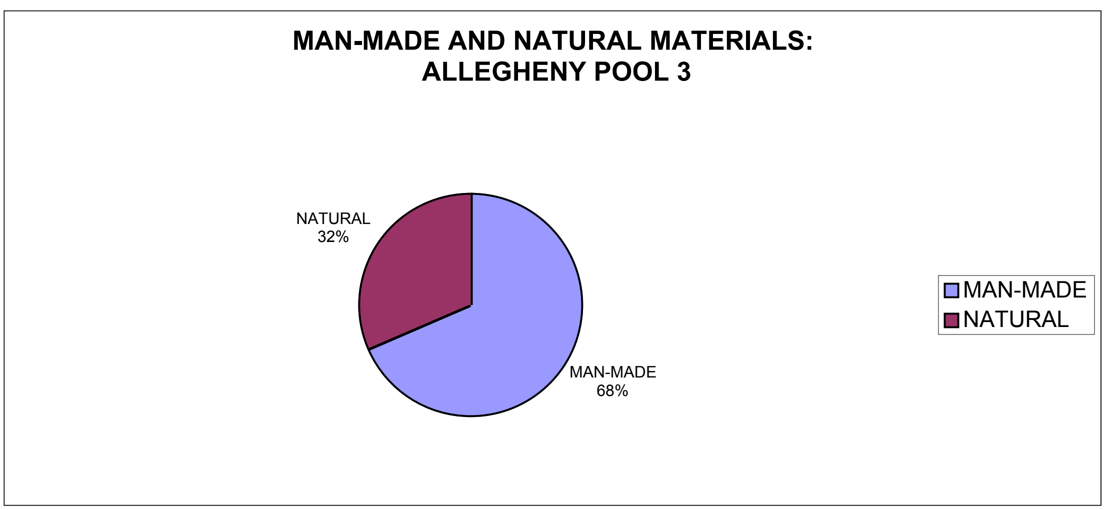

Fig. 52

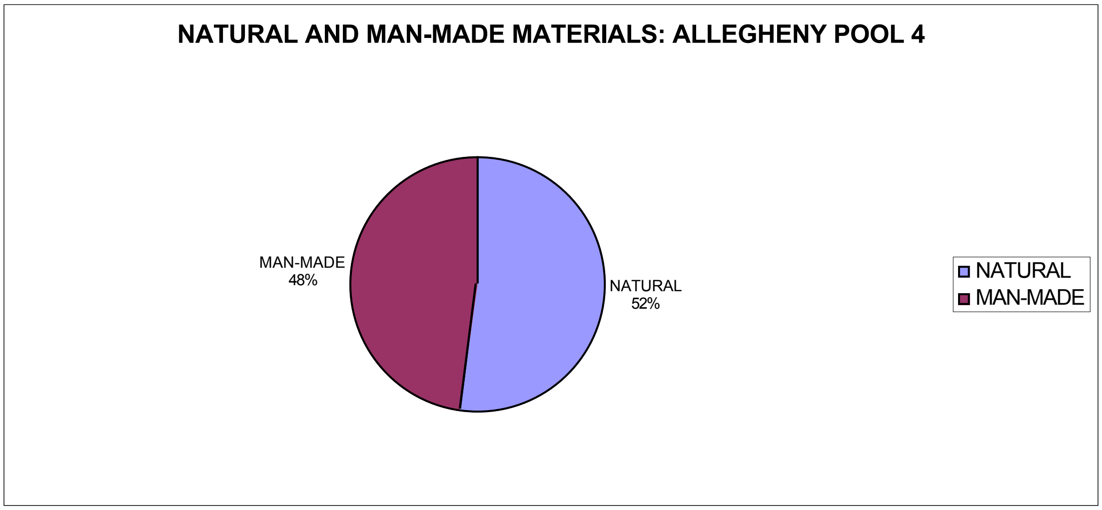
NATURAL AND MAN-MADE MATERIALS: ALLEGHENY POOL 4
MAN-MADE
48%
NATURAL
52%
NATURAL
MAN-MADE

Fig. 53

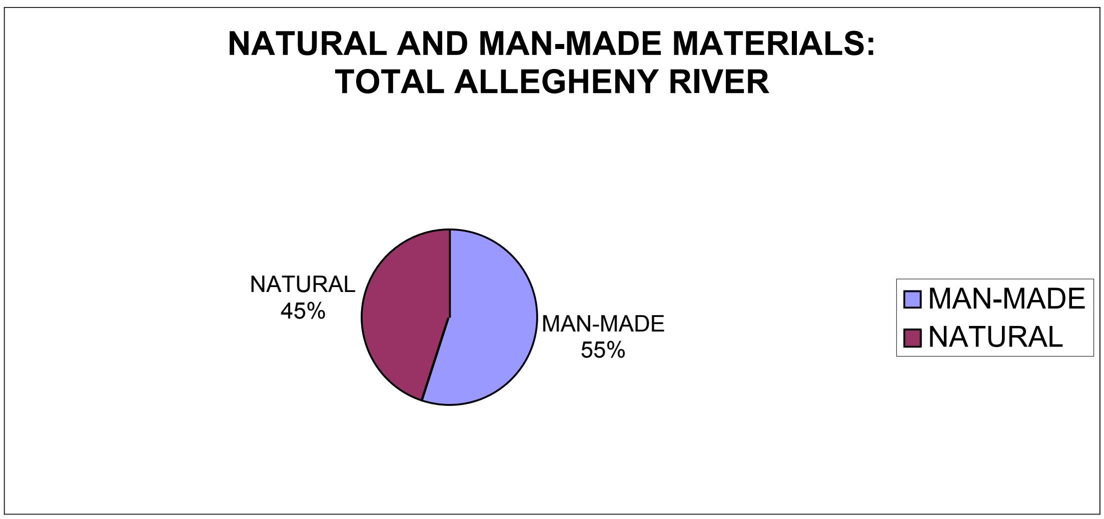
NATURAL AND MAN-MADE MATERIALS:
TOTAL ALLEGHENY RIVER
NATURAL
45%
MAN-MADE
55%
MAN-MADE
NATURAL

Fig. 54

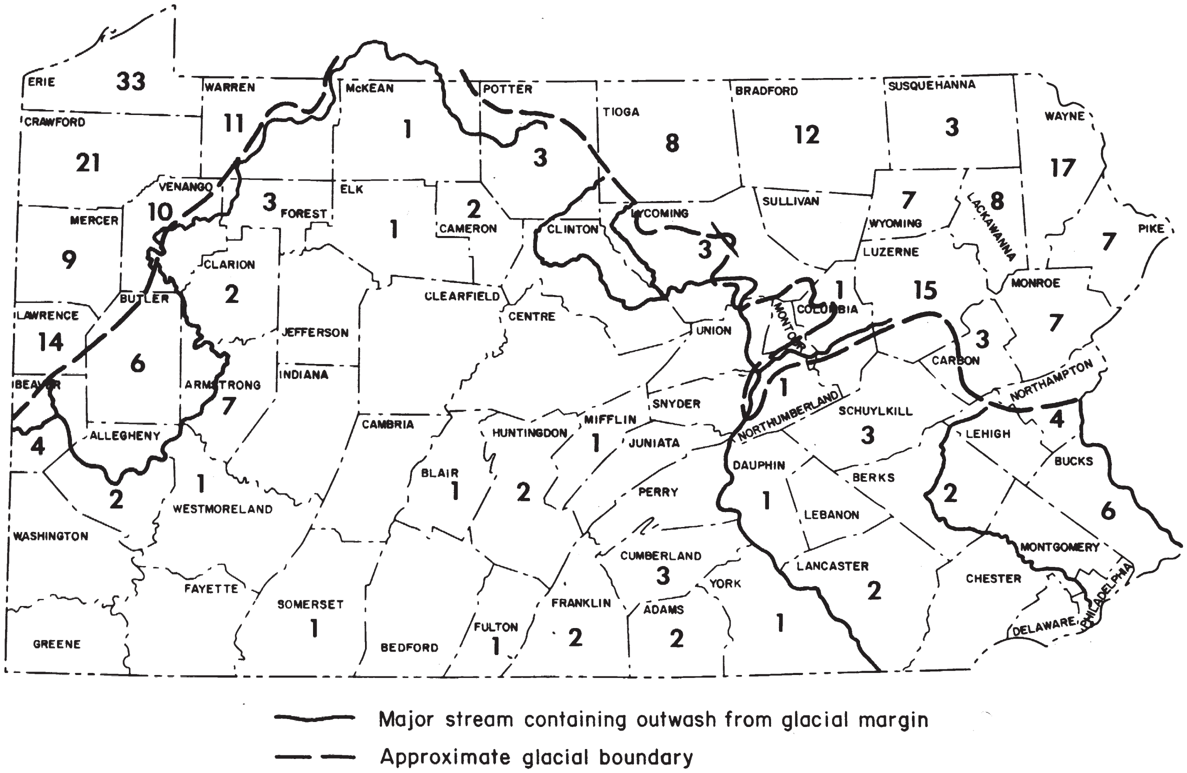

Fig. 55. Map of the gravel resources in Pennsylvania, showing glaciated areas, along with major streams that carry glacial outwash

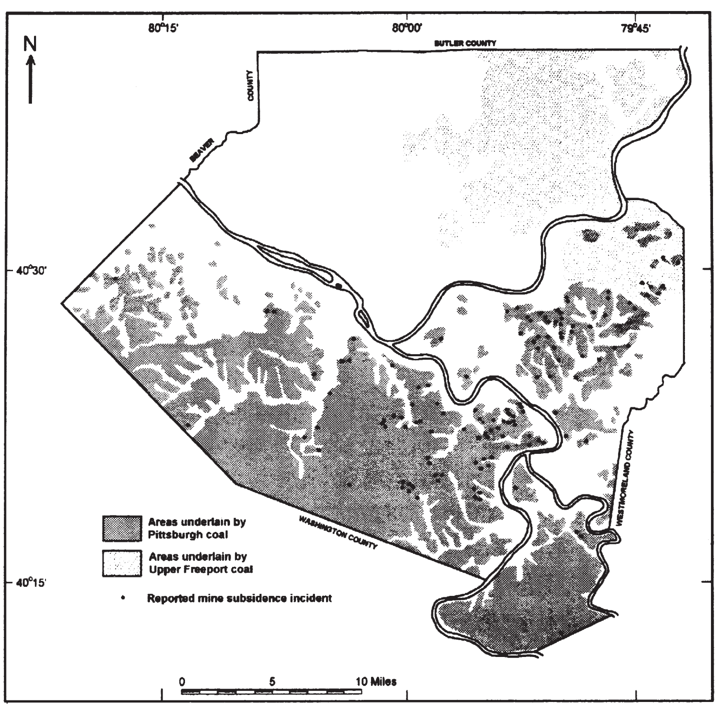

Fig. 56. Map of Allegheny County, showing where the Pittsburgh Seam occurs

Freight transported by river boats in 1925, in tons.

Commodity	Allegheny[a] River	Monongahela River	Ohio[b] River
Coal	915,255	18,697,832	4,087,878
Coke	92,268	892,851	396,812
Cement	9,084	30,151	1,600
Sand and gravel	3,443,209	2,591,916	2,648,396
Stone	22,136	2,100	15,975
Iron and steel	16,499	548,840	463,107
Oil and gasoline	10,510	14,389	24,652
Logs and lumber	7,394	18,015	6,522
Packet freight		53,807	57,846
Unclassified	228,488	866,220	26,427
	4,744,843	23,716,121	7,729,215

Fig. 57. Chart showing river transportation tonnage broken down by each commodity

VI. Appendix B

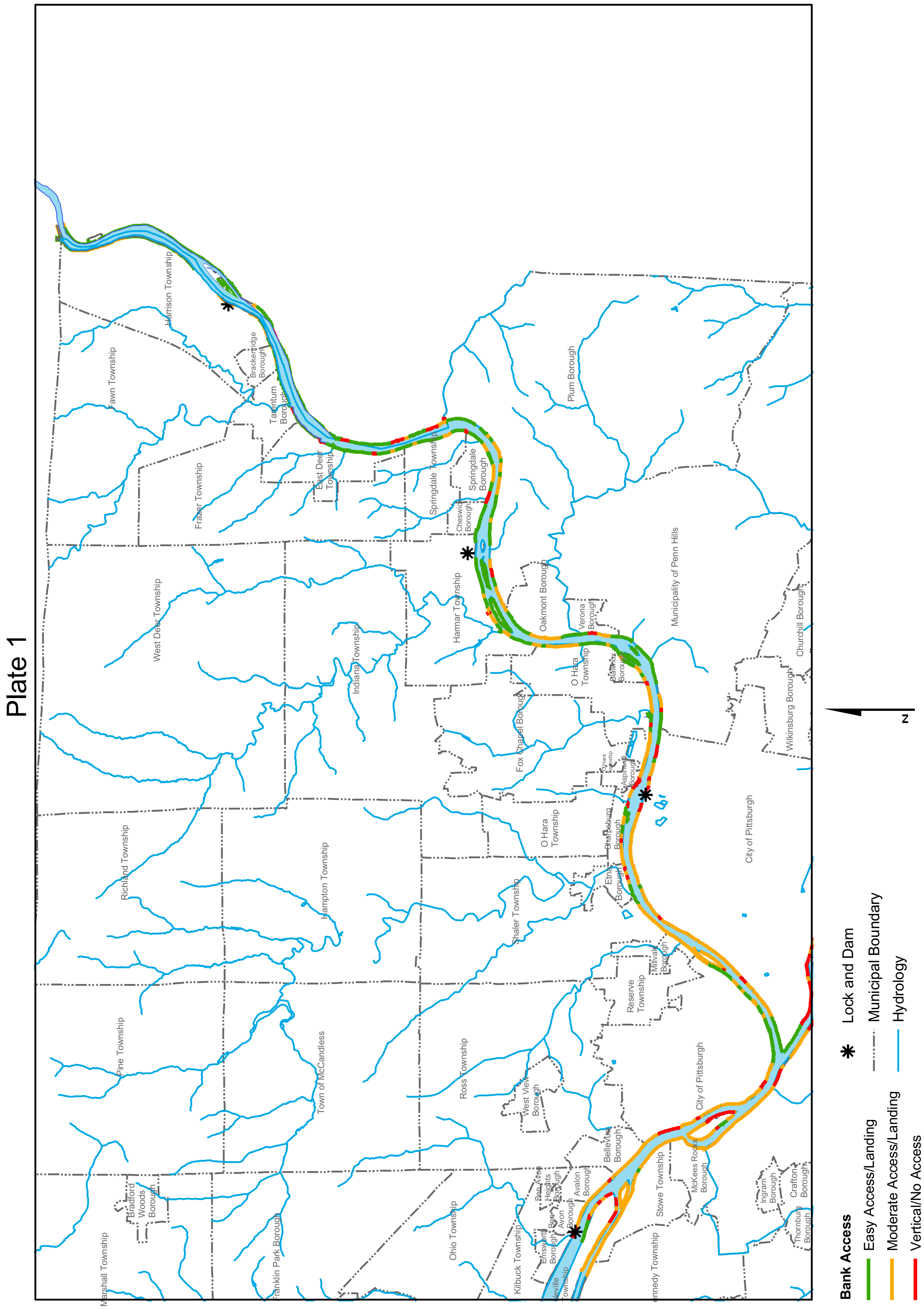

Fig. 35. River Access

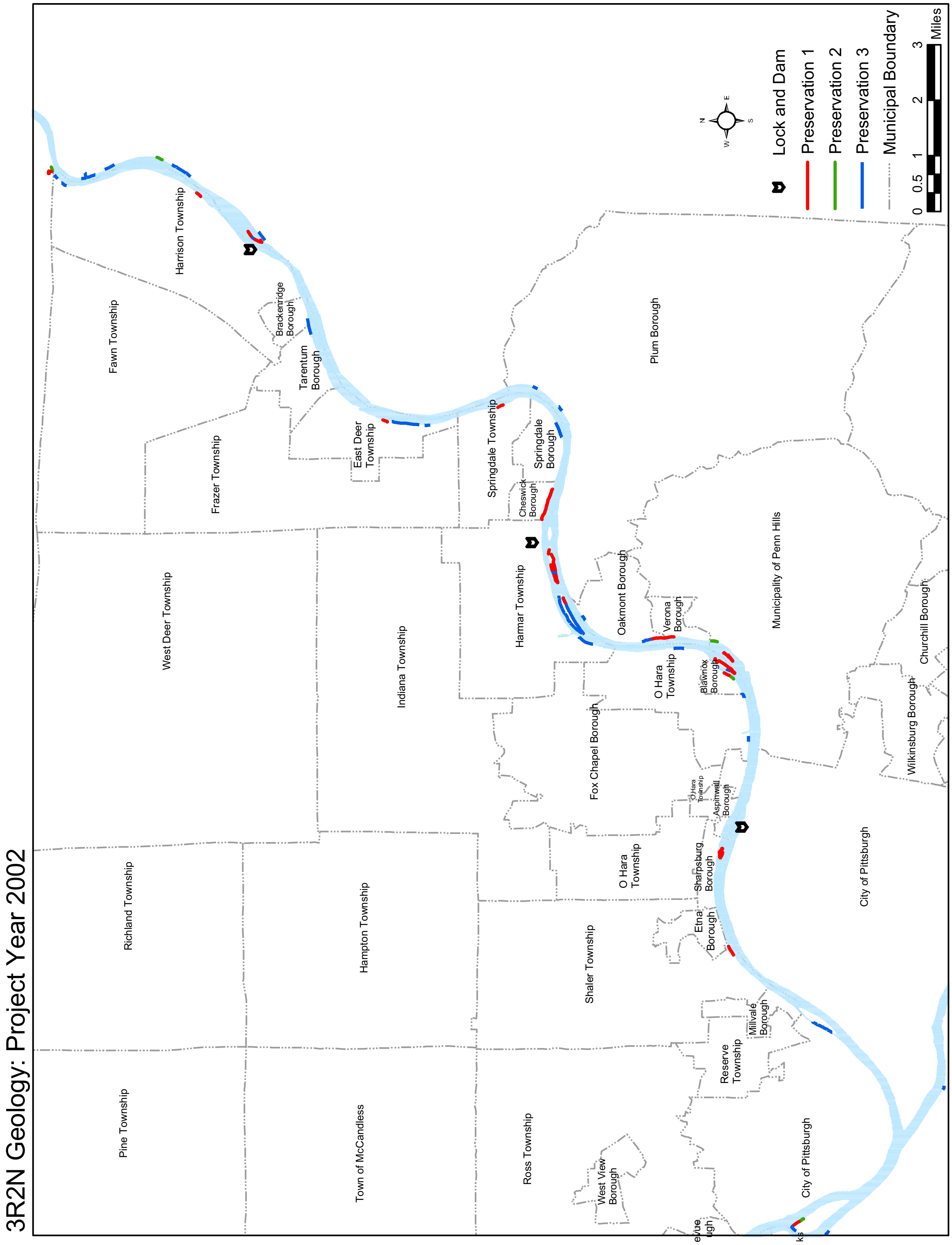

Fig. 36. River Preservation Potential

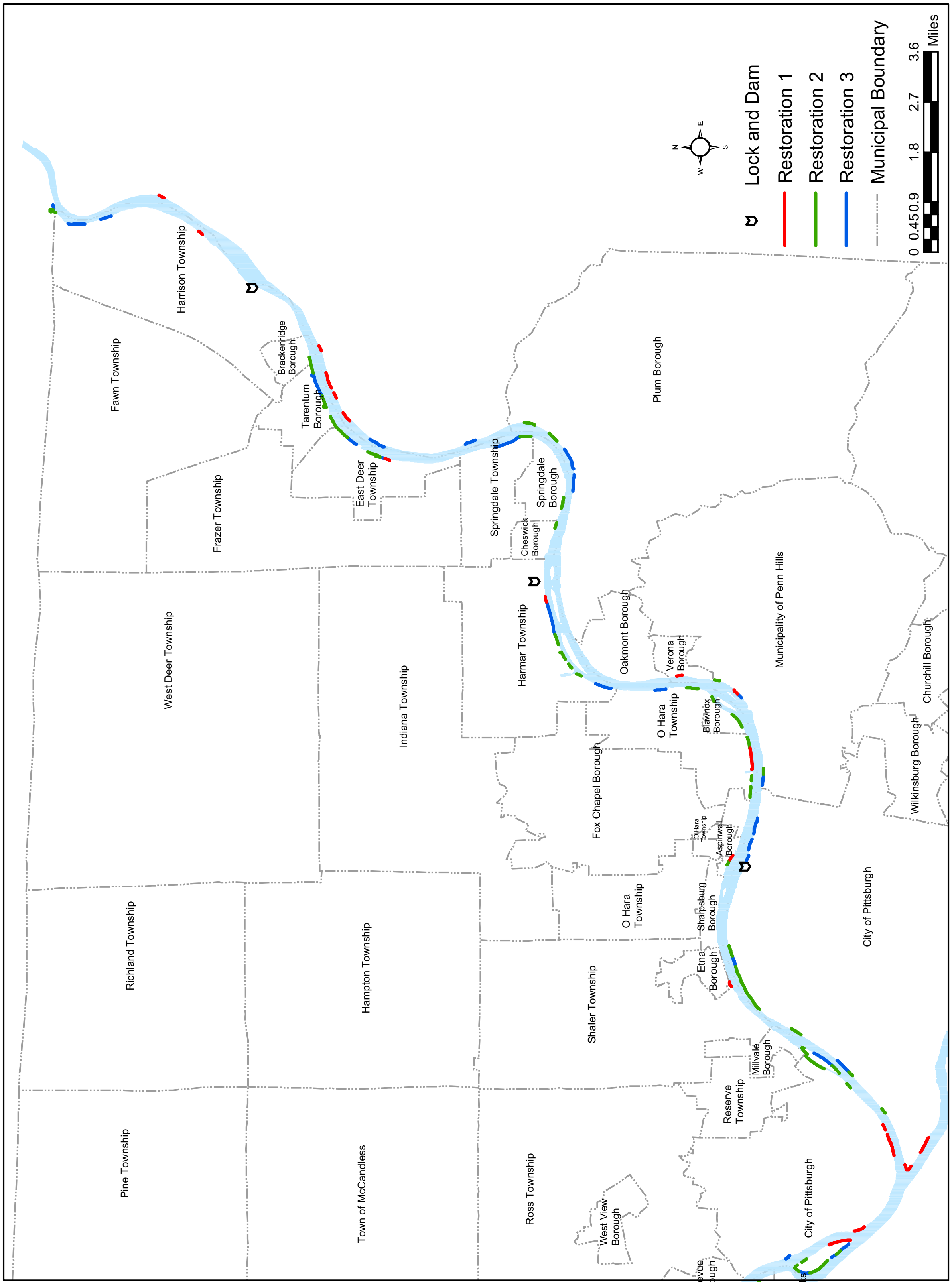

Fig. 37. River Restoration Potential

Fig. 38. Floodplains