4.0 REMEDIAL ALTERNATIVES

4.1 Introduction

This section discusses remedial alternatives that could be used to fulfill the project goals for ecosystem restoration and possible lifting of the swimming, wading, and fish consumption advisory along the Mahoning River. The main focus is on restoration of the aquatic and biotic ecosystem. The primary factor preventing such recovery is the contaminated sediments. The low head dams also limit the potential for restoration of the ecosystem within the project area (RM 42.9 - RM 12).

In Section 4.2, remedial approaches are reviewed based on technical criteria. In addition, general cost information is presented for purposes of comparison of major options. Based on this review, three remedial alternatives are developed: (1) a minimum cost alternative, which involves the use of the least expensive technically feasible alternatives; (2) a maximum cost alternative, which uses more expensive alternatives and is intended to provide a probable upper bound on the cost of remediation; and (3) an intermediate cost alternative, which includes elements of both the minimum and maximum cost alternatives. Detailed cost estimates and ecosystem benefits are developed in Section 4.3 for these three alternatives, and a "preferred" alternative is identified in Section 4.4.

4.2 Formulation of Remediation Alternatives

Two general approaches were considered for remediation of contaminated sediments in the Mahoning River: removal and isolation in place (capping of contaminated material) (Figure 16). Removal would involve dredging the sediments from the river, dewatering, and either on-site treatment or off-site disposal. Isolation in place would involve covering the sediments with an impermeable new substrate. Table 7 provides summary information about each of these methods including a description; generalized costs; advantages and disadvantages; and an overall appraisal of technical merit.

Other remedial options not dealing specifically with the contaminated sediments are also presented in this section, and include removal or breaching of the dams and the remediation of contaminated materials along the shore that have been covered with clean material. These other remedial options are summarized in Table 8. Alternatives are formulated using one or more of these options.

4.2.1 Dredging

The primary option for addressing the issue of contaminated sediments in the Mahoning River is to remove the contaminated material, dewater it, and either treat it and dispose of it within the project area, or dispose of it elsewhere. There are several major components to consider for this general option. These include:

- Type of dredging;
- Methods to minimize degradation of river water quality as a result of dredging (mitigation measures);
- Addition of appropriate riverbed substrate to replace dredged material;
- Handling of dredged material;
- Treatment of dredged material; and
- Disposal of dredged material.

These variables are considered in order in the following sections.

4.2.1.1 Dredging Methods

The two primary dredging methods that could be used to remove sediment from the Mahoning River are hydraulic dredging and mechanical dredging. Hydraulic dredging uses a suction pump to collect sediment admixed with water. The sediment-water mixture is pumped to a holding basin, which is designed to allow water to drain out the bottom. This water can be routed to a water treatment system prior to discharge to the receiving stream, as discussed in Section

4.2.1.6. Where large rocks and debris are present, it may be necessary to remove coarse material using mechanical dredging before hydraulic dredging can be conducted.

Mechanical dredging would involve the use of a clamshell dredge of a type designed to minimize disturbance to the water column during dredging. Dredged material would be loaded on to water-tight trucks and transported to a centrally-located holding basin. It is expected that the mechanical dredge would incorporate substantially less water in the dredged material than would the hydraulic dredge. As a result, the total holding volume required for the mechanically-dredged sediments is expected to be less than that required for the hydraulically-dredged sediments. However, the cleanup effectiveness of mechanical dredging may be less than that of hydraulic dredging, since mechanical dredging is less effective at removing sediment from recessed areas of the river bottom.

Another potential dredging option is to combine mechanical removal of sediments from the river bottom with hydraulic transport of the dredged material to the holding basin. There are several different options for the type of equipment on which either the mechanical or the hydraulic dredge would be mounted. These include (1) an amphibious excavator; (2) a small floating plant; or (3) a "long-stick" excavator. Because the amphibious excavator could theoretically move up the existing river bed, it would not require road construction. However, there is some question about whether the amphibious excavator could successfully travel up the channel of the Mahoning River. As a result, the amphibious excavator is not recommended.

The recommended approach for the pools behind the nine dams, where water depths exceed two feet, is to use a floating plant to mount the dredge. This would allow access to most of the width and length of the various pools at minimal cost. Since a floating plant requires a draft of at least two feet, an alternative method would be needed for dredging in shallower areas. In these areas, the recommended option is the use of a tracked crane or tracked "long-stick" excavator, which has a reach of about 50 feet, to mount the dredge. This option requires access to be developed along all shallow portions of the river, either with roads along both banks, or with a temporary road constructed in the existing river bed as dredging progresses. The temporary road within the existing river bed is the recommended option, because it would have minimal impact on the riparian zones. In addition, the used roadbed material could be distributed in the riverbed as new substrate after the road was abandoned. This is discussed in Section 4.2.1.3. Roads constructed along the river banks would have severe impacts on the riparian zones, and as a result are considered unacceptable. In addition to the construction of a road within the river bed, mechanical or hydraulic dredging would require access roads to the river to be constructed at roughly one-mile intervals. It is expected that one road would be located at the each of the nine dams on the Mahoning River.

Depending upon the method of execution, review under one or more of the following federal laws would be required: Section 10 of the River and Harbors Act; Section 404 of the Clean Water Act; Section 401 Water Quality Certification, and; the National Pollution Discharge Elimination System (NPDES).

The estimated cost of dredging is $10-11 per cubic yard for hydraulic dredging versus $12-16 per cubic yard for mechanical dredging. These costs include the cost of developing site access, but do not include construction of holding basins.

4.2.1.2 Mitigation Measures

Even with a dredge system designed to minimize impacts on the water column, the dredging operation may lead to an increase in turbidity, and may also introduce hydrocarbons into the water column. Moreover, the extensive disturbance of the river channel that may occur as the result of temporary road construction could also adversely affect river water quality. If no special measures are taken to mitigate these effects they may degrade water quality, at least temporarily within the reach in which the dredging operations are in progress. It is likely that much of the turbidity would be able to settle out behind the next downstream dam, although any hydrocarbons accumulated on the water surface would probably continue downstream. Compliance with Ohio water quality standards for non-drinking water Outside Mixing Zone Average (OMZA) concentrations of PCBs and PAH compounds would be reviewed and evaluated for a Permit To Install (PTI) by the OEPA.

The following options are available to reduce adverse impacts to water quality during the proposed dredging operation.

- Oil booms - An option to mitigate hydrocarbons released as a result of dredging is to deploy oil booms downstream of the dredging operation. These collect and absorb superficial hydrocarbons but do not absorb water. They do not address the issue of turbidity. This option is strongly recommended as a low-cost means of reducing the negative impacts of dredging.

- Silt curtains - Silt curtains are silt fences that are placed downstream of the dredging and road construction operations, such that all river flow passes through them. This has been found to be an efficient and inexpensive means of reducing turbidity in the river water downstream from these operations. It is strongly recommended that this technique be employed during the proposed dredging.

- Coffer cells - If the oil booms and silt curtains discussed above are found to be inadequate to protect river water quality downstream from dredging operations, then coffer cells could be constructed. The coffer cell method involves construction of temporary walls around a section of river, effectively isolating it from the flowing waters of the river. These would basically impound the water at the dredging site, allowing the suspended solids to settle out prior to discharge of the water into the river. Hydrocarbons could be skimmed from the water surface within the coffer cell. This option would add cost to the dredging operation and is not recommended unless the other, less-expensive mitigation measures are found to be ineffective.

The cost of oil booms and silt curtains is expected to be minor and to be included in the contractor's price for the overall dredging operation. A price for construction of coffer cells has not been developed for this report, as they are considered unlikely to be needed. The issue of whether to use oil booms, silt curtains, or coffer cells to control suspended sediments, oils, and other materials during dredging would be reviewed by the OEPA during the Section 401 water quality certification process.

4.2.1.3 Addition of River Bed Substrate

The dredging of sediments from the Mahoning River would remove at least part of the existing river substrate, presumably leaving a base composed predominantly of the natural glacial till. Over time, it is expected that sand and gravel would be transported into, and distributed throughout the remediated area. However, in order to expedite the ecosystem restoration of this area, it would useful to place a clean substrate suitable for colonization by benthic organisms into the river during the dredging operation. It is recommended that any materials used for construction of temporary roadways be appropriate for use as substrate. Once the temporary road was no longer needed, this roadway material could be distributed in the river channel to provide a high-quality substrate for benthic organisms to colonize. The hydraulic impact of each increment of fill used to create habitat would have to be analyzed to assure that it would not restrict channel capacity and contribute to flooding problems during high flow periods.

Temporary roads are expected to be built where the river is too shallow to use a floating plant. If it is assumed that temporary roads are constructed over 30% of the Mahoning River from RM 12 to RM 42.9, the estimated volume of gravel used would be 271,920 cubic yards. The cost of this material would be incidental to the dredging cost.

4.2.1.4 Handling and Dewatering of Dredged Material

The material dredged from the Mahoning River would be a sediment-water mixture. If hydraulic dredging is used, it is expected that the sediment:water ratio would be roughly 1:10. For mechanical dredging, the ratio is expected to be approximately 1:1. This is based on the observed water content of sediments collected for this project, which averaged 33 weight % but ranged from 10 to 60 weight % water. Although the handling of the dredged sediment would depend in large measure on its ultimate disposition, it is expected that in any case it would be advantageous to dewater this sediment as much as possible prior to proceeding to the next step of the remediation.

Storage. For purposes of sizing the holding basins to store the hydraulically dredged material, it is assumed that the total storage volume should be equal to 125% of the estimated sediment volume. Based on a sediment volume of 462,000 cubic yards (Section 2.4.3), this gives a total volume of 577,500 cubic yards for the holding basins. The actual storage volume required could be higher, depending on what percentage of water was retained by the sediments.

This volume would be obtained by constructing eight basins spaced roughly four miles apart. This spacing is dictated by the maximum distance of two miles that the sediments may be pumped without the installation of booster stations. The berms of the holding basins would be designed according to dam construction regulations with 6H:1V sidewalls. The material to construct the berms of the basins would be obtained from an off-site borrow source and transported to each of the work sites for grading and compaction. In order to allow for the sediments to dewater, a one-foot thick layer of gravel would be placed at the base of the holding basins. Water would settle out of the sediment material, permeate through the gravel layer and flow into a corrugated metal piping (CMP) system. Once in the CMPs, the water would continue to flow by gravity to a water treatment unit, as discussed in Section 4.2.1.6.

For the mechanical dredging option, one large holding area is assumed. The dredged material would be trucked to this basin, which would be located near the center of the project area. Because the amount of water present in the sediments is expected to be much lower than in the case of hydraulic dredging, this one large basin is assumed to require only 10% more volume than the estimated sediment volume of 462,000 cubic yards, or 508,200 cubic yards. The basin design would be the same as that described above for the basins used with hydraulic dredging, except that it would include a liner beneath the gravel layer, with underlying and overlying sand layers to protect it.

The cost of holding basin construction is estimated at $11 per cubic yard of basin volume without a liner, or $16 per cubic yard with a liner. As discussed in Section 4.3.2.2, the lower cost is used in the minimum and intermediate cost alternatives, and the higher cost is used in the maximum cost alternative.

Dewatering. The sediment-water mix produced by dredging would need to be dewatered. The purpose of this dewatering is (1) to reduce the weight of material to be treated and disposed of, and (2) to ensure that the material would pass the paint filter test, as is required under RCRA for landfill disposal. The dewatering techniques to be used would need to be evaluated using pilot scale testing of the actual dredged sediments. In addition, the extent of dewatering to be attained would depend on the ultimate disposition of the sediments. Potential dewatering options include:

- Settling and Draining. After placement in the holding basin, it is expected that the sediment would settle out, leaving a layer of water above it. This layer can be pumped out periodically. As noted above, the holding basins would also be designed with a gravel underdrain, which would allow water to drain from the bottom of the sediment pile. Both the supernatant water and water draining from the bottom of the basin may need to be treated prior to discharge to the river, as discussed in Section 4.2.1.6. The rate and extent of dewatering that occurs by natural fluid-water separation would need to be determined experimentally. Because it requires no major expense beyond engineering the holding basins, this type of dewatering is the preferred option.

- Natural Drying. This option involves spreading the sediment out and allowing it to dry in the sun. It is inexpensive but requires an area on which to place the sediment, and equipment to turn it so as to ensure complete drying. It may also require some arrangements to be made for inclement weather. Because there is no volatile contamination associated with the sediments (Section 2.4.4.2), it is not expected that this option would involve any type of air permitting.

- Other dewatering options. Other dewatering options were also considered. These include filter presses; industrial centrifuges; evaporators; and stabilization by addition of amendments. All of these methods would require construction of structures to hold the dewatering equipment, and maintenance. In addition, these processes are not generally used to treat the very high volumes of fluid expected on this project. As a result, it is recommended that these more complicated dewatering options be considered only if the natural dewatering approach discussed above is inadequate for the preferred final disposal or treatment option. The cost of these other dewatering options would depend in part on the water content of the sediment, and is expected to be at least $10 per cubic yard.

4.2.1.5 Treatment of Supernatant Water

As part of the dewatering process, large volumes of water would be removed from the holding basins built to receive sediments dredged from the Mahoning River. Although standard elution data suggest that the water associated with the dredged sediments would not be contaminated (Section 2.4.4.3), some treatment may be required before it can be discharged back into the river. This could include passing the water through an oil-water separator, and carbon filtration or sand filtration if required. An NPDES permit would be required for the discharge point or points back into the Mahoning River. Alternatively, the discharge could be piped to a Publicly-Owned Treatment Works (POTW) for treatment. POTWs along the river would have to be contacted to determine if they can receive the water and, if so, the cost for treatment. The cost for POTW treatment would have to be compared to on-site treatment and discharge via NPDES permits.

The principal cost for handling and disposal of the water removed from the holding basins would be for the pumps to remove the supernatant water; the oil-water separators installed at each basin; and the cost of NPDES permit compliance. The estimated total costs for these items is $40,000 per holding basin (excluding contingency cost).

4.2.1.6 Treatment and Disposal Options for Dredged Material

After dewatering is complete, the sediments would need to be treated and capped in place, or excavated and transported to a treatment or disposal facility.

The specific treatment or disposal options considered include disposal at a landfill, bioremediation, thermal treatment, and beneficial reuse (Figure 16).

Disposal of sediments at a landfill off-site. This option would involve disposing of the dewatered sediment at a landfill. The chemical data collected for this reconnaissance report indicate that the sediments to be dredged are Non-Hazardous as defined in 40 CFR 261. According to the OEPA, the sediments should be acceptable at a municipal solid waste landfill.

The major issue related to landfilling is the amount of water that is present in the sediments. In order to be landfilled, the sediments must pass the paint filter test under RCRA and Ohio EPA solid waste regulations. In addition, it may be economically beneficial to remove additional water from the sediments even if they pass the paint filter test. The decision regarding how much water to remove depends on the cost per unit weight of water removed, versus the cost of hauling and disposing of the additional water. Discharge from confined disposal areas to the Mahoning River would require both a NPDES permit and PTI from the OEPA/Division of surface Water. The OEPA would review and evaluate PTI requirements during the Section 401 water quality certification process.

The cost for disposal at a residual waste landfill is estimated to be $18 per ton, plus a hauling cost of between $10 per ton from Leavittsburg to $5.50 per ton from the Pennsylvania state line.

Bioremediation. Two commercially-available bioremediation technologies were reviewed: the DARAMEND system (Grace Technologies) and Bioblend products (Waste Stream Technologies). Both of these technologies have been used successfully in the remediation of PAH- and TRPH-contaminated soils, and both could be applied to the sediments in the holding basins after dewatering was completed.

Both bioremediation technologies are capable of treatment to a depth of about two feet below the ground surface. This limit is set by the maximum depth that can be reached by the tilling equipment, which is required to break up the soil and introduce the microbes or soil amendments used in these processes.

An important difference between the two bioremediation technologies involves the amount of dewatering required beforehand. The Bioblend approach involves the addition of microbes into an aerobic environment, and therefore requires fairly complete dewatering. In contrast, the DARAMEND system involves addition of an amendment which provides nutrients and a growth substrate for naturally-occurring microbes, and also solidifies the soil. This is likely to be a major advantage in the treatment of the Mahoning River sediments, which may have a relatively high water content at the outset. An additional advantage for the DARAMEND system is that it is currently being used on an analogous project involving remediation of 16,000 cubic yards of sediment for PAHs at Thunder Bay, Ontario. Based on these factors, the DARAMEND technology would probably be preferred over the Bioblend approach. The cost for the DARAMEND treatment is between $25 and $75 per ton. This would include the analytical work needed to document successful bioremediation. Costs associated with closure of the holding basins after completion of bioremediation are not included in the figure.

After bioremediation is completed, it is expected that in-place closure of the sediment basins would occur. This would involve capping and re-vegetating the sites, as well as any monitoring required by the OEPA. One potential problem with such a closure is that any metals contamination present in the sediments would not be addressed by the bioremediation. As part of the permitting process for on-site closure, it would therefore be necessary to demonstrate that the metal concentrations would be acceptable to the OEPA. This could possibly be accomplished under the Voluntary Action Program (VAP) limits that are currently in place for clean-ups at Brownfield sites in Ohio (OEPA Regulation 3745-300, December 6, 1996).

Thermal Treatment. Soil Remediation, Inc., provides thermal treatment of petroleum-contaminated soils at its facility in Lowellville. Sediments excavated from the Mahoning River could be removed from their holding basins after dewatering and hauled to this facility. The treatment involves desorption of organics at 600 degrees F., followed by thermal destruction in the discharge airstream. The system can potentially accept soil with other contaminants, if approval is granted by the EPA.

One disadvantage of the thermal treatment option is that it would require hauling of the sediment from the holding locations to the treatment location. Also, it requires relatively complete dewatering, because any water remaining in the sediments would increase the treatment cost. Finally, it is not clear what would be done with the sediments after thermal treatment was complete. As with the bioremediation option, thermal treatment does not reduce metals contamination in the sediments. Therefore, the treated sediments would need to be handled in a manner consistent with their degree of metal contamination.

The cost for thermal treatment is in the $20s per ton range, not including the cost of hauling to the treatment facility. With transportation costs included, the total cost would be about $30 per ton, assuming that all of the permits necessary for thermal treatment are already in order.

Beneficial Reuse. This method involves reuse of contaminated material in an economically beneficial manner. Typical examples of beneficial reuse include use of contaminated materials as filler in asphalt or other construction materials, or burning of petroleum-contaminated soils to obtain their BTU value.

4.2.2. Isolation

Isolation would involve placement of a layer of impermeable material over the top of the contaminated sediments in the Mahoning River. This option was reviewed with Hull Engineers, Inc., which markets "AquaBlok", a bentonite-based material. Aquablok can be applied by a variety of methods, including barges or conveyor belts. The river access required for its placement would be similar to that for dredging (Section 4.2.1.1).

Aquablok has been used successfully in pond/marsh environments and is currently being placed in a pilot study at the mouth of the Ottawa River in Toledo, Ohio. However, it has not been used in a fluvial environment such as the Mahoning River. Therefore, it is not clear how stable it would be over time in a dynamic setting. Its ability to support a healthy benthic community is also unknown. Because of the lack of prior experience in the use of AquaBlok in this type of environment, this technology is not currently recommended as a remedial option for the Mahoning River project.

4.2.3 Removal or Breaching of Dams

This remedial option would involve removal or breaching of some or all of the nine dams below the Leavittsburg-Lovers Lane Dam. If removal is selected, the dams would be demolished by either breaking the concrete into manageable pieces using a tracked excavator with a rammer attachment, or by blasting. In both methods, the first step would be to breach the dam so that the water behind it was released. After the water level on both sides of the dam had stabilized, dam demolition would be completed.

It is expected that debris produced by dam demolition could be crushed and returned to the river as substrate, or else hauled to a demolition debris landfill. Mitigation during the demolition would be similar to that presented in Section 4.2.1.2. The average estimated cost of dam removal is $372,900 per dam.

A modified version of this alternative would involve removal or breaching of only selected dams. This would allow any dams that are currently used to provide water intakes to remain intact.

It should be noted that breaching or removal of dams without prior dredging of contaminated sediment is not considered an acceptable option. Although this action could lead to some improvement in the physical habitat of the river, it would also be likely to mobilize large areas of contaminated sediment, leading to a deterioration in water quality and to transport and redeposition of contaminated sediment downstream.

4.2.4 Remediation of Contaminated Banks

Reconnaissance sampling of depositional bank material along the Mahoning River by the USACE indicates that it is chemically similar to the contaminated river sediments. No effort was made in the current study to estimate the volume of contaminated bank material. However, USACE (1976) estimated that there are 285,600 cubic yards of contaminated material in the banks. USACE (1976) also estimated that 95,200 cubic yards of clean material overlying the contaminated material would need to be removed in order to excavate the contaminated material.

If left in place, the bank material represents a potential source of contamination that would remain after the removal of the contaminated sediments in the river. The bank material would be expected to slough off into the Mahoning River over time, and also potentially to leach contaminants into the river. Removal of the dams (Section 4.2.3.1) could also destabilize the banks, increasing the rate at which material from the banks fell into the river. These considerations suggest that the contaminated bank material should be removed as part of the Mahoning River remediation project

The two general options considered for remediation of bank material are removal and stabilization of the banks. Based on the preliminary investigation of the banks conducted for this study, the largest and most seriously contaminated deposits of bank materials are covered by only a relatively thin cap of uncontaminated silt, and do not support large woody vegetation. Their removal would not directly harm the valuable corridor of mature riparian forest that lines the banks of the Mahoning River along much of the study reach. In sensitive reaches where the cap over the contaminated deposits is more substantial, and mature sycamores, cottonwoods, and other valuable riparian vegetation encroaches on the deposits, removal could have a significant impact on riparian habitat. In such locations, it might be possible to extract the underlying contaminated sediment with extraction wells on a barge, with diminished disturbance to the stream bank riparian zone. To replace the soils removed from the bank, a clay bentonite slurry could be injected into the excavated space. If needed, a geosynthetic liner could be used to stabilize the clay slurry mixture. This clay layer would also lessen future migration of any remaining bank contaminates into the river water.

Stabilization would involve placement of a geosynthetic liner over the bank to minimize sloughing of material or other transfer of contaminants from the banks to the river. In order to anchor the liner, it would need to extend six feet onto the shore above the bank. For purposes of developing a cost estimate, it is assumed that the liner section over the bank would be ten feet long. Together, this gives a sixteen foot length of liner along each bank. Rip rap would be placed over the top of this liner to stabilize the bank. It is assumed that a 1/2-yard thick layer of rip rap would be used for this purpose. Another alternative to rip-rap for bank stabilization is the use of natural vegetation to line banks and control erosion. Potential disadvantages of stabilization include the likelihood that ongoing maintenance would be required, and possible adverse effects of the contaminated material left at the site through migration to the surface, even though it is buried beneath a layer of cleaner material.

Excavation of bank material is estimated to cost from $48-60 per cubic yard. This cost includes dewatering of the excavated material in a holding basin, as with the dredged material, and also disposal at a landfill. Stabilization is estimated to cost from $2-5 per square yard for the geotextile liner, and from $35-75 per cubic yard for a 1/2-yard thick layer of rip rap placed over the liner. The costs of either excavation or stabilization of the banks would depend on whether the work was done from land or from water, with substantially lower costs for work done from land. The most economical and effective alternative would probably be a hybrid of the stabilization and removal options. Where the banks are steep, stable, and bank contamination problems are moderate to minimal, stabilization or even no action would be sufficient. For those portions of the river with large, highly contaminated, and extremely unstable deposition bank features, removal would be necessary.

4.2.5 Remediation of Selected Reaches

All of the remedial alternatives presented above would involve remediation of the entire project area. Another approach would be to remediate only a portion of the project area. For example, this could involve selecting only the reach with the largest sediment volume for remediation at this time. However, with such an approach, it is probable that the remediated area would be recontaminated by the migration of contaminated sediments from upstream. As a result, this selected reach remediation approach is not recommended.

The best implementation sequence for a "selected reach" option would be for treatment to be initiated at the upstream approach and proceed downstream. This would allow for a systematic treatment of the Mahoning River and resulting improved fishery to occur in a continuous fashion, from upstream to downstream.

4.3 Identification of Alternative Plans

There are four major variables to be considered in the identification of alternative plans for ecosystem restoration of the Mahoning River. These are

- **Dredging Method** - the percent hydraulic versus the percent mechanical dredging to be used;

- **Dam Removal or Breaching** - how many dams, if any, to remove or breach;

- **Bank Remediation** - what percentage of the contaminated banks to remediate using stabilization, and what percentage to remediate using removal; and

- **Treatment and or Disposal Method** - the treatment methods, if any, to be used on the sediments, and the ultimate disposal site.

The Isolation and Remediation of Selected Reaches components are not considered in the identification of alternatives. Due to concerns about effectiveness (Section 4.2.3), isolation technology is not considered in any alternative. Also, based on discussion in Section 4.2.5, it will also be assumed that all reaches are treated in an effective manner in each alternative. This will provide for the maximum amount of benefits in each alternative.

Based on the discussion in Section 4.2.1.5, natural dewatering followed by landfilling is currently the preferred treatment and disposal option. This conclusion is founded on two arguments. First, dewatering and landfilling is the least expensive of the disposal options considered. And second, landfilling has the fewest regulatory issues associated with it. Once the landfill has been permitted to accept the Mahoning sediments, there should be no other regulatory issues related to the final disposal. In contrast, other remedial options have many regulatory issues. For example, in-situ bioremediation or other treatment approaches would probably require permitting; on-going sampling and testing to determine if treatment goals were met; some type of site closure plan; and possibly long-term monitoring after closure. Moreover, there is always the possibility that the in-situ remediation would not work as well as planned.

For these reasons, the only treatment/disposal option considered in the remedial alternatives presented below is dewatering followed by landfilling. Other treatment alternatives presented in Section 4.2.1.5 can be considered further in the feasibility study, if appropriate.

By adjusting the remaining three variables (Dredging Method; Dam Removal; and Bank Remediation), innumerable restoration alternatives could be developed. In order to simplify the analysis of alternatives, only three are presented in this section. These are (1) A minimum-cost alternative, which includes the lowest cost option for the three variables noted above; (2) A maximum-cost alternative, which includes the highest cost option for each of these three variables; and (3) An intermediate cost alternative, which includes combinations for each of the four variables based on currently available technical, cost and other information.

The three alternatives identified are:

Alternative 1: Contaminated sediments would be removed exclusively by hydraulic dredging, which is the lowest-cost dredging option. Contaminated banks would be remediated exclusively by stabilization, which is the lowest-cost bank remediation option. No dams would be removed.

Alternative 2: Contaminated sediments would be removed exclusively by mechanical dredging, which is the highest-cost dredging option. Contaminated banks would be remediated exclusively by removal, which is the highest-cost bank remediation option. All nine dams would be removed.

Alternative 3: 70% of the contaminated sediments would be dredged hydraulically and 30% would be dredged by mechanical dredging. This split is based on general field observations made during the reconnaissance study, which suggest that most sediment would be accessible by a floating dredge, and would be sufficiently free of coarse debris so as to be amenable to hydraulic dredging. However, it also recognizes that there are likely to be reaches where mechanical dredging would be required. Contaminated banks would be remediated exclusively by removal in Alternative 3. This is because the stabilization option, although less expensive than removal, may not provide an adequate level of remediation and is therefore considered unacceptable for inclusion in the this alternative at this time. Finally, Alternative 3 includes removal of five out of nine dams. This number is for planning purposes, and is based on the estimate that five dams can be removed without impacting any current or planned river usage. The actual number of dams that can be removed should be determined in the Feasibility Study.

4.4 Evaluation of Remedial Alternatives

4.4.1 General Strategy

This section presents an evaluation of the three remedial alternatives developed in Section 4.3, based on the cost and the expected degree of ecosystem restoration. Costs were generated based on discussions with contractors familiar with environmental dredging projects, and with vendors of appropriate remediation services. Potential improvements to the Mahoning River ecosystem due to sediment restoration and dam breaching or removal were based on data presented in OEPA (1996) and Shroeder (1998, Appendix E). Economic benefits due to ecosystem restoration were based on Thorn (1981).

For this study, one "preferred" plan is selected from the three formulated and described in the previous section. These plans were developed based primarily on cost considerations and with the intention that the positive impacts increase as cost increases. The preferred plan is intended to represent the most environmentally efficient plan, based on the difference between costs and rough estimates of differences in the impacts on biologic indices. At this stage of study, a greater emphasis was placed on cost and, to a lesser extent, perceived technological effectiveness of the remediation technologies (i.e. dredging vs. capping) and less was placed on differences in ecologic benefits. However, there is some discussion of potential differences of the resulting biologic indices for the three alternatives based on the biologic assessment documented in Appendix E.

Significant feasibility study efforts would be devoted to more fully evaluating the ecological and possibly the technological issues. Specifically, impacts for varying the number of dams removed or breached would be evaluated by considering specific dams and the resulting hydraulic conditions (i.e. free-flowing vs. pooled reaches). Lengths of each type of river condition would be calculated, and resulting (With-Project) biologic index values calculated based on existing model reach values. These values would then be converted to some useful aquatic benchmark, such as estimated numbers of various fish species per unit, which would allow for a more quantifiable ecological difference to be determined. The evaluation of capping vs. dredging could be more difficult, but one possible outcome of a feasibility level analysis is to determine if it is worth considering alternatives to dredging further, possibly to include pilot tests in post-feasibility (Preconstruction, Engineering, and Design) studies.

4.4.2 Cost Analysis of Remedial Alternatives

In this subsection, cost estimates for the three remedial alternatives described in Section 4.2.4 are developed.

4.4.2.1 Alternative 1 (Minimum Cost/Benefit)

A cost estimate for Alternative 1 is presented in Table 9. The total cost is about \$66.5 million. Major expenses include hydraulic dredging of sediments (\$6.3 million); construction of eight holding basins (\$7.9 million); landfilling (\$21.3 million); and installation from land of a geotextile liner and rip rap along the banks (\$13.1 million). Utility relocation, at \$9 million, is a major expense that is expected to be the same for each of the three remedial alternatives. Note that in each of the cost estimates, remediation of the reach from RM 41 to RM 42.9 has been broken out as a separate line item, which includes all dredging, treatment, and disposal costs. This reach is treated separately because, as discussed in

Section 1.5, it is beyond regulatory navigability and may be remediated separately, or not at all.

4.4.2.2 Alternative 2 (Maximum Cost/Benefit)

A cost estimate for Alternative 2 is presented in Table 10. The total cost is about $101.3 million. Major expenses include mechanical dredging of sediments ($9.1 million); construction of two large holding basins ($16.4 million); excavation of banks from water ($11.9 million), and landfilling ($34.7 million). The significantly higher cost of landfilling relative to Alternative 1 reflects an increase of 285,600 cubic yards in the amount of material to be landfilled. This is the estimated volume of contaminated bank material. The increase in the unit rate for construction of the holding basins from $11 per cubic yard for Alternative 1 to $16 per cubic yard for Alternative 2 is caused by the addition of a liner and enclosing sand layers in the basin design for Alternative 2.

4.4.2.3 Alternative 3 (Intermediate Cost/Benefit)

A cost estimate for Alternative 3 is presented in Table 11. The total cost is about $91.5 million. Major expenses include dredging of sediments by combined hydraulic and mechanical methods ($7.1 million); construction of nine holding basins ($12.0 million); excavation from water of bank material ($11.9 million); and landfilling ($34.7 million).

4.4.3 <u>Benefits Analysis</u>

This section discusses the ecological and economic benefits that could be realized by restoration of the Mahoning River.

4.4.3.1 Ecological Evaluation Methodology

The methodology to evaluate the three alternatives is based on assessing expected changes to the biotic indices discussed in Section 3.2. These include the ICI for measuring the health of the invertebrate population; the IBI, MIwb and DELT for measuring the health of the fish population; and the QHEI for measuring the quality of river habitats. Successful ecosystem restoration would be defined as significant improvement or attainment of the WWH criteria for all of these indices throughout the project area.

4.4.3.2 Ecological Benefits of the Remedial Alternatives

The ecosystem effects of dredging and of dam removal presented below are based on the following conclusions supported by the Biological Assessment (conclusion numbers 7 and 8 on page 35, Appendix E):

- Sediment restoration alone would markedly improve the biotic community structure and function of the Lower Mahoning River. It is likely that sediment restoration alone would bring the biotic indicators to near the values required for WWH use designation.
- Removal of the dams would further improve the community indices with a high likelihood of achieving WWH designation for all OEPA community-based biotic indices (except DELT).

In addition to these assumptions, the ecological evaluation makes use of the data presented in Section 3.2 on various indices of biological health in both the reference zone and the target zone of the Mahoning River. These indices include the Invertebrate Community Index (ICI); the Index of Biotic Integrity (IBI) and the Modified Index of Well Being (MIwb), both of which measure of the health of the fish community; Deformities, Eroded Fins, Lesions and Tumors (DELT); and the Qualitative Habitat Evaluation Index (QHEI). These indices are particularly useful because they have WWH criteria established by the OEPA. Thus the present conditions, and the expected future conditions, in the Mahoning River for these indices can be expressed as a percentage of the WWH criteria.

Predicted values of the ICI, IBI, MIwb, and DELT, expressed as a percentage of the WWH criteria, are shown on Figure 17 and on Table 12. The black bars on Figure 17 are based on data in OEPA (1996). As discussed in Section 3.5, these bars also represent the expected ecological conditions if no remedial actions are taken (Without-Project Condition). The striped bars show the predicted values after dredging with no dam removal. This scenario closely approximates Alternative 1, except that Alternative 1 also involves capping contaminated sediments along the banks. All four of the indices show significant improvement relative to the no-action alternative, although only the IBI attains the WWH criteria. The cross-hatched bars in Figure 17 show the predicted values after both dredging and removal of all of the dams, and represents Alternative 2. Removal of the dams would further improve habitat quality by increasing stream velocity, increasing exposure of substrate with high habitat quality, preventing deposition from covering restored substrate habitat, and provide easy access for fish to colonize the river (Appendix E). For this scenario, the predicted ICI meets the WWH criteria, the IBI exceeds the criteria, and the MIwb is within 70% of the WWH criteria. However, the value of DELT is essentially unaffected by the dam removal. This is because the number of abnormalities produced in the fish population, unlike all of the other indices, is inferred to depend only on the degree of contamination, and not on the quality of habitat.

The ecosystem restoration produced by Alternative 3, which would involve removal of five of the nine dams, would be roughly half-way between that expected from Alternatives 1 and 2 on Figure 17. This would put the predicted values of all of the biotic indices except DELT within 10% of the WWH criteria (Table 12).

The QHEI is unique among the five parameters considered in that it does not reflect the health of the biological community in the stream, but rather the physical conditions, such as the nature of the substrate, the amount of pools and riffles, and other factors that influence the overall habitat quality. Currently, the Mahoning River exceeds the WWH criteria for the QHEI in free-flowing segments in both the target and reference zone, but fails to meet these criteria in pooled portions of both zones. Thus, the QHEI is degraded by the presence of the dams rather then by sediment contamination. Removal of all nine dams (Alternative 2) is predicted to improve the QHEI in currently pooled areas of the target zone from 82 percent to 122 percent of the WWH criteria. Removal of five of nine dams would be expected to yield roughly one half of this improvement, to about 102 percent of the WWH criteria in the currently pooled areas of the target zone.

Although removal of all nine dams (Alternative 2) would be expected to produce the greatest improvements in all of the biological indices considered, it may also have other detrimental health, aesthetic and economic impacts. If any of the pools that were eliminated by dam removal were being used to supply water, some provision would need to be made to ensure that these water supplies were not disrupted.

The significant improvement of values for the indices would mean that a diverse population of invertebrates would return to the project area. In addition, forage fish such as minnows, shiners and chubs would increase in abundance. These would be expected to support a healthy population of sport fish such as smallmouth bass, bluegill, muskellunge, walleye, perch, white bass, crappie and largemouth bass. Attainment of these benefits would be confirmed by post-project monitoring. The existing excellent and comprehensive OEPA monitoring program would support post project evaluation requirements.

Figure 15 shows the anticipated benefit of river restoration to average relative smallmouth bass populations. As shown on this figure, removal of contaminated sediments is expected to greatly enhance average relative smallmouth bass populations, with additional benefit yielded by removal or breaching of the dams. More specifically, the expected aquatic conditions after a remediation project in the lower Mahoning River mirror existing conditions of the Mahoning River between the Leavittsburg Dam and State Route 422 (approximate river miles 46 - 44), an area just upstream of the clean-up area with biologic indices indicative of a reach with clean river sediments. This reach of river is free of any HHA conditions and is home to invertebrate communities that support diverse and desirable fish species.

This analysis does not address a major concern with the stabilization of the contaminated material along the shore, a component of Alternative 1. This concern arises over the potential for remigration of contaminants to the water column. This shortcoming of stabilization could render the total effectiveness of Alternative 1 temporary at best. Stabilization of contaminated material along the newly formed banks would be effective only if remigration of contaminants to the river can be prevented.

One other issue not specifically addressed by the study the biological indices presented above is the human health advisory currently in effect for the Mahoning River below RM 41.5. Removal of this advisory is an important goal of the ecosystem restoration project. The upstream limit of the advisory is Packard Park, which roughly corresponds to the upstream limit of the project area, and to the border between the reference zone and the target zones used above to evaluate changes in biological indices occurring as a result of remediation. Removal of contaminated material is expected to address local concerns by eliminating the swimming, wading, and sediment contact portions of the human health advisory. Contact advisories during combined sewer overflow and sanitary sewer overflow incidents would still probably be periodically necessary. Also, some fish consumption limitations would almost certainly persist, especially for larger and older fish species with abundant fatty tissues (such as channel catfish and carp) that tend to accumulate PCBs and other organic chemicals. Such moderated caveats, however, are common to important urban recreational waters across the nation, and should not diminish the projected economic benefits of the restoration project quantified in the next section. Further, the potential for enhancing recovery of the fishery by replacing existing fish species with healthy populations, say by shock killing, natural recruitment, and/or restocking, would be evaluated in subsequent study stages. Potential positive impacts on the human health advisory by sediment remediation are also supported by opinions provided in the Biological Assessment (Appendix E, page 36) and the Planning Aid Report (Appendix F, page 8).

4.4.3.3 Economic Benefits Analysis

This section presents a discussion of the potential economic benefits that can be expected from restoration of the environmental quality of the Mahoning River. Under the authority of Section 312(b) of the WRDA of 1996, under which authority this study is being conducted, an economic analysis showing a positive benefit-cost ratio is not required. Therefore, funds were not expended during this phase of the study process for an economic analysis. However, it is clear from discussions held with the Steering Committee that economic impacts would be a crucial concern to any potential sponsor for a remediation project. Fortunately, economic benefits of a remediation project for the Mahoning River valley were determined in a 1981 report entitled "Study of the Social and Economic Benefits Resulting from the Implementation of the Best Available Technology Economically Achievable on the Mahoning River," by Dr. Richard Thorn of the University of Pittsburgh. These benefits have been updated to September 1998 by use of the Engineering News Record (ENR) cost index numbers. The following paragraphs briefly discuss the methodology and results of that earlier study, reflecting September 1998 benefits.

Thorn's (1981) study estimated net social and economic benefits that would occur from use and non-use values (defined below) resulting from a healthy ecosystem created by the proposed environmental restoration of the Mahoning River. The main economic and social use benefits of the remediation project would be derived from increases in recreational activities that would result from the environmental restoration of the aquatic ecosystem of the Mahoning River. Recreational uses considered included fishing, swimming, and boating. The increase in recreational activities associated with fishing would result from a general increase in aquatic wildlife diversity, but particularly from restoration of the smallmouth bass and other warmwater fish populations to the Mahoning River target area. Diversification of aquatic wildlife would help support this healthy freshwater fishery, which in turn would support increased demand for fishing. A healthy ecosystem would also support increases in boating and swimming activities within the Mahoning River target area.

Extractive use benefits for municipal and industrial water resulting from water quality improvements were also analyzed by Thorn (1981). However, since 1981, the water quality of the Mahoning River within the target area has dramatically improved, and the impact of a proposed remediation project on water quality would not be as significant as it would have been in 1981. Therefore, this economic and social benefit will be omitted from further consideration.

Non-user benefits resulting from the environmental restoration effort are more difficult to define and considerably more difficult to quantify. Non-user benefits are defined as those benefits accruing to individuals who do not make direct use of the natural resource. Three main categories of non-user benefits are generally recognized. They consist of aesthetic benefits, existence benefits, and option benefits. Aesthetic benefits are derived from the pleasure one gets from being surrounded by and observing the environs of a healthy ecosystem; bird watching is an example of aesthetic value derived from a diverse healthy ecosystem. Aesthetic quality also increases property values. Existence benefits are derived from just knowing that a natural resource exists and contributes to the quality of life of a community even though the individual has no intention to visit it. The best example of this is knowing that the Grand Canyon is there for all to enjoy. For the Mahoning River, it would be the pleasure derived from the fact that the river can be made into a viable and vital healthy ecosystem contributing to the quality of life in the Mahoning Valley even though certain members of society would not visit the river. Option benefits are benefits that are derived from having the option to choose among alternative environments in the future. This value implies there would be some irreversible change in the environment that would affect the ability of the resource to be used in the future. With respect to the Mahoning River ecosystem, years of pollution have eliminated the option value for the river in today's terms. The existing option value is virtually zero. Therefore, by restoring the ecosystem the potential option value would be available for current and future generations.

Thorn (1981) quantifies the above mentioned social and economic benefits by using acceptable economic metrics such as willingness-to-pay, travel cost methods, and questionnaires. The benefits were determined for both an upper and lower bound value under two categories of criteria. The categories were denoted as Gross Upper Bound Estimate and Best Upper Bound Estimate. The benefits derived, converted to September 1998 dollars using the ENR economic cost index numbers, would be $114.3 to $86.4 million for the Gross Upper Bound Estimate and $45.7 to $29.5 million for Best Upper Bound estimate, annually.

However, the user benefits neglected several important qualities that would enhance the benefits noted. Thorn's (1981) study did not consider benefits derived from increased diversity in the form of waterfowl and wildlife. These natural resources can contribute to both user and non-user benefits. Duck hunting and trapping are popular sports in Eastern Ohio and Western Pennsylvania, as well as, but not to as great an extent, bird watching. These activities can contribute greatly to the benefits noted above.

Another social benefit that was not fully explored by Thorn (1981) pertains to human health benefits from environmental restoration. As noted previously in this report, a Human Health Advisory was issued by the Ohio Department of Health warning individuals to not come in contact with the river sediments and recommending limits on fish consumption. The existing fish population is riddled with cancers and deformities. There is a good possibility that the proposed remediation of the Mahoning River would allow the Human Health Advisory to be lifted after the current generation of fish have died.

In conclusion, the Thorn (1981) study of economic and social benefits derived from a healthy freshwater ecosystem is a good first step in determining the environmental value and social and economic benefit, but probably underestimates actual benefits. The Mahoning River would be restored to an environmental quality that could offer economic opportunities.

4.5 Identification of Preferred Alternative

This section identifies a preferred remedial alternative, and explores ecological and real estate issues related to the alternative.

4.5.1 Preferred Alternative

Selection of the preferred alternative is based on comparing costs and expected benefits. Costs and benefits of the three remedial alternatives are summarized in Table 13.

Based solely on costs, Alternative 1 has the advantage as it represents only 65% and 73% of the total cost of Alternatives 2 and 3, respectively. However, as previously discussed, the reliability of that alternative to provide a restored ecosystem throughout the study period (50 years) is deemed considerably less than the other two. Although not quantified, this smaller reliability renders Alternative 1 to be inferior to the other two, at least until the effectiveness of the stabilization option can be confirmed. Further, until such effectiveness can be demonstrated, this alternative is deemed not to be in the Federal Interest.

The remaining two alternatives are considered reliable as they involve the dredging of all contaminated material. Additional restoration benefits over Alternative 1 would be provided by removal or breaching of several or all of the dams due to the ecological advantages described in subsection 4.4.3.2. Each of these alternatives are deemed to satisfy the conditions for a Federal Interest. These alternatives are separated in total first cost by $10 million. Neither has any annual cost. Further, the potential economic benefits of Alternatives 2 and 3 would be as indicated in Thorn (1981), who however did not consider impacts of dam breaching or removal. There could therefore be some slight increase in economic benefits resulting from the relatively improved aquatic conditions brought about by removal of four additional dams. This would probably give a slight benefit advantage to Alternative 3. However, removal of all dams is not currently deemed practical, as there would likely be considerable cost to existing private and public interests with facilities dependent upon current pool levels. This added cost would likely greatly outweigh any increase in benefits.

Alternative 3 is considered to be the preferred alternative. It is intermediate in both costs and predicted benefits between Alternatives 1 and 2, and is expected to restore the Mahoning River in the project area to 90% or better of most WWH criteria. Feasibility study, estimated to cost $1.5 million, would confirm all technical assumptions, work requirements, and associated costs for the plan recommended for implementation.

4.5.2. Real Estate Considerations for the Preferred Alternative

The purpose of this section is to outline the real estate issues for the preferred alternative, to discuss the real estate interests needed to implement the plan and to provide a cost estimate to acquire those interests.

The real estate considerations for this environmental dredging project are complex for several reasons. The first is the application of the Government's rights under navigation servitude. The navigation servitude is defined as the Government's dominant right to use, control and regulate the navigable waters of the United States and the submerged lands thereunder for various commerce-related activities, such as navigation and flood control. This power derives from the Commerce Clause of the U.S Constitution (U.S. CONST. art.I, §8, cl.3). The limit of the navigational servitude rights, for this project, is the Ordinary High Water (OHW) mark on each bank. All lands lying at or below the existing OHW elevation are considered part of the servitude rights that can be used by the Government . Application of these rights is determined by evaluating whether the waterway is navigable and if the project purpose serves commerce. The Mahoning River is classified as a navigable waterway of the United States of America. This classification will be further explored and documented in the feasibility phase. As a result, only the lands that lie outside the limits of the servitude are included in this section.

The preferred alternative calls for the removal of the material in the river by both hydraulic and mechanical dredging operations, removal of five of the nine dams in this reach of the Mahoning River and bank remediation by excavating the contaminated material and replacing it, where necessary, with clean fill. Most of the bank work will be below the existing OHW elevation, however, portions of the banks will be remediated by excavating them to a point 20-feet back from the ordinary high water line. A real estate interest will be required for these areas.

A second issue is the real estate interest, or estate, that will be acquired for the bank remediation by excavation. Normally, excavating and replacing material is considered a project feature which requires a permanent real estate interest for operation and maintenance. The excavation work for this project is intended solely to remove contaminated material from the banks and re-build the banks where necessary. The banks will then be allowed to return to their natural condition. No permanent real estate rights are needed for operation and maintenance purposes; therefore, only a temporary work area easement is recommended for removal of the bank deposits. The bank excavation work consists of approximately 115 acres of land.

Temporary work area easements are also needed for access roads to the river and for sediment storage ponds. The term for all of the temporary work area easements is one year, with the exception of the storage pond that is needed for the mechanical dredging method, that will be needed for a four year term and will be used in each phase of the dredging project.

The land uses along the Mahoning River include residential, commercial and industrial. The total land needed for the temporary work areas for contractor laydown and river access breaks down as 5.25 acres of residential land, 1.74 acres of commercial land and 11.94 acres of industrial land, for a total of 18.93 acres. The total amount of land needed for the eight hydraulic method storage ponds is approximately 92 acres of industrial land. An additional 14.6 acres of industrial land is needed for one mechanical method storage pond. The total acreage for all the temporary work areas is 125.53 acres and includes approximately 171 tracts of land. No residences, farms or businesses have to be relocated as part of the preferred alternative, although 7,200 feet of utility/facility relocations are included. These facilities will be impacted by the change in pool elevations due to the removal of five dams along with the proposed dredging operation. Attorney's Opinions of Compensability for these facilities will be prepared during the feasibility phase of the study to determine the Sponsor's responsibilities to provide a replacement utility/facility. The dredged material will be disposed of in an existing licensed landfill. The chemical data shows that the sediments are non-hazardous and according to Ohio EPA, are accepted at a municipal solid waste landfill.

The value of the land, including administrative costs, is estimated to be $3,465,400.