Vegetation Survey of Monongahela River
Phase 2 - 2001

VEGETATION SURVEY OF THE MONONGAHELA RIVER

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Published by the STUDIO for Creative Inquiry,
Rm 111, College of Fine Arts, Carnegie Mellon University
Pittsburgh PA 15213
412-268-3454
fax 268-2829
http:// www.cmu.edu/studio

First Edition, First Printing

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Introduction

"Seventy-seven percent of the total water discharge of the 139 largest river systems in North America north of Mexico, in Europe, and in the republics of the former Soviet Union is strongly or moderately affected by fragmentation of the river channels by dams and by water regulation resulting from reservoir operation, interbasin diversion, and irrigation. The remaining free-flowing large river systems are relatively small and nearly all situated in the far north, as are the 59 medium-sized river systems of Norway, Sweden, Finland, and Denmark. These conditions indicate that many types of river ecosystems have been lost and that the populations of many riverine species have become highly fragmented. *To improve the conservation of biodiversity and the sustainable use of biological resources, immediate action is called for to create an international preservation network of free-flowing river systems and to rehabilitate exploited rivers in areas that lack unaffected watercourses*." (Dynesius and Nilsson. 1994. Science 266: 753-762)

Statement of Purpose

The conservation and restoration of river systems is of global concern (Dynesius and Nilsson 1994). Riparian zones - the areas of contact between land and water along streams, rivers, ponds, lakes, and wetlands and the plants that live in them - are key components in river ecosystem stability (Wetzel, 2001 Chapter 10). Riparian plants' root systems help to stabilize riverbanks and stream banks, reduce erosion and decrease runoff and therefore significantly decrease the concentration of diverse nutrients, including nitrogen and phosphorus and other pollutants entering the river. Riparian plants provide habitat structure and food for terrestrial organisms. They also maintain water temperature through shading. Research indicates the importance of riparian zones in the overall health and function of watershed ecosystems (reviewed in Ward and Tockner, 2001).

However, long-standing disturbance of the river and riverbank creates conditions that diminish the local native biodiversity in the plant community and can foster the invasion of non-native plant species (e.g. Gilvear et al., 2000). Both of these factors can diminish ecosystem health. High levels of biodiversity have been shown to enhance the reliability of ecosystems in terms of primary productivity (Naeem and Li, 1997). Biodiversity within the plant community also distributes functional diversity across multiple physical scales of the ecosystems, which allows for subsequent renewal and recovery after disturbance (Peterson et al, 1998). This is particularly important when especially when habitats are fragmented. In addition, disturbances that cause declines in biodiversity correlate with increases to the invasibility of the community to non-native species (Tilman, 1999). Understanding the structure and composition of plant communities along rivers in the context of the management (disturbance) milieu is a key first step in maintaining and/or improving river function and health.

The Botany Team's goal is to create a large-scale spatially referenced database of woody vegetation and selected herbaceous plants. This database will be used to determine the occurrence of native plant communities and invasive species in the context of human management of the Three Rivers.

The Three Rivers Watershed belongs to the River Bed – Bank- Floodplain Plant Community Complex

Fike (1999) details the plant species and abiotic conditions that define typical native plant community complexes found in the state of Pennsylvania. [Note: These plant communities are cross listed by The Nature Conservancy's International Vegetation Classification and the Society of American Foresters' Forest Cover Types.] The River Bed – Bank- Floodplain Complex (RBBFC) (Fike 1999) is a mosaic of forest, shrub woodland, grassland, partially vegetated gravel or sand bar community found in association with major rivers. Because of the heterogeneous nature of river habitats due to factors such as flooding and variation in the substrate, this complex is composed of several distinct plant communities that can intergrade with no clear boundaries.

We applied Fike's (1999) plant community types to our database to determine the extent to which native riparian communities are present along the survey area of the Monongahela (2001) and Ohio Rivers (2000). In total, the database for 2001surveys includes 82+ species (Appendix A, Table 1), including 6 new species not found in 2000. This increase in plant diversity between the two years is likely due to the lower proportion of highly managed sites sampled in 2001 relative to the highly managed urban sites of 2000 (Appendix A, Figure 1). Additional data was collected on four herbaceous species or plant functional groups [see Methods at end of report for details]. The herbaceous species censused were *Iris pseudacorus, Polygonum cuspidatum, Lythrum salicaria* and *Justicia americana* (Appendix A, Table 2). All species in the dataset were categorized as native, introduced and/or invasive.

Despite Pittsburgh's long industrial history and intensive industrial use of the rivers, our data indicate that elements of the native plant community complex are present. Of the eight communities listed in the RBBFC, we found evidence of five present in our sample: four distinct native woody and one native herbaceous plant community. We have indicated the dominant elements of these 5 native communities on our maps. Locations referenced along the rivers are measured in tenths of miles. "ML" refers to the left bank of the Monongahela, while "MR" refers to the right bank of the Monongahela. For example, the location "ML15.9" refers to the left bank of the Monongahela, 15.9 miles from the Point.

Represented RBBFC plant communities of the Monongahela River Banks:

1. Sycamore – (River Birch) – Box-Elder Floodplain Forest (Appendix B, Figure 1)

This community type was the most common native plant community encountered on the Monongahela and was found throughout much of the surveyed area. These forests are typical of the floodplains of larger rivers in PA that receive periodic or seasonal flooding. They are characterized by dominance of *Platanus occidentalis* (sycamore) and *Acer negundo* (box elder) and in the eastern half of the state, *Betula nigra* (river birch). This type of river birch was not found in our survey of the Ohio River drainage. Excellent examples of this floodplain forest type can be found in Appendix B, Figure 2

map locations: ML15.9-12.1 and MR36.5-34.1

2. Silver Maple Floodplain Forest (Appendix B, Figure 1)

These forests occur on well-developed floodplains along large rivers. They are characterized by the predominance of *Acer saccharinum* (silver maple) but also include *Acer rubrum* (red maple), Salix nigra (black willow) *Acer negundo* (box elder) and *Ulmus americana* (American elm) and *Ulmus rubra* (red elm). This forest type was not common, but was found in some small stretches.

Examples of this forest type can be found in Appendix B, Figure 2 map locations: ML27.5-27.0, ML32.1-30.3 and MR14.1-13.5.

3. Black Willow Scrub/Shrub Wetland (Appendix B, Figure 1)

This community is typical found along riverbanks and stream habitats and is characterized by the predominance of *Salix nigra* (black willow) in association with several dogwood species, *Cornus* spp. as well as *Alnus rugosa* (speckled alder). In this survey we found the invasive species *Polygonum cuspidatum*, Japanese knotweed, co-occurring. This habitat was found in some small stretches, best exemplified by ML16.8-16.2, ML21.7-21.0 and MR28.3-27.8 (Appendix B, Figure 2)

4. Alder – ninebark wetland (Appendix B, Figure 1)

These wetlands are characterized as "shrub swamps" dominated by *Alder* spp and/or *Physocarpus opulifolius* (ninebark). In our surveys, the plant association reached the riverbank edges. This community was found in small stretches, with the two best examples at MR21.9-20.5 and MR27.6-26.8, (Appendix B, Figure 2)

In addition, one herbaceous community associated with the RBBFC was common along stretches of the Monongahela:

5. Water-willow (*Justicia americana*) – smartweed riverbed community (Appendix B, Figure 1)

This community is found on major rivers in areas where there is inundation of alluvium near the shore or where sediment develops among rocks in the river. Plants in this community withstand flooding of their roots for most of the year. Water-willow is dominant, with several species of smartweed (*Polygonum*) and several species of rushes (e.g. *Eleocharis*) in the mix.

Examples of this community type are found between ML15.3-14.3, MR15.3-14.3, MR26.3-26.0, (Appendix B, Figure 2)

Distribution of community types

It is clear from the mapped distributions of the community types (Appendix B, Figure 7) that no single community type is found in large expanses. Rather, elements of the four woody communities co-occur. Despite the history of human management of the rivers in our region, many elements of the native community exist all along the surveyed area. The best examples of an intact RBBF complex in the region are found associated with

floodplain areas (Appendix B, Figure 8) identified in the Geology Survey. Hardwood floodplain forests are among the most rare plant community types globally. The presence of relatively intact floodplain RBBF complexes and elements of the native forest throughout the surveyed region indicates that restoration of natural areas in the regions would have a high probability of success.

Introduced vs. Invasive Plant Species

Not all species that are introduced into an ecosystem become invasive. Many introduced species become naturalized in the ecosystem, and do not increase in abundance. Of the 81 woody species in our database (Appendix A, Table 1), 29 are introduced (2 from southern USA, 7 from Europe, and 20 from Asia). Of those 29 species, only 9 are considered invasive. The US federal government definition of an invasive species is:

> A species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112). Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species introductions.
>
> http://www.invasivespecies.gov

Invasive plant species are of concern in the Three Rivers. Over time, can be expected to supplant native species, resulting in a loss of biodiversity in the area. Our database will allow us to determine the occurrence and extent of woody and key herbaceous invasive exotic plants: The invasive woody plants in the 2001 survey area are listed in red in (Appendix A, Table 1). The two invasive herbaceous plants noted in the 2000/2001 survey area listed in red in (Appendix A, Table 2).

Overall, the distribution of native woody vs. native introduced species differed between the two areas surveyed (Appendix c, Figure 1,2). As a proportion of the total woody vegetation surveyed in each year, Japanese knotweed comprised a surprisingly high percentage.

Year	River	Native	Introduced	Japanese Knotweed
2000	Ohio	76%	24%	8%
2001	Monongahela	85%	15%	5%

Invasive plants are found throughout the survey area (Appendix C, Figure 4) . Interestingly, the proportion of introduced species changes significantly with distance from Point State Park on the Monongahela River. The Upper Monongahela River had 14% introduced species and 86% native while the Lower Monongahela River had 24% introduced and 76% native (Appendix C, Figure 3). This trend is likely due to the high degree of human disturbance of the riverbank closest to the Point State Park, which facilitates

invasion of exotic species. This idea is supported by the fact that all examples of relatively intact RBBF complex are found in the upstream reaches of the watershed.

Although many introduced species are found along the rivers, three aggressive invaders are particularly abundant. The invasive Tree of Heaven (Ailanthus altissima) constituted 8 and 6% of the woody species abundance, in 2000 and 2001 respectively. Nearly as abundant was the herbaceous Japanese knotweed *Polygonum cuspidatum,* comprising 8 and 5% of the total woody species abundance surveyed on the riverbanks in 2000 and 2001. Oriental bittersweet, *Celastrus orbiculatus,* the next most abundant woody invader comprises 5% in 2000 and less than 1% of the total woody biomass in 2001.

Summary and Conclusions

- The data to date from the vegetation surveys of 2000 and 2001 indicate that the riverbanks house a diverse assemblage of woody plant species from the River Bed-Bank-Floodplain Complex (RBBFC) .
- Four woody plant communities and one herbaceous plant community have been identified.
- Introduced species comprise 15-24% of the total woody species abundance of the riverbanks. A lower proportion of those are invasive.
- Tree of heaven and Japanese knotweed are the most common invasive species noted to date.
- Several remnant floodplain forests in this region contain novel and important geographical and anthropological features.
- These areas can be developed for recreation and tourism while protecting their ecological significance.

Field Methods for 2001

In 2001, pools two and three of the Monongahela River and small sections of the Allegheny and Ohio Rivers were the focus of the data collection. The length of the river studies was divided into one 0.1 mile segments. Locations of sampling were located through a hand-held GPS unit. Due to the fact that the vegetation types along the river rarely change significantly between 0.1mile distances, we modified the sampling protocol (from that used in 2000). Because of the spatial correlation in vegetation in adjacent segments, it became clear that sampling *every other 0.1mile segment* would provide sufficient detail to characterize the riverbank vegetation. We are able to accurately characterize the entire length of stream bank of pools two and three using this sampling scheme.

As in 2000, we focused on the determining the presence and relative abundances of the woody vegetation because they are diagnostic of plant community types (described below). When present, emergent woody and herbaceous aquatic vegetation was also recorded. Our primary survey method of the riverbank woody vegetation was taken by scanning the riverbank from the 3R2N vessel. We surveyed all woody vegetation from the shoreline to approximately 20 ft back from the river edge. This area encompasses the riparian zone. Because of the accessibility of the Monongahela River's edge, we were usually able to collect data within 30 feet of the shoreline. Most identifications were easily made using binoculars. If closer examination was required to make an identification, we did a survey on land, and either identified the plant(s) on-site or took a sample for later identification in the lab.

All raw data was recorded on data sheets and when conditions permitted, the data was also entered directly into a spreadsheet using a laptop computer at the survey site. When conditions did not permit the use of the laptop on the boat, the data was entered later.

Data Collection and Definition of Variables:

At each segment, woody species were identified and each species identified was given an abundance rating from 1 to 4, denoting the percent of the total sample area covered by that species (where total sample area = [(0.1 mile X 20 ft.); not a percent of the vegetated area alone). The scale for percent cover used is:

1 = <5% of the area

2 = 5-15%

3 = 16-40%

4 = >40%

Estimates of total percent cover and percent composition of woody plants was taken at <u>every</u> 0.1 mile segment, including the segments not surveyed in detail. Taking this data at every segment revealed any large

break in continuity that taking surveying every other segment might have missed. Percent composition of exotic woody plants was estimated at every other segment.

A rating of continuity was also given to every 0.1 mile segment, again to reveal any large break in continuity that might have been missed by surveying every other segment. Each segment was given a rating from 1 to 7, with 1 being not continuous and 7 being completely continuous.

Management type was recorded at the same locations in which we collected detailed vegetation data. The management type of every area was noted as one of four types of classification: industrial, managed, semi-managed, not managed. Definitions of the four management types are:

1. Industrial areas are the areas where plant growth was inhibited by industry. These are areas with drastic human impact.
2. Managed areas are areas where plant growth is directly controlled by humans (as in recreation areas or private homes).
3. Semi-managed areas are areas showing some human impact or control. These include relatively natural areas around railroad beds and power-lines through relatively natural areas.
4. Unmanaged areas are those that showed no, readily perceptible impact or control by humans, although those effects may have occurred in the past .

(Appendix D, Figure 1)

For the segments surveyed in detail, we also recorded average canopy height, maximum canopy height, and minimum canopy height. These variables typically correlate with the size/age of the trees and can indicate areas of significant shading of the river.

The abundance of standing dead trees was also noted at every other segment. Dead trees are ecologically important to a forest community as habitats for cavity nesting birds and mammals. Each segment was given a rating from zero to four based on the number of dead trees. This is the scale used:

0 = 0

1 = 1-5

2 = 6-10

3 = 11-15

4 = 16+

Additional data on non-woody species (Appendix D, Figure 2) was collected for a small number of species or plant functional groups. Data on *Polygonum cuspidatum* (Japanese knotweed) was collected in 2001 to retain consistency with data set from 2000 and because *P. cuspidatum* is an invasive species. In addition, three other herbaceous plants were inventoried and geo-referenced. These herbaceous plants are either useful

indicator species, plants of special concern, or invasive plants. Their place in the database is warranted as baseline data. The three additional herbaceous species are included in the survey:

- *Justicia americana* (water willow) is a native aquatic species found along edges of lakes, ponds, and streams. It usually indicates a healthy and intact riparian zone and is the dominant member of the Waterwillow-smartweed community.
- *Iris pseudacorus* (yellow iris) is an introduced species also found along edges of lakes, ponds, and streams. *I. pseudacorus* was often found growing near acid mine drainage in the pools studied in 2001. Further years of the study may reveal a more significant association.
- *Lythrum salicaria* (purple loose-strife) is a highly invasive species that was introduced to the United States from Europe It is found in scattered areas along our Pittsburgh Rivers and can be closely monitored for spread using this geo-referenced system.

The other non-woody plants noted, were emergent aquatic grasses, sedges, and rushes, which form a plant functional group. Due to the distance constraints, grasses and sedges were not distinguishable and were recorded as one category (grasses/sedges). Rushes were placed in a separate category. The presence of emergent grasses and sedges typically indicates the presence of sand bars and/or shallow water.

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Appendix A

Table 1

List of species identified in woody vegetation survey 2000-2001. Font color indicates status (Black=native, blue=introduced, red=introduced & invasive).

(Note: * represents new species not previously found 2000 survey.)

Scientific name	Family	Common name	Native/Introduced /Invasive
Acer cv.	Aceraceae	Maple cultivar	Introduced
Acer negundo	Aceraceae	Box-elder	Native
Acer platanoides	Aceraceae	Norway maple	Introduced from Europe/Invasive
Acer saccharinum	Aceraceae	Silver maple	Native
Acer saccharum	Aceraceae	Sugar maple	Native
Aesculus spp.	Sapindaceae	Buckeye	Native
Ailanthus altissima	Simaroubaceae	Tree of heaven	Introduced from Asia/Invasive
Alnus spp.	Betulaceae	Alder	Native
Amorpha fruitcosa	Fabaceae	False indigo	Native
Ampelopsis brevipedunculata	Vitaceae	Porcelain-berry	Introduced from Asia
Aralia spinosa	Apiaceae	Devil's walking stick	Native
Berberis cv.	Berberidaceae	Barberry cultivar	Introduced from Asia
Berberis thunbergii	Berberidaceae	Barberry	Introduced from Asia/Invasive
Betula cv.	Betulaceae	Birch cultivar	Introduced from Europe
Betula spp.	Betulaceae	Birch	Native
Carya spp.	Juglandaceae	Hickory	Native
Catalpa spp.	Bignoniaceae	Catalpa	Introduced from southern USA
Celastrus orbiculatus	Celastraceae	Oriental bittersweet	Introduced from Asia/Invasive
Celtis occidentalis	Ulmaceae	Hackberry	Native
Cephalanthus occidentalis	Rubiaceae	Buttonbush	Native
Cercis canadensis	Fabaceae	Redbud	Native
Cornus spp.	Cornaceae	Dogwood	Native
Crataegus spp.	Rosaceae	Hawthorn	Native
Forsythia cv.	Oleaceae	Forsythia	Introduced from Europe
Fraxinus spp.	Oleaceae	Ash	Native
Gleditsia triacanthos	Fabaceae	Honey locust	Native
Hamamelis virginiana	Hamaelidaceae	Witch-hazel	Native
Hibiscus syriacus	Malvaceae	Rose-of-Sharon	Introduced from Asia

*Hibiscus moscheutus**	Malvaceae	Swamp rose mallow	Native
Humulus spp.	Moraceae	Hops	Native/ Introduced from Asia
Hydrangea arborescens	Hydrangeaceae	Hydrangea	Native
Ilex cv.	Aquilfoliaceae	Holly cultivar	Native
Juglans spp.*	Juglandaceae	Black Walnut	Native
Juniperus cv.	Cupressaceae	Juniper	Native
Ligustrum vulgare	Oleaceae	Privet	Introduced from Europe
*Lindera benzoin**	Lauraceae	Spicebush	Native
Liquidambar styraciflua	Hamaelidaceae	Sweet-gum	Native
Liriodendron tulipifera	Magnoliaceae	Tulip tree	Native
Lonicera maackii	Caprifoliaceae	Amur honeysuckle	Introduced /Invasive
Scientific name	Family	Common name	Native/Introduced /Invasive
Lonicera spp. (shrub)	Caprifoliaceae	Honeysuckle	Introduced /Invasive
Lonicera spp. (vining)	Caprifoliaceae	Honeysuckle	Introduced /Invasive
Maclura pomifera	Moraceae	Osage orange	Introduced from southern USA
Malus coronaria	Rosaceae	Crabapple	Native
Malus pumila	Rosaceae	Apple	Introduced from Asia
Menispermum canadense	Menispermaceae	Moonseed	Native
Morus alba	Moraceae	White Mulberry	Introduced from Asia
Morus rubra	Moraceae	Red Mulberry	Native
*Nyssa sylvatica**	Nyssaceae	Tupelo, Black gum	Native
Ostrya virginiana	Betulaceae	Hophornbeam	Native
Parthenocissus quinquefolia	Vitaceae	Virginia creeper	Native
Physocarpus opulifolius	Rosaceae	Ninebark	Native
Picea cv.	Pinaceae	spruce cultivar	Introduced
Pinus cv.	Pinaceae	pine cultivar	Introduced
Platanus occidentalis	Platanaceae	Sycamore	Native
Populus tremuloides	Salicaceae	Quaking aspen	Native
Populus deltoids	Salicaceae	Cottonwood	Native
Prunus cv.	Rosaceae	Cherry cultivar	Introduced
Prunus spp.	Rosaceae	Wild Cherry	Native
Ptelea trifoliata	Rutaceae	Hop-tree	Native
Quercus spp.	Fagaceae	Oak	Native
Rhamnus frangula	Rhamnaceae	Buckthorn Alder	Introduced from EurAsia/Invasive
Rhus typhina	Anacardiaceae	Staghorn Sumac	Native

Ribes spp.	Saxifragaceae	Currant	Native/ Introduced
Robinia pseudoacacia	Fabaceae	Black Locust	Native
Rosa cv.	Rosaceae	Rose cultivar	Introduced
Rosa multiflora	Rosaceae	Multiflora rose	Introduced from Asia/Invasive
Rubus spp.	Rosaceae	Blackberry, raspberry	Native
Salix babylonica	Salicaceae	Weeping willow	Introduced from Asia
Salix spp.	Salicaceae	Willow	Native
Sambucus candensis	Adoxaceae	Elderberry	Native
Sassafras albidum	Lauraceae	Sassafras	Native
Sorbus aucuparia	Rosaceae	Mountain Ash	Introduced from Europe
Spiraea spp.	Rosaceae	Meadowsweet	Native
*Staphylia trifolia**	Staphyleaceae	Bladdernut	Native
Symphoricarpus albus	Caprifoliaceae	Snowberry	Native
Tilia americana	Tiliaceae	Basswood	Native
*Tsuga canadensis**	Pinaceae	Hemlock	Native
Toxicodendron radicans	Anacardiaceae	Poison ivy	Native
Ulmus spp.	Ulmaceae	Elm	Native
Viburnum sp.	Adoxaceae	Arrow-wood	Native
Vitis sp.	Vitaceae	Grapevine	Native/ Introduced
Wisteria floribunda	Fabaceae	Wisteria	Introduced from Europe

Table 2

Herbaceous species in database 2000- 2001. Font color indicates status (Black=native, blue=introduced, red=introduced & invasive).

Scientific name	Family	Common name	Native/Introduced /Invasive
Iris pseudacorus	Iridaceae	Yellow flag iris	Introduced from Europe/Invasive
Justicia americana	Acanthaceae	American water-willow	Native
Lythrum salicaria	Lythraceae	Purple loosestrife	Introduced from Europe/Invasive
Polygonum cuspidatum	Polygonaceae	Japanese knotweed	Introduced from Asia/ Invasive

Appendix A, Figure 1
List of species identified in woody vegetation survey 2000 - 2001

Acer saccharinum (Silver maple)
Native

Platanus occidentalis (Sycamore)
Native

Salix spp. (Willow)
Native

Acer negundo Box elder)
Native

Ulmus spp. (Elm)
Native

Ailanthus altissima (Tree of Heaven)
Introduced from Asia / invasive

Appendix A, Figure 1
List of species identified in woody vegetation survey 2000 - 2001

Toxicodendron radicans (Poison ivy)
Native

Robinia pseudoacacia (Black locust)
Native

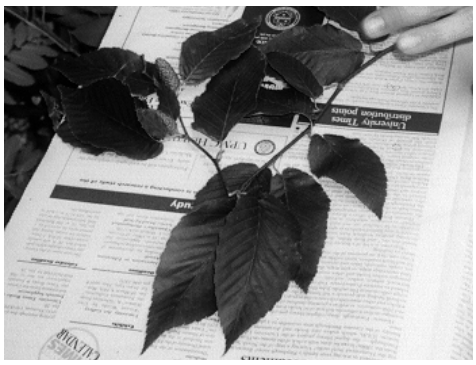
Amorpha fruitcosa (False indigo)
Native

Physocarpus opulifolius (Ninebark)
Native

Parthenocissus quinquefolia (Virginia creeper) Native

Rubus spp.(Blackberry, Raspberry)
Native

Native



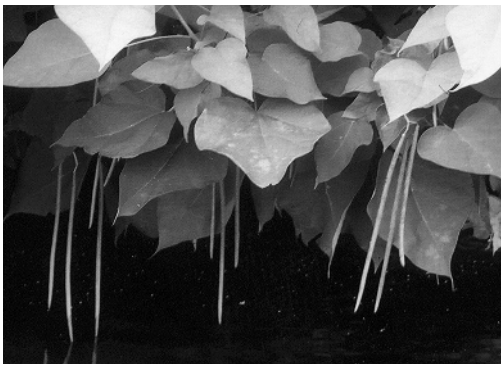
Appendix A, Figure 1
List of species identified in woody vegetation survey 2000 - 2001

Morus alba (White mulberry)
introduced

Prunus spp. (Wild cherry)
Native

Wisteria floribunda (Wisteria)
Introduced from Europe

Celastrus orbiculatus (Oriental bittersweet)
Introduced from Asia / Invasive



Catalpa spp. (Catalpa)
Introduced from southern USA

Lonicera spp. (vining) (Honeysuckle)
Introduced from Asia / Invasive

Populus deltoides (Cootonwood)
Native

Appendix B, Figure 1
Plant communities of the Monongahela River System

Sycamore - (river birch) - box-elder floodplain forest

Platanus occidentalis (sycamore)
Acer negundo (box elder)
Betula nigra (river birch)

Silver Maple Floodplain Forest

Acer saccharinum (silver maple)
Acer rubrum (red maple)
Salix nigra (black willow)
Acer negundo (box elder)
Ulmus amaericana (American elm)
Ulmus rubra (red elm)

Black Willow Scrub/Shrub Wetland

Salix nigra (black willow)
Cornus spp. (dogwood)
Alnus rugosa (speckled alder)

Alder - ninebark wetland

Alnus spp. (Alder)
Physocarpus opulifolius (Ninebark)

Water-willow –smart-weed riverbed community

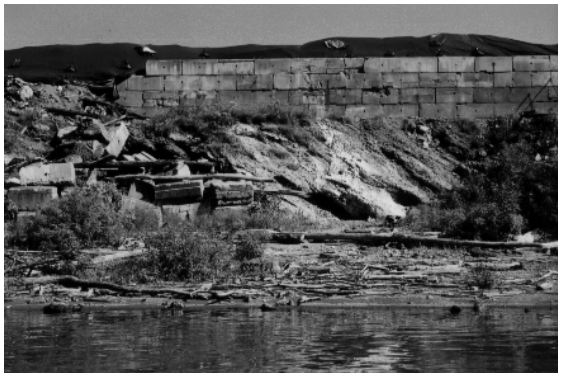
Water-willow (Justicia americana)
Polygonum amphibium var.
emersum (water smartweed)
Polygonum punctatum (dotted smartweed)
Sagittaria spp. (arrowhead)
Rotala ramosio (tooth-cup)
Schoenoplectus pungens (chairmaker's rysh)
E. acicularis (needle spike-rush)
E. erythropoda (a spike-rush)

Appendix D, Figure 1
Management type

Active management

Semi- management

not management



Industrial

Industrial (Acid mine drainage)

Appendix D, Figure 2
Non-woody species component

1. Lythrum salicaria (Purple loosetrife)...Introduced Invasive species
   Facultative wetland species
   Purple looserife originally came from Europe. It grows in a variety of wetland habitats including marshes, river banks, ditches, and wet

2. Justicia americana (Water willow)...Native
   Obligate wetland species

3. Iris pseudacorus (Yellow iris)...Introduced species
   Obligate wetland species

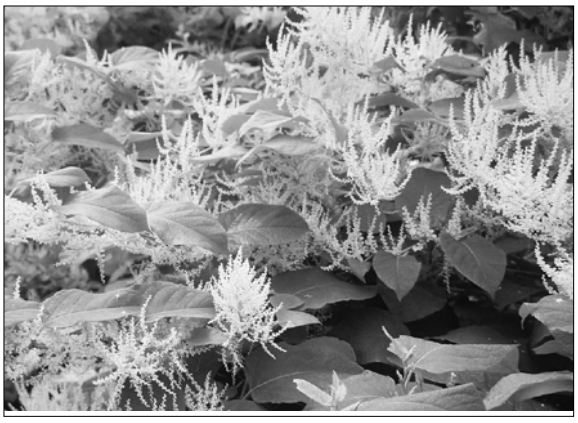
4. Polygonum cuspidatum (Japanese knotweed)...Introduced invasive species

1

2

3

4



Appendix B, Figure 2:

Appendix C, Figure 1

Appendix C, Figure 2

Appendix C, Figure 3